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Entergy

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Engineering Report Cover Sheet

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VY PSA Model - Evaluation of Containment Overpressure (COP)

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EXECUTIVE SUMMARY

The document reports on the risk impact assessment of the proposed licensing basis change to credit containment accident pressure (containment overpressure) to satisfy the net positive suction head (NPSH) requirements for RHR and Core Spray pumps.

A revision to Regulatory Guide 1.82 Rev. 3 allows individual plants to credit containment overpressure to ensure adequate NPSH. In performing the risk assessment evaluation the NRC Regulatory Guide 1.174, "An Approach for Using Probabilistic Risk Assessment In Risk-Informed Decisions on Plant-Specific Changes to the Licensing Basis" (RG 1.174) is used.

The risk assessment evaluation uses the current Vermont Yankee (VY) Probabilistic Safety Assessment (PSA) internal events model (i.e., transients, LOCAs, and internal flooding) that includes a Level 2 analysis of core damage scenarios and subsequent containment response resulting in various fission product releases. The Vermont Yankee Level 1 and Level 2 PSAs provide the necessary and sufficient scope and level of detail to allow the calculation of Core Damage Frequency (CDF) and Large Early Release Frequency (LERF) changes due to the risk assessment crediting the use of containment overpressure to satisfy the NPSH requirements for the RHR system and Core Spray system emergency core cooling pumps.

The risk assessment evaluation examined VY PSA plant specific accident sequences in which the containment integrity is necessary for success of the RHR system and Core Spray system emergency core cooling pumps.

The steps taken to perform this risk assessment evaluation are as follows:

1) Modify the VY PSA Containment Isolation System fault tree to reflect the latest probability on the occurrence of pre-existing containment leakage.
2) Revise the appropriate event trees to reflect the impact of containment overpressure on NPSH requirements.
3) Perform an uncertainty analysis on a number of important basic events associated with the containment overpressure modeling changes used in this risk assessment.
4) Characterized the risk assessment evaluation by the following risk metrics:
    - The change in Core Damage Frequency (CDF)
    - The change in Large Early Release Frequency (LERF)

The conclusion of the plant internal events risk associated with this assessment is as follows.

1) Regulatory Guide 1.174 provides guidance for determining the risk impact of plant-specific changes to the licensing basis. Regulatory Guide 1.174 defines very small changes in risk as resulting in increases of core damage frequency (CDF) below 10^{-6}/yr. Based on this criteria, the proposed change (i.e., use of COP to satisfy the net positive suction head (NPSH) requirements for RHR and Core Spray pumps) represents a very small change in CDF (approximately 5.78×10^{-7}/ry)
2) Regulatory Guide 1.174 provides guidance for determining the risk impact of plant-specific changes to the licensing basis. Regulatory Guide 1.174 defines very small changes in risk as resulting in increases of Large Early Release Frequency (LERF) below 10^{-7}/yr. Based on this criteria, the proposed change (i.e., use of COP to satisfy the net positive suction head (NPSH) requirements for RHR and Core Spray pumps) represents a very small change in LERF (approximately 4.50×10^{-8}/ry)

Nomenclature

ACRS	Advisory Committee on Reactor Safeguards
ATWS	Anticipated Transient without Scram
CDF	Core Damage Frequency
CET	Containment Event Tree
CI	Containment Isolation System
COP	Containment Overpressure
DW	Drywell
ECCS	Emergency Core Cooling Systems
HEP	Human Error Probability
HPCI	High Pressure Core Injection system
HRA	Human Reliability Analysis
IPE	Individual Plant Examination
IPEEE	Individual Plant Examination for External Events
ISLOCA	Interface System Loss of Coolant Accident
LB	Licensing Basis
LERF	Large Early Release Frequency
LNP	Loss of Normal Power event
LOCA	Loss of Coolant Accident
LOSP	Loss of Offsite Power event
LPCI	Low Pressure Coolant Injection
NPSH	Net Positive Suction Head
NRC	United States Nuclear Regulatory Commission
PRA	Probabilistic Risk Analysis
PSA	Probabilistic Safety Assessment
RCIC	Reactor Core Isolation Cooling System
RHR	Residual Heat Removal System
RPV	Reactor Pressure Vessel
TS	Technical Specifications
VDHS	Vernon Dam Hydro Station
VY	Vermont Yankee Nuclear Power Station
WW	Wetwell

Definitions

Accident sequence - a representation in terms of an initiating event followed by a combination of system, function and operator failures or successes, of an accident that can lead to undesired consequences, with a specified end state (e.g., core damage or large early release). An accident sequence may contain many unique variations of events that are similar.

Core damage - uncovery and heatup of the reactor core to the point at which prolonged oxidation and severe fuel damage is anticipated and involving enough of the core to cause a significant release.

Core damage frequency - expected number of core damage events per unit of time.

End State - is the set of conditions at the end of an event sequence that characterizes the impact of the sequence on the plant or the environment. End states typically include: success states, core damage sequences, plant damage states for Level 1 sequences, and release categories for Level 2 sequences.

Event tree - a quantifiable, logical network that begins with an initiating event or condition and progresses through a series of branches that represent expected system or operator performance that either succeeds or fails and arrives at either a successful or failed end state.

Initiating Event - An initiating event is any event that perturbs the steady state operation of the plant, if operating, or the steady state operation of the decay heat removal systems during shutdown operations such that a transient is initiated in the plant. Initiating events trigger sequences of events that challenge the plant control and safety systems.

ISLOCA - a LOCA when a breach occurs in a system that interfaces with the RCS, where isolation between the breached system and the RCS fails. An ISLOCA is usually characterized by the over-pressurization of a low-pressure system when subjected to RCS pressure and can result in containment bypass

Large early release - the rapid, unmitigated release of airborne fission products from the containment to the environment occurring before the effective implementation of off-site emergency response and protective actions.

Large early release frequency - expected number of large early releases per unit of time.

Level 1 - identification and quantification of the sequences of events leading to the onset of core damage.

Level 2 - evaluation of containment response to severe accident challenges and quantification of the mechanisms, amounts, and probabilities of subsequent radioactive material releases from the containment.

LOCAOC - a LOCA Outside of Containment (LOCAOC) is a breach occurs in a system that interfaces with the RCS and bypasses containment, with the potential to impact systems needed for mitigation of such events. LOCAOC includes breaks in high pressure piping, without the high-to-low pressure interface characteristic of ISLOCA.

Plant damage state - Plant damage states are collections of accident sequence end states according to plant conditions at the onset of severe core damage. The plant conditions considered are those that determine the capability of the containment to cope with a severe core damage accident. The plant damage states represent the interface between the Level 1 and Level 2 analyses.

Probability - is a numerical measure of a state of knowledge, a degree of belief, or a state of confidence about the outcome of an event.

Probabilistic risk assessment - a qualitative and quantitative assessment of the risk associated with plant operation and maintenance that is measured in terms of frequency of occurrence of risk metrics, such as core damage or a radioactive material release and its effects on the health of the public (also referred to as a probabilistic safety assessment, PSA).

Release category - radiological source term for a given accident sequence that consists of the release fractions for various radionuclide groups (presented as fractions of initial core inventory), and the timing, elevation, and energy of release. The factors addressed in the definition of the release categories include the response of the containment structure, timing, and mode of containment failure; timing, magnitude, and mix of any releases of radioactive material; thermal energy of release; and key factors affecting deposition and filtration of radionuclides. Release categories can be considered the end states of the Level 2 portion of a PSA.

Risk - encompasses what can happen (scenario), its likelihood (probability), and its level of damage (consequences).

Risk metrics - the quantitative value, obtained from a PRA analysis, used to evaluate the results of an application (e.g., CDF or LERF).

Severe accident - an accident that involves extensive core damage and fission product release into the reactor vessel and containment, with potential release to the environment.

Split Fraction - a unitless parameter (i.e., probability) used in quantifying an event tree. It represents the fraction of the time that each possible outcome, or branch, of a particular top event may be expected to occur. Split fractions are, in general, conditional on precursor events. At any branch point, the sum of all the split fractions representing possible outcomes should be unity. (Popular usage equates "split fraction" with the failure probability at any branch [a node] in the event tree.)

Vessel Breach - a failure of the reactor vessel occurring during core melt (e.g., at a penetration or due to thermal attack of the vessel bottom head or wall by molten core debris).

SECTION 1 INTRODUCTION

1.1. Purpose

The purpose of this analysis is to provide a risk assessment of using containment accident pressure or containment overpressure to satisfy the Net Positive Suction Head (NPSH) requirements for emergency core cooling pumps which take suction from the suppression pool.

1.2. Background

The design basis analysis evaluation of NPSH for various pumps used for Emergency Core Cooling and containment heat removal operating at Extended Power Uprate (EPU) conditions determined that NPSH requirements would not be satisfied for the large break LOCA and ATWS events. The difference in available NPSH between current licensed thermal power and EPU is attributed to higher reactor core decay heat during loss-of-coolant accidents (LOCAs), anticipated transient without scram (ATWS) and other transients events, which results in higher Torus pool temperatures. Because elevated Torus pool temperatures reduce available NPSH, a licensing basis change has been requested to credit containment overpressure (COP) to ensure adequate available NPSH for the following emergency core cooling system (ECCS) pumps in the large break LOCA and ATWS events:

- Core Spray (CS) Pumps
- Residual Heat Removal (RHR) Pumps used for Low Pressure Coolant Injection (LPCI)

The Nuclear Regulatory Commission (NRC) has allowed credit for COP to satisfy NPSH requirements in accordance with Regulatory Guide 1.82 (RG 1.82). Specifically, RG 1.82 Position 2.1.1.2 addresses containment overpressure as follows:

> *"For certain operating BWRs for which the design cannot be practicably altered conformance with Regulatory Position 2.1.1.1 may not be possible. In these cases, no additional containment pressure should be included in the determination of available NPSH than is necessary to preclude pump cavitation. Calculation of available containment pressure should underestimate the expected containment pressure when determining available NPSH for this situation. Calculation of suppression pool water temperature should overestimate the expected temperature when determining available NPSH."*

The proposed change in the Vermont Yankee (VY) 'License Basis' (LB) crediting COP meets the approved positions of RG 1.82 Rev. 3. Entergy has opted to perform a 'risk-informed' analysis in accordance with NRC Regulatory Guide 1.174, "An Approach for Using Probabilistic Risk Assessment In Risk-Informed Decisions on Plant-Specific Changes to the Licensing Basis" (RG 1.174) [Reference 1] to provide justification for crediting COP.

The use of RG 1.174 for risk-informed approach analysis for a proposed License Basis change involves five key elements:

1) Meets regulatory requirements
2) Consistent with 'defense-in-depth' attributes
3) Maintains sufficient safety margins
4) Increases in CDF and LERF should be small and consistent with NRC Safety Goal Policy Statement

5) Impact should be monitored using performance measurement strategies

This report documents the requirements of element #4. Specifically, the following:

- VY Probabilistic Safety Assessment (PSA) model description
- The impact of containment integrity on NSPH requirements
- Changes in CDF and LERF
- Considerations of model uncertainty

1.3. Vermont Yankee Probabilistic Safety Assessment Quality

The VY PSA is of sufficient quality and scope for this application. The VY PSA modeling is highly detailed, including a wide variety of initiating events (e.g., transients, internal floods, LOCAs inside and outside containment, support system failure initiators), modeled systems, extensive level of detail, operator actions, and common cause events.

The PSA model (Level 1 and Level 2) used for this analysis was the most recent internal events risk model for the VY PSA (Revision VY04R1) [Reference 2]. This current model is an updated version of the model used in the 1993 individual plant examination (IPE) [Reference 3] and reflects the VY PSA configuration and Extended Power Uprate design changes and SBO/Vernon Tie evaluation as of September 2004. The VY PSA model adopts the large event tree / small fault tree approach and uses the support state methodology, embodied in the RISKMAN code, for quantifying core damage frequency.

The PSA model has been updated several times since the IPE due to the following.

- Equipment performance – As data collection progresses, estimated failure rates and system unavailability data change.
- Plant configuration changes – Plant configuration changes are incorporated into the PSA model.
- Modeling changes – The PSA model is refined to incorporate the latest state of knowledge and recommendations from industry peer reviews.

The Vermont Yankee internal events received a formal industry PRA Peer Review in November 2000 [Reference 4]. *All of the A and B priority comments have been addressed by Entergy and incorporated* into the current VY PSA model as appropriate.

Refer to Attachment J for further details regarding the quality of the VY PSA.

SECTION 2 EVALUATION

2.1. Method of Analysis

2.1.1. General

The Vermont Yankee PSA model uses widely-accepted PRA techniques for event tree and fault tree analysis. Event trees are constructed to identify core damage and radionuclide release sequences. The event tree "top events" represent systems (and operator actions) that can prevent or mitigate core damage. Fault trees are constructed for each system in order to identify the failure modes. Analysis of component failure rates (including common cause failures) and human error rates is performed to develop the data needed to quantify the fault tree models.

In PRA terminology, the Vermont Yankee PSA modeling approach can be characterized as an "event tree linking" approach. The event tree top events correspond to systems, as opposed to the more general functions used by some analysts. This approach divides the plant systems into two categories:

1. Front-Line Systems, which directly satisfy critical safety functions (e.g., Core Spray and Torus Cooling), and
2. Support Systems, which are needed to support operation of front-line systems (e.g., ac power and service water).

Front-line event trees are linked to the end of the Support System event trees for sequence quantification. This allows us determination of the status of all support systems for each sequence before the front-line systems are evaluated. Quantification of the event tree and fault tree models is performed using Personal Computer version of the RISKMAN code. The Support System and Front-Line System event trees are "linked" together and solved for the core damage sequences and their frequencies. This calculation is performed with the RISKMAN code's event tree module. Each sequence represents an initiating event and combination of Top Event failures that results in core damage. The frequency of each sequence is determined by the event tree structure, the initiating event frequency and the Top Event split fraction frequencies specified by the RISKMAN master frequency file. RISKMAN allows the user to enter the split fraction names and the logic defining the split fractions (i.e., rules) to be selected for a given sequence based on the status of events occurring earlier in the sequence or on the type of initiating event.

2.1.2. Modification of the VY PSA Model

The risk assessment evaluation examined VY PSA plant specific accident sequences in which the containment integrity is necessary for success of the RHR system and Core Spray system emergency core cooling pumps.

The steps taken to perform this risk assessment evaluation are as follows:

1) Modify the VY PSA Containment Isolation System fault tree to reflect the EPRI-TR-1009325 probability for pre-existing containment leakage.
2) Revise the appropriate LOCAs, FLOODS, ATWS, TRANSIENT event trees to reflect the impact of COP on NPSH requirements.
3) Perform an uncertainty analysis on a number of important basic events associated with the containment overpressure modeling changes used in this risk assessment.

4) Characterized the risk assessment evaluation of containment overpressure impact on NPSH requirements by change in CDF and LERF risk metrics (as defined in (RG 1.174) [Reference 1].

The final step calculates the change in CDF and LERF and compares it to the acceptance guidelines presented in Figures 2.1 and 2.2 of Regulatory Guide 1.174 [Reference 1].

2.2. Fault Tree Analysis

The specific issue to be assessed by this evaluation – control of containment over-pressure (COP) for ensuring adequate NPSH for the RHR and Core Spray pumps – required creation of a new fault tree for Top Event (IP), "Primary Containment Integrity". In order to credit containment overpressure when necessary to maintain sufficient NPSH margin for LPCI and Core Spray pump operation, it is necessary that the primary containment remain intact. Because of the roles they play in the accident sequences of interest, information for Top Events (VT) and (AI) are included for completeness.

2.2.1. Containment Venting – Top Event (VT)

Top Event VT is used to evaluate containment venting as a means of depressurizing the containment during sequences when all containment heat removal capability fails or becomes inadequate. Successful use of the vent can provide the operator more time to recover heat removal equipment by limiting containment peak pressure to preserve containment structural integrity and the ECCS which rely on containment. The vent path is from the suppression pool air space to the plant vent stack.

The containment vent consists of 8" pipe connected to a suppression-pool-to-drywell vacuum line upstream of the vacuum breaker. The vent line is equipped with a rupture disc and one normally closed, remote/manual gate valve (MOV). The gate valve is used to initiate venting, and for manual isolation of the vent path after the containment has been depressurized to the desired pressure. Operators can reopen the vent path should periodic venting be appropriate.

No changes were made to this top event fault tree. See Attachment A for details on Top Event VT.

2.2.2. Primary Containment Integrity – Top Event (IP)

Top event IP is used to evaluate whether the containment is intact during the period of time that the hard-piped vent from torus air space is used to prevent over-pressurization (VT=S). Integrity of containment is a necessary condition in order to maintain sufficient pressure in the containment in support of continued operation of LPCI or Core Spray pumps taking suction from the suppression pool at elevated temperature.

Failure of containment integrity is defined to include failures in the containment boundary that allow leakage in excess of that which would maintain overpressure sufficient to satisfy the NPSH-r for the LPCI and Core Spray pumps at elevated suppression pool temperature. The leakage sources are divided into two principal categories:

- Isolation valve failures: These are related to the failure of the isolation valves in containment penetration lines or failure of the isolation signals or power to close these valves.
- Pre-existing failures: These are failures primarily related to hatches, electrical penetration assemblies (EPAs), and other containment leakage paths not associated with failure of isolation valves to close.

The following assumptions were utilized in the fault tree model for top event IP:

- The containment pre-existing leakage probabilities (basic events ISDWSMLEAK and ISDWLGLEAK) were determined using EPRI's TR-1009325 [Reference 6]:

  - Basic event ISDWSMLEAK represents the probability that containment pre-existing leakage is above the threshold at which adequate overpressure can be assured, but is less than the lower threshold used to define the large containment pre-existing leakage.
  - Basic event ISDWLGLEAK represents the probability that containment pre-existing leakage is above the threshold used to define the large containment leakage.
- The isolation valves included in the quantification are those that communicate directly with the atmosphere of the containment on the following penetration lines:
  - Drywell equipment drain sump lines
  - Drywell floor drain sump lines
  - Drywell and torus vent lines
  - Drywell and torus purge supply lines
  - Torus vacuum relief system
- Piping penetrations in systems which connect directly to the RPV are assumed to have negligible contribution to isolation failure since multiple isolation valves must fail in addition to the pipe rupturing.

A new fault tree was developed for this risk assessment. See Attachment B for details on Top Event IP.

2.2.3. Alternate Injection & COP Control – Top Event (AI)

Top Event AI is used to evaluate the success of long-term injection (from sources external to the containment) after containment heat removal challenges as a means of preventing core damage.

The alternate injection systems credited for Medium LOCA events are Condensate, CRD, and Condensate Transfer. In the case of Transient events, Internal Flooding events, and Small LOCA events, the Feedwater, HPCI, and RCIC systems are credited in addition to Condensate, CRD, and Condensate Transfer. In the case of Large LOCA events, the only alternate injection system credited is the Fire Water System via an emergency intertie provided between the Service Water System and the A Loop of the RHR System.

No changes were made to this top event fault tree. See Attachment C for details on Top Event AI.

2.3. Event Tree Analysis

The specific issue to be assessed by this evaluation – control of containment over-pressure (COP) for ensuring adequate NPSH of RHR and Core Spray pumps – required the addition of new Top Event (IP), "Primary Containment Integrity", to the event trees used to evaluate transients and LOCAs which occur inside containment.. For completeness, information for Event Tree (ATWS) is included. However, use of Alternate Injection (AI) as a mitigation strategy for ATWS events was not considered based upon the assumption that there is insufficient capacity from external injection sources (e.g., Condensate Transfer) and/or the limited time available to successfully implement this mitigation strategy for ATWS sequences when both the normal and emergency heat sinks are unavailable.

2.3.1. Transients – Event Tree (TRANSIENT)

The transient event tree is used to analyze a number of Transient initiating events, including some "special" initiators. The Transient event tree evaluates the critical safety functions of reactivity control, high pressure core injection, RPV depressurization, low pressure core injection, and containment heat removal. The Transient event tree does not evaluate the vapor suppression function, because transients do not involve discharge of reactor coolant inventory to the drywell (except briefly if the safety valves open for pressure relief). Also, because there is no break, reactor pressure control (using Turbine Bypass Valves or SRVs) is evaluated in the Transient event tree. Failure to scram is not analyzed explicitly in the Transient event tree. Transient sequences where control rods fail to insert are evaluated instead by the ATWS event tree. The transient initiating event frequencies are based on review of VY experience through April 2002, as well as data provided in NUREG/CR-5750, "Rates of Initiating Events at US Nuclear Power Plants: 1987-1995".

See Attachment D for details on the TRANSIENT event tree.

2.3.2. Anticipated Transients w/o SCRAM – Event Tree (ATWS)

Anticipated Transients without Scram (ATWS) are events where the plant is degraded in some manner such that a scram should have occurred, but the reactor remains at power due to failure of the Reactor Protection System. ATWS events have unique mitigating system requirements compared to Transient and LOCA events, including the need for alternate means of reactivity control. The ATWS initiating event frequencies are estimated by multiplying the transient related initiating event frequencies by the reactor scram failure probability. The reactor scram failure probability is represented in top events SM, SE and AR.

See Attachment E for details on the ATWS event tree.

2.3.3. Large LOCA – Event Tree (LOCA_LG)

A Large LOCA causes rapid depressurization of the reactor and requires rapid injection of water from high volume systems. Thus, the Large LOCA event tree does not credit use of HPCI and RCIC for high pressure injection to the reactor, and use of the ADS valves for reactor depressurization is not required. We assume that the break location is inside the drywell for all LOCAs.

We assume that the break is located on the discharge side of a recirculation line, since this will disable one train (two pumps) of LPCI injection. This assumption envelopes a break in a Core Spray line, since Core Spray line breaks would also disable a single train (but only one pump) of injection. Also, the assumed location is conservative for recirculation suction side breaks since the recirculation loop isolation valves are designed to close for these breaks such that no train of low pressure injection would be disabled by the break location. The Large LOCA event frequency was estimated using NUREG/CR-5750, "Rates of Initiating Events at US Nuclear Power Plants: 1987-1995". Frequencies were estimated by calculating the frequency of leaks or through-wall cracks that have occurred which challenge the piping integrity. Based on this reference, there were no medium or large pipe break LOCA events in worldwide experience. Additionally, conservative estimates were used for the conditional probability of a pipe break given leak. This analysis is elaborated in the Appendix J of NUREG/CR-5750.

See Attachment F for details on the LOCA_LG event tree.

2.3.4. Medium LOCA – Event Tree (LOCA_MD)

A Medium LOCA causes eventual depressurization of the reactor due to the break, but the rate of depressurization and rate of makeup required are less for a Medium LOCA. This allows use of HPCI in the early stage of a Medium LOCA to accomplish the high pressure injection function (we assume that the capacity of the RCIC System is insufficient to accomplish this function for Medium LOCAs). However, because the reactor is eventually depressurized by the break, low pressure injection systems are also required. Also, if high pressure systems fail to provide early injection rapid reactor depressurization via the ADS valves must occur in order for the low pressure systems to inject.

Because the break flow for a Medium LOCA is smaller than for a Large LOCA the Medium LOCA event tree considers drywell spray and RPV depressurization via the ADS valves as alternate means of accomplishing vapor suppression. Also, the smaller break flow for a Medium LOCA will divert less flow from the reactor for breaks located on LPCI or Core Spray System injection piping. We assume that no trains of injection systems are disabled directly as a result of such flow diversion for Medium LOCAs. The Medium LOCA event frequency was estimated using NUREG/CR-5750, "Rates of Initiating Events at US Nuclear Power Plants: 1987-1995". Frequencies were estimated by calculating the frequency of leaks or through-wall cracks that have occurred which challenge the piping integrity. Based on this reference, there were no medium or large pipe break LOCA events in worldwide experience. Additionally, conservative estimates were used for the conditional probability of a pipe break given leak. This analysis is elaborated in the Appendix J of NUREG/CR-5750.

See Attachment G for details on the LOCA_MD event tree.

2.3.5. Small LOCA – Event Tree (LOCA_SM)

Unlike Large and Medium LOCAs, Small LOCAs are assumed not to cause reactor depressurization via the break. This makes HPCI and RCIC viable long-term injection systems. However, if these high pressure injection systems fail, the reactor must be depressurized via the ADS valves in order for the low pressure injection systems to inject.

Like the Medium LOCA event tree, we assume that the break is located inside containment, and that no injection systems are disabled directly as a result of the flow diversion out the break. The Small LOCA event frequency was estimated using NUREG/CR-5750, "Rates of Initiating Events at US Nuclear Power Plants: 1987-1995". Frequencies were estimated by calculating the frequency of leaks or through-wall cracks that have occurred which challenge the piping integrity. Based on this reference, there were no medium or large pipe break LOCA events in worldwide experience. Additionally, conservative estimates were used for the conditional probability of a pipe break given leak. This analysis is elaborated in the Appendix J of NUREG/CR-5750.

See Attachment H for details on the LOCA_SM event tree.

2.3.6. Internal Flooding – Event Tree (FLOODS)

The scope of potential flooding sources includes pipe break events that result in water accumulation (flooding), water spray or potential adverse environment (steam). Failure of any hoses and failure of water tanks were also included in the review scope. Piping systems that are outside the scope of this evaluation include the Main Steam, Feedwater, HPCI and RCIC steam piping, and Reactor Water Cleanup (RWCU). Potential breaks in these high energy lines (HELBs) were included in the LOCA Outside Containment (LOCAOC) evaluation.

Based on the walkdowns performed, the principal internal flood sources include postulated breaks in the service water, fire water and circulating water systems. The principal buildings/areas subject to these internal flooding sources are the Reactor Building, Turbine Building, Intake Structure and Front Office Building. The flood initiating event frequency for each internal flood scenario was determined from pipe failure probabilities provided in EPRI TR 102266, "Pipe Failure Study Update", and from applicable industry event data in Nuclear Plant Experiences (NEP).

See Attachment I for details on the FLOODS event tree.

Figure 2.1

Acceptance Guidelines[1] for Core Damage Frequency [Reference 1]

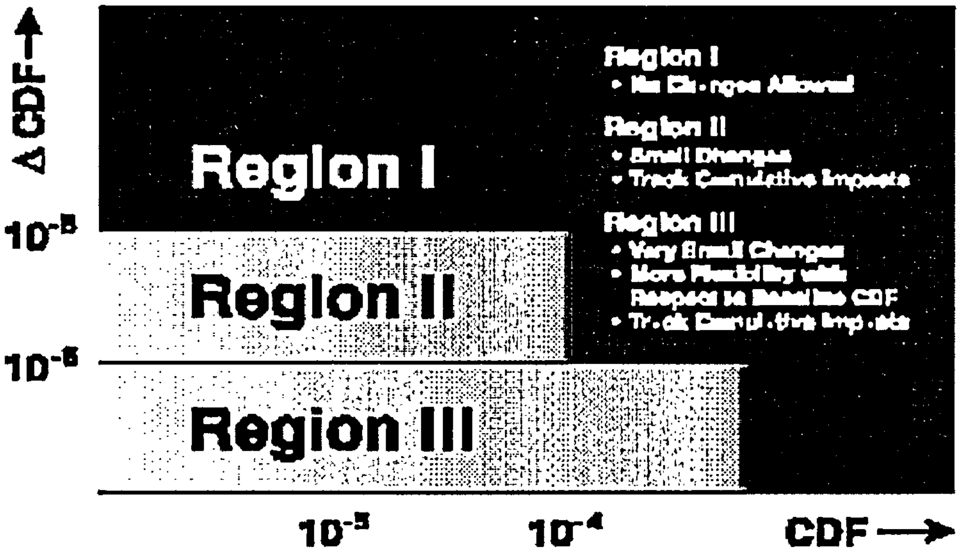
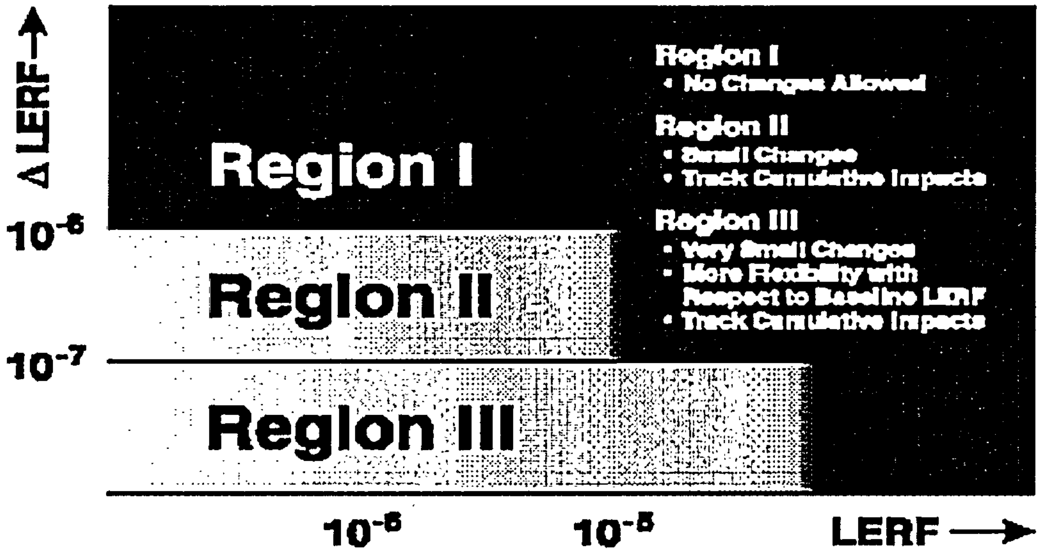


Figure 2.2

Acceptance Guidelines[1] for Large Early Release Frequency [Reference 1]



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[1] The analysis will be subject to increased technical review and management attention as indicated by the darkness of the shading of the figure. In the context of the integrated decision making, the boundaries between regions should not be interpreted as being definitive; the numerical values associated with defining the regions in the figure are to be interpreted as indicative values only.

SECTION 3 SUMMARY OF RESULTS

3.1. Core Damage

In order to assess the risk impact of utilizing containment accident pressure (containment overpressure) at EPU conditions to satisfy the net positive suction head (NPSH) requirements for RHR and Core Spray pumps, the PRA model changes described in Section 2 was created. This model was then exercised in the following configurations:

- CONFIG#1 The result from this model case (VYCOP2A) represents the risk when the COP is NOT available to satisfy RHR and CS pumps NPSH requirements.
- CONFIG#2 The result from this model case (VYCOP2) represents the risk when the <u>COP is available</u> to satisfy RHR and CS pumps NPSH requirements.

The results of the front-line event tree analysis are accident sequences and their frequencies. Because there may be many thousands of such sequences, it is convenient to group these sequences into "bins", where each bin represents a certain "type" of accident sequence. This binning can provide insights into the Core Damage Frequency (CDF) results. For example, there can be situations where many similar core damage sequences together represent a significant fraction of the CDF, even though each individual sequence alone only represents a small fraction of the total CDF. In this case, binning allows us to identify the total CDF contribution for this group of similar sequences.

The bins listed in Tables 3.2A, B, and C, are used to characterize the results of the front-end (i.e., Level I or CDF) analysis. As would be expected, the only difference between the two model cases lies in Endstate Bin IIV. This endstate contains sequences where (1) the main condenser and RHR fail, and the torus vent opens for containment pressure relief, or (2) the main condenser and RHR fail, and containment integrity failure exists from the onset of the event. Core damage occurs when ECCS systems fail due to inadequate NPSH. The incremental change in CDF, 5.78E-7/ry, indicates that use of the COP mitigation strategy has a very small risk impact. Comparison between the different sequence groups (i.e.: ALL, CDIPEV, FLOODS) reveals that the incremental change in CDF for transient and LOCA events (sequence group CDIPEV) accounts for 4.41E-7/ry of the total.

3.2. Radiological Release

The spectrum of possible release times is discretized into three categories: Early, Intermediate, and Late. The spectrum of possible release magnitudes is discretized into four categories: High, Medium, Low, and Low-Low. Combining both the timing and magnitude of release results in a total of twelve containment event tree (CET) endstate bins: Early/High, Intermediate/High, Late/High, Early/Medium, etc. These timing/magnitude bins are used to characterize the release.

The release timing is characterize based on the time at which the release begins, measured from the time of accident initiation:

- Early (0-6 hours)
- Intermediate (6-24 hours)
- Late (>24 hours)

Sequences with an "early" release time include those where the containment failure (and core damage) occurs in the "early" time frame. These include LOCA sequences where the containment fails due to vapor suppression failure. However, in the case of transient events and internal flooding events, the time until core damage would occur and when containment failure would subsequently occur will be much greater than 6 hours; thus these initiating event sequences are excluded from consideration in the determination of LERF.

The incremental change in Large Early Release Frequency (ΔLERF) for VY from internal events for this risk assessment is conservatively assumed equal to the incremental change in core damage frequency (ΔCDF) from LOCA events for this risk assessment. Thus from Table 3.4 – "LOCAs and Their Contribution to CDF", the ΔLERF is estimated to equal 4.50E-8/ry.

3.3. Parametric Uncertainty Analysis

3.3.1. Sources and Treatment of Uncertainty

Parametric uncertainty associated with the numerical results of this study primarily caused by insufficient component failure mode data, problems interpreting failure data and component performance records, the use of generic data in a plant-specific data analysis, and the intrinsic variability of failure data. In assessing the contribution of parametric uncertainty to the numerical results, the parameters of interest are those used by the accident-sequence logic models. They include initiating event frequencies, component failure rates and unavailability, and human error probabilities.

In this study, parametric uncertainties were handled by defining a probability distribution for the value of each parameter such that the "nth" percentile of the distribution represents the value for which the analyst has n% confidence that the true value lies below the value. This subjective approach to the representation of uncertainty makes the propagation of parametric uncertainty through the evaluation mathematically straightforward. The evaluation was made using the Monte Carlo sampling technique. The uncertainty ranges characterized by the distributions vary in origin. For example, if the estimates are based on plant-specific data, the range is characteristic of statistical uncertainty. If the estimates are generic (or non-plant specific) the range is characteristic of the factors that may affect the failure properties of the component in different uses and environments. Hence the range will include plant-to-plant variation.

The propagation of uncertainties was accomplished using the RISKMAN computer program to calculate probability distributions and determine the uncertainty in the accident frequency estimate. The modeling of uncertainties and their propagation is discussed and documented in NUREG/CR-4550, Volume 1, Revision 1.

3.3.2. Quantification of Uncertainty

The uncertainty of the parameter values was propagated through the PSA models VYCOP2A for CONFIG#1 and VYCOP2 for CONFIG#2 using the RISKMAN computer program.

RISKMAN has three analysis modules: Data Analysis Module, System Analysis Module, and Event Tree Analysis Module. Appropriate probability distributions for each uncertain parameter in the analysis is determined and included in the Data Module. The System Module combines the individual failure rates, maintenance, and common cause parameters into the split fraction frequencies that will be used by the Event Module. A Monte Carlo routine is used with the complete distributions to calculate the split fraction frequencies. Event trees are quantified and linked together in the Event Module. The important sequences from the results of the Event Module are used in another Monte Carlo sampling step to propagate the split fraction uncertainties and obtain the uncertainties in the overall results.

The descriptive statistics calculated by RISKMAN for the total core damage frequency of the plant caused by internal events include:

- Mean of the sample

- Variance of the sample
- 5th, 50th, and 95th percentiles of the sample.

3.3.3. Results of Uncertainty Analysis

The parametric uncertainty associated with core damage frequency was estimated for the two configurations using Monte Carlo techniques implemented in RISKMAN. Each configuration entails three sequence groups: ALL, CDIPEV, and FLOODS. The results are shown in Tables 3.5A and 3.5B.

To facilitate comparison between the two configurations, a sample size of 10,000 and identical random number seeds were used in the analysis. Split fractions of top events IP, LP, TC, CS, TCA, TCB, LA, LB, VA, VB, CA, and CB were correlated during the sampling process. Statistical input and output from the Monte Carlo simulation are provided in Tables 3.6A, B, and C (CONFIG#1) and Table 3.7A, B, and C (CONFIG#2).

3.4. Modeling Uncertainty Analysis

Modeling uncertainty is concerned with the sensitivity of the results due to uncertainties in the structure and assumptions in the logic model. Modeling uncertainty has not been explicitly treated in many PRAs, and is still an evolving area of analysis. The PRA industry is currently investigating methods for performing modeling uncertainty analysis. EPRI has developed a guideline for modeling uncertainty that is still in draft form and undergoing pilot testing. The EPRI approach currently being tested takes the rational approach of identifying key sources of modeling uncertainty and then performing appropriate sensitivity calculations. This approach is taken here.

The modeling issues selected here for assessment are those related to the risk assessment of the containment overpressure credit. This assessment does not involve investigating modeling uncertainty with regard to the overall VY PRA. The modeling issue identified for sensitivity analysis was pre-existing containment degradation.

3.4.1. Pre-existing Containment Leakage (ISDWSMLEAK)

An evaluation was performed to determine the maximum size hole in containment that would still assure adequate overpressure. Using the conservative 10CFR50 Appendix K containment analysis as the starting point, the maximum leak was determined to be approximately 60×L_a. L_a is defined in the VY TS Bases 4.7 as 0.8 wt % per day at 44 psig.

A conservative leak rate was determined to be approximately 27×L_a, using licensing-bases assumptions. Sensitivity studies using analysis assumptions that are more realistic, but still conservative or bounding, show that peak suppression pool temperature would not increase above a value where credit for containment overpressure would be required. Therefore, on this basis the maximum leak would be infinite, i.e. there would be no need for the containment from a containment overpressure retention perspective. A leak rate of 60×L_a was used in the PRA case described above (i.e., CONFIG#2), which is believed to be a more representative best-estimate value for this term.

Quantitative sensitivity cases to assess the response of CDF to changes in the allowable pre-existing leakage rate were performed, where the probability value assigned to basic event ISDWSMLEAK is determined using EPRI's TR-1009325. Based upon the results of these sensitivity cases, provided in the table below, it appears that as the allowable pre-existing leakage rate drops below ~30×La, the estimated CDF will increase significantly.

Table 3.1 Sensitivity Cases for ISDWSMLEAK

Sensitivity Case	Description	CDF (ALL Sequences)
#1	Assume max allowable = 10 x L_a ; assign ISDWSMLEAK=7.63E-3) (model case V4COPS3)	1.0377E-5
#2	Assume max allowable = 20 x L_a ; assign ISDWSMLEAK=3.75E-3) (model case V4COPS5)	7.8600E-6
#3	Assume max allowable = 30 x L_a ; assign ISDWSMLEAK=1.87E-3) (model case V4COPS2)	6.6407E-6
#4	Assume max allowable = 40 x L_a ; assign ISDWSMLEAK=8.80E-4) (model case V4COPS4)	5.9988E-6
#5	Assume max allowable = 60 x L_a ; assign ISDWSMLEAK=2.47E-4) (model case VYCOP2; i.e., CONFIG#2)	5.5884E-6

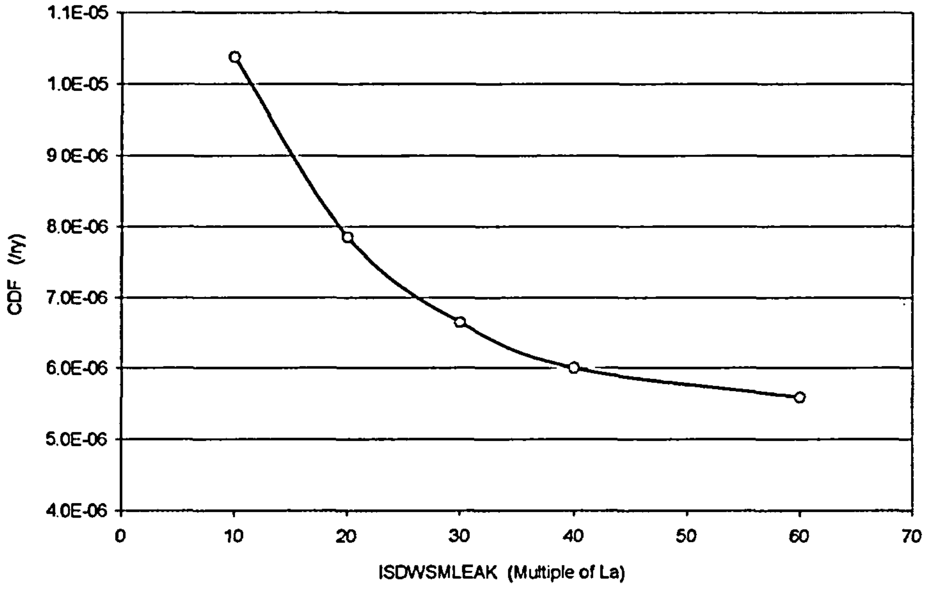

FIGURE 3.1 Pre-Existing Containment Leakage vs. CDF (model VYCOP2)

3.5. Completeness Uncertainty Analysis

Completeness uncertainty is addressed here by the qualitative assessment of the impact on the conclusions if external events and shutdown risk contributors are also considered.

3.5.1. Seismic

The Vermont Yankee seismic risk analysis was performed as part of the Individual Plant Examination of External Events (IPEEE). Vermont Yankee performed a seismic margins assessment (SMA) following the guidance of NUREG-1407 and EPRI NP-6041. The SMA is a deterministic evaluation process that does not calculate risk on a probabilistic basis. No core damage frequency sequences were quantified as part of the seismic risk evaluation.

The conclusions of the Vermont Yankee IPEEE seismic analysis are as follows:

For Vermont Yankee, the SMA identified that the lowest HCLPF components in the selected primary and alternate safe shutdown paths are the Condensate Storage Tank (CST) with a HCLPF of 0.25g and the Diesel Fuel Oil Storage Tank (FOST) with a HCLPF of 0.29g. The HCLPF for all other components in the safe shutdown paths meet or exceed the 0.3g review level earthquake. These values represent significant margin to the design basis 0.14g earthquake.

The conclusions of the SMA are judged to be unaffected by the EPU or the containment overpressure credit issue. The EPU has little or no impact on the seismic qualifications of the systems, structures and components (SSCs). Specifically, the power uprate results in additional thermal energy stored in the RPV, but the additional blowdown loads on the RPV and containment given a coincident seismic event, are judged not to alter the results of the SMA.

The decrease in time available for operator actions, and the associated increases in calculated HEPs, is judged to have a non-significant impact on seismic-induced risk. Industry BWR seismic PSAs have typically shown (e.g., Peach Bottom NUREG-1150 study; Limerick Generating Station Severe Accident Risk Assessment; NUREG/CR-4448) that seismic risk is overwhelmingly dominated by seismic induced equipment and structural failures.

Based on the above discussion, it is judged that seismic issues do not significantly impact the decision making for the VY EPU and containment overpressure credit.

3.5.2. Internal Fires

As discussed in the VY EPU submittal, internal fires risk is not a significant contributor to the risk profile of the proposed EPU. Credit for containment overpressure is not required for VY Appendix R fire accident sequences. As such, it is judged that fire issues do not significantly impact the decision making for the VY EPU and associated containment overpressure credit.

3.5.3. Other External Hazards

In addition to seismic events and internal fires, the VY IPEEE Submittal analyzed a variety of other external hazards:

- High Winds/Tornadoes
- External Floods
- Transportation and Nearby Facility Accidents
- Other External Hazards

The VY IPEEE analysis of high winds, tornadoes, external floods, transportation accidents, nearby facility accidents, and other external hazards was accomplished by reviewing the plant environs against regulatory requirements regarding these hazards. Based upon this review, it was concluded that VY meets the applicable NRC Standard Review Plan requirements and therefore has an acceptably low risk with respect to these hazards. As such, these other external hazards are judged not to significantly impact the decision making for the VY EPU and containment overpressure credit.

Note that the VY IPEEE also analyzed internal flooding scenarios. However, internal flooding scenarios are now incorporated into the current VY PSA internal events model of record.

3.5.4. Shutdown Risk

As discussed in the VY EPU submittal, shutdown risk is a non-significant contributor to the risk profile of the proposed EPU. The credit for containment overpressure is not required for accident sequences occurring during shutdown. As such, shutdown risk does not influence the decision making for the VY EPU containment overpressure credit.

Table 3.2A Bin Totals for Sequence Group = ALL

Bin	Bin Description	CONFIG#1 CDF/ry	CONFIG#2 CDF/ry	ΔCDF/ry
ID	Sequences with loss of all injection. Core damage occurs with the reactor at low pressure.	1.3942 E-06	1.7909 E-06	3.9670 E-07
IA	Sequences with loss of all high pressure injection and failure to depressurize. Core damage occurs with the reactor at high pressure.	1.1321 E-06	1.1321 E-06	0
IBL	'Late' SBO-type. Core cooling is maintained by HPCI/RCIC until batteries deplete.	8.3968 E-07	8.3968 E-07	0
IIA	Sequences with loss of all containment heat removal. Core damage is caused by containment failure.	4.2536 E-07	4.2536 E-07	0
IBE	'Early' SBO-type sequences. Core damage occurs due to early failure of HPCI and RCIC.	3.1904 E-07	3.1904 E-07	0
IIIB	Small or Medium LOCA sequences for which the reactor cannot be depressurized prior to core damage occurring.	2.0785 E-07	2.0785 E-07	0
IIV	Sequences where the main condenser and RHR fail, and the torus vent opens for containment pressure relief. Core damage occurs when ECCS systems fail NPSH, due to failure to reclose the vent.	1.9400 E-07	1.9398 E-07	-2.0 E-11
IIIC	Sequences with loss of injection. Core damage occurs with the reactor at low pressure.	1.3411 E-07	3.1555 E-07	1.8144 E-07
IVA	ATWS sequences where core damage is caused by containment failure.	1.1693 E-07	1.1692 E-07	-1.0 E-11
IED	'Early' SBO-type sequences caused by failure of DC-1 and DC-2.	5.6127 E-08	5.6127 E-08	0
V	Containment Bypass sequences. (Interfacing systems LOCA and LOCA outside of containment.)	5.3176 E-08	5.3176 E-08	0
IVL	ATWS sequences where core damage occurs due to overpressure failure of the Reactor Coolant System.	5.2938 E-08	5.2938 E-08	0
IIL	Loss of containment heat removal with RPV breach but no initial core damage; core damage after containment failure.	4.6871 E-08	4.6871 E-08	0
IC	ATWS sequences where core damage is caused by loss of injection during level/power control.	1.6074 E-08	1.6363 E-08	2.8900 E-10
IEC	Sequences with delayed loss of dc power due to failure of battery chargers.	1.0830 E-08	1.0830 E-08	0
IIID	Sequences where core damage is caused by containment failure. Containment fails due to failure of vapor suppression (stuck-open vacuum breaker.)	6.3348 E-09	6.3348 E-09	0
IIIA	RPV ruptures due to failure of all over-pressure protection systems (SO=F).	4.3631 E-09	4.3631 E-09	0
	Total	5.0100 E-06	5.5884 E-06	5.7840 E-07

Table 3.2B Bin Totals for Sequence Group = CDIPEV[2]

Bin	Bin Description	CONFIG#1 CDF/ry	CONFIG#2 CDF/ry	ΔCDF/ry
IBL	'Late' SBO-type. Core cooling is maintained by HPCI/RCIC until batteries deplete.	8.3968 E-07	8.3968 E-07	0
ID	Sequences with loss of all injection. Core damage occurs with the reactor at low pressure.	8.2931 E-07	1.2260 E-06	3.9669 E-07
IA	Sequences with loss of all high pressure injection and failure to depressurize. Core damage occurs with the reactor at high pressure.	7.1219 E-07	7.1219 E-07	0
IIA	Sequences with loss of all containment heat removal. Core damage is caused by containment failure.	3.3993 E-07	3.3993 E-07	0
IBE	'Early' SBO-type sequences. Core damage occurs due to early failure of HPCI and RCIC.	1.5294 E-07	1.5294 E-07	0
IIIB	Small or Medium LOCA sequences for which the reactor cannot be depressurized prior to core damage occurring.	1.3532 E-07	1.3532 E-07	0
IIIC	Sequences with loss of injection. Core damage occurs with the reactor at low pressure.	1.2242 E-07	1.6592 E-07	4.3500 E-08
IVA	ATWS sequences where core damage is caused by containment failure.	1.1304 E-07	1.1303 E-07	-1.0 E-11
IIV	Sequences where the main condenser and RHR fail, and the torus vent opens for containment pressure relief. Core damage occurs when ECCS systems fail NPSH, due to failure to reclose the vent.	9.4479 E-08	9.4466 E-08	-1.3 E-11
IED	'Early' SBO-type sequences caused by failure of DC-1 and DC-2.	5.6127 E-08	5.6127 E-08	0
V	Containment Bypass sequences. (Interfacing systems LOCA and LOCA outside of containment.)	5.3176 E-08	5.3176 E-08	0
IVL	ATWS sequences where core damage occurs due to overpressure failure of the Reactor Coolant System.	5.2938 E-08	5.2938 E-08	0
IIL	Loss of containment heat removal with RPV breach but no initial core damage; core damage after containment failure.	4.6871 E-08	4.6871 E-08	0
IC	ATWS sequences where core damage is caused by loss of injection during level/power control.	1.6074 E-08	1.6363 E-08	2.890 E-10
IEC	Sequences with delayed loss of dc power due to failure of battery chargers.	1.0830 E-08	1.0830 E-08	0
IIID	Sequences where core damage is caused by containment failure. Containment fails due to failure of vapor suppression (stuck-open vacuum breaker.)	6.3348 E-09	6.3348 E-09	0
IIIA	RPV ruptures due to failure of all over-pressure protection systems (SO=F).	4.2849 E-09	4.2849 E-09	0
	Total	3.5859 E-06	4.0264 E-06	4.4046 E-07

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[2] Sequence Group CDIPEV includes all Transient and LOCA initiating events.

Table 3.2C Bin Totals for Sequence Group = FLOODS

Bin	Bin Description	CONFIG#1 CDF/ry	CONFIG#2 CDF/ry	ΔCDF/ry
ID	Sequences with loss of all injection. Core damage occurs with the reactor at low pressure.	5.6491 E-07	5.6491 E-07	0
IA	Sequences with loss of all high pressure injection and failure to depressurize. Core damage occurs with the reactor at high pressure.	4.1989 E-07	4.1989 E-07	0
IBE	'Early' SBO-type sequences. Core damage occurs due to early failure of HPCI and RCIC.	1.6610 E-07	1.6610 E-07	0
IIV	Sequences where the main condenser and RHR fail, and the torus vent opens for containment pressure relief. Core damage occurs when ECCS systems fail NPSH, due to failure to reclose the vent.	9.9517 E-08	9.9517 E-08	0
IIA	Sequences with loss of all containment heat removal. Core damage is caused by containment failure.	8.5436 E-08	8.5436 E-08	0
IIIB	Small or Medium LOCA sequences for which the reactor cannot be depressurized prior to core damage occurring.	7.2531 E-08	7.2531 E-08	0
IIIC	Sequences with loss of injection. Core damage occurs with the reactor at low pressure.	1.1694 E-08	1.4963 E-07	1.3794 E-07
IVA	ATWS sequences where core damage is caused by containment failure.	3.8906 E-09	3.8906 E-09	0
IIIA	RPV ruptures due to failure of all over-pressure protection systems.	7.8268 E-11	7.8268 E-11	0
	Total	1.4240 E-06	1.5620 E-06	1.3794 E-07

Table 3.3 Accident Types and Their Contribution to CDF

Accident Type	CONFIG#1 CDF/ry	CONFIG#2 CDF/ry	ΔCDF/ry
TRANSIENTS	2.97857E-06	3.3737E-06	3.95134E-07
ATWS	1.45139E-07	1.45425E-07	2.8593E-10
Loss of Coolant Accident (LOCA)	4.0905E-07	4.54059E-07	4.5009E-08
Interfacing System LOCA (ISLOCA)	3.68603E-08	3.68603E-08	0
LOCA Outside Containment (LOCAOC)	1.63158E-08	1.63158E-08	0
Internal Flooding (FLOODS)	1.42404E-06	1.56199E-06	1.37944E-07
TOTALS	1.42404E-06	5.58835E-06	5.78373E-07

Table 3.4 LOCAs and Their Contribution to CDF

IE Name	IE Description	CONFIG#1 CDF/ry (COP not credited)	CONFIG#2 CDF/ry (COP credited)	Δ CDF
IORV	Inadvertent Opening of a Relief Valve	2.6907E-07	2.863E-07	1.7230E-08
SORV	Stuck-Open Relief Valve	6.8301E-08	7.3354E-08	5.0530E-09
LLOCA	Large LOCA	2.6159E-08	4.7324E-08	2.1165E-08
MLOCA	Medium LOCA	2.4724E-08	2.4766E-08	4.2000E-11
SLOCA	Small LOCA	2.0796E-08	2.2315E-08	1.5190E-09
			Total	4.5009E-08

Table 3.5A CONFIG#1 CDF (1/ry) Uncertainty

Confidence	CONFIG#1 (ALL)	CONFIG#1 (CDIPEV[3])	CONFIG#1 (FLOODS[4])
MEAN VALUE	5.50E-06	4.21E-06	1.32E-06
5th percentile	2.63E-06	1.75E-06	6.23E-07
50th percentile	4.36E-06	3.23E-06	1.05E-06
95th percentile	1.10E-05	8.70E-06	2.58E-06

Table 3.5B CONFIG#2 CDF (1/ry) Uncertainty

Confidence	CONFIG#2 (ALL)	CONFIG#2 (CDIPEV)	CONFIG#2 (FLOODS)
MEAN VALUE	6.12E-06	4.66E-06	1.46E-06
5th percentile	2.90E-06	1.93E-06	6.98E-07
50th percentile	4.82E-06	3.58E-06	1.16E-06
95th percentile	1.20E-05	9.48E-06	2.80E-06

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[3] Sequence Group CDIPEV includes all Transient and LOCA initiating events.

[4] Sequence Group FLOODS includes all internal flooding events.

Table 3.6A Monte Carlo Sampling Results for the CONFIG#1 (Sequence Group ALL)

Distribution: ALL 10000 Samples, Using Seeds: 8314 17851

Sequence Quantified: 387

MEAN	VARIANCE	5th %TILE	50th %TILE	95th %TILE
5.4959E-06	1.1245E-11	2.6348E-06	4.3624E-06	1.0986E-05

BIN	BOUNDARY	VALUE	DISCRETE	CUMULATIVE
1	1.6101E-06	1.9707E-06	5.0000E-03	5.0000E-03
2	2.1277E-06	2.2103E-06	5.0000E-03	1.0000E-02
3	2.2655E-06	2.3454E-06	1.0000E-02	2.0000E-02
4	2.3959E-06	2.4411E-06	1.0000E-02	3.0000E-02
5	2.4835E-06	2.5579E-06	2.0000E-02	5.0000E-02
6	2.6348E-06	2.7776E-06	5.0000E-02	1.0000E-01
7	2.9094E-06	3.1194E-06	1.0000E-01	2.0000E-01
8	3.3041E-06	3.4808E-06	1.0000E-01	3.0000E-01
9	3.6502E-06	3.8223E-06	1.0000E-01	4.0000E-01
10	3.9899E-06	4.1751E-06	1.0000E-01	5.0000E-01
11	4.3624E-06	4.5628E-06	1.0000E-01	6.0000E-01
12	4.7960E-06	5.0713E-06	1.0000E-01	7.0000E-01
13	5.3847E-06	5.8010E-06	1.0000E-01	8.0000E-01
14	6.2828E-06	7.0993E-06	1.0000E-01	9.0000E-01
15	8.1893E-06	9.3257E-06	5.0000E-02	9.5000E-01
16	1.0986E-05	1.2224E-05	2.0000E-02	9.7000E-01
17	1.3932E-05	1.5368E-05	1.0000E-02	9.8000E-01
18	1.7016E-05	2.1446E-05	1.0000E-02	9.9000E-01
19	2.7981E-05	3.1725E-05	5.0000E-03	9.9500E-01
20	3.8422E-05	5.7278E-05	5.0000E-03	1.0000E+00
21	1.8246E-04			

Table 3.6B Monte Carlo Sampling Results for the CONFIG#1 (Sequence Group CDIPEV)

Distribution: CDIPEV 10000 Samples, Using Seeds: 8314 17851

Sequence Quantified: 263

MEAN	VARIANCE	5th %TILE	50th %TILE	95th %TILE
4.2089E-06	7.3374E-12	1.7503E-06	3.2273E-06	8.7040E-06

BIN	BOUNDARY	VALUE	DISCRETE	CUMULATIVE
1	8.8111E-07	1.1925E-06	5.0000E-03	5.0000E-03
2	1.2936E-06	1.3530E-06	5.0000E-03	1.0000E-02
3	1.4047E-06	1.4760E-06	1.0000E-02	2.0000E-02
4	1.5391E-06	1.5861E-06	1.0000E-02	3.0000E-02
5	1.6197E-06	1.6883E-06	2.0000E-02	5.0000E-02
6	1.7503E-06	1.8714E-06	5.0000E-02	1.0000E-01
7	1.9813E-06	2.1565E-06	1.0000E-01	2.0000E-01
8	2.3199E-06	2.4586E-06	1.0000E-01	3.0000E-01
9	2.5883E-06	2.7465E-06	1.0000E-01	4.0000E-01
10	2.9013E-06	3.0607E-06	1.0000E-01	5.0000E-01
11	3.2273E-06	3.4143E-06	1.0000E-01	6.0000E-01
12	3.6172E-06	3.8698E-06	1.0000E-01	7.0000E-01
13	4.1608E-06	4.5174E-06	1.0000E-01	8.0000E-01
14	4.9333E-06	5.5954E-06	1.0000E-01	9.0000E-01
15	6.4895E-06	7.3487E-06	5.0000E-02	9.5000E-01
16	8.7040E-06	9.8300E-06	2.0000E-02	9.7000E-01
17	1.1150E-05	1.2223E-05	1.0000E-02	9.8000E-01
18	1.3786E-05	1.7209E-05	1.0000E-02	9.9000E-01
19	2.1314E-05	2.3706E-05	5.0000E-03	9.9500E-01
20	2.7797E-05	5.5878E-05	5.0000E-03	1.0000E+00
21	4.4100E-04			

Table 3.6C Monte Carlo Sampling Results for the CONFIG#1 (Sequence Group FLOODS)

Distribution: FLOODS 10000 Samples, Using Seeds: 8314 17851

Sequence Quantified: 124

MEAN	VARIANCE	5th %TILE	50th %TILE	95th %TILE
1.3227E-06	6.5392E-13	6.2256E-07	1.0475E-06	2.5769E-06

BIN	BOUNDARY	VALUE	DISCRETE	CUMULATIVE
1	3.1563E-07	4.5064E-07	5.0000E-03	5.0000E-03
2	4.8952E-07	5.0793E-07	5.0000E-03	1.0000E-02
3	5.2039E-07	5.4064E-07	1.0000E-02	2.0000E-02
4	5.5944E-07	5.7331E-07	1.0000E-02	3.0000E-02
5	5.8474E-07	6.0570E-07	2.0000E-02	5.0000E-02
6	6.2256E-07	6.5943E-07	5.0000E-02	1.0000E-01
7	6.9020E-07	7.4178E-07	1.0000E-01	2.0000E-01
8	7.8854E-07	8.3223E-07	1.0000E-01	3.0000E-01
9	8.7472E-07	9.1663E-07	1.0000E-01	4.0000E-01
10	9.5790E-07	1.0015E-06	1.0000E-01	5.0000E-01
11	1.0475E-06	1.0989E-06	1.0000E-01	6.0000E-01
12	1.1538E-06	1.2168E-06	1.0000E-01	7.0000E-01
13	1.2859E-06	1.3789E-06	1.0000E-01	8.0000E-01
14	1.4900E-06	1.6686E-06	1.0000E-01	9.0000E-01
15	1.9212E-06	2.1991E-06	5.0000E-02	9.5000E-01
16	2.5769E-06	2.8669E-06	2.0000E-02	9.7000E-01
17	3.2505E-06	3.5838E-06	1.0000E-02	9.8000E-01
18	3.9181E-06	4.8492E-06	1.0000E-02	9.9000E-01
19	6.7286E-06	8.2246E-06	5.0000E-03	9.9500E-01
20	1.0677E-05	1.6686E-05	5.0000E-03	1.0000E+00
21	4.4247E-05			

Table 3.7A Monte Carlo Sampling Results for the CONFIG#2 (Sequence Group ALL)

Distribution: ALL 10000 Samples, Using Seeds: 8314 17851

Sequence Quantified: 433

MEAN	VARIANCE	5th %TILE	50th %TILE	95th %TILE
6.1236E-06	1.5562E-11	2.8963E-06	4.8196E-06	0.00001202

BIN	BOUNDARY	VALUE	DISCRETE	CUMULATIVE
1	1.6761E-06	2.1403E-06	5.0000E-03	5.0000E-03
2	2.2878E-06	2.3556E-06	5.0000E-03	1.0000E-02
3	2.4204E-06	2.5087E-06	1.0000E-02	2.0000E-02
4	2.5843E-06	2.6539E-06	1.0000E-02	3.0000E-02
5	2.7244E-06	2.8095E-06	2.0000E-02	5.0000E-02
6	2.8963E-06	3.0718E-06	5.0000E-02	1.0000E-01
7	3.2134E-06	3.4451E-06	1.0000E-01	2.0000E-01
8	3.6463E-06	3.8285E-06	1.0000E-01	3.0000E-01
9	4.0241E-06	4.2226E-06	1.0000E-01	4.0000E-01
10	4.4159E-06	4.6148E-06	1.0000E-01	5.0000E-01
11	4.8196E-06	5.0667E-06	1.0000E-01	6.0000E-01
12	5.3256E-06	5.6243E-06	1.0000E-01	7.0000E-01
13	5.9585E-06	6.4174E-06	1.0000E-01	8.0000E-01
14	6.9417E-06	7.7876E-06	1.0000E-01	9.0000E-01
15	8.9533E-06	1.0234E-05	5.0000E-02	9.5000E-01
16	1.2020E-05	1.3636E-05	2.0000E-02	9.7000E-01
17	1.6023E-05	1.7738E-05	1.0000E-02	9.8000E-01
18	2.0543E-05	2.5084E-05	1.0000E-02	9.9000E-01
19	3.1829E-05	3.8688E-05	5.0000E-03	9.9500E-01
20	4.6405E-05	6.6594E-05	5.0000E-03	1.0000E+00
21	1.1716E-04			

Table 3.7B Monte Carlo Sampling Results for the CONFIG#2 (Sequence Group CDIPEV)

Distribution: CDIPEV 10000 Samples, Using Seeds: 8314 17851

Sequence Quantified: 295

MEAN	VARIANCE	5th %TILE	50th %TILE	95th %TILE
4.6631E-06	9.1553E-12	1.9265E-06	3.5846E-06	9.4815E-06

BIN	BOUNDARY	VALUE	DISCRETE	CUMULATIVE
1	9.8689E-07	1.3184E-06	5.0000E-03	5.0000E-03
2	1.4553E-06	1.5050E-06	5.0000E-03	1.0000E-02
3	1.5476E-06	1.6167E-06	1.0000E-02	2.0000E-02
4	1.6804E-06	1.7390E-06	1.0000E-02	3.0000E-02
5	1.7892E-06	1.8615E-06	2.0000E-02	5.0000E-02
6	1.9265E-06	2.0613E-06	5.0000E-02	1.0000E-01
7	2.1790E-06	2.3693E-06	1.0000E-01	2.0000E-01
8	2.5479E-06	2.7170E-06	1.0000E-01	3.0000E-01
9	2.8849E-06	3.0595E-06	1.0000E-01	4.0000E-01
10	3.2279E-06	3.4039E-06	1.0000E-01	5.0000E-01
11	3.5846E-06	3.7975E-06	1.0000E-01	6.0000E-01
12	4.0268E-06	4.2854E-06	1.0000E-01	7.0000E-01
13	4.5810E-06	4.9774E-06	1.0000E-01	8.0000E-01
14	5.4303E-06	6.1607E-06	1.0000E-01	9.0000E-01
15	7.1467E-06	8.1491E-06	5.0000E-02	9.5000E-01
16	9.4815E-06	1.0651E-05	2.0000E-02	9.7000E-01
17	1.2303E-05	1.3720E-05	1.0000E-02	9.8000E-01
18	1.5298E-05	1.8473E-05	1.0000E-02	9.9000E-01
19	2.3554E-05	2.7813E-05	5.0000E-03	9.9500E-01
20	3.2810E-05	6.3309E-05	5.0000E-03	1.0000E+00
21	3.1614E-04			

Table 3.7C Monte Carlo Sampling Results for the CONFIG#2 (Sequence Group FLOODS)

Distribution: FLOODS 10000 Samples, Using Seeds: 8314 17851

Sequence Quantified: 138

MEAN	VARIANCE	5th %TILE	50th %TILE	95th %TILE
1.4624E-06	8.0045E-13	6.9828E-07	1.1632E-06	2.7982E-06

BIN	BOUNDARY	VALUE	DISCRETE	CUMULATIVE
1	3.7976E-07	4.8475E-07	5.0000E-03	5.0000E-03
2	5.3439E-07	5.5720E-07	5.0000E-03	1.0000E-02
3	5.7962E-07	6.0132E-07	1.0000E-02	2.0000E-02
4	6.1991E-07	6.3654E-07	1.0000E-02	3.0000E-02
5	6.5300E-07	6.7692E-07	2.0000E-02	5.0000E-02
6	6.9828E-07	7.3300E-07	5.0000E-02	1.0000E-01
7	7.6377E-07	8.2314E-07	1.0000E-01	2.0000E-01
8	8.7788E-07	9.2440E-07	1.0000E-01	3.0000E-01
9	9.7020E-07	1.0175E-06	1.0000E-01	4.0000E-01
10	1.0665E-06	1.1147E-06	1.0000E-01	5.0000E-01
11	1.1632E-06	1.2202E-06	1.0000E-01	6.0000E-01
12	1.2837E-06	1.3585E-06	1.0000E-01	7.0000E-01
13	1.4379E-06	1.5396E-06	1.0000E-01	8.0000E-01
14	1.6592E-06	1.8505E-06	1.0000E-01	9.0000E-01
15	2.1155E-06	2.3958E-06	5.0000E-02	9.5000E-01
16	2.7982E-06	3.0877E-06	2.0000E-02	9.7000E-01
17	3.4983E-06	3.8274E-06	1.0000E-02	9.8000E-01
18	4.3019E-06	5.4149E-06	1.0000E-02	9.9000E-01
19	7.4320E-06	9.2798E-06	5.0000E-03	9.9500E-01
20	1.1861E-05	1.7881E-05	5.0000E-03	1.0000E+00
21	4.4536E-05			

SECTION 4 CONCLUSIONS

4.1. Acceptability of Change

Based on an evaluation of the results provided in Section 3, the aggregate effect of the proposed change (i.e., use of COP to satisfy the net positive suction head (NPSH) requirements for RHR and Core Spray pumps) represents a slight change of the potential risk associated with plant operation.

- Regulatory Guide 1.174 provides guidance for determining the risk impact of plant-specific changes to the licensing basis. Regulatory Guide 1.174 defines very small changes in risk as resulting in increases of core damage frequency (CDF) below 10^{-6}/ry. Based on this criteria, the proposed change (i.e., use of COP to satisfy the net positive suction head (NPSH) requirements for RHR and Core Spray pumps) represents a very small change in CDF (approximately 5.78×10^{-7}/ry)
- Regulatory Guide 1.174 provides guidance for determining the risk impact of plant-specific changes to the licensing basis. Regulatory Guide 1.174 defines very small changes in risk as resulting in increases of Large Early Release Frequency (LERF) below 10^{-7}/yr. Based on this criteria, the proposed change (i.e., use of COP to satisfy the net positive suction head (NPSH) requirements for RHR and Core Spray pumps) represents a very small change in LERF (approximately 4.50×10^{-8}/ry)

Table 4.3A SPLIT FRACTION SEQUENCES – CONFIG#1 (BIN = IC)

Rank	Index	Initiator	Frequency	Failed and Multi-State Split Fractions
1	5	AMS	8.2573E-09	///SMBASE*TBFAIL*LIBASE
2	4	AFWMS	5.0983E-09	///SMBASE*TBFAIL*LIBASE
3	3	APCLP	1.3488E-09	/O1FAIL*O2FAIL*//SMBASE*TBFAIL*LIBASE

Table 4.3B SPLIT FRACTION SEQUENCES – CONFIG#1 (BIN = IIIC)

Rank	Index	Initiator	Frequency	Failed and Multi-State Split Fractions
1	3	IORV	4.40E-08	//PIBASE*/LPFAIL*CSFAIL*CNBASE
2	7	IORV	1.59E-08	//TWBASE*PIBASE*/LPFAIL*CSFAIL*CNFAIL
3	2	SORV	1.30E-08	//PIBASE*/LPFAIL*CSFAIL*CNBASE
4	12	IORV	7.17E-09	/O2O1S*/PIBASE*/LPFAIL*CSFAIL*CNFAIL
5	4	LLOCA	7.03E-09	//PIBASE*/LPFAIL*CSFAIL
6	4	SORV	4.69E-09	//TWBASE*PIBASE*/LPFAIL*CSFAIL*CNFAIL
7	4	IORV	3.18E-09	//PIBASE*/HPBASE*FWTBBS*LPFAIL*CSFAIL*CNFWF1
8	22	IORV	2.88E-09	/D1BASE*/OSFAIL*A3FAIL*TWFAIL*V1FAIL*PI1A*/HPFAIL*FWFAIL*LPFAIL*CSFAIL*CNFAIL
9	15	IORV	2.71E-09	/D2D1S*/OSFAIL*A4FAIL*TWFAIL*V2FAIL*PI1B*/LPFAIL*CSFAIL*CNFAIL
10	7	SORV	2.11E-09	/O2O1S*/PIBASE*/LPFAIL*CSFAIL*CNFAIL
11	19	IORV	1.35E-09	/O1BASE*O2O1F*/PIBASE*/LPFAIL*CSFAIL*CNFAIL
12	8	IORV	1.15E-09	//TWBASE*PIBASE*/HPBASE*FWFAIL*LPFAIL*CSFAIL*CNFAIL
13	5	R303F1	1.11E-09	//OSFAIL*RWFAIL*TWFAIL*/V1FAIL*PI1A*/TBFAIL*SCBASE*FWFAIL*HPFAIL*CAFAIL*CBFAIL*VAFAIL*VBFAIL*CNFAIL*TCAFL*AICDFL*AICTFL*AIFAIL

Table 4.4A SPLIT FRACTION SEQUENCES – CONFIG#2 (BIN = IC)

Rank	Index	Initiator	Frequency	Failed and Multi-State Split Fractions
1	5	AMS	8.2573E-09	///SMBASE*TBFAIL*LIBASE
2	4	AFWMS	5.0983E-09	///SMBASE*TBFAIL*LIBASE
3	3	APCLP	1.3488E-09	/O1FAIL*O2FAIL*//SMBASE*TBFAIL*LIBASE

Table 4.4B SPLIT FRACTION SEQUENCES – CONFIG#2 (BIN = IIIC)

Rank	Index	Initiator	Frequency	Failed and Multi-State Split Fractions
1	4	IORV	4.40E-08	//PIBASE*/LPFAIL*CSFAIL*CNBASE
2	2	RBTRF4	4.14E-08	////FWFAIL*RCFAIL*HPFAIL*IPBASE*CNFAIL*AICDFL*AICTFL*AIFAIL
3	4	RBR3F1	2.58E-08	//OSFAIL*SWFAIL*TWFAIL*//LAFAIL*TBFAIL*FWFAIL*RCFAIL*HPFAIL*IPBASE*CAFAIL*VAFAIL*CNFAIL*TCAFL*RMFAIL*AICDFL
4	3	LLOCA	2.05E-08	///IPBASL
5	9	IORV	1.59E-08	//TWBASE*PIBASE*/LPFAIL*CSFAIL*CNFAIL
6	3	SORV	1.30E-08	//PIBASE*/LPFAIL*CSFAIL*CNBASE
7	2	TBSWF	1.14E-08	//OSFAIL*TWFAIL*IGFAIL*//TBFAIL*FWFAIL*RCBASE*HPRCF1*IPIG*CNFAIL*RMFAIL
8	1	IORV	9.08E-09	///HPBASE*FWTBBS*IPBASE
9	2	TBCWF	8.90E-09	//TWFAIL*IGFAIL*//TBFAIL*FWFAIL*RCBASE*HPRCF1*IPIG*CNFAIL*RMFAIL
10	15	IORV	7.17E-09	/O2O1S*/PIBASE*/LPFAIL*CSFAIL*CNFAIL
11	5	LLOCA	7.03E-09	//PIBASE*/LPFAIL*CSFAIL
12	2	DGBF2	5.42E-09	/B3FAIL*O1FAIL*/OSFAIL*A3FAIL*TWFAIL*IGFAIL*//TBFAIL*FWFAIL*RCBASE*HPFAIL*IPIG*CNFAIL*RMFAIL
13	3	DGAF2	4.80E-09	/S2FAIL*B4FAIL*O2FAIL*/OSFAIL*A4FAIL*TWFAIL*IGFAIL*//TBFAIL*FWFAIL*RCFAIL*HPBASE*IPIG*CAFAIL*CNFAIL*TCAFL*RMFAIL
14	5	SORV	4.69E-09	//TWBASE*PIBASE*/LPFAIL*CSFAIL*CNFAIL
15	1	RTRFT2	4.57E-09	//OSFAIL*TWFAIL*//TBFAIL*FWFAIL*RCFAIL*HPFAIL*IPBASE*CNFAIL*RMFAIL
16	3	DGAF1	4.42E-09	/IAFAIL*S2FAIL*B4FAIL*O2FAIL*/OSFAIL*A4FAIL*TWFAIL*IGFAIL*//TBFAIL*FWFAIL*RCFAIL*HPBASE*IPIG*CAFAIL*CNFAIL*TCAFL*RMFAIL

Table 4.4B SPLIT FRACTION SEQUENCES – CONFIG#2 (BIN = IIIC) [continued]

Rank	Index	Initiator	Frequency	Failed and Multi-State Split Fractions
17	2	DGBF1	3.76E-09	//AFAIL*B3FAIL*O1FAIL*/OSFAIL*A3FAIL*TWFAIL*IGFAIL*//TBFAIL*FWFAIL*RCBASE*HPFAIL*IPIG*CNFAIL*RMFAIL
18	7	IORV	3.27E-09	//TWBASE*/HPBASE*FWFAIL*IPBASE
19	5	IORV	3.18E-09	//PIBASE*/HPBASE*FWTBBS*LPFAIL*CSFAIL*CNFWF1
20	26	IORV	2.88E-09	/D1BASE*/OSFAIL*A3FAIL*TWFAIL*V1FAIL*PI1A*/HPFAIL*FWFAIL*LPFAIL*CSFAIL*CNFAIL
21	18	IORV	2.71E-09	/D2D1S*/OSFAIL*A4FAIL*TWFAIL*V2FAIL*PI1B*/LPFAIL*CSFAIL*CNFAIL
22	1	SORV	2.68E-09	///HPBASE*FWTBBS*IPBASE
23	8	SORV	2.11E-09	/O2O1S*/PIBASE*/LPFAIL*CSFAIL*CNFAIL
24	1	WMACHF	2.07E-09	//IGFAIL*//TBFAIL*FWFAIL*RCBASE*HPRCF1*IPIG*CNFAIL*RMFAIL
25	1	INTSWF	1.85E-09	//OSFAIL*SWFAIL*TWFAIL*//TBFAIL*FWFAIL*RCBASE*HPRCF1*IPBASE*CNFAIL*RMFAIL*AICDFL
26	2	CSTF	1.62E-09	////TBFAIL*FWFAIL*RCBASE*HPRCF1*IPBASE*CNFAIL*RMFAIL*AICDFL*AICTFL*AIFAIL
27	1	AOGCNF	1.61E-09	////TBFAIL*FWFAIL*RCBASE*HPRCF1*IPBASE*CNFAIL*RMFAIL
28	13	IORV	1.47E-09	/O2O1S*//HPBASE*FWFAIL*IPBASE
29	19	IORV	1.47E-09	/O1BASE*//HPBASE*FWFAIL*IPBASE
30	23	IORV	1.35E-09	/O1BASE*O2O1F*/PIBASE*/LPFAIL*CSFAIL*CNFAIL
31	10	IORV	1.15E-09	//TWBASE*PIBASE*/HPBASE*FWFAIL*LPFAIL*CSFAIL*CNFAIL
32	5	R303F1	1.11E-09	//OSFAIL*RWFAIL*TWFAIL*//V1FAIL*PI1A*/TBFAIL*SCBASE*FWFAIL*HPFAIL*CAFAIL*CBFAIL*VAFAIL*VBFAIL*CNFAIL*TCAFL*AICDFL*AICTFL*AIFAIL
33	4	TBSWF	1.10E-09	//OSFAIL*TWFAIL*IGFAIL*//TBFAIL*SCBASE*FWFAIL*HPBASE*IPIG*CNFAIL*RMFAIL

SECTION 5 REFERENCES

(1) U.S. Nuclear Regulatory Commission, "An Approach for Using Probabilistic Risk Assessment In Risk-Informed Decisions On Plant-Specific Changes to the Licensing Basis", Regulatory Guide 1.174, November 2002, Revision 1.

(2) Vermont Yankee Report VY-RPT-04-00004, Rev.1, "Vermont Yankee PSA Model Update", September 2004.

(3) Vermont Yankee Nuclear Power Station, Vermont Yankee Individual Plant Examination (IPE) Submittal, December 1993.

(4) Vermont Yankee PRA Peer Review Certification Report, GE Document BWROG/PRA-2000-03, November 2000.

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(6) Electric Power Research Institute, "Risk Impact Assessment of Extended integrated Leak Rate Testing Intervals", EPRI TR-1009325, December 2003.

(7) Generic Letter 88-20, "Individual Plant Examination for Severe Accident Vulnerabilities-10CFR50.54 (f)" dated November 23, 1988; and Supplement 1, dated August 29, 1989.

(8) USNRC NUREG-1335, "Individual Plant Examination: Submittal Guidance," U.S. Nuclear Regulatory Commission, August 1989.

(9) Entergy Nuclear Northeast Procedure ENN-DC-151, Rev.0, "PSA Maintenance and Update Procedure", July 2003

(10) Memo, Vincent Andersen (ERIN) to Mark Palionis (ENNE), "EPU COP Uncertainty Discussion Template", C166030001-6716, dated October 13, 2005.

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(14) USNRC NUREG/CR-4550, Vol.1, "Analysis of Core Damage Frequency: Internal Events Methodology", dated January 1990.

(15) USNRC NUREG 1407, "Procedural and Submittal Guidance for the Individual Plant Examination of External Events (IPEEE) for Severe Accident Vulnerabilities," June 1991.

(16) Electric Power Research Institute, "A Methodology for Assessment of Nuclear Power Plant Seismic Margin", EPRI-NP 6041 SL, Revision 1, August 1991.

(17) USNRC NUREG-1150, "Severe Accident Risks: An Assessment for Five U.S. Nuclear Power Plants.", December 1991.

(18) USNRC NUREG/CR-4448, "Shutdown Decay Heat Removal Analysis of a General Electric BWR3/ Mark I," Sandia National Laboratory, March 1987.

Attachment A

Top Event (VT)

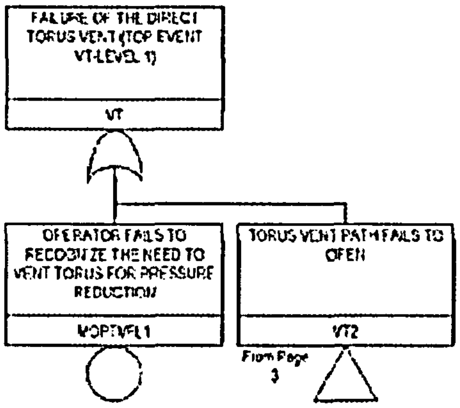

Figure A.1-A Fault Tree (VT)

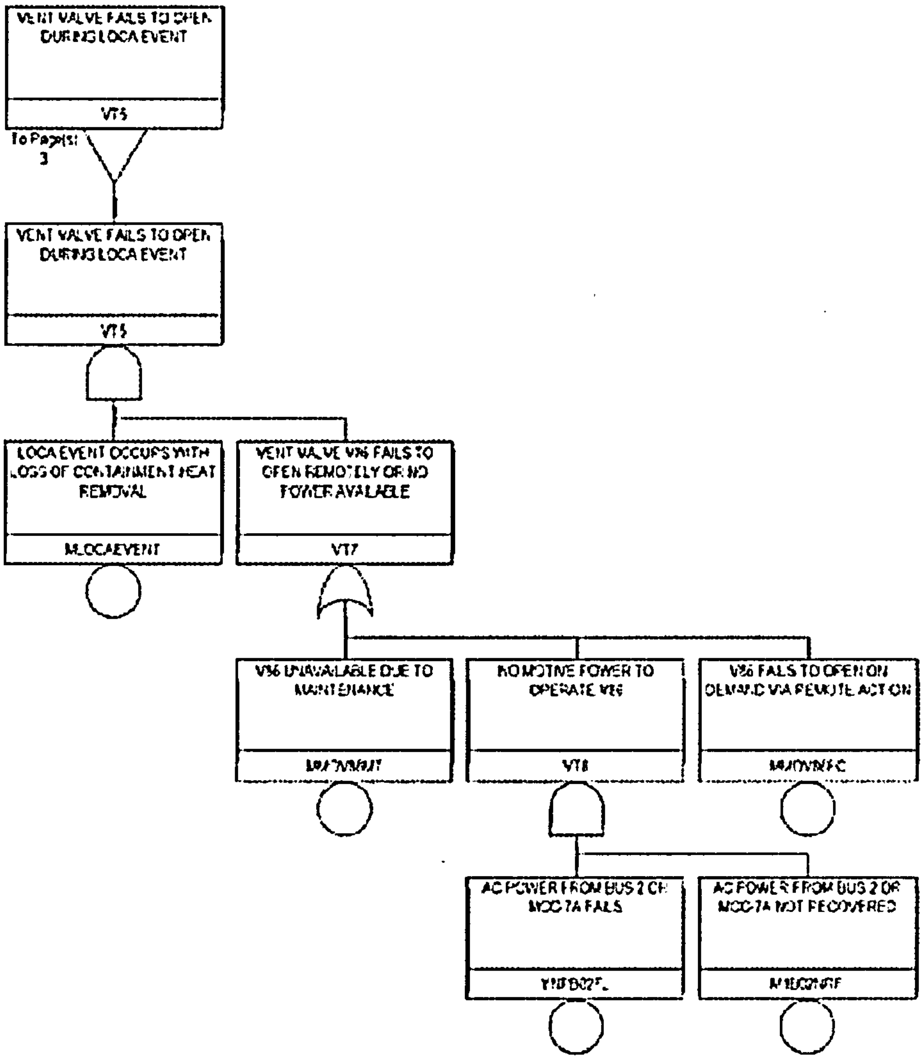

Figure A.1-B Fault Tree (VT)

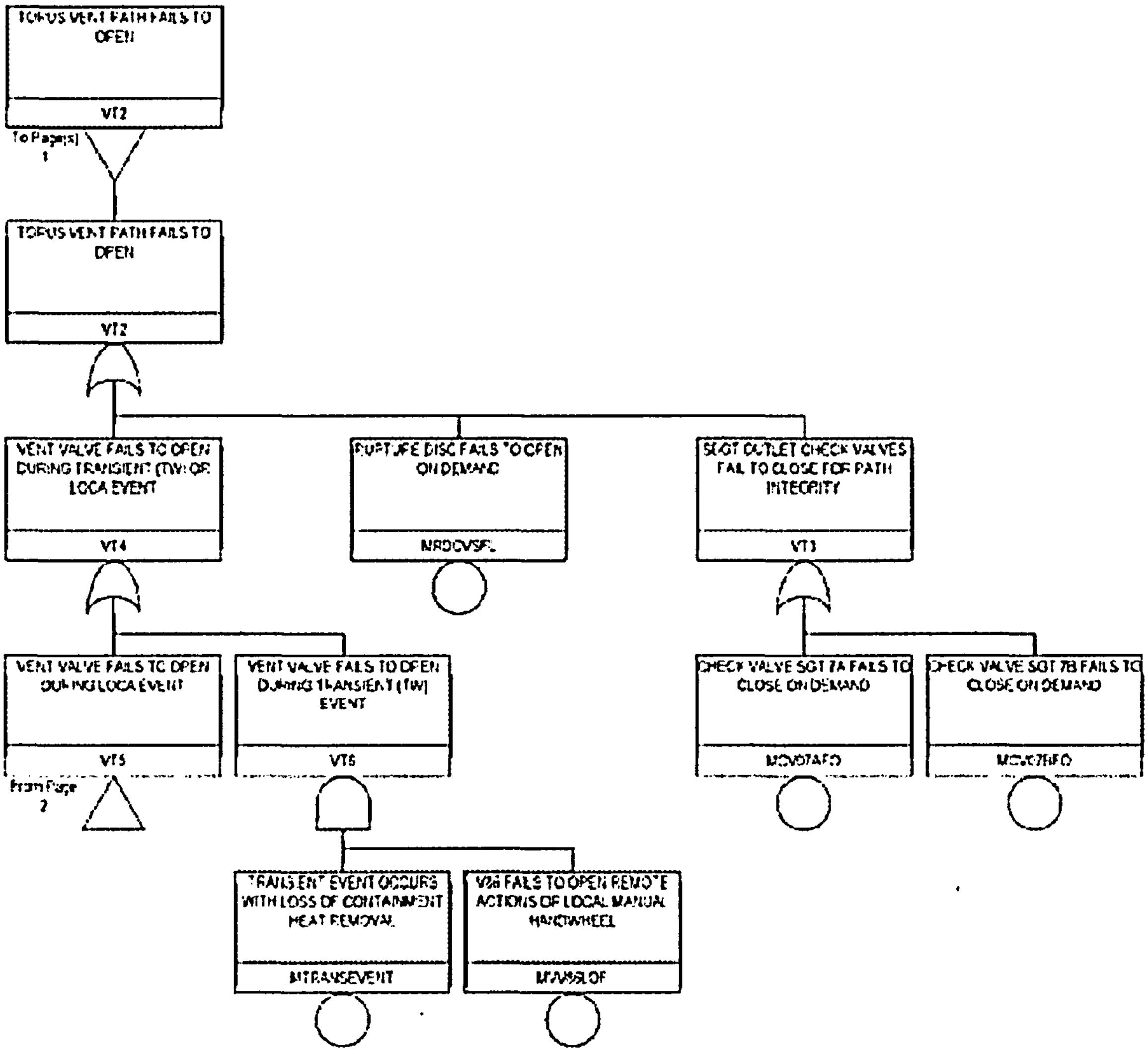

Figure A.1-C Fault Tree (VT)

Table A-1 Basic Events for Top Event (VT)

Basic Event Name	Basic Event Value	Basic Event Description
M1B02NRF	5.0000 E-01	AC POWER FROM BUS 2 OR MCC-7A NOT RECOVERED
MCV07AFO	8.3500 E-04	CHECK VALVE SGT.7A FAILS TO CLOSE ON DEMAND
MCV07BFO	8.3500 E-04	CHECK VALVE SGT.7B FAILS TO CLOSE ON DEMAND
MMOV86FC	4.3000 E-03	V86 FAILS TO OPEN ON DEMAND VIA REMOTE ACTION
MMOV86MT	4.6000 E-04	V86 UNAVAILABLE DUE TO MAINTENANCE
MOPTVFL1	1.3000 E-03	OPERATOR FAILS TO RECOGNIZE THE NEED TO VENT TORUS FOR PRESSURE
MRDCVSFL	1.0000 E-04	RUPTURE DISC FAILS TO OPEN ON DEMAND
MVV86LOF	1.0000 E-04	V86 FAILS TO OPEN REMOTE ACTIONS OR LOCAL MANUAL HANDWHEEL

Split Fraction: VTFAIL

SF Name	SF Value	Split Fraction Description
VTFAIL	1.0000E+00	TORUS VENT GUARANTEED FAILURE

Split Fraction IPFAIL Boundary Conditions

None.

Split Fraction: VTLCBS

SF Name	SF Value	Split Fraction Description
VTLCBS	7.8300E-03	TORUS VENT FAILS DURING LOCA EVENT WITH LOSS OF HEAT REMOVAL. V86 OPERATED REMOTELY, BUS2/MCC-7A ARE AVAILABLE.

Split Fraction VTLCBS Boundary Conditions

Basic Event	State	Basic Event Description
MLOCAEVENT	S	LOCA EVENT OCCURS WITH LOSS OF CONTAINMENT HEAT REMOVAL
MTRANSEVENT	F	TRANSIENT EVENT OCCURS WITH LOSS OF CONTAINMENT HEAT REMOVAL

Split Fraction: VTLCO2

SF Name	SF Value	Split Fraction Description
VTLCO2	5.0783E-01	TORUS VENT FAILS DURING LOCA EVENT. V86 OPERATED REMOTELY, FAILURE TO RECOVER BUS 2/MCC-7A

Split Fraction VTLCO2 Boundary Conditions

Basic Event	State	Basic Event Description
MLOCAEVENT	F	LOCA EVENT OCCURS WITH LOSS OF CONTAINMENT HEAT REMOVAL
MTRANSEVENT	S	TRANSIENT EVENT OCCURS WITH LOSS OF CONTAINMENT HEAT REMOVAL
YNPB02FL	F	AC POWER FROM BUS 2 OR MCC-7A FAILS

Split Fraction: VTTRBS

SF Name	SF Value	Split Fraction Description
VTTRBS	3.1700E-03	TORUS VENT FAILS DURING TRANSIENT (TW) EVENT. V86 OPERATED LOCALLY, BUS 2 POWER NOT REQUIRED.

Split Fraction VTTRBS Boundary Conditions

Basic Event	State	Basic Event Description
MLOCAEVENT	F	LOCA EVENT OCCURS WITH LOSS OF CONTAINMENT HEAT REMOVAL
MTRANSEVENT	S	TRANSIENT EVENT OCCURS WITH LOSS OF CONTAINMENT HEAT REMOVAL
YNPB02FL	S	AC POWER FROM BUS 2 OR MCC-7A FAILS

Attachment B

Top Event (IP)

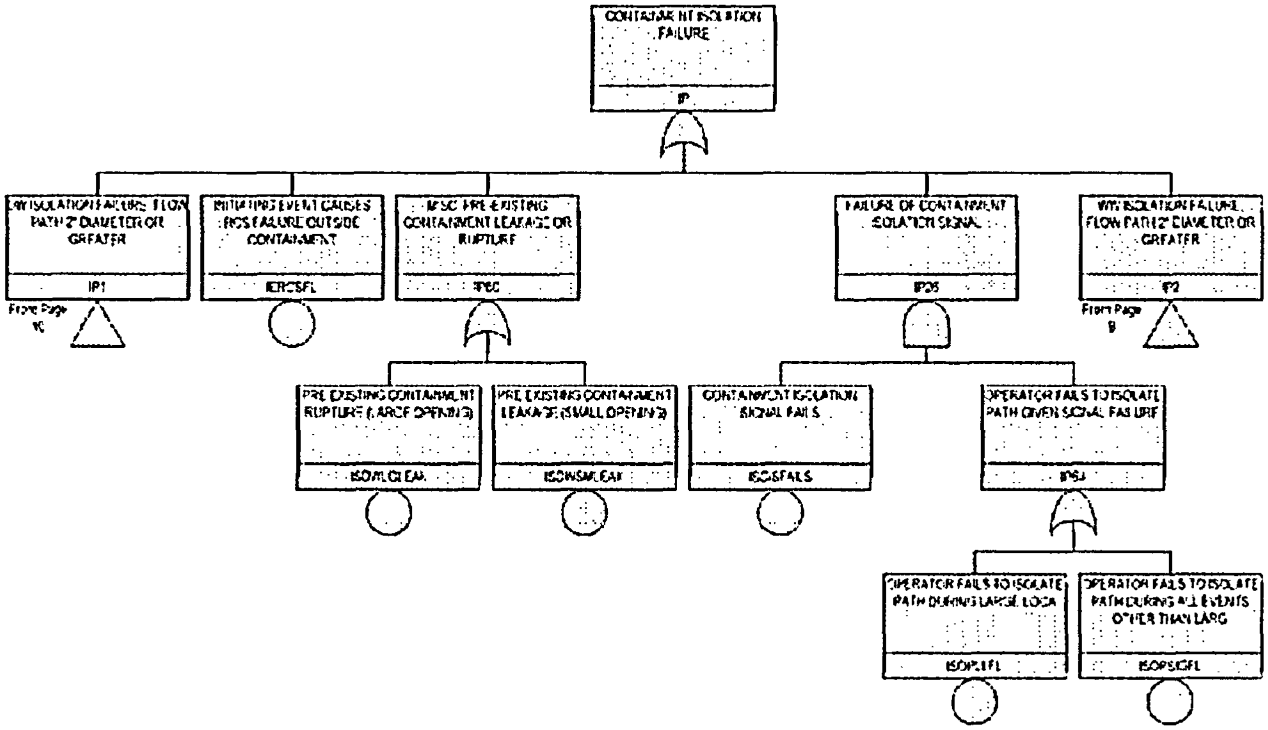

Figure B.1 - A Fault Tree (IP)

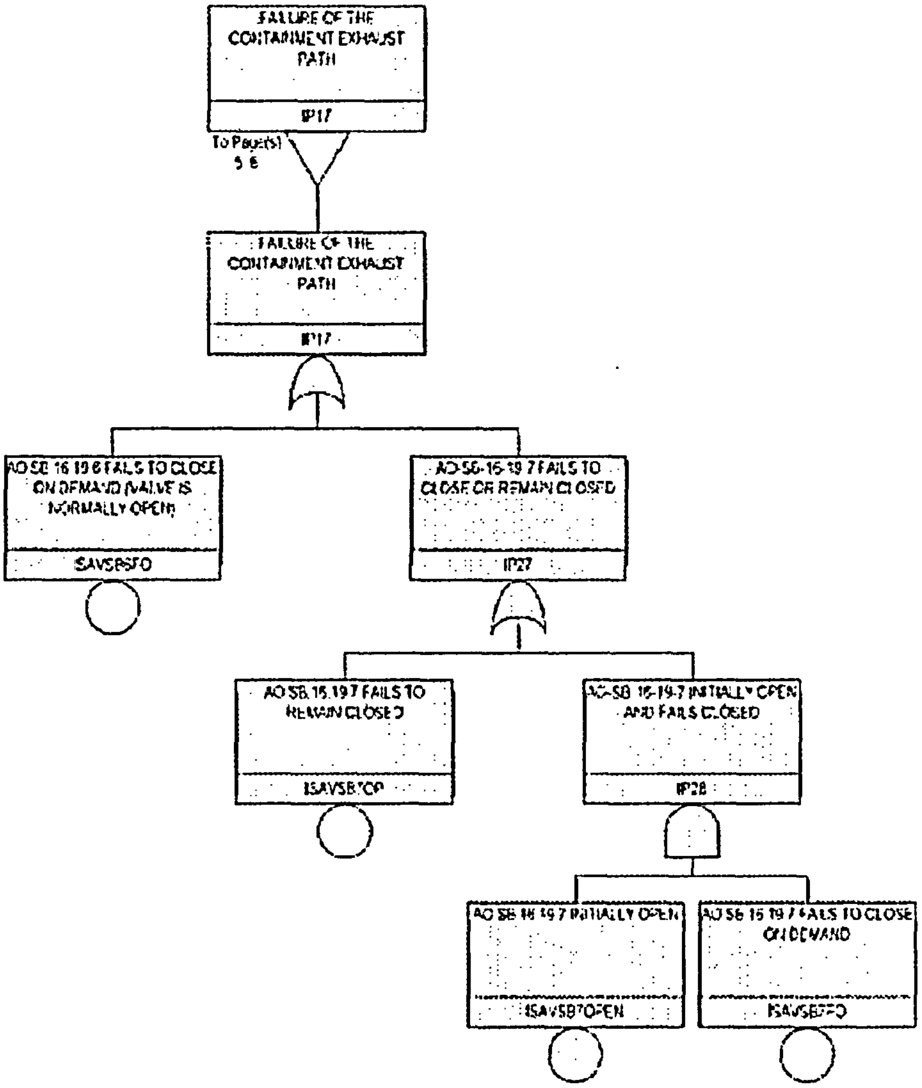

Figure B.1 - B Fault Tree (IP)

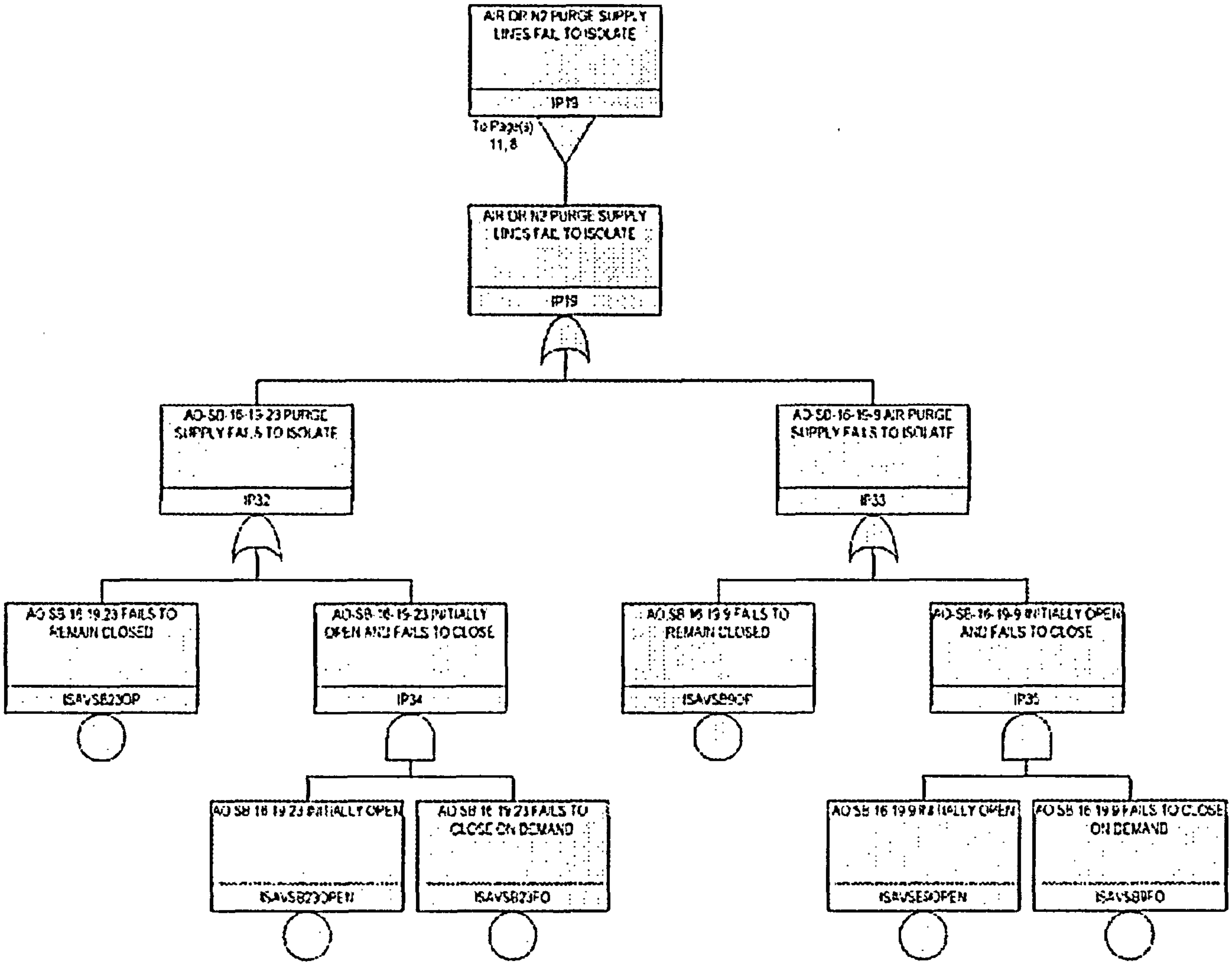

Figure B.1 - C Fault Tree (IP)

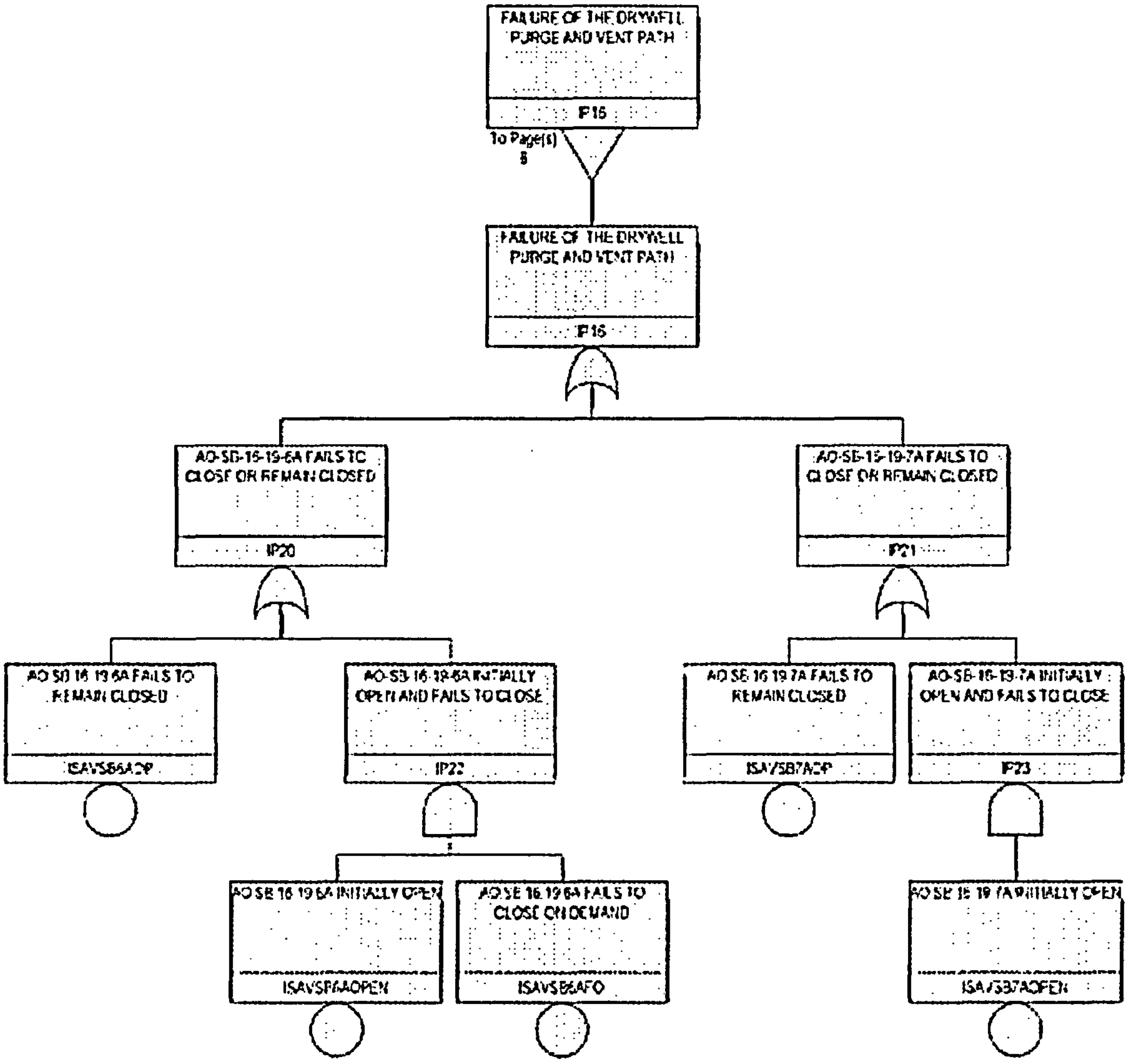

Figure B.1 - D Fault Tree (IP)

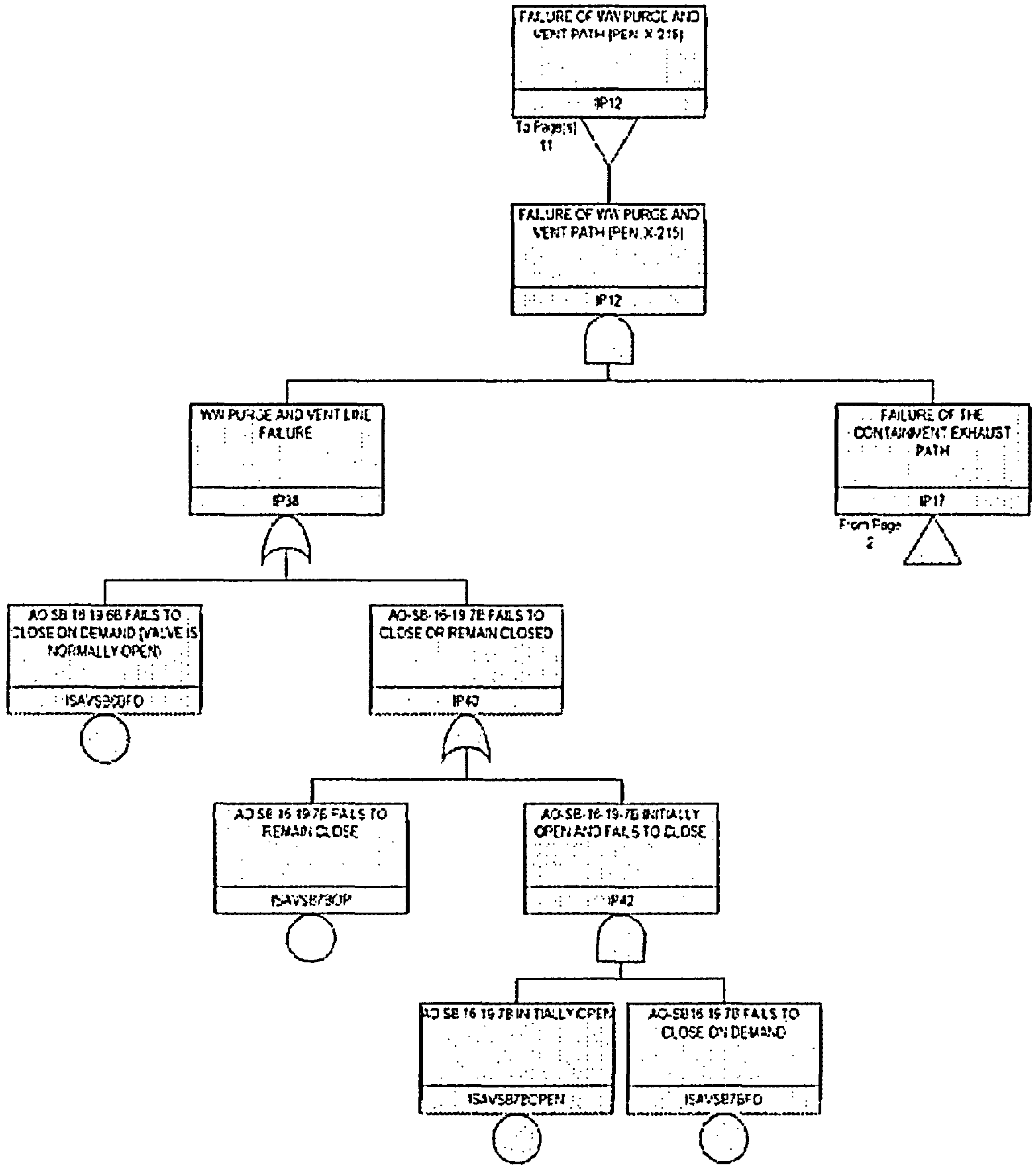

Figure B.1 - E Fault Tree (IP)

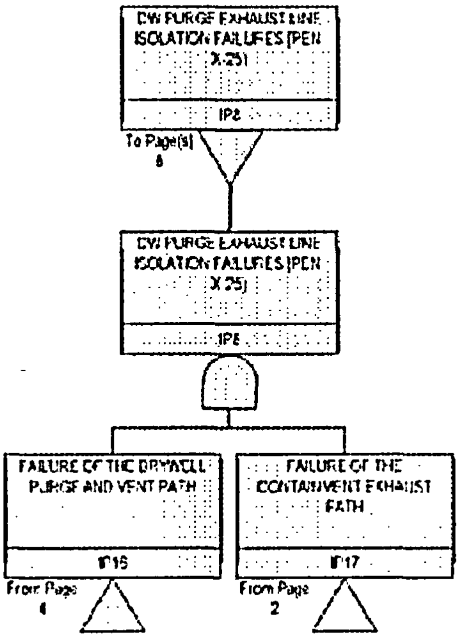

Figure B.1 - F Fault Tree (IP)

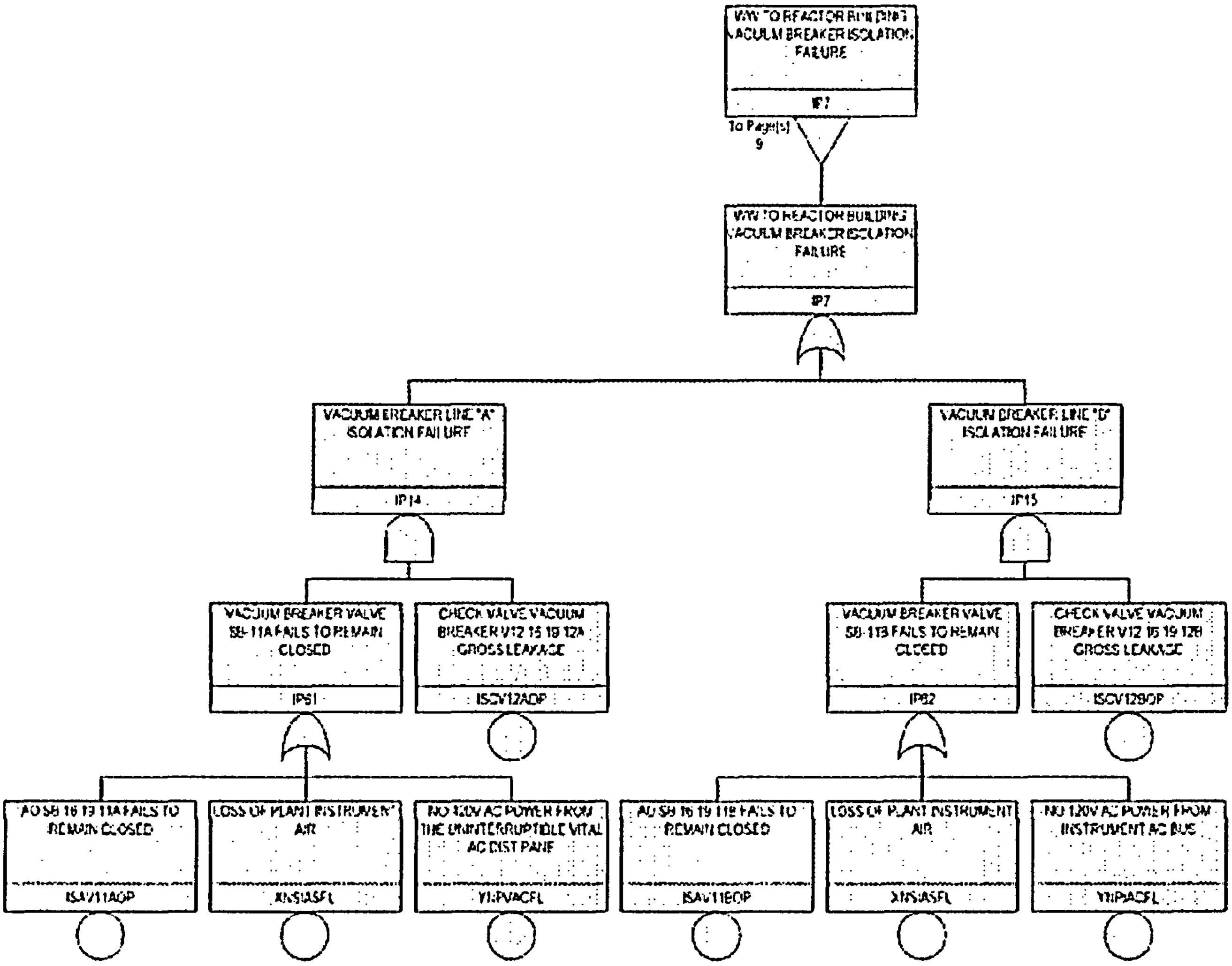

Figure B.1 - G Fault Tree (IP)

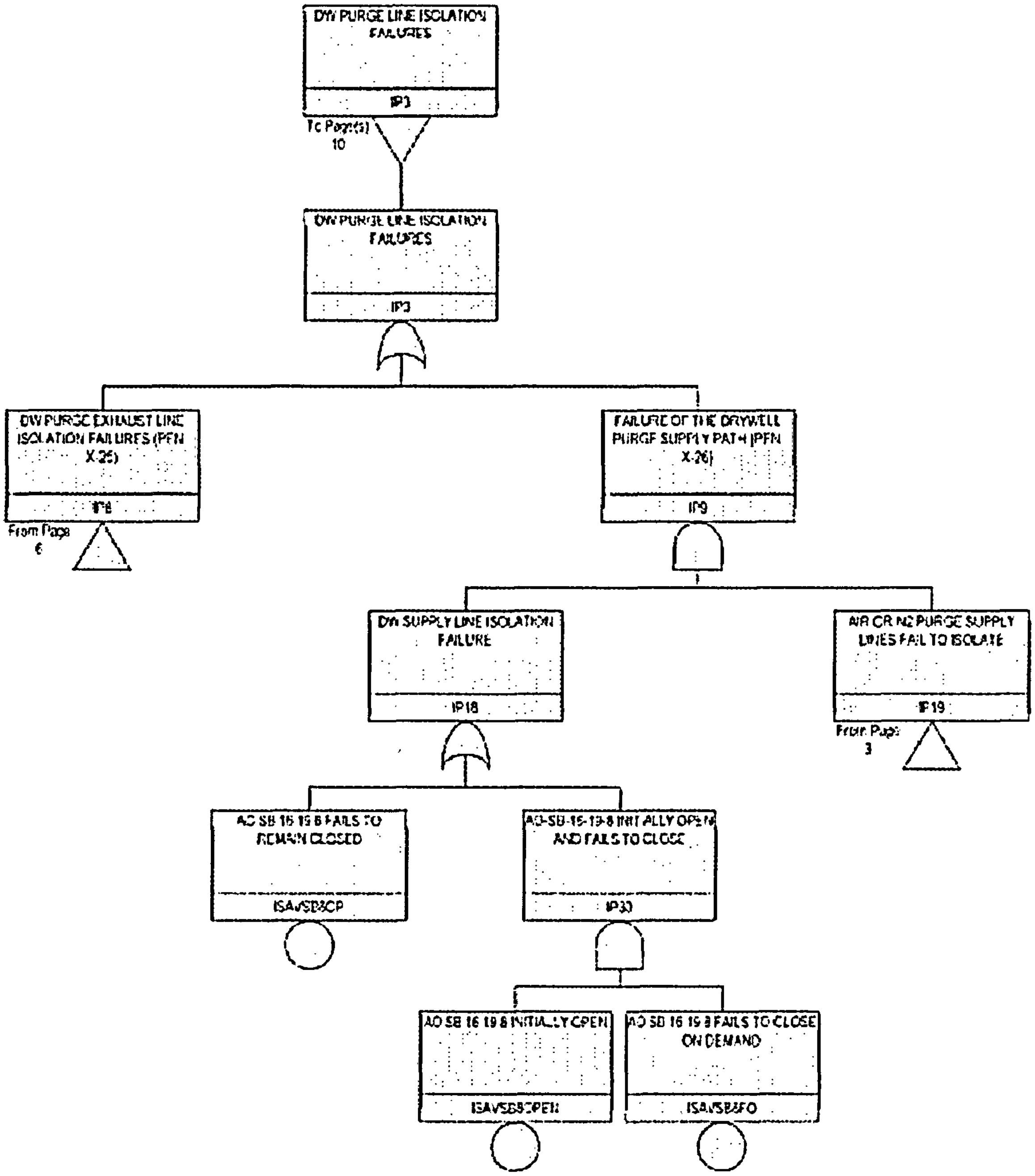

Figure B.1 - H Fault Tree (IP)

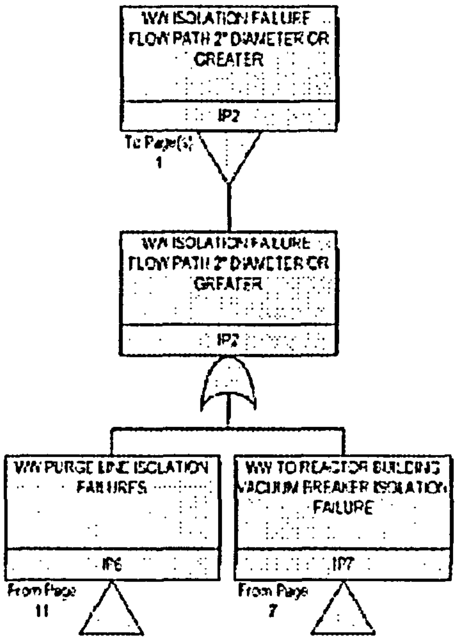

Figure B.1 - I Fault Tree (IP)

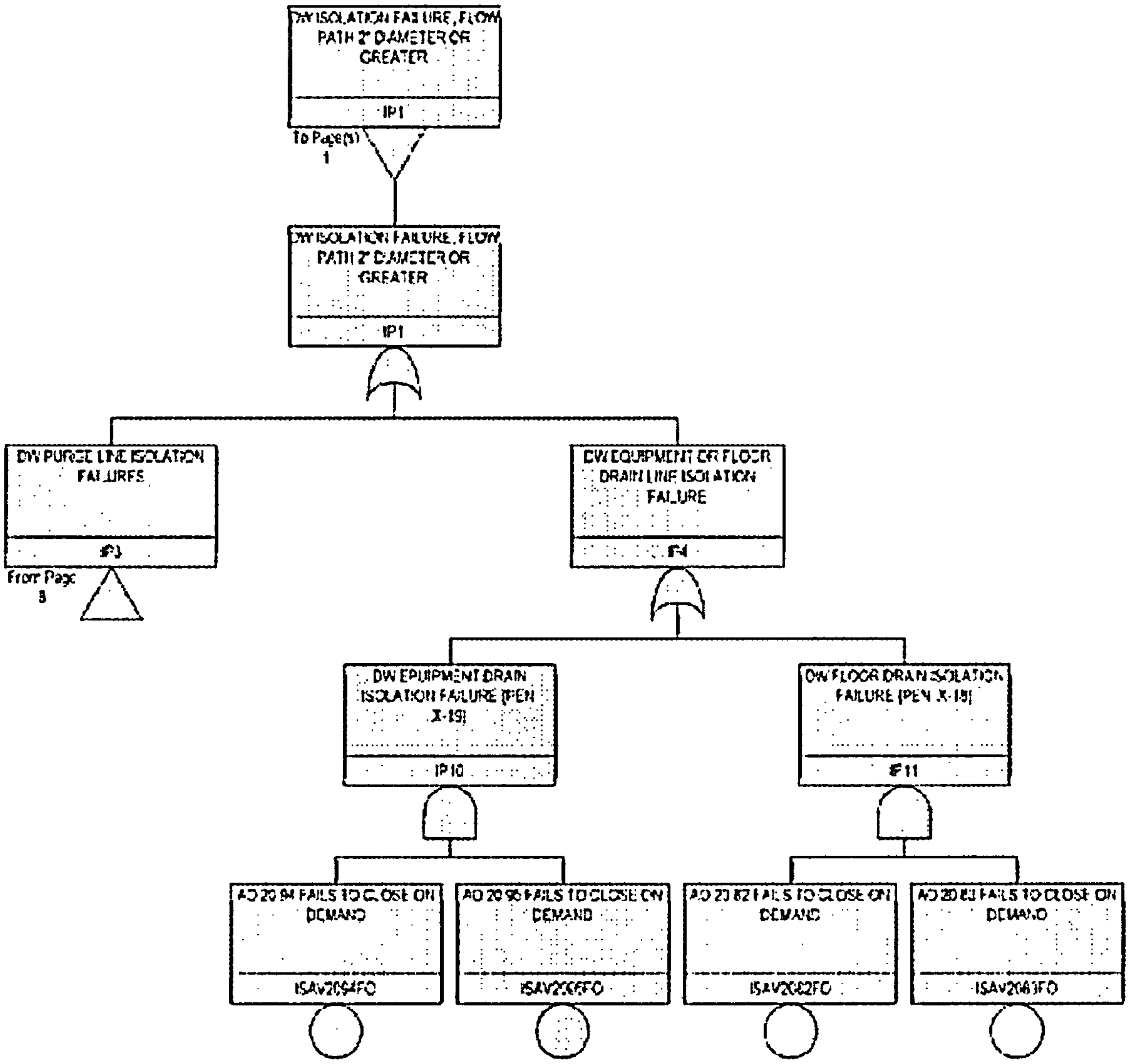

Figure B.1 - J Fault Tree (IP)

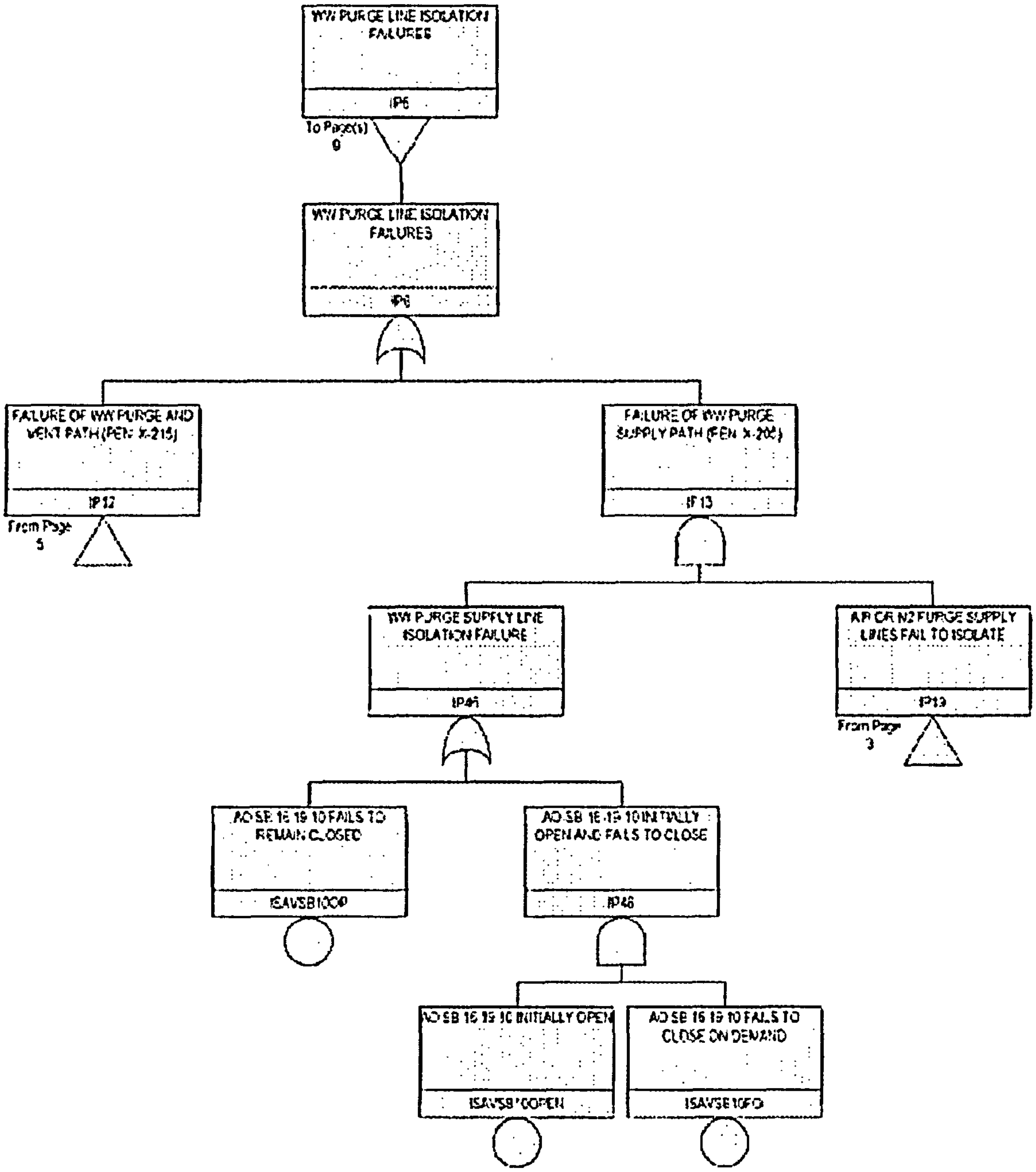

Figure B.1 - K Fault Tree (IP)

Table B-1 Basic Events for Top Event (IP)

Basic Event Name	Basic Event Value	Basic Event Description
ISAV11AOP	3.0492 E-05	AO.SB.16.19.11A FAILS TO REMAIN CLOSED
ISAV11BOP	3.0492 E-05	AO.SB.16.19.11B FAILS TO REMAIN CLOSED
ISAV2082FO	1.4150 E-03	AO.20.82 FAILS TO CLOSE ON DEMAND
ISAV2083FO	1.4150 E-03	AO.20.83 FAILS TO CLOSE ON DEMAND
ISAV2094FO	1.4150 E-03	AO.20.94 FAILS TO CLOSE ON DEMAND
ISAV2095FO	1.4150 E-03	AO.20.95 FAILS TO CLOSE ON DEMAND
ISAVSB10FO	1.5215 E-03	AO.SB.16.19.10 FAILS TO CLOSE ON DEMAND
ISAVSB10OP	3.0492 E-05	AO.SB.16.19.10 FAILS TO REMAIN CLOSED
ISAVSB10OPEN	2.0000 E-02	AO.SB.16.19.10 INITIALLY OPEN
ISAVSB23FO	1.5215 E-03	AO.SB.16.19.23 FAILS TO CLOSE ON DEMAND
ISAVSB23OP	3.0492 E-05	AO.SB.16.19.23 FAILS TO REMAIN CLOSED
ISAVSB23OPEN	2.0000 E-02	AO.SB.16.19.23 INITIALLY OPEN
ISAVSB6AFO	1.5215 E-03	AO.SB.16.19.6A FAILS TO CLOSE ON DEMAND
ISAVSB6AOP	3.0492 E-05	AO.SB.16.19.6A FAILS TO REMAIN CLOSED
ISAVSB6AOPEN	2.0000 E-02	AO.SB.16.19.6A INITIALLY OPEN
ISAVSB6BFO	1.4150 E-03	AO.SB.16.19.6B FAILS TO CLOSE ON DEMAND (VALVE IS NORMALLY OPEN)
ISAVSB6FO	1.4150 E-03	AO.SB.16.19.6 FAILS TO CLOSE ON DEMAND (VALVE IS NORMALLY OPEN)
ISAVSB7AFO	1.5215 E-03	AO.SB.16.19.7A FAILS TO CLOSE ON DEMAND
ISAVSB7AOP	3.0492 E-05	AO.SB.16.19.7A FAILS TO REMAIN CLOSED
ISAVSB7AOPEN	2.0000 E-02	AO.SB.16.19.7A INITIALLY OPEN
ISAVSB7BFO	1.5215 E-03	AO-SB16.19.7B FAILS TO CLOSE ON DEMAND
ISAVSB7BOP	3.0492 E-05	AO.SB.16.19.7B FAILS TO REMAIN CLOSE
ISAVSB7BOPEN	2.0000 E-02	AO.SB.16.19.7B INITIALLY OPEN
ISAVSB7FO	1.5215 E-03	AO.SB.16.19.7 FAILS TO CLOSE ON DEMAND
ISAVSB7OP	3.0492 E-05	AO.SB.16.19.7 FAILS TO REMAIN CLOSED
ISAVSB7OPEN	2.0000 E-02	AO.SB.16.19.7 INITIALLY OPEN
ISAVSB8FO	1.5215 E-03	AO.SB.16.19.8 FAILS TO CLOSE ON DEMAND
ISAVSB8OP	3.0492 E-05	AO.SB.16.19.8 FAILS TO REMAIN CLOSED
ISAVSB8OPEN	2.0000 E-02	AO.SB.16.19.8 INITIALLY OPEN
ISAVSB9FO	1.5215 E-03	AO.SB.16.19.9 FAILS TO CLOSE ON DEMAND
ISAVSB9OP	3.0492 E-05	AO.SB.16.19.9 FAILS TO REMAIN CLOSED
ISAVSB9OPEN	2.0000 E-02	AO.SB.16.19.9 INITIALLY OPEN
ISCISFAILS	1.0000 E-04	CONTAINMENT ISOLATION SIGNAL FAILS
ISCV12AOP	1.2000 E-04	CHECK VALVE VACUUM BREAKER V12.16.19.12A GROSS LEAKAGE
ISCV12BOP	1.2000 E-04	CHECK VALVE VACUUM BREAKER V12.16.19.12B GROSS LEAKAGE
ISDWLGLEAK	2.4700 E-04	PRE.EXISTING CONTAINMENT RUPTURE (LARGE OPENING)
ISDWSMLEAK	2.4700 E-04	PRE.EXISTING CONTAINMENT LEAKAGE (SMALL OPENING)
ISOPLLFL	3.4000 E-01	OPERATOR FAILS TO ISOLATE PATH DURING LARGE LOCA
ISOPSIGFL	3.2000 E-02	OPERATOR FAILS TO ISOLATE PATH DURING ALL EVENTS OTHER THAN LOCA_LG

Split Fraction: IPBASE

SF Name	SF Value	Split Fraction Description
IPBASE	8.5244E-04	CONT. ISOL. FAILS -- ALL SUPPORT SYS AVAIL

Split Fraction IPBASE Boundary Conditions

Basic Event	State	Basic Event Description
IERCSFL	S	INITIATING EVENT CAUSES RCS FAILURE OUTSIDE CONTAINMENT
ISOPLLFL	S	OPERATOR FAILS TO ISOLATE PATH DURING LARGE LOCA
XNSIASFL	S	LOSS OF PLANT INSTRUMENT AIR
YNPIACFL	S	NO 125V AC POWER FROM INSTRUMENT AC BUS
YNPVACFL	S	NO 120V AC POWER FROM THE UNINTERRUPTIBLE VITAL AC DIST PANE

Split Fraction: IPBASL

SF Name	SF Value	Split Fraction Description
IPBASL	8.8324E-04	CNT ISOL FAILS (LLOCA) – ALL SUPPORT SYS AVAIL

Split Fraction IPBASL Boundary Conditions

Basic Event	State	Basic Event Description
IERCSFL	S	INITIATING EVENT CAUSES RCS FAILURE OUTSIDE CONTAINMENT
ISOPSIGFL	S	OPERATOR FAILS TO ISOLATE PATH DURING ALL EVENTS OTHER THAN LARG
XNSIASFL	S	LOSS OF PLANT INSTRUMENT AIR
YNPIACFL	S	NO 125V AC POWER FROM INSTRUMENT AC BUS
YNPVACFL	S	NO 120V AC POWER FROM THE UNINTERRUPTIBLE VITAL AC DIST PANE

Split Fraction: IPFAIL

SF Name	SF Value	Split Fraction Description
IPFAIL	1.0000E+00	CONT. ISOL. GUARANTEED FAILURE

Split Fraction IPFAIL Boundary Conditions

None.

Split Fraction: IPGVIL

SF Name	SF Value	Split Fraction Description
IPGVIL	1.1232E-03	CNT ISOL FAILS (LLOCA) -- IG & VITAL/INSTR AC FAIL

Split Fraction IPGVIL Boundary Conditions

Basic Event	State	Basic Event Description
IERCSFL	S	INITIATING EVENT CAUSES RCS FAILURE OUTSIDE CONTAINMENT
ISOPSIGFL	S	OPERATOR FAILS TO ISOLATE PATH DURING ALL EVENTS OTHER THAN LARG
XNSIASFL	F	LOSS OF PLANT INSTRUMENT AIR
YNPIACFL	F	NO 125V AC POWER FROM INSTRUMENT AC BUS
YNPVACFL	F	NO 120V AC POWER FROM THE UNINTERRUPTIBLE VITAL AC DIST PANE

Split Fraction: IPIAC

SF Name	SF Value	Split Fraction Description
IPIAC	9.7243E-04	CONT. ISOL. FAILS -- INSTR AC FAILS

Split Fraction IPIAC Boundary Conditions

Basic Event	State	Basic Event Description
IERCSFL	S	INITIATING EVENT CAUSES RCS FAILURE OUTSIDE CONTAINMENT
ISOPLLFL	S	OPERATOR FAILS TO ISOLATE PATH DURING LARGE LOCA
XNSIASFL	S	LOSS OF PLANT INSTRUMENT AIR
YNPIACFL	F	NO 125V AC POWER FROM INSTRUMENT AC BUS
YNPVACFL	S	NO 120V AC POWER FROM THE UNINTERRUPTIBLE VITAL AC DIST PANE

Split Fraction: IPIACL

SF Name	SF Value	Split Fraction Description
IPIACL	1.0032E-03	CNT ISOL FAILS (LLOCA) -- INSTR AC FAILS

Split Fraction IPIACL Boundary Conditions

Basic Event	State	Basic Event Description
IERCSFL	S	INITIATING EVENT CAUSES RCS FAILURE OUTSIDE CONTAINMENT
ISOPSIGFL	S	OPERATOR FAILS TO ISOLATE PATH DURING ALL EVENTS OTHER THAN LARG
XNSIASFL	S	LOSS OF PLANT INSTRUMENT AIR
YNPIACFL	F	NO 125V AC POWER FROM INSTRUMENT AC BUS
YNPVACFL	S	NO 120V AC POWER FROM THE UNINTERRUPTIBLE VITAL AC DIST PANE

Split Fraction: IPIG

SF Name	SF Value	Split Fraction Description
IPIG	1.0924E-03	CONT. ISOL. FAILS -- IG FAILS

Split Fraction IPIG Boundary Conditions

Basic Event	State	Basic Event Description
IERCSFL	S	INITIATING EVENT CAUSES RCS FAILURE OUTSIDE CONTAINMENT
ISOPLLFL	S	OPERATOR FAILS TO ISOLATE PATH DURING LARGE LOCA
XNSIASFL	F	LOSS OF PLANT INSTRUMENT AIR
YNPIACFL	S	NO 125V AC POWER FROM INSTRUMENT AC BUS
YNPVACFL	S	NO 120V AC POWER FROM THE UNINTERRUPTIBLE VITAL AC DIST PANE

Split Fraction: IPIGAC

SF Name	SF Value	Split Fraction Description
IPIGAC	1.0924E-03	CONT. ISOL. FAILS -- IG & VITAL/INSTRU AC FAIL

Split Fraction IPIGAC Boundary Conditions

Basic Event	State	Basic Event Description
IERCSFL	S	INITIATING EVENT CAUSES RCS FAILURE OUTSIDE CONTAINMENT
ISOPLLFL	S	OPERATOR FAILS TO ISOLATE PATH DURING LARGE LOCA
XNSIASFL	F	LOSS OF PLANT INSTRUMENT AIR
YNPIACFL	F	NO 125V AC POWER FROM INSTRUMENT AC BUS
YNPVACFL	F	NO 120V AC POWER FROM THE UNINTERRUPTIBLE VITAL AC DIST PANE

Split Fraction: IPIGL

SF Name	SF Value	Split Fraction Description
IPIGL	1.1232E-03	CNT ISOL FAILS (LLOCA) -- IG FAILS

Split Fraction IPIGL Boundary Conditions

Basic Event	State	Basic Event Description
IERCSFL	S	INITIATING EVENT CAUSES RCS FAILURE OUTSIDE CONTAINMENT
ISOPSIGFL	S	OPERATOR FAILS TO ISOLATE PATH DURING ALL EVENTS OTHER THAN LARG
XNSIASFL	F	LOSS OF PLANT INSTRUMENT AIR
YNPIACFL	S	NO 125V AC POWER FROM INSTRUMENT AC BUS
YNPVACFL	S	NO 120V AC POWER FROM THE UNINTERRUPTIBLE VITAL AC DIST PANE

Split Fraction: IPSE

SF Name	SF Value	Split Fraction Description
IPSE	3.2849E-02	CONT. ISOL FAILS -- SE PORTION OF RPS SIGNAL

Split Fraction IPSE Boundary Conditions

Basic Event	State	Basic Event Description
IERCSFL	S	INITIATING EVENT CAUSES RCS FAILURE OUTSIDE CONTAINMENT
ISCISFAILS	F	CONTAINMENT ISOLATION SIGNAL FAILS
ISOPLLFL	S	OPERATOR FAILS TO ISOLATE PATH DURING LARGE LOCA
XNSIASFL	S	LOSS OF PLANT INSTRUMENT AIR
YNPIACFL	S	NO 125V AC POWER FROM INSTRUMENT AC BUS
YNPVACFL	S	NO 120V AC POWER FROM THE UNINTERRUPTIBLE VITAL AC DIST PANE

Split Fraction: IPVAC

SF Name	SF Value	Split Fraction Description
IPVAC	9.7243E-04	CONT. ISOL. FAILS -- VITAL AC FAILS

Split Fraction IPVAC Boundary Conditions

Basic Event	State	Basic Event Description
IERCSFL	S	INITIATING EVENT CAUSES RCS FAILURE OUTSIDE CONTAINMENT
ISOPLLFL	S	OPERATOR FAILS TO ISOLATE PATH DURING LARGE LOCA
XNSIASFL	S	LOSS OF PLANT INSTRUMENT AIR
YNPIACFL	S	NO 125V AC POWER FROM INSTRUMENT AC BUS
YNPVACFL	F	NO 120V AC POWER FROM THE UNINTERRUPTIBLE VITAL AC DIST PANE

Split Fraction: IPVACL

SF Name	SF Value	Split Fraction Description
IPVACL	1.0032E-03	CNT ISOL FAILS (LLOCA) -- VITAL AC FAILS

Split Fraction IPVACL Boundary Conditions

Basic Event	State	Basic Event Description
IERCSFL	S	INITIATING EVENT CAUSES RCS FAILURE OUTSIDE CONTAINMENT
ISOPSIGFL	S	OPERATOR FAILS TO ISOLATE PATH DURING ALL EVENTS OTHER THAN LARG
XNSIASFL	S	LOSS OF PLANT INSTRUMENT AIR
YNPIACFL	S	NO 125V AC POWER FROM INSTRUMENT AC BUS
YNPVACFL	F	NO 120V AC POWER FROM THE UNINTERRUPTIBLE VITAL AC DIST PANE

Split Fraction: IPVIAC

SF Name	SF Value	Split Fraction Description
IPVIAC	1.0924E-03	CONT. ISOL. FAILS -- VITAL & INSTRU AC FAIL

Split Fraction IPVIAC Boundary Conditions

Basic Event	State	Basic Event Description
IERCSFL	S	INITIATING EVENT CAUSES RCS FAILURE OUTSIDE CONTAINMENT
ISOPLLFL	S	OPERATOR FAILS TO ISOLATE PATH DURING LARGE LOCA
XNSIASFL	S	LOSS OF PLANT INSTRUMENT AIR
YNPIACFL	F	NO 125V AC POWER FROM INSTRUMENT AC BUS
YNPVACFL	F	NO 120V AC POWER FROM THE UNINTERRUPTIBLE VITAL AC DIST PANE

Split Fraction: IPVIL

SF Name	SF Value	Split Fraction Description
IPVIL	1.1232E-03	CNT ISOL FAILS (LLOCA) -- VITAL & INSTR AC FAIL

Split Fraction IPVIL Boundary Conditions

Basic Event	State	Basic Event Description
IERCSFL	S	INITIATING EVENT CAUSES RCS FAILURE OUTSIDE CONTAINMENT
ISOPSIGFL	S	OPERATOR FAILS TO ISOLATE PATH DURING ALL EVENTS OTHER THAN LARG
XNSIASFL	S	LOSS OF PLANT INSTRUMENT AIR
YNPIACFL	F	NO 125V AC POWER FROM INSTRUMENT AC BUS
YNPVACFL	F	NO 120V AC POWER FROM THE UNINTERRUPTIBLE VITAL AC DIST PANE

Attachment C

Top Event (AI)

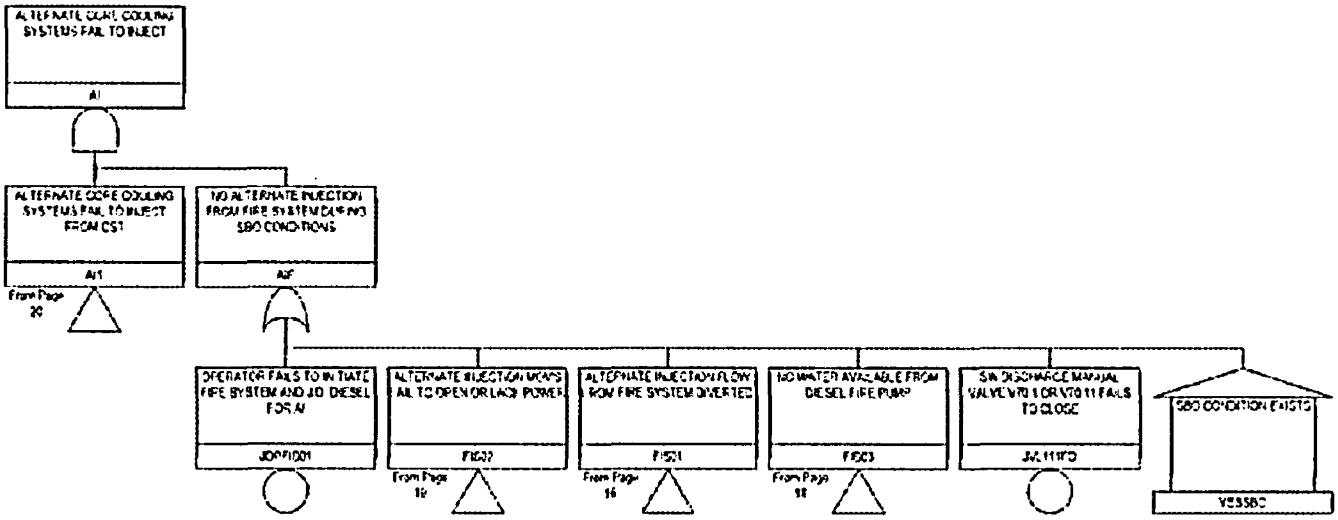

Figure C.1A Fault Tree (IP)

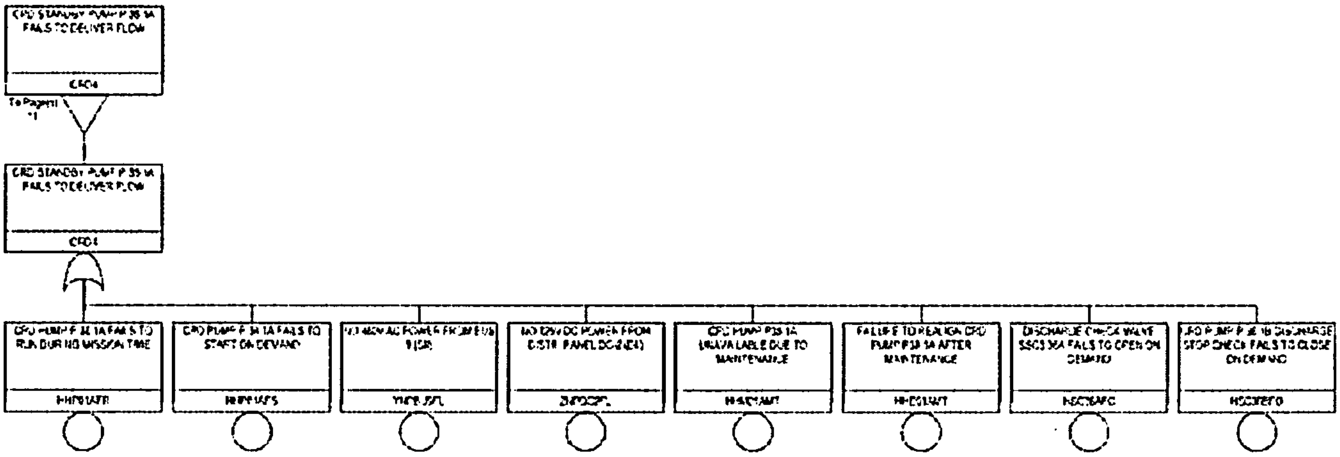

Figure C.1B Fault Tree (IP)

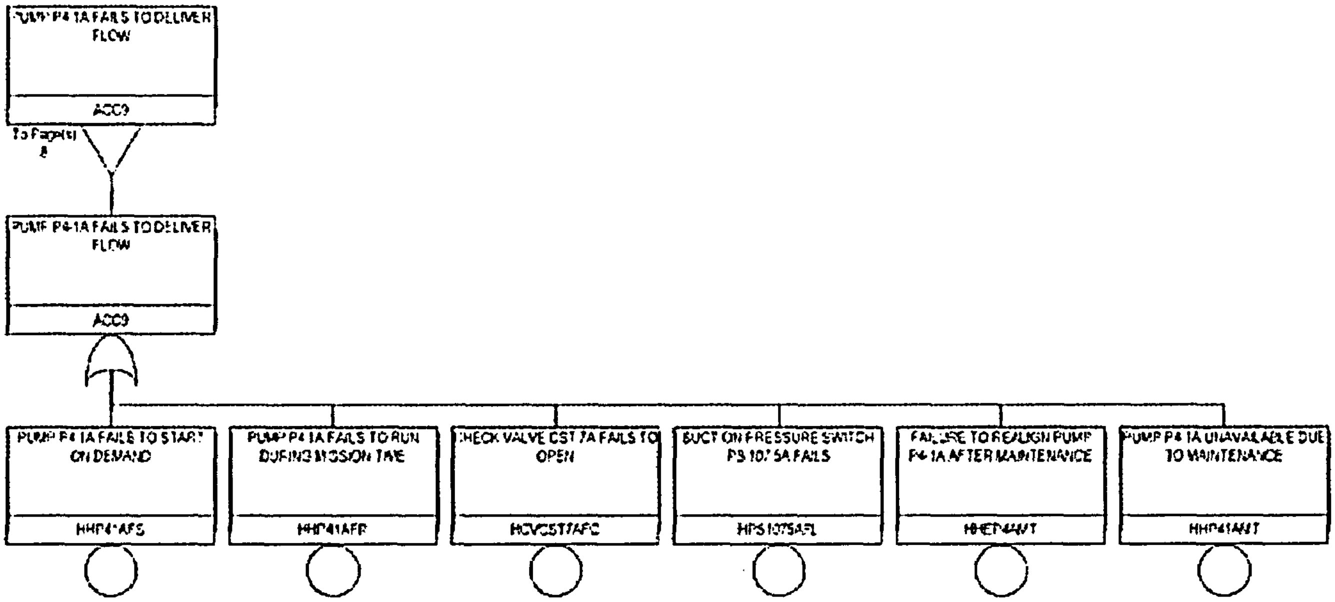

Figure C.1C Fault Tree (IP)

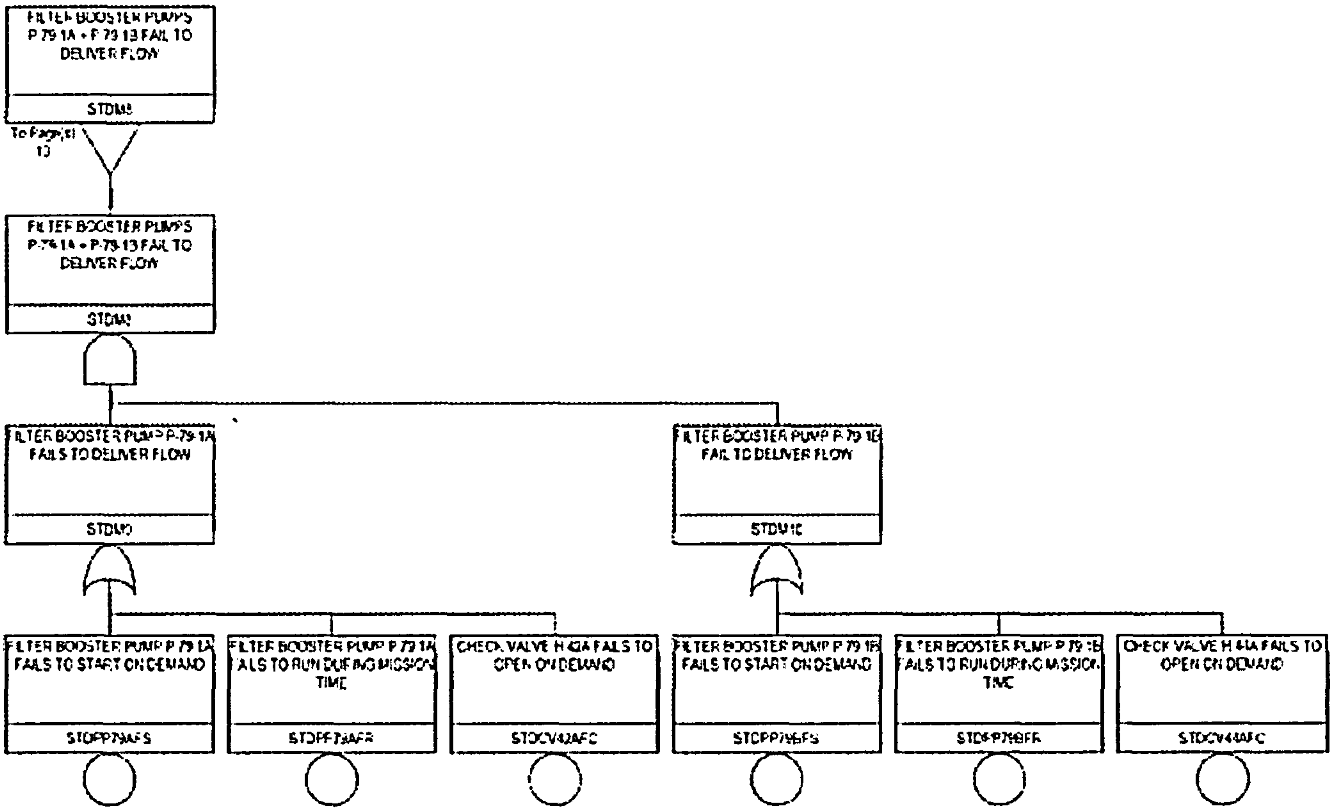

Figure C.1D Fault Tree (IP)

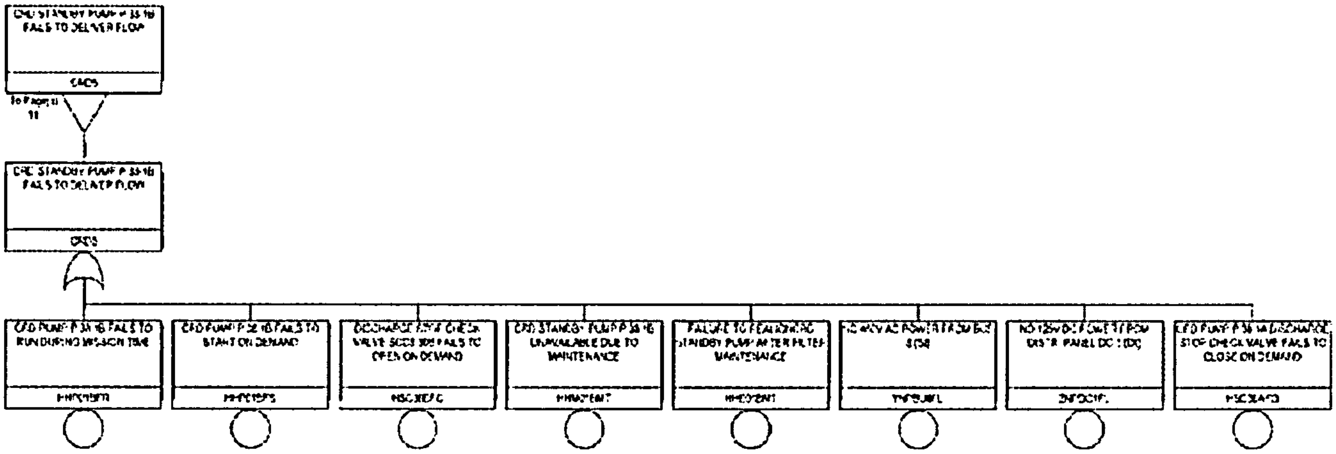

Figure C.1E Fault Tree (IP)
]

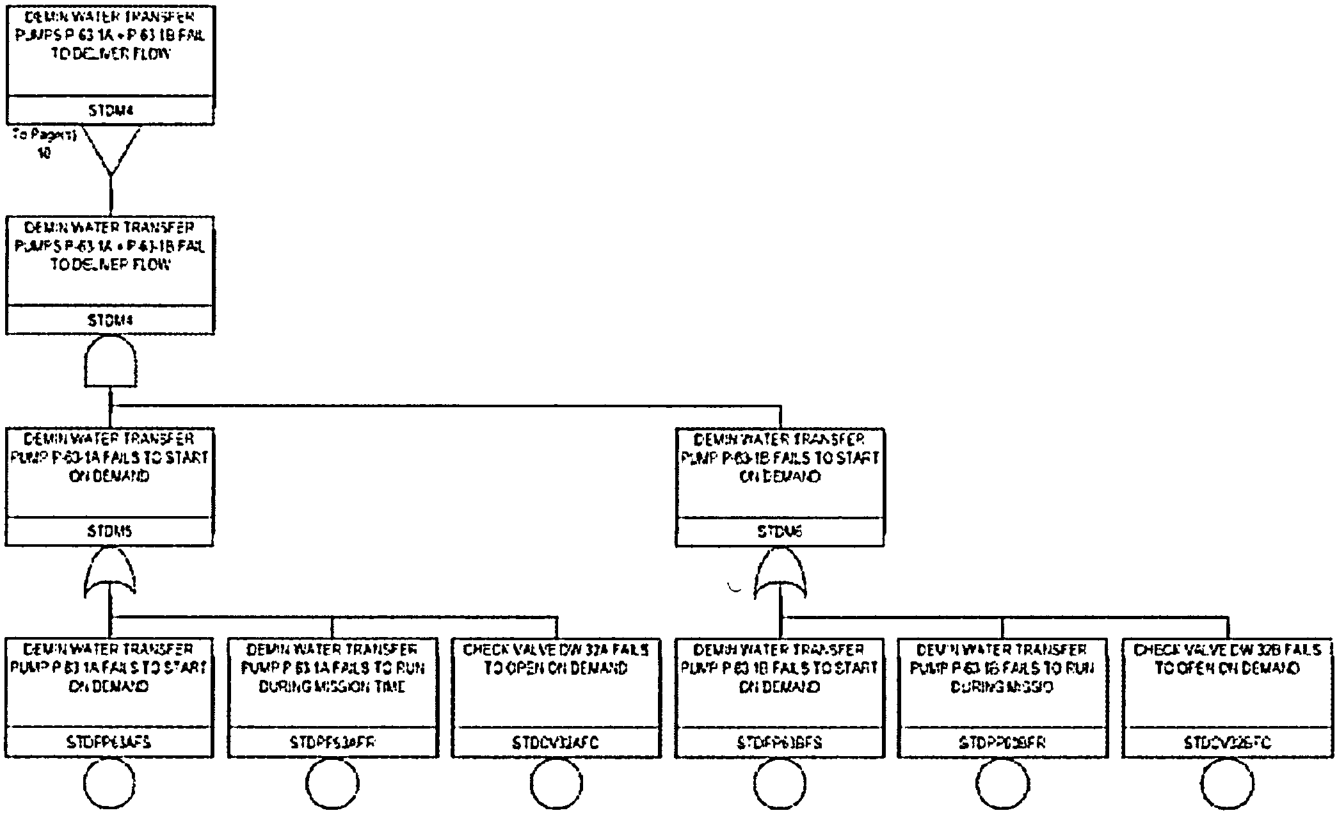

Figure C.1F Fault Tree (IP)

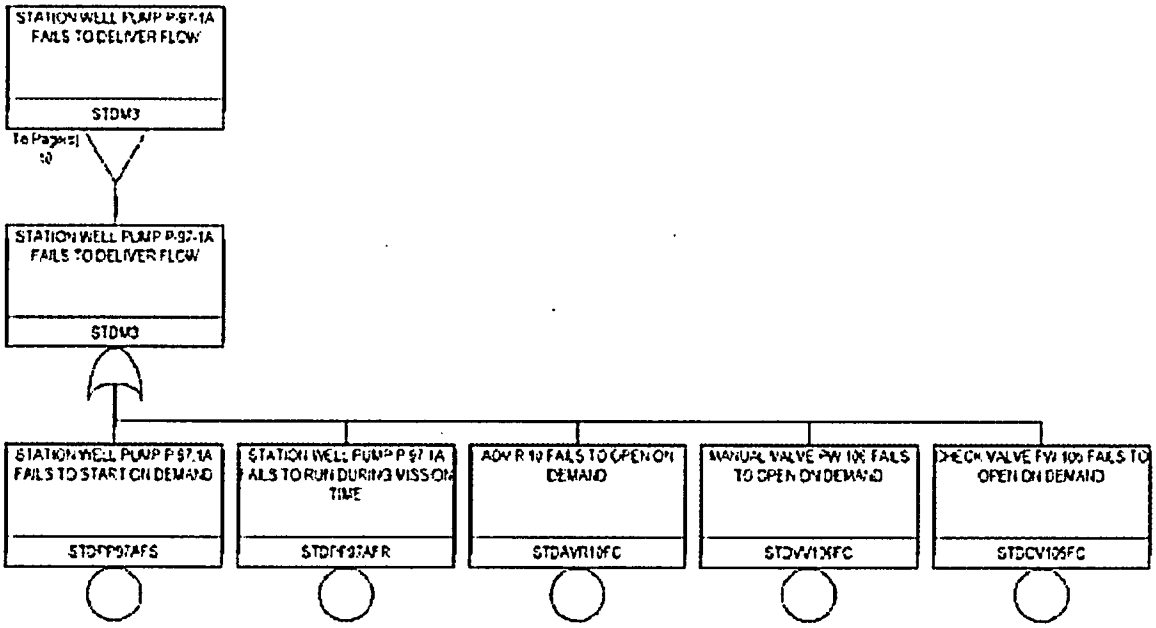

Figure C.1G Fault Tree (IP)

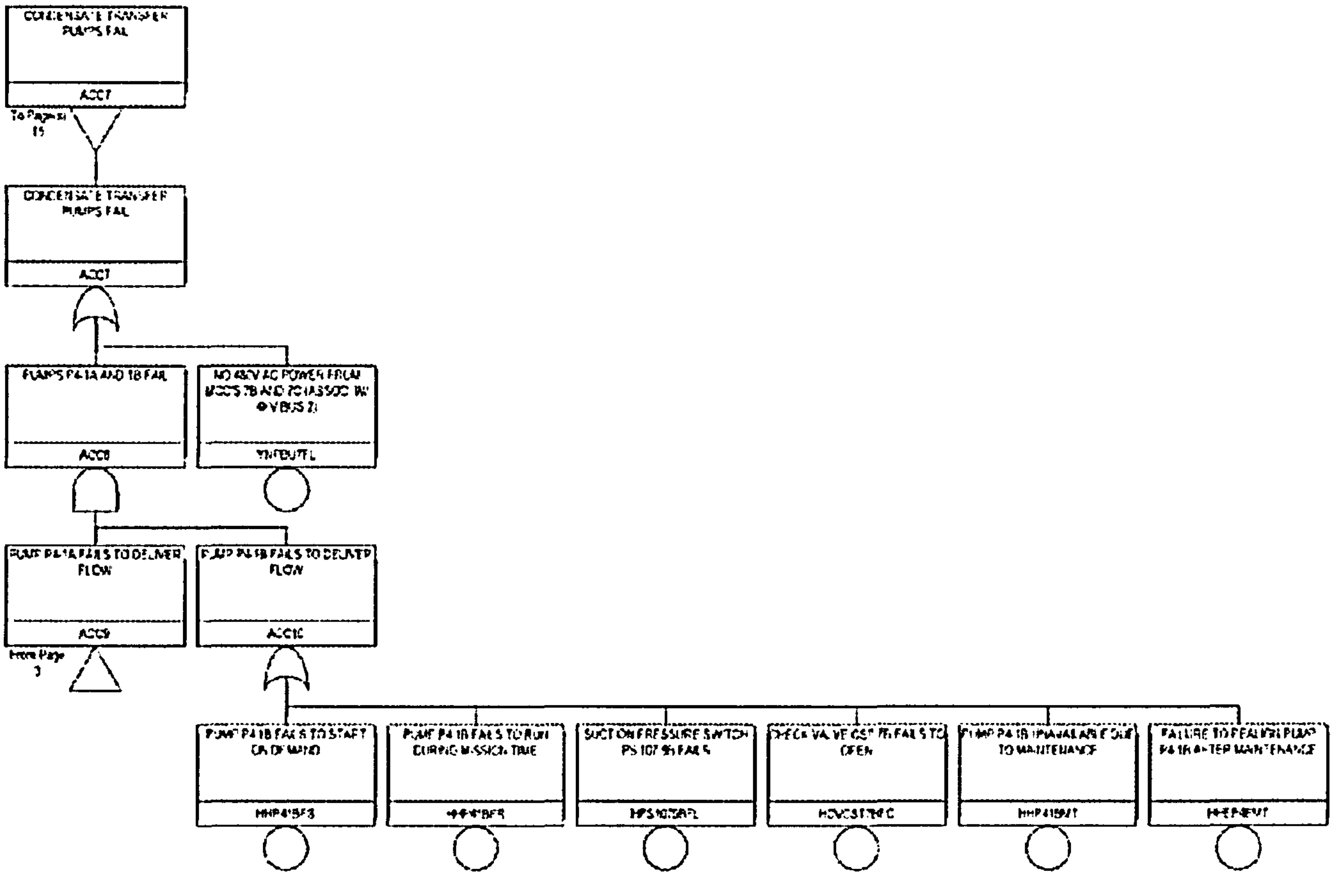

Figure C.1H Fault Tree (IP)

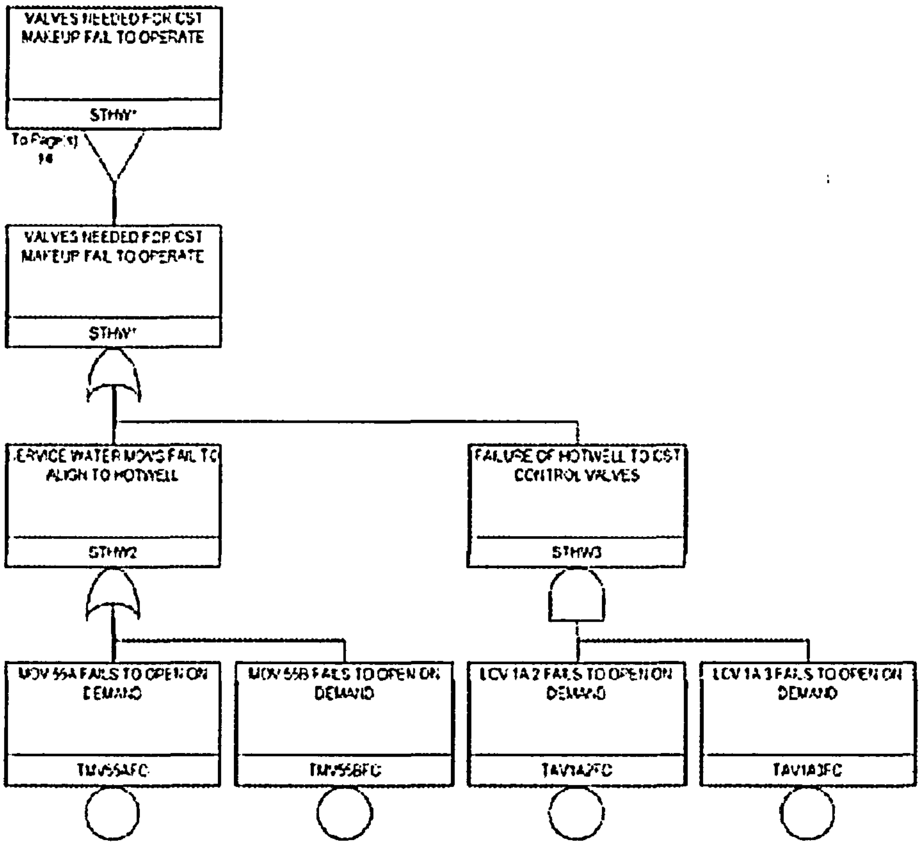

Figure C.1J Fault Tree (IP)

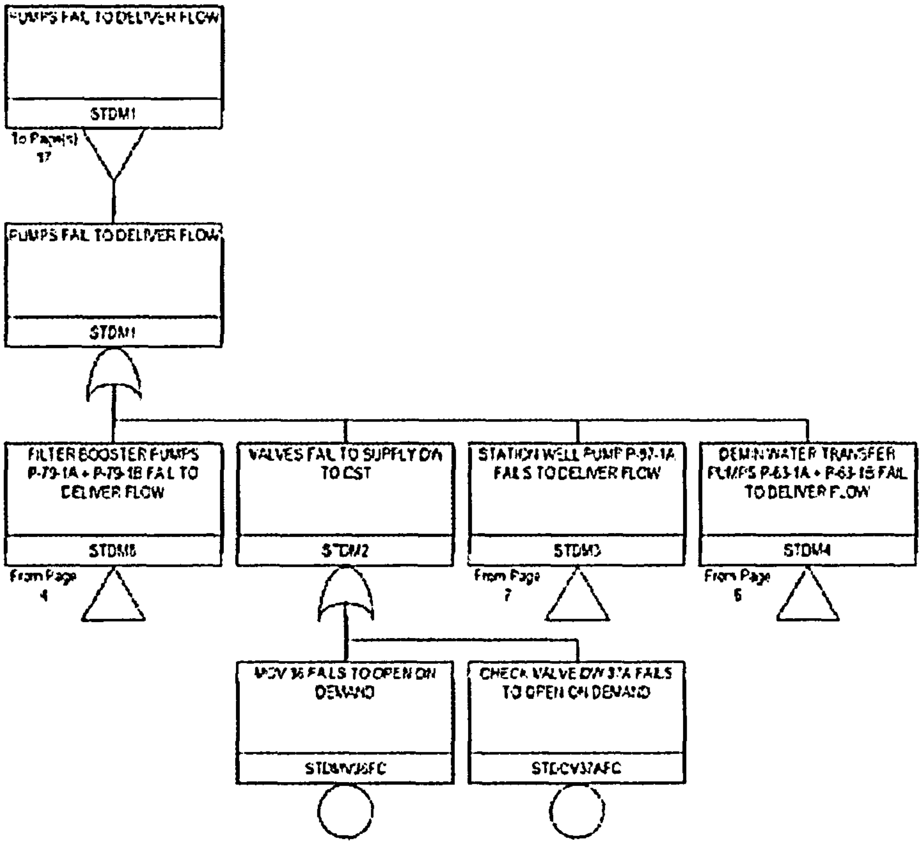

Figure C.1K Fault Tree (IP)

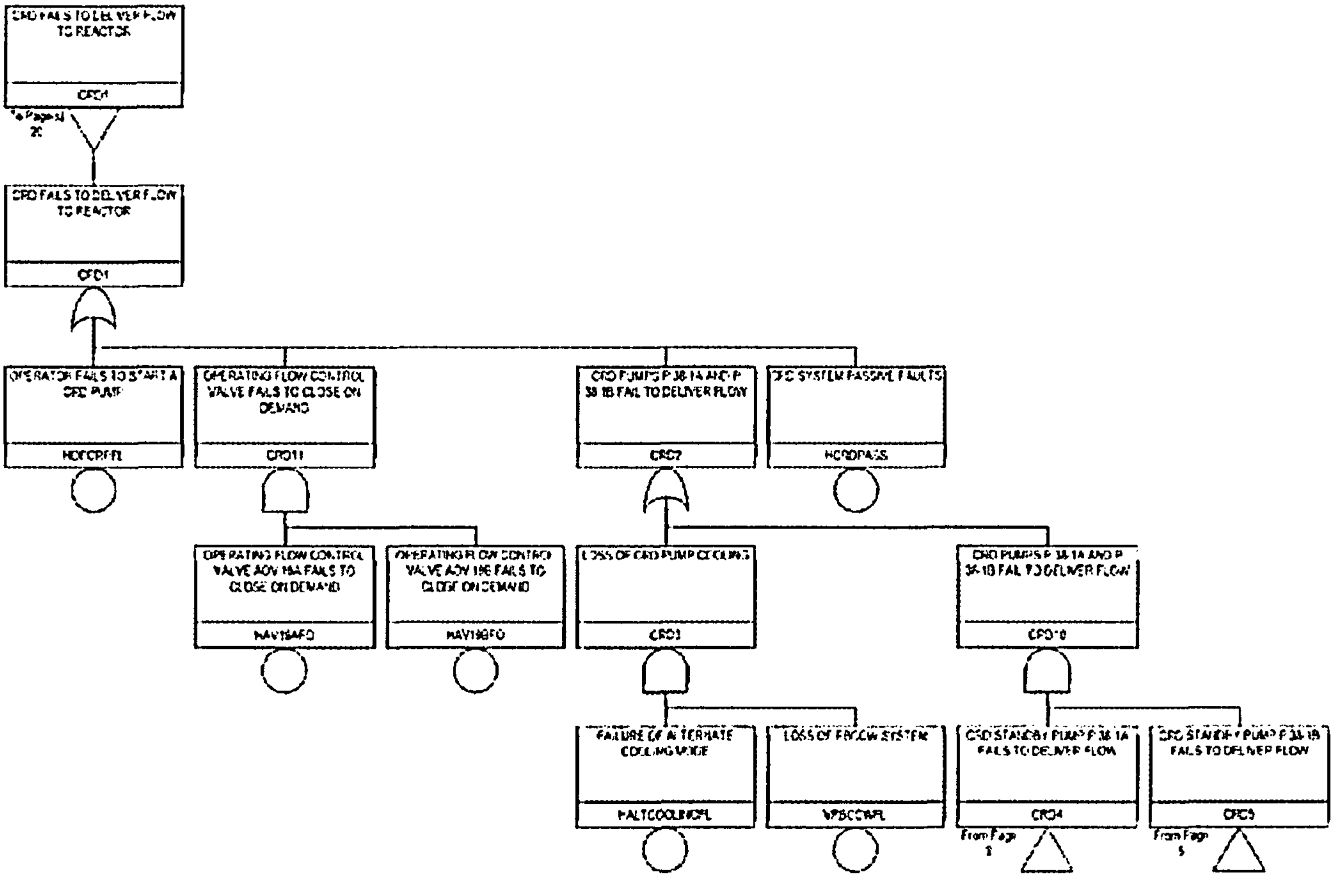

Figure C.1L Fault Tree (IP)

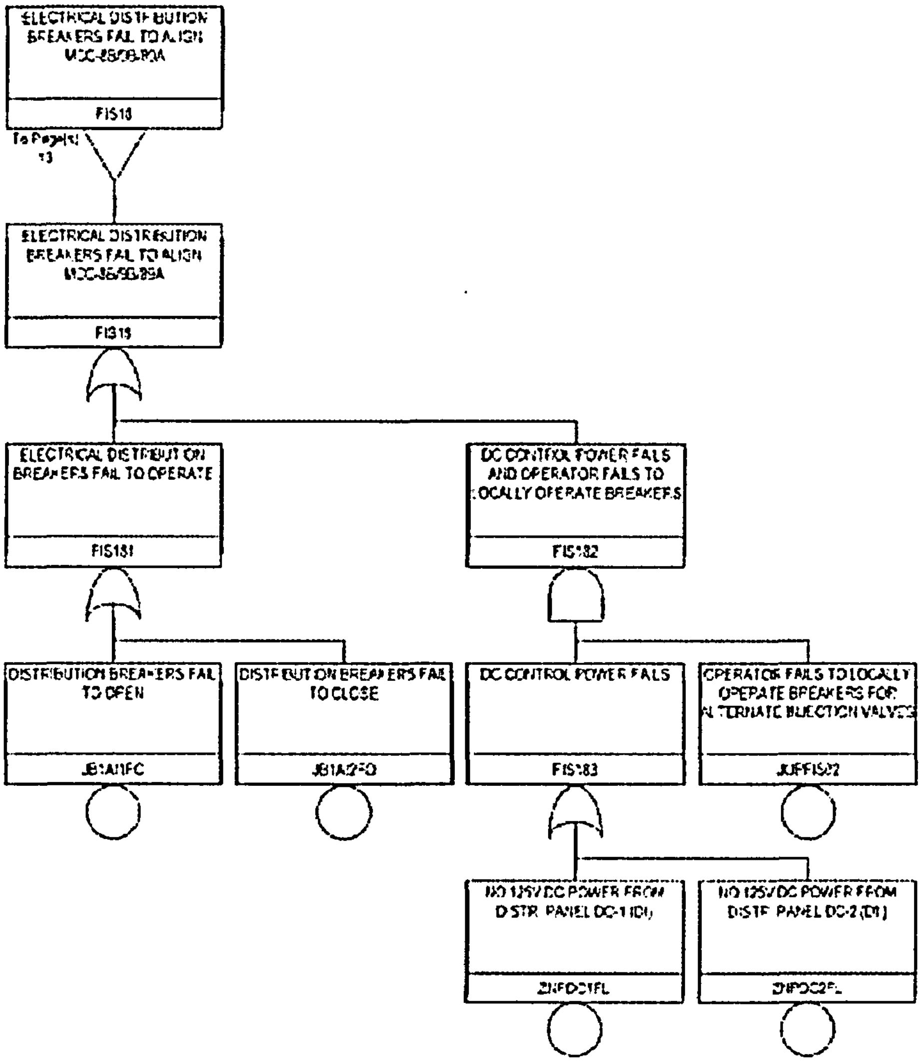

Figure C.1M Fault Tree (IP)

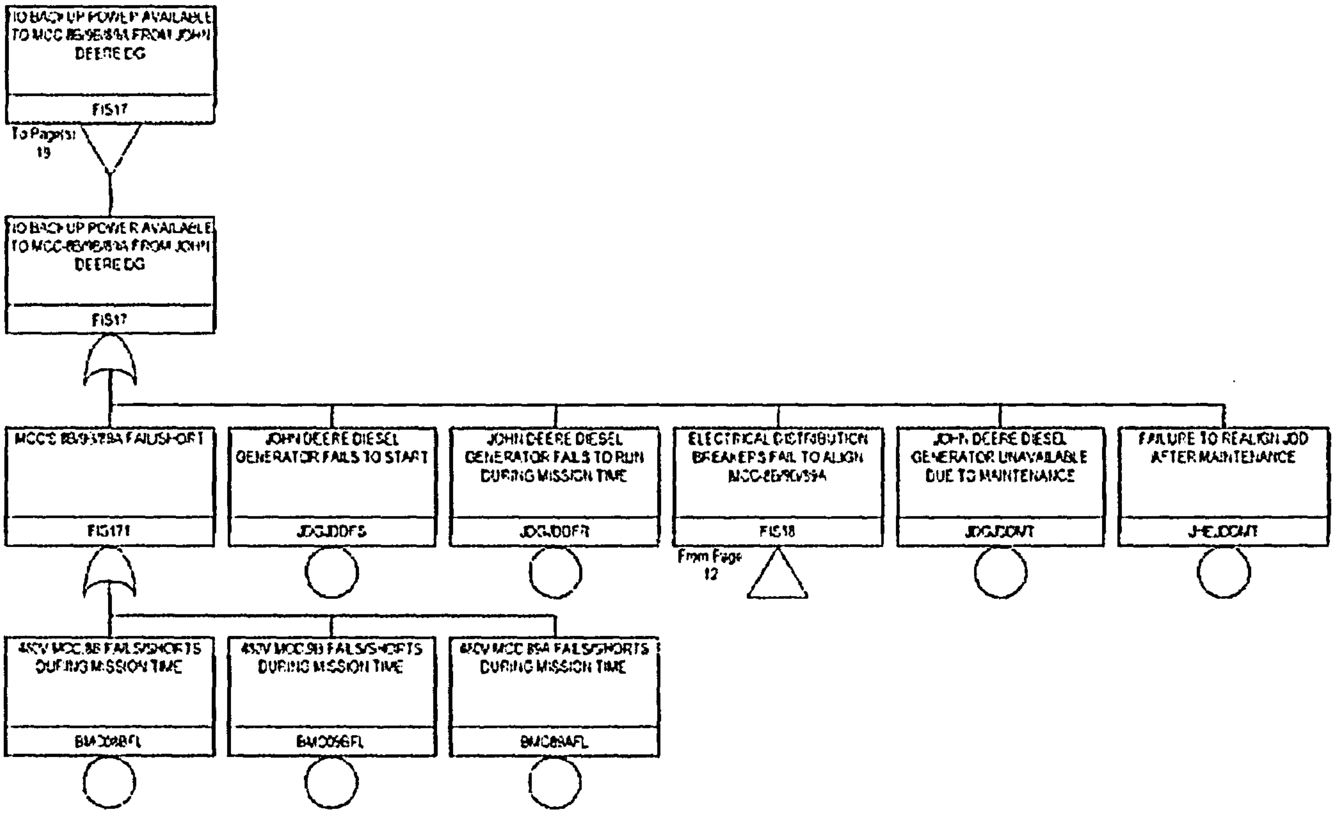

Figure C.1N Fault Tree (IP)

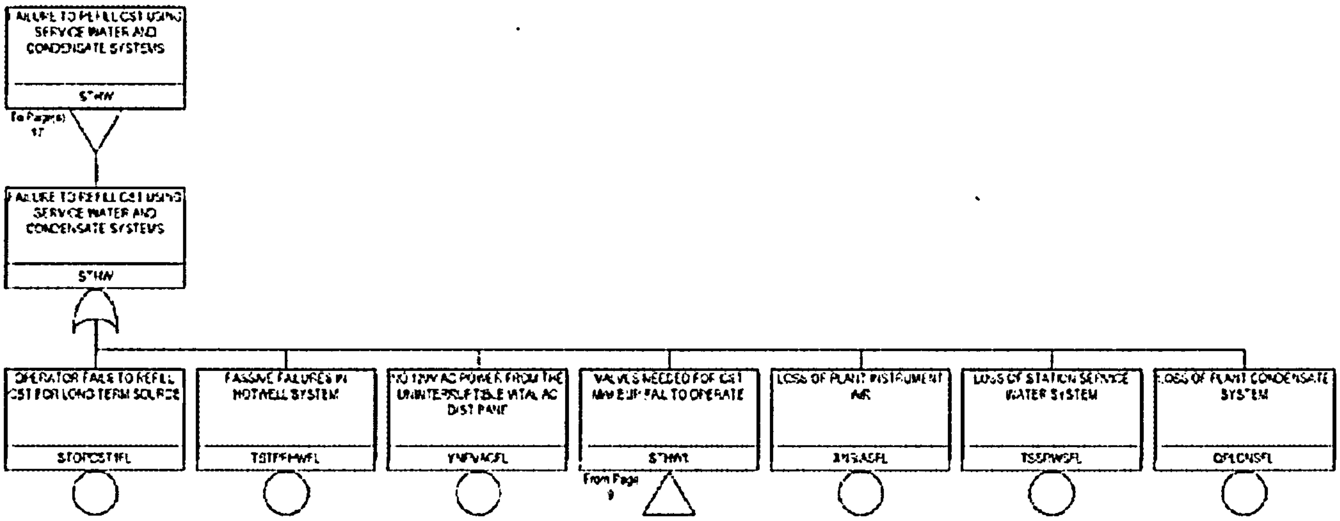

Figure C.1P Fault Tree (IP)

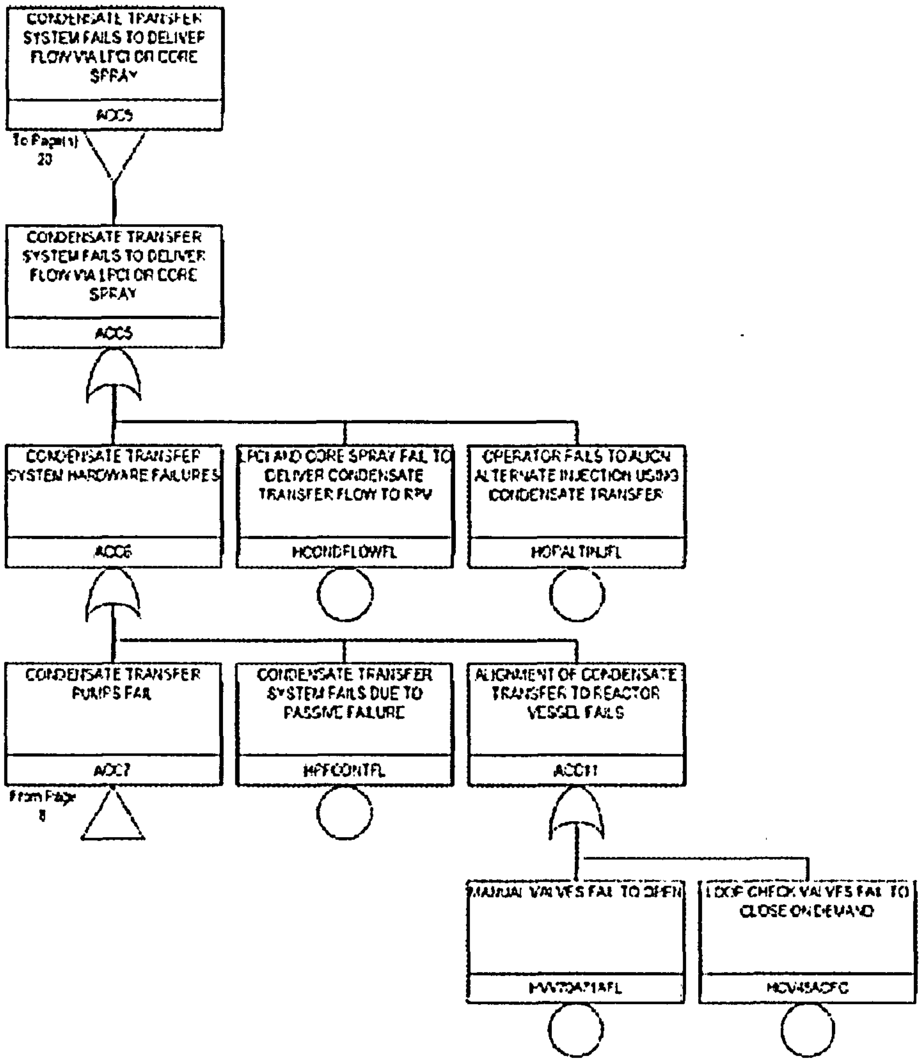

Figure C.1R Fault Tree (IP)

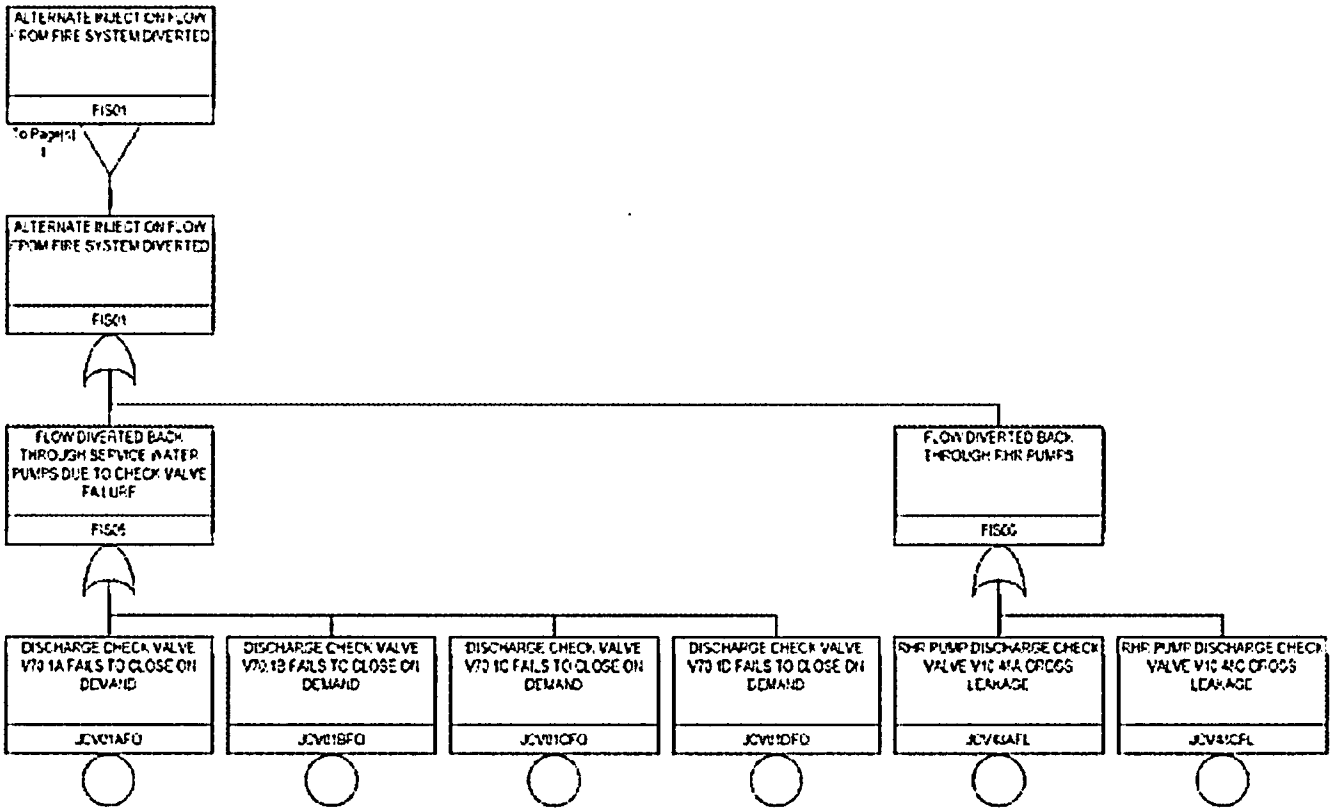

Figure C.1S Fault Tree (IP)

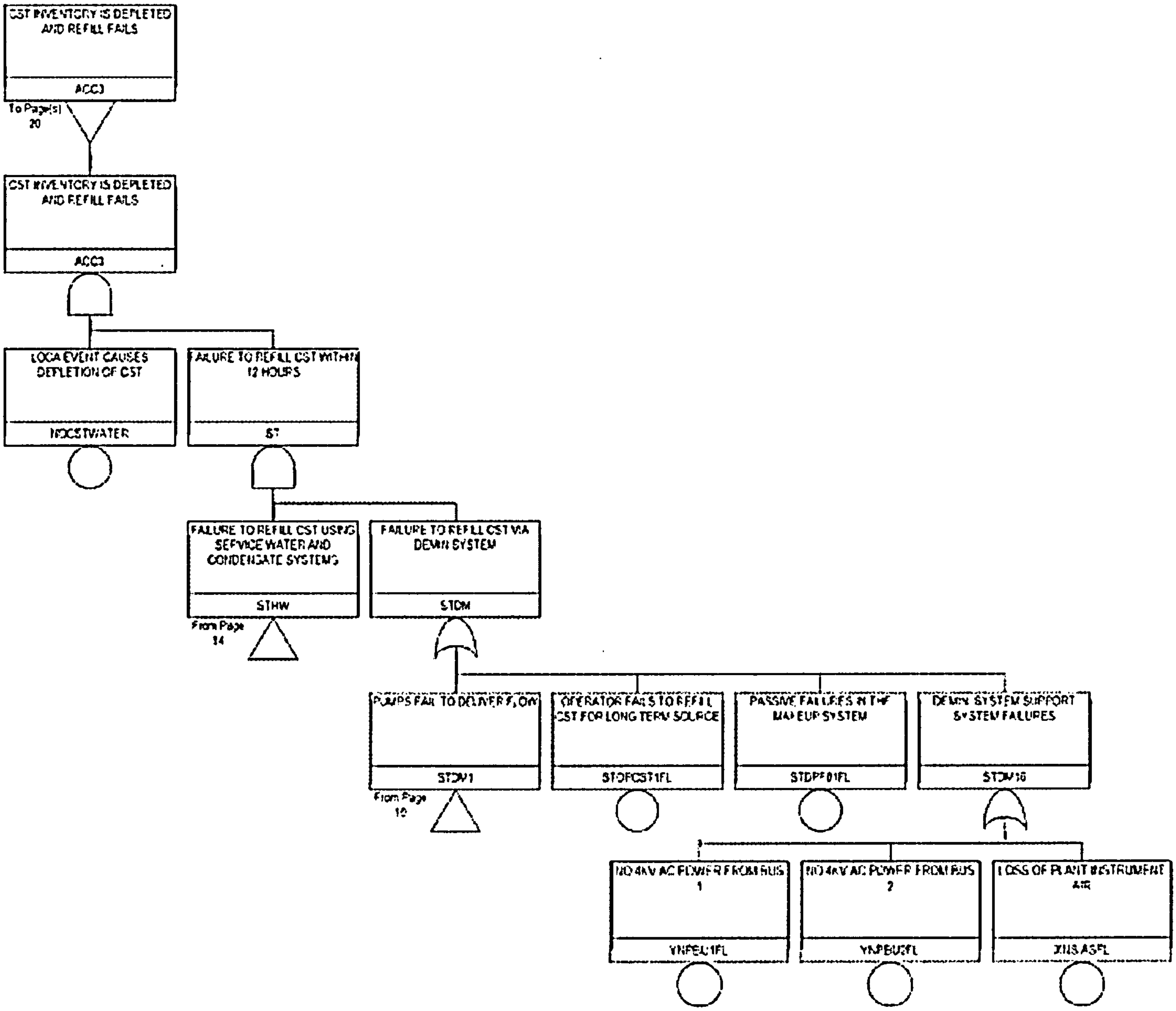

Figure C.1T Fault Tree (IP)

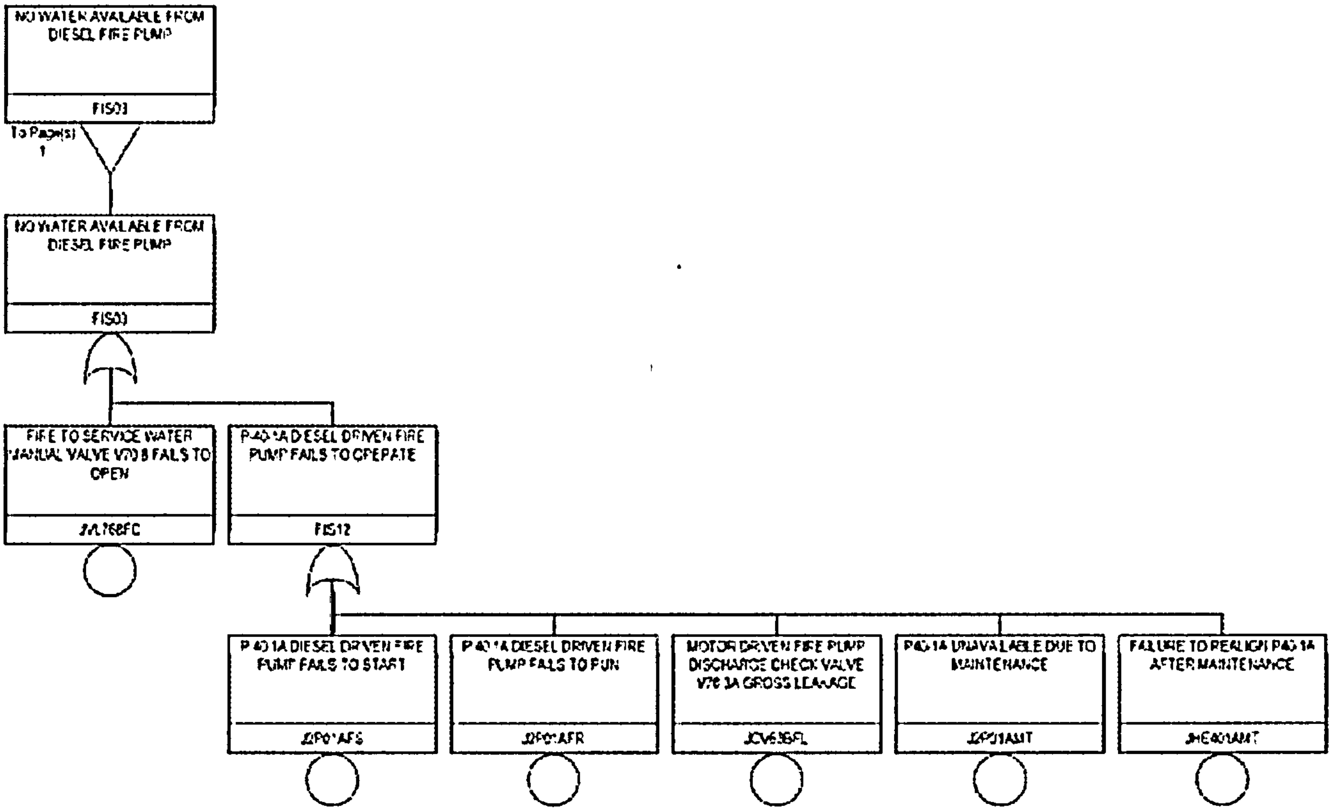

Figure C.1U Fault Tree (IP)

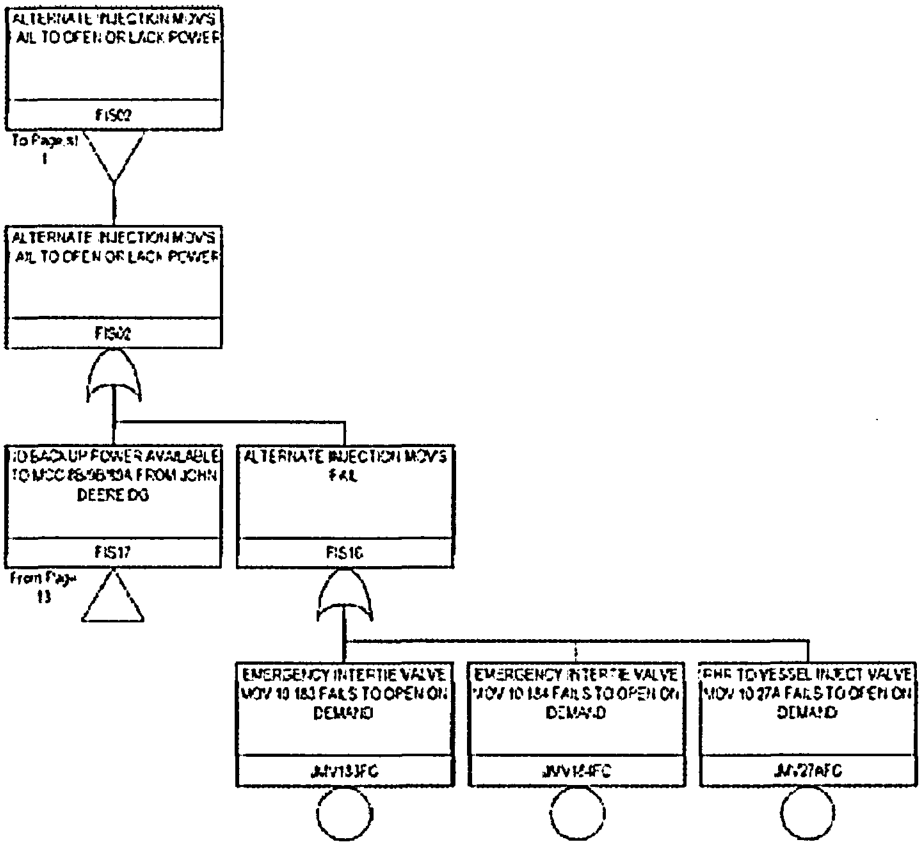

Figure C.1V Fault Tree (IP)

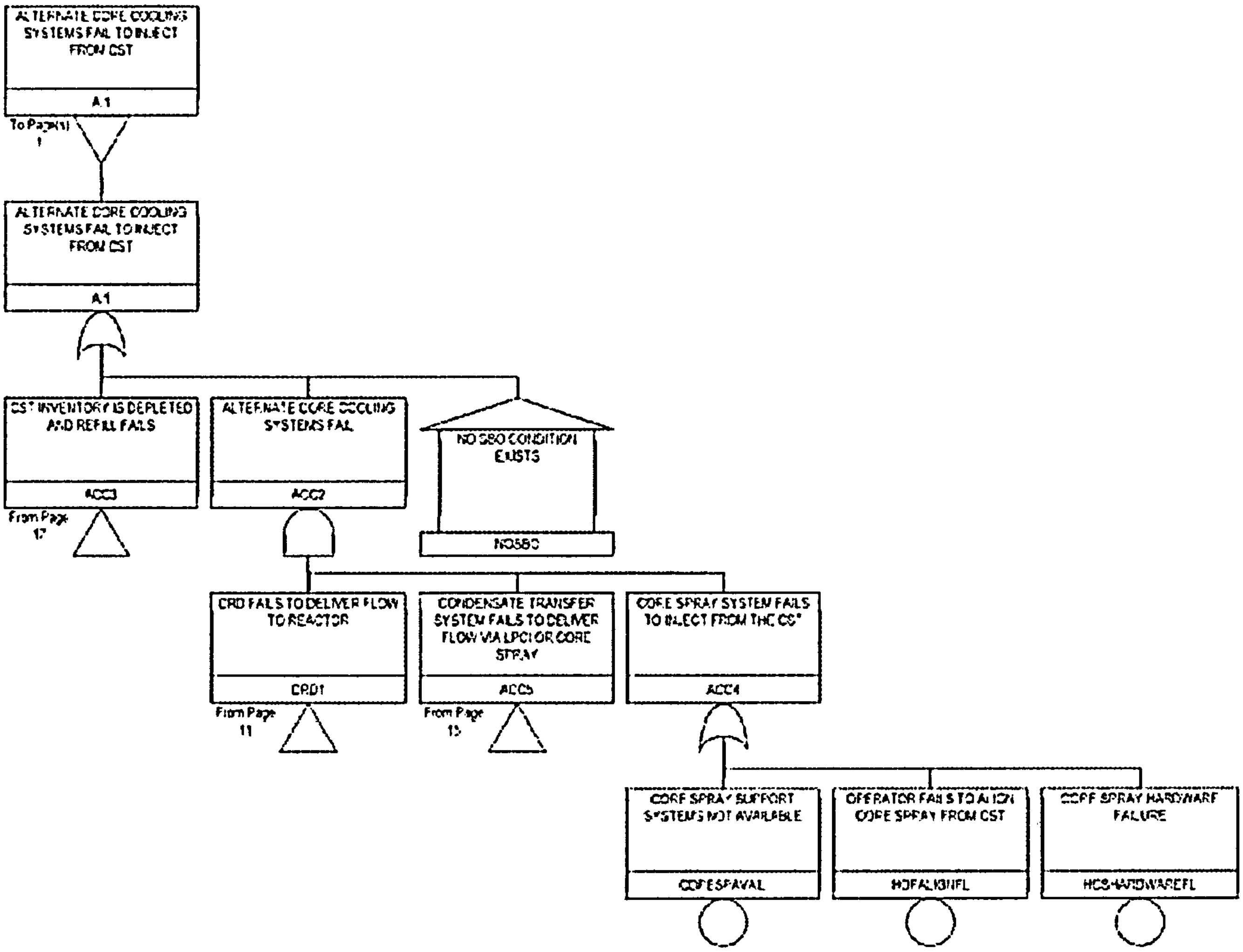

Figure C.1W Fault Tree (IP)

Table C-1 Basic Events for Top Event (AI)

Basic Event Name	Basic Event Value	Basic Event Description
BMC08BFL	9.9504 E-07	480V MCC.8B FAILS/SHORTS DURING MISSION TIME
BMC09BFL	9.9504 E-07	480V MCC.9B FAILS/SHORTS DURING MISSION TIME
BMC89AFL	9.9504 E-07	480V MCC.89A FAILS/SHORTS DURING MISSION TIME
HCV48ACFC	1.6700 E-03	LOOP CHECK VALVES FAIL TO CLOSE ON DEMAND
HCVCST7AFC	1.8272 E-04	CHECK VALVE CST 7A FAILS TO OPEN
HCVCST7BFC	1.8272 E-04	CHECK VALVE CST 7B FAILS TO OPEN
HHEP4AMT	1.0000 E-04	FAILURE TO REALIGN PUMP P4-1A AFTER MAINTENANCE
HHEP4BMT	1.0000 E-04	FAILURE TO REALIGN PUMP P4-1B AFTER MAINTENANCE
HHP41AFR	8.1190 E-04	PUMP P4.1A FAILS TO RUN DURING MISSION TIME
HHP41AFS	3.0597 E-03	PUMP P4.1A FAILS TO START ON DEMAND
HHP41AMT	2.1000 E-03	PUMP P4-1A UNAVAILABLE DUE TO MAINTENANCE
HHP41BFR	8.1190 E-04	PUMP P4.1B FAILS TO RUN DURING MISSION TIME
HHP41BFS	3.0597 E-03	PUMP P4.1B FAILS TO START ON DEMAND
HHP41BMT	2.1000 E-03	PUMP P4-1B UNAVAILABLE DUE TO MAINTENANCE
HOPALTINJFL	3.1000 E-02	OPERATOR FAILS TO ALIGN ALTERNATE INJECTION USING CONDENSATE TRAIN
HPFCONTFL	1.0000 E-04	CONDENSATE TRANSFER SYSTEM FAILS DUE TO PASSIVE FAILURE
HPS1075AFL	3.0139 E-07	SUCTION PRESSURE SWITCH PS.107.5A FAILS
HPS1075BFL	3.0139 E-07	SUCTION PRESSURE SWITCH PS.107.5B FAILS
HVV70A71AFL	2.0000 E-04	MANUAL VALVES FAIL TO OPEN
J2P01AFR	2.4641 E-02	P 40.1A DIESEL DRIVEN FIRE PUMP FAILS TO RUN
J2P01AFS	3.3088 E-02	P 40.1A DIESEL DRIVEN FIRE PUMP FAILS TO START
J2P01AMT	6.7800 E-04	P40-1A UNAVAILABLE DUE TO MAINTENANCE
JB1AI1FC	2.5975 E-03	DISTRIBUTION BREAKERS FAIL TO OPEN
JB1AI2FO	9.6594 E-03	DISTRIBUTION BREAKERS FAIL TO CLOSE
JCV01AFO	8.3529 E-04	DISCHARGE CHECK VALVE V70.1A FAILS TO CLOSE ON DEMAND
JCV01BFO	8.3529 E-04	DISCHARGE CHECK VALVE V70.1B FAILS TO CLOSE ON DEMAND
JCV01CFO	8.3529 E-04	DISCHARGE CHECK VALVE V70.1C FAILS TO CLOSE ON DEMAND

Table C-1 Basic Events for Top Event (AI) (continued)

Basic Event Name	Basic Event Value	Basic Event Description
JCV01DFO	8.3529 E-04	DISCHARGE CHECK VALVE V70.1D FAILS TO CLOSE ON DEMAND
JCV48AFL	1.2860 E-05	RHR PUMP DISCHARGE CHECK VALVE V10.48A GROSS LEAKAGE
JCV48CFL	1.2860 E-05	RHR PUMP DISCHARGE CHECK VALVE V10.48C GROSS LEAKAGE
JCV63BFL	1.2860 E-05	MOTOR DRIVEN FIRE PUMP DISCHARGE CHECK VALVE V76.3A GROSS LEAKAGE
JDGJDDFR	7.4434 E-02	JOHN DEERE DIESEL GENERATOR FAILS TO RUN DURING MISSION TIME
JDGJDDFS	2.1373 E-02	JOHN DEERE DIESEL GENERATOR FAILS TO START
JDGJDDMT	9.8200 E-04	JOHN DEERE DIESEL GENERATOR UNAVAILABLE DUE TO MAINTENANCE
JHE401AMT	1.0000 E-04	FAILURE TO REALIGN P40-1A AFTER MAINTENANCE
JHEJDDMT	1.0000 E-04	FAILURE TO REALIGN JDD AFTER MAINTENANCE
JMV183FC	4.2953 E-03	EMERGENCY INTERTIE VALVE MOV.10.183 FAILS TO OPEN ON DEMAND
JMV184FC	4.2953 E-03	EMERGENCY INTERTIE VALVE MOV.10.184 FAILS TO OPEN ON DEMAND
JMV27AFC	4.2953 E-03	RHR TO VESSEL INJECT VALVE MOV.10.27A FAILS TO OPEN ON DEMAND
JOPFIS01	1.0000 E-01	OPERATOR FAILS TO INITIATE FIRE SYSTEM AND J.D. DIESEL FOR AI
JOPFIS02	6.0000 E-02	OPERATOR FAILS TO LOCALLY OPERATE BREAKERS FOR ALTERNATE INJECTION
JVL111FO	1.5215 E-03	SW DISCHARGE MANUAL VALVE V70.1 OR V70.11 FAILS TO CLOSE
JVL768FC	1.5215 E-03	FIRE TO SERVICE WATER MANUAL VALVE V70.8 FAILS TO OPEN
QPLCNSFL	5.1300 E-03	LOSS OF PLANT CONDENSATE SYSTEM
STDAVR10FC	1.5215 E-03	AOV R.10 FAILS TO OPEN ON DEMAND
STDCV105FC	1.8272 E-04	CHECK VALVE PW.105 FAILS TO OPEN ON DEMAND
STDCV32AFC	1.8272 E-04	CHECK VALVE DW.32A FAILS TO OPEN ON DEMAND
STDCV32BFC	2.6906 E-04	CHECK VALVE DW.32B FAILS TO OPEN ON DEMAND
STDCV37AFC	1.8272 E-04	CHECK VALVE DW.37A FAILS TO OPEN ON DEMAND
STDCV42AFC	1.8272 E-04	CHECK VALVE H.42A FAILS TO OPEN ON DEMAND
STDCV44AFC	1.8272 E-04	CHECK VALVE H.44A FAILS TO OPEN ON DEMAND
STDMV36FC	4.2953 E-03	MOV.36 FAILS TO OPEN ON DEMAND
STDPF01FL	1.0000 E-04	PASSIVE FAILURES IN THE MAKEUP SYSTEM
STDPP63AFR	8.1190 E-04	DEMIN WATER TRANSFER PUMP P.63.1A FAILS TO RUN DURING MISSION TIME

Table C-1 Basic Events for Top Event (AI) (continued)

Basic Event Name	Basic Event Value	Basic Event Description
STDPP63AFS	3.0597 E-03	DEMIN WATER TRANSFER PUMP P.63.1A FAILS TO START ON DEMAND
STDPP63BFR	8.1190 E-04	DEMIN WATER TRANSFER PUMP P.63.1B FAILS TO RUN DURING MISSIO
STDPP63BFS	3.0597 E-03	DEMIN WATER TRANSFER PUMP P.63.1B FAILS TO START ON DEMAND
STDPP79AFR	8.1190 E-04	FILTER BOOSTER PUMP P.79.1A FAILS TO RUN DURING MISSION TIME
STDPP79AFS	3.0597 E-03	FILTER BOOSTER PUMP P.79.1A FAILS TO START ON DEMAND
STDPP79BFR	8.1190 E-04	FILTER BOOSTER PUMP P.79.1B FAILS TO RUN DURING MISSION TIME
STDPP79BFS	3.0597 E-03	FILTER BOOSTER PUMP P.79.1B FAILS TO START ON DEMAND
STDPP97AFR	8.2010 E-04	STATION WELL PUMP P.97.1A FAILS TO RUN DURING MISSION TIME
STDPP97AFS	3.2899 E-03	STATION WELL PUMP P.97.1A FAILS TO START ON DEMAND
STDVV106FC	1.0000 E-04	MANUAL VALVE PW.106 FAILS TO OPEN ON DEMAND
STOPCST1FL	5.0000 E-02	OPERATOR FAILS TO REFILL CST FOR LONG TERM SOURCE
TAV1A2FC	1.5215 E-03	LCV.1A.2 FAILS TO OPEN ON DEMAND
TAV1A3FC	1.5215 E-03	LCV.1A.3 FAILS TO OPEN ON DEMAND
TMV55AFC	4.2953 E-03	MOV 55A FAILS TO OPEN ON DEMAND
TMV55BFC	4.2953 E-03	MOV 55B FAILS TO OPEN ON DEMAND
TSTPFHWFL	1.0000 E-04	PASSIVE FAILURES IN HOTWELL SYSTEM
YNPBU9FL	5.0000 E-01	NO 480V AC POWER FROM BUS 9 (SII)
ZNPDC1FL	5.0000 E-01	NO 125V DC POWER FROM DISTR. PANEL DC-1 (DI)
ZNPDC2FL	5.0000 E-01	NO 125V DC POWER FROM DISTR. PANEL DC-2 (DII)

Split Fraction: AIBASE

SF Name	SF Value	Split Fraction Description
AIBASE	2.2193E-05	ALTERNATE CORE COOLING SYSTEMS; 2 TRAINS OF CRD AND CONDENSATE TRANSFER AVAILABLE (BASECASE)

Split Fraction AIBASE Boundary Conditions

Basic Event	State	Basic Event Description
CORESPAVAIL	F	CORE SPRAY SUPPORT SYSTEMS NOT AVAILABLE
HALTCOOLINGFL	S	FAILURE OF ALTERNATE COOLING MODE
HCONDFLOWFL	S	LPCI AND CORE SPRAY FAIL TO DELIVER CONDENSATE TRANSFER FLOW TO
HCSHARDWAREFL	S	CORE SPRAY HARDWARE FAILURE
HOPALIGNFL	F	OPERATOR FAILS TO ALIGN CORE SPRAY FROM CST
NOCSTWATER	S	LOCA EVENT CAUSES DEPLETION OF CST
NOSBO	S	NO SBO CONDITION EXISTS
TSSRWSFL	S	LOSS OF STATION SERVICE WATER SYSTEM
VRBCCWFL	S	LOSS OF RBCCW SYSTEM
YESSBO	S	SBO CONDITION EXISTS
YNPBU2FL	S	NO 4KV AC POWER FROM BUS 2
YNPBU7FL	S	NO 480V AC POWER FROM MCC'S 7B AND 7C (ASSOC; W/ 4KV BUS 2)
YNPBU8FL	S	NO 480V AC POWER FROM BUS 8 (SI)
YNPBU9FL	S	NO 480V AC POWER FROM BUS 9 (SII)
ZNPDC1FL	S	NO 125V DC POWER FROM DISTR. PANEL DC-1 (DI)
ZNPDC2FL	S	NO 125V DC POWER FROM DISTR. PANEL DC-2 (DII)

Split Fraction: AICRAF

SF Name	SF Value	Split Fraction Description
AICRAF	2.9494E-04	ALT CORE CLG; CRD 'A' FAILED (AC4 OR D2 FAILED)

Split Fraction AICRAF Boundary Conditions

Basic Event	State	Basic Event Description
CORESPAVAIL	F	CORE SPRAY SUPPORT SYSTEMS NOT AVAILABLE
HALTCOOLINGFL	S	FAILURE OF ALTERNATE COOLING MODE
HCONDFLOWFL	S	LPCI AND CORE SPRAY FAIL TO DELIVER CONDENSATE TRANSFER FLOW TO
HCSHARDWAREFL	S	CORE SPRAY HARDWARE FAILURE
HOPALIGNFL	F	OPERATOR FAILS TO ALIGN CORE SPRAY FROM CST
NOCSTWATER	S	LOCA EVENT CAUSES DEPLETION OF CST
NOSBO	S	NO SBO CONDITION EXISTS
TSSRWSFL	S	LOSS OF STATION SERVICE WATER SYSTEM
VRBCCWFL	S	LOSS OF RBCCW SYSTEM
YESSBO	S	SBO CONDITION EXISTS
YNPBU2FL	S	NO 4KV AC POWER FROM BUS 2
YNPBU7FL	S	NO 480V AC POWER FROM MCC'S 7B AND 7C (ASSOC; W/ 4KV BUS 2)
YNPBU8FL	S	NO 480V AC POWER FROM BUS 8 (SI)
YNPBU9FL	F	NO 480V AC POWER FROM BUS 9 (SII)
ZNPDC1FL	S	NO 125V DC POWER FROM DISTR. PANEL DC-1 (DI)
ZNPDC2FL	F	NO 125V DC POWER FROM DISTR. PANEL DC-2 (DII)

Split Fraction: AICRBF

SF Name	SF Value	Split Fraction Description
AICRBF	2.9494E-04	ALT CORE CLG; CRD 'B' FAILED (AC3 OR D1 FAILED)

Split Fraction AICRBF Boundary Conditions

Basic Event	State	Basic Event Description
CORESPAVAIL	F	CORE SPRAY SUPPORT SYSTEMS NOT AVAILABLE
HALTCOOLINGFL	S	FAILURE OF ALTERNATE COOLING MODE
HCONDFLOWFL	S	LPCI AND CORE SPRAY FAIL TO DELIVER CONDENSATE TRANSFER FLOW TO
HCSHARDWAREFL	S	CORE SPRAY HARDWARE FAILURE
HOPALIGNFL	F	OPERATOR FAILS TO ALIGN CORE SPRAY FROM CST
NOCSTWATER	S	LOCA EVENT CAUSES DEPLETION OF CST
NOSBO	S	NO SBO CONDITION EXISTS
TSSRWSFL	S	LOSS OF STATION SERVICE WATER SYSTEM
VRBCCWFL	S	LOSS OF RBCCW SYSTEM
YESSBO	S	SBO CONDITION EXISTS
YNPBU2FL	S	NO 4KV AC POWER FROM BUS 2
YNPBU7FL	S	NO 480V AC POWER FROM MCC'S 7B AND 7C (ASSOC; W/ 4KV BUS 2)
YNPBU8FL	F	NO 480V AC POWER FROM BUS 8 (SI)
YNPBU9FL	S	NO 480V AC POWER FROM BUS 9 (SII)
ZNPDC1FL	F	NO 125V DC POWER FROM DISTR. PANEL DC-1 (DI)
ZNPDC2FL	S	NO 125V DC POWER FROM DISTR. PANEL DC-2 (DII)

Split Fraction: AICRBS

SF Name	SF Value	Split Fraction Description
AICRBS	1.1536E-02	ALTERNATE CORE COOLING SYSTEM; CONDENSATE TRANSFER AVAIL. WITH CRD FAILED INJECTION

Split Fraction AICRBS Boundary Conditions

Basic Event	State	Basic Event Description
CORESPAVAIL	F	CORE SPRAY SUPPORT SYSTEMS NOT AVAILABLE
HALTCOOLINGFL	F	FAILURE OF ALTERNATE COOLING MODE
HCONDFLOWFL	S	LPCI AND CORE SPRAY FAIL TO DELIVER CONDENSATE TRANSFER FLOW TO
NOCSTWATER	S	LOCA EVENT CAUSES DEPLETION OF CST
NOSBO	S	NO SBO CONDITION EXISTS
TSSRWSFL	F	LOSS OF STATION SERVICE WATER SYSTEM
VRBCCWFL	F	LOSS OF RBCCW SYSTEM
XNSIASFL	F	LOSS OF PLANT INSTRUMENT AIR
YESSBO	S	SBO CONDITION EXISTS
YNPBU1FL	F	NO 4KV AC POWER FROM BUS 1
YNPBU2FL	S	NO 4KV AC POWER FROM BUS 2
YNPBU7FL	S	NO 480V AC POWER FROM MCC'S 7B AND 7C (ASSOC; W/ 4KV BUS 2)
YNPBU8FL	F	NO 480V AC POWER FROM BUS 8 (SI)
YNPBU9FL	F	NO 480V AC POWER FROM BUS 9 (SII)
YNPVACFL	F	NO 120V AC POWER FROM THE UNINTERRUPTIBLE VITAL AC DIST PANE
ZNPDC1FL	F	NO 125V DC POWER FROM DISTR. PANEL DC-1 (DI)

Split Fraction: AICTAF

SF Name	SF Value	Split Fraction Description
AICTAF	8.9461E-03	ALT CORE CLG; CTS (BUS2 FAILED) & CRD 'A' FAILED (AC4 OR D2 FAILED)

Split Fraction AICTAF Boundary Conditions

Basic Event	State	Basic Event Description
CORESPAVAIL	F	CORE SPRAY SUPPORT SYSTEMS NOT AVAILABLE
HALTCOOLINGFL	S	FAILURE OF ALTERNATE COOLING MODE
HCONDFLOWFL	S	LPCI AND CORE SPRAY FAIL TO DELIVER CONDENSATE TRANSFER FLOW
HCSHARDWAREFL	S	CORE SPRAY HARDWARE FAILURE
HOPALIGNFL	F	OPERATOR FAILS TO ALIGN CORE SPRAY FROM CST
NOCSTWATER	S	LOCA EVENT CAUSES DEPLETION OF CST
NOSBO	S	NO SBO CONDITION EXISTS
TSSRWSFL	S	LOSS OF STATION SERVICE WATER SYSTEM
VRBCCWFL	S	LOSS OF RBCCW SYSTEM
YESSBO	S	SBO CONDITION EXISTS
YNPBU1FL	F	NO 4KV AC POWER FROM BUS 1
YNPBU2FL	F	NO 4KV AC POWER FROM BUS 2
YNPBU7FL	F	NO 480V AC POWER FROM MCC'S 7B AND 7C (ASSOC; W/ 4KV BUS 2)
YNPBU8FL	S	NO 480V AC POWER FROM BUS 8 (SI)
YNPBU9FL	F	NO 480V AC POWER FROM BUS 9 (SII)
ZNPDC1FL	S	NO 125V DC POWER FROM DISTR. PANEL DC-1 (DI)

Split Fraction: AICTBF

SF Name	SF Value	Split Fraction Description
AICTBF	8.9461E-03	ALT CORE CLG; CTS (BUS2 FAILED) & CRD 'B' FAILED (AC3 OR D1 FAILED)

Split Fraction AICTBF Boundary Conditions

Basic Event	State	Basic Event Description
CORESPAVAIL	F	CORE SPRAY SUPPORT SYSTEMS NOT AVAILABLE
HALTCOOLINGFL	S	FAILURE OF ALTERNATE COOLING MODE
HCONDFLOWFL	S	LPCI AND CORE SPRAY FAIL TO DELIVER CONDENSATE TRANSFER FLOW TO
HCSHARDWAREFL	S	CORE SPRAY HARDWARE FAILURE
HOPALIGNFL	F	OPERATOR FAILS TO ALIGN CORE SPRAY FROM CST
NOCSTWATER	S	LOCA EVENT CAUSES DEPLETION OF CST
NOSBO	S	NO SBO CONDITION EXISTS
TSSRWSFL	S	LOSS OF STATION SERVICE WATER SYSTEM
VRBCCWFL	S	LOSS OF RBCCW SYSTEM
YESSBO	S	SBO CONDITION EXISTS
YNPBU1FL	F	NO 4KV AC POWER FROM BUS 1
YNPBU2FL	F	NO 4KV AC POWER FROM BUS 2
YNPBU7FL	F	NO 480V AC POWER FROM MCC'S 7B AND 7C (ASSOC; W/ 4KV BUS 2)
YNPBU8FL	F	NO 480V AC POWER FROM BUS 8 (SI)
YNPBU9FL	S	NO 480V AC POWER FROM BUS 9 (SII)
ZNPDC1FL	F	NO 125V DC POWER FROM DISTR. PANEL DC-1 (DI)

Split Fraction: AICTBS

SF Name	SF Value	Split Fraction Description
AICTBS	7.3462E-04	ALTERNATE CORE COOLING SYSTEMS; 2 TRAINS OF CRD AVAILABLE, NO CT DUE TO BUS 2 FAILURE) (CRD BASECASE)

Split Fraction AICTBS Boundary Conditions

Basic Event	State	Basic Event Description
CORESPAVAIL	F	CORE SPRAY SUPPORT SYSTEMS NOT AVAILABLE
HALTCOOLINGFL	S	FAILURE OF ALTERNATE COOLING MODE
HCONDFLOWFL	S	LPCI AND CORE SPRAY FAIL TO DELIVER CONDENSATE TRANSFER FLOW TO
HCSHARDWAREFL	S	CORE SPRAY HARDWARE FAILURE
HOPALIGNFL	F	OPERATOR FAILS TO ALIGN CORE SPRAY FROM CST
NOCSTWATER	S	LOCA EVENT CAUSES DEPLETION OF CST
NOSBO	S	NO SBO CONDITION EXISTS
TSSRWSFL	S	LOSS OF STATION SERVICE WATER SYSTEM
VRBCCWFL	S	LOSS OF RBCCW SYSTEM
YESSBO	S	SBO CONDITION EXISTS
YNPBU1FL	S	NO 4KV AC POWER FROM BUS 1
YNPBU2FL	S	NO 4KV AC POWER FROM BUS 2
YNPBU7FL	F	NO 480V AC POWER FROM MCC'S 7B AND 7C (ASSOC; W/ 4KV BUS 2)
YNPBU8FL	S	NO 480V AC POWER FROM BUS 8 (SI)
YNPBU9FL	S	NO 480V AC POWER FROM BUS 9 (SII)
ZNPDC1FL	S	NO 125V DC POWER FROM DISTR. PANEL DC-1 (DI)

Split Fraction: AIFAIL

SF Name	SF Value	Split Fraction Description
AIFAIL	1.0000E+00	ALTERNATE CORE COOLING SYSTEMS; GUARANTEED FAILURE

Split Fraction AIFAIL Boundary Conditions

None.

Split Fraction: AISBO

SF Name	SF Value	Split Fraction Description
AISBO	2.8696E-01	FAILURE OF ALTERNATE INJECTION VIA DIESEL DRIVEN FIRE PUMP AND JOHN DEERE DIESEL GENERATOR

Split Fraction AISBO Boundary Conditions

Basic Event	State	Basic Event Description
JOPFIS02	S	OPERATOR FAILS TO LOCALLY OPERATE BREAKERS FOR ALTERNATE INJECTI
NOSBO	F	NO SBO CONDITION EXISTS
YESSBO	S	SBO CONDITION EXISTS
ZNPDC1FL	S	NO 125V DC POWER FROM DISTR. PANEL DC-1 (DI)
ZNPDC2FL	S	NO 125V DC POWER FROM DISTR. PANEL DC-2 (DII)

Split Fraction: AISUCC

SF Name	SF Value	Split Fraction Description
AISUCC	0.0000E+00	ALTERNATE CORE COOLING SYSTEMS; GUARANTEED SUCCESS

Split Fraction AISUCC Boundary Conditions

None.

Attachment D

Event Tree (TRANSIENT)

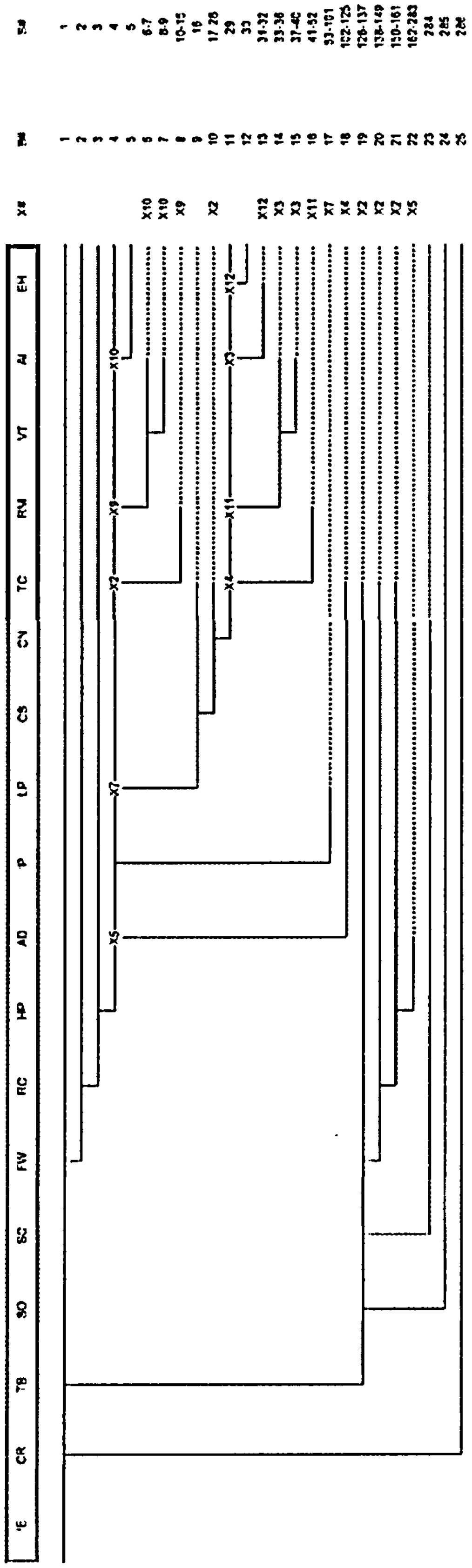

Figure D.1 TRANSIENT Event Tree

TRANSIENT Event Tree – List of Top Events

Top Event Name	Description
CR	CONTROL ROD INJECTION - REACTOR SHUTDOWN
TB	TURBINE BYPASS MODEL
SO	SRVS FAIL TO OPEN ON DEMAND
SC	SRVS FAIL TO CLOSE AFTER SUCCESSFUL OPEN
FW	FEEDWATER SYSTEM
RC	RCIC SYSTEM
HP	HPCI SYSTEM
AD	AUTOMATIC DEPRESSURIZATION SYSTEM (ADS)
IP	PRIMARY CONT. INTEGRITY FOR LEVEL 1 ANALYSIS
LP	LPCI SYSTEM
CS	LOW PRESSURE CORE SPRAY SYSTEM
CN	CONDENSATE SYSTEM
TC	TORUS COOLING SYSTEM
RM	RECOVERY OF MAIN CONDENSER
VT	TORUS HARD-PIPED VENT FOR LEVEL 1 ANALYSIS
AI	ALTERNATE CORE COOLING SYSTEM, CRD, CONDENSATE TRANSFER, CST REFILL, COP
EH	HPCI AND RCIC UNAVAILABILITY DURING SBO EVENT

Initiators:

T	(General Transient)
TMS	(Transient initiated with MSIV closure)
TFWMS	(Transient initiated with MSIV closure and loss of FW)
TPCLP	(Transient initiated with plant-centered LOSP)
TGRLP	(Transient initiated with grid-related LOSP)
TA3	(Transient initiated with loss of Bus 3)
TA4	(Transient initiated with loss of Bus 4)
TD1	(Transient initiated with loss of DC-1)
TD2	(Transient initiated with loss of DC-2)
TSW	(Transient initiated with loss of Service Water)

Modified Endstate Binning Rules – TRANSIENT

CONFIG#1 (model VYCOP2A)

Bin ID	**Rule**
ID	(CN=F)*(AI=F)+(VT=B)*(AI=F)*(-(TC=S))

Sequences with loss of all injection. Core damage occurs with the reactor at low pressure.

CONFIG#2 (model VYCOP2)

Bin ID	**Rule**
ID	(CN=F) * (AI=F) + (VT=B) * (AI=F) * (-(TC=S)) + (((RM=S) * (AI=F) * (TC=F)) + ((TC=S) * (RM=F))) * (IP=F) * ((LP=S) + (CS=S))

Sequences with loss of all injection. These sequences fail after successful depressurization using ADS. For sequences where LPCI and Core Spray are initially available, injection failure will occur due to inadequate NPSH if containment isolation is unsuccessful (IP=F). Core damage occurs with the reactor at low pressure.

Top Event: CR – Control Rod Insertion

CR General Notes: None.

CR Split Fraction Rules:

CRBASE 1

CR is considered to be independent of all other systems, hence the base case split fraction is used for all cases, i.e., CR has no support systems.

Top Event: TB – Turbine Bypass/Main Condenser

TB General Notes:

Support system failures for top event TB (Turbine Bypass & Main Condenser) are as follows:

Support System Failure	Impact on TB
4kV Bus 1 (O1)	TB/MC fail (failure of auxiliary oil pump, one circulating water pump, and steam packing exhauster)
4kV Bus 2 (O2)	TB/MC fail (failure of CST emergency makeup to main condenser (MOV-64-31), two circulating water pumps, all three circulating water booster pumps, and vacuum priming pump)
Instru. Air (IG)	TB/MC fail (SJAE assumed to fail)
120V Vital Bus (VC) and 120V Instru. Bus (IC)	TB/MC fail (SJAE assumed to fail)
Service Water (SW	TB/MC fail (failure of pump cooling for circulating water pumps)

The following transient initiators impact TB (Turbine Bypass & Main Condenser):

Initiator	Impact
TMS	TB/MC fail (MSIV closure)
TFWMS	TB/MC fail (MSIV closure is assumed to occur for loss of FW initiator)
TPCLP	TB/MC fail (loss of power to 4KV Buses 1 and 2)
TGRLP	TB/MC fail (loss of power to 4KV Buses 1 and 2)
TSW	TB/MC fail (see SW impact above)
TD1	TB/MC fail (loss of AC-1 (Bus 1) breaker control power)
TD2	TB/MC fail (loss of AC-2 (Bus 2) breaker control power)

TB Split Fraction Rules:

TBFAIL (INIT=TMS) + (INIT=TFWMS) +
(-O1=S) + (-O2=S) + (SW=F) + (-IG=S) + ((-IC=S) * (-VC=S))

Note that the rule -O1=S covers initiator TD1 (similarly for -O2=S and initiator TD2).

TBBASE 1

We assume that TB has all support systems available for other transient initiators and support system combinations. Note that we use TBBASE even when TB is degraded by the failure of IC alone or VC alone (TBFAIL is used when both IC and VC fail).

Top Event: SO – Safety/Relief Valves Open

SO General Notes:

- SO models opening of the SRVs/SVs for the pressure relief function.

SO Split Fraction Rules:

SOBASE 1

SRV/SV opening to satisfy the pressure relief function has no support systems.

Top Event: SC – Safety/Relief Valves Close

SC General Notes:

- Given the demand to open the SRVs/SVs in top event SO, top event SC models the failure probability of the SRVs/SVs to close.

SC Split Fraction Rules:

SCBASE 1

SRV closing after successful pressure relief function has no support systems.

Top Event: FW – Feedwater System (high pressure injection)

FW General Notes:

- Top event FW in the Transient Event Tree is the same as top event FW in the Medium and Small LOCA event trees with the following exceptions:
  1. FW is guaranteed failure for transient initiators TFWMS, TLP, TD1, TD2, TSW (SW failure leads to TW failure which, is assumed to fail Feedwater pump cooling).
  2. FW success does not require a hotwell makeup source of water for transients events where TB is available.

The support system impacts assumed for FW are:

Support System Failure	Impact of Feedwater
4kV Bus 1 (O1)	FW fails, FW pumps A & B fail, aux. oil pump for pump C fails, Cond. pump A fails.
4kV Bus 2 (O2)	FW fails, FW pump C fails, Cond. pumps B & C fail, also fails hotwell emergency makeup valve MOV 64-31.
125V DC-1 (D1)	FW fails, loss of Bus 1 (O1).
125V DC-2 (D2)	FW fails, loss of Bus 2 (O2).
120V Vital Bus (VC)	FW fails, loss of power to FW reg. valves, including low flow valve.
120V Instru. Bus (IC)	FW fails, loss of pumps A,B,C.
Instru. Air (IG)	FW fails, loss of air to FW reg. valves, including low flow valve.
TBCCW (TW)	FW fails, loss of cooling for FW and Cond. pumps A,B,C.

FW Split Fraction Rules:

FWFAIL (-O1=S) + (-O2=S) + (-VC=S) + (-IC=S) + (-IG=S) + (-TW=S) + (INIT=TFWMS)

Refer to the FWFAIL rule developed for the Medium LOCA event tree.

FWTBBS (-TB=S) + (INIT=TMS)

When FW is not guaranteed failure by the FWFAIL rule, then the FW split fraction depends on whether TB is failed. When TB fails (-TB=S or INIT=TMS), then the FWTBBS split fraction is used. Because TB succeeds for all other cases, the FWBASE split fraction (below) is used.

FWBASE 1

Top Event: RC – Reactor Core Isolation Cooling

RC General Notes:

- The Top events RC/HP in the TRANSIENT event tree are modeled as a common-cause failure group. Because RC is asked before HP in the transient tree, RC is always evaluated independent of HP. We also assume that RCIC must be manually initiated and controlled and there is no credit for automatic initiation on low RPV level or high drywell pressure signals. For Plant-Centered Loss of Offsite Power transients (INIT=TPCLP) where offsite power is recovered in 4 hours (RO=S), we credit the potential for recovering the AC power supply to the battery chargers. Thus, RC failure due to battery depletion requires that A4 fail (A4=F) and that A4 is not recovered (-A4R). For Grid-Related Loss of Offsite Power transients (INIT=TGRLP), the potential for recovering AC power supply via the Vernon Tie (A9R) is instead evaluated. Also, we note that although the RCIC fault tree model and split fraction values include "failure of auto suction transfer from CST to torus" as a failure mode, the contents/volume of the CST is not challenged (suction transfer judged not needed according to MAAP analyses) and this failure mode is thus a slightly conservative aspect of the fault tree and event tree models.

The support system impacts for RC are:

Support System Failure	Impact on RCIC
125V DC-2 (D2)	RC fails (no MOV motive power, etc.)
120V Vital Bus (VC)	RC fails (loss of flow controller power)
24V ECCS Division B (V2)	Failure of the automatic function to transfer suction from the CST to the suppression pool (requires manual operator action for success)

Note that there are no other auto signal requirements for RC since we assume that the operator must manually initiate the system. The operator action for initiation and control of HPCI and RCIC is also assumed to be a completely dependent action.

RC Split Fraction Rules:

RCFAIL **(D2=F) + ((-C2=S)*(-A9R)) + ((A4=F) * (-A4R)*(-A9R)) + (-VC=S)**

RC is guaranteed failure when DC-2 fails. RC also fails if the battery charger fails (long term DC power, top event C2), or if AC power for the chargers is not recovered (A9R), or if A4 fails and is not recovered (A4R and A9R). Failure of the 120V Vital Bus (VC) will also fail RCIC.

RCV2F **(-V2=S)**

This split fraction is used if the 24vdc ECCS Division B power supply is failed, preventing automatic transfer of RCIC suction from the normal source (CST) to its alternate source (suppression pool).

RCBASE **1**

Top Event: HP – High Pressure Coolant Injection

HP General Notes:

- In the TRANSIENT event tree, HPCI is evaluated dependent on RCIC. HPCI has only two support systems, 125V DC-1 and 120V Vital Bus. We also assume that HPCI must be manually initiated and controlled and there is no credit for automatic initiation on low RPV level or high drywell pressure signals. For Plant-Centered Loss of Offsite Power transients (INIT=TPCLP) where offsite power is recovered in 4 hours (RO=S), we credit the potential for recovering the AC power supply to the battery chargers. Thus, RC failure due to battery depletion requires that A4 fail (A3=F) and that A3 is not recovered (-A3R). For Grid-Related Loss of Offsite Power transients (INIT=TGRLP), the potential for recovering AC power supply via the Vernon Tie (A8R) is instead evaluated. Also, we note that although the HPCI fault tree model and split fraction values include "failure of auto suction transfer from CST to torus" as a failure mode, the contents/volume of the CST is not challenged (suction transfer judged not needed according to MAAP analyses, refer to Transient rule descriptions) and this failure mode is thus a slightly conservative aspect of the fault tree and event tree models.

Support system failure impact on HPCI is as follows:

Support System Failure	Impact on HPCI
DC-1 fails	HPCI fails
120v Vital AC fails	HPCI auto suction transfer from CST to torus fails (requires manual operator action for HP success)

HP Split Fraction Rules:

HPFAIL (D1=F) + ((-C1=S)*(-A8R)) + ((A3=F) * (-A3R)*(-A8R))

HP is guaranteed failure when DC-1 fails. HP also fails if the battery charger fails (long term DC power, top event C1), or if AC power for the chargers is not recovered (A8R), A3 fails and is not recovered (A3R and A8R).

HPVCF (-VC=S)

This split fraction is used if the 120v Vital AC power supply is failed, preventing automatic low-level transfer of HPCI suction from the normal source (CST) to its alternate source (suppression pool).

HPBASE (D2=F) + (-C2=S) + ((A4=F) * (-A4R))

These split fraction rules for HPVCF and HPBASE cover cases where RC is bypassed and HP is asked independent of RC. Note that the event tree structure never asks HP if RC=B, hence there is no RC=B rule. HP is independent of RC only when RC is guaranteed to fail by support system failures. This only occurs when (-VC=S) which degrades HP (split fraction HPVCF), or when (D2, C2 or A4 fail) which has no impact on HP (split fraction HPBASE).

HPRCF2 (RC=F) * (-V2=S)

HPRCF1 (RC=F)

These split fraction rules for HPRCF2 and HPRCF1 cover the cases where HP is asked dependent on RC. Note that there are no rules for RC=S since HP is bypassed in the event tree structure when RC=S.

HPFAIL 1

If none of the above rules apply, the HPFAIL rule will ensure a conservative result and assist in checking the validity of the results.

Top Event: AD – RPV Depressurization

AD General Notes:

- AD models manual depressurization of the RPV via the SRVs (discharging to the suppression pool) as a means of reducing RPV pressure to allow injection of low pressure systems. We assume that AD requires long-term operation of the SRVs, hence we require success of the containment gas nitrogen supply (top event CG). The only other support systems for AD are 125V DC-1 and DC-2. Given the system design, failure of both DC power sources is required to fail the depressurization function (fail all SRVs). DC-2 supplies the "normal" control power to each SRV solenoid valve. Upon failure of DC-2, control power to each solenoid valve will automatically transfer to DC-1 via de-energized relay K11A, B, C and D.

AD Split Fraction Rules:

ADFAIL (-CG=S) + ((D1=F) * (D2=F))

AD is guaranteed to fail when CG fails or when both DC-1 and DC-2 fail.

ADSDA (D1=F)

ADSDB (D2=F)

Split fraction ADSDA(B) applies the operator action HEP associated with RPV depressurization during Small LOCA events when Division 1 (2) of DC power has failed.

ADSBS 1

Split fraction ADSBS applies the operator action HEP associated with RPV depressurization during Small LOCA events when all support systems are available.

Top Event: IP – Primary Containment Integrity

IP General Notes:

- Top event IP is asked in order to establish whether the containment is intact when the hard-piped vent from torus air space is used to prevent over-pressurization (VT=S). Integrity of containment is a necessary condition in order for the operator to control and maintain sufficient pressure in the containment in support of continued operation of LPCI or Core Spray pumps taking suction from the suppression pool at elevated temperature.
- Failure of containment integrity is defined to include failures in the containment boundary that allow leakage in excess of that which would prevent maintaining overpressure sufficient to satisfy the NPSH-r or the LPCI and Core Spray pumps at elevated suppression pool temperature. The leakage sources are divided into two principal categories:
    - Isolation valve failures: These are related to the failure of the isolation valves in containment penetration lines or failure of the isolation signals or power to close these valves.
    - Pre-existing failures: These are failures primarily related to hatches, electrical penetration assemblies (EPAs), and other containment leakage paths not associated with failure of isolation valves to close.

IP Split Fraction Rules

IPIG (IG=F)+((VC=F)*(IC=F))

This split fraction is used when both the "inboard" and "outboard" isolation valves fail due to support system failures.

The "inboard" and "outboard" valves for the PCAC system require instrument air (IG) for normal operation.

The isolation valves will fail CLOSED on interruption of air supply pressure. The "inboard" isolation valves are dependent on Vital Bus (VC) 120vac, and the "outboard" isolation valves are dependent on Instrument Bus (IC) 120vac. These isolation valves will fail CLOSED on loss of control power.

Inboard torus-to-RB vacuum breaker SB-16-19-11A requires Vital Bus (VC), while the SB-16-19-11B vacuum breaker requires Instrument Bus (IC). These valves will fail OPEN on loss of air pressure or electric power. Note that the outboard torus-to-RB swing-check valves are in-series with the air-operated vacuum breakers, hence failure of the air-operated vacuum breakers to close does not necessarily cause failure of containment isolation.

IPVAC (VC=F)

This split fraction is used when torus-to-RB vacuum breaker SB-16-19-11A fails due to failure of the Vital Bus (VC) 120vac power supply. Note that the outboard torus-to-drywell swing-check valve is in-series with the air-operated vacuum breakers, hence failure of the air-operated

IPIAC (IC=F)

This split fraction is used when torus-to-RB vacuum breaker SB-16-19-11B fails due to failure of the Instrument Bus (IC) 120vac power supply. Note that the outboard torus-to-drywell swing-check valve is in-series with the air-operated vacuum breakers, hence failure of the air-operated

IPBASE **1**

No other support system failures affect the containment isolation system. Thus, the base case (all support systems available) split fraction applies to all sequences not captured by one of the previous rules.

Top Event: LP – Low Pressure Coolant Injection

LP General Notes:

- LP independent split fraction rules are the same as those used in the Medium/Small LOCA trees.
- the min. flow valve in each LPCI loop (MOV-16A/16B) is maintained normally open and success of the LPCI loop does not depend on successful closure of the associated min. flow valve. Therefore, we assume LPCI success does not depend on the min. flow valve hardware or the associated power supply.

Support System	Impacts on LP
125V DC-I (D1) fails	RHR Pumps C and D fail; degraded injection valve ECCS signal.
125V DC-2 (D2) fails	RHR Pumps A and B fail; degraded injection valve ECCS signal.
4kV Bus 3 (A3) fails	RHR Pumps C and D fail; injection valve ECCS signal not degraded.
4kV Bus 4 (A4) fails	RHR Pumps A and B fail; injection valve ECCS signal not degraded.
RRU7 (R7) fails	No impact assumed based on room heatup assessment.
RRU8 (R8) fails	No impact assumed based on room heatup assessment.
SW fails	No impact assumed based on room heatup assessment. Also, RHR pump seal and bearing cooling via SW/RBCCW assumed not needed for injection mode.
RBCCW (RW) fails	No impact; RHR pump seal and bearing cooling via RBCCW assumed not needed for the injection mode function.
ECCS Signal (SIG) fails	Failure of the ECCS signal and failure to manually initiate low pressure pumps are assumed to cause failure of LPCI (and CS). Failure of the signal and manual backup action is handled in the SIGF rule.

LP Split Fraction Rules:

SIGF: (-PI=S) + ((-DW=S) *((-LV=S) + (-PS=S))) * (-OI=S)

This is the Marco rule for developing the failure logic if the ECCS signal. The SIGF macro is used below in the rules for LPCI and later for Core Spray. The ECCS signal is made up of a combination of low pressure interlock (PI), drywell high pressure (DW), low reactor level (LV), low reactor pressure (PS). The operator (OI) can also fail to "backup" a failed signal provided that the signal did not fail due to PI.

LPFAIL (SIGF) + ((D1=F) + (A3=F)) * ((D2=F) + (A4=F))

All of LPCI is guaranteed to fail when the ECCS signal fails or all support systems fail.

LP2VA	(D1=F)
LP2VB	(D2=F)

LPCI configuration will be 2 pump failure with degraded LPCI injection valve logic given DC-1 or DC-2 failure.

LP2FA	(A3=F)
LP2FB	(A4=F)

LPCI configuration will be 2 pump failure without degraded LPCI injection valve logic given failure of 4KV AC Bus 3 (LP2FA) or AC Bus 4 (LP2FB) failure.

LPBASE	(-SIGF) * (D1=S) * (A3=S) * (D2=S) * (A4=S)

LPCI base case reliability is applied when all support systems are successful and the SIGF has not failed.

LPFAIL	1

If none of the above rules apply, the LPFAIL rule will ensure a conservative result and assist in checking the validity of the results.

Top Event: CS – Core Spray

CS General Notes:

- The min. flow valve in each CS loop (MOV-5A/5B) is maintained normally open and success of the CS loop does not depend on successful closure of the associated min. flow valve. Therefore, we assume CS success does not depend on the min. flow valve hardware or the associated power supply.

Support System	Impacts on CS
125V DC-I (D1) fails	CS Loop B fails - Pump B and MOV-11B/12B.
125V DC-2 (D2) fails	CS Loop A fails - Pump A and MOV-11A/12A.
4kV Bus 3 (A3) fails	CS Loop B fails - Pump B and MOV-11B/12B.
4kV Bus 4 (A4) fails	CS Loop A fails - Pump A and MOV-11A/12A.
RRU7 (R7) fails	No impact assumed based on room heatup assessment.
RRU8 (R8) fails	No impact assumed based on room heatup assessment.
SW/RW fail	No impact on Core Spray.
ECCS Signal (SIG) fails	Assumed to cause failure of CS for large break LOCA event (*).

(*) Refer to top event LP above for summary of the SIGF rule.

CS Split Fraction Rules:

CSFAIL (SIGF) + ((D1=F) + (A3=F)) * ((D2=F) + (A4=F))

Both divisions of CS are guaranteed to fail when the ECCS signal fails or all support systems fail.

CSA4F ((A4=F) + (D2=F)) * ((A3=S) * (D1=S))

This is a train-specific split fraction, which applies the reliability of CS division B when AC Bus 4 or DC Bus 2 fail, but AC Bus 3 and DC Bus 1 are success.

CSA3F ((A3=F) + (D1=F)) * ((A4=S) * (D2=S))

This is a train-specific split fraction, which applies the reliability of CS Division A when AC Bus 3 or DC Bus 1 fail, but AC Bus 4 and DC Bus 2 are both success.

CSBASE 1

CS base case reliability is applied when the above rules are not satisfied.

Top Event: CN – Condensate System (low pressure injection)

CN General Notes:

None.

Support System Failure	Impact of CN
4kV Bus 1 (O1)	CN Pump A fails
4kV Bus 2 (O2)	CN Pumps B & C fail, also fails hotwell emergency makeup valve MOV 64-31)
125V DC-2 (D2)	CN fails (O2 failure)
120V Vital Bus (VC)	CN fails (no power to FW reg. valves)
Instru. Air (IG)	CN fails (no air to FW reg. valves)
TBCCW (TW)	CN fails (no pump motor cooling)

CN Split Fraction Rules:

CNFAIL (-O2=S) + (-VC=S) + (-IG=S) + (-TW=S) + (INIT=TPCLP) + (INIT=TGRLP) + (INIT=TFWMS) + (INIT=TSW)

This rule for the transient tree also includes CN failure due to initiators TFWMS. We assume that the TFWMS initiator causes loss of both FW and CN.

CN is asked independent of FW when FW is bypassed by the event tree structure or when FW is guaranteed failure by support system failures. This occurs only when (FW=B) or (-O1=S) or (-IC=S). Failure of 4kV Bus 1 (-O1=S) degrades the CN model. Thus we have the following two split fraction case, CN1F and CNBASE. These rules apply when CN is not already failed (see CNFAIL) and is asked independently of FW.

CN1F (-O1=S)

Condensate system is degraded (one pump fails) when 4KV Bus 1 fails.

CNBASE (-IC=S)

The transient event tree structure asks CN only after FW=F. Thus, CN is independent of FW only when FW is guaranteed failure by support system failures. The only support system failures that fail FW and not CN are -O1=S (Bus 1 fails, which degrades CN, split fraction CN1F) and -IC=S (Instrument Bus fails FW but does not degrade CN, split fraction CNBASE).

All other cases involve FW=F (CN is only asked after FW=F) with CN dependent on FW. All support systems for FW and CN have been accounted for by previous rules except for TB. The next two rules below (CNFWF1 and CNFWF2) apply to cases where CN is dependent on FW and TB is either failed (CNFWF1) or is success (CNFWF2).

CNFWF1 (FW=F) * ((-TB=S) + (INIT=TMS))

Condensate System fails given Feedwater fails (TBCCW unavailable).

CNFWF2 (FW=F) * (TB=S)

Condensate System fails given Feedwater fails (TBCCW available).

CNFAIL 1

If none of the above rules apply, the CNFAIL rule will ensure a conservative result and assist in checking the validity of the results.

Top Event: TC – Torus Cooling

General Notes:

- In general, Torus Cooling (top event TC) is dependent on Low Pressure Coolant Injection (top event LP) due to shared RHR equipment. The impact of single support system failures on TC are as follows:

Support System Failure	Impact on Torus Cooling
125V DC-I (D1) fails	RHR Pumps C & D fail; RHRSW Pumps B & D fail; TC Loop B MOVs fail.
125V DC-2 (D2) fails	RHR Pumps A & B fail; RHRSW Pumps A & C fail; TC Loop A MOVs fail.
4kV Bus 3 (A3) fails	RHR Pumps C & D fail; RHRSW Pumps B & D fail; TC Loop B MOVs fail.
4kV Bus 4 (A4) fails	RHR Pumps A & B fail; RHRSW Pumps A & C fail; TC Loop A MOVs fail.
RRU7 (R7) fails	No impact on equipment is assumed based on room heatup assessment.
RRU8 (R8) fails	No impact on equipment is assumed based on room heatup assessment.
SW fails	RHR Pumps A, C & B, D fail due to loss of seal and bearing injection water cooling (assumed needed for long term TC mode), RHRSW Pumps A, C & B, D fail due loss of service water suction.
ECCS Signal (SIG) fails	No impact on TC function is assumed.

TC Split Fraction Rules:

TCFAIL ((SW=F) * (-AW=S)) + ((D1=F) + (A3=F)) * ((D2=F) + (A4=F))

This rule captures all cases for which support system failures will fail both trains of TC. Note that we credit AW (which considers recovery of service water and use of the Alternate Cooling Mode) as a backup to SW in top event TC for Transient events.

TC3FA ((LP=B)+(SIGF))*((D1=F)+(A3=F))

TC3FB ((LP=B)+(SIGF))*((D2=F)+(A4=F))

Single loop TC with 2 RHRSW pump and 1 RHR pump available, D1(D2) or A3(A4) unavailable.

TCBASE ((LP=B) + (SIGF))

TC split fractions TC3FA(B) and TCBASE evaluate TC independent of LP. The LPFAIL rule (see top event LP) defines the cases where LP is guaranteed to fail by support system failures. Some of the same support system combinations that fail LP also fail TC and are accounted for in the TCFAIL rule. The only support system failure which appears in the LPFAIL rule and does not guarantee failure of TC is SIGF. Because SIGF guarantees failure of LP, TC is being evaluated independent of LP for these cases. LP can also be "bypassed" in the Small LOCA event tree because other injection systems can satisfy the RPV inventory function, consequently TC must still be evaluated (independently). Therefore, we have also included the (LP=B) portion of the rule. The above rules for TC3FA(B), and TCBASE capture these cases.

Note: If TC3FA(B) and TCBASE split fractions do not apply, TC must be evaluated "dependent" upon the success or failure of LP. The following "dependent" LP/TC split fractions were developed to cover the various support system states given LP success /failure.

TCLS7A (LP=S)*(D1=F)

TCLS7B (LP=S)*(D2=F)

TC failure given LP success when either D1 (TCLS7A) or D2 (TCLS7B) has failed.

TCLS6A (LP=S)*((A3=F))

TCLS6B (LP=S)*((A4=F))

TC failure given LP success when either A3 (TCLS6A) or A4 (TCLS6B) has failed.

TCLPS5 (LP=S)

TC failure given LP success when all support systems are available/successful.

TCLF7A (LP=F)*((D1=F))

TCLF7B (LP=F)*((D2=F))

TC failure given LP failure when either D1 (TCLF7A) or D2 (TCLF7B) has failed.

TCLF6A (LP=F)*((A3=F))

TCLF6B (LP=F)*((A4=F))

TC failure given LP failure when either A4 (TCLF6A) or A3 (TCLF6A) has failed.

TCLPF5 (LP=F)

TC failure given LP failure when all support systems are available/successful.

TCFAIL 1

If none of the above rules apply, the TCFAIL rule will ensure a conservative result and assist in checking the validity of the results.

Top Event: RM – Recover Main Condenser

RM General Notes:

- For Transient events, we credit recovery of the main condenser providing that all support systems are success. The support system failures for top event TB (Turbine Bypass & Main Condenser) are assumed as follows:

Support System Failure	Impact on TB/Main Condenser
4kV Bus 1 (O1)	TB/MC fail (failure of auxiliary oil pump, one circulating water pump, and steam packing exhauster)
4kV Bus 2 (O2)	TB/MC fail (failure of CST emergency makeup to main condenser (MOV-64-31), two circulating water pumps, all three circulating water booster pumps, and vacuum priming pump)
120V Vital Bus (VC)	TB/MC fail (SJAE assumed to fail)
120V Instru. Bus (IC)	TB/MC fail (SJAE assumed to fail)
Instru. Air (IG)	TB/MC fail (SJAE assumed to fail)
Service Water (SW)	TB/MC fail (failure of pump cooling for circulating water pumps)

RM Split Fraction Rules:

RMBASE (((O1=S) * (O2=S)) + (O1R * O2R)) * (SW=S) * (IG=S) * ((IC=S) + (VC=S))

The base case split fraction (RMBASE) is used whenever all support systems for the main condenser are available. , For AC power, we require that either O1 and O2 are available (O1=S * O2=S), or that both O1 and O2 are recovered (O1R * O2R). We credit recovery of offsite power for RM because > 4 hours exists to establish heat removal with the main condenser before containment is threatened by overpressure, and before suppression pool temperature increase would threaten continued operation of LP/CS pumps.

RMFAIL 1

Recovery of the main condenser is assumed to fail for all remaining cases (RMFAIL) because one or more support systems are unavailable. Also, if the RMBASE rule does not apply, the RMFAIL rule will ensure a conservative result and assist in checking the validity of the results.

Top Event: VT – Torus Vent (hard-piped vent from torus air space)

VT General Notes:

- Torus vent valve (TVS-86) is "normally" closed and requires manual action to open the valve and enable the use of the venting path with rupture disc. For transients, we assume that the valve can be operated remotely from the control room if 480V MCC-7A (associated w/ 4kV Bus 2) is available, or the valve can be operated locally. Local operation is assumed possible because there is sufficient time before the vent path would be needed (12 to 24 hours). Also, because of the potential for a harsh environment is remote, the Reactor Building is assumed to remain habitable to perform the local operation.

VT Split Fraction Rules:

VTTRBS 1

Local manual operation of the vent valve is assumed, therefore no AC power support systems are necessary for success and the VTTRBS (Vent-Torus-Transient-Base-Case) split fraction is assigned for transients.

Top Event: AI – Alternate Injection (Long Term Injection)

AI General Notes:

Top event AI is asked after containment heat removal, top events TC, RM and VT, in order to establish the availability of "alternate" injection. "Alternate" injection may be required because:

1. Other injection systems have failed earlier in the event tree (i.e. for SBO sequences or when AD=F), or

2. Systems which have succeeded earlier are jeopardized by high suppression pool temperature when TC=F.

Among the injection systems (for non-SBO sequences) credited for AI are FW/HP/RC/CN all with suction from the CST (if such systems had succeeded earlier), LP (if it had succeeded earlier, with bearing/seal cooling provided by RW or AW), CRD , Condensate Transfer (with injection via the LPCI or Core Spray injection lines), and using the diesel-driven fire pump via the RHRSW-to-RHR cross-tie (MOVs 183 and 184).

Note that the capacity of some of these systems (CRD, Condensate Transfer) is limited to approximately 100 gpm (each). Because AI is asked "late" (at least several hours after scram), even these "low capacity" injection systems will provide sufficient flow to assure core cooling. Note also that no credit is taken for Core Spray injection with suction directly from the CST.

Finally, note that, with the exception of LP (and the diesel fire pump), all systems credited for AI take suction from the CST. Based on a review of the Level 1 "Success Criteria" runs made with MAAP, we conclude that the normal CST inventory (350,000 gallons, which is 70% of the 500,000 gallon capacity) provides enough inventory to assure core cooling for at least 24 hours after a transient event.

The various sequences where AI is credited are discussed below.

Station Blackout

Station Blackout (SBO) refers to sequences where 4kV Buses 3 and 4 have no power, A3=F and A4=F. We credit RPV injection using the diesel-driven fire pump after 4 hours for SBOs. That is, for SBO sequences, AI success is defined as "RPV injection using the diesel-driven fire pump after four hours". Note that AI=S alone will not assure success of an SBO sequence. For us to bin such sequences to success, we require that "early" RPV injection be accomplished with HPCI or RCIC until the batteries deplete at about four hours (see top event EH).

AI Split Fraction Rules:

AISBO (A3=F) * (A4=F) * (AD=S)

The AISBO split fraction is used whenever A3 and A4 are failed (SBO), but AD succeeds in depressurizing the RPV. This split fraction accounts for hardware failures, as well as for the operator action to align the diesel-driven fire pump for RPV injection (including alignment of the John Deere diesel generator for supplying motive power to the necessary MOVs, including MOVs 183 and 184).

Rules for non-SBO type sequences:

AIFAIL ((AD=S) * (CN=F)) + (AD=F)

For AI to succeed, both RPV depressurization and early injection from a high capacity system (LP, CS, FW or CN) must succeed. CN is only asked if all other early injection sources have failed, therefore CN=F indicates total failure of early injection.

AISUCC (FW=S) + (HP=S) + (RC=S) + (CN=S)

This first part of this rule applies regardless of whether RM=S or VT=S is responsible for accomplishing heat removal, since FW/HP/RC/CN do not take suction from the suppression pool (in the first 24 hours): FW/CN take suction from the Hotwell/CST and HP/RC take suction from the CST. Based on MAAP calculations, we assume that refill of the CST is not necessary for the first 24 hours of transient sequences. Thus, if either FW, HP, RC or CN had succeeded earlier for core cooling, then AI is set to guaranteed success.

AISUCC (RM=S) *((LP=S) + (CS=S))

The second part of the AISUCC rule accounts for sequences where LP/CS has succeeded earlier in the event tree. Note that this rule only applies when RM=S, because of concerns with loss of NPSH for pumps taking suction from the suppression pool when TV=S.

AISBO (AD=S)*(-(RW=S)) *((-O2=S)) + (LP=F) * (CS=F))

AI using the diesel-driven fire pump is examined when the failure of support systems or injection paths for both CRD and CT has occurred. For injection via the diesel-driven to succeed, the RPV must be depressurized and early injection must have succeeded. Note that cases where both ADS and early injection have failed are already captured in the first rule.

AICTAF (((A4=F)+(D2=F))*(RW=S))*((-(O2=S))+((LP=F)*(CS=F)))

AICTBF (((A3=F)+(D1=F))*(RW=S))*((-(O2=S))+((LP=F)*(CS=F)))

AICTAF(BF) is used when only 1 CRD pump is available for alternate injection. It is conservatively assumed that CRD pump operation requires that RBCCW (RW) be available. Only 1 CRD pump is available because <u>either</u> Bus 3 (AICTAF) or Bus 4 (AICTBF) power is success and component cooling via RBCCW is success. CT has failed because Bus 2 is not success or the injection paths via LP and CS have failed.

AICTBS (RW=S)) * ((-O2=S)) + ((LP=F) + (CS=F))

AICTBS is for the configuration of 2 CRD pumps available for alternate injection with no CT pump capability. CT is failed because either 1) failure of LP and CS is assumed to fail the injection paths or 2) power via Bus 2 (O2) is unavailable. Both CRD pumps are available because both 4kV Buses 3 and 4 are available.

AICRBS (((A3=F)*(A4-F)) + (-(RW=S))) * ((O2=S) * ((LP=S) + (CS=S)))

AICRBS is used for configurations where both CT pumps are available but neither of the CRD pumps is available. CT pumps have power from Bus 2 and at least one injection path via LP or CS is available. CRD pumps have failed either from lack of motive power from Bus 3 and Bus 4 or from failure or RBCCW.

AICRAF ((A4=F)+(D2=F))*((O2=S)*((LP=S)+(CS=S)))*(RW=S)

AICRBF ((A3=F)+(D1=F))*((O2=S)*((LP=S)+(CS=S)))*(RW=S)

AICRAF(BF) is used when both CT pumps and only 1 CRD pump are available for alternate injection. Only 1 CRD pump is available because <u>either</u> Bus 3 (AICRAF) or Bus 4 (AICRBF) power is success and component cooling via RBCCW is success (satisfied by the above rule). Both CT pumps are available because support systems are success (Bus 2) and an injection pathway to the RPV via LPCI or Core Spray is success.

AIBASE ((O2=S) * ((LP=S) + (CS=S))) * (RW=S)

AIBASE is used when both CT pumps and both CRD pumps are available for alternate injection. All support systems needed by CRD and CT are success. CT requires the injection pathway to the RPV via LPCI or Core Spray, which is success.

AIFAIL 1

If none of the above rules apply, the AIFAIL rule will ensure a conservative result and assist in checking the validity of the results.

Top Event: EH – Early HPCI/RCIC Injection for SBO

EH General Notes:

Top event EH is evaluated only for Station Blackout (SBO) sequences where 4kV Buses 3 and 4 have failed (A3=F and A4=F), and where ac power is not recovered within 4 hours (-A3R and –A4R). For these sequences, HPCI and RCIC are assumed to be failed (i.e., HPFAIL and RCFAIL split fractions apply; see earlier rules for top events HP and RC) due to the eventual depletion of the batteries at about 4 hours. EH is used to determine whether HP/RC succeed for "early" core cooling (i.e., before the batteries deplete). EH is needed to divide the accident Class 1B (SBO) sequences into "early" SBO (core damage < 4 hours) and "late" SBO (core damage > 4 hours).

The existing HP/RC fault tree models are used to develop split fraction values for EH. The "unique" support system impacts for the HP/RC "merged" model are:

Support System	Failure Impact
125V DC-I fails (D1)	causes failure of HP
125V DC-2 fails (D2)	causes failure of RC
120V AC Vital Bus fails (VC)	fails RC flow controller and requires operator action for HP suction transfer
24V ECCS Battery fails (V2)	requires operator action for RC suction transfer

Although the "mission time" for EH is only 4 hours, we will use the split fraction values already calculated for the HP/RC merged model (which assume a 24 mission time). This is conservative for EH because it overestimates the "failure to run". However, because EH is only needed for 4 hours, we will assume that VC and V2 are not needed for the HP/RC suction transfers (refer to MAAP runs). Thus, we will assume the following unique impacts for EH:

Support System	Failure Impact
D1 fails	fails HP, no impact on RC
D2 or VC fail	fails RC, no impact on HP

The existing split fractions for HP/RC which we use here for EH are:

HPRCBS	HP/RC merged model with all support systems available.
HPBASE	HP model (RC failed) with all HP support systems available.
RCBASE	RC model (HP failed) with all RC support systems available.

We define the following split fractions for EH:

EH Split Fraction	Corresponding HP/RC Split Fraction Value
EHBASE	**HPRCBS**
EHHP	**HPBASE**
EHRC	**RCBASE**
EHFAIL	**PFAIL/RCFAIL**

EH Split Fraction Rules:

EHFAIL (C2=S) * ((A4=S) + (A4R)) * (C1=S) * ((A3=S) + (A3R))

This rule ensures that EH is evaluated only during SBO sequences, i.e. when power to A3 and A4 have failed. EH should not be applied (split fraction value 1.0) to non-SBO sequences, which are identified in this rule when long term DC power is success (C1=S and C2=S), Buses 3 and 4 are success (A3=S and A4=S) or AC power to these buses has been recovered (A4R/A3R). The first half of the rule, (C2=S) * ((A4=S) + (A4R)), checks for non-SBO sequences associated RCIC long term support systems. The second half of the rule, (C1=S) * ((A3=S) + (A3R)), checks for non-SBO sequences associated with HPCI long term support systems.

EHFAIL (D1=F) * ((D2=F) + (-VC=S))

HPCI is guaranteed failure by failure of DI. RCIC is guaranteed failure by failure of either D2 or VC.

EHRC (D1=F) * ((D2=S) * (VC=S))

EHHP ((D2=F) + (-VC=S)) * (D1=S)

EHRC split fraction applies when HPCI is guaranteed failure by support system failures, but RCIC support systems are available. EHHP is used when RCIC is failed by support system failures, but HPCI support systems are available.

EHBASE (D1=S) * (D2=S) * (VC=S)

The EHBASE split fraction is used when all support systems are available for both HPCI and RCIC.

EHFAIL 1

If none of the above rules apply, the EHFAIL rule will ensure a conservative result and assist in checking the validity of the results.

Attachment E

Event Tree (ATWS)

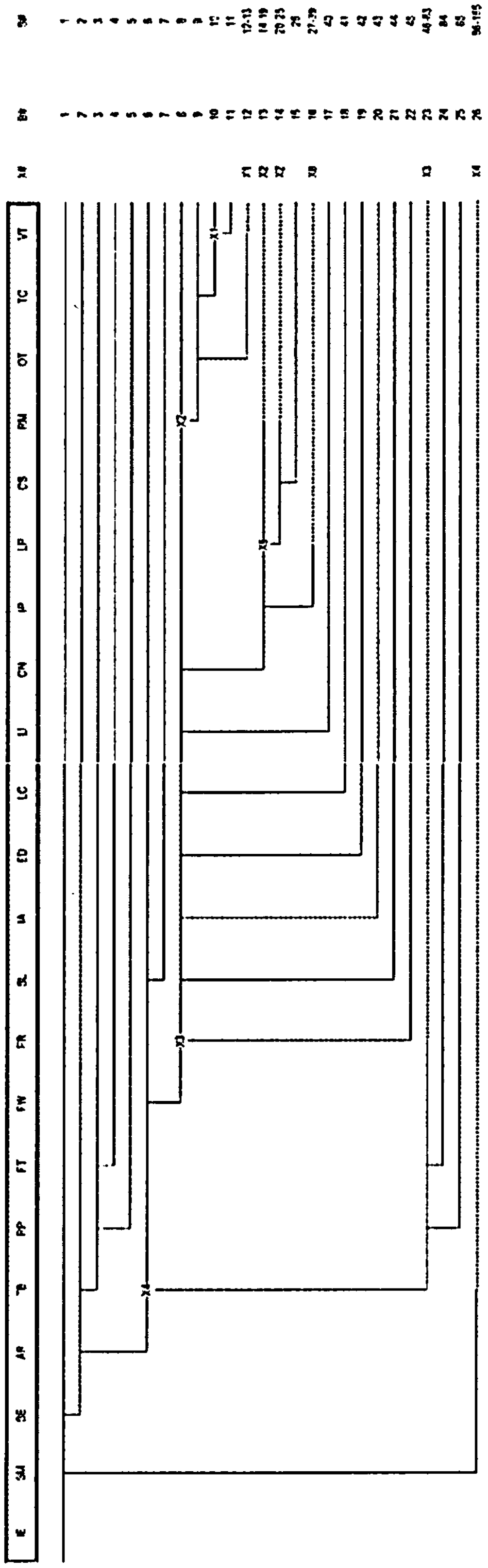

Figure E.1 ATWS Event Tree

Top Event Name	Description
SM	FAILURE TO SCRAM - MECHANICAL FAULT
SE	FAILURE TO SCRAM - ELECTRICAL FAULT
AR	ALTERNATE ROD INJECTION SYSTEM
TB	TURBINE BYPASS MODEL
RP	RPT SYSTEM
FT	FEEDWATER PUMP TRIP LOGIC (USED FOR ATWS MITIGATION)
FW	FEEDWATER SYSTEM
PR	PRESSURE RELIEF SYSTEM - ATWS MITIGATION
SL	STANDBY LIQUID CONTROL SYSTEM (SLC)
IA	INHIBIT ADS DURING ATWS
ED	EMERGENCY DEPRESSURIZATION SYSTEM (USED FOR ATWS MITIGATION)
LC	LEVEL CONTROL DURING ATWS
LI	OPER. ACTION TO STOP INJECTION BEFORE RX DEPRESSURIZATION DURING ATWS
CN	CONDENSATE SYSTEM
LP	LPCI SYSTEM
CS	LOW PRESSURE CORE SPRAY SYSTEM
RM	RECOVERY OF MAIN CONDENSER
OT	OPERATE INITIATES TORUS COOLING DURING ATWS
TC	TORUS COOLING SYSTEM
VT	TORUS HARD-PIPED VENT FOR LEVEL 1 ANALYSIS

Initiators:

☐ A	(ATWS General Transient)
☐ AMS	(ATWS Transient initiated with MSIV closure)
☐ AFWMS	(ATWS Transient initiated with MSIV closure and loss of FW)
☐ APCLP	(ATWS Transient initiated with plant-centered LOSP)
☐ AGRLP	(ATWS Transient initiated with grid-related LOSP)

Modified Endstate Binning Rules – ATWS

CONFIG#1 (model VYCOP2A)

Bin Rule

IC (LI=F)+(CS=F)

ATWS sequences where core damage is caused by loss of injection during level/power control.

IVA (SL=F) + (IA=F) + (ED=F) + (LC=F) + (VT=F) + ((RM=F) * ((OT=F) + (TC=F)))

ATWS sequences where core damage is caused by containment failure.

CONFIG#2 (model VYCOP2)

Bin Rule

IC (LI=F) + (CS=F) + (((LP=S) + (CS=S)) * (IP=F))

ATWS sequences where core damage is caused by loss of injection during level/power control. If initially successful, LPCI and Core Spray are assumed to ultimately fail due to inadequate NPSH resulting from failure to maintain containment overpressure. Loss of containment overpressure will occur if primary containment isolation fails (IP=F).

IVA (SL=F) + (IA=F) + (ED=F) + (LC=F) + (VT=F) + ((RM=F) * ((OT=F) + (TC=F) + (IP=F)))

ATWS sequences where core damage is caused by containment failure. For sequences where RHR is initially available, suppression pool cooling failure will occur due to inadequate NPSH if containment isolation is unsuccessful (IP=F).

Note: The RPS can be divided into two principal parts. These are:

- Scram Electrical (SE): The electrical portion of the RPS involving the logic, signal generation. and relays required to initiate a reactor scram.
- Scram Mechanical (SM): The mechanical portion of reactor scram involving the physical movement of the control rods including: depressurization of the scram air header, alignment of high pressure accumulator water to the under side of the drive pistons, discharge water to the Scram Discharge Volume (SDV), and movement of the control rod.

It is necessary to evaluate SE and SM separately so that the effectiveness of ARI/RPT independent electrical design features can be evaluated as an alternate means of inserting the control rods given that SE has failed but SM is successful.

Top Event: SM – SCRAM – Mechanical Function

SM General Notes:

- SM has no support systems, hence the base case split fraction is used for all ATWS sequences.

SM Split Fraction Rules:

SMBASE 1

Top Event: SE – SCRAM – Electrical Function

SE General Notes:

- SE has no support systems, hence the base case split fraction is used for all ATWS sequences.

SE Split Fraction Rules:

SEBASE **1**

Top Event: AR – Alternate Rod Insertion

AR General Notes:

- The Alternate Rod Insertion (ARI) feature provides an automatic backup to SE (Scram electrical) on either low reactor water level or high reactor pressure signals. We assume that either a low water level or high pressure condition actually exists. The split fraction values for AR (and later top event RP) are the same for low water level and high pressure, hence we do not discriminate between these conditions in the split fraction rules below.

The support system impacts on the ARI instrumentation are as follows:

Support System Failure	Impact on ARI
120V Vital Bus	ARI Logic Channels B & D fail, Channels A & C are OK.
125V DC-1	ARI Logic Channels B & D fail, Channels A & C are OK.
120V Instrument Bus	ARI Logic Channels A & C fail, Channels B & D are OK.
125V DC-2	ARI Logic Channels A & C fail, Channels B & D are OK.

ARI is a one-out-of-two-taken-twice logic. Thus, either Channels A AND C OR Channels B AND D are needed for actuation success.

AR Split Fraction Rules:

ARFAIL ((-VC=S) + (D1=F)) * ((-IC=S) + (D2=F))

ARI is guaranteed to fail whenever a "divisional" power supply fails to both logic divisions.

ARAF (-IC=S) + (D2=F)

ARBF (-VC=S) + (D1=F)

Split fraction ARAF(ARBF) is applied to model degraded ARI logic due to a single logic division failed whenever one of its supporting power supplies fails.

ARBASE 1

If the above rules for ARFAIL and AR1F do not apply, the base case ARI split fraction (fully redundant logics) is applied since all support systems are success.

Top Event: TB – Turbine Bypass, Main Condenser

TB General Notes: None.

Support system failures for top event TB (Turbine Bypass & Main Condenser) are as follows:

Support System Failure	Impact on TB
4kV Bus 1 (O1)	TB/MC fail (failure of auxiliary oil pump, one circulating water pump, and steam packing exhauster)
4kV Bus 2 (O2)	TB/MC fail (failure of CST emergency makeup to main condenser (MOV-64-31), two circulating water pumps, all three circulating water booster pumps, and vacuum priming pump)
Instru. Air (IG)	TB/MC fail (SJAE assumed to fail)
120V Vital Bus (VC) and 120V Instru. Bus (IC)	TB/MC fail (SJAE assumed to fail)
Service Water (SW)	TB/MC fail (failure of pump cooling for circulating water pumps)

The following ATWS-transient initiators also impact TB (Turbine Bypass & Main Condenser):

Initiator	Impact
AMS	TB/MC fail (MSIV closure)
AFWMS	TB/MC fail (MSIV closure is assumed to occur for loss of FW initiator)
APCLP	TB/MC fail (loss of power to 4KV Buses 1 and 2)
AGRLP	TB/MC fail (loss of power to 4KV Buses 1 and 2)
ASW	TB/MC fail (see SW impact above)

TB Split Fraction Rules:

TBFAIL **(INIT=AMS) + (INIT=AFWMS) +**
(-O1=S) + (-O2=S) + (SW=F) + (-IG=S) + ((-IC=S) * (-VC=S))

Note that the -O1=S rule or the –O2=S rule covers initiators APCLP and AGRLP.

TBBASE **1**

We assume that TB has all support systems available for other transient initiators and support system combinations. Note that we use TBBASE even when TB is degraded by the failure of IC alone or VC alone (TBFAIL is used when both IC and VC fail).

Top Event: RP – Recirculation Pump Trip

RP General Notes:

- The recirculation pump trip signal shares components with ARI (top event AR). Thus, top event RP is evaluated both "independent" of AR and "dependent" of AR success or failure. The AR support systems also support RP.

RP Split Fractions:

RPFAIL ((-VC=S) + (D1=F)) * ((-IC=S) + (D2=F))

RP is guaranteed to fail whenever a "divisional" power supply fails to both logic divisions.

RPAF (AR=B) * ((-IC=S) + (D2=F))

RPBF (AR=B) * ((-VC=S) + (D1=F))

RP is evaluated independent of AR when AR is bypassed in the event tree. The RP logic is degraded to a single logic division (RPAF/RPBF) whenever one power supply fails.

RPBASE (AR=B)

If the above rules for RPFAIL and RP1F do not apply, the base case RP split fraction (fully redundant logics) is applied since all support systems are success. RP is evaluated independent of AR when AR is bypassed in the event tree.

Note: The RP split fractions below are used for situations where RP is asked dependent on AR success or failure.

RPARAF (AR=F) * ((-IC=S) + (D2=F))

RPARBF (AR=F) * ((-VC=S) + (D1=F))

RP is evaluated dependent on AR failure when the logics are degraded to a single logic division (i.e., RPARAF or RARBF) whenever one power supply fails.

RPARAS (AR=S) * ((-IC=S) + (D2=F))

RPARBS (AR=S) * ((-VC=S) + (D1=F))

RP is evaluated dependent on AR success when the logics are degraded to a single logic division (i.e., RPARAS or RARBS) whenever one power supply fails.

RPARF (AR=F)

If the above rules for RPARAF/ RPARBF and RPARAS/ RPARBS do not apply, the base case split fraction (fully redundant logics) is applied since all support systems are success. RP is evaluated dependent on AR failure.

RPARS (AR=S)

If the above rules for RPARAF/ RPARBF and RPARAS/ RPARBS do not apply, the base case split fraction (fully redundant logics) is applied since all support systems are success. RP is evaluated dependent on AR success.

RPFAIL 1

If none of the above rules apply, the RPFAIL rule will ensure a conservative result and assist in checking the validity of the results.

Top Event: FT – Feedwater Pump Trip

FT General Notes:

- The feedwater pump trip logic is dependent on the following support systems.

Support System Failure	Impact on FT
24V ECCS Battery A (top event V1)	FT fails
125V Bus DC-1 (top event DI)	FT fails
24V ECCS Battery B (top event V2)	FT fails
125V Bus DC-2 (top event D2)	FT fails
RPV ECCS Level channels 72A and 72B	FT fails

Note: The logic for FT is a "two-of-two" logic design. Thus, failure of one of the DC support systems guarantees failure of FT. Also, we take no credit for manual operator action to trip the feedwater pumps during ATWS events.

FT Split Fractions:

FTSUCC (INIT=AFWMS) + (INIT=APCLP) + (INIT=AGRLP)

We assume that the feedwater pump trip is not required for initiating events where feedwater is lost at time zero. These include loss of feedwater transients where the MSIVs are assumed to close (INIT=AFWMS), and loss of offsite power events (INIT=APCLP and INIT=AGRLP). No credit is taken for other situations involving loss of feedwater (e.g., random failure of TBCCW) since the loss of feedwater may be delayed well past the time at which the feedwater pump trip is required for reactor pressure mitigation.

FTFAIL (V1=F) + (D1=F) + (V2=F) + (D2=F) + (LV=F)

In addition to V1, D1, V2 and D2, we assume that failure of the ECCS low level signal (top event LV) also fails FT. This is because FT uses the ECCS analog trip devices 72A and 72B which are also used for LV. We assume that FT is completely dependent on LV because of the common cause failure of the common level devices.

FTBASE 1

The base case split fraction is used for all remaining cases since all support systems are success.

Top Event: FW – Feedwater System

FW General Notes:

- *Single support system impacts are assumed for FW:*

Support System Failure	Impact of Feedwater
4kV Bus 1 (O1)	FW fails, FW pumps A & B fail, aux. oil pump for pump C fails, Cond. pump A fails.
4kV Bus 2 (O2)	FW fails, FW pump C fails, Cond. pumps B & C fail, also fails hotwell emergency makeup valve MOV 64-31.
125V DC-1 (D1)	FW fails, loss of Bus 1 (O1).
125V DC-2 (D2)	FW fails, loss of Bus 2 (O2).
120V Vital Bus (VC)	FW fails, loss of power to FW reg. valves, including low flow valve.
120V Instru. Bus (IC)	FW fails, loss of pumps A,B,C.
Instru. Air (IG)	FW fails, loss of air to FW reg. valves, including low flow valve.
TBCCW (TW)	FW fails, loss of cooling for FW and Cond. pumps A,B,C.
Service Water (SW)	FW fails due to TBCCW failure (captured as TBCCW support system).

Note: FW is independent of FT since FT is bypassed in the ATWS event tree structure whenever FW is asked (i.e., when turbine bypass is success, TB=S). Because FW is only asked after TB success, the FW rules are the same as the "FW with TB=S" rules developed for the Transient event tree.

FW Split Fraction Rules:

FWFAIL (-O1=S) + (-O2=S) + (-VC=S) + (-IC=S) + (-IG=S) + (-TW=S) +
(SW=F) + (INIT=AFWMS)

Note that this rule is redundant in that most of these support system failures would cause failure of TB, hence the event tree structure would bypass top event FW.

FWBASE (TB=S)

This is the transient FW split fraction for use when TB is success and all other FW support systems are success.

FWFAIL 1

If none of the above rules apply, the FWFAIL rule will ensure a conservative result and assist in checking the validity of the results.

__Top Event: PR – Pressure Relief for ATWS__

PR General Notes:

- PR models SRV/SV opening to provide reactor pressure relief during an ATWS condition. Top event PR evaluates use of the Safety Relief Valves (SRVs) and Spring Safety Valves (SSVs) to accomplish pressure relief of the Reactor Coolant System during ATWS event sequences. PR has no support systems. For ATWS we assume that a total of any four valves must open.
- Top Event PR is only evaluated when the MSIVs close (i.e., either TB is failed or FW fails to maintain water level above the MSIV closure setpoint) since pressure control is otherwise accomplished by turbine bypass to the main condenser. PR success relies upon prior success of the Recirculation Pump Trip (top event RP) in conjunction with feedwater pump trip (top event FT) to limit the reactor pressure/power increase transient.

PR Split Fraction Rules:

PRBASE 1

There are no support systems for the "mechanical" opening (overpressure relief function) of the SRVs and SVs.

Top Event: SL – Standby Liquid Control Injection

SL General Notes:

- The Standby Liquid control System has the following support system impacts:
- The RWCU valves are considered because the model assumes that RWCU must isolate in order to ensure SLC success (i.e., one RWCU MOV must close).
- SLC is dependent on manual initiation. We assume that the time available for operator action depends the suppression pool heatup rate, hence on whether the MSIVs are open or closed. With the MSIVs open and main condenser available (TB success), we assume the operator has one hour to initiate SLC injection. With TB failure, we assume that the operator must initiate SLC in six minutes.

Support System Failure	Impact on SLC
480V MCC-8B (associated w/top event A3)	SLC pump B, squib valve B, and RWCU MOV-15
480V MCC-9B (associated w/top event A4)	SLC pump A, squib valve A, and RWCU MOV-68
125V DC-2 (D2)	RWCU MOV-18

SL Split Fraction Rules:

These split fractions are used when the main condenser is not available and reactor steam is being discharged to the suppression pool. Hence, the values for these split fractions reflect the six minute operator action HEP.

SLCADF (TB=F) * ((A3=S) * (A4=F)) * (D2=F)
SLCBDF (TB=F) * ((A3=F) * (A4=S)) * (D2=F)

Turbine bypass is unavailable. One SLC pump/squib valve/RWCU isolation valve division is unavailable because one power division (Bus 3 or Bus 4) has failed, and closure capability of MOV-18 is unavailable due to D2 failure.

SLCAF (TB=F) * ((A3=S) * (A4=F))
SLCBF (TB=F) * ((A3=F) * (A4=S))

Turbine bypass is unavailable. One SLC pump/squib valve/RWCU isolation valve division is unavailable because one power division (Bus 3 or Bus 4) has failed.

SLCBS (TB=F)

Turbine bypass is unavailable, but all SLC support systems are success.

Note: The split fractions below are used when the MSIVs are open and the main condenser is available. Hence, reactor steam is NOT being discharged to the suppression pool and the values for these split fractions reflect the one hour operator action HEP.

SLADF (TB=S) * (A3=F) * (A4=S) * (D2=F)
SLBDF (TB=S) * (A3=S) * (A4=F) * (D2=F)

Turbine bypass is success, one SLC pump/squib valve/RWCU isolation valve division is unavailable because one power division (Bus 3 or Bus 4), and closure capability of MOV-18 is unavailable due to D2 failure.

SLAF (TB=S) * (A3=F) * (A4=S)

SLBF (TB=S) * (A3=S) * (A4=F)

Turbine bypass is success, one SLC pump/squib valve/RWCU isolation valve division is unavailable because one power division (Bus 3 or Bus 4) has failed.

SLBASE (TB=S)

Turbine bypass is success, and all SLC support systems are success.

SLFAIL 1

If none of the above rules apply, the SLFAIL rule will ensure a conservative result and assist in checking the validity of the results.

Top Event: IA – Inhibit ADS

IA General Notes:

- This is the operator action to inhibit automatic initiation of ADS. There are no support systems, and we assume that the time available to accomplish IA does not depend on whether HPCI/RCIC injection is available (e.g., to delay the ADS low level initiation). Thus, IA is independent of all other top events and the base case IA split fraction is always used.

IA Split Fraction Rules:

IABASE **1**

Top Event: ED – Emergency RPV Depressurization

ED General Notes:

- This is the operator action to Emergency Depressurize the RPV on Heat capacity Temperature Limit (HCTL). For ATWS events with the MSIVs closed, we assume that the suppression pool will heatup rapidly and that the HCTL will be reached. This top event is dependent on support systems for remote manual operation of the SRVs and associated pilot solenoid valves.
- We assume that ED requires long-term operation of the SRVs, hence we require success of the containment gas nitrogen supply (top event CG). The only other support systems for ED are 125V DC-1 and DC-2. Given the system design, failure of both DC power sources is required to fail the depressurization function (fail all SRVs). DC-2 supplies the "normal" control power to each SRV solenoid valve. Upon failure of DC-2, control power to each solenoid valve will automatically transfer to DC-1 via de-energized relay K11A, B, C and D.

ED Split Fraction Rules:

These rules are similar to the AD rules in the Transient event tree.

EDFAIL (-CG=S) + ((D1=F) * (D2=F))

The EDFAIL split fraction is used when containment nitrogen supply system (CG) has failed, or when both 125vdc power supplies (D1 and D2) to SRV solenoid valves has failed.

EDDA (D1=F)

EDDB (D2=F)

ED is degraded when one 125vdc power supply, either DI (EDDA) or D2 (EDDB), has failed.

EDBASE 1

The EDBASE split fraction is used for all other cases where all support systems are available/success.

Top Event: LC – RPV Level/Power Control – Operator Action

LC General Notes:

- This top event includes operator actions related to level/power control. It includes the following specific operator actions:
  1. Terminate and prevent injection before RPV depressurization (HEP basic event identifier LCATWS1FL).

     AND

  2. Lower reactor water level to TAF or below until enough SLC is injected to shutdown the reactor and restore water level after SLC injection to assure adequate boron mixing (HEP basic event identifier LCATWS2FL).

  The failure rates for these operator actions are summed to obtain the base case split fraction value, which is used for all cases of LC evaluation.
- LC is a model of the operator action, there are no support systems modeled, and the base case LC split fraction is used. There is no fault tree needed to support split fraction development.

LC Split Fraction Rules:

LCBASE 1

Top Event: LI – RPV Low Pressure Injection – Operator Action

LI General Notes:

- LI models the operator action to manually initiate low pressure injection after RPV depressurization. Manual initiation is necessary to assure core cooling because LI is only asked in the event tree after LC succeeds in "terminating and preventing injection before RPV depressurization".
- LI only models the operator action. There are no support systems modeled, and the base case LIBASE split fraction is used for all cases where LI is evaluated.

LI Split Fraction Rules:

LIBASE	**1**

Top Event: CN – Condensate System (Low Pressure Injection)

CN General Notes:

- CN is evaluated in the event tree structure for cases where turbine bypass is success (TB=S) and feedwater has failed (FW=F), and for cases where turbine bypass has failed (TB=F) and feedwater is bypassed (FW=B). However, when TB=S and FW=F, the failure of FW is assumed to cause MSIV closure and subsequent failure of TB. Thus, we need rules to cover two cases:
    1. TB unavailable and FW=F.
    2. TB unavailable and FW=B.

The support system impacts for CN are as follows:

Support System Failure	Impact of CN
4kV Bus 1 (O1)	CN Pump A fails
4kV Bus 2 (O2)	CN Pumps B & C fail, also fails hotwell emergency makeup valve MOV 64-31)
125V DC-2 (D2)	CN fails (O2 failure)
120V Vital Bus (VC)	CN fails (no power to FW reg. valves)
Instru. Air (IG)	CN fails (no air to FW reg. valves)
TBCCW (TW)	CN fails (no pump motor cooling)

CN Split Fraction Rules:

CNFAIL (-O2=S) + (-VC=S) + (-IG=S) + (-TW=S) + (INIT=APCLP)
+ (INIT=AGRLP) + (INIT=AFWMS)

This split fraction is assigned when the support systems for Condensate fail. CN is also assumed unavailable when the initiators are APCLP, AGRLP and AFWMS.

CN1F (-O1=S)

Failure of 4kV Bus 1 (-O1=S) degrades the CN model. This rule applies when CN is not already failed (see CNFAIL) and is evaluated independently of FW.

CNBASE (FW=B) + (-IC=S)

CN is asked independent of FW when FW is bypassed by the event tree structure or when FW is guaranteed failure by support system failures. This occurs only when (FW=B) or (-IC=S). This rule applies when CN is not already failed (see CNFAIL) and is evaluated independently of FW.

CNFWF1 (FW=F)

The CNFWF1 rule covers cases where CN is asked dependent on FW. CN is asked dependent on FW only when TB is initially successful, but then FW fails which causes MSIV closure and the loss of TB. Thus, the CNFWF1 split fraction (which assumes TB failure) is appropriate.

CNFAIL 1

If none of the above rules apply, the CNFAIL rule will ensure a conservative result and assist in checking the validity of the results.

Top Event: IP – Primary Containment Integrity

IP General Notes:

- Top event IP is asked in order to establish whether the containment is intact when the hard-piped vent from torus air space is used to prevent over-pressurization (VT=S). Integrity of containment is a necessary condition in order for the operator to control and maintain sufficient pressure in the containment in support of continued operation of LPCI or Core Spray pumps taking suction from the suppression pool at elevated temperature.
- Failure of containment integrity is defined to include failures in the containment boundary that allow leakage in excess of that which would prevent maintaining overpressure sufficient to satisfy the NPSH-r or the LPCI and Core Spray pumps at elevated suppression pool temperature. The leakage sources are divided into two principal categories:
    - Isolation valve failures: These are related to the failure of the isolation valves in containment penetration lines or failure of the isolation signals or power to close these valves.
    - Pre-existing failures: These are failures primarily related to hatches, electrical penetration assemblies (EPAs), and other containment leakage paths not associated with failure of isolation valves to close.

IP Split Fraction Rules

IPIG (IG=F)+((VC=F)*(IC=F))

This split fraction is used when both the "inboard" and "outboard" isolation valves fail due to support system failures.

The "inboard" and "outboard" valves for the PCAC system require instrument air (IG) for normal operation.

The isolation valves will fail CLOSED on interruption of air supply pressure. The "inboard" isolation valves are dependent on Vital Bus (VC) 120vac, and the "outboard" isolation valves are dependent on Instrument Bus (IC) 120vac. These isolation valves will fail CLOSED on loss of control power.

Inboard torus-to-RB vacuum breaker SB-16-19-11A requires Vital Bus (VC), while the SB-16-19-11B vacuum breaker requires Instrument Bus (IC). These valves will fail OPEN on loss of air pressure or electric power. Note that the outboard torus-to-RB swing-check valves are in-series with the air-operated vacuum breakers, hence failure of the air-operated vacuum breakers to close does not necessarily cause failure of containment isolation.

IPVAC (VC=F)

This split fraction is used when torus-to-RB vacuum breaker SB-16-19-11A fails due to failure of the Vital Bus (VC) 120vac power supply. Note that the outboard torus-to-drywell swing-check valve is in-series with the air-operated vacuum breakers, hence failure of the air-operated

IPIAC (IC=F)

This split fraction is used when torus-to-RB vacuum breaker SB-16-19-11B fails due to failure of the Instrument Bus (IC) 120vac power supply. Note that the outboard torus-to-drywell swing-check valve is in-series with the air-operated vacuum breakers, hence failure of the air-operated

IPBASE 1

No other support system failures affect the containment isolation system. Thus, the base case (all support systems available) split fraction applies to all sequences not captured by one of the previous rules.

Top Event: LP – Low Pressure Coolant Injection

LP General Notes:

- For ATWS scenarios, we assume that low pressure injection systems must be manually initiated and controlled by the operator (see top event LC). Thus, the LPFAIL split fraction here includes the term (-PI=S) instead of the (SIGF) term contained in the corresponding rule in the Transient event tree. PI is the only portion of the automatic initiation signal that the operator cannot override, hence PI failure is assumed to fail LP.

Support System Impacts on LP

The impact of single support system failures on LP is as follows. Note that the min. flow valve in each LPCI loop (MOV-16A/16B) is maintained normally open and success of the LPCI loop does not depend on successful closure of the associated min. flow valve. Therefore, we assume LPCI success does not depend on the min. flow valve hardware or the associated power supply.

Support System Failure	Impact on LPCI
125V DC-I (D1)	RHR Pumps C and D fail; degraded injection valve ECCS signal.
125V DC-2 (D2)	RHR Pumps A and B fail; degraded injection valve ECCS signal.
4kV Bus 3 (A3)	RHR Pumps C and D fail; injection valve ECCS signal not degraded.
4kV Bus 4 (A4)	RHR Pumps A and B fail; injection valve ECCS signal not degraded.
RRU7 (R7)	No impact assumed based on room heatup assessment.
RRU8 (R8)	No impact assumed based on room heatup assessment.
Service Water (SW)	No impact assumed based on room heatup assessment. Also, RHR pump seal and bearing cooling via SW/RBCCW assumed not needed for injection mode.
RBCCW (RW)	No impact; RHR pump seal and bearing cooling via RBCCW assumed not needed for the injection mode function.
Low Pressure Interlock (PI)	Failure of capability to manually open low pressure injection MOVs.

LP Split Fraction Rules:

LPFAIL (-PI=S) + ((D1=F) + (A3=F)) * ((D2=F) + (A4=F))

The LPFAIL rule covers all support system failure combinations which guarantee failure of LP.

LP2VA (D1=F)

LP2VB (D2=F)

LPCI configuration will be 2 pump failure with degraded LPCI injection valve logic given DC-1 (LP2VA) or DC-2 (LP2VB) failure.

LP2FA (A3=F)

LP2FB (A4=F)

LPCI configuration will be 2 pump failure without degraded LPCI injection valve logic given failure of 4KV AC Bus 3 (LP2FA) or AC Bus 4 (LP2FB) failure.

LPBASE 1

LPCI base case reliability is applied when all support systems are successful and PI has not failed.

Top Event: CS – Core Spray

CS General Notes:

- The rules for CS are the same as those developed for the Transient event tree except for the SIGF term. Like LP, we assume that the operator must initiate and control CS (see top event LP) and that he cannot override the Low pressure Interlock (PI) signal and open low pressure injection valves.

Support System Impacts on CS

The impact of single support system failures on CS is as follows. Note that the min. flow valve in each CS loop (MOV-5A/5B) is maintained normally open and success of the CS loop does not depend on successful closure of the associated min. flow valve. Therefore, we assume CS success does not depend on the min. flow valve hardware or the associated power supply.

Support System Failure	Impact on LPCI
125V DC-I (D1) fails	CS Loop B fails - Pump B and MOV-11B/12B.
125V DC-2 (D2) fails	CS Loop A fails - Pump A and MOV-11A/12A.
4kV Bus 3 (A3) fails	CS Loop B fails - Pump B and MOV-11B/12B.
4kV Bus 4 (A4) fails	CS Loop A fails - Pump A and MOV-11A/12A.
RRU7 (R7) fails	No impact assumed based on room heatup assessment.
RRU8 (R8) fails	No impact assumed based on room heatup assessment.
SW/RW fail	No impact on Core Spray.
Low Pressure Interlock (PI)	Failure of capability to manually open low pressure injection MOVs.

CS Split Fraction Rules:

CSFAIL (-PI=S) + ((D1=F) + (A3=F)) * ((D2=F) + (A4=F))

The CSFAIL split fraction accounts for all combinations of support system failures which fail both trains of Core Spray.

CSA4F ((A4=F) + (D2=F)) * ((A3=S) * (D1=S))

The CSA4F split fraction accounts for all support system failures which fail CS Train A, where CS Train B is available because of successful support systems.

CSA3F ((A3=F) + (D1=F)) * ((A4=S) * (D2=S))

The CSA3F split fraction accounts for all support system failures which fail CS Train B, where CS Train A is available because of successful support systems.

CSBASE 1

If none of the earlier rules apply, then all CS support systems are available and we evaluate CS failure probability based on both CS trains being available (base case).

<u>Top Event: RM – Recover Main Condenser</u>

RM General Notes:

- Recovery of the main condenser for reactor heat removal is assumed to involve the following two operator actions:
  1. Restoration of the main condenser during an ATWS with successful SLC injection and level/power control, and
  2. Bypassing MSIV closure interlocks to allow re-opening of MSIVs.

  The HEPs for these two operator actions are summed to obtain the RMATBS split fraction value (see rule below).
- We credit recovery of the main condenser providing that all support systems are success.

The support systems needed to recover the condenser are the same as top event TB (Turbine Bypass & Main Condenser):

Support System Failure	Impact on TB/Main Condenser
4kV Bus 1 (O1)	TB/MC fail (failure of auxiliary oil pump, one circulating water pump, and steam packing exhauster)
4kV Bus 2 (O2)	TB/MC fail (failure of CST emergency makeup to main condenser (MOV-64-31), two circulating water pumps, all three circulating water booster pumps, and vacuum priming pump)
120V Vital Bus (VC)	TB/MC fail (SJAE assumed to fail)
120V Instru. Bus (IC)	TB/MC fail (SJAE assumed to fail)
Instru. Air (IG)	TB/MC fail (SJAE assumed to fail)
Service Water (SW)	TB/MC fail (failure of pump cooling for circulating water pumps)

RM Split Fraction Rules:

RMATBS (O1=S) * (O2=S) * (SW=S) * (IG=S) * ((IC=S) + (VC=S))

The base case ATWS split fraction (RMATBS) is used whenever all support systems for the main condenser are available. This split fraction includes the operator error rate for the ATWS conditions.

RMFAIL 1

Recovery of the main condenser is assumed to fail for all remaining cases (RMFAIL) because one or more support systems are unavailable. Also, if the RMATBS rule does not apply, the RMFAIL rule will ensure a conservative result and assist in checking the validity of the results.

Top Event: OT – Operator Action to Initiate Torus Cooling

OT General Notes:

- This top event models the operator action to initiate torus cooling for ATWS scenarios. This action is different than the HEP used to initiate torus cooling for Transient events (in top event TC), since the suppression pool heatup will be much more rapid for ATWS scenarios. Since OT models only the operator action, we have a single split fraction applicable to all ATWS cases.

OT Split Fraction Rules:

OTBASE **1**

Top Event: TC – Torus Cooling

TC General Notes:

- The operator action to initiate torus cooling was evaluated in top event OT. Thus, top event TC evaluates the success/failure of hardware only. Note that we use the same split fractions as were used for Transients, even though the Transient split fractions included manual initiation in top event TC. This is conservative for ATWS because we are "double accounting" the operator initiation HEP (i.e., we have already considered it in OT), but this double counting is not significant since the operator error rate for Transients is very low (1E-06).

Support System Impacts on TC

Torus Cooling (top event TC) is dependent on Low Pressure Coolant Injection (top event LP) due to shared RHR equipment. The impact of single support system failures on TC are as follows:

Support System Failure	Impact on Torus Cooling
125V DC-I (D1)	RHR Pumps C & D fail; RHRSW Pumps B & D fail; TC Loop B MOVs fail.
125V DC-2 (D2)	RHR Pumps A & B fail; RHRSW Pumps A & C fail; TC Loop A MOVs fail.
4kV Bus 3 (A3)	RHR Pumps C & D fail; RHRSW Pumps B & D fail; TC Loop B MOVs fail.
4kV Bus 4 (A4)	RHR Pumps A & B fail; RHRSW Pumps A & C fail; TC Loop A MOVs fail.
RRU7 (R7)	No impact on equipment is assumed based on room heatup assessment.
RRU8 (R8)	No impact on equipment is assumed based on room heatup assessment.
Service Water (SW)	RHR Pumps A, C & B, D fail due to loss of seal and bearing injection water cooling (assumed needed for long term TC mode), RHRSW Pumps A, C & B, D fail due loss of service water suction.
RBCCW (RW) fails	RHR Pumps A, C & B, D fail due to loss of seal and bearing injection water cooling (assumed needed for long term TC mode). No impact on RHRSW pumps.
Low Pressure Interlock (PI)	No impact on TC function is assumed.

TC Split Fraction Rules:

TCFAIL **(SW=F) + ((D1=F) + (A3=F)) * ((D2=F) + (A4=F))**

This rule captures all cases for which support system failures will fail both trains of TC.

TC3FA ((LP=B)+((-PI=S))*((D1=F)+(A3=F))

TC3FB ((LP=B)+((-PI=S))*((D2=F)+(A4=F))

Single loop TC with 2 RHRSW pump and 1 RHR pump available, D1(D2) or A3(A4) unavailable.

TCBASE (LP=B) + (-PI=S)

TC split fractions TC3F and TCBASE evaluate TC independent of LP. The LPFAIL rule (see top event LP) defines the cases where LP is guaranteed to fail by support system failures.

Note: The only support system failure which appears in the LPFAIL rule and does not guarantee failure of TC is (-PI=S). Because PI failure guarantees failure of LP, TC is being evaluated independent of LP for these cases. LP can also be "bypassed" in the ATWS event tree because other injection systems, such as condensate (CN) can satisfy the RPV inventory function, consequently TC is evaluated (independently). Therefore, we have also included the (LP=B) portion of the rule. The above rules for TC3F, and TCBASE capture these cases.

Note: If TC3FA, TC3FB, and TCBASE split fractions do not apply, TC must be evaluated "dependent" upon the success or failure of LP. The following "dependent" LP/TC split fractions were developed to cover the various support system states given LP success /failure.

TCLS7A (LP=S)*(D1=F)

TCLS7B (LP=S)*(D2=F)

TC failure given LP success when either D1 (TCLS7A) or D2 (TCLS7B) has failed.

TCLS6A (LP=S)*((A3=F))

TCLS6B (LP=S)*((A4=F))

TC failure given LP success when either A3 (TCLS6A) or A4 (TCLS6B) has failed.

TCLPS5 (LP=S)

TC failure given LP success when all support systems are available/successful

TCLF7A (LP=F)*((D1=F))

TCLF7B (LP=F)*((D2=F))

TC failure given LP failure when either D1 (TCLF7A) or D2 (TCLF7B) has failed.

TCLF6A (LP=F)*((A3=F))

TCLF6B (LP=F)*((A4=F))

TC failure given LP failure when either A4 (TCLF6A) or A3 (TCLF6A) has failed.

TCLPF5 (LP=F)

TC failure given LP failure when all support systems are available/successful.

TCFAIL **1**

If none of the above rules apply, the TCFAIL rule will ensure a conservative result and assist in checking the validity of the results.

Top Event: VT – Torus Vent (hard-piped vent from torus air space)

VT General Notes:

- The ATWS event tree structure only evaluates the torus vent (VT) when the reactor is successfully shutdown by SLC. Therefore, the transient base case split fraction is assumed to apply to these ATWS cases.
- Torus vent valve (TVS-86) is "normally" closed and requires manual action to open the valve and enable the use of the venting path with rupture disc. For ATWS type transients with successful SLC, we assume that the valve can be operated remotely from the control room if 480V MCC-7A (associated w/ 4kV Bus 2) is available, or the valve can be operated locally. Local operation is assumed possible because there is sufficient time before the vent path would be needed. Also, in this Level 1 event tree, venting is performed to prevent core damage, therefore, the Reactor Building is assumed to remain habitable to perform the local operation.

VT Split Fraction Rules:

VTTRBS 1

Local manual operation of the vent valve is assumed, therefore, there are no AC power support systems needed and the VTTRBS (Vent-Torus-Transient-Base-Case) split fraction is assigned for ATWS type transients with successful SLC.

Attachment F

Event Tree (LOCA_LG)

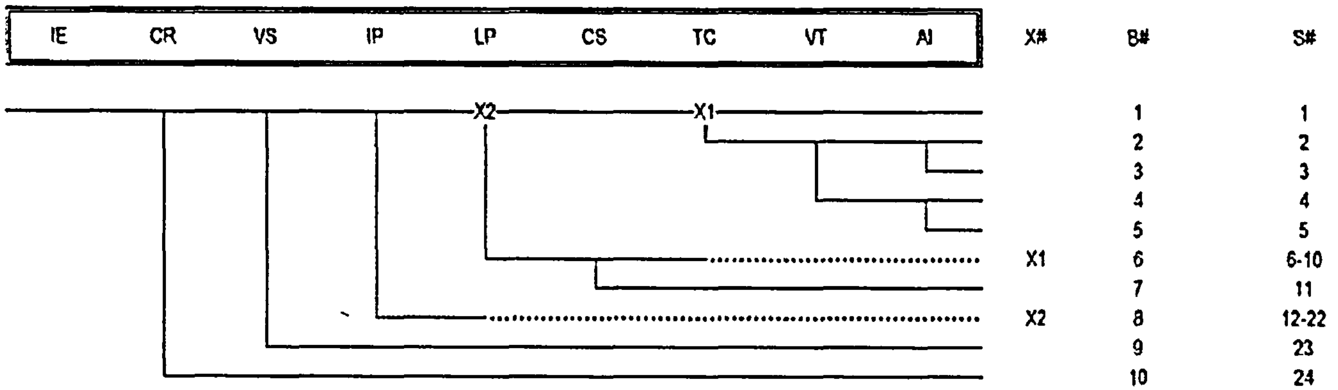

Figure F.1 Large LOCA Event Tree

Top Event Name	Description
CR	CONTROL ROD INJECTION - REACTOR SHUTDOWN
VS	VAPOR SUPPRESSION SYSTEM
LP	LPCI SYSTEM
CS	LOW PRESSURE CORE SPRAY SYSTEM
TC	TORUS COOLING SYSTEM
VT	TORUS HARD-PIPED VENT FOR LEVEL 1 ANALYSIS
IP	PRIMARY CONT. INTEGRITY FOR LEVEL 1 ANALYSIS
AI	ALTERNATE CORE COOLING SYSTEM, CRD, CONDENSATE TRANSFER, AND CST REFILL

Initiator:

- **LLOCA** (Large LOCA)

Modified Endstate Binning Rules – Large LOCA

CONFIG#1 (model VYCOP2A)

Bin	Rule
IIIC	(CS=F)

LOCA sequences with loss of injection. Core damage occurs with the reactor at low pressure.

CONFIG#2 (model VYCOP2)

Bin	Rule
IIIC	(CS=F)+(IP=F)

LOCA sequences with loss of injection. For sequences where LPCI and Core Spray are initially available, injection failure occurs due to inadequate NPSH if containment isolation is unsuccessful (IP=F). Core damage occurs with the reactor at low pressure.

Top Event: CR – Control Rods Insert

CR General Notes:

None.

CR Split Fraction Rules:

CRBASE 1

CR is considered to be independent of all other systems, hence the base case split fraction is used for all cases, i.e., CR has no support systems.

Top Event: VS – Vapor Suppression

VS General Notes:

- VS models the capability of the torus to drywell vacuum breakers to remain closed, thus forcing delivery of the drywell steam to the suppression pool via the vent header and downcomers.

VS Split Fraction Rules:

VSBASE 1

Like top event CR, VS has no support systems. Therefore, VS is assumed independent of all other systems.

Top Event: IP – Primary Containment Integrity

IP General Notes:

- Top event IP is asked in order to establish whether the containment is intact when the hard-piped vent from torus air space is used to prevent over-pressurization (VT=S). Integrity of containment is a necessary condition in order for the operator to control and maintain sufficient pressure in the containment in support of continued operation of LPCI or Core Spray pumps taking suction from the suppression pool at elevated temperature.
- Failure of containment integrity is defined to include failures in the containment boundary that allow leakage in excess of that which would prevent maintaining overpressure sufficient to satisfy the NPSH-r or the LPCI and Core Spray pumps at elevated suppression pool temperature. The leakage sources are divided into two principal categories:
  - Isolation valve failures: These are related to the failure of the isolation valves in containment penetration lines or failure of the isolation signals or power to close these valves.
  - Pre-existing failures: These are failures primarily related to hatches, electrical penetration assemblies (EPAs), and other containment leakage paths not associated with failure of isolation valves to close.

IP Split Fraction Rules

IPIGL **(IG=F)+((VC=F)*(IC=F))**

This split fraction is used when both the "inboard" and "outboard" isolation valves fail due to support system failures.

The "inboard" and "outboard" valves for the PCAC system require instrument air (IG) for normal operation.

The isolation valves will fail CLOSED on interruption of air supply pressure. The "inboard" isolation valves are dependent on Vital Bus (VC) 120vac, and the "outboard" isolation valves are dependent on Instrument Bus (IC) 120vac. These isolation valves will fail CLOSED on loss of control power.

Inboard torus-to-RB vacuum breaker SB-16-19-11A requires Vital Bus (VC), while the SB-16-19-11B vacuum breaker requires Instrument Bus (IC). These valves will fail OPEN on loss of air pressure or electric power. Note that the outboard torus-to-RB swing-check valves are in-series with the air-operated vacuum breakers, hence failure of the air-operated vacuum breakers to close does not necessarily cause failure of containment isolation.

IPVACL **(VC=F)**

This split fraction is used when torus-to-RB vacuum breaker SB-16-19-11A fails due to failure of the Vital Bus (VC) 120vac power supply. Note that the outboard torus-to-drywell swing-check valve is in-series with the air-operated vacuum breakers, hence failure of the air-operated

IPIACL **(IC=F)**

This split fraction is used when torus-to-RB vacuum breaker SB-16-19-11B fails due to failure of the Instrument Bus (IC) 120vac power supply. Note that the outboard torus-to-drywell swing-check valve is in-series with the air-operated vacuum breakers, hence failure of the air-operated

IPBASL 1

No other support system failures affect the containment isolation system. Thus, the base case (all support systems available) split fraction applies to all sequences not captured by one of the previous rules.

Top Event: LP – Low Pressure Coolant Injection

LP General Notes:

- The min. flow valve in each LP loop (MOV-16A/16B) is maintained normally open and success of the LP loop does not depend on successful closure of the associated min. flow valve. Therefore, we assume LPCI success does not depend on the min. flow valve hardware or the associated power supply.

Support System	Impacts on LP
125V DC-I (D1) fails	RHR Pumps C and D fail; degraded injection valve ECCS signal.
125V DC-2 (D2) fails	RHR Pumps A and B fail; degraded injection valve ECCS signal.
4kV Bus 3 (A3) fails	RHR Pumps C and D fail; injection valve ECCS signal not degraded.
4kV Bus 4 (A4) fails	RHR Pumps A and B fail; injection valve ECCS signal not degraded.
RRU7 (R7) fails	No impact assumed based on room heatup assessment.
RRU8 (R8) fails	No impact assumed based on room heatup assessment.
SW fails	No impact assumed based on room heatup assessment. Also, RHR pump seal and bearing cooling via SW/RBCCW assumed not needed for injection mode.
RBCCW (RW) fails	No impact; RHR pump seal and bearing cooling via RBCCW assumed not needed for the injection mode function.
ECCS Signal (SIG) fails	Assumed to cause failure of LP for large break LOCA event (*).

(*) Success of the automatic ECCS actuation signal is assumed to be necessary for success of LPCI and Core Spray. For the Large LOCA, we take no credit for operator action to manually initiate ECCS after failure of the automatic initiation signal (top event OI in the Auxiliary Support State Event Tree). The following Macro establishes whether the signal is failed based on failures of: PI (Low Pressure Interlock), DW (Drywell Pressure), LV (RPV Level) and PS (RPV Pressure). These individual signals are evaluated probabilistically in the Auxiliary Support State Event Tree.

SIGF: **(-PI=S) + (-DW=S) * ((-LV=S) + (-PS=S))**

Initiating Event Impact of LP

For the large LOCA initiating event, we assume that the break is located on the "A" recirculation loop and disables the A loop (pumps A and C) of LPCI. Always assuming that the break is recirculation loop A is done to simplify the model. Because the frequency of a large break LOCA is low and does not significantly contribute to the total risk of core damage, this assumption is reasonable. A future model upgrade would be to assign half of the initiating event frequency to each recirculation loop if more rigor is needed. With the large break LOCA in recirculation loop A, we assume that LPCI loop A is guaranteed failure. Because of the large break-assumed system degradation, special "large break LOCA split fractions" have been generated to account for associated LPCI system failure probability (reliability) for use in the evaluation of large break events. The above list of support system impacts is revised for the large LOCA as follows:

System/Event	Assumed Impact on LPCI
Large LOCA Loop A	RHR Pumps A and C assumed failed.
125V DC-I (D1) fails	RHR Pump D fails; degraded injection valve ECCS signal. Pump B in Loop B ok.

125V DC-2 (D2) fails	RHR Pump B fails; degraded injection valve ECCS signal. Pump D in Loop B ok.
4kV Bus 3 (A3) fails	RHR Pump D fails; injection valve ECCS signal not degraded. Pump B in Loop B ok.
4kV Bus 4 (A4) fails	RHR Pump B fails; injection valve ECCS signal not degraded. Pump D in Loop B ok.
RRU7 (R7) fails	No impact assumed based on room heatup assessment.
RRU8 (R8) fails	No impact assumed based on room heatup assessment.
SW fails	No impact assumed based on room heatup assessment. Also, RHR pump seal and bearing cooling via SW/RBCCW assumed not needed for injection mode.
RBCCW (RW) fails	No impact; RHR pump seal and bearing cooling via RBCCW assumed not needed for the injection mode function.
ECCS Signal (SIG) fails	All LPCI fails given large break.

LP Split Fraction Rules:

SIGF: **(-PI=S) + (-DW=S) * ((-LV=S) + (-PS=S))**

SIGF macro is applied as described above. Failure of the ECCS signal is assumed to fail all of LP for the large break LOCA initiating event. Operator action to "back-up" a failed ECCS signal is not credited for large break because we assume that there is insufficient time for the operator to respond for the large break LOCA event.

LPFAIL **(SIGF) + ((D1=F) * (D2=F)) + ((D1=F) * (A4=F)) + ((D2=F) * (A3=F)) + ((A3=F) * (A4=F))**

Based on the above impacts, LPCI is considered failed any time failure of a combination of support system divisions occurs.

LPL3VA **D1=F**

LPL3VB **D2=F**

Split fraction LPL3VA(VB) applies to large break LOCA where three pumps fail and the ECCS signal to injection valve MOV 27A(B) is degraded. Two pumps A & C or B & D fail because of the LOCA break location assumption. Pump A(D) fails when D1=F, Pump B(C) fails when D2=F.

LPL3FA **A3=F**

LPL3FB **A4=F**

Split fraction LPL3FA(B) involves large break LOCA where three pumps fail and there is no degradation of the injection valve ECCS signal. Pumps A & C or B & D fail because of our LOCA assumption. Pump A (D) fails when A4=F, Pump B(C) fails when A3=F.

LPL2F **1**

This split fraction rule covers all remaining large LOCA cases where two pumps are assumed to be disabled due to the LOCA location of Loop A. All support systems are available, and the LPL2F essentially becomes the LPCI "base case" model for large break (2 LP pumps in Loop B are available).

Top Event: CS – Core Spray

CS General Notes:

- The min. flow valve in each CS loop (MOV-5A/5B) is maintained normally open and success of the CS loop does not depend on successful closure of the associated min. flow valve. Therefore, we assume CS success does not depend on the min. flow valve hardware or the associated power supply.

Support System Impacts on CS

Support System	Impact on CS
125V DC-I (D1) fails	CS Loop B fails - Pump B and MOV-11B/12B.
125V DC-2 (D2) fails	CS Loop A fails - Pump A and MOV-11A/12A.
4kV Bus 3 (A3) fails	CS Loop B fails - Pump B and MOV-11B/12B.
4kV Bus 4 (A4) fails	CS Loop A fails - Pump A and MOV-11A/12A.
RRU7 (R7) fails	No impact assumed based on room heatup assessment.
RRU8 (R8) fails	No impact assumed based on room heatup assessment.
SW/RW fail	No impact on Core Spray.
ECCS Signal (SIG) fails	Assumed to cause failure of CS for large break LOCA event (*).
	(*) Refer to top event LP above for summary of no credit for operator action to backup a failed ECCS signal for large break LOCA.

CS Split Fraction Rules:

CSFAIL (SIGF) + ((D1=F) + (A3=F)) * ((D2=F) + (A4=F))

The CSFAIL split fraction accounts for all combinations of support system failures which fail both trains of Core Spray. Note that the "SIGF" macro rule in CSFAIL is the same as that defined by the Macro SIGF earlier under top event LP.

CSA4F ((A4=F) + (D2=F)) * ((A3=S) * (D1=S))

The CSA4F split fraction accounts for all support system failures which fail CS Train A, where CS Train B is available because of successful support systems.

CSA3F ((A3=F) + (D1=F)) * ((A4=S) * (D2=S))

The CSA3F split fraction accounts for all support system failures which fail CS Train B, where CS Train A is available because of successful support systems.

CSBASE 1

If none of the earlier rules apply, then all CS support systems are available and we evaluate CS failure probability based on both CS trains being available (base case).

Top Event: TC – Torus Cooling

TC General Notes:

Support System Impacts on TC

In general, Torus Cooling (top event TC) is dependent on Low Pressure Coolant Injection (top event LP) due to shared RHR equipment. The impact of single support system failures on TC are as follows:

Support System	Impact on RHR
125V DC-I (D1) fails	RHR Pumps C & D fail; RHRSW Pumps B & D fail; TC Loop B MOVs fail.
125V DC-2 (D2) fails	RHR Pumps A & B fail; RHRSW Pumps A & C fail; TC Loop A MOVs fail.
4kV Bus 3 (A3) fails	RHR Pumps C & D fail; RHRSW Pumps B & D fail; TC Loop B MOVs fail.
4kV Bus 4 (A4) fails	RHR Pumps A & B fail; RHRSW Pumps A & C fail; TC Loop A MOVs fail.
RRU7 (R7) fails	No impact on equipment is assumed based on room heatup assessment.
RRU8 (R8) fails	No impact on equipment is assumed based on room heatup assessment.
SW fails	RHR Pumps A, C & B, D fail due to loss of seal and bearing injection water cooling (assumed needed for long term TC mode), RHRSW Pumps A, C & B, D fail due loss of service water suction.
ECCS Signal (SIG) fails	No impact on TC function is assumed.
Large LOCA Loop A	No impact on TC function is assumed.

TC Split Fraction Rules:

TCFAIL ((SW=F) * (-AW=S)) + ((D1=F) + (A3=F)) * ((D2=F) + (A4=F))

This rule captures all cases for which support system failures will fail both trains of TC. Note that we credit use of AW as an alternative to SW.

TC3FA (SIGF)*((D1=F)+(A3=F))

TC3FB (SIGF)*((D2=F)+(A4=F))

Single loop TC with 2 RHRSW pump and 1 RHR pump available, D1(D2) or A3(A4) unavailable.

TCBASE (SIGF)

TC split fractions TC3FA(B) and TCBASE evaluate TC independent of LP. The LPFAIL rule (see top event LP) defines the cases where LP is guaranteed to fail by support system failures. Some of the same support system combinations that fail LP also fail TC and are accounted for in the TCFAIL rule. The only support system failure which appears in the LPFAIL rule and does not guarantee failure of TC is SIGF. Because SIGF guarantees failure of LP, TC is being evaluated independent of LP for these cases. The above rules for TC3FA(B), and TCBASE capture these cases.

Note: If TC3FA(B) and TCBASE split fractions do not apply, TC must be evaluated "dependent" upon the success or failure of LP. The following "dependent" LP/TC split fractions were developed to cover the various support system states given LP success /failure.

TCLS4A (LP=S)*((D1=F))

TCLS4B (LP=S)*((D2=F))

TC failure given LP success when either D1 (TCLS4A) or D2 (TCLS4B) have failed.

TCLS3A (LP=S)*((A3=F))

TCLS3B (LP=S)*((A4=F))

TC failure given LP success when either A3 (TCLS3A) or A4 (TCLS3B) have failed.

TCLPS1 (LP=S)

TC failure given LP success when all support systems are available/successful

TCLF4A (LP=F)*((D1=F))

TCLF4B (LP=F)*((D2=F))

TC failure given LP failure when either D1 (TCLF4A)or D2 (TCLF4B) have failed.

TCLF3A (LP=F)*((A3=F))

TCLF3B (LP=F)*((A4=F))

TC failure given LP failure when either A4 (TCLF3A) or A3 (TCLF3B) have failed.

TCLF1 (LP=F)

TC failure given LP failure when all support systems are available/successful.

TCFAIL 1

If none of the above rules apply, the TCFAIL rule will ensure a conservative result and assist in checking the validity of the results.

Top Event: VT – Torus Vent (hard-piped vent from torus air space)

VT General Notes:

Support System Impacts on TC

- Torus vent valve (TVS-86) is "normally" closed and requires manual action to open the valve and enable the use of the venting path with rupture disc. For the large LOCA initiating event, we assume that TSV-86 must be opened remotely from the control room. Local operator action to open this valve is not credited because of the potential for a harsh environment, even though venting takes place in Level 1 before core damage occurs. The power source needed for remote opening of TSV-86 is 480V MCC-7A (associated w/ 4kV Bus 2).

VT Split Fraction Rules:

VTLCBS (O2=S)

The VTLCBS split fraction evaluates the reliability of the torus vent when power from MCC-7A/Bus2 (top event O2) available/successful and remote operator action can accomplish opening of TSV-86.

VTFAIL 1

VTFAIL split fraction is assigned since power from Bus 2 has failed. We conservatively assume no recovery of the power source or local operation of the valve, thus VT is assumed to be guaranteed failure.

Top Event: AI – Alternate Injection (Long Term Injection)

AI General Notes:

- Top event AI is used to account for potential (late) effects of high suppression pool temperature (i.e., TC=F) on injection systems that take suction from the pool (i.e., LP and CS). The effects of high pool temperature on pump seal and bearing cooling were not considered in the evaluation of top events LP and CS. Also, the operator action to control containment pressure after the torus vent opens was not considered in top event VT.

AI Split Fraction Rules:

AIFAIL 1

For large LOCA initiating events, AI assumes no credit for injection systems which take suction from outside containment. These include CRD, Condensate, Condensate Transfer (injection via Core Spray or LPCI injection lines), RHRSW or Firewater (injection via the RHR cross-tie). These systems either do not have adequate capacity or would require manual action to align for injection (for which we assume insufficient time is available) during a large break scenario.

Attachment G

Event Tree (LOCA_MD)

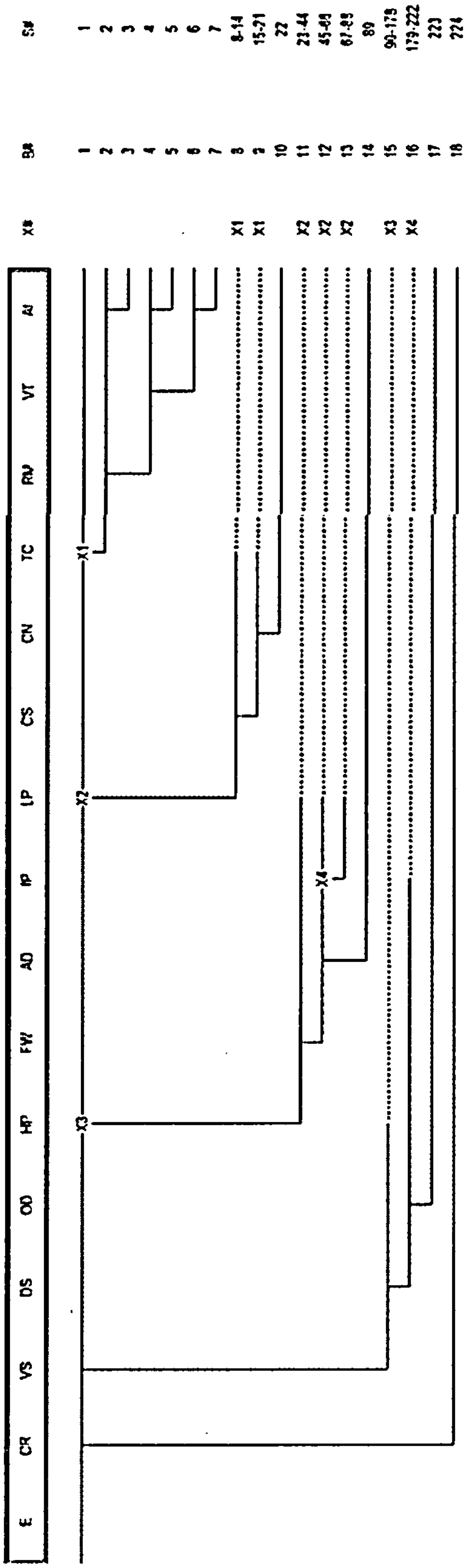

Figure G.1 Medium LOCA Event Tree

Top Event Name	Description
CR	CONTROL ROD INJECTION - REACTOR SHUTDOWN
VS	VAPOR SUPPRESSION SYSTEM
DS	DRYWELL SPRAY SYSTEM USED IN LOCA_SM AND LOCA_MED
OD	MANUAL DEPRESSURIZATION USED FOR VAPOR SUPPRESSION ALTERNATIVE
HP	HPCI SYSTEM
FW	FEEDWATER SYSTEM
AD	AUTOMATIC DEPRESSURIZATION SYSTEM (ADS)
LP	LPCI SYSTEM
CS	LOW PRESSURE CORE SPRAY SYSTEM
CN	CONDENSATE SYSTEM
TC	TORUS COOLING SYSTEM
RM	RECOVERY OF MAIN CONDENSER
VT	TORUS HARD-PIPED VENT FOR LEVEL 1 ANALYSIS
IP	PRIMARY CONT. INTEGRITY FOR LEVEL 1 ANALYSIS
AI	ALTERNATE CORE COOLING SYSTEM, CRD, CONDENSATE TRANSFER, AND CST REFILL

Initiators:

▫ **MLOCA**	(Medium LOCA)
▫ **IORV**	(Inadvertent Opening of Relief Valve)
▫ **SORV**	(Stuck Open Relief Valve)

Modified Endstate Binning Rules – Medium LOCA

CONFIG#1 (model VYCOP2A)

Bin	Rule
IIIC	(CN=F) + (VT=B) * (AI=F)

LOCA sequences with loss of injection. Core damage occurs with the reactor at low pressure.

CONFIG#2 (model VYCOP2)

Bin	Rule
IIIC	(CN=F) + (VT=B) * (AI=F) + (((RM=S) * (AI=F)) + (TC=S)) * (IP=F) * ((LP=S) + (CS=S))

LOCA sequences with loss of injection. For sequences where LPCI and Core Spray are initially available, injection failure occurs due to inadequate NPSH if containment isolation is unsuccessful (IP=F). Core damage occurs with the reactor at low pressure.

Top Event: CR – Control Rods Insert

CR General Notes:

None.

CR Split Fraction Rules:

CRBASE 1

CR is considered to be independent of all other systems, hence the base case split fraction is used for all cases, i.e., CR has no support systems.

Top Event: VS – Vapor Suppression

VS General Notes: None.

VS Split Fraction Rules:

VSSUCC **(INIT=IORV) + (INIT=SORV)**

Although the inadvertent opening of an SRV (IORV) and stuck open SRV (SORV) both use the medium LOCA event tree, these events vent steam directly to the torus water volume, and therefore do not require vapor suppression via the downcomers.

VSBASE **1**

Like top event CR, VS has no support systems. Therefore, VS is assumed independent of all other systems.

Top Event: DS – Drywell Spray

DS General Notes:

- Top event DS considers the use of drywell sprays as a means of vapor suppression when top event VS fails. Rigorous modeling of DS must consider potential dependencies between DS and later top events LP and TC (due to common RHR equipment in the LPCI, Torus Cooling and Drywell Spray modes). Also, rigorous treatment would consider the dependence between operator actions to initiate drywell sprays and to depressurize the RPV (see top event OD), since both actions are designed to limit the containment pressure/temperature rise. To simplify the modeling of top event dependencies, we conservatively take no credit for DS as a means of vapor suppression. However, the medium LOCA event tree (and other event trees) were constructed with Top Event DS as a place holder if the drywell function is ever re-evaluated and credited in the future. Note that because of equipment functional dependencies with the RHR LP injection function and RHR torus cooling function as mentioned earlier, we judge that crediting the drywell spray function will have marginal benefit to the model results. More importantly, crediting DS in addition to LP and TC would add complication to the model which should be considered against the marginal benefit.

DS Split Fraction Rules:

DSFAIL 1

DS is not credited, therefore, the guaranteed failure split fraction is assigned.

Top Event: OD – Manual RPV Depressurization for Containment Pressure Control

OD General Notes:

- OD models operator depressurization of the RPV via the SRVs (discharging to the suppression pool) as a means of mitigating the containment pressure rise for LOCA (Medium or Small) sequences with vapor suppression failure (stuck-open vacuum breakers). We assume that OD requires long-term operation of the SRVs, hence we require success of the containment gas nitrogen supply (top event CG). The only other support systems for OD are 125V DC-1 and DC-2. Given the system design, failure of both DC power sources is required to fail the depressurization function (fail all SRVs). DC-2 supplies the "normal" control power to each SRV solenoid valve. Upon failure of DC-2, control power to each solenoid valve will automatically transfer to DC-1 via de-energized relay K11A, B, C and D.

OD Split Fraction Rules:

ODFAIL **(-CG=S) + ((D1=F) * (D2=F))**

OD is guaranteed to fail when CG fails or when both DC-1 and DC-2 fail.

ODMLDA **(D1=F)**

ODMLDB **(D2=F)**

Split fraction ODMLDA(B) applies the operator action HEP associated with Medium LOCA events when Division 1(2) of DC power has failed.

ODMLBS **1**

Split fraction ODMLBS applies the operator action HEP associated with Medium LOCA events when all support systems are available.

Top Event: HP – High Pressure Coolant Injection

HP General Notes:

- In the Medium LOCA event tree, HPCI is evaluated independent of RCIC because RCIC is not credited in the evaluation of Medium LOCA events. HPCI has only two support systems, 125V DC-1 and 120V Vital Bus. We also assume that HPCI must be manually initiated and controlled and there is no credit for automatic initiation on low RPV level or high drywell pressure signals. Also, we note that although the HPCI fault tree model and split fraction values include "failure of auto suction transfer from CST to torus" as a failure mode, the contents/volume of the CST is not challenged (suction transfer judged not needed according to MAAP analyses, refer to Transient rule descriptions) and this failure mode is thus a slightly conservative aspect of the fault tree and event tree models.

Support System Failure Impact:

Support System	Impacts on HP
DC-1 fails	HPCI fails
VC fails	HPCI auto suction transfer from CST to torus fails (requires manual operator action for HP success)

HP Split Fraction Rules:

HPFAIL **(D1=F) + (-C1=S) + (A3=F)**

Note that we assume that HPCI requires long-term power from DC-1 (i.e., battery charging), hence HP fails if either D1, C1 (battery charging) or A3 (ac power for battery charging to DC-1) fail.

HPVCF **(-VC=S)**

This split fraction represents the HPCI system failure probability when the 120V Vital Bus fails and the auto suction transfer is initiated manually.

HPBASE **1**

HPCI base case with all support systems available.

Top Event: FW – Feedwater System

FW General Notes:

The support system impacts assumed for FW are:

Support System	Impacts on FW
4kV Bus 1 (O1)	FW fails, FW pumps A & B fail, aux. oil pump for pump C fails, Cond. pump A fails.
4kV Bus 2 (O2)	FW fails, FW pump C fails, Cond. pumps B & C fail, also fails hotwell emergency makeup valve MOV 64-31.
125V DC-1 (D1)	FW fails, loss of Bus 1 (O1).
125V DC-2 (D2)	FW fails, loss of Bus 2 (O2).
120V Vital Bus (VC)	FW fails, loss of power to FW reg. valves, including low flow valve.
120V Instru. Bus (IC)	FW fails, loss of pumps A,B,C.
Instru. Air (IG)	FW fails, loss of air to FW reg. valves, including low flow valve.
TBCCW (TW)	FW fails, loss of cooling for FW and Cond. pumps A,B,C.

FW Split Fraction Rules:

FWFAIL (-O1=S) + (-O2=S) + (-VC=S) + (-IC=S) + (-IG=S) + (-TW=S)

Note that no rules were written to cover D1=F or D2=F, because the event tree structure bypasses top event O1 or O2 (O1=B or O2=B) when D1 or D2 fail. These cases are captured by the –O1=S and –O2=S rules. Note also that the Medium LOCA initiator is assumed not to cause failure of FW (i.e., the LOCA is not in the feedwater piping).

FWTBBS 1

This is the split fraction for FW with Turbine Bypass (TB) not unavailable (MSIVs are assumed closed) and with all other support systems available. The MSIVs are assumed closed (and turbine bypass/main condenser not available) because the initiating event is a Medium LOCA.

Top Event: AD – RPV Depressurization System

AD General Notes:

- Top event AD (RPV depressurization for use of low pressure injection) is evaluated independent of top event OD (manual depressurization for vapor suppression) because AD is not evaluated in the Medium LOCA event tree structure if OD is bypassed or successful.
- We assume that the ADS function has been inhibited by the operator (per EOPs), hence AD is a manual action, not automatic. This makes the AD model identical to the OD model except that the operator action involves different circumstances (i.e., is expected to have a different operator error rate).
- Similar to OD, we assume that AD requires long-term operation of the SRVs, hence we require success of the containment gas nitrogen supply (top event CG). The only other support systems for AD are 125V DC-1 and DC-2. Given the system design, failure of both DC power sources is required to fail the depressurization function (fail all SRVs). DC-2 supplies the "normal" control power to each SRV solenoid valve. Upon failure of DC-2, control power to each solenoid valve will automatically transfer to DC-1 via de-energized relay K11A, B, C and D.

AD Split Fraction Rules:

ADFAIL (-CG=S) + ((D1=F) * (D2=F))

AD is guaranteed to fail when CG fails or when both DC-1 and DC-2 fail.

ADMDA (D1=F)

ADMDB (D2=F)

Split fraction ADMDA(B) applies the operator action HEP associated with RPV depressurization during Medium LOCA events when division D1(D2) of DC power has failed.

ADMBS 1

Split fraction ADMBS applies the operator action HEP associated with RPV depressurization during Medium LOCA events when all support systems are available.

Top Event: IP – Primary Containment Integrity

IP General Notes:

- Top event IP is asked in order to establish whether the containment is intact when the hard-piped vent from torus air space is used to prevent over-pressurization (VT=S). Integrity of containment is a necessary condition in order for the operator to control and maintain sufficient pressure in the containment in support of continued operation of LPCI or Core Spray pumps taking suction from the suppression pool at elevated temperature.
- Failure of containment integrity is defined to include failures in the containment boundary that allow leakage in excess of that which would prevent maintaining overpressure sufficient to satisfy the NPSH-r or the LPCI and Core Spray pumps at elevated suppression pool temperature. The leakage sources are divided into two principal categories:
  - Isolation valve failures: These are related to the failure of the isolation valves in containment penetration lines or failure of the isolation signals or power to close these valves.
  - Pre-existing failures: These are failures primarily related to hatches, electrical penetration assemblies (EPAs), and other containment leakage paths not associated with failure of isolation valves to close.

IP Split Fraction Rules

IPIG (IG=F)+((VC=F)*(IC=F))

This split fraction is used when both the "inboard" and "outboard" isolation valves fail due to support system failures.

The "inboard" and "outboard" valves for the PCAC system require instrument air (IG) for normal operation.

The isolation valves will fail CLOSED on interruption of air supply pressure. The "inboard" isolation valves are dependent on Vital Bus (VC) 120vac, and the "outboard" isolation valves are dependent on Instrument Bus (IC) 120vac. These isolation valves will fail CLOSED on loss of control power.

Inboard torus-to-RB vacuum breaker SB-16-19-11A requires Vital Bus (VC), while the SB-16-19-11B vacuum breaker requires Instrument Bus (IC). These valves will fail OPEN on loss of air pressure or electric power. Note that the outboard torus-to-RB swing-check valves are in-series with the air-operated vacuum breakers, hence failure of the air-operated vacuum breakers to close does not necessarily cause failure of containment isolation.

IPVAC (VC=F)

This split fraction is used when torus-to-RB vacuum breaker SB-16-19-11A fails due to failure of the Vital Bus (VC) 120vac power supply. Note that the outboard torus-to-drywell swing-check valve is in-series with the air-operated vacuum breakers, hence failure of the air-operated

IPIAC (IC=F)

This split fraction is used when torus-to-RB vacuum breaker SB-16-19-11B fails due to failure of the Instrument Bus (IC) 120vac power supply. Note that the outboard torus-to-drywell swing-check valve is in-series with the air-operated vacuum breakers, hence failure of the air-operated

IPBASE 1

No other support system failures affect the containment isolation system. Thus, the base case (all support systems available) split fraction applies to all sequences not captured by one of the previous rules.

Top Event: LP – Low Pressure Coolant Injection

LP General Notes:

- The min. flow valve in each LPCI loop (MOV-16A/16B) is maintained normally open and success of the LPCI loop does not depend on successful closure of the associated min. flow valve. Therefore, we assume LPCI success does not depend on the min. flow valve hardware or the associated power supply.

Support System Impacts on LP

Support System	Impacts on LP
125V DC-I (D1) fails	RHR Pumps C and D fail; degraded injection valve ECCS signal.
125V DC-2 (D2) fails	RHR Pumps A and B fail; degraded injection valve ECCS signal.
4kV Bus 3 (A3) fails	RHR Pumps C and D fail; injection valve ECCS signal not degraded.
4kV Bus 4 (A4) fails	RHR Pumps A and B fail; injection valve ECCS signal not degraded.
RRU7 (R7) fails	No impact assumed based on room heatup assessment.
RRU8 (R8) fails	No impact assumed based on room heatup assessment.
SW fails	No impact assumed based on room heatup assessment. Also, RHR pump seal and bearing cooling via SW/RBCCW assumed not needed for injection mode.
RBCCW (RW) fails	No impact; RHR pump seal and bearing cooling via RBCCW assumed not needed for the injection mode function.
ECCS Signal (SIG) fails	Failure of the ECCS signal and failure to manually initiate low pressure pumps are assumed to cause failure of LPCI (and CS) for the Medium LOCA event. Failure of the signal and manual backup action is handled in the SIGF rule (*).
Medium LOCA Event	No impact on the number of available LP loops (both loops available, no degradation assumed).

(*) Success of either the automatic ECCS actuation signal or manual action to backup a failed signal are credited in the evaluation of LPCI and Core Spray for Medium LOCA events. For the Medium LOCA, we take credit for operator action to manually initiate ECCS after failure of the automatic initiation signal (top event OI in the Auxiliary Support State Event Tree), providing that the PI (low pressure interlock) was successful. Signal and operator action top events are evaluated probabilistically in the Auxiliary State Support Event Tree: PI (Low Pressure Interlock), DW (Drywell Pressure), LV (RPV Level), PS (RPV Pressure) and OI (operator action). The combination of individual signals and operator action success or failure is evaluated before LPCI (and before Core Spray) using the SIGF Macro rule shown below. If the ECCS signal fails because of failure of the PI signal, we assume that this prevents the operator from initiating low pressure injection (will not be able to open injection valves). However, if the ECCS signal fails because of LV, PS or DW signal failures, the operator (OI) can still manually initiate the low pressure systems.

SIGF: (-PI=S) + ((-DW=S) * ((-LV=S) + (-PS=S))) * (-OI=S)

LP Split Fraction Rules:

LPFAIL	(SIGF) + ((D1=F) + (A3=F)) * ((D2=F) + (A4=F))

The LPFAIL rule covers all support system failure combinations which guarantee failure of LP.

LP2VA	(D1=F)
LP2VB	(D2=F)

LPCI configuration will be 2 pump failure with degraded LPCI injection valve logic given DC-1 (LP2VA) or DC-2 (LP2VB) failure.

LP2FA	A3=F
LP2FB	A4=F

LPCI configuration will be 2 pump failure without degraded LPCI injection valve logic given failure of 4KV AC Bus 3 (LP2FA) or AC Bus 4 (LP2FB) failure.

LPBASE	(-SIGF) * (D1=S) * (A3=S) * (D2=S) * (A4=S)

LPCI base case reliability is applied when all support systems are successful and SIGF has not failed.

LPFAIL	1

If none of the above rules apply, the LPFAIL rule will ensure a conservative result and assist in checking the validity of the results.

Top Event: CS – Core Spray System

Support System Impacts on CS

The impact of single support system failures on CS is as follows. Note that the min. flow valve in each CS loop (MOV-5A/5B) is maintained normally open and success of the CS loop does not depend on successful closure of the associated min. flow valve. Therefore, we assume CS success does not depend on the min. flow valve hardware or the associated power supply.

Support System	Impacts on CS
125V DC-I (D1) fails	CS Loop B fails - Pump B and MOV-11B/12B.
125V DC-2 (D2) fails	CS Loop A fails - Pump A and MOV-11A/12A.
4kV Bus 3 (A3) fails	CS Loop B fails - Pump B and MOV-11B/12B.
4kV Bus 4 (A4) fails	CS Loop A fails - Pump A and MOV-11A/12A.
RRU7 (R7) fails	No impact assumed based on room heatup assessment.
RRU8 (R8) fails	No impact assumed based on room heatup assessment.
SW/RW fail	No impact on Core Spray.
ECCS Signal (SIG) fails	Assumed to cause failure of CS for large break LOCA event (*).

(*) Refer to top event LP above for summary of the SIGF rule.

CS Split Fraction Rules:

CSFAIL (SIGF) + ((D1=F) + (A3=F)) * ((D2=F) + (A4=F))

Both divisions of CS are guaranteed to fail when the ECCS signal fails or all support systems fail.

CSA4F ((A4=F) + (D2=F)) * ((A3=S) * (D1=S))

This is a train-specific split fraction, which applies the reliability of CS division B when AC Bus 4 or DC Bus 2 fail, but AC Bus 3 and DC Bus 1 are success.

CSA3F ((A3=F) + (D1=F)) * ((A4=S) * (D2=S))

This is a train-specific split fraction, which applies the reliability of CS Division A when AC Bus 3 or DC Bus 1 fail, but AC Bus 4 and DC Bus 2 are both success.

CSBASE 1

CS base case reliability is applied when the above rules are not satisfied.

Top Event: CN – Condensate System (Low Pressure Injection)

CN General Notes: None.

Support System	Impacts on CN
4kV Bus 1 (O1)	CN Pump A fails
4kV Bus 2 (O2)	CN Pumps B & C fail, also fails hotwell emergency makeup valve MOV 64-31)
125V DC-2 (D2)	CN fails (O2 failure)
120V Vital Bus (VC)	CN fails (no power to FW reg. valves)
Instru. Air (IG)	CN fails (no air to FW reg. valves)
TBCCW (TW)	CN fails (no pump motor cooling)

CN Split Fraction Rules:

CNFAIL (-O2=S) + (-VC=S) + (-IG=S) + (-TW=S)

This split fraction is assigned when the support systems for Condensate fail. No rule is written for D2=F since O2 is bypassed in the event tree structure when D2=F. This is captured by the –O2=S rule.

CN1F (-O1=S)

CNBASE (FW=B) + (-IC=S)

CN is asked independent of FW when FW is bypassed by the event tree structure or when FW is guaranteed failure by support system failures. This occurs only when (FW=B) or (-O1=S) or (-IC=S). Failure of 4kV Bus 1 (-O1=S) degrades the CN model. Thus we have the above two split fraction case, CN1F and CNBASE. These rules apply when CN is not already failed (see CNFAIL) and is asked independently of FW.

CNFWS1 (FW=S)

Condensate System fails given Feedwater succeeds (TBCCW unavailable).

CNFWF1 (FW=F)

Condensate System fails given Feedwater fails (TBCCW unavailable).

CNFAIL 1

If none of the above rules apply, the CNFAIL rule will ensure a conservative result and assist in checking the validity of the results.

Top Event: TC – Torus Cooling

TC General Notes: None.

Support System Impacts on TC

In general, Torus Cooling (top event TC) is dependent on Low Pressure Coolant Injection (top event LP) due to shared RHR equipment. The impact of single support system failures on TC are as follows:

Support System	Impacts on TC
125V DC-I (D1) fails	RHR Pumps C & D fail; RHRSW Pumps B & D fail; TC Loop B MOVs fail.
125V DC-2 (D2) fails	RHR Pumps A & B fail; RHRSW Pumps A & C fail; TC Loop A MOVs fail.
4kV Bus 3 (A3) fails	RHR Pumps C & D fail; RHRSW Pumps B & D fail; TC Loop B MOVs fail.
4kV Bus 4 (A4) fails	RHR Pumps A & B fail; RHRSW Pumps A & C fail; TC Loop A MOVs fail.
RRU7 (R7) fails	No impact on equipment is assumed based on room heatup assessment.
RRU8 (R8) fails	No impact on equipment is assumed based on room heatup assessment.
SW fails	RHR Pumps A, C & B, D fail due to loss of seal and bearing injection water cooling (assumed needed for long term TC mode), RHRSW Pumps A, C & B, D fail due loss of service water suction.
ECCS Signal (SIG) fails	No impact on TC function is assumed.
Medium LOCA	No impact on TC function is assumed.

TC Split Fraction Rules:

TCFAIL ((SW=F) * (-AW=S))) + ((D1=F) + (A3=F)) * ((D2=F) + (A4=F))

This rule captures all cases for which support system failures will fail both trains of TC. Note that we credit use of AW as an alternative to SW and RW.

TC3FA ((LP=B)+(SIGF))*((D1=F)+(A3=F))

TC3FB ((LP=B)+(SIGF))*((D2=F)+(A4=F))

Single loop TC with 2 RHRSW pump and 1 RHR pump available, D1(D2) or A3(A4) unavailable.

TCBASE (LP=B) + (SIGF)

TC split fractions TC3FA(B) and TCBASE evaluate TC independent of LP. The LPFAIL rule (see top event LP) defines the cases where LP is guaranteed to fail by support system failures. Some of the same support system combinations that fail LP also fail TC and are accounted for in the TCFAIL rule. The only support system failure which appears in the LPFAIL rule and does not guarantee failure of TC is SIGF. Because SIGF guarantees failure of LP, TC is being evaluated independent of LP for these cases. LP can also be "bypassed" in the Medium

LOCA event tree because other injection systems can satisfy the RPV inventory function, consequently TC must still be evaluated (independently). Therefore, we have also included the (LP=B) portion of the rule. The above rules for TC3FA(B), and TCBASE capture these cases.

Note: If TC3FA(B) and TCBASE split fractions do not apply, TC must be evaluated "dependent" upon the success or failure of LP. The following "dependent" LP/TC split fractions were developed to cover the various support system states given LP success /failure.

TCLS7A	(LP=S)*(D1=F)
TCLS7B	(LP=S)*(D2=F)

TC failure given LP success when either D1 (TCLS7A) or D2 (TCLS7B) has failed.

TCLS6A	(LP=S)*((A3=F))
TCLS6B	(LP=S)*((A4=F))

TC failure given LP success when either A3 (TCLS6A) or A4 (TCLS6B) has failed.

TCLPS5	(LP=S)

TC failure given LP success when all support systems are available/successful

TCLF7A	(LP=F)*((D1=F))
TCLF7B	(LP=F)*((D2=F))

TC failure given LP failure when either D1 (TCLF7A) or D2 (TCLF7B) has failed.

TCLF6A	(LP=F)*((A3=F))
TCLF6B	(LP=F)*((A4=F))

TC failure given LP failure when either A4 (TCLF6A) or A3 (TCLF6A) has failed.

TCLPF5	(LP=F)

TC failure given LP failure when all support systems are available/successful.

TCFAIL	1

If none of the above rules apply, the TCFAIL rule will ensure a conservative result and assist in checking the validity of the results.

Top Event: RM – Recover Main Condenser

RM General Notes:

This top event models recovery of the main condenser. We do not credit RM for Medium LOCA initiating events. However, the Medium LOCA event tree is also used for IORV and SORV initiators (which include Transient initiators where the relief valves fail to close). For IORV and SORV initiators, we only credit RM if all support systems for the main condenser are available. See top event TB in the Transient event tree for a description of these support systems.

RM Split Fraction Rules:

RMBASE ((INIT=IORV)+(INIT=SORV)) * (O1=S) * (O2=S) * (SW=S) * (IG=S) * ((IC=S) + (VC=S))

The base case split fraction (RMBASE) is used whenever the initiator is IORV or SORV and all support systems for the main condenser are available.

RMFAIL 1

Recovery of the main condenser is assumed to fail for all remaining cases (RMFAIL) because one or more support systems are unavailable. Also, if the RMBASE rule does not apply, the RMFAIL rule will ensure a conservative result and assist in checking the validity of the results.

Top Event: VT – Torus Vent (hard-piped vent from torus air space)

VT General Notes:

Support System Impacts on TC

Torus vent valve (TVS-86) is "normally" closed and requires manual action to open the valve and enable the use of the venting path with rupture disc. For the Medium LOCA initiating event, we assume that TSV-86 must be opened remotely from the control room. Local operator action to open this valve is not credited because of the potential for a harsh environment, even though venting takes place in Level 1 before core damage occurs. The power source needed for remote opening of TSV-86 is 480V MCC-7A (associated w/ 4kV Bus 2).

VT Split Fraction Rules:

VTLCBS **(O2=S)**

The VTLCBS split fraction evaluates the reliability of the torus vent when power from MCC-7A/Bus2 (top event O2) available/successful and remote operator action can accomplish opening of TSV-86.

VTFAIL **1**

VTFAIL split fraction is assigned since power from Bus 2 has failed. We conservatively assume no recovery of the power source or local operation of the valve, thus VT is assumed to be guaranteed failure.

Top Event: AI – Alternate Injection (Long term Injection)

AI General Notes: None.

AI Split Fractions:

AISUCC (CN=S)

The Medium LOCA event tree takes credit for CN as an injection system. Because CN takes suction from outside containment, CN is not affected by high suppression pool temperature or loss of NPSH due to failure to control venting. Thus, we assign guaranteed success to AI whenever CN has succeeded earlier in the event tree.

AIFAIL (INIT=MLOCA)

This rule guarantees failure of AI for Medium LOCA initiators which do not satisfy the AISUCC or AINPSH rule. No credit is taken for "external" injection systems such as CRD, Condensate Transfer, RHRSW or Firewater for Medium LOCAs. This is based on the assumption that these systems would not be made available in a reasonable amount of time.

Because the Medium LOCA event tree is also used for IORV and SORV initiators, we use the following split fraction rules for IORV/SORV transient sequences.

AISUCC (RM=S) * ((LP=S) + (CS=S))

The AISUCC rule accounts for sequences where LP has succeeded earlier in the event tree, and where continued success of LP (at high suppression pool temperatures) is assured by RW or AW cooling.

AISBO (((A3=F) * (A4=F)) + ((-RW=S) * (-AW=S))) * ((-O2=S) + ((LP=F) * (CS=F)))

AISBO is used when neither CRD nor CT is available for injection. CRD fails due to either motive power failure or failure of cooling via RBCCW (RW) and alternate cooling (AW). CT fails due to motive power failure or lack of an injection path via LP or CS.

AICTAF (((A4=F)+(D2=F))*(RW=S))*((-(O2=S))+((LP=F)*(CS=F)))

AICTBF (((A3=F)+(D1=F))*(RW=S))*((-(O2=S))+((LP=F)*(CS=F)))

AICTAF(BF) is used when only 1 CRD pump is available for alternate injection. It is conservatively assumed that CRD pump operation requires that RBCCW (RW) be available. Only 1 CRD pump is available because either Bus 3 (AICTAF) or Bus 4 (AICTBF) power is a success, and component cooling via RBCCW is success. CT has failed because Bus 2 is not success (-O2=S) or the injection paths via LP and CS have failed.

AICTBS (RW=S) * ((-O2=S) + ((LP=F) * (CS=F)))

AICTBS is for the configuration of 2 CRD pumps available for alternate injection with no CT pump capability. CT is failed because either 1) failure of LP and CS is assumed to fail the injection paths or 2) power via Bus 2 (O2) is unavailable. Both CRD pumps are available because both 4kV Buses 3 and 4 are available.

AICRBS (((A3=F) * (A4=F)) + (-RW=S)) * ((O2=S) * ((LP=S) + (CS=S)))

AICRBS is used for configurations where both CT pumps are available but neither of the CRD pumps is available. CT pumps have power from Bus 2 and at least one injection path via LP or CS is available. CRD pumps have failed either from lack of motive power from Bus 3 and Bus 4 or from failure or RBCCW.

AICRAF ((A4=F)+(D2=F))*((O2=S)*((LP=S)+(CS=S)))*(RW=S)

AICRBF ((A3=F)+(D1=F))*((O2=S)*((LP=S)+(CS=S)))*(RW=S)

AICRAF(BF) is used when both CT pumps and only 1 CRD pump are available for alternate injection. Only 1 CRD pump is available because either Bus 3 (AICRAF) or Bus 4 (AICRBF) power is success and component cooling via RBCCW is success (satisfied by the above rule). Both CT pumps are available because support systems are success (Bus 2) and an injection pathway to the RPV via LPCI or Core Spray is success.

AIBASE ((O2=S) * ((LP=S) + (CS=S))) * (RW=S)

AIBASE is used when both CT pumps and both CRD pumps are available for alternate injection. All support systems needed by CRD and CT are success. CT requires the injection pathway to the RPV via LPCI or Core Spray, which is success.

AIFAIL 1

If none of the above rules apply, the AIFAIL rule will ensure a conservative result and assist in checking the validity of the results.

Attachment H

Event Tree (LOCA_SM)

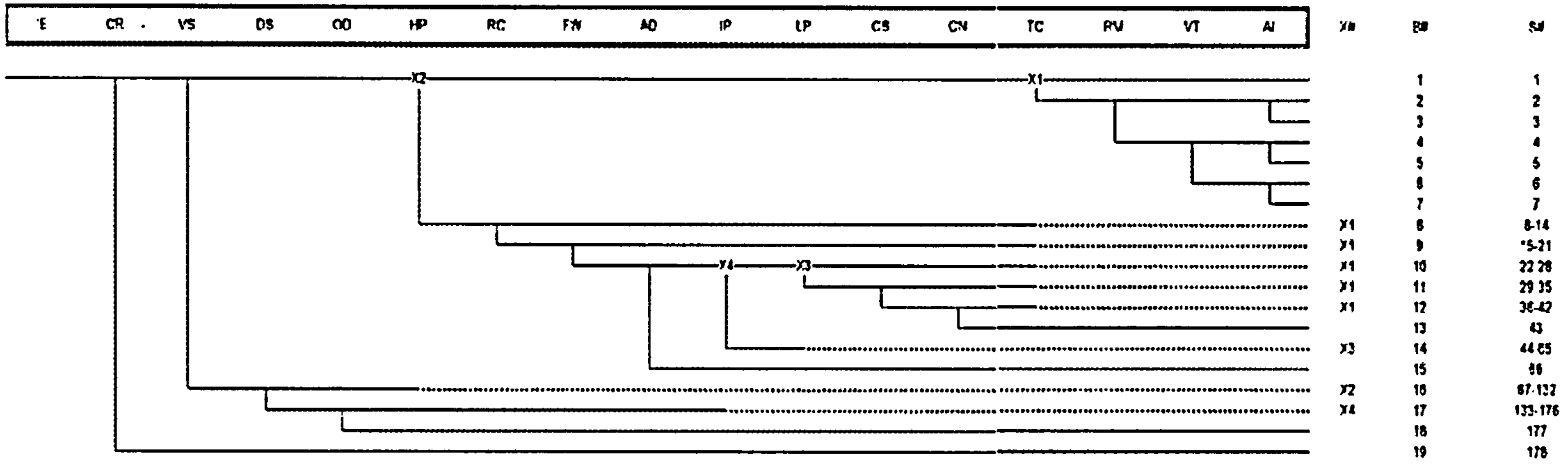

Figure H.1 Small LOCA Event Tree

Top Event Name	**Description**
CR	CONTROL ROD INJECTION - REACTOR SHUTDOWN
VS	VAPOR SUPPRESSION SYSTEM
DS	DRYWELL SPRAY SYSTEM USED IN LOCA_SM AND LOCA_MED
OD	MANUAL DEPRESSURIZATION USED FOR VAPOR SUPPRESSION ALTERNATIVE
HP	HPCI SYSTEM
RC	RCIC SYSTEM
FW	FEEDWATER SYSTEM
AD	AUTOMATIC DEPRESSURIZATION SYSTEM (ADS)
LP	LPCI SYSTEM
CS	LOW PRESSURE CORE SPRAY SYSTEM
CN	CONDENSATE SYSTEM
TC	TORUS COOLING SYSTEM
RM	RECOVERY OF MAIN CONDENSER
VT	TORUS HARD-PIPED VENT FOR LEVEL 1 ANALYSIS
IP	PRIMARY CONT. INTEGRITY FOR LEVEL 1 ANALYSIS
AI	ALTERNATE CORE COOLING SYSTEM, CRD, CONDENSATE TRANSFER, AND CST REFILL

Initiator:

- **SLOCA** (Small LOCA)

Modified Endstate Binning Rules – Small LOCA

CONFIG#1 (model VYCOP2A)

Bin **Rule**
ID **(CN=F) + ((VT=B) * (AI=F))**

Sequences with loss of all injection. Core damage occurs with the reactor at low pressure.

CONFIG#2 (model VYCOP2)

Bin **Rule**
ID **(CN=F) + ((VT=B) * (AI=F)) + (((RM=S) * (AI=F)) + (TC=S)) * (IP=F) * ((LP=S) + (CS=S))**

Sequences with loss of all injection. For sequences where LPCI and Core Spray are initially available, injection failure occurs due to inadequate NPSH if containment isolation is unsuccessful (IP=F).Core damage occurs with the reactor at low pressure.

Top Event: CR – Control Rods Insert

CR General Notes:

None.

CR Split Fraction Rules:

CRBASE 1

CR is considered to be independent of all other systems, hence the base case split fraction is used for all cases, i.e., CR has no support systems.

Top Event: VS – Vapor Suppression

VS General Notes: None.

VS Split Fraction Rules:

VSBASE 1

Like top event CR, VS has no support systems. Therefore, VS is assumed independent of all other systems.

Top Event: OD – Manual RPV Depressurization for Containment Pressure Control

OD General Notes:

The split fraction rules for OD are similar for Small and Medium LOCAs. The only difference is that the split fraction values account for the greater time available for operator action for the small LOCA.

OD models operator depressurization of the RPV via the SRVs (discharging to the suppression pool) as a means of mitigating the containment pressure rise for LOCA (Medium or Small) sequences with vapor suppression failure (stuck-open vacuum breakers). We assume that OD requires long-term operation of the SRVs, hence we require success of the containment gas nitrogen supply (top event CG). The only other support systems for OD are 125V DC-1 and DC-2. Given the system design, failure of both DC power sources is required to fail the depressurization function (fail all SRVs). DC-2 supplies the "normal" control power to each SRV solenoid valve. Upon failure of DC-2, control power to each solenoid valve will automatically transfer to DC-1 via de-energized relay K11A, B, C and D.

OD Split Fraction Rules:

ODFAIL (-CG=S) + ((D1=F) * (D2=F))

OD is guaranteed to fail when CG fails or when both DC-1 and DC-2 fail.

ODSLDA (D1=F)

ODSLDB (D2=F)

Split fraction ODSLDA(B) applies the operator action HEP associated with Small LOCA events when one Division 1 (2) of DC power has failed.

ODSLBS 1

Split fraction ODSLBS applies the operator action HEP associated with Small LOCA events when all support systems are available.

Top Event: HP – High Pressure Coolant Injection

HP General Notes:

Support system failure impact on HPCI is as follows:

Support System Failure	Impact on HPCI
DC-1 fails	HPCI fails
VC fails	HPCI auto suction transfer from CST to torus fails (requires manual operator action for HP success)

HP Split Fraction Rules:

HPFAIL **(D1=F) + (-C1=S) + ((A3=F) * (-A3R))**

HP is guaranteed failure when DC-1 fails HP also fails if the battery charger fails (long term DC power, top event C1), or if AC power is unavailable to the charger, A3 fails and is not recovered, A3R.

HPVCF **(-VC=S)**

Failure of VC fails HPCI auto suction transfer from CST to torus. This requires manual operator action for HP success

HPBASE **1**

Top Event RC – Reactor Core Isolation Cooling

RC General Notes:

The small LOCA tree structure evaluates RCIC (RC) after HPCI (HP). RC is therefore dependent on HP when HP is asked first since we account for potential common cause mechanisms between the RC and HP turbine-driven pumps. Note that RC is only evaluated in the event tree structure after HP fails. (If HPCI is success, the event tree structure does not evaluate RCIC. Thus, the only way that RC could be asked independent of HP is if HP was guaranteed failure by support system failures.

The operator action for initiation and control of HPCI and RCIC is also assumed to be a completely dependent action.

The support system impacts for RC are:

Support System Failure	Impact on RCIC
125V DC-2 (D2)	RC fails (no MOV motive power, etc.)
120V Vital Bus (VC)	RC fails (loss of flow controller power)
24V ECCS Battery B (V2)	Failure of the automatic function to transfer suction from CST to torus (requires manual operator action for success)

Note that there are no other auto signal requirements for RC since we assume that the operator must manually initiate the system.

RC Split Fraction Rules:

RCFAIL **(D2=F) + (-VC=S) + (-C2=S) + (A4=F)**

The RCFAIL split fraction accounts for the failure of RC which occurs when DC-2 fails or when VC fails. Note that we assume long-term success of RCIC. This requires that the DC-2 battery is receiving charge (top event C2 battery charging) and that AC power (top event A4) is available to the charger.

RCV2F **((D1=F) + (-C1=S) + (A3=F)) * (-V2=S)**

Split fraction RCV2F evaluates RCIC independent of HPCI when the 24V ECCS battery B (V2) failed (V2 failure degrades RCIC by failing the auto suction transfer). This independent split fraction is applied when the support systems of HPCI (D1, C1 and A3) have failed, thus HPCI is guaranteed failure and RCIC is evaluated independently. Note that we assume long-term success of HPCI and that is the reason for HPCI failure when C1 and A3 fail.

RCBASE (D1=F) + (-C1=S) + (A3=F)

Split fraction RCBASE evaluates RCIC independent of HPCI when all RCIC support systems are success. This independent split fraction is applied when the support systems of HPCI (D1, C1 and A3) have failed, thus HPCI is guaranteed failure and RCIC is evaluated independently.

The split fractions below address the case where RC is asked dependent on HP and HP failed randomly (HP support systems were success) . Note that there are no rules for HP=S since RC is bypassed in the event tree structure when HP=S as noted above.

RCHPF2 (HP=F) * (-V2=S)

RCHPF2 evaluates the RCIC failure probability given HPCI random failure when RCIC is degraded because of failure of the auto suction transfer (V2 failed).

RCHPF1 (HP=F)

RCHPF1 evaluates the RCIC failure probability given HPCI random failure when all RCIC support systems are available (base case configuration).

RCFAIL 1

If none of the above rules apply, the RCFAIL *rule will ensure a conservative result and assist in checking the* validity of the results.

Top Event: FW – Feedwater System (high pressure injection)

FW General Notes:

Top event FW in the Small LOCA Event Tree is the same as top event FW in the Medium LOCA and Transient event trees with the following exceptions:

- FW is guaranteed failure for transient initiators TFWMS, TLP, TD1, TD2, TSW (SW failure leads to TW failure which, is assumed to fail Feedwater pump cooling).
- FW success does not require a hotwell makeup source of water for transients events where TB is available.

Support System Failure	Impact of Feedwater
4kV Bus 1 (O1)	FW fails, FW pumps A & B fail, aux. oil pump for pump C fails, Cond. pump A fails.
4kV Bus 2 (O2)	FW fails, FW pump C fails, Cond. pumps B & C fail, also fails hotwell emergency makeup valve MOV 64-31.
125V DC-1 (D1)	FW fails, loss of Bus 1 (O1).
125V DC-2 (D2)	FW fails, loss of Bus 2 (O2).
120V Vital Bus (VC)	FW fails, loss of power to FW reg. valves, including low flow valve.
120V Instru. Bus (IC)	FW fails, loss of pumps A,B,C.
Instru. Air (IG)	FW fails, loss of air to FW reg. valves, including low flow valve.
TBCCW (TW)	FW fails, loss of cooling for FW and Cond. pumps A,B,C.

FW Split Fraction Rules:

FWFAIL (-O1=S) + (-O2=S) + (-VC=S) + (-IC=S) + (-IG=S) + (-TW=S)

Note that no rules were written to cover D1=F or D2=F, because the event tree structure bypasses top event O1 or O2 (O1=B or O2=B) when D1 or D2 fail. These cases are captured by the –O1=S and –O2=S rules. Note also that the Small LOCA initiator is assumed not to cause failure of FW (i.e., the LOCA is not in the feedwater piping).

FWTBBS 1

This is the split fraction for FW with Turbine Bypass (TB) unavailable (MSIVs are assumed closed) and with all other support systems available. The MSIVs are assumed closed (and turbine bypass/main condenser not available).

Top Event: AD – RPV Depressurization System

AD General Notes:

- For evaluation of AD in the Small LOCA event tree, the only difference between the Small and Medium LOCA is in the time available for operator action. An "S" is used in the AD split fraction names to identify applicability to "Small" LOCA.
- Top event AD (RPV depressurization for use of low pressure injection) is evaluated independent of top event OD (manual depressurization for vapor suppression) because AD is not evaluated in the Small LOCA event tree structure if OD is bypassed or successful.
- We assume that the ADS function has been inhibited by the operator (per EOPs), hence AD is a manual action, not automatic. This makes the AD model identical to the OD model except that the operator action involves different circumstances (i.e., is expected to have a different operator error rate).
- Similar to OD, we assume that AD requires long-term operation of the SRVs, hence we require success of the containment gas nitrogen supply (top event CG). The only other support systems for AD are 125V DC-1 and DC-2. Given the system design, failure of both DC power sources is required to fail the depressurization function (fail all SRVs). DC-2 supplies the "normal" control power to each SRV solenoid valve. Upon failure of DC-2, control power to each solenoid valve will automatically transfer to DC-1 via de-energized relay K11A, B, C and D.

AD Split Fraction Rules:

ADFAIL **(-CG=S) + ((D1=F) * (D2=F))**

AD is guaranteed to fail when CG fails or when both DC-1 and DC-2 fail.

ADSDA **(D1=F)**
ADSDB **(D2=F)**

Split fraction ADSDA(B) applies the operator action HEP associated with RPV depressurization during Small LOCA events when Division 1 (2) of DC power has failed.

ADSBS **1**

Split fraction ADSBS applies the operator action HEP associated with RPV depressurization during Small LOCA events when all support systems are available.

Top Event: IP – Primary Containment Integrity

IP General Notes:

Top event IP is asked in order to establish whether the containment is intact when the hard-piped vent from torus air space is used to prevent over-pressurization (VT=S). Integrity of containment is a necessary condition in order for the operator to control and maintain sufficient pressure in the containment in support of continued operation of LPCI or Core Spray pumps taking suction from the suppression pool at elevated temperature.

Failure of containment integrity is defined to include failures in the containment boundary that allow leakage in excess of that which would prevent maintaining overpressure sufficient to satisfy the NPSH-r or the LPCI and Core Spray pumps at elevated suppression pool temperature. The leakage sources are divided into two principal categories:

- Isolation valve failures: These are related to the failure of the isolation valves in containment penetration lines or failure of the isolation signals or power to close these valves.
- Pre-existing failures: These are failures primarily related to hatches, electrical penetration assemblies (EPAs), and other containment leakage paths not associated with failure of isolation valves to close.

IP Split Fraction Rules

IPIG (IG=F)+((VC=F)*(IC=F))

This split fraction is used when both the "inboard" and "outboard" isolation valves fail due to support system failures.

The "inboard" and "outboard" valves for the PCAC system require instrument air (IG) for normal operation.

The isolation valves will fail CLOSED on interruption of air supply pressure. The "inboard" isolation valves are dependent on Vital Bus (VC) 120vac, and the "outboard" isolation valves are dependent on Instrument Bus (IC) 120vac. These isolation valves will fail CLOSED on loss of control power.

Inboard torus-to-RB vacuum breaker SB-16-19-11A requires Vital Bus (VC), while the SB-16-19-11B vacuum breaker requires Instrument Bus (IC). These valves will fail OPEN on loss of air pressure or electric power. Note that the outboard torus-to-RB swing-check valves are in-series with the air-operated vacuum breakers, hence failure of the air-operated vacuum breakers to close does not necessarily cause failure of containment isolation.

IPVAC (VC=F)

This split fraction is used when torus-to-RB vacuum breaker SB-16-19-11A fails due to failure of the Vital Bus (VC) 120vac power supply. Note that the outboard torus-to-drywell swing-check valve is in-series with the air-operated vacuum breakers, hence failure of the air-operated

IPIAC (IC=F)

This split fraction is used when torus-to-RB vacuum breaker SB-16-19-11B fails due to failure of the Instrument Bus (IC) 120vac power supply. Note that the outboard torus-to-drywell swing-check valve is in-series with the air-operated vacuum breakers, hence failure of the air-operated

IPBASE 1

No other support system failures affect the containment isolation system. Thus, the base case (all support systems available) split fraction applies to all sequences not captured by one of the previous rules.

Top Event: LP – Low Pressure Coolant Injection

LP General Notes:

- The min. flow valve in each LPCI loop (MOV-16A/16B) is maintained normally open and success of the LPCI loop does not depend on successful closure of the associated min. flow valve. Therefore, we assume LPCI success does not depend on the min. flow valve hardware or the associated power supply.

Support System Impacts on LP

Support System Failure	Impact of LP
125V DC-I (D1) fails	RHR Pumps C and D fail; degraded injection valve ECCS signal.
125V DC-2 (D2) fails	RHR Pumps A and B fail; degraded injection valve ECCS signal.
4kV Bus 3 (A3) fails	RHR Pumps C and D fail; injection valve ECCS signal not degraded.
4kV Bus 4 (A4) fails	RHR Pumps A and B fail; injection valve ECCS signal not degraded.
RRU7 (R7) fails	No impact assumed based on room heatup assessment.
RRU8 (R8) fails	No impact assumed based on room heatup assessment.
SW fails	No impact assumed based on room heatup assessment. Also, RHR pump seal and bearing cooling via SW/RBCCW assumed not needed for injection mode.
RBCCW (RW) fails	No impact; RHR pump seal and bearing cooling via RBCCW assumed not needed for the injection mode function.
ECCS Signal (SIG) fails	Failure of the ECCS signal and failure to manually initiate low pressure pumps are assumed to cause failure of LPCI (and CS). Failure of the signal and manual backup action is handled in the SIGF rule.

LP Split Fraction Rules:

SIGF: **(-PI=S) + ((-DW=S) *((-LV=S) + (-PS=S))) * (-OI=S)**

This is the Marco rule for developing the failure logic if the ECCS signal. The SIGF macro is used below in the rules for LPCI and later for Core Spray. The ECCS signal is made up of a combination of low pressure interlock (PI), drywell high pressure (DW), low reactor level (LV), low reactor pressure (PS). The operator (OI) can also fail to "backup" a failed signal provided that the signal did not fail due to PI.

LPFAIL **(SIGF) + ((D1=F) + (A3=F)) * ((D2=F) + (A4=F))**

All of LPCI is guaranteed to fail when the ECCS signal fails or all support systems fail.

LP2VA (D1=F)

LP2VB (D2=F)

LPCI configuration will be 2 pump failure with degraded LPCI injection valve logic given DC-1 (LP2VA) or DC-2 (LP2VB) failure.

LP2FA (A3=F)

LP2FB (A4=F)

LPCI configuration will be 2 pump failure without degraded LPCI injection valve logic given failure of 4KV AC Bus 3 (LP2FA) or AC Bus 4 (LP2FB) failure.

LPBASE (-SIGF) * (D1=S) * (A3=S) * (D2=S) * (A4=S)

LPCI base case reliability is applied when all support systems are successful and the SIGF has not failed.

LPFAIL 1

If none of the above rules apply, the LPFAIL rule will ensure a conservative result and assist in checking the validity of the results.

Top Event: CS – Core Spray System

CS General Notes:

- The min. flow valve in each CS loop (MOV-5A/5B) is maintained normally open and success of the CS loop does not depend on successful closure of the associated min. flow valve. Therefore, we assume CS success does not depend on the min. flow valve hardware or the associated power supply.

Support System Impacts on CS

Support System Failure	Impact of CS
125V DC-I (D1) fails	CS Loop B fails - Pump B and MOV-11B/12B.
125V DC-2 (D2) fails	CS Loop A fails - Pump A and MOV-11A/12A.
4kV Bus 3 (A3) fails	CS Loop B fails - Pump B and MOV-11B/12B.
4kV Bus 4 (A4) fails	CS Loop A fails - Pump A and MOV-11A/12A.
RRU7 (R7) fails	No impact assumed based on room heatup assessment.
RRU8 (R8) fails	No impact assumed based on room heatup assessment.
SW/RW fail	No impact on Core Spray.
ECCS Signal (SIG) fails	Assumed to cause failure of CS for large break LOCA event (*).
	(*) Refer to top event LP above for summary of the SIGF rule.

CS Split Fraction Rules:

CSFAIL (SIGF) + ((D1=F) + (A3=F)) * ((D2=F) + (A4=F))

Both divisions of CS are guaranteed to fail when the ECCS signal fails or all support systems fail.

CSA4F ((A4=F) + (D2=F)) * ((A3=S) * (D1=S))

This is a train-specific split fraction, which applies the reliability of CS division B when AC Bus 4 or DC Bus 2 fail, but AC Bus 3 and DC Bus 1 are success.

CSA3F ((A3=F) + (D1=F)) * ((A4=S) * (D2=S))

This is a train-specific split fraction, which applies the reliability of CS Division A when AC Bus 3 or DC Bus 1 fail, but AC Bus 4 and DC Bus 2 are both success.

CSBASE 1

CS base case reliability is applied when the above rules are not satisfied.

Top Event: CN – Condensate System (Low Pressure Injection)

CN General Notes: None

Support System Failure	Impact of CN
4kV Bus 1 (O1)	CN Pump A fails
4kV Bus 2 (O2)	N Pumps B & C fail, also fails hotwell emergency makeup valve MOV 64-31
125V DC-2 (D2)	CN fails (O2 failure)
120V Vital Bus (VC)	CN fails (no power to FW reg. valves)
Instru. Air (IG)	CN fails (no air to FW reg. valves)
TBCCW (TW)	CN fails (no pump motor cooling)

CN Split Fraction Rules:

CNFAIL (-O2=S) + (-VC=S) + (-IG=S) + (-TW=S)

This split fraction is assigned when the support systems for Condensate fail. No rule is written for D2=F since O2 is bypassed in the event tree structure when D2=F. This is captured by the –O2=S rule.

CN is asked independent of FW when FW is bypassed by the event tree structure or when FW is guaranteed failure by support system failures. This occurs only when (FW=B) or (-O1=S) or (-IC=S). Failure of 4kV Bus 1 (-O1=S) degrades the CN model. Thus we have the following two split fraction case, CN1F and CNBASE. These rules apply when CN is not already failed (see CNFAIL) and is asked independently of FW.

CN1F (-O1=S)

Condensate system is degraded (one pump fails) when 4KV Bus 1 fails.

CNBASE (FW=B) + (-IC=S)

All other cases involve FW=F (CN is only asked after FW=F) with CN dependent on FW. All support systems for FW and CN have been accounted for by previous rules. The next two rules below (CNFWF1 and CNFWF2) apply to cases where CN is dependent on FW; success (CNFWS1) or failure (CNFWF1).

CNFWF1 (FW=F) * ((-TB=S) + (INIT=TMS))

Condensate System fails given Feedwater fails (TBCCW unavailable).

CNFWF2 (FW=F) * (TB=S)

Condensate System fails given Feedwater fails (TBCCW available).

CNFAIL 1

If none of the above rules apply, the CNFAIL rule will ensure a conservative result and assist in checking the validity of the results.

Top Event: TC – Torus Cooling

TC General Notes:

Support System Impacts on TC

In general, Torus Cooling (top event TC) is dependent on Low Pressure Coolant Injection (top event LP) due to shared RHR equipment. The impact of single support system failures on TC are as follows:

Support System Failure	Impact on Torus Cooling
125V DC-I (D1) fails	RHR Pumps C & D fail; RHRSW Pumps B & D fail; TC Loop B MOVs fail.
125V DC-2 (D2) fails	RHR Pumps A & B fail; RHRSW Pumps A & C fail; TC Loop A MOVs fail.
4kV Bus 3 (A3) fails	RHR Pumps C & D fail; RHRSW Pumps B & D fail; TC Loop B MOVs fail.
4kV Bus 4 (A4) fails	RHR Pumps A & B fail; RHRSW Pumps A & C fail; TC Loop A MOVs fail.
RRU7 (R7) fails	No impact on equipment is assumed based on room heatup assessment.
RRU8 (R8) fails	No impact on equipment is assumed based on room heatup assessment.
SW fails	RHR Pumps A, C & B, D fail due to loss of seal and bearing injection water cooling (assumed needed for long term TC mode), RHRSW Pumps A, C & B, D fail due loss of service water suction.
ECCS Signal (SIG) fails	No impact on TC function is assumed.
Small LOCA	No impact on TC function is assumed.

TC Split Fraction Rules:

TCFAIL ((SW=F) * (-AW=S))) + ((D1=F) + (A3=F)) * ((D2=F) + (A4=F))

This rule captures all cases for which support system failures will fail both trains of TC. Note that we credit AW (which considers recovery of service water and use of the Alternate Cooling Mode) as a backup to SW in top event TC for Transient events.

TC3FA ((LP=B)+(SIGF))*((D1=F)+(A3=F))

TC3FB ((LP=B)+(SIGF))*((D2=F)+(A4=F))

Single loop TC with 2 RHRSW pump and 1 RHR pump available, D1(D2) or A3(A4) unavailable.

TCBASE (LP=B) + (SIGF)

TC split fractions TC3FA(B) and TCBASE evaluate TC independent of LP. The LPFAIL rule (see top event LP) defines the cases where LP is guaranteed to fail by support system failures. Some of the same support system combinations that fail LP also fail TC and are accounted for in the TCFAIL rule. The only support system failure which appears in the LPFAIL rule and does not guarantee failure of TC is SIGF. Because SIGF guarantees failure of LP, TC is being evaluated independent of LP for these cases. LP can also be "bypassed" in the Small

LOCA event tree because other injection systems can satisfy the RPV inventory function, consequently TC must still be evaluated (independently). Therefore, we have also included the (LP=B) portion of the rule. The above rules for TC3FA(B), and TCBASE capture these cases.

Note: If TC3FA(B) and TCBASE split fractions do not apply, TC must be evaluated "dependent" upon the success or failure of LP. The following "dependent" LP/TC split fractions were developed to cover the various support system states given LP success /failure.

TCLS7A (LP=S)*(D1=F)

TCLS7B (LP=S)*(D2=F)

TC failure given LP success when either D1 (TCLS7A) or D2 (TCLS7B) has failed.

TCLS6A (LP=S)*((A3=F))

TCLS6B (LP=S)*((A4=F))

TC failure given LP success when either A3 (TCLS6A) or A4 (TCLS6B) has failed.

TCLPS5 (LP=S)

TC failure given LP success when all support systems are available/successful

TCLF7A (LP=F)*((D1=F))

TCLF7B (LP=F)*((D2=F))

TC failure given LP failure when either D1 (TCLF7A) or D2 (TCLF7B) has failed.

TCLF6A (LP=F)*((A3=F))

TCLF6B (LP=F)*((A4=F))

TC failure given LP failure when either A4 (TCLF6A) or A3 (TCLF6A) has failed.

TCLPF5 (LP=F)

TC failure given LP failure when all support systems are available/successful.

TCFAIL 1

If none of the above rules apply, the TCFAIL rule will ensure a conservative result and assist in checking the validity of the results.

Top Event: RM – Recover Main Condenser

RM General Notes:

For Small LOCA events, we credit recovery of the main condenser providing that all support systems are success. The support system failures for top event TB (Turbine Bypass & Main Condenser) are as follows:

Support System Failure	Impact on TB/Main Condenser
4kV Bus 1 (O1)	TB/MC fail (failure of auxiliary oil pump, one circulating water pump, and steam packing exhauster)
4kV Bus 2 (O2)	TB/MC fail (failure of CST emergency makeup to main condenser (MOV-64-31), two circulating water pumps, all three circulating water booster pumps, and vacuum priming pump)
120V Vital Bus (VC)	TB/MC fail (SJAE assumed to fail)
120V Instru. Bus (IC)	TB/MC fail (SJAE assumed to fail)
Instru. Air (IG)	TB/MC fail (SJAE assumed to fail)
Service Water (SW)	TB/MC fail (failure of pump cooling for circulating water pumps)

RM Split Fraction Rules:

RMBASE (O1=S) * (O2=S) * (SW=S) * (IG=S) * ((IC=S) + (VC=S))

The base case split fraction (RMBASE) is used whenever all support systems for the main condenser are available. For AC power, we require that either O1 and O2 are available (O1=S * O2=S), or that both O1 and O2 are recovered (O1R * O2R). We credit recovery of offsite power for RM because > 4 hours exists to establish heat removal with the main condenser before containment is threatened by overpressure, and before suppression pool temperature increase would threaten continued operation of LP/CS pumps.

RMFAIL 1

Recovery of the main condenser is assumed to fail for all remaining cases (RMFAIL) because one or more support systems are unavailable. Also, if the RMBASE rule does not apply, the RMFAIL rule will ensure a conservative result and assist in checking the validity of the results.

Top Event: VT – Torus Vent (hard-piped vent from torus air space)

VT General Notes:

Support System Impacts on TC

Torus vent valve (TVS-86) is "normally" closed and requires manual action to open the valve and enable the use of the venting path with rupture disc. For the Small LOCA initiating event, we assume that TSV-86 must be opened remotely from the control room. Local operator action to open this valve is not credited because of the potential for a harsh environment, even though venting takes place in Level 1 before core damage occurs. The power source needed for remote opening of TSV-86 is 480V MCC-7A (associated w/ 4kV Bus 2).

VT Split Fraction Rules:

VTLCBS (O2=S)

The VTLCBS split fraction evaluates the reliability of the torus vent when power from MCC-7A/Bus2 (top event O2) available/successful and remote operator action can accomplish opening of TSV-86.

VTFAIL 1

VTFAIL split fraction is assigned since power from Bus 2 has failed. We conservatively assume no recovery of the power source or local operation of the valve, thus VT is assumed to be guaranteed failure.

Top Event: AI – Alternate Injection

AI General Notes:

- The AI rules for Small LOCA are the same as those used for IORV initiators, except that the Small LOCA rule for AISUCC includes the term (FW=S) + (HP=S) + (RC=S) + (CN=S). This is because these systems can satisfy the long-term (up to 24 hours) core cooling function for small LOCAs (but not for Medium LOCAs). The AI split fraction rules for Small LOCA are also the same as those used in the Transient event tree, except the small LOCA (and IORV) rules do not credit CRD as a high pressure injection source when AD fails. This is reflected in the Small LOCA event tree structure which guarantees failure of AI (bypasses AI) when AD=F. For completeness, the AI rules for Small LOCA are provided below.

AI Split Fraction Rules:

AISUCC (FW=S) + (HP=S) + (RC=S) + (CN=S) + (RM=S) * ((RW=S) + (AW=S)) * (LP=S)

The AISUCC rule accounts for sequences where systems that take suction from sources other than the suppression pool (and thus not subject to suppression pool heatup) are successful. This is the (FW=S) + (HP=S) + (RC=S) + (CN=S) portion of the rule. The remaining portion of the rule (RM=S) * ((RW=S) + (AW=S)) * (LP=S) is for sequences when LP has succeeded earlier in the event tree, and where continued success of LP (at high suppression pool temperatures) is assured by RW or AW cooling. Note that this rule only applies when RM=S because loss of NPSH is a concern when VT=S. (RM=S implies that venting was not needed for decay heat removal.)

AISBO (((A3=F) * (A4=F)) + ((-RW=S) * (-AW=S))) * ((-O2=S) + ((LP=F) * (CS=F)))

AISBO is used when neither CRD nor CT is available for injection. CRD fails due to either motive power failure or failure of cooling via RBCCW (RW) and alternate cooling (AW). CT fails due to motive power failure or lack of an injection path via LP or CS.

AICTAF (((A4=F)+(D2=F))*(RW=S))*((-(O2=S))+((LP=F)*(CS=F)))

AICTBF (((A3=F)+(D1=F))*(RW=S))*((-(O2=S))+((LP=F)*(CS=F)))

AICTAF(BF) is used when only 1 CRD pump is available for alternate injection. It is conservatively assumed that CRD pump operation requires that RBCCW (RW) be available. Only 1 CRD pump is available because either Bus 3 (AICTAF) or Bus 4 (AICTBF) power is a success, and component cooling via RBCCW is success. CT has failed because Bus 2 is not success (-O2=S) or the injection paths via LP and CS have failed.

AICTBS (RW=S) * ((-O2=S) + ((LP=F) * (CS=F)))

AICTBS is for the configuration of 2 CRD pumps available for alternate injection with no CT pump capability. CT is failed because either 1) failure of LP and CS is assumed to fail the injection paths or 2) power via Bus 2 (O2) is unavailable. Both CRD pumps are available because both 4kV Buses 3 and 4 are available.

AICRBS (((A3=F) * (A4=F)) + (-RW=S)) * ((O2=S) * ((LP=S) + (CS=S)))

AICRBS is used for configurations where both CT pumps are available but neither of the CRD pumps is available. CT pumps have power from Bus 2 and at least one injection path via LP or CS is available. CRD pumps have failed either from lack of motive power from Bus 3 and Bus 4 or from failure or RBCCW.

AICRAF ((A4=F)+(D2=F))*((O2=S)*((LP=S)+(CS=S)))*(RW=S)

AICRBF ((A3=F)+(D1=F))*((O2=S)*((LP=S)+(CS=S)))*(RW=S)

AICRAF(BF) is used when both CT pumps and only 1 CRD pump are available for alternate injection. Only 1 CRD pump is available because either Bus 3 (AICRAF) or Bus 4 (AICRBF) power is success and component cooling via RBCCW is success (satisfied by the above rule). Both CT pumps are available because support systems are success (Bus 2) and an injection pathway to the RPV via LPCI or Core Spray is success.

AIBASE ((O2=S) * ((LP=S) + (CS=S))) * (RW=S)

AIBASE is used when both CT pumps and both CRD pumps are available for alternate injection. All support systems needed by CRD and CT are success. CT requires the injection pathway to the RPV via LPCI or Core Spray, which is success.

AIFAIL 1

If none of the above rules apply, the AIFAIL rule will ensure a conservative result and assist in checking the validity of the results.

Attachment I

Event Tree (FLOODS)

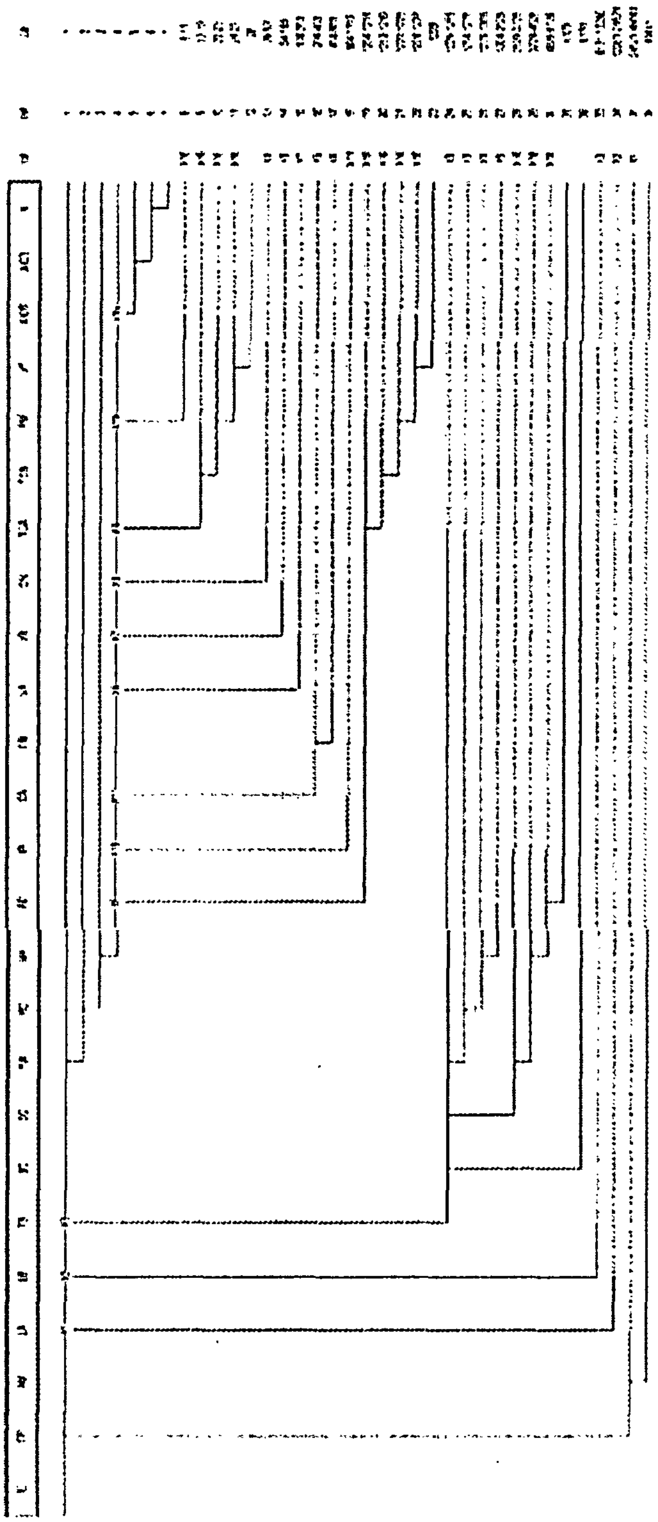

Figure I.1 FLOODS Event Tree

Top Event Name	Description
CR	CONTROL ROD INJECTION - REACTOR SHUTDOWN
AM	ATWS MITIGATION (SIMPLIFIED)
LA	LPCI PUMPS IN LOOP A
LB	LPCI PUMPS IN LOOP B
TB	TURBINE BYPASS MODEL
SO	SRVS FAIL TO OPEN ON DEMAND
SC	SRVS FAIL TO CLOSE AFTER SUCCESSFUL OPEN
FW	FEEDWATER SYSTEM
RC	RCIC SYSTEM
HP	HPCI SYSTEM
AD	AUTOMATIC DEPRESSURIZATION SYSTEM (ADS)
CA	CORE SPRAY TRAIN A
CB	CORE SPRAY TRAIN B
VA	LPCI INJECTION PATH - LOOP A VALVES
VB	LPCI INJECTION PATH - LOOP B VALVES
CN	CONDENSATE SYSTEM
TCA	TORUS COOLING TRAIN A
TCB	TORUS COOLING TRAIN B
RM	RECOVERY OF MAIN CONDENSER
VT	TORUS HARD-PIPED VENT FOR LEVEL 1 ANALYSIS
IP	PRIMARY CONT. INTEGRITY FOR LEVEL 1 ANALYSIS
AICD	ALTERNATE CORE COOLING SYSTEM, CRD, CONDENSATE TRANSFER, AND CST REFILL
AICT	ALTERNATE CORE COOLING SYSTEM, CRD, CONDENSATE TRANSFER, AND CST REFILL
AI	ALTERNATE CORE COOLING SYSTEM, CRD, CONDENSATE TRANSFER, AND CST REFILL

Initiators:

RBTRF1	FLOOD EVENT REACTOR BUILDING TORUS ROOM DUE TO ISOLABLE SERVICE WATER PIPE BREAK
RBNEF1	FLOOD EVENT REACTOR BUILDING NE ECCS CORNER ROOM - SERVICE WATER PIPE BREAK
RBSEF1	FLOOD EVENT REACTOR BUILDING SE ECCS CORNER ROOM DUE TO SERVICE WATER PIPE BREAK
R303F1	FLOOD EVENT REACTOR BLDG EL 303 DUE TO SERVICE WATER FLDPLY PIPE BREAK
RBRCUF	FLOOD EVENT REACTOR BUILDING NW UPPER RCIC ROOM EL 232 DUE TO FIRE WATER PIPE BREAK
RBTRF4	FLOOD EVENT IN TORUS ROOM DUE TO CST PIPE BREAK
R280F1	FLOOD EVENT REACTOR BUILDING EL 280 DUE TO SERVICE WATER PIPE BREAK
TBCWF	FLOOD EVENT TURBINE BUILDING DUE TO CIRC. WATER PIPE BREAK
INTSWF	FLOOD EVENT IN INTAKE STRUCTURE SERVICE WATER PUMP ROOM
RBR3F1	FLOOD EVENT REACTOR BUILDING EL 252 NORTH DUE TO SERVICE WATER PIPE BREAK
RBR3F2	FLOOD EVENT REACTOR BUILDING EL 252 NORTH DUE TO FIRE WATER PIPE BREAK
DGBF2	AUX STEAM, POTABLE WATER PIPE BREAK IN DG B ROOM
TBHVF	FLOOD EVENT TB-HVAC ROOM AND FRONT OFFICE BLDG DUE TO SERVICE WATER PIPE BREAK
TBSWF	FLOOD EVENT TURBINE BUILDING DUE TO SERVICE WATER AND FIRE WATER PIPE BREAKS
DGAF2	AUX STEAM, POTABLE WATER PIPE BREAK IN DG A ROOM
DGAF1	FLOOD EVENT IN DG-A ROOM DUE TO SERVICE WATER PIPE BREAK
DGBF1	FLOOD EVENT IN DG-B ROOM DUE TO SERVICE WATER PIPE BREAK
RTRFR2	Unisol. SW brk. on RB Side of V18
RTRFT2	Unisol. SW Brk on TB Side of V18
R280F2	SPRAY EVENT REACTOR BLDG EL 280 NORTH SIDE DUE TO CORE SPRAY PIPE BREAK
CSTF	FLOOD EVENT AT CONDENSATE STORAGE TANK AND VALVE ENCLOSURE
WMACHF	FLOOD EVENT WATER TREATMENT AND MACH SHOP AREA DUE TO CLEARWELL RUPTURE
AOGCNF	FLOOD EVENT IN THE AOG BUILDING DUE TO CONDENSATE PIPE FAILURE
INTCWF	FLOOD EVENT IN INTAKE STRUCTURE CIRC. WATER PUMP ROOM
RBNEF2	FLOOD EVENT REACTOR BUILDING NE ECCS CORNER ROOM - CST LINE BREAK
R280F4	SPRAY EVENT REACTOR BUILDING EL 280 SOUTH SIDE DUE TO CORE SPRAY/RBCCW PIPE BREAK
FOBF1	FLOOD EVENT IN FRONT OFFICE BLDG DUE TO FIRE WATER PIPE BREAK
RBR4F1	FLOOD EVENT REACTOR BUILDING EL 252 SOUTH DUE TO FIRE WATER PIPE BREAK
RBSEF2	FLOOD EVENT REACTOR BUILDING SE ECCS CORNER ROOM - CST LINE BREAK
DGOPF	FLOOD EVENT IN DG FUEL OIL TRANSFER PUMP HOUSE
RBTRF3	FLOOD EVENT REACTOR BUILDING TORUS ROOM DUE TO FIRE WATER PIPE BREAK AT EL. 213
DISCHF	FLOOD EVENT IN DISCHARGE STRUCTURE DUE TO CIRC. WATER PIPE BREAK
R280F5	FLOOD EVENT REACTOR BUIILDING EL. 280 DUE TO FIRE WATER PIPE BREAK
RBTRF2	FLOOD EVENT REACTOR BUILDING DUE TO UN-ISOLABLE SERVICE WATER PIPE BREAK AT EL. 303, 280, 252 AND TORUS ROOM

CTWF	FLOOD EVENT AT WEST COOLING TOWER DUE TO CIRC. WATER PIPE BREAK
CTEF	FLOOD EVENT AT EAST COOLING TOWER DUE TO CIRC. WATER PIPE BREAK
RBR4F2	SPRAY EVENT REACTOR BUILDING EL 252 SOUTH/EAST DUE TO RBCCW PIPE BREAK
R280F3	SPRAY EVENT REACTOR BUILDING EL 280 EAST SIDE DUE TO RBCCW PIPE BREAK
RB345F	RB EL. 345 STEAM BREAK AFFECT ON CONDUIT

Modified Endstate Binning Rules – FLOODS

CONFIG#1 (model VYCOP2A)

Bin **Rule**

SUCCESS ((TB=S) * ((FW=S) + (RC=S) + (HP=S))) + (((FW=S) + (RC=S) + (HP=S) + (CA=S) + (CB=S) + (LA=S) * (VA=S)) + ((LB=S) * (VB=S)) + (CN=S)) * ((TCA=S) + (TCB=S) + (((RM=S) + (VT=S)) * ((AICD=S) + (AICT=S) + (RC=S) + (HP=S) + FW=S) + (CN=S)))))

Decay heat removal is satisfied rather via turbine bypass (no challenge to containment from loss of heat removal) or turbine bypass has failed, thus reactor heat must be removed by the containment cooling systems. Core injection can be satisfied by either high pressure or low pressure systems.

IIIC (SC=F) *(((LA=F) + (VA=F)) * ((LB=F) + (VB=F)) * (CA=F) * (CB=F) * (CN=F) + (VT=B) + ((AICD=F) * (AICT=F))) + (((RM=S) * (AICD=F) * (AICT=F)) + (TCA=S) + (TCB=S)) * (IP=F) * (((LA=S) * (VA=S)) + ((LB=S) * (VB=S)) + (CA=S) + (CB=S))

This captures sequences where ADS has been successful to reduce reactor pressure but a relief valve fails to re-close (SC=F), followed by loss of all injection. Core damage occurs with the reactor at low pressure.

CONFIG#2 (model VYCOP2)

Bin **Rule**

SUCCESS ((TB=S) * ((FW=S) + (RC=S) + (HP=S))) + (((FW=S) + (RC=S) + (HP=S) + (CN=S)) * ((TCA=S) + (TCB=S) + (((RM=S) + (VT=S)) * ((AICD=S) + (AICT=S) + (RC=S) + (HP=S) + (FW=S) + (CN=S))))) + (((CA=S) + (CB=S + ((LA=S) *(VA=S)) + ((LB=S) * (VB=S)))* ((((TCA=S) + (TCB=S)) * (IP=S)) + (((RM=S) + (VT=S)) * ((AICD=S) + (AICT=S) + (RC=S) + (HP=S) + (FW=S) + (CN=S)))))

Decay heat removal is satisfied rather via turbine bypass (no challenge to containment from loss of heat removal) or turbine bypass has failed, thus reactor heat must be removed by the containment cooling systems. Core injection can be satisfied by either high pressure or low pressure systems. LPCI and Core Spray will fail if there is inadequate NPSH resulting from failure to maintain containment overpressure. Loss of containment overpressure will occur if primary containment isolation fails (IP=F) Loss off containment overpressure is also assumed if torus venting.

IIIC (SC=F) * (((LA=F) + (VA=F)) * ((LB=F) + (VB=F)) * (CA=F) * (CB=F) * (CN=F) + (VT=B) + ((AICD=F) * (AICT=F))) + (((RM=S) * (AICD=F) * (AICT=F)) + (TCA=S) + (TCB=S)) * IP=F) * (((LA=S) * (VA=S)) + ((LB=S) * (VB=S)) + (CA=S) + (CB=S))

This captures sequences where ADS has been successful to reduce reactor pressure but a relief valve fails to re-close (SC=F), followed by loss of all injection. LPCI and Core Spray will fail if there is inadequate NPSH resulting from failure to maintain containment overpressure. Loss of containment overpressure will occur if primary containment isolation fails (IP=F) Loss off containment overpressure is also assumed if torus venting via the hard-piped vent is initiated (VT=S). Core damage occurs with the reactor at low pressure.

Top Event: CR – Control Rods Insert

CR General Notes:

None.

CR Split Fraction Rules:

CRBASE 1

CR is considered to be independent of all other systems, hence the base case split fraction is used for all cases, i.e., CR has no support systems.

Top Event: AM – ATWS Mitigation

AM General Notes: None.

AM Split Fraction Rules:

AMFAIL	(D1=F)+(D2=F)+(A3=F)+(A4=F)+(PI=F)+(LV=F)
AMBASE	1

Top Events: LA/LB – LPCI Trains and A and B

LPCI General Notes:

- The min. flow valve in each LPCI loop (MOV-16A/16B) is maintained normally open and success of the LPCI loop does not depend on successful closure of the associated min. flow valve. Therefore, we assume LPCI success does not depend on the min. flow valve hardware or the associated power supply.

Support System	Impacts on LPCI
125V DC-I (D1) fails	RHR Pumps C and D fail; degraded injection valve ECCS signal.
125V DC-2 (D2) fails	RHR Pumps A and B fail; degraded injection valve ECCS signal.
4kV Bus 3 (A3) fails	RHR Pumps C and D fail; injection valve ECCS signal not degraded.
4kV Bus 4 (A4) fails	RHR Pumps A and B fail; injection valve ECCS signal not degraded.
RRU7 (R7) fails	No impact assumed based on room heatup assessment.
RRU8 (R8) fails	No impact assumed based on room heatup assessment.
SW fails	No impact assumed based on room heatup assessment. Also, RHR pump seal and bearing cooling via SW/RBCCW assumed not needed for injection mode.
ECCS Signal (SIG) fails	Failure of the ECCS signal and failure to manually initiate low pressure pumps are assumed to cause failure of LPCI (and CS). Failure of the signal and manual backup action is handled in the PSIGF rule.

LP Split Fraction Rules:

PSIGF **(-(DW=S))*((-(LV=S))+(-(PS=S)))*(-(OI=S))**

The macro SIGF models ECCS actuation either by automatic signals from the drywell (DW) and RPV (LV and PS) or by the operator action to initiate LPCI.

Top Event: LA – LPCI Train A

LAFAIL **(INIT=RBR3F1)+(INIT=RBNEF1)+(INIT=RBNEF2)**

LA is assumed to be a guaranteed failure based on the impact of the above flooding initiating events.

LAFAIL (IOA=F) * ((INIT=R303F1) + (INIT=R280F1) +(INIT=R280F5) + (INIT=RBR3F2) + (INIT=RBR4F + (INIT=RBTRF1) + (INIT=RTRFR2) + (INIT=RTRFT2) + INIT=RBTRF3) + (INIT=RBRCUF) + (INIT=RBSEF1))

LA is assumed to be a guaranteed failure base on the impacts of the above flooding initiating events if the operator fails to isolate the break within approximately 1½ hours (IOA) to prevent flooding of ECCS Corner Room A.

LAFAIL PSIGF

Failure of both automatic ECCS signals and operator manual actions to initiate LPCI will result in guaranteed failure of LA.

LAFAIL ((A4=F) + (D2=F)) * ((A3=F) + (D1=F))

This models a guaranteed failure of LPCI Train A due to both a failure of AC or DC power of Division 2 (Pump A) and Division 1 (Pump C).

LA1PF (A4=F) + (D2=F) + (A3=F) + (D1=F)

This models a failure of one pump in Train A due to either a failure of AC or DC Power of Division 2 (Pump A) or of Division 1 (Pump C).

LABASE (A4=S) * (D2=S) * (A3=S) * D1=S)

This models the base case of LPCI Train A with all support systems available.

LAFAIL 1

Top Event: LB – LPCI Train B

LBFAIL (INIT=RBSEF1) + (INIT=RBSEF2)

LB is assumed to be a guaranteed failure based on the impact of the above flooding initiating events.

LBFAIL (IOA=F) * ((INIT=R303F1) + (INIT=R280F1) + (INIT=R280F5) + (INIT=RBR3F1) + (INIT=RBR3F 2) + (INIT=RBR4F1) + (INIT=RBTRF1) + (INIT=RTRFR2) + (INIT=RTRFT2) + (INIT=RBTRF3) + (INIT = RBRCUF)+(INIT=RBNEF1))

LA is assumed a guaranteed failure of the above flooding initiating events if the operator fails to isolate the break within approximately 1½ hours (IOA) to prevent flooding of ECCS Corner Room B.

LBFAIL PSIGF

Failure of both automatic ECCS signals and operator manual actions to initiate LPCI will result in guaranteed failure of LB.

LBFAIL ((A4=F) + (D2=F)) * ((A3=F) + (D1=F))

This models a guaranteed failure of LPCI Train A due to both a failure of AC or DC power of Division 2 (Pump B) and Division 1 (Pump D).

LB1PF ((A3=F) + (D1=F) + (A4=F) + (D2=F)) * ((INIT=RBR3F1) + (INIT=RBNEF1) + (INIT=RBNEF2))

This models a failure of one pump in Train B due to either a failure of AC or DC Power of Division 2 (Pump A) or of Division 1 (Pump C).

LBBASE (A3=S) * (D1=S) * (A4=S) * (D2=S) * ((INIT=RBR3F1) + (INIT=RBNEF1) + (INIT=RBNEF2))

This models the base case of LPCI Train B with all support systems available.

LBLAF1 (LA=F) * (A4=S) * (D2=S) * (A3=S) * (D1=S)

This models the conditional probability that Train B fails, given Train A failure, with all support systems available.

LBLAS1 (LA=S) * (A3=S) * (D1=S) * (A4=S) * (D2=S)

This models the conditional probability that Train B fails, given Train A success, with all support systems available.

LBLAF2 (LA=F) * ((A4=F) + (D2=F) + (A3=F) + (D1=F))

This models the conditional probability that Train B fails, given Train A failure, with a failure of either Division 1 or Division 2 support systems..

LBLAS2 (LA=S) * ((A4=S) * (D2=S) + (A3=S) * (D1=S))

This models the conditional probability that Train B fails, given Train A success, with a failure of either Division 1 or Division 2 support systems..

LBFAIL 1

Top Event: TB – Turbine Bypass/Main Condenser

Support System Failure	Impact on TB
4kV Bus 1 (O1)	TB/MC fail (failure of auxiliary oil pump, one circulating water pump, and steam packing exhauster)
4kV Bus 2 (O2)	TB/MC fail (failure of CST emergency makeup to main condenser (MOV-64-31), two circulating water pumps, all three circulating water booster pumps, and vacuum priming pump)
Instru. Air (IG)	TB/MC fail (SJAE assumed to fail)
120V Vital Bus (VC) and 120V Instru. Bus (IC)	TB/MC fail (SJAE assumed to fail)
Service Water (SW)	TB/MC fail (failure of pump cooling for circulating water pumps)

TB Split Fraction Rules:

TBFAIL (IOA=F) * (INIT=RTRFR2)

TB is assumed to fail for the above initiating event if the operator fails to restore SW to the Turbine Building (IOA).

TBFAIL (INIT=AOGCNF) + (INIT=CSTF) + (INIT=CTEF) + (INIT=CTWF) + (INIT=DISCHF) + (INIT=TBCWF) + (INIT=FOBF1) + (INIT=INTCWF) + (INIT=RBRCUF) + (INIT=RBNEF2) + (INIT=RBSEF2) + (INIT= RTRFT2)

TB is assumed to fail following the above flooding initiating events.

TBFAIL (CR=F) + (OS=F) + (-(O1=S)) + (-(O2=S)) + (SW=F) + (-(IG=S)) + ((-(IC=S)) * (-(VC=S)))

TB is guaranteed to fail based on failure of the above support system failures.

TBBASE (O1=S) * (O2=S) * (SW=S) * (IG=S) * ((IC=S) + (VC=S))

This models the probability of TB failure given all support systems are available.

Note: We use TBBASE even when TB is degraded by the failure of IC alone or VC alone (TBFAIL is used when both IC and VC fail).

TBFAIL 1

Top Event: SO – Safety/Relief Valves Open

SO General Notes:

- SO models opening of the SRVs/SVs for the pressure relief function.

SO Split Fraction Rules:

SOBASE 1

SRV/SV opening to satisfy the pressure relief function has no support systems.

Top Event: SC – Safety/Relief Valves Close

SC General Notes:

- Given the demand to open the SRVs/SVs in top event SO, top event SC models the failure probability of the SRVs/SVs to close.

SC Split Fraction Rules:

SCBASE 1

SRV closing after successful pressure relief function has no support systems.

Top Event: FW – Feedwater System (high pressure injection)

FW General Notes:

None

Support System Failure	Impact of Feedwater
4kV Bus 1 (O1)	FW fails, FW pumps A & B fail, aux. oil pump for pump C fails, Cond. pump A fails.
4kV Bus 2 (O2)	FW fails, FW pump C fails, Cond. pumps B & C fail, also fails hotwell emergency makeup valve MOV 64-31.
125V DC-1 (D1)	FW fails, loss of Bus 1 (O1).
125V DC-2 (D2)	FW fails, loss of Bus 2 (O2).
120V Vital Bus (VC)	FW fails, loss of power to FW reg. valves, including low flow valve.
120V Instru. Bus (IC)	FW fails, loss of pumps A,B,C.
Instru. Air (IG)	FW fails, loss of air to FW reg. valves, including low flow valve.
TBCCW (TW)	FW fails, loss of cooling for FW and Cond. pumps A,B,C.

FW Split Fraction Rules:

FWFAIL (INIT=AOGCNF) + (INIT=CSTF) + (INIT=TBCWF) + (INIT=FOBF1) + (INIT=RBRCUF) + (INIT=RBTRF4) + (INIT=RBNEF2) + (INIT=RBSEF2) + (INIT=RBR3F2)

FW is assumed to fail for any of the above initiating events.

FWFAIL (CR=F) + (-(O1=S)) + (-(O2=S)) + (-(VC=S)) + (-(IC=S)) + (-(IG=S))+(-(TW=S))

FW is assumed to fail following failure of the above support systems.

FWTBBS ((TB=F) * (O1=S) * (O2=S) * (VC=S) * (IC=S) * (IG=S) * (TW=S))

When FW is not guaranteed failure by the FWFAIL rule, then the FW split fraction depends on whether TB is failed. When TB fails, then the FWTBBS split fraction is used. Because TB succeeds for all other cases, the FWBASE split fraction (below) is used.

FWBASE ((TB=S) * (O1=S) * (O2=S) * (VC=S) * (IC=S) * (IG=S) * (TW=S))

FW base case with all support systems available.

FWFAIL 1

Top Event: RC – Reactor Core Isolation Cooling

RC General Notes:

- Because RC is asked before HP in the FLOODS tree, RC is always independent of HP.

Support System Failure	Impact on RCIC
125V DC-2 (D2)	RC fails (no MOV motive power, etc.)
120V Vital Bus (VC)	RC fails (loss of flow controller power)
24V ECCS Battery B (V2)	Failure of the automatic function to transfer suction from CST to torus (requires manual operator action for success)

Note There are no other auto signal requirements for RC since we assume that the operator must manually initiate the system. The operator action for initiation and control of HPCI and RCIC is also assumed to be a completely dependent action.

RC Split Fraction Rules:

RCFAIL (INIT=R303F1) + (INIT=R280F1) + (INIT=R280F5) + (INIT=RBR3F1) + (INIT=RBR3F2) + (INIT=RBR4F1) + (INIT=RBTRF1) + (INIT=RTRFR2) + (INIT=RTRFT2) + (INIT=RBTRF3) + (INIT=RBTRF4) + (INIT=RBRCUF) + (INIT=RBNEF1) + (INIT=RBSEF1)

RC is assumed to be a guaranteed failure due to the flooding impacts of the above initiating events or because the initiating event is a break in the RCIC system.

RCFAIL (IOA=F) * ((INIT=RBNEF2) + (INIT=RBSEF2))

RC is assumed to fail for the above initiating events if the operator fails to isolate the break within approximately 30 minutes to prevent flooding of the RCIC system.

RCFAIL (D2=F) + (-(C2=S)) + ((A4=F) * (-A4R)) + (-(VC=S)) + (SC=F) + (CR=F)

RC is guaranteed failure when DC-2 fails. RC also fails if the battery charger fails (long term DC power, top event C2), or if AC power is unavailable to the chargers, A4 fails and is not recovered, A4R. Failure of the 120V Vital Bus (VC) will also fail RCIC.

RCV2F (-V2=S)

Failure of 24 V ECCS power V2 degrades the reliability of RC by failing the auto suction transfer function.

RCBASE	(D2=S) * (C2=S) * ((A4=S) + (A4R)) * (VC=S) * (V2=S)

The above models the base case RC failure probability with all support systems available.

RCFAIL	1

Top Event: HP – High Pressure Coolant Injection

HP General Notes:

None.

Support System Failure	Impact on HPCI
DC-1 fails	HPCI fails
VC fails	HPCI auto suction transfer from CST to torus fails (requires manual operator action for HP success)

HP Split Fraction Rules:

HPFAIL (INIT=R303F1) + (INIT=R280F1) + (INIT=R280F5) + (INIT=RBR3F1) + (INIT=RBR3F2) + (INIT=RBR4F1) + (INIT=RBTRF1) + (INIT=RTRFR2) + (INIT=RTRFT2) + (INIT=RBTRF3) + (INIT=RBTRF4) + (INIT=RBRCUF) + (INIT=RBNEF1) + (INIT=RBSEF1)

RC is assumed to be a guaranteed failure due to the flooding impacts of the above initiating events or because the initiating event is a break in the HPCI system

HPFAIL (IOA=F)*((INIT=RBNEF2) + (INIT=RBSEF2))

RC is assumed to fail for the above initiating events if the operator fails to isolate the break within approximately 30 minutes to prevent flooding of the HPCI system.

HPFAIL (D1=F) + (-(C1=S)+((A3=F)*-A3R))+(CR=F)

HP is guaranteed failure when DC-1 fails. HP also fails if the battery charger fails (long term DC power, top event C1), or if AC power is unavailable to the charger, A3 fails and is not recovered, A3R.

HPBASE (RC=B) + ((D2=F) + (-(C2=S)) + ((A4=F) * (-A4R))) * ((D1=S) * (C1=S) * ((A3=S) + (A3R)) * (VC=S))

HP is evaluated independent of RC if RC is bypassed or RC fails due to a failure in one of its support systems. All HP support systems are available.

HPVCF (RC=B) + ((D2=F) + (-(C2=S)) + ((A4=F) * (-A4R))) * ((D1=S) * (C1=S) * ((A3=S) + (A3R)) * (-(VC=S))

HP is evaluated independent of RC if RC is bypassed or RC fails due to a failure in one of its support systems. All HP support systems are available with the exception that Vital AC (VC) has failed.

HPRCF2 (RC=F) * (-(V2=S))

This models the dependent failure probability of HPCI given failure of Vital AC (VC) a random (not support system) failure of RCIC

HPRCF1 (RC=F) * (V2=S)

This models the dependent failure probability of HP given that RC has failed randomly and V2 is successful.

HPFAIL 1

If none of the above rules apply, the HPFAIL rule will ensure a conservative result and assist in checking the validity of the results.

Top Event: AD – RPV Depressurization

AD General Notes:

- AD models manual depressurization of the RPV via the SRVs (discharging to the suppression pool) as a means of reducing RPV pressure to allow injection of low pressure systems. We assume that AD requires long-term operation of the SRVs, hence we require success of the containment gas nitrogen supply (top event CG). The only other support systems for AD are 125V DC-1 and DC-2. Given the system design, failure of both DC power sources is required to fail the depressurization function (fail all SRVs). DC-2 supplies the "normal" control power to each SRV solenoid valve. Upon failure of DC-2, control power to each solenoid valve will automatically transfer to DC-1 via de-energized relay K11A, B, C and D.
- Top event SC models the failure to close of an SRV following a required opening. Failure to close results in RPV inventory loss similar to that of an MLOCA, resulting in reduced operator time to perform AD.

AD Split Fraction Rules:

ADFAIL (-CG=S) + ((D1=F) * (D2=F))

RPV depressurization is guaranteed to fail if the above support system failure combinations occur.

ADSDA (-(SC=F)) * (D1=F)

This models the failure probability of AD, given a degraded condition resulting from failure of Division 1 of DC power. SRVs have either not been challenged or have successfully closed following opening.

ADSDB (-(SC=F)) * (D2=F)

This models the failure probability of AD, given a degraded condition resulting from failure of Division 2 of DC power. SRVs are closed, either not being challenged or successfully closing following opening.

ADSBS (-(SC=F)) * ((CG=S) * (D1=S) * (D2=S))

This models the base case probability of AD (all support systems available). SRVs are closed, either not being challenged or successfully closing following opening.

ADMDA (SC=F) * ((D1=F))

This models the failure probability of AD, given a degraded condition resulting from failure of Division 1 of DC power. One or more SRV has failed to close after opening.

ADMDB (SC=F) * ((D2=F))

This models the failure probability of AD, given a degraded condition resulting from failure of Division 2 of DC power. One or more SRV has failed to close after opening.

ADMBS (SC=F) * ((CG=S) * (D1=S) * (D2=S))

This models the base case probability of AD (all support systems available) with one or more SRV has failing to close after opening.

ADFAIL 1

Top Event: IP – Primary Containment Integrity

IP General Notes:

- Top event IP is asked in order to establish whether the containment is intact when the hard-piped vent from torus air space is used to prevent over-pressurization (VT=S). Integrity of containment is a necessary condition in order for the operator to control and maintain sufficient pressure in the containment in support of continued operation of LPCI or Core Spray pumps taking suction from the suppression pool at elevated temperature.
- Failure of containment integrity is defined to include failures in the containment boundary that allow leakage in excess of that which would prevent maintaining overpressure sufficient to satisfy the NPSH-r or the LPCI and Core Spray pumps at elevated suppression pool temperature. The leakage sources are divided into two principal categories:
  - Isolation valve failures: These are related to the failure of the isolation valves in containment penetration lines or failure of the isolation signals or power to close these valves.
  - Pre-existing failures: These are failures primarily related to hatches, electrical penetration assemblies (EPAs), and other containment leakage paths not associated with failure of isolation valves to close.

IP Split Fraction Rules

IPIGL (IG=F) + ((VC=F)*(IC=F))

This split fraction is used when both the "A" and "B" air-operated vacuum breakers fail due to support system failures. The "A" and "B" vacuum breakers both require instrument air (IG). The "A" vacuum breakers require Vital Bus (VC), while the "B" vacuum breakers require Instrument Bus (IC). Note that check-valve vacuum breakers are in-series with the air-operated vacuum breakers, hence failure of the air-operated vacuum breakers to close does not necessarily cause failure of containment isolation.

IPVACL (VC=F)

This split fraction is used when both the "A" air-operated vacuum breakers fail due to failure of Vital Bus (VC). Note that check-valve vacuum breakers are in-series with the air-operated vacuum breakers, hence failure of the air-operated

IPIACL (IC=F)

This split fraction is used when both the "B" air-operated vacuum breakers fail due to failure of Instrument Bus (IC). Note that check-valve vacuum breakers are in-series with the air-operated vacuum breakers, hence failure of the air-operated

IPBASL 1

No other support system failures affect the containment isolation system. Thus, the base case (all support systems available) split fraction applies to all sequences not captured by one of the previous rules.

Top Events: CA/CB – Core Spray

General Notes:

None.

Support System Impacts on CA/CB

- The impact of single support system failures on CA/CB are as follows. Note that the min. flow valve in each CS loop (MOV-5A/5B) is maintained normally open and success of the CS loop does not depend on successful closure of the associated min. flow valve. Therefore, we assume CS success does not depend on the min. flow valve hardware or the associated power supply.

Support System Failure	Impact of CA/CB
125V DC-I (D1) fails	CB fails - Pump B and MOV-11B/12B.
125V DC-2 (D2) fails	CA fails - Pump A and MOV-11A/12A.
4kV Bus 3 (A3) fails	CB fails - Pump B and MOV-11B/12B.
4kV Bus 4 (A4) fails	CA fails - Pump A and MOV-11A/12A.
RRU7 (R7) fails	No impact assumed based on room heatup assessment.
RRU8 (R8) fails	No impact assumed based on room heatup assessment.
SW/RW fail	No impact on Core Spray.
ECCS Signal (SIG) fails	Failure of the ECCS signal and failure to manually initiate low pressure pumps are assumed to cause failure of LPCI (and CS). Failure of the signal and manual backup action is handled in the VSIGF rule.

CA Split Fraction Rules:

VSIGF (-(PI=S))+((-(DW=S))*((-(LV=S))+(-(PS=S)))*(-(OI=S)))

PSIGF macro models ECCS actuation either by automatic signals from the drywell (DW) and RPV (LV and PS), Low Pressure Interlock (PI) or operator action to initiate LPCI.

CAFAIL (INIT=R280F2)+(INIT=RBR3F1)+(INIT=RBNEF1)+(INIT=RBNEF2)

For the above initiating events, CA is assumed to be a guaranteed failure due to the fact that the flood either originates within CS Train A or the flood directly impacts CS Train A.

CAFAIL (IOA=F) * ((INIT=R303F1) + (INIT=R280F1) + (INIT=R280F5) + (INIT=RBR3F2) + (INIT=RBR4F1) + (INIT=RBTRF1) + (INIT=RTRFR2) + (INIT=RTRFT2) + (INIT=RBTRF3) + (INIT=RBRCUF) + (INIT=RBSEF1))

The above initiating events will fail CA in the event that operators fail to isolate the break within approximately 1 ½ hours to prevent flooding of the ECCS corner room.

CAFAIL (A4=F)+(D2=F)+(VSIGF)

CA is guaranteed to fail when AC or DC power fails or signals fail.

CABASE (A4=S) * (D2=S)

This represents the probability of CA failure with all support systems available.

CAFAIL 1

CB Split Fraction Rules

CBFAIL (INIT=R280F4)+(INIT=RBSEF1)+(INIT=RBSEF2)

For the above initiating events, CB is assumed to be a guaranteed failure due to the fact that the flood either originates within CS Train B or the flood directly impacts CS Train B.

CBFAIL IOA=F) * ((INIT=R303F1) + (INIT=R280F1) + (INIT=R280F5) + (INIT=RBR3F1) + (INIT=RBR3F 2) + (INIT=RBR4F1) + (INIT=RBTRF1) + (INIT=RTRFR2) + (INIT=RTRFT2) + (INIT=RBTRF3) + (INIT=RBRCUF) + (INIT=RBNEF1))

The above initiating events will fail CB in the event that operators fail to isolate the break within approximately 1 ½ hours to prevent flooding of the ECCS corner room.

CBFAIL (A3=F) + (D1=F) + (VSIGF)

CB is guaranteed to fail when AC or DC power fails or signals fail..

CBCAF (CA=F) * (A4=S) * (D2=S) * (-(INIT=R280F2)) * (-(INIT=RBR3F1)) * ((INIT=RBNEF1)) * (-(I NIT=RBNEF2))

This models the conditional probability of CB (with all support systems available) failure given that CA has failed randomly, that is, CA did not fail due to support system failures or flooding impacts.

CBBASE ((A4=F) + (D2=F) + (INIT=R280F2) + (INIT=RBR3F1) + INIT=RBNEF1) + (INIT=RBNEF2)) * ((A3=S) * (D1=S))

This models the base case failure probability for CB where either support system failures or flooding impacts have resulted in guaranteed failure of CA.

CBFAIL 1

Top Events: VA/VB LPCI Injection Path - Loop A/B Valves

General Notes:

None

VA Split Fraction Rules:

VAFAIL (INIT=RBR3F1)

VA assumed to be a guaranteed failure for the above initiating event.

VAFAIL ((D1=F) * (D2=F)) + (VSIGF)

VA will be guaranteed to fail on loss of both Division 1 and 2 of DC power and loss of signals. VSIGF models both automatic signals and also operator action to initiate LPCI Loop A.

VADF (D1=F) + (D2=F)

If either Division 1 or 2 of DC power fail, VA is degraded due to the impact on either Train A or B logic relays.

VABASE (D1=S) * (D2=S)

This models the base case failure probability of VA with both systems of DC power available.

VAFAIL 1

VB Split Fraction Rules:

VBFAIL (INIT=RB345F) + (INIT=RBR4F2)

VB is assumed to be a guaranteed failure for the above initiating events.

VBFAIL ((D1=F) * (D2=F))+(VSIGF)

VB will be guaranteed to fail on loss of both Division 1 and 2 of DC power and loss of signals. VSIGF models both automatic signals and also operator action to initiate LPCI Loop B.

VBBASE ((D1=S) * (D2=S) * (INIT=RBR3F1))

This models failure of VB, independent of VA, with both divisions of DC power available. For initiating event RBR3F1, VA has failed due to the impact of flooding.

VBDF ((D1=F) + (D2=F)) * (INIT=RBR3F1)

This models failure of VB, independent of VA, with one division of DC power available. For initiating event RBR3F1, VA has failed due to the impact of flooding.

VBVAF1 ((VA=F) * (D1=S) * (D2=S))

This models the dependent failure of VB, following a random failure of VA, with both systems of DC power available.

VBVAF2 (VA=F) * ((D1=F) + (D2=F))

This models the dependent failure of VB, following a random failure of VA, with VA/VB systems degraded by the failure of one division of DC power.

VBVAS1 ((VA=S) * (D1=S) * (D2=S))

This models the dependent failure of VB, following success of VA, with both systems of DC power available.

VBVAS2 (VA=S) * ((D1=F)+(D2=F))

This models the dependent failure of VB, following success of VA, with VA/VB systems degraded by the failure of one division of DC power.

VBFAIL 1

Top Event: CN – Condensate System (low pressure injection)

CN General Notes:

None

Support System Failure	Impact of CN
4kV Bus 1 (O1)	CN Pump A fails
4kV Bus 2 (O2)	CN Pumps B & C fail, also fails hotwell emergency makeup valve MOV 64-31)
125V DC-2 (D2)	CN fails (O2 failure)
120V Vital Bus (VC)	CN fails (no power to FW reg. valves)
Instru. Air (IG)	CN fails (no air to FW reg. valves)
TBCCW (TW)	CN fails (no pump motor cooling)

CN Split Fraction Rules:

CNFAIL (INIT=AOGCNF) + (INIT=CSTF) + (INIT=TBCWF) + (INIT=FOBF1) + (INIT=RBR3F2) + (INIT=RBRCUF) + (INIT=RBTRF4) + (INIT=RBNEF2) + (INIT=RBSEF2)

For the above initiating events, CN is assumed to be a guaranteed failure due to the fact that the flood either originates within CN or the flood directly impacts CN.

CNSUCC (FW=S)

Since feedwater is dependent on the operation of the condensate system for success, FW success implies CN success.

CNFAIL (CR=F)+(-(O2=S))+(-(VC=S))+(-(IG=S))+(-(TW=S))

Failure of the above support systems guarantee failure of CN due to control systems failures or cooling to the condensate pumps..

CN1F (-(O1=S))

This models the failure probability of CN, with the system degraded by the failure of Bus 1, resulting in the failure of Pump A.

CNBASE (-(IC=S))

The FLOODS event tree structure asks CN only after FW=F. Thus, CN is independent of FW only when FW is guaranteed failure by support system failures. The only support system failures that fail FW and not CN are -O1=S (Bus 1 fails, which degrades CN, split fraction CN1F) and -IC=S (Instrument Bus fails FW but does not degrade CN, split fraction CNBASE).

CNFWF1 (FW=F) * (-(TB=S))

The above models the dependent failure probability of CN following the failure of feedwater (FW) and failure of turbine bypass (TB).

CNFWF2 (FW=F) * (TB=S)

The above models the dependent failure probability of CN following the failure of feedwater (FW) and success of turbine bypass (TB).

CNFAIL 1

Top Events: TCA/TCB – Torus Cooling Loops A/B

General Notes:

None.

Support System Impacts on TCA/TCB

- In general, Torus Cooling (top event TC) is dependent on Low Pressure Coolant Injection (top event LP) due to shared RHR equipment. The impact of single support system failures on TC are as follows:

Support System Failure	Impact on Torus Cooling
125V DC-l (D1) fails	RHR Pumps C & D fail; RHRSW Pumps B & D fail; TC Loop B MOVs fail.
125V DC-2 (D2) fails	RHR Pumps A & B fail; RHRSW Pumps A & C fail; TC Loop A MOVs fail.
4kV Bus 3 (A3) fails	RHR Pumps C & D fail; RHRSW Pumps B & D fail; TC Loop B MOVs fail.
4kV Bus 4 (A4) fails	RHR Pumps A & B fail; RHRSW Pumps A & C fail; TC Loop A MOVs fail.
RRU7 (R7) fails	No impact on equipment is assumed based on room heatup assessment.
RRU8 (R8) fails	No impact on equipment is assumed based on room heatup assessment.
SW fails	RHR Pumps A, C & B, D fail due to loss of seal and bearing injection water cooling (assumed needed for long term TC mode), RHRSW Pumps A, C & B, D fail due loss of service water suction.
RBCCW (RW) fails	RHR Pumps A, C & B, D fail due to loss of seal and bearing injection water cooling (assumed needed for long term TC mode). No impact on RHRSW pumps.
ECCS Signal (SIG) fails	No impact on TC function is assumed.

TCA Split Fraction Rules:

TCAFL **(INIT=DGAF1) + (INIT=R303F1) + (INIT=R280F1) + (INIT=RBR3F1) + (INIT=RBTRF1) + (INIT=RTRFR2 + (INIT=RBNEF1) + (INIT=RBNEF2)**

For the above initiating events, TCA is assumed to be a guaranteed failure due to the fact that the flood either originates within TC Train A or the flood directly impacts TC Train A.

TCAFL **(IOA=F) * ((INIT=R280F5) + (INIT=RBR3F2) + (INIT=RBR4F1) + (INIT=RTRFT2) + (INIT=RBTRF 3) + INIT=RBRCUF) + (INIT=RBSEF1))**

The above initiating events will fail TCA in the event that operators fail to isolate the break within approximately 1 ½ hours to prevent flooding of the ECCS corner room.

TCAFL ((SW=F) * (-(AW=S))) + (D2=F) + (A4=F) + (LA=F)

TCA will be guaranteed to fail in the event that the above combinations of support systems fail.

TCABS ((SW=S) + (AW=S)) * (A4=S) * (D2=S) * (LA=S)

The above models the base case failure probability of TCA with all support systems available.

TCAFL 1

TCB Split Fractions

TCBFL (INIT=DGBF1) + (INIT=RBSEF1) + (INIT=RBSEF2) + (INIT=RTRFR2)

For the above initiating events, TCB is assumed to be a guaranteed failure due to the fact that the flood either originates within TC Train B or the flood directly impacts TC Train B.

TCBFL (IOA=F) * ((INIT=R303F1) + (INIT=R280F1) + (INIT=R280F5) + (INIT=RBR3F1) +
(INIT=RBR3F 2) + (INIT=RBR4F1) + (INIT=RBTRF1)+ (INIT=RTRFT2) +
(INIT=RBTRF3) + (INIT=RBRCUF)+(INIT=RBNEF1))

The above initiating events will fail TCB in the event that operators fail to isolate the break within approximately 1 ½ hours to prevent flooding of the ECCS corner room.

TCBFL ((SW=F) * (-(AW=S))) + (A3=F)+ (D1=F) + (LB=F)

TCB will be guaranteed to fail in the event that the above combinations of support systems fail.

TCBTAF ((TCA=F) * (A4=S) * (D2=S) * (LB=S) * (-(INIT=DGAF1)) * (-(INIT=R303F1)) * (-
(INIT=R280F1))* (-(INIT=RBR3F1)) * (-(INIT=RBTRF1)) * (-(INIT=RBNEF1)) * (-
(INIT=RBNEF2)))

The above model the failure of TCB independent of TCA. Failure of TCA was guaranteed due to failure of support systems or as the result of the flooding impact.

TCBTAF (TCA=F) * (A4=S) * (D2=S) * (LB=S)

The above model the failure of TCB independent of TCA but dependent on LB success.. Failure of TCA was guaranteed due to failure of support systems or as the result of the flooding impact.

TCBBS ((TCA=F) * ((SW=S) + (AW=S)) * (A3=S) * (D1=S) * (LB=S))

The above models the failure probability of TCB dependent on the failure of TCA but dependent on success of LB. TCA has failed randomly and all support systems are available.

TCBFL 1

Top Event: RM – Recover Main Condenser

RM General Notes:

- For flooding events, we credit recovery of the main condenser providing that all support systems are success. The support system failures for top event TB (Turbine Bypass & Main Condenser) are assumed as follows:

Support System Failure	Impact on TB/Main Condenser
4kV Bus 1 (O1)	TB/MC fail (failure of auxiliary oil pump, one circulating water pump, and steam packing exhauster)
4kV Bus 2 (O2)	TB/MC fail (failure of CST emergency makeup to main condenser (MOV-64-31), two circulating water pumps, all three circulating water booster pumps, and vacuum priming pump)
120V Vital Bus (VC)	TB/MC fail (SJAE assumed to fail)
120V Instru. Bus (IC)	TB/MC fail (SJAE assumed to fail)
Instru. Air (IG)	TB/MC fail (SJAE assumed to fail)
Service Water (SW)	TB/MC fail (failure of pump cooling for circulating water pumps)

RM Split Fraction Rules:

RMFAIL **(INIT=AOGCNF) + (INIT=CSTF) + (INIT=FOBF1) + (INIT=TBHVF) + (INIT=TBCWF) + (INIT=TBSWF) + (INIT=INTCWF) + (INIT=DGAF1)+ (INIT=DGBF1) + (INIT=RTRFT2)**

RM is assumed to be a guaranteed failure due to the impacts of the above flooding initiating events.

RMFAIL **(CR=F)**

RM is assumed to fail on failure to scram (CR)

RMBASE **(((O1=S) * (O2=S)) + (O1R * O2R)) * (SW=S) * (IG=S) * ((IC=S) + (VC=S))**

The base case split fraction (RMBASE) is used whenever all support systems for the main condenser are available. For AC power, we require that both O1 and O2 are available (O1=S * O2=S), or that both O1 and O2 are recovered (O1R * O2R). We credit recovery of offsite power for RM because > 4 hours exists to establish heat removal with the main condenser before containment is threatened by overpressure.

RMFAIL **1**

Recovery of the main condenser is assumed to fail for all remaining cases (RMFAIL) because one or more support systems are unavailable.

Top Event: VT – Torus Vent (hard-piped vent from torus air space)

VT General Notes:

- Torus vent valve (TVS-86) is "normally" closed and requires manual action to open the valve and enable the use of the venting path with rupture disc. For floods, we assume that the valve can be operated remotely from the control room if 480V MCC-7A (associated w/ 4kV Bus 2) is available, or the valve can be operated locally. Local operation is assumed possible because there is sufficient time before the vent path would be needed (12 to 24 hours). Also, in this Level 1 event tree, venting is performed to prevent core damage, therefore, the Reactor Building is assumed to remain habitable to perform the local operation.

VT Split Fraction Rules:

VTTRBS 1

Local manual operation of the vent valve is assumed, therefore, there are no AC power support systems needed and the VTTRBS.

Top Event: AICD– Alternate Injection Using the CRD System

General Notes

- CRD is a low capacity high pressure system that can be used as an alternate source of RPV injection in the event that all other sources of injection have failed. Alternate injection provides an adequate source of makeup, provide the following conditions are met:
  (a) The RPV has been successfully depressurized using ADS.
  (b) Early injection has been successfully been accomplished by higher capacity systems (LP, CS or CN).
  (c) Decay heat removal is being accomplished by either recovery of the main condenser (RM) or by containment venting (VT).

Support System Failure	Impact on AICD
RBCCW	The CRD pumps fail due to loss of pump lube oil cooling.
4 kV Bus 3 (A3)	Loss of CRD Pump B
4 kV Bus 4 (A4)	Loss of CRD Pump A
125V DC-1	Loss of CRD Pump B
125V DC-2	Loss of CRD Pump A

AICD Split Fraction Rules

AICDFL (IOA=F)* ((INIT=R303F1) + (INIT=R280F1) + (INIT=R280F5) + (INIT=RBR3F1) + (INIT=RBR3F2) + (INIT=RBR4F1) + (INIT=RBTRF1) + (INIT=RTRFR2) + (INIT=RTRFT2) + (INIT=RBTRF3) + (INIT=RBTRF4) + (INIT=RBRCUF) + (INIT=RBNEF1) + (INIT=RBSEF1))

The above initiating events are conservatively assumed to fail AICD in the event that operators fail to initially isolate the break, even though the elevation may be well below the elevation of the CRD pumps.

AICDFL (INIT=CSTF) + (INIT=RBTRF4) + (INIT=RBNEF2) + (INIT=RBSEF2)

The above initiating events are assumed to guarantee failure of AICD.

AICDFL ((A3=F) + (D1=F)) * ((A4=F) + (D2=F)) + (-(RW=S)) + (CR=F)

AICD is guaranteed to fail with the above combinations of support system failures..

AICDFL (AD=F)

Although the CRD system is a high pressure system, its limited capacity will likely prevent adequate injection if operators fail to depressurize the RPV.

AICDFL ((LA=F) + (VA=F)) * ((LB=F)+(VB=F)) * (CA=F) * (CB=F) * (CN=F)

Injection using the CRD system is only credited for late scenarios, where the decay heat removal requirements are reduced. Therefore, low pressure injection must initially be accomplished by one of the pressure systems questioned above.

AICDAF ((A3=S) * (D1=S)) * ((RW=S)) * ((A4=F) + (D2=F))

This models AIDC when CRD Train A has failed due to support system failure.

AICDBF ((A4=S) * (D2=S)) * ((RW=S)) * ((A3=F) + (D1=F))

This models AIDC when CRD Train B has failed due to support system failure.

AICDBS (A4=S) * (D2=S) * (A3=S) * (D1=S) * (RW=S)

The above models the AICD base case with all support systems available.

AICDFL 1

Top Event: AICT– Alternate Injection Using the Condensate Transfer System

General Notes

CST is a low pressure system that can be used as an alternate source of RPV injection in the event that all other sources of injection have failed. Alternate injection provides an adequate source of makeup, provide the following conditions are met:

(a) The RPV has been successfully depressurized using ADS.
(b) Early injection has been successfully been accomplished by higher capacity systems (LP, CS or CN).
(c) Decay heat removal is being accomplished by either recovery of the main condenser (RM) or by containment venting (VT).

Support System Failure	Impact on AICT
4 kV Bus 2 (O2)	Loss of CST Pumps A and B
Injection Pathways	CST injection requires an injection pathway to the RPV using either the LPCI or Core Spray systems.

AICT Split Fraction Rules

AICTFL **(UA=F) * ((INIT=FOBF1) + (INIT=TBHVF) + (INIT=DGAF1) + (INIT=DGBF1) + INIT=R303F1) + (INIT=R280F1) + (INIT=R280F5) + (INIT=RBR3F1) + (INIT=RBR3F2) + (INIT=RBTRF1) + (INIT=RT RFR2) + (INIT=RTRFT2) + (INIT=RBTRF3) + (INIT=RBRCUF) + (INIT=RBNEF1) + (INIT=RBSEF1) + (INIT=RBR4F1))**

The above initiating events are conservatively assumed to fail AICD in the event that operator ultimate action (UA) fails to initially isolate the break. Because of the higher elevation of the CST pumps relative to the CRD pumps, operators will have a longer time to isolate the break and prevent CST pump failure.

AICTFL **(INIT=CSTF) + (INIT=TBCWF) + (INIT=TBSWF) + (INIT=RBTRF4) + (INIT=RBNEF2) + (INIT=RBSEF2)**

The above flooding initiating events are assumed to guarantee failure of alternate injection using the CST system.

AICTFL **(CR=F) + (-(O2=S)) + (AD=F) + (CTPATHF)**

Failure of Bus 2 (O2) fails motive power to both CST pumps. Since these are low pressure pumps, the RPV must be depressurized (AD) for successful injection.

AICTAB **(O2=S) * (AD=S)**

Base case failure probability of AICT with all supports systems available and successful ADS.

AICTFL 1

Top Event: AI – Operators Successfully Control Containment Pressure (NPSH)

AI General Notes:

- If injection is maintained by either LPCI or Core Spray, taking suction from the torus, along with decay heat removal being accomplished by torus venting (VT), containment overpressure must be maintained to provide adequate NPSH to these pumps. In these scenarios, successful AI requires both containment isolation (IP), operator action to control venting and successful operation of one of the LPCI or CS pumps.

AI Split Fraction Rules

AIFAIL **1**

If none of the above rules apply, the AIFAIL rule will ensure a conservative result and assist in checking the validity of the results.

Attachment J

PRA Quality

The following manifests the quality of the Vermont Yankee PSA models used in performing the risk assessment crediting containment overpressure on NPSH requirements for RHR system and Core Spray system pumps:

- Level of detail in PSA
- Maintenance of the PSA
- Comprehensive Critical Reviews

J.1 LEVEL OF DETAIL

The Vermont Yankee PSA modeling is highly detailed, including a wide variety of initiating events, modeled systems, operator actions, and common cause events.

The PSA model (Level 1 and Level 2) used for the containment overpressure risk assessment was the most recent internal events risk model for the Vermont Yankee plant (Revision VY04R1). This current model is an updated version of the model used in the 1993 individual plant examination and reflects the VY configuration and extended power uprate design changes, and SBO/Vernon Tie evaluation as of September 2004. The VY model adopts the large event tree / small fault tree approach and uses the support state methodology, contained in the RISKMAN code, for quantifying core damage frequency. The PSA model has been updated several times since the IPE due to the following.

- Equipment performance – As data collection progresses, estimated failure rates and system unavailability data change.
- Plant configuration changes – Plant configuration changes are incorporated into the PSA model.
- Modeling changes – The PSA model is refined to incorporate the latest state of knowledge and recommendations of industry peer reviews.

The PSA model contains the following modeling attributes.

J.1.1 Initiating Events

The Vermont Yankee at-power PSA explicitly models a large number of internal initiating events:

- General transients
- LOCAs
- Support system failures
- Internal Flooding events

The initiating events explicitly modeled in the Vermont Yankee at-power PSA are summarized in Table J-1. The number of internal initiating events modeled in the Vermont Yankee at-power PSA is similar to the majority of U.S. BWR PRAs currently in use.

J.1.2 System Models

The Vermont Yankee at-power PSA explicitly models a large number of frontline and support systems that are credited in the accident sequence analyses. The Vermont Yankee systems explicitly modeled in the Vermont Yankee at-power PSA are summarized in Table J-2. The number and level of detail of plant systems modeled in the Vermont Yankee at-power PSA is equal to or greater than the majority of U.S. BWR PRAs currently in use.

J.1.3 Operator Actions

The Vermont Yankee at-power PSA explicitly models a large number of operator actions:

- Pre-Initiator actions
- Post-Initiator actions
- Recovery Actions
- Dependent Human Actions

Over one hundred operator actions are explicitly modeled. Given the large number of actions modeled in the Vermont Yankee at-power internal events PSA, a summary table of the individual actions modeled is not provided here.

The human error probabilities for the actions are modeled with accepted industry HRA techniques and include input based on discussion with plant operators, trainers, and other pertinent personnel.

The VY PSA includes an explicit assessment of the dependence of post-initiator operator actions. The approach used to assess the level of dependence between operator actions is based on the method presented in the Handbook of Human Reliability Analysis, NUREG/CR-1278.

The number of operator actions modeled in the Vermont Yankee at-power PSA, and the level of detail of the HRA, is equal to or greater than many U.S. BWR PRAs currently in use.

J.1.4 Common Cause Events

The Vermont Yankee at-power PSA explicitly models a large number of common cause component failures. More than 500 common cause terms are included in the VY PSA. Given the large number of CCF terms modeled in the Vermont Yankee at-power internal events PSA, a summary table of them is not provided here. The number and level of detail of common cause component failures modeled in the Vermont Yankee at-power PSA is equal to or greater than the majority of U.S. BWR PRAs currently in use.

J.1.5 Level 2 PSA

The Vermont Yankee Level 2 has been updated to incorporate insights from the independent peer review and the NEI Guidelines, NEI 00-02, on PRA Peer Review. The analysis is designed to calculate the LERF frequency consistent with NRC Regulatory Guidance (e.g. Reg. Guides 1.174 and 1.177) and the PSA Application Guide.

A separate Level 2 model was created that linked the Transient, LOCA and Flooding initiators to the containment (CET) event tree. The linking of the flooding events to the containment event tree is new to this model, not having been incorporated in previous VY models. This enhancement required new frontline macros to be applied to the CET split fraction rules and endstate definitions.

The following aspects of the Level 2 model reflect the more than adequate level of detail and scope:

1. Dependencies from Level 1 accidents are carried forward directly into the Level 2 by transfer of sequences to ensure that their effects on Level 2 response is accurately treated.
2. Virtually all phenomena identified by the NRC and industry for inclusion in BWR Mark I Level 2 analyses are treated explicitly within the model.
3. The model truncation is sufficiently low to be consistent with the NEI PRA Peer Review Guidelines for Risk-Informed Applications.

J.2 MAINTENANCE OF PSA

Approximately every two refueling outages, a formal review of the VY PSA model is performed to evaluate whether, or not, the model continues to reflect the plant design and operating procedures, refer to procedure ENN-DC-151 [Reference L-5]. The review shall encompass the following areas:

5) All major design changes implemented since the last PSA update. The review shall include implemented design changes and other material.

6) Maintenance Rule unavailability data for impacts on current fault tree unavailability assumptions.

7) Maintenance Rule Functional Failure (MRFF) reliability data to determine if any component failure rates require updating.

8) Review recent plant scram history, and update initiating event types / frequencies if warranted.

9) Review TS changes, calculations, and recent industry experience for possible impact on the PSA models and update modeling if warranted.

10) Review EOP/SAGs and other operating procedure changes/training, and modify human error rates and / or modeling, if warranted.

Significant changes identified in the areas listed above may be implemented in the model at the time the change occurs if their impact is significant enough to warrant implementation (i.e., interim PSA model updates)

J.2.1 History of Vermont Yankee PSA Models

The Vermont Yankee PSA model and documentation has been maintained living and is routinely updated to reflect the current plant configuration following refueling outages and to reflect the accumulation of additional plant operating history and component failure data.

The Vermont Yankee PSA has been updated five times since the original IPE.

The PSA models are routinely implemented and studied by plant PSA personnel in the performance of their duties. Potential model modifications/enhancements are itemized and maintained for further investigation and subsequent implementation, if warranted.

Each supporting element of the Vermont Yankee PSA is documented, typically in a stand-alone report. Each analysis element is reviewed by cognizant personnel and comments reconciled before final approval.

Formal comprehensive model reviews are discussed in Section L.3.

J.3 COMPREHENSIVE CRITICAL REVIEWS

The Vermont Yankee PSA model has benefited from the following comprehensive technical reviews:

- PSA Model Peer Review
- External reviews during the development of the IPE (not discussed here)

PSA Model Peer Review

The Vermont Yankee internal events PSA received a formal industry PRA Peer Review in September 2000. [Reference C-3] The purpose of the PRA Peer Review process is to provide a method for establishing the technical quality of a PSA for the spectrum of potential risk-informed plant licensing applications for which the PSA may be used. The PRA Peer Review process uses a team composed of PSA and system analysts, each with significant expertise in both PSA development and PSA applications. This team provides both an objective review of the PSA technical elements and a subjective assessment, based on their PSA experience, regarding the acceptability of the PSA elements. The team uses a set of checklists as a framework within which to evaluate the scope, comprehensiveness, completeness, and fidelity of the PSA products available.

The Vermont Yankee review team used the Revision A-3 NEI draft "Probabilistic Risk Assessment (PRA) Peer Review Process Guidance" dated June 2, 2000 as the basis for the review. [Reference-2]

The general scope of the implementation of the PRA Peer Review includes review of eleven main technical elements, using checklist tables (to cover the elements and sub-elements), for an at-power PSA including internal events, internal flooding, and containment performance, with focus on large early release frequency (LERF). The eleven technical elements are shown in Tables J-3 through J-5.

The comments from the PRA Peer Review were prioritized into four categories A-D based upon importance to the completeness of the model. All comments in Categories A and B (recommended actions and items for consideration) were identified to Vermont Yankee as priority 'items to be resolved in the next model update. The comments in Categories C and D (good practices and editorial) are potential enhancements and remain for consideration in future updates of the Level 1 and 2 PSA models.

All of the 'A' and 'B' priority PRA Peer Review comments have been addressed by VY and incorporated into the VY PSA model as appropriate.

The Peer Review Certification identified the following strengths and areas of improvements for the VY PSA model:

- Containment Capability: The Vermont Yankee containment failure analysis represents a state of the art analysis of the containment strength and failure probability. A detailed plant specific analysis developed by Chicago Bridge and Iron supported the analysis. The documentation was detailed, traceable and available for review.
- Interfacing System LOCA: A realistic plant specific evaluation of the interfacing system LOCA frequency was prepared. The model was well documented and provided a systematic process identification and evaluation of potential containment bypass paths.
- Maintenance Unavailability and Failure Rate Analysis: The maintenance unavailability incorporated in the PRA was based on an excellent review and analysis of plant-specific data. Plant component failure date had also been recently evaluated at the time of the review.
- Tier 2 System Analysis Documentation: Vermont Yankee has maintained Tier 2 notebooks for the system analyses containing extensive background material. This information source proved useful to the reviewers, and is a valuable resource for the PRA staff.
- System Dependencies: Although there was no single system dependency matrix, the system dependencies were clearly presented for each system in the system analysis notebook.
- Human Reliability Analysis: The Vermont Yankee PRA included a comprehensive treatment of human reliability. This included extensive incorporation of pre-initiator actions and a solid and calculations for post-initiators
- Spatial Dependencies: Internal flooding and HVAC dependencies were systematically evaluated and documented. Plant-specific analyses supporting the models and modeling assumptions were provided.
- Level 2 Analysis: The Level 1/Level 2 interface, including the plant damage state and containment event tree end state definitions, was very detailed. The full spectrum of severe accident phenomena listed in the ASME PRA Draft Standard was considered in the Level 2 evaluation.
- Maintenance and Update Process: VY follows the ENN-DC-151 PSA Maintenance and Update is used to maintain VY PSA model current.

Recommended Areas of Improvement

The Peer Review Certification identified the following areas of improvement of the VY PRA:

- PRA Guidance: The lack of guidance documents was cited as a weakness for most of the technical elements examined as part of this review. In some areas (e.g., elements SY, HR, L2 and AS), the documentation has sufficient detail as to provide a certain level of guidance. But the reviewers agreed that the development of guidance documents, if followed and maintained, can be an important element in maintaining the quality of the PRA.

  Resolution:
  The ENNE fleet has developed and utilizes standardized practice guidance for documentation of PSA model elements, which will be used in planned future updates of the Vermont Yankee PSA model in accordance with procedure ENN-DC-151.

- Dependence of Human Actions: There did not seem to be any systematic check to insure that where multiple human actions are included in a scenario, the potential dependence between these actions had been considered. One significant scenario, containing potential dependence between human actions (the third highest in core damage frequency) was identified by the reviewers (see Fact and Observation sheet QU-6). A sensitivity quantification (e.g., set all human actions to 0.1) is commonly performed as part of the PRA quantification process to confirm that the CDF frequency is not being understated by treating multiple human failure probabilities as independent events.

  Resolution:
  Dependencies between human actions were examined and documented in "Vermont Yankee Dependent HEP Assessment". All of the dynamic operator actions modeled in the VY PRA were included in this assessment. The approach used to judge the level of dependence between operator actions was based on dependency level categories and conditional probabilities developed in the "Handbook of Human Reliability Analysis with Emphasis on Nuclear Power Plant Applications" NUREG/CR-1278. NUREG/CR-1278 identifies five levels of dependence: ZD (zero dependence), LD (low dependence), MD (moderate dependence), HD (high dependence), and CD (complete dependence). Based on the NUREG/CR-1278, Time, Function, and Spatial attributes were used to determine the level of dependence between operator actions within an accident sequence.
  These attributes were used to develop qualitative criteria (rules) that were used to assign the level of dependence (CD, HD, MD, LD, ZD) between the operator actions. Quantitative values associated with the level of dependence were assigned and used in a quantitative sensitivity assessment. These updated dependencies resulted in increase in CDF of 0.61%, compared to the base model. Based on the 5E-07 threshold it can be concluded that this negligible change did not justify the need for a permanent model change.

- Independent Review Process: There is little documentation of any independent review associated with most documents. A documented process calling for a review by a qualified, independent analyst should be added to the PRA maintenance procedure. This would improve the quality of the PRA.

Resolution

The PRA update procedure calls for the undertaking and documentation of an independent review of modeling changes and evaluations, and this has been implemented for all PRA updates.

- Generic Initiating Event Data: The generic sources of LOCA and loss of offsite power frequencies referenced in the PRA are outdated. More recent data is available in NUREG/CR-5750 (LOCAs) and NUREG/CR-5496 (LOSP) and should be incorporated during he next PRA update.

  Resolution

  Initiating event frequencies were reviewed and updated as documented in 2002 (ref: "Vermont Yankee Nuclear Power Station PRA Initiating Event Frequency Update – 2002 Notebook"), as well as in the 2004 (ref: Technical Evaluation TE-2004-015, "VY04 – PSA Base Model Update for 2004").

- Success Criteria Traceability: Documentation of the accident sequence model success criteria and their bases should be improved. There are notebooks containing some of the necessary documentation, although no clear roadmap is provided linking MAAP calculations and other supporting analyses to the accident sequence model.

  Resolution

  In 2002 the PSA success criteria were reviewed and documented, definitions clarified and references identified.

- System Modeling: The system models were graded as capable of supporting risk significant evaluations, but the review team had difficulty reaching consensus on this grade as there were a number of areas identified that should be improved to make the models more flexible and easier to use for applications. The Vermont Yankee PRA uses a number of modeling simplifications that reduce the capabilities of the RISKMAN program to produce potentially insightful reports (e.g. basic event importance, system importance). For example, taking advantage of model symmetries reduces the of split fractions that need to be quantified and simplified the event tree input, but skews the basic event importance results (see F&O Sys-14). Also, there is an optional conditional split fraction replacement logic input that allows the software to associate the correct basic event importance (for a class of scenarios) that has not been developed in the Vermont Yankee model (see F&OSys-13). These modeling simplifications had distinct advantages when PRA software and personal computers were less powerful, but should be removed to take advantage or all the reporting features.

  Resolution

  Symmetric split fractions have been developed for all multi-train top events as part the 2004 EPU RISKMAN model (VY04R1).

- Common Cause Parameters: Common cause failures are modeled extensively and appropriately in the PRA, but the data source for the common cause failure parameters is outdated. New data available through the NRC and INEEL need to be incorporated in the PRA as part of the next update. This is critical due the importance of common cause failures with respect to CDF.

Resolution

As part of the PSA 2002 update a review of the Common Cause Failure (CCF) parameters presented in NUREG-5497 was performed and the results compared with the values used in the VY PSA model. It was concluded that the values utilized in the Vermont Yankee PSA model remain appropriate and there is not a strong basis for replacing our current common cause factors with those provided in NUREG-5497 at this time.

- Presentation and Interpretation of Results: The presentation of PRA results should be expanded to assist in developing insights. Additional reports could be generated with the current model (e.g., initiator contribution to CDF), and the model should be requantified with the "save sequence cutoff" reduced to include a higher percentage of total CDF in the split fraction and top event importance reports. It is also suggested that the LERF results be requantified as part of the PRA update.

Resolution

The cutoff values for importance calculations have been reduced from the original IPE. LERF results are included in all major PSA model updates.

- Uncertainty Analysis: No data uncertainty analysis has been performed for the current Vermont Yankee PRA. A documented analysis in this area may provide additional insights into the PRA results. It is again noted that the current structure of the model makes the uncertainty calculation engine of the RISKMAN PRA software ineffective. Many of the basic event failure rates loaded into the program are point estimates. The model simplifications identified in F&Os SY-13 (CSF replacement) and SY-14 (symmetry) also need to be addressed before the RISKMAN uncertainty engine can be used effectively.

Resolution

F&Os SY-13 and SY-14 were resolved and implemented in models VY00 and VY04, respectively. The uncertainty associated with the core damage frequency was estimated using Monte Carlo techniques implemented in RISKMAN for the base case model VY04R1. Results include mean, 5th, 50th, and 95th percentile values. These values reflect the uncertainties associated with the data distributions used in the analysis.

- Maintenance and Update Process: The PRA update procedure was in a draft form at the time of the review. As mentioned under "PRA Strengths", it is the opinion of the review team that the Vermont Yankee PRA staff is headed in the direction with this procedure. It is mentioned here to emphasize the importance of addressing the review comments and finalizing this procedure in the near future.

Resolution

The VY PSA Update Procedure was completed and was utilized for the VY 2002 PRA Update and subsequent updates. This procedure has since been replaced by an Entergy fleet procedure ENN-DC-151 PSA Maintenance and Update.

Major Changes since Original IPE Submittal:

The following major changes have been incorporated in the Vermont Yankee PSA model since the original IPE submittal.

1. Updated HEP Values

   HEP values were updated to reflect the following changes since the original IPE:

   - EOP's updated to be consistent with the latest BWROG EPG/SAG revision.
   - New Severe Accident Management Guidelines (SAMG).
   - Plant modifications and Extended Power Uprate.

2. Modifications to operator training.

3. Flooding Events Modeling

   - Significant changes were made to the modeling of flooding events to reflect enhancements to operating procedures and evaluation of component vulnerability to flooding.

4. Main Station Battery Chargers

   A plant upgrade was made to the Main Station Battery Charges to provide 100% redundancy and improve reliability for the 125 VDC Main Station Batteries and DC buses DC-1 and DC-2.
   This upgrade consisted of the following:

   - Adding a new 125 VDC charger, designated BC-1-1D, dedicated to 125 VDC bus DC-2. This charger will be identical to the existing chargers, except for some small electronics parts on circuit cards.
   - Dedication of the existing battery charger BC-1-1C, formerly called the 'swing charger', to 125 VDC bus DC-1.
   - All 4-battery chargers are modeled. If either, or both, aligned battery chargers fail, its corresponding backup charger is questioned. It is conservatively assumed that operator failure to align one backup charger will also guarantee failure to align the other backup charger.
   - Removal of the load shed feature from each of the 480 VAC feeder breakers to the three existing battery chargers. Consistent with this modification, there will be no load-shed feature on the feeder breaker to the new battery charger. Removal of the load shed feature eliminates the need for plant operators to restore the battery charges following a loss of normal power event. This results in the elimination of LNP specific split fractions for C1C2.

     Note: The original IPE model took no credit is taken for alignment of the swing charger (BC-1-1C) in the event that one of the two normally aligned battery chargers.

5. Modeling of the recirculation loop discharge valves MOVs 53A/53B for LPCI injection (1998).

   The original LPCI fault tree did not model the recirculation loop discharge valves as a "failure mode" of the associated LPCI subsystem. This was questioned during the VY AE inspection (May/June 1997) because not including the recircirculation loop isolation valves appeared different from other PRA studies and could under-estimate the total failure probability of LPCI for some LOCA events. Depending on the postulated break size and location (particularly a large, suction side break), LPCI flow to the intact loop could short-circuit the core by flowing through the RPV lower plenum and out the break if the intact loop discharge valve is not closed. Thus, failure to close the intact recirculation loop discharge valve could be a LPCI subsystem failure mode for some events and should be considered in the model.

   The LPCI fault tree has been revised to include failure of the recirculation loop discharge valves as a failure mode of the associated LPCI subsystem for all events. Including these valves for all events is a conservative but reasonable approach based on the following:

6. Modification to OS rules to better reflects operating procedures.

   Automatic isolation of non-essential SW loads was implemented to satisfy conservative design basis criteria. Based on our review, this modification has little effect on the "best estimate" IPE analysis which is not limited to design basis.

   Service water valves SW-20, SW-19A and SW-19B were modified to automatically close when SW header pressure (as measured in the ECCS corner rooms) decreases below 50 PSIG for greater than 27 seconds. Sustained low SW header pressure is indicative of a loss of normal power event (LNP) which causes all operating SW pumps to stop and only two SW pumps to automatically restart. When postulating conservative design basis assumptions of single active pump failure and no credit for operator action, only one operating pump may be subject to damage from run-out flow, and flow to critical components (EDGs) may be deficient. Automatic isolation of non-essential cooling loads will quickly increase the SW system flow resistance, limit pump run-out, and allow time for operators to manually start other pumps if needed. The original plant design required control room operators to manually isolate the non-essential loads if a loss of normal power (LNP) event occurred.

7. Symmetric split fraction values.

   The PRA models many multi-train systems as single top event. The original IPE often used the same split fraction to model a top event where one train was degraded or failed due to support system failures. This provided accurate CDF values, but did not always accurately reflect the risk importance of specific components or trains. An update to the PRA model was performed to create train specific split fractions for all top events.

8. Updated generic failure rate data for selected components.

   The failure rates of selected components for which generic failure rates were applied were updated to reflect more recent industry data. In the LPCI ISLOCA (Interfacing System LOCA) analysis, the probability for the LPCI check valve LCV-46A leakage failure was inadvertently doubled. The correct failure probability for LCV-46A is 7.45E-04/yr, (IPE Section 3.2.36) but the value used in the model was 1.48E-03/yr.

Using the correct check valve failure probability, the frequency of the LCPI ISLOCA initiating event was reduced by approximately 30%. The total annual ISLOCA frequency (for LPCI, CS, and SDC) changed from 2.29E-07/yr to 1.71E-07/yr, a reduction of 25%. There were no other model changes required to correct this error.

9. ARI/RPT Instrumentation

New ARI/RPT instrumentation was installed to satisfy the ATWS Rule equipment diversity requirements. The diverse equipment installed by this EDCR included new reactor level and reactor pressure transmitters, alarm relay modules and relays and modification of two existing water level transmitter loops. The intent of the design upgrade is to diversify the ATWS mitigation equipment (ARI/RPT) from Reactor Protection System (RPS) equipment so as to reduce the likelihood of common mode failures between both systems.

10. Modification to Feedwater/Condensate (FWCN) System

The original Feedwater/Condensate model conservatively credited only the low feedwater low flow valve as an injection path for power levels below 10 percent power, when in fact success could also be achieved though either of the main Feedwater control valves. A modification was made to the FWCN model to credit either of the main Feedwater regulation valves, in addition to the low flow valve, for power levels below 10 percent power.

11. 24VDC ECCS System

- *The following modifications were made to the 24V DC ECCS system:*
    - The 24V ECCS batteries were removed.
    - The 24V DC battery chargers were replaced with 24V DC converters.

12. Containment N_2 System

A large portion of the Containment Air System piping in the Drywell is NNS/non-seismic and is assume to fail in a seismic event. To meet A46/SUAG program commitments, a seismically designed backup system has been installed (EDCR 98-405). This system consists of 2 high pressure N2 cylinders regulated to feed the SRV accumulators when normal N2 system pressure degrades. This modification was added to the N_2 systems model.

13. Improvement in the Service Water Recovery model

Changes were made to the AW top event fault tree to include an improved SW recovery model, in place of the estimated recovery factor that was being used. The recovery model reflects operator response to a variety of system failure modes. The SW recovery model was based upon the Vermont Yankee LOSW initiating event fault tree analysis.

14. Effects associated with the Extended Power Uprate (EPU)

    The Extended Power Uprate (EPU) for Vermont Yankee was reviewed to determine the net impact on the risk profile associated with Vermont Yankee operation at an increase in power level to 1912 MWt (Ref: Identification of Risk Implications Due to Extended Power Uprate at Vermont Yankee, ERIN Engineering and Research, Inc., by Letter C16603001-5585, dated August 26, 2003). This involved the identification and review of plant and procedural changes, plus changes to the risk spectrum due to changes in the plant response.

15. Review of deterministic thermal hydraulic calculations using the MAAP computer code at the proposed increased power level indicated that the number of times that an SRV would be expected to cycle open/closed would increase by approximately 15%. This increased cycling would increase the probability that an SRV would fail to re-close. Using this information, the stuck open relief valve probabilities given a transient initiator for the individual SRVs was increased a similar amount.

16. Vermont Yankee installed an additional spring safety valve (SSV) to provide additional overpressure capacity to satisfy ASME code requirements at the proposed increased power level. Top event fault trees SO (i.e., "Safety/Relief Valves Fail to Open") and PR (i.e., "Pressure Relief System - ATWS Mitigation") were revised to incorporate the addition of this new valve.

17. Update of RPS Fault Tree Model

    The VY 2004 PSA model update incorporated an update of the scram failure probabilities using NUREG/CR-5500, Vol.3, "Reliability Study: General Electric Reactor Protection System, 1984-1995", May 1999. This report documents an analysis of the safety-related performance of the reactor protection system (RPS) at U.S. General Electric commercial reactors during the period 1984 through 1995. The General Electric RPS designs covered in the unavailability estimation included those with relay-based trip systems. The fault tree developed for this design assumed a BWR/4 plant – virtually identical to that used at VY.

18. Updated IE frequencies.

    Initiating event frequencies were reviewed and updated as documented in 2002 (ref: "Vermont Yankee Nuclear Power Station PRA Initiating Event Frequency Update – 2002 Notebook"), as well as in the 2004 (ref: Technical Evaluation TE-2004-015, "VY04 – PSA Base Model Update for 2004." This evaluation documents changes made to reflect a new understanding of the SBO event sequence, specifically to treatment of the Vernon Tie).

19. Revision of Human Error Probabilities (HEPs) was incorporated in the VY PSA model. The Vermont Yankee risk profile, like other plants, is dependent on the operating crew actions for successful accident mitigation. The success of these actions is in turn dependent on a number of performance shaping factors. The performance-shaping factor that is principally influenced by the power uprate is the time available within which to detect, diagnose, and perform required actions. The higher power level results in reduced times available for some actions. To quantify the potential impact of this performance shaping factor, deterministic thermal hydraulic calculations using the MAAP computer code was used to re-quantify a number of the HEPs used in the Vermont Yankee PSA model.

J.4 PSA QUALITY SUMMARY

The quality of modeling and documentation of the Vermont Yankee PSA models has been demonstrated by the foregoing discussions on the following aspects:

- Level of detail in PSA
- Maintenance of the PSA
- Comprehensive Critical Reviews

The Vermont Yankee Level 1 and Level 2 PRAs provide the necessary and sufficient scope and level of detail to allow the calculation of CDF and LERF changes due to the risk assessment crediting the use of containment overpressure evaluating the NPSH requirements for emergency core cooling and containment heat removal pumps.

Table J-1

INITIATING EVENTS FOR VERMONT YANKEE PSA

Initiator ID	*Description*
T	Transient (MSIVs and Feedwater Available)
TMS	MSIV Closure Transient (Feedwater Available)
TFWMS	MSIV Closure Transient with Loss of Feedwater
TLP	Loss of Off-Site Power Transient
LLOCA	Large LOCA
MLOCA	Medium LOCA
SLOCA	Small LOCA
A	ATWS for Transient type "T"
AMS	ATWS for Transient type "TMS"
AFWMS	ATWS for Transient type "TFWMS"
ALP	ATWS for Transient type "TLP"
TD1	Loss of 125 V DC Bus 1
TD2	Loss of 125 V DC Bus 2
TA3	Loss of 4,160 V AC Bus 3
TA4	Loss of 4,160 V AC Bus 4
TSW	Loss of Service Water
IORV	Inadvertent Opening Relief Valve
SORV	Stuck Open Relief Valve
ISLOCA	Interfacing Systems LOCA (48 unique IEs)
LOCAOC	LOCA Outside Containment (24 unique IEs)
Floods	Internal Flooding initiators (39 unique IEs)

Table J-2

VERMONT YANKEE PSA SYSTEMS

System Name	Event Tree Top Event
High Pressure Coolant Injection	HP, EH
Low Pressure Coolant Injection	LP
Low Pressure Core Spray	CS
Reactor Core Isolation Cooling	RC, EH
ECCS Actuation System: Reactor Low Level Reactor Low Pressure Drywell pressure Reactor Low Pressure Permissive	 LV PS DW PI
Auto Depressurization Manual Depressurization Emergency Depressurization	AD OD ED
Shutdown Cooling System	-
Containment Spray System	DS, SD
Containment Vent System	VT
Suppression Pool Cooling System	TC, HR
Main Steam Isolation	-
Standby Liquid Control System	SL
Control Rod Drive Alternate Injection	AI
Feedwater and Condensate System	FW, CN
Turbine Bypass and Main Condenser	TB, RM
Station Service Water	SW
RHR Service Water	DS, TC
Reactor Building Closed Cooling Water	RW
AC Electric Distribution	
4 kV AC Bus 1 and Bus 2	01, 02
4 kV AC Bus 3 and Bus 4	B3, B4
Diesel Generator DG-1-1A and DG-1-1B	GA, GB
Vernon Tie	VN

Table J-2

VERMONT YANKEE PSA SYSTEMS

System Name	Event Tree Top Event
120 V Instrument AC	IC
120 V Vital AC	VC
125V and 24V DC Electric Distribution	
Short-Term 125V DC Power (DC-1 and DC-2)	D1, D2
Long-Term 125V DC Power (DC-1 and DC-2)	C1, C2
Alternate DC Power (DC-1AS and DC-2AS)	S1, S2
24V DC ECCS Battery Panels A and B	V1, V2
Station Instrument Air System	IG
Containment N2 System	CG
Firewater Injection System	AI
Loss of Drywell RRU Cooling - Initiating Event	-
Turbine Building Closed Cooling Water	TW
Vapor Suppression	VS
Pressure Relief System SV/SRVs Fail to Open SRVs Fail to Reclose	PR SO SC
ARI and RPT Alternate Rod Insertion Recirculation Pump Trip	 AR RP
Reactor Protection System	CR, SE, SM
Feedwater Pump Trip on High Rx Level	FT
Primary Containment Isolation	IS
External Injection Using RHR-SW	VR, CF
Alternate Cooling Mode Using RHR-SW	AW
Refill of Condensate Storage Tank	AI
Condensate Transfer System as Alternate Injection	AI

Table J-3

PRA PEER REVIEW TECHNICAL ELEMENTS FOR LEVEL 1

PRA ELEMENT	CERTIFICATION SUB-ELEMENTS
Initiating Events	• Guidance Documents for Initiating Event Analysis • Groupings - Transient - LOCA - Support System/Special - ISLOCA - Break Outside Containment - Internal Floods • Subsumed Events • Data • Documentation
Accident Sequence Evaluation (Event Trees)	• Guidance on Development of Event Trees • Event Trees (Accident Scenario Evaluation) - Transients - SBO - LOCA - ATWS - Special - ISLOCA/BOC - Internal Floods • Success Criteria and Bases • Interface with EOPs/AOPs • Accident Sequence Plant Damage States • Documentation

Table J-3

PRA PEER REVIEW TECHNICAL ELEMENTS FOR LEVEL 1

PRA ELEMENT	CERTIFICATION SUB-ELEMENTS
Thermal Hydraulic Analysis	• Guidance Document • Best Estimate Calculations (e.g., MAAP) • Generic Assessments • FSAR - Chapter 15 • Room Heat Up Calculations • Documentation
System Analysis (Fault Trees)	• System Analysis Guidance Document(s) • System Models - Structure of models - Level of Detail - Success Criteria - Nomenclature - Data (see Data Input) - Dependencies (see Dependency Element) - Assumptions • Documentation of System Notebooks

Table J-3

PRA PEER REVIEW TECHNICAL ELEMENTS FOR LEVEL 1

PRA ELEMENT	CERTIFICATION SUB-ELEMENTS
Data Analysis	• Guidance • Component Failure Probabilities • System/Train Maintenance Unavailabilities • Common Cause Failure Probabilities • Unique Unavailabilities or Modeling Items - AC Recovery 2.0 Scram System - EDG Mission Time - Repair and Recovery Model - SORV - LOOP Given Transient - BOP Unavailability - Pipe Rupture Failure Probability • Documentation
Human Reliability Analysis	• Guidance • Pre-Initiator Human Actions - Identification - Analysis - Quantification • Post-Initiator Human Actions and Recovery - Identification - Analysis - Quantification • Dependence among Actions • Documentation

Table J-3

PRA PEER REVIEW TECHNICAL ELEMENTS FOR LEVEL 1

PRA ELEMENT	CERTIFICATION SUB-ELEMENTS
Dependencies	• Guidance Document on Dependency Treatment • Intersystem Dependencies • Treatment of Human Interactions (see also HRA) • Treatment of Common Cause • Treatment of Spatial Dependencies • Walkdown Results • Documentation
Structural Capability	• Guidance • RPV Capability (pressure and temperature) - ATWS - Transient • Containment (pressure and temperature) • Reactor Building • Pipe Over-pressurization for ISLOCA • Documentation
Quantification/Results Interpretation	• Guidance • Computer Code • Simplified Model (e.g., cutset model usage) • Dominant Sequences/Cutsets • Non-Dominant Sequences/Cutsets • Recovery Analysis • Truncation • Uncertainty • Results Summary

Table J-4

PRA CERTIFICATION TECHNICAL ELEMENTS FOR LEVEL 2

PRA ELEMENT	CERTIFICATION SUB-ELEMENTS
Containment Performance Analysis	• Guidance Document • Success Criteria • L1/L2 Interface • Phenomena Considered • Important HEPs • Containment Capability Assessment • End state Definition • LERF Definition • CETs • Documentation

Table J-5

PRA CERTIFICATION TECHNICAL ELEMENTS FOR MAINTENANCE AND UPDATE PROCESS

PRA ELEMENT	CERTIFICATION SUB-ELEMENTS
Maintenance and Update Process	• Guidance Document • Input - Monitoring and Collecting New Information • Model Control • PSA Maintenance and Update Process • Evaluation of Results • Re-evaluation of Past PSA Applications • Documentation

REFERENCES

[J-1] Vermont Yankee PSA Dependent HEP Assessment, Rev. 0, February 20, 2001.

[J-2] Probabilistic Risk Assessment (PRA) Peer Review Process Guidance", Rev. A-3 (Draft), NEI, June 2, 2000.

[J-3] Vermont Yankee PRA Peer Review Certification Report, GE Document BWROG/PRA-2000-03, November 2000.

[J-4] Letter from USNRC (D.H. Dorman) to D.A. Reid (VY), Vermont Yankee Nuclear Power Station Individual Plant Examination (IPE) Internal Events (TAC No. M74484), dated February 9, 1996.

[J-5] Entergy Nuclear Northeast, "PSA Maintenance and Update", Procedure ENN-DC-151, Rev. 0, 07/31/03.