PLG-0367
Revised

SOUTH TEXAS PROJECT
PRELIMINARY SCOPING STUDY RESULTS

Prepared for
HOUSTON LIGHTING AND POWER COMPANY
Houston, Texas
May 1985

Pickard, Lowe and Garrick, Inc.
Engineers • Applied Scientists • Management Consultants
Newport Beach, CA Washington, DC

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SOUTH TEXAS PROJECT PRELIMINARY SCOPING STUDY RESULTS

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ACKNOWLEDGMENT

The South Texas Project study team is indebted to those not identified on the title page who made invaluable contributions to the successful completion of this report. Mr. Richard P. Murphy, the project manager from Houston Lighting and Power Company, made an outstanding contribution through his project management support and coordination of the essential participation of several different HL&P organizations. These organizations included nuclear services, project engineering, nuclear licensing, reactor operations, technical support, operator training, and maintenance organizations that support the South Texas Project Electric Generating Station as well as HL&P power supply planning and engineering and system load control. Through their supply of information, interactions with the study team, and review of project deliverables, the objective of achieving substantial realism and accuracy in modeling the STPEGS plant and system was achieved.

The authors extend a special appreciation to the noteworthy contributions of those responsible for publishing this report on a very tight schedule and without compromising report quality as well as those who provided valuable administrative support.

ABSTRACT

Houston Lighting and Power Company, as project manager for the South Texas Project Electric Generating Station, embarked on this Preliminary Scoping Study early in 1984 as a preliminary analysis of plant safety using probabilistic methods. The study was performed solely to satisfy internal HL&P needs for timely feedback of risk management insights into the process of completing construction on STPEGS and preparing the plant for operation. With the design nearing its final form and the operating staff beginning the process of training and procedure development, the time was ripe for a review of the integrated plant--the interconnected hardware systems and their operating environment. The Preliminary Scoping Study provides that analysis.

The Preliminary Scoping Study employs an advanced probabilistic risk assessment methodology developed and applied by Pickard, Lowe and Garrick, Inc., as expert technical consultant to HL&P. The work has benefited from substantial participation and support from the HL&P engineering, operations, and training organizations. The objectives of the study are aimed toward the development of a plant risk model uniquely applicable to STPEGS, both to provide early insights into the risk sensitivities for design and procedural purposes and to be continually used throughout plant life as a living risk management tool.

The completion of the Preliminary Scoping Study has resulted in the development of the nucleus of a plant model, a preliminary safety quantification, and the identification of early insights into risk-sensitive factors about STPEGS.

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HL&P Perspective

Houston Lighting & Power Company, as Project Manager for the South Texas Project Electric Generating Station, initiated this Preliminary Scoping Study early in 1984 as part of a phased program aimed at developing a risk model through programmatic activities consistent with the development of a Level 1 PRA. This Preliminary Scoping Study supports this objective through the development of a preliminary model for analyzing plant safety.

The primary objectives of the Preliminary Scoping Study were to provide early insights into the design and operational sensitivities related to plant safety and to provide a comprehensive training vehicle for HL&P personnel in the probabilistic safety technology. These goals have been accomplished through the completion of this preliminary model, which this report documents. During the time this Study was being completed, calculations were performed to provide additional information related to temperature rise on loss of EAB HVAC and the decision was made to install fail-closed isolation valves in the Supplemental Containment Purge Subsystem. No additional activities are indicated at this time other than further development of the plant model through the reduction of uncertainties.

In planning and implementing the STP plant model development program, the technology transfer required for HL&P personnel to assume a larger responsibility in the expansion of the model was provided through the integration of HL&P personnel into the PL&G Study team. The next phase will consist of an in-house program, supplemented by outside resources, to reduce uncertainties in key areas. Periodically the program will be reevaluated to define the level of activity required to support STP needs.

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Figure

LIST OF ACRONYMS

Abbreviation	Definition
AFW	auxiliary feedwater
AFST	auxiliary feedwater storage tank
CCWS	component cooling water system
DGB	diesel generator building
EAB	electrical auxiliary building
ECCS	emergency core cooling system
ECH	essential chilled water
ECW	essential cooling water
EDG	emergency diesel generator
ESD	event sequence diagram
ESF	engineered safety features
ESFAS	engineered safety features actuation system
ET	event tree
FHB	fuel handling building
FMEA	failure modes and effects analysis
FSAR	final safety analysis report
HL&P	Houston Lighting and Power Company
HVAC	heating, ventilating, and air conditioning system
IVC	isolation valve cubicle
LOCA	loss of coolant accident
MAB	mechanical auxiliary building
MOV	motor-operated valve
NRC	Nuclear Regulatory Commission
NREP	National Reliability Evaluation Report
PLG	Pickard, Lowe and Garrick, Inc.
PORV	power-operated relief valve
PRA	probabilistic risk assessment
PWR	pressurized water reactor
QA	quality assurance
RCB	reactor containment building
RCP	reactor coolant pump
RCS	reactor coolant system
RHR	residual heat removal
RSS	Reactor Safety Study
RWST	refueling water storage tank

LIST OF ACRONYMS (continued)

Abbreviation	Definition
SI	safety injection
SMA	Structural Mechanics Associates, Inc.
SSSP	solid state protection system
STPEGS	South Texas Project Electric Generating System
TMI	Three Mile Island

1. INTRODUCTION

This report documents the results of the South Texas Project Electric Generating Station Preliminary Scoping Study of plant safety--a limited application of probabilistic risk assessment technology. The study provides a preliminary risk model of the integrated STP plant, a first-cut quantification, and early insights into the sensitivities for design and procedural purposes. It can serve as the foundation for a practical risk management program for STPEGS.

1.1 THE PRELIMINARY SCOPING STUDY PROJECT

Houston Lighting and Power Company, as project manager for STPEGS, conceived of the Scoping Study as a means to examine the integrated response of the plant to unplanned departures from steady-state operations. Such an integrated analysis was especially appropriate at this time. Individual system designs, all meeting their own independent design criteria, were nearing completion. They could be used to develop corresponding system models, which could be linked together to study interactions and whole-plant response. Moreover, significant construction remained and the operating staff was just beginning to train and write procedures on integrated plant operations.

The Scoping Study described in this report began on March 28, 1984 to satisfy internal HL&P needs for timely feedback of risk management insights into the process of completing construction on STPEGS and preparing the plant for operation. PLG assumed the lead responsibility as expert technical consultant to plan, direct, and conduct the study and to begin the process of providing HL&P with PRA technology. This technology transfer has enabled HL&P's direct participation in the study and can develop at HL&P the type of intimate knowledge of the STPEGS risk model that will be necessary for a variety of risk management applications. To help focus the technology transfer effort, two HL&P engineers were assigned full time to the project team for the duration of the Scoping Study. In addition, the engineering, operations, and training organizations at HL&P provided plant documentation, answered numerous technical inquiries, and reviewed project deliverables. HL&P's project manager coordinated this effort and represented the third full-time HL&P engineer participating on the project team. The results of this study, therefore, reflect the contributions of both HL&P and PLG. Nevertheless, PLG was given and fully assumes the responsibility for the results of this Scoping Study and is fully prepared to explain the results.

STPEGS design information included in this report is derived from design data available during the period from April to July 1984. Changes that have been made in the normal course of plant design since that time generally have not been analyzed or incorporated into the study results. Specific cases where more recent information has been included are explicitly identified in the HL&P comments attached as Appendices A and B.

The ANS/IEEE PRA Procedures Guide (Reference 1-1) defines three levels of PRA coverage. A Level 1 PRA analyzes only the performance of the plant systems, whereas a Level 2 PRA also considers core and containment phenomenology. A Level 3 PRA includes a complete consequence analysis. The Procedures Guide describes the effort required to conduct and fully document a state-of-the-art analysis at each of the three levels. Such analyses strive for completeness in coverage of initiating events and the modeling of the ensuing scenarios as well as the development of thorough, stand-alone documentation. This Preliminary Scoping Study is much more limited in coverage than any of the PRAs discussed above. The core of work in this effort could be expanded into a complete Level 1 PRA at a later date. The analytical coverage has been limited to those initiating events and aspects of plant response judged most important by the study team. Such limitations lead to broad uncertainties in the study results in comparison to a full-scope assessment. Documentation in this report has been limited to that required to present the results and their bases.

The validity of the current study in describing the risk comes from the experience of its analysts--their involvement in many full-scope PRAs, their familiarity with the plant, and their first-hand knowledge of plant operations. Its utility in risk management comes from its completeness as a model of the integrated plant and its flexibility: completeness in terms of how thoroughly it models the interrelationships among plant systems at an appropriate level of detail and flexibility in terms of ease of expansion to include analytical refinements; i.e., the ability to take important parts of the model to the full-scope level to answer particular risk-related questions requiring more detail. Although the Preliminary Scoping Study is complete, it is not as detailed as a full-scope assessment.

The objectives of the Preliminary Scoping Study can be summarized as follows:

- Provide a basis for timely feedback of risk management insights into the process of completing construction on STPEGS.

- Develop a cadre of experienced experts in the STP plant model, systems, and operations at PLG and HL&P.

- Develop the nucleus of an STPEGS plant risk model consisting of event sequence diagrams and event trees for a limited set of initiating events, abbreviated systems models, a generic data base, a simplified containment model, and a qualitative analysis of the impact of event and accident sequences.

- Provide a state-of-knowledge estimate of the frequency of accidents involving severe core damage, plant damage states, and impact categories; i.e., an estimate including uncertainty.

- Develop a basis for optimizing the allocation of resources to complete the development of risk assessment and risk management capability at HL&P.

The purpose of this report is to document the successful completion of the Scoping Study objectives. The uncertainties in the numerical results presented in this report have been quantified and are large because the model is incomplete and both the state of knowledge of the study team and the extent of supporting documentation are not as strong as they would be following a full-scope study on a completed plant. Rather than draw undue emphasis in this report to the numerical results, the authors have attempted to use these results to lend credence to the qualitative engineering conclusions and recommendations that were developed. The point value numerical results would most assuredly change at the completion of a full-scope PRA. However, past PLG experience with similar studies provides the authors with confidence that a major portion of the principal risk contributors and risk-sensitive factors of STPEGS have been identified in this study.

This report incorporates the authors' response to HL&P written comments on earlier review drafts. As required by HL&P Policies and Practices (Reference 1-2), the appendices contain those comments and our resolution of them.

1.2 PRA PERSPECTIVE: WHAT IS A PRELIMINARY SCOPING STUDY?

With the growth of the nuclear industry and the accumulation of a substantial body of operating experience, a relatively new method of safety assessment has developed that differs from the safety analyses traditionally employed in the licensing process. This method is known as probabilistic risk assessment. Its development for nuclear power plant application follows its successful application in the aerospace industry. The introduction of PRA was inspired by the assessment that PRA can be a powerful decision-making and risk management tool (References 1-3 through 1-6).

PRA looks quantitatively at both the consequences that could potentially result from nuclear reactor accidents and the likelihoods of such occurrences. Consequences of all scenarios are calculated, rather than simple bounding cases. Then, for each consequence level, PRA calculates the likelihood of occurrence rather than assuming that some events are "incredible" and all others have equal weight. Combining consequences, likelihood of consequences, and uncertainty enables the ranking of priorities for accident scenarios with respect to risk. Also, PRA establishes a framework for putting the risk of nuclear plant operation into context with other public risks.

An identifying characteristic of PRA is its probabilistic rather than deterministic viewpoint toward safety. The use of probabilities and frequencies provides a means for dealing with random elements such as variation in certain environmental conditions (e.g., occurrence of earthquakes and floods) and certain internal plant failures exhibiting random behavior. It also provides a framework for quantifying uncertainty in otherwise deterministic accident simulation and consequence models. PRA has also evolved a technology for handling rare events that expands the completeness of accidents considered. Consideration of man-machine interfaces in PRA is also given emphasis.

Final results of a PRA are expressed in the "probability of frequency" format; i.e., as a family of curves giving the frequency of exceeding damage levels and the uncertainty in these frequencies. This family of curves embodies the three-dimensional aspects of risk: uncertainty, likelihood, and consequences.

A common misconception about PRA is that its validity or usefulness strongly hinges on having large quantities of data available. In fact, modern PRA accounts for variability in data (or lack of data) by assigning probability distributions to model these uncertainties and examining the effects of these distributions on the results. The outcome is a probability distribution of the results. These distributions describe the results in terms of means, medians, modes, high and low percentile values, and other distribution parameters of interest.

Oversimplified thinking by some people in the past has led to the identification of the central tendency prediction (i.e., mean, median, or mode) as the "bottom-line" result. This thinking ignores the distribution that embodies the statement of uncertainty. The uneasiness about the accuracy of the central estimate wrongly leads to a discounting of the value of PRA, ironically because of a concern about the uncertainties. These uncertainties are an important consideration because the results may be telling us to study the issue further before making decisions about plant modifications or other actions to reduce risk.

PRA has been developed and applied in a number of activities. A partial list of examples is presented in Figure 1-1. Included are PRAs on chemical plants and commercial aircraft systems (References 1-7 through 1-11). However, the most common application of PRA has been to assess the safety of nuclear power plants (References 1-12 through 1-21, for example). The first of these was the Reactor Safety Study (Reference 1-12), which was completed in 1975. It calculated the risk to the public from the operation of 100 (then current design) light water reactors in the United States based on a plant specific analysis of two plants on a composite of many different existing sites. The finished document formed a basis for risk methodology discussion, criticism, review, and improvement. Its influence on PRA continues to be felt to this day.

More recent PRAs--for example, those performed on Zion, Indian Point, Seabrook, and Midland (References 1-18 through 1-21)--have incorporated methodology improvements, some of which emanate from RSS critiques such as that provided by the Lewis panel (Reference 1-22). These improvements include more complete analysis of dependent failures and human interactions, uncertainty quantification methods, methods for assembling and dissecting the results, containment and core response analysis, modeling of external events (earthquakes, fires, floods, etc.), and incorporation of the site-specific topography, emergency preparedness plans, and changing weather patterns in the site model. In this report, a PRA incorporating all these features is termed a "full-scope, Level 3 PRA," in accordance with the ANS/IEEE PRA Procedures Guide (Reference 1-1).

Two impacts of the above methodological advances are worth noting. One is a more accurate specification of the contributors to risk. The methodology allows us to identify the contributors to risk and observe in increasing detail what is driving the risk level. This is vital for decision making on design or procedural options and other risk management actions by the utility. Knowing what the risk is and the fine structure of that risk enables its control and effective management. A second impact of recent methodological advances is to enhance the usefulness of PRA in risk management and in the regulatory process. The latter includes conformance with regulatory safety goals (Reference 1-23), post-TMI accident licensing requirements (Reference 1-24), environmental impact reports, and emergency preparedness plans (Reference 1-25).

Despite the limitations of this STP Preliminary Scoping Study, both impacts of methodological advances are clear in the results presented in Section 2. Note further that the Scoping Study is a much more useful description of the risk from STP than any existing full-scope PRA. The risk profiles from other PRAs cannot be used for STPEGS. Recent experience indicates that risk profiles are even more plant-specific than realized following the early PRAs. A striking example is the difference in risk levels and dominant contributors between Indian Point Units 2 and 3, which are similar units located on the same site (Reference 1-19). Indeed, the results presented in Section 2 for STPEGS indicate several plant-specific factors not seen in prior work.

It now becomes clear why a plant-specific PRA is performed. In particular, the ultimate reason for doing a risk assessment is that there are underlying decisions to be made. The risk assessment provides vital input to the decision-making process. A complete decision analysis requires not only an assessment of risk but also an assessment of costs and benefits. Only the risk assessment input to the decision-making process is addressed in this report. Importantly, assessments of risk, cost, and benefit should be done for each available decision option.

If the decision in question is whether to modify a plant or its procedures for operation and maintenance, PRA can be most helpful in the following way: After the final risk curves have been assembled, the methodology permits a clear examination of risk contributors from several different perspectives. The structure of the risk model allows us to determine risk contributors in successive levels of detail. With this detail, we are in a position to identify options that can reduce risk in a cost-effective manner and, conversely, recognize that some proposed changes can have no effect on risk. Thus, the quantitative presentation of risk, before and after any proposed change, allows us to decide whether the change is effective or warranted. It also allows us to provide a perspective by comparison with other sources of risk and with various proposed "safety goals" or "acceptable risk criteria." The PRA procedures also allow us to evaluate plant changes that take place, for example, as the plant ages. The idea is to be aware of any new contributors that might be significant in the future.

Risk reduction may result from changes in specific plant components, personnel training, procedures, safeguards, containment, or emergency

plans. The plant-specific and site-specific risk model being developed in this project is designed to accommodate any and all such changes in the decision analysis.

1.2.1 RISK MANAGEMENT PERSPECTIVE: EXAMPLES FROM OTHER STUDIES

Although the preoccupation of PRA thus far has been with risk quantification and, hence, full-scope PRA projects, there have been numerous applications of PRA to resolve particular issues and to implement risk management (Reference 1-26). These applications afford the opportunity to identify with concrete examples the important interface between PRA and the decision-making process. They also demonstrate how the performance of a limited-scope or full-scope PRA enhances the understanding of the safety significance of design features and identifies design weaknesses.

One important application was the investigation of several proposed design modifications in a PWR plant. These modifications included a refractory core ladle; a filtered, vented containment; and the addition of hydrogen recombiners, all of which had been selected for consideration prior to the performance of the PRA. In the course of the PRA, it was readily identified that a fourth option, a diesel-driven containment spray pump modified to be independent of AC power, would not only cost considerably less, but would effect a greater reduction in an already very low risk level than the three costly alternatives that had been proposed prior to the PRA. More importantly, the results supported the decision option to leave the plant the way it was.

A second example of a risk management action enhanced by a PRA pertains to the issue of backfitting a third auxiliary feedwater system pump in a PWR plant to meet one of its post-TMI requirements. The detailed analysis of dependent failures involving support systems in this PRA determined that the number and type of pumps in the original (two-pump) design, which included one motor and one turbine-driven pump, was not the key to this system's contribution to risk. The key was that both pumps were dependent on an electrically powered chilled water system. The third pump was installed in the turbine building so that it would be independent of the chilled water system. The merit of this aspect of the design had not been appreciated prior to the performance of an integrated plant-level PRA.

There are several other examples of this type in which use of PRA models led to enhanced risk management. Many of these provided a basis for identifying a more cost-effective solution than otherwise would have been obtained. The most important lesson from these applications is that PRA not only provides a means of evaluating the risk significance of different decision alternatives, it also helps in defining what decision options should be considered.

The above management and technical lessons from earlier PRAs have been taken into account in planning and conducting this scoping effort for STPEGS. Because the risk analysts have conducted or participated in most of the recent industry-sponsored PRA projects, the methodology used has

benefited from the most recent advances to the state of the art. This methodology is fully described in Chapter 4 of the Seabrook Station Probabilistic Safety Assessment (Reference 1-20) and the mathematical bases are documented in Reference 1-27.

1.2.2 PERSPECTIVE ON THE PRELIMINARY SCOPING STUDY

The basic idea of the Preliminary Scoping Study is to gain a substantial portion of the benefit of a full-scope PRA for a small fraction of the cost. One aspect of the full-scope PRA approach that has prevented a rapid movement toward application to all plants has been the considerable costs associated with their performance. A full-scope PRA such as that completed on Seabrook can require as much as 20 to 25 man-years of analysis, documentation, and review, including the necessary utility support. A second concern has been that when the PRA is conducted in one pass from beginning to end, there is little benefit to be derived for the plant owner until near the end of the project when the first results appear.

In response to the above concerns, a phased approach to PRA was developed and successfully demonstrated on the Seabrook Station PRA. Since then, we have adopted and refined several variations on this basic idea on PRAs now in progress on Beznau (Swiss plant), Three Mile Island Unit 1, and Salem Unit 1. This Scoping Study is similar to the first-phase, limited-scope analysis of those phased projects. Having observed that the simple "delta on WASH-1400" approach was unsuccessful (the dominant contributors from this type of study never matched the dominant contributors from full-scope PRAs on the same plants), PLG developed a phased approach in which experienced analysts learn all they can about the plant during the scoping phase. Working at the client's plant and engineering offices, they study all available documentation; talk with engineers, operators, and maintenance personnel; and inspect the plant. Within the first 2 months, they develop detailed intersystem dependency models, a detailed support system model, and a detailed event tree for general transient initiating events suitable for use in the final risk assessment. Only coarse system models are prepared, but based on our extensive experience, they include all important components. Quantification relies on suitable data and system analyses from other studies and includes an appropriate allowance for common cause failures.

Four of these preliminary scoping studies have been performed to date, and the results have been most encouraging. For the only one that has completed the full-scope effort, the dominant contributors identified in the scoping phase were very much in line with those eventually found from the full assessment, even though the uncertainty in the quantitative results is much reduced in the final assessment.

A full-scope risk assessment is a large, complex project and the questions it seeks to answer are broad and open-ended. Futhermore, we cannot know a priori what will be important at any specific plant. Therefore, it is difficult to carefully control and focus project effort and costs. The preliminary study helps to control costs by focusing attention on the areas where detailed analysis will be most beneficial in

realistically reflecting the plant risk. Systems or initiating events that will never be significant contributors to risk can be identified during the preliminary scoping assessment so that relatively little effort can be spent on them during the full assessment. Especially important, the preliminary assessment can reveal troublesome phenomena that must be evaluated in more detail before the full assessment event trees can be completed.

For instance, in the Seabrook PRA, the preliminary scoping phase found that great uncertainty existed about the amount of reactor coolant pump seal leakage that could occur following a total loss of component cooling water. As a result, this event was treated conservatively and appeared as an important contributor to the frequency of severe core damage. After this was revealed, the Westinghouse Owners Group was able to initiate pump seal leakage tests. If this had not been found until later, when full quantification results became available, it would have been difficult to initiate the same tests without serious disruption of project budget and schedule. More importantly, an appropriate emphasis on scenarios involving pump seal LOCAs in the SSPSA risk model was made possible.

In our past experience with the limited-scope analyses, two different approaches were used to develop uncertainty distributions in the scoping phase. Method 1 consisted of simply fitting a lognormal distribution to upper and lower bound estimates of core melt frequency. The upper bound was taken to be the point estimate from the preliminary risk model with no credit for operator recovery actions, such as offsite power recovery or manual scram following an ATWS. The lower bound was a subjective estimate by the study team of the lower bound core melt frequency attainable by a modern light water reactor. In Method 2, uncertainties were propagated through the preliminary risk model with an allowance for those risk contributors (such as external events) that were left out or treated in a cursory manner.

As Figure 1-2 illustrates for the Seabrook PRA, the full assessment results were represented by a narrower distribution than the results of Method 1 and were situated near the center of the uncertainty distribution obtained by Method 1. This is logical, since these results represent an enhanced state of knowledge and therefore the distribution should be narrower. The fact that the distribution is near the center of the Method 1 result indicates that the degree of conservatism embodied in the estimate of the upper bound in Method 1 was balanced by the degree of optimism in the estimate of the lower bound. In contrast, Method 2 appears to have understated the effects of uncertainty on the low side and is high relative to the final results. This can be explained by conservatisms in the preliminary model that were not factored into the quantification, the chief such conservatism being the treatment of the pump seal LOCA. In the preliminary phase, an unmitigated pump seal LOCA was assumed to lead to core uncovery in 30 minutes compared with nearly 4 hours in the full assessment. This led to an underestimate of the effects of operator recovery in the preliminary study. Therefore, the Method 1 approach to quantifying uncertainty seemed to more reasonably represent the state of knowledge that existed at the completion of the scoping phase for Seabrook.

In the current STP Scoping Study, we have followed the more rigorous propagation of uncertainties used in Seabrook's Method 2, and have allowed for the possibility of excessively conservative success criteria in the best estimate case by assigning probabilities to 14 possible definitions of these criteria--some less stringent and some more. We believe this approach superior to those used earlier; i.e., it should more accurately represent our true state of knowledge or uncertainty.

With regard to the qualitative insights and list of dominant risk contributors developed in the preliminary phase for Seabrook, a comparison with the final results reveals many similarities and a few differences. The similarities include the appearance of station blackout scenarios in both lists of dominant accident sequences, a high conditional frequency of delayed overpressurization failure of the containment given core melt in both cases, and the prominence of sequences involving failure of the primary component cooling water system. The preliminary results also provided an early indication of the importance of assumptions about the behavior of the reactor coolant pump seals after a loss of seal injection and cooling. The most significant difference between the two sets of results was the failure of the preliminary phase to identify the risk significance of the interfacing systems LOCA.

The importance of the interfacing systems LOCA with respect to early fatality risk in the scoping phase of Seabrook was masked by a simplified site (consequence) model that overestimated the consequences of delayed overpressurization relative to those resulting from containment bypass. Since the frequency of delayed overpressurization of the containment was estimated to be much greater than the frequency of the interfacing systems LOCA, the risk of the latter scenario was masked by that of the former.

In summary, the preliminary scoping analysis provided a good perspective on core melt frequency, a first cut at the dominant risk contributors, and an improved allocation of resources for the full assessment. On the other hand, a first-cut, preliminary risk assessment cannot be regarded as a substitute for a full-scope PRA, or even for a full-scale plant model.

A better perspective on the relationship between the limited and full-coverage analyses can be seen by comparing the accident sequences identified in the two phases of the Seabrook PRA. The top six accident sequences identified in the preliminary phase of the Seabrook PRA are listed in Table 1-1. These sequences resulted from a plant model of a comparable level of detail to that in the final phase, but covering only a small set of initiating events: general transients, loss of offsite power, loss of service water, loss of primary component cooling water, large LOCA, and interfacing systems LOCA. In contrast, 58 initiating events were analyzed in the final phase, including the subdivision of the general transient category into 14 separate transient events. The preliminary initiators covered both internal causes and allowances for some external events. The list of sequences from the preliminary phase indicated a high importance for station blackout, transients both with and without scram, and failures of the component cooling system. This stemmed from the treatment of pump seal LOCA as discussed above.

The top 10 sequences with respect to core melt frequency in the final phase of the Seabrook PRA are listed in Table 1-2. As shown, the top sequence from the preliminary phase was confirmed; the same station blackout scenario also ranked first in the final phase. Different variations of station blackout involving service water system failures as the cause of diesel generator failure also appeared high on the list in the final results. Similar success was achieved in forecasting the importance of the PCC system and ATWS events to the final risk results for Seabrook.

In summary, we are very encouraged about the capability to anticipate the most important results of a full probabilistic risk assessment in a relatively short preliminary scoping analysis. Any following analysis can thus focus on the sequences that matter most. Figure 1-3 graphically depicts the relationship among options for limited-scope and full-scope studies. The current report deals with the Scoping Study requantification option. It is suitable for supporting risk management decisions on specific issues, but should not be confused with more complete and realistic full-scope studies.

Readers are warned against using point estimate results of this study independent of their broad uncertainty bounds. Comparison of point estimate Scoping Study results with point estimates from completed full-scope PRAs is especially inappropriate. Such comparisons will yield unreliable, almost surely incorrect and misleading conclusions. The Preliminary Scoping Study is incomplete, uses conservative approximations when they do not numerically impact core melt frequency results, and makes significant assumptions about the future content of plant procedures. Its results have great uncertainty and must be used only with great care and judgment. Nonetheless, when the limitations are understood, these results should provide an important basis for risk management at STPEGS.

1.3 STP/PRELIMINARY SCOPING STUDY PROJECT PERSPECTIVE

To effect project control, a Preliminary Scoping Study Project Plan (Reference 1-28) was developed and published in the first month of the study. This plan defined the project tasks, schedule, flow of documents, and detailed allocation of manpower resources needed to complete the Scoping Study. The project plan provided the basis for measuring progress, which is documented in monthly progress reports.

The scope of work was organized into the following technical and administrative tasks to effect project management:

Number	Task
1	Plant Familiarization
2	Initiating Event Identification
3	Systems Analysis
4	Support System Model Development
5	Frontline System Model Development
6	Survey of External Events and Spatial Interactions

Number	Task (continued)
7	Data Analysis
8	Risk Quantification
9	Technology Transfer
10	Definition of Phase II Approach
11	Interim Report Preparation
12	Project Management
13	Technical Review
14	Quality Assurance
15	Administration and Support
16	Authorized Meetings

The above tasks are highly interrelated and most were performed in an integrated fashion by the project team. During the first 2 weeks, the plant familiarization task (Task 1) began at PLG offices in California with the transfer and review of a large volume of plant documentation. Then, over a 3-week period, the nucleus of the team, under the direction of the principal investigator, was moved to the Houston area. During this period, the team members met with HL&P engineering, operations, and training personnel at the HL&P offices at 5400 Westheimer, Southpoint, and at the STP site while performing technical work in Tasks 1 through 5. This intensive effort accelerated plant familiarization and enabled access to information not readily attainable from the plant documentation. This visibility of the team in the Houston area helped stimulate thinking among the HL&P organizations about the mutual benefits to be realized from interactions with the effort. The remaining 11 weeks of the Scoping Study were conducted at PLG offices in California in completion of the tasks leading to the development of the nucleus of a plant risk model and preliminary quantitative results.

The technical quality of the Preliminary Scoping Study and subsequent phases of this effort has been and will continue to be held to the highest standards. Six principal approaches were followed to ensure high technical quality:

- The assignment of highly competent, experienced personnel to the team.
- The use of state-of-the-art methods, subject to limitation in scope.
- The documentation of models, input data, computer programs, and other facets of the analysis.
- The involvement of owner/operator engineers and operators to ensure that the models accurately described the plant and its operating environment.
- The conduct of independent technical reviews.
- The use of comprehensive QA procedures to document that technical standards have been achieved.

A PLG technical review board chaired by Dr. Stan Kaplan performed independent technical reviews of all project deliverables and received presentations on the results from the project team. These reviews, plus those of the analysts, task leaders, project manager, and HL&P, were documented according to the QA procedures in Reference 1-29. The QA procedures, which include those elements of 10CFR50, Appendix B, judged by PLG to be relevant and useful for PRAs, include procedures for computer program verification and documentation, document control, procurement, QA audits, and technical reviews. The QA program was administered by the PLG QA manager. The QA procedures are believed to be generally more strict than those normally followed in PRAs. For example, a computer program (SETS) used extensively in Nuclear Regulatory Commission-sponsored PRAs, such as the Interim Reliability Evaluation Program had not been independently verified until PLG QA procedures were applied to it in PRA projects carried out by PLG.

1.4 REPORT GUIDE

The results of the Preliminary Scoping Study are presented in Section 2. These results include numerical estimates of the frequencies of severe core damage accidents and radioactivity release states with different potential for offsite consequences. Also, the major contributors to risk and to core melt frequency are presented with a statement of the important issues for resolution and other qualitative conclusions.

The matrix formalism used to assemble and disassemble the results and other key aspects of PRA methodology are briefly summarized in Section 3. This methodology presentation briefly reviews full-scope, Level 3 PRA methods, and spells out in additional detail the limitations of the Scoping Study risk model.

The remaining sections in the report document the application of the Scoping Study methodology to STPEGS. The plant event sequence model, or plant model, is discussed in Section 4. This section includes the selection and quantification of the Scoping Study initiating events and a modularized event sequence model with separate modules to cover the responses of the auxiliary systems and the frontline systems.

The systems analysis task is described in Section 5. It includes the qualitative analysis of all STPEGS systems, categorization of systems for risk model inclusion and exclusion, the quantification of the unavailabilities of subsystems (generally, the redundant trains of systems), and operator actions that correspond with the event tree top events. Section 5 includes one example of the 87 systems analysis summaries that were prepared during the Scoping Study and provided to HL&P as separate deliverables. Additionally, it tabulates significant qualitative results at the systems level.

The preliminary survey of external events that was conducted as part of the Scoping Study is documented in Section 6. This section is organized into separate subsections for seismic events, in-plant hazards and spatial interactions, and other external events. This survey includes qualitative analyses of events such as seismic events, internal fires and

floods, and external flooding due to hurricanes, which were assessed to have some chance of impacting the results. Section 6 also includes bounding analyses of events that were found to have negligible risk contributions, including events such as aircraft crash, turbine missile, tornado missile, and hazardous chemical releases. Allowances for all external events and spatial interactions were made in the quantification of uncertainty in the results presented in Section 2.

The scoping analysis of the containment response is documented in Section 7. It describes the containment design and defines the plant damage states tracked in the plant model in Section 4. These states set the needed input parameters for the containment analysis. Two C matrices relating plant damage states to release categories are developed, one for each of two possible building configurations. Section 7 concludes with a qualitative analysis of offsite impact that was achieved simply by grouping the analyzed accident sequences according to the potential for affecting risk to the public.

1.5 REFERENCES

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TABLE 1-1. DOMINANT ACCIDENT SEQUENCES FOR SEABROOK PHASE I RESULTS

Ranking by Core Melt Frequency with Recovery	Initiating Event	Auxiliary System End State	Early Response Tree End State	Plant State	Release Category	Independent System Failures	Dependent System Failures*	Sequence Frequency (events/ reactor year)**	Ranking by Risk Contribution	
									Early Fatalities	Latent Cancer Fatalities
1	Loss of Offsite Power	A23	Fail	3D	2RW	Onsite Power	SSPS, ESFAS, PCC, EAH, CS, SI, RH, CBS, RCP Seal LOCA	3.0×10^{-3} (3.0×10^{-4})	1	1
2	Loss of Component Cooling	A4	M	4D	2RW	None	CS, SI, EAH, RH, and CBS (long-term)	9.9×10^{-5} (9.9×10^{-5})	2	2
3	General Transient	A0	M	4A	8B	Reactor Trip	None	3.3×10^{-4} (3.3×10^{-5})	No Early Fatalities	Low
4	General Transient	A23	Fail	3D	2RW	Onsite Power, Offsite Power	SSPS, ESFAS, PCC, EAH, CS, SI, RH, CBS, RCP Seal LOCA	3.0×10^{-4} (3.0×10^{-5})	3	3
5	General Transient	A12	MF	4A	8B	ESFAS Signal (both trains)	CS, SI, RH, EFW	2.6×10^{-4} (2.6×10^{-5})	No Early Fatalities	Low
6	General Transient	A4	M	4D	2RW	Component Cooling Water (both trains)	CS, SI, EAH, RH, and CBS (long-term)	1.4×10^{-4} (1.4×10^{-5})	4	4
							TOTAL	4.1×10^{-3} (5.0×10^{-4})		
							Total, All Remaining Sequences	2.7×10^{-4} (1.2×10^{-4})		

*Indicated are specific systems at Seabrook Station.
**Numbers shown without parentheses are frequency without recovery; numbers in parentheses are with recovery.

TABLE 1-2. SU[illegible] OF ACCIDENT SEQUENCES WITH SIGNIFICANT RISK AND CORE MELT FREQUENCY CONTRIBUTIC[illegible]OM PHASE II OF THE SEABROOK PRA WITH APPLICABLE PHASE I SEQUENCES

Initiating Event	Additional System Failures/ Human Actions	Resulting Dependent Failures	Sequence Frequency (per reactor year)	Sequence Ranking			Applicable Phase I Sequence
				Core Melt	Latent Health Risk	Early Health Risk	
Loss of Offsite Power	Onsite AC Power, No Recovery of AC Power Before Core Damage	Component cooling, high pressure makeup (ECCS), reactor coolant pump seal LOCA, containment filtration and heat removal.	3.3-5	1	1	*	1
Loss of Offsite Power	Service Water, No Recovery of Offsite Power	Onsite AC power, component cooling, high and low pressure makeup (ECCS), reactor coolant pump seal LOCA, containment filtration and heat removal.	9.2-6	2	2	*	1
Small LOCA	Residual Heat Removal	None.	8.9-6	3	*	*	**
Control Room Fire	None	Component cooling, high and low pressure makeup (ECCS), reactor coolant pump seal LOCA, containment filtration and heat removal.	8.7-6	4	3	*	2
Loss of Main Feedwater	Solid State Protection System	Reactor trip, emergency feedwater, high and low pressure makeup (ECCS), containment filtration and heat removal.	8.3-6	5	4	*	3
Steam Line Break Inside Containment Heat Removal	Operator Failure to Establish Long-Term Heat Removal		5.6-6	6	*	*	†
Reactor trip	Component Cooling	High and low pressure makeup (ECCS), reactor coolant pump seal LOCA, containment filtration and heat removal.	4.6-6	7	5	*	6
Loss of Offsite Power	Train A Onsite Power, Train B Service Water, No Recovery of AC Power Before Core Damage	Train B onsite power, component cooling, high and low pressure makeup (ECCS), reactor coolant pump seal LOCA, containment filtration and heat removal.	4.4-6	8	6	*	1
Loss of Offsite Power	Train B Onsite Power, Train A Service Water, No Recovery of AC Power Before Core Damage	Train A onsite power, component cooling, high and low pressure makeup (ECCS), reactor coolant pump seal LOCA, containment filtration and heat removal.	4.4-6	9	7	*	1
PCC Area Fire	None	Component cooli[illegible] high and low pressure makeup (ECCS), reac[illegible] pump seal LOCA, containment filtration, and heat removal.	4.1-6	10	8	*	2

*Negligible contribution to risk.
**Identified but ranked low in Phase I.
†Not included in Phase I initiators.

NOTE: Exponential notation is indicated in abbreviated form; i.e., 3.3-5 = 3.3×10^{-5}.

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- Protective systems for chemical plants - Imperial Chemical Industries, Ltd. (Reference 1-6).
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- Transport of radioactive materials (Reference 1-8).
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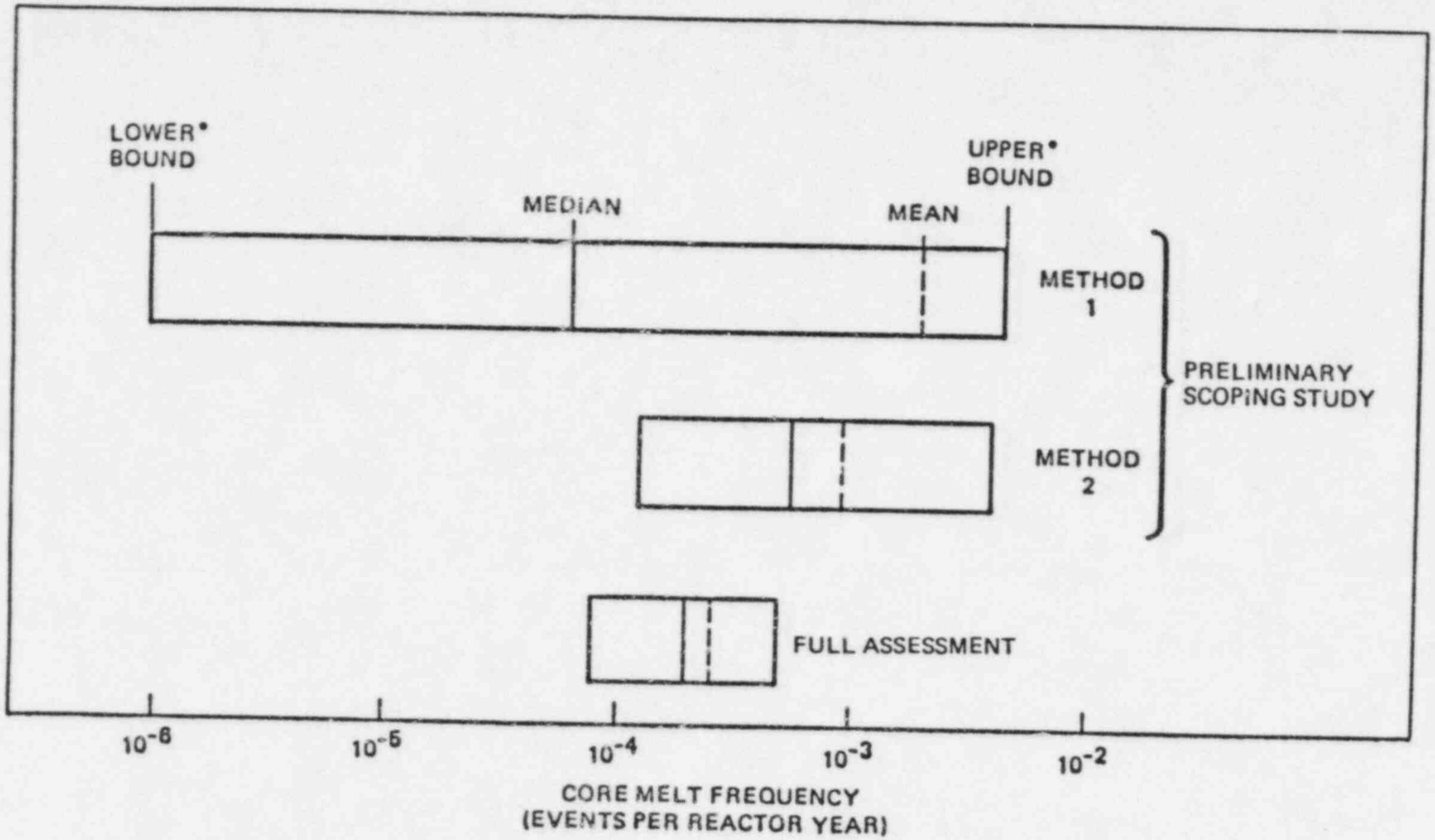
- OPSA, Oyster Creek Probabilistic Safety Analysis - a comprehensive risk analysis of the Oyster Creek Nuclear Power Plant (Reference 1-13).
- Accident initiation and progression analysis - a probabilistic risk assessment of the high temperature gas-cooled reactor (Reference 1-14).
- Clinch River Breeder Reactor Plant Risk Assessment Report - a risk assessment of the Clinch River Breeder Reactor (Reference 1-15).
- Crystal River-3 Safety Study - a safety study to determine the expected frequency of selected accident sequences associated with the operation of the Crystal River 3 power plant (Reference 1-16).
- Zion Probabilistic Safety Study - a comprehensive risk analysis of the Zion nuclear power plant (Reference 1-17).
- Indian Point Probabilistic Safety Study - a comprehensive risk analysis of the Indian Point nuclear power plants, Units 2 and 3 (Reference 1-18).
- Seabrook Station Probabilistic Safety Assessment - a comprehensive risk analysis of Seabrook Station Units 1 and 2 (Reference 1-19).
- Midland Nuclear Plant PRA (Reference 1-20).

FIGURE 1-1. EXAMPLES OF PRA APPLICATIONS



* LOWER AND UPPER BOUNDS CORRESPOND, RESPECTIVELY, TO 5TH AND 95TH PERCENTILES OF THE UNCERTAINTY DISTRIBUTIONS.

FIGURE 1-2. COMPARISON OF CORE MELT FREQUENCY RESULTS OBTAINED IN THE PRELIMINARY AND FULL ASSESSMENT PHASES OF THE SSPSA

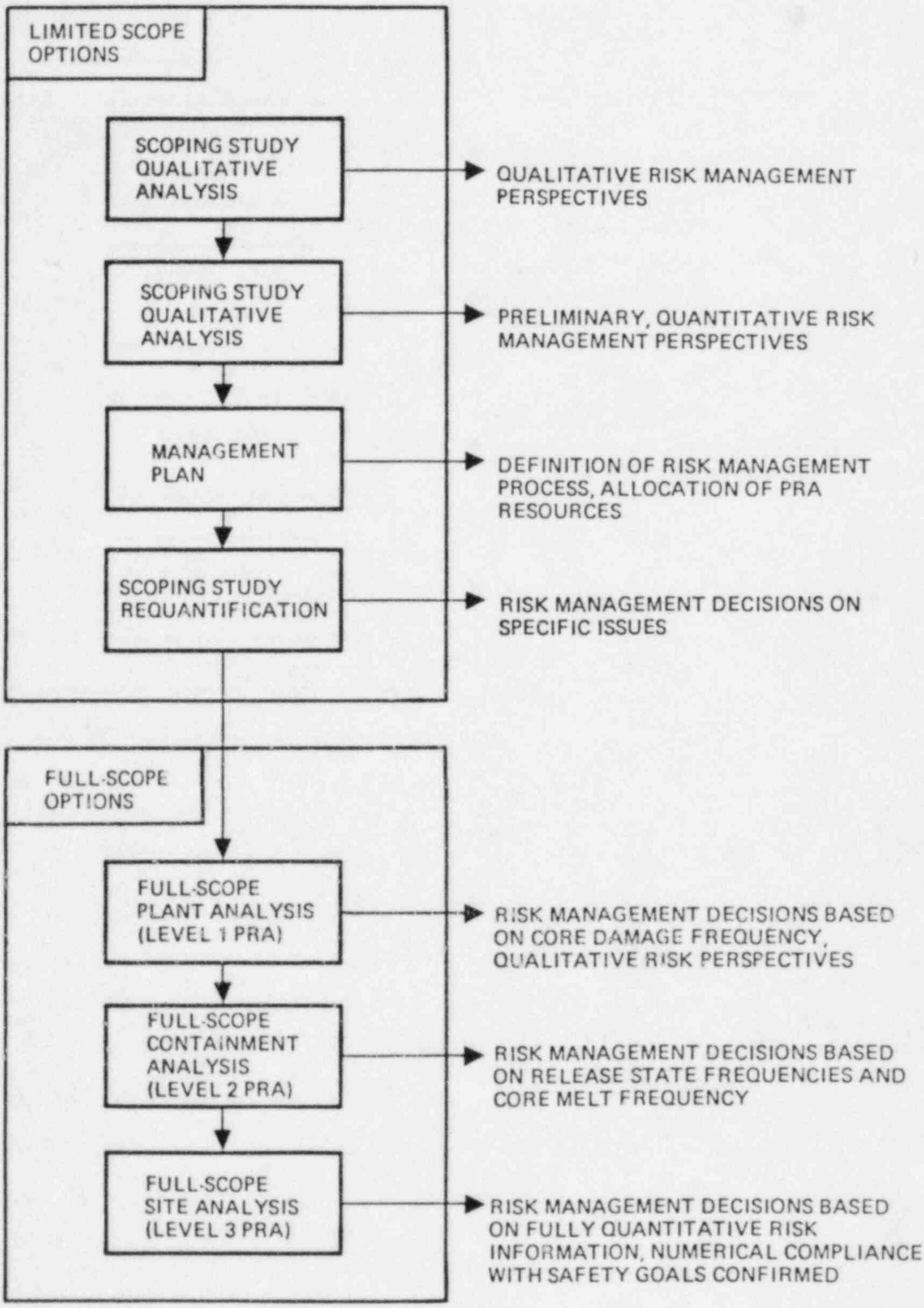


FIGURE 1-3. SEVEN OPTIONS TO DEFINING THE SCOPE OF A RISK ANALYSIS

2. RESULTS

The two reactor units at STPEGS are essentially identical and have certain shared structures. The degree of similarity is sufficient to permit the results to be applied to either reactor unit insofar as single-unit operations are concerned. Therefore, the results presented in this section apply to each unit viewed separately. The units for expressing accident frequency are "events per reactor year."

The results are presented in two parts to provide answers to the following two questions:

1. What is the likelihood of core melt?
2. What is the likelihood of offsite impact?

These questions provide a structure for the analytical work of this study and a framework for organizing the numerical results. Preliminary answers to these questions are provided by this Preliminary Scoping Study. The first answer is based on a detailed study of the plant and simplified plant models. The second answer is based on a survey of the STPEGS containment and extrapolations from existing containment and site analyses based on expert judgment.

To answer the important questions asked by the Scoping Study, we begin by identifying those events disturbing steady-state operation of the plant. The selection process for these "initiating events" is described in Section 4.2. A list of the initiating events analyzed in this study and their mean frequencies is given in Table 2-1. In our computations, the information in Table 2-1 is organized into a vector called the φ^I vector. The use of matrix algebra to assemble and analyze the risk contributors is explained in Section 3 but is not a prerequisite to understanding the results in this section.

It is important to distinguish among several broad groups of initiating events that have significantly different impacts. First are plant transients and loss of coolant accident (events 1 and 3 in Table 2-1). Some of these occur frequently, but the standby safety systems have been designed for such events and have a good chance to work. The rest of the initiators are really "common cause" events, which is to say that in addition to initiating a sequence of events, they degrade the performance of systems useful in stabilizing the plant.

The interfacing systems LOCA (event 2) is very unlikely to occur. Nevertheless, because it degrades safety injection and recirculation cooling, it leads directly to core melt. Furthermore, it bypasses containment, increasing the potential for offsite impacts. Thus, it is worth including and has been found to be significant for other plants.

The support system faults (events 4 through 7) degrade and fail key safety systems. Although their frequencies are much lower than simple transients, their occurrence can have significant impact. Current design practice that emphasizes train separation can exacerbate their effects.

Finally, the external events and internal plant hazards (events 8 through 16) can have modest to very far reaching common cause effects. They are mostly very rare events. Current design practice is aimed at reducing the impacts of these events and PRA results have generally shown that this practice has been quite successful.

The accident sequences following the initiating events, as well as the models tracking them to core melt, and plant damage states are described in Sections 4 and 7. Section 7 also discusses phenomenological paths through the containment model to release categories and their relationship to offsite impacts. These relationships are summarized in Table 2-2, where we see that scenarios bypassing or failing the containment and having no containment spray to scrub fission products have significant effects. Additionally, if a large breach of containment occurs with no containment spray before or just after core melt, significant early impact can result.

2.1 WHAT IS THE LIKELIHOOD OF CORE MELT?

Since the principal inventory of radioactive material at STPEGS is held within the zircaloy clad uranium dioxide fuel assemblies in the reactor core, there can be no significant release of this material from the reactor core unless there is core damage. A small proportion of this inventory is contained in the gaps between the fuel and cladding. The remainder, a much larger proportion, is trapped in the ceramic matrix of the fuel, which would have to be raised toward its melting temperature (about 5,000°F) before a major release could occur. In order for the integrity of the containment to be challenged as a consequence of a severe damage event, it is necessary for core damage to proceed to the point of full-scale melting of the fuel and penetration of the molten core debris through the bottom of the reactor vessel. Thus, our first concern is with the likelihood of severe core damage or damage of a significant number of these assemblies. A second concern is with the likelihood of full-scale core melt.

The level of resolution of the plant damage states used to categorize the accident sequences in the STP Scoping Study event trees does not permit a distinction between severe core damage and full-scale core melting that proceeds to penetration of the reactor vessel. In other words, any accident sequence that involves severe core damage to the point of onset of significant fuel melting is assumed in this study to result in core melt and vessel penetration. In earlier studies, the possibility of specifying additional plant states to distinguish between core melting and core damage short of melting was considered. The idea was rejected, however, upon finding that the time interval between onset of core damage and full scale fuel melting is short compared with the time interval between the initiating event and the time of core damage for risk significant scenarios. Therefore, there was a physical basis for the assumption that, given the onset of core damage, the conditional likelihood of core melt approaches unity. Thus, the terms "core melting" and "severe core damage" are used interchangeably in the discussion of the results presented below and in the remainder of the report. Depending on the scenario analyzed, the molten core debris may be cooled

within the reactor cavity and does not necessarily melt through the containment basemat as assumed in some prior PRA studies, such as the Reactor Safety Study.

Because of uncertainties, it is not possible to estimate a meaningful point value of the frequency of accident scenarios. Hence, we express our results for core melt frequency in terms of probability distributions. These distributions specify a range of possible core melt frequency values and probability weights for each value within this range.

Figure 2-1 presents the probability distribution for the frequency of core melt estimated the South Texas Project Preliminary Scoping Study. As can be seen from the figure, the median core melt frequency is about 3×10^{-4} events per reactor year. In other words, there is roughly a 50% chance that further study would find the core melt frequency for the South Texas plant as designed to be less than 3×10^{-4}, and a 50% chance that the actual frequency will be found to be greater. The mean frequency of core melt is slightly greater than 1×10^{-3} per reactor year, or about once in 700 reactor years of operation.

To get some feeling for the source of the core melt frequency curve, Figure 2-2 shows the contributions from internal events and the combination of external events and the interfacing systems LOCA (dominated by external event scenario frequencies). It is clear that the external event-generated sequences have only a small impact on the total core melt frequency. Section 2.3.2 explains the assumptions used in the various point value quantifications of internal events using the STP model and identifies uncertainties associated with those assumptions. It explains how the uncertainties in assumptions as well as other uncertainties were quantified and propagated through the results to develop the STP Scoping Study probability of frequency curves. Section 2.4 provides a detailed list of the most significant scenarios contributing to one example assumption set result.

Returning to the probability of core melt frequency, Figure 2-1, the highest values are a result of the small chance that the most pessimistic assumptions that were considered in this study apply combined with the possibility that our most pessimistic data for operator recovery and hardware failure also apply. Conversely, the lowest values result from the small chance that our most optimistic assumptions and data apply. Each possible combination of assumptions and data is weighted by the probability that it represents the "true state of the plant system," a system including hardware, procedures, and trained personnel that have not yet been built, written, or trained. Substantial uncertainty is inherent in the Scoping Study results.

The current value of the mean frequency of core melt reflects the large degree of uncertainty associated with the Scoping Study rather than a strong degree of evidence that a core melt is actually so likely to occur. Note that the distribution is quite broad. According to the results of our analysis, the core melt frequency has a 90% chance of being in the interval between 3×10^{-5} and 5×10^{-3}.

2.2 WHAT IS THE LIKELIHOOD OF OFFSITE IMPACT?

A wide spectrum of different radioactive material releases can be postulated. Each such release could have a different magnitude and composition of radionuclides, time-dependent release rate, thermal energy of release, and other factors that influence the calculation of accident impact. Release categories have been defined that group scenarios by these parameters. For a given release, the impact to the public is dependent on many external factors such as the directions of the wind at the time of the hypothesized accident, the atmospheric stability, weather conditions, the time of day, day of the week, season of the year, speed and effectiveness of evacuation, and many other factors. As stated earlier, we have grouped all these effects into three impact categories as shown in Table 2-2.

Figure 2-3 decomposes the probability distribution for the frequency of core melt into the contributions to each impact category. Category II, with potential for latent impacts, and Category III, with little public risk, provide similar contributions to core melt frequency. They arise from related but significantly different scenario groups. Both come primarily from RCP seal LOCA events. In the case of Category III, electric power remains available, making it possible to operate containment spray and scrub fission products from the containment atmosphere. Category II scenarios lead to the failure of onsite AC power; thus, sprays are unavailable following melt and the frequency of these scenarios are somewhat lower. The Category I scenario group with potential for early and latent impacts have much lower frequency and occur primarily when the containment supplementary purge valves remain open with no containment spray.

Details of the scenarios are given in Section 2.4. Consider the following as a greatly simplified summary of the basic scenario groups:

- Category III. A loss of cooling water (ECW or CCW) event leads to the loss of charging pumps and RCP thermal barrier cooling. An RCP seal LOCA results, followed by successful safety injection. When the shift to the recirculation mode occurs on low RWST level, no cooling is available. Core melt and eventual containment failure occur because decay heat is not removed. Containment sprays operate. Small containment bypass paths may exist.

- Category II. The loss of all AC power leads to an RCP LOCA with no safety injection, no containment spray, and no fan coolers. The scenario group is initiated either by a long term failure of EAB HVAC (both normal and smoke purge modes) or an unrecovered loss of offsite power followed by failure to deliver onsite diesel generator power. Core melt and eventual containment overpressure are guaranteed. Small containment bypass paths may exist. Scenarios with large bypass paths through the supplemental purge valves with containment sprays operable make a small contribution to this category.

- Category I. Scenarios similar to Category II in which the supplementary purge valves fail to close either because of valve problems or a failure of ESF actuation signal combined with the

failure of the operators to generate a signal. Note that no power is available to close the MOVs inside containment. The interfacing systems LOCA makes a small contribution to this category.

2.3 IDENTIFICATION AND QUANTIFICATION OF UNCERTAINTY

Assessing the risk from extremely rare events such as the potential accident sequences considered in a PRA is subject to significant uncertainties. In view of this, the authors have adopted an approach in which the expression of uncertainty is a fundamental consideration in presenting the results. As explained more fully in Section 3, this consideration is embodied in the definition of risk itself. The risk associated with potential accidents is defined by a list of accident sequences, an assessment of the likelihood and impact of each sequence, and a statement of the uncertainty. What is particularly special about the approach adopted by the authors is that every attempt is made to express this statement of uncertainty quantitatively. While the quantification of uncertainty is an important element in any PRA results, it is especially important in this limited-coverage Scoping Study.

The Preliminary Scoping Study includes many sources of uncertainty. Some are identical to those found in complete Level 1 studies on operating plants such as uncertainty in basic human error rates. Many are identical to those found in complete Level 1 studies on other plants in the construction stage with no operating history, such as plant-to-plant variability in equipment failure rates, uncertainty in common cause failure data for two-train systems, and uncertainty in the exact plant layout needed for fire analysis. Others are common to limited-scope studies such as incompleteness in coverage of initiating events, incompleteness in supporting analyses (e.g., equipment fragilities to temperature and seismic excitation and room heatup analyses), and simplified systems analyses. Finally some are peculiar to the STPEGS design and site such as uncertainty in common cause data for three-train and four-train systems and the capability of the RHR pumps to operate following a LOCA, or a bleed and feed operation that creates a hot, moist environment inside containment.

The general approach to quantification of uncertainty in the Preliminary Scoping Study results consisted of the following steps:

- Step 1. Point estimate quantification of STPEGS risk model using a "reasonable" set of assumptions for internally initiated sequences only.

- Step 2. Determination of the principal contributors to the point estimate result.

- Step 3. Identification of key sources uncertainty in the results of Steps 1 and 2 to include uncertainties in data, models, success criteria, plant behavior under accident conditions and sequences and contributors missing from the model.

- Step 4. Construction of a simplified risk model for propagation of sources of uncertainty.

- Step 5. Quantification of the effects of uncertainty in terms of probability distributions of the frequencies of accident sequences.

In applying Step 3 to the STPEGS risk model, the following major categories of uncertainties were identified.

- Data Uncertainties. These include uncertainties in the data used to quantify the risk model, especially that associated with the common cause events and operator actions in the dominant accident sequences of Table 2-3.

- Uncertainties in Assumptions. The most important uncertainties in assumptions were found to be the success criteria for HVAC systems, the thermal transient response of rooms resulting from degraded HVAC equipment, the effects of elevated temperatures on critical components, and the performance of RCP seals under loss of CCW and AC electric power conditions.

- Completeness. The approach to quantify these uncertainties was to make an allowance for missing sequences based on the results of completed, full-scope PRAs on plants similar to STPEGS.

The key uncertainties in the study and the methods used to account for them in the quantification process are described in the following sections.

2.3.1 DATA UNCERTAINTIES

The Scoping Study used the generic PLG data base for PWRs developed in the PRAs on Seabrook (Reference 2-1), Midland (Reference 2-2), and other plants was used without detailed review for applicability to STPEGS. It is expected that, if a Level 1 PRA were completed for STPEGS, the data base for component failure rates, maintenance frequencies and durations, and human errors would not change very much in relation to the data used in the Scoping Study results. The most important type of data that could change considerably is the common cause event data.

A common cause event is a failure of two or more redundant components due to a cause other than the failure of another component. Examples of such causes are design, manufacturing, and construction errors, erroneous procedures, human errors in following procedures, and environmental stresses. Common cause events are modeled primarily through the use of common cause parameters that express proportions of the component failure rates attributable to varying degrees of common cause failure. In a three-train or four-train system, such as the AFW system, several common cause parameters must be quantified for each redundant component and each failure mode applicable to the model. In a completed Level 1 PRA, these parameters are quantified by screening each event in a dependent events data base for a given component for assessment of applicability and degree of impact for each system in the risk model. In this fashion, design and operation-specific common cause parameters are quantified.

In this Scoping Study, common cause parameters were assumed, based on prior studies. Unfortunately, these parameters are known to exhibit large variability between designs and the results of systems quantification are quite sensitive to variations in these parameters. Generally, they are more sensitive to changes in these parameters than to variations in failure rates. In reviewing the quantifications of the dominant sequences, common cause parameters for the following components either dominated or made significant contributions to the accident sequence frequencies.

- Essential Cooling Water Pumps and Motor-Operated Valves
- Component Cooling Water Pumps and Motor-Operated Valves
- Essential Chilled Water Pumps and Chillers
- EAB HVAC Fans and Dampers
- Class 1E Diesel Generators
- AFWS Pumps and Motor-Operated Stop Check Valves

In addition to the above, there are many other components whose quantification was sensitive to assumptions regarding common cause parameters. A large portion of the uncertainty now appearing in the results in Figure 2-2 for internally initiated accident sequences is associated with the relatively large uncertainties in these common cause parameters.

A second category of uncertainty particularly important in the Scoping Study was the quantification of human actions. This is reflected in the facts that no in-depth human actions analysis was performed to quantify the operator actions and that detailed procedures to carry out such actions are not yet available for STPEGS. While the Westinghouse Emergency Response Guidelines were useful to help characterize several operator actions, no procedures were available for effecting others such as "smoke purge" HVAC operation. On balance, human action made the second most important contribution to the quantification of internally initiated sequences, insofar as the data-related uncertainties are concerned.

2.3.2 UNCERTAINTIES IN ASSUMPTIONS

Uncertainties in the study's assumptions about the RCP seal LOCA and the impact of degraded HVAC capability have been quantified using the basic PRA approach set forth in Section 3. We simply list the possibilities for the true state of the world (the scenarios, s_i), the probability that each is the true state (p_i), and the consequence associated with that state (x_i). Then, the set of triplets

$$\{<s_i, p_i, x_i>\}$$

is the complete representation of our state of knowledge and is the result of the PRA. Here, each scenario, s_i, is a discrete set of assumptions; the probability, p_i, represents the collective judgment of the study team that the set of assumptions is the true set; and the consequence, x_i, is the set of core melt sequence frequencies that would occur if the assumption set is the true set.

The judgments expressed in the probabilities reflects discussions with HL&P engineers, discussions with Bechtel and Westinghouse in the presence of HL&P engineers, and a review of limited Bechtel calculations of EAB heatup as well as the previous analytical and operational experience of the team. Note also that under each set of assumptions, a different list of dominant sequences is possible.

For the RCP seal LOCA, two discrete cases were considered. Based on previous review of the Westinghouse Owners' Group seal LOCA studies, current conversations with Westinghouse, and a consideration of modeling capabilities in the Scoping Study, the following two assumptions were quantified:

Assumption	Probability
S1 - RCP seal LOCA occurs in 2 hours.	0.22
S2 - RCP seal LOCA occurs in 16 hours.	0.78

For the case when 16 hours are available, additional recovery modes are possible: for example, operators could rig alternative cooling for the RCP thermal barriers (exact method would depend on the availability of power and the cause of the original loss of cooling) or they could adapt the existing Emergency Response Guideline for loss of all AC power to this situation and reduce RCS pressure and temperature to prevent the seal LOCA. Recovery analysis under assumption S2 evaluated such actions.

For the HVAC success criteria, many possibilities exist. For example, the EAB heatup calculations for the hottest day in the data base showed that with two trains of smoke purge, a peak temperature of 113°F coincided with the peak outside air temperature. At the end of 24 hours, EAB temperature fell to 109°F (16°F above initial value). No calculations were carried out for the next 24 hour temperature cycle. Calculations also showed that a single ECH train in normal operation would hold average temperature below 117°F for 24 hours. However, temperature was still rising. In both cases, equipment failure might still be possible if the operators are unable to restore normal HVAC, if the outside temperature were higher, if local hotspots exist in the EAB, or if some key equipment fails at lower temperature. Furthermore, outside air brought into the plant by smoke purge might be so humid that moisture-induced failures occur. On the other hand, electric power might be maintained and core melt averted even when the calculations show temperatures exceeding 120°F. For example, combinations of favorable weather conditions, exact HVAC status, and operator actions (with no procedures) such as stripping buses to reduce heat loads, rigging temporary blowers, and restoring or replacing failed equipment may work. Key equipment may not really fail until much hotter.

Because of all these wide-ranging uncertainties, a two-step process was used to select and evaluate possible sets of assumptions. First, based on available design information and supplementary calculations, we selected three discrete HVAC success criteria as follows:

EAB HEAT LOAD IS BASED ON THE NUMBER OF AC BUSES ENERGIZED

HVAC Success Criteria Assumptions	3	2	1
H1 - Smoke purge effective. Number of fan trains required (well supported case).	2	1	1
H2 - Smoke purge effective. Number of fan trains required (optimistic case).	1	1	1
H3 - Smoke purge ineffective. Normal HVAC required with the following equipment:			
Fan trains.	2	2	1
Tons of chiller capacity required.	750	600	450

If the normal HVAC criteria of assumption 3 are met (and they will be met if no system failures have occurred), no failures caused by HVAC can occur. The need for smoke purge arises only when the fan and chiller requirements of H3 are not satisfied.

Second, even if the "correct" success criteria (to really avoid equipment failure due to ambient temperature rise) based on limiting environmental conditions are known precisely, AC power may not fail. Uncertainties in actual environmental conditions (weather, etc.), heat loads (initially running equipment decay as equipment fails sequentially, etc.), and operator response can affect EAB heatup. To address these possibilities, we considered three discrete assumptions, trying the fragility of AC power to the "correct" success criteria and assessed the likelihood of each:

Fragility Assumption	Probability
F1 - AC power is guaranteed to fail if the HVAC success criteria are not met. (Probability of success is 0 if success criteria not met.)	0.170

Fragility Assumption	Probability
F2 - If the HVAC success criteria are not met, power may fail or succeed depending on the existing heat load, exact state of HVAC, outside air temperature, and effectiveness of ad hoc measures used by operators to control temperature (probability of success is 0.5).	0.710
F3 - AC power will not fail even if all HVAC (including smoke purge) fails. Minimal actions by the operators in response to rising temperature will occur. (Probability of success is 1.0 if success criteria not met.)	0.120

For our uncertainty analysis, it is necessary to combine the effects of the HVAC success criteria assumptions with the fragility assumptions. To do so, we first assess the probability of H1, H2, or H3, being the "correct" success criteria, conditional on (given that) F1 (then F2, then F3) is the fragility assumption:

Under This Fragility Assumption	This is the Conditional Probability of Each HVAC Success Criteria		
	H1 Smoke Purge (2,1,1)	H2 Smoke Purge (1,1,1)	H3 Normal HVAC Required
F1: AC Fails if Success Criteria Not Met	0.64	0.20	0.16
F2: 50/50 Chance of AC Failure if Success Criteria Not Met	0.53	0.37	0.10
F3: AC Not Failed by HVAC Failure	0	1	0

Combining the probability of each fragility assumption with the conditional probability of each success criteria, we obtain the joint probability of each combined HVAC assumption set:

The Joint Probability of Each Combined Fragility and Success Criteria Assumption Set*			
	H1 Smoke Purge (2,1,1)	H2 Smoke Purge (1,1,1)	H3 Normal HVAC Required
F1: AC Fails if Success Criteria Not Met	.11	.03	.03
F2: 50/50 Chance of AC Failure if Success Criteria Not Met	.38	.26	.06
F3: AC Not Failed by HVAC Failure	0	.12	0

Finally, the 7 possible HVAC assumption sets are combined with the 2 RCP seal LOCA assumptions to yield the 14 quantified assumption sets:

Assumption Set	Probability That This is the "Right" Assumption Set*	Mean Frequency of Core Melt Given These Assumptions
S2 F3 H2	0.09	1.70×10^{-4}
S2 F2 H2	0.20	2.87×10^{-4}
S2 F1 H2	0.03	3.97×10^{-4}
S2 F2 H1	0.30	5.17×10^{-4}
S2 F1 H1	0.09	8.67×10^{-4}
S1 F3 H2	0.03	9.73×10^{-4}
S1 F2 H2	0.06	1.09×10^{-3}
S1 F1 H2	0.01	1.20×10^{-3}
S1 F2 H1	0.08	1.32×10^{-3}
S1 F1 H1	0.02	1.67×10^{-3}
S2 F2 H3	0.05	5.65×10^{-3}
S1 F2 H3	0.02	6.45×10^{-3}
S2 F1 H3	0.02	1.11×10^{-2}
S1 F1 H3	0.01	1.19×10^{-2}

The distribution of uncertainty in assumptions, which includes a distribution on frequency for each assumption set, has been propagated

*The joint probabilities do not sum to 1.00 because of round-off error.

through the analytical results given in Sections 2.1 and 2.2. The different assumption sets generated distinct sets of dominant sequences. Dominant sequences are discussed in Sections 2.4 and 2.5.

2.3.3 COMPLETENESS

The final major source of uncertainty that was quantified in the Preliminary Scoping Study results was that associated with the completeness of the risk model. In addressing the issue of completeness, it is important to recognize that only selected internally initiated events were propagated through the detailed event sequence model. The most important initiating events not accounted for in the internal events analysis based on the results of published PRAs are external events and internal plant hazards.

The approach taken in the Scoping Study to quantify the uncertainty results associated with these events was to estimate, based on a limited state of knowledge, their possible range of contribution. In effect, this required the construction of a simplified risk model for external events and in-plant hazards and a quantification based on the results of completed PRAs on similar plants such as Seabrook. The higher level of uncertainty associated with this abbreviated treatment is reflected in much broader distributions for these Scoping Study results in Figure 2-2.

The simplified model for these events consists of two types of accident sequences: (1) events resulting in a nonrecoverable loss of offsite power combined with an independent loss of onsite AC power, and (2) events that lead directly to core melt because of the damage caused by the external event or in-plant hazard. The events considered in this analysis are listed in Table 2-1 as events 8 through 16, along with their mean occurrence frequencies. The nonrecoverable loss of offsite power events, Nos. 13, 15 and 16, were combined with events from the internal events analysis (such as loss of all three Class 1E diesel generators and loss of EAB HVAC equipment in violation of ventilation success criteria) to provide accident sequences which were assigned to impact Category II. The remaining external events were assigned directly to core melt and impact Category II. The quantification of these events was based on the results of completed PRAs with a subjective stretching of the distributions to account for the limited extent of the analysis. The results presented in Figure 2-2 reflect a large degree of uncertainty for this class of events and help to put the overall results into proper perspective. It is expected that a completed Level 1 PRA for STPEGS would exhibit vastly reduced ranges of uncertainty for this class of events.

2.4 QUANTIFICATION FOR ONE EXAMPLE ASSUMPTION SET

The results for core melt frequency in Figure 2-1 were obtained using the matrix approach to risk assembly for each assumption set. The approach is described in Section 3. It first leads to the development of point estimates of the frequencies of a large number of accident sequences. These sequences are categorized with respect to whether core melt occurs, and for core melt sequences, they are further grouped on the basis of the resulting plant damage states, release states, and impact categories. A

sequence of matrix operations is used to assemble and decompose the results to identify risk contributions. A result of this process is the listing of important accident scenarios that contribute to risk.

A word of caution is appropriate before proceeding to the example set results. Recall that the example set is only one of several possible cases considered in the full state-of-knowledge uncertainty treatment of Section 2.3. It is, in fact, assumption set S1, F2, H1 and is only assigned about an 8% chance of being the true state of the plant. Therefore, if an attempt is made to compare the example set with point estimates derived from the curves of this section, only partial agreement can be expected. For example, the relative magnitudes of Categories II and III change. (Category III is larger in the example set and smaller when uncertainty is quantified.) The primary reason is that a lower probability is assigned to the example set assumption that an RCP seal LOCA will develop in 2 hours than to an assumption that it takes much longer. With more time and with available equipment and power, the chance for the operators to successfully intercede increases and the probability of developing the LOCA decreases. Therefore, scenarios that proceed to melt via the seal LOCA alone (such as those in the scenario group described for Category III) become relatively less important.

The reader must wonder why we chose one of the less likely assumption sets as the example case. Presenting the most likely set would be more desirable. The reason is historical. One assumption set that appeared most likely early in the project was selected for detailed analysis. The results for the example case are more complete than for other assumption sets and remain our selection for detailed presentation. Unfortunately, toward the end of the project, with more complete information in hand and the full group of assumption sets defined for final quantification, the picture has changed. Nevertheless, it is still reasonable to present the example case. It is most complete and scenario definitions from the example case served as the basis for calculating changes under changed assumptions.

2.4.1 ASSUMPTIONS

The example set calculation is based on a single set of assumptions, which had been adopted as a reasonable set for developing the basic point estimate results of the study. The key assumptions are the following:

1. EAB HVAC success criteria as a function of the Class 1E ESF buses energized (assumption H1):

Buses Energized	Normal Mode		Smoke Purge Mode
	Fan Trains	Tons of Chiller Capacity Required	Fan Trains
3	2	750	2
2	2	600	1
1	1	450	1

2. Even if the HVAC success criteria are not met, there is assessed a 50% chance that no loss of AC power will occur (assumption F2).

3. Following loss of seal injection and thermal barrier cooling, the RCP seals will degrade in about 2 hours, causing a LOCA of several hundred gpm per pump (assumption S1).

2.4.2 RECOVERY ANALYSIS

In PRA, the usual approach is to include only those operator actions in the progression of scenarios that are required by procedure. In a second pass ("recovery analysis"), additional operator actions are considered on a scenario-by-scenario basis. There are two important reasons for adopting this approach. The first addresses the question of dependency: operator response to an adverse condition is heavily scenario-dependent. The number of operators available, the other demands competing for their attention, the time window available for action, the specific cues identifying the problem and the distractions that create the potential for misperceptions are just some of the unique aspects of each scenario. Failure to account for these dependencies can lead to overly optimistic evaluation of human response. The second reason for this approach addresses the practical realities of analysis. There are limitless combinations of possible human actions during any scenario. If any analysis is to reach closure, the cases considered must be limited to the important classes of actions that can be frequent enough to impact study results.

The Scoping Study has followed the usual practice and a recovery analysis has been performed to improve the level of realism of the results. Any sequence contributing at least 1% of the example set core melt frequency has been examined and, if reasonable, additional operator response ("recovery") has been incorporated. The kinds of recovery actions considered include the following:

- Starting redundant trains of support equipment such as ECW trains, CCW trains, etc.

- Shifting HVAC to the smoke purge mode if sufficient chiller trains are unavailable.

- Manually generating a safeguards signal if the automatic system fails.

- Manually opening AFWS valves if the motor operators fail.

- Restoring offsite power following a LOSP.

- Remote closing of the motor-operated supplementary purge valves, which are inside containment, if power is available.

These recovery analyses have been applied to the dominant scenarios of Section 2.4.3 below.

2.4.3 PRINCIPAL CONTRIBUTORS TO THE RESULTS

The ultimate benefits of a risk model such as the one developed for STPEGS in this Scoping Study are the quantitative and qualitative bases that it provides for effecting risk management. One such basis is an understanding of the relationship between the results and important characteristics of the plant design, its operational procedures, and the state of knowledge regarding how it behaves under a spectrum of abnormal and accident conditions. The essence of this relationship is conveyed in terms of the principal contributors to the results. The PRA methodology used to develop and quantify the STPEGS risk model has been carefully designed to facilitate tracing of the important contributors as well as to generate the numerical results themselves. A summary of this methodology is provided in Section 3.

The elemental form of the results of a risk assessment is a listing of event sequences or scenarios, an estimate of the frequency and impact of each sequence, and a quantification of the uncertainty associated with these estimates. There are several different ways to express the contributors to the results. One way is to put the accident sequences into groups based on sequence characteristics such as initiating event, plant damage state or impact. One such a breakdown of contributors was provided in Figure 2-2 which showed that internally initiated accident sequences were dominant with respect to core melt frequency. Another such breakdown was shown in Figure 2-3 with the message that, when grouped by impact potential, only a small contribution of the core melt frequency comes from sequences assigned to the most severe impact category, Category I.

Another perspective on contributors is provided by tracing specific accident sequences through the risk model from initiating event to termination in a plant state. By following specific paths through the event sequence model that are responsible for the major portion of the frequency of each group of sequences defined previously, important system failures, human actions, design features and modeling uncertainties can be identified. In Table 2-3, a listing of the most important accident sequences under the assumption set S1, F2, H1 is provided. These sequences are ranked in terms of their contribution to core melt frequency. This table describes individual paths through the STPEGS plant model in three parts: (1) the initiating event, (2) additional plant and operator actions contributing to sequence frequency and plant state, and (3) functionally dependent failures resulting from events in Parts 1 and 2.

Because of the limitations in scope and objectives of this Scoping Study, detailed tracing of contributors was only possible for the internally initiated group of accident sequences. In terms of the example set point estimate results, this group comprised about 87% of the total core melt frequency. The 11 sequences in Table 2-3 cover more than 95% of the core melt frequency associated with the internally initiated group, or roughly 82% of the total point estimate core melt frequency. The remaining 18% of the core melt frequency not shown in this table is distributed over a large number of internally initiated sequences, each having a small frequency and externally initiated sequences that were not subdivided into individual sequences in this Scoping Study analysis.

As evident in Table 2-3, support system failures and operator actions dominate the results at the event sequence level of analysis. Take, for example, the first sequence, which is initiated by a general transient event such as a turbine trip from full power. In normal plant operation, there is one running train of essential cooling water, one train in standby and ready to start automatically if the normally running train fails, and one train in the "OFF" position, which can be brought online via remote manual action. (All three trains of ECW are signalled to start automatically upon generation of a safety injection signal.) In this first sequence, the normally running train of ECW fails to continue running following the initiating event and the standby train fails to start on demand. The operator then attempts to start the "OFF" train of ECW and, when it fails, puts the EAB HVAC system into the "smoke purge" or open loop mode of operation. The latter action successfully prevents damage to EAB and control room envelope equipment and, therefore, AC power availability is maintained. However, all three trains of ECW are lost. The integrity of the reactor coolant pump seals is dependent on the success of at least one train of ECW, because with no ECW, there can be no component cooling water and, therefore, the RCP thermal barrier coolers and the charging pumps that provide RCP seal injection cease functioning. Also, because the ECW through the CCW provides heat removal for the ECCS/RHR heat exchangers and the containment fan coolers, core recirculation cooling and containment heat removal functions are lost. The high head safety injection pumps provide ECCS injection, but when ECCS shifts to recirculation, no cooling is available to the RHR heat exchanger and core melt follows. Note that the dependent failures in Part 3 of the sequence definition occur with a conditional frequency of 1, given the events in Parts 1 and 2, because of functional intersystem dependencies in the plant design. Hence, the frequency of each accident sequence is determined by the events that occur in Parts 1 and 2.

The second ranking sequence in Table 2-3 begins with a general transient event such as turbine trip and includes support system failures and important operator actions as with sequence 1. In this case, the support system exhibiting failures is the EAB HVAC system. In normal plant operation before the initiating event, there are two normally running trains of HVAC fans and the third train is in the "OFF" position so that only operator action or safety injection signal can initiate a start signal. In this second sequence, one of the two normally running HVAC fan trains fails to continue running following the initiating event. Because of the need to properly line up the ECW, essential chilled water and HVAC fan trains, the operator takes action to start the "OFF" trains of ECW, ECH, and EAB HVAC. Subsequently, however, a second train of EAB HVAC fails and that, according to the assumptions for this example set, violates the success criterion for EAB ventilation. As noted earlier for the example set of assumptions, successful EAB ventilation requires two trains of EAB HVAC fans and dampers when three buses are energized. Variations in the results due to uncertainties in these and other important success criteria assumptions are described and quantified in Sections 2.3 and 2.5. Because of the violation of the EAB ventilation criterion for sequence 2, AC power is assumed lost and, therefore, so is all electrically driven equipment, including ECW and CCW. The dependent failures listed in part 3 for this sequence include those for sequence 1, loss of ECCS injection capability and the inability to close any initially open containment isolation valve with an AC motor operator.

The third sequence in Table 2-3 is similar to sequence 1 except that, instead of losing all three trains of ECW following a general transient initiator, all three trains of CCW are lost. Sequences 4 and 5 correspond with sequences 1 and 3 except that, instead of ECW or CCW loss subsequent to a general transient initiating event, the loss occurs as the initiating event itself.

Sequence 6 is a loss of offsite power initiating event followed by failure of all three Class 1E diesel generators and failure to recover offsite power within 2 hours. The example set point estimate assumptions reflected in the results of this table include the assumption that the RCP seal LOCA occurs quickly and is severe enough to result in core uncovery and damage within 2 hours. The possibility of a more slowly developing seal LOCA with core uncovery in 16 hours is considered in the quantification of uncertainty as described in Sections 2.3 and 2.5. The prolonged loss of AC power postulated in this sequence results in the same set of dependent failures as sequence 2.

Accident sequence 7 is the same as sequence 2 except that an additional train of equipment is postulated to fail the "OFF" train of ECW. As with sequence 2, the EAB ventilation success criteria are violated and the dependent failures include loss of AC electrically driven equipment. Sequence 8 is the same as sequence 7 except that it is the "OFF" train of ECH that fails, rather than the "OFF" train of ECW; however, the resulting dependent failures are the same.

Sequence 9 is the first sequence encountered in which key equipment failures are located within frontline safety systems, rather than support systems. This is typical of PRA results for modern PWR plants like STPEGS. This sequence begins with a small LOCA initiating event, successful reactor trip and ECCS injection, and operator action to isolate the RWST and to enable switchover to core recirculation cooling. As a result of valve failures of various types; e.g., a check valve failing to close in a non-isolated RWST injection path, core recirculation cooling fails and core melt occurs. However, all containment systems function properly for this sequence, largely due to the proper functioning of support systems.

In sequence 10, as with several higher ranking sequences, equipment failures in HVAC systems are postulated following a general transient initiating event. Unlike the higher ranking sequences, in which favorable operator actions are postulated, in this sequence the operator fails to start the "OFF" trains of HVAC and support equipment and fails to initiate "smoke purge" HVAC operation. The dependent failures for this sequence are like sequence 2 because of the assumed loss of EAB ventilation.

The final sequence presented in Table 2-3 is only the second sequence presented in which crucial equipment failures occur in the frontline systems and not in the support systems. It is initiated by a general transient initiating event and a postulated failure of all four trains of the auxiliary feedwater system. The operator attempts to manually start the AFW train with the steam turbine-driven pump, but nonrecover pump or

MOV failures are encountered. The operator then fails to initiate bleed and feed cooling in time to be effective and core melt ensues. The availability of support systems along this sequence precludes additional dependent failures in part 3 of the sequence description.

The impact category assignments for each of the above 11 sequences are listed in the last column of Table 2-3. None of these 11 sequences were assigned to impact Category I, which is associated with the most severe levels of impact, because of the lower frequency associated with these sequences. A Category I impact requires early, gross failure of the containment due to either an interfacing systems LOCA or an initially open and failed-open supplementary purge containment isolation valve and failure of containment spray. The total frequency of Category I sequences for the example set was only 6.6 x 10^{-6}; therefore, none of these appear in Table 2-3. Of those sequences that do appear, the ones that have no AC electric power belong to Category II and the ones with AC electric power to Category III, the most benign impact category. Category II sequences are typified by a delayed containment overpressurization and loss of sprays, while Category III includes containment intact, basemat melt-through and overpressurization with spray cases.

2.4.4 SENSITIVITY TO SUPPLEMENTARY PURGE OPTIONS

An important objective of the Preliminary Scoping Study was to provide information about the sensitivity of the results to a number of options associated with the supplementary purge isolation valves. Six options were investigated as defined in Table 2-4. What was varied among these options were the number of fail-closed type valves in each of the two supplementary purge penetrations and the fraction of time all the valves in these penetrations are left initially open (i.e., are assumed to be open at the time of the initiating event). Fail closed-type valves have the characteristic of initiating closure upon loss of AC electric power, whereas both fail-closed and fail-as-is valves initiate closure upon receipt of a containment isolation signal. Among these options, the example set results described in the previous sections correspond with option 2.

The sensitivity of the results to the different supplementary purge containment isolation valve options required the STPEGS risk model to be requantified separately for each option. Top events in the event trees associated with containment isolation had to be requantified for each case and the modeling of front line system to support system interdependencies had to be modified as appropriate. The results in terms of point estimates for the frequencies of impact categories and core melt are shown in Table 2-5. As seen in this table, there is no variation in core melt frequency because the design options considered are independent of core cooling. Also, the differences are very minor for impact Category III and only one significant departure from the example set result was noted in Category II; namely, option 1. As expected, the principal sensitivity in the results to these options was observed in impact Category I.

As noted above, Category I sequences include the interfacing systems LOCA and sequences with failed-open supplementary purge isolation valves and failure of containment sprays. The departure in Category II observed in option 1 is due to the difference in frequency associated with sequences involving failed-open supplementary purge isolation valves with sprays working. Because the assessment of interfacing systems LOCA was not affected by these options, all the variations in impact Category I are due to variations in the frequency of sequences with failed-open supplementary purge isolation valves and failed containment sprays. Starting from the example set of option 2, the frequency of impact Category I increases by almost 2 orders of magnitude for option 1, which mostly reflects the reliability assumed for one fail-closed type valve. Surprisingly, when moving to option 3, which has a considerably greater cost, the reduction in Category I frequency is minimal. This is because of the relatively high contribution to both of these cases from sequences with electric power available, in which the failed-closed feature is unimportant. Options 4, 5 and 6 correspond with options 1, 2, and 3 in terms of contributors, but the frequencies are lower to correspond with the smaller fraction of time the valves are initially open.

It is very important to note that the impact category assignments in Table 2-3 are applicable to the example set (option 2 only). For example, in the case of option 1, the sequences in Table 2-3 assigned to Category II would have to be reassigned to Category I, since the loss of all AC power would leave the initially opened supplementary purge isolation valves open and the containment sprays failed.

2.5 IMPACT OF ASSUMPTION SETS ON DOMINANT SEQUENCES

As we move through the assumption sets defined in Section 2.3.2, it is obvious that the dominant sequences of Section 2.4.3 will change. A straight-forward summary of those changes is provided below.

First, consider the RCP seal LOCA. All but 2 of the scenarios (numbers 8 and 11) progress to core damage by a seal LOCA combined with failure of safety injection or recirculation cooling. If the seal LOCA takes longer to occur (assumption S2), then in the example case (S1), the frequency of core damage due to these scenarios decreases because the operator has more time to take corrective action as discussed in Section 2.3.2. The S1/S2 assumptions have no impact on consequence category.

Second, consider the HVAC Success Criteria Assumptions H1, H2, and H3 (see Section 2.3.2). Assumption H1 is the example set. Under Assumption H2, some loss of ventilation scenarios leading to core melt in the example set would become successes. Thus, the contributions from the loss of all AC power scenario groups (like sequence 2 in Table 2-3) would decrease and the frequencies of core melt and especially impact Category II would decrease. Under assumption H3, all the smoke purge recovery actions of the example set would be ineffective. Frequent sequences now going to success would go to core melt and the frequencies of melt and Categories I and II would increase.

Finally, consider the fragility assumptions on electric power, F1, F2, amd F3. The example set uses the most likely assumption F2. Under F1 (i.e., AC power fails if the HVAC success criteria are not met), the chance of core melt via HVAC induced failure of AC power would increase. Scenarios similar to number 2 in Table 2-3 become more frequent and begin to dominate the loss of ECW scenarios (number 1 in Table 2-3). Under F3, AC power is essentially independent of HVAC. Scenario number 2 and those like it would disappear, and the frequency of core melt would be substantially reduced.

2.6 REFERENCES

2-1. Pickard, Lowe and Garrick, Inc., "Seabrook Station Probabilistic Safety Assessment," prepared for Public Service Company of New Hampshire and Yankee Atomic Electric Company, PLG-300, December 1983.

2-2. Pickard, Lowe and Garrick, Inc., "Midland Probabilistic Risk Assessment," prepared for the Consumers Power Company, May 1984.

TABLE 2-1. INITIATING EVENT FREQUENCIES FOR STPEGS SCOPING STUDY QUANTIFICATION

Group	Initiating Event Category	Code	Frequency (events per reactor year)
Loss of Coolant Inventory	1. Small LOCA	SLOCA	1.7-2
	2. Interfacing Systems LOCA	ISLOCA	1.6-7
Transients	3. General Transient	GT	1.1+1
Common Cause Initiating Events			
Support System Faults	4. Loss of Offsite Power	LOSP	9.5-2
	5. Loss of Essential Chilled Water	LECH	7.3-3
	6. Loss of Component Cooling Water	LCCW	3.9-5
	7. Loss of Essential Cooling Water	LECW	1.3-4
External Events	8. Aircraft Crash Leading to Core Damage	AC	7.0-8
	9. Turbine Missile Leading to Core Damage	TM	5.7-8
	10. Tornado Excessive Wind Leading to Core Damage	TRW	1.1-8
	11. Tornado Missile Leading to Core Damage	TRM	7.4-8
	12. Hazardous Chemical Release Leading to Control Room Inhabitability	HCR	7.6-6
	13. Seismic-Induced LOSP	SLOSP	2.0-5
	14. Other Events Leading to Core Damage	OCM	1.2-4
Internal Plant Hazards	15. Fire-Induced LOSP	FLOSP	5.2-4
	16. Flood-Induced LOSP	FLEP	2.6-4

NOTE: Exponential notation is indicated in abbreviated form; i.e., 1.7-2 = 1.7 x 10^{-2}.

CAUTION: PRELIMINARY RESULTS
IMPORTANT UNCERTAINTIES
DESCRIBED IN THIS SECTION

TABLE 2-2. RELATIONSHIPS OF SCENARIOS TO OFFSITE IMPACT CATEGORIES

Impact Category	Description	Typical Scenarios
I	Significant potential for early and latent health effects.	A large containment leak path exists at the time of core melt with containment sprays failed.
II	Significant potential for latent health effects and, at most, only small numbers of early health effects.	A small containment leak path exists at the time of core melt with containment sprays failed (late overpressure containment failure is also possible if there is no containment heat removal); a large containment leak path with sprays operating; or containment intact at core melt but no containment sprays or heat removal--late overpressure containment failure or basemat melt-through with fission products "burped" to atmosphere between basemat and concrete mud mat.
III	Potential for at most only small numbers of latent health effects.	Any other scenario--most likely both containment spray and heat removal are available.

CAUTION: PRELIMINARY RESULTS
IMPORTANT UNCERTAINTIES
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TABLE 2-3. ACCIDENT SEQUENCES WITH SIGNIFICANT CONTRIBUTIONS TO CORE MELT FREQUENCY BASED ON POINT ESTIMATE EXAMPLE CASE ASSUMPTIONS AND STPEGS MODEL

Core Melt Frequency Rank	Event Sequence Definition			Event Sequence Frequency (events/reactor-year)	Impact Category
	Part 1 - Initiating Event	Part 2 - Plant Failures and Operator Actions Contributing to Sequence Frequency and Plant Damage State	Part 3 - Functionally Dependent Failures Resulting from Events in Parts 1 and 2		
1	General Transient	Failure of running and standby trains of ECW, operator starts "OFF" ECW train which fails, and starts "SMOKE PURGE," AC power and ECCS injection availability maintained.	RCP seal LOCA, core recirculation cooling and containment heat removal.	3.7×10^{-4}	III
2	General Transient	Failure of one of two running trains of EAB HVAC fans, operator starts "OFF" trains of ECW, ECH, and EAB HVAC fans and, subsequently, a second train of EAB HVAC fans fails.	EAB ventilation, AC power, RCP seal LOCA, ECCS injection, containment heat removal, motor-operated containment isolation valves.	2.2×10^{-4}	II
3	General Transient	Failure of running and standby trains of CCW, operator starts "OFF" trains of CCW and ECW; subsequently, the third train of CCW fails, AC power and ECCS injection availability maintained.	RCP seal LOCA, core recirculation cooling and containment heat removal.	1.6×10^{-4}	III
4	Loss of All Three ECW Trains	Operator starts "SMOKE PURGE," AC power and ECCS injection availability maintained.	RCP seal LOCA, core recirculation cooling and containment heat removal.	1.3×10^{-4}	III
5	Loss of All Three CCW Trains	No additional failures, AC power and ECCS injection availability maintained.	RCP seal LOCA, core recirculation cooling and containment heat removal.	3.9×10^{-5}	III
6	Loss of Offsite Power	Failure of all three standby Class 1E diesel generators, operator fails to recover offsite power (no credit for diesel generator recovery).	AC power, RCP seal LOCA, ECCS injection, containment heat removal, motor-operated containment isolation valves.	3.5×10^{-5}	II
7	General Transient	Failure of one of two running trains of EAB HVAC fans, operator starts "OFF" trains of ECW, ECH, and EAB HVAC fans. Subsequently, the "OFF" train of ECW and a second train of EAB HVAC fans fail.	EAB ventilation, AC power, RCP seal LOCA, ECCS injection, containment heat removal, motor-operated	3.3×10^{-5}	II

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TABLE 2-3 (continued)

Sheet 2 of 2

Core Melt Frequency Rank	Event Sequence Definition			Event Sequence Frequency (events/reactor-year)	Impact Category
	Part 1 - Initiating Event	Part 2 - Plant Failures and Operator Actions Contributing to Sequence Frequency and Plant Damage State	Part 3 - Functionally Dependent Failures Resulting from Events in Parts 1 and 2		
8	General Transient	Failure of one of two running trains of HVAC fans, operator starts "OFF" trains of ECW, ECH, and EAB HVAC fans. Subsequently, the "OFF" train of ECH and a second train of EAB HVAC fans fail.	EAB ventilation, AC power, RCP seal LOCA, ECCS injection, containment heat containment isolation valves.	3.2×10^{-5}	II
9	Small LOCA	ECCS switchover to core recirculation cooling attempted but sump recirculation valves fail; all other systems available except that noted in Part 3.	Core recirculation cooling.	1.6×10^{-5}	III
10	General Transient	Failure of one of two running trains of EAB HVAC fans or one running 300-ton chiller, operator fails to start "OFF" trains of ECW and ECH, failure to start "SMOKE PURGE."	EAB ventilation, AC power, RCP seal LOCA, ECCS injection, containment heat removal, motor-operated containment isolation valves.	1.4×10^{-5}	II
11	General Transient	Failure of all four trains of AFW, operator resets AFW turbine and manually opens motor-operated stop/check valve in turbine-driven AFW train, turbine-driven AFW pump train still fails to start, operator fails to initiate bleed and feed cooling, all other systems available.	None	1.2×10^{-5}	III

CAUTION: PRELIMINARY RESULTS
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DESCRIBED IN THIS SECTION

TABLE 2-4. DEFINITION OF SUPPLEMENTAL PURGE ISOLATION VALVE OPTIONS QUANTIFIED USING STPEGS MODEL

Case	Number of Fail Closed Type Valves Per Penetration	Fraction of Time (hours per year) Valves Initially Open
1	0	1.00 (8,766)
2*	1	1.00 (8,766)
3	2	1.00 (8,766)
4	0	.06 (500)
5	1	.06 (500)
6	2	.06 (500)

*Also corresponds with example case results.

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TABLE 2-5. SENSITIVITY OF RESULTS TO SUPPLEMENTARY PURGE ISOLATION VALVE DESIGN OPTIONS

Design Option*	Accident Frequency (events/reactor-year)**			
	Impact Category			Core Melt
	I	II	III	
1. Zero FC, Two MOV 100% Open	4.0-4	2.0-4	8.3-4	1.4-3
2. One FC, One MOV 100% Open (base case)	6.6-6	5.9-4	8.3-4	1.4-3
3. Two FC, Zero MOV 100% Open	6.3-6	5.9-4	8.3-4	1.4-3
4. Zero FC, Two MOV 6% Open	3.3-5	5.7-4	8.4-4	1.4-3
5. One FC, One MOV 6% Open	7.0-7	6.0-4	8.4-4	1.4-3
6. Two FC, Zero MOV 6% Open	6.7-7	5.9-4	8.4-4	1.4-3

*FC = fail-closed type valve
MOV = motor-operated valve (fail-as-is)
**All results are point estimates.

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IMPORTANT UNCERTAINTIES
DESCRIBED IN THIS SECTION

CAUTION. PRELIMINARY RESULTS
IMPORTANT UNCERTAINTIES
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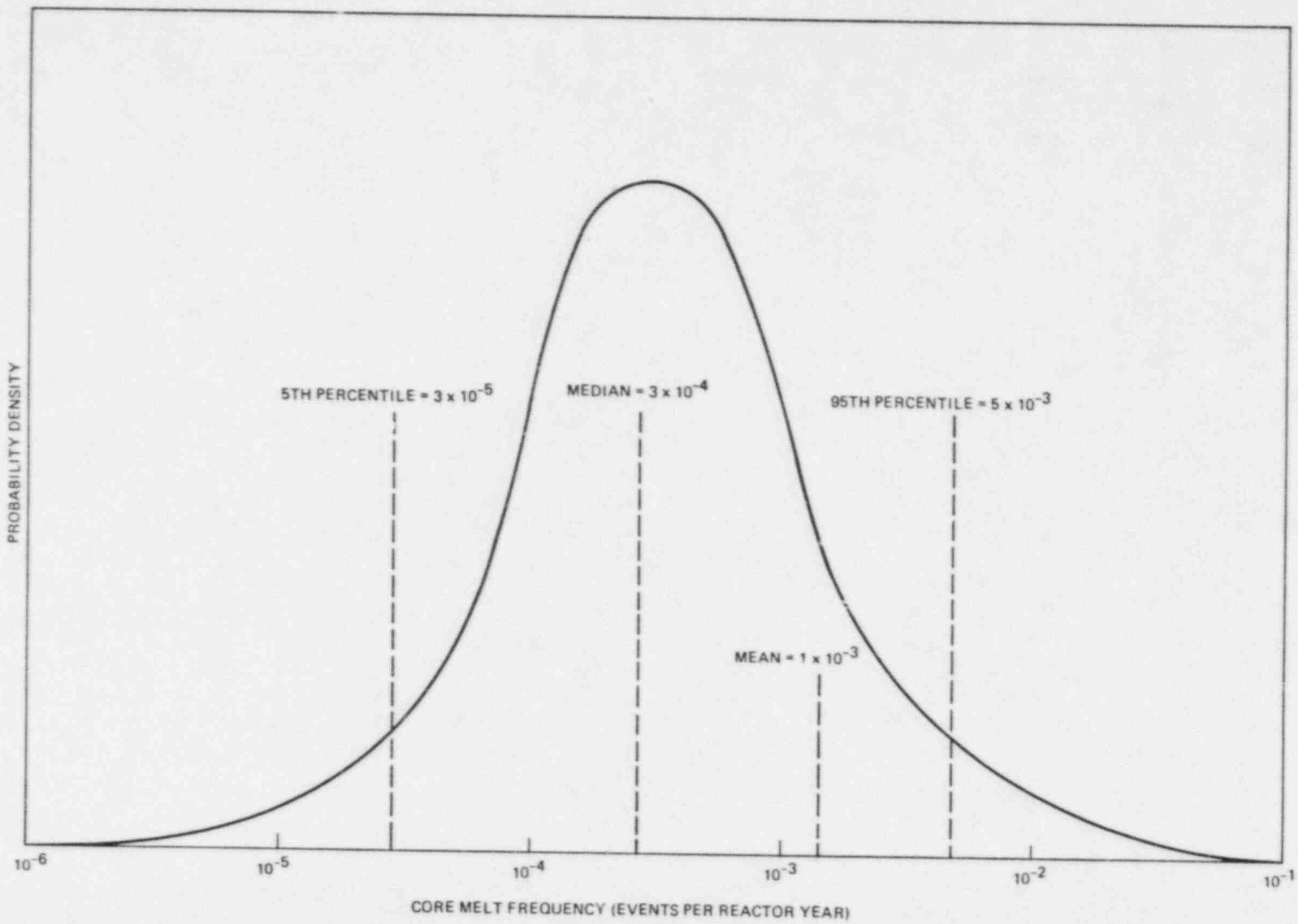


FIGURE 2-1. PROBABILITY DISTRIBUTION FOR CORE MELT FREQUENCY

CAUTION: PRELIMINARY RESULTS
IMPORTANT UNCERTAINTIES
DESCRIBED IN THIS SECTION

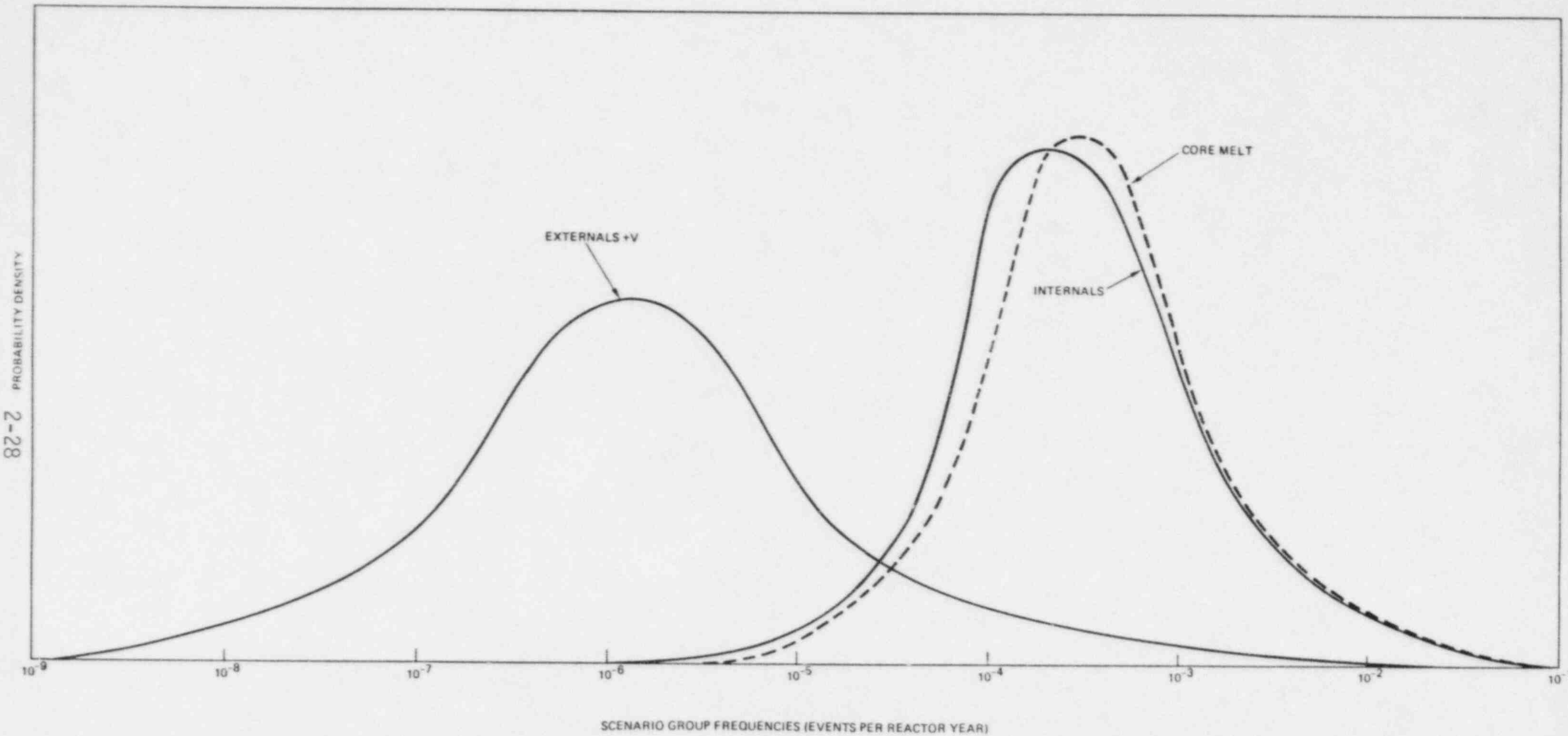


FIGURE 2-2. PROBABILITY DISTRIBUTIONS FOR SCENARIO GROUP FREQUENCIES

CAUTION: PRELIMINARY RESULTS
IMPORTANT UNCERTAINTIES
DESCRIBED IN THIS SECTION

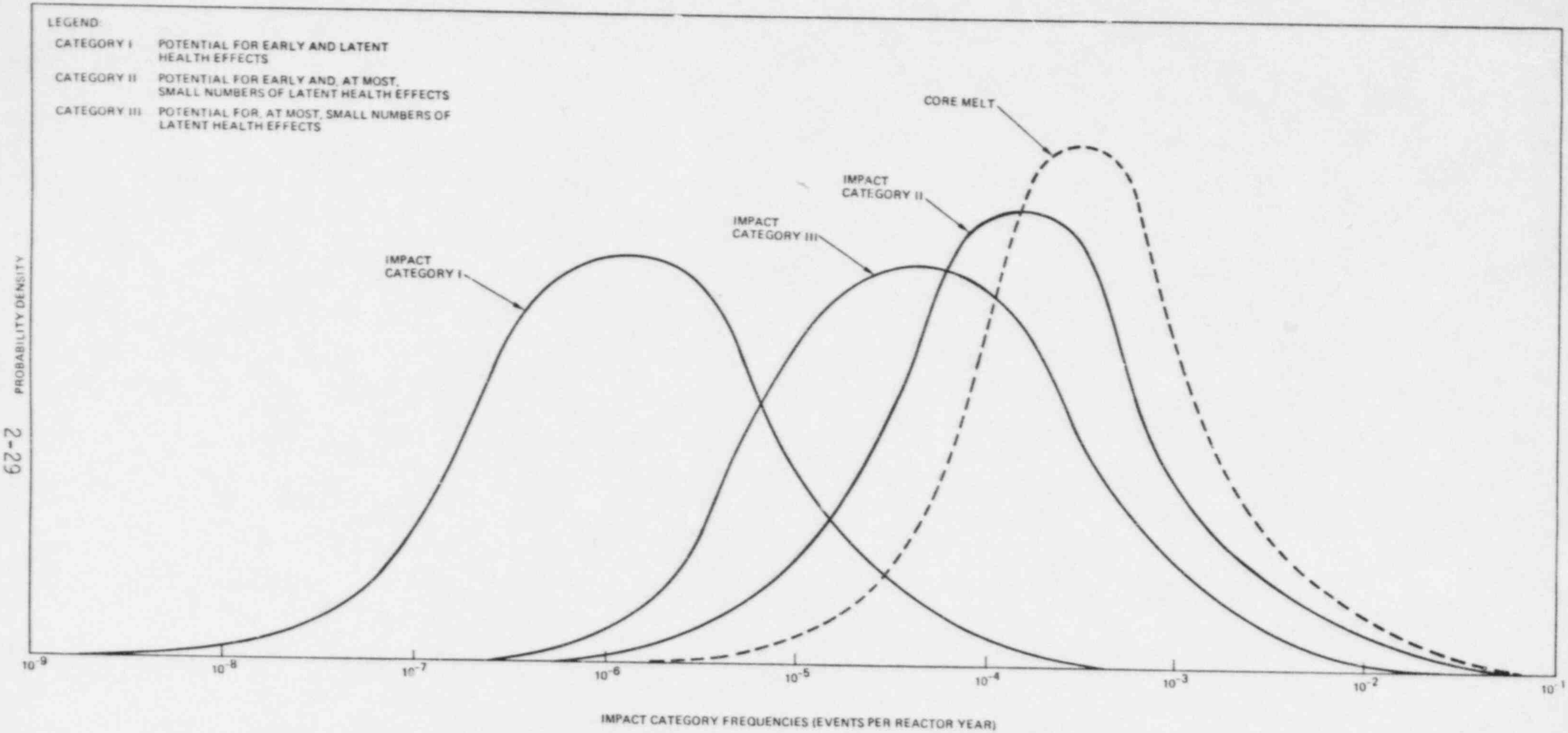


FIGURE 2-3. PROBABILITY DISTRIBUTIONS FOR IMPACT CATEGORY FREQUENCIES

3. STPEGS RISK MODEL OVERVIEW

The purpose of this section is to provide a sufficient description of the STPEGS risk model to enable an understanding of how the results of the previous section were developed. This presentation's flow is from the general to the specific. Thus, the basic concepts and definitions of PRA are presented first, followed by a description of the architecture of a general plant risk model. To provide a proper perspective for viewing the limited-scope risk model of the Preliminary Scoping Study, the general plant risk model is described for a full-scope, Level 3, completed PRA. With this perspective, the particular capabilities and limitations of the Scoping Study risk model and a limited-scope, Level 1 PRA are described. A more in-depth discussion of the major elements of the STPEGS risk model can be found in the remaining sections of this report.

3.1 BASIC CONCEPTS AND DEFINITIONS IN PRA

There are several concepts that need to be understood in order to successfully transform generic plant operating experience and STPEGS design-specific data into an overall model of plant risk. The following sections highlight the most important and basic of these concepts and serve as an introduction to the STPEGS risk model. Additional concepts are incorporated, as appropriate, by reference.

3.1.1 PROBABILITY AND FREQUENCY

To describe the reliability performance of equipment or components, a simple model of the failure process is used. This model is commonly referred to as a "random process" or "stochastic" model. In this model, an object fails "randomly" over time (i.e., with no discernible pattern) and with a constant failure rate, λ.

The stochastic model can be grouped into two types of models, each of which gives rise to a specific definition of a type of failure rate. If the equipment is idle until called upon to perform, at which time it may or may not succeed to perform its function, a binomial model is assumed. In this model, the likelihood of observing x failures in n demands (or, alternatively, x failures out of n components, all of which are demanded), L(x), is

$$L(x) = \frac{n!}{x!(n-x)!} \lambda^x (1-\lambda)^{n-x}$$

The failure rate, λ, in this case is approximately the number of failures x occurring in n demands, or

$$\lambda \simeq \frac{x}{n}$$

If the equipment is in constant use (that is, always on demand), the binomial model generalizes to the Poisson model. The likelihood of observing x failures in a time T is expressed by

$$L(x) = \frac{\lambda^x}{x!} e^{-\lambda}$$

Here, the failure rate λ is characterized by the number of failures, x, within the given time period, T, or

$$\lambda \simeq \frac{x}{T}$$

The exponential distribution models the probability of survival over a period T for the stochastic process; i.e.,

$$R = e^{-\lambda T}$$

where R is the survival probability.

The failure rate λ is a parameter of these models; that is, λ is a constant characterizing the exponential distribution of failures.

Hence, the Poisson model for n components corresponds with an exponential distribution for the time of failure of each component. The following are properties of the exponential distribution that afford a more formal definition of the parameter λ and additional insight into this basic model of component reliability.

The probability density function, f(t)dt, defines the probability of failure in the time interval [t,t + dt]. For the exponential distribution

$$f(t)dt = \lambda e^{-\lambda t}dt = R(t)\lambda dt$$

Note that the definition of the reliability function, $R(t) = e^{-\lambda t}$, is the probability of no failures in the time interval [o,t]. This helps explain the formal definition of λ as

λdt = the conditional probability of failure in the time interval [t, t + dt] given that it survives up to time t.

What typifies the exponential distribution is that λ is a constant. The mean time to failure, $\overline{t}$, of the exponential distribution is given by

$$\overline{t} = \int_0^\infty tf(t)dt = \frac{1}{\lambda}$$

When it is known that failure has occurred sometime in the interval [0, T], the conditional mean time to failure, t_T, is given by

$$t_T = \frac{\int_0^T tf(t)dt}{\int_0^T f(t)dt} \approx \frac{T}{2} \; ; \; T << \frac{1}{\lambda}$$

Another basic measure of equipment performance is its availability; i.e., the probability that the equipment is capable of performing its function at a point in time. This contrasts with reliability, which is the probability that no failures occur over a time interval (referred to as the mission time in reliability engineering parlance). In risk assessment, the average availability, or its complement, unavailability, (averaged over time) is often used, which corresponds to the proportion of time the equipment is "up," as opposed to "failed" or being repaired. When the exponential failure model is used to model failure and the process of restoration is either exponential or of fixed duration, the average equipment availability A is given by

$$A = \frac{\bar{t}}{\bar{t} + (MTTR)} = 1 - \frac{\lambda}{\lambda + \mu}$$

where

MTTR = mean time to repair = $\frac{1}{\mu}$.

μ = repair rate.

For the Poisson and binomial models, the parameter λ approximates the long-term frequency of failure of the equipment. The exact value of the failure frequency is uncertain, and this uncertainty must be quantified. Our approach to quantify the uncertainty is to use a "Bayesian" method to combine one's "prior" state of knowledge in the form of probability versus frequency curves with experimental evidence or observations.

In the Bayesian methodology, a "prior" probability distribution characterizes the state of knowledge about the possible values of λ prior to any actual measurements of the failure rate. In this context, the assertion that the probability is .9 that λ is greater than 2 is taken to mean that the person expressing this probability is willing to accept nine-to-one odds that λ is indeed greater than 2 [in informal betting terminology, nine-to-one "odds" corresponds to a probability of 1/(9 + 1)]. The probability distribution for the value of λ is developed by essentially asking the odds a person is willing to accept at each value of the frequency λ.

The probability distribution can be updated explicitly using the appropriate model assumption as data about the value of λ become available. Thus, data may change the odds that one is willing to accept

on the values of the failure frequency λ. As an example, a person's prior knowledge of the failure rate of a pump, based on the pump salesman's assertion of a failure rate of 2, might look like Figure 3-1. (This figure includes the fact the person believes the failure rate is more likely to be 3 or 4 rather than 2 as the salesman asserted.)

If it is found that the same sort of pump has been operating at a neighboring plant with an average failure rate of 2.5 per year over the last 10 years, the updated (or "posterior") probability distribution on the value of λ would look like Figure 3-2. The uncertainty in the failure frequency can then be propagated through the underlying stochastic model to give ranges of uncertainty for times to first failures, etc.

3.1.2 HAZARD AND RISK

Hazard is defined as a source of danger, loss, or injury. An automobile, for example, is a hazard. Driving an automobile poses a risk due to the chance of crashes, but the risk would be lessened by the use of seat belts, airbags, crash helmets, and other safeguards and the hazard remains unchanged. The risk would also be lessened by reduction or avoidance of car usage or by enhanced driver training. Thus, both preventive and mitigative factors influence the level of risk. Risk can thus be viewed as proportional to the hazard presented and inversely proportional to the effectiveness of the safeguards used and precautions taken. The concept of risk, therefore, involves the concepts of both danger and uncertainty; that is, uncertainty about whether or when any consequences will occur.

Thus, to quantify the notion of risk associated with a particular hazard (or "accident sequence" or "scenario"), say the ith scenario s_i, both the level x_i of damage or injury and the frequency ϕ_i with which scenario i is expected to occur must be determined. For complex systems such as nuclear power plants, the overall risk can be expressed as a set of triplets ranging over all possible scenarios, each triplet being expressed as

$$\langle s_i, \phi_i, x_i \rangle$$

where s_i labels the ith scenario, ϕ_i the frequency of its occurrence, and x_i the damage level associated with the scenario. One very basic definition of risk is simply the set of all such triplets, or symbolically

$$\text{risk} \equiv R = \{\langle s_i, \phi_i, x_i \rangle\}_{\text{all } i}$$

The need for completeness that is implied in this definition cannot be fulfilled rigorously in any practical application of PRA. Fortunately, however, PRA methods have been used that provide a high degree of confidence that overlooked or missing scenarios do not make significant contributions to risk.

The development of a risk model that provides these triplets can be simply thought of as the process in which the answers to three fundamental safety questions are determined:

- What can go wrong?
- What is the likelihood of these different sequences?
- What are the damage levels associated with these sequences?

To answer these three questions for STPEGS, a structured thinking process has been employed. This process begins with a systematic identification and categorization of the scenarios that might lead to significant damage to the plant. Each scenario is then analyzed to determine its frequency of occurrence and its consequences. Each scenario consists of an initiator, which might be a system failing, a pipe breaking, or a human error, and several manually and automatically actuated actions and passive processes that determine the consequences of the scenario. In principle, each scenario can be divided into four parts:

1. The initiating event.

2. The subsequent performance of the plant systems.

3. The phenomenological events that occur in the core and containment after the initiation of core damage.

4. The weather-related and evacuation-related events.

A Level 1 PRA analyzes only the performance of the plant systems, while a Level 2 PRA also considers core and containment phenomenology and a Level 3 PRA includes a complete consequence analysis. These three levels of scope are represented by the plant model, the containment model, and the "site" (really offsite) model, respectively. This means that each Level 3 PRA scenario consists of three fragments, one from each of these three models. The events in each fragment are defined as being conditional on a certain set of events having previously occurred. Therefore, after a set of interfaces or "pinch points" between the three models has been agreed upon, each model can be developed separately.

The form typically used in presenting Level 3 risk assessment results is the complementary cumulative or frequency of exceedance form. In this form, the frequencies of all scenarios exceeding a particular level of damage are summed. Curves are then plotted for each damage type to show the frequency of exceeding each level of damage.

Figure 3-3 illustrates a curve of φ frequency of exceeding damage level x, (x) versus x for a set of similar scenarios (or defined radioactivity release). The scenario risk is described by the entire curve, which includes all possible damage levels and the frequency of exceeding each level. As will be explained more fully in Section 3.3, the assessment of damage levels in the Scoping Study is limited to the qualitative assessment of the potential of each analyzed release state to produce various impacts.

To evaluate the overall plant risk as would be performed in a full-scope, Level 3 PRA, risk curves for the set of accident scenarios are combined into an overall risk curve, which has the same form as in Figure 3-3. This is done by summing for each damage level x_i the corresponding ϕ_i on each scenario curve.

The risk curve illustrated in Figure 3-3 incorporates variations in the frequency of damage levels from scenarios through the plant, containment, and site models. Uncertainty in the parameters and phenomena incorporated in the three models is set forth in a family of risk curves indexed by the probability P of a particular curve's occurrence as illustrated in Figure 3-4. This family of curves is analogous to the probability distribution of the failure frequency λ, but it describes a surface rather than a single curve. The interpretation of the probability associated with each curve represents the analyst's "confidence" that each curve is the "correct" curve in light of the underlying uncertainties. Alternatively, the curves may be labeled by the cumulative probability as in Figure 3-4. With this interpretation, the curve shown, for example, may be read as "with probability .9, the frequency of exceeding damage level x_1 is no greater than ϕ_1."

3.1.3 DECISION ANALYSIS

The results of a probabilistic risk assessment are really only an input into a more general decision model, described by Figure 3-5. At each point of a decision, there are two or more options from which to choose, including the options to not decide or to seek more information. Options (including not deciding or seeking more information) have associated with them uncertain outcomes of costs, benefits, and risk. These uncertainties must be expressed by probability curves such as those shown in Figure 3-5.

The outcomes for each option, then, may be regarded as a triplet <C, B, R>, each element of which is characterized by a probability curve (or surface in the case of risk), and the objective of the decision maker is to choose the most desirable triplet. The object of PRA is to provide the risk information to the decision analysis, not to actually make these decisons.

3.2 RISK MODEL STRUCTURE

3.2.1 QUALITATIVE DESCRIPTION OF STPEGS RISK MODEL

A PRA is basically a listing and analysis of scenarios, and a full-scope PRA can contain literally billions of scenarios depending on how finely the scenarios are described. Accounting for all event tree paths incorporated into a plant risk model requires specific modeling and quantification of all these sceanrios. To provide a logic structure to the qualitative progression of an accident scenario, the overall risk model can be thought of as three linked models: the plant model, the containment model, and the site model, as shown in Figure 3-6. A single accident scenario progressing to offsite consequences spans all three of these models. For most accident scenarios, the input to the containment

and site models depends only on the state of the plant or containment and not on the history of the arrival to that state. This fact enables much of the work on the three models to be done independently and in parallel by the various analysts, which is especially useful since different expertise is needed for each of the three models.

3.2.1.1 The Plant Model

Billions of possible scenarios must be enumerated in the plant model. To do this requires detailed modeling of the plant, its systems, its components, and their interdependencies. Physical and human interactions with the plant that can affect the frequency of occurrence of an accident scenario must also be included.

Event frequencies and their associated uncertainties are quantified using historical evidence in both nuclear and nonnuclear experience when applicable. The plant model contains all the systems reliability aspects, including the engineered safety features of the containment. The containment model (explained below) deals with only the issues of containment response once core damage or melt occurs. A more in-depth presentation of the STPEGS plant model can be found in Section 4.

3.2.1.2 The Core and Containment Model

The core and containment model represents the subsequent progression of a scenario once core damage or melt is experienced. The outcome of the scenario is principally determined by the physical processes of the scenario (for example, the pressure and temperature response, the cooling of core debris, etc.) as well as the passive response of the containment structure itself.

The containment event tree models the scenario in approximate chronological order and gives special consideration to effects that unique and specific plant features have on the accident simulation. The results of the model are a continuation of the scenario structure, expressed by release categories, quantification of their frequencies, and a source term for estimating accident impacts. Section 7 contains a discussion of the Scoping Study core and containment model.

3.2.1.3 The Site Model

The site model represents the progression of scenarios from the release categories, output from the containment model, to the actual offsite impacts. The site model in Level 3 PRA uses Monte Carlo simulation rather than the event trees used in the plant and containment models to describe the extremely large number of meteorological states that could exist at the time of a release and the randomly changing nature of these states. The computer code CRACIT uses a plume dispersion model for the release, and site-specific demographic, geographic, and meteorological data as well as evacuation route information in simulating the possible effects. For each particular release, the model traces the movement of radioisotopes, their possible deposition on the ground, and their possible effect on the population.

The output of the site model estimates the damages that could occur as a result of the release. As noted earlier, only a qualitative site analysis was performed in the Scoping Study. The results are briefly summarized in Section 7.

3.2.2 LOGICAL STRUCTURE OF A RISK MODEL

The first step in the development of a risk model is to identify "initiating events" that may, depending on the response of the plant, lead to core damage. These are identified using several independent approaches including a fault tree analysis of the plant energy balance, a "master logic diagram" (which is another form of a fault tree), failure modes and effects analysis of plant systems, and cross-checks against reactor operating experience, events identified in other PRAs, plant design documents, and the systems analyses.

Once the initiating events are identified, scenarios or accident sequences that could result are identified using a "plant event tree." As explained in Section 4, the plant event tree is actually a network of event tree modules. The top events of each event tree represent the responses of the various plant systems so that each path through the tree represents an event sequence. In this way, the event tree embodies a truth table of all significant success/failure combinations of the plant systems. At the end of each sequence, the plant either is in a stable, recovered condition or has suffered some core damage. A set of plant states y_j is defined, and each path through the tree is assigned to one of these states. This point in the analysis is called a "pinch point." Once a scenario has reached this point, its further development depends only on the plant state y_j and not on how that state was reached. Each plant state is carefully defined so that further analysis is the same whether that state was reached because of a LOCA or loss of offsite power, etc.

Given that the plant is in state y_j, the subsequent events in the scenario are represented by the "containment event tree." The methodology used is analogous to the plant model. There are, however, subtle differences in the way in which the event tree frequencies and probabilities are quantified, as explained more fully in Section 5. The entry states to the containment event tree are the plant damage states, and the top events of the tree correspond with various containment phenomena, such as hydrogen burning, debris bed cooling, etc. At the end of each sequence, core damage has resulted in a release of varying magnitude. A set of release categories ρ_k, representing types, quantities, timings, and elevations of radioisotopes released, is defined and each path through the containment tree is assigned to one of these states. This is another pinch point in the sense that the impacts of release category ρ_k are independent of how the release category was reached.

In a full-scope, Level 3 PRA, the impacts of the various radioactive releases are analyzed using a site-specific atmospheric model and the code CRACIT. The results are "conditional frequencies" $s_{k\ell}$, which express the likelihood of a damage level x_ℓ or greater to the public, given that release category ρ_k has occurred.

The four sets of pinch points defined above enable the convenient modularization of the event sequence model into three event sequence "fragments." These fragments correspond to portions of the entire event sequence that are modeled in the plant model, core and containment response model, and site model. This provides the basis for the standard form of defining event sequences in the risk model, which is illustrated in Figure 3-7.

3.3 MATRIX FORMULATION OF A RISK MODEL

The key idea in the matrix formulation of the risk (Reference 3-1), which is illustrated in Figure 3-8, is that the event trees may be considered equivalent to transition matrices: the trees define the likelihood of moving from various input states to various output states.

In the plant event trees, the input states are the initiating events, i, and the output states are the plant states, y_j. From the event tree, the number m_{ij}, representing the conditional frequency of being in plant state y_j, given that initiating event i has occurred, can be calculated. The trees can then be represented by a matrix M composed of these m_{ij}. Because the plant event tree is very large, it is actually a set of event trees that are connected by several sets of intermediate pinch points (see Section 4 for a discussion of this point). Similarly, the containment event tree can be represented by a C matrix whose entries C_{jk} represent the conditional frequency of having a release category ρ_k given that the plant was in state y_j.

In a full-scope, Level 3 PRA, the site matrix S is not derived explicitly from an event tree. Its elements $s_{k\ell}$ are derived from Monte Carlo simulations of the interaction between time dependent meteorological conditions and evacuation, but the interpretation of these matrix elements is again the conditional frequency of having damage level x_ℓ given that release category ρ_k occurred.

Products of these matrices retain the transition frequency interpretation:

- The product matrix (MC) is the transition matrix from initiating events to release categories. The i,kth element of this product matrix is the conditional frequency that a release of type k occurs given that an initiating event i has occurred.

- The product matrix (CS) is the transition matrix from plant states to damage levels. The j,ℓth element of this product matrix is the conditional frequency that a damage level ℓ occurs given that the jth plant state has occurred.

- The product matrix (MCS) is the transition matrix from initiating events to damage levels. The i,ℓth element of this product matrix is the conditional frequency that damage level ℓ occurs given that initiating event i has occurred.

To determine the unconditional frequencies associated with the various states, an "initiating event vector" ϕ^I must be introduced. ϕ^I is a row vector whose entries ϕ^I_i denote the frequency of occurrence of each initiating event i.

These frequencies can be quantified with the aid of a "thought experiment" in which identical plants are imagined to undergo the various initiating events and the number of occurrences of such events per plant year are counted. When multiplied by the plant matrix M, the result is the "plant state vector" ϕ^y whose elements ϕ^y_j denote the (unconditional) frequency of occurrence of plant state y_j. This, in turn, multiplied by the containment matrix, C, results in ϕ^ρ, the "release vector." When ϕ^ρ is multiplied by the site matrix, S, the final result is the damage vector ϕ^x where ϕ^x_ℓ is the frequency of exceeding damage state x_ℓ.

This "assembly process" can be summarized as follows:

$\phi^y = \phi^I M$ (frequencies of the plant damage states)

$\phi^\rho = \phi^y C = \phi^I MC$ (frequencies of the release categories)

$\phi^x = \phi\rho S = \phi^y CS = \phi^I MCS$ (exceedance frequencies as a function of damage level, i.e., the points of the risk curve)

This equation is the "master assembly equation," or the "Kaplan equation," for processing the results from a full-scope risk assessment. Figure 3-9 summarizes the relationship between the event tree model and the matrix formalism, forming the basis of the assembly equation.

3.4 DECOMPOSITION OF RISK AND CAUSE TABLES

If the initiating event vector ϕ^I is written as a diagonal matrix

$$\phi^I_D = \begin{bmatrix} \phi^I_1 & & & 0 \\ & \phi^I_2 & & \\ & & \ddots & \\ 0 & & & \phi^I_N \end{bmatrix}$$

the i,jth element of the product matrix $\phi^I_D M$ is the frequency of occurrence of the jth plant state resulting from the ith initiating event. Comparison of this i,jth element of $\phi^I_D M$ with the jth element of ϕ^y gives the fraction of the total frequency of the jth plant state attributable to the ith initiating event. The vector ϕ^y is actually the column sum of this product matrix. In the same way, the product matrices $\phi^I_D MC$ and $\phi^I_D MCS$ show the contributions that each initiating event makes to a release category frequency and damage level frequency, respectively. Contributions of the plant state to release categories and damage levels and of the release states to damage levels can be determined by defining ϕ^y and $\phi\rho$ and diagonal matrices ϕ^y_D and ϕ^ρ_D, and forming the products $\phi^y_D C$, $\phi^y_D CS$, and $\phi^\rho_D S$.

The overall logic of the risk decomposition is shown in Figure 3-10. The steps below matrix operation $\phi^I_D M$ are performed with the aid of a computer program called MAXIMA, which traces through the event sequence logic to identify paths between the initiating events and plant damage states that make major risk contributions. The results of an application of the risk decomposition process to the STPEGS risk model was presented in Section 2.

3.5 OVERVIEW OF STPEGS PRELIMINARY SCOPING STUDY RISK MODEL

In the Preliminary Scoping Study, we have not achieved the kind of full-scope PRA conceptually defined above. To understand what the results of this preliminary study really mean, it is essential that the limitations in scope be fully understood.

3.5.1 PLANT MODEL LIMITATIONS

The principal parameters of the plant model that are subject to possible limitation in the Scoping Study are (1) completeness in the choice of initiating events, (2) completeness in the definition of accident sequences, (3) completeness and degree of rigor in the quantification of accident frequency, (4) assumptions about the dependence of safety related equipment on HVAC systems and assumptions regarding the development and progression of the RCP seal LOCA. The quantification of initiating events in the Scoping Study was limited to a set of 16, as described in Section 4.2. This set of initiators, while typical for a Phase I-type preliminary risk quantification, is much less extensive than the corresponding list for a completed, full-scope PRA such as that recently completed for Seabrook Station (Reference 3-2). The initiating event set analyzed in the Seabrook Station PRA included 58 events that were subjected to plant model quantification. The 16 for STPEGS were selected by the Scoping Study team as those likely to be important, based on prior PRA experience and a careful examination of the plant design.

The second principal parameter, completeness in the definition of accident sequences, appears to be limited in the Scoping Study only to the extent that the choice of initiating events is limited. For the initiating events in the Scoping Study, therefore, the definition of accident sequences is about as complete as would be expected for a full-scope study. One exception to this is that scenarios initiating transients without reactor trip were only partially integrated into the Scoping Study quantification, even though the event tree logic for these sequences was in fact completed.

With respect to the degree of rigor in the quantification of accident frequency, the third parameter of the plant model, the Scoping Study was developed from a full-scope treatment of intersystem functional dependencies and simplified plant-specific system models. Departures from the full-scope quantification methodology could give rise to variations in the results. For example, neither a complete treatment of test and maintenance nor a complete propagation of uncertainty distributions for component unavailability parameters was performed in the Scoping Study. In addition, design specific failure rates and common cause failure parameters were based on generic data which was not reviewed nor screened for detailed applicability to STPEGS. Based on experience with the Seabrook PRA and the degree of familiarity with STPEGS achieved in this Scoping Study, these quantification variabilities are not expected to produce many surprises. However, a completed Level 1 PRA would enable the reduction in the range of uncertainty, especially with regard to common cause parameters.

Finally, the assumptions regarding vulnerability to degradation of HVAC and susceptibility RCP seal LOCA are crucial to the study results. In the Scoping Study, the study team used their judgment of the likelihood of possible true states of those conditions (based on experience, partial calculations, and discussions with vendors, architect/engineer and utility personnel, and testing organizations) to include the full range of possibilities in the uncertainty calculations. Additional analysis or testing of these phenomena would reduce the range of uncertainty in the results. A discussion of the impact of these model limitations and uncertainties on the results is presented in Section 2.

3.5.2 CONTAINMENT MODEL LIMITATIONS

The scope of the containment analysis in the Scoping Study was very modest in relation to a completed, Level 2 or 3 PRA. Only a very small portion of the Scoping Study manpower resources--less than 2%--was devoted to the containment analysis. However, the relatively lower scope in this area was balanced by the fact that no rigorous quantification of accident consequences was performed. Only that limited analysis necessary to establish the relative impacts of accident sequences was performed in the Scoping Study containment analyses. The scope of work in a completed Level 2 containment analysis normally includes, among other tasks, the definition of plant damage states and release categories, the computer simulation of plant and containment transient response to a wide spectrum of accident scenarios, the analysis of the physical processes of core melt sequences, the analysis of containment failure modes, the calculation of the source terms for offsite release, and the construction and quantification of the containment event tree. By contrast, the coverage of this Scoping Study was limited to the definition of plant damage states and release categories, qualitative survey of containment structural and systems features, and a judgmental quantification of the containment, or C matrix, without explicit quantification of a containment event tree. These limitations, while not permitting a quantification of accident consequences per se, do permit the Scoping Study accident sequences to be put into perspective. A more in-depth discussion of plant damage states and release categories is presented in Section 7.

3.5.3 SITE MODEL LIMITATIONS

Of the three major elements of the STPEGS risk model, the site model was the most limited in scope in relation to a completed, full-scope (Level 3) PRA. Rather than probabilistically calculating the consequences of accident sequences in each release category through a Monte Carlo simulation of the interaction between releases, meteorological, transport, and evacuation scenarios, only a very limited qualitative analysis was performed. Of the release categories that were defined, only a gross grouping by relative impact was performed.

Based on experience with previous PRAs, the accident sequences belonging to each release category were placed into one of three "impact categories:"

- <u>Category I</u>. Significant potential for early and latent health effects.

- Category II. Significant potential for latent health effects and possibly small numbers of early health effects.

- Category III. Potential for, at most, only small numbers of latent health effects.

This grouping enabled the addition of a qualitative public impact perspective to the results that otherwise would be limited to the quantification of core damage frequency. Section 7 includes the results of the assignment of accident sequences to impact cateogries.

The above discussion highlights some of the more important limitations in the STPEGS risk model. Those limitations that are particularly risk sensitive have been defined in the presentation of the Scoping Study results in Section 2.

3.6 REFERENCES

3-1. Kaplan, S., "A Matrix Theory Formalism for Event Tree Analysis--Application to Nuclear Risk Analysis," Risk Analysis, Vol. 2, No. 1, March 1982.

3-2. Pickard, Lowe and Garrick, Inc., "Seabrook Station Probabilistic Safety Assessment," prepared for Public Service Company of New Hampshire and Yankee Atomic Electric Company, PLG-0300, December 1983.

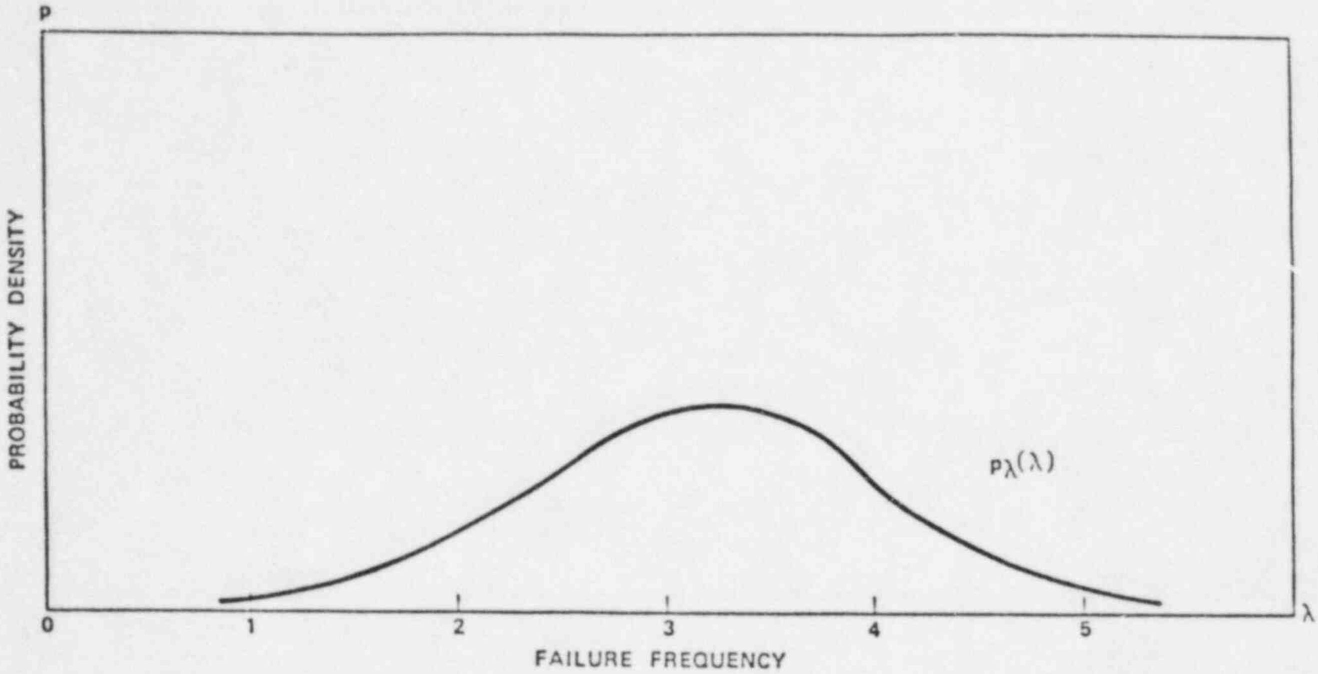


FIGURE 3-1. PROBABILITY CURVE AGAINST FAILURE FREQUENCY BASED ON SALESMAN'S STATEMENT AND PERCEIVED BIAS OF SALESMAN

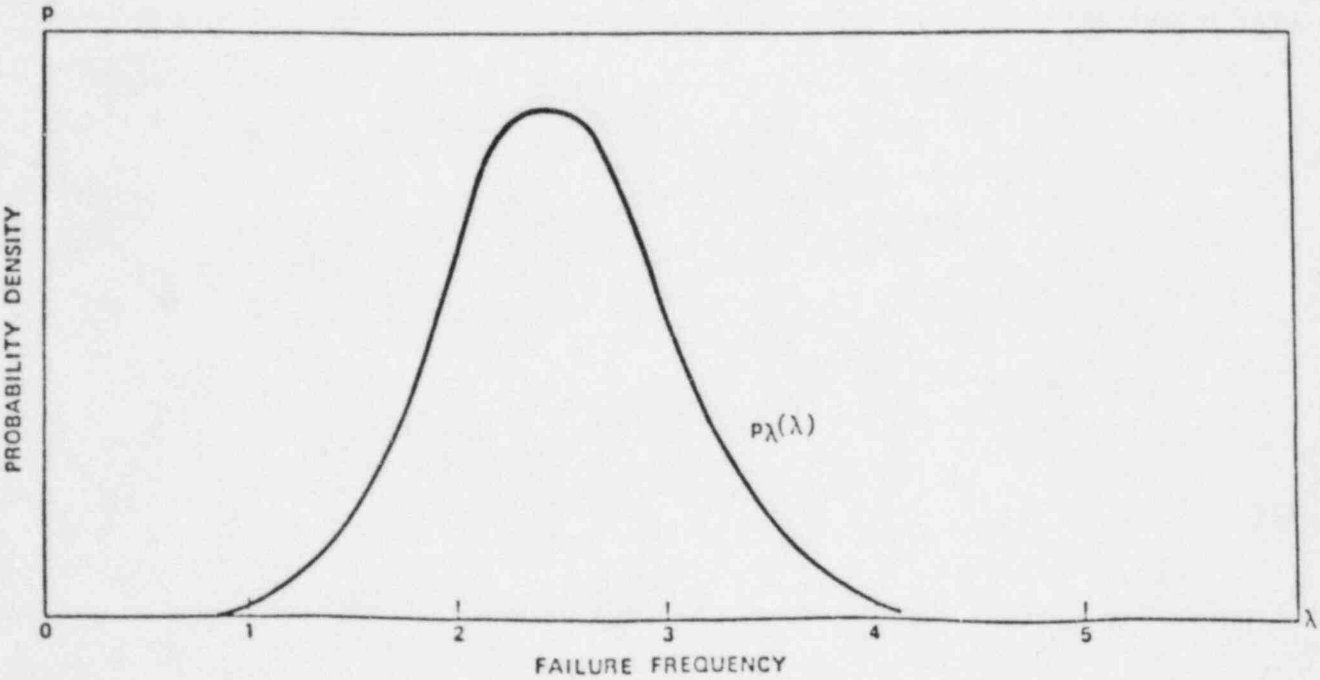


FIGURE 3-2. STATE OF KNOWLEDGE PROBABILITY CURVE AFTER LEARNING NEIGHBOR'S EXPERIENCE

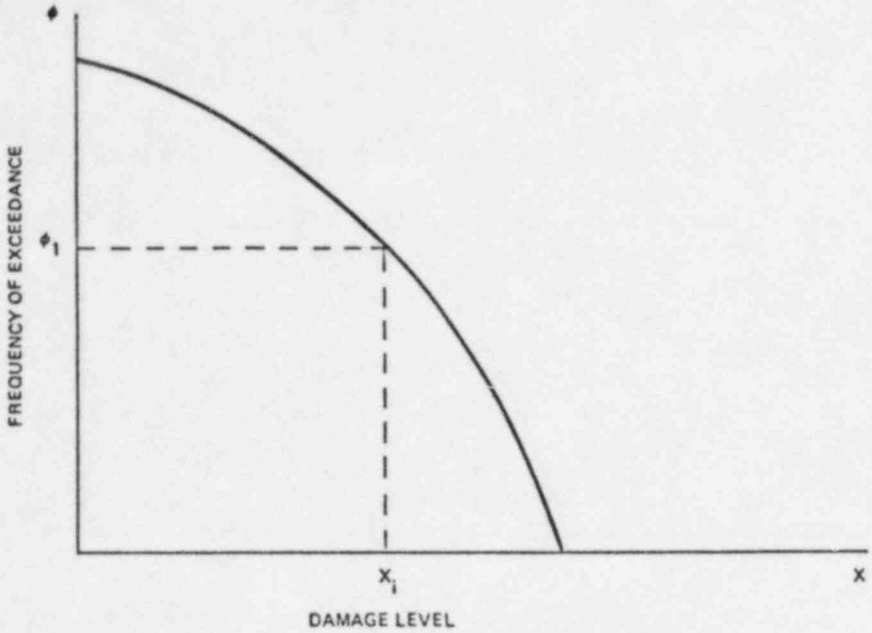


FIGURE 3-3. POINT ESTIMATE RISK CURVE
WITH NO UNCERTAINTY QUANTIFICATION

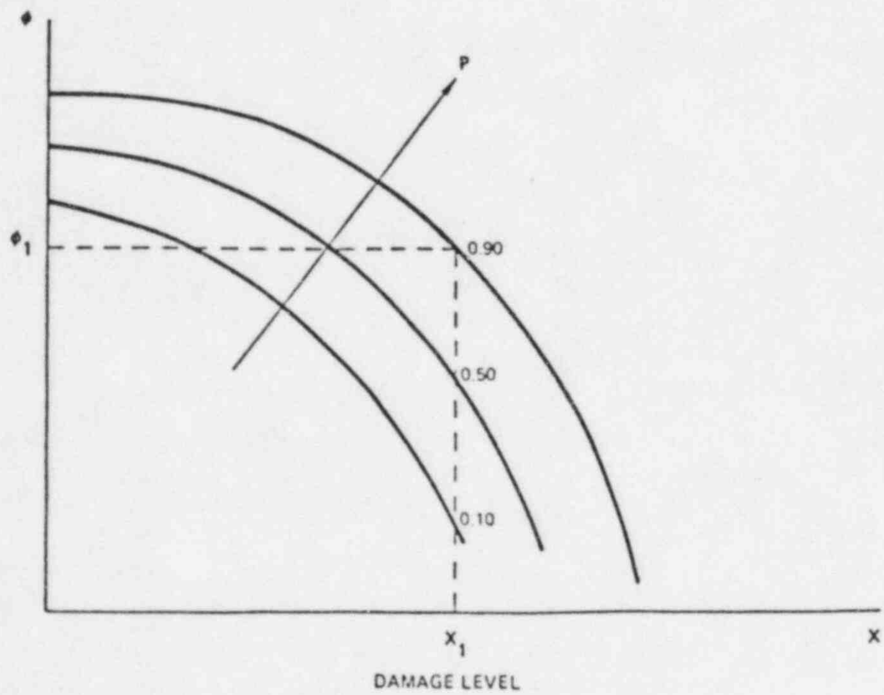


FIGURE 3-4. FAMILY OF RISK CURVES
WITH UNCERTAINTY QUANTIFIED

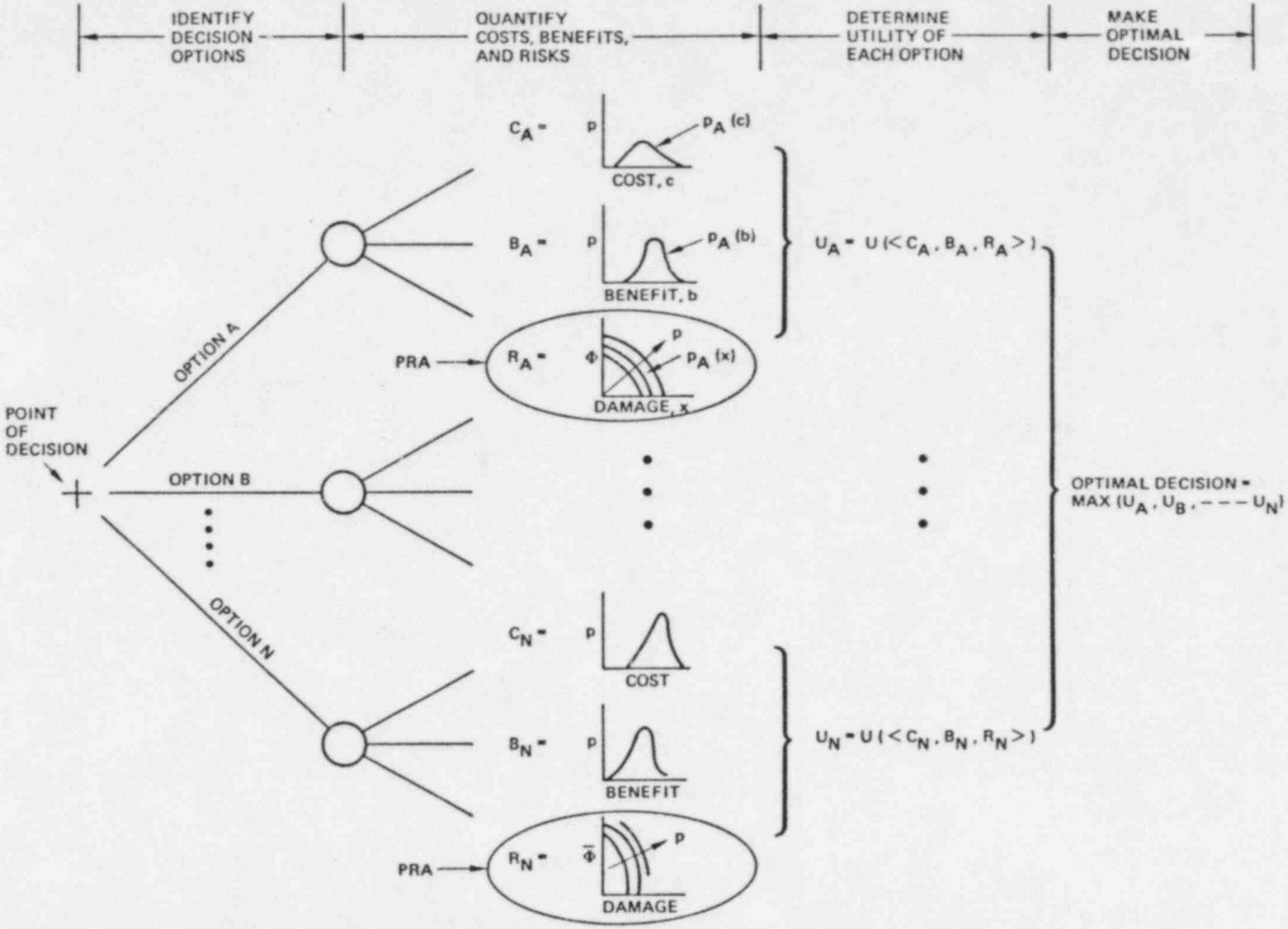


FIGURE 3-5. ROLE OF PRA IN DECISION ANALYSIS PROCESS

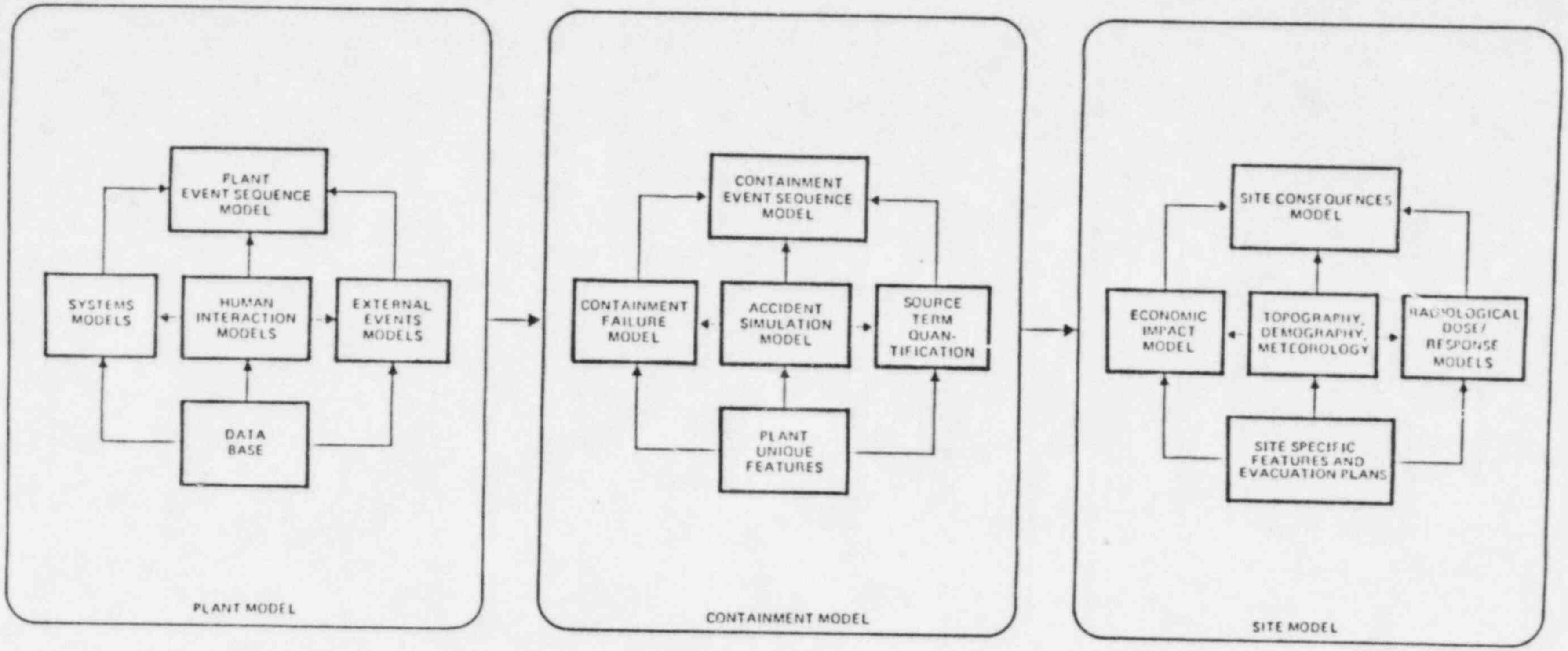


FIGURE 3-6. BLOCK DIAGRAM STRUCTURE OF A FULL-SCOPE LEVEL 3 RISK MODEL

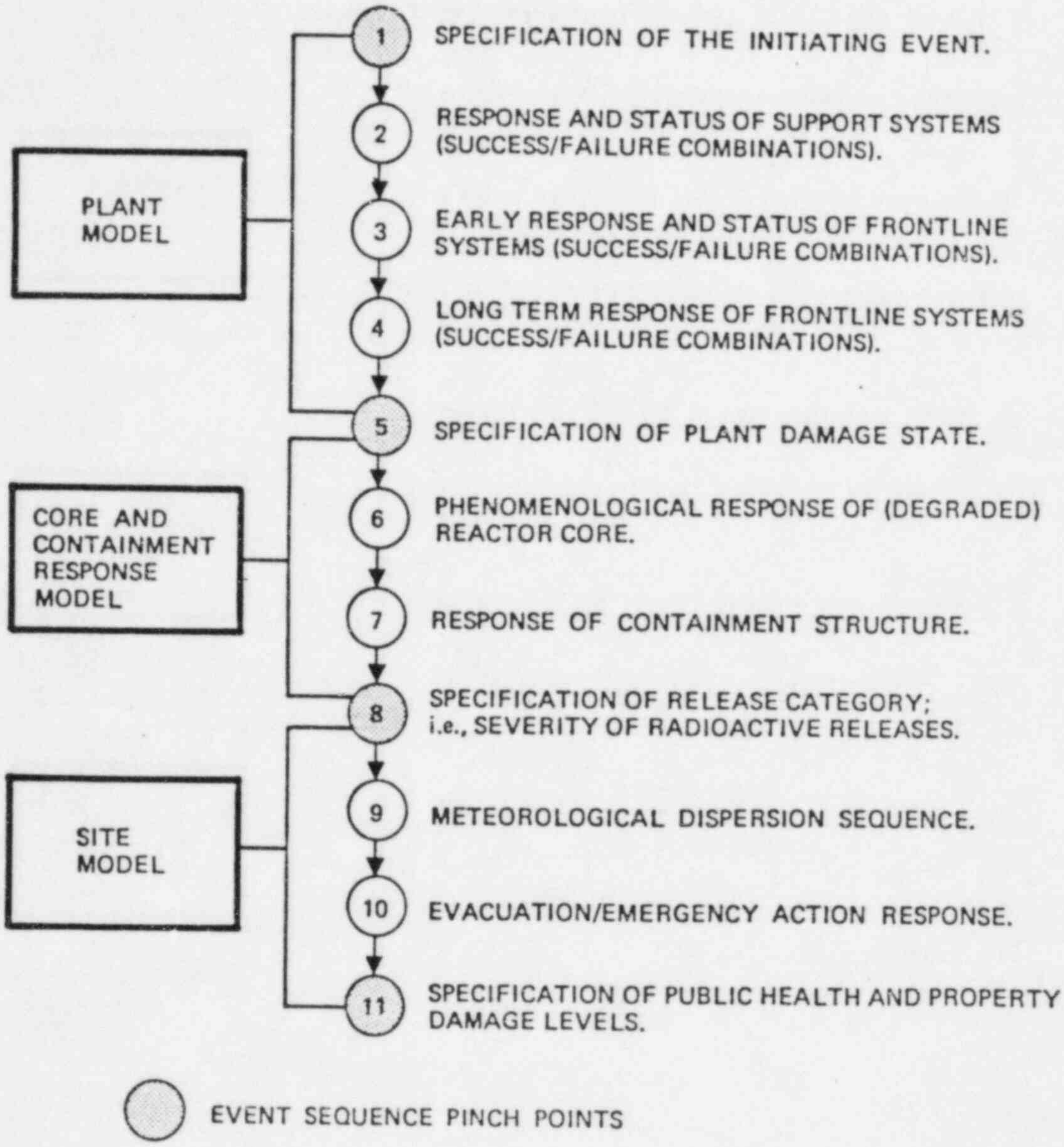
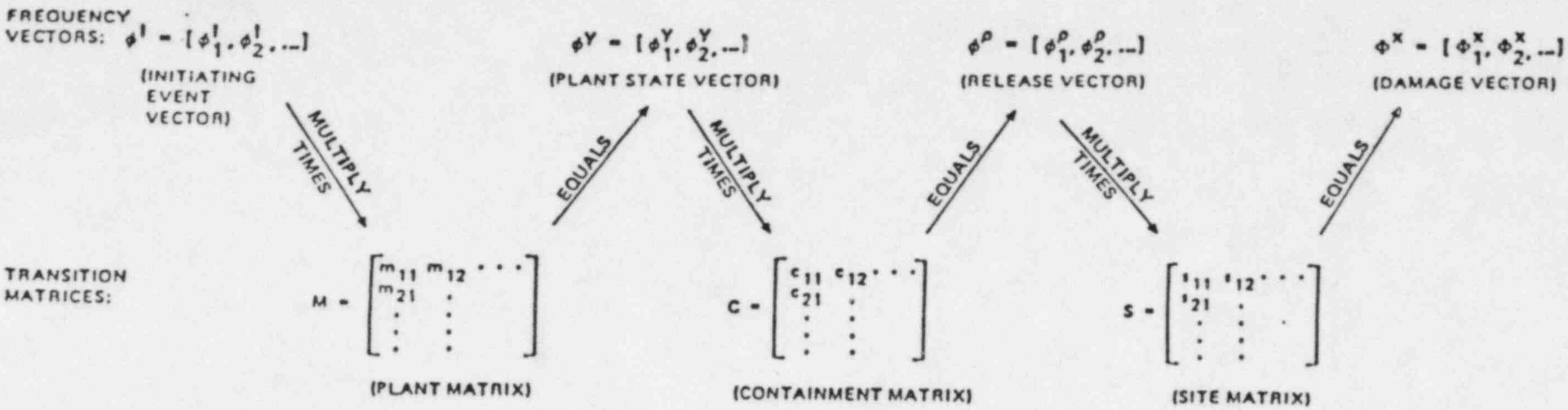


FIGURE 3-7. STANDARD FORM OF ACCIDENT SEQUENCES
IN A FULL-SCOPE, LEVEL 3 RISK MODEL



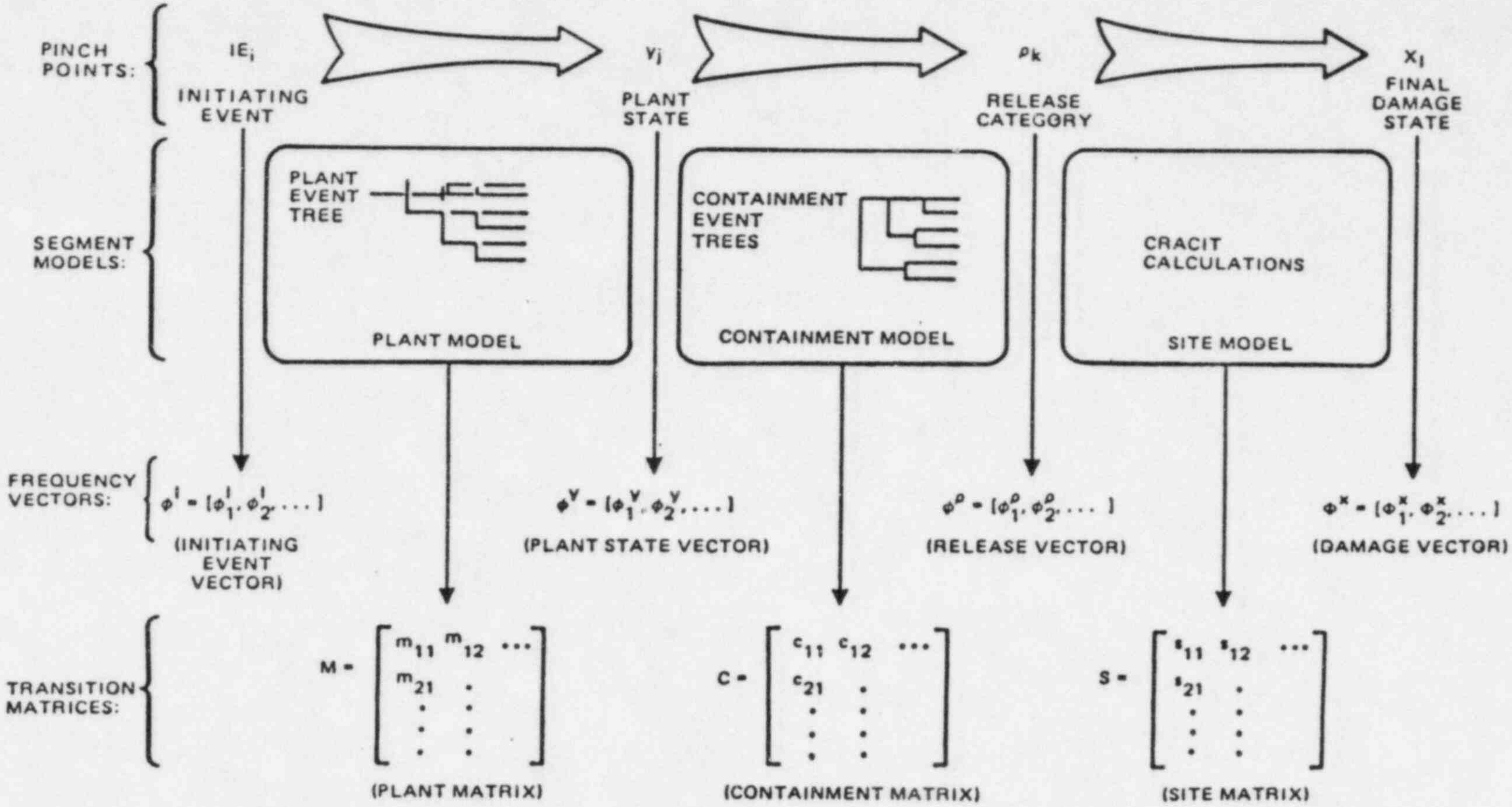
ASSEMBLY PROCESS:

$\phi^Y = \phi^I M$

$\phi^\rho = \phi^Y C = \phi^I MC$

$\Phi^x = \phi^\rho S = \phi^Y CS = \phi^I MCS$

FIGURE 3-8. MATRIX FORMULATION AND RISK ASSEMBLY PROCESS



ASSEMBLY PROCESS:

$\phi^Y = \phi^I M$

$\phi^\rho = \phi^Y C = \phi^I MC$

$\phi^x = S\phi^\rho = \phi^Y CS = {}^I MCS$

FIGURE 3-9. OVERALL VIEW OF THE PRA ASSEMBLY PROCESS SHOWING RELATIONSHIPS OF PINCH POINTS, EVENT TREES, FREQUENCY VECTORS, AND TRANSITION MATRICES

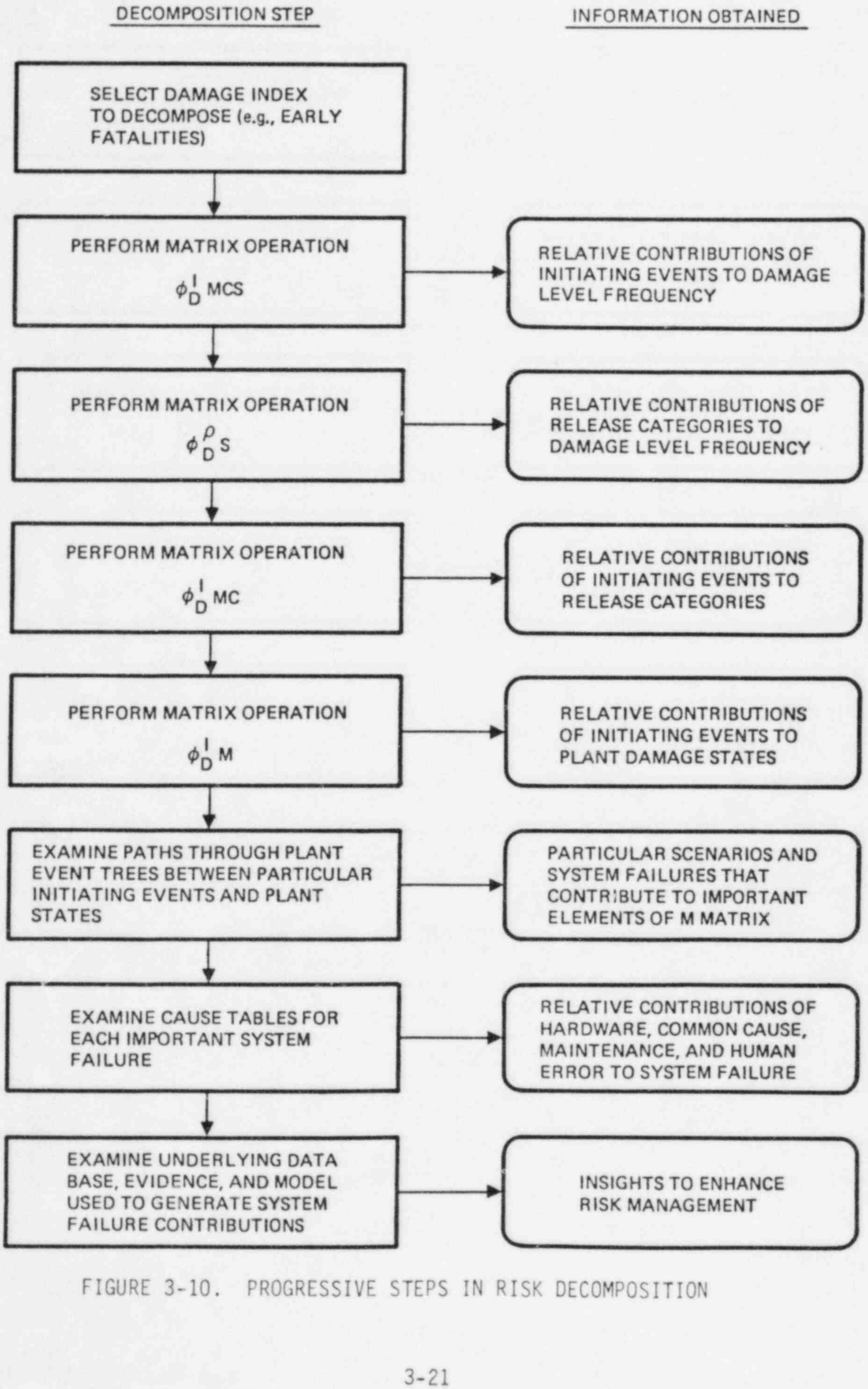


FIGURE 3-10. PROGRESSIVE STEPS IN RISK DECOMPOSITION

4. EVENT SEQUENCE MODEL

4.1 OVERVIEW - INITIATING EVENTS, AUXILIARY AND FRONTLINE SYSTEM MODELS

The plant-level event sequence model is divided into four separate parts, as illustrated in Figure 4-1. The first part of the plant event sequence analysis enumerates the initiating events; i.e., those events upsetting equilibrium conditions such that standby systems must operate to maintain core cooling. The selected initiating events are discussed in Section 4.2.

The second part of the plant event sequence analysis evaluates the response of the various auxiliary (or support) systems to the specific initiating event category in question. Auxiliary systems include electric power supplies, various cooling systems, control and protection systems, and the reactor trip function itself. They are modeled separately from the so-called "frontline" systems, since they are required to support several frontline systems and, therefore, represent a potential source of dependent failures. A single failure in an auxiliary system can give rise to multiple failures in frontline systems because of functional dependencies. The auxiliary system model is an event tree that is used to determine the conditional frequencies of various unique auxiliary system states, given the specific initiating event in question. Each state has an associated frequency of occurrence and an impact vector describing the downstream effects the auxiliary system state has on the frontline systems. The auxiliary system model is described in Section 4.3.

The third part of the plant event sequence analysis evaluates the early response of the frontline equipment and the plant operators to the specific initiating event in question. "Early" refers to the timing relative to the initiating event. The sequences included in the early response models terminate in one of three possible conditions:

- Successful long-term decay heat removal by either the steam generators or a residual heat removal loop.
- Successful core cooling and inventory control by injection of the contents of the refueling water storage tank into the reactor coolant system. Transfer is then made to the LT1 long-term response model. LT1 addresses long-term recirculation cooling and, if long-term cooling is not established, the operability of containment systems for accident mitigation.
- Inadequate core cooling, which leads to a core melt condition, and which transfers to the LT2 long-term core melt response model that addresses the operability of containment systems for accident mitigation.

The fourth part of the plant event sequence analysis evaluates the long-term response of the plant if recirculation cooling is called for or, if core melt occurs, the operability of containment systems. In some

cases, the containment systems are modeled prior to the occurrence of core melt in instances where core cooling is provided, partly by operation of containment systems. The sequences in the long-term response models terminate in either successful core cooling or specific plant damage states that define conditions important to the core and containment response analysis activities (as noted in Figure 4-1). PDSs for STPEGS are discussed in Section 7.3 and the frontline systems models are developed in Section 4.4.

A hot shutdown condition is included as a possible success state for those initiating events after which it can be expected that a return to power operation will occur. This avoids the need to artificially assume, as in some other PRA studies, that each successful sequence must result in a cold shutdown condition.

For initiating events that are expected to require an extended shutdown for inspection and/or repair (such as LOCA events), the success states are assumed to be cold shutdown conditions. The mission time selected for system operation in the event sequence models is 24 hours, with the plant conditions stabilized and with every reason to expect continued long-term core heat removal. Should running failures occur after the 24-hour or mission time, the temperatures are quite low and the core decay heat rate is sufficiently small that considerable time is available to provide whatever corrective action may be required.

4.2 INITIATING EVENTS

The purpose of this section is to describe the selection of initiating events for the Preliminary Scoping Study. As described more fully above, an initiating event is a disturbance to steady-state plant conditions. It can begin a sequence of events having the potential to lead to core damage. Because knowledge of this potential for damage implies an analysis of the ensuing sequences, possible initiating events are selected by searching for all events that disturb the steady state.

Within the initiating events groups, specific events can degrade the performance of systems useful in restoring the plant to stable conditions. Such "common cause" initiating events can often be identified by hypothesizing "external" or environmentally induced disturbances and employing failure mode and effects analysis to find support system failure modes impacting plant operations.

In selecting the set of initiating events for the Scoping Study, the goals are the following:

- Identify the core melt frequency and our uncertainty about it.
- Quantify preliminary contributors to core melt frequency.

In previously completed, full-scope PRAs, logical inductive and deductive procedures have evolved for the selection of initiating events. Two deductive procedures are the master logic diagram and heat balance fault

tree method. Both of these procedures can be described as plant-level, qualitative fault tree analyses. An inductive procedure for identifying plant specific common cause initiating events is failure modes and effects analyses. This method is normally applied to plant support systems and provides enhanced assurance of completeness, especially with respect to the common cause initiators.

Experience using the above procedures on four-loop Westinghouse PWRs with large, dry containments similar to STPEGS and the collective experience for other PRAs and related studies provided a long list of potential initiating events. For example, the 58 Seabrook initiators, listed in Table 4-1, served as an important starting point for the selection of initiators for the STPEGS Study.

The next step in the process of selecting initiators was to fully account for specific and unique features of the STPEGS plant and systems. The focal point of this step in the Scoping Study was the qualitative analysis of initiating event potential in all STPEGS systems. This analysis was documented in the systems summaries that were completed as part of the plant familiarization task.

On the basis of the plant-specific evidence and experience with previous PRAs, and in view of the limited scope and objectives of the STP study, a list of five initiating event groups was selected for quantification. These events are presented in Table 4-2 and include 2 loss of coolant inventory initiators, 1 general transient category, and 13 common cause initiating events. The last group includes four support system faults, seven external events, and two internal plant hazards. By comparing Table 4-2 with Table 4-1, the limits of the Scoping Study are evident.

The degree of analysis performed for each of the initiating events in Table 4-2 varied substantially from case to case. Initiators 1 (Small LOCA), 3 (General Transient), 4 (Loss of Offsite Power), 5 (Loss of Essential Chilled Water), 6 (Loss of Component Cooling Water), and 7 (Loss of Essential Cooling Water) were analyzed in conjunction with a complete set of plant event trees. Initiator 2 (Interfacing Systems LOCA) did not require propagation through the event tree logic because it could be determined that it would result in a particular plant damage state irrespective of the response of plant systems. External events 8 through 12 were analyzed in the Scoping Study in the form of bounding analyses that are described in Section 6. The remaining initiating events were taken into account in the quantification of uncertainties about the Scoping Study results. These results were presented in Section 2.

4.3 AUXILIARY SYSTEMS MODEL

4.3.1 GENERAL INFORMATION

The analysis of the detailed plant initiating event specific event trees described in Section 4.4 is greatly facilitated and simplified by excluding the various auxiliary systems that support the successful

operation of the main line systems and functions included in the detailed plant event trees. Because these auxiliary systems are required to operate following any initiating event, they are analyzed and quantified in separate auxiliary system event trees for each general category of plant initiating event. The auxiliary systems included in the auxiliary systems event trees are identified in Table 4-3.

The auxiliary systems have been modeled in three detailed event trees that account for the intersystem dependencies among the various auxiliary systems. The event trees are the following:

- Electric Power System Event Tree
- Auxiliary Systems Event Tree for Electric Power States with Offsite Power Available
- Auxiliary Systems Event Tree for Loss of Offsite Power

Figure 4-2 presents in block diagram form the relationships among the three auxiliary systems event trees. Three event trees are required to present and quantify the STPEGS auxiliary system and states because of the large number of combinations of auxiliary system individual train failures.

Table 4-4 presents the relationships among the various auxiliary systems. This matrix is used to develop the detailed auxiliary systems event trees. Table 4-4 lists each train of a particular auxiliary system and the effect of its failure upon other auxiliary systems. An "X" indicates a guaranteed failure of the auxiliary systems train if the associated train fails. The plant auxiliary systems that are not listed in Table 4-4 (but are included in the Scoping Study) are presented in Table 4-5 along with their function and the section where they are analyzed. In general, the systems shown in Table 4-5 only affect a single main line system or function and are included in the analysis of that system or function.

4.3.2 EVENT TREE DESCRIPTION

4.3.2.1 Electric Power Systems Event Tree

Figure 4-3 presents the electric power system event tree developed for the STPEGS risk analysis. This event tree questions the status of the offsite grid; the generator output breaker; the standby transformers; 13.8 kV buses 1F, 1G, 1H, and 1L; Class 1E 4,160V buses E1A, E1B, and E1C; Class 1E DC distribution buses E1A11, E1B11, and E1C11; and the emergency diesel generators DG-11, DG-12, and DG-13. This model was constructed assuming a plant transient has occurred that requires a trip of the main generator from the grid. The various methods of assuring power to the Class 1E 4,160V AC distribution system are shown explicitly in this model, some of which require operator action. Each sequence through the event tree is assigned a unique end state that describes the status of the plant electric power system. These end states are defined in Table 4-6.

4.3.2.1.1 Top Event Descriptions

- Event [OG]. This top event questions the availability of the offsite power grid. This event may fail as a result of the grid disturbance associated with the initiating event and subsequent generator trip, or may be a guaranteed failure for the loss of offsite power initiating events. Success of this event assures a source of power to the standby transformers for both units and, if the generator breaker functions, to unit auxiliary transformer for the affected unit. Failure of this event leaves the emergency diesel generators as the only source of power for the Class 1E 4,160V distribution buses E1A, E1B, and E1C.

- Event [UA]. This top event models the availability of the unit auxiliary transformer to supply power to the 13.8 kV buses 1F, 1G, 1H, and 1J and the operation of the generator output breaker. Success of this event assures a supply of power to these non-Class 1E main buses and Class 1E 4,160V bus E1A. Failure of this top event causes a loss of power to the main bus sections of buses 1F, 1G, 1H, and 1J and the standby bus section of bus 1F, which normally supplies power to 4,160V Class 1E bus E1A. Backup power is available to the 13.8 kV buses from either standby transformer. Operator action is necessary to line up these standby power sources.

- Event [S1]. This top event models the availability of the standby transformer for Unit 1. This transformer normally supplies power to the standby bus sections of 13.8 kV buses 1G and 1H and, through the auxiliary engineered safety feature transformers, to 4,160V Class 1E buses E1B and E1C. Success of this event assures a supply of power to these bus sections. Failure of this top event causes a loss of power to these bus sections. Backup power to these bus sections can be supplied by the unit auxiliary transformer, if available, through the bus section crosstie breakers, or from the standby transformer for Unit 2. Operator action is necessary to line up these power sources.

- Event [S2]. This top event models the availability of the standby transformer for Unit 2. This transformer can supply power to the standby bus sections of 13.8 kV buses 1F, 1G, and 1H. This top event is only questioned upon failure of Top Event S1. Operator action is necessary to line up this power source. Failure of this source in conjunction with failure of Event S1 causes a loss of power at the 13.8 kV buses supplied by these transformers.

- Event [1F]. This top event models the continued availability of 13.8 kV bus 1F. Success of this event assures a power supply through the auxiliary ESF transformer supplying 4,160V Class 1E bus E1A. Failure of this event causes a loss of this source of power to bus E1A.

- Event [1G]. This top event models the continued availability of 13.8 kV bus 1G. This top event is similar to Top Event 1F. This bus normally supplies 4,160V Class 1E bus E1B.

- Event [1H]. This top event models the continued availability of 13.8 kV bus 1H. This top event is similar to Top Event 1F. This bus normally supplies 4,160V Class 1E bus E1C.

- Event [1L]. This top event models the availability of the emergency transformer and associated bus. This bus supplies an alternative source of power to the auxiliary ESF transformers in the event of loss of the normal AC power feed. No credit is taken for this transformer in the Scoping Study.

- Event [EA]. This top event models the availability of 4,160V Class 1E bus E1A, given a source of non-Class 1E power. Success of this event implies power is available to all equipment and buses supplied by this bus. Failure of this top event is assumed to result in a nonrecoverable loss of power to the equipment supplied by this bus due to the failure modes involved (primarily bus fault). This top event is not questioned if power from the non-Class 1E distribution system is not available. Under this condition, bus faults and other failures that result in sustained loss of this bus are included with failure of the emergency diesel generator, which supplies bus E1A.

- Event [EB]. This top event models the availability of 4,160V Class 1E bus E1B and is similar to Top Event [EA].

- Event [EC]. This top event models the availability of 4,160V Class 1E bus E1C and is similar to Top Event [EA].

- Event [DA]. This top event models the availability of Class 1E DC bus E1A11 after an initial loss of the AC feed to the battery chargers. This top event is not questioned if AC power to the chargers is supplied by the offsite grid. If power is lost to 4,160V Class 1E bus E1A, DC bus E1A11 must supply control power for bus E1A and the 4,160V breakers that must function to ensure transfer of AC power from the offsite grid sources to this emergency diesel generator. Success of this event assures DC power for control of the emergency diesel generator and the breakers that must function. Failure of this event is assumed to result in failure of bus E1A and failure of all equipment supplied by this bus.

  With no AC power to the battery charger for longer than 2 hours, the associated battery is assumed to be failed due to the design capacity of the battery.

  Class 1E DC bus E1D11 is also supplied power from Class 1E AC bus E1A. Failure of this battery after a loss of AC power at bus E1A is included in the failure frequency for the turbine-driven auxiliary feedwater pump.

- Event [DB]. This top event models the availability of Class 1E DC bus E1B11 and is similar to Top Event [DA].

- Event [DC]. This top event models the availability of Class 1E DC bus E1C11 and is similar to Top Event [DA].

- Event [GA]. This top event models the availability of emergency diesel generator DG-11 after a loss of power to 4,160V Class 1E bus E1A. Success of this top event assures a source of AC power to the equipment supplied by this bus. Failure of this emergency diesel generator fails all equipment that receives power from bus E1A. This top event includes E1A bus failures, load sequencer failure, and emergency diesel generator support system failures that lead to a failure of diesel generator 11.

- Event [GB]. This top event models the availability of diesel generator 12 and is similar to Top Event [GA].

- Event [GC]. This top event models the availability of diesel generator 13 and is similar to Top Event [GA].

Figure 4-4 presents the electric power systems event tree that is used to determine the unavailability of the Class 1E electric power system after a loss of offsite power. This event tree only includes Top Events [DA], [DB], [DC], [GA], [GB], and [GC].

4.3.2.1.2 Transfer of Information from Electric Power Tree to Other Auxiliary System Event Trees

The unique end states assigned to the various electric power tree sequence and contributions of bus failures have different effects on the systems and top events contained in the other auxiliary system event trees. Table 4-7 presents in matrix form an overview of these effects. An "X" in a column for a unique end state signifies guaranteed failure of the associated auxiliary system train.

4.3.2.2 Other Auxiliary Systems Event Tree - Offsite Power Available

Figure 4-5 presents the other auxiliary systems event tree for the condition offsite power available. This event tree questions the status of the SSPS, the three trains of the ESFAS, the three trains of the essential cooling water system, the three trains of the CCWS, and the three trains of the essential chilled water system. This model was constructed under the following assumptions:

- ECW train A is operating; train C is on standby; train B starts automatically in response to a safety injection actuation signal or load sequences start signal only.

- CCW train A is operating; train C is on standby; train B starts automatically in response to a safety injection actuation signal or load sequences start signal only.

- ECH trains A and B are operating with cooling water supplied from ECW train A; ECH train C starts automatically in response to a safety injection actuation signal or load sequencer start signal only.

- EAB emergency auxiliary building ventilation trains A and B are operating; train C starts automatically in response to a safety injection actuation signal or load sequences start signal only.

The status of the third train of ECW, CCW, and ECH is always questioned, although for some initiating events, these trains can only be started by operator action.

Each sequence through this event tree is assigned a unique end state that describes the status of the auxiliary systems shown in this model. These end states are presented and defined in Tables 4-8 and 4-9. The top events of this model are defined below:

- Event [SS]. This top event questions the status of the SSPS. Two trains of SSPS are provided, train R and train S. Operation of either train ensures the appropriate actuation signals are sent to all trains of ESFAS and at least one reactor trip breaker. Failure of this top event results in failure of all train of the ESFAS and failure of the reactor trip function if offsite power is available. This system is affected by the status of the Class 1E DC system because the instrumentation that provides the input signals is powered from the Class 1E DC distribution system through the 120V vital AC distribution channels, and because the SSPS cabinets are powered from the 120V AC vital AC distribution system.

- Event [EA]. This top event models the availability of ESFAS train A. The ESFAS receives actuation signals from the SSPS. The types of signals and the output required depend on the initiating event under consideration. Success of this top event implies automatic signals are present at the necessary equipment. Failure of this top event is defined as failure to provide signals for all necessary functions provided by the ESFAS. From this definition, failure to provide a single function (e.g., containment spray actuation) fails the associated ESFAS actuation train. This ESFAS train is affected by the status of Class 1E DC bus E1A11. Failure of this DC bus fails ESFAS train A.

- Event [EB]. This top event models the availability of ESFAS train B and is similar to Top Event [EA]. This ESFAS train fails if Class 1E DC bus E1B11 fails.

- Event [EC]. This top event models the availability of ESFAS train C and is similar to Top Event [EA]. This ESFAS train fails if Class 1E DC bus E1C11 fails.

- Event [WA]. This top event models the availability of ECW train A and its associated auxiliary systems. For purposes of analysis, this train is assumed to be operating prior to the initiating event, providing cooling water for train A CCW and condensing water for the ECH chillers in train A and train B. Should the operating ECW or CCW pump fail, the standby ECW and CCW pump trains start automatically. For purposes of analysis, train C ECW and CCW pumps are selected for standby operation. Success of this top event implies a continued

supply of cooling water for CCW train A and ECH trains A and B. Failure of this top event fails CCW train A and results in an automatic trip of the ECH chillers in trains A and B if ECW train B is not operating. This train is affected by the status of power at Class 1E AC bus E1A and Class 1E DC bus E1A11.

- Event [WB]. This top event models the availability of ECW train B and is similar to Top Event [WA]. This ECW system is assumed to start automatically in response to a safety injection actuation signal or load sequencer start signal only. Failure of this top event fails CCW train B and, with failure of Top Event [WA], ECH trains A and B. This train is affected by the status of power at Class 1E AC bus E1B and Class 1E DC bus E1B11.

- Event [WC]. This top event models the availability of ECW train C and is similar to Top Event [WA]. This ECW train is assumed to be selected for standby operation and will start automatically on failure of ECW or CCW train A. In addition, this train starts automatically in response to a safety injection actuation signal or load sequencer start signal. Failure of this top event fails CCW train C and ECH train C. ECH train C fails due to the assumed lineup for the train C chiller condensing water supply. This top event is affected by the status of power at Class 1E AC bus E1C and Class 1E DC bus E1C11.

- Event [CA]. This top event models the availability of CCW train A and its associated auxiliary systems. For purposes of analysis, this train is assumed to be operating prior to the initiating event. Should the operating ECW or CCW pump fail, the standby ECW and CCW pumps start automatically. For purposes of analysis, train C ECW and CCW pumps are selected for standby operation. Success of this top event implies a continued supply of CCW to the train A CCW loads and, depending on the initiating event, to the CCW loads that are supplied by the common header. Failure of this top event fails the equipment cooled by CCW train A. This train is affected by the status of power at Class 1E AC bus E1A and Class 1E DC bus E1A11, and by the status of ECW train A.

- Event [CB]. This top event models the availability of CCW train B and is similar to Top Event [CA]. This CCW train is assumed to start automatically in response to a safety injection actuation signal or load sequencer start signal only. Failure of this top event fails the equipment cooled by CCW train B. This train is affected by the status of power at Class 1E AC bus E1B and Class 1E DC bus E1B11, and by the status of ECW train B.

- Event [CC]. This top models the availability of CCW train C and is similar to Top Event [CA]. This CCW train is assumed to be selected for standby operation and will start automatically on failure of ECW or CCW train A. In addition, this train starts automatically in response to a safety injection actuation signal or load sequencer start signal. Failure of this top event fails the equipment cooled by CCW train C. This train is affected by the status of power at

Class 1E AC bus E1C and Class 1E DC bus E1C11, and by the status of ECW train C.

- Event [SA]. This top event models the availability of ECH train A. Each ECH train contains two water chillers, one rated at 150 tons of air conditioning, the other rated at 300 tons of air conditioning. Success of this top event implies chilled water is at the design temperature and flow is supplied to the systems serviced by this train. The chillers in the ECH train are automatically tripped if condensing water flow is lost for more than 5 seconds. If condenser water flow is restored, the chillers automatically restart. Condensing water for this ECH train is assumed to be normally supplied by ECW train A and cross-connected to ECW train B. Failure of both ECW trains A and B is assumed to result in failure of ECH train A. Failure of this ECH train is assumed to result in (1) long-term failure of the equipment supplied only by this chiller train (primarily pump and valve room coolers) and (2) loss of one-half of the heat removal capacity for those systems supplied by any ECH train (primarily the EAB area ventiliation systems). This train is affected by the status of power at Class 1E AC bus E1A and Class 1E DC bus E1A11, and by the status of ECW trains A and B.

- Event [SB]. The top event models the availability of ECH train B and is similar to Top Event [SA]. Condensing water for this chiller is assumed to be supplied normally by ECW train A and cross-connected to ECW train B. This train is affected by the status of power at Class 1E AC bus E1B and Class 1E DC bus E1B11, and by the status of ECW trains A and B.

- Event [SC]. This top event models the availability of ECH train C and is similar to Top Event [SA]. This ECH train is assumed to be off. This train starts automatically in response to safety injection actuation or load sequencer start signals only. Condensing water for this chiller is assumed to be lined up to CH train C only. Operator action would be required to cross-connect the condensing water supply to another ECW train. Operator action is also necessary to start this chiller in response to the failure of chiller train A or B if safety injection actuation has not occurred. This ECH train is affected by the status of power at Class 1E AC bus E1C and Class 1E DC bus E1C11, and by the status of ECW train C.

- Event [EV]. This top event models the availability of the EAB HVAC system. The system consists of three trains of supply and exhaust fans and associated cooling units. Each train is supplied chilled water from the associated ECH train. During normal plant operation, two fan trains are operating to satisfy the cooling requirements of the EAB. The third EAB fan train starts automatically in response to safety injection actuation or load sequencer start signals only. The three EAB HVAC rains are affected by the following auxiliary systems:

  - EAB HVAC Train A. Class 1E AC power at E1A, Class 1E DC power at E1A11, ECW trains A and B, and ECH train A.

- EAB HVAC Train B. Class 1E AC power at E1B, Class 1E DC power at E1B11, ECW trains A and B, and ECH train B.

- EAB HVAC Train C. Class 1E AC power at E1C, Class 1E DC power at E1C11, ECW train C, and ECH train C.

4.3.2.3 Other Auxiliary Systems Event Tree - Loss of Offsite Power

Figure 4-6 presents the other auxiliary systems event tree for the condition loss of offsite power. This event tree, including the systems modeled, is similar to the other auxiliary system event tree for the condition offsite power available. The differences in the top event descriptions and the resulting effect on the event tree structure are described below:

- Event [WA]. Failure of Top Event [WA] results in loss of cooling to diesel generator 11 with a subsequent loss of power to Class 1E AC bus E1A. Equipment powered from E1A fails. ECW train A must restart after power is available.

- Event [WB]. Failure of Top Event [WB] results in loss of cooling to diesel generator 12 with a subsequent loss of power to Class 1E AC bus E1B. Equipment powered from E1B fails. ECW train B starts automatically when power is available.

- Event [WC]. Failure of Top Event [WC] results in loss of cooling to diesel generator 13 with a subsequent loss of power to Class 1E AC bus E1C. Equipment powered from bus E1C fails. ECW train C starts automatically when power is available.

- Event [CA]. CCW train A restarts when power is available to Class 1E AC bus E1A.

- Event [CB]. CCW train B starts automatically when power is available to Class 1E AC bus E1B.

- Event [CC]. CCW train C starts automatically when power is available to Class 1E AC bus E1C.

- Event [SA]. CH train A restarts automatically when power is available to Class 1E AC bus E1A.

- Event [SB]. CH train B restarts automatically when power is available to Class 1E AC bus E1B.

- Event [SC]. CH train C starts automatically when power is available to Class 1E AC bus E1C.

- Event [EV]. All three EAB HVAC trains start automatically when power is available at their respective Class 1E AC buses.

4.3.3 DEPENDENCIES BETWEEN MAIN LINE SYSTEMS AND AUXILIARY SYSTEMS

The dependencies identified for the various main line systems and functions on the plant auxiliary systems are presented in a matrix format in Table 4-10. An "X" in a column for a particular main line system or function indicates failure of that function, given failure of the associated auxiliary system train. For SSPS and ESFAS failures, an "X" implies failure of the automatic start of the associated main line function.

4.3.4 QUANTIFICATION OF THE AUXILIARY TREES

Three initiating events were chosen as representative of all initiating events for the Scoping Study quantification of the auxiliary trees. These initiating events are a general plant transient requiring a reactor trip and auxiliary feedwater actuation from the ESFAS, a loss of offsite power requiring diesel generator operations, and a small LOCA requiring actuation of the emergency core cooling systems.

The auxiliary system failure frequencies presented in Section 5.4 were used to quantify the auxiliary systems event trees for the three initiating events used in the Scoping Study. The computer code MAXIMA was used to assemble the results of the auxiliary systems quantification by initiating event, electric power end state, and auxiliary systems end states. The assembled results were used to determine the auxiliary systems impact vectors described below.

4.3.5 AUXILIARY SYSTEMS EVENT TREE RESULTS

One purpose of the auxiliary systems quantification in the Scoping Study was to determine a unique set of auxiliary system impact vectors for us in quantifying the main line event trees. An impact vector defines an auxiliary system end state with a certain effect on the main line systems. A unique impact vector is a combination of all auxiliary system impact vectors having the same effect on the main line systems. For the Scoping Study analysis, 17 unique impact vectors are defined for the auxiliary systems. These impact vectors and their associated auxiliary systems failures are presented in Table 4-11. All auxiliary tree end states presented in Table 4-9 were mapped into one of these impact vectors. Table 4-12 presents a mathematical representation of these impact vectors and their effects on the various main line event tree top events.

The impact vector having the highest frequency is "AUX," which describes the state in which all auxiliaries are available. Impact vector "9," which describes the loss of EAB HVAC, has the next highest frequency. For this point estimate analysis, impact vector "9" is assumed to result in the loss of plant-essential AC power. Impact vector "9" and impact vector P, which is associated with loss of essential cooling and loss of component cooling with electric power available, were found to contain the most important contributors to core melt frequency as described more fully in Section 2.

4.4 FRONTLINE SYSTEMS MODEL

Four event sequence models have been developed to analyze the plant response to three major initiating event categories that are to be considered in the Scoping study. These event sequence models are as follows:

Model	Events Analyzed
General Transient	General Transient Loss of Offsite Power Loss of Essential Chilled Water Loss of Component Cooling Water Loss of Essential Cooling Water
Small LOCA	Small LOCA
Long-Term Response (LT1)	Sequences Successfully Exiting the SLOCA and General Transient Models Following Injection of the RWST
Long-Term Core Melt Response (LT2)	Sequences Exiting the SLOCA and General Transient Models in a Core Melt Condition

The general transient and small LOCA models analyze the early response of the plant, whereas the LT1 and LT2 models analyze the long-term response. Each model is described below, first in the form of an event sequence diagram, then in the form of an event tree. The ESDs are made up of several explanatory blocks with symbology as noted in Figure 4-7. ESDs are useful in describing in a more general and easily understood manner the various sequence paths; ESDs are used for documentation purposes and developing the event trees but do not easily lend themselves to direct quantification. The event trees illustrate the same logic information portrayed in an ESD but in a different manner; event trees explicitly show each possible sequence and are used in the actual quantification process.

The top events in the event trees correspond to groups of event blocks in the ESD. A node is shown in the event tree when a top event is questioned in a specific sequence. If the questioned top event is successful, the sequence continues to the right of the node; if the top event fails, the sequence continues downward from the node. When transfer is made from the early response model to either the LT1 or LT2 long-term response models, certain information that will affect the long-term response must be specified as a long-term model entry condition.

4.4.1 THE GENERAL TRANSIENT EVENT SEQUENCE MODEL

The general transient event sequence model is used to evaluate the early response of a broad range of initiating events including reactor trip,

turbine trip, loss of main feedwater flow, and loss of load and offsite power. The impact of the specific initiating event category on both the auxiliary systems and the frontline systems is determined as part of the systems analysis activity, and the corresponding information is included as an integral part of the event tree quantification. The general transient event sequence diagram is shown in Figure 4-8.

The events shown in each block of the ESD are, for the most part, self-explanatory. The ESD events are numbered 1E through 32E. The ESD events are combined into functional groups (within dashed lines in Figure 4-8) and numbered 1 through 19 in the simplified ESD of Figure 4-9. That diagram provides an easy-to-follow logic of the top event represented in the general transient event tree (Figure 4-10). This event tree provides the logic in a readily quantifiable form. The following discussion explains some of the events in the general transient ESD and its relationship to the simplified ESD and the event tree. Reasons for the branching logic of the event tree are also given.

The general transient ESD begins with the transient itself, then in event 1E asks whether the reactor has tripped. This event is actually handled in the auxiliary systems model described in Section 4.3. Following the event sequence diagram beyond the reactor trip event leads to the question of whether steam demand is secured. This is accomplished either by tripping the turbine or shutting the MSIVs. If successful, the decay heat must be removed by steaming the steam generators through either the turbine bypass or the atmospheric steam dumps, or via the steam generator safety valves. In cases where excessive steam demand continues, overcooling events occur and questions are raised concerning pressurized thermal shock.

In event 14E, the high head injection system responds to the overcooling depressurization of the reactor coolant system and the question asked is: "Does the operator control high head injection?" If not, pressurized thermal shock conditions exist and the integrity of the reactor vessel is questioned. If intact, the event sequence continues to event 6E with the constraint that steam-driven auxiliary feedwater and main feedwater pumps are not available. If vessel integrity is lost, core melt is assumed and it is questioned whether containment spray provides water to flood the reactor cavity region.

For cases where no steam generator heat removal occurs, the sequence branches to event 29E for bleed and feed cooling. In the cases with successful steam removal, questions regarding the availability of feedwater are then asked. These questions include events 5E, 6E, 21E, 22E, 25E, and 26E. With no feedwater available, the sequence again branches to bleed and feed at event 29E. With no auxiliary feedwater, if the operator does not recognize this condition and respond properly, core melt ensues. Again, questions are asked about the containment spray. In scenarios with successful feedwater, it is possible that a pressurizer PORV opens and, if so, must reclose. Failure here is equivalent to a small LOCA. With the PORV reseated, other questions of potential loss of RCS inventory arise. Event 8E includes a variety of potential leak paths; e.g., reactor coolant pump seal leak LOCA via the letdown system

either to the VCT or to the containment via the 600 psia relief valve; and a low flow LOCA via the reactor coolant pump seal return lines. Under LOCA conditions, a branch is made to event 33E for RCS makeup. On successful inventory control, it is questioned whether the operator controls feed, what the effects of failure to control feed are, and finally, long-term questions of stabilization.

Bleed and feed event 29E involves the operator opening two pressurizer PORVs and supplying high head injection. Success along this path can be either via the close loop residual heat removal system or through a branch to long-term tree LT1 and open loop recirculation. In core melt cases, containment spray is questioned and we branch to LT2. Event 33E follows the LOCAs in event 8E and questions whether the operator controls the LOCA by decreasing RCS pressure. If so, continued cooldown is asked via event 9E. If the operator failed to depressurize, it questions whether response to the small LOCA condition is successful, i.e., did we have high head injection and either closed loop recirculation or open loop via LT1?

Some of the events in the ESD need not be quantified for various reasons. The following discussion takes us from the ESD to the top events of the event tree as depicted in the simplified ESD. For steam relief, we have decided to consider only the atmospheric steam dumps, event 12E for several reasons. First, there is a variety of conditions under reduced auxiliary system states where turbine bypass will not work, often due to loss of condensate flow and instrument air arising from loss of nonvital AC power. Also, the atmospheric steam dumps are very reliable; thus, including the turbine bypass is not essential to obtaining accurate results.

Again, because of atmospheric steam dump reliability, questions of the steam generator safety valve are not, in general, essential. Moreover, use of the safety valves is an unusual operating mode. They may stick open and lead to depressurization of a steam generator, raising questions in the operators' minds as to whether continued use of the affected steam generators is warranted. As a result of safety valves sticking open, the operator loses direct control of steam generator pressure and reactor coolant system temperature. Therefore, only steam relief via the ASDs is included in event tree tops 4 and 5, and turbine trip and MSIV closure are grouped as a single event for the event tree top event 1.

In overcooling scenarios, events 14E and 15E are combined into a single event 2, for the event tree. Here, high head injection is almost guaranteed to work. The only serious question is whether the operator can control high head injection.

A rather large group of events are combined into event tree events 4, 5, and 6. First, as discussed earlier, all steam relief is modeled simply as the opening of the atmospheric steam dump on the steam generators. Next, a combination of ASDs, and situations of two or more auxiliary feedwater trains operating are combined into event 4 of the event tree. Given the failure of event 4, one train of auxiliary feedwater combined with atmospheric steam dump makes up event 5. The main feedwater system

is guaranteed to trip under normal situations when the turbine bypass automtically brings the RCS average temperature to the no-load T_{ave} setpoint. It is not very likely the operator will need to turn to the startup feed pump. Finally, it is assumed that if two or more trains of auxiliary feedwater work, the pressurizer PORVs will not be demanded. To allow the chance that PORVs are at times demanded, we ask for their opening and reclosure for every situation in which only one train of auxiliary feedwater is working. This is event 6 in the event tree.

It is unlikely that the operators will overfill the steam generators (event 9E). Even if they do, it is extremely unlikely that the main steam lines fail; and, even if they fail, the only substantial effect contributing to core melt is the loss of turbine-driven feed pumps. For these reasons, we have decided not to model events 9E, 27E, and 28E.

The remaining events provide much more obvious linkage between the ESD and event tree tops. For example, each train of ECCS can be affected by common failures, and some common failures can even couple trains. These effects are modeled in event tree tops 10, 11, and 12 to account for trainwise common failures among two trains and common failures among three trains such as RWST failures. Each train is modeled separately because of trainwise effect between the ECCS common equipment, the high head injection equipment and the containment spray equipment. These interdependencies are also important in the long-term trees for further common recirculation equipment and low head injection equipment for each train.

Now, examining the generalized transient event tree in Figure 4-10, we find the same top events just discussed. Table 4-13 gives the success criteria for each of the top events. These are modeled and quantified in the systems analysis of Section 5. For scenarios in the general transient tree that branch to either the LT1 tree or the LT2 tree, it is essential to keep track of the boundary conditions that are of importance in those later trees. Tables 4-14 and 4-15 give the coding used for transfer state between early and long term response event trees. For example, LT1E transfer state branches from an early event tree with two high head safety injection pumps failed (one due to an ECCS common effect) and no loss of RCS inventory control (i.e., event OI succeeds).

Proceeding directly to the general transient event tree, the normal expected sequence of events is event sequence 1 in which all events succeed. If event ON fails, i.e., the operator fails to provide the long-term cooling, core melt surely occurs, and in sequences 2 through 28 we branch to the LT2 tree. In defining each branch, we keep track of the number of containment spray system failures and whether these failures are due to common effect. This is important for defining whether water can be present in the reactor vessel cavity. The presence of water is important in assessing the plant damage states as described in Section 7.2.

If event OI fails and we have a loss of reactor inventory control, i.e., either a reactor coolant pump seal LOCA, a LOCA via the letdown system, or a LOCA via the reactor coolant pump seal return line, safety injection

is required. If both safety injection and closed loop residual heat removal cooling are successful, we are in a success state on event sequence 29. If closed loop residual heat removal is not successful, we branch via sequence 30 to LT1G to consider long-term open loop recirculation. Sequences 31 through 93 represent variations on the scheme with 0, 1, 2, or 3 high head injection pumps failed either directly or through common failures in EA, EB, and EC as well as all possible failure states for containment spray injection for the core melt scenarios.

Should AF fail (less than two auxiliary feedwater trains and steam relief are available) we can proceed to a success state in sequence 94 if F1 (one auxiliary feedwater train), PR (pressurizer power-operated relief valve opens and closes), OI and OA are successful. If OI fails, sequences 122 through 186 duplicate sequences 29 through 93. If ON fails, sequences 95 through 121 duplicate sequences 1 through 28. If PR fails, a small LOCA exists because either the PORV stuck open or it did not open and rising pressure caused a leak elsewhere in the reactor coolant system. Sequences 187 through 251 represent the early tree response to the small LOCA condition and are identical with sequences 29 through 93 except that the LT1 and LT2 codes are given for no OI failure. The OI branch is not asked in this case because, first, a LOCA already exists and, second, release paths outside containment are also tracked in event CI in the LT1 and LT2 trees.

With failure at AF and F1, no auxiliary feedwater is available so heat removal via the steam generators fails. In this case, the only route to success is bleed and feed cooling via event OB. PR is not asked because, although the PORVs may indeed lift, bleed and feed requires they both be manually opened; otherwise, core melt will follow. Event OI is not asked since, as above event OB induces a LOCA and if OB fails, core melt will ensue; also, release paths outside containment induced by the OI branch are also tracked in the LT trees in event CI. When event OB is successful and the operator decides to initiate bleed and feed cooling and open the PORVs, sequences 252 through 316 are identical to sequences 187 through 251, which is the response to a small LOCA. If OB fails, core melt is guaranteed and sequences 316 through 343 are identical to sequences 2 through 28.

When TT fails (i.e., steam demand is not secured and a rapid cooldown ensues) the operator should control high head injection event OH. If the operator is successful, scenarios 344 through 686 look exactly like the 343 scenario already described. If the operator fails to control high head injection but the reactor vessel remains intact, the same 343 sequences are replicated as sequences 687 through 1,029. If the reactor vessel fails through the pressurized thermal shock, core melt is guaranteed and scenarios 1,030 through 1,056 are replicates of sequences 2 through 28.

4.4.2 THE SMALL LOCA EVENT SEQUENCE MODEL

The small LOCA event sequence model is used to evaluate the early response to small LOCA events. Small LOCAs include unisolated breaks or openings in the RCS pressure boundary of a sufficient size so that the

charging pump is unable to maintain adequate RCS inventory (implying leak rates in excess of 120 gpm) but not large enough to be considered medium LOCAs. The effective diameter of small LOCA breaks range from 3/8 inch to 2 inches. Breaks smaller than 3/8-inch diameter are considered to be leaks that result in an orderly plant shutdown. Although the equipment required to prevent core melt during a small LOCA may vary somewhat depending on the size of the break within the range considered, conservative success criteria will be used. Accordingly, the flow out the break will be considered too small to remove sufficient energy compared to the core decay heat, so it is assumed that at least one PORV will need to be opened if bleed and feed cooling is required. One of three high head injection pumps is required for adequate inventory makeup.

The small LOCA model is a special case of the events included in the general transient model. Therefore, only a discussion of the restrictions on the general transient model leading to the small LOCA model is given here. The success criteria for the top events in the small LOCA event tree (Figure 4-11) are identical for similar events in the general transient tree except as discussed below.

The first difference between the general transient and small LOCA event trees is that events AF and F1 of the general transient are replaced by the single event F1 in the small LOCA tree. This is because a LOCA already exists so that examination of the PORV lifting and reclosing is not essential. Thus, for the small LOCA event F1 represents the operation of one or more trains of auxiliary feedwater combined with steam relief from a steam generator receiving feedwater. Event PR is no longer required. Again, since a LOCA already exists event OI is not required. Event ON is not required either, because success in the case of small LOCAs requires actions of the operator in the long-term response tree LT1. The only remaining difference is that event OR, closed loop residual heat removal cooling, has not been included in the small LOCA event tree because the residual heat removal pumps are located inside the containment and are not qualified for a hot, moist atmosphere that would exist following a LOCA. The logic for branching is as described under general transient.

4.4.3 THE LT1 LONG-TERM RESPONSE EVENT SEQUENCE MODEL

The LT1 long-term response event sequence diagram, Figure 4-12, is entered from either the early response general transient or small LOCA models for sequences where a significant portion of the RWST has been injected into the vessel and addresses the transfer to either high or low pressure recirculation cooling. In the ESD we first question whether fan coolers provide long-term containment, and hence recirculation, cooling. If the fan coolers work, all that it is required to reach a successful end state is that the common recirculation equipment and one out of three high head safety injection pumps operate. On failure of the common recirculation equipment no long-term containment spray is possible and only the containment isolation questions are asked. If the high head safety injection system fails, low head recirculation is possible; if that fails, both containment spray and containment isolation are important.

If the fan coolers fail, successful core cooling requires that reactor pressure be low enough for low head recirculation through the residual heat removal heat exchanger to cool the core. If low head recirculation is not possible prior to core melt it could still provide long term containment sump cooling after reactor vessel melt-through permits low head flow. To prevent pressure buildup in the containment, fission product heat must be removed from the containment atmosphere, either via operating containment spray system or one operating fan cooler. In the baseline model we have not tracked the remote chance that only one containment fan cooler is operating with no containment spray pumps and one train of low head recirculation with a residual heat removal heat exchanger. With this discussion, the events in the LT1 ESD are self-explanatory and directly convert into the LT1 event tree (Figure 4-13). The only additional information in the event tree involves the tracking of the separate trains of common recirculation equipment and low head safety injection. Table 4-16 gives success criteria of the LT1 event tree sequences in accordance with the definitions of Section 7.2.

4.4.4 THE LT2 LONG-TERM CORE MELT RESPONSE EVENT SEQUENCE MODEL

The LT2 long-term response core melt event sequence diagram, Figure 4-14, is entered from either the general transient or the small LOCA model for sequences that have resulted in or are leading to core melt. The model questions whether sufficient RWST water has been injected into the containment to provide debris bed cooling as well as whether containment functions that can mitigate the offsite consequences (namely, containment isolation, spray, and heat removal) are working. The ESD is a subset of the LT1 ESD and requires no further explanation. The corresponding event tree shown in Figure 4-15 and the top event success criteria are as given for LT1.

TABLE 4-1. CATALOG OF POTENTIAL INITIATING EVENTS (TAKEN FROM THE SEABROOK STATION PROBABILISTIC SAFETY ASSESSMENT)

Sheet 1 of 2

Group	Initiating Event Categories Selected for Separate Quantification
Loss of Coolant Inventory	1. Excessive LOCA 2. Large LOCA 3. Medium LOCA 4. Small LOCA 5. Interfacing Systems LOCA 6. Steam Generator Tube Rupture
General	7. Reactor TripTransients 8. Turbine Trip 9. Total Main Feedwater Loss 10. Partial Main Feedwater Loss 11. Excessive Feedwater Flow 12. Loss of Condenser Vacuum 13. Closure of One MSIV 14. Closure of All MSIVs 15. Core Power Excursion 16. Loss of Primary Flow 17. Steam Line Break Inside Containment 18. Steam Line Break Outside Containment 19. Main Steam Relief Valve Opening 20. Inadvertent Safety Injection
Common Cause Initiating Events	
Support System Faults	21. Loss of Offsite Power 22. Loss of One DC Bus 23. Total Loss of Service Water 24. Total Loss of Component Cooling Water
Seismic Events	25. 0.7g Seismic LOCA 26. 1.0g Seismic LOCA 27. 0.2g Seismic Loss of Offsite Power 28. 0.3g Seismic Loss of Offsite Power 29. 0.4g Seismic Loss of Offsite Power 30. 0.5g Seismic Loss of Offsite Power 31. 0.7g Seismic Loss of Offsite Power 32. 1.0g Seismic Loss of Offsite Power

CAUTION: PRELIMINARY RESULTS-IMPORTANT UNCERTAINTIES DESCRIBED IN SECTION 2

TABLE 4-1 (continued)

Sheet 2 of 2

Group	Initiating Event Categories Selected for Separate Quantification
Common Cause Initiating Events (continued)	
Fires	33. Cable Spreading Room - PCC Loss 34. Cable Spreading Room - AC Power Loss 35. Control Room - PCC Loss 36. Control Room - Service Water Loss 37. Control Room - AC Power Loss 38. Electrical Tunnel 1 39. Electrical Tunnel 3 40. PCC Area 41. Turbine Building - Loss of Offsite Power
Turbine Missile	42. Steam Line Break 43. Large LOCA 44. Loss of Condenser Vacuum 45. Control Room Impact 46. Condensate Storage Tank Impact 47. Loss of PCC
Tornado Missile	48. Loss of Offsite Power and One Diesel Generator 49. Loss of PCC 50. Control Room Impact
Aircraft Crash	51. Containment Impact 52. Control Room Impact 53. Primary Auxiliary Building Impact
Flooding	54. Loss of Offsite Power 55. Loss of Offsite Power and One Switchgear Room 56. Loss of Offsite Power and Two Switchgear Rooms 57. Loss of Offsite Power and Service Water Pumps
Others	58. Truck Crash into Transmission Lines

CAUTION: PRELIMINARY RESULTS-
IMPORTANT UNCERTAINTIES
DESCRIBED IN SECTION 2

TABLE 4-2. INITIATING EVENTS QUANTIFIED IN THE STPEGS STUDY

Group		Initiating Event Categories Selected for Separate Quantification	Code Designator
Loss of Coolant Inventory	1.	Small LOCA	SLOCA
	2.	Interfacing Systems LOCA	ISLOCA
General Transients	3.	General Transient	GT
Common Cause Initiating Events			
Support System Faults	4.	Loss of Offsite Power	LOSP
	5.	Total Loss of Essential Chilled Water	TLECH
	6.	Loss of Component Cooling Water	
	7.	Loss of Essential Cooling Water	
External Events	8.	Aircraft Crash	AC
	9.	Turbine Missile	TBM
	10.	Tornado Excessive Wind	TW
	11.	Tornado Missile	TM
	12.	Hazardous Chemical Release	HCR
	13.	Seismic Events	EQ
	14.	External Flooding	EFL
Internal Plant Hazards	15.	Fire	IF
	16.	Internal Flood	IFL

CAUTION: PRELIMINARY RESULTS-
IMPORTANT UNCERTAINTIES
DESCRIBED IN SECTION 2

TABLE 4-3. AUXILIARY SYSTEMS INCLUDED IN AUXILIARY EVENT TREES

Sheet 1 of 2

System	Function
ELECTRIC POWER SYSTEM	
Non-Class 1E Distribution	Provides power to Class 1E AC distribution systems during normal and transient plant operations. Provides power for certain nonsafety systems analyzed in the Scoping Study.
1E - AC Distribution	Provides power to other auxiliary systems and plant main line systems to allow mitigation of plant transient events. Includes emergency diesel generators.
1E - DC Distribution	Provides control power for large AC loads and various solenoid-operated valves. Provides normal source of power for the 120V vital AC distribution systems. Provides power for the engineered safety features actuation system, emergency diesel generator operation, and other DC loads.
SOLID STATE PROTECTION SYSTEM	Receives input from various plant monitoring systems; using this input, sends signals to the engineered safety features actuation system, the reactor trip system, the Class 1E AC distribution system, and other functions. The signals developed depend on the input parameters and the plant initiating event.
ENGINEERED SAFETY FEATURES ACTUATION SYSTEM	Receives actuation signals from the SSPS and, using master relay/slave relay combinations, sends these signals to the equipment that must operate to mitigate the initiating event.
ESSENTIAL COOLING WATER SYSTEM	Provides cooling water from the ECW pond to the component cooling water heat exchangers, essential chilled water chiller condensers, and emergency diesel generator coolers, and returns the water to the ECW pond.
COMPONENT COOLING WATER SYSTEM	Supplies cooling water to the reactor coolant pumps, centrifugal charging pumps, residual heat removal pumps and heat exchangers, the containment fan cooler units under accident conditions, and other process loads to remove generated heat.

CAUTION: PRELIMINARY RESULTS-
IMPORTANT UNCERTAINTIES
DESCRIBED IN SECTION 2

TABLE 4-3 (continued)

Sheet 2 of 2

System	Function
ESSENTIAL CHILLED WATER SYSTEM	Provides chilled water to various safety related ventilation system cooling coils to provide suitable environmental conditions for continued equipment operation and for the plant operators.
ELECTRICAL AUXILIARY BUILDING MAIN AREA HVAC SYSTEM	Supplies cooled air to vital equipment located in the main area of the EAB.
REACTOR TRIP SYSTEM	Provides negative reactivity to shut down the fission process. Although a main line function, reactor trip is quantified with the plant auxiliary systems because of its direct relationship with the non-Class 1E distribution system and the SSPS.

CAUTION: PRELIMINARY RESULTS-
IMPORTANT UNCERTAINTIES
DESCRIBED IN SECTION 2

TABLE 4-4. MATRIX OF AUXILIARY SYSTEM T

Other System Failed / Failed System/Train	Class 1E 4,160V AC Buses			Class 1E DC Buses				EDGs			SSPS	
	E1A	E1B	E1C	E1A11	E1B11	E1C11	E1D11	DG11	DG12	DG13	Train R	Tra S
Offsite Grid	(a)	(a)	(a)	(b)	(b)	(b)	(b)	(c)	(c)	(c)		
4,160V Bus E1A 4,160V Bus E1B 4,160V Bus E1C	-	-	-	(f)	(f)	(f)	(f)	(g)	(g)	(g)		
DC Bus E1A11 DC Bus E1B11 DC Bus E1C11 DC Bus E1D11				-	-	-	-	X	X	X	(i) (i) (i) (i)	(i (i (i (i
EDG DG11 EDG DG12 EDG DG13	(j)	(j)	(j)	(f)	(f)	(f)	(f)	-	-	-		
SSPS Train R SSPS Train S											-	-
ESFAS Train A ESFAS Train B ESFAS Train C												
ECW Train A ECW Train B ECW Train C								X	X	X		
CCW Train A CCW Train B CCW Train C												
ECH Train A ECH Train B ECH Train C	(q) (q) (q)	(q) (q) (q)	(q) (q) (q)	(q) (q) (q)	(q) (q) (q)	(q) (q) (q)	(q) (q) (q)				(r) (r) (r)	(r (r (r
EAB HVAC	(q)	(q)	(q)	(q)	(q)	(q)						
Reactor Trip												

*Letters in parentheses refer to notes on the following page.
**An "X" denotes a guaranteed failure of the systems train if the associated train fails.

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) AUXILIARY SYSTEM INTERDEPENDENCIES*

Sheet 1 of 2

	ESFAS			Essential Cooling Water			CCW			Essential Chilled Water			EAB HVAC	Reactor Trip
	Train A	Train B	Train C	Train A	Train B	Train C	Train A	Train B	Train C	Train A	Train B	Train C		
				(d)	(d)	(d)	(d)	(d)	(d)	(d)	(d)	(d)	(d)	(e)
				X**	X	X	X	X	X	X	X	X	(h) (h) (h)	
	X	X	X	X	X	X	X	X	X	X	X	X	(h) (h) (h)	
				X	X	X	X	X	X	X	X	X	(h) (h) (h)	
	(k) (k)	(k) (k)	(k) (k)											(l) (l)
	-	-	-	(m)	(m)	(m)	(m)	(m)	(m)	(m)	(m)	(m)	(n)	
				-	-	-	X	X	X	(o)	(o)	X	(p)	
							-	-	-					
										-	-	-		
													-	
														-

Also Available On Aperture Card

TI APERTURE CARD

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CAUTION: PRELIMINARY RESULTS-
IMPORTANT UNCERTAINTIES
DESCRIBED IN SECTION 2

a. For a loss of the offsite grid, bus failures represented by Top Events [EA], [EB], and [EC] are included in the frequency of failure of the respective emergency diesel generator.
b. DC buses are only questioned following a loss of AC power to the associated battery charger(s).
c. With a loss of the offsite grid, or loss of power to a Class 1E 4,160V AC bus, the EDGs receive automatic start signals. The load sequencers are included with the associated EDGs.
d. With a loss of offsite power, these auxiliary system trains receive automatic start signals from the load sequencer when the EDG is supplying power to the associated bus.
e. With a loss of offsite power, the control rod drive motor generator sets lose power. Successful reactor trip for this case does not require reactor trip breaker operation.
f. With no AC power to the battery chargers, the batteries are assumed to fail after 2 hours (rated battery capacity).
g. Top Events [EA], [EB], and [EC] represent bus failure or distribution failures that cannot be recovered by EDG operation.
h. Loss of one EAB HVAC train.
i. Loss of power at a Class 1E DC bus results in a loss of power to the associated 120V vital AC power distribution channel. The associated instrumentation is designed to "fail safe."
j. If the EDGs are required, the bus failures represented by Top Events [EA], [EB], and [EC] are included with the frequency of failure of the associated EDG.
k. Loss of a single SSPS train results in a loss of one of two input, available to the ESFAS train.
l. Loss of a single SSPS results in a loss of trip signal to the associated reactor trip breaker.
m. Loss of an ESFAS train results in no automatic start signals to the associated ECW train, CCW train, ECH train, and ventilation train for those plant initiating events that require safety injection actuation. If the ECW and CCW trains selected for standby operation are associated with the failed ESFAS train, the failure of this ESFAS train has no effect on the operation of the ECW and CCW train. With concurrent loss of offsite power, failure of an ESFAS train does not affect the operation of the associated ECW, CCW, and ECH trains because the load sequencer will provide start signals to these trains.
n. Train C of EAB HVAC does not start automatically if safeguards actuation is required.
o. For purposes of quantification, ECH trains A and B are assumed to be operating with chiller condenser water supplied by ECW train A. With loss of ECW train A, ECW train B can supply chiller condenser water to ECH trains A and B without valve lineup changes. ECH train C is assumed to be lined up to receive chiller condenser water only from ECW train C.
p. Loss of train C of EAB HVAC.
q. Failure of a single operating ECH train will result in increasing temperatures in the areas supplied by the electrical auxiliary building main area ventilation system. This may have an effect on the operation of the Class 1E switchgear and batteries supplied by this EAB ventilation system. Operator action is necessary to start the third ECH train if offsite power is available and no safety injection actuation signal is expected.
r. Failure of a single operating ECH train will result in increasing temperature in the area supplied by the EAB main control room ventilation system. This may have an effect on the operation of the SSPS and other equipment cooled by this ventilation system. Operator action is necessary to start the third ECH train if offsite power is available and no safety injection actuation signal is expected.

CAUTION: PRELIMINARY RESULTS
IMPORTANT UNCERTAINTIES
DESCRIBED IN SECTION 2

TABLE 4-5. AUXILIARY SYSTEMS NOT SHOWN IN THE PLANT AUXILIARY SYSTEM MODELS

System	Function and Where Included
EAB Main Control Room HVAC System	Supplies cooled air to equipment located in the main control room HVAC envelope. Not analyzed in the Scoping Study.
MAB Supplementary Coolers System	Supplies cooled air to the charging pump cubicles and to the component cooling pump cubicles. Included with the associated equipment.
MAB Supplementary Fan Coil Cooling System	Supplies cooled air to the essential chiller areas. Included with the associated essential chilled water train.
FHB Supplementary Cooler System	Supplies cooled air to the safety injection system pump and valve area cooler. Included with the associated safety injection system train.
Penetration Space HVAC System Cooling Subsystem	Supplies cooled air to the three elevations of the electrical penetration area. Not analyzed in the Scoping Study.
Isolation Valve Cubicle and Pipe Penetration Area Ventilation System	Supplies air to the auxiliary feedwater pump cubicles and valve cubicle. Included with the auxiliary feedwater system analysis.
Diesel Generator Building Emergency Ventilation System	Removes heat from the associated emergency diesel generator building during operation of the emergency diesel generator. Included with the analysis of the emergency diesel generators in the electric power analysis.
Essential Cooling Water Intake Structure Ventilating System	Provides a suitable environment for the essential cooling water pumps and associated equipment. Included with the analysis of the essential cooling water system.
Plant Instrument Air	Provides air for the operation of various process control valves and supports plant operation. Not analyzed in the Scoping Study.

CAUTION: PRELIMINARY RESULTS-
IMPORTANT UNCERTAINTIES
DESCRIBED IN SECTION 2

TABLE 4-6. ELECTRIC POWER TREE UNIQUE END STATES

Sheet 1 of 4

End State Designation	Definition
AC	AC power is available from the offsite grid. Operating equipment continues to run.
ACS	AC power is available to the Class 1E equipment from the emergency diesel generators. Previously operating equipment must restart.
B11	Initial power loss to Class 1E AC bus E1A. Power is restored from the offsite grid or the emergency diesel generator. Equipment powered from bus E1A receives start signals from the bus load sequencer. Previously operating equipment powered from bus E1A must restart.
B12	Initial power loss to Class 1E AC bus E1B. Similar to end state B11.
B13	Initial power loss to Class 1E AC bus E1C. Similar to end state B11.
B21	Initial power loss to Class 1E AC buses E1A and E1B. Power is restored from the offsite grid or the emergency diesel generators. Previously operating equipment must restart.
B22	Initial power loss to Class 1E AC buses E1A and E1C. Similar to end state B21.
B23	Initial power loss to Class 1E AC buses E1B and E1C. Similar to end state B21.
A11	Loss of Class 1E AC bus E1A due to bus faults or distribution failures. Offsite power is available.
A12	Loss of Class 1E AC bus E1B. Similar to end state A11. Offsite power is available.
A13	Loss of Class 1E AC bus E1C. Similar to end state A11. Offsite power is available.
C11	Loss of Class 1E DC bus E1A11. Offsite power is available. Loss of Class 1E AC bus E1A by definition.
C12	Loss of Class 1E DC bus E1B11. Offsite power is available. Loss of Class 1E AC bus E1B by definition.
C13	Loss of Class 1E DC bus E1C11. Offsite power is available. Loss of Class 1E AC bus E1C by definition.
A1B1	Loss of Class 1E AC bus E1A, initial power loss with restoration for Class 1E AC bus E1B. Offsite power is available.
A1B2	Loss of Class 1E AC bus E1B, initial power loss with restoration for Class 1E AC bus E1A. Offsite power is available.
A1B3	Loss of Class 1E AC bus E1A, initial power loss with restoration for Class 1E AC bus E1C. Offsite power is available.
A1B4	Loss of Class 1E AC bus E1C, initial power loss with restoration for Class 1E AC bus E1A. Offsite power is available.
A1B5	Loss of Class 1E AC bus E1B, initial power loss with restoration for Class 1E AC bus E1C. Offsite power is available.
A1B6	Loss of Class 1E AC bus E1C, initial power loss with restoration for Class 1E AC bus E1B. Offsite power is available.
AB21	Loss of Class 1E AC bus E1A, initial power loss with restoration for Class 1E AC buses E1B and E1C. Offsite power is available.

CAUTION: PRELIMINARY RESULTS IMPORTANT UNCERTAINTIES DESCRIBED IN SECTION 2

TABLE 4-6 (continued)

Sheet 2 of 4

End State Designation	Definition
AB22	Loss of Class 1E AC bus E1B, initial power loss with restoration for Class 1E AC buses E1A and E1C. Offsite power is available.
AB23	Loss of Class 1E AC bus E1C, initial power loss with restoration for Class 1E AC buses E1A and E1B. Offsite power is available.
B1C1	Initial power loss with restoration for Class 1E AC bus E1A, loss of Class 1E DC bus E1B11. Offsite power is available.
B1C2	Initial power loss with restoration for Class 1E AC bus E1B, loss of Class 1E DC bus E1A11. Offsite power is available.
B1C3	Initial power loss with restoration for Class 1E AC bus E1A, loss of Class 1E DC bus E1C11. Offsite power is available.
B1C4	Initial power loss with restoration for Class 1E AC bus E1C, loss of Class 1E DC bus E1A11. Offsite power is available.
B1C5	Initial power loss with restoration for Class 1E AC bus E1B, loss of Class 1E DC bus E1C11. Offsite power is available.
B1C6	Initial power loss with restoration for Class 1E AC bus E1C, loss of Class 1E DC bus E1B11. Offsite power is available.
B2C1	Initial power loss with restoration for Class 1E AC buses E1A and E1B, loss of Class 1E DC bus E1C. Offsite power is available.
B2C2	Initial power loss with restoration for Class 1E AC buses E1A and E1C, loss of Class 1E DC bus E1B. Offsite power is available.
B2C3	Initial power loss with restoration for Class 1E AC buses E1B and E1C, loss of Class 1E DC bus E1A. Offsite power is available.
E11	Loss of offsite power and Class 1E AC bus E1A.
E12	Loss of offsite power and Class 1E AC bus E1B.
E13	Loss of offsite power and Class 1E AC bus E1C.
D11	Loss of offsite power and Class 1E DC bus E1A11.
D12	Loss of offsite power and Class 1E DC bus E1B11.
D13	Loss of offsite power and Class 1E DC bus E1C11.
A21	Loss of power at Class 1E AC buses E1A and E1B. Offsite power is available.
A22	Loss of power at Class 1E AC buses E1A and E1C. Offsite power is available.
A23	Loss of power at Class 1E AC buses E1B and E1C. Offsite power is available.
A2B1	Loss of power at Class 1E AC buses E1A and E1B, initial power loss with restoration for Class 1E AC bus E1C. Offsite power is available.
A2B2	Loss of power at Class 1E AC buses E1A and E1C, initial power loss with restoration for Class 1E AC bus E1B. Offsite power is available.
A2B3	Loss of power at Class 1E AC buses E1B and E1C, initial power loss with restoration for Class 1E AC bus E1A. Offsite power is available.
A1C1	Loss of power at Class 1E AC bus E1A and Class 1E DC bus E1B11. Offsite power is available.

TABLE 4-6 (continued)

Sheet 3 of 4

End State Designation	Definition
A1C2	Loss of power at Class 1E AC bus E1B and Class 1E DC bus E1A11. Offsite power is available.
A1C3	Loss of power at Class 1E AC bus E1A and Class 1E DC bus E1C11. Offsite power is available.
A1C4	Loss of power at Class 1E AC bus E1C and Class 1E DC bus E1A11. Offsite power is available.
A1C5	Loss of power at Class 1E AC bus E1B and Class 1E DC bus E1C11. Offsite power is available.
A1C6	Loss of power at Class 1E AC bus E1C and Class 1E DC bus E1B11. Offsite power is available.
ACB1	Loss of power at Class 1E AC bus E1A and Class 1E DC bus E1B11, initial power loss with restoration at Class 1E AC bus E1C. Offsite power is available.
ACB2	Loss of power at Class 1E AC bus E1A and Class 1E DC bus E1C11, initial power loss with restoration at Class 1E AC bus E1B. Offsite power is available.
ACB3	Loss of power at Class 1E AC bus E1B and Class 1E DC bus E1A11, initial power loss with restoration at Class 1E AC bus E1C. Offsite power is available.
ACB4	Loss of power at Class 1E AC bus E1B and Class 1E DC bus E1C11, initial power loss with restoration at Class 1E AC bus E1A. Offsite power is available.
ACB5	Loss of power at Class 1E AC bus E1C and Class 1E DC bus E1A11, initial power loss with restoration at Class 1E AC bus E1B. Offsite power is available.
ACB6	Loss of power at Class 1E AC bus E1C and Class 1E DC bus E1B11, initial power loss with restoration at Class 1E AC bus E1A. Offsite power is available.
C21	Loss of power at Class 1E DC buses E1A11 and E1B11. Offsite power is available.
C22	Loss of power at Class 1E DC buses E1A11 and E1C11. Offsite power is available.
C23	Loss of power at Class 1E DC buses E1B11 and E1C11. Offsite power is available.
BC21	Initial loss of power with restoration at Class 1E AC bus E1A, loss of power at Class 1E DC buses E1B11 and E1C11. Offsite power is available.
BC22	Initial loss of power with restoration at Class 1E AC bus E1B, loss of power at Class 1E DC buses E1A11 and E1C11. Offsite power is available.
BC23	Initial loss of power with restoration at Class 1E AC bus E1C, loss of power at Class 1E DC buses E1A11 and E1B11. Offsite power is available.
E21	Loss of offsite power and Class 1E AC buses E1A and E1B.
E22	Loss of offsite power and Class 1E AC buses E1A and E1C.

CAUTION: PRELIMINARY RESULTS
IMPORTANT UNCERTAINTIES
DESCRIBED IN SECTION 2

TABLE 4-6 (continued)

Sheet 4 of 4

End State Designation	Definition
E23	Loss of offsite power and Class 1E AC buses E1B and E1C.
D1E1	Loss of offsite power, Class 1E DC bus E1A11, and Class 1E AC bus E1B.
D1E2	Loss of offsite power, Class 1E DC bus E1B11, and Class 1E AC bus E1A.
D1E3	Loss of offsite power, Class 1E DC bus E1A11, and Class 1E AC bus E1C.
D1E4	Loss of offsite power, Class 1E DC bus E1C11, and Class 1E AC bus E1A.
D1E5	Loss of offsite power, Class 1E DC bus E1B11, and Class 1E AC bus E1C.
D1E6	Loss of offsite power, Class 1E DC bus E1C11, and Class 1E AC bus E1B.
D21	Loss of offsite power and Class 1E DC buses E1A11 and E1B11.
D22	Loss of offsite power and Class 1E DC buses E1A11 and E1C11.
D23	Loss of offsite power and Class 1E DC buses E1B11 and E1C11.
A2C1	Loss of Class 1E AC buses E1A and E1B, and Class 1E DC bus E1C11. Offsite power is available.
A2C2	Loss of Class 1E AC buses E1A and E1C, and Class 1E DC bus E1B11. Offsite power is available.
A2C3	Loss of Class 1E AC buses E1B and E1C, and Class 1E DC bus E1A11. Offsite power is available.
AC21	Loss of Class 1E AC bus E1A, and Class 1E DC buses E1B11 and E1C11. Offsite power is available.
AC22	Loss of Class 1E AC bus E1B, and Class 1E DC buses E1A11 and E1C11. Offsite power is available.
AC23	Loss of Class 1E AC bus E1C, and Class 1E DC buses E1A11 and E1B11. Offsite power is available.
E3	Loss of all Class 1E AC power, with or without a loss of offsite power.
DE21	Loss of offsite power, Class 1E DC power at bus E1A11, and Class 1E AC power at buses E1B and E1C.
DE22	Loss of offsite power, Class 1E DC power at bus E1B11, and Class 1E AC power at buses E1A and E1C.
DE23	Loss of offsite power, Class 1E DC power at bus E1C11, and Class 1E AC power at buses E1A and E1B.
D2E1	Loss of offsite power, Class 1E DC buses E1A11 and E1B11, and Class 1E AC bus E1C.
D2E2	Loss of offsite power, Class 1E DC buses E1A11 and E1C11, and Class 1E AC bus E1B.
D2E3	Loss of offsite power, Class 1E DC buses E1B11 and E1C11, and Class 1E AC bus E1A.
D3	Loss of all Class 1E DC power, with or without a loss of offsite power.

TABLE 4-7a. EFFECT OF ELECTRIC POWER END STATES
ON OTHER AUXILIARY SYSTEMS (GENERAL TRANSIENT)

Sheet 1 of 4

Electric Power End State	SSPS	Engineered Safety Features Actuation System			Essential Cooling Water			Component Cooling Water			Essential Chilled Water System			EAB HVAC
	SS	EA	EB	EC	WA	WB	WC	CA	CB	CC	SA	SB	SC	EV
AC														
ACS					(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(b)
B11					(a)		(a)	(a)		(a)	(a)	(a)		(c)
B12						(a)			(a)			(a)		(c)
B13							(a)			(a)			(a)	(d)
B21					(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)		(e)
B22					(a)		(a)	(a)		(a)	(a)	(a)	(a)	(f)
B23						(a)	(a)		(a)	(a)		(a)	(a)	(f)
A11					XXX		(a)	XXX		(a)	XXX	(g)	(g)	(h)
A12						XXX			XXX			XXX	(g)	(h)
A13							XXX			XXX			XXX	
C11		XXX			XXX		(a)	XXX		(a)	XXX	(g)	(g)	(h)
C12			XXX			XXX			XXX			XXX	(g)	(h)
C13				XXX			XXX			XXX			XXX	
A1B1					XXX	(a)	(a)	XXX	(a)	(a)	XXX	(a)	(g)	(i)
A1B2					(a)	XXX	(a)	(a)	XXX	(a)	(a)	XXX	(g)	(i)
A1B3					XXX		(a)	XXX		(a)	XXX	(g)	(a)	
A1B4					(a)		XXX	(a)		XXX	(a)	(a)	XXX	(c)
A1B5						XXX	(a)		XXX	(a)		XXX	(a)	
A1B6						(a)	XXX		(a)	XXX		(a)	XXX	
AB21					XXX	(a)	(a)	XXX	(a)	(a)	XXX	(a)	(a)	
AB22					(a)	XXX	(a)	(a)	XXX	(a)	(a)	XXX	(a)	
AB23					(a)	(a)	XXX	(a)	(a)	XXX	(a)	(a)	XXX	
B1C1			XXX		(a)	XXX	(a)	(a)	XXX	(a)	(a)	XXX	(g)	(i)
B1C2		XXX			XXX	(a)	(a)	XXX	(a)	(a)	XXX	(a)	(g)	(i)

a. Equipment indicated starts or restarts automatically.
b. All EAB HVAC fans start.
c. One previously operating EAB HVAC fan train restarts.
d. Third EAB HVAC fan train starts. Three trains operating.
e. Operating EAB HVAC fan trains restart.
f. Previously operating EAB HVAC fan train restarts, third EAB HVAC fan train starts. Three trains operating.
g. Operator action is necessary to start or restart this equipment.
h. One EAB HVAC fan train operating.
i. Restart of previously operating EAB HVAC fan train, operator action is necessary to start a second EAB HVAC fan train.

CAUTION: PRELIMINARY RESULTS
IMPORTANT UNCERTAINTIES
DESCRIBED IN SECTION 2

TABLE 4-7a (continued)

Electric Power End State	SSPS	Engineered Safety Features Actuation System			Essential Cooling Water			Component Cooling Water			Essential Chilled Water System			EAB HVAC
	SS	EA	EB	EC	WA	WB	WC	CA	CB	CC	SA	SB	SC	EV
B1C3				XXX	(a)		XXX	(a)		XXX	(a)	(a)	XXX	(c)
B1C4		XXX			XXX		(a)	XXX		(a)	XXX	(g)	(a)	
B1C5				XXX		(a)	XXX		(a)	XXX		(a)	XXX	
B1C6			XXX			XXX	(a)		XXX	(a)		XXX	(a)	
B2C1				XXX	(a)	(a)	XXX	(a)	(a)	XXX	(a)	(a)	XXX	(e)
B2C2			XXX		(a)	XXX	(a)	(a)	XXX	(a)	(a)	XXX	(a)	(a)
B2C3		XXX			XXX	(a)	(a)	XXX	(a)	(a)	XXX	(a)	(a)	(a)
E11					XXX	(a)	(a)	XXX	(a)	(a)	XXX	(a)	(a)	(a)
E12					(a)	XXX	(a)	(a)	XXX	(a)	(a)	XXX	(a)	(a)
E13					(a)	(a)	XXX	(a)	(a)	XXX	(a)	(a)	XXX	(e)
D11		XXX			XXX	(a)	(a)	XXX	(a)	(a)	XXX	(a)	(a)	(a)
D12			XXX		(a)	XXX	(a)	(a)	XXX	(a)	(a)	XXX	(a)	(a)
D13				XXX	(a)	(a)	XXX	(a)	(a)	XXX	(a)	(a)	XXX	(e)
A21					XXX	XXX	(a)	XXX	XXX	(a)	XXX	XXX	(g)	(g)
A22					XXX	(g)	XXX	XXX	(g)	XXX	XXX	(g)	XXX	(g)
A23						XXX	XXX		XXX	XXX		XXX	XX	(h)
A2B1					XXX	XXX	(a)	XXX	XXX	(a)	XXX	XXX	(a)	(h)
A2B2					XXX	(a)	XXX	XXX	(a)	XXX	XXX	(a)	XXX	(h)
A2B3					(a)	XXX	XXX	(a)	XXX	XXX	(a)	XXX	XXX	(h)
A1C1			XXX		XXX	XXX	(a)	XXX	XXX	(a)	XXX	XXX	(g)	(h)
A1C2		XXX			XXX	XXX	(a)	XXX	XXX	(a)	XXX	XXX	(g)	(h)
A1C3				XXX	XXX	(g)	XXX	XXX	(g)	XXX	XXX	(g)	XXX	(h)
A1C4		XXX			XXX	(g)	XXX	XXX	(g)	XXX	XXX	(g)	XXX	(h)
A1C5				XXX		XXX	XXX		XXX	XXX		XXX	XXX	(h)
A1C6			XXX			XXX	XXX		XXX	XXX		XXX	XXX	(h)
ACB1			XXX		XXX	XXX	(a)	XXX	XXX	(a)	XXX	XXX	(a)	(h)

a. Equipment indicated starts or restarts automatically.
b. All EAB HVAC fans start.
c. One previously operating EAB HVAC fan train restarts.
d. Third EAB HVAC fan train starts. Three trains operating.
e. Operating EAB HVAC fan trains restart.
f. Previously operating EAB HVAC fan train restarts, third EAB HVAC fan train starts. Three trains operating.
g. Operator action is necessary to start or restart this equipment.
h. One EAB HVAC fan train operating.
i. Restart of previously operating EAB HVAC fan train, operator action is necessary to start a second EAB HVAC fan train.

CAUTION: PRELIMINARY RESULTS
IMPORTANT UNCERTAINTIES
DESCRIBED IN SECTION 2

TABLE 4-7a (continued)

Sheet 3 of 4

Electric Power End State	SSPS	Engineered Safety Features Actuation System			Essential Cooling Water			Component Cooling Water			Essential Chilled Water System			EAB HVAC
	SS	EA	EB	EC	WA	WB	WC	CA	CB	CC	SA	SB	SC	EV
ACB2				XXX	XXX	(a)	XXX	XXX	(a)	XXX	XXX	(a)	XXX	(h)
ACB3		XXX			XXX	XXX	(a)	XXX	XXX	(a)	XXX	XXX	(a)	(h)
ACB4				XXX	(a)	XXX	XXX	(a)	XXX	XXX	(a)	XXX	XXX	(h)
ACB5		XXX			XXX	(a)	XXX	XXX	(a)	XXX	XXX	(a)	XXX	(h)
ACB6			XXX		(a)	XXX	XXX	(a)	XXX	XXX	(a)	XXX	XXX	(h)
C21		XXX	XXX		XXX	XXX	(a)	XXX	XXX	(a)	XXX	XXX	(g)	(g)
C22		XXX		XXX	XXX	(g)	XXX	XXX	(g)	XXX	XXX	(g)	XXX	(g)
C23			XXX	XXX		XXX	XXX		XXX	XXX		XXX	XX	(h)
BC21			XXX	XXX	(a)	XXX	XXX	(a)	XXX	XXX	(a)	XXX	XXX	(h)
BC22		XXX		XXX	XXX	(a)	XXX	XXX	(a)	XXX	XXX	(a)	XXX	(h)
BC23		XXX	XXX		XXX	XXX	(a)	XXX	XXX	(a)	XXX	XXX	(a)	(h)
E21					XXX	XXX	(a)	XXX	XXX	(a)	XXX	XXX	(a)	(h)
E22					XXX	(a)	XXX	XXX	(a)	XXX	XXX	(a)	XXX	(h)
E23					(a)	XXX	XXX	(a)	XXX	XXX	(a)	XXX	XXX	(h)
D1E1		XXX			XXX	XXX	(a)	XXX	XXX	(a)	XXX	XXX	(a)	(h)
D1E2			XXX		XXX	XXX	(a)	XXX	XXX	(a)	XXX	XXX	(a)	(h)
D1E3		XXX			XXX	(a)	XXX	XXX	(a)	XXX	XXX	(a)	XXX	(h)
D1E4				XXX	XXX	(a)	XXX	XXX	(a)	XXX	XXX	(a)	XXX	(h)
D1E5			XXX		(a)	XXX	XXX	(a)	XXX	XXX	(a)	XXX	XXX	(h)
D1E6				XXX	(a)	XXX	XXX	(a)	XXX	XXX	(a)	XXX	XXX	(h)
D21		XXX	XXX		XXX	XXX	(a)	XXX	XXX	(a)	XXX	XXX	(a)	(h)
D22		XXX		XXX	XXX	(a)	XXX	XXX	(a)	XXX	XXX	(a)	XXX	(h)
D23			XXX	XXX	(a)	XXX	XXX	(a)	XXX	XXX	(a)	XXX	XXX	(h)
A2C1				XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XX
A2C2			XXX		XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XX
A2C3		XXX			XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XX
AC21			XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XX
AC22		XXX		XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XX

a. Equipment indicated starts or restarts automatically.
b. All EAB HVAC fans start.
c. One previously operating EAB HVAC fan train restarts.
d. Third EAB HVAC fan train starts. Three trains operating.
e. Operating EAB HVAC fan trains restart.
f. Previously operating EAB HVAC fan train restarts, third EAB HVAC fan train starts. Three trains operating.
g. Operator action is necessary to start or restart this equipment.
h. One EAB HVAC fan train operating.
i. Restart of previously operating EAB HVAC fan train, operator action is necessary to start a second EAB HVAC fan train.

CAUTION: PRELIMINARY RESULTS-
IMPORTANT UNCERTAINTIES
DESCRIBED IN SECTION 2

TABLE 4-7a (continued)

Sheet 4 of 4

Electric Power End State	SSPS	Engineered Safety Features Actuation System			Essential Cooling Water			Component Cooling Water			Essential Chilled Water System			EAB HVAC
	SS	EA	EB	EC	WA	WB	WC	CA	CB	CC	SA	SB	SC	EV
AC23		XXX	XXX		XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XX
E3					XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XX
DE21		XXX			XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XX
DE22			XXX		XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XX
DE23				XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XX
D2E1		XXX	XXX		XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XX
D2E2		XXX		XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XX
D2E3			XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XX
D3	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XX

a. Equipment indicated starts or restarts automatically.
b. All EAB HVAC fans start.
c. One previously operating EAB HVAC fan train restarts.
d. Third EAB HVAC fan train starts. Three trains operating.
e. Operating EAB HVAC fan trains restart.
f. Previously operating EAB HVAC fan train restarts, third EAB HVAC fan train starts. Three trains operating.
g. Operator action is necessary to start or restart this equipment.
h. One EAB HVAC fan train operating.
i. Restart of previously operating EAB HVAC fan train, operator action is necessary to start a second EAB HVAC fan train.

CAUTION: PRELIMINARY RESULTS
IMPORTANT UNCERTAINTIES
DESCRIBED IN SECTION 2

TABLE 4-7b. EFFECT OF ELECTRIC POWER END STATES ON OTHER AUXILIARY SYSTEMS (SMALL LOCA)[(a)]

Sheet 1 of 3

Electric Power End State	SSPS	Engineered Safety Features Actuation System			Essential Cooling Water			Component Cooling Water			Essential Chilled Water System			EAB HVAC
	SS	EA	EB	EC	WA	WB	WC	CA	CB	CC	SA	SB	SC	EV
AC						(a)	(a)		(a)	(a)			(a)	(b)
ACS					(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(c)
B11					(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(b)
B12						(a)	(a)		(a)	(a)		(a)	(a)	(b)
B13						(a)	(a)		(a)	(a)		(a)	(a)	(b)
B21					(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(d)
B22					(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(d)
B23						(a)	(a)		(a)	(a)		(a)	(a)	(d)
A11					XXX	(a)	(a)	XXX	(a)	(a)	XXX	(a)	(a)	(e)
A12						XXX	(a)		XXX	(a)		XXX	(a)	(e)
A13						(a)	XXX		(a)	XXX		(a)	XXX	(e)
C11		XXX			XXX	(a)	(a)	XXX	(a)	(a)	XXX	(a)	(a)	(e)
C12			XXX			XXX	(a)		XXX	(a)		XXX	(a)	(e)
C13				XXX		(a)	XXX		(a)	XXX		(a)	XXX	(e)
A1B1					XXX	(a)	(a)	XXX	(a)	(a)	XXX	(a)	(a)	(e)
A1B2					(a)	XXX	(a)	(a)	XXX	(a)	(a)	XXX	(a)	(e)
A1B3					XXX	(a)	(a)	XXX	(a)	(a)	XXX	(a)	(a)	(e)
A1B4					(a)	(a)	XXX	(a)	(a)	XXX	(a)	(a)	XXX	(e)
A1B5						XXX	(a)		XXX	(a)		XXX	(a)	(e)
A1B6						(a)	XXX		(a)	XXX		(a)	XXX	(e)
AB21					XXX	(a)	(a)	XXX	(a)	(a)	XXX	(a)	(a)	(e)
AB22					(a)	XXX	(a)	(a)	XXX	(a)	(a)	XXX	(a)	(e)
AB23					(a)	(a)	XXX	(a)	(a)	XXX	(a)	(a)	XXX	(e)
B1C1			XXX		(a)	XXX	(a)	(a)	XXX	(a)	(a)	XXX	(a)	(e)
B1C2		XXX			XXX	(a)	(a)	XXX	(a)	(a)	XXX	(a)	(a)	(e)
B1C3				XXX	(a)	(a)	XXX	(a)	(a)	XXX	(a)	(a)	XXX	(e)
B1C4		XXX			XXX	(a)	(a)	XXX	(a)	(a)	XXX	(a)	(a)	(e)
B1C5				XXX		(a)	XXX		(a)	XXX		(a)	XXX	(e)

a. All standby equipment starts or restarts automatically.
b. All EAB HVAC fans start.
c. Third EAB HVAC fan train starts. Three trains operating.
d. Previously operating EAB HVAC fan train restarts, third EAB HVAC fan train starts. Three trains operating.
e. Two EAB HVAC fan trains operating.
f. One EAB HVAC fan train operating.

CAUTION: PRELIMINARY RESULTS IMPORTANT UNCERTAINTIES DESCRIBED IN SECTION 2

TABLE 4-7b (continued)[a]

Sheet 2 of 3

Electric Power End State	SSPS	Engineered Safety Features Actuation System			Essential Cooling Water			Component Cooling Water			Essential Chilled Water System			EAB HVAC
	SS	EA	EB	EC	WA	WB	WC	CA	CB	CC	SA	SB	SC	EV
B1C6			XXX			XXX	(a)		XXX	(a)		XXX	(a)	(e)
B2C1				XXX	(a)	(a)	XXX	(a)	(a)	XXX	(a)	(a)	XXX	(e)
B2C2			XXX		(a)	XXX	(a)	(a)	XXX	(a)	(a)	XXX	(a)	(e)
B2C3		XXX			XXX	(a)	(a)	XXX	(a)	(a)	XXX	(a)	(a)	(e)
E11					XXX	(a)	(a)	XXX	(a)	(a)	XXX	(a)	(a)	(e)
E12					(a)	XXX	(a)	(a)	XXX	(a)	(a)	XXX	(a)	(e)
E13					(a)	(a)	XXX	(a)	(a)	XXX	(a)	(a)	XXX	(e)
D11		XXX			XXX	(a)	(a)	XXX	(a)	(a)	XXX	(a)	(a)	(e)
D12			XXX		(a)	XXX	(a)	(a)	XXX	(a)	(a)	XXX	(a)	(e)
D13				XXX	(a)	(a)	XXX	(a)	(a)	XXX	(a)	(a)	XXX	(e)
A21					XXX	XXX	(a)	XXX	XXX	(a)	XXX	XXX	(a)	(f)
A22					XXX	(a)	XXX	XXX	(a)	XXX	XXX	(a)	XXX	(f)
A23						XXX	XXX		XXX	XXX		XXX	XXX	(f)
A2B1					XXX	XXX	(a)	XXX	XXX	(a)	XXX	XXX	(a)	(f)
A2B2					XXX	(a)	XXX	XXX	(a)	XXX	XXX	(a)	XXX	(f)
A2B3					(a)	XXX	XXX	(a)	XXX	XXX	(a)	XXX	XXX	(f)
A1C1			XXX		XXX	XXX	(a)	XXX	XXX	(a)	XXX	XXX	(a)	(f)
A1C2		XXX			XXX	XXX	(a)	XXX	XXX	(a)	XXX	XXX	(a)	(f)
A1C3				XXX	XXX	(a)	XXX	XXX	(a)	XXX	XXX	(a)	XXX	(f)
A1C4		XXX			XXX	(a)	XXX	XXX	(a)	XXX	XXX	(a)	XXX	(f)
A1C5				XXX		XXX	XXX		XXX	XXX		XXX	XXX	(f)
A1C6			XXX			XXX	XXX		XXX	XXX		XXX	XXX	(f)
ACB1			XXX		XXX	XXX	(a)	XXX	XXX	(a)	XXX	XXX	(a)	(f)
ACB2				XXX	XXX	(a)	XXX	XXX	(a)	XXX	XXX	(a)	XXX	(f)
ACB3		XXX			XXX	XXX	(a)	XXX	XXX	(a)	XXX	XXX	(a)	(f)
ACB4				XXX	(a)	XXX	XXX	(a)	XXX	XXX	(a)	XXX	XXX	(f)
ACB5		XXX			XXX	(a)	XXX	XXX	(a)	XXX	XXX	(a)	XXX	(f)
ACB6			XXX		(a)	XXX	XXX	(a)	XXX	XXX	(a)	XXX	XXX	(f)
C21		XXX	XXX		XXX	XXX	(a)	XXX	XXX	(a)	XXX	XXX	(a)	(f)
C22		XXX		XXX	XXX	(a)	XXX	XXX	(a)	XXX	XXX	(a)	XXX	(f)
C23			XXX	XXX		XXX	XXX		XXX	XXX		XXX	XXX	(f)
BC21			XXX	XXX	(a)	XXX	XXX	(a)	XXX	XXX	(a)	XXX	XXX	(f)

a. All standby equipment starts or restarts automatically.
b. All EAB HVAC fans start.
c. Third EAB HVAC fan train starts. Three trains operating.
d. Previously operating EAB HVAC fan train restarts, third EAB HVAC fan train starts. Three trains operating.
e. Two EAB HVAC fan trains operating.
f. One EAB HVAC fan train operating.

CAUTION: PRELIMINARY RESULTS-
IMPORTANT UNCERTAINTIES
DESCRIBED IN SECTION 2

TABLE 4-7b (continued)[(a)]

Sheet 3 of 3

Electric Power End State	SSPS	Engineered Safety Features Actuation System			Essential Cooling Water			Component Cooling Water			Essential Chilled Water System			EAB HVAC
	SS	EA	EB	EC	WA	WB	WC	CA	CB	CC	SA	SB	SC	EV
BC22		XXX		XXX	XXX	(a)	XXX	XXX	(a)	XXX	XXX	(a)	XXX	(f)
BC23		XXX	XXX		XXX	XXX	(a)	XXX	XXX	(a)	XXX	XXX	(a)	(f)
E21					XXX	XXX	(a)	XXX	XXX	(a)	XXX	XXX	(a)	(f)
E22					XXX	(a)	XXX	XXX	(a)	XXX	XXX	(a)	XXX	(f)
E23					(a)	XXX	XXX	(a)	XXX	XXX	(a)	XXX	XXX	(f)
D1E1		XXX			XXX	XXX	(a)	XXX	XXX	(a)	XXX	XXX	(a)	(f)
D1E2			XXX		XXX	XXX	(a)	XXX	XXX	(a)	XXX	XXX	(a)	(f)
D1E3		XXX			XXX	(a)	XXX	XXX	(a)	XXX	XXX	(a)	XXX	(f)
D1E4				XXX	XXX	(a)	XXX	XXX	(a)	XXX	XXX	(a)	XXX	(f)
D1E5			XXX		(a)	XXX	XXX	(a)	XXX	XXX	(a)	XXX	XXX	(f)
D1E6				XXX	(a)	XXX	XXX	(a)	XXX	XXX	(a)	XXX	XXX	(f)
D21		XXX	XXX		XXX	XXX	(a)	XXX	XXX	(a)	XXX	XXX	(a)	(f)
D22		XXX		XXX	XXX	(a)	XXX	XXX	(a)	XXX	XXX	(a)	XXX	(f)
D23			XXX	XXX	(a)	XXX	XXX	(a)	XXX	XXX	(a)	XXX	XXX	(f)
A2C1				XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	X
A2C2			XXX		XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	X
A2C3		XXX			XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	X
AC21			XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	X
AC22		XXX		XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	X
AC23		XXX	XXX		XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	X
E3					XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	X
DE21		XXX			XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	X
DE22			XXX		XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	X
DE23				XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	X
D2E1		XXX	XXX		XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	X
D2E2		XXX		XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	X
D2E3			XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	X
D3	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	X

a. All standby equipment starts or restarts automatically.
b. All EAB HVAC fans start.
c. Third EAB HVAC fan train starts. Three trains operating.
d. Previously operating EAB HVAC fan train restarts, third EAB HVAC fan train starts. Three trains operating.
e. Two EAB HVAC fan trains operating.
f. One EAB HVAC fan train operating.

CAUTION: PRELIMINARY RESULTS-
IMPORTANT UNCERTAINTIES
DESCRIBED IN SECTION 2

TABLE 4-7c. EFFECT OF ELECTRIC POWER END STATES ON OTHER AUXILIARY SYSTEMS (LOSS OF OFFSITE POWER)[a]

Electric Power End State	SSPS	Engineered Safety Features Actuation System			Essential Cooling Water			Component Cooling Water			Essential Chilled Water System			EAB HVAC
	SS	EA	EB	EC	WA	WB	WC	CA	CB	CC	SA	SB	SC	EV
ACS					(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)
E11					XX	(a)	(a)	XX	(a)	(a)	XX	(a)	(a)	(b)
E12					(a)	XX	(a)	(a)	XX	(a)	(a)	XX	(a)	(b)
E13					(a)	(a)	XX	(a)	(a)	XX	(a)	(a)	XX	(b)
D11		XX			XX	(a)	(a)	XX	(a)	(a)	XX	(a)	(a)	(b)
D12			XX		(a)	XX	(a)	(a)	XX	(a)	(a)	XX	(a)	(b)
D13				XX	(a)	(a)	XX	(a)	(a)	XX	(a)	(a)	XX	(b)
E21					XX	XX	(a)	XX	XX	(a)	XX	XX	(a)	(c)
E22					XX	(a)	XX	XX	(a)	XX	XX	(a)	XX	(c)
E23					(a)	XX	XX	(a)	XX	XX	(a)	XX	XX	(c)
D1E1		XX			XX	XX	(a)	XX	XX	(a)	XX	XX	(a)	(c)
D1E2			XX		XX	XX	(a)	XX	XX	(a)	XX	XX	(a)	(c)
D1E3		XX			XX	(a)	XX	XX	(a)	XX	XX	(a)	XX	(c)
D1E4				XX	XX	(a)	XX	XX	(a)	XX	XX	(a)	XX	(c)
D1E5			XX		(a)	XX	XX	(a)	XX	XX	(a)	XX	XX	(c)
D1E6				XX	(a)	XX	XX	(a)	XX	XX	(a)	XX	XX	(c)
D21		XX	XX		XX	XX	(a)	XX	XX	(a)	XX	XX	(a)	(c)
D22		XX		XX	XX	(a)	XX	XX	(a)	XX	XX	(a)	XX	(c)
D23			XX	XX	(a)	XX	XX	(a)	XX	XX	(a)	XX	XX	(c)
E3					XX	XX	XX	XX	XX	XX	XX	XX	XX	XX
DE21		XX			XX	XX	XX	XX	XX	XX	XX	XX	XX	XX
DE22			XX		XX	XX	XX	XX	XX	XX	XX	XX	XX	XX
DE23				XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX
D2E1		XX	XX		XX	XX	XX	XX	XX	XX	XX	XX	XX	XX
D2E2		XX		XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX
D2E3			XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX
D3	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX

a. All equipment starts or restarts automatically.
b. Two EAB HVAC fan trains operating.
c. One EAB HVAC fan train operating.

CAUTION: PRELIMINARY RESULTS
IMPORTANT UNCERTAINTIES
DESCRIBED IN SECTION 2

TABLE 4-8. AUXILIARY TREE END STATES

Sheet 1 of 2

End State	Description
A	Loss of one train of the engineered safety features actuation system.
B	Loss of two ESFAS trains.
C	Loss of three ESFAS trains.
D(a)	Loss of one essential cooling water train.
E	Loss of one ECW train [not the same as ESFAS train(s)].
F(b)	Loss of two ECW trains.
G	Loss of two ECW trains [not the same trains as ESFAS train(s)].
H(c)	Loss of three ECW trains.
I(d)	Loss of one ECW train after loss of offsite power or loss of power at the associated bus.
J(d)	Loss of one ECW train after LOSP [not the same train as ESFAS train(s)].
K(d)	Loss of two ECW trains after LOSP.
L(d)	Loss of two ECW trains after LOSP [not the same trains as ESFAS train(s)].
M	Loss of three ECW trains after LOSP.
N	Loss of one component cooling train.
O	Loss of two CCW trains.
P	Loss of three CCW trains.
Q	Loss of one CCW train [not the same train as ESFAS train(s)].
R	Loss of two CCW trains (not the same trains as previous systems train failures).
S	Loss of the solid state protection system output.
T(e)	Loss of one essential chilled water system train.
U	Loss of two ECH trains.
V	Loss of three ECH trains.
W	Loss of one ECH train (not the same train as previous systems train failures).

a. Loss of one ECW train fails the associated CCW train.
b. Loss of two ECW trains fails the associated CCW trains and one associated ECH train.
c. Loss of three ECW trains fails all CCW and ECH trains.
d. Loss of an ECW train with LOSP fails the associated emergency diesel generator resulting in no power to the associated 4160V AC bus.
e. The end states for ECH are based upon the following initial conditions:
   (1) ECW train A operating; ECW train C in standby
   (2) ECH trains A and B are operating (both trains can be supplied from either ECW train A or train B)
   (3) ECH train C can only be suppied from ECW train C.

CAUTION: PRELIMINARY RESULTS
IMPORTANT UNCERTAINTIES
DESCRIBED IN SECTION 2

TABLE 4-8 (continued)

Sheet 2 of 2

End State	Description
X	Loss of two ECH trains [not the same trains as previous systems train failure(s)].
Y	Loss of one ECH train (different train from preceding systems failures).
Z	Loss of two ECH trains (different trains from preceding systems failures).
1	Loss of one ECW train after AC power is lost at the associated bus and loss of a second ECW train. Not for LOSP.
2	Loss of one ECW train after AC power is lost at the associated bus and loss of the remaining ECW trains. Not for LOSP.
3	Loss of one ECW train after AC power is lost at the associated bus (not the same train as previous systems train failures) and loss of a second ECW train. Not for LOSP.
4	Loss of one ECW train after AC power is lost at the associated bus and loss of a second ECW train [not the same trains as previous systems train failures]. Not for LOSP.
5	Loss of one ECW train after AC power is lost at the associated bus (not the same train as previous systems train failures) and loss of the remaining ECW trains. Not for LOSP.
6	Loss of two ECW trains after AC power is lost at the associated buses and loss of the third ECW train. Not for LOSP.
7	Loss of two ECW trains after AC power is lost at the associated buses [not the same trains as previous systems train failures] and loss of the third ECW train. Not for LOSP.
9	Loss of the electrical auxiliary building ventilation system (long-term failure of the electric power systems).

a. Loss of one ECW train fails the associated CCW train.
b. Loss of two ECW trains fails the associated CCW trains and one associated ECH train.
c. Loss of three ECW trains fails all CCW and ECH trains.
d. Loss of an ECW train with LOSP fails the associated emergency diesel generator resulting in no power to the associated 4160V AC bus.
e. The end states for ECH are based upon the following initial conditions:
   (1) ECW train A operating; ECW train C in standby
   (2) ECH trains A and B are operating (both trains can be supplied from either ECW train A or train B)
   (3) ECH train C can only be suppied from ECW train C.

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CAUTION: PRELIMINARY RESULTS-
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TABLE 4-9. AUXILIARY TREE END STATES 1

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End States	Auxiliary Systems and Numbers of Trains Affected	Notes
AUX		All auxiliaries available.
T	1-ECH	
U	2-ECH	
V	3-ECH	
N	1-CCW	
NT	1-CCW 1-ECH	CCW, ECH same train.
NW	1-CCW 1-ECH	CCW, ECH different trains.
NU	1-CCW 2-ECH	CCW, one train ECH same.
NX	1-CCW 2-ECH	CCW, ECH different trains.
NV	1-CCW 3-ECH	
O	2-CCW	
OT	2-CCW 1-ECH	One train CCW, ECH same.
OW	2-CCW 1-ECH	CCW, ECH different trains.
OU	2-CCW 2-ECH	CCW, ECH same trains.
OX	2-CCW 2-ECH	One train CCW, one train ECH different.
OV	2-CCW 3-ECH	
P	3-CCW	
PT	3-CCW 1-ECH	
PU	3-CCW 2-ECH	
PV	3-CCW 3-ECH	
D	1-ECW 1-CCW	
DT	1-ECW 1-CCW 1-ECH	ECW, ECH same train.
DW	1-ECW 1-CCW 1-ECH	ECW, ECH different trains.
DU	1-ECW 1-CCW 2-ECH	ECW, one train ECH same.
DX	1-ECW 1-CCW 2-ECH	ECW, ECH different trains.
DV	1-ECW 1-CCW 3-ECH	
DO	1-ECW 2-CCW	
DOT	1-ECW 2-CCW 1-ECH	ECW, ECH same train.
DOW	1-ECW 2-CCW 1-ECH	ECW, ECH different trains; one train CCW, ECH same.
DOY	1-ECW 2-CCW 1-ECH	CCW, ECH different trains.
DOU	1-ECW 2-CCW 2-ECH	ECW, ECH same trains.
DOX	1-ECW 2-CCW 2-ECH	One train CCW, one train ECH different.
DOZ	1-ECW 2-CCW 2-ECH	ECW, ECH different trains.
DOV	1-ECW 2-CCW 3-ECH	
DP	1-ECW 3-CCW	
DPT	1-ECW 3-CCW 1-ECH	ECW, ECH same train.
DPW	1-ECW 3-CCW 1-ECH	ECW, ECH different trains.
DPU	1-ECW 3-CCW 2-ECH	ECW, one train ECH same.
DPX	1-ECW 3-CCW 2-ECH	ECW, ECH different trains.
DPV	1-ECW 3-CCW 3-ECH	
I	1-ECW 1-CCW 1-ECH (after LOSP)	
IU	1-ECW 1-CCW 2-ECH (after LOSP)	
IV	1-ECW 1-CCW 3-ECH (after LOSP)	

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TABLE 4-9 (continued)

End States	Auxiliary Systems and Numbers of Trains Affected	Notes
IO	1-ECW 2-CCW 1-ECH (after LOSP)	
IOU	1-ECW 2-CCW 2-ECH (after LOSP)	CCW, ECH same trains.
IOX	1-ECW 2-CCW 2-ECH (after LOSP)	One train CCW, one train ECH different.
IOV	1-ECW 2-CCW 3-ECH (after LOSP)	
IP	1-ECW 3-CCW 1-ECH (after LOSP)	
IPU	1-ECW 3-CCW 2-ECH (after LOSP)	
IPV	1-ECW 3-CCW 3-ECH (after LOSP)	
F	2-ECW 2-CCW 1-ECH	
FU	2-ECW 2-CCW 2-ECH	ECW, ECH same trains.
FX	2-ECW 2-CCW 2-ECH	One train ECW, one train ECH different.
FV	2-ECW 2-CCW 3-ECH	
FP	2-ECW 3-CCW 1-ECH	
FPU	2-ECW 3-CCW 2-ECH	ECW, ECH same trains.
FPX	2-ECW 3-CCW 2-ECH	One train ECW, one train ECH different.
FPV	2-ECW 3-CCW 3-ECH	
K	2-ECW 2-CCW 2-ECH (after LOSP)	
KV	2-ECW 2-CCW 3-ECH (after LOSP)	
KP	2-ECW 2-CCW 2-ECH (after LOSP)	
KPV	2-ECW 2-CCW 3-ECH (after LOSP)	
1	2-ECW 2-CCW 1-ECH (after LOP one bus)	Loss of AC power at one bus.
1U	2-ECW 2-CCW 2-ECH (after LOP one bus)	ECW, ECH same trains.
1X	2-ECW 2-CCW 2-ECH (after LOP one bus)	One train ECW, one train ECH different.
1V	2-ECW 2-CCW 3-ECH (after LOP one bus)	
1P	2-ECW 3-CCW 1-ECH (after LOP one bus)	
1PU	2-ECW 3-CCW 2-ECH (after LOP one bus)	ECW, ECH same trains.
1PX	2-ECW 3-CCW 2-ECH (after LOP one bus)	One train ECW, one train ECH different.
1PV	2-ECW 3-CCW 3-ECH (after LOP one bus)	
H	3-ECW 3-CCW 3-ECH	
M	3-ECW 3-CCW 3-ECH (after LOSP)	
2	3-ECW 3-CCW 3-ECH (after LOP one bus)	Loss of AC power at one bus only.
6	3-ECW 3-CCW 3-ECH (after LOP 2-buses)	Loss of AC power at two buses only.
9	Electrical Auxiliary Building Ventilation	
A	1-ESFAS	
AT	1-ESFAS 1-ECH	ESFAS, ECH same train.
AW	1-ESFAS 1-ECH	ESFAS, ECH different trains.
AU	1-ESFAS 2-ECH	ESFAS, one train ECH same.
AX	1-ESFAS 2-ECH	ESFAS, ECH different trains.
AV	1-ESFAS 3-ECH	
AN	1-ESFAS 1-CCW	ESFAS, CCW same train.
ANT	1-ESFAS 1-CCW 1-ECH	ESFAS, ECH same train.
ANW	1-ESFAS 1-CCW 1-ECH	ESFAS, ECH different trains.
ANU	1-ESFAS 1-CCW 2-ECH	ESFAS, one train ECH same.
ANX	1-ESFAS 1-CCW 2-ECH	ESFAS, ECH different trains.
ANV	1-ESFAS 1-CCW 3-ECH	
AQ	1-ESFAS 1-CCW	ESFAS, CCW different trains.
AQT	1-ESFAS 1-CCW 1-ECH	ESFAS, ECH same train.

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TABLE 4-9 (continued)

Sheet 3 of 14

End States	Auxiliary Systems and Numbers of Trains Affected	Notes
AQW	1-ESFAS 1-CCW 1-ECH	CCW, ECH same train.
AQY	1-ESFAS 1-CCW 1-ECH	ESFAS, CCW, ECH different trains.
AQU	1-ESFAS 1-CCW 2-ECH	ESFAS, one train ECH same; CCW, other train ECH same.
AQX	1-ESFAS 1-CCW 2-ECH	ESFAS, one train ECH same; CCW, other train ECH different.
AQZ	1-ESFAS 1-CCW 2-ECH	ESFAS, ECH different trains.
AQV	1-ESFAS 1-CCW 3-ECH	
AO	1-ESFAS 2-CCW	ESFAS, one train CCW same.
AOT	1-ESFAS 2-CCW 1-ECH	ESFAS, ECH same train.
AOW	1-ESFAS 2-CCW 1-ECH	ESFAS, ECH different trains; one train CCW, ECH same.
AOY	1-ESFAS 2-CCW 1-ECH	CCW, ECH different trains.
AOU	1-ESFAS 2-CCW 2-ECH	CCW, ECH same trains.
AOX	1-ESFAS 2-CCW 2-ECH	ESFAS, one train ECH same; CCW, ECH different trains.
AOZ	1-ESFAS 2-CCW 2-ECH	ESFAS, ECH different trains.
AOV	1-ESFAS 2-CCW 3-ECH	
AR	1-ESFAS 2-CCW	ESFAS, CCW different trains.
ART	1-ESFAS 2-CCW 1-ECH	ESFAS, ECH same train.
ARW	1-ESFAS 2-CCW 1-ECH	ESFAS, ECH different trains.
ARU	1-ESFAS 2-CCW 2-ECH	ESFAS, one train ECH same.
ARX	1-ESFAS 2-CCW 2-ECH	ESFAS, ECH different trains.
ARV	1-ESFAS 2-CCW 3-ECH	
AP	1-ESFAS 3-CCW	
APT	1-ESFAS 3-CCW 1-ECH	ESFAS, ECH same train.
APW	1-ESFAS 3-CCW 1-ECH	ESFAS, ECH different trains.
APU	1-ESFAS 3-CCW 2-ECH	ESFAS, one train ECH same.
APX	1-ESFAS 3-CCW 2-ECH	ESFAS, ECH different trains.
APV	1-ESFAS 3-CCW 3-ECH	
AD	1-ESFAS 1-ECW 1-CCW	ESFAS, ECW same train.
ADT	1-ESFAS 1-ECW 1-CCW 1-ECH	ESFAS, ECH same train.
ADW	1-ESFAS 1-ECW 1-CCW 1-ECH	ESFAS, ECH different trains.
ADU	1-ESFAS 1-ECW 1-CCW 2-ECH	ESFAS, one train ECH same.
ADX	1-ESFAS 1-ECW 1-CCW 2-ECH	ESFAS, ECH different trains.
ADV	1-ESFAS 1-ECW 1-CCW 3-ECH	
ADO	1-ESFAS 1-ECW 2-CCW	
ADOT	1-ESFAS 1-ECW 2-CCW 1-ECH	ESFAS, ECH same train.
ADOW	1-ESFAS 1-ECW 2-CCW 1-ECH	ESFAS, ECH different trains; one train CCW, ECH same.

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TABLE 4-9 (continued)

Sheet 4 of 14

End States	Auxiliary Systems and Numbers of Trains Affected	Notes
ADOY	1-ESFAS 1-ECW 2-CCW 1-ECH	CCW, ECH different trains.
ADOU	1-ESFAS 1-ECW 2-CCW 2-ECH	CCW, ECH same trains.
ADOX	1-ESFAS 1-ECW 2-CCW 2-ECH	ESFAS, one train ECH same; one train CCW, one train ECH different.
ADOZ	1-ESFAS 1-ECW 2-CCW 2-ECH	ESFAS, ECH different trains.
ADOV	1-ESFAS 1-ECW 2-CCW 3-ECH	
ADP	1-ESFAS 1-ECW 3-CCW	
ADPT	1-ESFAS 1-ECW 3-CCW 1-ECH	ESFAS, ECH same train.
ADPW	1-ESFAS 1-ECW 3-CCW 1-ECH	ESFAS, ECH different trains.
ADPU	1-ESFAS 1-ECW 3-CCW 2-ECH	ESFAS, one train ECH same.
ADPX	1-ESFAS 1-ECW 3-CCW 2-ECH	ESFAS, ECH different trains.
ADPV	1-ESFAS 1-ECW 3-CCW 3-ECH	
AE	1-ESFAS 1-ECW 1-CCW	ESFAS, ECW different trains.
AET	1-ESFAS 1-ECW 1-CCW 1-ECH	ESFAS, ECH same train.
AEW	1-ESFAS 1-ECW 1-CCW 1-ECH	ECW, ECH same train.
AEY	1-ESFAS 1-ECW 1-CCW 1-ECH	ESFAS, ECW, ECH different trains.
AEU	1-ESFAS 1-ECW 1-CCW 2-ECH	ESFAS, one train ECH same; ECW, other train ECH same.
AEX	1-ESFAS 1-ECW 1-CCW 2-ECH	ECW, ECH different trains.
AEZ	1-ESFAS 1-ECW 1-CCW 2-ECH	ESFAS, ECH different trains.
AEV	1-ESFAS 1-ECW 1-CCW 3-ECH	
AEO	1-ESFAS 1-ECW 2-CCW	ESFAS, one train CCW same.
AEOT	1-ESFAS 1-ECW 2-CCW 1-ECH	ESFAS, ECH same train.
AEOW	1-ESFAS 1-ECW 2-CCW 1-ECH	ECW, ECH same train.
AEOY	1-ESFAS 1-ECW 2-CCW 1-ECH	CCW, ECH different trains.
AEOU	1-ESFAS 1-ECW 2-CCW 2-ECH	CCW, ECH same trains.
AEOX	1-ESFAS 1-ECW 2-CCW 2-ECH	ECW, ECH different trains.
AEOZ	1-ESFAS 1-ECW 2-CCW 2-ECH	ESFAS, ECH different trains.
AEOV	1-ESFAS 1-ECW 2-CCW 3-ECH	
AER	1-ESFAS 1-ECW 2-CCW	ESFAS, CCW different trains.
AERT	1-ESFAS 1-ECW 2-CCW 1-ECH	ESFAS, ECH same train.
AERW	1-ESFAS 1-ECW 2-CCW 1-ECH	ECW, ECH same train.
AERY	1-ESFAS 1-ECW 2-CCW 1-ECH	ESFAS, ECW, ECH different trains.
AERU	1-ESFAS 1-ECW 2-CCW 2-ECH	ESFAS, one train ECH same; ECW, other train ECH same.
AERX	1-ESFAS 1-ECW 2-CCW 2-ECH	ECW, ECH different trains.
AERZ	1-ESFAS 1-ECW 2-CCW 2-ECH	ESFAS, ECH different trains.
AERV	1-ESFAS 1-ECW 2-CCW 3-ECH	
AEP	1-ESFAS 1-ECW 3-CCW	
AEPT	1-ESFAS 1-ECW 3-CCW 1-ECH	ESFAS, ECH same train.

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TABLE 4-9 (continued)

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End States	Auxiliary Systems and Numbers of Trains Affected	Notes
AEPW	1-ESFAS 1-ECW 3-CCW 1-ECH	ECW, ECH same train.
AEPY	1-ESFAS 1-ECW 3-CCW 1-ECH	ESFAS, ECW, ECH different trains.
AEPU	1-ESFAS 1-ECW 3-CCW 2-ECH	ESFAS, one train ECH same; ECW, other train ECH same.
AEPX	1-ESFAS 1-ECW 3-CCW 2-ECH	ECW, ECH different trains.
AEPZ	1-ESFAS 1-ECW 3-CCW 2-ECH	ESFAS, ECH different trains.
AEPV	1-ESFAS 1-ECW 3-CCW 3-ECH	
AI	1-ESFAS 1-ECW 1-CCW 1-ECH (after LOSP)	ESFAS, ECW same train.
AIU	1-ESFAS 1-ECW 1-CCW 2-ECH (after LOSP)	
AIV	1-ESFAS 1-ECW 1-CCW 3-ECH (after LOSP)	
AIO	1-ESFAS 1-ECW 2-CCW 1-ECH (after LOSP)	
AIOU	1-ESFAS 1-ECW 2-CCW 2-ECH (after LOSP)	CCW, ECH same trains.
AIOX	1-ESFAS 1-ECW 2-CCW 2-ECH (after LOSP)	One train CCW, one train ECH different.
AIOV	1-ESFAS 1-ECW 2-CCW 3-ECH (after LOSP)	
AIP	1-ESFAS 1-ECW 3-CCW 1-ECH (after LOSP)	
AIPU	1-ESFAS 1-ECW 3-CCW 2-ECH (after LOSP)	
AIPV	1-ESFAS 1-ECW 3-CCW 3-ECH (after LOSP)	
AJ	1-ESFAS 1-ECW 1-CCW 1-ECH (after LOSP)	ESFAS, ECW different trains.
AJU	1-ESFAS 1-ECW 1-CCW 2-ECH (after LOSP)	ESFAS, one train ECH same.
AJX	1-ESFAS 1-ECW 1-CCW 2-ECH (after LOSP)	ESFAS, ECH different trains.
AJV	1-ESFAS 1-ECW 1-CCW 3-ECH (after LOSP)	
AJO	1-ESFAS 1-ECW 2-CCW 1-ECH (after LOSP)	ESFAS, one train CCW same.
AJOU	1-ESFAS 1-ECW 2-CCW 2-ECH (after LOSP)	CCW, ECH same trains
AJOX	1-ESFAS 1-ECW 2-CCW 2-ECH (after LOSP)	ESFAS, ECH different trains.
AJOV	1-ESFAS 1-ECW 2-CCW 3-ECH (after LOSP)	
AJR	1-ESFAS 1-ECW 2-CCW 1-ECH (after LOSP)	ESFAS, CCW different trains.
AJRU	1-ESFAS 1-ECW 2-CCW 2-ECH (after LOSP)	ESFAS, one train ECH same.
AJRX	1-ESFAS 1-ECW ?-CCW 2-ECH (after LOSP)	ESFAS, ECH different trains.
AJRV	1-ESFAS 1-ECW 2-CCW 3-ECH (after LOSP)	
AJP	1-ESFAS 1-ECW 3-CCW 1-ECH (after LOSP)	
AJPU	1-ESFAS 1-ECW 3-CCW 2-ECH (after LOSP)	ESFAS, one train ECH same.
AJPX	1-ESFAS 1-ECW 3-CCW 2-ECH (after LOSP)	ESFAS, ECH different trains.
AJPV	1-ESFAS 1-ECW 3-CCW 3-ECH (after LOSP)	
AFT	1-ESFAS 2-ECW 2-CCW 1-ECH	ESFAS, one train ECW same; ESFAS, ECH same train.
AFW	1-ESFAS 2-ECW 2-CCW 1-ECH	ESFAS, ECH different trains.
AFU	1-ESFAS 2-ECW 2-CCW 2-ECH	ECW, ECH same trains.
AFX	1-ESFAS 2-ECW 2-CCW 2-ECH	ESFAS, one train ECH same.
AFV	1-ESFAS 2-ECW 2-CCW 3-ECH	
AFPT	1-ESFAS 2-ECW 3-CCW 1-ECH	
AFPW	1-ESFAS 2-ECW 3-CCW 1-ECH	ESFAS, ECH different trains.
AFPU	1-ESFAS 2-ECW 3-CCW 2-ECH	

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TABLE 4-9 (continued)

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End States	Auxiliary Systems and Numbers of Trains Affected	Notes
AFPX	1-ESFAS 2-ECW 3-CCW 2-ECH	ESFAS, one train ECH same.
AFPV	1-ESFAS 2-ECW 3-CCW 3-ECH	
AG	1-ESFAS 2-ECW 2-CCW 1-ECH	ESFAS, ECW different trains.
AGU	1-ESFAS 2-ECW 2-CCW 2-ECH	ESFAS, one train ECH same.
AGX	1-ESFAS 2-ECW 2-CCW 2-ECH	ESFAS, ECH different trains.
AGV	1-ESFAS 2-ECW 2-CCW 3-ECH	
AGP	1-ESFAS 2-ECW 3-CCW 1-ECH	ESFAS, ECH different trains.
AGPU	1-ESFAS 2-ECW 3-CCW 2-ECH	ESFAS, one train ECH same.
AGPX	1-ESFAS 2-ECW 3-CCW 2-ECH	ESFAS, ECH different trains.
AGPV	1-ESFAS 2-ECW 3-CCW 3-ECH	
AK	1-ESFAS 2-ECW 2-CCW 2-ECH (after LOSP)	ESFAS, one train ECW same.
AKV	1-ESFAS 2-ECW 2-CCW 3-ECH (after LOSP)	
AKP	1-ESFAS 2-ECW 3-CCW 2-ECH (after LOSP)	
AKPV	1-ESFAS 2-ECW 3-CCW 3-FCH (after LOSP)	
AL	1-ESFAS 2-ECW 2-CCW 2-ECH (after LOSP)	ESFAS, ECW different trains.
ALV	1-ESFAS 2-ECW 2-CCW 3-ECH (after LOSP)	
ALP	1-ESFAS 2-ECW 3-CCW 2-ECH (after LOSP)	
ALPV	1-ESFAS 2-ECW 3-CCW 3-ECH (after LOSP)	
A1	1-ESFAS 2-ECW 2-CCW 1-ECH (after LOP one bus)	ESFAS, ECW(LOP) same train.
A1U	1-ESFAS 2-ECW 2-CCW 2-ECH (after LOP one bus)	ECW, ECH same trains.
A1X	1-ESFAS 2-ECW 2-CCW 2-ECH (after LOP one bus)	One train ECW, one train ECH different.
A1V	1-ESFAS 2-ECW 2-CCW 3-ECH (after LOP one bus)	
A1P	1-ESFAS 2-ECW 3-CCW 1-ECH (after LOP one bus)	
A1PU	1-ESFAS 2-ECW 3-CCW 2-ECH (after LOP one bus)	ECW, ECH same trains.
A1PX	1-ESFAS 2-ECW 3-CCW 2-ECH (after LOP one bus)	One train ECW, one train ECH different.
A1PV	1-ESFAS 2-ECW 3-CCW 3-ECH (after LOP one bus)	
A3	1-ESFAS 2-ECW 2-CCW 1-ECH (after LOP one bus)	ESFAS, ECW(LOP) different trains.
A3U	1-ESFAS 2-ECW 2-CCW 2-ECH (after LOP one bus)	ECW, ECH same trains.
A3X	1-ESFAS 2-ECW 2-CCW 2-ECH (after LOP one bus)	ESFAS, ECH different trains.
A3V	1-ESFAS 2-ECW 2-CCW 3-ECW (after LOP one bus)	
A3P	1-ESFAS 2-ECW 3-CCW 1-ECH (after LOP one bus)	
A3PU	1-ESFAS 2-ECW 3-CCW 2-ECH (after LOP one bus)	ECW, ECH same trains.
A3PX	1-ESFAS 2-ECW 3-CCW 2-ECH (after LOP one bus)	ESFAS, ECH different trains.
A3PV	1-ESFAS 2-ECW 3-CCW 3-ECH (after LOP one bus)	
A4	1-ESFAS 2-ECW 2-CCW 1-ECH (after LOP one bus)	ESFAS, ECW different trains.
A4U	1-ESFAS 2-ECW 2-CCW 2-ECH (after LOP one bus)	ESFAS, one train ECH same.
A4X	1-ESFAS 2-ECW 2-CCW 2-ECH (after LOP one bus)	ESFAS, ECH different trains.
A4V	1-ESFAS 2-ECW 2-CCW 3-ECH (after LOP one bus)	
A4P	1-ESFAS 2-ECW 3-CCW 1-ECH (after LOP one bus)	
A4PU	1-ESFAS 2-ECW 3-CCW 2-ECH (after LOP one bus)	ESFAS, one train ECH same.
A4PX	1-ESFAS 2-ECW 3-CCW 2-ECH (after LOP one bus)	ESFAS, ECH different trains.

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TABLE 4-9 (continued)

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End States	Auxiliary Systems and Numbers of Trains Affected	Notes
A4PV	1-ESFAS 2-ECW 3-CCW 3-ECH (after LOP one bus)	
AH	1-ESFAS 3-ECW 3-CCW 3-ECH	
AM	1-ESFAS 3-ECW 3-CCW 3-ECH (after LOSP)	
A2	1-ESFAS 3-ECW 3-CCW 3-ECH (after LOP one bus)	ESFAS, ECW(LOP) same train.
A5	1-ESFAS 3-ECW 3-CCW 3-ECH (after LOP one bus)	ESFAS, ECW(LOP) different trains.
A6	1-ESFAS 3-ECW 3-CCW 3-ECH (after LOP 2-buses)	ESFAS, ECW(LOP) same train.
A7	1-ESFAS 3-ECW 3-CCW 3-ECH (after LOP 2-buses)	ESFAS, both trains ECW(LOP) different.
B	2-ESFAS	
BT	2-ESFAS 1-ECH	One train ESFAS, ECH same.
BW	2-ESFAS 1-ECH	ESFAS, ECH different trains.
BU	2-ESFAS 2-ECH	ESFAS, ECH same trains.
BX	2-ESFAS 2-ECH	One train ESFAS, one train ECH different.
BV	2-ESFAS 3-ECH	
BN	2-ESFAS 1-CCW	One train ESFAS, CCW same.
BNT	2-ESFAS 1-CCW 1-ECH	CCW, ECH same train.
BNW	2-ESFAS 1-CCW 1-ECH	One train ESFAS, ECH same; CCW, ECH different trains.
BNY	2-ESFAS 1-CCW 1-ECH	ESFAS, ECH different trains.
BNU	2-ESFAS 1-CCW 2-ECH	ESFAS, ECH same trains.
BNX	2-ESFAS 1-CCW 2-ECH	One train ESFAS, one train ECH different.
BNZ	2-ESFAS 1-CCW 2-ECH	CCW, ECH different trains.
BNV	2-ESFAS 1-CCW 3-ECH	
BQ	2-ESFAS 1-CCW	ESFAS, CCW different trains.
BQT	2-ESFAS 1-CCW 1-ECH	One train ESFAS, ECH same.
BQW	2-ESFAS 1-CCW 1-ECH	ESFAS, ECH different trains.
BQU	2-ESFAS 1-CCW 2-ECH	ESFAS, ECH same trains.
BQX	2-ESFAS 1-CCW 2-ECH	ESFAS, one train ECH same; CCW, other train ECH same.
BQV	2-ESFAS 1-CCW 3-ECH	
BO	2-ESFAS 2-CCW	ESFAS, CCW same trains.
BOT	2-ESFAS 2-CCW 1-ECH	One train ESFAS, ECH same.
BOW	2-ESFAS 2-CCW 1-ECH	ESFAS, ECH different trains.
BOU	2-ESFAS 2-CCW 2-ECH	ESFAS, ECH same trains.
BOX	2-ESFAS 2-CCW 2-ECH	One train ESFAS, one train ECH different.
BOV	2-ESFAS 2-CCW 3-ECH	
BR	2-ESFAS 2-CCW	One train ESFAS, one train CCW different.
BRT	2-ESFAS 2-CCW 1-ECH	One train ESFAS, one train CCW, ECH same.
BRW	2-ESFAS 2-CCW 1-ECH	CCW, ECH different trains.
BRY	2-ESFAS 2-CCW 1-ECH	ESFAS, ECH different trains.

CAUTION: PRELIMINARY RESULTS-
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TABLE 4-9 (continued)

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End States	Auxiliary Systems and Numbers of Trains Affected	Notes
BRU	2-ESFAS 2-CCW 2-ECH	ESFAS, ECH same trains.
BRX	2-ESFAS 2-CCW 2-ECH	CCW, ECH same trains.
BRZ	2-ESFAS 2-CCW 2-ECH	One train ESFAS, one train ECH different.
BRV	2-ESFAS 2-CCW 3-ECH	
BP	2-ESFAS 3-CCW	
BPT	2-ESFAS 3-CCW 1-ECH	One train ESFAS, ECH same.
BPW	2-ESFAS 3-CCW 1-ECH	ESFAS, ECH different trains.
BPU	2-ESFAS 3-CCW 2-ECH	ESFAS, ECH same trains.
BPX	2-ESFAS 3-CCW 2-ECH	One train ESFAS, one train ECH different.
BPV	2-ESFAS 3-CCW 3-ECH	
BD	2-ESFAS 1-ECW 1-CCW	One train ESFAS, ECW same.
BDT	2-ESFAS 1-ECW 1-CCW 1-ECH	ECW, ECH same train.
BDW	2-ESFAS 1-ECW 1-CCW 1-ECH	One train ESFAS, ECH same; ECW, ECH different trains.
BDY	2-ESFAS 1-ECW 1-CCW 1-ECH	ESFAS, ECH different trains.
BDU	2-ESFAS 1-ECW 1-CCW 2-ECH	ESFAS, ECH same trains.
BDX	2-ESFAS 1-ECW 1-CCW 2-ECH	One train ESFAS, one train ECH different.
BDZ	2-ESFAS 1-ECW 1-CCW 2-ECH	ECW, ECH different trains.
BDV	2-ESFAS 1-ECW 1-CCW 3-ECH	
BDO	2-ESFAS 1-ECW 2-CCW	ESFAS, CCW same trains.
BDOT	2-ESFAS 1-ECW 2-CCW 1-ECH	ECW, ECH same train.
BDOW	2-ESFAS 1-ECW 2-CCW 1-ECH	One train ESFAS, ECH same; ECW, ECH different trains.
BDOY	2-ESFAS 1-ECW 2-CCW 1-ECH	ESFAS, ECH different trains.
BDOU	2-ESFAS 1-ECW 2-CCW 2-ECH	ESFAS, ECH same trains.
BDOX	2-ESFAS 1-ECW 2-CCW 2-ECH	One train ESFAS, one train ECH different.
BDOZ	2-ESFAS 1-ECW 2-CCW 2-ECH	ECW, ECH different trains.
BDOV	2-ESFAS 1-ECW 2-CCW 3-ECH	
BDR	2-ESFAS 1-ECW 2-CCW	One train ESFAS, one train CCW different.
BDRT	2-ESFAS 1-ECW 2-CCW 1-ECH	ECW, ECH same train.
BDRW	2-ESFAS 1-ECW 2-CCW 1-ECH	CCW, ECH different trains.
BDRY	2-ESFAS 1-ECW 2-CCW 1-ECH	ESFAS, ECH different trains.
BDRU	2-ESFAS 1-ECW 2-CCW 2-ECH	ESFAS, ECH same trains.
BDRX	2-ESFAS 1-ECW 2-CCW 2-ECH	CCW, ECH same trains.
BDRZ	2-ESFAS 1-ECW 2-CCW 2-ECH	ECW, ECH different trains.
BDRV	2-ESFAS 1-ECW 2-CCW 3-ECH	
BDP	2-ESFAS 1-ECW 3-CCW	
BDPT	2-ESFAS 1-ECW 3-CCW 1-ECH	ECW, ECH same train.
BDPW	2-ESFAS 1-ECW 3-CCW 1-ECH	One train ESFAS, ECH same; ECW, ECH different trains.
BDPY	2-ESFAS 1-ECW 3-CCW 1-ECH	ESFAS, ECH different trains.
BDPU	2-ESFAS 1-ECW 3-CCW 2-ECH	ESFAS, ECH same trains.

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IMPORTANT UNCERTAINTIES
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TABLE 4-9 (continued)

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End States	Auxiliary Systems and Numbers of Trains Affected	Notes
BDPX	2-ESFAS 1-ECW 3-CCW 2-ECH	One train ESFAS, one train ECH different.
BDPZ	2-ESFAS 1-ECW 3-CCW 2-ECH	ECW, ECH different trains.
BDPV	2-ESFAS 1-ECW 3-CCW 3-ECH	
BE	2-ESFAS 1-ECW 1-CCW	ESFAS, ECW different trains.
BET	2-ESFAS 1-ECW 1-CCW 1-ECH	One train ESFAS, ECH same.
BEW	2-ESFAS 1-ECW 1-CCW 1-ECH	ESFAS, ECH different trains.
BEU	2-ESFAS 1-ECW 1-CCW 2-ECH	ESFAS, ECH same trains.
BEX	2-ESFAS 1-ECW 1-CCW 2-ECH	One train ESFAS, one train ECH different.
BEV	2-ESFAS 1-ECW 1-CCW 3-ECH	
BER	2-ESFAS 1-ECW 2-CCW	One train ESFAS, one train CCW different.
BERT	2-ESFAS 1-ECW 2-CCW 1-ECH	One train ESFAS, ECH same.
BERW	2-ESFAS 1-ECW 2-CCW 1-ECH	CCW, ECH different trains.
BERY	2-ESFAS 1-ECW 2-CCW 1-ECH	ESFAS, ECH different trains.
BERU	2-ESFAS 1-ECW 2-CCW 2-ECH	ESFAS, ECH same trains.
BERX	2-ESFAS 1-ECW 2-CCW 2-ECH	CCW, ECH same trains.
BERZ	2-ESFAS 1-ECW 2-CCW 2-ECH	One train ESFAS, one train ECH different.
BERV	2-ESFAS 1-ECW 2-CCW 3-ECH	
BEP	2-ESFAS 1-ECW 3-CCW	
BEPT	2-ESFAS 1-ECW 3-CCW 1-ECH	One train ESFAS, ECH same.
BEPW	2-ESFAS 1-ECW 3-CCW 1-ECH	ESFAS, ECH different trains.
BEPU	2-ESFAS 1-ECW 3-CCW 2-ECH	ESFAS, ECH same trains.
BEPX	2-ESFAS 1-ECW 3-CCW 2-ECH	One train ESFAS, one train ECH different.
BEPV	2-ESFAS 1-ECW 3-CCW 3-ECH	
BI	2-ESFAS 1-ECW 1-CCW 1-ECH (after LOSP)	One train ESFAS, ECH same.
BIU	2-ESFAS 1-ECW 1-CCW 2-ECH (after LOSP)	ESFAS, ECH same trains.
BIX	2-ESFAS 1-ECW 1-CCW 2-ECH (after LOSP)	One train ESFAS, one train ECH different.
BIV	2-ESFAS 1-ECW 1-CCW 3-ECH (after LOSP)	
BIO	2-ESFAS 1-ECW 2-CCW 1-ECH (after LOSP)	ESFAS, CCW same trains.
BIOU	2-ESFAS 1-ECW 2-CCW 2-ECH (after LOSP)	ESFAS, ECH same trains.
BIOX	2-ESFAS 1-ECW 2-CCW 2-ECH (after LOSP)	One train ESFAS, one train ECH different.
BIOV	2-ESFAS 1-ECW 2-CCW 3-ECH (after LOSP)	
BIR	2-ESFAS 1-ECW 2-CCW 1-ECH (after LOSP)	One train ESFAS, one train CCW different.
BIRU	2-ESFAS 1-ECW 2-CCW 2-ECH (after LOSP)	ESFAS, ECH same trains.
BIRX	2-ESFAS 1-ECW 2-CCW 2-ECH (after LOSP)	CCW, ECH same trains.
BIRV	2-ESFAS 1-ECW 2-CCW 3-ECH (after LOSP)	
BIP	2-ESFAS 1-ECW 3-CCW 1-ECH (after LOSP)	
BIPU	2-ESFAS 1-ECW 3-CCW 2-ECH (after LOSP)	ESFAS, ECH same trains.
BIPX	2-ESFAS 1-ECW 3-CCW 2-ECH (after LOSP)	One train ESFAS, one train ECH different.
BIPV	2-ESFAS 1-ECW 3-CCW 3-ECH (after LOSP)	
BJ	2-ESFAS 1-ECW 1-CCW 1-ECH (after LOSP)	ESFAS, ECW different trains.
BJX	2-ESFAS 1-ECW 1-CCW 2-ECH (after LOSP)	One train ESFAS, one train ECH different.

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TABLE 4-9 (continued)

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End States	Auxiliary Systems and Numbers of Trains Affected	Notes
BJV	2-ESFAS 1-ECW 1-CCW 3-ECH (after LOSP)	
BJR	2-ESFAS 1-ECW 2-CCW 1-ECH (after LOSP)	One train ESFAS, one train CCW different.
BJRX	2-ESFAS 1-ECW 2-CCW 2-ECH (after LOSP)	CCW, ECH same trains.
BJRZ	2-ESFAS 1-ECW 2-CCW 2-ECH (after LOSP)	One train ESFAS, one train ECH different.
BJRV	2-ESFAS 1-ECW 2-CCW 3-ECH (after LOSP)	
BJP	2-ESFAS 1-ECW 3-CCW 1-ECH (after LOSP)	
BJPX	2-ESFAS 1-ECW 3-CCW 2-ECH (after LOSP)	One train ESFAS, one train ECH different.
BJPV	2-ESFAS 1-ECW 3-CCW 3-ECH (after LOSP)	
BF	2-ESFAS 2-ECW 2-CCW 1-ECH	ESFAS, ECW same trains.
BFU	2-ESFAS 2-ECW 2-CCW 2-ECH	ECW, ECH same trains.
BFX	2-ESFAS 2-ECW 2-CCW 2-ECH	One train ESFAS, one train ECH different.
BFV	2-ESFAS 2-ECW 2-CCW 3-ECH	
BFP	2-ESFAS 2-ECW 3-CCW 1-ECH	
BFPU	2-ESFAS 2-ECW 3-CCW 2-ECH	ECW, ECH same trains.
BFPX	2-ESFAS 2-ECW 3-CCW 2-ECH	One train ESFAS, one train ECH different.
BFPV	2-ESFAS 2-ECW 3-CCW 3-ECH	
BGT	2-ESFAS 2-ECW 2-CCW 1-ECH	One train ESFAS, one train ECW different; one train ESFAS, ECH same.
BGW	2-ESFAS 2-ECW 2-CCW 1-ECH	ESFAS, ECH different trains.
BGU	2-ESFAS 2-ECW 2-CCW 2-ECH	ESFAS, ECH same trains.
BGX	2-ESFAS 2-ECW 2-CCW 2-ECH	ECW, ECH same trains.
BGZ	2-ESFAS 2-ECW 2-CCW 2-ECH	One train ESFAS, one train ECH different.
BGV	2-ESFAS 2-ECW 2-CCW 3-ECH	
BGPT	2-ESFAS 2-ECW 3-CCW 1-ECH	One train ESFAS, one train ECW different; one train ESFAS, ECH same.
BGPW	2-ESFAS 2-ECW 3-CCW 1-ECH	ESFAS, ECH different trains.
BGPU	2-ESFAS 2-ECW 3-CCW 2-ECH	ESFAS, ECH same trains.
BGPX	2-ESFAS 2-ECW 3-CCW 2-ECH	ECW, ECH same trains.
BGPZ	2-ESFAS 2-ECW 3-CCW 2-ECH	One train ESFAS, one train ECH different.
BGPV	2-ESFAS 2-ECW 3-CCW 3-ECH	
BK	2-ESFAS 2-ECW 2-CCW 2-ECH (after LOSP)	ESFAS, ECW same trains.
BKV	2-ESFAS 2-ECW 2-CCW 3-ECH (after LOSP)	
BKP	2-ESFAS 2-ECW 3-CCW 2-ECH (after LOSP)	
BKPV	2-ESFAS 2-ECW 3-CCW 3-ECH (after LOSP)	
BL	2-ESFAS 2-ECW 2-CCW 2-ECH (after LOSP)	One train ESFAS, one train ECW different.
BLV	2-ESFAS 2-ECW 2-CCW 3-ECH (after LOSP)	
BLP	2-ESFAS 2-ECW 3-CCW 2-ECH (after LOSP)	
BLPV	2-ESFAS 2-ECW 3-CCW 3-ECH (after LOSP)	
BI	2-ESFAS 2-ECW 2-CCW 1-ECH (after LOP one bus)	ESFAS, ECW same trains.
BIU	2-ESFAS 2-ECW 2-CCW 2-ECH (after LOP one bus)	ESFAS, ECH same trains.
BIX	2-ESFAS 2-ECW 2-CCW 2-ECH (after LOP one bus)	One train ESFAS, one train ECH different.
BIV	2-ESFAS 2-ECW 2-CCW 3-ECH (after LOP one bus)	
BIP	2-ESFAS 2-ECW 3-CCW 1-ECH (after LOP one bus)	
BIPU	2-ESFAS 2-ECW 3-CCW 2-ECH (after LOP one bus)	ESFAS,ECH same trains.
BIPX	2-ESFAS 2-ECW 3-CCW 2-ECH (after LOP one bus)	One train ESFAS, one train ECH different.

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TABLE 4-9 (continued)

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End States	Auxiliary Systems and Numbers of Trains Affected	Notes
B1PV	2-ESFAS 2-ECW 3-CCW 3-ECH (after LOP one bus)	
B3	2-ESFAS 2-ECW 2-CCW 1-ECH (after LOP one bus)	One train ESFAS, one train ECW different; one train ESFAS, ECW(LOP) same.
B3U	2-ESFAS 2-ECW 2-CCW 2-ECH (after LOP one bus)	ESFAS, ECH same trains.
B3X	2-ESFAS 2-ECW 2-CCW 2-ECH (after LOP one bus)	ECW, ECH same trains.
B3V	2-ESFAS 2-ECW 2-CCW 3-ECW (after LOP one bus)	
B3P	2-ESFAS 2-ECW 3-CCW 1-ECH (after LOP one bus)	One train ESFAS, one train ECW different; one train ESFAS, ECW(LOP) same.
B3PU	2-ESFAS 2-ECW 3-CCW 2-ECH (after LOP one bus)	ESFAS, ECH same trains.
B3PX	2-ESFAS 2-ECW 3-CCW 2-ECH (after LOP one bus)	ECW, ECH same trains.
B3PV	2-ESFAS 2-ECW 3-CCW 3-ECW (after LOP one bus)	
B4	2-ESFAS 2-ECW 2-CCW 1-ECH (after LOP one bus)	ESFAS, ECW(LOP) different trains.
B4X	2-ESFAS 2-ECW 2-CCW 2-ECH (after LOP one bus)	ECW, ECH same trains.
B4Z	2-ESFAS 2-ECW 2-CCW 2-ECH (after LOP one bus)	One train ECW, one train ECH different.
B4V	2-ESFAS 2-ECW 2-CCW 3-ECH (after LOP one bus)	
B4P	2-ESFAS 2-ECW 3-CCW 1-ECH (after LOP one bus)	ESFAS, ECW(LOP) different trains.
B4PX	2-ESFAS 2-ECW 3-CCW 2-ECH (after LOP one bus)	ECW, ECH same trains.
B4PZ	2-ESFAS 2-ECW 3-CCW 2-ECH (after LOP one bus)	One train ECW, one train ECH different.
B4PV	2-ESFAS 2-ECW 3-CCW 3-ECH (after LOP one bus)	
BH	2-ESFAS 3-ECW 3-CCW 3-ECH	
BM	2-ESFAS 3-ECW 3-CCW 3-ECH (after LOSP)	
B2	2-ESFAS 3-ECW 3-CCW 3-ECH (after LOP one bus)	One train ESFAS, ECW(LOP) same.
B5	2-ESFAS 3-ECW 3-CCW 3-ECH (after LOP one bus)	ESFAS, ECW(LOP) different trains.
B6	2-ESFAS 3-ECW 3-CCW 3-ECH (after LOP 2-buses)	ESFAS, ECW(LOP) same trains.
B7	2-ESFAS 3-ECW 3-CCW 3-ECH (after LOP 2-buses)	One train ESFAS, one train ECW(LOP) different.
C	3-ESFAS	
CT	3-ESFAS 1-ECH	
CU	3-ESFAS 2-ECH	
CV	3-ESFAS 3-ECH	
CN	3-ESFAS 1-CCW	
CNT	3-ESFAS 1-CCW 1-ECH	CCW, ECH same train.
CNW	3-ESFAS 1-CCW 1-ECH	CCW, ECH different trains.
CNU	3-ESFAS 1-CCW 2-ECH	CCW, one train ECH same.
CNX	3-ESFAS 1-CCW 2-ECH	CCW, ECH different trains.
CNV	3-ESFAS 1-CCW 3-ECH	
CO	3-ESFAS 2-CCW	
COT	3-ESFAS 2-CCW 1-ECH	One train CCW, ECH same.
COW	3-ESFAS 2-CCW 1-ECH	CCW, ECH different trains.
COU	3-ESFAS 2-CCW 2-ECH	CCW, ECH same trains.
COX	3-ESFAS 2-CCW 2-ECH	One train CCW, one train ECH different.
COV	3-ESFAS 2-CCW 3-ECH	
CP	3-ESFAS 3-CCW	

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TABLE 4-9 (continued)

Sheet 12 of 14

End States	Auxiliary Systems and Numbers of Trains Affected	Notes
CPT	3-ESFAS 3-CCW 1-ECH	
CPU	3-ESFAS 3-CCW 2-ECH	
CPV	3-ESFAS 3-CCW 3-ECH	
CD	3-ESFAS 1-ECW 1-CCW	
CDT	3-ESFAS 1-ECW 1-CCW 1-ECH	ECW, ECH same train.
CDW	3-ESFAS 1-ECW 1-CCW 1-ECH	ECW, ECH different trains.
CDU	3-ESFAS 1-ECW 1-CCW 2-ECH	ECW, one train ECH same.
CDX	3-ESFAS 1-ECW 1-CCW 2-ECH	ECW, ECH different trains.
CDV	3-ESFAS 1-ECW 1-CCW 3-ECH	
CDO	3-ESFAS 1-ECW 2-CCW	
CDOT	3-ESFAS 1-ECW 2-CCW 1-ECH	ECW, ECH same train.
CDOW	3-ESFAS 1-ECW 2-CCW 1-ECH	ECW, ECH different trains; one CCW train, ECH same.
CDOY	3-ESFAS 1-ECW 2-CCW 1-ECH	CCW, ECH different trains.
CDOU	3-ESFAS 1-ECW 2-CCW 2-ECH	CCW, ECH same trains.
CDOX	3-ESFAS 1-ECW 2-CCW 2-ECH	One train CCW, one train ECH different.
CDOZ	3-ESFAS 1-ECW 2-CCW 2-ECH	ECW, ECH different trains.
CDOV	3-ESFAS 1-ECW 2-CCW 3-ECH	
CDP	3-ESFAS 1-ECW 3-CCW	
CDPT	3-ESFAS 1-ECW 3-CCW 1-ECH	ECW, ECH same train.
CDPW	3-ESFAS 1-ECW 3-CCW 1-ECH	ECW, ECH different trains.
CDPU	3-ESFAS 1-ECW 3-CCW 2-ECH	ECW, one train ECH same.
CDPX	3-ESFAS 1-ECW 3-CCW 2-ECH	ECW, ECH different trains.
CDPV	3-ESFAS 1-ECW 3-CCW 3-ECH	
CI	3-ESFAS 1-ECW 1-CCW 1-ECH (after LOSP)	
CIU	3-ESFAS 1-ECW 1-CCW 2-ECH (after LOSP)	
CIV	3-ESFAS 1-ECW 1-CCW 3-ECH (after LOSP)	
CIO	3-ESFAS 1-ECW 2-CCW 1-ECH (after LOSP)	
CIOU	3-ESFAS 1-ECW 2-CCW 2-ECH (after LOSP)	CCW, ECH same trains.
CIOX	3-ESFAS 1-ECW 2-CCW 2-ECH (after LOSP)	One train CCW, one train ECH different.
CIOV	3-ESFAS 1-ECW 2-CCW 3-ECH (after LOSP)	
CIP	3-ESFAS 1-ECW 3-CCW 1-ECH (after LOSP)	
CIPU	3-ESFAS 1-ECW 3-CCW 2-ECH (after LOSP)	
CIPV	3-ESFAS 1-ECW 3-CCW 3-ECH (after LOSP)	
CF	3-ESFAS 2-ECW 2-CCW 1-ECH	
CFU	3-ESFAS 2-ECW 2-CCW 2-ECH	ECW, ECH same trains.
CFX	3-ESFAS 2-ECW 2-CCW 2-ECH	One train ECW, one train ECH different.
CFV	3-ESFAS 2-ECW 2-CCW 3-ECH	
CFP	3-ESFAS 2-ECW 3-CCW 1-ECH	
CFPU	3-ESFAS 2-ECW 3-CCW 2-ECH	ECW, ECH same trains.
CFPX	3-ESFAS 2-ECW 3-CCW 2-ECH	One train ECW, one train ECH different.
CFPV	3-ESFAS 2-ECW 3-CCW 3-ECH	
CK	3-ESFAS 2-ECW 2-CCW 2-ECH (after LOSP)	
CKV	3-ESFAS 2-ECW 2-CCW 3-ECH (after LOSP)	
CKP	3-ESFAS 2-ECW 3-CCW 2-ECH (after LOSP)	
CKPV	3-ESFAS 2-ECW 3-CCW 3-ECH (after LOSP)	
Cl	3-ESFAS 2-ECW 2-CCW 1-ECH (after LOP one bus)	
ClU	3-ESFAS 2-ECW 2-CCW 2-ECH (after LOP one bus)	ECW, ECH same trains.

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TABLE 4-9 (continued)

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End States	Auxiliary Systems and Numbers of Trains Affected	Notes
C1X	3-ESFAS 2-ECW 2-CCW 2-ECH (after LOP one bus)	One train ECW, one train ECH different.
C1V	3-ESFAS 2-ECW 2-CCW 3-ECH (after LOP one bus)	
C1P	3-ESFAS 2-ECW 3-CCW 1-ECH (after LOP one bus)	
C1PU	3-ESFAS 2-ECW 3-CCW 2-ECH (after LOP one bus)	ECW, ECH same trains.
C1PX	3-ESFAS 2-ECW 3-CCW 2-ECH (after LOP one bus)	One train ECW, one train ECH different.
C1PV	3-ESFAS 2-ECW 3-CCW 3-ECH (after LOP one bus)	
CH	3-ESFAS 3-ECW 3-CCW 3-ECH	
CM	3-ESFAS 3-ECW 3-CCW 3-ECH (after LOSP)	
C2	3-ESFAS 3-ECW 3-CCW 3-ECH (after LOP one bus)	
C6	3-ESFAS 3-ECW 3-CCW 3-ECH (after LOP 2-buses)	
S	SSPS	
ST	SSPS 1-ECH	
SU	SSPS 2-ECH	
SV	SSPS 3-ECH	
SN	SSPS 1-CCW	
SNT	SSPS 1-CCW 1-ECH	CCW, ECH same train.
SNW	SSPS 1-CCW 1-ECH	CCW, ECH different trains.
SNU	SSPS 1-CCW 2-ECH	CCW, one train ECH same.
SNX	SSPS 1-CCW 2-ECH	CCW, ECH different trains.
SNV	SSPS 1-CCW 3-ECH	
SO	SSPS 2-CCW	
SOT	SSPS 2-CCW 1-ECH	One train CCW, ECH same.
SOW	SSPS 2-CCW 1-ECH	CCW, ECH different trains.
SOU	SSPS 2-CCW 2-ECH	CCW, ECH same trains.
SOX	SSPS 2-CCW 2-ECH	One train CCW, one train ECH different.
SOV	SSPS 2-CCW 3-ECH	
SP	SSPS 3-CCW	
SPT	SSPS 3-CCW 1-ECH	
SPU	SSPS 3-CCW 2-ECH	
SPV	SSPS 3-CCW 3-ECH	
SD	SSPS 1-ECW 1-CCW	
SDT	SSPS 1-ECW 1-CCW 1-ECH	ECW, ECH same train.
SDW	SSPS 1-ECW 1-CCW 1-ECH	ECW, ECH different trains.
SDU	SSPS 1-ECW 1-CCW 2-ECH	ECW, one train ECH same.
SDX	SSPS 1-ECW 1-CCW 2-ECH	ECW, ECH different trains.
SDV	SSPS 1-ECW 1-CCW 3-ECH	
SDO	SSPS 1-ECW 2-CCW	
SDOT	SSPS 1-ECW 2-CCW 1-ECH	ECW, ECH same train.
SDOW	SSPS 1-ECW 2-CCW 1-ECH	ECW, ECH different trains; one train CCW, ECH same.
SDOY	SSPS 1-ECW 2-CCW 1-ECH	CCW, ECH different trains.
SDOU	SSPS 1-ECW 2-CCW 2-ECH	CCW, ECH same trains.
SDOX	SSPS 1-ECW 2-CCW 2-ECH	One train CCW, one train ECH different.
SDOZ	SSPS 1-ECW 2-CCW 2-ECH	ECW, ECH different trains.
SDOV	SSPS 1-ECW 2-CCW 3-ECH	
SDP	SSPS 1-ECW 3-CCW	

CAUTION: PRELIMINARY RESULTS
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TABLE 4-9 (continued)

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End States	Auxiliary Systems and Numbers of Trains Affected	Notes
SDPT	SSPS 1-ECW 3-CCW 1-ECH	ECW, ECH same train.
SDPW	SSPS 1-ECW 3-CCW 1-ECH	ECW, ECH different trains.
SDPU	SSPS 1-ECW 3-CCW 2-ECH	ECW, one train ECH same.
SDPX	SSPS 1-ECW 3-CCW 2-ECH	ECW, ECH different trains.
SDPV	SSPS 1-ECW 3-CCW 3-ECH	
SI	SSPS 1-ECW 1-CCW 1-ECH (after LOSP)	
SIU	SSPS 1-ECW 1-CCW 2-ECH (after LOSP)	
SIV	SSPS 1-ECW 1-CCW 3-ECH (after LOSP)	
SIO	SSPS 1-ECW 2-CCW 1-ECH (after LOSP)	
SIOU	SSPS 1-ECW 2-CCW 2-ECH (after LOSP)	CCW, ECH same trains.
SIOX	SSPS 1-ECW 2-CCW 2-ECH (after LOSP)	One train CCW, one train ECH different.
SIOV	SSPS 1-ECW 2-CCW 3-ECH (after LOSP)	
SIP	SSPS 1-ECW 3-CCW 1-ECH (after LOSP)	
SIPU	SSPS 1-ECW 3-CCW 2-ECH (after LOSP)	
SIPV	SSPS 1-ECW 3-CCW 3-ECH (after LOSP)	
SF	SSPS 2-ECW 2-CCW 1-ECH	
SFU	SSPS 2-ECW 2-CCW 2-ECH	ECW, ECH same trains.
SFX	SSPS 2-ECW 2-CCW 2-ECH	One train ECW, one train ECH different.
SFV	SSPS 2-ECW 2-CCW 3-ECH	
SFP	SSPS 2-ECW 3-CCW 1-ECH	
SFPU	SSPS 2-ECW 3-CCW 2-ECH	ECW, ECH same trains.
SFPX	SSPS 2-ECW 3-CCW 2-ECH	One train ECW, one train ECH different.
SFPV	SSPS 2-ECW 3-CCW 3-ECH	
SK	SSPS 2-ECW 2-CCW 2-ECH (after LOSP)	
SKV	SSPS 2-ECW 2-CCW 3-ECH (after LOSP)	
SKP	SSPS 2-ECW 3-CCW 2-ECH (after LOSP)	
SKPV	SSPS 2-ECW 3-CCW 3-ECH (after LOSP)	
S1	SSPS 2-ECW 2-CCW 1-ECH (after LOP one bus)	
S1U	SSPS 2-ECW 2-CCW 2-ECH (after LOP one bus)	ECW, ECH same trains.
S1X	SSPS 2-ECW 2-CCW 2-ECH (after LOP one bus)	One train ECW, one train ECH different.
S1V	SSPS 2-ECW 2-CCW 3-ECH (after LOP one bus)	
S1P	SSPS 2-ECW 3-CCW 1-ECH (after LOP one bus)	
S1PU	SSPS 2-ECW 3-CCW 2-ECH (after LOP one bus)	ECW, ECH same trains.
S1PX	SSPS 2-ECW 3-CCW 2-ECH (after LOP one bus)	One train ECW, one train ECH different.
S1PV	SSPS 2-ECW 3-CCW 3-ECH (after LOP one bus)	
SH	SSPS 3-ECW 3-CCW 3-ECH	
SM	SSPS 3-ECW 3-CCW 3-ECH (after LOSP)	
S2	SSPS 3-ECW 3-CCW 3-ECH (after LOP one bus)	
S6	SSPS 3-ECW 3-CCW 3-ECH (after LOP 2-buses)	

TABLE 4-10. MATRIX OF AUXILIARY SYSTEM TO MAI

Main Line Systems / Auxiliary Systems	Turbine Trip	MSIV	Auxiliary Feedwater Pumps				Steam Generator Relief Valves				Charging Pumps		High Pressure Safety Injection Pumps		
			11	12	13	14	PV-7411	PV-7421	PV-7431	PV-7441	1A	1B	1A	1B	1C
Offsite Grid	(a)										(b)	(b)			
4,160V Bus E1A			X				X			X		X	X		
4,160V Bus E1B				X				X						X	
4,160V Bus E1C					X				X		X				X
DC Bus E1A11		(e)	X				X					X	X		
DC Bus E1B11		(e)		X				X						X	
DC Bus E1C11					X				X		X				X
DC Bus E1D11						X				X					
EDG DG-11			X				X			X		X	X		
EDG DG-12				X				X						X	
EDG DG-13					X				X		X				X
SSPS Train R†	(f)	(g)	(h)	(h)	(h)	(h)					(i)	(i)	(h)	(h)	(h)
SSPS Train S	(f)	(g)	(h)	(h)	(h)	(h)					(i)	(i)	(h)	(h)	(h)
ESFAS Train A†	(k)	X			(l)						(i)	X			
ESFAS Train B		(k)		X										X	
ESFAS Train C					X						(i)				X
ECW Train A											(m)	(m)	(n)	(n)	
ECW Train B											(m)	(m)	(n)	(n)	
ECW Train C											(m)	(m)			(q)
CCW Train A											(m)	(m)			
CCW Train B											(n)	(n)			
CCW Train C											(n)	(n)			
ECH Train A													(q)		
ECH Train B														(q)	
ECH Train C															(q)
EAB HVAC			(s)	(s)	(s)	(s)	(s)	(s)	(s)	(s)	(s)	(s)	(s)	(s)	(s)
Reactor Trip	(r)														

*Letters in parentheses refer to notes on the following page.
**An "X" in a column for a particular main line system or function indicates failure of that function given failure of the associated auxiliary system trai
†For SSPS and ESFAS failures, an "X" inplies failure of the automatic start of the accociated main line function.

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Pressurizer Relief Valves		Low Pressure Safety Injection Pumps			Containment Spray Pumps			Safety Injection Recirculation			Reactor Containment Fan Cooling Units						Containment Isolation	Reactor Coolant Pumps				Residual Heat Removal Pumps		
PCV655A	PCV656A	1A	1B	1C	A	B	C	A	B	C	11A	12A	11B	12B	11C	12C		A	B	C	D	A	B	C
											(b)	(b)	(b)	(b)	(b)	(b)		X**	X	X	X			
(c)	(c)	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	(d) (d) (d)					X	X	X
X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	(d) (d) (d)					X	X	X
(c)	(c)	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	(d) (d) (d)					X	X	X
		(h) (h)	(h) (h)	(h) (h)	(h) (h)	(h) (h)	(h) (h)	(h) (h)	(h) (h)	(h) (h)	(j) (j)	(j) (j)	(j) (j)	(j) (j)	(j) (j)	(j) (j)	(d) (d)							
		X	X	X	X	X	X	X	X	X	(j)	(j)	(j)	(j)	(j)	(j)	(d) (d) (d)							
		(n) (n)	(n) (n)	(q)	(n) (n)	(n) (n)	(q)	(o)	(o)	(o)	X	X	X	X	X	X		(p) (p) (p)	(p) (p) (p)	(p) (p) (p)	(p) (p) (p)	X	X	X
								(o)	(o)	(o)	X	X	X	X	X	X		(p) (p) (p)	(p) (p) (p)	(p) (p) (p)	(p) (p) (p)	X	X	X
		(q)	(q)	(q)	(q)	(q)	(q)	(q)	(q)	(q)														
		(s)	(s)	(s)	(s)	(s)	(s)	(s)	(s)	(s)	(s)	(s)	(s)	(s)	(s)	(s)	(s)	(s)	(s)	(s)	(s)	(s)	(s)	(s)

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a. Offsite grid failure as a result of an initiating event other than loss of offsite power is assumed to guarantee successful turbine trip.
b. The previously operating charging pump will restart when power is available to its Class 1E AC bus.
c. Power is lost to the associated block valve.
d. Failure of the indicated auxiliary system train fails certain containment isolation valves.
e. Loss of the indicated DC bus deenergizes one MSIV solenoid valve resulting in MSIV closure.
f. Failure of both SSPS trains results in loss of turbine trip signals from the SSPS.
g. Failure of both SSPS trains results in failure of the main steam isolation function.
h. Failure of both SSPS trains results in failure of the automatic start function for the indicated equipment.
i. Failure of SSPS or the indicated ESFAS trains has an effect on the centrifugal charging pumps.
j. Failure of both SSPS trains or the indicated ESFAS train results in no automatic start signal and no automatic open signal to the CCW isolation valves for the associated reactor containment fan cooling units.
k. Failure of ESFAS trains A and B results in failure of the main steam line isolation function.
l. Failure of ESFAS train A results in failure of the automatic start function for AFW pump 14 (turbine-driven pump).
m. Loss of all ECW or CCW pumps fails the centrifugal charging pumps due to loss of lubrication and cooling from the CCW systems. Loss of ECW or CCW train C and plant instrument air fails charging pump 1A. Loss of ECW or CCW trains A and B and plant instrumentation air fails charging pump 1B.
n. Loss of ECW trains A and B fails ECH trains A and B. Loss of an ECH train fails the associated safety injection and containment spray pumps in the long term (after the start of recirculation) due to the loss of room cooling.
o. Failure of the indicated ECW or CCW train fails cooling to the associated residual heat removal heat exchanger.
p. Failure of all ECW or CCW trains results in loss of reactor coolant pump motor and thermal barrier cooling. With charging pump failure, a reactor coolant pump seal loss of coolant accident may result.
q. Loss of the indicated ECW or ECH train fails the associated safety injection and containment spray pumps in the long term (after the start of recirculation) due to the loss of room cooling.
r. If reactor trip breakers fail to open, no automatic turbine trip signal from reactor trip will occur.
s. Loss of EAB HVAC is assumed to result in loss of all AC power for the Scoping Study analysis with resulting loss of power to the systems indicated.

CAUTION: PRELIMINARY RESULTS
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TABLE 4-11. AUXILIARY SYSTEMS IMPACT VECTORS

Impact Vector Designation	Definition	Auxiliary Event Tree End States Included
AUX	All required auxiliary systems are available.	AUX, D(GT), NT(GT), NW(GT),DW(GT)
T	Loss of one ECH train.	T, DU(GT), DX(GT)
N	Loss of one CCW train.	N, D, DO(GT), DOT(GT) DOW(GT)
NT	Loss of one CCW train and the same ECH train.	NT, DT, DOU(GT)
NW	Loss of one CCW train and an opposite ECH train.	NW, DW, DOY(GT)
NU	Loss of one CCW train and two ECH trains.	NU, DU, FU, FX, FV, NX, DX
O	Loss of two CCW trains.	O, DO, DPW(GT), H(GT)
F	Loss of two CCW trains and one ECH train, only two trains affected.	F, OT, DOT, OW, DOW
P	Loss of three CCW trains, RCP seal LOCA.	P, PT, FP, FPV, DPU, DPX
I	Loss of one AC power bus after a loss of offsite power.	I, BI, CI, CIOU, C1, C1V
1	Loss of one AC power bus, offsite power is available, and loss of a second ECW train.	1, IO
IU	Loss of one AC power bus and a second ECH train after a loss of offsite power.	IU, IV
IOU	Loss of one AC power bus , a second CCW train, and a second ECH train after a loss of offsite power.	IOU, 1U, IOX, 1V, IOV, 1X
IP	Loss of one AC power bus and all CCW trains after a loss of offsite power, RCP seal LOCA.	IP, 1P, IPU, 1PU
K	Loss of two AC power buses.	K, AK, AL, BK, CK
KV	Loss of two AC power buses and the third ECH train.	KV, AKV
KP	Loss of two AC power buses and the third CCW train.	KP, 2, AKP
M	Loss of all AC power.	M, AM, BM, CM
9	Loss of the EAB ventilation system.	9
A	Loss of one actuation signal.	A, AT, AN, ANT, AQW, AD, ADT, ADOW, ADOY
AU	Loss of one actuation signal and two ECH trains.	AU, AW, AX, ADOV, AEY, ADOU, ADOZ, AEOU, AEX, AEOX, AEOV, AERX, AFU, AERZ, AERV, AEPY, AFV, AFPV, AGV
AO	Loss of one actuation signal and two CCW trains.	AO, AQ, ADO, ADPW, AEPT, AH, AE, AET, AEOT, AEOY, AERT, AERY, AG
ADW	Loss of one actuation signal, one ECW train and an opposite ECH train, two trains affected.	ADW, AEW, AFW
AI	Loss of one actuation signal and one AC power bus, same train affected.	AI, AIO, AIOU, A1, A1V, AIU
AJ	Loss of one actuation signal and one AC power bus, two trains affected.	AJ, AJU, AJX, AJR, A4, AJO, AJOU, A3, A3V, AJRX, A4V
B	Loss of two actuation signals.	B, BD, BDOW, BDR, BDRY, BERT, BDP
C	Loss of three actuation signals, or failure of SSPS.	C, CN, CDW, CDO, CDOW, CDOY, CDOU, CDOZ, CFV, CDP

All auxiliary event tree end states not shown above are included with auxiliary systems impact vector "M" because of the low frequency of occurrence of these end states.

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TABLE 4-12. IMPACT VECTOR DEFINITION

General Transient Tree Top Events	AUX	T	U	N	NT	NW	NU	O	F	P	I	1	IU	IOU	IP	K	KV	KP	M	9	A	AU	AO	ADW	AI	AJ	B	C	Top Events
	IMPACT VECTORS																												
TT	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	2	2	2	2	2	2	TT
OH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	OH
VI	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	VI
AF	0	0	0	0	0	0	0	0	0	0	2	2	2	2	2	1	1	1	1	1	2	2	2	2	2	1	1	1	AF
F1	0	0	0	0	0	0	0	0	0	0	2	2	2	2	2	2	2	2	1	1	2	2	2	2	2	2	2	1	F1
PR	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	1	PR
OI	0	0	0	2	2	2	2	2	2	1	2	2	2	2	1	2	2	1	1	1	2	2	2	2	2	2	2	1	OI
ON	0	0	0	0	0	0	0	0	0	0	2	2	2	2	2	2	2	2	1	1	0	0	0	0	2	2	2	1	ON
OB	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	1	OB
EA	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	EA
EB	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	0	0	0	0	0	1	1	1	EB
EC	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	1	EC
HA	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	HA
HB	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	0	0	0	0	0	1	1	1	HB
HC	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	1	HC
OR	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	OR
SA	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	SA
SB	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	0	0	0	0	0	1	1	1	SB
SC	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	1	SC

Small LOCA Tree Top Events	AUX	T	U	N	NT	NW	NU	O	F	P	I	1	IU	IOU	IP	K	KV	KP	M	9	A	AU	AO	ADW	AI	AJ	B	C	Top Events
	IMPACT VECTORS																												
TT	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	2	2	2	2	2	2	TT
OH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	OH
VI	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	VI
F1	0	0	0	0	0	0	0	0	0	0	2	2	2	2	2	2	2	2	1	1	2	2	2	2	2	2	2	1	F1
OB	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	1	OB
EA	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	EA
EB	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	0	0	0	0	0	1	1	1	EB
EC	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	1	EC
HA	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	HA
HB	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	0	0	0	0	0	1	1	1	HB
HC	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	1	HC
SA	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	SA
SB	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	0	0	0	0	0	1	1	1	SB
SC	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	1	SC

egend:

0 = auxiliary systems impact vector has no effect on the top event.
1 = auxiliary systems impact vector fails the top event.
2 = auxiliary systems impact vector affects the top event failure split fraction.
3 = auxiliary systems impact vector do not map to these top events because of previous failures.

TABLE 4-12 (continued)

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LT-1 Tree Top Events	IMPACT VECTORS																												Top Events
	AUX	T	U	N	NT	NW	NU	O	F	P	I	1	IU	IOU	IP	K	KV	KP	M	9	A	AU	AO	ADW	AI	AJ	B	C	
FC	0	0	0	2	2	2	2	2	2	3	2	2	2	2	3	2	2	3	3	3	2	2	2	2	2	2	2	3	FC
RA	0	1	1	0	1	1	1	0	1	3	1	1	1	1	3	1	1	3	3	3	1	1	1	1	1	1	1	3	RA
RB	0	0	1	0	0	0	1	0	0	3	0	1	1	1	3	1	1	3	3	3	0	1	0	1	0	1	1	3	RB
RC	0	0	1	0	0	0	1	0	0	3	0	0	1	1	3	0	1	3	3	3	0	1	0	0	0	0	0	3	RC
SI	0	0	0	0	0	0	0	0	0	3	0	0	0	0	3	0	0	3	3	3	0	0	0	0	0	0	0	3	SI
OL	0	0	0	0	0	0	0	0	0	3	0	0	0	0	3	0	0	3	3	3	0	0	0	0	0	0	0	3	OL
LA	0	1	1	1	1	1	1	1	1	3	1	1	1	1	3	1	1	3	3	3	1	1	1	1	1	1	1	3	LA
LB	0	0	1	0	0	1	1	1	1	3	0	1	1	1	3	1	1	3	3	3	0	1	1	1	0	1	1	3	LB
LC	0	0	1	0	0	0	1	0	0	3	0	0	1	1	3	0	1	3	3	3	0	1	0	0	0	0	0	3	LC
RX	0	0	1	0	0	0	1	0	0	3	0	0	1	1	3	0	1	3	3	3	0	1	0	0	0	0	0	3	RX
CS	0	2	1	0	2	2	1	0	2	3	2	2	1	1	3	1	1	3	3	3	2	1	2	1	2	1	1	3	CS
CP	0	0	0	0	0	0	0	0	0	3	0	0	0	0	3	0	0	3	3	3	2	2	2	2	2	2	2	3	CP
CI	0	0	0	0	0	0	0	0	0	3	2	2	2	2	3	2	2	3	3	3	2	2	2	2	2	2	2	3	CI

LT-2 Tree Top Events	IMPACT VECTORS																												Top Events
	AUX	T	U	N	NT	NW	NU	O	F	P	I	1	IU	IOU	IP	K	KV	KP	M	9	A	AU	AO	ADW	AI	AJ	B	C	
FC	0	0	0	2	2	2	2	2	2	1	2	2	2	2	1	2	2	1	1	1	2	2	2	2	2	2	2	1	FC
RA	0	1	1	0	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	RA
RB	0	0	1	0	0	0	1	0	0	0	0	1	1	1	0	1	1	1	1	1	0	1	0	1	0	1	1	1	RB
RC	0	0	1	0	0	0	1	0	0	0	0	0	1	1	0	0	1	0	1	1	0	1	0	0	0	0	0	1	RC
CS	0	2	1	0	2	2	1	0	2	2	2	2	1	1	2	1	1	1	1	1	2	1	2	1	2	1	1	1	CS
LA	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	LA
LB	0	0	1	0	0	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	0	1	1	1	0	1	1	1	LB
LC	0	0	1	0	0	0	1	0	0	1	0	0	1	1	1	0	1	1	1	1	0	1	0	0	0	0	0	1	LC
RX	0	0	1	0	0	0	1	0	0	1	0	0	1	1	1	0	1	1	1	1	0	1	0	0	0	0	0	1	RX
CP	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	2	2	2	2	2	1	CP
CI	0	0	0	0	0	0	0	0	0	0	2	2	2	2	2	2	2	2	1	1	2	2	2	2	2	2	2	1	CI

Legend:

0 = auxiliary systems impact vector has no effect on the top event.
1 = auxiliary systems impact vector fails the top event.
2 = auxiliary systems impact vector affects the top event failure split fraction.
3 = auxiliary systems impact vector do not map to these top events because of previous failures.

CAUTION: PRELIMINARY RESULTS-
IMPORTANT UNCERTAINTIES
DESCRIBED IN SECTION 2

TABLE 4-13. GENERAL TRANSIENT EVENT TREE SUCCESS CRITERIA

Sheet 1 of 4

Top Event	Description	Success Criteria
TT	Turbine Trip or Main Steam Isolation Trip	Automatic turbine trip (four valves shut to block steam flow) or automatic trip of all four MSIVs on SI due to rapid cooldown.
OH	Operator controls High Head Injection	Because the reactor coolant system refills and repressurizes quickly one high head injection starts and OH is assumed failed for the Scoping Study.
VI	Vessel Integrity	Should PTS conditions occur (rapid cooldown and repressurization) there is a small chance of crack initiation and propagation. In such a case, a loss of coolant accident beyond the capability of the ECCS would lead to core melt. NOTE: One condition under which PTS occurs has not been included in the Scoping Study model--bleed and feed with the reactor coolant pumps secured; our judgment is that the chance of vessel failure will be negligible compared to other contributors to all plant damage states.
AF	Two or More Trains of Auxiliary Feedwater and Steam Relief Relief	Automatic operation of two, three, or four AFW pumptrains and their associated ARVs.
F1	One Train of AFW and Steam Relief	Automatic operation of one AFW pump train and its associated ARV given failure of auxiliary feedwater.
PR	Pressurizer Power-Operated Relief Valve Opens and Closes	Automatic opening of either PORV and automatic closure of both PORVs. Failure to open a relief path on demand is assumed to lead to a small LOCA, and failure to reclose such a relief path is a small LOCA.
OI	RCS Inventory Control	This is essentially a LOCA path. The LOCAs considered occur primarily as a result of support system and charging system failures. Success requi s that none of

CAUTION: PRELIMINARY RESULTS-
IMPORTANT UNCERTAINTIES
DESCRIBED IN SECTION 2

TABLE 4-13 (continued)

Top Event	Description	Success Criteria
		the following LOCA paths are established. 1. The reactor coolant pump seal LOCA, which occurs some time following loss of seal injection and loss of component cooling water to the reactor coolant pump thermal barrier. 2. Two distinct LOCA paths can occur via letdown system. If charging flow is lost and the letdown system does not isolate automatically, a flow path to either the containment or outside containment to the VCT will exist. Motor-operated valves in the letdown system receive isolation signals on low pressurizer level. If none of the valves shut, a flow path exists outside containment to the VCT. If either letdown system isolation valve closes, there will be no LOCA. If the two isolation valves remain open and either one of the containment isolation valves shut, a 600 psi relief valve will open causing a LOCA inside containment. 3. The last of these LOCA paths is the seal return line that goes outside containment. This line should isolate on an SI signal. If any of these LOCA paths is established, event OI fails. The two paths outside containment, the VCT or the seal return lines, also provide small paths for containment bypass in case of a core melt. LOCAs via these paths spill water outside containment so there is no possibility of containment sump recirculation cooling in the long-term. For the Scoping Study, we conservatively assume that if event OI fails a containment bypass path exists. If OI fails and high head injection succeeds, the scenario branches to the LT1 tree and requires

CAUTION: PRELIMINARY RESULTS-
IMPORTANT UNCERTAINTIES
DESCRIBED IN SECTION 2

TABLE 4-13 (continued)

Top Event	Description	Success Criteria
		successful recirculation cooling. While this appears nonconservative for the two LOCAs outside containment, the maximum combined flow rate via those LOCAs is only 100 gpm. At this flow rate, with high pressure injection working, several days are required before the RWST inventory is expended. In that time, many actions outside the scope of the present analysis could be carried out to stabilize the plant. Therefore, if anything, branching to the LT1 tree is slightly conservative.
ON	Operator Provides Long Term Cooling	This event allows for the very slight chance that in a completely stabilized condition the operators may intercede improperly or neglect simple long-term actions for which a great many redundant cues are available and induce failure of cooling in the long-term.
OB	Operator Initiates Bleed and Feed	The operator must recognize the loss of secondary cooling conditions, decide to carry out bleed and feed cooling, and actually follow the procedures for bleed and feed cooling. The procedures described in the ERGs have been used in evaluating operator response. Basically, the operator must decide to carry out bleed and feed, push the SI button to start high head injection, and turn the switch to open each of two pressurizer PORVs all within approximately 20 minutes following the loss of secondary cooling. This allows for the time required to boil dry the steam generators before RCS pressure would increase too high for successful high head injection. Success of this event also requires that the two PORVs physically open on demand.
EA	ECCS Common A	Train A of ECCS includes high head injection pump A, low head injection pump A, and containment spray pump A. All three pumps share a common header such that common valves in that header, maintenance on

CAUTION: PRELIMINARY RESULTS
IMPORTANT UNCERTAINTIES
DESCRIBED IN SECTION 2

TABLE 4-13 (continued)

Sheet 4 of 4

Top Event	Description	Success Criteria
EA		any of the three pumps, or ventilation to the common room can fail all three pumps. Failure of any of that common equipment leads to failure of Top Event EA.
EB	ECCS Common B	All common ECCS train B equipment must operate as above. Additionally, any common events that can fail two trains of ECCS (e.g., common cause failure of one supply valve in each train) are included in the quantification of this top event.
EC	ECCS Common C	All common ECCS train C equipment must operate as above. Additionally, any common events that can fail all three trains of ECCS (e.g., loss of the RWST) are included in the quantification of this top event.
HA	High Head Safety Injection Pump A	Must start and successfully operate for 24 hours.
HB	High Head Safety Injection Pump B	Same as Top Event HA; however, for train B, any common causes not included in EB that can fail, two trains of high head injection are quantified in this top event.
HC	High Head Safety Injection Pump C	Same as Top Event HA; however, for train C, any common cause events not included in Top Event EC that can fail three trains of high head injection are quantified in this top event.
OR	Closed Loop RHR Cooling	For the Scoping Study, OR is assumed failed since the RHR pumps are not qualified for high temperature or high humidity environment.
SA	Containment Spray A	Containment spray pump train A must start and run for 24 hours.
SB	Containment Spray B	Same as Top Event SA; however, for train B, any common cause events not included in HB that can fail two trains of containment spray are quantified.
SC	Containment Spray C	Same as Top Event SA; however, for train C, any common cause events not modeled in EC that can fail three trains of containment spray are quantified.

TABLE 4-14. CODING FOR TRANSFER STATES BETWEEN EARLY AND LONG-TERM (LT-1) RESPONSE EVENT TREES

Equipment Status	LT-1 Entry State											
	OI Succeeds						OI Fails					
	A	B	C	D	E	F	G	H	I	J	K	L
Number of High Head Safety Injection Failures (Top Events HA, HB, HC)	0	1	1	2	2	2	0	1	1	2	2	2
Due to ECCS Common Failures (Top Events EA, EB, EC)	-	-	Yes	-	1	2	-	-	Yes	-	1	2
Loss of RCS Inventory Control (Top Event OI)	No	No	No	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes

NOTE: On branch LT-1, at least one high head safety injection pump works; water is in sump.

CAUTION: PRELIMINARY RESULTS-
IMPORTANT UNCERTAINTIES
DESCRIBED IN SECTION 2

TABLE 4-15. CODING FOR TRANSFER STATES BETWEEN EARLY AND LONG TERM (LT2) CORE MELT RESPONSE EVENT TREES

Equipment Status	LT-2 Entry State																			
	OI Succeeds										OI Fails									
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
Number of Containment Spray Failures (Top Events SA, SB, SC)	0	1	1	2	2	2	3	3	3	3	0	1	1	2	2	2	3	3	3	3
Due to ECCS Common Failures (Top Events EA ,EB, EC)	-	-	Yes	-	1	2	-	1	2	3	-	-	1	-	1	2	-	1	2	3
Loss of RCS Inventory Control (Top Event OI)	No	No	No	No	No	No	No	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

CAUTION: PRELIMINARY RESULTS-
IMPORTANT UNCERTAINTIES
DESCRIBED IN SECTION 2

TABLE 4-16. LT1 LONG-TERM EVENT TREE SUCCESS CRITERIA

Sheet 1 of 3

Top Event	Description	Success Criteria
FC	Fan Coolers	Fan coolers are the primary source of containment cooling. Success requires that two out of six fan coolers operate and be supplied with cooling water.
RA	Recirculation Common A	Each ECCS train can operate in a recirculation mode moving water from the containment sump to the reactor coolant system via the high head safety injection pump or the low head safety injection pump and through the containment spray system via the containment spray pump. Common sumps, suction piping, and valves supply each of the three ECCS pumps in train A. Any failures in this common equipment lead to failure of Top Event RA.
RB	Recirculation Common B	Same as Top Event RA for train B; also, any common causes that can fail two trains of ECCS in the recirculation phase (e.g., common cause valve failures) are included in this top event.
RC	Recirculation Commmon C	Same as Top Event RA for train C; also, any common cause events that can fail all three trains of ECCS in the recirculation model (such as failure of the RWST to be isolated) are included in this top event.
SI	High Head Safety Injection	If one out of three trains of high head safety injection is operating, water will be supplied to the reactor coolant system at high pressure. This keeps the core covered and prevents injection via the low head safety injection pump and this precludes cooling by the RHR heat exchanger. This event is really just a switch based on the entry state to the LT1 event tree which depends on high head safety injection pumps performance in Top Events HA, HB, and HC.

CAUTION: PRELIMINARY RESULTS-
IMPORTANT UNCERTAINTIES
DESCRIBED IN SECTION 2

TABLE 4-16 (continued)

Sheet 2 of 3

Top Event	Description	Success Criteria
OL	RCS Pressure Below Low Head Safety Injection Design	When Top Event SI has failed, RCS pressure should below low head safety injection design before the RWST runs empty unless the reactor coolant pumps are not running. In that case, high temperatures in the reactor vessel head region may not be adequately cooled and a steam bubble may form in that region, maintaining RCS pressure high. Therefore, Top Event OL succeeds when nonvital power is available to run reactor coolant pumps, and Top Event OL fails in auxiliary states when nonvital power is failed.
LA	Low Head Safety Injection A	Low head safety injection pump train A must start and operate for 24 hours.
LB	Low Head Safety Injection B	Same as Top Event LA for train B; also includes common cause events not modeled in Top Event RB that fail two trains of low head safety injection.
LC	Low Head Safety Injection C	Same as Top Event LA for train C; also includes common cause events not modeled in event RC that fail all three trains of low head safety injection.
RX	RHR Heat Exchanger	Success requires component cooling water to be supplied to one RHR heat exchanger that has low head recirculation flow; i.e., any one of Top Events LA, LB, or LC has succeeded.
CS	Containment Spray	Two containment spray pumps are required to generate adequate spray dispersal in the containment spray system. Operability of the containment spray pumps has been established in the early tree. Therefore, Top Event CS is a switch conditional on entry state and Top Events RA, RB, and RC.

CAUTION: PRELIMINARY RESULTS-
IMPORTANT UNCERTAINTIES
DESCRIBED IN SECTION 2

TABLE 4-16 (continued)

Sheet 3 of 3

Top Event	Description	Success Criteria
CP	Gross Containment Isolation (greater than 3 inches)	The large containment purge lines must be isolated or gross failure of containment isolation occurs. Failure of this event r quires that the purge line valves be open at the time of the initiating event and fail to close following that event. Closure is automatic on SI signal, but since these valves are MOVs, success depends on the state of electric power.
CI	Containment Isolation (less than 3 inches)	If any small line that connects the containment to the outside atmosphere fails to isolate following safety injection signal, Top Event CI fails. Among the most likely failure paths are the letdown lines to the VCT and the reactor coolant pump seal return lines.

CAUTION: PRELIMINARY RESULTS-
IMPORTANT UNCERTAINTIES
DESCRIBED IN SECTION 2

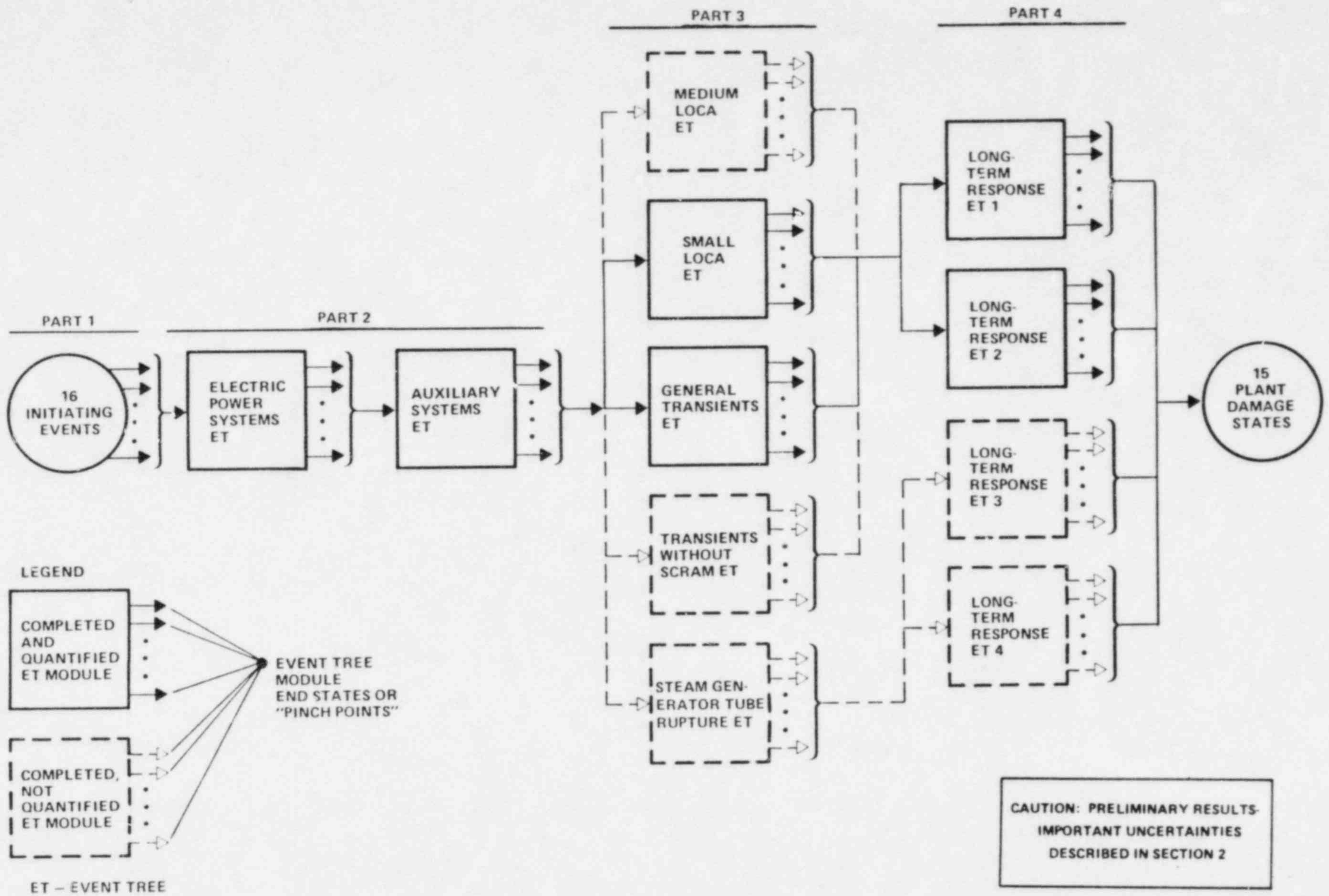


FIGURE 4-1. STPEGS PLANT EVENT SEQUENCE MODEL

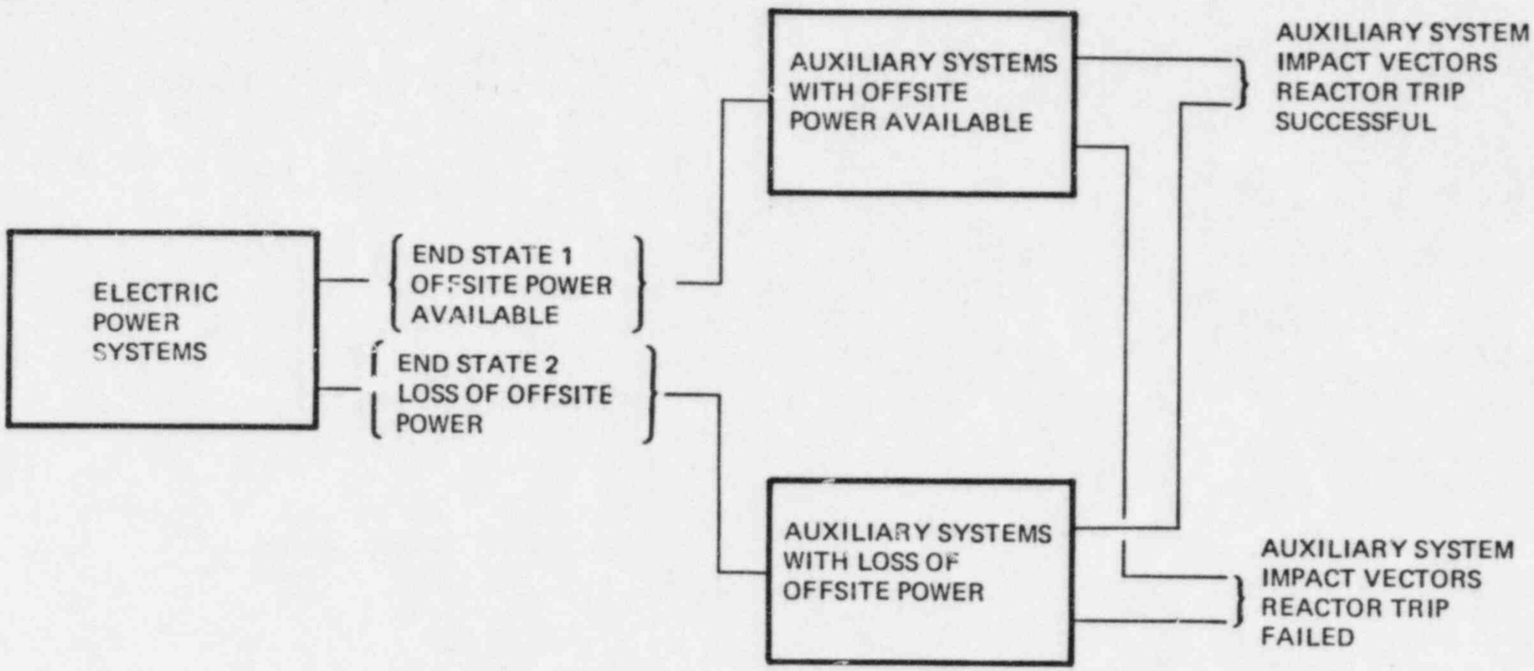


FIGURE 4-2. AUXILIARY SYSTEM EVENT TREE RELATIONSHIPS

LEGEND:
GF GUARANTEED FAILURE
GS GUARANTEED SUCCESS
NN NOT NECESSARY

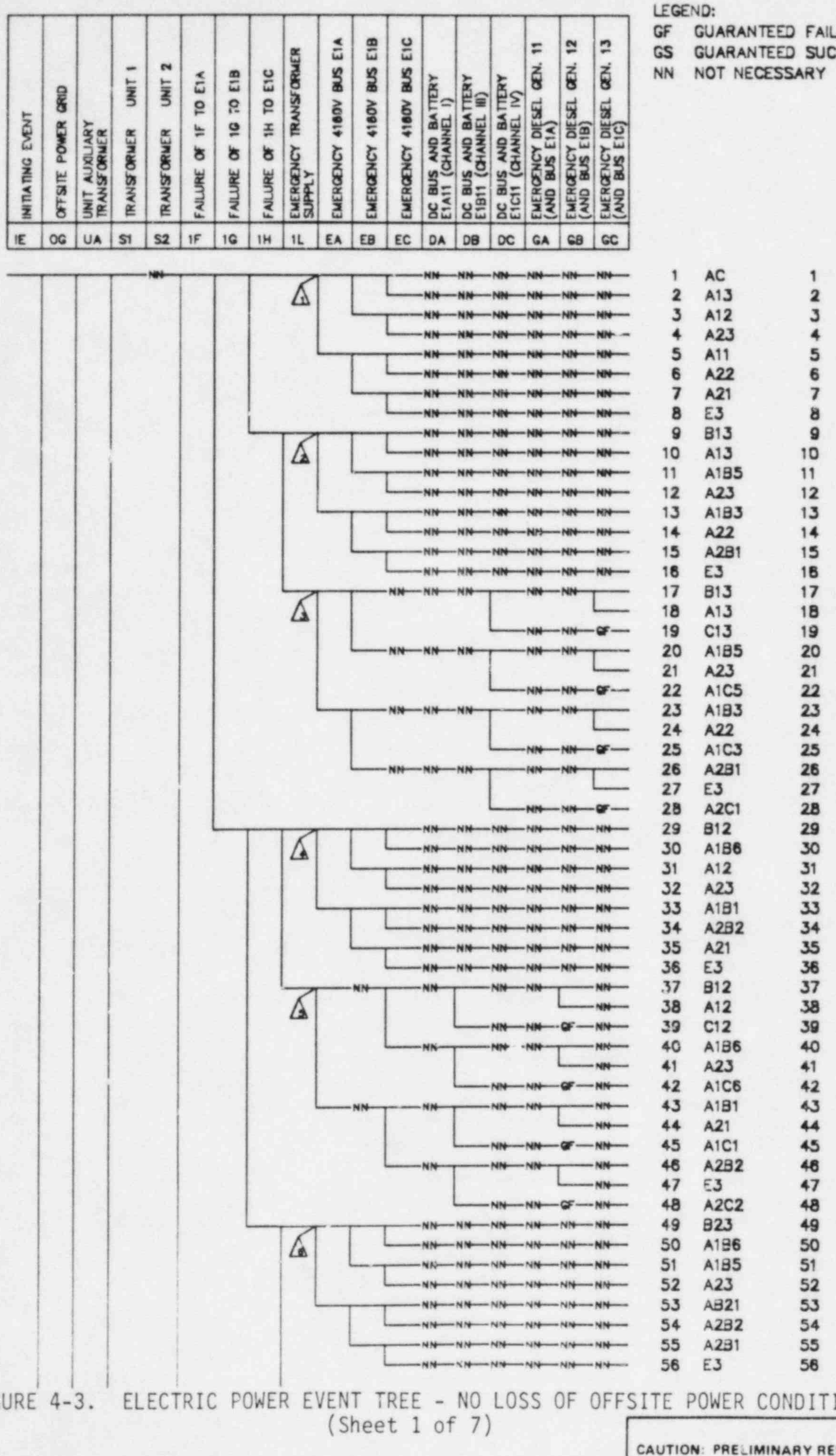
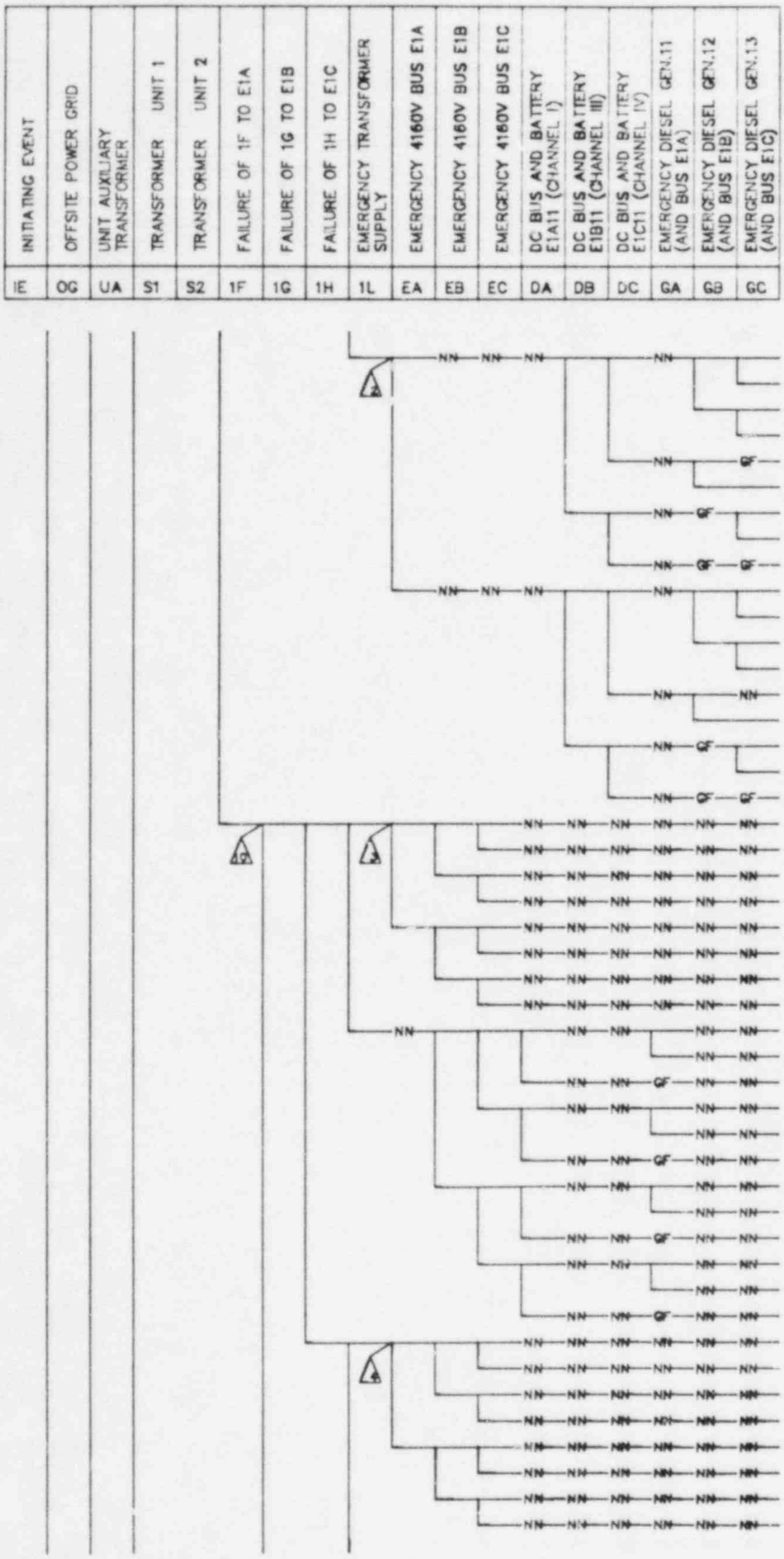


FIGURE 4-3. ELECTRIC POWER EVENT TREE - NO LOSS OF OFFSITE POWER CONDITION
(Sheet 1 of 7)

CAUTION: PRELIMINARY RESULTS-
IMPORTANT UNCERTAINTIES
DESCRIBED IN SECTION 2

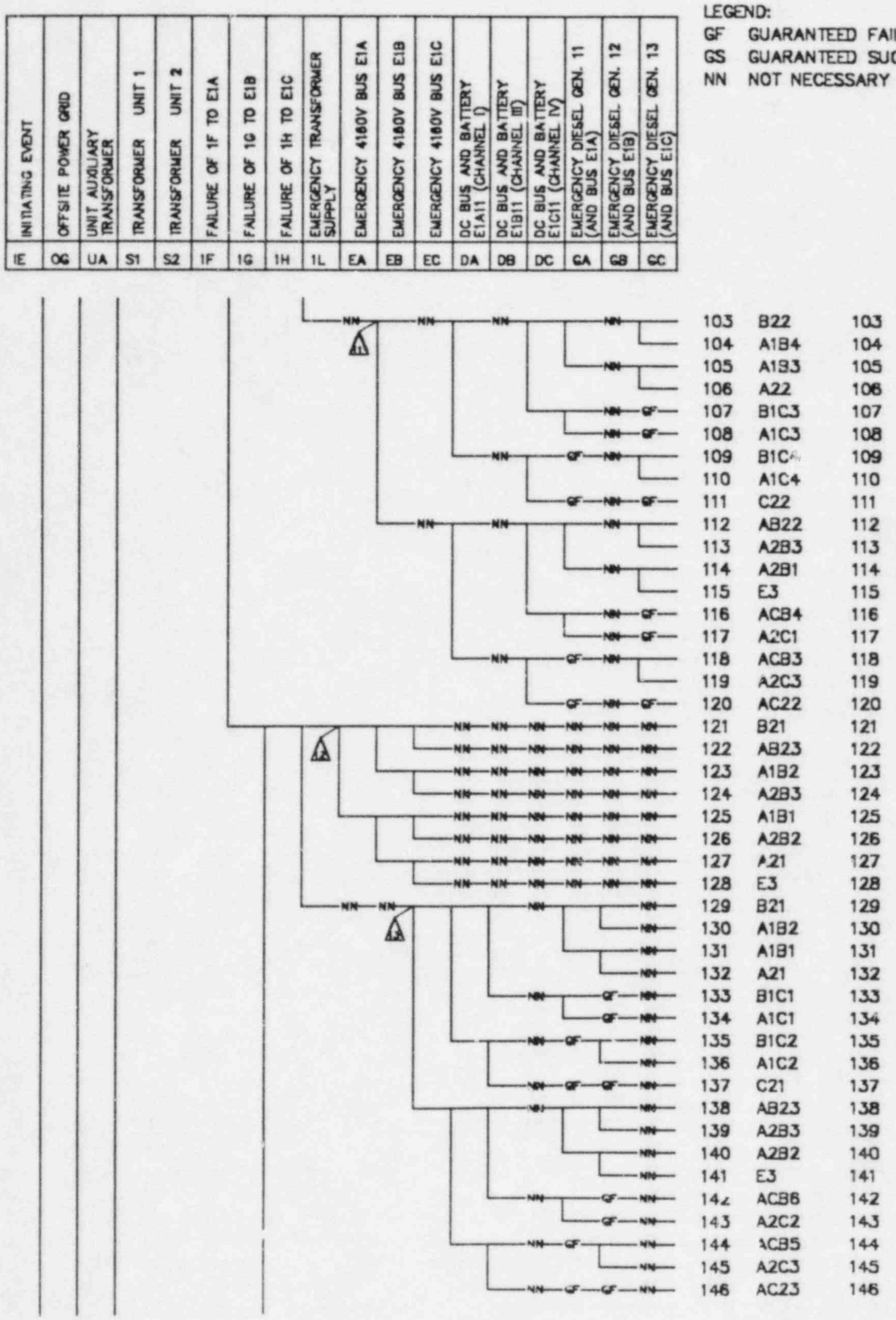
CAUTION: PRELIMINARY RESULTS-
IMPORTANT UNCERTAINTIES
DESCRIBED IN SECTION 2



LEGEND:
GF GUARANTEED FAILURE
GS GUARANTEED SUCCESS
NN NOT NECESSARY

SEQUENCE	END STATE	FULL TREE SEQUENCE
57	B23	57
58	A1B6	58
59	A1B5	59
60	A23	60
61	B1C5	61
62	A1C5	62
63	B1C6	63
64	A1C6	64
65	C23	65
66	AB21	66
67	A2B2	67
68	A2B1	68
69	E3	69
70	ACB2	70
71	A2C1	71
72	ACB1	72
73	A2C2	73
74	AC21	74
75	B11	75
76	A1B4	76
77	A1B2	77
78	A2B3	78
79	A11	79
80	A22	80
81	A21	81
82	E3	82
83	B11	83
84	A11	84
85	C11	85
86	A1B4	86
87	A22	87
88	A1C4	88
89	A1B2	89
90	A21	90
91	A1C2	91
92	A2B3	92
93	E3	93
94	A2C3	94
95	B22	95
96	A1B4	96
97	AB22	97
98	A2B3	98
99	A1B3	99
100	A22	100
101	A2B1	101
102	E3	102

FIGURE 4-3 (Sheet 2 of 7)



LEGEND:
GF GUARANTEED FAILURE
GS GUARANTEED SUCCESS
NN NOT NECESSARY

CAUTION: PRELIMINARY RESULTS-
IMPORTANT UNCERTAINTIES
DESCRIBED IN SECTION 2

FIGURE 4-3 (Sheet 3 of 7)

LEGEND:
GF GUARANTEED FAILURE
GS GUARANTEED SUCCESS
NN NOT NECESSARY

CAUTION: PRELIMINARY RESULTS-IMPORTANT UNCERTAINTIES DESCRIBED IN SECTION 2

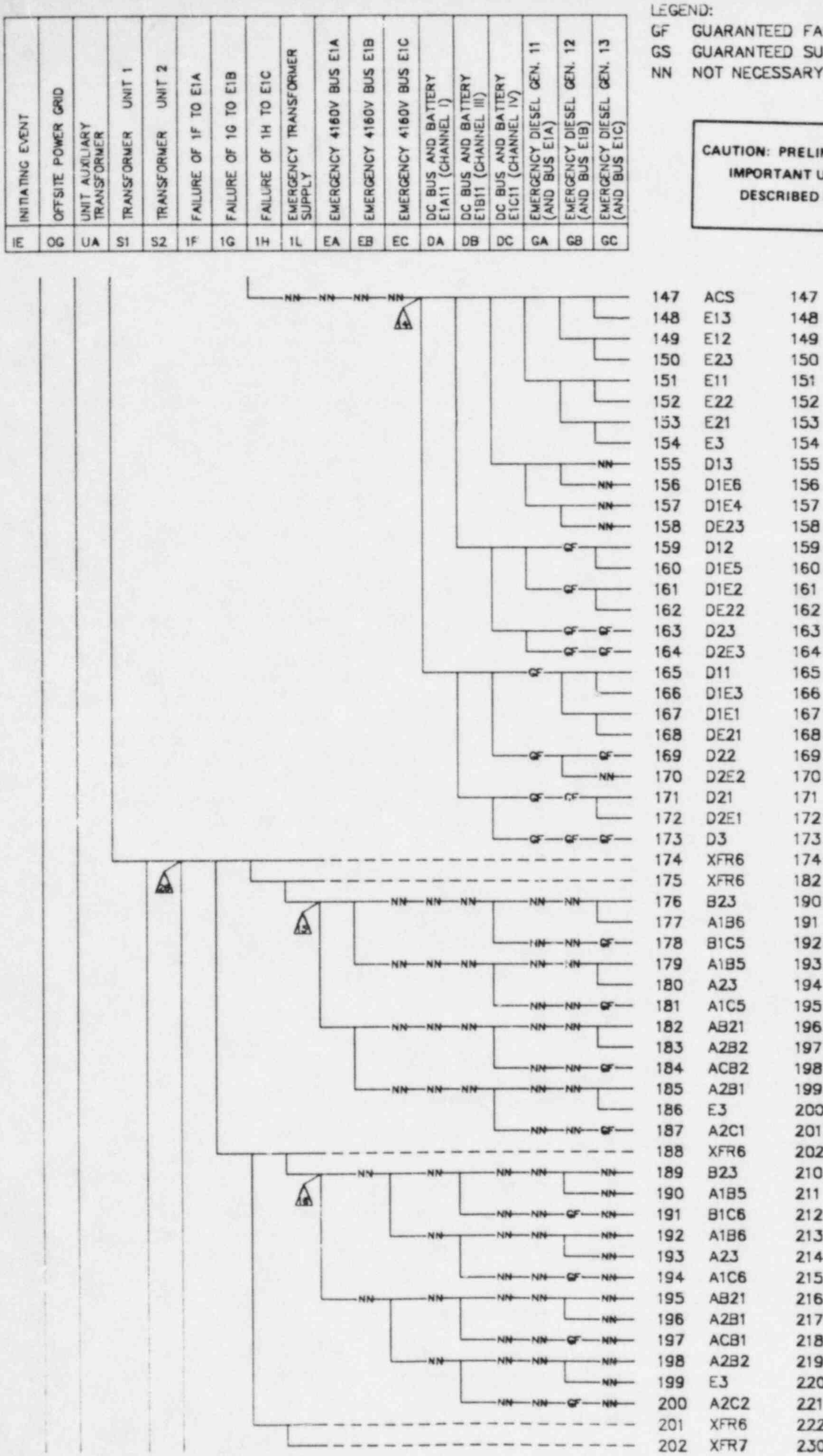


FIGURE 4-3 (Sheet 4 of 7)

LEGEND:
GF GUARANTEED FAILURE
GS GUARANTEED SUCCESS
NN NOT NECESSARY

CAUTION: PRELIMINARY RESULTS
IMPORTANT UNCERTAINTIES
DESCRIBED IN SECTION 2

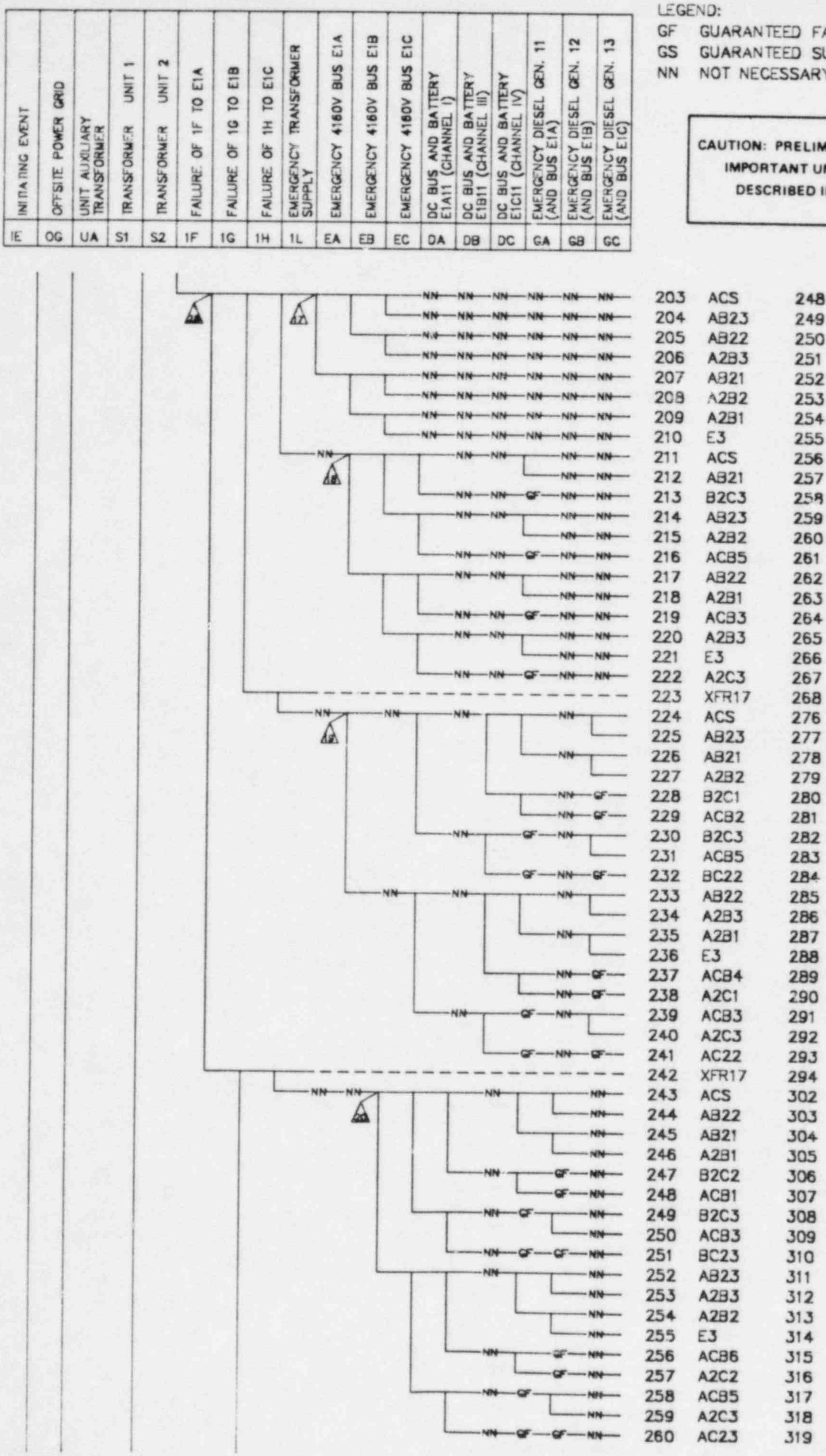
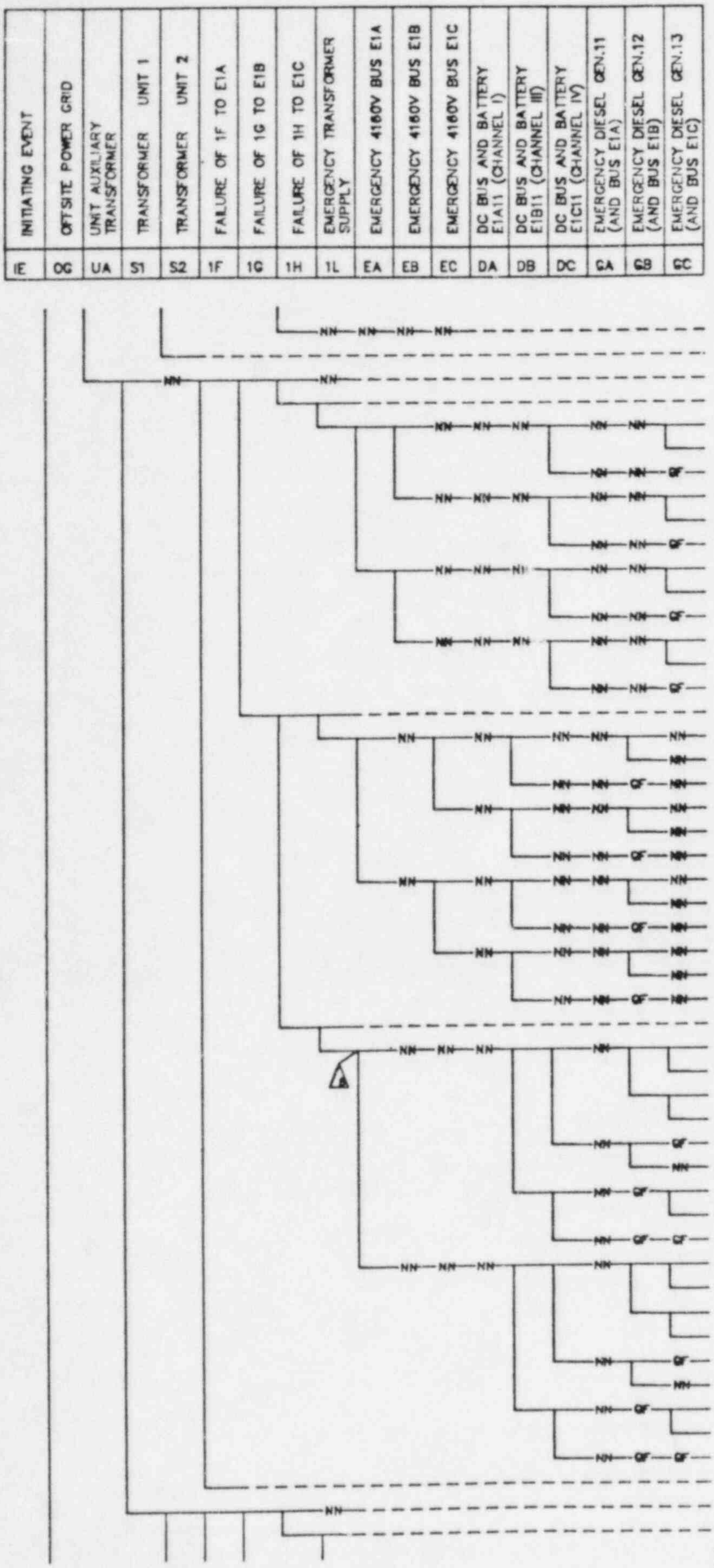


FIGURE 4-3 (Sheet 5 of 7)



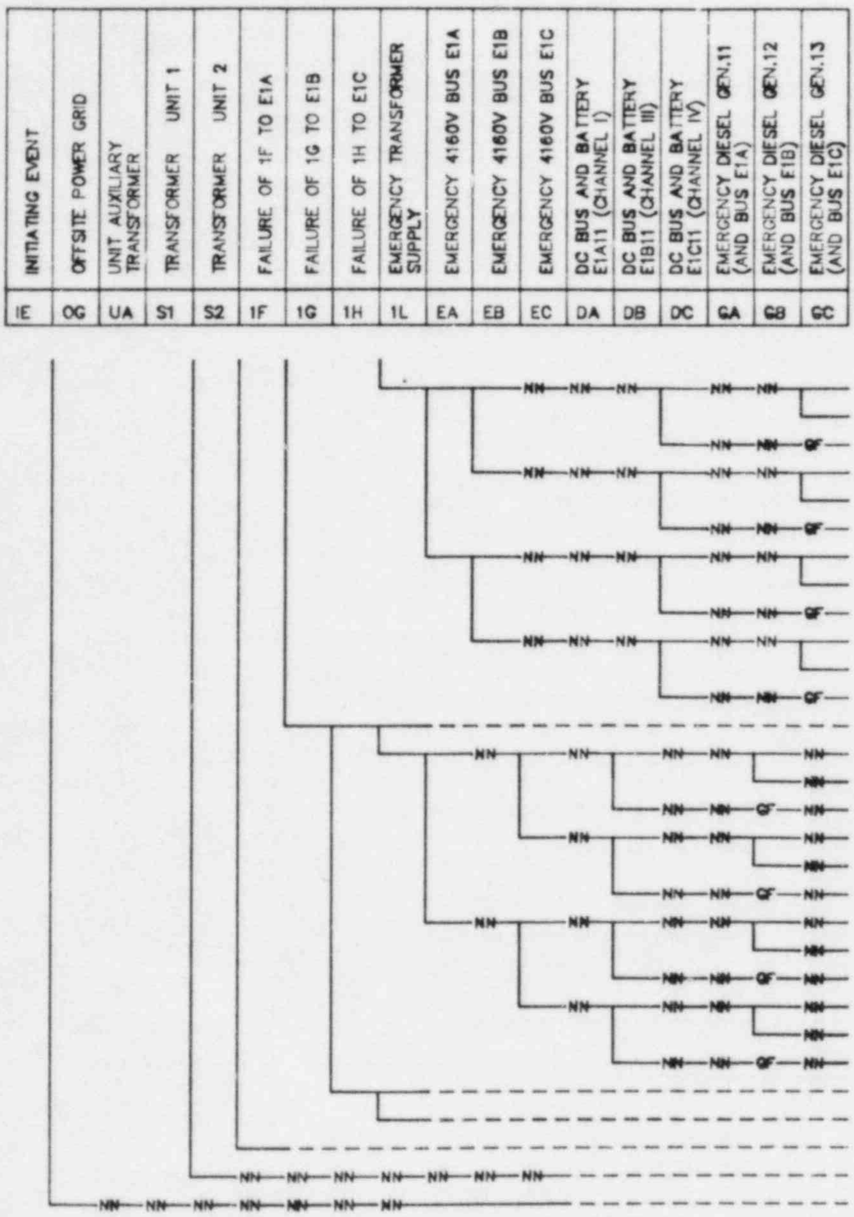
LEGEND:
GF GUARANTEED FAILURE
GS GUARANTEED SUCCESS
NN NOT NECESSARY

SEQUENCE	END STATE	FULL TREE SEQUENCE
261	XFR6	320
262	XFR9	347
263	XFR3	520
264	XFR4	528
265	B22	536
266	A1B4	537
267	B1C3	538
268	AB22	539
269	A2B3	540
270	ACB4	541
271	A1B3	542
272	A22	543
273	A1C3	544
274	A2B1	545
275	E3	546
276	A2C1	547
277	XFR5	548
278	B21	556
279	A1B2	557
280	B1C1	558
281	AB23	559
282	A2B3	560
283	ACB6	561
284	A1B1	562
285	A21	563
286	A1C1	564
287	A2B2	565
288	E3	566
289	A2C2	567
290	XFR7	568
291	ACS	576
292	AB23	577
293	AB22	578
294	A2B3	579
295	B2C1	580
296	ACB4	581
297	B2C2	582
298	ACB6	583
299	BC21	584
300	AB21	585
301	A2B2	586
302	A2B1	587
303	E3	588
304	ACB2	589
305	A2C1	590
306	ACB1	591
307	A2C2	592
308	AC21	593
309	XFR10	594
310	XFR7	693
311	XFR7	701

CAUTION: PRELIMINARY RESULTS-
IMPORTANT UNCERTAINTIES
DESCRIBED IN SECTION 2

FIGURE 4-3 (Sheet 6 of 7)

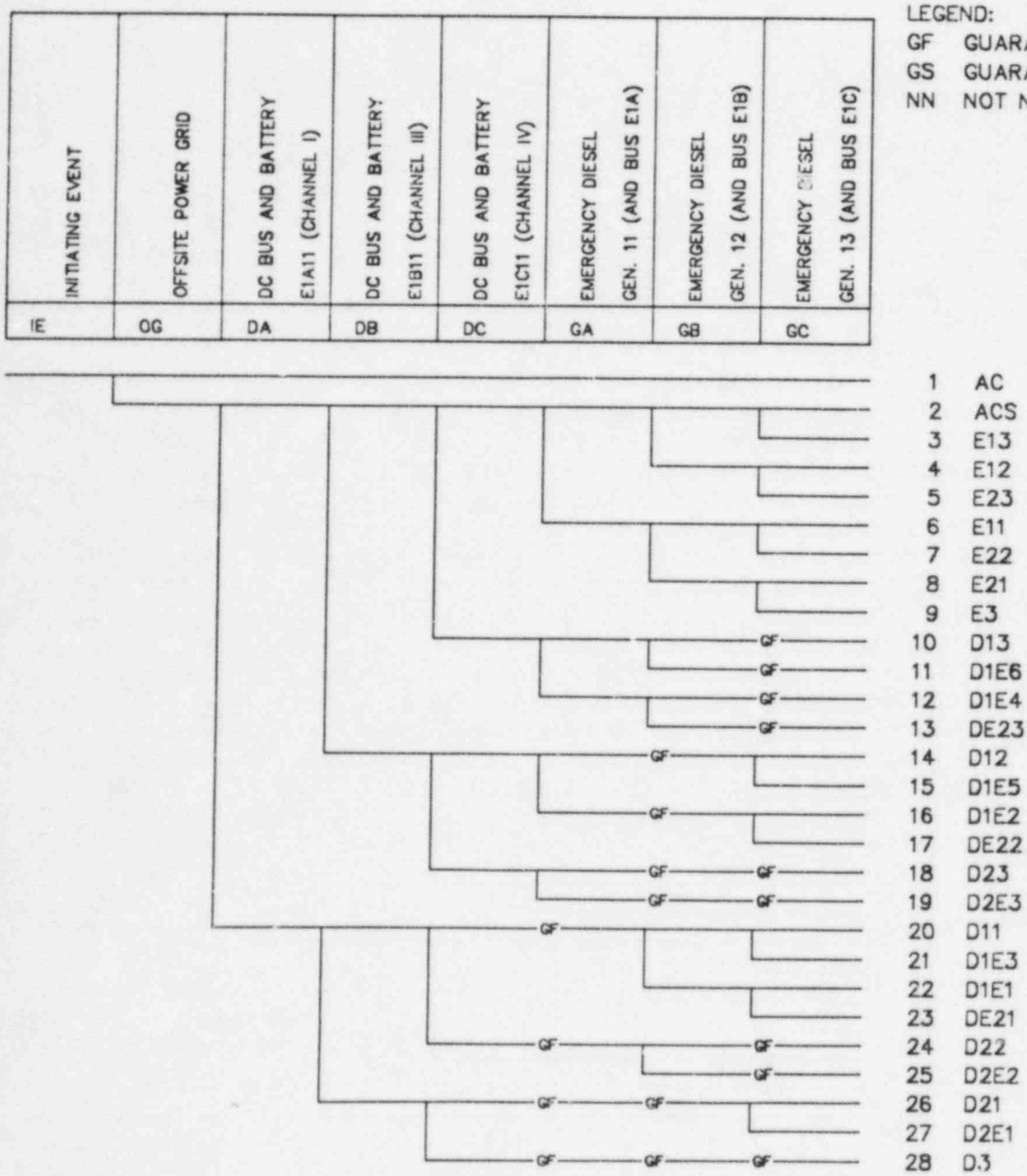
LEGEND:
GF GUARANTEED FAILURE
GS GUARANTEED SUCCESS
NN NOT NECESSARY



SEQUENCE	END STATE	FULL TREE SEQUENCE
312	ACS	709
313	AB23	710
314	B2C1	711
315	AB22	712
316	A2B3	713
317	ACB4	714
318	AB21	715
319	A2B2	716
320	ACB2	717
321	A2B1	718
322	E3	719
323	A2C1	720
324	XFR7	721
325	ACS	729
326	AB22	730
327	B2C2	731
328	AB23	732
329	A2B3	733
330	ACB6	734
331	AB21	735
332	A2B1	736
333	ACB1	737
334	A2B2	738
335	E3	739
336	A2C2	740
337	XFR7	741
338	XFR8	749
339	XFR11	767
340	XFR6	866
341	XFR6	893

CAUTION: PRELIMINARY RESULTS-
IMPORTANT UNCERTAINTIES
DESCRIBED IN SECTION 2

FIGURE 4-3 (Sheet 7 of 7)

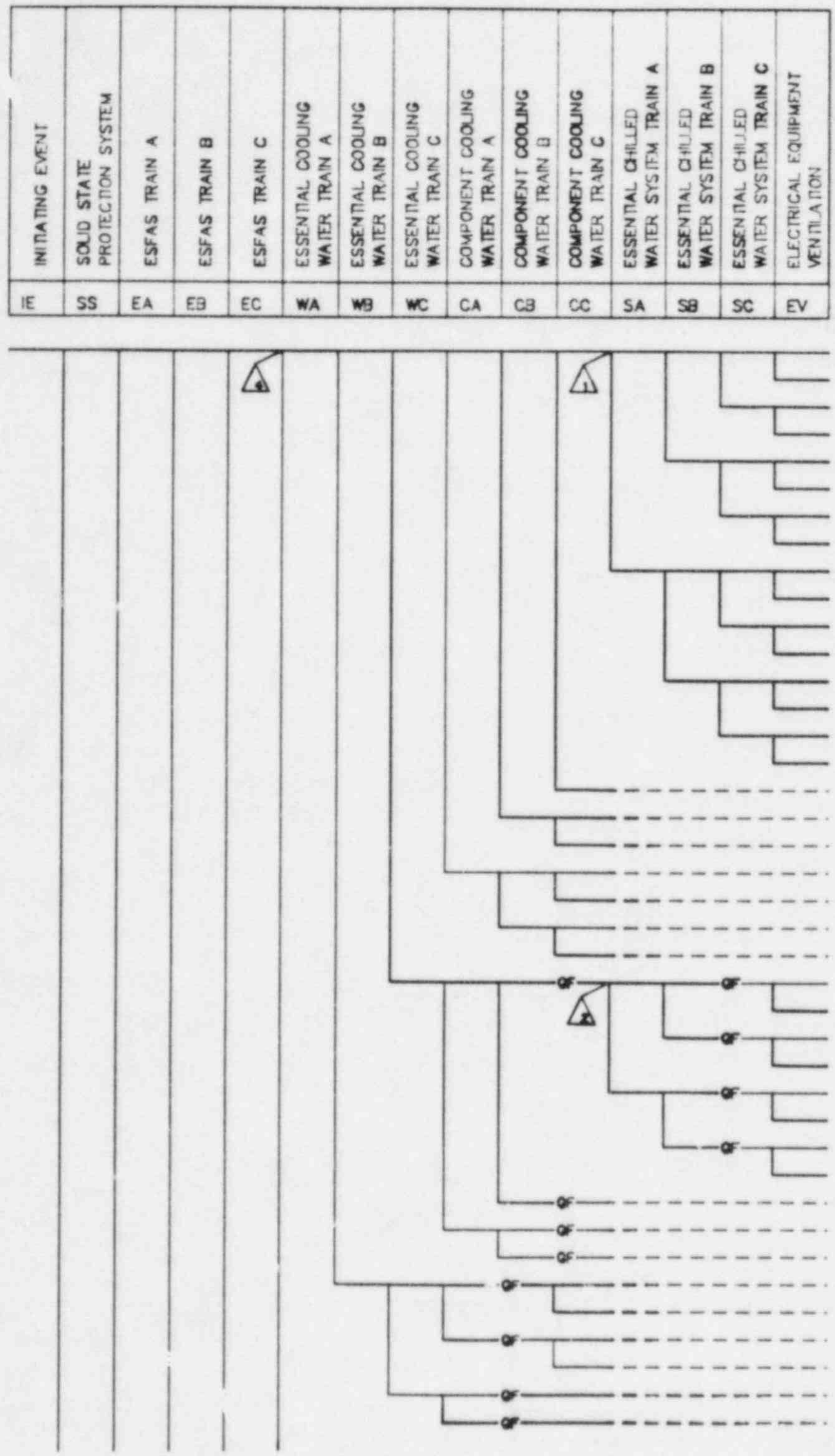


LEGEND:
GF GUARANTEED FAILURE
GS GUARANTEED SUCCESS
NN NOT NECESSARY

CAUTION: PRELIMINARY RESULTS-
IMPORTANT UNCERTAINTIES
DESCRIBED IN SECTION 2

FIGURE 4-4. SIMPLIFIED ELECTRIC POWER EVENT TREE FOR LOSS OF OFFSITE POWER

LEGEND:
GF GUARANTEED FAILURE



SEQUENCE	TRANSFER	FULL TREE SEQUENCE
1		1
2		2
3		3
4		4
5		5
6		6
7		7
8		8
9		9
10		10
11		11
12		12
13		13
14		14
15		15
16		16
17	XFR1	17
18	XFR1	33
19	XFR1	49
20	XFR1	65
21	XFR1	81
22	XFR1	97
23	XFR1	113
24		129
25		130
26		131
27		132
28		133
29		134
30		135
31		136
32	XFR2	137
33	XFR2	145
34	XFR2	153
35	XFR1	161
36	XFR1	177
37	XFR1	193
38	XFR1	209
39	XFR2	225
40	XFR2	233

FIGURE 4-5. AUXILIARY SYSTEMS EVENT TREE FOR OFFSITE POWER AVAILABLE
(Sheet 1 of 6)

CAUTION: PRELIMINARY RESULTS-
IMPORTANT UNCERTAINTIES
DESCRIBED IN SECTION 2

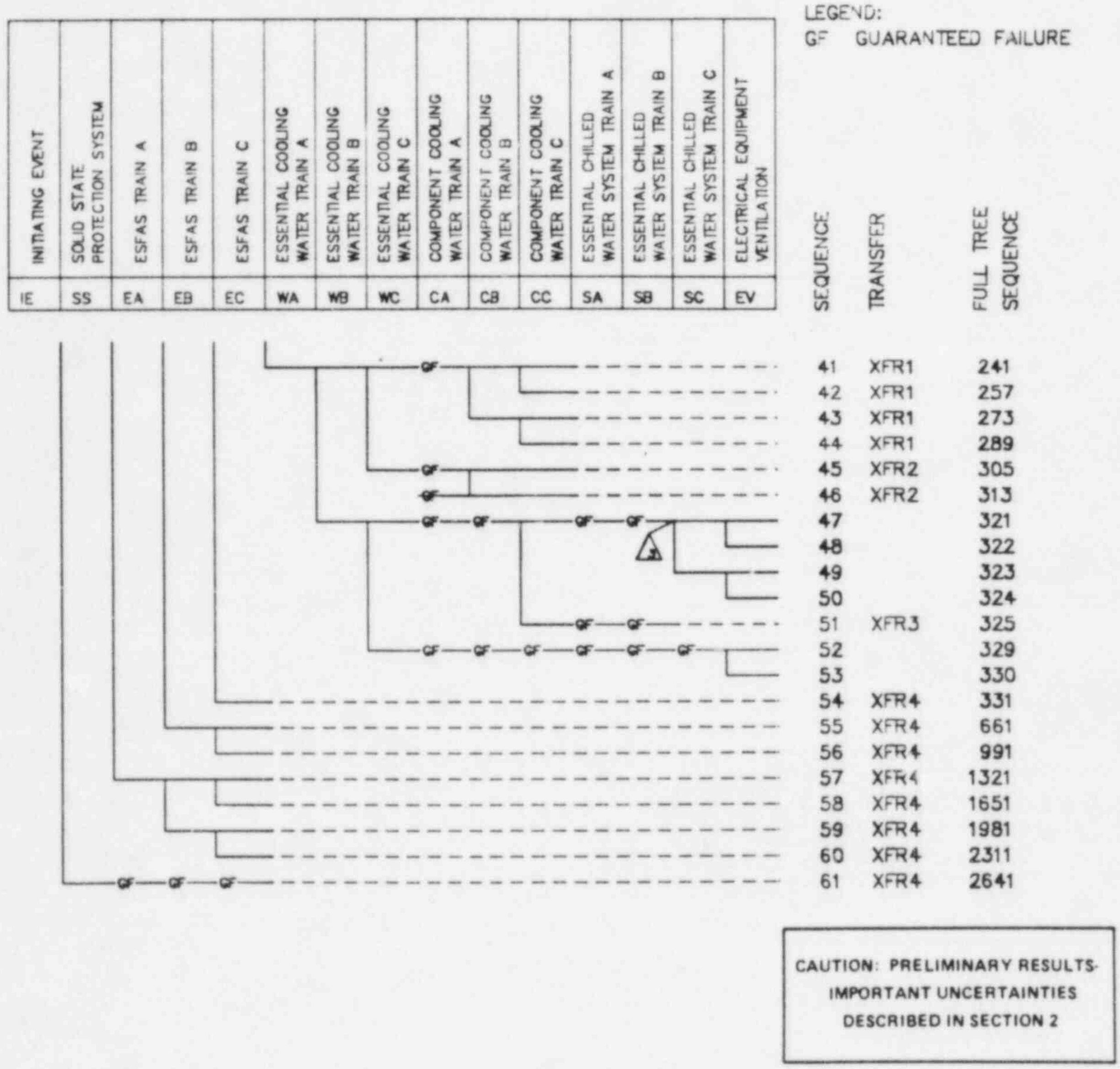


FIGURE 4-5 (Sheet 2 of 6)

SEQ. NO.	END STATE	SEQ. NO.	END STATE	SEQ. NO.	END STATE	SEQ. NO.	END STATE	SEQ. NO.	END STATE	SEQ. NO.	END STATE	SEQ. NO.	END STATE	SEQ. NO.	END STATE	SEQ. NO.	END STATE
1	AUX	331	A	661	A	991	B	1321	A	1651	B	1981	B	2311	C	2641	C
2	9	332	9	662	9	992	9	1322	9	1652	9	1982	9	2312	9	2642	9
3	T	333	AT	663	AW	993	BT	1323	AW	1653	BT	1983	BW	2313	CT	2643	CT
4	9	334	9	664	9	994	9	1324	9	1654	9	1984	9	2314	9	2644	9
5	T	335	AW	665	AT	995	BT	1325	AW	1655	BW	1985	BT	2315	CT	2645	CT
6	9	336	9	666	9	996	9	1326	9	1656	9	1986	9	2316	9	2646	9
7	U	337	AU	667	AU	997	BU	1327	AX	1657	BX	1987	BX	2317	CU	2647	CU
8	9	338	9	668	9	998	9	1328	9	1658	9	1988	9	2318	9	2648	9
9	T	339	AW	669	AW	999	BW	1329	AT	1659	BT	1989	BT	2319	CT	2649	CT
10	9	340	9	670	9	1000	9	1330	9	1660	9	1990	9	2320	9	2650	9
11	U	341	AU	671	AX	1001	BX	1331	AU	1661	BU	1991	BX	2321	CU	2651	CU
12	9	342	9	672	9	1002	9	1332	9	1662	9	1992	9	2322	9	2652	9
13	U	343	AX	673	AU	1003	BX	1333	AU	1663	BX	1993	BU	2323	CU	2653	CU
14	9	344	9	674	9	1004	9	1334	9	1664	9	1994	9	2324	9	2654	9
15	V	345	AV	675	AV	1005	BV	1335	AV	1665	BV	1995	BV	2325	CV	2655	CV
16	9	346	9	676	9	1006	9	1336	9	1666	9	1996	9	2326	9	2656	9
17	N	347	AN	677	AQ	1007	BN	1337	AQ	1667	BN	1997	BQ	2327	CN	2657	CN
18	9	348	9	678	9	1008	9	1338	9	1668	9	1998	9	2328	9	2658	9
19	NT	349	ANT	679	AQW	1009	BNT	1339	AQW	1669	BNT	1999	BQW	2329	CNT	2659	CNT
20	9	350	9	680	9	1010	9	1340	9	1670	9	2000	9	2330	9	2660	9
21	NW	351	ANW	681	AQT	1011	BNW	1341	AQY	1671	BNY	2001	BQT	2331	CNW	2661	CNW
22	9	352	9	682	9	1012	9	1342	9	1672	9	2002	9	2332	9	2662	9
23	NU	353	ANU	683	AQU	1013	BNU	1343	AQZ	1673	BNX	2003	BQX	2333	CNU	2663	CNU
24	9	354	9	684	9	1014	9	1344	9	1674	9	2004	9	2334	9	2664	9
25	NW	355	ANW	685	AQY	1015	BNY	1345	AQT	1675	BNW	2005	BQT	2335	CNW	2665	CNW
26	9	356	9	686	9	1016	9	1346	9	1676	9	2006	9	2336	9	2666	9
27	NU	357	ANU	687	AQZ	1017	BNX	1347	AQU	1677	BNU	2007	BQX	2337	CNU	2667	CNU
28	9	358	9	688	9	1018	9	1348	9	1678	9	2008	9	2338	9	2668	9
29	NX	359	ANX	689	AQX	1019	BNZ	1349	AQX	1679	BNZ	2009	BQU	2339	CNX	2669	CNX
30	9	360	9	690	9	1020	9	1350	9	1680	9	2010	9	2340	9	2670	9
31	NV	361	ANV	691	AQV	1021	BNV	1351	AQV	1681	BNV	2011	BQV	2341	CNV	2671	CNV
32	9	362	9	692	9	1022	9	1352	9	1682	9	2012	9	2342	9	2672	9
33	N	363	AQ	693	AN	1023	BN	1353	AQ	1683	BQ	2013	BN	2343	CN	2673	CN
34	9	364	9	694	9	1024	9	1354	9	1684	9	2014	9	2344	9	2674	9
35	NW	365	AQT	695	ANW	1025	BNW	1355	AQY	1685	BQT	2015	BNY	2345	CNW	2675	CNW
36	9	366	9	696	9	1026	9	1356	9	1686	9	2016	9	2346	9	2676	9
37	NT	367	AQW	697	ANT	1027	BNT	1357	AQW	1687	BQW	2017	BNT	2347	CNT	2677	CNT
38	9	368	9	698	9	1028	9	1358	9	1688	9	2018	9	2348	9	2678	9
39	NU	369	AQU	699	ANU	1029	BNU	1359	AQZ	1689	BQX	2019	BNX	2349	CNU	2679	CNU
40	9	370	9	700	9	1030	9	1360	9	1690	9	2020	9	2350	9	2680	9
41	NW	371	AQY	701	ANW	1031	BNY	1361	AQT	1691	BQT	2021	BNW	2351	CNW	2681	CNW
42	9	372	9	702	9	1032	9	1362	9	1692	9	2022	9	2352	9	2682	9
43	NX	373	AQX	703	ANX	1033	BNZ	1363	AQX	1693	BQU	2023	BNZ	2353	CNX	2683	CNX
44	9	374	9	704	9	1034	9	1364	9	1694	9	2024	9	2354	9	2684	9
45	NU	375	AQZ	705	ANU	1035	BNX	1365	AQU	1695	BQX	2025	BNU	2355	CNU	2685	CNU
46	9	376	9	706	9	1036	9	1366	9	1696	9	2026	9	2356	9	2686	9
47	NV	377	AQV	707	ANV	1037	BNV	1367	AQV	1697	BQV	2027	BNV	2357	CNV	2687	CNV
48	9	378	9	708	9	1038	9	1368	9	1698	9	2028	9	2358	9	2688	9
49	O	379	AO	709	AO	1039	BO	1369	AR	1699	BR	2029	BR	2359	CO	2689	CO
50	9	380	9	710	9	1040	9	1370	9	1700	9	2030	9	2360	9	2690	9
51	OT	381	AOT	711	AOW	1041	BOT	1371	ARW	1701	BRT	2031	BRY	2361	COT	2691	COT
52	9	382	9	712	9	1042	9	1372	9	1702	9	2032	9	2362	9	2692	9
53	OT	383	AOW	713	AOT	1043	BOT	1373	ARW	1703	BRY	2033	BRT	2363	COT	2693	COT
54	9	384	9	714	9	1044	9	1374	9	1704	9	2034	9	2364	9	2694	9
55	OU	385	AOU	715	AOU	1045	BOU	1375	ARX	1705	BRX	2035	BRX	2365	COU	2695	COU
56	9	386	9	716	9	1046	9	1376	9	1706	9	2036	9	2366	9	2696	9
57	OW	387	AOY	717	AOY	1047	BOW	1377	ART	1707	BRW	2037	BRW	2367	COW	2697	COW
58	9	388	9	718	9	1048	9	1378	9	1708	9	2038	9	2368	9	2698	9
59	OX	389	AOX	719	AOZ	1049	BOX	1379	ARU	1709	BRU	2039	BRZ	2369	COX	2699	COX
60	9	390	9	720	9	1050	9	1380	9	1710	9	2040	9	2370	9	2700	9
61	OX	391	AOZ	721	AOX	1051	BOX	1381	ARU	1711	BRZ	2041	BRU	2371	COX	2701	COX
62	9	392	9	722	9	1052	9	1382	9	1712	9	2042	9	2372	9	2702	9
63	OV	393	AOV	723	AOV	1053	BOV	1383	ARV	1713	BRV	2043	BRV	2373	COV	2703	COV
64	9	394	9	724	9	1054	9	1384	9	1714	9	2044	9	2374	9	2704	9
65	N	395	AQ	725	AQ	1055	BQ	1385	AN	1715	BN	2045	BN	2375	CN	2705	CN
66	9	396	9	726	9	1056	9	1386	9	1716	9	2046	9	2376	9	2706	9
67	NW	397	AQT	727	AQY	1057	BQT	1387	ANW	1717	BNW	2047	BNY	2377	CNW	2707	CNW
68	9	398	9	728	9	1058	9	1388	9	1718	9	2048	9	2378	9	2708	9
69	NW	399	AQY	729	AQT	1059	BQT	1389	ANW	1719	BNY	2049	BNW	2379	CNW	2709	CNW
70	9	400	9	730	9	1060	9	1390	9	1720	9	2050	9	2380	9	2710	9
71	NX	401	AQX	731	AQX	1061	BQU	1391	ANX	1721	BNZ	2051	BNZ	2381	CNX	2711	CNX
72	9	402	9	732	9	1062	9	1392	9	1722	9	2052	9	2382	9	2712	9
73	NT	403	AQW	733	AQW	1063	BQW	1393	ANT	1723	BNT	2053	BNT	2383	CNT	2713	CNT
74	9	404	9	734	9	1064	9	1394	9	1724	9	2054	9	2384	9	2714	9
75	NU	405	AQU	735	AQZ	1065	BQX	1395	ANU	1725	BNU	2055	BNX	2385	CNU	2715	CNU
76	9	406	9	736	9	1066	9	1396	9	1726	9	2056	9	2386	9	2716	9
77	NU	407	AQZ	737	AQU	1067	BQX	1397	ANU	1727	BNX	2057	BNU	2387	CNU	2717	CNU
78	9	408	9	738	9	1068	9	1398	9	1728	9	2058	9	2388	9	2718	9
79	NV	409	AQV	739	AQV	1069	BQV	1399	ANV	1729	BNV	2059	BNV	2389	CNV	2719	CNV
80	9	410	9	740	9	1070	9	1400	9	1730	9	2060	9	2390	9	2720	9
81	O	411	AO	741	AR	1071	BR	1401	AO	1731	BO	2061	BR	2391	CO	2721	CO
82	9	412	9	742	9	1072	9	1402	9	1732	9	2062	9	2392	9	2722	9
83	OT	413	AOT	743	ARW	1073	BRT	1403	AOW	1733	BOT	2063	BRY	2393	COT	2723	COT
84	9	414	9	744	9	1074	9	1404	9	1734	9	2064	9	2394	9	2724	9
85	OW	415	AOY	745	ART	1075	BRW	1405	AOY	1735	BOW	2065	BRW	2395	COW	2725	COW

FIGURE 4-5 (Sheet 3 of 6)

**CAUTION: PRELIMINARY RESULTS-
IMPORTANT UNCERTAINTIES
DESCRIBED IN SECTION 2**

SEQ. NO.	END STATE	SEQ. NO.	END STATE	SEQ. NO.	END STATE	SEQ. NO.	END STATE	SEQ. NO.	END STATE	SEQ. NO.	END STATE	SEQ. NO.	END STATE	SEQ. NO.	END STATE	SEQ. NO.	END STATE
86	9	416	9	746	9	1076	9	1406	9	1736	9	2066	9	2396	9	2726	9
87	OX	417	AOX	747	ARU	1077	BRU	1407	AOZ	1737	BOX	2067	BRZ	2397	COX	2727	COX
88	9	418	9	748	9	1078	9	1408	9	1738	9	2068	9	2398	9	2728	9
89	OT	419	AOW	749	ARW	1079	BRY	1409	AOT	1739	BOT	2069	BRT	2399	COT	2729	COT
90	9	420	9	750	9	1080	9	1410	9	1740	9	2070	9	2400	9	2730	9
91	OU	421	AOU	751	ARX	1081	BRX	1411	AOU	1741	BOU	2071	BRX	2401	COU	2731	COU
92	9	422	9	752	9	1082	9	1412	9	1742	9	2072	9	2402	9	2732	9
93	OX	423	AOZ	753	ARU	1083	BRZ	1413	AOX	1743	BOX	2073	BRU	2403	COX	2733	COX
94	9	424	9	754	9	1084	9	1414	9	1744	9	2074	9	2404	9	2734	9
95	OV	425	AOV	755	ARV	1085	BRV	1415	AOV	1745	BOV	2075	BRV	2405	COV	2735	COV
96	9	426	9	756	9	1086	9	1416	9	1746	9	2076	9	2406	9	2736	9
97	O	427	AR	757	AO	1087	BR	1417	AO	1747	BR	2077	BO	2407	CO	2737	CO
98	9	428	9	758	9	1088	9	1418	9	1748	9	2078	9	2408	9	2738	9
99	OW	429	ART	759	AOY	1089	BRW	1419	AOY	1749	BRW	2079	BOW	2409	COW	2739	COW
100	9	430	9	760	9	1090	9	1420	9	1750	9	2080	9	2410	9	2740	9
101	OT	431	ARW	761	AOT	1091	BRT	1421	AOW	1751	BRY	2081	BOT	2411	COT	2741	COT
102	9	432	9	762	9	1092	9	1422	9	1752	9	2082	9	2412	9	2742	9
103	OX	433	ARU	763	AOX	1093	BRU	1423	AOZ	1753	BRZ	2083	BOX	2413	COX	2743	COX
104	9	434	9	764	9	1094	9	1424	9	1754	9	2084	9	2414	9	2744	9
105	OT	435	ARW	765	AOW	1095	BRY	1425	AOT	1755	BRT	2085	BOT	2415	COT	2745	COT
106	9	436	9	766	9	1096	9	1426	9	1756	9	2086	9	2416	9	2746	9
107	OX	437	ARU	767	AOZ	1097	BRZ	1427	AOX	1757	BRU	2087	BOX	2417	COX	2747	COX
108	9	438	9	768	9	1098	9	1428	9	1758	9	2088	9	2418	9	2748	9
109	OU	439	ARX	769	AOU	1099	BRX	1429	AOU	1759	BRX	2089	BOU	2419	COU	2749	COU
110	9	440	9	770	9	1100	9	1430	9	1760	9	2090	9	2420	9	2750	9
111	OV	441	ARV	771	AOV	1101	BRV	1431	AOV	1761	BRV	2091	BOV	2421	COV	2751	COV
112	9	442	9	772	9	1102	9	1432	9	1762	9	2092	9	2422	9	2752	9
113	P	443	AP	773	AP	1103	BP	1433	AP	1763	BP	2093	BP	2423	CP	2753	CP
114	9	444	9	774	9	1104	9	1434	9	1764	9	2094	9	2424	9	2754	9
115	PT	445	APT	775	APW	1105	BPT	1435	APW	1765	BPT	2095	BPW	2425	CPT	2755	CPT
116	9	446	9	776	9	1106	9	1436	9	1766	9	2096	9	2426	9	2756	9
117	PT	447	APW	777	APT	1107	BPT	1437	APW	1767	BPW	2097	BPT	2427	CPT	2757	CPT
118	9	448	9	778	9	1108	9	1438	9	1768	9	2098	9	2428	9	2758	9
119	PU	449	APU	779	APU	1109	BPU	1439	APX	1769	BPX	2099	BPX	2429	CPU	2759	CPU
120	9	450	9	780	9	1110	9	1440	9	1770	9	2100	9	2430	9	2760	9
121	PT	451	APW	781	APW	1111	BPW	1441	APT	1771	BPT	2101	BPT	2431	CPT	2761	CPT
122	9	452	9	782	9	1112	9	1442	9	1772	9	2102	9	2432	9	2762	9
123	PU	453	APU	783	APX	1113	BPX	1443	APU	1773	BPU	2103	BPX	2433	CPU	2763	CPU
124	9	454	9	784	9	1114	9	1444	9	1774	9	2104	9	2434	9	2764	9
125	PU	455	APX	785	APU	1115	BPX	1445	APU	1775	BPX	2105	BPU	2435	CPU	2765	CPU
126	9	456	9	786	9	1116	9	1446	9	1776	9	2106	9	2436	9	2766	9
127	PV	457	APV	787	APV	1117	BPV	1447	APV	1777	BPV	2107	BPV	2437	CPV	2767	CPV
128	9	458	9	788	9	1118	9	1448	9	1778	9	2108	9	2438	9	2768	9
129	DT	459	ADT	789	AEW	1119	BDT	1449	AEW	1779	BDT	2109	BEW	2439	CDT	2769	CDT
130	9	460	9	790	9	1120	9	1450	9	1780	9	2110	9	2440	9	2770	9
131	DU	461	ADU	791	AEU	1121	BDU	1451	AEZ	1781	BDX	2111	BEX	2441	CDU	2771	CDU
132	9	462	9	792	9	1122	9	1452	9	1782	9	2112	9	2442	9	2772	9
133	DU	463	ADU	793	AEZ	1123	BDX	1453	AEU	1783	BDU	2113	BEX	2443	CDU	2773	CDU
134	9	464	9	794	9	1124	9	1454	9	1784	9	2114	9	2444	9	2774	9
135	DV	465	ADV	795	AEV	1125	BDV	1455	AEV	1785	BDV	2115	BEV	2445	CDV	2775	CDV
136	9	466	9	796	9	1126	9	1456	9	1786	9	2116	9	2446	9	2776	9
137	DOT	467	ADOT	797	AEOW	1127	BDOT	1457	AERW	1787	BDRT	2117	BERW	2447	CDOT	2777	CDOT
138	9	468	9	798	9	1128	9	1458	9	1788	9	2118	9	2448	9	2778	9
139	DOU	469	ADOU	799	AEOU	1129	BDOU	1459	AERZ	1789	BDPX	2119	BERX	2449	CDOU	2779	CDOU
140	9	470	9	800	9	1130	9	1460	9	1790	9	2120	9	2450	9	2780	9
141	DOX	471	ADOX	801	AEOZ	1131	BDOX	1461	AERU	1791	BDRU	2121	BERZ	2451	CDOX	2781	CDOX
142	9	472	9	802	9	1132	9	1462	9	1792	9	2122	9	2452	9	2782	9
143	DOV	473	ADOV	803	AEOV	1133	BDOV	1463	AERV	1793	BDRV	2123	BERV	2453	CDOV	2783	CDOV
144	9	474	9	804	9	1134	9	1464	9	1794	9	2124	9	2454	9	2784	9
145	DOT	475	ADOT	805	AERW	1135	BDRT	1465	AEOW	1795	BDOT	2125	BERW	2455	CDOT	2785	CDOT
146	9	476	9	806	9	1136	9	1466	9	1796	9	2126	9	2456	9	2786	9
147	DOX	477	ADOX	807	AERU	1137	BDRU	1467	AEOZ	1797	BDOX	2127	BERZ	2457	CDOX	2787	CDOX
148	9	478	9	808	9	1138	9	1468	9	1798	9	2128	9	2458	9	2788	9
149	DOU	479	ADOU	809	AERZ	1139	BDRX	1469	AEOU	1799	BDOU	2129	BERX	2459	CDOU	2789	CDOU
150	9	480	9	810	9	1140	9	1470	9	1800	9	2130	9	2460	9	2790	9
151	DOV	481	ADOV	811	AERV	1141	BDRV	1471	AEOV	1801	BDOV	2131	BERV	2461	CDOV	2791	CDOV
152	9	482	9	812	9	1142	9	1472	9	1802	9	2132	9	2462	9	2792	9
153	DPT	483	ADPT	813	AEPW	1143	BDPT	1473	AEPW	1803	BDPT	2133	BEPW	2463	CDPT	2793	CDPT
154	9	484	9	814	9	1144	9	1474	9	1804	9	2134	9	2464	9	2794	9
155	DPU	485	ADPU	815	AEPU	1145	BDPU	1475	AEPZ	1805	BDPX	2135	BEPX	2465	CDPU	2795	CDPU
156	9	486	9	816	9	1146	9	1476	9	1806	9	2136	9	2466	9	2796	9
157	DPU	487	ADPU	817	AEPZ	1147	BDPX	1477	AEPU	1807	BDPU	2137	BEPX	2467	CDPU	2797	CDPU
158	9	488	9	818	9	1148	9	1478	9	1808	9	2138	9	2468	9	2798	9
159	DPV	489	ADPV	819	AEPV	1149	BDPV	1479	AEPV	1809	BDPV	2139	BEPV	2469	CDPV	2799	CDPV
160	9	490	9	820	9	1150	9	1480	9	1810	9	2140	9	2470	9	2800	9
161	D	491	AE	821	AD	1151	BD	1481	AE	1811	BE	2141	BD	2471	CD	2801	CD
162	9	492	9	822	9	1152	9	1482	9	1812	9	2142	9	2472	9	2802	9
163	DW	493	AET	823	ADW	1153	BDW	1483	AEY	1813	BET	2143	BDY	2473	CDW	2803	CDW
164	9	494	9	824	9	1154	9	1484	9	1814	9	2144	9	2474	9	2804	9
165	DT	495	AEW	825	ADT	1155	BDT	1485	AEW	1815	BEW	2145	BDT	2475	CDT	2805	CDT
166	9	496	9	826	9	1156	9	1486	9	1816	9	2146	9	2476	9	2806	9
167	DU	497	AEU	827	ADU	1157	BDU	1487	AEZ	1817	BEX	2147	BDX	2477	CDU	2807	CDU
168	9	498	9	828	9	1158	9	1488	9	1818	9	2148	9	2478	9	2808	9
169	DW	499	AEY	829	ADW	1159	BDY	1489	AET	1819	BET	2149	BDW	2479	CDW	2809	CDW
170	9	500	9	830	9	1160	9	1490	9	1820	9	2150	9	2480	9	2810	9

FIGURE 4-5 (Sheet 4 of 6)

CAUTION: PRELIMINARY RESULTS
IMPORTANT UNCERTAINTIES
DESCRIBED IN SECTION 2

SEQ. NO.	END STATE	SEQ. NO.	END STATE	SEQ. NO.	END STATE	SEQ. NO.	END STATE	SEQ. NO.	END STATE	SEQ. NO.	END STATE	SEQ. NO.	END STATE	SEQ. NO.	END STATE	SEQ. NO.	END STATE
171	DX	501	AEX	831	ADX	1161	BDZ	1491	AEX	1821	BEU	2151	BDZ	2481	CDX	2811	CDX
172	9	502	9	832	9	1162	9	1492	9	1822	9	2152	9	2482	9	2812	9
173	DU	503	AEZ	833	ADU	1163	BDX	1493	AEU	1823	BEX	2153	BDU	2483	CDU	2813	CDU
174	9	504	9	834	9	1164	9	1494	9	1824	9	2154	9	2484	9	2814	9
175	DV	505	AEV	835	ADV	1165	BDV	1495	AEV	1825	BEV	2155	BDV	2485	CDV	2815	CDV
176	9	506	9	836	9	1166	9	1496	9	1826	9	2156	9	2486	9	2816	9
177	DO	507	AEO	837	ADO	1167	BDO	1497	AER	1827	BER	2157	BDR	2487	CDO	2817	CDO
178	9	508	9	838	9	1168	9	1498	9	1828	9	2158	9	2488	9	2818	9
179	DOW	509	AEOT	839	ADOW	1169	BDOW	1499	AERY	1829	BERT	2159	BDRY	2489	CDOW	2819	CDOW
180	9	510	9	840	9	1170	9	1500	9	1830	9	2160	9	2490	9	2820	9
181	DOT	511	AEOW	841	ADOT	1171	BDOT	1501	AERW	1831	BERY	2161	BDRT	2491	CDOT	2821	CDOT
182	9	512	9	842	9	1172	9	1502	9	1832	9	2162	9	2492	9	2822	9
183	DOU	513	AEOU	843	ADOU	1173	BDOU	1503	AERZ	1833	BERX	2163	BDRX	2493	CDOU	2823	CDOU
184	9	514	9	844	9	1174	9	1504	9	1834	9	2164	9	2494	9	2824	9
185	DOY	515	AEOY	845	ADOY	1175	BDOY	1505	AERT	1835	BERW	2165	BDRW	2495	CDOY	2825	CDOY
186	9	516	9	846	9	1176	9	1506	9	1836	9	2166	9	2496	9	2826	9
187	DOZ	517	AEOX	847	ADOZ	1177	BDOZ	1507	AERX	1837	BERU	2167	BDRZ	2497	CDOZ	2827	CDOZ
188	9	518	9	848	9	1178	9	1508	9	1838	9	2168	9	2498	9	2828	9
189	DOX	519	AEOZ	849	ADOX	1179	BDOX	1509	AERU	1839	BERZ	2169	BDRU	2499	CDOX	2829	CDOX
190	9	520	9	850	9	1180	9	1510	9	1840	9	2170	9	2500	9	2830	9
191	DOV	521	AEOV	851	ADOV	1181	BDOV	1511	AERV	1841	BERV	2171	BDRV	2501	CDOV	2831	CDOV
192	9	522	9	852	9	1182	9	1512	9	1842	9	2172	9	2502	9	2832	9
193	DO	523	AER	853	ADO	1183	BDR	1513	AEO	1843	BER	2173	BDO	2503	CDO	2833	CDO
194	9	524	9	854	9	1184	9	1514	9	1844	9	2174	9	2504	9	2834	9
195	DOY	525	AERT	855	ADOY	1185	BDRW	1515	AEOY	1845	BERW	2175	BDOY	2505	CDOY	2835	CDOY
196	9	526	9	856	9	1186	9	1516	9	1846	9	2176	9	2506	9	2836	9
197	DOT	527	AERW	857	ADOT	1187	BDRT	1517	AEOW	1847	BERY	2177	BDOT	2507	CDOT	2837	CDOT
198	9	528	9	858	9	1188	9	1518	9	1848	9	2178	9	2508	9	2838	9
199	DOX	529	AERU	859	ADOX	1189	BDRU	1519	AEOZ	1849	BERZ	2179	BDOX	2509	CDOX	2839	CDOX
200	9	530	9	860	9	1190	9	1520	9	1850	9	2180	9	2510	9	2840	9
201	DOW	531	AERY	861	ADOW	1191	BDRY	1521	AEOT	1851	BERT	2181	BDOW	2511	CDOW	2841	CDOW
202	9	532	9	862	9	1192	9	1522	9	1852	9	2182	9	2512	9	2842	9
203	DOZ	533	AERX	863	ADOZ	1193	BDRZ	1523	AEOX	1853	BERU	2183	BDOZ	2513	CDOZ	2843	CDOZ
204	9	534	9	864	9	1194	9	1524	9	1854	9	2184	9	2514	9	2844	9
205	DOU	535	AERZ	865	ADOU	1195	BDRX	1525	AEOU	1855	BERX	2185	BDOU	2515	CDOU	2845	CDOU
206	9	536	9	866	9	1196	9	1526	9	1856	9	2186	9	2516	9	2846	9
207	DOV	537	AERV	867	ADOV	1197	BDRV	1527	AEOV	1857	BERV	2187	BDOV	2517	CDOV	2847	CDOV
208	9	538	9	868	9	1198	9	1528	9	1858	9	2188	9	2518	9	2848	9
209	DP	539	AEP	869	ADP	1199	BDP	1529	AEP	1859	BEP	2189	BDP	2519	CDP	2849	CDP
210	9	540	9	870	9	1200	9	1530	9	1860	9	2190	9	2520	9	2850	9
211	DPW	541	AEPT	871	ADPW	1201	BDPW	1531	AEPY	1861	BEPT	2191	BDPY	2521	CDPW	2851	CDPW
212	9	542	9	872	9	1202	9	1532	9	1862	9	2192	9	2522	9	2852	9
213	DPT	543	AEPW	873	ADPT	1203	BDPT	1533	AEPW	1863	BEPW	2193	BDPT	2523	CDPT	2853	CDPT
214	9	544	9	874	9	1204	9	1534	9	1864	9	2194	9	2524	9	2854	9
215	DPU	545	AEPU	875	ADPU	1205	BDPU	1535	AEPZ	1865	BEPX	2195	BDPX	2525	CDPU	2855	CDPU
216	9	546	9	876	9	1206	9	1536	9	1866	9	2196	9	2526	9	2856	9
217	DPW	547	AEPY	877	ADPW	1207	BDPY	1537	AEPT	1867	BEPT	2197	BDPW	2527	CDPW	2857	CDPW
218	9	548	9	878	9	1208	9	1538	9	1868	9	2198	9	2528	9	2858	9
219	DPX	549	AEPX	879	ADPX	1209	BDPZ	1539	AEPX	1869	BEPU	2199	BDPZ	2529	CDPX	2859	CDPX
220	9	550	9	880	9	1210	9	1540	9	1870	9	2200	9	2530	9	2860	9
221	DPU	551	AEPZ	881	ADPU	1211	BDPX	1541	AEPU	1871	BEPX	2201	BDPU	2531	CDPU	2861	CDPU
222	9	552	9	882	9	1212	9	1542	9	1872	9	2202	9	2532	9	2862	9
223	DPV	553	AEPV	883	ADPV	1213	BDPV	1543	AEPV	1873	BEPV	2203	BDPV	2533	CDPV	2863	CDPV
224	9	554	9	884	9	1214	9	1544	9	1874	9	2204	9	2534	9	2864	9
225	F	555	AFT	885	AFW	1215	BF	1545	AG	1875	BGT	2205	BGW	2535	CF	2865	CF
226	9	556	9	886	9	1216	9	1546	9	1876	9	2206	9	2536	9	2866	9
227	FU	557	AFU	887	AFU	1217	BFU	1547	AGX	1877	BGX	2207	BGX	2537	CFU	2867	CFU
228	9	558	9	888	9	1218	9	1548	9	1878	9	2208	9	2538	9	2868	9
229	FX	559	AFX	889	AFX	1219	BFX	1549	AGU	1879	BGU	2209	BGZ	2539	CFX	2869	CFX
230	9	560	9	890	9	1220	9	1550	9	1880	9	2210	9	2540	9	2870	9
231	FV	561	AFV	891	AFV	1221	BFV	1551	AGV	1881	BGV	2211	BGV	2541	CFV	2871	CFV
232	9	562	9	892	9	1222	9	1552	9	1882	9	2212	9	2542	9	2872	9
233	FP	563	AFPT	893	AFPW	1223	BFP	1553	AGP	1883	BGPT	2213	BGPW	2543	CFP	2873	CFP
234	9	564	9	894	9	1224	9	1554	9	1884	9	2214	9	2544	9	2874	9
235	FPU	565	AFPU	895	AFPU	1225	BFPU	1555	AGPX	1885	BGPX	2215	BGPX	2545	CFPU	2875	CFPU
236	9	566	9	896	9	1226	9	1556	9	1886	9	2216	9	2546	9	2876	9
237	FPX	567	AFPX	897	AFPX	1227	BFPX	1557	AGPU	1887	BGPU	2217	BGPZ	2547	CFPX	2877	CFPX
238	9	568	9	898	9	1228	9	1558	9	1888	9	2218	9	2548	9	2878	9
239	FPV	569	AFPV	899	AFPV	1229	BFPV	1559	AGPV	1889	BGPV	2219	BGPV	2549	CFPV	2879	CFPV
240	9	570	9	900	9	1230	9	1560	9	1890	9	2220	9	2550	9	2880	9
241	D	571	AE	901	AE	1231	BE	1561	AD	1891	BD	2221	BD	2551	CD	2881	CD
242	9	572	9	902	9	1232	9	1562	9	1892	9	2222	9	2552	9	2882	9
243	DW	573	AET	903	AEY	1233	BET	1563	ADW	1893	BDW	2223	BDY	2553	CDW	2883	CDW
244	9	574	9	904	9	1234	9	1564	9	1894	9	2224	9	2554	9	2884	9
245	DW	575	AEY	905	AET	1235	BET	1565	ADW	1895	BDY	2225	BDW	2555	CDW	2885	CDW
246	9	576	9	906	9	1236	9	1566	9	1896	9	2226	9	2556	9	2886	9
247	DX	577	AEX	907	AEX	1237	BEU	1567	ADX	1897	BDZ	2227	BDZ	2557	CDX	2887	CDX
248	9	578	9	908	9	1238	9	1568	9	1898	9	2228	9	2558	9	2888	9
249	DT	579	AEW	909	AEW	1239	BEW	1569	ADT	1899	BDT	2229	BDT	2559	CDT	2889	CDT
250	9	580	9	910	9	1240	9	1570	9	1900	9	2230	9	2560	9	2890	9

FIGURE 4-5 (Sheet 5 of 6)

CAUTION: PRELIMINARY RESULTS-
IMPORTANT UNCERTAINTIES
DESCRIBED IN SECTION 2

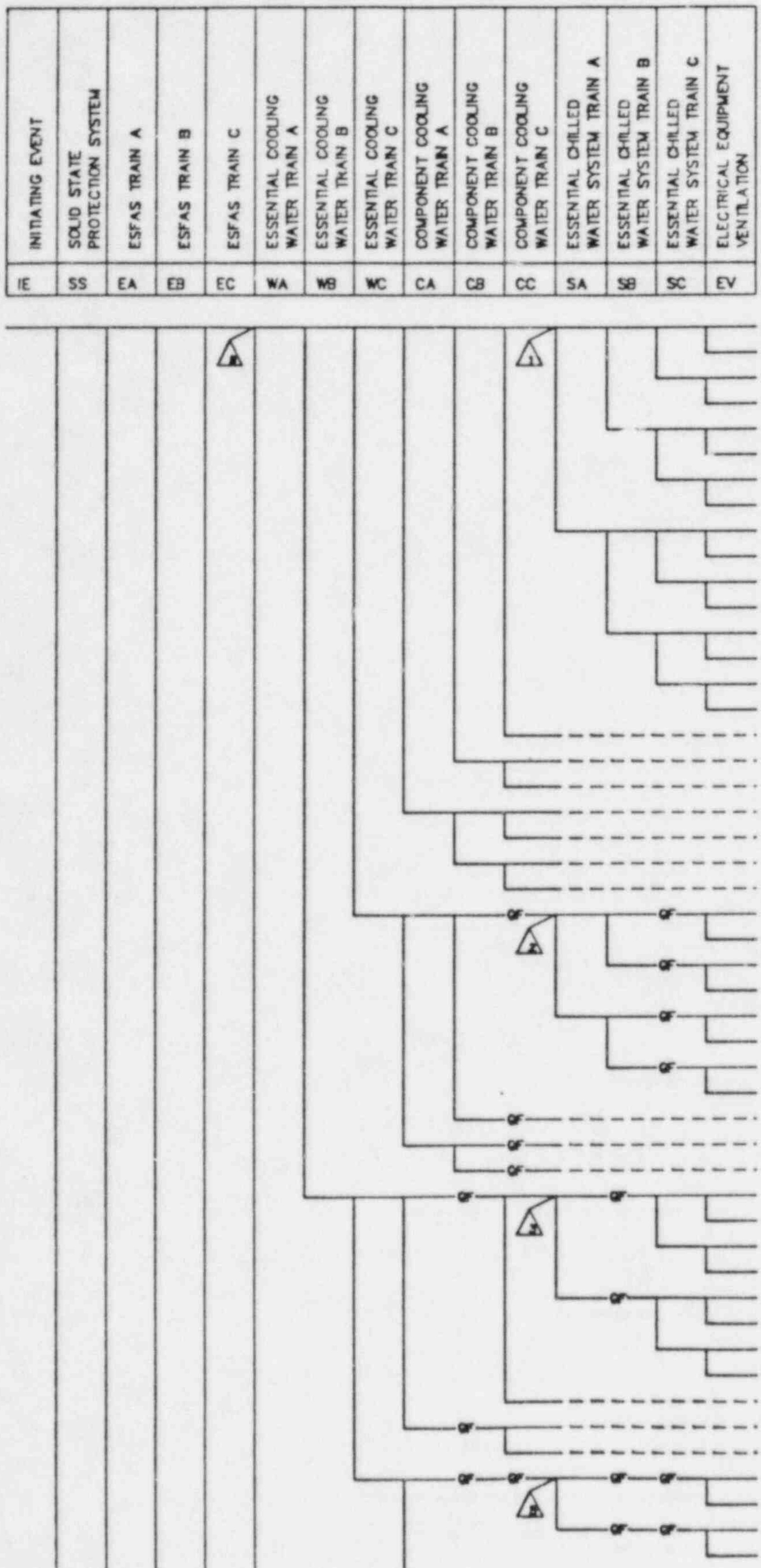
SEQ. NO.	END STATE	SEQ. NO.	END STATE	SEQ. NO.	END STATE	SEQ. NO.	END STATE	SEQ. NO.	END STATE	SEQ. NO.	END STATE	SEQ. NO.	END STATE	SEQ. NO.	END STATE	SEQ. NO.	END STATE
251	DU	581	AEU	911	AEZ	1241	BEX	1571	ADU	1901	BDU	2231	BDX	2561	CDU	2891	CDU
252	9	582	9	912	9	1242	9	1572	9	1902	9	2232	9	2562	9	2892	9
253	DU	583	AEZ	913	AEU	1243	BEX	1573	ADU	1903	BDX	2233	BDU	2563	CDU	2893	CDU
254	9	584	9	914	9	1244	9	1574	9	1904	9	2234	9	2564	9	2894	9
255	DV	585	AEV	915	AEV	1245	BEV	1575	ADV	1905	BDV	2235	BDV	2565	CDV	2895	CDV
256	9	586	9	916	9	1246	9	1576	9	1906	9	2236	9	2566	9	2896	9
257	DO	587	AEO	917	AER	1247	BER	1577	ADO	1907	BDO	2237	BDR	2567	CDO	2897	CDO
258	9	588	9	918	9	1248	9	1578	9	1908	9	2238	9	2568	9	2898	9
259	DOW	589	AEOT	919	AERY	1249	BERT	1579	ADOW	1909	BDOW	2239	BDRY	2569	CDOW	2899	CDOW
260	9	590	9	920	9	1250	9	1580	9	1910	9	2240	9	2570	9	2900	9
261	DOY	591	AEOY	921	AERT	1251	BERW	1581	ADOY	1911	BDOY	2241	BDRW	2571	CDOY	2901	CDOY
262	9	592	9	922	9	1252	9	1582	9	1912	9	2242	9	2572	9	2902	9
263	DOZ	593	AEOX	923	AERX	1253	BERU	1583	ADOZ	1913	BDOZ	2243	BDRZ	2573	CDOZ	2903	CDOZ
264	9	594	9	924	9	1254	9	1584	9	1914	9	2244	9	2574	9	2904	9
265	DOT	595	AEOW	925	AERW	1255	BERY	1585	ADOT	1915	BDOT	2245	BDRT	2575	CDOT	2905	CDOT
266	9	596	9	926	9	1256	9	1586	9	1916	9	2246	9	2576	9	2906	9
267	DOU	597	AEOU	927	AERZ	1257	BERX	1587	ADOU	1917	BDOU	2247	BDRX	2577	CDOU	2907	CDOU
268	9	598	9	928	9	1258	9	1588	9	1918	9	2248	9	2578	9	2908	9
269	DOX	599	AEOZ	929	AERU	1259	BERZ	1589	ADOX	1919	BDOX	2249	BDRU	2579	CDOX	2909	CDOX
270	9	600	9	930	9	1260	9	1590	9	1920	9	2250	9	2580	9	2910	9
271	DOV	601	AEOV	931	AERV	1261	BERV	1591	ADOV	1921	BDOV	2251	BDRV	2581	CDOV	2911	CDOV
272	9	602	9	932	9	1262	9	1592	9	1922	9	2252	9	2582	9	2912	9
273	DO	603	AER	933	AEO	1263	BER	1593	ADO	1923	BDR	2253	BDO	2583	CDO	2913	CDO
274	9	604	9	934	9	1264	9	1594	9	1924	9	2254	9	2584	9	2914	9
275	DOY	605	AERT	935	AEOY	1265	BERW	1595	ADOY	1925	BDRW	2255	BDOY	2585	CDOY	2915	CDOY
276	9	606	9	936	9	1266	9	1596	9	1926	9	2256	9	2586	9	2916	9
277	DOW	607	AERY	937	AEOT	1267	BERT	1597	ADOW	1927	BDRY	2257	BDOW	2587	CDOW	2917	CDOW
278	9	608	9	938	9	1268	9	1598	9	1928	9	2258	9	2588	9	2918	9
279	DOZ	609	AERX	939	AEOX	1269	BERU	1599	ADOZ	1929	BRZ	2259	BDOZ	2589	CDOZ	2919	CDOZ
280	9	610	9	940	9	1270	9	1600	9	1930	9	2260	9	2590	9	2920	9
281	DOT	611	AERW	941	AEOW	1271	BERY	1601	ADOT	1931	BDRT	2261	BDOT	2591	CDOT	2921	CDOT
282	9	612	9	942	9	1272	9	1602	9	1932	9	2262	9	2592	9	2922	9
283	DOX	613	AERU	943	AEOZ	1273	BERZ	1603	ADOX	1933	BDRU	2263	BDOX	2593	CDOX	2923	CDOX
284	9	614	9	944	9	1274	9	1604	9	1934	9	2264	9	2594	9	2924	9
285	DOU	615	AERZ	945	AEOU	1275	BERX	1605	ADOU	1935	BDRX	2265	BDOU	2595	CDOU	2925	CDOU
286	9	616	9	946	9	1276	9	1606	9	1936	9	2266	9	2596	9	2926	9
287	DOV	617	AERV	947	AEOV	1277	BERV	1607	ADOV	1937	BDRV	2267	BDOV	2597	CDOV	2927	CDOV
288	9	618	9	948	9	1278	9	1608	9	1938	9	2268	9	2598	9	2928	9
289	DP	619	AEP	949	AEP	1279	BEP	1609	ADP	1939	BDP	2269	BDP	2599	CDP	2929	CDP
290	9	620	9	950	9	1280	9	1610	9	1940	9	2270	9	2600	9	2930	9
291	DPW	621	AEPT	951	AEPY	1281	BEPT	1611	ADPW	1941	BDPW	2271	BDPY	2601	CDPW	2931	CDPW
292	9	622	9	952	9	1282	9	1612	9	1942	9	2272	9	2602	9	2932	9
293	DPW	623	AEPY	953	AEPT	1283	BEPT	1613	ADPW	1943	BDPY	2273	BDPW	2603	CDPW	2933	CDPW
294	9	624	9	954	9	1284	9	1614	9	1944	9	2274	9	2604	9	2934	9
295	DPX	625	AEPX	955	AEPX	1285	BEPU	1615	ADPX	1945	BDPZ	2275	BDPZ	2605	CDPX	2935	CDPX
296	9	626	9	956	9	1286	9	1616	9	1946	9	2276	9	2606	9	2936	9
297	DPT	627	AEPW	957	AEPW	1287	BEPW	1617	ADPT	1947	BDPT	2277	BDPT	2607	CDPT	2937	CDPT
298	9	628	9	958	9	1288	9	1618	9	1948	9	2278	9	2608	9	2938	9
299	DPU	629	AEPU	959	AEPZ	1289	BEPX	1619	ADPU	1949	BDPU	2279	BDPX	2609	CDPU	2939	CDPU
300	9	630	9	960	9	1290	9	1620	9	1950	9	2280	9	2610	9	2940	9
301	DPU	631	AEPZ	961	AEPU	1291	BEPX	1621	ADPU	1951	BDPX	2281	BDPU	2611	CDPU	2941	CDPU
302	9	632	9	962	9	1292	9	1622	9	1952	9	2282	9	2612	9	2942	9
303	DPV	633	AEPV	963	AEPV	1293	BEPV	1623	ADPV	1953	BDPV	2283	BDPV	2613	CDPV	2943	CDPV
304	9	634	9	964	9	1294	9	1624	9	1954	9	2284	9	2614	9	2944	9
305	F	635	AFT	965	AG	1295	BGT	1625	AFW	1955	BF	2285	BGW	2615	CF	2945	CF
306	9	636	9	966	9	1296	9	1626	9	1956	9	2286	9	2616	9	2946	9
307	FX	637	AFX	967	AGU	1297	BGU	1627	AFX	1957	BFX	2287	BGZ	2617	CFX	2947	CFX
308	9	638	9	968	9	1298	9	1628	9	1958	9	2288	9	2618	9	2948	9
309	FU	639	AFU	969	AGX	1299	BGX	1629	AFU	1959	BFU	2289	BGX	2619	CFU	2949	CFU
310	9	640	9	970	9	1300	9	1630	9	1960	9	2290	9	2620	9	2950	9
311	FV	641	AFV	971	AGV	1301	BGV	1631	AFV	1961	BFV	2291	BGV	2621	CFV	2951	CFV
312	9	642	9	972	9	1302	9	1632	9	1962	9	2292	9	2622	9	2952	9
313	FP	643	AFPT	973	AGP	1303	BGPT	1633	AFPW	1963	BFP	2293	BGPW	2623	CFP	2953	CFP
314	9	644	9	974	9	1304	9	1634	9	1964	9	2294	9	2624	9	2954	9
315	FPX	645	AFPX	975	AGPU	1305	BGPU	1635	AFPX	1965	BFPX	2295	BGPZ	2625	CFPX	2955	CFPX
316	9	646	9	976	9	1306	9	1636	9	1966	9	2296	9	2626	9	2956	9
317	FPU	647	AFPU	977	AGPX	1307	BGPX	1637	AFPU	1967	BFPU	2297	BGPX	2627	CFPU	2957	CFPU
318	9	648	9	978	9	1308	9	1638	9	1968	9	2298	9	2628	9	2958	9
319	FPV	649	AFPV	979	AGPV	1309	BGPV	1639	AFPV	1969	BFPV	2299	BGPV	2629	CFPV	2959	CFPV
320	9	650	9	980	9	1310	9	1640	9	1970	9	2300	9	2630	9	2960	9
321	FU	651	AGX	981	AFU	1311	BGX	1641	AFU	1971	BGX	2301	BFU	2631	CFU	2961	CFU
322	9	652	9	982	9	1312	9	1642	9	1972	9	2302	9	2632	9	2962	9
323	FV	653	AGV	983	AFV	1313	BGV	1643	AFV	1973	BGV	2303	BFV	2633	CFV	2963	CFV
324	9	654	9	984	9	1314	9	1644	9	1974	9	2304	9	2634	9	2964	9
325	FPU	655	AGPX	985	AFPU	1315	BGPX	1645	AFPU	1975	BGPX	2305	BFPU	2635	CFPU	2965	CFPU
326	9	656	9	986	9	1316	9	1646	9	1976	9	2306	9	2636	9	2966	9
327	FPV	657	AGPV	987	AFPV	1317	BGPV	1647	AFPV	1977	BGPV	2307	BFPV	2637	CFPV	2967	CFPV
328	9	658	9	988	9	1318	9	1648	9	1978	9	2308	9	2638	9	2968	9
329	H	659	AH	989	AH	1319	BH	1649	AH	1979	BH	2309	BH	2639	CH	2969	CH
330	9	660	9	990	9	1320	9	1650	9	1980	9	2310	9	2640	9	2970	9

FIGURE 4-5 (Sheet 6 of 6)

CAUTION: PRELIMINARY RESULTS. IMPORTANT UNCERTAINTIES DESCRIBED IN SECTION 2

LEGEND:
GF GUARANTEED FAILURE

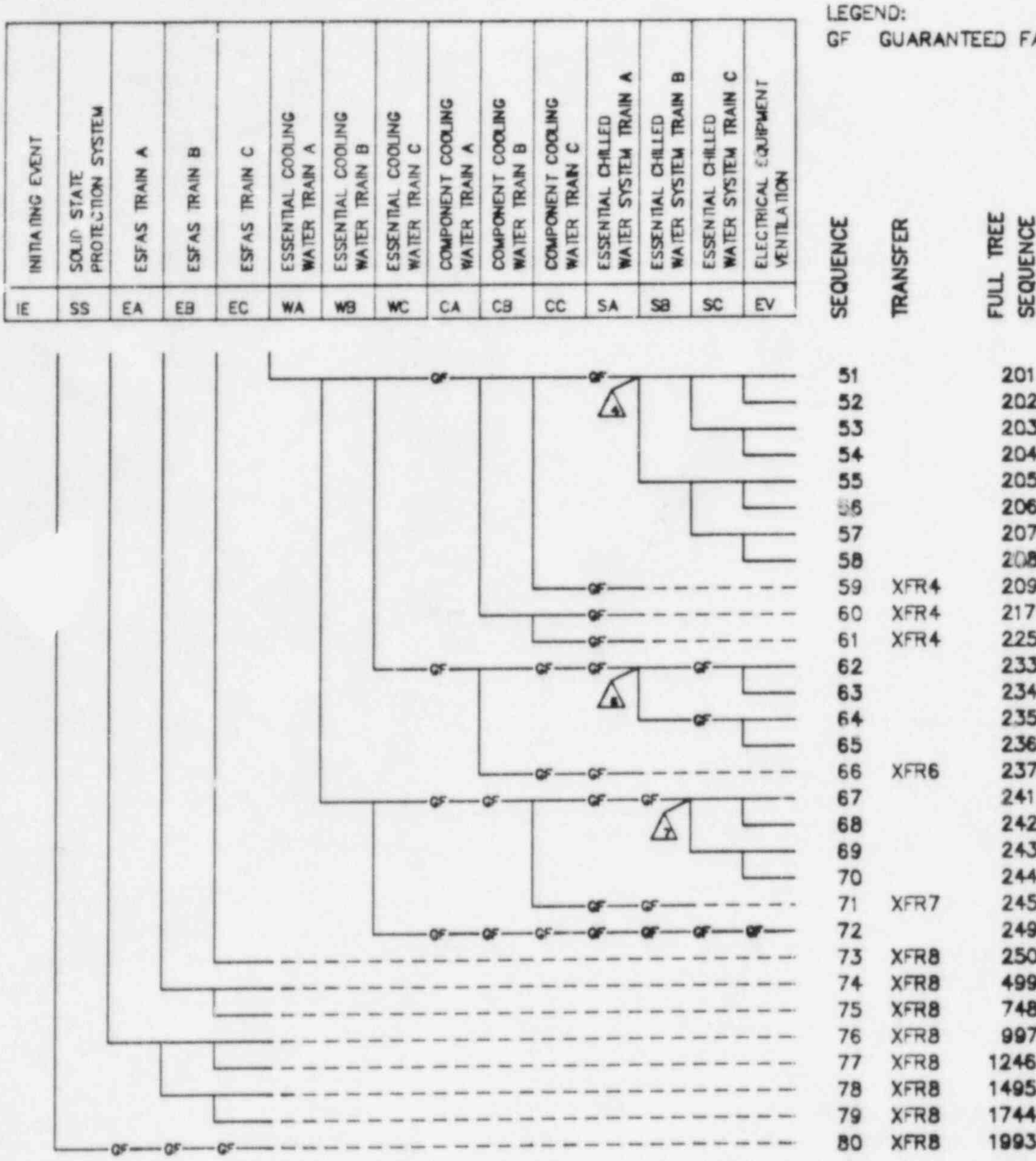
CAUTION: PRELIMINARY RESULTS-IMPORTANT UNCERTAINTIES DESCRIBED IN SECTION 2



SEQUENCE	TRANSFER	FULL TREE SEQUENCE
1		1
2		2
3		3
4		4
5		5
6		6
7		7
8		8
9		9
10		10
11		11
12		12
13		13
14		14
15		15
16		16
17	XFR1	17
18	XFR1	33
19	XFR1	49
20	XFR1	65
21	XFR1	81
22	XFR1	97
23	XFR1	113
24		129
25		130
26		131
27		132
28		133
29		134
30		135
31		136
32	XFR2	137
33	XFR2	145
34	XFR2	153
35		161
36		162
37		163
38		164
39		165
40		166
41		167
42		168
43	XFR3	169
44	XFR3	177
45	XFR3	185
46		193
47		194
48		195
49		196
50	XFR5	197

FIGURE 4-6. AUXILIARY SYSTEMS EVENT TREE FOR LOSS OF OFFSITE POWER CONDITION (Sheet 1 of 5)

LEGEND:
GF GUARANTEED FAILURE



CAUTION: PRELIMINARY RESULTS-
IMPORTANT UNCERTAINTIES
DESCRIBED IN SECTION 2

FIGURE 4-6 (Sheet 2 of 5)

SEQ. NO.	END STATE	SEQ. NO.	END STATE	SEQ. NO.	END STATE	SEQ. NO.	END STATE	SEQ. NO.	END STATE	SEQ. NO.	END STATE	SEQ. NO.	END STATE	SEQ. NO.	END STATE	SEQ. NO.	END STATE
1	AUX	250	A	499	A	748	B	997	A	1246	B	1495	B	1744	C	1993	C
2	9	251	9	500	9	749	9	998	9	1247	9	1496	9	1745	9	1994	9
3	T	252	AT	501	AW	750	BT	999	AW	1248	BT	1497	BW	1746	CT	1995	CT
4	9	253	9	502	9	751	9	1000	9	1249	9	1498	9	1747	9	1996	9
5	T	254	AW	503	AT	752	BT	1001	AW	1250	BW	1499	BT	1748	CT	1997	CT
6	9	255	9	504	9	753	9	1002	9	1251	9	1500	9	1749	9	1998	9
7	U	256	AU	505	AU	754	BU	1003	AX	1252	BX	1501	BX	1750	CU	1999	CU
8	9	257	9	506	9	755	9	1004	9	1253	9	1502	9	1751	9	2000	9
9	T	258	AW	507	AW	756	BW	1005	AT	1254	BT	1503	BT	1752	CT	2001	CT
10	9	259	9	508	9	757	9	1006	9	1255	9	1504	9	1753	9	2002	9
11	U	260	AU	509	AX	758	BX	1007	AU	1256	BU	1505	BX	1754	CU	2003	CU
12	9	261	9	510	9	759	9	1008	9	1257	9	1506	9	1755	9	2004	9
13	U	262	AX	511	AU	760	BX	1009	AU	1258	BX	1507	BU	1756	CU	2005	CU
14	9	263	9	512	9	761	9	1010	9	1259	9	1508	9	1757	9	2006	9
15	V	264	AV	513	AV	762	BV	1011	AV	1260	BV	1509	BV	1758	CV	2007	CV
16	9	265	9	514	9	763	9	1012	9	1261	9	1510	9	1759	9	2008	9
17	N	266	AN	515	AQ	764	BN	1013	AQ	1262	BN	1511	BQ	1760	CN	2009	CN
18	9	267	9	516	9	765	9	1014	9	1263	9	1512	9	1761	9	2010	9
19	NT	268	ANT	517	AQW	766	BNT	1015	AQW	1264	BNT	1513	BQW	1762	CNT	2011	CNT
20	9	269	9	518	9	767	9	1016	9	1265	9	1514	9	1763	9	2012	9
21	NW	270	ANW	519	AQT	768	BNW	1017	AQY	1266	BNY	1515	BQT	1764	CNW	2013	CNW
22	9	271	9	520	9	769	9	1018	9	1267	9	1516	9	1765	9	2014	9
23	NU	272	ANU	521	AQU	770	BNU	1019	AQZ	1268	BNX	1517	BQX	1766	CNU	2015	CNU
24	9	273	9	522	9	771	9	1020	9	1269	9	1518	9	1767	9	2016	9
25	NW	274	ANW	523	AQY	772	BNY	1021	AQT	1270	BNW	1519	BQT	1768	CNW	2017	CNW
26	9	275	9	524	9	773	9	1022	9	1271	9	1520	9	1769	9	2018	9
27	NU	276	ANU	525	AQZ	774	BNX	1023	AQU	1272	BNU	1521	BQX	1770	CNU	2019	CNU
28	9	277	9	526	9	775	9	1024	9	1273	9	1522	9	1771	9	2020	9
29	NX	278	ANX	527	AQX	776	BNZ	1025	AQX	1274	BNZ	1523	BQU	1772	CNX	2021	CNX
30	9	279	9	528	9	777	9	1026	9	1275	9	1524	9	1773	9	2022	9
31	NV	280	ANV	529	AQV	778	BNV	1027	AQV	1276	BNV	1525	BQV	1774	CNV	2023	CNV
32	9	281	9	530	9	779	9	1028	9	1277	9	1526	9	1775	9	2024	9
33	N	282	AQ	531	AN	780	BN	1029	AQ	1278	BQ	1527	BN	1776	CN	2025	CN
34	9	283	9	532	9	781	9	1030	9	1279	9	1528	9	1777	9	2026	9
35	NW	284	AQT	533	ANW	782	BNW	1031	AQY	1280	BQT	1529	BNY	1778	CNW	2027	CNW
36	9	285	9	534	9	783	9	1032	9	1281	9	1530	9	1779	9	2028	9
37	NT	286	AQW	535	ANT	784	BNT	1033	AQW	1282	BQW	1531	BNT	1780	CNT	2029	CNT
38	9	287	9	536	9	785	9	1034	9	1283	9	1532	9	1781	9	2030	9
39	NU	288	AQU	537	ANU	786	BNU	1035	AQZ	1284	BQX	1533	BNX	1782	CNU	2031	CNU
40	9	289	9	538	9	787	9	1036	9	1285	9	1534	9	1783	9	2032	9
41	NW	290	AQY	539	ANW	788	BNY	1037	AQT	1286	BQT	1535	BNW	1784	CNW	2033	CNW
42	9	291	9	540	9	789	9	1038	9	1287	9	1536	9	1785	9	2034	9
43	NX	292	AQX	541	ANX	790	BNZ	1039	AQX	1288	BQU	1537	BNZ	1786	CNX	2035	CNX
44	9	293	9	542	9	791	9	1040	9	1289	9	1538	9	1787	9	2036	9
45	NU	294	AQZ	543	ANU	792	BNX	1041	AQU	1290	BQX	1539	BNU	1788	CNU	2037	CNU
46	9	295	9	544	9	793	9	1042	9	1291	9	1540	9	1789	9	2038	9
47	NV	296	AQV	545	ANV	794	BNV	1043	AQV	1292	BQV	1541	BNV	1790	CNV	2039	CNV
48	9	297	9	546	9	795	9	1044	9	1293	9	1542	9	1791	9	2040	9
49	O	298	AO	547	AO	796	BO	1045	AR	1294	BR	1543	BR	1792	CO	2041	CO
50	9	299	9	548	9	797	9	1046	9	1295	9	1544	9	1793	9	2042	9
51	OT	300	AOT	549	AOW	798	BOT	1047	ARW	1296	BRT	1545	BRY	1794	COT	2043	COT
52	9	301	9	550	9	799	9	1048	9	1297	9	1546	9	1795	9	2044	9
53	OT	302	AOW	551	AOT	800	BOT	1049	ARW	1298	BRY	1547	BRT	1796	COT	2045	COT
54	9	303	9	552	9	801	9	1050	9	1299	9	1548	9	1797	9	2046	9
55	OU	304	AOU	553	AOU	802	BOU	1051	ARX	1300	BRX	1549	BRX	1798	COU	2047	COU
56	9	305	9	554	9	803	9	1052	9	1301	9	1550	9	1799	9	2048	9
57	OW	306	AOY	555	AOY	804	BOW	1053	ART	1302	BRW	1551	BRW	1800	COW	2049	COW
58	9	307	9	556	9	805	9	1054	9	1303	9	1552	9	1801	9	2050	9
59	OX	308	AOX	557	AOZ	806	BOX	1055	ARU	1304	BRU	1553	BRZ	1802	COX	2051	COX
60	9	309	9	558	9	807	9	1056	9	1305	9	1554	9	1803	9	2052	9
61	OX	310	AOZ	559	AOX	808	BOX	1057	ARU	1306	BRZ	1555	BRU	1804	COX	2053	COX
62	9	311	9	560	9	809	9	1058	9	1307	9	1556	9	1805	9	2054	9
63	OV	312	AOV	561	AOV	810	BOV	1059	ARV	1308	BRV	1557	BRV	1806	COV	2055	COV
64	9	313	9	562	9	811	9	1060	9	1309	9	1558	9	1807	9	2056	9
65	N	314	AQ	563	AQ	812	BQ	1061	AN	1310	BN	1559	BN	1808	CN	2057	CN
66	9	315	9	564	9	813	9	1062	9	1311	9	1560	9	1809	9	2058	9
67	NW	316	AQT	565	AQY	814	BQT	1063	ANW	1312	BNW	1561	BNY	1810	CNW	2059	CNW
68	9	317	9	566	9	815	9	1064	9	1313	9	1562	9	1811	9	2060	9
69	NW	318	AQY	567	AQT	816	BQT	1065	ANW	1314	BNY	1563	BNW	1812	CNW	2061	CNW
70	9	319	9	568	9	817	9	1066	9	1315	9	1564	9	1813	9	2062	9
71	NX	320	AQX	569	AQX	818	BQU	1067	ANX	1316	BNZ	1565	BNZ	1814	CNX	2063	CNX
72	9	321	9	570	9	819	9	1068	9	1317	9	1566	9	1815	9	2064	9
73	NT	322	AQW	571	AQW	820	BQW	1069	ANT	1318	BNT	1567	BNT	1816	CNT	2065	CNT
74	9	323	9	572	9	821	9	1070	9	1319	9	1568	9	1817	9	2066	9
75	NU	324	AQU	573	AQZ	822	BQX	1071	ANU	1320	BNU	1569	BNX	1818	CNU	2067	CNU
76	9	325	9	574	9	823	9	1072	9	1321	9	1570	9	1819	9	2068	9
77	NU	326	AQZ	575	AQU	824	BQX	1073	ANU	1322	BNX	1571	BNU	1820	CNU	2069	CNU
78	9	327	9	576	9	825	9	1074	9	1323	9	1572	9	1821	9	2070	9
79	NV	328	AQV	577	AQV	826	BQV	1075	ANV	1324	BNV	1573	BNV	1822	CNV	2071	CNV
80	9	329	9	578	9	827	9	1076	9	1325	9	1574	9	1823	9	2072	9
81	O	330	AO	579	AR	828	BR	1077	AO	1326	BO	1575	BR	1824	CO	2073	CO
82	9	331	9	580	9	829	9	1078	9	1327	9	1576	9	1825	9	2074	9
83	OT	332	AOT	581	ARW	830	BRT	1079	AOW	1328	BOT	1577	BRY	1826	COT	2075	COT
84	9	333	9	582	9	831	9	1080	9	1329	9	1578	9	1827	9	2076	9
85	OW	334	AOY	583	ART	832	BRW	1081	AOY	1330	BQW	1579	BRW	1828	COW	2077	COW

FIGURE 4-6 (Sheet 3 of 5)

CAUTION: PRELIMINARY RESULTS
IMPORTANT UNCERTAINTIES
DESCRIBED IN SECTION 2

SEQ. NO.	END STATE	SEQ. NO.	END STATE	SEQ. NO.	END STATE	SEQ. NO.	END STATE	SEQ. NO.	END STATE	SEQ. NO.	END STATE	SEQ. NO.	END STATE	SEQ. NO.	END STATE	SEQ. NO.	END STATE
86	9	335	9	584	9	833	9	1082	9	1331	9	1580	9	1829	9	2078	9
87	OX	336	AOX	585	ARU	834	BRU	1083	AOZ	1332	BOX	1581	BRZ	1830	COX	2079	COX
88	9	337	9	586	9	835	9	1084	9	1333	9	1582	9	1831	9	2080	9
89	OT	338	AOW	587	ARW	836	BRY	1085	AOT	1334	BOT	1583	BRT	1832	COT	2081	COT
90	9	339	9	588	9	837	9	1086	9	1335	9	1584	9	1833	9	2082	9
91	OU	340	AOU	589	ARX	838	BRX	1087	AOU	1336	BOU	1585	BRX	1834	COU	2083	COU
92	9	341	9	590	9	839	9	1088	9	1337	9	1586	9	1835	9	2084	9
93	OX	342	AOZ	591	ARU	840	BRZ	1089	AOX	1338	BOX	1587	BRU	1836	COX	2085	COX
94	9	343	9	592	9	841	9	1090	9	1339	9	1588	9	1837	9	2086	9
95	OV	344	AOV	593	ARV	842	BRV	1091	AOV	1340	BOV	1589	BRV	1838	COV	2087	COV
96	9	345	9	594	9	843	9	1092	9	1341	9	1590	9	1839	9	2088	9
97	O	346	AR	595	AO	844	BR	1093	AO	1342	BR	1591	BO	1840	CO	2089	CO
98	9	347	9	596	9	845	9	1094	9	1343	9	1592	9	1841	9	2090	9
99	OW	348	ART	597	AOY	846	BRW	1095	AOY	1344	BRW	1593	OW	1842	COW	2091	COW
100	9	349	9	598	9	847	9	1096	9	1345	9	1594	9	1843	9	2092	9
101	OT	350	ARW	599	AOT	848	BRT	1097	AOW	1346	BRY	1595	BOT	1844	COT	2093	COT
102	9	351	9	600	9	849	9	1098	9	1347	9	1596	9	1845	9	2094	9
103	OX	352	ARU	601	AOX	850	BRU	1099	AOZ	1348	BRZ	1597	BOX	1846	COX	2095	COX
104	9	353	9	602	9	851	9	1100	9	1349	9	1598	9	1847	9	2096	9
105	OT	354	ARW	603	AOW	852	BRY	1101	AOT	1350	BRT	1599	BOT	1848	COT	2097	COT
106	9	355	9	604	9	853	9	1102	9	1351	9	1600	9	1849	9	2098	9
107	OX	356	ARU	605	AOZ	854	BRZ	1103	AOX	1352	BRU	1601	BOX	1850	COX	2099	COX
108	9	357	9	606	9	855	9	1104	9	1353	9	1602	9	1851	9	2100	9
109	OU	358	ARX	607	[illegible]	856	BRX	1105	AOU	1354	BRX	1603	BOU	1852	COU	2101	COU
110	9	359	9	608	9	857	9	1106	9	1355	9	1604	9	1853	9	2102	9
111	OV	360	ARV	609	AOV	858	BRV	1107	AOV	1356	BRV	1605	BOV	1854	COV	2103	COV
112	9	361	9	610	9	859	9	1108	9	1357	9	1606	9	1855	9	2104	9
113	P	362	AP	611	AP	860	BP	1109	AP	1358	BP	1607	BP	1856	CP	2105	CP
114	9	363	9	612	9	861	9	1110	9	1359	9	1608	9	1857	9	2106	9
115	PT	364	APT	613	APW	862	BPT	1111	APW	1360	BPT	1609	BPW	1858	CPT	2107	CPT
116	9	365	9	614	9	863	9	1112	9	1361	9	1610	9	1859	9	2108	9
117	PT	366	APW	615	APT	864	BPT	1113	APW	1362	BPW	1611	BPT	1860	CPT	2109	CPT
118	9	367	9	616	9	865	9	1114	9	1363	9	1612	9	1861	9	2110	9
119	PU	368	APU	617	APU	866	BPU	1115	APX	1364	BPX	1613	BPX	1862	CPU	2111	CPU
120	9	369	9	618	9	867	9	1116	9	1365	9	1614	9	1863	9	2112	9
121	PT	370	APW	619	APW	868	BPW	1117	APT	1366	BPT	1615	BPT	1864	CPT	2113	CPT
122	9	371	9	620	9	869	9	1118	9	1367	9	1616	9	1865	9	2114	9
123	PU	372	APU	621	APX	870	BPX	1119	APU	1368	BPU	1617	BPX	1866	CPU	2115	CPU
124	9	373	9	622	9	871	9	1120	9	1369	9	1618	9	1867	9	2116	9
125	PU	374	APX	623	APU	872	BPX	1121	APU	1370	BPX	1619	BPU	1868	CPU	2117	CPU
126	9	375	9	624	9	873	9	1122	9	1371	9	1620	9	1869	9	2118	9
127	PV	376	APV	625	APV	874	BPV	1123	APV	1372	BPV	1621	BPV	1870	CPV	2119	CPV
128	9	377	9	626	9	875	9	1124	9	1373	9	1622	9	1871	9	2120	9
129	I	378	AI	627	AJ	876	BI	1125	AJ	1374	BI	1623	BJ	1872	CI	2121	CI
130	9	379	9	628	9	877	9	1126	9	1375	9	1624	9	1873	9	2122	9
131	IU	380	AIU	629	AJU	878	BIU	1127	AJX	1376	BIX	1625	BJX	1874	CIU	2123	CIU
132	9	381	9	630	9	879	9	1128	9	1377	9	1626	9	1875	9	2124	9
133	IU	382	AIU	631	AJX	880	BIX	1129	AJU	1378	BIU	1627	BJX	1876	CIU	2125	CIU
134	9	383	9	632	9	881	9	1130	9	1379	9	1628	9	1877	9	2126	9
135	IV	384	AIV	633	AJV	882	BIV	1131	AJV	1380	BIV	1629	BJV	1878	CIV	2127	CIV
136	9	385	9	634	9	883	9	1132	9	1381	9	1630	9	1879	9	2128	9
137	IO	386	AIO	635	AJO	884	BIO	1133	AJR	1382	BIR	1631	BJR	1880	CIO	2129	CIO
138	9	387	9	636	9	885	9	1134	9	1383	9	16 2	9	1881	9	2130	9
139	IOU	388	AIOU	637	AJOU	886	BIOU	1135	AJRX	1384	BIRX	1633	BJRX	1882	CIOU	2131	CIOU
140	9	389	9	638	9	887	9	1136	9	1385	9	1634	9	1883	9	2132	9
141	IOX	390	AIOX	639	AJOX	888	BIOX	1137	AJRU	1386	BIRU	1635	BJRZ	1884	CIOX	2133	CIOX
142	9	391	9	640	9	889	9	1138	9	1387	9	1636	9	1885	9	2134	9
143	IOV	392	AIOV	641	AJOV	890	[illegible]	1139	AJRV	1388	BIRV	1637	BJRV	1886	CIOV	2135	CIOV
144	9	393	9	642	9	891	9	1140	9	1389	9	1638	9	1887	9	2136	9
145	IO	394	AIO	643	AJR	892	BIR	1141	AJO	1390	BIO	1639	BJR	1888	CIO	2137	CIO
146	9	395	9	644	9	893	9	1142	9	1391	9	1640	9	1889	9	2138	9
147	IOX	396	AIOX	645	AJRU	894	BIRU	1143	AJOX	1392	BIOX	1641	BJRZ	1890	CIOX	2139	CIOX
148	9	397	9	646	9	895	9	1144	9	1393	9	1642	9	1891	9	2140	9
149	IOU	398	AIOU	647	AJRX	896	BIRX	1145	AJOU	1394	BIOU	1643	BJRX	1892	CIOU	2141	CIOU
150	9	399	9	648	9	897	9	1146	9	1395	9	1644	9	1893	9	2142	9
151	IOV	400	AIOV	649	AJRV	898	[illegible]	1147	AJOV	1396	BIOV	1645	BJRV	1894	CIOV	2143	CIOV
152	9	401	9	650	9	899	9	1148	9	1397	9	1646	9	1895	9	2144	9
153	IP	402	AIP	651	AJP	900	BIP	1149	AJP	1398	BIP	1647	BJP	1896	CIP	2145	CIP
154	9	403	9	652	9	901	9	1150	9	1399	9	1648	9	1897	9	2146	9
155	IPU	404	AIPU	653	AJPU	902	BIPU	1151	AJPX	1400	BIPX	1649	BJPX	1898	CIPU	2147	CIPU
156	9	405	9	654	9	903	9	1152	9	1401	9	1650	9	1899	9	2148	9
157	IPU	406	AIPU	655	AJPX	904	BIPX	1153	AJPU	1402	BIPU	1651	BJPX	1900	CIPU	2149	CIPU
158	9	407	9	656	9	905	9	1154	9	1403	9	1652	9	1901	9	2150	9
159	IPV	408	AIPV	657	AJPV	906	BIPV	1155	AJPV	1404	BIPV	1653	BJPV	1902	CIPV	2151	CIPV
160	9	409	9	658	9	907	9	1156	9	1405	9	1654	9	1903	9	2152	9
161	I	410	AJ	659	AI	908	BI	1157	AJ	1406	BJ	1655	BI	1904	CI	2153	CI
162	9	411	9	660	9	909	9	1158	9	1407	9	1656	9	1905	9	2154	9
163	IU	412	AJU	661	AIU	910	BIU	1159	AJX	1408	BJX	1657	BIX	1906	CIU	2155	CIU
164	9	413	9	662	9	911	9	1160	9	1409	9	1658	9	1907	9	2156	9
165	IU	414	AJX	663	AIU	912	BIX	1161	AJU	1410	BJX	1659	BIU	1908	CIU	2157	CIU
166	9	415	9	664	9	913	9	1162	9	1411	9	1660	9	1909	9	2158	9
167	IV	416	AJV	665	AIV	914	BIV	1163	AJV	1412	BJV	1661	BIV	1910	CIV	2159	CIV
168	9	417	9	666	9	915	9	1164	9	1413	9	1662	9	1911	9	2160	9
169	IO	418	AJO	667	AIO	916	BIO	1165	AJR	1414	BJR	1663	BIR	1912	CIO	2161	CIO
170	9	419	9	668	9	917	9	1166	9	1415	9	1664	9	1913	9	216[illegible]	9

FIGURE 4-6 (Sheet 4 of 5)

CAUTION: PRELIMINARY RESULTS IMPORTANT UNCERTAINTIES DESCRIBED IN SECTION 2

SEQ. NO.	END STATE	SEQ. NO.	END STATE	SEQ. NO.	END STATE	SEQ. NO.	END STATE	SEQ. NU.	END STATE	SEQ. NO.	END STATE	SEQ. NO.	END STATE	SEQ. NO.	END STATE	SEQ. NO.	END STATE
171	IOU	420	AJOU	669	AIOU	918	BIOU	1167	AJRX	1416	BJRX	1665	BIRX	1914	CIOU	2163	CIOU
172	9	421	9	670	9	919	9	1168	9	1417	9	1666	9	1915	9	2164	9
173	IOX	422	AJOX	671	AIOX	920	BIOX	1169	AJRU	1418	BJRZ	1667	BIRU	1916	CIOX	2165	CIOX
174	9	423	9	672	9	921	9	1170	9	1419	9	1668	9	1917	9	2166	9
175	IOV	424	AJOV	673	AIOV	922	BIOV	1171	AJRV	1420	BJRV	1669	BIRV	1918	CIOV	2167	CIOV
176	9	425	9	674	9	923	9	1172	9	1421	9	1670	9	1919	9	2168	9
177	IO	426	AJR	675	AIO	924	BIR	1173	AJO	1422	BJR	1671	BIO	1920	CIO	2169	CIO
178	9	427	9	676	9	925	9	1174	9	1423	9	1672	9	1921	9	2170	9
179	IOX	428	AJRU	677	AIOX	926	BIRU	1175	AJOX	1424	BJRZ	1673	BIOX	1922	CIOX	2171	CIOX
180	9	429	9	678	9	927	9	1176	9	1425	9	1674	9	1923	9	2172	9
181	IOU	430	AJRX	679	AIOU	928	BIRX	1177	AJOU	1426	BJRX	1675	BIOU	1924	CIOU	2173	CIOU
182	9	431	9	680	9	929	9	1178	9	1427	9	1676	9	1925	9	2174	9
183	IOV	432	AJRV	681	AIOV	930	BIRV	1179	AJOV	1428	BJRV	1677	BIOV	1926	CIOV	2175	CIOV
184	9	433	9	682	9	931	9	1180	9	1429	9	1678	9	1927	9	2176	9
185	IP	434	AJP	683	AIP	932	BIP	1181	AJP	1430	BJP	1679	BIP	1928	CIP	2177	CIP
186	9	435	9	684	9	933	9	1182	9	1431	9	1680	9	1929	9	2178	9
187	IPU	436	AJPU	685	AIPU	934	BIPU	1183	AJPX	1432	BJPX	1681	BIPX	1930	CIPU	2179	CIPU
188	9	437	9	686	9	935	9	1184	9	1433	9	1682	9	1931	9	2180	9
189	IPU	438	AJPX	687	AIPU	936	BIPX	1185	AJPU	1434	BJPX	1683	BIPU	1932	CIPU	2181	CIPU
190	9	439	9	688	9	937	9	1186	9	1435	9	1684	9	1933	9	2182	9
191	IPV	440	AJPV	689	AIPV	938	BIPV	1187	AJPV	1436	BJPV	1685	BIPV	1934	CIPV	2183	CIPV
192	9	441	9	690	9	939	9	1188	9	1437	9	1686	9	1935	9	2184	[illegible]
193	K	442	AK	691	AK	940	BK	1189	AL	1438	BL	1687	BL	1936	CK	2185	CK
194	9	443	9	692	9	941	9	1190	9	1439	9	1688	9	1937	9	2186	9
195	KV	444	AKV	693	AKV	942	BKV	1191	ALV	1440	BLV	1689	BLV	1938	CKV	2187	CKV
196	9	445	9	694	9	943	9	1192	9	1441	9	1690	9	1939	9	2188	9
197	KP	446	AKP	695	AKP	944	BKP	1193	ALP	1442	BLP	1691	BLP	1940	CKP	2189	CKP
198	9	447	9	696	9	945	9	1194	9	1443	9	1692	9	1941	9	2190	9
199	KPV	448	AKPV	697	AKPV	946	BKPV	1195	ALPV	1444	BLPV	1693	BLPV	1942	CKPV	2191	CKPV
200	9	449	9	698	9	947	9	1196	9	1445	9	1694	9	1943	9	2192	9
201	I	450	AJ	699	AJ	948	BJ	1197	AI	1446	BI	1695	BI	1944	CI	2193	CI
202	9	451	9	700	9	949	9	1198	9	1447	9	1696	9	1945	9	2194	9
203	IU	452	AJU	701	AJX	950	BJX	1199	AIU	1448	BIU	1697	BIX	1946	CIU	2195	CIU
204	9	453	9	702	9	951	9	1200	9	1449	9	1698	9	1947	9	2196	9
205	IU	454	AJX	703	AJU	952	BJX	1201	AIU	1450	BIX	1699	BIU	1948	CIU	2197	CIU
206	9	455	9	704	9	953	9	1202	9	1451	9	1700	9	1949	9	2198	9
207	IV	456	AJV	705	AJV	954	BJV	1203	AIV	1452	BIV	1701	BIV	1950	CIV	2199	CIV
208	9	457	9	706	9	955	9	1204	9	1453	9	1702	9	1951	9	2200	9
209	IO	458	AJO	707	AJR	956	BJR	1205	AIO	1454	BIO	1703	BIR	1952	CIO	2201	CIO
210	9	459	9	708	9	957	9	1206	9	1455	9	1704	9	1953	9	2202	9
211	IOU	460	AJOU	709	AJRX	958	BJRX	1207	AIOU	1456	BIOU	1705	BIRX	1954	CIOU	2203	CIOU
212	9	461	9	710	9	959	9	1208	9	1457	9	1706	9	1955	9	2204	9
213	IOX	462	AJOX	711	AJRU	960	BJRZ	1209	AIOX	1458	BIOX	1707	BIRU	1956	CIOX	2205	CIOX
214	9	463	9	712	9	961	9	1210	9	1459	9	1708	9	1957	9	2206	9
215	IOV	464	AJOV	713	AJRV	962	BJRV	1211	AIOV	1460	BIOV	1709	BIRV	1958	CIOV	2207	CIOV
216	9	465	9	714	9	963	9	1212	9	1461	9	1710	9	1959	9	2208	9
217	IO	466	AJR	715	AJO	964	BJR	1213	AIO	1462	BIR	1711	BIO	1960	CIO	2209	CIO
218	9	467	9	716	9	965	9	1214	9	1463	9	1712	9	1961	9	2210	9
219	IOX	468	AJRU	717	AJOX	966	BJRZ	1215	AIOX	1464	BIRU	1713	BIOX	1962	CIOX	2211	CIOX
220	9	469	9	718	9	967	9	1216	9	1465	9	1714	9	1963	9	2212	9
221	IOU	470	AJRX	719	AJOU	968	BJRX	1217	AIOU	1466	BIRX	1715	BIOU	1964	CIOU	2213	CIOU
222	9	471	9	720	9	969	9	1218	9	1467	9	1716	9	1965	9	2214	9
223	IOV	472	AJRV	721	AJOV	970	BJRV	1219	AIOU	1468	BIRV	1717	BIOV	1966	CIOV	2215	CIOV
224	9	473	9	722	9	971	9	1220	9	1469	9	17[illegible]	9	1967	9	2216	9
225	IP	474	AJP	723	AJP	972	BJP	1221	AIP	1470	BIP	17[illegible]	BIP	1968	CIP	2217	CIP
226	9	475	9	724	9	973	9	1222	9	1471	9	1720	9	1969	9	2218	9
227	IPU	476	AJPU	725	AJPX	774	BJPX	1223	AIPU	1472	BIPU	1721	BIPX	1970	CIPU	2219	CIPU
228	9	477	9	726	9	975	9	1224	9	1473	9	1722	9	1971	9	2220	9
229	IPU	478	AJPX	727	AJPU	976	BJPX	1225	AIPU	1474	BIPX	1723	BIPU	1972	CIPU	2221	CIPU
230	9	479	9	728	9	977	9	1226	9	1475	9	1724	9	1973	9	2222	9
231	IPV	480	AJPV	729	AJPV	978	BJPV	1227	AIPV	1476	BIPV	1725	BIPV	1974	CIPV	2223	CIPV
232	9	481	9	730	9	979	9	1228	9	1477	9	1726	9	1975	9	2224	9
233	K	482	AK	731	AL	980	BL	1229	AK	1478	BK	1727	BL	1976	CK	2225	CK
234	9	483	9	732	9	981	9	1230	9	1479	9	1728	9	1977	9	2226	9
235	KV	484	AKV	733	ALV	982	BLV	1231	AKV	1480	BKV	1729	BLV	1978	CKV	2227	CKV
236	9	485	9	734	9	983	9	1232	9	1481	9	1730	9	1979	9	2228	9
237	KP	486	AKP	735	ALP	984	BLP	1233	AKP	1482	BKP	1731	BLP	1980	CKP	2229	CKP
238	9	487	9	736	9	985	9	1234	9	1483	9	1732	9	1981	9	2230	9
239	KPV	488	AKPV	737	ALPV	986	BLPV	1235	AKPV	1484	BKPV	1733	BLPV	1982	CKPV	2231	CKPV
240	9	489	9	738	9	987	9	1236	9	1485	9	1734	9	1983	9	2232	9
241	K	490	AL	739	AK	988	BL	1237	AK	1486	BL	1735	BK	1984	CK	2233	CK
242	9	491	9	740	9	989	9	1238	9	1487	9	1736	9	1985	9	2234	9
243	KV	492	ALV	741	AKV	990	BLV	1239	AKV	1488	BLV	1737	BKV	1986	CKV	2235	CKV
244	9	493	9	742	9	991	9	1240	9	1489	9	1738	9	1987	9	2236	9
245	KP	494	ALP	743	AKP	992	BLP	1241	AKP	1490	BLP	1739	BKP	1988	CKP	2237	CKP
246	9	495	9	744	9	993	9	1242	9	1491	9	1740	9	1989	9	2238	9
247	KPV	496	ALPV	745	AKPV	994	BLPV	1243	AKPV	1492	BLPV	1741	BKPV	1990	CKPV	2239	CKPV
248	9	497	9	746	9	995	9	1244	9	1493	9	1742	9	1991	9	2240	9
249	M	498	AM	747	AM	996	BM	1245	AM	1494	BM	1743	BM	1992	CM	2241	CM

FIGURE 4-6 (Sheet 5 of 5)

**CAUTION: PRELIMINARY RESULTS-
IMPORTANT UNCERTAINTIES
DESCRIBED IN SECTION 2**

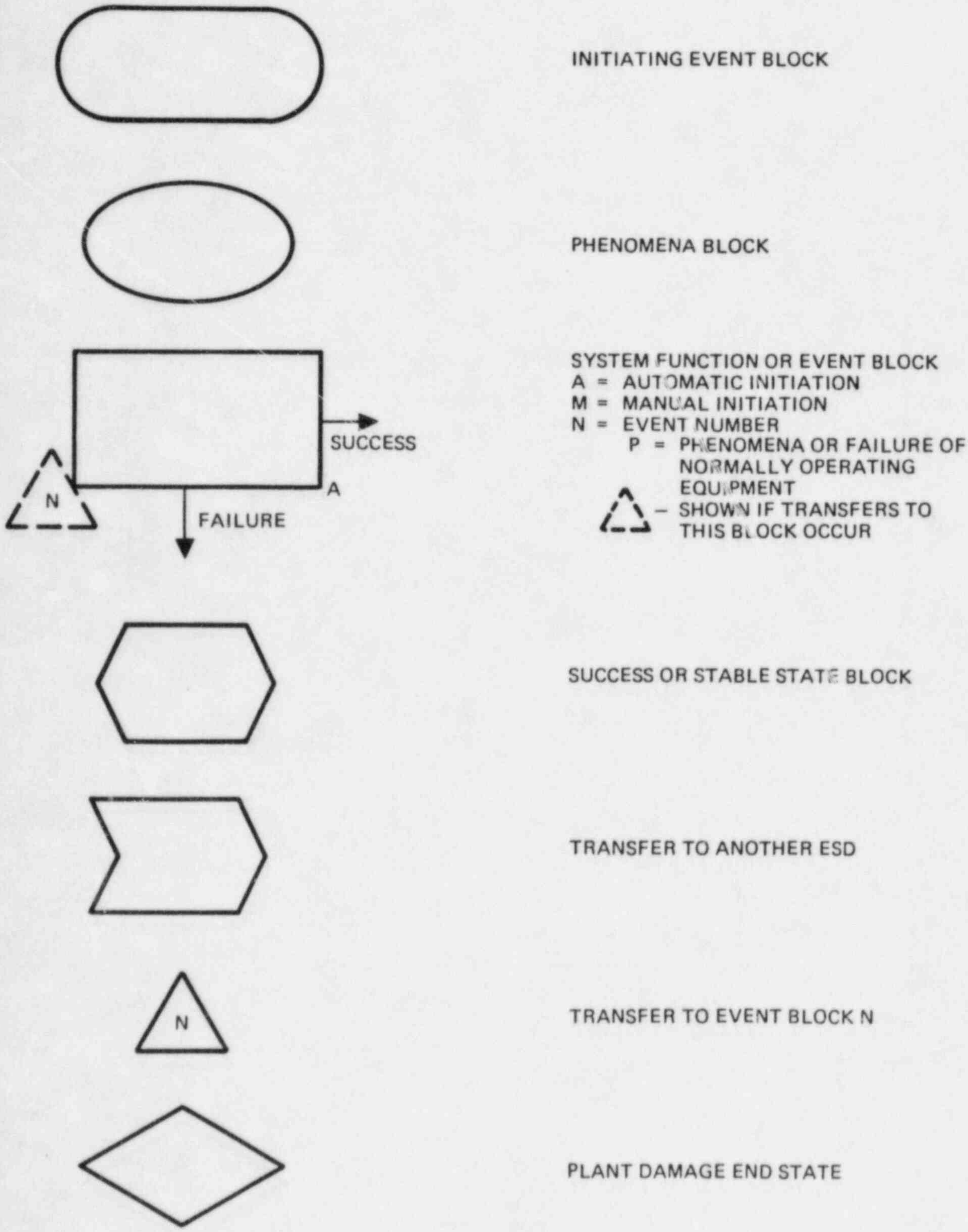
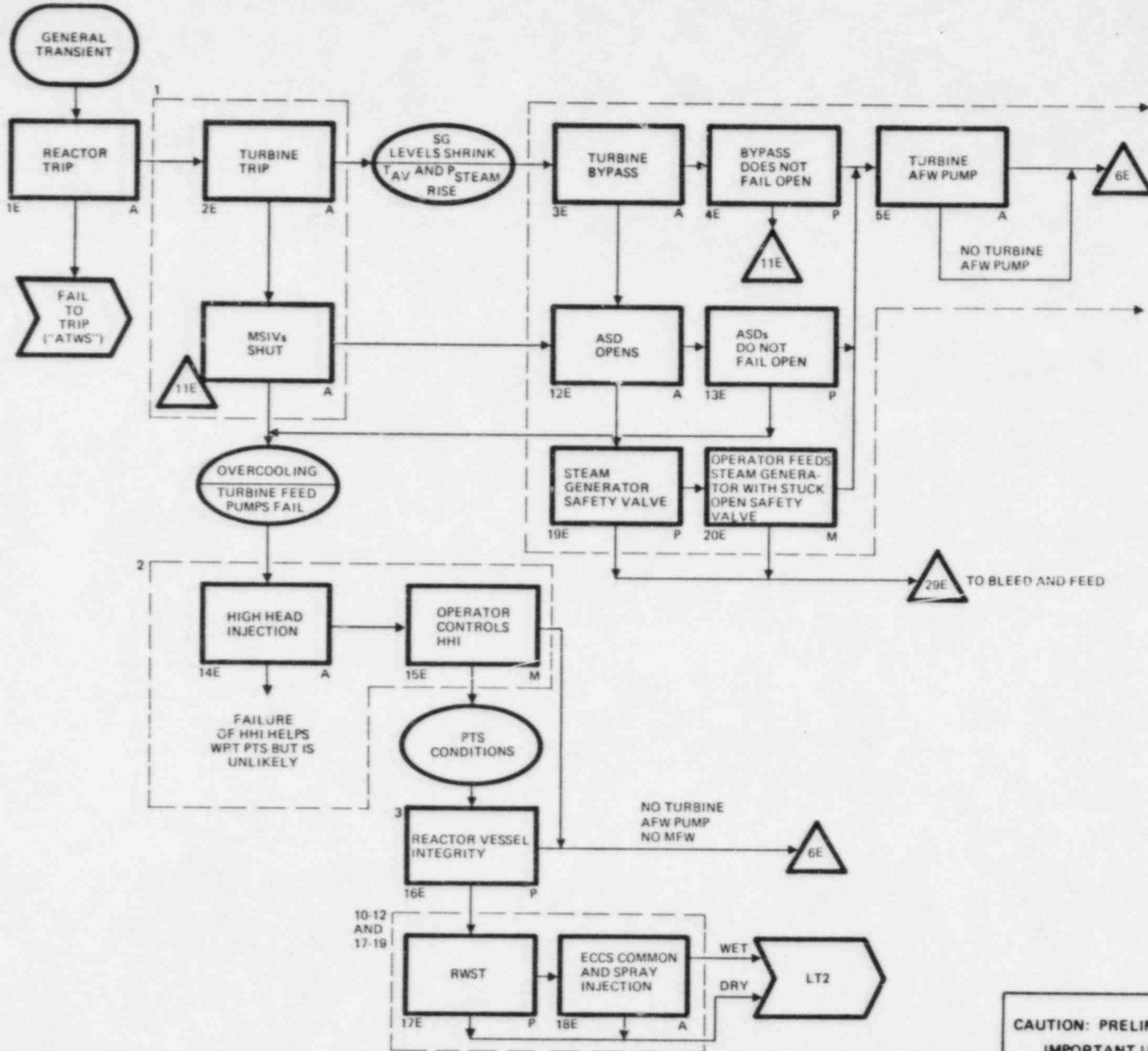


FIGURE 4-7. EVENT SEQUENCE DIAGRAM SYMBOLOGY



CAUTION: PRELIMINARY RESULTS-
IMPORTANT UNCERTAINTIES
DESCRIBED IN SECTION 2

FIGURE 4.9. GENERAL TRANSIENT EVENT SEQUENCE DIAGRAM

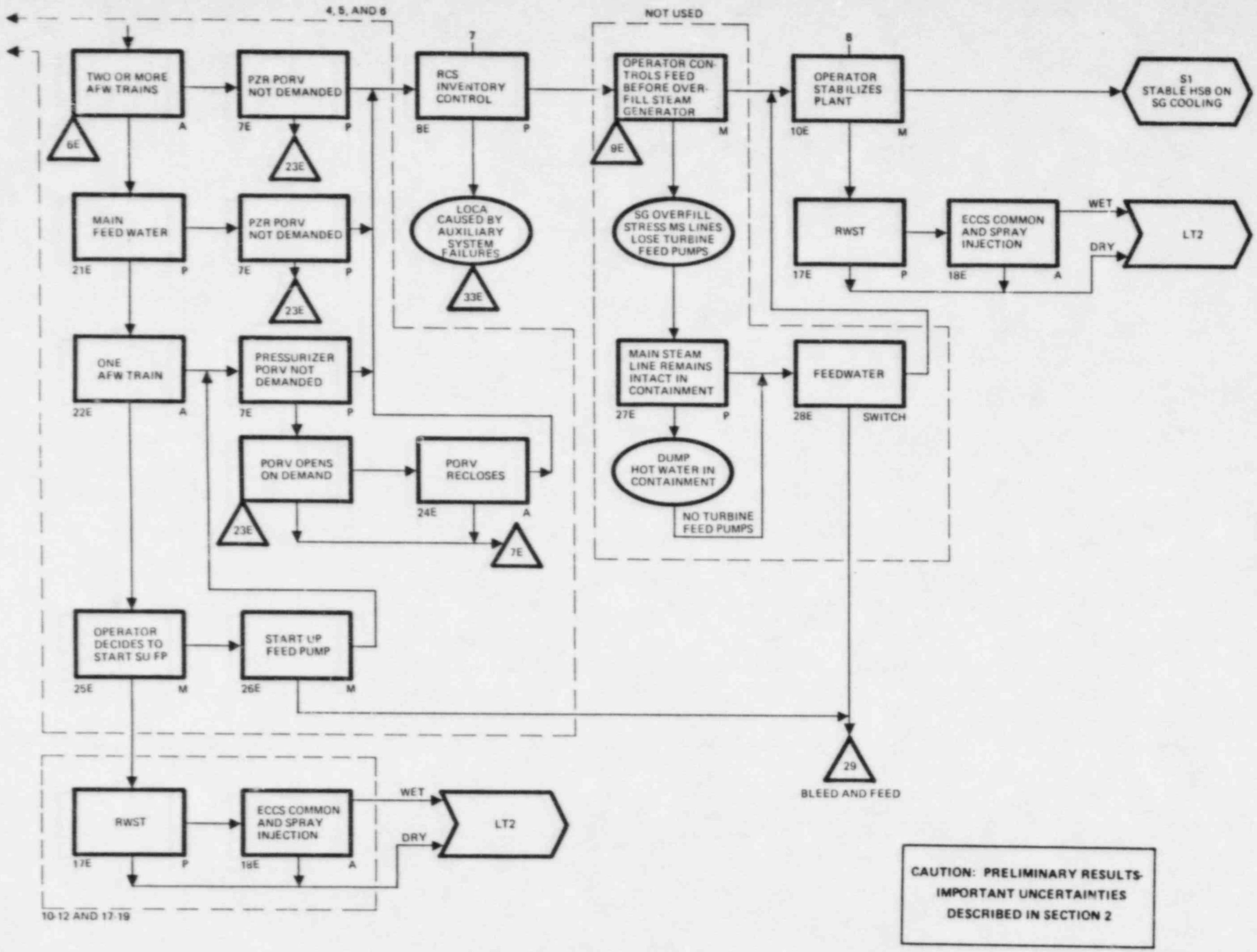
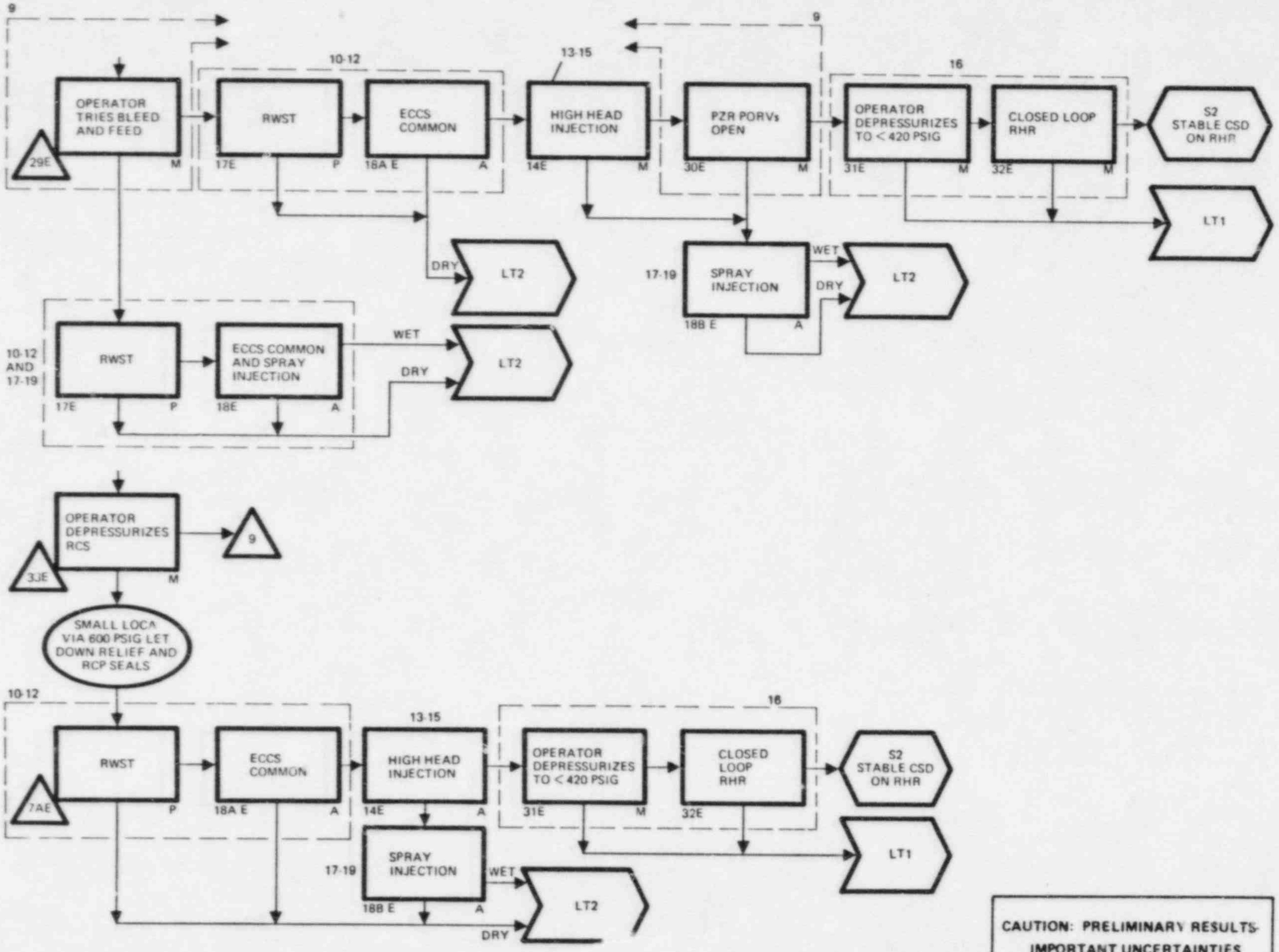
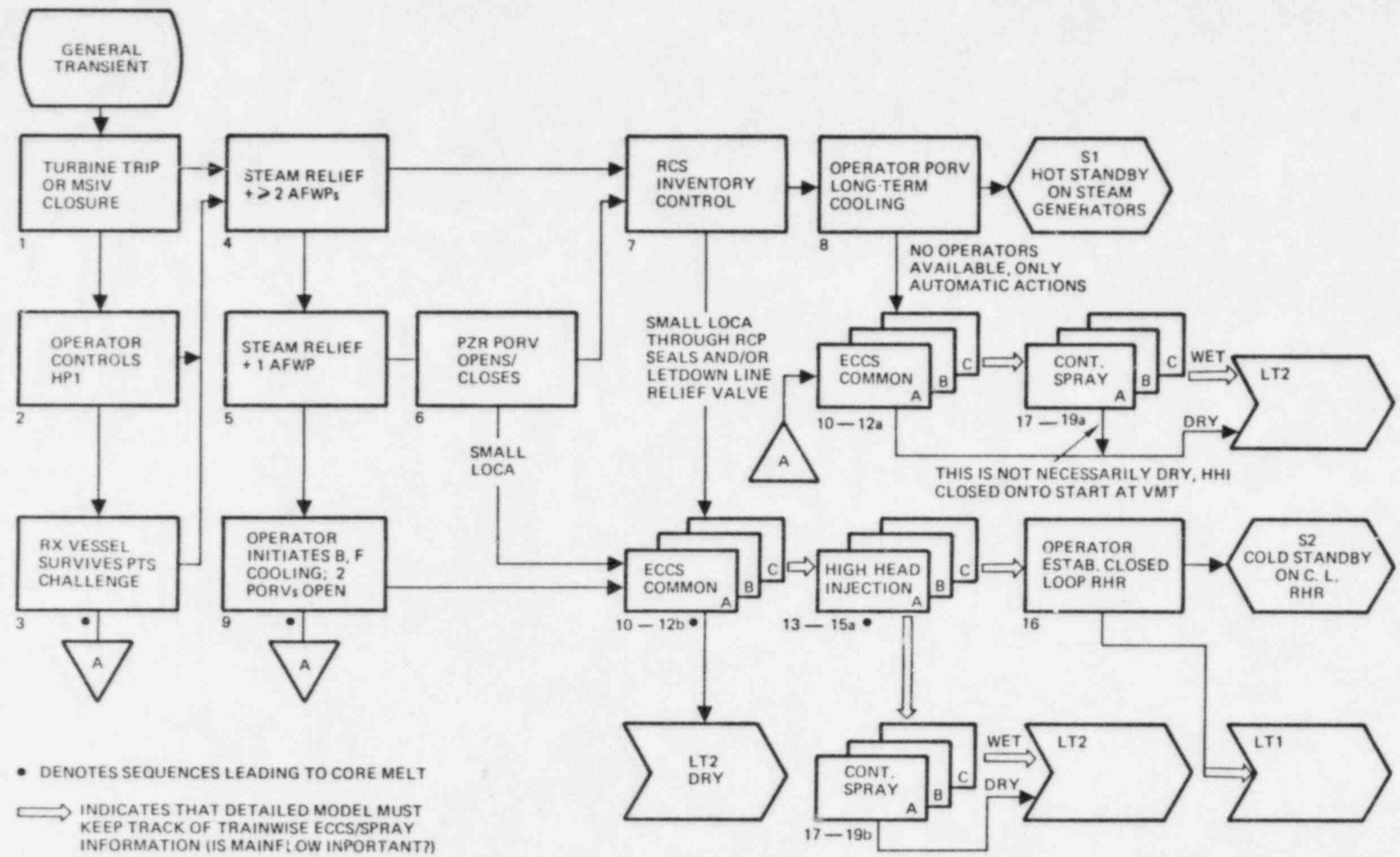


FIGURE 4-8 (Sheet 2 of 3)



CAUTION: PRELIMINARY RESULTS-IMPORTANT UNCERTAINTIES DESCRIBED IN SECTION 2

FIGURE 4-8 (Sheet 3 of 3)



CAUTION: PRELIMINARY RESULTS- IMPORTANT UNCERTAINTIES DESCRIBED IN SECTION 2

FIGURE 4-9. SIMPLIFIED GENERAL TRANSIENT ESD USING ONLY THE EVENT TREE TOP EVENTS

LEGEND:
GF GUARANTEED FAILURE
GS GUARANTEED SUCCESS
NN NOT NECESSARY

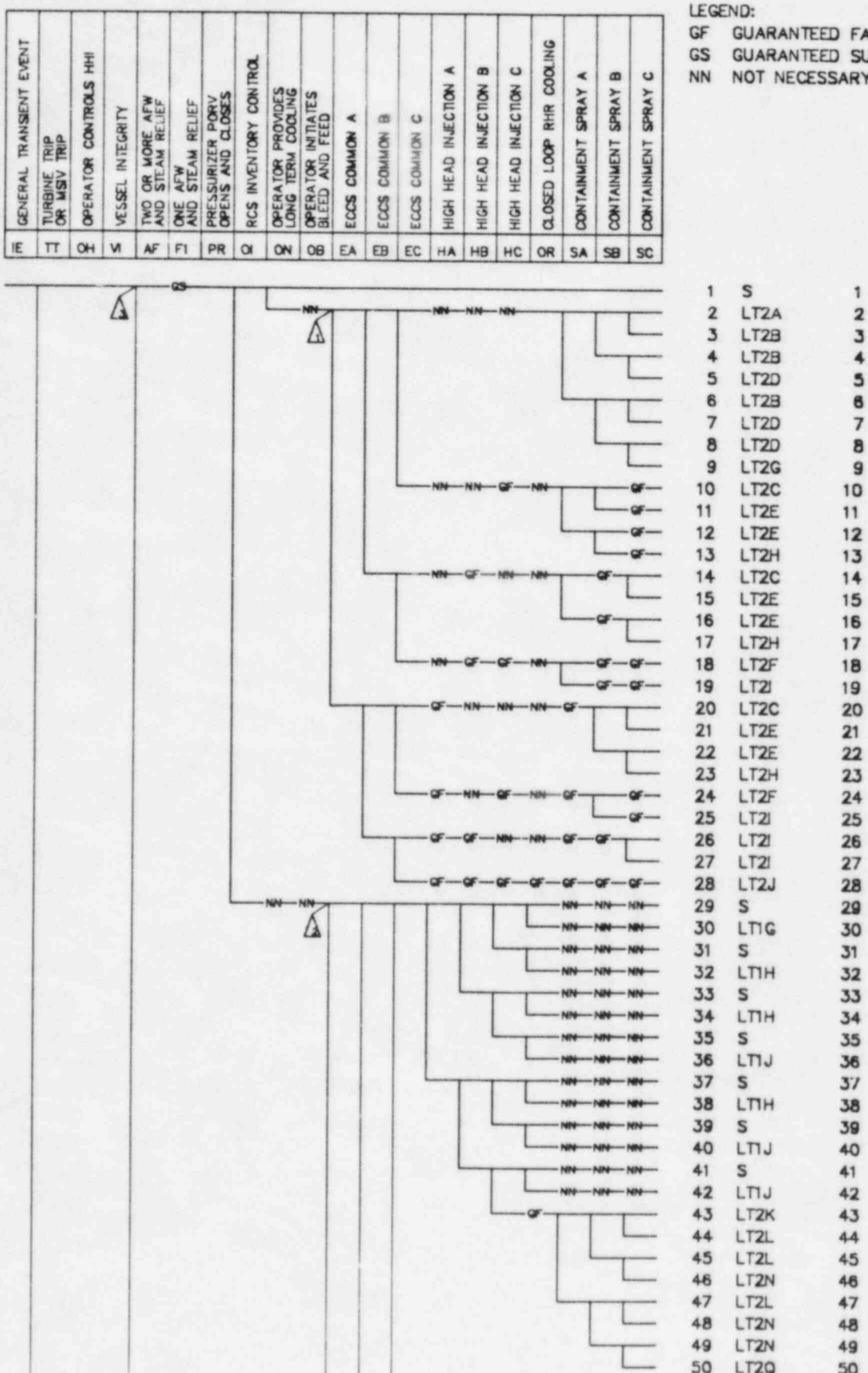
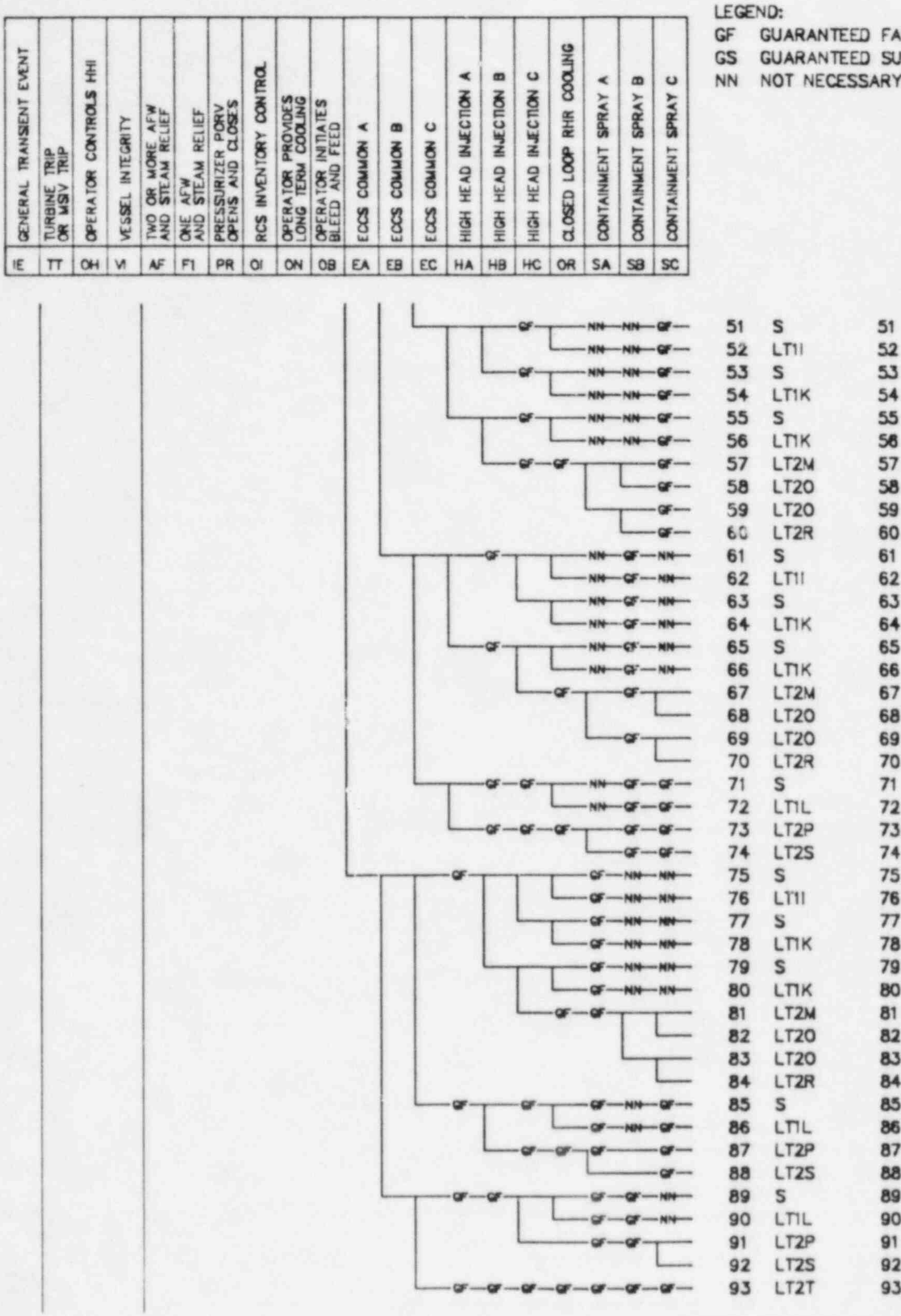


FIGURE 4-10. GENERAL TRANSIENT EVENT TREE (Sheet 1 of 4)

CAUTION: PRELIMINARY RESULTS- IMPORTANT UNCERTAINTIES DESCRIBED IN SECTION 2

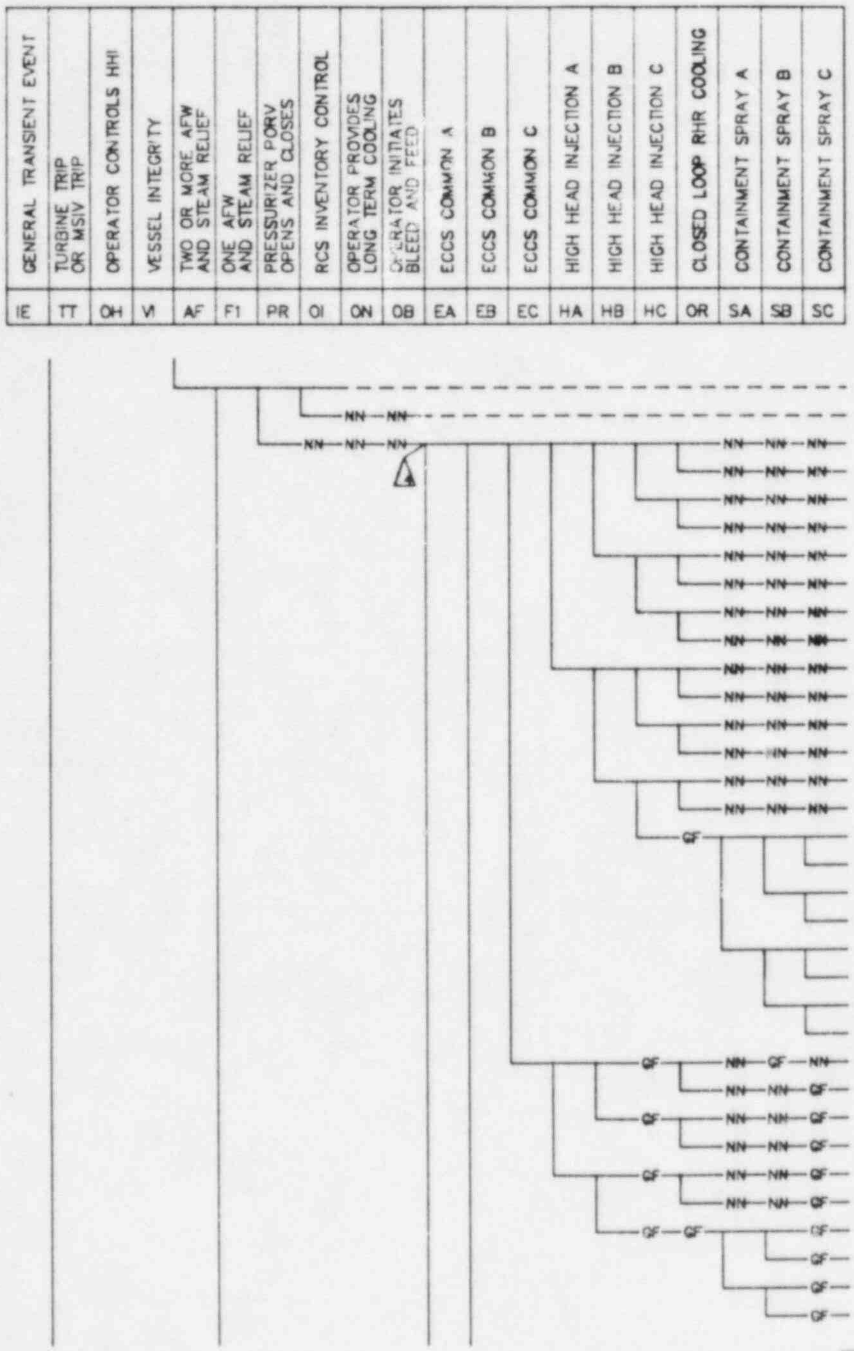


LEGEND:
GF GUARANTEED FAILURE
GS GUARANTEED SUCCESS
NN NOT NECESSARY

CAUTION: PRELIMINARY RESULTS-
IMPORTANT UNCERTAINTIES
DESCRIBED IN SECTION 2

FIGURE 4-10 (Sheet 2 of 4)

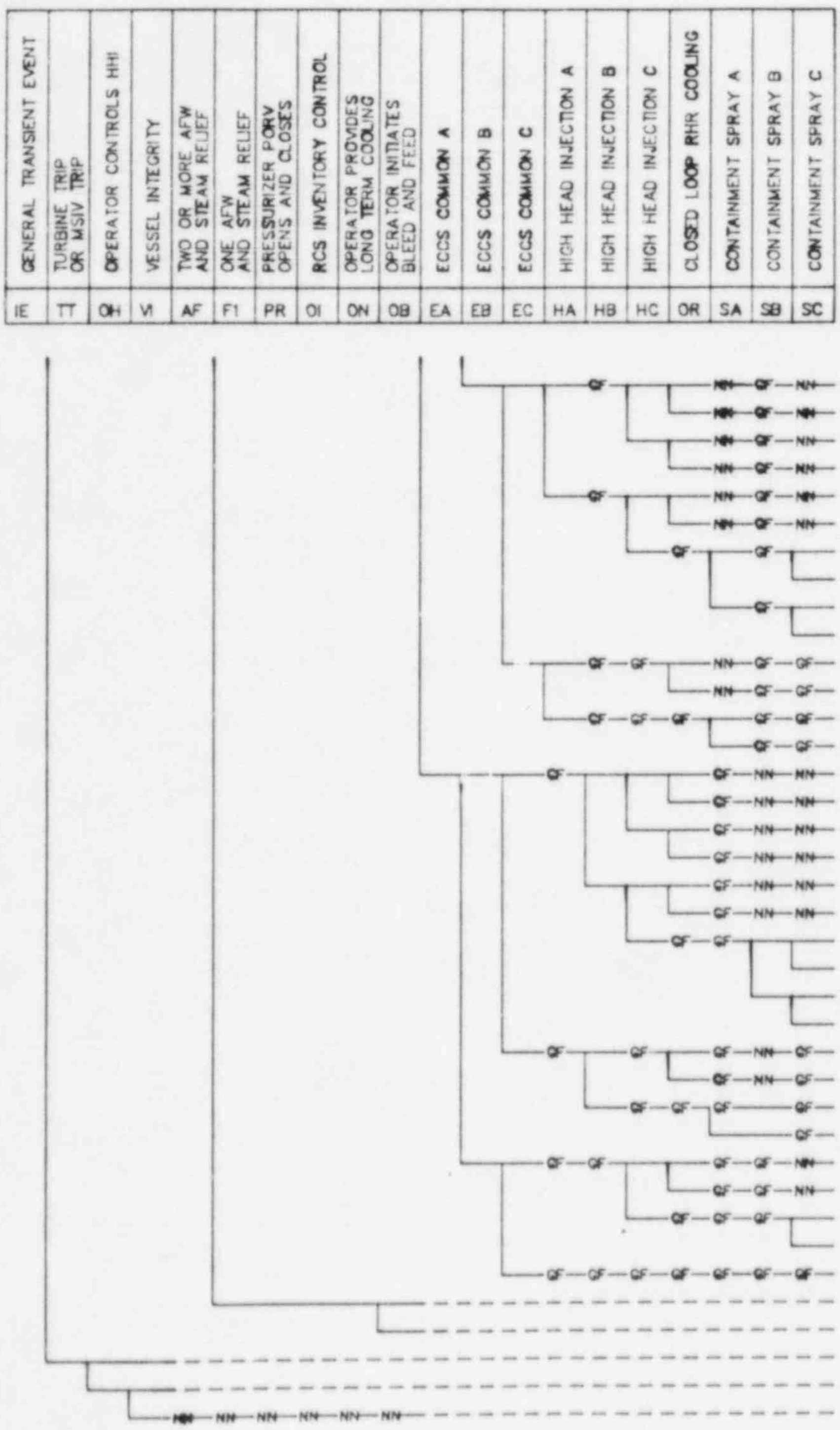
LEGEND:
GF GUARANTEED FAILURE
GS GUARANTEED SUCCESS
NN NOT NECESSARY



SEQUENCE	END STATE	FULL TREE SEQUENCE
94	XFR5	94
95	XFR2	122
96	S	187
97	LT1A	188
98	S	189
99	LT1B	190
100	S	191
101	LT1B	192
102	S	193
103	LT1D	194
104	S	195
105	LT1B	196
106	S	197
107	LT1D	198
108	S	199
109	LT1D	200
110	LT2A	201
111	LT2B	202
112	LT2B	203
113	LT2D	204
114	LT2B	205
115	LT2D	206
116	LT2D	207
117	LT2G	208
118	S	209
119	LT1C	210
120	S	211
121	LT1E	212
122	S	213
123	LT1E	214
124	LT2C	215
125	LT2E	216
126	LT2E	217
127	LT2H	218

CAUTION: PRELIMINARY RESULTS-IMPORTANT UNCERTAINTIES DESCRIBED IN SECTION 2

FIGURE 4-10 (Sheet 3 of 4)



LEGEND:
GF GUARANTEED FAILURE
GS GUARANTEED SUCCESS
NN NOT NECESSARY

SEQUENCE	END STATE	FULL TREE SEQUENCE
128	S	219
129	LT1C	220
130	S	221
131	LT1E	222
132	S	223
133	LT1E	224
134	LT2C	225
135	LT2E	226
136	LT2E	227
137	LT2H	228
138	S	229
139	LT1F	230
140	LT2F	231
141	LT2I	232
142	S	233
143	LT1C	234
144	S	235
145	LT1E	236
146	S	237
147	LT1E	238
148	LT2C	239
149	LT2E	240
150	LT2E	241
151	LT2H	242
152	S	243
153	LT1F	244
154	LT2F	245
155	LT2I	246
156	S	247
157	LT1F	248
158	LT2F	249
159	LT2I	250
160	LT2J	251
161	XFR4	252
162	XFR1	317
163	XFR3	344
164	XFR3	687
165	XFR1	1030

CAUTION: PRELIMINARY RESULTS.
IMPORTANT UNCERTAINTIES
DESCRIBED IN SECTION 2

FIGURE 4-10 (Sheet 4 of 4)

LEGEND:
GF GUARANTEED FAILURE
GS GUARANTEED SUCCESS
NN NOT NECESSARY

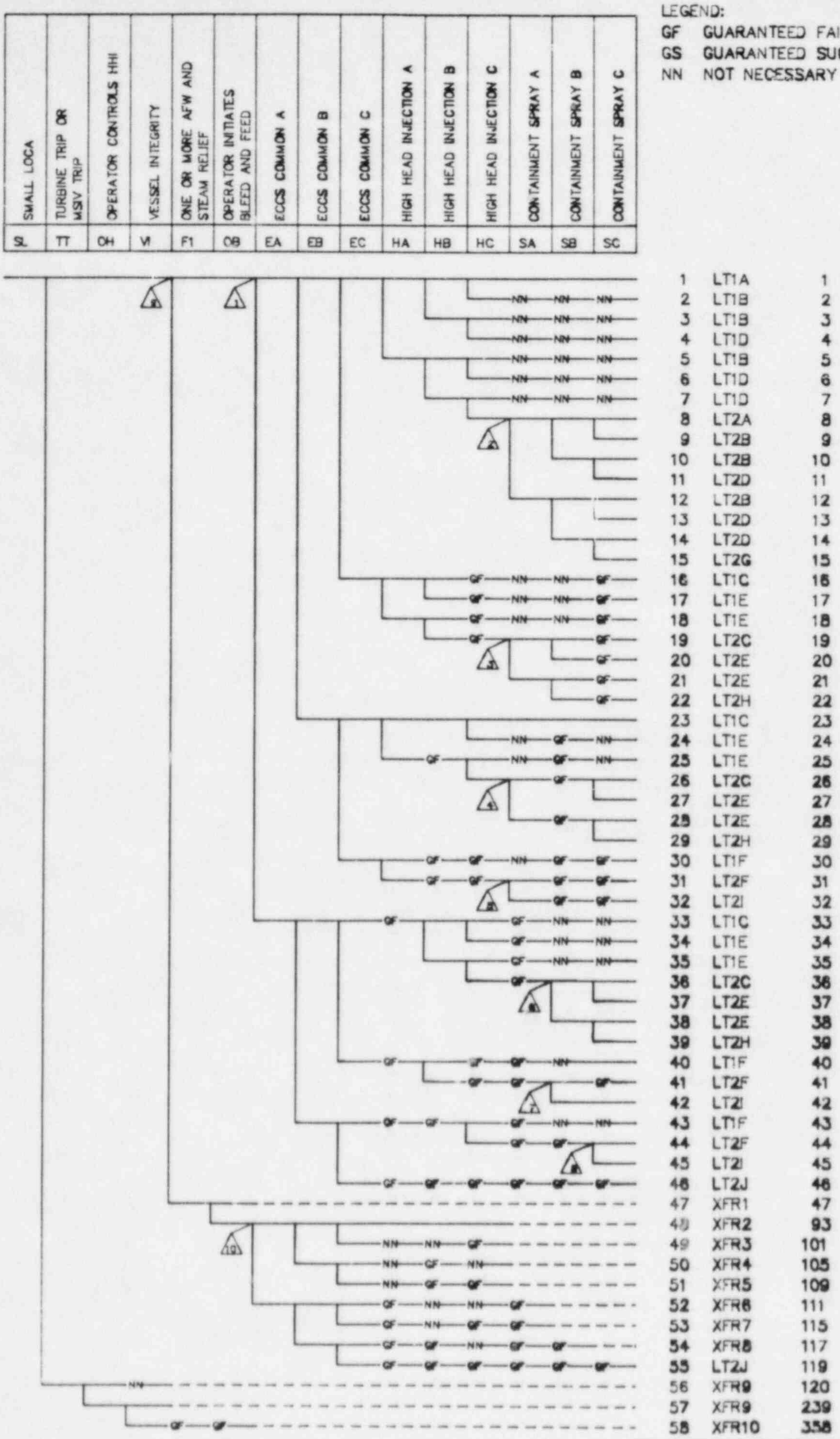


FIGURE 4-11. SMALL LOCA EVENT TREE

CAUTION: PRELIMINARY RESULTS-
IMPORTANT UNCERTAINTIES
DESCRIBED IN SECTION 2

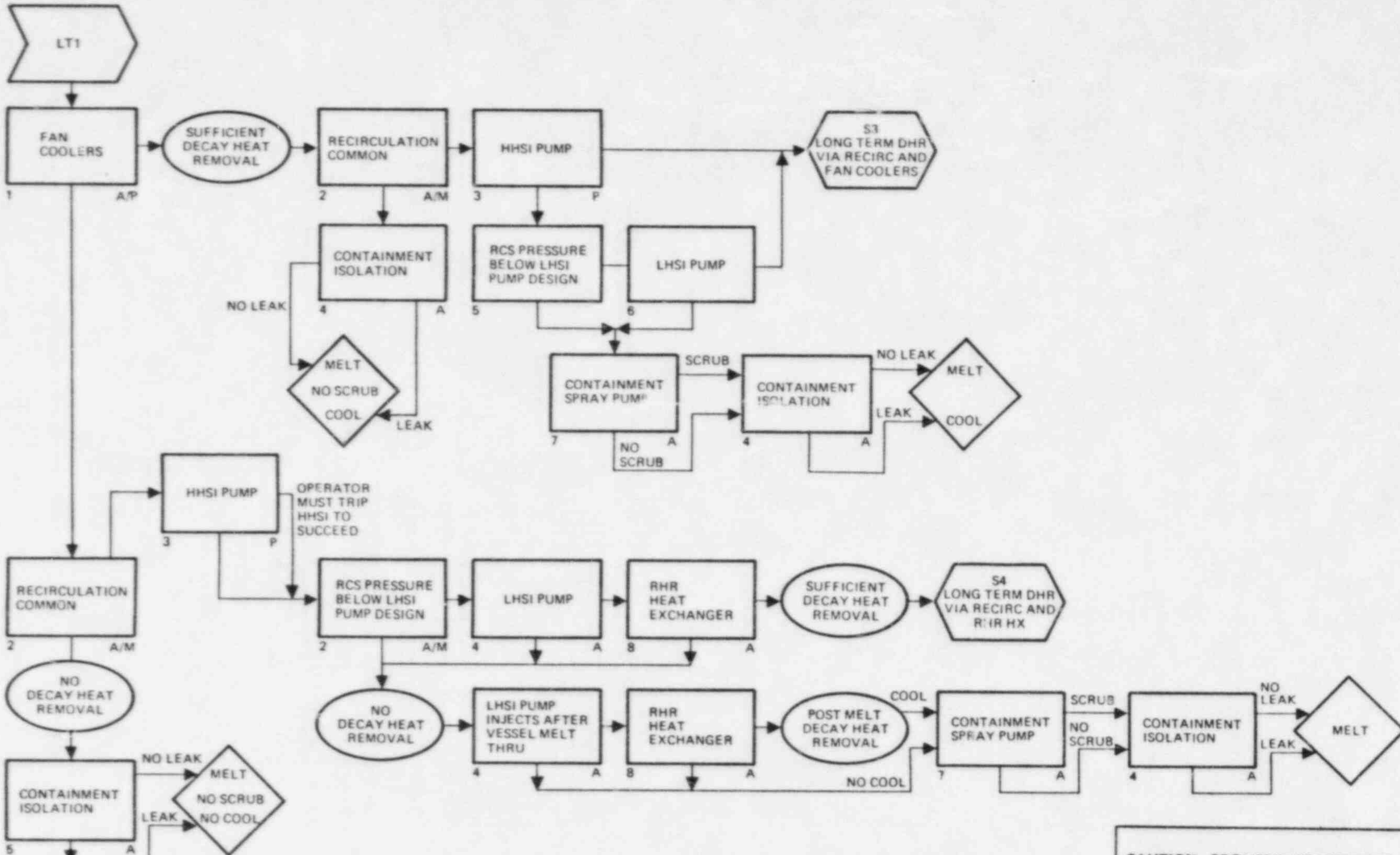
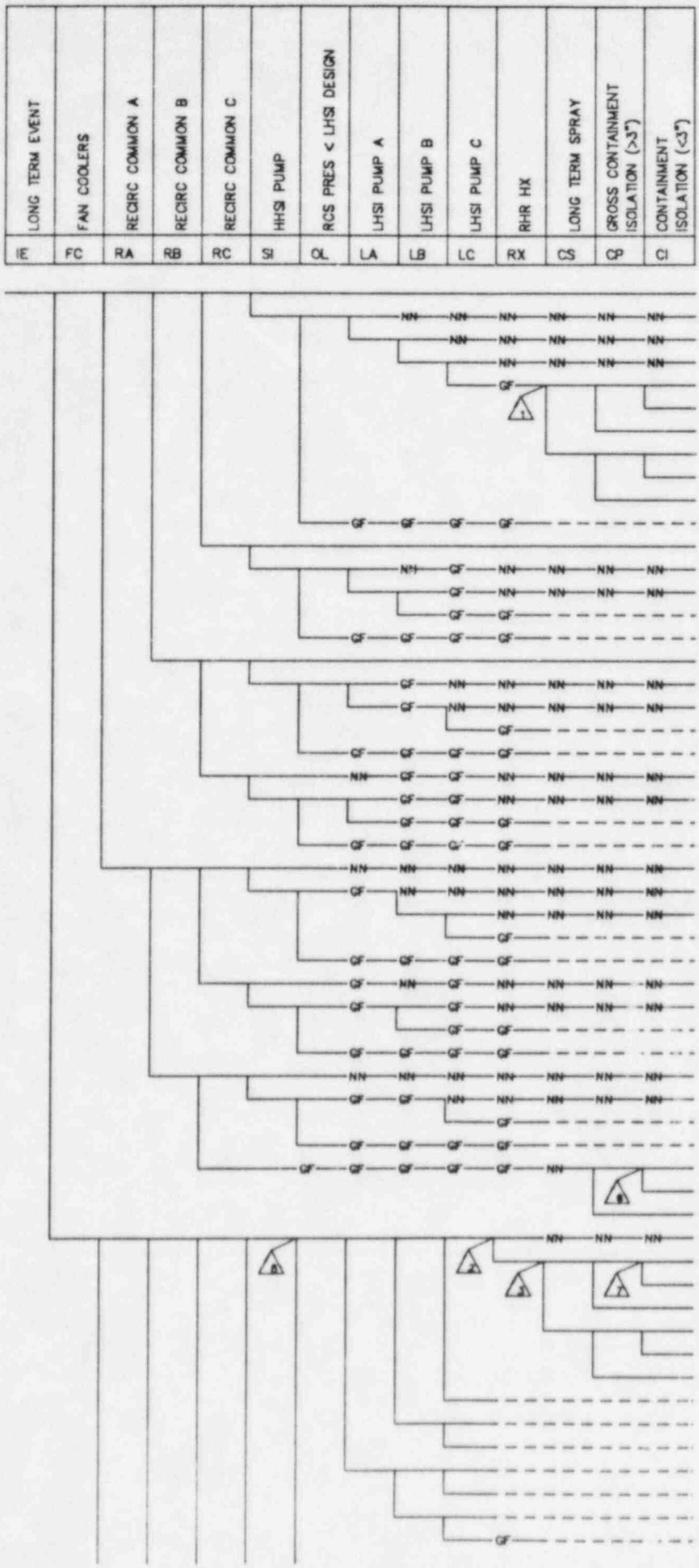


FIGURE 4-12. LT1 LONG-TERM RESPONSE ESD

CAUTION: PRELIMINARY RESULTS-IMPORTANT UNCERTAINTIES DESCRIBED IN SECTION 2

LEGEND:
GF GUARANTEED FAILURE
GS GUARANTEED SUCCESS
NN NOT NECESSARY



1	S	1
2	S	2
3	S	3
4	S	4
5	2A	5
6	2G	6
7	2E	7
8	2B	8
9	2H	9
10	2F	10
11	XFR1	11
12	S	17
13	S	18
14	S	19
15	XFR1	20
16	XFR1	26
17	S	32
18	S	33
19	S	34
20	XFR1	35
21	XFR1	41
22	S	47
23	S	48
24	XFR1	49
25	XFR1	55
26	S	61
27	S	62
28	S	63
29	XFR1	64
30	XFR1	70
31	S	76
32	S	77
33	XFR1	78
34	XFR1	84
35	S	90
36	S	91
37	XFR1	92
38	XFR1	98
39	2B	104
40	2H	105
41	2F	106
42	S	107
43	2C	108
44	2I	109
45	2E	110
46	2D	111
47	2J	112
48	2F	113
49	XFR2	114
50	XFR2	121
51	XFR2	128
52	XFR2	135
53	XFR2	142
54	XFR2	149
55	XFR3	156

FIGURE 4-13. FRONTLINE EVENT TREE LT1
(Sheet 1 of 2)

CAUTION: PRELIMINARY RESULTS
IMPORTANT UNCERTAINTIES
DESCRIBED IN SECTION 2

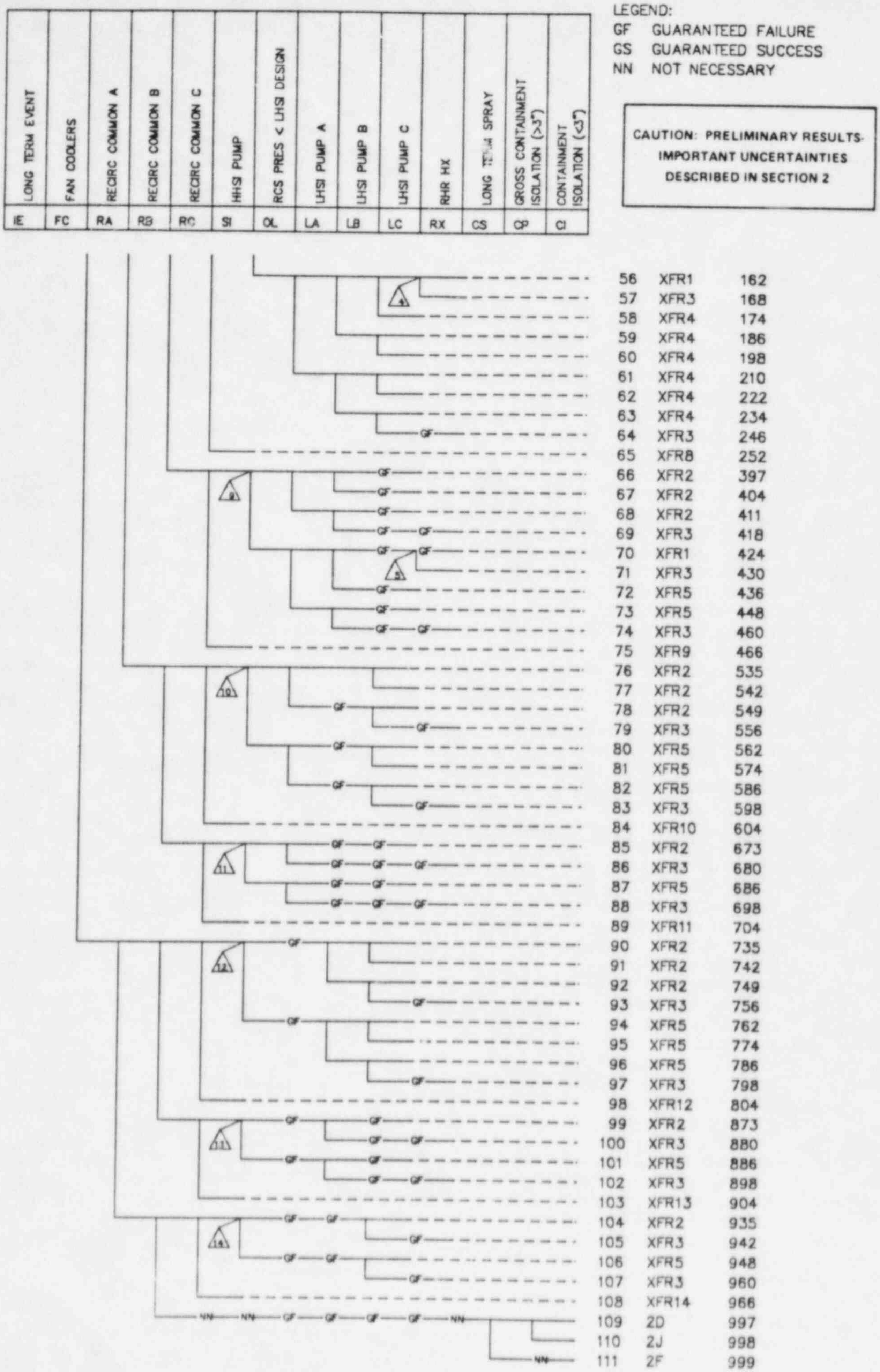
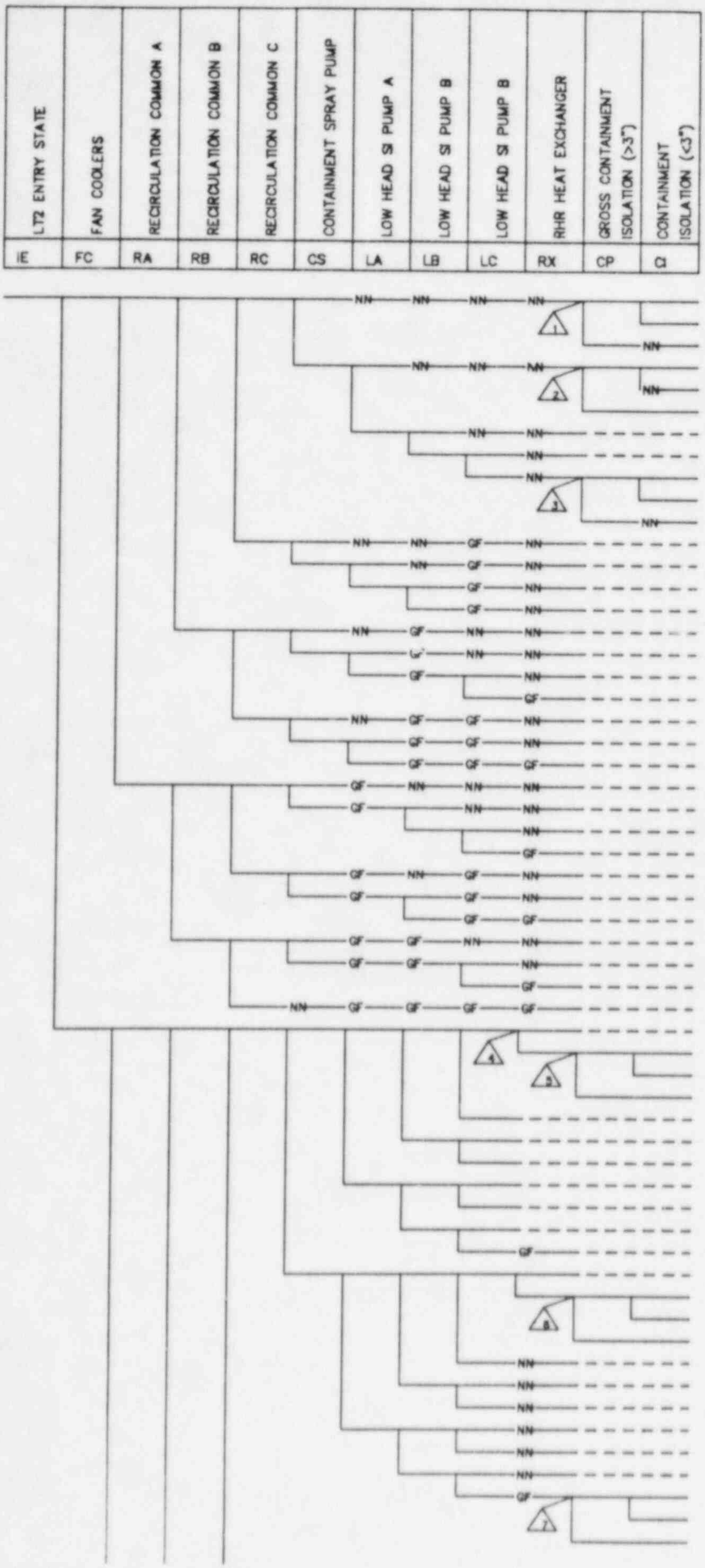


FIGURE 4-13 (Sheet 2 of 2)

LEGEND:

GF GUARANTEED FAILURE
GS GUARANTEED SUCCESS
NN NOT NECESSARY

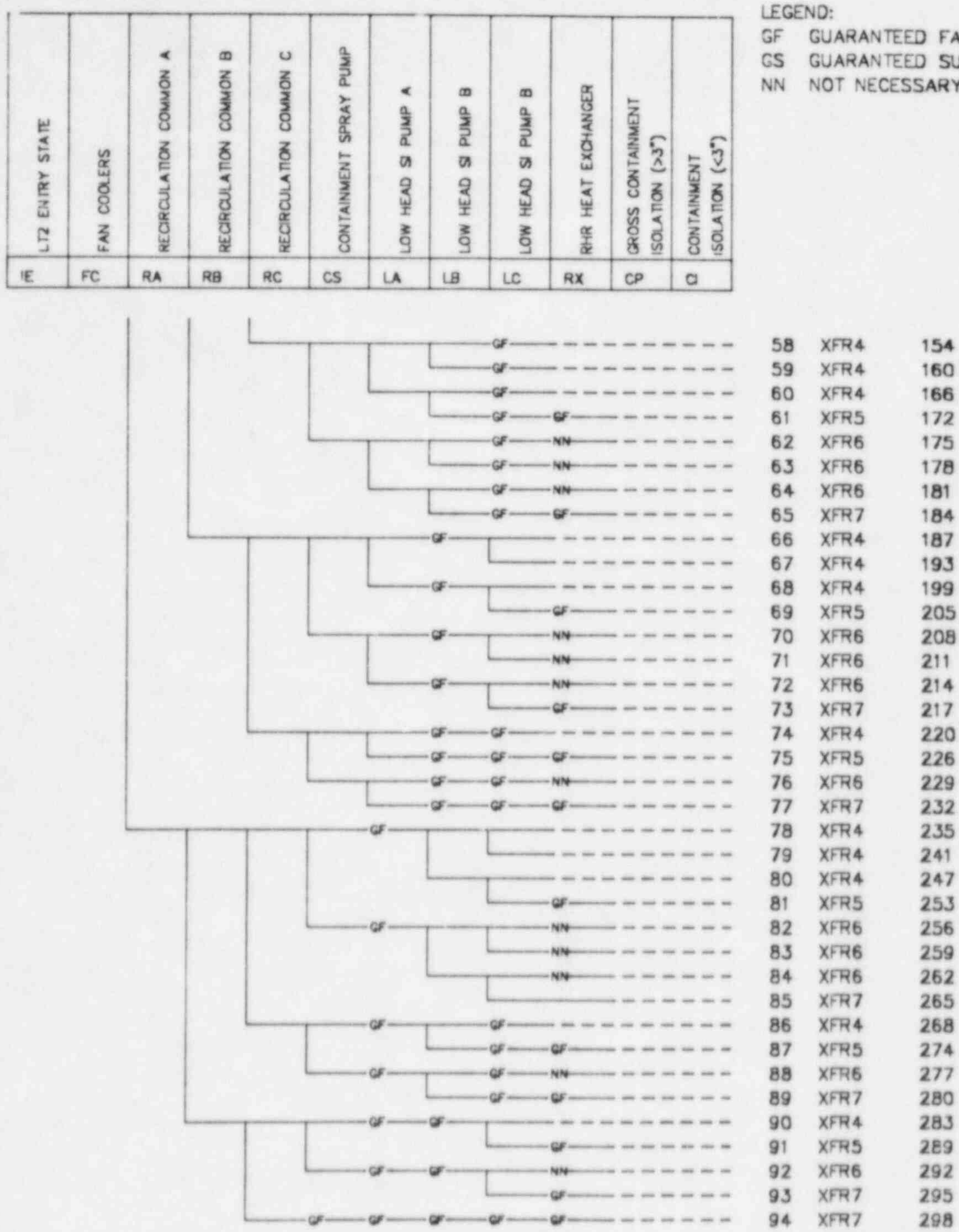


1	2A	1
2	2G	2
3	2E	3
4	2B	4
5	2H	5
6	2F	6
7	XFR2	7
8	XFR2	10
9	2B	13
10	2H	14
11	2F	15
12	XFR1	16
13	XFR2	19
14	XFR2	22
15	XFR3	25
16	XFR1	28
17	XFR2	31
18	XFR2	34
19	XFR3	37
20	XFR1	40
21	XFR2	43
22	XFR3	46
23	XFR1	49
24	XFR2	52
25	XFR2	55
26	XFR3	58
27	XFR1	61
28	XFR2	64
29	XFR3	67
30	XFR1	70
31	XFR2	73
32	XFR3	76
33	XFR3	79
34	XFR1	82
35	2C	85
36	2I	86
37	2E	87
38	XFR4	88
39	XFR4	94
40	XFR4	100
41	XFR4	106
42	XFR4	112
43	XFR4	118
44	XFR5	124
45	XFR2	127
46	2D	130
47	2J	131
48	2F	132
49	XFR6	133
50	XFR6	136
51	XFR6	139
52	XFR6	142
53	XFR6	145
54	XFR6	148
55	2D	151
56	2J	152
57	2F	153

FIGURE 4-15. FRONTLINE EVENT TREE LT2
(Sheet 1 of 2)

CAUTION: PRELIMINARY RESULTS-
IMPORTANT UNCERTAINTIES
DESCRIBED IN SECTION 2

LEGEND:
GF GUARANTEED FAILURE
GS GUARANTEED SUCCESS
NN NOT NECESSARY



CAUTION: PRELIMINARY RESULTS-IMPORTANT UNCERTAINTIES DESCRIBED IN SECTION 2

FIGURE 4-15 (Sheet 2 of 2)

5. SYSTEMS ANALYSIS

5.1 SYSTEMS ANALYSIS APPROACH

The purposes of systems analyses are to provide the qualitative knowledge about the plant systems needed to construct a plant risk model and to provide the input quantification of the event sequence model (i.e., to quantify top event split fractions in the plant event trees).

The systems analysis was conducted in two parts. The first part was an initial screening that encompassed all STP systems. The screening determined each system's normal and transient alleviating actions. These actions characterize the response of the plant to initiating events. Success requirements were established for all alleviating actions as discussed in Section 4.4. The second part of the systems analysis was a detailed analysis of those systems that passed the initial screening.

One result of the initial screening was a classification of each system as either a "frontline" system or a "support" system. Each system was also classified as to whether further analysis was required. Those requiring no further analysis were so noted and their system summaries were filed.

The second portion of the baseline systems analysis determined the intersystem dependencies for the support system model and recorded the details required to properly model the system. Items covered were as follows:

- Support Systems Needed
- Systems Supported
- Equipment Shared with Other Systems
- Normal Automatic Actions
- Normal Manual Actions
- Operator Emergency/Recovery Actions
- Controlling Station Locations, Indications, and Alarms
- Testing and Maintenance Requirements
- Technical Specifications, Limiting Conditions for Operation, and Surveillance

Also noted in a general comment section were any other system characteristics important to the system model.

Once the systems were studied and documented and the event sequence diagrams developed, the systems were assigned to event tree top events and actions in a way that preserved dependencies between tops. Initiating events that would disable each system were also identified.

System logic models were considered next. When necessary, system boundaries were defined and block diagrams were drawn. These block diagrams were modified for each success criterion and for each support system state for a given top event.

The final step in systems analysis was the estimation of conditional split fractions. This estimation was performed in one of two ways, depending on the systems involved:

1. For those systems that are very similar to their Midland or Seabrook counterparts and whose models were not significantly different (i.e., similar logic, success criteria, and support system states), the conditional split fractions from the Midland or Seabrook PRA (References 5-1 and 5-2) were used.

2. Where significant differences in system logic were noted, block diagram logic models were used that included independent hardware failure, maintenance, testing, human error, and common cause failure terms. The unavailability expressions were then quantified using data from the Seabrook PRA data bases.

5.2 SUMMARY OF SYSTEMS ANALYZED

Tables 5-1 and 5-2 and Figure 5-1 document all plant systems considered in the Scoping Study and the disposition of the initial screening process described above. Those systems classified as important to risk were studied in detail and modeled to the level required for the Scoping Study. Table 5-1 lists these systems. In some cases, only portions of the system were included in the risk model. Table 5-2 lists those systems that were classified as not needing further analysis in the Scoping Study but whose further analysis might prove useful during risk management efforts. Systems that are not required for safety and offer little or no potential for affecting accident scenarios appear in Figure 5-1.

5.3 EXAMPLE SYSTEMS SUMMARY - ESSENTIAL COOLING WATER SYSTEM

A brief summary of the ECW's systems analysis is presented in this section of the report to familiarize the reader with the system analysis methodology used in the Scoping Study. Although the ECW's analysis provides a relatively simple example of the evaluation and quantification process, the same general methods were applied for each of the systems modeled in the event trees. To obtain a complete picture of the modeling of systems in the Scoping Study, it is helpful to also review the event sequence model in Section 4. The event sequence model represents an important interface between the risk assessment and the modeling of systems.

Information about each plant system was collected and documented in a system analysis summary. An example summary outline is shown in Figure 5-2. Important information about the ECW system is summarized in Tables 5-3, 5-4, and 5-5.

Figure 5-3 is the ECW's piping and instrumentation diagram. Figure 5-4 is a block program model of the ECWs used for system unavailability quantification. Table 5-6 lists the components included in each model block.

The block diagram model forms the basis for the Boolean logic expressions used to quantify system unavailability. The block diagram portrays the "success paths" of the system. These paths are combinations of component success states that enable successful functioning of the system. The success paths, which have the same logical information contained in a listing of the minimal cutsets, provide the basis for calculating system unavailability. Table 5-7 presents these expressions for the ECW system under each of the eight general boundary conditions of support system availability derived from the auxiliary systems' dependency information.

Quantification of ECW's unavailability is performed in two steps. The first step develops unavailability information for each system model block by evaluating the effects on each component in the block from hardware failures, testing, maintenance, human errors, environmental effects, and other causes. Table 5-8 illustrates an example calculation of the hardware failure contribution to the unavailability of one ECW system model block for a specific system operating condition. The second step of the quantification process develops system level unavailability results by combining the model blocks through the Boolean logic expression for each support system boundary condition. The system-level calculations account for all the causes for each block's unavailability, and they include combinations of causes affecting components in redundent system blocks. For example, in the ECW system model from Figure 5-4, the joint unavailability of model blocks PA and PB (pump trains 1A and 1B) has contributions from each of the following causes:

- Coincident hardware failures of pumps 1A and 1B.
- Maintenance of pump 1B and hardware failures of pump 1A.
- Dependent failures of pumps 1A and 1B during operation.

There are no contributions from maintenance of pump 1A, because it is the normally running pump and cannot be out of service for maintenance when a plant initiating event occurs. Table 5-9 illustrates an example ECW's unavailability calculation for a specific system operating condition under one support system boundary condition.

The top events of the event trees were quantified using generic component failure rate data, maintenance frequency and duration data, human error rates, and common cause failure rate data from References 5-1, 5-2, and other sources. Where specific component dependent failure rate data were not available from these studies, point estimate values of β = 0.05 and γ = 0.50 were used. β is the fraction of component failures in which one or more similar components are failed due to a shared, common cause. γ is the fraction of the common cause failures that are shared by three or more similar components. These parameters are estimated from component failure event data at U.S. nuclear plants. This summary level quantification is consistent with a preliminary, scoping level analysis. Additional documentation would be needed for a comprehensive, stand-alone analysis.

5.4 REFERENCES

5-1. Pickard, Lowe and Garrick, Inc., "Midland Probabilistic Risk Assessment," prepared for the Consumers Power Company, May 1984.

5-2. Pickard, Lowe and Garrick, Inc., "Seabrook Station Probabilistic Safety Assessment," prepared for Public Service Company of New Hampshire and Yankee Atomic Electric Company, PLG-0300, December 1983.

IMPORTANT UNCERTAINTIES DESCRIBED IN SECTION 2

TABLE 5-1. STPEGS SYSTEMS PARTIALLY OR FULLY ANALYZED IN THE PRELIMINARY SCOPING STUDY

System	Frontline (F) or Support (S)	Included in the Preliminary Scoping Study	Top Events	Support Systems	Disposition
Reactor Containment Fan Coolers	F	Yes	FC	EP,ESFAS,CCW	Provides heat removal and limits pressure of containment atmosphere after a large energy release inside containment. Full analysis required.
Containment Isolation	F	Yes	CI,CP	EP,ESFAS	Isolates lines penetrating containment to prevent radioactive releases. Full analysis required.
Emergency Core Cooling	F	Yes		EP,ESFAS,ECH,CCW	The primary method of keeping the core covered in many scenarios. Provides alternate core cooling method in bleed and feed. Provides long-term core cooling in recirculation scenarios.
• Reactor Water Storage Tank Suction Lines			EA,EB,EC		
• Containment Sump Suction Lines			RA,RB,RC		
• High Head Safety Injection			HA,HB,HC,SI		
• Low Head Safety Injection			LA,LB,LC,RX		
Auxiliary Feedwater	F	Yes	AF,F1	EP,ESFAS,MS	Backup to main feedwater for reactor coolant system heat removal. Full analysis required.
Containment Spray	F	Yes	SA,SB,SC,CS	EP,ESFAS,ECH	Removes fission products and limits pressure of containment atmosphere after a large energy release inside containment. Full analysis required.
Component Cooling Water	S	Yes	CA,CB,CC	EP,ESFAS,ECW	Provides cooling to vital components during both normal and accident conditions. Full analysis required.
Essential Cooling Water	S	Yes	WA,WB,WC	EP,ESFAS	Removes heat loads from safety related equipment to the ultimate heat sink. Full analysis required.
Electric Power	S	Yes			This system supports all vital systems. The analysis includes all Class 1E power supplies, associated switchgear and support systems, and DC Power.
• Offsite Grid			OG		
• Generator Breaker, Main, and Unit Auxiliary Transformer			UA		
• Standby Transformer			S1,S2		
• 13.8 kV Buses			1F,1G,1H,1L		
• Vital 4.16 kV Buses			EA,EB,EC	EV	
• Vital DC Buses			DA,DB,DC	EV	
• Standby Diesel Generators			GA,GB,GC	ECW	

CAUTION: PRELIMINARY RESULTS
IMPORTANT UNCERTAINTIES
DESCRIBED IN SECTION 2

TABLE 5-1 (continued)

System	Frontline (F) or Support (S)	Included in the Preliminary Scoping Study	Top Events	Support Systems	Disposition
Reactor Trip System (solid state protection system)	S	Yes	SS	-	Anticipated transients without scram not quantified in the Preliminary Scoping Study. Full analysis required in a complete Level 1 PRA.
Engineered Safety Features Actuation	S	Yes	EA,EB,EC	EP	Safety systems receive actuation signals from ESFAS. Full analysis required.
Steam Dump Control (steam relief)	F	Yes	AF,F1	IA,SDC,ESFAS, EP,IA	Provides reactor coolant system cooling via secondary side. Steam relief includes steam generator PORVs, steam generator safeties, and condenser vacuum.
Ultimate Heat Sink	-	-	-	-	Included in essential cooling water analysis.
Primary Relief	F	Yes	PR,OB	EP	Provides overpressure protection and is used in feed and bleed. Analysis includes the pressurizer PORVs, block valves, and safeties. A complete Level 1 PRA may include the vessel head vent system.
Essential Chilled Water	S	Yes	SA,SB,SC	EP,ESFAS, ECW	Removes heat from essential equipment area HVAC unit coolers and rejects heat to the ECWS. Full analysis required.
Electrical Auxiliary Building HVAC	S	Yes	EV	EP,ECH	Supplies cooling to switchgear for safety related equipment. Room heatup calculations and additional equipment qualification analyses should be performed.
Chemical and Volume Control	F	Yes	OI,CI	EP,ESFAS,CCW	Provides reactor coolant system inventory control. The Preliminary Scoping Study includes charging pumps, normal charging line, letdown line to containment isolation valves, RCP seal injection and return lines, and RCP cooling.
Main Steam	F	Yes	TT	ESFAS,EP	The main steam isolation valves are analyzed in the Preliminary Scoping Study.
Electrohydraulic Control	F	Yes	TT	EP	This system is analyzed for turbine trip logic and turbine stop and governor valves.

TABLE 5-2. OTHER SIPEGS SYSTEMS UNDER CONSIDERATION FOR PHASE II ANALYSIS

System	Frontline (F) or Support (S)	Included in the Preliminary Scoping Study	Top Events	Support Systems	Disposition
Main Feedwater	F	No	None	EP,MS,ESFAS	This system is not analyzed in the Preliminary Scoping Study because it is automatically isolated after a reactor trip with low reactor coolant system T_{avg}.
Reactor Coolant	F	No	None	-	This system is not explicitly analyzed. Loss of coolant accident analyses will account for the loss of this system.
Residual Heat Removal	F	No	OR	EP,CCWS	Not evaluated in the Preliminary Scoping Study due to lack of equipment qualification analyses supporting pump operation in high temperature and high humidity environments. Further analyses may be required in a complete Level 1 PRA to justify residual heat removal operation in degraded conditions.
Fuel Handling Building HVAC	S	No	-	-	ECCS pumps cubicle coolers are included in ECCS model.
Control Room Envelope HVAC	S	No	-	EP,ESFAS,ECH	Effects of failure are bounded by EAB HVAC analysis.
Auxiliary Cooling Water	S	No	-	-	Not analyzed for the Preliminary Scoping Study. System does not serve any equipment analyzed in the Preliminary Scoping Study.
Instrument Air	S	No	-	EP,ACS	Not analyzed for the Preliminary Scoping Study. Instrument air failure does not affect any systems modeled in the Preliminary Scoping Study.
Mechanical Auxiliary Building HVAC	S	Yes	-	-	HVAC explicitly modeled with individual systems as appropriate.
Diesel Generator Building HVAC	S	Yes	-	-	Included in diesel generator analysis.
Diesel Generator Fuel Oil Storage and Transfer	S	Yes	-	-	Included in diesel generator analysis.
Diesel Generator Closed Cooling Water	S	Yes	-	-	Included in diesel generator analysis.
Diesel Generator Starting	-	-	-	-	Included in diesel generator analysis.
Diesel Generator Lubrication	-	-	-	-	Included in diesel generator analysis.

TABLE 5-3. ESSENTIAL COOLING WATER SYSTEM COMPONENT DEPENDENCIES

Component	AC Power	DC Power	ESFAS Train	ESFAS Relay
Pump 1A	Bus E1A	Bus E1A11	A	Sequencer
MOV0121 (discharge valve)	MCC E1A3			
Pump 1A Strainer	MCC E1A3			
FV6935 (blowdown valve)		Bus E1A11	A	K817
Traveling Screen 1A	MCC E1A3		A	K817
Screen Wash Booster Pump 1A	MCC E1A3		A	K817
FV6914 (screen wash valve)		Bus E1A11		
Vent Fan FN001	MCC E1A3			
Vent Fan FN002	MCC E1A3			
Pump 1B	Bus E1B	Bus E1B11	B	Sequencer
MOV0137 (discharge valve)	MCC E1B3			
Pump 1B Strainer	MCC E1B3			
FV6936 (blowdown valve)		Bus E1B11	B	K817
Traveling Screen 1B	MCC E1B3		B	K817
Screen Wash Booster Pump 1B	MCC E1B3		B	K817
FV6924 (screen wash valve)		Bus E1B11		
Vent Fan FN003	MCC E1B3			
Vent Fan FN004	MCC E1B3			
Pump 1C	Bus E1C	Bus E1C11	C	Sequencer
MOV0151 (discharge valve)	MCC E1C3			
Pump 1C Strainer	MCC E1C3			
FV6937 (blowdown valve)		Bus E1C11	C	K817
Traveling Screen 1C	MCC E1C3		C	K817
Screen Wash Booster Pump 1C	MCC E1C3		C	K817
FV6934 (screen wash valve)		Bus E1C11		
Vent Fan FN005	MCC E1C3			
Vent Fan FN006	MCC E1C3			

CAUTION: PRELIMINARY RESULTS. IMPORTANT UNCERTAINTIES DESCRIBED IN SECTION 2

TABLE 5-4. ESSENTIAL COOLING WATER SYSTEM LOADS

ECWS Train	Components Supplied Cooling Water
1A	Standby Diesel Generator 1A Standby Diesel Generator 1A Auxiliaries Skid Component Cooling Water Heat Exchanger 1A Component Cooling Water Pump 1A Supplementary Cooler Train 1A Essential Chiller CH001* Train 1A Essential Chiller CH004*
1B	Standby Diesel Generator 1B Standby Diesel Generator 1B Auxiliaries Skid Component Cooling Water Heat Exchanger 1B Component Cooling Water Pump 1B Supplementary Cooler Train 1B Essential Chiller CH002* Train 1B Essential Chiller CH005*
1C	Standby Diesel Generator 1C Standby Diesel Generator 1C Auxiliaries Skid Component Cooling Water Heat Exchanger 1C Component Cooling Water Pump 1C Supplementary Cooler Train 1C Essential Chiller CH003* Train 1C Essential Chiller CH006*

*Essential chillers can be supplied from any ECWS train through crossties.

CAUTION: PRELIMINARY RESULTS
IMPORTANT UNCERTAINTIES
DESCRIBED IN SECTION 2

TABLE 5-5. NORMAL ALIGNMENT FOR ESSENTIAL COOLING WATER, COMPONENT COOLING WATER, AND ESSENTIAL CHILLED WATER USED FOR THE PRELIMINARY SCOPING STUDY

System	Running Train	Standby Train	Off Train
Essential Cooling Water	A	C	B
Component Cooling Water	A	C	B
Essential Chilled Water	A+B		C

NOTE: Crosstie valves EW0265 and EW0274 are open to supply the chillers for essential chilled water trains A and B from ECWS train A. All other ECWS crosstie valves are closed.

CAUTION: PRELIMINARY RESULTS IMPORTANT UNCERTAINTIES DESCRIBED IN SECTION 2

TABLE 5-6. COMPONENTS INCLUDED IN ESSENTIAL COOLING WATER SYSTEM MODEL BLOCKS

Model Block	Components
PA	Pump 1A Check Valve EW0006 Discharge Valve MOV0121 Strainer 1A Traveling Screen 1A Vent Fan FN001 Vent Fan FN002
PB	Pump 1B Check Valve EW0042 Discharge Valve MOV0137 Strainer 1B Traveling Screen 1B Vent Fan FN003 Vent Fan FN004
PC	Pump 1C Check Valve EW0079 Discharge Valve MOV0151 Strainer 1C Traveling Screen 1C Vent Fan FN005 Vent Fan FN006
CP	Essential Cooling Pond (system common)

CAUTION: PRELIMINARY RESULTS
IMPORTANT UNCERTAINTIES
DESCRIBED IN SECTION 2

TABLE 5-7. ESSENTIAL COOLING WATER SYSTEM UNAVAILABILITY EXPRESSIONS

Support Available for ECWS Trains	Unavailability Expression
None	Qecw = 1.0
A	Qecw = PA + CP
B	Qecw = PB + CP
C	Qecw = PC + CP
A+B	Qecw = (PA)(PB) + CP
A+C	Qecw = (PA)(PC) + CP
B+C	Qecw = (PB)(PC) + CP
A+B+C	Qecw = (PA)(PB)(PC) + CP

CAUTION: PRELIMINARY RESULTS-
IMPORTANT UNCERTAINTIES
DESCRIBED IN SECTION 2

TABLE 5-8. EXAMPLE CALCULATION OF HARDWARE UNAVAILABILITY FOR ESSENTIAL COOLING WATER SYSTEM MODEL BLOCK PA (System Operating Condition: Pump 1A Restart Required)

Component Failure Mode	Variable	Failure Rate	Mission Time
Pump 1A Fails to Restart	PS	2.4-3/d	
Pump 1A Fails During Operation	PR	3.4-5/h	24h
Check Valve EW0006 Fails to Reopen	CVO	2.7-4/d	
Check Valve EW0006 Transfers Closed	CVC	1.0-8/h	24h
MOV0121 Transfers Closed	MVC	9.3-8/h	24h
Strainer 1A Plugs	SP	6.2-6/h	24h
Traveling Screen 1A Plugs	TP	6.2-6/h	24h
Fan FN001 Fails to Restart	FS	4.8-4/d	
Fan FN001 Fails During Operation	FR	7.9-6/h	24h
Fan FN002 Fails to Restart	FS	4.8-4/d	
Fan FN002 Fails During Operation	FR	7.9-6/h	24h
Dependent Fan Failure to Restart	β_{FS}	.05	
Dependent Fan Failure During Operation	β_{FR}	.05	

NOTES:

1. Exponential notation is indicated in abbreviated form; i.e., 2.4-3 = 2.4×10^{-3}.
2. d = demand; h = hour.

$$QPA = PS+PR+CVO+CVC+MVC+SP+TP+(FS + FR)^2+\beta_{FS}(FS)+\beta_{FR}(FR)$$

$$= (2.4\text{-}3) + (3.4\text{-}5)(24) + (2.7\text{-}4) + (1.0\text{-}8)(24) + (9.3\text{-}8)(24)$$

$$+ (6.2\text{-}6)(24) + (6.2\text{-}6)(24) + \{[(4.8\text{-}4) + (7.9\text{-}6)(24)]^2$$

$$+ (3.8\text{-}7)\} + (.05)(4.8\text{-}4) + (.05)(7.9\text{-}6)(24)$$

$$QPA = 3.8\text{-}3$$

CAUTION: PRELIMINARY RESULTS
IMPORTANT UNCERTAINTIES
DESCRIBED IN SECTION 2

TABLE 5-9. EXAMPLE CALCULATION OF ESSENTIAL COOLING WATER SYSTEM UNAVAILABILITY

[Support System Boundary Condition: Support Available for ECWS Trains A and B (e.g., Power Available at Buses E1A and E1B)]

(System Operating Condition: Pump 1A Restart Required)

Model Block	Hardware Unavailability
PA	3.8-3
PB	8.1-3
CP	2.7-6

Component	Variable	Maintenance Unavailability
Pump 1B	PM	2.6-3

Component Failure Mode	Variable	Failure Rate	Mission Time
Pump Fails to Start	PS	2.4-3/d	
Pump Fails During Operation	PR	3.5-5/H	24h
Check Valve Fails to Open	CVO	2.7-4/d	
Fan Fails to Start	FS	4.8-4/d	
Fan Fails During Operation	FR	7.9-6/h	24h

NOTES:

1. Exponential notation is indicated in abbreviated form; i.e., 2.4-3 = 2.4 x 10^{-3}.
2. d = demand, h = hour.

CAUTION: PRELIMINARY RESULTS-
IMPORTANT UNCERTAINTIES
DESCRIBED IN SECTION 2

TABLE 5-9 (continued)

Dependent Failure Fraction	Variable	Point Estimate
Pump Fails to Start	βPS	1.1-1
Pump Fails During Operation	βPR	7.6-2
Check Valve Fails to Open	βCVO	.05
Fan Fails to Start (two fans)	βFS	.05
Fan Fails During Operation (two fans)	βFR	.05
Intertrain Dependencies	βT	.05

Unavailability Expression: Q_{ECW} = (PA)(PB) + CP

$$Q_{ECW} = (PA)(PB + PM) + CP + \beta_{PS}(PS) + \beta_{PR}(PR) + \beta_{CVO}(CVO) + \beta_T\beta_{FS}(FS) + \beta_T\beta_{FR}(FR)$$

$$= \{(3.8\text{-}3)[(8.1\text{-}3) + (2.6\text{-}3)] + (9.3\text{-}6) + (1.2\text{-}6) + (5.7\text{-}8) + (3.5\text{-}14) + (4.8\text{-}12) + (1.4\text{-}8) + (1.8\text{-}11) + 5.6\text{-}15)\} + (2.7\text{-}6) + (1.1\text{-}1)(2.4\text{-}3) + (7.6\text{-}2)(3.4\text{-}5)(24) + (.05)(2.7\text{-}4) + (.05)(.05)(4.8\text{-}4) + (.05)(.05)(7.9\text{-}6)(24)$$

Q_{ECW} = 4.0-4

NOTES:

1. Exponential notation is indicated in abbreviated form; i.e., 1.1-1 = 1.1×10^{-1}.

2. Additional terms in braces { } account for the effects of correlated uncertainties between the failure rates for similar components in blocks PA and PB.

CAUTION: PRELIMINARY RESULTS. IMPORTANT UNCERTAINTIES DESCRIBED IN SECTION 2

Control Room Habitability	Condensate Polishing Demineralizers
Digital Rod Position Indication	Potable and Sanitary Water
Reactor Coolant Leak Detection	Station Sewage Treatment
Combustible Gas Control	Sodium Hypochlorite Feed
Containment Air Purification and Cleanup	Reactor Control
Reactor Makeup Water	Pressurizer Pressure Control
Pressurizer Level Control	Fuel Handling
Spent Fuel Cooling and Cleanup	Steam Generator Level Control
Process Sampling	Equipment and Floor Drain
Service Air	In-Core Instrumentation
Plant Lighting	Rod Control
Turbine-Generator	Reactor Makeup Water
Main Condensate	Communications
Condenser Evacuation	Fire Protection
Turbine Gland Sealing	Reactor Containment Building HVAC
Turbine Bypass	Steam Generator Blowdown
Turbine-Generator Building HVAC	Liquid Waste Processing
Gaseous Waste Processing	Boron Concentration Measurement
Solid Waste Processing	Boron Thermal Regeneration
Radiation Monitoring	P2500 Plant Computer
Circulating Water	Main Reservoir
Auxiliary Steam	Extraction Steam
Secondary System Chemical Addition	Lube Oil Purification and Transfer
Makeup Demineralized Water	Generator Stator and Cooling
Generator Stator Water Cooling	Vibration and Loose
Isolated Bus Duct Cooling	Generator Hydrogen Gas
Vibration Monitoring	Parts Monitoring

FIGURE 5-1. STPEGS SYSTEMS REQUIRING LITTLE OR NO FURTHER ANALYSIS

CAUTION: PRELIMINARY RESULTS-
IMPORTANT UNCERTAINTIES
DESCRIBED IN SECTION 2

A. Evaluation for System Screening

1. References
2. System Function During All Normal Modes of Operation
3. Impact on Plant if Normal Functions Are Lost
4. Safety Functions
5. Events That This System Could Initiate
6. FSAR Success Requirements for Normal and Safety Functions (number of pumps or trains and timing) and for What Conditions They Are Needed
7. System Classification
8. Disposition

B. Development of Intersystem Dependencies Matrices

9. Support Systems Needed
10. Systems Supported
11. Shared Equipment with Other Systems

C. Detailed Description for Systems Analysis

12. Normal Automatic Actions (initiation logic, setpoints)
13. Normal Plant Manual Actions
14. Operator Emergency/Recovery Actions
15. Controlling Station Locations, Indications, and Alarms
16. Testing and Maintenance Requirements
17. Technical Specifications/LCOs/Surveillance

D. Interface with Event Sequence Task

18. Initiating Events Disabling This System
19. Event Tree Top Events Involving This System
20. Support System Boundary Condition States to be Modeled

E. Comments/Questions and Answers

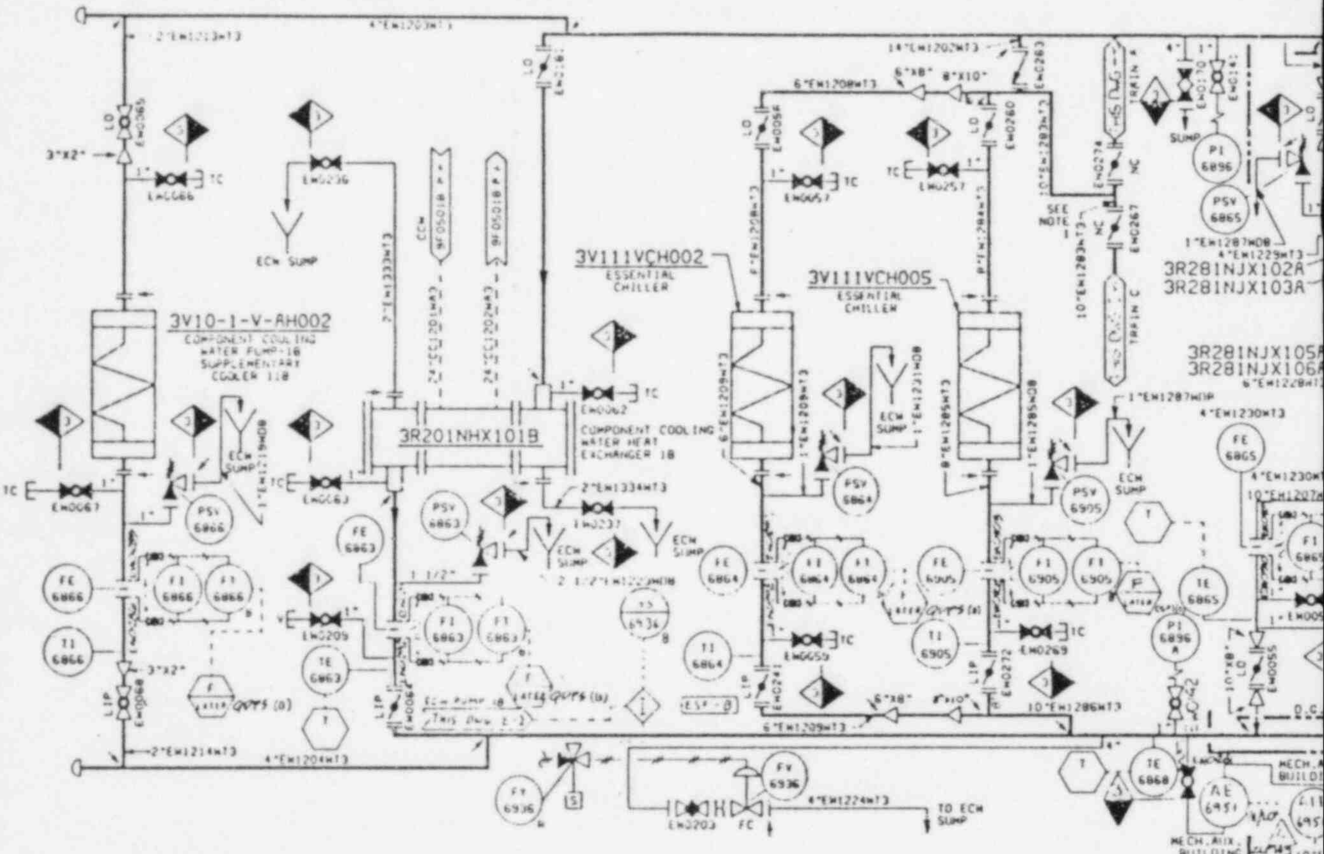
F. Logic Models

21. Define Boundaries of Logic Model
22. PRA Study Failure Conditions for Each Function Analyzed
23. System Block Diagram
24. System Block Descriptions

G. System Quantification

25. System Equations
26. Conditional Split Fraction

FIGURE 5-2. SOUTH TEXAS PROJECT SYSTEMS ANALYSIS SUMMARY OUTLINE



NOTES:

1. ONE NORMALLY OPERATING ECWS TRAIN WILL SERVICE TWO NORMALLY OPERATING ECHWS TRAINS. THE ESSENTIAL CHILLER TRAIN CROSSTIE VALVES, SHOWN NORMALLY CLOSED, WILL NORMALLY BE OPEN OR CLOSED ACCORDING TO THE ECHWS TRAIN COMBINATION TO BE USED FOR NORMAL OPERATION. THE CROSSTIE VALVES ARE BIDIRECTIONAL.

2. INSTRUMENT TAKEOFF PIPE AND FITTINGS TO AND INCLUDING THE ROOT VALVE SHALL CONFORM TO THE MAIN LINE SPEC.

3. LOCATE FLANGE OUTSIDE INTAKE STRUCTURE.

4. ALL INSTRUMENTS ON THIS P&ID HAVE SYSTEM DESIGNATOR EW.

5. ALL INSTRUMENTS ON THIS P&ID ARE SEPARATION GROUP N UNLESS OTHERWISE DESIGNATED.

6. UNLESS OTHERWISE NOTED, UNIT 1 IS SHOWN ON THIS P&ID. FOR APPLICATION OF THIS P&ID TO UNIT 2, USE UNIT 2 IDENTIFICATION NUMBERS FOR PIPING, VALVES, INSTRUMENTS, EQUIPMENT, ETC. REFER TO DRAWINGS 9A310F00001 AND 9A310F00002 FOR IDENTIFICATION NUMBER DETAILS.

7. WHEN APPLYING THIS P&ID TO UNIT 2, CHANGE ALL UNIT DESIGNATORS OF 1 IN CROSS REFERENCE ARROWS TO 2.

8. THE "EW" VALVES LISTED BELOW ARE PLUG VALVES ON UNIT 2:

0004, 0005 0009,
0010, 0017, 0018,
0021, 0022, 0025,
0026, 0029, 0030,
0037, 0038, 0040,
0041, 0045, 0046,
0053, 0054, 0057,
0058, 0059, 0062,
0063, 0066, 0067,
0077, 0078, 0082,
0083, 0090, 0091,
0094, 0095, 0096,
0099, 0100, 0103,
0104, 0114, 0115,
0116, 0119, 0120,
0123, 0124, 0126,
0127, 0131, 0132,
0135, 0136, 0139,
0140, 0141, 0142,
0145, 0146, 0149,
0150, 0153, 0154,
0155, 0156, 0167,
0171, 0174, 0195,
0196, 0197, 0207,
0208, 0209, 0210,
0236, 0237, 0238,
0239, 0012, 0028,
0032, 0036, 0048,
0065, 0069, 0073,
0085, 0102, 0106,
0110, 0015, 0031,
0035, 0039, 0051,
0068, 0072, 0076,
0088, 0105, 0109,
0113, 0211, 0212, 0213, 0214,
0215, 0216, 0217, 0218, 0219,
0220, 0221, 0222, 0223, 0224,
0225, 0226, 0227, 0228, 0229,
0230, 0117, 0133, 0148, 0118,
0134, 0147, 0234, 0235,

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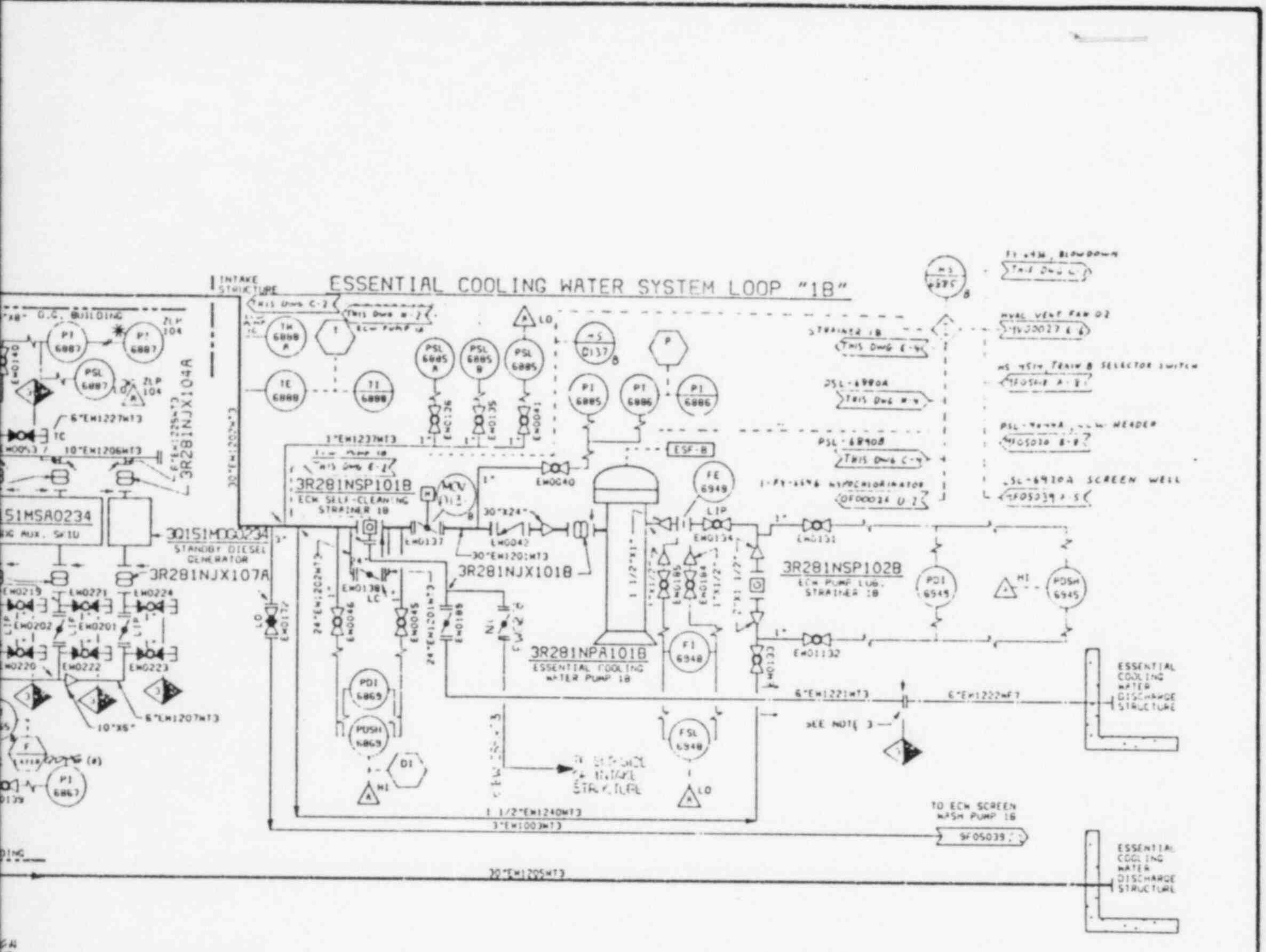
Figure 9.2.1-

NOTE:
ONE TRAI



EXAS PROJECT
ITS 1 & 2

GRAM ESSENTIAL
WATER SYSTEM
1 OF 2
NO. 5R289F05038

Amendment 35

YPICAL OF THREE

Also Available On
Aperture Card

TI
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FIGURE 5-3. ESSENTIAL COOLING WATER SYSTEM PIPING AND INSTRUMENTATION DIAGRAM

(Sheet 1 of 2)

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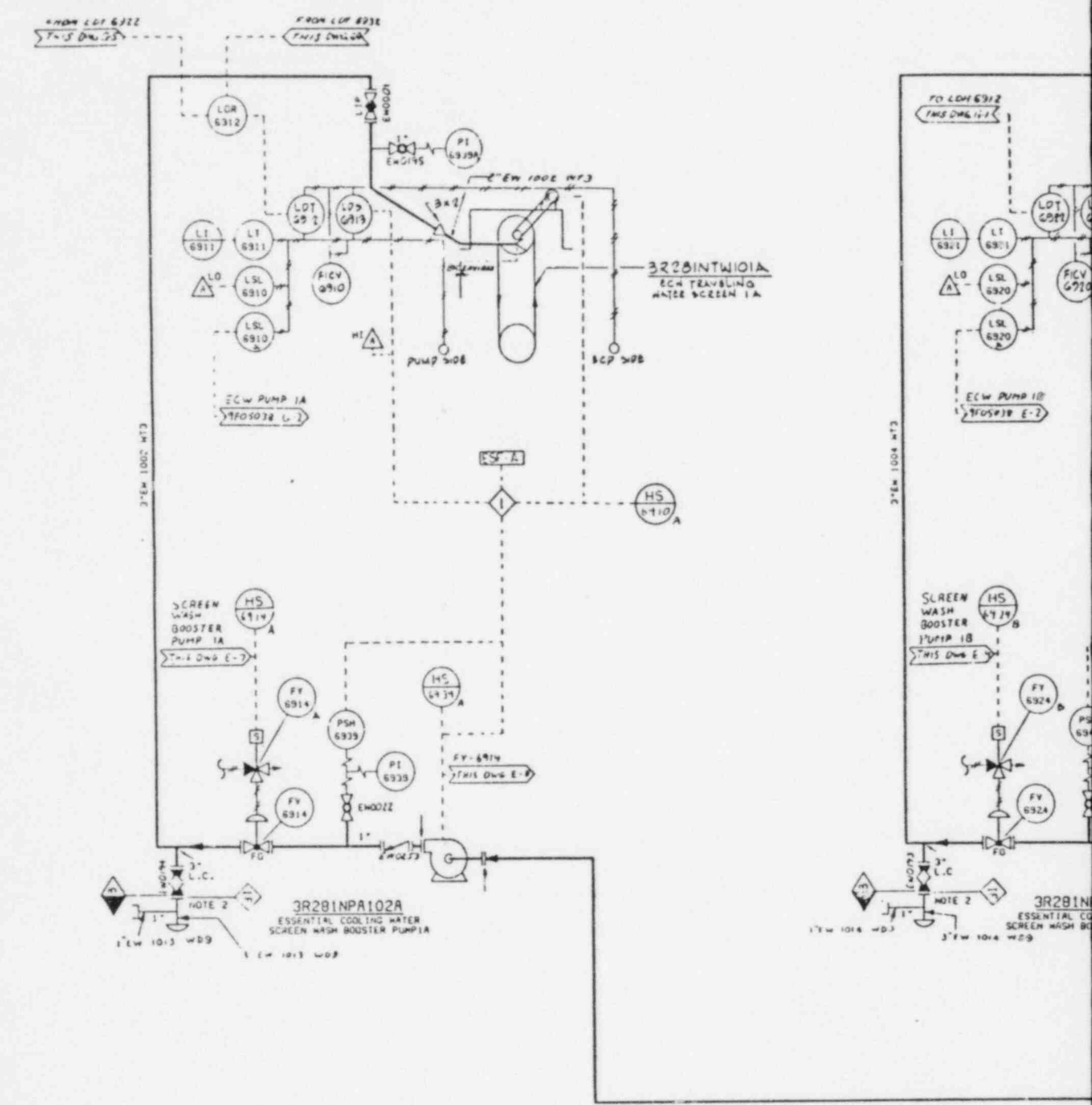
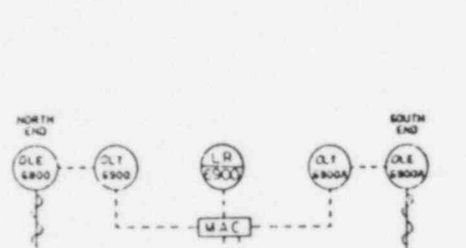


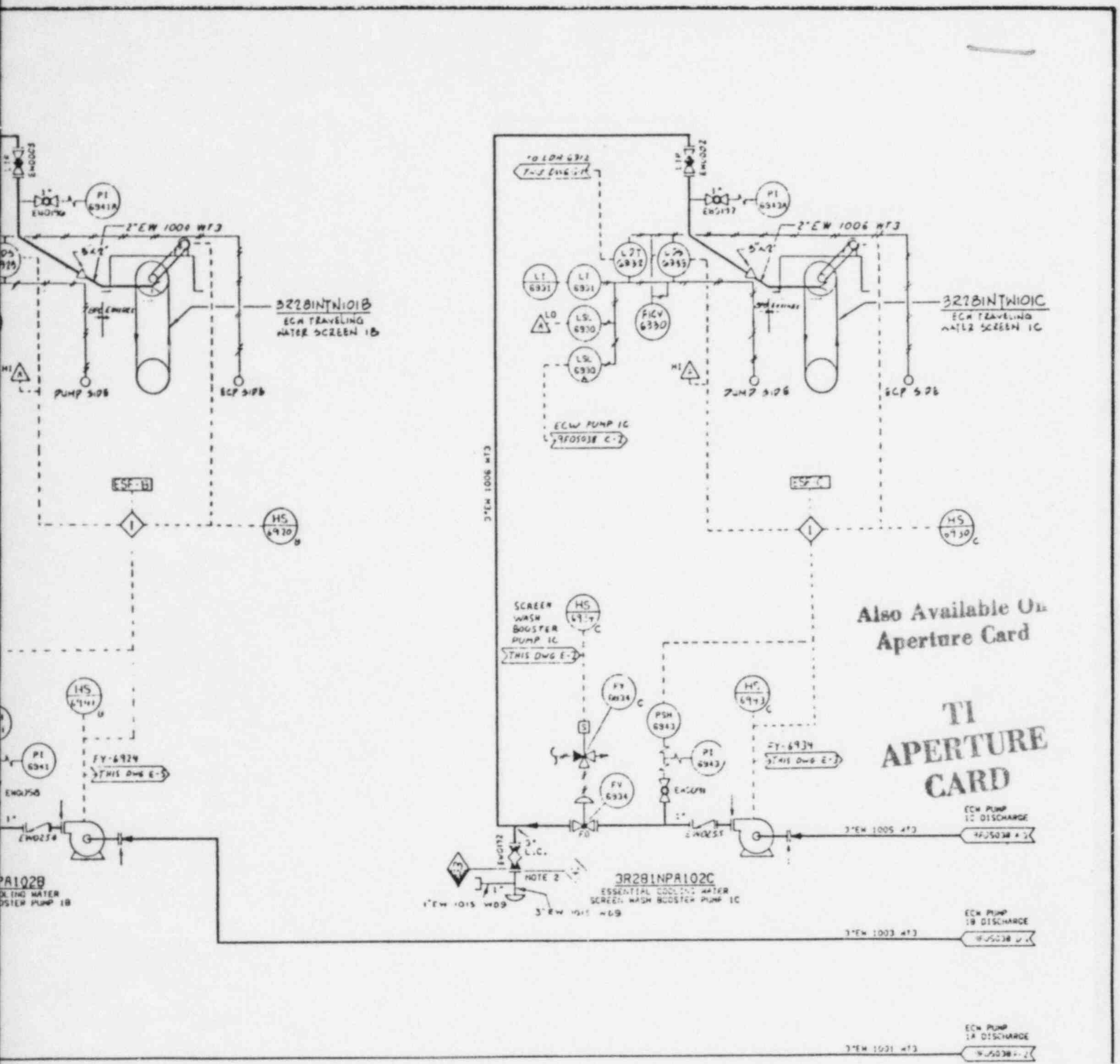


ESSENTIAL COOLING POND LEVEL

7. WHEN APPLYING THIS P&ID TO UNIT 2, CHANGE ALL UNIT DESIGNATORS OF "1" IN CROSS-REFERENCE ARROWS TO "2"
8. INSTRUMENT TAKEOFF PIPE AND FITTINGS TO AND INCLUDING THE ROOT VALVE SHALL CONFORM TO THE MAIN LINE SPEC.

NOTES:

1. ALL INSTRUMENT TAG NUMBERS SHOWN ON THIS DIAGRAM ARE PREFIXED BY THE UNIT NUMBER 1 UNLESS OTHERWISE NOTED. SEE GENERAL NOTE D ON 9A36-F00002
2. LOCATE VALVES AND HOSE CONNECTIONS IN TRAVELING WATER SCREEN ROOMS.
3. DELETED
4. ALL INSTRUMENTS ON THIS P&ID HAVE SYSTEM DESIGNATOR EW
5. ALL INSTRUMENTS ON THIS P&ID HAVE SEPARATION GROUP N UNLESS OTHERWISE NOTED
6. UNLESS OTHERWISE NOTED, UNIT 1 IS SHOWN ON THIS P&ID. FOR APPLICATION OF THIS P&ID TO UNIT 2 USE UNIT 2 IDENTIFICATION NUMBERS FOR PIPING, VALVES, INSTRUMENTS, EQUIPMENT ETC. REFER TO DRAWINGS 9A36-F00001 AND 9A36-F00002 FOR IDENTIFICATION NUMBER DETAILS



SOUTH TEXAS PROJECT
UNITS 1 & 2

PIPING DIAGRAM ESSENTIAL COOLING WATER SYSTEM
SHEET 2 OF 2
DWG. NO. 5R289F05039

Figure 9.2.1-4 Amendment 35

FIGURE 5-3 (Sheet 2 of 2)

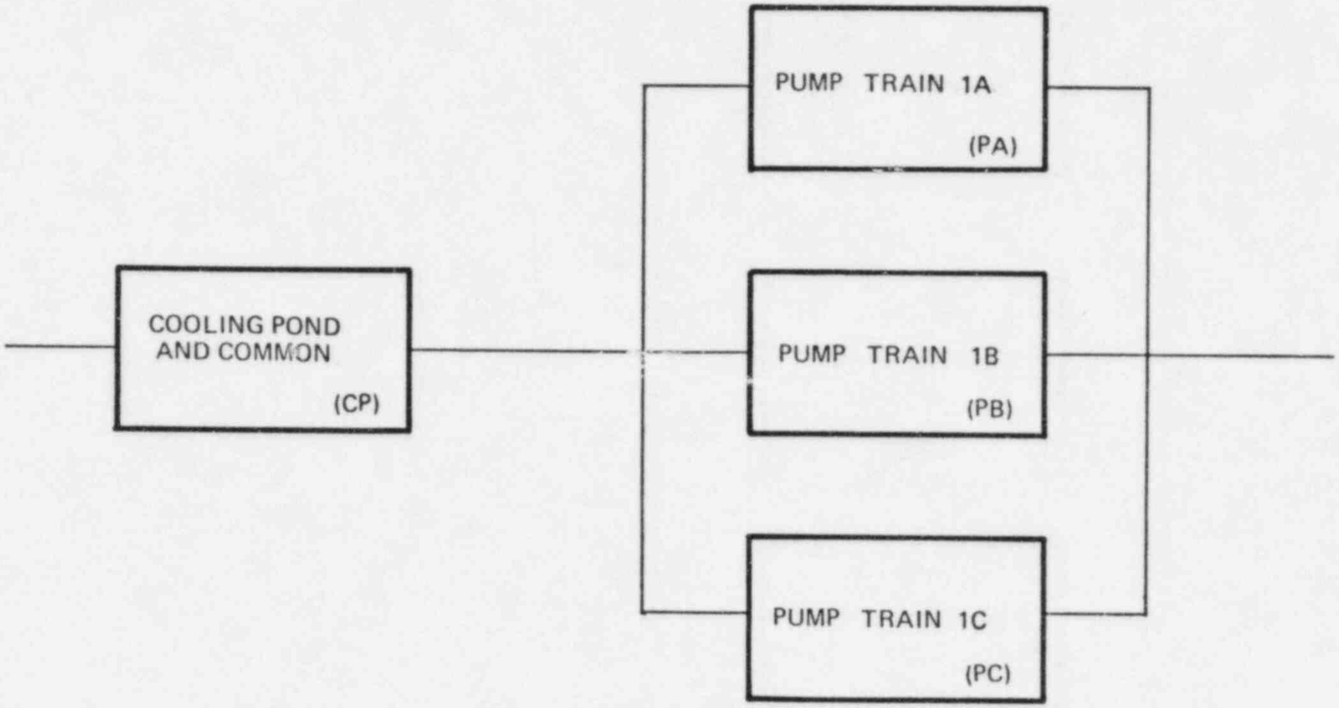


FIGURE 5-4. ESSENTIAL COOLING WATER SYSTEM BLOCK DIAGRAM MODEL

6. SURVEY OF EXTERNAL EVENTS AND INTERNAL PLANT HAZARDS

6.1 OVERVIEW

In performing a full-scope plant risk model for a Level 1, 2, or 3 PRA, the inclusion of external events and internal plant hazards is logically phased after much of the work to develop the basic plant event sequence and systems models has been completed. The objectives of this task in the Preliminary Scoping Study are the following:

- Screen a large number of potential external events and internal plant hazards using bounding risk estimates and knowledge of site-specific and plant-specific characteristics.
- Provide a basis for quantifying the approximate range of possible accident frequencies that could result from these events (performed in Section 2).

With respect to the above objectives, the results have been organized into three sections. In Section 6.2, seismic events are discussed. Although this discussion is purely qualitative, it provided a basis for quantifying uncertainties in the Scoping Study results in Section 2. A key finding is that the scope of the seismic analysis to fully document seismic risk could probably be reduced below the normal level in view of the low seismicity of the STPEGS and a relatively high safe shutdown earthquake level in relation to the seismicity.

In Section 6.3, internal plant hazards are discussed. Again, this section is purely qualitative but provides part of the basis for the probability distributions in Section 2 that characterize the state of knowledge at the end of the Scoping Study about core melt and release frequencies. The most critical plant locations, especially for the analysis of internal fires and floods were identified in this task.

The remaining external events are discussed in Section 6.4. In this section, bounding estimates are made for external events discussed in the FSAR. Based on these bounding estimates, it is unlikely that any additional work would be needed to document that these events are insignificant contributors to risk for STPEGS.

6.2 SEISMIC EVENTS

A preliminary review of the FSAR and discussions with the systems analysis team were accomplished for the purpose of scoping the tasks to complete a fully documented PRA seismic analysis. Adequate site specific geologic and seismologic information exists in the final safety analysis report to be used in the seismicity analysis. The FSAR indicates that there are no tectonic faults in the vicinity of the site, and that there is an absence of historic seismic activity there. Postulated earthquake magnitudes are low and are not expected to present any significant frequency of acceleration levels that could damage plant components. However, in order for PRA documentation to be complete, it would be

necessary to develop probability of frequency exceedance curves for peak ground acceleration at the STP.

The FSAR was also reviewed for general design information relative to fragility of structures and equipment. Nothing was found that suggests STP's facilities would have any particular weaknesses from predicted seismic events, but it must be remembered that physical inspection was not possible because of the early stage of plant construction. Although some summary design stress and capacity information is contained in the FSAR, additional information would be required in order to perform a detailed fragility analysis.

This information--strong evidence of low seismicity and no indication of weak structures or equipment--was combined with our experience in seismic risk assessment and our new knowledge of the STP plant to estimate the possible range of frequency of seismically induced core damage events. The most useful experience was in PRAs of PWRs with similar capabilities and higher seismicity.

6.3 IN-PLANT HAZARDS AND SPATIAL INTERACTIONS

This section describes a qualitative evaluation of the vulnerability of the STPEGS to internal plant environmental hazards, such as fires, internal floods, smoke, steam environments, etc., that are triggered from within the plant. To provide a basis for this investigation, the STPEGS plant model at the HL&P offices on Westheimer Avenue, Houston, Texas, was inspected and the following documents were reviewed: plant layout drawings, an STPEGS fire hazards analysis report (Reference 6-1), and STPEGS FSAR (Reference 6-2).

Because of the nature of this category of external events, the investigation in the Scoping Study was carried out on an location-by-location basis as opposed to an event-by-event basis. Several areas corresponding to fire zones within buildings that could be important to plant risk are identified below. These are areas where a physical interaction associated with a particular hazard could disable several vital pieces of equipment. Areas of particular interest are those capable of involving scenarios impacting equipment in multiple trains of a support or frontline system as well as those scenarios involving equipment in more than one support or frontline system. The Scoping Study identifies only the obvious potential paths of hazard progagation among the locations.

Reference 6-1 describes the separation among the three safety trains for safe shutdown equipment. This description includes all the equipment items of interest to this study except the HHSI pumps, containment spray pumps and their associated valves, piping, and electrical circuits. Also, the exact routing of cables is not yet determined for STPEGS; however, the fire hazard analysis report clearly indicates the location of cable trays and conduits by their train designations.

Using the above referenced documents, a preliminary qualitative evaluation of the potential for risk significant spatial interactions within the STPEGS buildings has been performed based on knowledge gained on the STPEGS plant during the Scoping Study. Each building is discussed separately below.

6.3.1 ELECTRICAL AUXILIARY BUILDING

The electrical auxiliary building houses most of the electrical circuits for plant control, safety-related equipment, and accident mitigation. The control room, the relay room, the safety-related switchgear rooms, the cable penetrations into the containment, the auxiliary shutdown panel, and other related areas such as cable spreading rooms and cable vaults are located in this building.

Separation in this building is achieved primarily by dedicating each compartment to only one train. In a few compartments, some cable trays or conduits from a redundant train are present. In these cases, trays and conduits will be wrapped in 1-hour fire rated insulation and the area will be provided with an automatic fire suppression system. The exceptions to this rule are the control room, the relay room, the auxiliary shutdown area (designated as FA017.01), and cable spreading room B.

The auxiliary shutdown panel is a standby system and is electrically isolated from the main electrical circuits. Therefore, all environmental hazards affecting this panel have only a small likelihood of adversely affecting safe plant shutdown.

The control room and the relay room are not separated, and hazardous environments can severely impact the plant. The operators can use the auxiliary shutdown panel as a redundant point for plant control. Scenarios for the relay room and control room hazardous environments would be analyzed in detail to evaluate operator response (possible errors or significant delay in taking action) in a fully documented PRA. Experience in completed PRAs combined with knowledge of the STP design permits us to estimate the possible impacts of such scenarios. An example of the scenarios considered is the case of loss of all component cooling water pumps and operator delay (because of conflicting information on the control board) in tripping the reactor coolant pumps before seal damage occurs.

Cable spreading room B contains a few control and instrumentation cable trays from train C. It is not clear which circuits are in these trays. Thus, there may be potential for disabling both trains B and C of some equipment.

The redundant trains of electrical circuits in the EAB are generally well separated in terms of fire impact with the use of barriers. By contrast, high energy missiles and flooding hazards can penetrate these barriers and affect the redundant trains. Such hazards were not found in this building in this preliminary analysis. Thus, the spatial interaction analysis should primarily concentrate on the occurrence of fires and floods in this building. In this regard, spatial interactions caused by

failures or unavailability of component cooling, HVAC, and chilled water systems have been explicitly integrated into the plant and systems analysis models.

6.3.2 MECHANICAL AUXILIARY BUILDING

The mechanical auxiliary building houses the CCW system, the chemical and volume control system, and the waste processing systems as well as other mechanical systems for plant operation, monitoring, and shutdown. This building is similar to the EAB in the sense that in all fire areas and fire zones where redundant sets of cable trays appear, one set of trays will be wrapped in 1-hour rated fire barriers and the area will be provided with an automatic fire suppression system. An exception to this rule is fire area FA102.07, which contains all three CCW heat exchangers.

For the MAB, only high energy hazards (such as water jet and pipe whip) and internal floods are deemed important. A rigorous investigation could be performed for the ways that the high energy hazard sources present in the MAB may disable redundant cable trays and conduits. The high energy hazards are deemed to have significant likelihood for penetrating the 1-hour rated fire barriers, ground cable trays, and conduits.

An important source of flooding in the MAB is the essential water cooling system that provides cooling to the component cooling water systems heat exchangers. A break in the essential water cooling system can spill a very large volume of water into the MAB. The water can accumulate at Elevation 10'-0" of the MAB and jeopardize safety class components; e.g., CCW and charging pumps, etc. Such large breaks are unlikely to occur. For the MAB, the spatial interaction analysis should concentrate on scenarios involving high energy hazards, water sprays, and rising pools of water.

6.3.3 FUEL HANDLING BUILDIING

The fuel handling building contains the high head safety injection system, the low head safety injection system, the containment spray system, and spent and new fuel handling equipment. The three redundant trains of the above-mentioned safety-related systems are separated by 3-hour rated fire barriers. The only exception is fire area FA303 at Elevation 4'-0", which contains all three trains of FHB exhaust and booster fans.

The fire hazard analysis report does not indicate the location of cable trays and conduits for this building. Therefore, the routing locations of certain cables inside the FHB could have some impact on risk. If the redundant cables are also well separated, the spatial interaction analysis should concentrate on environmental hazard scenarios originating at the higher elevations of the building and impacting the three safety-related systems at Elevation 29'-0".

6.3.4 REACTOR CONTAINMENT BUILDING

The reactor containment building houses the nuclear steam supply system, the residual heat removal pumps and heat exchangers, and chemical volume and control system related equipment. The RCB does not have any completely enclosed compartments. There are communication paths among all fire areas within this building. Separation among the redundant trains is achieved by distance (either vertical or horizontal).

The building contents are well designed for most of the potential environmental hazards, such as high energy line break, steam, and hydrogen combustion. Only very large fires can impact redundant cable trays and conduits.

6.3.5 DIESEL GENERATOR BUILDING

The diesel generator building houses all three emergency diesel generators. The building has three separate sections. Each section houses one diesel generator and its support equipment. All significant environmental hazards generated from within the building are deemed to be contained within the section of origin and to impact only one diesel generator. Only extremely high energy sources, such as fire in a fuel storage tank, could conceivably impact two or more locations.

6.3.6 ISOLATION VALVE CUBICLE

The isolation valve cubicle houses the main steam line isolation valves, the atmospheric steam relief valves, main feedwater piping, and the auxiliary feedwater system. Four auxiliary feedwater pumps are located at Elevation 10'-0" of the building. Except for a few cables, these pumps and their associated cabling are well separated from one another.

Fires affecting redundant cables in some of the fire areas within the building could affect risk results. Thre is some potential for steam line and feedwater breaks with propagation of steam and water to the separated sections of the building.

6.3.7 ESSENTIAL COOLING WATER INTAKE STRUCTURE

The essential cooling water pumps are located in the essential cooling water intake structure. Each pump train is in a completely separate section of the intake structure. There is no interaction among these sections. The spatial interaction analysis should include scenarios involving multiple events; e.g., separation is breached via a door left open and an environmental hazard occurs independently.

6.3.8 OTHER BUILDINGS AND THE YARD

All other buildings of the plant not mentioned explicitly here do not contain safety-related equipment and do not pose any hazards to the buildings mentioned above. Therefore, they are given lower priority in the spatial interaction analysis.

The yard area contains, among many nonsafety items, the auxiliary feedwater storage tank and the auxiliary transformers. No internally generated sources of hazard that could disable the auxiliary feedwater pump were identified. The auxiliary ESF transformer will be analyzed in detail in the spatial interaction analysis.

The offsite power and diesel generator power leading to the engineered safety feature switchgear in the EAB are routed via an underground separated bus duct system. Therefore, no internally generated environmental hazards can disable them.

6.4 OTHER EXTERNAL EVENTS

Several other external events are analyzed in this section. They consist of events that do not usually contribute significantly to the core melt frequency and often can be dismissed in a screening analysis. The following sections present the results of such screening analyses of risk associated with aircraft crash, turbine missile, tornado wind and missile, hazardous chemicals, and external flooding.

6.4.1 AIRCRAFT HAZARD ANALYSIS

There are two airports within 10 miles of STPEGS. These are C-Level Farm, 9.5 miles west-northwest of the site, and Collegeport Airfield, located approximately 8.5 miles southwest. The latter is no longer in active use. However, an airfield has been constructed about 1/4 mile east of the old runway and will be used primarily for agricultural aviation. It is estimated that during the peak growing season, there will be approximately 100 takeoffs and landings per day.

The C-Level Farm facility is also used for crop-dusting operations. During working seasons, there are 25 to 35 landings or takeoffs per day. There are also several small grass strips within 10 miles of the site used during aerial crop-dusting operations. Since the aircraft used for agricultural purposes are typically very light and the annual number of flights is not large, the risk associated with such aircraft activities is not considered significant.

There are two low level federal airways within 10 miles of the site. These are airways V70 and V20 with centerlines 5 and 9 miles from the site, respectively. Of these two airways, only V70 has a significant contribution to the risk of aircraft because of its relative proximity to the site.

6.4.1.1 Analytical Model

The frequency of aircraft crashes into different structures of the plant is estimated using the following model (Reference 6-3)

$$f_k = \sum_{i=1}^{M} \sum_{j=1}^{L} N_{ij} \lambda_j d_j \frac{A_{kj}}{A_{pj}} \qquad (6.1)$$

where

f_k = annual frequency of impact on the kth structure (events per year).

M = number of different flight paths that take aircraft past the site.

L = number of different type of aircraft that pass the site.

N_{ij} = annual number of operations of aircraft of type j to or from airport i or along airway i.

λ_j = crash rate of aircraft of type j (accident/mile flown).

d_j = distance traveled by the aircraft while the plant site is within its potential impact area (miles).

A_{kj} = effective impact area of the kth structure of the plant for aircraft of type j (square miles).

A_{pj} = potential impact area for aircraft type j (square miles).

The product $N_{ij}\lambda_j d_j$ is the number of aircraft accidents of type j within the defined distance segment d_j per year that could potentially affect the plant from the ith airway or airport. The ratio A_{kj}/A_{pj} is the probability of hitting a particular structure given that the aircraft accident is in the vicinity of the site.

The quantities d and A_p (the aircraft type index j is dropped for convenience) can be calculated by assuming that any given time a crash initiating malfunction occurs, there is an equal probability of crash termination anywhere in a sector of radial length, gh, and angular width, ϕ, located directly in front of the aircraft, where g is the glide distance per unit of altitude lost and h is the altitude. The situation is shown in Figure 6-2, where b is defined as the distance of closest lateral approach between the normal flight path of the aircraft and the site.

Figure 6-2 shows that the distance d is given by

$$d = \left[(gh)^2 - b^2\right]^{\frac{1}{2}} + b/\tan\beta \qquad (6.2)$$

This quantity can be averaged over all allowable values of b. The result is

$$d = \frac{1}{2}\, gh(\frac{\phi}{2})/\mathrm{Sin}(\frac{\phi}{2}) \qquad (6.3)$$

A_p is the area of the sector defined by the angle ϕ and radius gh

$$A_p = (gh)^2(\frac{\phi}{2}) \qquad (6.4)$$

6.4.1.2 Crash Rates

Crash rate statistics are provided either in the form of the number of crashes in the total number of miles or the number of hours flown by a particular type of aircraft. The latter can be converted to the former by multiplying the number of hours by an average speed for the type of aircraft under consideration.

Table 6-1 shows 10 years' statistics for fatal accidents involving air carriers (Reference 6-4). The mean and the variance of the annual inflight crash rates are 1.51×10^{-9} and 4.39×10^{-19}, respectively. These values are used to fit a lognormal distribution by matching moments method. Other characteristics of the distribution are as follows:

5th Percentile: 6.95×10^{-10}

50th Percentile: 1.39×10^{-9}

95th Percentile: 2.76×10^{-9}

By using the data from 1970 to 1979 to construct our state of knowledge distribution for the crash ratio during the period of operation of STP, we are reflecting the possiblity of changes in the crash rates that might occur due to introduction of new technology.

The accident rates for general aviation aircraft are given in Table 6-2 (Reference 6-5). The classification into single and multiple engine aircraft is due to the difference in their impact effects on the plant structures. The following values characterize the lognormal distributions chosen to represent our uncertainty concerning these rates:

CRASHES PER MILE FLOWN

Characteristics of Distribution	Single Engine	Multiple Engine
5th Percentile	1.91×10^{-7}	5.54×10^{-8}
50th Percentile	2.27×10^{-7}	7.14×10^{-8}
95th Percentile	2.70×10^{-7}	9.20×10^{-8}
Mean	2.28×10^{-7}	7.23×10^{-8}

The distribution in each case is derived by using the mean and variance of the crash rates based on Table 6-2 as the mean and variance of a lognormal distribution.

6.4.1.3 Number of Operations (N)

The majority of aircraft activities near the site take place along the low level federal airway V70. The centerline of V70 has a closest approach of approximately 5 miles. According to Reference 6-2, a 1983 survey of flights in the vicinity of the site indicates that there are about 25 flights per day. Approximately half of these flights have altitudes less than 17,000 feet and are categorized as general aviation aircraft. The other half, with an altitude greater than 17,000 feet, are mainly air carriers. Therefore, the following values are estimated for the number of flights for these two categories of aircraft:

General Aviation: $N_1 = 4,563$

Air Carriers: $N_2 = 4,563$

6.4.1.4 Exposure Parameters d and Ap

To obtain the exposure parameters d and Ap as defined by Equations (6.3) and (6.4), several other parameters (namely, g, the glide ratio; h, the altitude; and ϕ, the exposure angle) are needed for each category of aircraft.

In this analysis, a glide ratio of 17 was used for both categories of aircraft. It was also assumed that $\phi/2 \geq 90°$ for the two categories. The altitude of general aviation flights was taken to be about half of the 17,000 feet altitude, which was used to distinguish between two categories of aircraft. For the large aircraft flying above 17,000 feet, an average altitude of 23,500 feet was used.

6.4.1.5 Impact Area and Fragility of Different Structures

The total exposed area of the plant is about 0.034 square miles, which consists of the plant area (approximately 0.0095 square miles), shadow area (about 0.013 square miles), and slide area (approximately 0.011). It is assumed that concrete structures can withstand impact of general aviation aircraft but would collapse upon impact by air carriers.

6.4.1.6 Impact Frequency

The annual frequency of aircraft crashes into any structure at the plant was calculated in Equation (6.1) using values of the various parameters obtained above. The total frequency is 6.95×10^{-7} per year, which is the sum of the general aviation contribution of 6.94×10^{-7} and the air carrier contribution of 1.66×10^{-9} per year. Given that the impact area of the general aviation type of aircraft is relatively small, and that most critical structures of the plant can withstand the impact load of this type of aircraft that usually weigh less than 12,500 lbs., the frequency of substantial damage to any given safety-related structure of the plant and the impact of such damage would be at least an order of magnitude smaller than approximately 7×10^{-7}. With such a low initiating event frequency, aircraft crash-initiated scenarios are not anticipated to rank high among the contributors to core melt frequency.

6.4.2 TURBINE MISSILE RISK

This section presents a screening analysis of the risk to the STP plant from missiles that can potentially be generated in the event of a steam turbine failure.

6.4.2.1 Turbine Missile Impact and Damage Frequency

The frequency, f, of serious damage to a specific system due to a turbine missile is calculated from

$$f = f_1 \cdot f_2 \cdot f_3 \qquad (6.5)$$

where

f_1 = annual frequency of missile generation.

f_2 = conditional probability of a missile striking an essential system given that a turbine missile has been generated.

f_3 = conditional probability of unacceptable damage to the system given that a missile strikes the system.

6.4.2.2 Frequency of Turbine Missile Generation, f_1

The STP plant utilizes Westinghouse turbine generators. Each turbine is a four-casing, tandem compound six-flow reheat, 1,800 rpm unit with 40-inch last stage blades (Reference 6-2). Failures of turbine generator rotating elements are generally categorized into (1) failure at or near operating speed, and (2) overspeed failure that results from failure of the steam admission control components.

An analysis of the likelihood of each of the above failure modes based on Westinghouse experience (Reference 6-6) provides the following estimates for missile generation frequency:

Operating Speed: $f_1 = 1.6 \times 10^{-6}$ per unit/year

Overspeed: $f_1' = 1.7 \times 10^{-10}$ per unit/year

More recent analyses based on generic data indicate that missiles can be generated at much higher frequencies. In this analysis, we use the generic estimates obtained by Bush and Heasler (Reference 6-7)

$f_1 = 1.1 \times 10^{-4}$ per unit/year

$f_1' = 4.3 \times 10^{-5}$ per unit/year

It is noted that the values assumed above for f_1 and f_1' are greater than the values used in a similar analysis in the FSAR. (Reference 6-2). The authors had already reviewed the estimates of Reference 6-8 as part of the SSPSA. Rather than use additional resources to review the FSAR estimates, the estimates of Reference 6-8 were used for this bounding analysis.

6.4.2.3 Conditional Probability of Missile Impact, f_2

To obtain f_2, the conditional probability of a missile striking an essential system given turbine failure, the behavior of potential missiles ejected from the turbine must be analyzed, taking into account the kinetic energy and possible trajectories of the missiles as well as the location of potential targets. Such an analysis has been performed for STP and the results are reported in Reference 6-2 and shown in Tables 6-3 and 6-4 for two failure mechanisms. These tables also provide the estimated total frequencies of damage to each safety-related structure, which are obtained by using the appropriate values of f_1, f_2, and f_3 in Equation (6.5).

Tables 6-1 and 6-2 show that the annual frequency of damage to any given target is not greater than 5.65×10^{-8}, which is the estimated damage frequency for the Unit 2 isolation valve cubicle. However, damage to the structure does not necessarily mean damage to the equipment inside. Furthermore, even complete destruction of a single system is not likely to lead to core melt directly. Based on these considerations, we conclude that turbine missile initiated scenarios at STPEGS are insignificant contributors to the total core melt frequency.

6.4.3 TORNADO WIND AND MISSILE RISK

This section presents the results of analysis of the risk associated with tornado wind and missiles. In general, winds can affect critical structures of the plant in two ways:

- If wind forces exceed the load capacity of a building or other external structures, the incident walls or framing might collapse or the structure overturn from excessive loading.
- In case of strong winds, such as in tornadoes, objects might be lifted and thrust as missiles against a critical facility that, if not designed to resist missile penetration, might be damaged and lose its function. The following section discusses the risk due to tornado wind load, followed by a tornado missile risk analysis.

6.4.3.1 Tornado Wind Risk

The design basis tornado windspeed for critical structures of STPEGS is 360 mph. This windspeed is composed of a translational component of 70 mph and a rotational component of 290 mph (Reference 6-2). The annual frequency, ϕ, of excessive tornado wind load on structures can be found using

$$\phi = \phi_t \cdot \phi_{v|t} \qquad (6.6)$$

where ϕ_t is the annual frequency of a tornado striking the plant and $\phi_{v|t}$ is the fraction of tornadoes with peak windspeed greater than 360 mph.

The algorithm used to estimate ϕ_t is (Reference 6-8)

$$\phi_t = n \cdot \frac{W}{A} \qquad (6.7)$$

where

W = mean destructive path area of a tornado in square miles.

A = area of interest within which it is assumed the tornado could strike the site.

n = mean number of tornado occurrences per year in this area, A.

Tornado statistics for the site region indicate that from January 1951 through June 1978, 62 tornadoes have occurred within a 50-mile radius of the STP site (Reference 6-2). This is an average of 2.25 tornadoes per year. The same statistics also provide an estimate of 0.05 square miles for the tornado mean path area. Approximately 1,100 square miles of the area within 50 miles of the site is the Gulf of Mexico. Since the tornado data are normally provided for the areas over the land, the area of water was excluded in calculating the mean annual frequency of a tornado hitting the site. The result is

$$\phi_t = (2.25)\,\frac{0.05}{6,750} = 1.67 \times 10^{-5} \text{ strike per year}$$

Tornado wind exceedance probability, $\phi_{v|t}$, is more difficult to estimate because of the inaccuracy of indirect measuring techniques and the lack of a good analytical model for tornado behavior. An analysis of 4,582 tornadoes whose intensities were classified according to the Fujita F-scale is presented in Reference 6-9. Table 6-5 shows the histogram of frequencies of tornado windspeeds based on a Johnson S_B distribution fit to the data for NRC tornado Region 1, which is applicable to the STP site. According to this distribution, the frequency of windspeed exceedance in Region 1 for tornado intensity $F \geq F6$ is obviously an upper bound for the frequency of windspeeds exceeding 360 mph. Therefore, 0.0005 was conservatively chosen as the value of $\phi_{v|t}$.

Although no upperbound for the windspeed is indicated in this histogram, Reference 6-9 proposes a value of 300 mph as the maximum windspeed in Region 1. Other experts indicate that a tornado windspeed higher than 400 mph is not possible due to atmospheric friction. In this analysis, it is assumed that 400 mph is the maximum windspeed for Region 1 tornadoes.

Finally, the annual frequency, ϕ, of excessive tornado windspeeds in excess of 360 mph is found by multiplying the values of ϕ_t and $\phi_{v|t}$.

$$\phi = (1.67 \times 10^{-5})(5 \times 10^{-4}) = 8.33 \times 10^{-9} \text{ per year}$$

6.4.3.2 Tornado Wind Fragility of Structures

As mentioned earlier, the design tornado windspeed for seismic Category I structures is 360 mph. According to Reference 6-2, to calculate tornado

wind load on such structures, maximum windspeed pressure, q_{max}, was obtained from the following formula

$$q_{max}(V) = 0.00256V^2$$

where V is the total tornado windspeed. Therefore, for V = 360 mph, $q_{max}(360)$ = 332 psf is obtained.

For V = 400 mph, which was used as the maximum possible tornado windspeed, $q_{max}(400)$ = 410 psf, which is higher than the design pressure calculated for a 360 mph windspeed by a factor of 1.23. The conservative factor of safety applied to material yield stress in order to obtain design allowable stresses was judged to be well within the margin of safety for Category I structures. Therefore, the lower end of tornado wind fragility curve for such structures is assumed to be in the vicinity of 400 mph.

We conservatively assumed a step function fragility curve for wind load on the safety-related concrete structures at 400 mph. In other words, it is assumed that these structures do not fail under 400 mph wind load and that failure is certain above that value.

This means that wind load is not likely to damage the safety-related concrete structures because, as discussed earlier, 400 mph is the maximum possible windspeed at the site. Therefore, the issue does not merit further investigation.

There are some critical pieces of equipment outdoors that can be damaged at windspeeds far below 360 mph. For instance, power lines, transformers, and related equipment would be lost in weaker but more frequent tornadoes. This loss would result in a transient initiating event.

The critical exterior metal vessels such as the refueling water storage tank and the auxiliary feedwater storage tank may also be subject to failure from negative or positive pressures generated by winds at tornado levels. However, these tanks are normally about 2/3 to 3/4 full when in service with resultant uniform internal pressures ranging to over 2,000 psf at the bottom walls. As long as they carry such a capacity, large external wind pressures cannot develop sufficiently to cause asymmetrical loads that would threaten buckling of the tanks, although the tanks top might be blown out from negative pressures. This, however, would not create buckling effects on the tank walls. Therefore, loss of contents from these metal vessels due to tornado wind load is highly unlikely.

6.4.3.3 Tornado Wind-Initiated Scenarios

Most tornadoes are capable of causing power lines to fail. Therefore, it can be reasonably assumed that offsite power is lost in a tornado event. However, additional failures caused by the tornado or other causes are required in order to have a core melt. As discussed, critical exterior

metal vessels are extremely unlikely to fail due to wind load. Moreover, even with the conservative assumption of step function fragility for safety-related concrete structures at a windspeed of 400 mph, the possible core melt scenarios will have frequencies less than 1.12×10^{-8} per year, which is the frequency of tornado winds exceeding 360 mph.

The above analysis provides a good indication that the risk contribution from tornado wind scenarios is small. Based on the Preliminary Scoping Study Technical Review Board's recommendation, additional analyses considering scenarios involving nonrecoverable offsite power loss would be required to fully document the low contribution of tornado wind scenarios.

6.4.3.4 Tornado Missile Risk

Tornado missile analysis involves information about the likelihood of a spectrum of available missiles in the plant vicinity, representation of the wind field in the tornado, and aerodynamic behavior relative to "liftoff," and flight of the potential missile. The analysis leads to a spectrum of missiles and missile impact velocities with their respective probabilities. A detailed analysis that integrated all these effects for typical plant layouts has previously been performed (Reference 6-10). The results of that work are considered to be reasonable gross estimates for the hazard of tornado missiles at STP.

In Reference 6-10, calculations were made using tornado histories of each tornado region defined by the NRC. It used a typical two-unit plant layout to establish the target envelope and a 26-missile spectrum which includes the six missiles defined in the NRC Standard Review Plan, Section 3.5.1.4 (wood plank, steel pipe, steel rod, utility pole, automobile). In general, the 26-missile spectrum of Reference 1-21 is more conservative than the SRP spectrum with respect to damage potential. Calculations were made for the combined design life of a two-unit plant in which initially one unit is operational for 3 years while the other unit is being completed, followed by both units operating. Assuming 5,000 available missiles during the construction phase and 1,000 missiles during the operating phase, the study estimates the following mean values for the annual impact and damage frequency for all structures of a plant in NRC Region 1:

- Case 1: One Unit Operating, Other Unit Being Built

  Mean: 7.51×10^{-6}

- Case 2: Two Units Operating

  Mean: 3.33×10^{-6}

The surface area of the plant studied in Reference 6-10 is about 500,000 square feet for each unit, which is nearly the same as the total exposed surface area of each STP unit.

However, the impact frequencies of Reference 6-10 were calculated based on a tornado strike frequency of 2.3×10^{-3} per year, whereas the tornado strike frequency at the STP site is 2.25×10^{-5} per year. Adjusting the impact frequencies for the site-specific strike frequency, 7.36×10^{-8} and 3.24×10^{-8} are obtained for the annual impact frequency for the first and the second case, respectively.

The above values are the annual frequency of inside wall scabbing for the safety-related structures (except the turbine building). All damages are believed to be localized and, therefore, it is very conservative to assume scabbing causes damage to all the contents. Even if it is assumed that such scabbing for Class 1 structures causes damage to enough vital components located near exterior walls and leads to core melt, the frequency of such an event is a negligible contribution to the total core melt frequency. As with the wind component of the tornado-initiated scenarios, the missile component appears to be a low contribution to risk. Also, as with tornado wind, more work would be needed to fully document scenario involving a nonrecoverable loss of offsite power.

6.4.4 HAZARDOUS CHEMICAL ANAYLSIS

This section presents a bounding analysis of the contribution to the risk from hazardous chemicals in the area surrounding the plant.

According to Reference 6-2, there are four industrial facilities within 5 miles of the plant. Only two of these facilities store chemicals: the Crysen Terminal facility, located 4.8 miles from the plant, which has a storage capacity for 120,000 barrels of gasoline, and the Celanese Chemical Company facility, located 5 miles from the site.

Because of its distance from the site, Crysen Terminal facility does not pose any hazard to the plant in the event of gasoline-air explosion. The chemicals stored at and shipped to and from the Celanese Chemical Company include five chemicals that could be considered potential hazards to the plant. These are anhydrous ammonia, hydrochloric acid, naptha, acetic acid and vinyl acetate. The chemicals are shipped to or from the plant via road FM 521 (nearest distance to the plant 0.89 miles) or the Colorado River (nearest distance to the plant 2.75 miles).

To perform a bounding analysis, we use the results of a detailed analysis of the risk associated with hazardous chemicals for the Midland Nuclear Plant (Reference 1-21). The hazard to the Midland plant has been shown to be dominated by the Dow Chemical plant to the north and by the Dow Corning plant to the east. Both sites have storage tanks, rail lines, and pipelines where large inventories of a variety of hazardous chemicals are stored. The distance of most of these storage facilities to the Midland site is approximately 1 mile.

Reference 1-21 calculated a total frequency of 7.55×10^{-6} per year for all relevant plant damage states resulting from relases of toxic chemicals from the Dow plants. The analysis was based on an annual frequency of 1.74×10^{-4} for toxic gas release due to direct storage tank failure and an annual frequency of between 1.8×10^{-4} and

5.4 x 10^{-4} for indirect release depending on the chemical substance stored. The indirect release is the result of tank failure due to shock wave from the explosion caused by another tank failure or some other mechanism. Another factor considered in the analysis was the availability of the hazardous gas monitoring system for the control room air intake system. The results in general indicated that all of the frequencies of the resulting plant damage states were at least more than one order of magnitude smaller than the frequency of same plant damage states due to other initiators.

There are several factors that would lead us to believe that the core melt frequency due to hazardous chemicals at STPEGS is bounded by the frequency calculated for the Midland plant. One factor is the quantity of the chemicals stored or shipped to or from at the Celanese Chemical Company, which is substantially smaller than that of Dow plants near Midland. Second, the distance of the Celanese plant to STPEGS is almost five times more than the distance between Midland and Dow plants, which would make any vapor clouds with high concentration of hazardous material less likely to reach the STPEGS site. Also, similar to the Midland plant, STPEGS is equipped with detection, alarm, and automatic control room isolation for the hazardous material. It is therefore concluded that the frequency of core melt at STPEGS due to release of hazardous chemicals is much smaller than 7.55 x 10^{-6} per year and that no further analysis of the subject is needed.

There are several potentially hazardous chemicals stored at the site. These are relatively small quantities of Anhydrous Ammonia, Ammonium Hydroxide and Hydrazine. Scoping analysis of the accident scenarios initiated by large releases of these substances indicate that the core melt frequency is no greater than 3 x 10^{-6} per year. This frequency is calculated based on large leaks of ammonia from its storage tank with a frequency of 2 x 10^{-4} per year; a probability of 0.16 that the wind direction would be N, NNW, or NW at the time of release, resulting in a high concentration of toxic gases in the control room; and 0.1 as the conditional probability of core melt given such an accident scenario. The conclusion is that the frequency of core melt scenarios initiated by release of onsite hazardous chemicals is bounded by other core melt scenarios.

6.4.5 EXTERNAL FLOODING

The STPEGS site is located about 10 miles north of the Gulf of Mexico. The Colorado River to the east of the site passes about 2.75 miles from the plant at its nearest distance from the site. The only major dam upstream from the site is Mansfield Dam. There is also a reservoir south of the site with surface area in excess of 14 square miles, which is used as a cooling pond.

According to meterological data (Reference 6-2), tropical storms and hurricanes are frequent in the general area surrounding the site. The average frequency of such storms for the entire Texas cost is approximately one per year. In 1961, Hurricane Carla passed near the

site and dropped 17.10 inches of rain in Bay City, 12 miles north-northeast of the site. Other hurricanes that passed near the site in recent years were Celia in 1970, Allen in 1980, and Alicia in 1983. This gives a frequency of 0.2 per year for occurrence of major hurricanes.

Reference 6-2 states that a breech of the cooling reservoir embankment is capable of producing the maximum possible flood level at the site. The critical structures of the plant are designed to withstand the effects of such flooding. The possible combination of a major storm and failure of the cooling reservoir embankment may have potential for plant damage. In fact, this combination represents the only identified external flood event with possible implications on risk. If we knew nothing about the structure and fragility of the reservoir embankment, use of historical generic dam failure data would yield an annual frequency of major site flooding of 10^{-4} and a much lower frequency of core damage from such events would be expected. However, we do know considerably more about this embankment than some unspecified dam--information that makes us believe that the frequency of site flooding would be much less than 10^{-4} per year.

Amendment 43 to Reference 6-2 explains that significant measures have been taken to ensure positive protection of the embankment against failure. The cooling reservoir water level is controlled; i.e., it is not subject to uncontrolled increases in water level such as a dam collecting water from a water shed. The embankment conditions and hydrostatic pressure are monitored, yielding information that provides a basis to decrease embankment water level prior to danger of failure. There is a program for the reduction of hydrostatic pressure beneath the embankment through the use of relief wells at locations along the perimeter of the reservoir. The embankment is protected against errosion. Conservative calculations combining the effects of rain, wind setup, and wave runup show that overtopping will not occur. Additionally, the STP impoundment does not have a connection to dissimilar materials (e.g., the side of a hill) so that historical data that resulted in failure associated with this interface is not applicable.

6.5 REFERENCES

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TABLE 6-1. AIRCRAFT ACCIDENTS AND ACCIDENT RATES: U.S. AIR CARRIERS, 1970 THROUGH 1979

Year	Number of Fatal Accidents		Aircraft Miles Flown (10^3)	Inflight Crash Rates*
	Inflight	Landing and Takeoff		
1970	4	4	2,684,552	1.49-9
1971	6	2	2,660,731	2.25-9
1972	3	5	2,619,043	1.14-9
1973	5	4	2,646,669	1.89-9
1974	7	2	2,464,295	2.84-9
1975	1	2	2.477,764	0.40-9
1976	2	2	2,568,113	0.78-9
1977	4	1	2,684,072	1.49-9
1978	4	2	2,742,860	1.46-9
1979	4	2	2,889,131	1.36-9

*Accidents per aircraft mile flown.

NOTE: Exponential notation is indicated in abbreviated form; i.e., 1.49-9 = 1.49×10^{-9}.

TABLE 6-2. FATAL ACCIDENT RATES FOR
U.S. GENERAL AVIATION AIRCRAFT

Year	Fatal Accident Rates Per Miles Flown		
	Single Engine	Multiple Engine	All Types
1972	2.63-7	8.7-8	2.11-7
1973	2.52-7	8.2-8	2.09-7
1974	2.45-7	7.6-8	1.88-7
1975	2.30-7	6.9-8	1.71-7
1976	2.02-7	6.4-8	1.66-7
1977	2.03-7	5.1-8	1.59-7
1978	2.02-7	7.7-8	1.59-7

NOTE: Exponential notation is indicated in abbreviated form; i.e., 2.63-7 = 2.63×10^{-7}.

TABLE 6-3. PROBABILITIES f_2 AND f_3 OF TARGETS DUE TO UNITS 1 AND 2 TURBINE MISSILES (SHEAR FAILURE)

Target*	Turbine Generator					
	Unit 1			Unit 2		
	f_2 (10^{-3})	f_3	f	f_2 (10^{-3})	f_3	f
RCB 1				1.4303	.0118	2.59-9
RCB 2	.3450	0.0	0.0			
DGB 1	.3176	.1583	7.70-9	.1615	.7850	1.94-8
DGB 2	.5206	.5122	4.08-8	.3176	.1583	7.70-9
FHB 1						
FHB 2						
MEAB 1				.2155	.1206	3.98-9
MEAB 2	.0190	0.0	0.0			
AFW Tank 1				.2018	.8332	2.57-8
AFW Tank 2						
IVC 1				.4072	.8178	5.09-8
IVC 2	.0377	.1709	9.79-10			
ECW Intake Structure				.1350	.8089	1.67-8
Total	1.2399		4.85-8	2.8689		1.27-7

*RCB 1 designates reactor containment building Unit 1; DGB 1 designates diesel generator building Unit 1, etc. MEAB designates mechanical/electrical auxiliary building, comprising the MAB and the EAB.

NOTES:

1. Blanks are for those targets either located outside the low trajectory missile strike zone or shaded by other targets.
2. Exponential notation is indicated in abbreviated form; i.e., 2.59-9 = 2.59×10^{-9}.

CAUTION: PRELIMINARY RESULTS-
IMPORTANT UNCERTAINTIES
DESCRIBED IN SECTION 2

TABLE 6-4. PROBABILITIES f_2 AND f_3 OF TARGETS DUE TO UNITS 1 AND 2 TURBINE MISSILES (SHEAR AND ROTATION FAILURE)

Target*	Turbine Generator					
	Unit 1			Unit 2		
	f_2 (10^{-3})	f_3	f	f_2 (10^{-3})	f_3	f
RCB 1				1.5660	0.0	0.0
RCB 2	.3779	0.0	0.0			
DGB 1	.5288	0.0	0.0	0.0	0.0	0.0
DGB 2	.7882	.3782	4.56-8	.5288	0.0	0.0
FHB 1						
FHB 2						
MEAB 1				.2534	.0073	2.91-10
MEAB 2	.0234	0.0	0.0			
AFW Tank 1				.2066	.7849	2.48-8
AFW Tank 2						
IVC 1				.4502	.8207	5.65-8
IVC 2	.0457	.1438	1.01-9			
ECW Intake Structure				.1422	.7197	1.57-8
Total	1.7640		4.66-8	3.1472		9.73-8

*RCB 1 designates reactor containment building Unit 1; DGB 1 designates diesel generator building Unit 1, etc. MEAB designates mechanical/electrical auxiliary building, comprising the MAB and the EAB.

NOTES:

1. Blanks are for those targets either located outside the low trajectory missile strike zone or shaded by other targets.
2. Exponential notation is indicated in abbreviated form; i.e., 4.56-8 = 4.56×10^{-8}.

CAUTION: PRELIMINARY RESULTS-
IMPORTANT UNCERTAINTIES
DESCRIBED IN SECTION 2

TABLE 6-5. TORNADO WINDSPEED FRACTIONS

F-Scale	indspeed Range (mph)	Frequency (NRC Region 1)
0	40 to 72	0.2440
1	72 to 112	0.4241
2	112 to 157	0.2375
3	157 to 206	0.0735
4	206 to 260	0.0172
5	260 to 318	0.0032
6	318 to 380	0.0005
> 6	> 380	

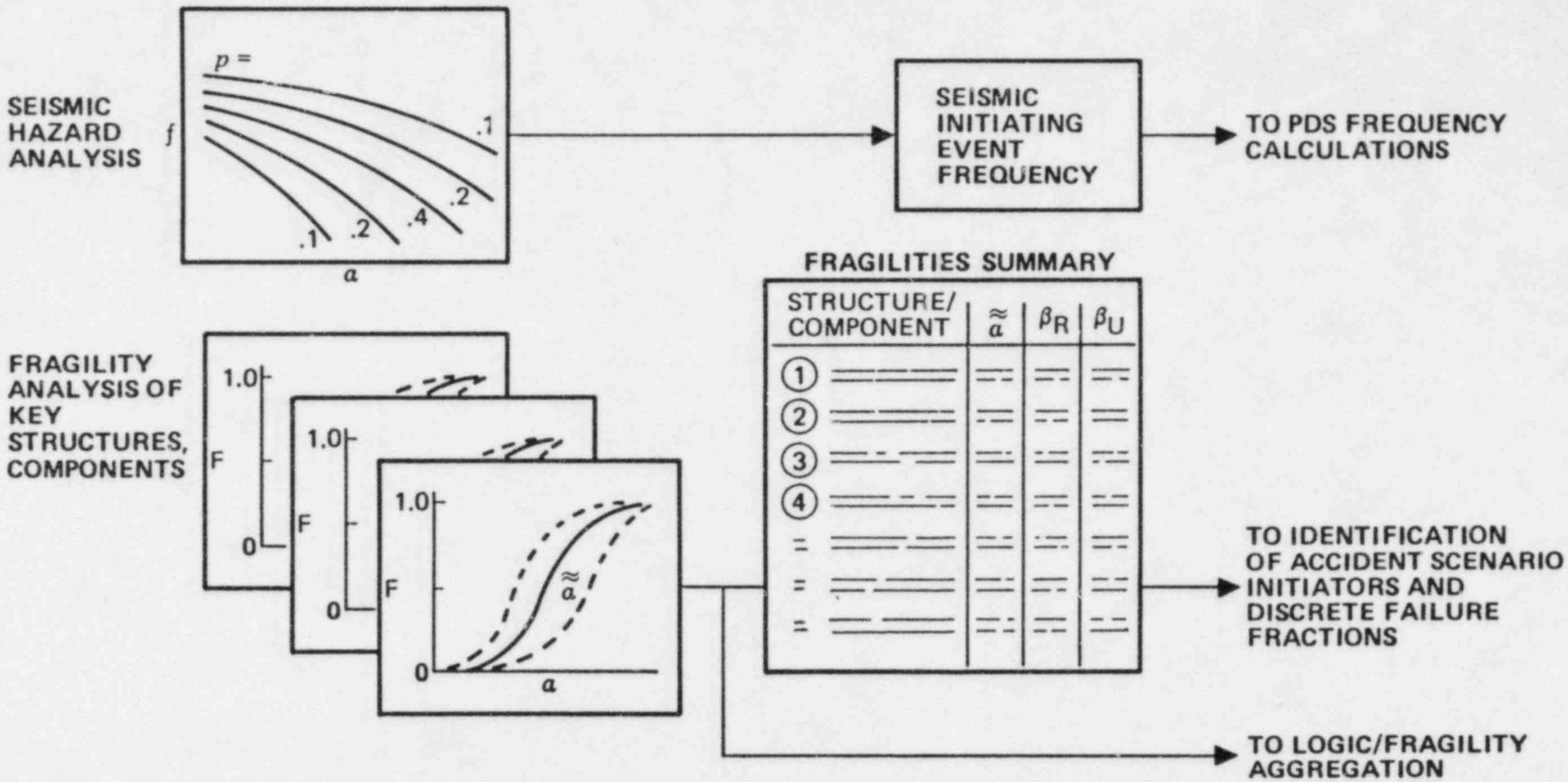

FIGURE 6-1. SEISMIC ANALYSIS
(Sheet 1 of 3)

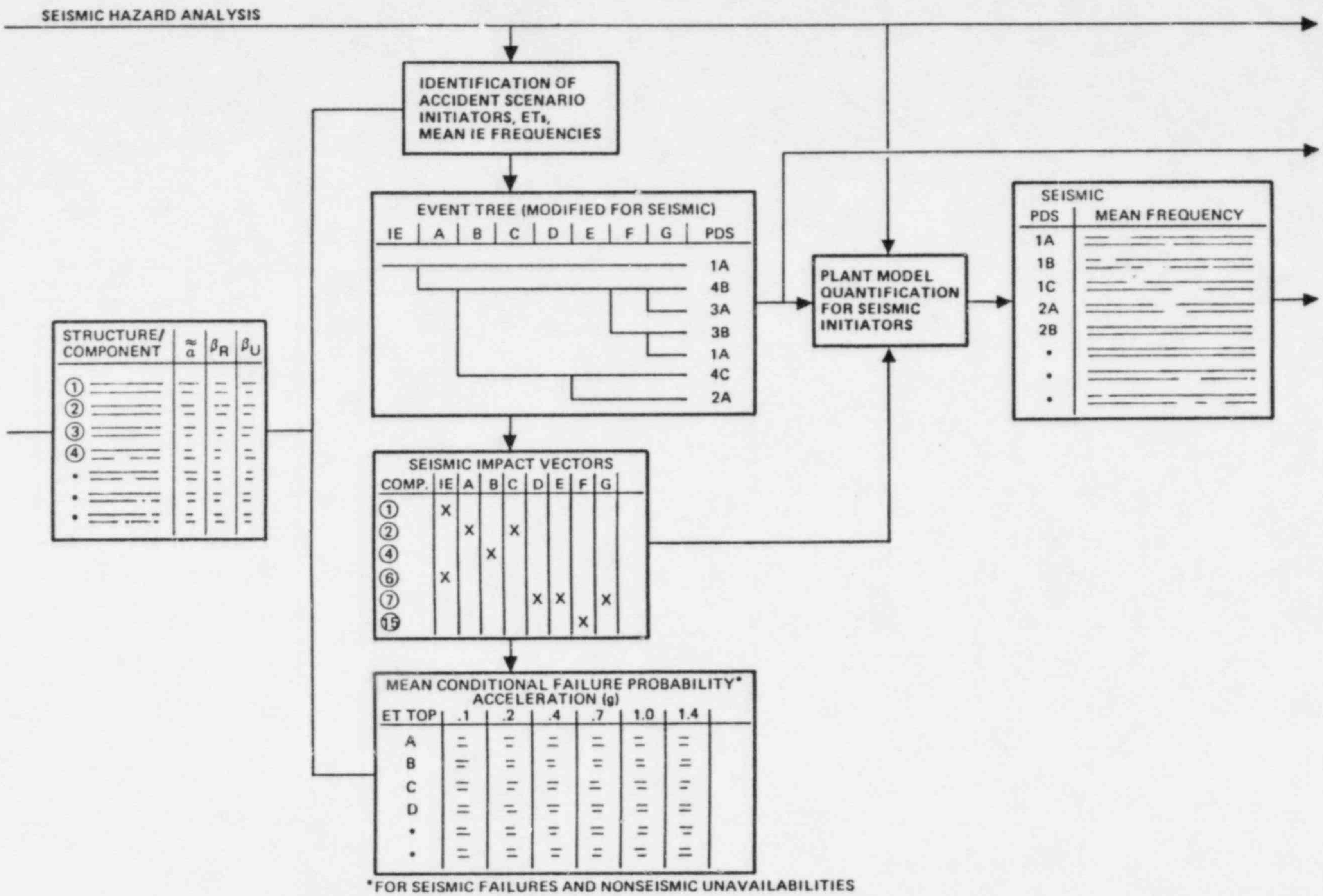

FIGURE 6-1 (continued)
(Sheet 2 of 3)

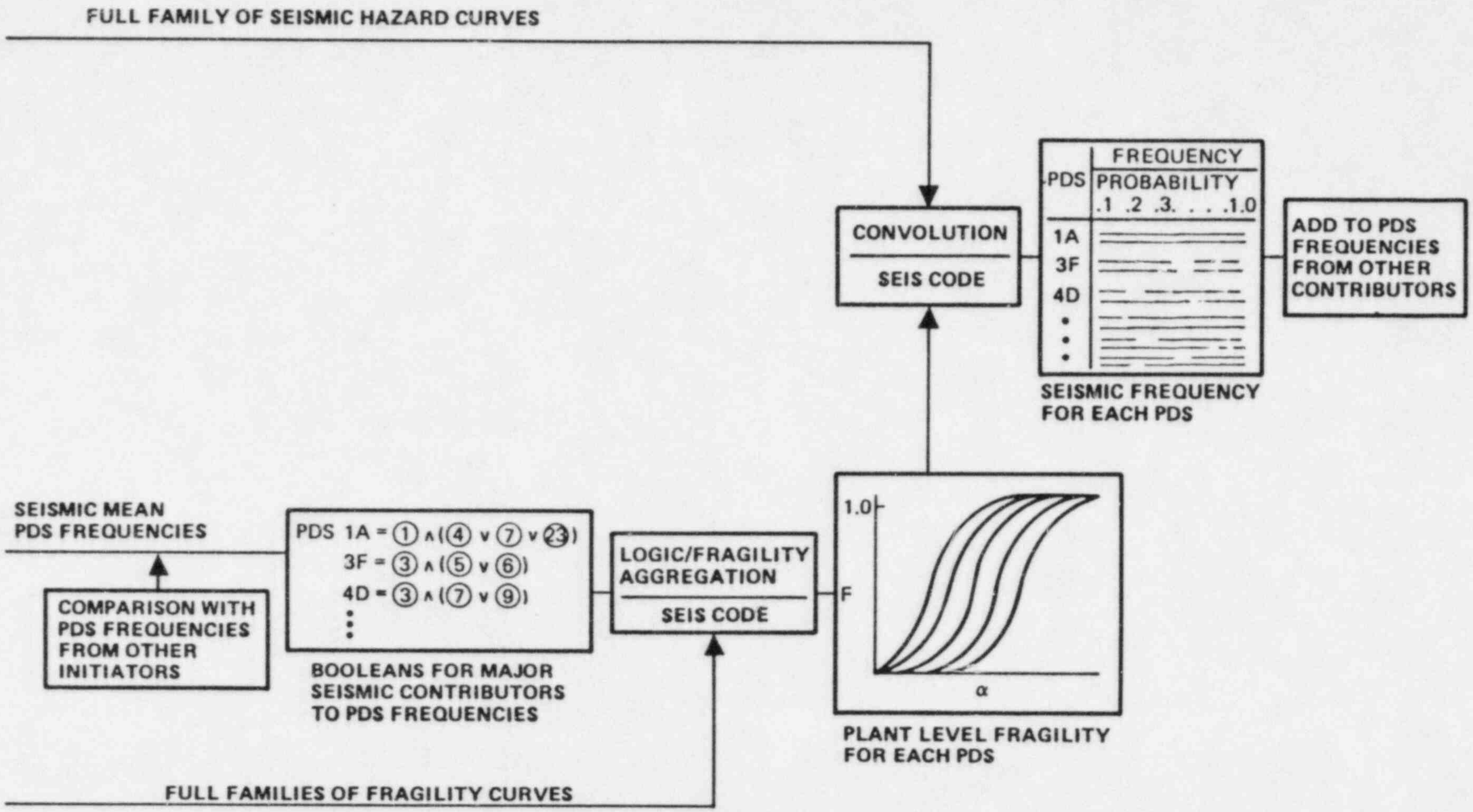

FIGURE 6-1 (continued)
(Sheet 3 of 3)

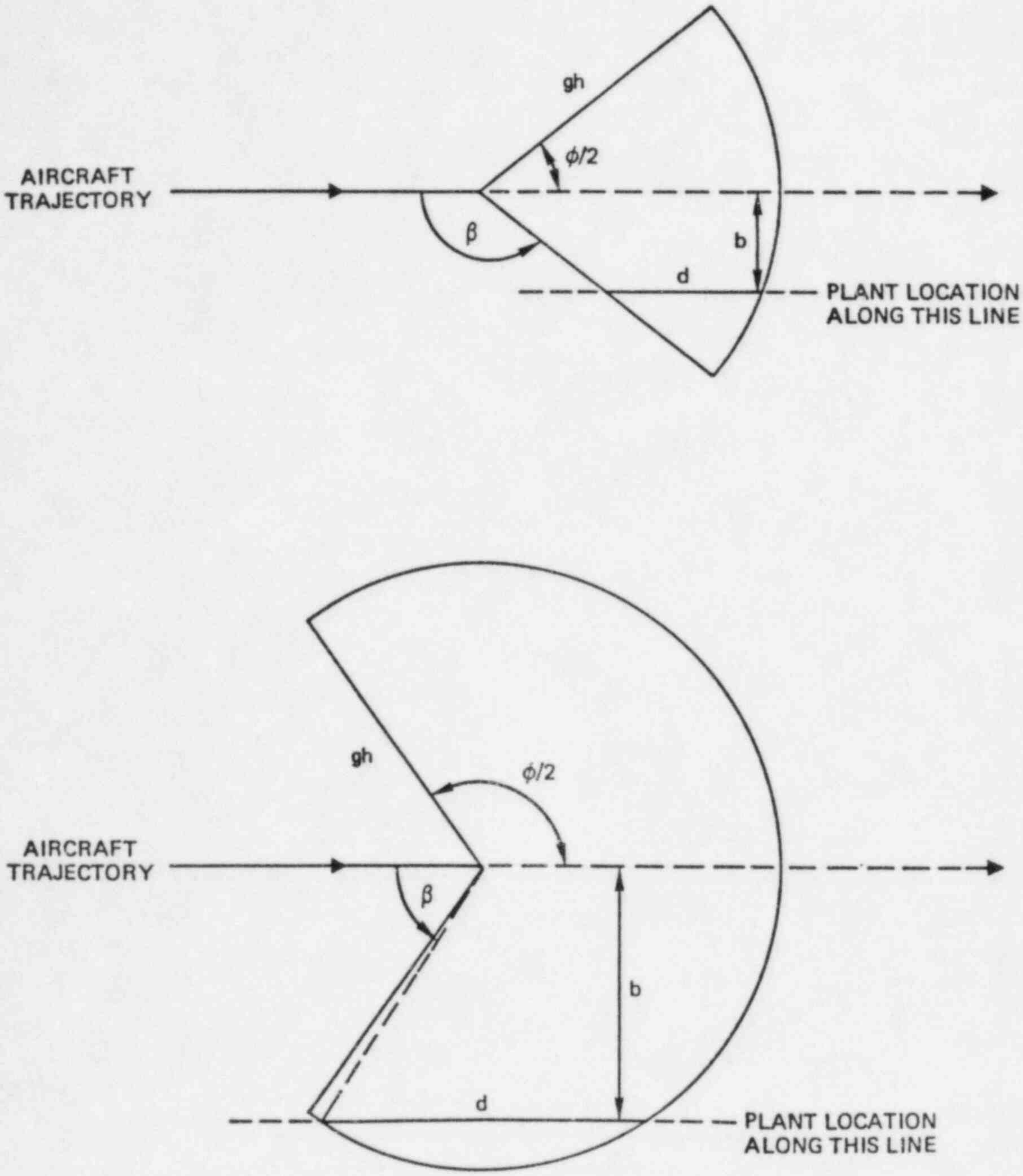

FIGURE 6-2. GEOMETRY FOR IMPACT PROBABILITY MODEL

7. SCOPING CONTAINMENT RESPONSE ANALYSIS

7.1 INTRODUCTION

This section presents a scoping overview of the containment response and source term characteristics of the STPEGS design. The assessment is based on an inspection of the containment design and an evaluation of its characteristics, relying to a large extent on PLG's experience from detailed containment response analyses of Westinghouse PWRs in large, dry containments. This section defines the plant damage states used in the Preliminary Scoping Study, develops an experience-based C matrix,* and develops release category definitions that can be used to qualitatively assess the health impact potential of the various release states.

7.2 STPEGS CONTAINMENT DESIGN

The STPEGS containment is a very large, dry PWR containment with a design pressure of 56.5 psig and a net free volume of 3.4×10^6 ft^3. The free volume is approximately 25% larger than other large, dry PWR containments with a comparable design pressure. This design feature will favorably extend the time when containment failure would occur in the absence of heat removal by active systems during postulated core melt accidents. The containment is steel-lined and post-tensioned. Our experience with this type of containment indicates that a realistic failure pressure can be expected to be between 150 and 200 psia. The positive impact of high containment failure pressure on the containment response will be discussed in Section 7.4.

The reactor cavity in the STPEGS design has a total floor area of 650 square feet, or about 30% larger than the Zion, Indian Point, or Seabrook reactor cavity floor area. The reactor cavity is level with the containment floor, which should facilitate the dispersal of debris out of the reactor cavity, if a dispersal path exists. However, from the available information, it was not possible to determine the structural strength and watertightness of the doors that are to be installed at the current access door to the reactor cavity, which is located at Elevation -11'.

If this boundary around the reactor cavity is very strong and watertight, most of the core debris emanating from the reactor vessel may be trapped in the reactor cavity. In this case, the question of water accessibility to the cavity becomes important. Again, based on the information available, it was not possible to identify clear and unambiguous paths by which water (several hundred gpm) could access the reactor cavity to cool core debris on the floor. The access paths examined included:

- Manway at Elevation -11'
- Manway at Elevation -2'

---

*The C matrix, as described in Section 3, contains the results of the containment event tree quantification and is used to map plant damage states into release categories.

- Instrument Tube Penetrations
- Reactor Cavity Floor Drains to Containment Sump
- Drainage Around the Reactor Vessel from the Refueling Pit Floor

Water accessibility to the reactor cavity is important because with the large cavity size, the debris bed is sufficiently shallow to be coolable even if all the core debris is trapped in the cavity. Debris coolability requires, however, that the debris is flooded with water, which requires that the water level equalizes between the reactor cavity and the outside area. Since it was not possible to establish a clear access path for water, it was decided to examine two configurations:

- Case I. Debris is trapped in the reactor cavity, water has no access to the reactor cavity.

- Case II. Debris is dispersed from the reactor cavity and water has access to flood the debris in the reactor cavity.

A separate analysis including the C matrix and separate sets of release categories was performed for each case.

7.3 PLANT DAMAGE STATES

The plant damage states define a discrete set of end states for accident sequences that lead to core damage. As the pinch point between the plant model and the containment model, they define the end states for accident sequences through the plant event trees. They also define the initial conditions for the containment event tree. Therefore, two observations are important:

- The plant damage states must be defined so that all the plant event sequences collected within a given PDS have similar characteristics in the containment response model and can be represented by one representative initiator in the containment response model.

- Even if a containment and source term analysis is planned for a future time, it is necessary to define the plant damage states as the plant model end states so that it will not be necessary to revise and requantify the plant model later when the containment analysis is performed.

The plant damage states for the STPEGS Scoping Study are shown in Table 7-1. A PDS is identified by a number/letter designator ranging from 1A to 2J. States 1 and 2 distinguish sequences with RWST injection from those where only the RCS inventory is released to the containment. For "1" states, there will only be a few inches of water on the containment floor, whereas for the "2" states, the depth of water will be several feet. States A to D characterize intact containment configurations differentiated according to the availability of containment heat removal and/or fission product removal. The success criteria are indicated in the bottom row. One train of sump recirculation or two fan cooling units are adequate for containment heat removal. Two spray recirculation trains are required for fission product scrubbing.

Containment states E and F represent large containment bypass configurations differentiated according to fission product scrubbing along the release path. Containment states G through I represent small containment bypass leak configurations differentiated according to the same criteria used for the intact containment states A through D.

7.4 RELEASE CATEGORIES

The purpose of this section is to define a set of release categories appropriate to the STPEGS design, based on potential containment failure modes and radionuclide release characteristics. The intent is not to quantify these release categories; rather, it is to associate them with health impact potential based on our experience with similar release categories from completed PRAs. Table 7-2 lists the six basic release category distinctions according to the containment failure modes, numbered 1 through 6. The "T" designator is used to indicate that the release categories are applicable specifically to STPEGS.

For each of the six basic containment failure modes T1 to T6, release categories are defined according to the following three criteria:

- A "C" designator means that containment heat removal is available to reduce the containment pressure and thus the driving force for leakage.
- A "B" designator means that the containment spray system is not available to scrub fission products from the containment atmosphere.
- A "V" designator means that a vaporization release has occurred as a result of debris penetration into the concrete basemat.

Furthermore, release category set T1 is always assumed to include an oxidation release of fission products as a result of fine particulate fragmentation of the debris in the containment atmosphere. The full set of release categories used for Cases I and II is tabulated in Table 7-3 according to these abbreviations.

7.5 THE C MATRIX

Table 7-4 shows the C matrix estimated for the Scoping Study for Case I, no water access to the reactor cavity. Table 7-5 shows the C matrix for Case II. The plant damage states are listed on the left-hand side of the table, whereas the appropriate release categories are listed across the top. The numerical values indicate the conditional probability that a given plant damage state will lead to a given release category. These numerical values were estimated on the basis of PLG's prior experience with detailed containment response analyses for large, dry PWR containments. An ϵ entry designates a very low value (less than 0.01). In past analyses, the ϵ values usually were found to be between 10^{-3} and 10^{-6}. It is noted that for PDSs with intact containments (A through D), the early containment failure release category T1 is very unlikely because of the very high anticipated containment failure pressure that is well above the range of peak

pressures expected from vessel failure blowdown pressure spikes or from hydrogen burns. Therefore, early containment failure can be expected to be extremely unlikely.

The remaining entries basically reflect the competition between release categories for late overpressure failure (T3), basemat melt-through (T4), and intact containment (T5) as influenced by the availability of containment systems.

Plant damage states that represent bypassed containments are assigned to the appropriate containment bypass release category (T2, T6) with a probability of 1.0.

7.6 SITE CONSEQUENCE ANALYSIS

All release categories of the previous section have been related to those defined in the SSPSA. Based on a careful review of the consequence curves for each release category and some knowledge of the STPEGS site characteristics, we have assigned each release category to one of the following four coarse "impact categories":

- Category I. Significant potential for early and latent health effects.
- Category II. Significant potential for latent health effects and possibly small numbers of early health effects.
- Category III. Potential for, at most, only small numbers of latent health effects.

Two S matrices based on judgment are given in Tables 7-6 and 7-7, one for each C matrix defined earlier. These matrices simply show how release categories are mapped into the impact categories. Interestingly, the CS product matrix in Table 7-8 is the same for either pair, $C_I S_I$ or $C_{II} S_{II}$. Therefore, on the basis of the analysis performed in the Scoping Study, it does not appear that the uncertainty about water flows into the reactor cavity that gave rise to the definition of Cases I and II is a particularly risk-sensitive issue.

TABLE 7-1. PLANT DAMAGE STATES FOR THE STPEGS PRELIMINARY SCOPING STUDY

RWST Injection Initiated At Vessel Melt-Through		Containment Intact at Core Melt Initiation									
		Yes				No					
		Containment Functions Available				Containment Leak Size					
						>3 Inch Diameter Equivalent		<3 Inch Diameter Equivalent			
		CHR + FPR	CHR Only	FPR Only	None	Release		Containment Functions			
						Filtered	Not Filtered	CHR + FPR	CHR	FPR	None
	State	A	B	C	D	E	F	G	H	I	J
No	1		1B		1D		1F		1H		1J
Yes	2	2A	2B	2C	2D	2E	2F	2G	2H	2I	2J
Success Criteria		{2/6 CFC or 1/3 SRC} + 2/3 CSR	2/6 CFC or {1/6 CFC + 1/3 SRC}	2/3 CSR	None	2/3 CSR	None	{2/6 CFC or 1/3 SRC} + 2/3 CSR	2/6 CFC or {1/6 CFC + 1/3 SRC}	2/3 CSR	None

Legend:

(hatched box) Plant Damage State Not Possible

CHR = Containment Heat Removal
FPR = Fission Product Removal
SRC = Sump Recirculation Cooling
CSR = Containment Spray Recirculation
CFC = Containment Fan Coolers

CAUTION: PRELIMINARY RESULTS
IMPORTANT UNCERTAINTIES
DESCRIBED IN SECTION 2

TABLE 7-2. DEFINITION OF RELEASE CATEGORY SETS BASED ON CONTAINMENT FAILURE MODES

Release Category Set	Description
T1	Airborne release due to early containment failure. Source term includes oxidation release from fine particulates involving 50% of core inventory as a result of debris fragmentation and dispersal into the containment atmosphere.
T2	Early increase in the containment design basis leak rate due to early pressure spike or small penetration isolation failure.
T3	Airborne release due to late overpressure failure of containment, which is due to either lack of containment heat removal or gas generation during concrete penetration.
T4	Ground release due to concrete basemat melt-through of the debris prior to aboveground containment shell failure.
T5	Containment integrity is maintained. Represents slow release to atmosphere at design leakage rate.
T6	Containment is not isolated (large penetration) or is bypassed due to initiating event failures. Containment remains unisolated, resulting in continuous release.

CAUTION: PRELIMINARY RESULTS-
IMPORTANT UNCERTAINTIES
DESCRIBED IN SECTION 2

TABLE 7-3. DEFINITION OF RELEASE CATEGORIES FOR STPEGS PRELIMINARY SCOPING STUDY

Release Category	Case	Containment Failure Mode	Containment Spray Operating	Containment Heat Removal	Oxidation Release	Vaporization Release
T1	II	Early Containment Failure	Yes	-	Yes	No
T1B	II	Early Containment Failure	No	-	Yes	No
T1V	I	Early Containment Failure	Yes	-	Yes	Yes
T1BV	I	Early Containment Failure	No	-	Yes	Yes
T2	II	Early Increased Leak Rate	Yes	No	No	No
T2C	II	Early Increased Leak Rate	Yes	Yes	No	No
T2B	II	Early Increased Leak Rate	No	No	No	No
T2CB	II	Early Increased Leak Rate	No	Yes	No	No
T2BV	I, II	Early Increased Leak Rate	No	No	No	Yes
T2CBV	I, II	Early Increased Leak Rate	No	Yes	No	Yes
T2V	I	Early Increased Leak Rate	Yes	No	No	Yes
T2CV	I	Early Increased Leak Rate	Yes	Yes	No	Yes
T3	II	Late Overpressure	Yes	No	No	No
T3B	II	Late Overpressure	No	No	No	No
T3BV	I, II	Late Overpressure	No	No	No	Yes
T3V	I	Late Overpressure	Yes	No	No	Yes
T4	II	Basemat Melt-Through	Yes	No	No	No
T4BV	I, II	Basemat Melt-Through	No	No	No	Yes
T4CBV	I, II	Basemat Melt-Through	No	Yes	No	Yes
T4V	I	Basemat Melt-Through	Yes	No	No	Yes
T4CV	I	Basemat Melt-Through	Yes	Yes	No	Yes
T5	II	Containment Intact	Yes	Yes	No	No
T5B	II	Containment Intact	No	Yes	No	No
T5BV	I, II	Containment Intact	No	Yes	No	Yes
T5V	I	Containment Intact	Yes	Yes	No	Yes
T6	II	Large Containment Bypass	Yes	-	No	No
T6B	II	Large Containment Bypass	No	-	No	No
T6BV	I, II	Large Containment Bypass	No	-	No	Yes
T6V	I	Large Containment Bypass	Yes	-	No	Yes

CAUTION: PRELIMINARY RESULTS-
IMPORTANT UNCERTAINTIES
DESCRIBED IN SECTION 2

TABLE 7-4. C MATRIX FOR STPEGS PRELIMINARY SCOPING STUDY

CASE I: NO WATER ACCESS TO REACTOR CAVITY; DEBRIS NOT COOLABLE

Plant Damage State	STPEGS Release Category															
	T1V	T2V	T2CV	T3V	T4V	T4CV	T5V	T6V	T1BV	T2BV	T2CBV	T3BV	T4BV	T4CBV	T5BV	T6BV
1B									ε*		.05	ε		.7	.25	
1D									ε	ε		.9	.1			
1F																1.0
1H											1.0					
1J										1.0						
2A	ε		.05	ε		.7	.25									
2B									ε		.05	ε		.7	.25	
2C	ε	.05		.85	.1											
2D									ε	ε		.9	.1			
2E								1.0								
2F																1.0
2G			1.0													
2H											1.0					
2I		1.0														
2J										1.0						

*ε = negligible probability

CAUTION: PRELIMINARY RESULTS-
IMPORTANT UNCERTAINTIES
DESCRIBED IN SECTION 2

TABLE 7-5. C MATRIX FOR STPEGS PRELIMINARY SCOPING STUDY

CASE II: WATER ACCESS TO REACTION CAVITY; DEBRIS COOLABLE

Plant Damage State	STPEGS Release Category																			
	T1	T2	T2C	T3	T4	T5	T6	T1B	T2B	T2CB	T2BV	T2CBV	T3B	T3BV	T4BV	T4CBV	T5B	T5BV	T6B	T6BV
1B								ϵ*			ϵ	.05		ϵ		.7		.25		
1D								ϵ			ϵ			.9	.1					
1F																				1.0
1H												1.0								
1J											1.0									
2A	ϵ		.05	ϵ	ϵ	.95														
2B								ϵ		.05			ϵ		ϵ		.95			
2C	ϵ	.05		.95	ϵ															
2D								ϵ	ϵ				1.0		ϵ					
2E							1.0													
2F																			1.0	
2G			1.0																	
2H										1.0										
2I		1.0																		
2J									1.0											

*ϵ = negligible probability

CAUTION: PRELIMINARY RESULTS-
IMPORTANT UNCERTAINTIES
DESCRIBED IN SECTION 2

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TABLE 7-6. S MATRIX FOR CASE I - THE CONDITIONAL PROBABILITIES OF IMPACT CATEGORIES GIVEN RELEASE CATEGORIES (Corresponds to C Matrix for Case I)

Release Category	Impact Category		
	I	II	III
T1V	1		
T2V			1*
T2CV			1*
T3V			1
T4V			1
T4CV			1
T5V			1
T6V		1	
T1BV	1		
T2BV		1	
T2CBV		1	
T3BV		1	
T4BV		1**	
T4CBV			1
T5BV			1
T6BV	1		

*Inconsistent with Seabrook PRA, which conservatively equated these low frequency categories to the more severe and frequent T2BV. Although no quantitative site model calculations have been performed, operation of containment spray should eliminate the possibility of early effects and minimize latent effects.

**In this basemat melt-through category, no water is available to trap fission products and high containment pressures can cause fission products to "burp" to atmosphere between the failed basemat and the underlying concrete.

CAUTION: PRELIMINARY RESULTS IMPORTANT UNCERTAINTIES DESCRIBED IN SECTION 2

TABLE 7-7. S MATRIX FOR CASE II - FOR CONDITIONAL PROBABILITIES OF IMPACT CATEGORIES GIVEN RELEASE CATEGORIES (Corresponds to C Matrix for Case II)

Release Category	Impact Category		
	I	II	III
T1	1		
T2			1*
T2C			1*
T3			1
T4			1
T5			1
T6		1	
T1B	1		
T2B		1	
T2CB		1	
T2BV		1	
T2CBV		1	
T3B		1	
T3BV		1	
T4BV		1**	
T4CBV			1
T5B			1
T5BV			1
T6B	1		
T6BV	1		

* Inconsistent with Seabrook, which conservatively equated these low frequency categories to the more severe and frequent T2BV. Although no quantitative site model calculations have been performed, operation of containment spray should eliminate the possibility of early effects and minimize latent effects.

**In this basemat melt-through category, no water is available to trap fission products and high containment pressures can cause fission products to "burp" to atmosphere between the failed basemat and the underlying concrete mud mat.

CAUTION: PRELIMINARY RESULTS. IMPORTANT UNCERTAINTIES DESCRIBED IN SECTION 2

TABLE 7-8. THE CS PRODUCT MATRIX-CONDITIONAL PROBABILITIES OF IMPACT CATEGORIES GIVEN PLANT DAMAGE STATES

Plant Damage State	Consequence Category		
	I	II	III
1B			1
1D		1	
1F	1		
1H		1	
1J		1	
2A			1
2B			1
2C			1
2D		1	
2E		1	
2F	1		
2G			1
2H		1	
2I			1
2J		1	

CAUTION: PRELIMINARY RESULTS-
IMPORTANT UNCERTAINTIES
DESCRIBED IN SECTION 2

APPENDIX A

RESOLUTION OF HL&P COMMENTS ON STP PROBABILISTIC SAFETY ASSESSMENT BASELINE STUDY INTERIM REPORT DATED JULY 1984

Comment Number: 1

Report Reference: General

Comment:

Note caution related to "realism" contained in letter of transmittal and review the wording of this Report accordingly.

Response:

Appropriate revisions were made to the report, particularly to Section 1 (Introduction) and Section 2 (Results). These revisions emphasize the limitations of the baseline risk model, the substantial uncertainties, especially for a Baseline Study, and how conservative assumptions were taken into account in the quantification of uncertainty to provide a balanced perspective of the results.

Comment Number: 2

Report Reference: General

Comment:

The Interim Report should summarize the results of the Baseline Study as such without programmatic references to any future work, including the Management Plan.

Response:

Programmatic references to future work have been deleted from the report. Care has been taken to explain the limitations of the study. Areas where additional work would be needed to remove those limitations are identified.

Comment Number: 3

Report Reference: General

Comment:

Figures contained in the Interim Report should prominantly display a caution in their use and should reference a section of the report that provides an appropriate discussion as to the meaning to be ascribed to the results at this stage of analysis.

Response:

A warning or caution label, "Preliminary Results for Project Scoping Purposes Only" was applied to all results, figures and tables in the draft report. A new caution label; "Caution: Preliminary Results - Important Uncertainties Described in Section 2" has been applied to these pages in the final draft.

Comment Number: 4

Report Reference: General

Comment:

An assessment of the consequences of radioactive releases was not in the scope of the Study and was not performed per se. Therefore all references in the Study to "consequences" or "health effects" should be deleted and references should be made only to "release categories." The only exception should be in the definition of the "Release Categories" currently contained in Table 2-2.

Response:

Assessment of consequences in the Baseline Study was limited to a qualitative grouping of accident sequences according to their approximate potential for offsite health effects. References to "consequences" and "health effects" have been removed in accordance with comment.

For this revised Baseline Study, the four consequence categories have been condensed into three impact categories as follows:

Old Consequence Category	New Impact Category
I	I
II	II
III	II
IV	III

Old categories II and III have been combined because they were quite similar. Both provided substantial potential for latent effects; OLD Category II only gave a small potential for a very few early effects. Keeping them separate provided very little additional information and led to some confusion among reviewers.

Comment Number: 5

Report Reference: General

Comment:

In scenarios resulting in station blackout, the availability of alternate sources of AC power should be noted in mitigating the consequences of the blackout. The Technical Support Center or Balance of Plant diesels are available as auto-start (on undervoltage) AC power sources. Additionally, the Emergency Transformer can be energized via operator action and through selective switching, placed on the ESF buses to regain AC power to vital loads (although 3 buses can be energized, only 2 full trains of loads can be handled by the transformer).

Response:

The comment is noted. The BOP diesel supplies power to support the instrument air compressor which is required to operate the EAB dampers for the smoke purge mode of HVAC. It was modeled for loss of offsite power scenarios that could benefit from smoke purge cooling.

In a completed, full-scope Level 1, 2, or 3 PRA, a detailed recovery analysis of station blackout is typically performed. An example of such a detailed blackout recovery analysis is found in the SSPSA (Reference A-1). In such an analysis for STPEGS, the BOP diesel generator would be fully taken into account. In the more limited-scope analysis of this Baseline Study, accident sequences involving postulated failure of all three Class 1E diesel generators were incorporated into the model and recovery of offsite power was included in the quantification of this sequence. As analyzed, this sequence made a small contribution to risk and to core melt frequency as indicated in Section 2.

In a completed Level 1 PRA, there are several key uncertainties whose removal would be sought regarding the analysis of station blackout. The uncertainties include the possible variation between generic diesel generator failure rates and common cause parameters and those uniquely appropriate for STPEGS, the performance of RCP seals with loss of CCW and the attendant loss of seal injection, and the effect of the BOP diesel. Resolution of these uncertainties is outside the scope of the Baseline Study and apparently not as important as some of the other sources of uncertainty mentioned in Section 2.

Comment Number: 6

Report Reference: Abstract

Comment:

The purpose of an abstract is to convey the subject of the report indicating its intent, methodology, and general statement of results and limitations. The third and fourth sentences of the second paragraph are inconsistent with the intent of the abstract, and the subject matter should be reserved for the report. The abstract should recognize HL&P as the Project Manager for the South Texas

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Project and should indicate that the Study was undertaken on HL&P's own initiative to provide early insights as to the risk [sensitivities] for design and procedural purposes. The Study was not performed due to regulatory requirements.

Response:

The comment is noted and the suggested text modifications have been made.

Comment Number: 7

Report Reference: Section 1

Comment:

Before the Objectives of the Baseline Study are stated, the introduction should describe the program undertaken by HL&P leading to the Interim Report and the preliminary nature of the results contained in the Report. In this connection, Probabilistic Risk Assessment should be defined, the scope of the various levels of PRA should be discussed, the relationship of the Baseline Study to a full scope PRA should be clearly stated, and what is meant by a risk management program should be indicated. The program undertaken by HL&P up to this point has been composed of the Baseline Study and technology transfer, including training. Provide the Objectives of the Baseline Study only. The first and most important Objective of the Baseline Study is to "Provide a basis for timely feedback of risk management insights into the process of completing construction on STPEGS," and should precede all other objectives listed.

Response:

The comment is noted and the suggested text modifications have been made.

Comment Number: 8

Report Reference: Section 1, page 1-3

Comment:

The paragraph succeeding the last of the objectives should be placed in the "Introduction" with a caution and a perspective as to the purpose and meaning of numerical results at this stage of the risk model development. It is also appropriate that the introduction clearly explain the meaning of the term "Point Estimate", its relationship to the results, and a caution in making comparisons at this stage in the PRM development.

Response:

The comment is noted and appropriate text modifications have been made.

Comment Number: 9

Report Reference: Section 1

Comment:

Sections 1.2, 1.2.1 & 1.2.2 should be deleted in their entirety since they provide general discussions not related directly to the STPEGS study results. The Baseline Study does not in any way comprise an analysis of consequences and should not be related or compared to any previous full scope studies and the level of detail, documentation, degree of realism, methodology, or magnitude of results provided by those studies. Judgments and comparisons in either methodology or results are considered inappropriate due to the preliminary nature of and approach to the analysis of the Baseline Study as compared to other studies.

Response:

The comment is noted. These report sections have been rewritten to make use of a general PRA discussion that focuses on the specific objectives and limitations of the Baseline Study performed for STPEGS and on the use of PRA as a risk management tool.

Comment Number: 10

Report Reference: Section 1.4 - Report Guide

Comment:

The limitations of the Baseline Study risk model should be summarized more prominantly in the Introduction.

Response:

An increased visibility of the limitations of the Baseline Study now appears in the Introduction (Section 1) and in the Summary of Results (Section 2).

Comment Number: 11

Report Reference: Section 4 - Event Sequence Model

Comment:

An overcooling transient that results in reactor vessel rupture is included in the event sequence analysis. The Westinghouse Owner's Group has performed calculations that demonstrate that total RTndT for STP vessels is very low (i.e., 88 degrees F for Unit 1 and 68 degrees F for Unit 2 for 32 effective full power years). Therefore, it is not a concern for STP and should be so indicated in the Report (Reference ST-QG-HL-90169).

Response:

The comment is noted. The inclusion of a question of reactor vessel integrity following certain overcooling transients has become standard practice in the construction of event sequence models at PLG. We recognize the cited reference as strong evidence that the potential for reactor vessel failure resulting from pressurized thermal shock to be low relative to other plants. However, the conservative bounding treatment of this phenomena in the Baseline Study has shown that such scenarios are negligible risk contributors at STPEGS. Similar conclusions were reached for Seabrook without the need for performing an accurate estimate of reactor vessel failure probability. Hence, we concur that PTS is not a concern for STPEGS from a PRA perspective. The only identified scenario in which cooling below the RTndT is possible is the one involving injection of cold RWST water following an RCP trip. With no loop flow, it is possible to subject the vessel wall to RWST temperature water. This scenario was not modeled in the Baseline Study, but from other PRAs, is not expected to make a significant contribution.

Comment Number: 12

Report Reference: Section 5 - Systems Analysis - CVCS Letdown Isolation Valves

Comment:

The design of this system has been changed--valves LCV465 and LCV468 will both have fail-closed pneumatic actuators. [As a revision to HL&P's comments, instructions were given not to change assumptions regarding the type of actuators in the CVCS letdown lines.]

Response:

HL&P has subsequently notified PLG that these valves will be motor-operated. They have no significant impact on the frequencies of Categories I, II, or III.

Comment Number: 13

Report Reference: Section 5 - Systems Analysis - SG PORVS

Comment:

The PORV's have enough energy stored in their accumulators to operate one full open and closed cycle. This is sufficient to ensure the PORV will fail in the closed position on loss of power. In order to provide cooling of the steam generator, two methods are available. A short term method is to increase the secondary side pressure high enough to actuate a spring operated SRV. The second method is manual actuation of the PORV's. A hand pump was procured with the PORV's which can be connected to the PORV to open and close

the valve. The manner in which this hand pump's use will be implemented has not been determined in time for incorporation into the Baseline Study.

Response:

The steam generator PORVs are modeled as failing to the closed position on loss of AC power for their hydraulic pumps. Manual operation of the valves with the hand pump is not included in the Baseline Study. Local recovery actions will be evaluated, if necessary, in subsequent analyses if PORV failures contribute significantly to the Baseline Study results. However, the current results in Section 2 do not seem to be sensitive to this conservative treatment of PORV recovery. The current model includes operation of the steam generator safety valves for intermediate-term heat removal if the PORVs are not available.

Comment Number: 14

Report Reference: Section 5 - Systems Analysis - Supplemental Purge Isolation Valves

Comment:

The design of this system has been changed--the actuators on both containment inlet valves and both containment outlet valves have been changed to failed closed actuators. The type of actuator, pneumatic or electro-hydraulic, has not been determined. [In a revision to HL&Ps comments, instructions were provided to quantify the sensitivity in the results to various assumptions regarding the design and operation of the supplemental purge isolation valves].

Response:

Subsequent to receipt of these comments, HL&P requested that the results in Section 2.4 include sensitivities to six different sets of assumptions regarding the design of the containment isolation valves and the fraction of time they are left in the open initial position. Those sensitivities are provided.

Comment Number: 15

Report Reference: Section 5 - Systems Analysis - AFWS Stop Check Isolation Valves

Comment:

The turbine-driven AFW pump stop-check valve is not identical to the valves provided in the three motor-driven AFW trains, with respect to pressure class and actuator type. These valves are normally closed to reduce the possibility of steam binding in the AFW pumps. The potential for common mode failure of all four valves may be affected in light of these facts and accordingly may change the analysis in

the Baseline Study as it assumed the same design in all four trains. The valves, motors and operators will be specified to take into consideration changes in process conditions due to leakage of upstream check valves. This is consistent with the findings of AEOD report C-203, "Survey of Valve Operator-related Events Occurring during 1978, 1979 and 1980."

Response:

Consistent with the limited scope and objectives of the Baseline Study generic values of common cause parameters (β , γ and σ) and values taken from other studies on similar plants were used throughout the systems analyses. The following values were used throughout for all components with a few exceptions (β = .05, γ = .5, σ = 1). These values are supported by generic data. In a completed Level 1 PRA, we normally use system and plant specific common cause parameters obtained by event-by-event screening of generic data.

Our data base for common cause failures of motor-operated valves includes some 42 events out of 400 reactor years of data in which two or more MOVs experienced failure or some degradation in performance due to a common, shared cause. This data has been documented in an EPRI report which will be completed in early 1985 (Reference A-2). A detailed screening of these data for applicability to both types of stop check isolation valves in the AFWS at STPEGS would be performed in a Level 1 PRA. A cursory review of this data, however, indicates that a large fraction of the applicable common cause events for MOVs would not have been prevented by the differences noted in the comment. A large number of the experienced common cause events were associated with defective torque and limit switch components, environmental stresses, and various human errors in test and maintenance. A recovery model was included in the baseline requantification to account for local manual operation of these valves. A residual contribution to failure of all four valves from mechanical binding was retained. A more quantitative resolution of this comment would be accomplished in a complete Level 1 PRA.

Comment Number: 16

Report Reference: Section 5 - Systems Analysis - Essential Chilled Water System

Comment:

The ECH system provides chilled water to selected room coolers in the MAB and FHB, as well as the EAB HVAC and Control Room air handling units. For room coolers serviced by the ECH system in the MAB and FHB, one ECH train supplies 100% heat removal capability. However, for the EAB HVAC and Control Room Envelop HVAC, two trains of ECH are needed to remove 100% of the design basis heat load. An analysis was performed to calculate the rate of temperature increase upon loss of two and three ECH trains. The results are documented in an attachment to the comments transmittal letter.

Response:

The information provided in Attachment A regarding thermal transient response of EAB and control room envelope HVAC service areas, thermal capacity of equipment and the beneficial effects of smoke purge operation of the HVAC provides a significantly enhanced basis for assuming the impact of HVAC loss than was possible using information that was made available during the original Baseline Study. Significant revisions to the Baseline Analysis of HVAC were made to account for this enhanced state of knowledge and the effects on the results are evident in Section 2. Despite this enhanced perspective, significant uncertainties remain regarding the variation between local and average room temperature, the effects of humidity condensation in smoke purge, and the quantitative values of equipment fragilities as a function of temperature. These uncertainties should be emphasized in any continuation of the Baseline Study toward the completion of a Level 1 PRA.

Comment Number: 17

Report Reference: Section 5 - System 5 - Systems Analysis - Containment Purge

Comment:

The "large" containment purge valves will always be shut during plant operation at power by administrative procedure. The Supplemental Purge Valves will be opened 100% of the time while at power to allow operator entry to the RCB on a daily, routine basis. As indicated elsewhere, these supplemental purge valves will fail closed upon loss of AC. [See also comment 14.]

Response:

Comment noted and the distinction between these different sets of purge valves and assumptions regarding initial position conform to the comment. [See also response to comment 14.]

Comment Number: 18

Report Reference: Section 5 - System Analysis - Auxiliary Feedwater Storage Tank (AFST)

Comment:

The AFST, formerly termed the CST, is surrounded by a reinforced concrete cylindrical structure, covered by a reinforced concrete roof. In addition, AFST is designed for all credible loading combinations, including dead loads, live loads, earthquake loads, normal wind loads and tornado loads (reference Bechtel Design Criteria 4S199HQ1019), and is therefore not considered to be "subject to failure".

Response:

Comment noted. Our interpretation of the comment is that the design criteria for the AFST are very stringent and that the likelihood of failure within these design bases is very low. Within the PRA framework, the potential for failure modes such as clogged vents, debris clogging suction, and structural failures from beyond design basis conditions is normally considered for safety grade tanks such as the AFST. The Baseline Study results support the view that failures of this tank are not a significant risk contributor.

Comment Number: 19

Report Reference: Systems Analysis - RHR

Comment:

The Jockey Pumps in the RHR System are being deleted. RCP#3 seal standpipes will be used as head-tanks to keep the RHR Hx's full of water.

Response:

This design change is noted and the Baseline Study Risk model conforms to the comment.

Comment Number: 20

Report Reference: Section 6 - Survey of External Events

Comment:

The data used in the external events analysis should be consistent with the STPEGS FSAR, e.g., crash rates, number of flights, seismic acceleration, turbine missiles, values for destructive overspeed and design overspeed, strikes per year, etc. Independent development and justification of parameters is to be avoided unless PL&G has sufficient data & information to justify otherwise.

Response:

A very limited scope survey of external events was included in the Baseline Study. To conserve resources, maximum possible use was made of the work done for the SSPSA, especially in regard to the bounding analysis of turbine missiles, aircraft crash and wind-driven missiles. The parameter valves taken from the SSPSA were used in lieu of spending additional HL&P resources to review and verify the references cited in the FSAR. Since in all cases the parameter values used were conservative in relation to the FSAR values, this approach was deemed suitable for bounding purposes. In no cases were independent valves generated without such a justification. All the affected events were found to be negligible risk contributors.

A.1 REFERENCES

A-1. Pickard, Lowe and Garrick, Inc., "Seabrook Station Probabilistic Safety Assessment," prepared for Public Service Company of New Hampshire and Yankee Atomic Electric Company, PLG-0300, December 1983.

A-2. Fleming, K. N., et al., "Classification and Analysis of Reactor Operating Experience Involving Dependent Events," prepared for the Electric Power Research Institute, Research Project 2169-4, to be published in 1985.

APPENDIX B

RESOLUTION OF HL&P COMMENTS ON STP PROBABILISTIC SAFETY ASSESSMENT BASELINE STUDY READING DRAFT DATED DECEMBER 1984

Comment Number: 1

HL&P suggests that the value to be derived by undertaking more detailed evaluations utilizing PRA should be discussed in the Management Plan rather than in the "results" section.

Response:

Except as required to clarify the limitations of the Baseline Study risk model, discussion of the value to be derived by undertaking more detailed evaluations utilizing PRA have been removed from the Baseline Study report. See Appendix A, comment number 10.

Comment Number 2:

HL&P suggests a clear definition be included in Section 1.1 of the basic differences between the various levels of PRA analyses.

Response:

Section 1.1 has been revised to clearly define the basic differences between the various levels of PRA analysis.

Comment Number 3:

In Section 6.1 and in Section 6.4.5, the effects of external flooding are described focusing on the potential failures of the cooling reservoir embankment. A careful consideration of the STP embankment and ability to control water level in the impoundment has been undertaken in substantial detail such as to make the use of generic statistical dam failure data inappropriate relative to STP. The cooling reservoir water level is positively controlled and is not subject to uncontrolled increases in water level such as a dam collecting water from a water shed. The monitoring of embankment conditions and hydrostatic pressure also yields information that provides a basis to decrease embankment water level prior to danger of failure. Given the ability to positively control the impoundment water level, the absence of an uncontrolled fill mechanism for the impoundment, and the current program for the reduction of hydrostatic pressure through the use of relief wells at selected locations along the embankment, it seems inappropriate to apply historic dam failure rates to STP. Additionally, the STP impoundment does not have a connection to dissimilar materials, e.g., the side of a hill so that historical data that resulted in failure associated with this interface is similarly inappropriate. Thus, to use historical dam

failure data at the STP site would require that those failures that resulted from conditions which cannot exist at STP be removed from the data base. We believe that information that recognizes the differences between STP and generic statistical dam failure probability should be recognized in the Baseline report. Attached is information recently published in the FSAR [Amendment 43] that bears on embankment failure conditions that we believe you should review in connection with our comment. If you have any questions concerning this issue, we would be pleased to have our technical people discuss this matter with your staff.

Response:

Section 6.4.5 has been revised to include the new information supplied by HL&P. We concur that the frequency of failure of the STP embankment should be lower than the generic dam failure frequency.

Comment Number 4:

The report should identify that the STP design information included in the report is derived from design data available during the period April to July 1984. Changes which have been made in the normal course of plant design since that time have not been explicitly analyzed or incorporated in the Baseline results with specific exceptions, such as heatup calculations and supplemental containment purge valves, that are explicitly noted in the appendixes to the report.

Response:

Section 1.1 has been revised to identify sources of design data.

Comment Number 5a:

The discussion of HVAC success criteria on Page 2-16 should be clarified. The reference to "smoke purge" and its relationship to the conditions "below 117° at 24 hours" appear to be inconsistent with the heatup calculations which indicate that 1 ECH train would similarly comply, thus apparently conflicting with the success criteria enumerated on Page 2-6. In order to avoid this apparent contradiction with the example case HVAC success criteria, the distinction needs to be made that in the smoke purge mode, the peak temperature was 113° at 9 hours, while the 1 ECH mode resulted in 117° at 24 hours and increasing. Understanding of this section would be improved by a discussion of the scenarios in which electric power would be maintained utilizing 1 ECH train. An indication of some of these are provided in Item 2 on Page 2-6.

Response:

The error in referencing the heatup calculations has been corrected. The section describing the alternative success criterion (assumption sets) has been rewritten to aid the readers' understanding. Each possible alternative has been assigned a probability of being the true case.

Comment Number 5b:

General Section 2 - Please clarify if the reference to "EAB HVAC System" refers to both the "EAB Main Area HVAC System" and the "Control Room HVAC System."

Response:

In Section 2 "EAB HVAC System" refers to the "EAB Main Area HVAC System." Our primary concern has been with loss of AC power to needed equipment due to overheating of circuit breakers (especially solid state protection devices) in the EAB. While loss of control room HVAC could cause problems, the operators would be directly aware of increasing temperatures and could shift plant control to the auxiliary shutdown panels.

Comment Number 5c:

The reference to "Ton of Chillers" on pages 2-6 and 2-17 should be rewritten as "Tons of Chiller Capacity Required."

Response:

The two references have been rewritten.

Comment Number 5d:

Page 2-7, Section 2.3.2 - In the area marked with bullets, the final bullet refers to "motor-operated supplementary purge valves." Since the supplementary purge steam valve design has been changed, and the outboard valve is now an air-operated fail-closed valve, the statement should be clarified to refer to the "inboard" MOV.

Response:

The section has been revised to indicate that the MOVs are inside containment.

Comment Number 5e:

Page 2-9, Paragraph 2 - Given the failures indicated, there is no need to put the HVAC into the "smoke purge" mode. Please clarify.

Response:

We concur. The analysis was correct and did not require placing HVAC into the smoke purge mode. The error in the sequence description has been corrected to agree with the existing analysis.

Comment Number 5f:

Page 2-10, Paragraph 3 - The discussion included of accident Sequences 7 and 8 in relation to Sequence 1 does not appear to agree with the scenarios described in Table 2-3. It appears that accident

sequences 7 and 8 may be similar to accident sequence 1 in effect, but not in sequence of events. All the accident sequence descriptions should be reviewed for clarity.

Response:

Accident sequences 7 and 8 are similar to sequence 2, not sequence 1. The text has been revised.

Comment Number 5g:

Page 2-10, Accident Sequence 7 describes scenarios where failure of EAB HVAC fans may result in subsequent AC power losses. The Baseline study should state that the criteria used in EAB HVAC analysis is conservative with respect to the number of fan failures required to disable an EAB HVAC train and to delineate the assumptions and design considerations used to quantify EAB HVAC fan failure.

Response:

We do not concur with this comment. First, no single criterion is used in EAB HVAC analysis. Section 2.3.2 describes a group of 14 discrete assumption sets used in the Baseline Study. Some are conservative; some are very optimistic. All are weighted by the probability that they represent the true success criteria for the modeled scenarios. Note that we even allow some chance that the plant can survive with no HVAC operable.

It is sometimes suggested that average success criteria should be used for probabilistic studies. We do not agree. Consider a case in which some unlikely, but possible, condition leads to adverse effects while average conditions do not. The truth would be that the adverse condition is unlikely, but possible. Probabilistic studies should determine how likely such conditions are, rather than mask them via "average" or "best estimate" analysis. Conservatism is not desired, but a true picture of consequences and their probabilities.

One specific example of relevance for the STP HVAC system would be an assumption that a single supply fan would be sufficient if only one bus is energized. While it may very well succeed, it also might not. With no exhaust fan running, the supply fan could possibly overheat and trip. Such behavior has been observed elsewhere. Also, dampers may trip under this arrangement.

While we have not attempted to define all combinations of specific HVAC operating modes, heat loads, equipment fragilities, and external conditions, we feel the 14 discrete assumption sets reasonably span the possibilities. The assigned probabilities (weights) represent a realistic, rather than a conservative, assessment of criteria for HVAC.

Comment Number 5h:

Page 2-15, Section 2.5.2, 1st Paragraph, last sentence - The text of this sentence is not clear.

Response:

The text has been clarified.

Comment Number 5i:

Page 2-17, the F2 row does not add to 1.0.

Response:

Due to a change in display format, the round-off error is no longer visible in this table, but it is in two others that have been added.

Comment Number 5j:

Page 2-23, Table 2-3, Frequency Rank 9 - The Sump Recirculation valves can be manually repositioned. Clarify whether operator action was included in the recovery model and its effect, if any, on current results.

Response:

The scenario in question involves failure of the "sump recirculation path." In the model, that path fails if either all three sump recirculation valves fail to open or any one of the three RWST supply line check valves fails to close. We agree that the recirculation valves can be repositioned and that, given the remaining RWST inventory at switchover, sufficient time exists for such manual recovery. However, failure of the recirculation path is dominated by the second failure mode (failure of one-of-three check valves to close), so the indicated operator action would give no noticible improvement for this scenario.

Failure of a check valve to close provides a direct path from containment to the RWST to atmosphere. Furthermore, the containment may be pressurized and the path to atmosphere involves the recirculation (safety injection) pump suction line. Flashing in that line and the RWST could cause failure of the recirculation pumps. In fact, in the Midland PRA, failure under this condition was assumed, based on information supplied by the architect/engineer.

No alternative pump failure assumption or recovery by operator action (closing the associated MOV) was modeled for the following reasons:

- o If failure of the check valve to close will cause pump failure, little indication of the problem exists, and the time for operator response is short. The emergency procedures will probably call for manual closing of the three RWST isolation MOVs, but the time available to protect the pumps is not clear.

- o The number of additional assumption sets could be quite large. Damage could occur immediately, within several minutes, or over longer periods. Containment pressure can vary depending on break size and operability of containment safeguards. These possibilities multiply the existing number of assumption sets.

- o The scenario gives less than 1% contribution to core melt frequency. Thus, even if its frequency were reduced, it would have little effect on current results.

Comment Number 5k:

Page 2-26, 2-27, and 2-28, Figures 2-1, 2-2, and 2-3 - The axis for frequencies presented in these figures should be changed to reflect powers of 10, not 1.0.

Response:

The figures have been corrected.

Comment Number 5l:

The notes regarding RHR operation on pages 4-64 and 5-7 should be rewritten to indicate that the environment in question is "high temperature and high humidity."

Response:

The notes have been rewritten.

Comment Number 5m:

Pages 5-18 and 5-19, Figure 5-3 - This Figure is not legible and should be replaced. PLG should take necessary steps to assure the legibility of all tables and figures. Foldouts should be used if necessary.

Response:

The new figure supplied by HL&P has been used as a foldout. It is more legible than the earlier one.

Comment Number 5n:

Page 6-7, Section 6.3.2 - The third sentence of the second paragraph should be revised to indicate "safety class components (e.g., CCW and charging pumps, etc.)."

Response:

The sentence has been revised.

Comment Number 5o:

Page 6-7, Section 6.3.3 - In the last sentence of the first paragraph, change "main exhaust fans" to "FHB exhaust and booster fans."

Response:

The sentence has been revised.

Comment Number 5p:

Page 6-8, Section 6.3.5, last sentence - It is HL&P's position that fire in the Diesel Fuel Storage Tank is not a major risk contributor and further analysis is not necessary.

Response:

We agree that this fire is not a major risk contributor and have not called for further analysis.

Comment Number 5q:

The hazardous chemical analysis described in Section 6.4.4 does not mention any chemicals stored on site (Reference Table 2.2-5 in the FSAR). Please clarify whether consideration has been given in the report to the storage of hazardous chemicals on site.

Response:

The section has been revised to include a discussion of chemicals stored on site.

APPENDIX C

RESOLUTION OF HL&P COMMENTS ON STP DRAFT REPORT

DATED FEBRUARY 1985

LETTER COMMENTS

Comment:

...in keeping with your terminology utilized on page 7 of this draft, and to more accurately describe the state of completion of the work which this report documents, it is suggested that this report be referred to as a Preliminary Scoping Study, a preliminary analysis of plant safety using probabilistic methods. This terminology should be employed throughout the report. Thus terminology which refers to the STP Preliminary Scoping Study as a probabilistic risk assessment, in the sense of the levels defined in the PRA Procedures Guide (NUREG/CR-2300), or a baseline study, should be changed or otherwise omitted...

Response:

We agree and the report has been so revised. Although the suggested title is not as informative as we might like, it is important to ensure that the current, limited-scope study is not confused with the more familiar PRA studies.

Comment:

To place this study in a perspective to HL&P's overall activities related to the STP Risk Model Development Program, it is requested that the attached "HL&P Perspective" be inserted near the front of the report and included in the Table of Contents, clearly identified as an HL&P document. With this perspective this report's role as a Preliminary Scoping Study would be clarified.

Response:

The "HL&P Perspective" is now included in the report's front matter.

NUMBERED COMMENTS

Comment Number 1:

References that could be interpreted to imply that the HL&P program is not going to be continued, such as that in the first full paragraph on page 1-3, should be changed throughout the report.

Response:

All references we could identify that were subject to such an interpretation have been changed.

Comment Number 2:

In the sixth line of the last paragraph on page 2-2, the word "full" should be corrected to "fuel".

Response:

The correction has been made.

Comment Number 3:

On page 2-10 in the continuation of the table at the top of the page, under F3, it appears that the last expression in parentheses should be corrected to read "Probability of success is 1.0 if success criteria are not met."

Response:

The error has been corrected as suggested.

Comment Number 4:

In the tables on page 2-11, since the probabilities listed do not add to 1.0 due to round-off error, these tables should be footnoted to that effect.

Response:

An appropriate footnote has been added.

Comment Number 5:

The first column of the bottom table on page 4-60 should be corrected to be entitled "LT II Tree Top Events."

Response:

Both tables on page 4-60 were mislabeled. They have been corrected to read "LT-1" and "LT-2" as appropriate.