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Evaluation of Severe Accident Risks: Surry Unit 1

Main Report

Prepared by
R. J. Breeding, J. C. Helton, W. B. Murfin, L. N. Smith

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Prepared by
R. J. Breeding, J. C. Helton[1], W. B. Murfin[2], L. N. Smith[3]

Sandia National Laboratories
Albuquerque, NM 87185

Prepared for
Division of Systems Research
Office of Nuclear Regulatory Research
U.S. Nuclear Regulatory Commission
Washington, DC 20555
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[1]Arizona State University, Tempe, AZ
[2]Technadyne Engineering Consultants, Inc., Albuquerque, NM
[3]Science Applications International Corporation, Albuquerque, NM

ABSTRACT

In support of the Nuclear Regulatory Commission's (NRC's) assessment of the risk from severe accidents at commercial nuclear power plants in the U.S. reported in NUREG-1150, the Severe Accident Risk Reduction Program (SARRP) has completed a revised calculation of the risk to the general public from severe accidents at the Surry Power Station, Unit 1. This power plant, located in southeastern Virginia, is operated by the Virginia Electric Power Company.

The emphasis in this risk analysis was not on determining a "so-called" point estimate of risk. Rather, it was to determine the distribution of risk, and to discover the uncertainties that account for the breadth of this distribution.

The offsite risk from internal initiating events was found to be generally below the risk estimates reported about a decade ago in the Reactor Safety Study (RSS) (WASH-1400). The upper end of the current distributions for common risk measures is of the same order of magnitude as the point estimates obtained by the RSS, but the bulk of the distribution is much lower. The containment appears to be quite likely to successfully withstand the loads that might be placed upon it if the core melts and the reactor vessel fails. Most of the risk, in the current view, comes from initiating events which bypass the containment, such as interfacing system pipe breaks and steam generator tube ruptures. These events are estimated to have a relatively low frequency of occurrence, but their consequences are relatively large. The uncertainties in risk from internal initiators are largely due to uncertainties in the initiating frequency of these bypass events, and in the magnitude of the radioactive release that results.

The offsite risk from external initiating events was found to be of the same order of magnitude or higher than the risk from internal initiating events. Only fires and earthquakes were found to be important enough external initiators to warrant a complete analysis. The risk from seismic initiators is an order of magnitude or more greater than that from fires. The Surry containment is not expected to fail directly due to an earthquake. As there are no seismic bypass initiators, the offsite risk from a radioactive release due to an earthquake is low unless the ground motion indirectly fails the containment. Failure of the supports of the reactor coolant pumps or the steam generators was judged to have this potential. There is great uncertainty in the frequency with which large magnitude earthquakes may be expected in the eastern U.S. Risk was calculated for two hazard distributions, which differ markedly. Both the absolute value of the seismic risk distributions and the uncertainties in these distributions are driven by the uncertainties in the seismic hazard. The RSS considered external initiating events only in a cursory manner.

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FOREWORD

This is one of numerous documents that support the preparation of the final NUREG-1150 document by the NRC Office of Nuclear Regulatory Research. Figure 1 illustrates the documentation of the accident progression, source term, consequence, and risk analyses. The direct supporting documents for the first draft of NUREG-1150 and for the revised draft of NUREG-1150 are given in Table 1. They were produced by the three interfacing programs at Sandia National Laboratories that performed the work: the Accident Sequence Evaluation Program (ASEP), the Severe Accident Risk Reduction Program (SARRP), and the PRA Phenomenology and Risk Uncertainty Evaluation Program (PRUEP). The Zion volumes were written by Brookhaven National Laboratory and Idaho National Engineering Laboratory.

The Accident Frequency Analysis, and its constituent analyses, such as the Systems Analysis and the Initiating Event Analysis, are reported in NUREG/CR-4550. Originally, NUREG/CR-4550 was published without the designation "Draft for Comment." Thus, the current revision of NUREG/CR-4550 is designated Revision 1. The label Revision 1 is used consistently on all volumes, including Volume 2 which was not part of the original documentation. NUREG/CR-4551 was originally published as a "Draft for Comment". While the current version could have been issued without a revision indication, all volumes of NUREG/CR-4551 have been designated Revision 1 for consistency with NUREG/CR-4550.

The material contained in NUREG/CR-4700 in the original documentation is now contained in NUREG/CR-4551; NUREG/CR-4700 is not being revised. The contents of the volumes in both NUREG/CR-4550 and NUREG/CR-4551 have been altered. In both documents now, Volume 1 describes the methods utilized in the analyses, Volume 2 presents the elicitation of expert judgment, Volume 3 concerns the analyses for Surry, Volume 4 concerns the analyses for Peach Bottom, and so on. Note that the Surry volume of NUREG/CR-4551, now Volume 3, was Volume 1 in the original Draft for Comment version of NUREG/CR-4551, published in February 1987. The Surry plant was also treated in Volume 1 of the original Draft for Comment version of NUREG/CR-4700. The topics covered in NUREG/CR-4700 are now included in NUREG/CR-4551.

In addition to NUREG/CR-4550 and NUREG/CR-4551, there are several other reports published in association with NUREG-1150 that explain the methods used, document the computer codes that implement these methods, or present the results of calculations performed to obtain information specifically for this project. These reports include:

NUREG/CR-5032, SAND87-2428, "Modeling Time to Recovery and Initiating Event Frequency for Loss of Off-site Power Incidents at Nuclear Power Plants," R. L. Iman and S. C. Hora, Sandia National Laboratories, Albuquerque, NM, January 1988.

NUREG/CR-4840, SAND88-3102, "Recommended Procedures for Simplified External Event Risk Analyses," M. P. Bohn and J. A. Lambright, Sandia National Laboratories, Albuquerque, NM, December 1988.

NUREG/CR-5174, SAND88-1607, J. M. Griesmeyer and L. N. Smith, "A Reference Manual for the Event Progression and Analysis Code (EVNTRE)," Sandia National Laboratories, Albuquerque, NM, 1989.

NUREG/CR-5380, SAND88-2988, S. J. Higgins, "A User's Manual for the Post Processing Program PSTEVNT," Sandia National Laboratories, Albuquerque, NM, 1989.

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NUREG/CR-4624, BMI-2139, R. S. Denning et al., "Radionuclide Release Calculations for Selected Severe Accident Scenarios," Volumes I-V, Battelle's Columbus Division, Columbus, OH, 1986.

NUREG/CR-5062, BMI-2160, M. T. Leonard et al., "Supplemental Radionuclide Release Calculations for Selected Severe Accident Scenarios," Battelle Columbus Division, Columbus, OH, 1988.

NUREG/CR-5331, SAND89-0072, S. E. Dingman et al., "MELCOR Analyses for Accident Progression Issues," Sandia National Laboratories, Albuquerque, NM, 1989.

NUREG/CR-5253, SAND88-2940, R. L. Iman, J. C. Helton, and J. D. Johnson, "A Users Guide for PARTITION: A Program for Defining the Source Term/Consequence Analysis Interfaces in the NUREG-1150 Probabilistic Risk Assessments," Sandia National Laboratories, Albuquerque, NM, 1989.

NUREG/CR-5382, SAND88-2695, J. C. Helton et al., "Incorporation of Consequence Analysis Results into the NUREG-1150 Probabilistic Risk Assessments," Sandia National Laboratories, Albuquerque, NM, 1989.

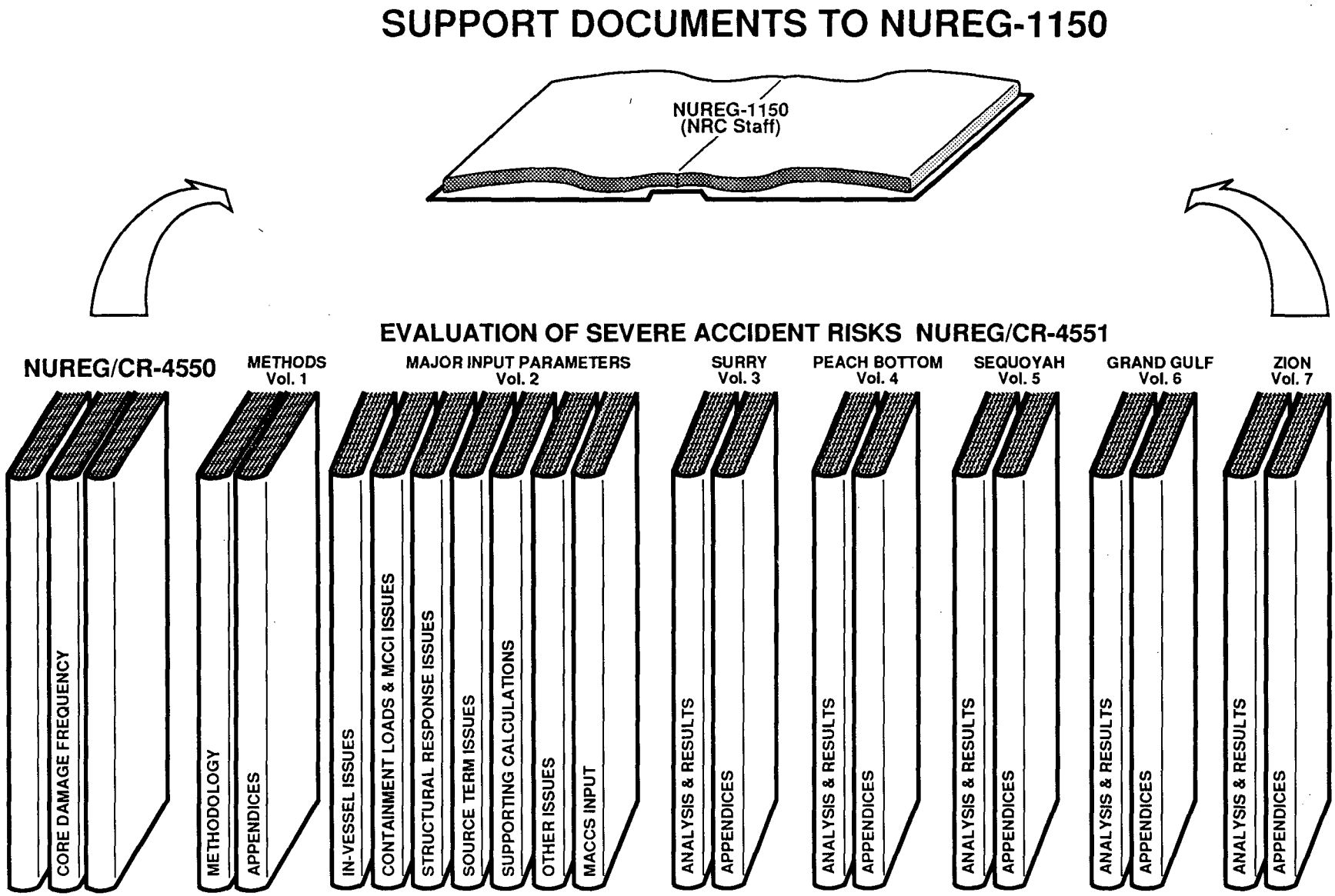

Figure 1. Back-End Documentation for NUREG-1150.

Table 1. NUREG-1150 Analysis Documentation

Original Documentation

NUREG/CR-4550

Analysis of Core Damage Frequency From Internal Events

Vol. 1 Methodology
2 Summary (Not Published)
3 Surry Unit 1
4 Peach Bottom Unit 2
5 Sequoyah Unit 1
6 Grand Gulf Unit 1
7 Zion Unit 1

NUREG/CR-4551

Evaluation of Severe Accident Risks and the Potential for Risk Reduction

Vol. 1 Surry Unit 1
2 Sequoyah Unit 1
3 Peach Bottom Unit 2
4 Grand Gulf Unit 1

NUREG/CR-4700

Containment Event Analysis for Potential Severe Accidents

Vol. 1 Surry Unit 1
2 Sequoyah Unit 1
3 Peach Bottom Unit 2
4 Grand Gulf Unit 1

Revised Documentation

NUREG/CR-4550, Rev. 1, Analysis of Core Damage Frequency

Vol. 1 Methodology
2 Part 1 Expert Judgment Elicit. Expert Panel
Part 2 Expert Judgment Elicit.Project Staff
3 Part 1 Surry Unit 1 Internal Events
Part 2 Surry Unit 1 Internal Events App.
Part 3 Surry External Events
4 Part 1 Peach Bottom Unit 2 Internal Events
Part 2 Peach Bottom Unit 2 Int. Events App.
Part 3 Peach Bottom Unit 2 External Events
5 Part 1 Sequoyah Unit 1 Internal Events
Part 2 Sequoyah Unit 1 Internal Events App.
6 Part 1 Grand Gulf Unit 1 Internal Events
Part 2 Grand Gulf Unit 1 Internal Events App.
7 Zion Unit 1 Internal Events

NUREG/CR-4551, Rev. 1, Eval. of Severe Accident Risks

Vol. 1 Part 1, Methodology; Part 2, Appendices
2 Part 1 In-Vessel Issues
Part 2 Containment Loads and MCCI Issues
Part 3 Structural Issues
Part 4 Source Term Issues
Part 5 Supporting Calculations
Part 6 Other Issues
Part 7 MACCS Input
3 Part 1 Surry Analysis and Results
Part 2 Surry Appendices
4 Part 1 Peach Bottom Analysis and Results
Part 2 Peach Bottom Appendices
5 Part 1 Sequoyah Analysis and Results
Part 2 Sequoyah Appendices
6 Part 1 Grand Gulf Analysis and Results
Part 2 Grand Gulf Appendices
7 Part 1 Zion Analysis and Results
Part 2 Appendices

ACRONYMS AND INITIALISMS

ADV	atmospheric dump valves
AFW	auxiliary feedwater
AFWS	auxiliary feedwater system
APB	accident progression bin
APET	accident progression event tree
ASEP	accident sequence evaluation
ATWS	anticipated transient without scram
BMT	basemat melt-through
BNL	Brookhaven National Laboratory
BWR	boiling water reactor
CCF	common cause failure
CCDF	complementary cumulative distribution function
CCI	core-concrete interaction
CCW	component cooling water
CDF	cumulative distribution function
CF	containment failure
CFW	chronic fatality weight
CHR	containment heat removal
CSS	containment spray system
CST	condensate storage tank
CST	condensate storage tank
DCH	direct containment heating
DG	diesel generator
EACPS	emergency ac power system
ECCS	emergency core cooling system(s)
EF	early fatalities
EFW	early fatality weight
EOP	emergency operating procedures
EPRI	Electric Power Research Institute
ESW	emergency service water
EVSE	ex-vessel steam explosion
FSAR	final safety analysis report
HPI	high pressure injection
HPIS	high pressure injection system
HPRS	high pressure recirculation system
HPME	high pressure melt ejection
HRA	human reliability analysis
ICIR	in-core instrumentation room
INEL	Idaho National Engineering Laboratory
IVSE	in-vessel steam explosion
LCF	latent cancer fatalities
LHS	Latin Hypercube Sampling
LLNL	Lawrence Livermore National Laboratory
LOCA	loss-of-coolant accident

LOSP	loss of offsite power
LPI	low pressure injection
LPIS	low pressure injection system
LPRS	low pressure recirculation system
LWR	light water reactor
MCDF	mean core damage frequency
MDP	motor-driven pump
MFWS	main feedwater system
MOV	motor-operated valve
MSIV	main steam isolation valve
MSL	main steam line
NRC	Nuclear Regulatory Commission
PCC	partial correlation coefficient
PDS	plant damage state
PGA	peak ground acceleration
PORV	power-operated relief valve
PRA	probabilistic risk analysis
PRCC	partial rank correlation coefficient
PWR	pressurized water reactor
PZR	pressurizer
RCP	reactor coolant pump
RCS	reactor coolant system
RHR	residual heat removal
RPS	reactor protection system
RSS	Reactor Safety Study
RWST	refueling water storage tank
SBO	station blackout
SERG	steam explosion review group
SG	steam generator
SGTR	steam generator tube rupture
SLC	standby liquid control
SNL	Sandia National Laboratories
SOV	solenoid-operated valve
SRV	safety relief valve
STSG	source term subgroup
TAF	top of active fuel
TDP	turbine-driven pump
T-I	temperature-induced
UTAF	uncovering of TAF
VB	vessel breach

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SUMMARY

S.1 Introduction

The United States Nuclear Regulatory Commission (NRC) has recently completed a major study to provide a current characterization of severe accident risks from light water reactors (LWRs). This characterization is derived from integrated risk analyses of five plants. The summary of this study, NUREG-1150,[1] has been issued as a second draft for comment.

The risk assessments on which NUREG-1150 is based can generally be characterized as consisting of four analysis steps, an integration step, and an uncertainty analysis step:

1. Accident frequency analysis: the determination of the likelihood and nature of accidents that result in the onset of core damage.

2. Accident progression analysis: an investigation of the core damage process, both within the reactor vessel before it fails and in the containment afterwards, and the resultant impact on the containment.

3. Source term analysis: an estimation of the radionuclide transport within the reactor coolant system (RCS) and the containment, and the magnitude of the subsequent releases to the environment.

4. Consequence analysis: the calculation of the offsite consequences, primarily in terms of health effects in the general population.

5. Risk integration: the assembly of the outputs of the previous tasks into an overall expression of risk.

6. Uncertainty analysis: the propagation of the uncertainties in the initiating events, failure events, accident progression branching ratios and parameters, source term parameters through the first three analyses above, and the determination of which of these uncertainties contributes the most to the uncertainty in risk.

This volume presents the details of the last five of the six steps listed above for the Surry Power Station, Unit 1. The first step is described in NUREG/CR-4550.[2]

S.2 Overview of Surry Power Station, Unit 1

The Surry Power Station, Unit 1 is operated by the Virginia Electric Power Company and is located on the south bank of the James River in southeastern Virginia, about 10 miles south of Williamsburg, VA, and approximately 35 miles northwest of Norfolk, VA. Two units are located on the site; Unit 2 is essentially identical to Unit 1.

Surry Unit 1 nuclear reactor is a 2441-MWt pressurized water reactor (PWR) designed and built by Westinghouse. The RCS has three U-tube steam generators (SGs) and three reactor coolant pumps (RCPs). The containment

and the balance of the plant were designed and built by Stone and Webster. Unit 1 began commercial operation in December 1972.

Table S.1 summarizes the design features of the plant that are relevant to severe accidents. Of particular interest is the large, dry containment that is kept at subatmospheric pressure during operation. The high pressure injection system (HPIS) and auxiliary feedwater system (AFWS) crossties between the two units make the core damage frequency lower than it would be without the crossties.

S.3 Description of the Integrated Risk Analysis

Risk is determined by combining the results of four constituent analyses: the accident frequency, accident progression, source term, and consequence analyses. Uncertainty in risk is determined by assigning distributions to important variables, generating a sample from these variables, and propagating each observation of the sample through the entire analysis. The sample for Surry consisted of 200 observations involving variables from the first three constituent analyses. The risk analysis synthesizes the results of the four constituent analyses to produce measures of offsite risk and the uncertainty in that risk. This process is depicted in Figure S.1. This figure shows, in the boxes, the computer codes utilized. The interfaces between constituent analyses are shown between the boxes. A mathematical summary of the process, using a matrix representation, is given in Section 1.4 of this volume.

The accident frequency analysis uses event tree and fault tree techniques to investigate the manner in which various initiating events can lead to core damage and the frequency of various types of accidents. Experimental data, past observational data, and modeling results are combined to produce frequency estimates for the minimal cut sets that lead to core damage. A minimal cut set is a unique combination of initiating event and individual hardware or operator failures. The minimal cut sets are grouped into plant damage states (PDSs), where all minimal cut sets in a PDS provide a similar set of initial conditions for the subsequent accident progression analysis. Thus, the PDSs form the interface between the accident frequency analysis and the accident progression analysis. The outcome of the accident frequency analysis is a frequency for each PDS or group of PDSs for each observation in the sample.

The accident progression analysis uses large, complex event trees to determine the possible ways in which an accident might evolve from each PDS. The definition of each PDS provides enough information to define the initial conditions for the accident progression event tree (APET) analysis. Past observations, experimental data, mechanistic code calculations, and expert judgment were used in the development of the model for accident progression that is embodied in the APET and in the selection of the branch probabilities and parameter values used in the APET. Due to the large number of questions in the Surry APET and the fact that many of these questions have more than two outcomes, there are far too many paths through the APET to permit their individual consideration in subsequent source term and consequence analysis. Therefore, the paths through the trees are grouped into accident progression bins (APBs), where each bin is a group of paths through the event tree that define a similar set of conditions for

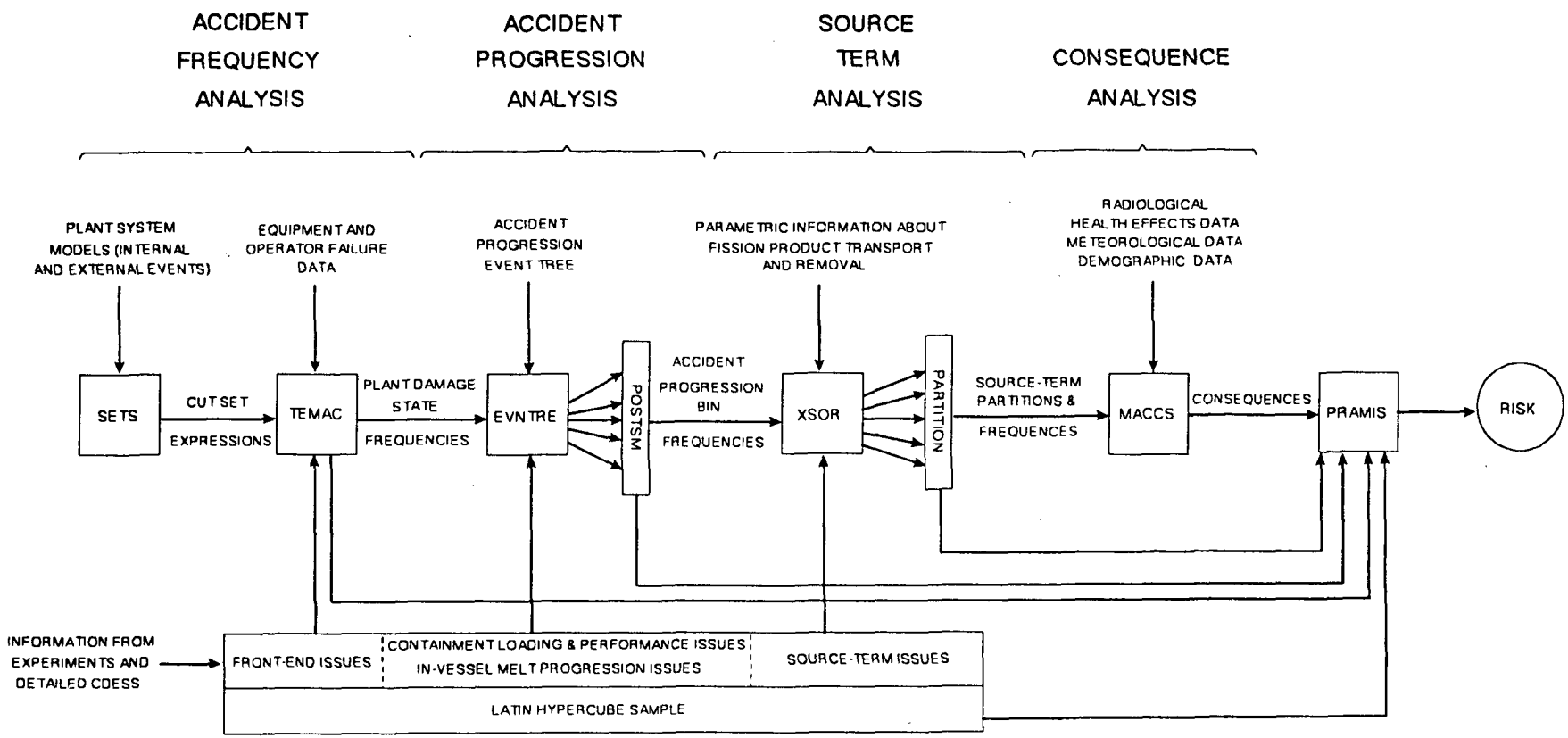


Figure S.1. Overview of Integrated Plant Analysis in NUREG-1150

source term analysis. The properties of each accident progression bin define the initial conditions for the estimation of a source term. The result of the accident progression analysis is a probability for each APB, conditional on the occurrence of a PDS, for each observation in the sample.

Table S.1
Design Features Relevant to Severe Accidents
Surry Unit 1

Emergency Core Cooling (ECCS)	HPIS Three motor-driven pumps (MDPs) (charging pumps) Suction from low pressure injection system (LPIS) discharge Dedicated two-train cooling system Crosstie to Unit 2 HPIS LPIS Two self-cooled MDPs Suction from the refueling water storage tank (RWST) or containment sump Accumulators Three accumulators containing borated water pressurized to 650 psig
Emergency Core Heat Removal	Auxiliary Feedwater System (AFWS) Two MDPs and one turbine-driven pump (TDP) Crosstie to Unit 2 AFWS Feed and Bleed Utilizes HPIS and power-operated relief valves (PORVs)
Reactivity Control	Reactor Protection System (RPS) (automatic scram) Manual scram
Emergency Electrical Power	AC Electrical Power Three diesel generators (DGs) for both units Dedicated DG always aligned to Unit 1 Swing DG may be aligned to either Unit DGs are self-contained and self-cooled DC Electrical Power Station batteries designed to last 2 h Batteries estimated to last 4 h due to design margin and load shedding

Table S.1 (continued)

Containment Structure	Built of reinforced concrete with welded steel liner Volume is about 1.8 million ft^3 Design pressure is 45 psig Maintained at 10 psia during reactor operation
Containment Heat Removal	All emergency heat removal is by spray systems Two-spray injection trains Four-spray recirculation trains All spray trains are independent
Cooling of Reactor Coolant Pump Seals	Two independent sources of RCP seal cooling Component cooling water system Charging (HPIS) pumps RCP seal failures likely only in SBO accidents
Service Water	Supplied from an elevated canal Canal likely to drain during extended SBOs Delay in restoring ECCS after power recovery Service water for cooling the ECCS pumps comes from the canal The canal must be refilled before starting the ECCS pumps
Sump and Reactor Cavity	No connection between sump and cavity at a low level in the containment Sump capacity is large, so there is no possibility of overflow from the sump filling the cavity Cavity can be filled with water only by operating the containment sprays

A source term is calculated for each APB with a non-zero conditional probability for each observation in the sample by SURSOR, a fast-running parametric computer code. SURSOR is not a detailed mechanistic model; it is not designed to be a realistic simulation of fission product transport, physics, and chemistry. Instead, SURSOR integrates the results of many detailed codes and the conclusions of many experts. Most of the parameters used to calculate fission product release fractions in SURSOR are sampled from distributions provided by an expert panel. Because of the large number of APBs, it is necessary to use a fast-executing code like SURSOR.

The number of APBs for which source terms are calculated is so large that it is not computationally practical to perform a consequence calculation for every source term. As a result, the source terms had to be combined into source term groups. Each source term group is a collection of source terms that result in similar consequences. The process of determining which APBs go to which source term group is called partitioning. It involves considering the potential of each source term group to cause early fatalities and latent cancer fatalities. The result of the source term calculation and subsequent partitioning is that each APB for each observation is assigned to a source term group.

A consequence analysis is performed for each source term group, generating both mean consequences and distributions of consequences. As each APB is assigned to a source term group, the consequences are known for each APB of each observation in the sample. The frequency of each PDS for each observation is known from the accident frequency analysis, and the conditional probability of each APB is determined for each PDS group for each observation in the accident progression analysis. Thus, for each APB of each observation in the sample, both frequency and consequences are determined. The risk analysis consists of assembling and analyzing all these separate estimates of offsite risk.

S.4 Results of the Accident Frequency Analysis

The accident frequency analysis for Surry is documented elsewhere.[2] This section only summarizes the results of the internal, fire, and seismic accident frequency analyses since these form the starting point for the analyses that are covered here. Table S.2 lists four summary measures of the core damage frequency distributions for Surry for the seven internally initiated PDS groups, the fire PDS group, and the six seismic PDS groups. The four summary measures are the mean, and the 5th, 50th (median) and 95th percentiles.

The 25 internally initiated PDSs that had mean frequencies above 1.0E-7/R-yr are placed into the seven PDS groups listed in Table S.2. These 25 PDSs account for over 99% of the total mean core damage frequency (MCDF) of 4.1E-5/R-yr. In both SBO groups, offsite power is lost and the DGs fail to start and run. In the slow SBO group, the steam-turbine-driven (STD) AFWS operates until the batteries are depleted; in the fast SBO group the STD AFWS fails. In both SBO groups, core melt may be arrested before the vessel fails, if offsite power is recovered in time. The loss-of-coolant accident (LOCA) PDS group consists of accidents initiated by breaks of all four sizes (A, S_1, S_2, and S_3). In some of the PDSs in this group, the LPIS is operating at the onset of core damage; therefore, it is possible to arrest core degradation before the vessel lower head fails for these PDSs.

Event V is initiated by the failure of two check valves that isolate LPIS piping from the RCS. The check valve failures expose the low pressure piping to full primary system pressure, causing the pipes to rupture. Since the break is outside containment, the break fails both the RCS and the injection system, and bypasses the containment. The Transient group consists of two PDSs that have failure of both the AFWS and Feed and Bleed. Core damage arrest is possible for this PDS group if the RCS pressure can

Table S.2
Surry Core Damage Frequencies
Internal, Fire, and Seismic Initiators

PDS Group	Core Damage Frequency (1/R-yr) 5%	Median	Mean	95%	% Mean TCD Frequency
1 Slow SBO	1.6E-06	1.1E-05	2.2E-05	6.4E-05	56
2 LOCAs	1.2E-06	3.9E-06	6.1E-06	2.0E-05	15
3 Fast SBO	1.2E-07	1.5E-06	5.4E-06	2.1E-05	13
4 Event V	3.6E-11	4.9E-08	1.6E-06	8.2E-06	4
5 Transients	1.1E-07	8.2E-07	1.8E-06	5.5E-06	4
6 ATWS	2.9E-08	4.2E-07	1.4E-06	6.5E-06	4
7 SGTRs	4.5E-07	1.4E-06	1.8E-06	4.7E-06	4
Internal Initiators	9.8E-06	2.5E-05	4.1E-05	1.0E-04	
FIRE	2.3E-6	8.4E-6	1.1E-5	2.6E-5	
Seismic Initiators					
LLNL Hazard Distribution -- Peak Ground Acceleration > 0.6 g					
EQ 1 LOSP	9.1E-9	5.8E-7	9.4E-6	3.4E-5	5
EQ 2 SBO	2.2E-8	9.2E-7	1.1E-5	5.3E-5	6
EQ 3 LOCAs	9.5E-9	5.5E-7	7.5E-6	3.6E-5	4
High PGA	5.6E-8	2.4E-6	2.8E-5	1.3E-4	15
LLNL Hazard Distribution -- Peak Ground Acceleration < 0.6 g					
EQ 1 LOSP	1.0E-7	6.2E-6	8.1E-5	3.5E-4	42
EQ 2 SBO	1.2E-7	5.8E-6	6.8E-5	2.9E-4	35
EQ 3 LOCAs	1.8E-8	1.1E-6	1.5E-5	7.3E-5	8
Low PGA	4.9E-7	1.5E-5	1.6E-4	6.4E-4	85
All PGA - LLNL	5.3E-7	1.8E-5	1.9E-4	7.6E-4	

Table S.2 (continued)
Seismic Initiators

PDS Group	Core Damage Frequency (1/R-yr) 5%	Median	Mean	95%	% Mean TCD Frequency
EPRI Hazard Distribution -- Peak Ground Acceleration > 0.6 g					
EQ 1 LOSP	8.8E-9	2.5E-7	1.1E-6	4.9E-6	4
EQ 2 SBO	1.8E-8	3.2E-7	1.1E-6	4.7E-6	4
EQ 3 LOCAs	2.1E-9	2.0E-7	9.8E-7	5.5E-6	3
High PGA	3.3E-8	9.9E-7	3.2E-6	1.4E-5	11
EPRI Hazard Distribution -- Peak Ground Acceleration < 0.6 g					
EQ 1 LOSP	9.6E-8	3.6E-6	1.4E-5	7.6E-5	50
EQ 2 SBO	1.3E-7	2.5E-6	8.4E-6	3.5E-5	30
EQ 3 LOCAs	5.3E-9	5.0E-7	2.5E-6	1.2E-5	9
Low PGA	3.4E-7	8.6E-6	2.5E-5	1.3E-4	89
All PGA - EPRI	3.7E-7	9.4E-6	2.8E-5	1.4E-4	

be reduced since the LPIS is operable in one PDS and both LPIS and HPIS are operable in the other. The ATWS group contains three PDSs in which the nuclear reaction is not brought under control at the start of the accident. The four PDSs that comprise the steam generator tube rupture (SGTR) group include two PDSs in which the safety relief valves (SRVs) in the secondary system stick open ("H" SGTRs), and two PDSs in which these SRVs reclose after opening ("G" SGTRs).

There are only four fire PDSs, all placed together in a single fire PDS group. Significant fire locations for Surry are: emergency switchgear room, auxiliary building, control room, and cable vault and tunnel. Core damage arrest is not possible for the fire PDSs since the fire destroys either the control or motive power cables.

The seismic PDS frequencies are calculated for two different sets of hazard distributions: one generated by Lawrence Livermore National Laboratory (LLNL) and one generated by the Electric Power Research Institute (EPRI). Table S.2 shows that use of the EPRI hazard distributions results in a total core damage frequency that is almost an order of magnitude lower than the total core damage frequency obtained using the LLNL hazard distributions. The seismic PDSs are divided into three groups. However, as the evacuation response differs for earthquakes with a peak ground acceleration (PGA) over 0.6 g and earthquakes with a PGA below 0.6 g, it is necessary to subdivide these groups on this basis. The loss of offsite power (LOSP) PDS group consists of accidents triggered by the LOSP, but in which the DGs

start and run so there is no SBO. In the SBO accidents, the LOSP is followed by failure of the DGs. Some of the PDSs in the SBO group have large A-size pipe breaks. When the earthquake caused both SBO and LOCA, the PDS was placed in the SBO group. Large LOCA PDSs appear in both the SBO and the LOCA PDS groups. These A-size pipe breaks are due to failure of the steam generator or reactor coolant pump supports. In addition to causing a break in the primary recirculation lines, these support failures are judged to place enough strain on the main steam line penetrations to fail the containment pressure boundary. Thus, these "A" PDS have initial containment failure.

S.5 Accident Progression Analysis

S.5.1 Description of the Accident Progression Analysis

The accident progression analysis is performed by means of a large and detailed event tree called the APET. This event tree forms a high-level model of the accident progression, including the response of the containment to the loads placed upon it. The APET is not meant to be a substitute for detailed, mechanistic computer simulation codes; rather, it is a framework for integrating the results of these codes together with experimental results and expert judgment. The detailed, mechanistic codes require too much computer time to be run for all the possible accident progression paths. Furthermore, no single available code treats all the important phenomena in a complete and thorough manner that is acceptable to all those knowledgeable in the field. Therefore, the results from these codes, as interpreted by experts, are summarized in an event tree. The resulting APET can be evaluated quickly by computer so that the full diversity of possible accident progressions can be considered and the uncertainty in the many phenomena involved.

The APET treats the progression of the accident from the onset of core damage to the core-concrete interaction (CCI). The APET accounts for all the events that may lead to the release of fission products due to the accident, even though some of the events may not occur until several days after the accident. The Surry APET consists of 71 questions, most of which have more than two branches. There are seven time periods considered in the tree. The recovery of offsite power is considered both before vessel failure as well as after vessel failure. The possibility of arresting the core degradation process before failure of the vessel is explicitly considered. Core damage arrest may occur following the recovery of offsite power or when depressurization of the RCS allows injection by an operating system (HPIS or LPIS) that previously could not function. Containment failure is considered at vessel breach (due to vessel blowdown, hydrogen combustion, direct containment heating, and steam explosions), after vessel failure (due to hydrogen combustion), and after several days (due to basemat meltthrough or eventual overpressure if containment cooling is not restored). Five mechanisms, four of them inadvertent, for depressurizing the vessel before failure are included in the APET.

The APET is so large and complex that it cannot be presented graphically and must be evaluated by computer. A computer code, EVNTRE, has been

written for this purpose. In addition to evaluating the APET, EVNTRE sorts the myriad possible paths through the tree into a manageable number of outcomes called the APBs.

S.5.2 Results of the Accident Progression Analysis

Results of the accident progression analysis for internal initiators at Surry are summarized in Figures S.2, S.3, and S.4. Figure S.2 shows the mean distribution among the summary accident progression bins for the summary PDS groups. Technically, this figure displays the mean probability of a summary APB conditional on the occurrence of a PDS group. Since only mean values are shown, Figure S.2 gives no indication of the range of values encountered. Figure S.3 shows the distributions of the expected conditional probability for core damage arrest given a PDS group. Similarly, the distributions of the expected conditional probability for early containment failure (CF) given a PDS group are displayed in Figure S.4. Early CF means CF at or before vessel breach (VB).

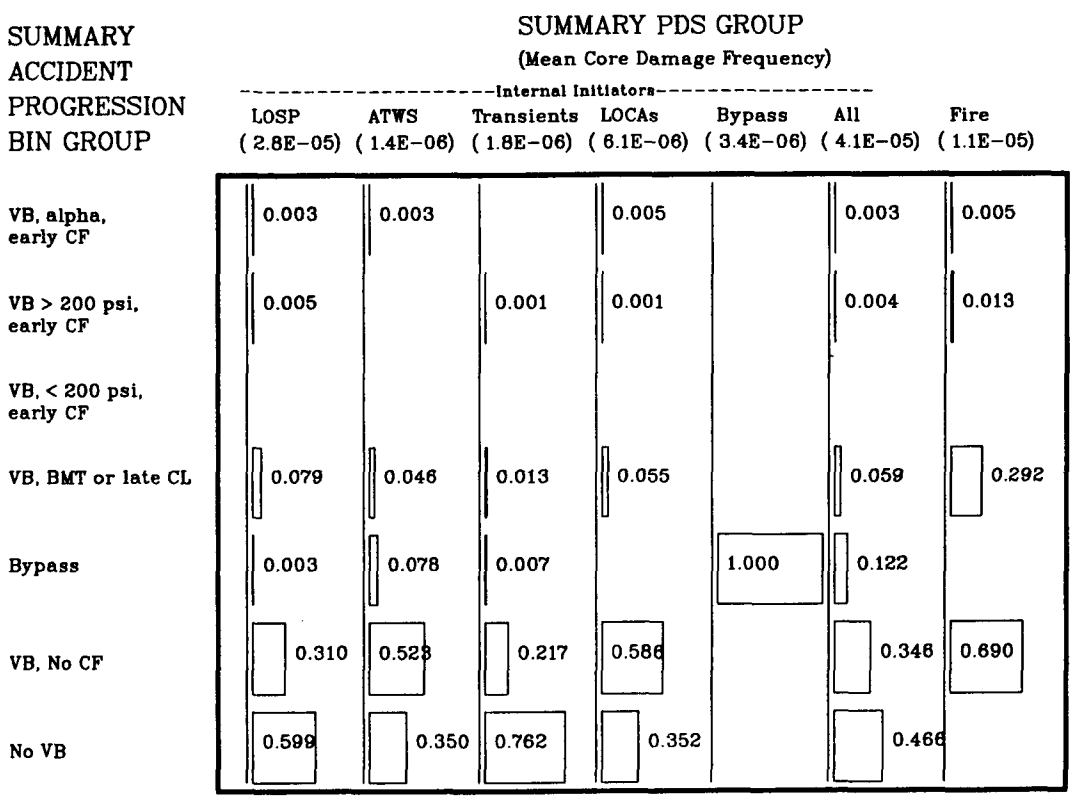
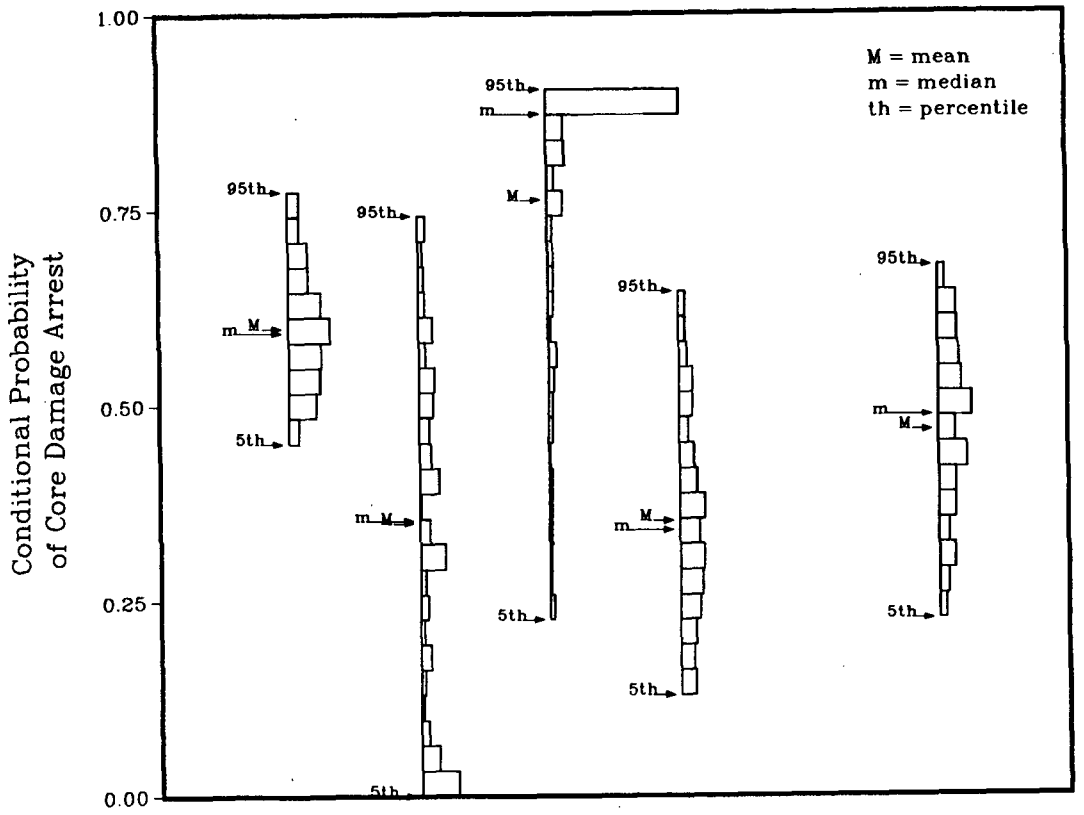
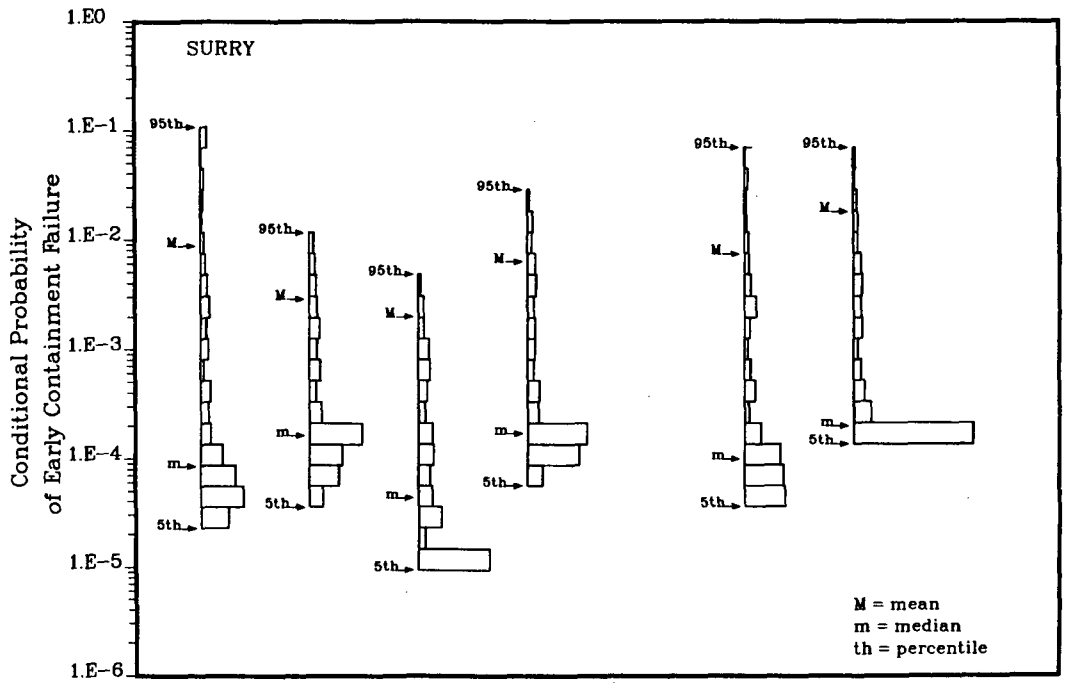


Figure S.2. Mean Probability of APBs for PDSs--Internal and Fire



PDS Group	LOSP	ATWS	Transients	LOCA	Bypass	All
Core Damage Freq.	2.8E-05	1.4E-06	1.8E-06	6.1E-06	3.4E-06	4.1E-05

Figure S.3. Probability of Core Damage Arrest--Internal



PDS Group	SBO	ATWS	Transients	LOCAs	Bypass	All	Fire
Core Damage Freq.	2.8E-05	1.4E-06	1.8E-06	6.1E-06	3.4E-06	4.1E-05	1.1E-05

Figure S.4. Probability of Early Containment Failure--Internal

Figure S.2 indicates the mean probability of the possible outcomes of the accident progression analysis. The width of each box in the figure indicates how likely each accident progression outcome is for each type of accident. Except for the Bypass initiators, either no failure of the vessel (safe stable state) or no failure of the containment are by far the most likely outcomes for internal initiators and fire initiators.

If core damage is not arrested and the accident proceeds to failure of the vessel, Figure S.2 shows that no failure of the containment is the most likely outcome for all types of accidents. If CF does occur, late failure is more likely than failure at or before VB. Late failure may be due to hydrogen ignition some hours after VB, basemat meltthrough, or eventual overpressure after several days if CHR is not restored. Of these three late failure modes, basemat meltthrough is the most likely for internal initiators.

Results of the accident progression analysis for fire initiators at Surry are summarized in Figures S.2 and S.4. Figure S.2 shows that early CF is very unlikely for core damage accidents started by fires, but that the probability of late CF is about 0.30. This is because the initiating fires destroy the ability to operate or restore CHR (sprays) within a few days of the accident. Arresting the core damage process before vessel failure is not possible for the fire initiators because the fires render all the injection systems inoperable. Figure S.4 shows that early CF is quite unlikely for fire initiators. All four fire PDSs have a break that partially depressurizes the RCS before VB.

Figure S.5 summarizes the results of the accident progression analysis for seismic initiators. As the core damage frequency of a PDS group has no effect on the evaluation of the APET, the accident progression analysis results for the two hazard distributions are very similar. The differences are due to differences in the frequencies of the individual PDSs relative to other PDSs in the group. The majority of seismic core damage accidents result in either no vessel failure or no containment failure. There is no possibility of avoiding vessel failure for the SBO accidents. The mean probability of early containment failure is on the order of 0.01 if the initial failures due to SG or RCP support failures are excluded. Initial CF occurs only for large breaks, so essentially all the low pressure early CFs are attributable to SG or RCP failures. The probability of late CF is relatively high for the SBO accidents because there is no long-term recovery of CHR as there is in the seismic LOSP and internal SBO accidents. The probability of late CF in the seismic accidents is higher than it is for internal initiators because many of the PDSs (including the most frequent ones) in the LOSP and LOCA groups are ones in which the sprays have failed.

<u>Core Damage Arrest</u>. It is possible to arrest the core damage process, avoid VB, and achieve a safe, stable state [as at Three Mile Island (TMI-2)] if coolant injection is restored before the core degradation process has gone too far. Recovery of injection is due to one of two events. In the LOSP accidents, recovery of injection follows the restoration of offsite power. In other types of accidents, an injection system is operating when core degradation starts, but no injection is taking place

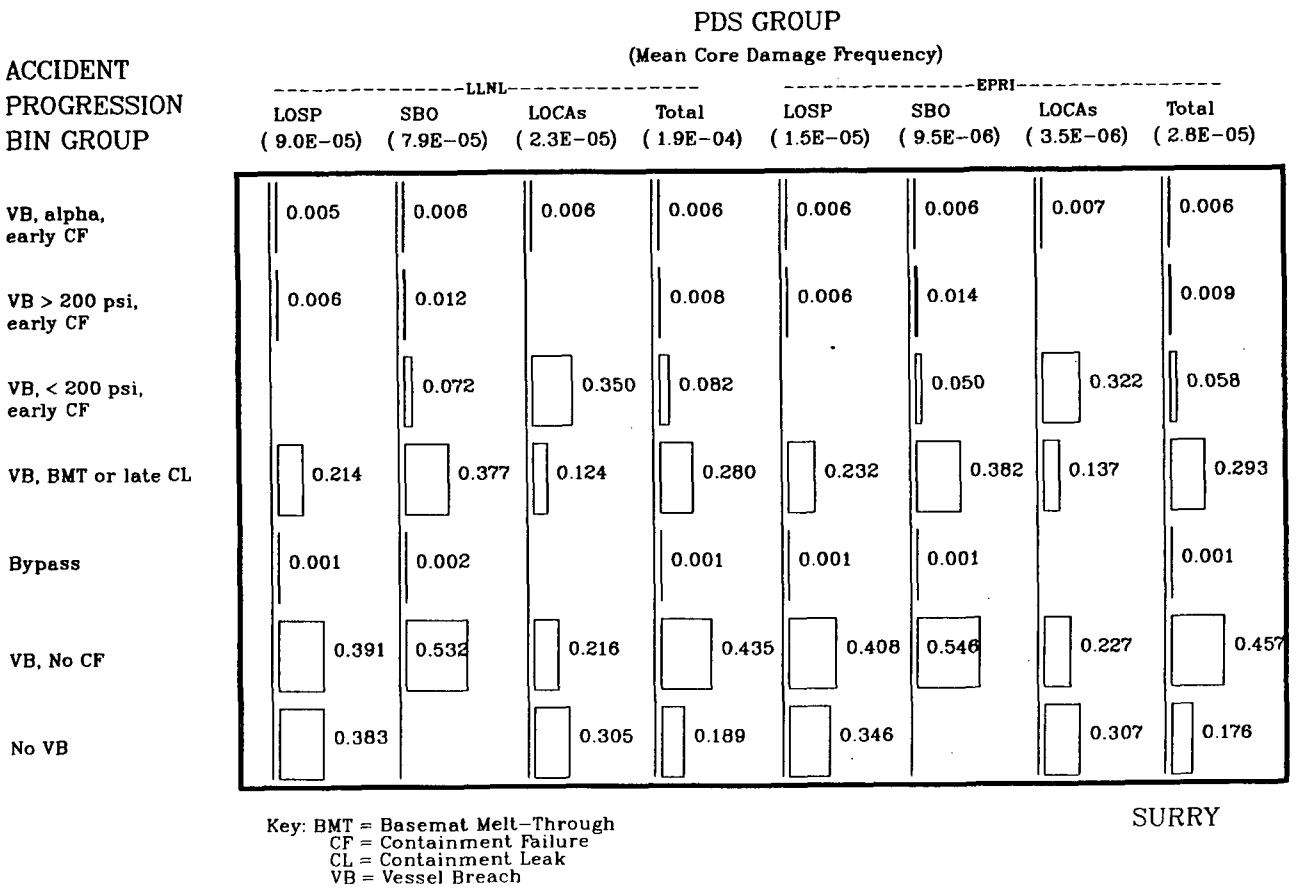


Figure S.5. Mean Probabilities of APBs for PDSs--Seismic

because the RCS pressure is too high. If a break in the RCS pressure boundary allows the RCS pressure to decrease to the point where the operating system can inject, then there is some chance of arresting the core degradation process. The probability of arresting core degradation depends on the time the injection starts relative to the state of the core. The RCS failure that allows injection to commence may be an initiating break or a temperature-induced failure that occurs after the onset of core damage (such as a break in the hot leg or surge line, the failure of an RCP seal failure, or the sticking-open of a PORV.)

For the internally initiated PDS groups, core damage arrest is possible for all groups except Event V. Offsite power may be recovered for the two SBO groups. Some PDSs in the Transients, LOCAs, ATWS, and SGTR groups have LPIS, or LPIS and HPIS operating. The initiating break in the interfacing LOCA fails the LPIS by diverting the flow out the break. Figure S.3 contains no plot for the bypass accidents since the fission products may escape to the environment whether or not the vessel and containment fail, so vessel failure is not of particular interest. Figure S.3 indicates that core damage arrest before VB is especially likely for the Transients PDS

group. One of the PDSs in this group has the LPIS operating, and the other has both LPIS and HPIS operating, at the onset of core damage. The probability of core damage arrest for this group reflects the probability that one of the five means of depressurizing the RCS reduces the RCS to a sufficiently low pressure to allow injection.

Core damage arrest (no VB) is not possible for the fire initiators because each fire initiator destroys the ability to supply either motive or control power to the ECCS.

Figure S.6 displays distribution of the probability of arresting the core-melt process and avoiding failure of the reactor vessel for the seismic initiators. For seismic initiators, recovery of offsite power in the SBO accidents is not considered feasible due to damage to the switchyard; no histogram is shown for the SBO PDS group as core damage arrest is not possible. Inclusion of the SBO accidents in the total accounts for the fact that the total distribution shows core damage arrest to be less likely than it is for either the LOSP or LOCA groups. The differences between the distributions for the hazard distributions are due to differences in the frequencies of the PDSs in which an injection system is operable relative to other PDSs in the group. The probability of core damage arrest for the seismic initiators is lower than it is for internal initiators because the

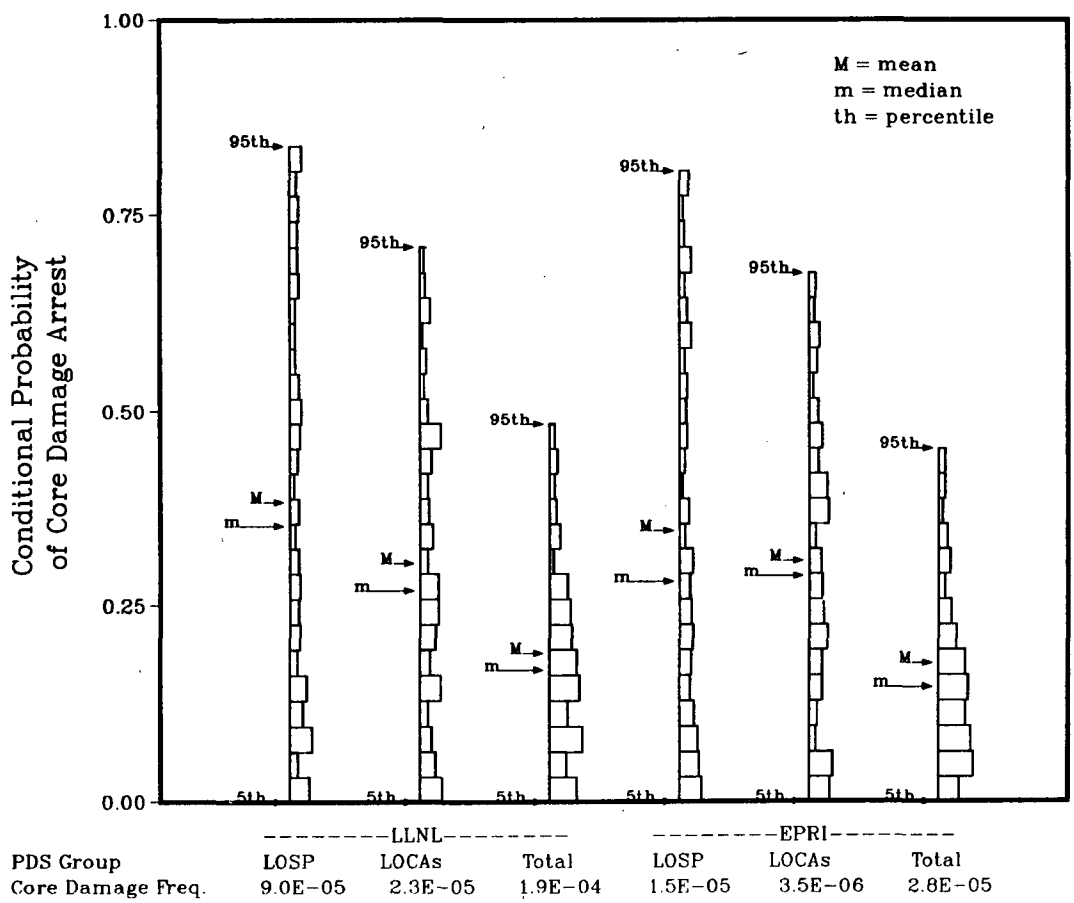


Figure S.6. Probability of Core Damage Arrest--Seismic

frequencies of the PDSs with one or more injection systems operable are lower relative to the total frequency than they are for internal initiators.

RCS Depressurization. The reduction of the RCS pressure in the period between the onset of core damage and VB is important for two reasons. First, pressure reduction may allow the LPIS to function and thus avoid vessel failure in accidents where the LPIS is operable but not injecting due to high RCS pressure. Second, lower RCS pressures at VB reduce the loads placed on the containment structure at that time and reduce the probability of containment failure at VB.

Four of the five means of depressurizing the RCS considered in the Surry accident progression analysis are temperature-induced (T-I) and inadvertent. The five mechanisms are:

1. T-I hot leg or surge line failure;
2. PORVs or SRVs stuck open;
3. T-I RCP seal failure;
4. T-I SGTR; and
5. Deliberate opening of the PORVs by the operators.

T-I failures of the RCP seals and PORVs sticking open are also considered in the accident frequency analysis. Of these five mechanisms, only the first three are effective for most accidents. Expert panels provided distributions for the probability of hot leg failure, SGTR, and RCP seal failure. The effective means of RCS depressurization ensured that very few accidents proceeded from the onset of core damage to lower head failure at the PORV setpoint pressure (about 2500 psi).

Early Containment Failure. For those accidents in which the containment is not bypassed, the offsite risk depends strongly on the probability that the containment will fail early, i.e., before or at VB. There are four possibilities for early CF:

1. Pre-existing containment leak;
2. Isolation failure;
3. CF before VB due to hydrogen combustion; and
4. CF at VB due to the events at VB.

As the Surry containment is maintained about 5 psia below ambient atmospheric pressure during operation, an unsealed hatch or an open vent line would be quickly discovered since the vacuum pumps could not keep the containment at the desired pressure. Thus, the probability of a pre-existing leak at Surry is negligible. Isolation failures at Surry are also negligible. Because the structural experts considering this issue found the Surry containment to be quite strong, CF due to hydrogen burns before VB is not considered at Surry. It was estimated to be unlikely that sufficient hydrogen would be generated in the vessel and escape to the containment before VB to cause a hydrogen deflagration large enough to threaten the Surry containment. This failure mode was included in the APET used in the previous analysis for the first draft of NUREG-1150, and CFs before VB were negligible.

Except for the initial CF in some seismic PDSs, the only significant cause of early CF at Surry is the pressure rise due to the events that occur at VB. Figure S.4 indicates that early CF is fairly unlikely for the internal and fire initiators. The probability distributions for early CF in this figure are conditional on VB, not on core damage. There is no histogram for Bypass accidents. When the containment function is bypassed by Event V or SGTR, early CF ceases to be important in determining the release of fission products and the offsite risk. Thus, the conditional probability of early CF is not plotted for the Bypass group.

For internal and fire accidents other than Bypass, Figure S.4 shows that the mean probability of early CF is on the order of 0.01, and the median is about two orders of magnitude lower. This is largely due to the robust nature of the Surry containment relative to the loads expected at VB and the effectiveness of the RCS depressurization mechanisms. The pressure loads on the containment due to the failure of the reactor vessel and the escape of the molten core into the reactor cavity are strongly dependent on the pressure in the RCS at the time the lower head of the vessel fails. Therefore, depressurization of the RCS before VB plays an important part in determining the probability of containment failure at VB.

Even without RCS depressurization, the distribution for the containment failure pressure at Surry provided by the Structural Response Expert Panel falls generally above the distributions for the loads expected to be observed at VB from the expert panel on containment loads.

The conclusion that CF at VB is unlikely for Surry also holds for the fire initiators and the seismic initiators. The initial CF due to seismic failures of the SG or RCP pump supports constitutes a separate failure mechanism. Figure S.7 shows that the mean probability of early CF for all PDS groups for the LLNL and EPRI seismic hazard distributions are on the order of 0.10. Most of these early failures of the containment are initial failures due to SG and RCP support failures. These initial CFs account for the fact that early CF is more likely for the LOCA group than for the SBO group, and more likely for the SBO group than for the LOSP group (which contains no "A" PDSs).

S.6 Source Term Analysis

S.6.1 Description of the Source Term Analysis

The source term for a given bin consists of the release fractions for the nine radionuclide classes for the early release and for the late release, and additional information about the timing of the releases, the energy associated with the releases, and the height of the releases. It includes the information required for the calculation of consequences in the succeeding analysis. A source term is calculated for each APB for each observation in the sample. The nine radionuclide classes are: inert gases, iodine, cesium, tellurium, strontium, ruthenium, lanthanum, cerium, and barium.

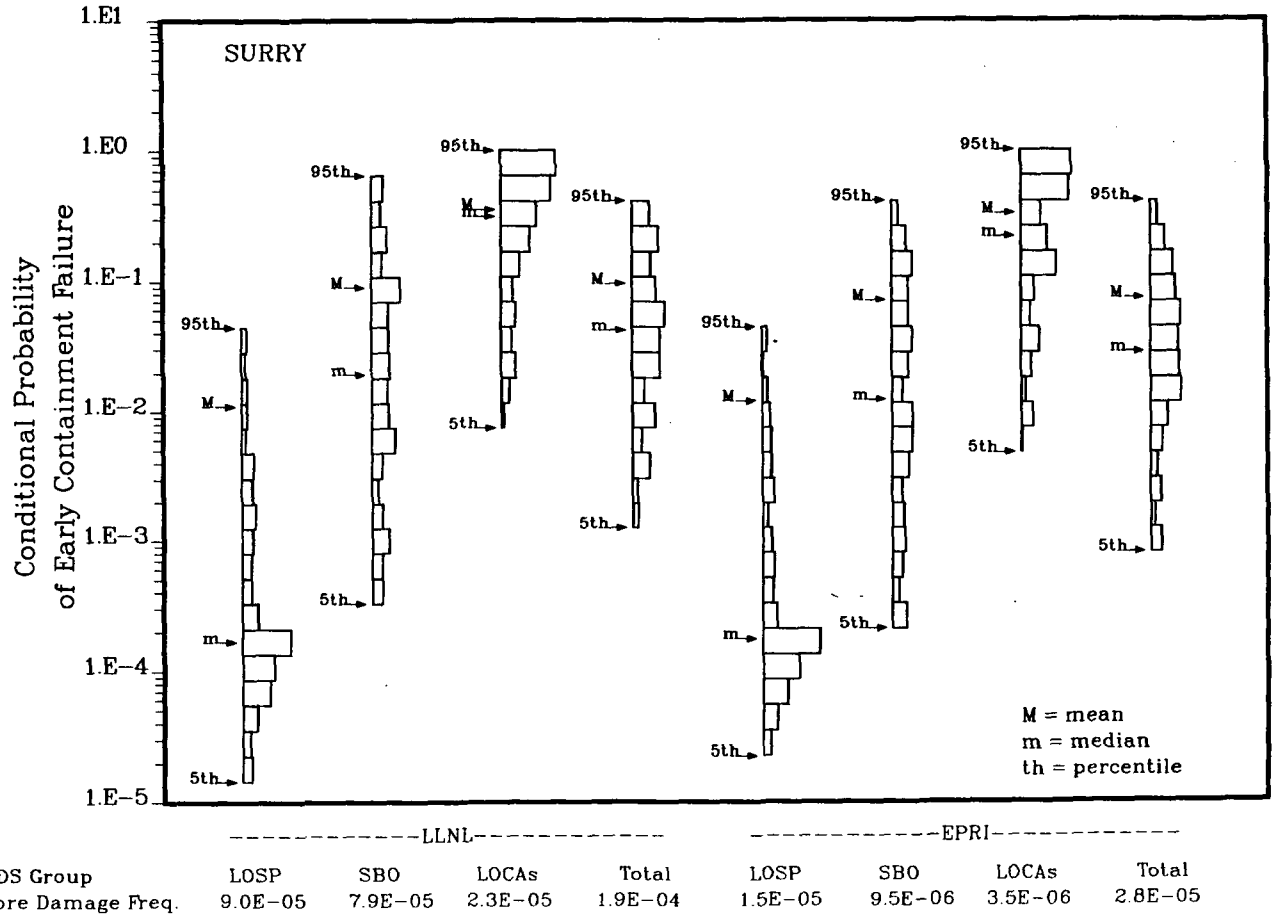


Figure S.7. Mean Probability of Early Containment Failure--Seismic

The source term analysis is performed by a relatively small computer code, SURSOR. The purpose of this code is <u>not</u> to calculate the behavior of the fission products from their chemical and physical properties and the flow and temperature conditions in the reactor and the containment. Instead, SURSOR provides a means of incorporating into the analysis the results of the more detailed codes that do consider these quantities. This approach is needed because the detailed codes require too many computer resources to be able to compute source terms for the numerous APBs and the 200 observations that result from the sampling approach used in NUREG-1150.

SURSOR is a fast-running, parametric computer code used to calculate the source terms for each APB for each observation for Surry. Since there are normally about a hundred bins for each observation, and 200 observations in the sample, the need for a source term calculation method that requires few computer resources for one evaluation is obvious. SURSOR provides a framework for synthesizing the results of experiments and mechanistic codes, as interpreted by experts in the field. The reason for "filtering" the detailed code results through the experts is that no code available

treats all the phenomena in a manner generally acceptable to those knowledgeable in the field. Thus, the experts are used to extend the code results in areas where the codes are deficient and to judge the applicability of the model predictions. They also factor in the latest experimental results and modify the code results in areas where the codes are known or suspected of oversimplifying. Since the majority of the parameters used to compute the source term are derived from distributions determined by an expert panel, the dependence of SURSOR on various detailed codes reflects the preferences of the experts on the panel.

It is not possible to perform a separate consequence calculation for each of the approximately 20,000 source terms computed for the Surry integrated risk analysis. Therefore, the interface between the source term analysis and the consequence analysis is formed by grouping the source terms into a much smaller number of source term groups. These groups are defined so that the source terms within them have similar properties, and a single consequence calculation is performed for the mean source term for each group. This grouping of the source terms is performed with the PARTITION program, and the process is referred to as "partitioning."

The partitioning process involves the following steps: definition of an early health effect weight (EH) for each source term, definition of a chronic health effect weight (CH) for each source term, subdivision (partitioning) of the source terms on the basis of EH and CH, a further subdivision on the basis of the time the evacuation starts relative to the start of the release, and calculation of frequency-weighted mean source terms.

The result of the partitioning process is that the source term for each accident progression bin is assigned to a source term group. In the risk computations, each accident progression bin is represented by the mean source term for the group to which it is assigned, and the consequences are calculated for that mean source term.

S.6.2 Results of the Source Term Analysis

When all the internally initiated accidents at Surry are considered together, the plots shown in Figure S.8 are obtained. These plots show four statistical measures of the 200 curves (one for each observation in the sample) that give the frequencies at which release fractions are exceeded. Figure S.8 summarizes the complementary cumulative distribution functions (CCDFs) for four representative radionuclide groups (iodine, cesium, strontium, and lanthanum). The mean frequency of exceeding a release fraction of 0.10 for idoine and cesium is on the order of 10^{-6}/yr. The mean exceedance frequency for release of 0.10 of the core strontium is somewhat lower. The mean frequency of exceeding a release fraction of 0.01 for lanthanum is on the order of 10^{-6}/yr. The highest fractional releases are computed for bypass accidents (Event V and SGTRs) and early containment failures. The releases for late containment failures, most of which are basemat meltthroughs, are quite small.

Regression-based sensitivity studies for the internally initiated accidents indicate that the largest contributors to the uncertainty in release

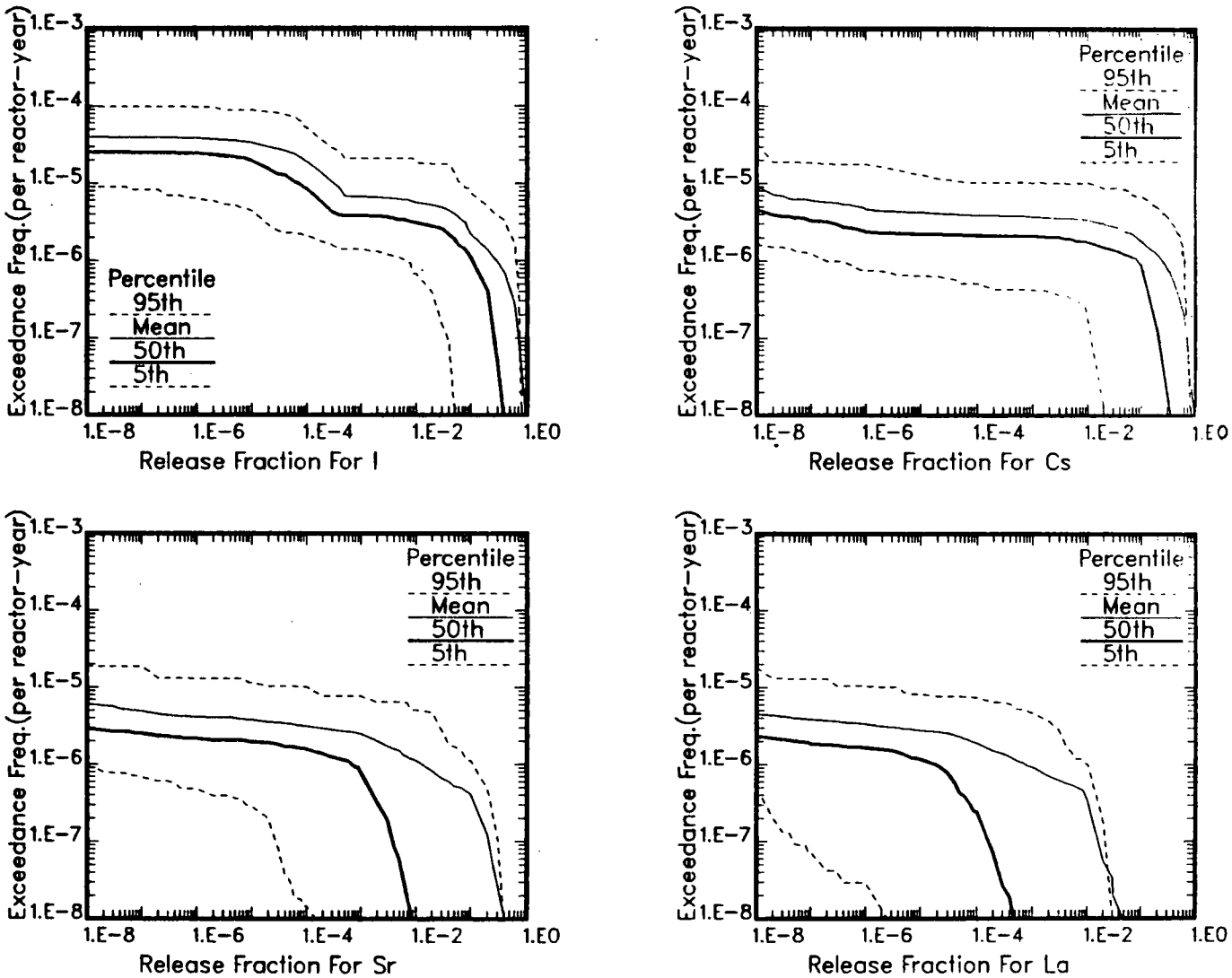


Figure S.8. Exceedance Frequencies for Release Fractions for Surry: All Internal Initiators

fractions and their frequencies are accident frequency and source term variables. Few accident progression variables are important in determining the uncertainty. The important initiating event variables are the frequencies for Event V and SGTR. Failures of the DG to start and run are also important. For the less volatile radionuclide classes (tellurium, strontium, ruthenium, barium, lanthanum, cerium, and barium), the variable that contributed the most to uncertainty is the fractional release from the core to the vessel. Also important are the fractional release from the vessel to the environment for SGTRs, and the release fraction for CCIs.

The frequency of any given size release due to fire initiators at Surry is so low relative to the frequency of a similar release due to internal initiators that no fire source term results are presented. The release frequencies for seismic initiators are much larger than those for fires. Figures S.9 and S.10 present statistical measures of the families of curves that give the frequencies with which release fractions are exceeded for the LLNL and EPRI hazard distributions. They may be compared to Figure S.8 for internal initiators. It may be seen that the seismic releases based on the EPRI hazard distribution are roughly comparable to those due to the internal initiators, while the seismic releases based on the LLNL hazard distribution are greater than those due to the internal initiators.

S.7 Consequence Analysis

S.7.1 Description of the Consequence Analysis

MACCS is used to calculate offsite consequences for each of the source term groups defined in the partitioning process. MACCS tracks the dispersion of the radioactive material in the atmosphere from the plant and computes its deposition on the ground. MACCS then calculates the effects of this radioactivity on the population and the environment. Doses and the ensuing health effects from 60 radionuclides are computed for the following pathways: immersion or cloudshine, inhalation from the plume, groundshine, deposition on the skin, inhalation of resuspended ground contamination, ingestion of contaminated water, and ingestion of contaminated food. MACCS treats atmospheric dispersion by using multiple, straight-line Gaussian plumes. Each plume can have a different direction, duration, and initial radionuclide concentration. Cross-wind dispersion is treated by a multi-step function. Dry and wet deposition are treated as independent processes. The weather variability is treated by means of a stratified sampling process.

For early exposure, the following pathways are considered: immersion or cloudshine, inhalation from the plume, groundshine, deposition on the skin, and inhalation of resuspended ground contamination. For the long-term exposure, MACCS considers the following four pathways: groundshine, inhalation of resuspended ground contamination, ingestion of contaminated water, and ingestion of contaminated food. The direct exposure pathways, groundshine, and inhalation of resuspended ground contamination, produce doses in the population living in the area surrounding the plant. The indirect exposure pathways, ingestion of contaminated water and food, produce doses in those who ingest food or water emanating from the area around the accident site. The contamination of water bodies is estimated

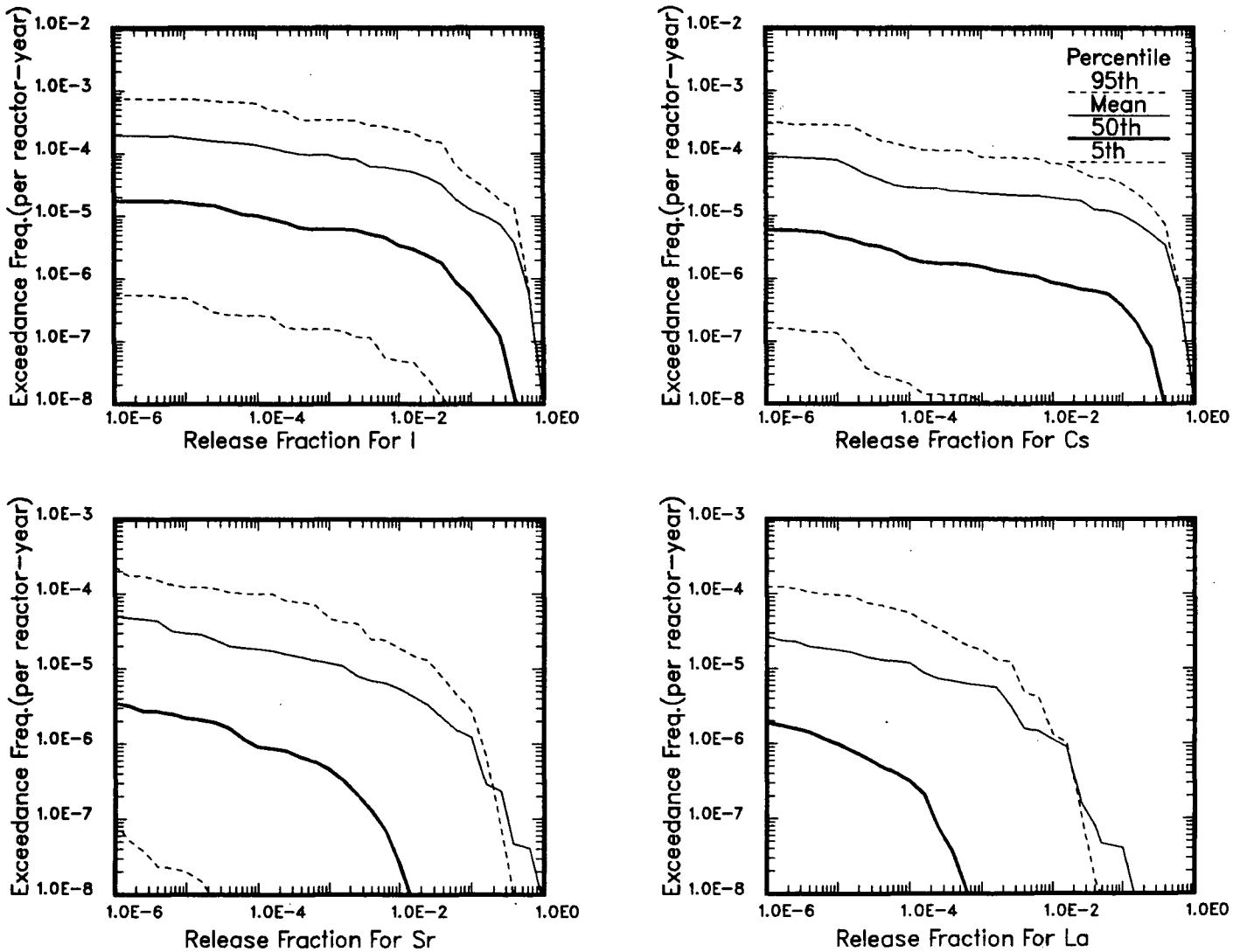


Figure S.9. Exceedance Frequencies for Release Fractions.
Seismic Initiators for LLNL Hazard Distributions

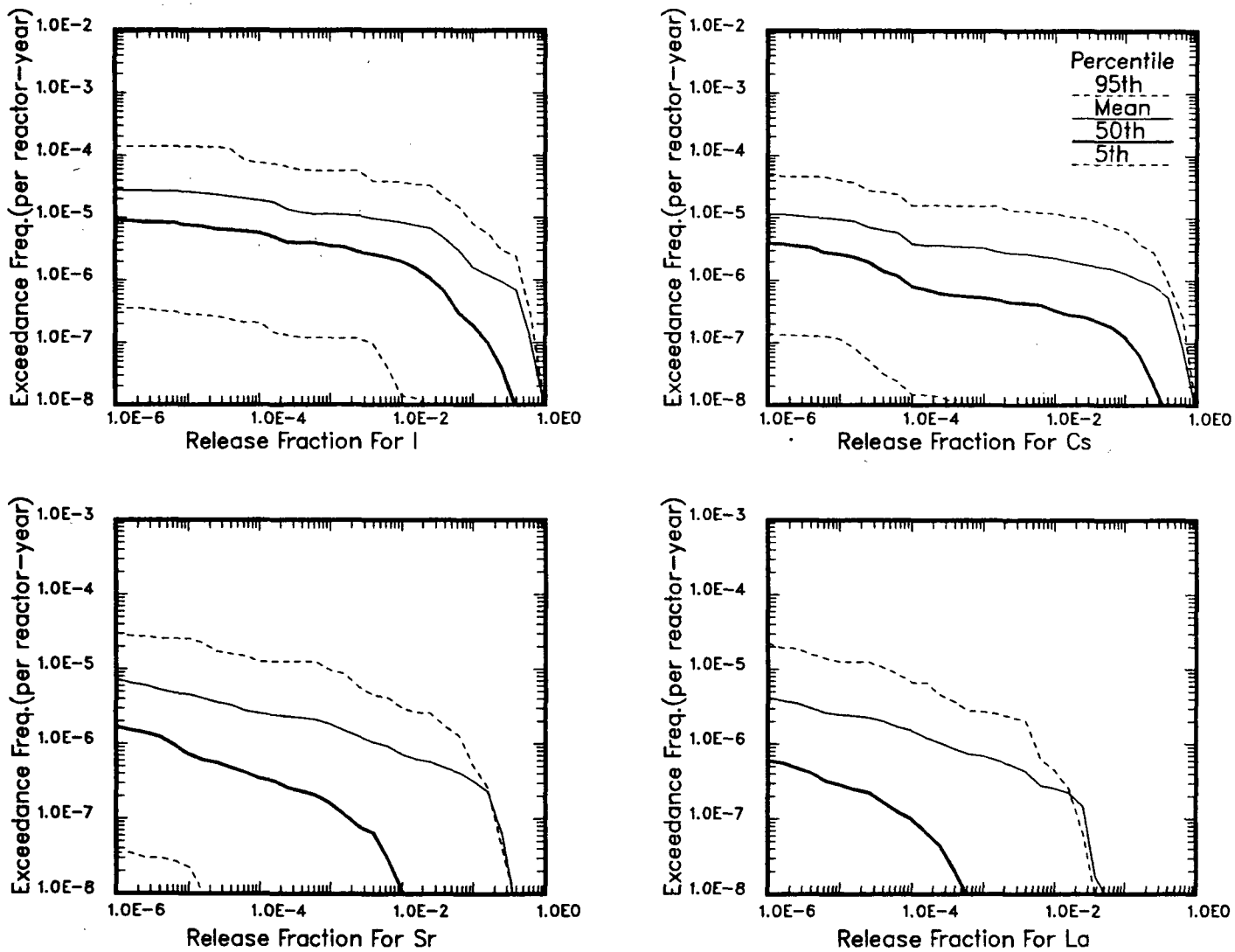


Figure S.10. Exceedance Frequencies for Release Fractions.
Seismic Initiators for EPRI Hazard Distributions

for the washoff of land-deposited material as well as direct deposition. The food pathway model includes direct deposition onto the crop species and uptake from the soil.

Both short-term and long-term mitigative measures are modeled in MACCS. Short-term actions include evacuation, sheltering, and emergency relocation out of the emergency planning zone. Long-term actions include relocation and restrictions on land use and crops. Relocation and land decontamination, interdiction, and condemnation are based on projected long-term doses from groundshine and the inhalation of resuspended radioactivity. The disposal of agricultural products and the removal of farmland from crop production are based on ground contamination criteria.

The health effects models link the dose received by an organ to morbidity or mortality. The models used in MACCS calculate both short-term and long-term effects to a number of organs.

Although the variables thought to be the largest contributors to the uncertainty in risk are sampled from distributions in the accident frequency, accident progression, and source term analyses, there is no analogous treatment of uncertainties in the consequence analysis. Variability in the weather is fully accounted for, but the uncertainty in other parameters, such as the dry deposition velocity or the evacuation rate, is not considered.

The MACCS consequence model calculates a large number of different consequence measures. This report gives results for the following six consequence measures: early fatalities, total latent cancer fatalities, population dose within 50 miles, population dose for the entire region, early fatality risk within 1 mile, and latent cancer fatality risk within 10 miles. For NUREG-1150, 99.5% of the population evacuates and 0.5% of the population continues normal activity. For internal initiators at Surry, the evacuation delay time between warning and the beginning of evacuation is 2 h.

For seismic initiators, the evacuation parameters were altered since earthquakes are judged to affect the evacuation. There is no evacuation at all for those earthquakes in which the maximum peak ground acceleration (PGA) exceeds 0.6 g. These earthquakes form a relatively small portion of the seismic distribution at Surry. The evacuation is degraded for earthquakes in which the maximum PGA does not exceed 0.6 g. The delay period (from the warning to the start of evacuation) is increased to 1.5 times its normal value, and the evacuation speed is decreased to half its normal value.

S.7.2 Results of the Consequence Analysis

The results presented in this section depend on the occurrence of a source term group. That is, if a release takes place with release fractions and other characteristics as defined by one of the source term groups, then the tables and figures in this section give the consequences expected. This section contains no indication at all about the frequency with which these consequences may be expected. Implicit in the results given in this

section is that 0.5% of the population does not evacuate and that there is a 2-h delay between the warning to evacuate and the actual start of the evacuation.

CCDFs display the results of the consequence calculation in a compact and complete form. The CCDFs in Figure S.11 for early fatalities and latent cancer fatalities display the relationship between consequence size and consequence frequency due to variability in the weather for each source term group that has a non-zero frequency. Depending on the occurrence of a release, each of these CCDFs gives the probability that individual consequence values will be exceeded due to the uncertainty in the weather conditions that will exist at the time of an accident. Figure S.11 shows that there is considerable variability in the consequences that is solely due to the weather. There is, of course, considerable variability among the consequences that is due to the size and timing of the release as well.

The risk from fire initiators at Surry is low relative to that from internal initiators, so no fire consequence results are displayed in this summary. Figures S.12 and S.13 present CCDFs for the LLNL and EPRI hazard distributions for the non-zero source term groups. As these results are conditional on the occurrence of the release, and contain no information about the expected frequency of the release, no conclusions concerning risk can be drawn from Figures S.11, S.12, and S.13.

S.8 Integrated Risk Analysis

S.8.1 Determination of Risk

Risk is determined by bringing together the results of the four constituent analyses: the accident frequency analysis, the accident progression analysis, the source term analysis, and the consequence analysis. This process is described in general terms in Section S.2 of this summary, and in mathematical terms in Section 1.4 of this volume. Specifically, the accident frequency analysis produces a frequency for each PDS group for each observation, and the accident progression analysis results in a probability for each APB, conditional on the occurrence of the PDS group. The absolute frequency for each bin for each observation is obtained by summing the product of the PDS group frequency for that observation and the conditional probability for the APB for that observation over all the PDS groups.

For each APB for each observation, a source term is calculated; this source term is then assigned to a source term group in the partitioning process. Then the consequences are computed for each source term group. The overall result of the source term calculation, the partitioning, and the consequence calculation is that a set of consequence values is identified with each APB for each observation. Because the absolute frequency of each APB is known from the accident frequency and accident progression results, both frequency and consequences are known for each APB. The risk analysis consists of assembling and analyzing all these separate estimates of offsite risk.

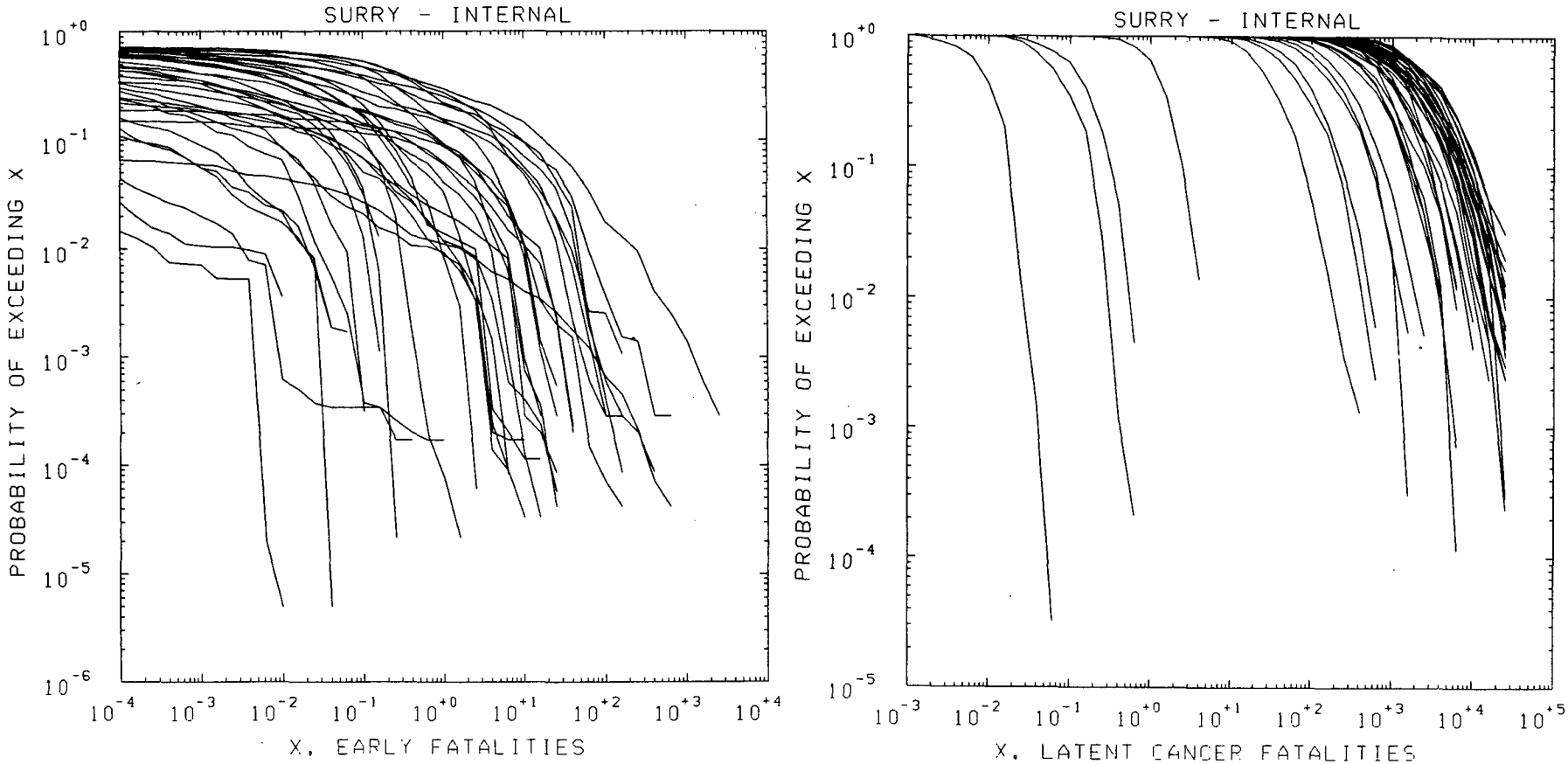


Figure S.11. Internal Initiators

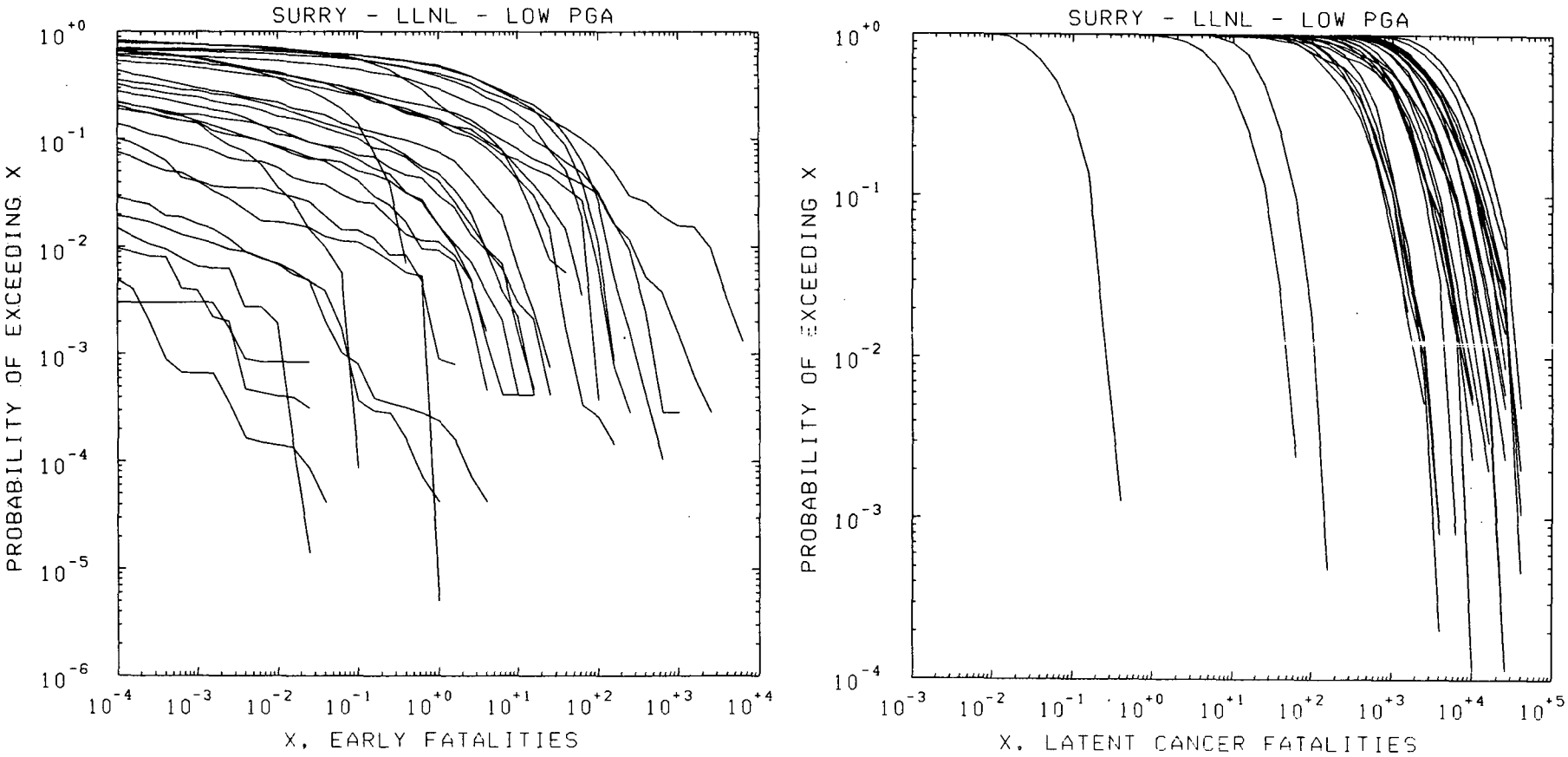


Figure S.12. LLNL Hazard Distributions, Low PGA

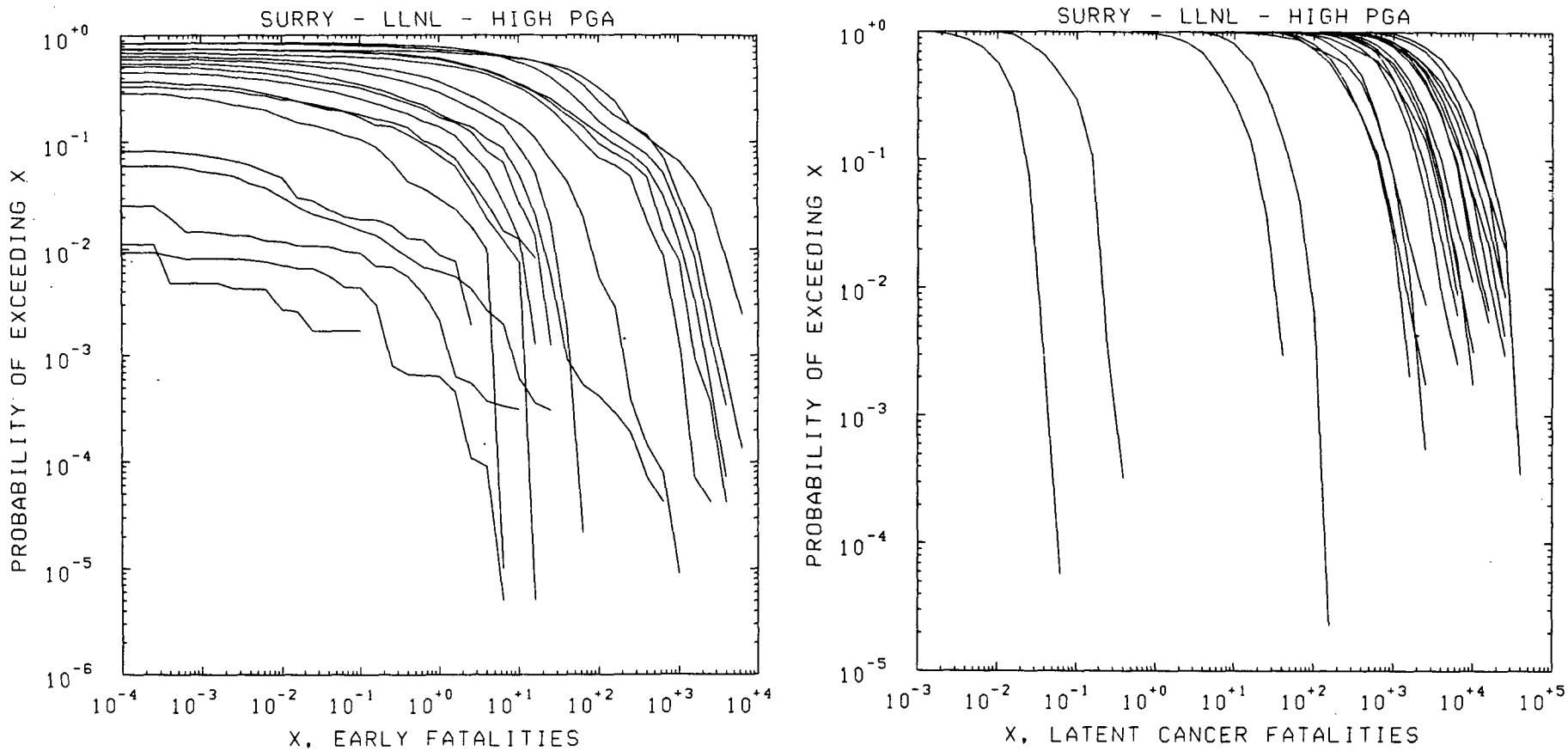


Figure S.12. LLNL Hazard Distributions, High PGA

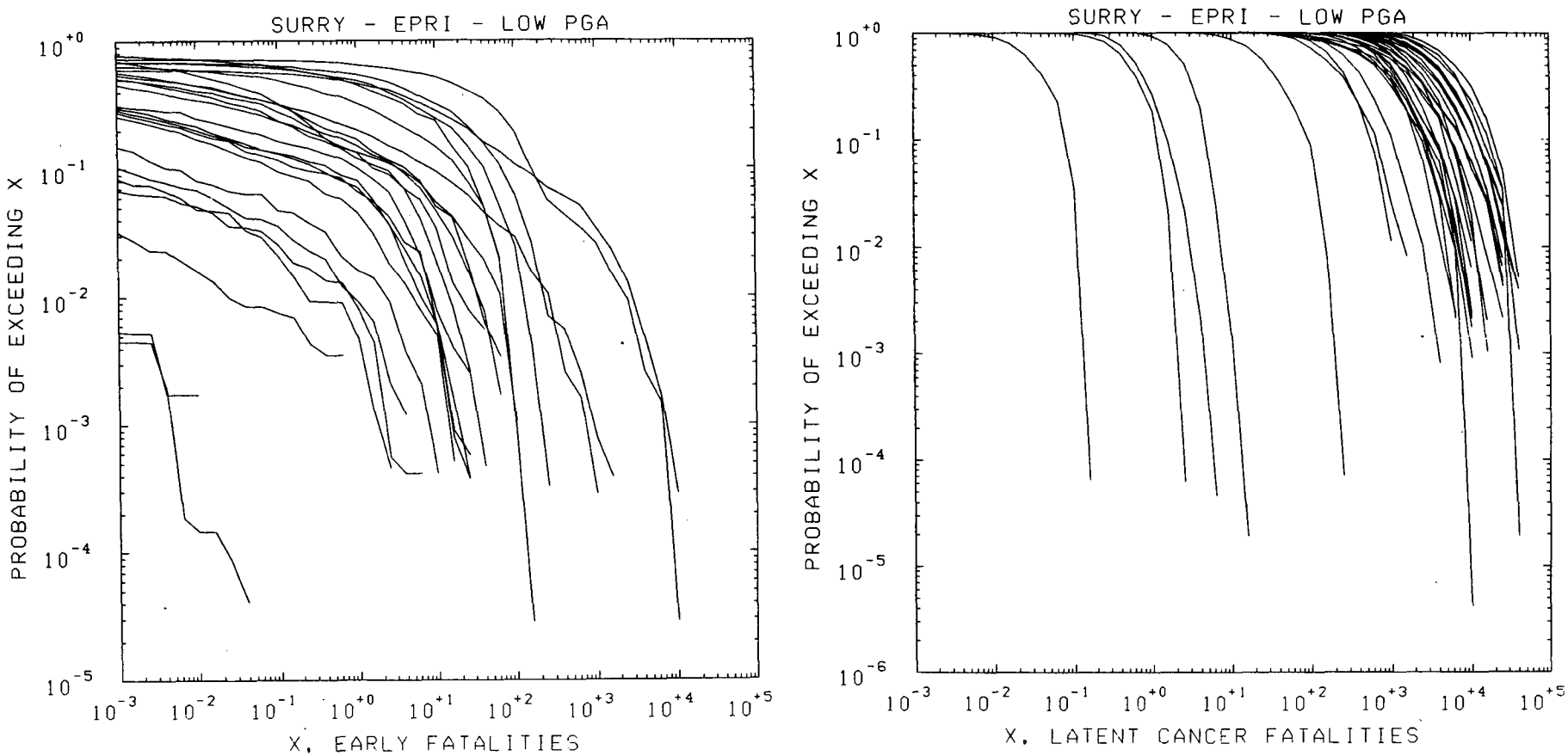


Figure S.13. EPRI Hazard Distributions, Low PGA.

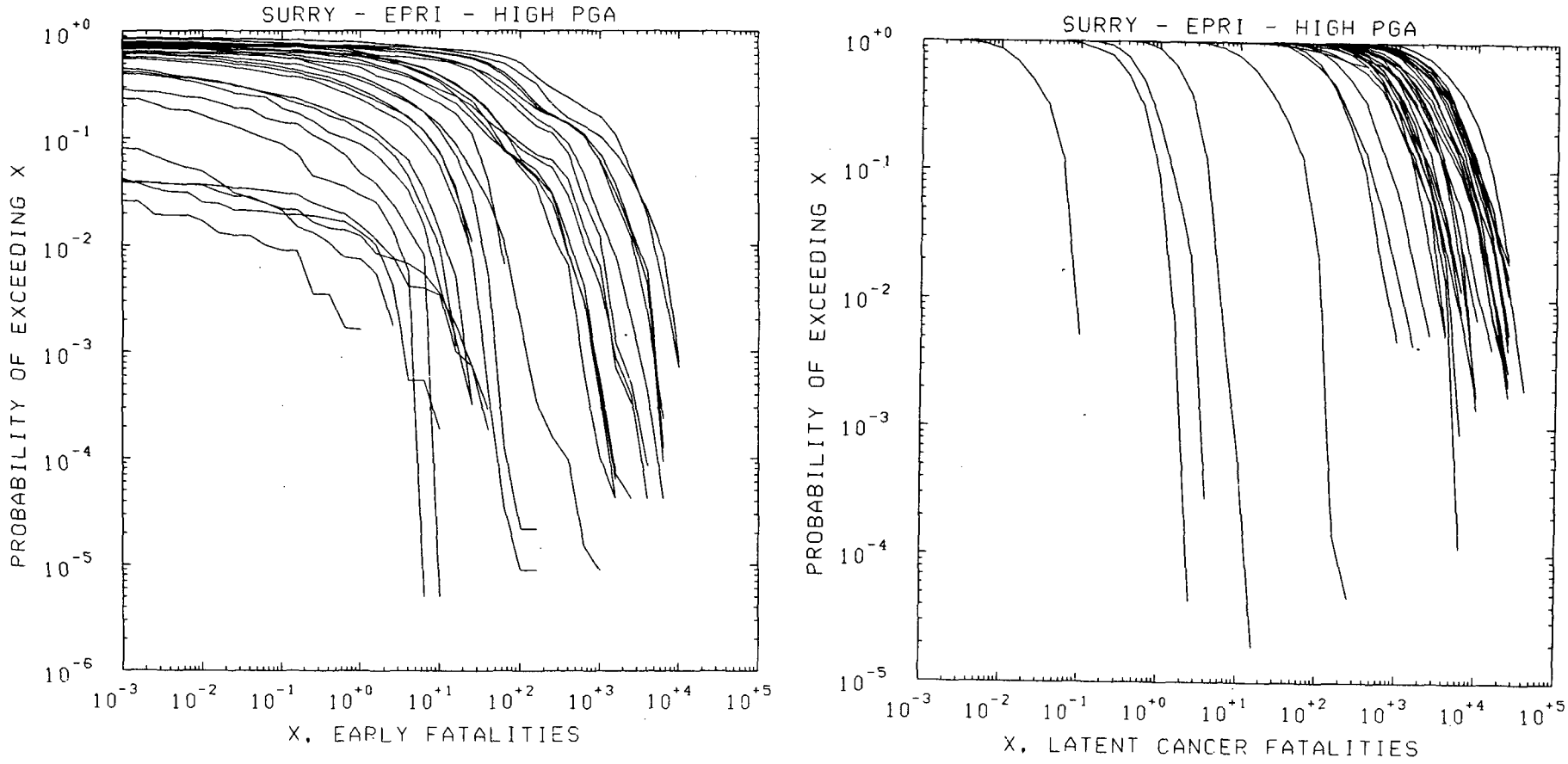


Figure S.13. EPRI Hazard Distributions, High PGA.

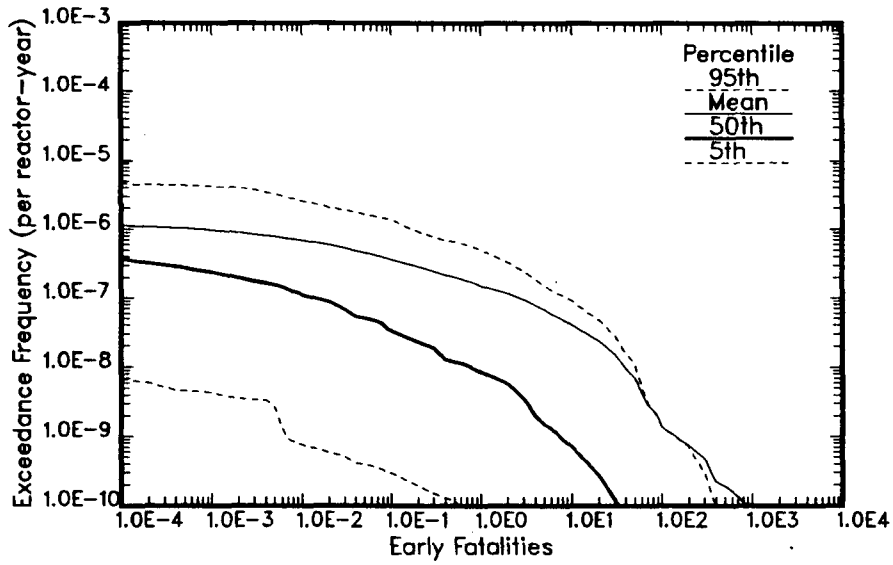
S.8.2 Results of the Risk Analysis

Measures of Risk. Figure S.14 shows the basic results of the integrated risk analysis for internal initiators at Surry. This figure shows four statistical measures of the families of the CCDFs for early fatalities, latent cancer fatalities, individual risk of early fatality within 1 mile of the site boundary, and individual risk of latent cancer fatality within 10 miles of the plant. The CCDFs display the relationship between the frequency of the consequence and the magnitude of the consequence. Since there are 200 observations in the sample for Surry, the actual risk results at the most basic level are 200 CCDFs for each consequence measure. Figure S.14 displays the 5th percentile, median, mean, and 95th percentile for these 200 curves, and shows the relationship between the magnitude of the consequence and the frequency at which the consequence is exceeded, as well as the variation in that relationship.

The 5th and 95th percentile curves provide an indication of the spread between observations, which is often large. This spread is due to uncertainty in the sampled variables, and not to differences in the weather at the time of the accident. As the magnitude of the consequence measure increases, the mean curve typically approaches or exceeds the 95th percentile curve. This results when the mean is dominated by a few observations, which often happens for large values of the consequences. Only a few observations have nonzero exceedance frequencies for these large consequences. Taken as a whole, the results in Figure S.14 indicate that large consequences are relatively unlikely to occur.

Although the CCDFs convey the most information about the offsite risk, summary measures are also useful. Such a summary value, denoted expected risk, may be determined for each observation in the sample by summing the product of the frequencies and consequences for all the points used to construct the CCDF. This has the effect of averaging over the different weather states as well as over the different types of accidents that can occur. Since the complete analysis consisted of a sample of 200 observations, there are 200 values of expected risk for each consequence measure. These 200 values may be ranked and plotted as histograms, which is done in Figure S.15. The same four statistical measures used above are shown on these plots as well. Note that considerable information has been lost in going from the CCDFs in Figure S.14 to the histograms of expected values in Figure S.15; the relationship between the size of the consequence and its frequency has been sacrificed to obtain a single value for risk for each observation.

The plots in Figure S.15 show the variation in the expected risk for internal initiators for four consequence measures. Where the mean is close to the 95th percentile, a relatively small number of observations dominate the mean value. This is more likely to occur for the early fatality consequence measures than for the latent cancer fatality or population dose consequence measures due to the threshold effect for early fatalities.



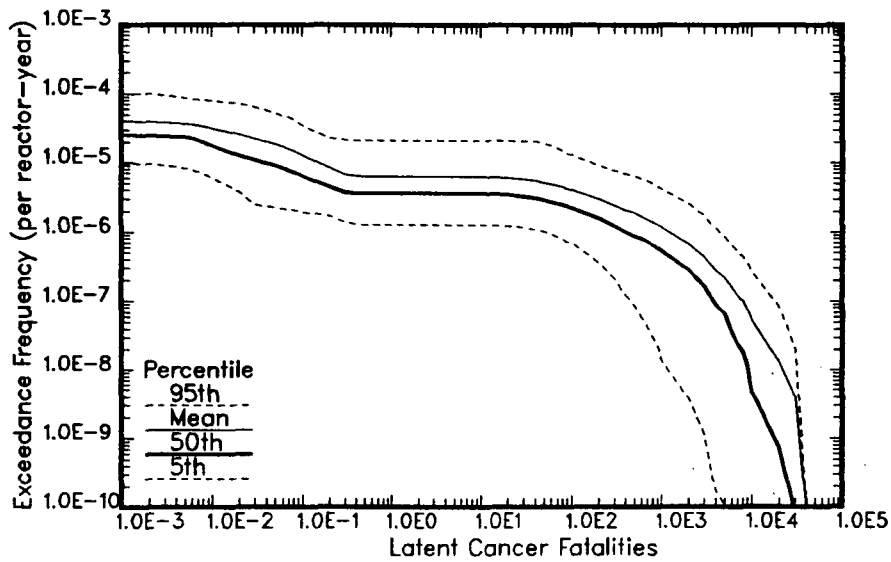
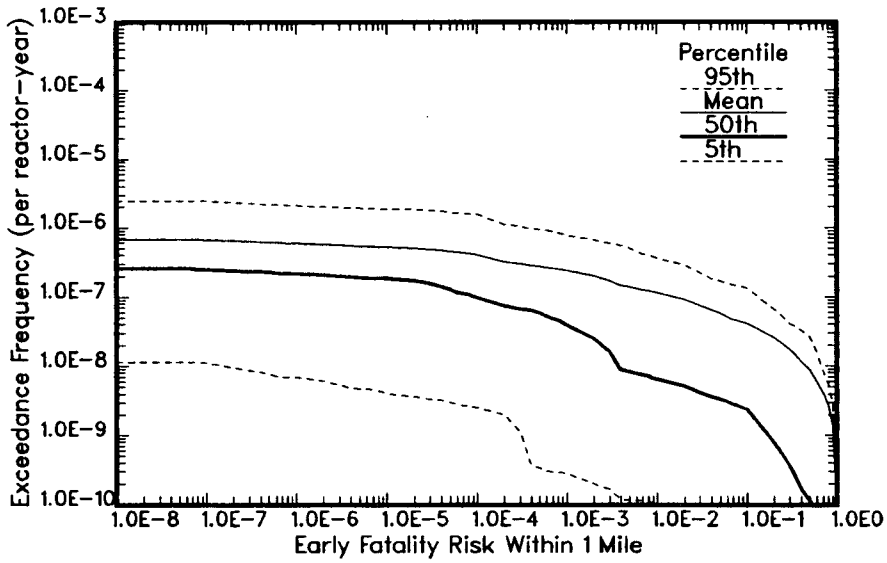


Figure S.14. Results of the Integrated Risk Analysis for Internal Initiators



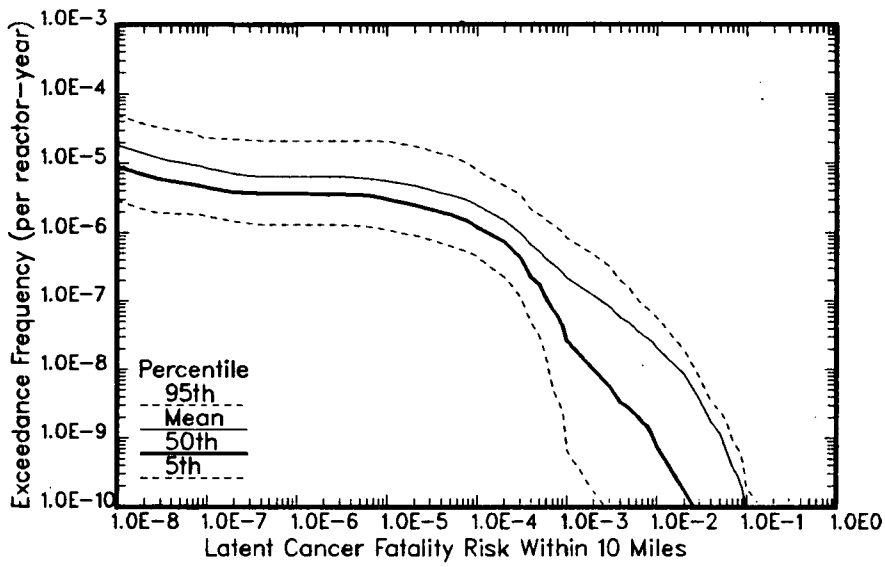
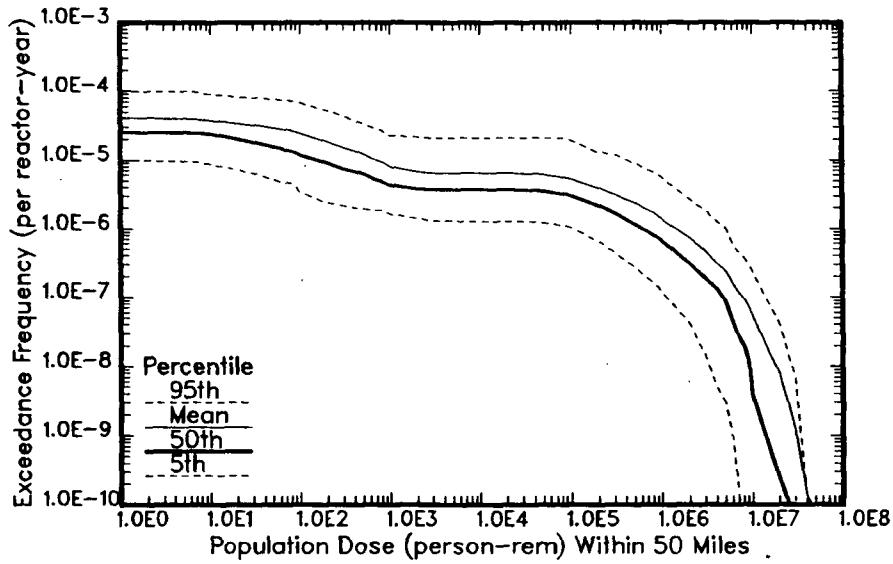


Figure S.14. (continued)



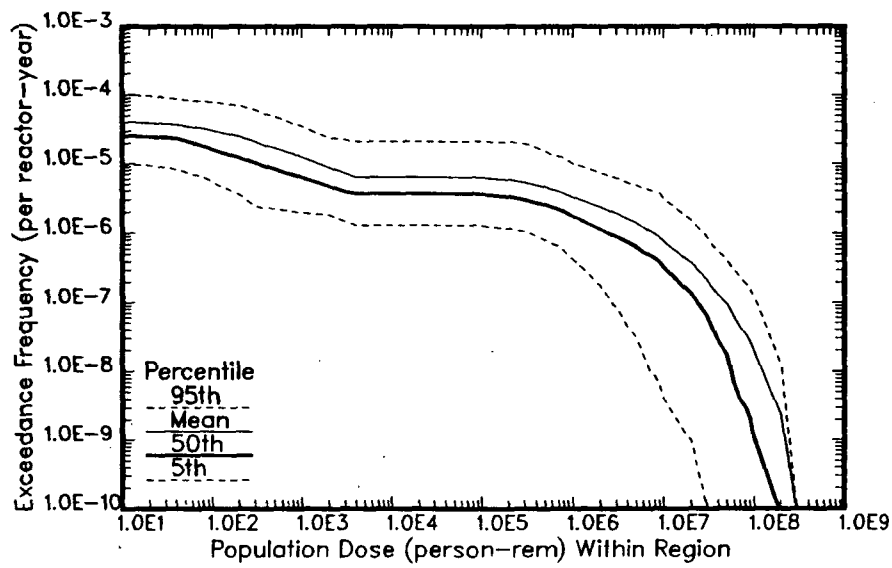


Figure S.14. (continued)

The safety goals are written in terms of individual fatality risks. The plots in Figure S.15 for individual early fatality risk and individual latent cancer fatality risk show that essentially the entire risk distribution for Surry falls below the safety goals.

A single measure of risk for the entire sample may be obtained by taking the mean value of the distribution for expected risk. This measure of risk is commonly called mean risk, although it is actually the average of the expected risk, or the mean value of the mean risk. Mean risk values for internal initiators for four consequence measures are given in Figure S.15.

The risk from fire initiators at Surry is well below that from internal initiators. The mean early fatality risk due to fires is 3.8E-8/R-yr, and the mean latent cancer fatality risk due to fires is 2.7E-4/R-yr. Both these values are more than an order of magnitude lower than the comparable values for internal initiators.

The risk from seismic initiators at Surry is comparable to, or higher than, that from internal initiators. Figures S.16 and S.17 present the statistical summaries of the CCDFs for the LLNL and EPRI hazard distributions. They may be compared to Figure S.14 for internal initiators. Figures S.18 and S.19 present the histograms of mean risk for the LLNL and EPRI hazard distributions. They may be compared to Figure S.15 for internal initiators. Offsite seismic risk based on the EPRI hazard distribution is roughly comparable to the risk due to internal initiators; the seismic risk based on the LLNL hazard distribution is greater than the risk due to the internal initiators.

Comparison with Previous Studies. The offsite risk at Surry from internal initiators is lower than that computed in the Reactor Safety Study[3] (RSS) of 1975. For early fatalities, Figure S.15 shows that almost the entire distribution is now below the lower end of the RSS distribution. The median value for this study is about two orders of magnitude below the median for the RSS. (The RSS did not report mean values, nor did it consider risk from external events.) For latent cancer fatalities, the 5th percentile of the RSS distribution falls between the mean and median of the current distribution. The median value for this study is about one order of magnitude below the median for the RSS.

These decreases in risk are greater than the decrease in the core damage frequency. The RSS reported a point estimate value of 4.6E-5/R-yr. For the integrated risk analysis, the median and mean of the core damage frequency distribution are 2.5E-5/R-yr and 4.1E-5/R-yr, respectively. Because the changes in the consequence calculation are relatively small, much of the decrease in the risk at Surry compared with those in the RSS comes from changes in our understanding of how reactor accidents progress, and how much of the fission product inventory may be expected to be released in the course of an accident.

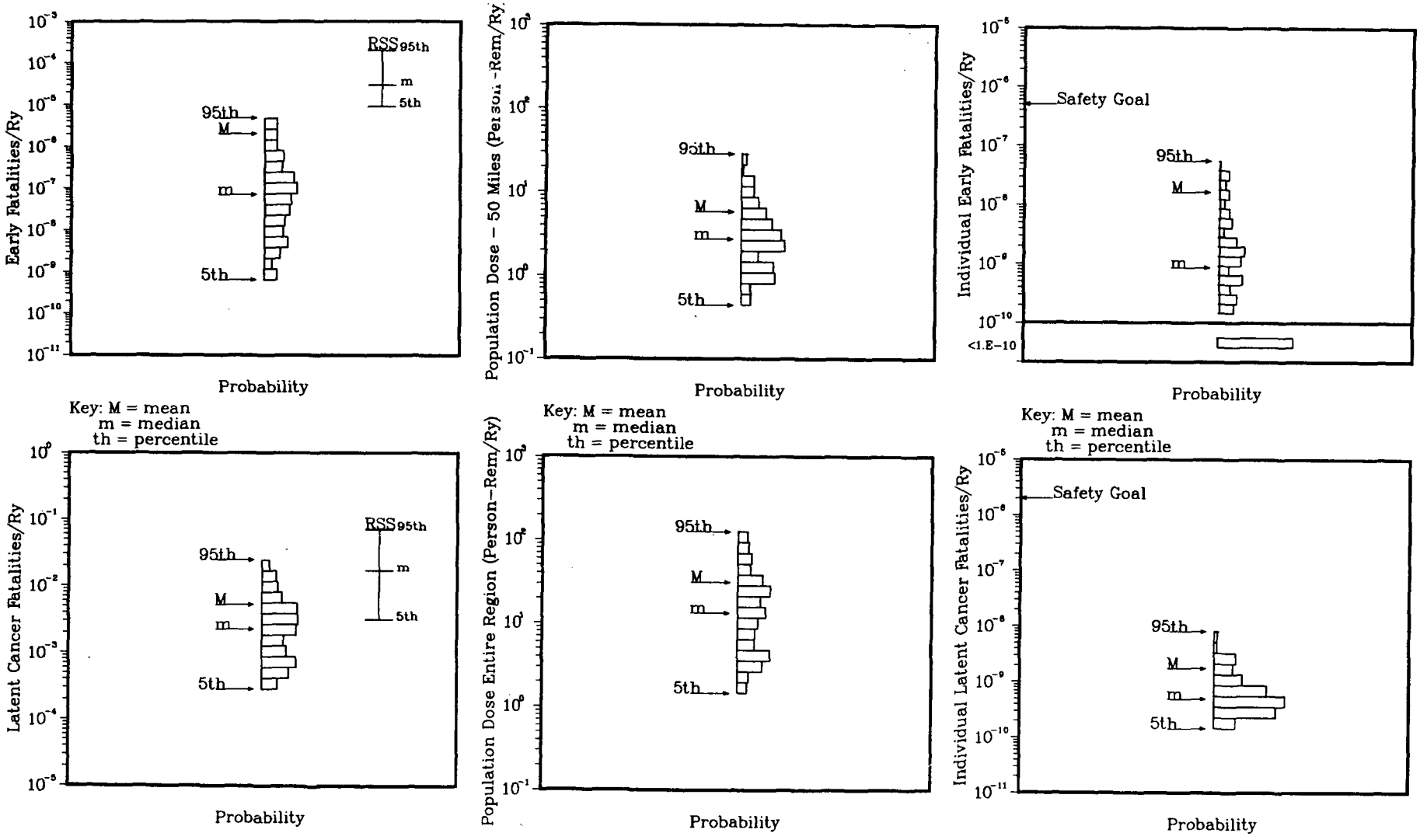
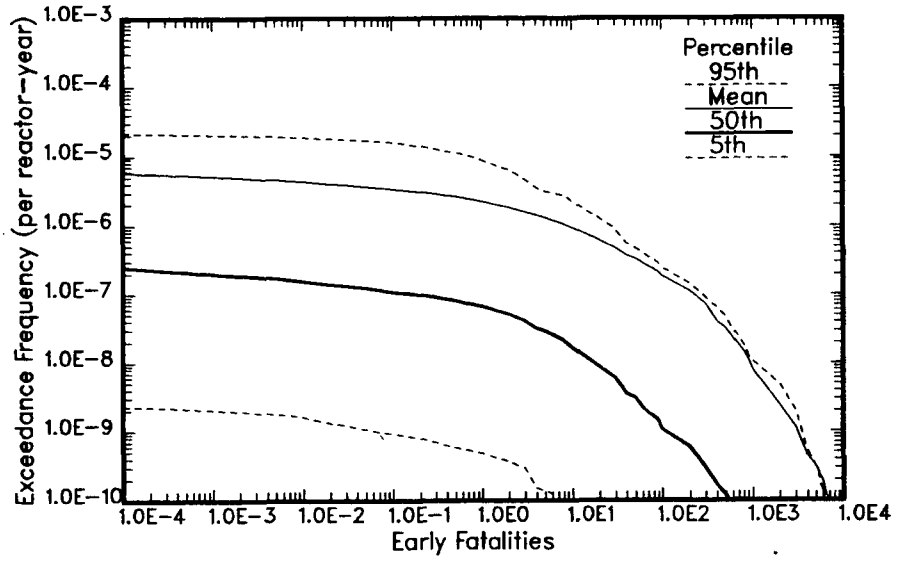


Figure S.15. Distributions of Annual Risk. Surry: Internal Initiators



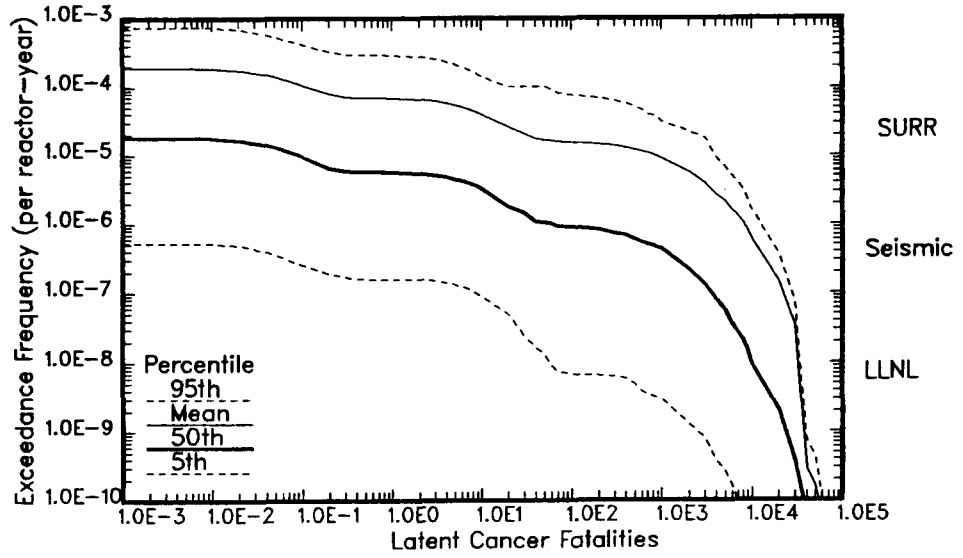
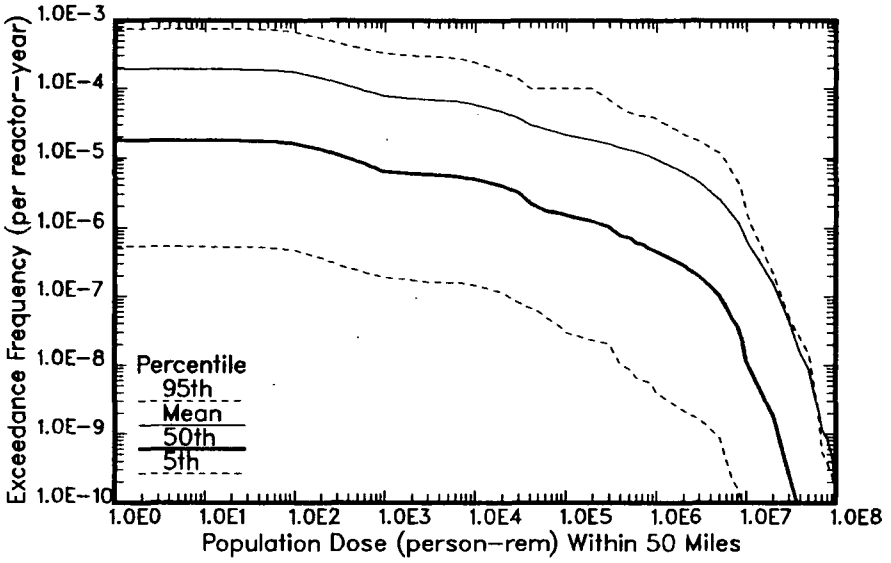


Figure S.16. Results of Integrated Risk Analysis for for Seismic Initiators. LLNL Hazard Distributions



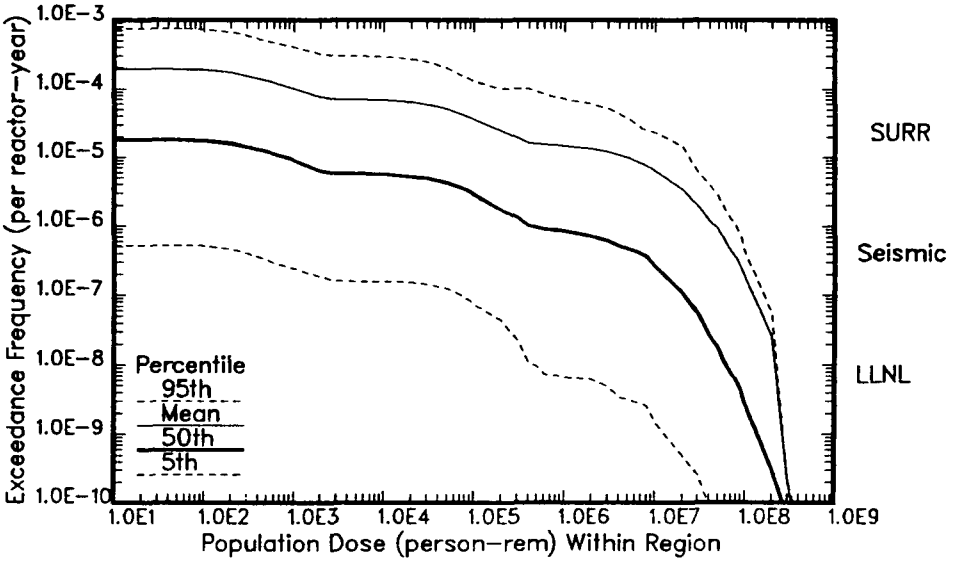
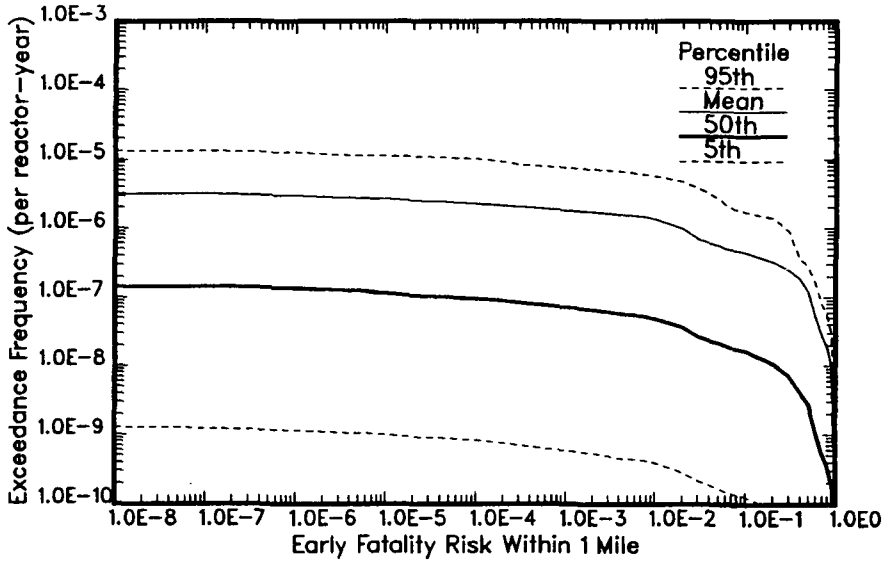


Figure S.16 (continued)



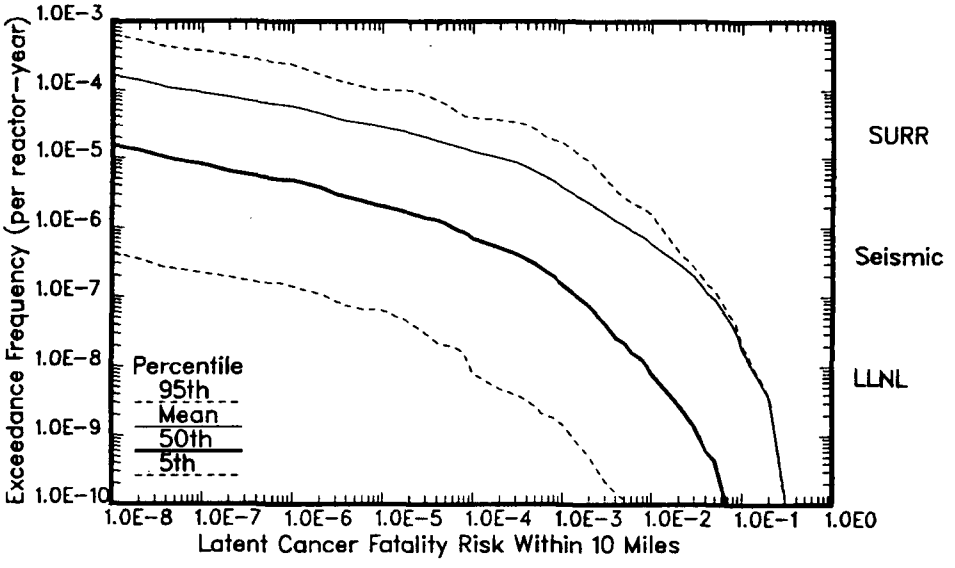
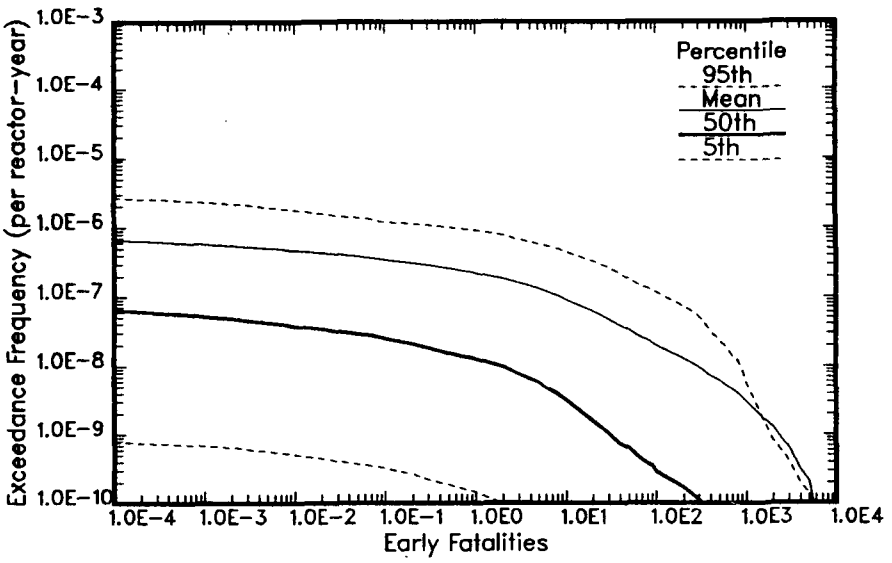


Figure S.16 (continued)



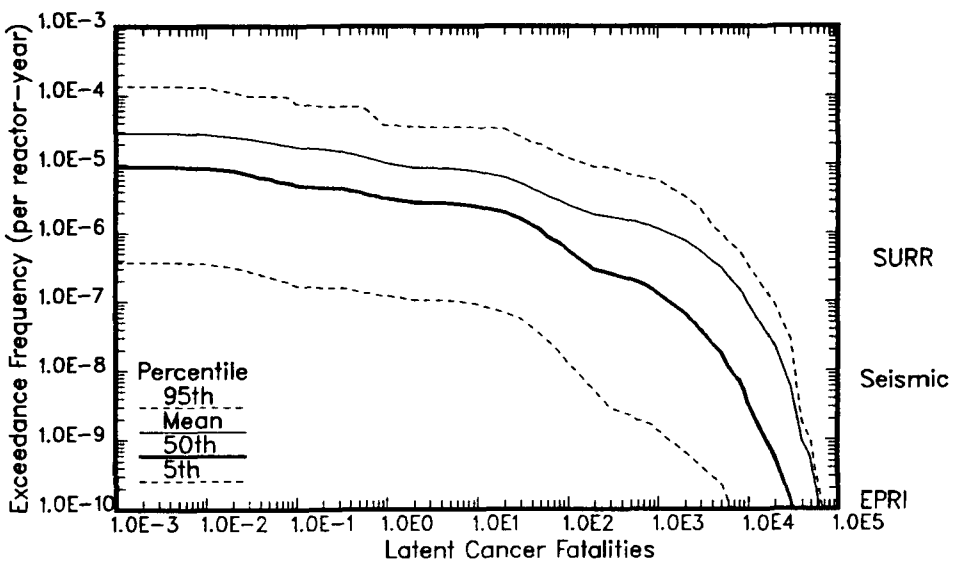
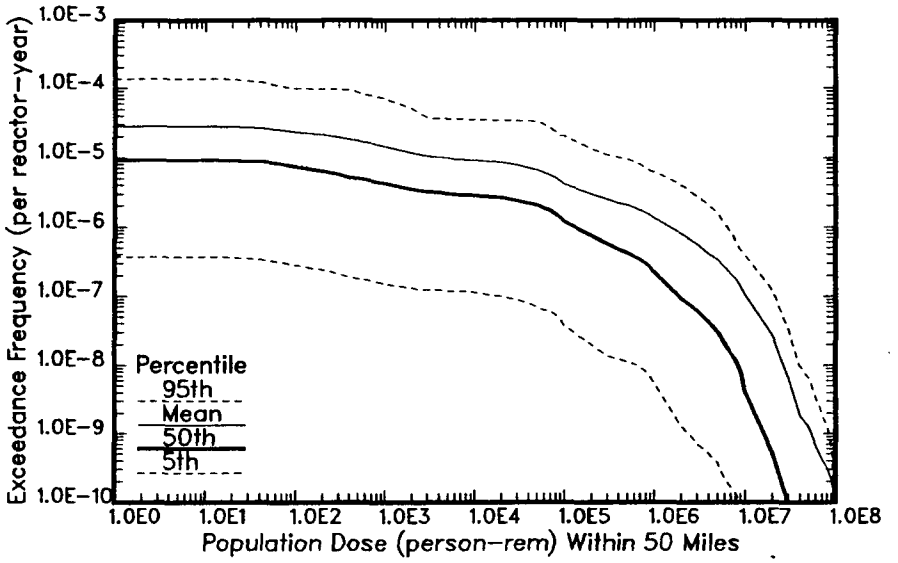


Figure S.17. Results of Integrated Risk Analysis for Seismic Initiators. EPRI Hazard Distributions



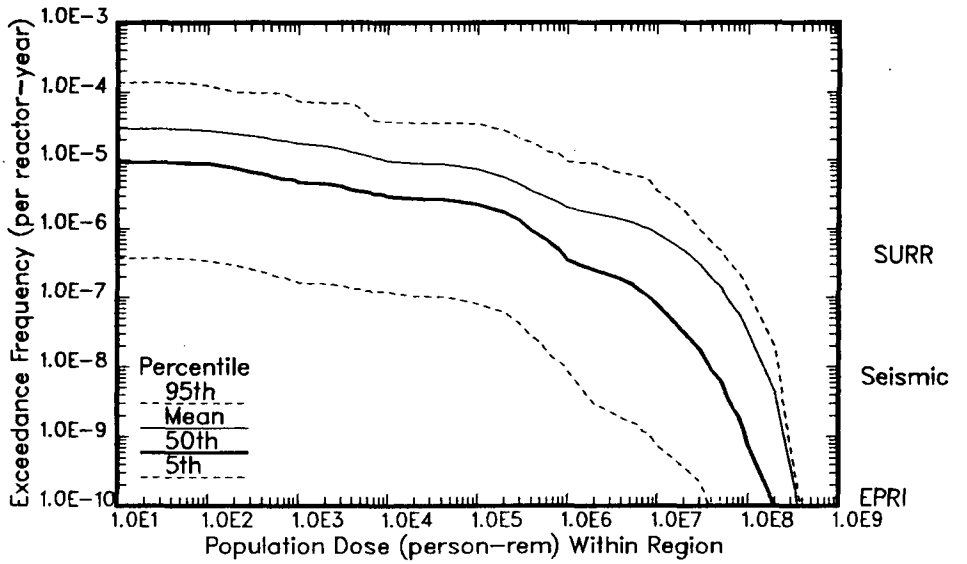
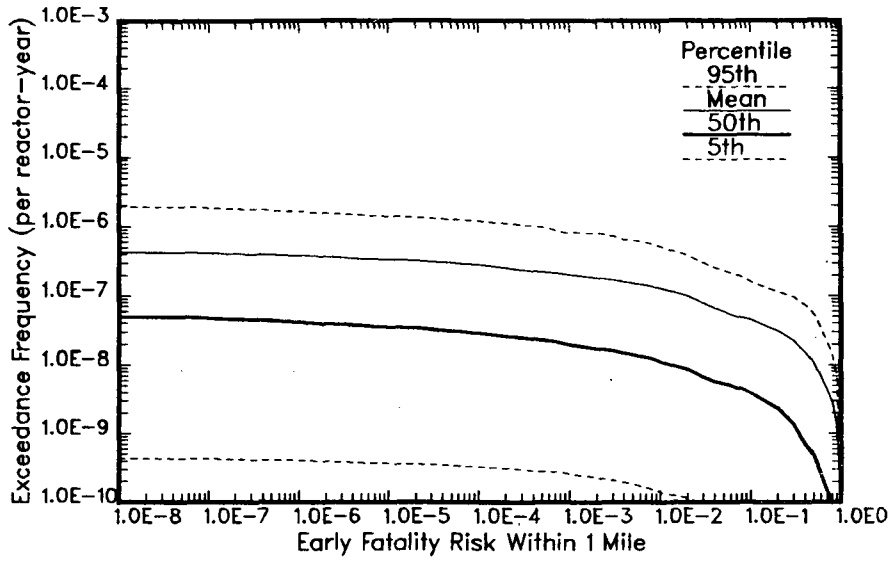


Figure S.17 (continued)



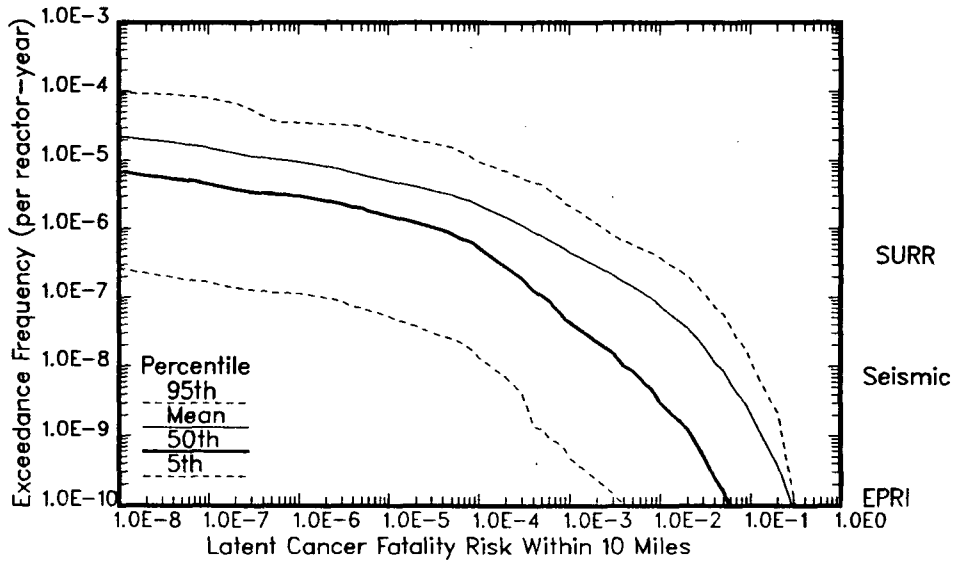


Figure S. 17 (continued)

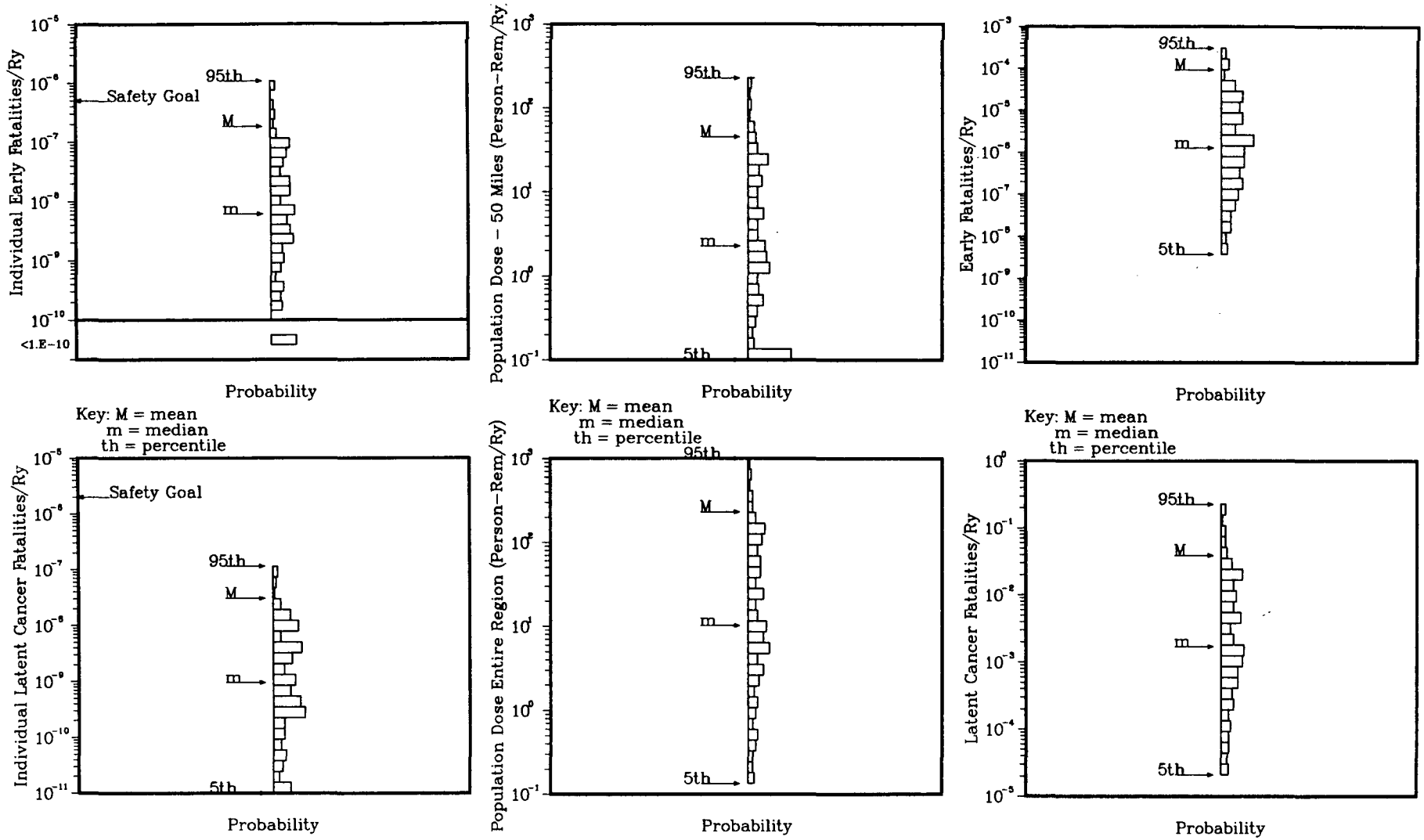


Figure S.18. Distributions of Annual Risk for Seismic Initiators
LLNL Hazard Distributions

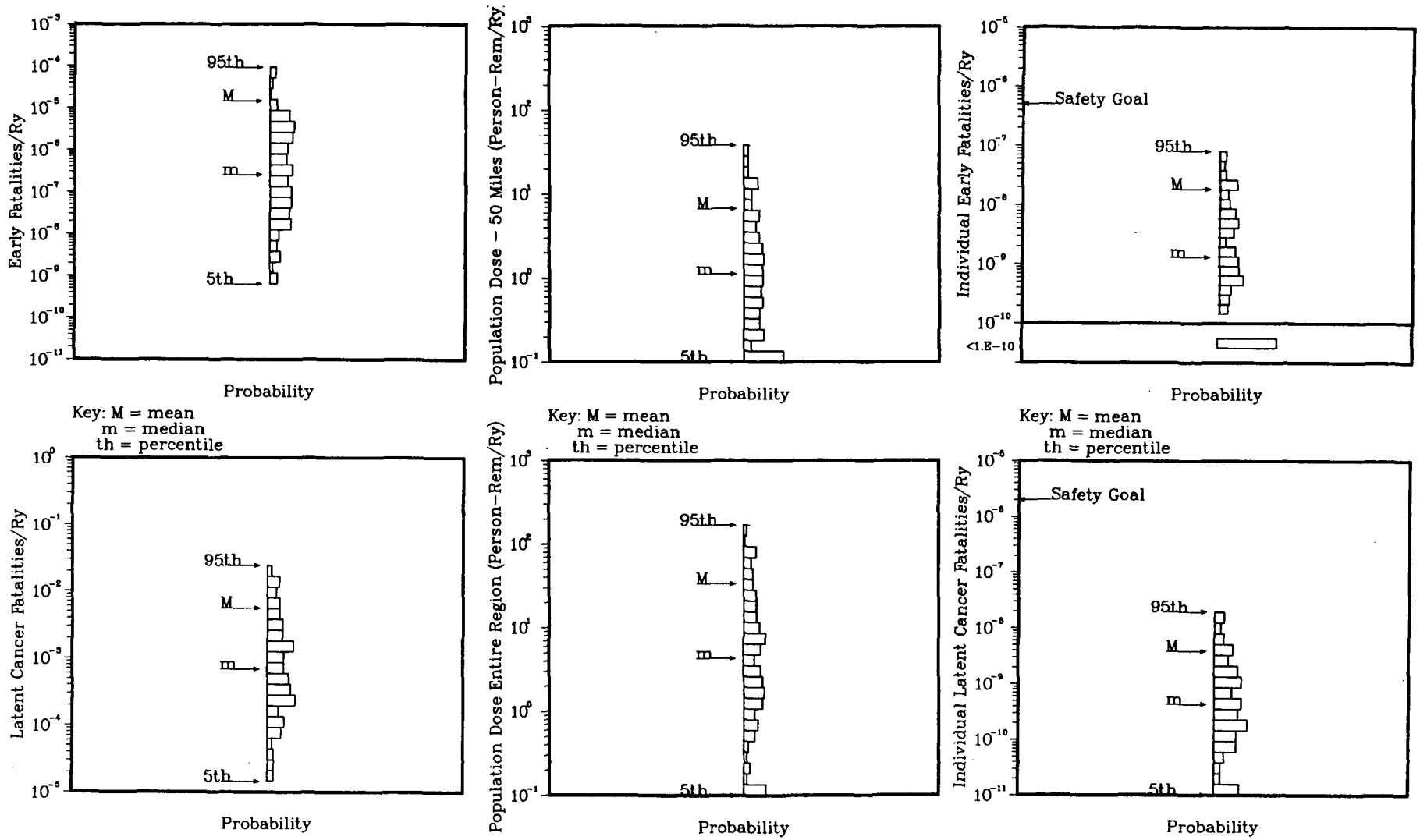


Figure S.19. Distributions of Annual Risk for Seismic Initiators
EPRI Hazard Distributions

A major change in this study relative to the RSS is the decreased probability of early failure of the containment for non-bypass accidents. The estimates of the failure pressure of the Surry containment have increased, while the estimates of the containment loads at the time of lower head failure have decreased. Although the pressure rise at VB now contains the contributions from direct heating of the containment, this addition has been more than offset by the consideration of mechanisms that lead to depressurization of the RCS before failure of the vessel. Furthermore, the current analysis includes the possibility of arresting the core damage process before vessel failure and achieving a safe, stable state.

This analysis includes accidents initiated by SGTRs that are not treated in the RSS. The normal ("G") SGTRs are not large contributors to risk, but the "H" SGTRs, in which the SRVs on the secondary system stick open, are major contributors to latent cancer fatalities.

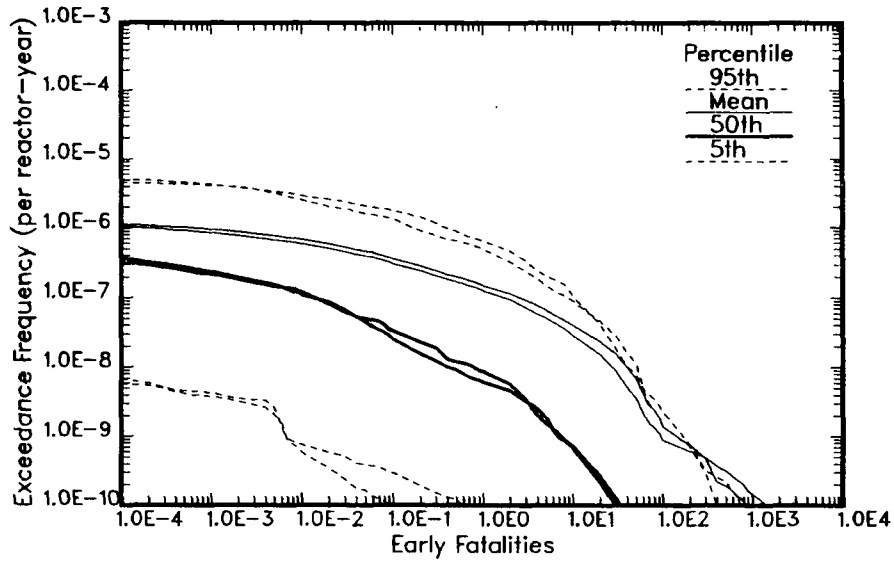
Stability of the Analysis. To determine the stability of the integrated risk analyses performed for NUREG-1150, a second sample was generated and the entire analysis for internal initiators at Surry was repeated. The second sample is just as valid as the first sample, and differs from the first sample only in the use of a different random seed in the Latin Hypercube Sampling (LHS) program. Therefore, differences in the results between the two samples are an indication of the robustness of the analysis methods.

Figure S.20 displays four statistical measures of the families of CCDFs for both samples. Considering the range of the distributions, as indicated by the distance between the 5th and the 95th percentile curves, the agreement between the two samples is remarkably good. Since the family of CCDFs is the most basic measure of risk, this agreement indicates that the methods used for the propagation of this integrated risk analysis are sound.

S.8.3 Important Contributors to Risk

There are two ways to calculate the contribution to mean risk. The fractional contribution to mean risk (FCMR) is found by dividing the average risk for the subset of interest for the sample by the average total risk for the sample. The mean fractional contribution to risk (MFCR) is found by determining the ratio of the risk for the subset of interest to the total risk for each observation, and then averaging over the sample.

Results of computing the contributions to the mean risk for internal initiators by the two methods are given below. Percentages are shown for the two samples for early fatalities and latent cancer fatalities for the four PDS groups making substantial contributions to risk. LOCAs, Transients, and ATWS each contributed less than 3% of the mean risk for all risk measures.



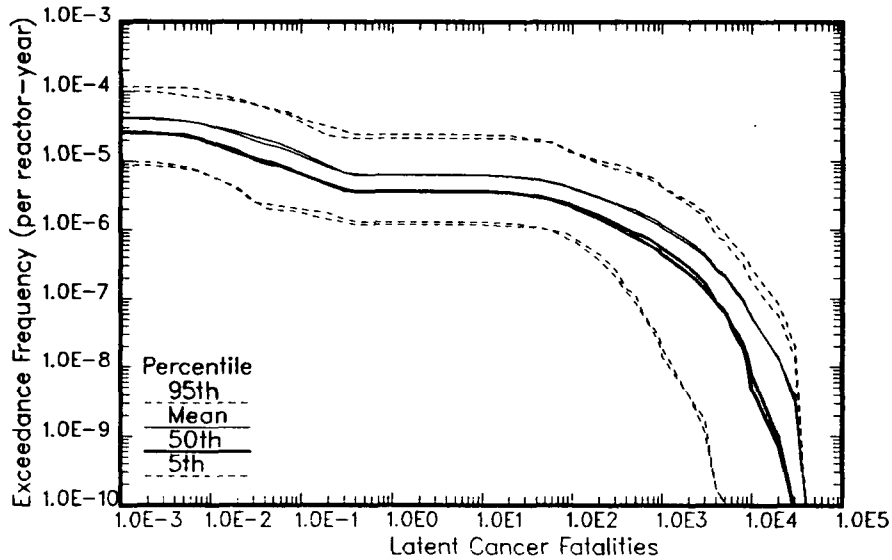


Figure S.20. Statistical Measures for Both Samples

Contributors (%) to Mean
Early Fatality Risk for Internal Initiators

	Sample 1		Sample 2	
PDS Group	FCMR	MFCR	FCMR	MFCR
Slow SBO	8.6	7.7	15.6	7.3
Fast SBO	8.6	1.3	13.9	1.7
Event V	77.3	57.4	62.6	64.0
SGTR	4.1	29.0	6.9	22.3

Contributors (%) to Mean Latent
Cancer Fatality Risk for Internal Initiators

	Sample 1		Sample 2	
PDS Group	FCMR	MFCR	FCMR	MFCR
Slow SBO	10.9	15.2	14.6	14.9
Fast SBO	4.6	3.6	8.6	3.9
Event V	34.3	15.9	25.5	15.8
SGTR	46.5	57.0	47.0	56.8

Figure S.21 shows pie charts for the contributions of the summary PDS groups to mean risk for internal initiators for these two risk measures for both methods and both samples. Figure S.22 displays similar pie charts for the contributions of the summary APBs to mean risk. Since the second sample is as valid as the first sample, and more basic measures of risk indicate that the analysis is robust and repeatable, it is clear that the fractional contributions to mean risk can only be interpreted in a broad sense. That is, it is valid to say that Event V is the major contributor to early fatality risk at Surry, or that Event V contributes on the order of 2/3 of the mean risk due to internally initiated accidents at Surry. It is not valid to state that Event V contributes 77.3% of the early fatality risk at Surry.

The reason the contributors to mean risk appear to be unstable is that the expected risk for each observation is typically dominated by a few APBs which have both high frequency and high source terms, and that the mean risk is dominated by a few observations which have very large values of expected risk. About 10 observations contribute to most of the mean risk. While the sample as a whole is reproducible, the 10 or so observations that control mean risk are generally not reproducible. Since it is the exact nature of these 10 (approximately) observations that determine the contributors to mean risk, it is not surprising that this is not a robust measure of the entire risk analysis.

Even though the measures for determining the contributors to mean risk are only approximate, the types of accidents that are the largest contributors to the risk from internal initiators at Surry are clear. For early fatalities, which depend on a large early release, the risk is dominated by Event V. Event V not only proceeds quickly to VB, but it creates a bypass

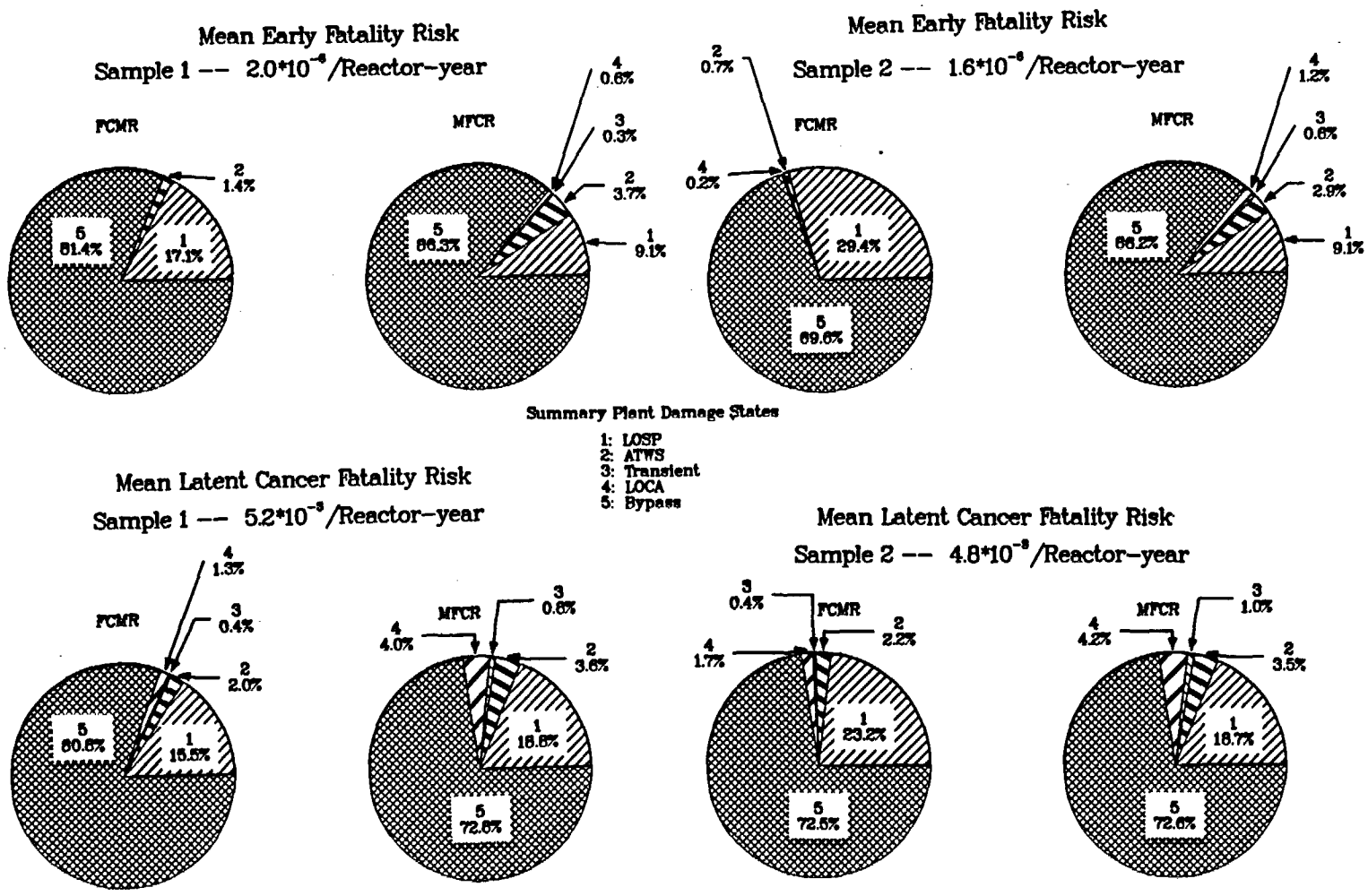


Figure S.21. Contributions of Summary PDS Groups to Mean Risk

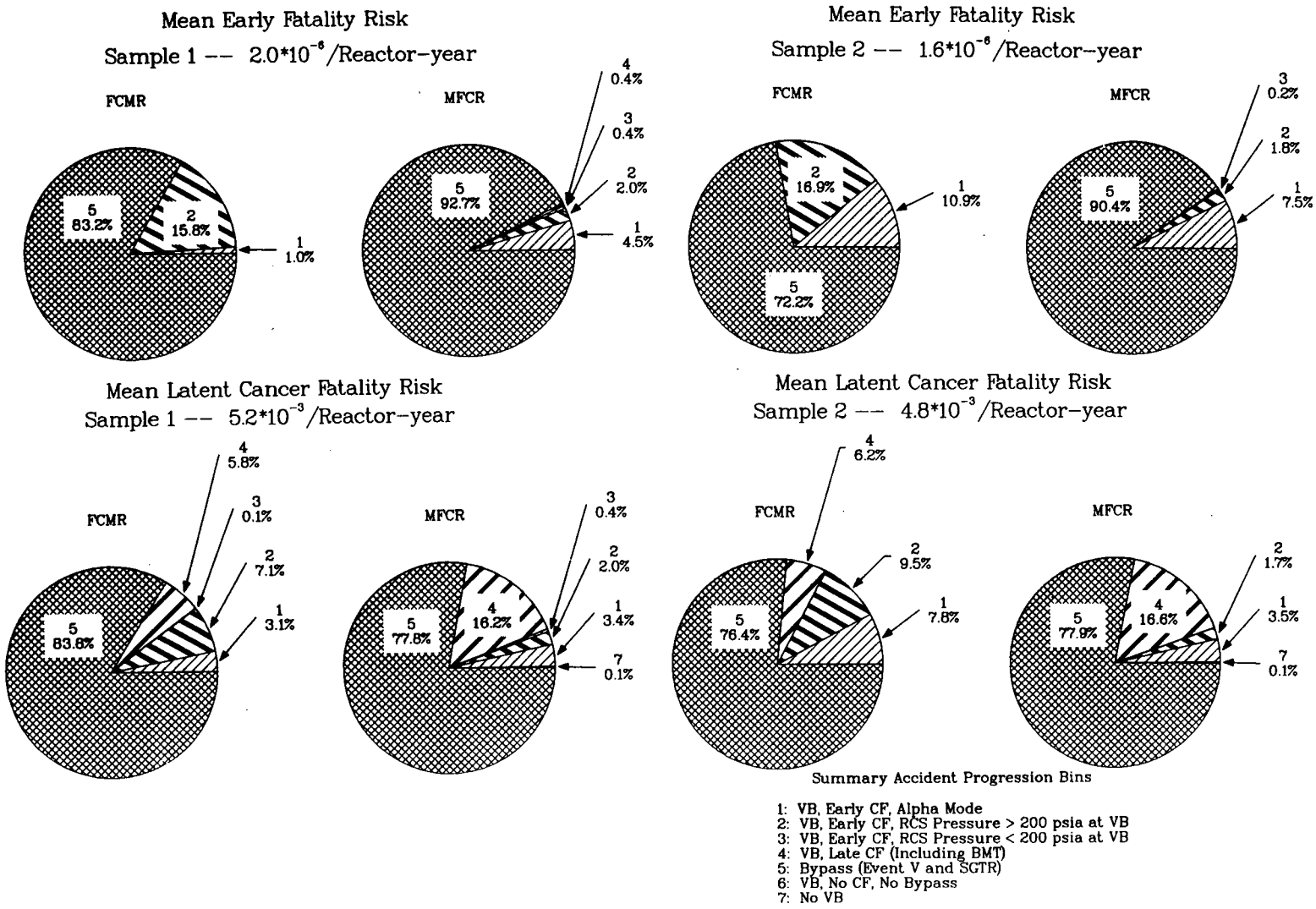


Figure S.22. Contributions of Summary APBs to Mean Risk

of the containment as well. The probability of CF at VB is low at Surry for the most frequent CD accidents, SBO and LOCA, as discussed above. The SGTR accidents that lead to large releases, the "H" SGTRs with stuck-open secondary SRVs, progress to VB only after many hours. Thus, Event V accounts for most of the large, early releases, and most of the early fatality risk.

For latent cancer fatalities, and the other consequence measures that depend primarily on the total amount of radioactivity released, the risk is dominated by Event V and SGTRs. The SGTRs contribute more than Event V, and most of this contribution comes from the "H" SGTRs (stuck-open secondary SRVs). Although this accident is unlikely (MCDF about 1.0E-6/R-yr), there is a direct open path from the reactor vessel to the environment throughout the accident. The probability that the break point in Event V will be underwater when the releases start is estimated to be about 0.85.

Results of computing the contributions to the mean risk for seismic initiators by the two methods are given below. Percentages are shown for the two hazard distributions for early fatalities and latent cancer fatalities for the three seismic PDS groups.

Contributors (%) to Mean
Early Fatality Risk for Seismic Initiators

	LLNL		EPRI	
PDS Group	FCMR	MFCR	FCMR	MFCR
LOSP	4.7	4.0	1.4	6.5
SBO	65.2	37.2	44.1	38.1
LOCA	30.2	58.8	54.5	55.5

Contributors (%) to Mean Latent
Cancer Fatality Risk for Seismic Initiators

	LLNL		EPRI	
PDS Group	FCMR	MFCR	FCMR	MFCR
LOSP	6.0	8.9	10.8	15.4
SBO	62.3	43.8	43.1	43.2
LOCA	31.7	47.3	46.2	41.4

There are no bypass initiators among the seismic accidents, and the probability of CF at VB is low, so early fatality risk is largely due to the initial containment failures that accompany failure of the SG or RCP supports and CF at VB.

S.8.4 Important Contributors to the Uncertainty in Risk

The important contributors to the uncertainty in internally initiated risk are determined by performing regression-based sensitivity analyses for the mean values for risk and partial rank correlation analyses for the risk CCDFs. The largest contributors to the uncertainty in the risk at Surry are variables that determine the frequency of bypass accidents and parameters that determine the release fractions.

The most important contributors to the uncertainty in mean risk are: the initiating event frequency for Event V, the initiating event frequency for SGTRs, the fractional release from the reactor core to the vessel, and the release fraction from the vessel to the environment for SGTRs.

These same four variables are the largest contributors to the variability in the risk CCDFs as well. While not dominant for all risk measures for all values of the risk measure, they, or a subset of them, are important for a significant fraction of the range of the risk measure for all risk measures. Other variables that are important for some parts of the range, or for some risk measures, include: the release fractions from the containment, the LOSP event, failure of the DGs to start, and failure of the DGs to run.

Important contributors to risk are not determined for the fire initiators. Uncertainty in the seismic risk is dominated by the variability in the seismic hazard distribution.

S.9 Insights and Conclusions

Core Damage Arrest. The inclusion of the possibility of arresting the core degradation process before vessel failure is an important feature of this analysis. For internal initiators, there is a good chance that non-bypass accidents will be arrested before vessel failure. This may be due to the recovery of offsite power or the reduction of RCS pressure to the point where an operable system can inject. The arrest of core damage before VB plays an important part in reducing the risk due to the most frequent types of internal accidents--SBOs and LOCAs. For fires, there is no possibility of core damage arrest since the initiating fire destroys the ability to provide control or motive power to the coolant injection systems. For accidents initiated by earthquakes, core damage arrest is not possible in the SBO accidents because the switchyard is destroyed. The fraction of accidents that do not progress to vessel failure in the LOSP (No SBO) and LOCA seismic groups is significant, however.

Depressurization of the RCS. Depressurization of the RCS before the vessel fails is important in reducing the loads placed upon the containment at vessel breach and in arresting core damage before VB. For accidents in which the RCS is at the PORV setpoint pressure during core degradation, the effective mechanisms for pressure reduction are temperature-induced failure of the hot leg or surge line, temperature-induced failure of the RCP seals, and the sticking open of the PORVs. All of these mechanisms are inadvertent and beyond the control of the operators. The apparent beneficial effects of reducing the pressure in the RCS when lower head failure is

imminent indicate that further investigation of depressurization may be warranted. It is somewhat unsettling that the probability of containment failure depends on RCS pressure boundary failures that occur at unpredictable locations and times. Studies of the effects of increasing PORV capacity, providing the means to open the PORVs in blackout situations, and changing the procedures to remove restrictive conditions on deliberate RCS pressure reduction might prove rewarding in decreasing the probability of early containment failure at PWRs.

Containment Failure. If a core damage accident proceeds to the point where the lower head of the reactor vessel fails, the containment is unlikely to fail at this time. This is partially due to the depressurization of the RCS before vessel failure and partially due to the strength of the Surry containment relative to the loads expected. No containment failure is more likely than containment failure for all types of initiators. If the containment does fail, it is more likely to fail many hours after VB than at VB. The mode and time of failure depends upon the availability of CHR. If CHR is recovered within a day or so, basemat meltthrough is the most probable failure mode. If CHR is not recovered within days, an overpressure failure is the likely mode about a week after the start of the accident. For seismic initiators, almost all early failures of the containment result from initial failures to failures of the steam generator or reactor coolant pump supports.

Bypass Accidents. Bypass accidents dominate the risks that depend on a large early release as well as those which are functions of the total release. Event V is the accident most likely to result in a large, early release for internal initiators. SGTRs are also important contributors to large releases, but most of the large releases due to SGTRs occur many hours after the start of the accident. The most important SGTRs are those in which the SRVs on the secondary system stick open. Although the bypass accidents are not the most frequent types of internal accidents, the low probability of CF, especially early CF, for the non-bypass accidents results in the large contributions of the bypass accidents to risk.

Fission Product Releases. There is considerable uncertainty in the release fractions for all types of accidents. For most accidents, the central portions of the release fraction distributions are below most release fraction estimates made several years ago. While the upper portions of the release fraction distributions are comparable with the values of the RSS,[3] many of these distributions now extend to release fractions several orders of magnitude lower than those of the RSS.

Comparison with the RSS. The distributions for annual risk resulting from the current analysis of the offsite risk from internally initiated accidents at the Surry nuclear power plant are lower than those found about 15 years ago in the RSS. For early fatalities, the 95th percentile of the current distribution lies below the 5th percentile of the RSS distribution. For latent cancer fatalities, the 95th percentile of the current distribution is slightly greater than the median of the RSS distribution. The most frequent accidents, SBOs and LOCAs, are unlikely to result in early containment failure. This is due to a number of factors, including: consider-

ation of core damage arrest, higher estimates of the containment failure pressure, reduced estimates of the pressure rise at VB, and lower release fractions for many accidents.

Uncertainty in Risk. Considerable uncertainty is associated with the risk estimates produced in this analysis. The largest contributors to this uncertainty are the frequencies of the initiating events, especially for the bypass and seismic initiators, and the uncertainty in some of the parameters that determine the magnitude of the fission product release to the environment. The distributions for annual risk resulting from this analysis are much wider than those from the RSS. The additional uncertainty is all in the direction of lower risk. Propagation of the uncertainties in the accident frequency, accident progression, and source term analyses through to risk allows the uncertainty to be quantitatively calculated and displayed.

Risk from Fire. The risk due to fires at Surry is lower than that from internal initiators or earthquakes. While there is no chance of core damage arrest due to disruption of ECCS control or motive power, the fire core damage frequency is about one fourth that for internal initiators, there are no bypass initiators, and the probability of early containment failure is small.

Risk from Earthquakes. The offsite risk at Surry due to earthquakes depends very strongly on the set of hazard distributions used in the accident frequency analysis. If the LLNL hazard distributions are used, the upper portions of the annual risk distributions are about an order of magnitude higher than the risk distributions from internal initiators. If the EPRI hazard distributions are used, the annual risk distributions are roughly comparable with the risk distributions from internal initiators. Much of the offsite seismic risk is attributable to initial containment failures due to the RCP or steam generator support failures that accompany the large "A" LOCAs. Containment failure at vessel breach is relatively unlikely for the seismic initiators.

Comparison with the Safety Goals. For both distributions for individual fatality probability for internal and fire initiators, the 95th percentile value for annual risk falls more than an order of magnitude below the safety goal. For the seismic initiators, the 95th percentile values for individual latent cancer fatality risk are more than an order of magnitude below the safety goal for both the LLNL and EPRI hazard distributions. For the probability of an individual early fatality from seismic initiators using the EPRI hazard distributions, the 95th percentile value is about a factor of four below the safety goal. If the LLNL hazard distributions are used, the upper 10% or 15% of the distribution for the probability of an individual early fatality exceeds the safety goal.

References

1. USNRC, "Severe Accident Risks: An Assessment for Five U.S. Nuclear Power Plants," Second Draft for Peer Review, NUREG-1150, June 1989.

2. R. C. Bertucio and J. A. Julius, "Analysis of Core Damage Frequency: Surry Unit 1," Sandia National Laboratories, NUREG/CR-4550, Vol. 3, Rev. 1, SAND86-2084, April 1990.

3. USNRC, "Reactor Safety Study--An Assessment of Accident Risks in U.S. Commercial Nuclear Power Plants," WASH-1400 (NUREG 75/014), October 1975.

1. INTRODUCTION

The United States Nuclear Regulatory Commission (NRC) has recently completed a major study to provide a current characterization of severe accident risks from light water reactors (LWRs). The characterization was derived from the analysis of five plants. The report of that work, NUREG-1150[1] has recently been issued as a second draft for comment. NUREG-1150 is based on extensive investigations by NRC contractors. Several series of reports document these analyses as discussed in the Foreword.

These risk assessments can generally be characterized as consisting of four analysis steps, an integration step, and an uncertainty step.

1. Accident frequency analysis: the determination of the likelihood and nature of accidents that result in the onset of core damage.

2. Accident progression analysis: an investigation of the core damage process, both within the reactor vessel before it fails and in the containment afterwards, and the resultant impact on the containment.

3. Source term analysis: an estimation of the radionuclide transport within the reactor coolant system (RCS) and the containment, and the magnitude of the subsequent releases to the environment.

4. Consequence analysis: the calculation of the offsite consequences in terms of health effects and financial impact.

5. Risk integration: the combination of the outputs of the previous tasks into an overall expression of risk.

6. Uncertainty analysis: the determination of which uncertainties in the preceding analyses contribute the most to the uncertainty in risk.

This volume is one of seven that comprise NUREG/CR-4551. NUREG/CR-4551 presents the details of the last five of the six analyses listed above. The analyses reported here start with the onset of core damage and conclude with an integrated estimate of overall risk and uncertainty in risk. This volume, Volume 3, describes these analyses, the inputs utilized in them, and the results obtained, for Surry Power Station, Unit 1. The methods utilized in these analyses are described in detail in Volume 1 of this report and are only briefly discussed here.

1.1 Background and Objectives of NUREG-1150

Assessment of risk from the operation of nuclear power plants, involves determination of the likelihood of various accident sequences and their potential offsite consequences. In 1975, the NRC completed the first comprehensive study of the probabilities and consequences of core meltdown accidents--the "Reactor Safety Study" (RSS).[2] This report showed that the probabilities of such accidents were higher than previously believed, but that the consequences were significantly lower. The product of probability

and consequence--a measure of the risk of core melt accidents--was estimated to be quite low when compared with natural events such as floods and earthquakes and with other societal risks such as automobile and airplane accidents. Since that time, many risk assessments of specific plants have been performed. In general, each of these has progressively reflected at least some of the advances that have been made in reactor safety and in the ability to predict the frequency of several accidents, the amount of radioactive material released as a result of such accidents, and the offsite consequences of such a release.

In order to investigate the significance of more recent developments in a comprehensive fashion, it was concluded that the current efforts of research programs being sponsored by the NRC should be coalesced to produce an updated representation of risk for operating nuclear power plants. "Severe Accident Risks: An Assessment for Five U.S. Nuclear Power Plants"[1] is the result of this program. The five nuclear power plants are Surry, Peach Bottom, Sequoyah, Grand Gulf, and Zion. The analyses of the first four plants were performed by Sandia National Laboratories (SNL). The analysis of Zion was performed by Idaho National Engineering Laboratory (INEL) and Brookhaven National Laboratory (BNL).

The overall objectives of the NUREG-1150 program are given below.

1. Provide a current assessment of the severe accident risks to the public from five nuclear power plants, which will:

    a. Provide a "snapshot" of the risks reflecting plant design and operational characteristics, related failure data, and severe accident phenomenological information extant in 1988;

    b. Update the estimates of the NRC's 1975 risk assessment, the "Reactor Safety Study";[2]

    c. Include quantitative estimates of risk uncertainty, in response to the principal criticism of the "Reactor Safety Study"; and

    d. Identify plant-specific risk vulnerabilities, in the context of the NRC's individual plant examination process.

2. Summarize the perspectives gained in performing these risk analyses, with respect to:

    a. Issues significant to severe accident frequencies, consequences, and risk;

    b. Uncertainties for which the risk is significant and which may merit further research; and

    c. Potential for risk reduction.

3. Provide a set of methods for the prioritization of potential safety issues and related research.

These objectives required special considerations in the selection and development of the analysis methods. This report describes those special considerations and the solutions implemented in the analyses supporting NUREG-1150.

1.2 Overview of Surry Power Station, Unit 1

The subject of the analyses reported in this volume is the Surry Power Station, Unit 1. It is operated by the Virginia Electric Power Company and is located on the south bank of the James River in southeastern Virginia, about 10 miles south of Williamsburg, Virginia. The nearest large city is Norfolk, Virginia, approximately 35 airline miles to the southeast of the plant. Two units are located on the site; Unit 2 is essentially identical to Unit 1.

The nuclear reactor of Surry Unit 1 is a 2441 MWt pressurized water reactor (PWR) designed and built by Westinghouse. The RCS has three U-tube steam generators (SGs) and three reactor coolant pumps (RCPs). The containment and the balance of the plant were designed and built by Stone and Webster. Unit 1 began commercial operation in December 1972.

There are three diesel generators (DGs) at the Surry site to supply emergency ac power if offsite power from the grid is lost. One of these DGs is dedicated to Unit 1, one is dedicated to Unit 2, and the third DG may be aligned to supply either unit. Each unit has its own set of batteries to supply general emergency dc power. Each DG obtains starting power from a separate set of batteries.

The auxiliary feedwater system (AFWS) has three pumps: two are driven by electric motors; the third is driven by a steam turbine. The AFWS takes suction from the condensate storage tank (CST). There are three charging pumps; they also serve as high-pressure injection (HPI) pumps. There are two low-pressure injection (LPI) pumps; they are self-cooled. Both the HPIS and the LPIS can function in a recirculation mode as well as in an injection mode. In the injection mode they take suction from the refueling water storage tank (RWST); in the recirculation mode they take suction from the sump. Surry also has three accumulators to provide immediate, high-flow, low-pressure injection. Reactor coolant system (RCS) overpressure protection is provided by three code safety valves and two power-operated relief valves (PORVs). Service water for cooling condensers, pumps, and heat exchangers is obtained by gravity flow from an elevated service water canal. This canal is continuously supplied with river water by electric pumps. If ac power is lost, the service water canal will drain in approximately 30 minutes unless a number of large manual valves are closed.

The Surry containment is a reinforced concrete cylinder with a hemispherical dome. A welded steel liner forms the pressure boundary. Figure 1.1 shows a section through the Surry containment. The volume is 1,800,000 ft^3, and the design pressure is 45 psig. During operation, the interior of the containment is maintained about 5 psig below ambient atmospheric pressure. Normal containment cooling is by fan coolers. These are not safety grade and they will be partially submerged if the sump is full of water. Emergency containment heat removal is by the spray systems.

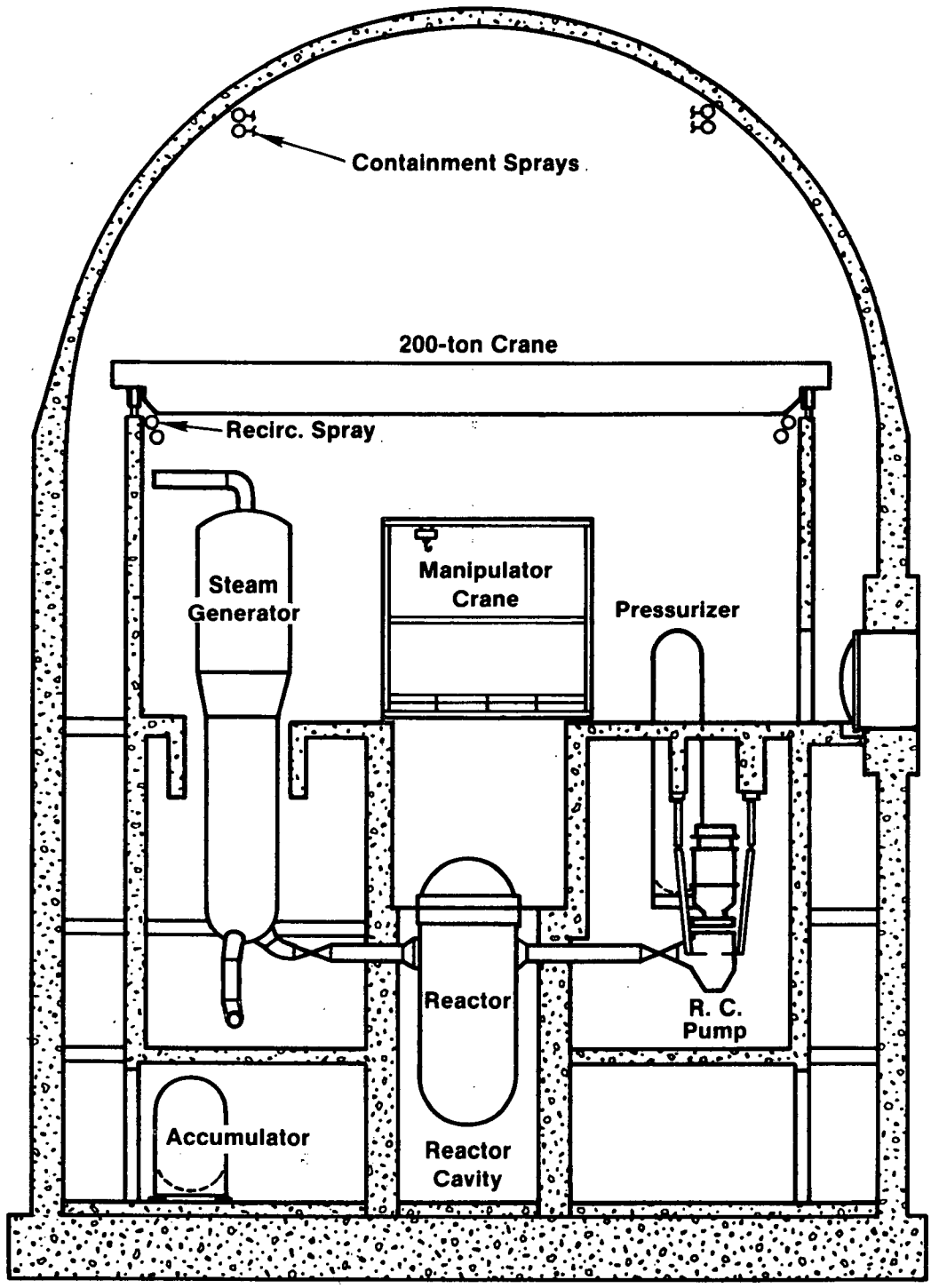


Figure 1.1. Section of Surry Containment.

The containment spray injection system has two trains, each with one pump which takes suction from the RWST. There are two containment spray recirculation systems, each with two trains. Each of the six containment spray trains is independent of the other spray systems; except for that, each train requires electrical power for the pumps. Each containment spray recirculation train includes a heat exchanger that is cooled by the service water system and a pump that takes suction directly from the containment sump. One system has its pumps located inside the containment and the other has its pumps located outside the containment. There is no connection between the sump and the reactor cavity at a low elevation in the Surry containment. Water from a pipe break in containment will flow to the sump. The reactor cavity will remain dry unless the containment sprays operate.

Section 2.1 of this volume contains more detail on the plant's features important to the progression of the accident and to the containment's performance.

1.3 Changes Since the Draft Report

The Surry analyses for the February 1987 draft of NUREG-1150 were presented in Volumes 1 of the original "Draft for Comment" versions of NUREG/CR-4551 and NUREG/CR-4700, also published in February 1987. The analyses performed for NUREG-1150, Second Draft for Peer Review, June 1989, and reported in this volume, are completely new. While they build on the previous analyses and the basic approach is the same, very little from the first analyses is used directly in these analyses. This section presents the major differences between the two analyses. Essentially, the accident progression analysis and the source term analysis were completely redone to incorporate new information and to take advantage of expanded methods and analysis capabilities.

Quantification. A major change since the previous analyses is the expert elicitation process used to quantify variables and parameters thought to be large contributors to the uncertainty in risk. This process was used both for the accident progression analysis and the source term analysis. The sizes of the panels were expanded, with each panel containing experts from industry and academia in addition to experts from the NRC contractors. The number of issues addressed was also increased to about thirty. Separate panels of experts were convened for In-Vessel Processes, Containment Loads, Containment Structural Response, Molten Core-Concrete Interactions, and Source Term Issues.

To ensure that expert opinion was obtained in a manner consistent with the state of the art in this area, specialists in the process of obtaining expert judgments in an unbiased fashion were involved in designing the elicitation process, explaining it to the experts, and training them in the methods used. The experts were given several months between the meeting at which the problem was defined and the meeting at which their opinions were elicited so that they could review the literature, discuss the problem with colleagues, and perform independent analyses. The results of the elicitation of each expert were carefully recorded, and the reasoning of each expert and the process by which their individual conclusions were aggregated into the final distribution are thoroughly documented.

Accident Progression Analysis. Not only was the Accident Progression Event Tree (APET) for Surry completely rewritten for this analysis, but the capabilities of EVNTRE, the code that evaluates the APET, were considerably expanded. The major improvements to EVNTRE were the ability to utilize user functions and the ability to treat continuous distributions. A user function is a FORTRAN subprogram which is linked with the EVNTRE code. When referenced in the APET, the user function is evaluated to perform calculations too complex to be handled directly in the APET. In the current Surry APET, the user function is called to determine the mode of containment failure and to compute the pressure rise in containment due to hydrogen deflagrations. These problems were handled in a much simpler fashion in the previous analysis. The current method explicitly treats the failure modes due to pressure rises that are fast with respect to the depressurization rates from small failures of the containment.

The event tree used for the analysis for the 1987 draft of NUREG-1150 could only treat discrete distributions. For example, for the containment failure pressure, only values of 67, 85, 119, 143, and 180 psig were possible in the previous analysis. In the analysis reported here, a continuous distribution is used for containment failure pressure, so the values are not constrained to these five values. Use of continuous distributions removes a significant constraint from the expert elicitations and eliminates any errors introduced by discrete levels in the previous analysis.

Another major change in the accident progression analysis is in the binning or grouping of the results of evaluating the APET. In the first analysis, all results were placed in one of about 30 previously defined bins. There were many pathways through the tree that did not fit well into these previously defined bins. For the current analysis, a flexible bin structure, defined by the characteristics important to the subsequent source term analysis was used. This eliminates a major problem in the original analysis process.

The event tree that forms the basis of this analysis was completely rewritten. In addition to utilizing a user function for added flexibility, the APET now considers offsite electric power recovery in the period between the onset of core damage and vessel failure. This led to a significant portion of the station blackout accidents terminating not with vessel breach but in an arrested core damage state similar to TMI-2. Additional means of depressurizing the RCS are now in the event tree. These additional mechanisms, along with the higher probabilities for some of them that resulted from the expert elicitations, mean that the likelihood is small that an accident that is at full system pressure at the onset of core damage will still be at that pressure when the vessel fails. Accidents in which core damage begins with LPIS, or both LPIS and HPIS operating are treated in the current APET whereas they were omitted in the previous version. If an event occurs to reduce the RCS pressure in these situations, core damage may be arrested before the vessel fails, leading, by another path, to an arrested core damage state similar to that of TMI-2.

Source Term Analysis. While the basic parametric approach used in the original version of SURSOR, the code used to compute source terms, has been retained in the present version of SURSOR, the code has been completely rewritten with a different orientation. The previous version was designed primarily to produce results that could be compared directly with the results of the Source Term Code Package (STCP). Discrete values for the parameters that differed from those that produced results close to STCP results were then used in the sampling process, with the probabilities for each value or level determined by a small panel of experts. Thus, the first version of SURSOR determined uncertainty in the amount of fission products released for the limited number of predefined bins from the STCP as a base.

The current version of SURSOR is quite different. First, it is not tied to the STCP in any way. It was recognized before the new version was developed that most of the parameters would come from continuous distributions defined by an expert panel. Thus, the current version does not rely on results from the STCP or any other specific code. The experts utilized the results of one or more codes in deriving their distributions, but SURSOR itself merely combines the parameters defined by the expert panel. Second, SURSOR now treats any consistent accident progression state defined by the eleven characteristics that constitute an accident progression bin for Surry. It is not limited to a small number of pre-defined bins as it was in the original version.

Finally, a new method to group the source terms computed by SURSOR has been devised. A source term is calculated for each accident progression bin for each observation in the sample. As a result, there are too many source terms to perform a consequence calculation for each and the source terms have to be grouped before the consequence calculations are performed. The "clustering" method utilized in the previous analysis was somewhat subjective and not as reproducible as desired. The new "partitioning" scheme developed for grouping the source terms in this analysis eliminates these problems.

Consequence Analysis. The consequence analysis for the current NUREG-1150 does not differ so markedly from that for the previous version of NUREG-1150 as does the accident progression analysis and the source term analysis. Version 1.4 of MACCS was used for the original analysis, while version 1.5 is used for this analysis. The major difference between the two versions is in the data used in the lung model. Version 1.4 used the lung data contained in the original version of "Health Effects Models for Nuclear Power Plant Accident Consequence Analysis",[3] whereas version 1.5 of MACCS uses the lung data from Revision 1 (1989) of this report.[4] Other changes were made to the structure of the code in the transition from 1.4 to 1.5, but the effects of these changes on the consequence values calculated are small.

Another difference in the consequence calculation is that the NRC specified evacuation of 99.5% of the population in the evacuation area for this analysis, as compared with the previous analysis in which 95% of the population was evacuated.

Risk Analysis. The risk analysis combines the results of the accident frequency analysis, the accident progression analysis, the source term analysis, and the consequence analysis to obtain estimates of risk to the offsite population and the uncertainty in those estimates. This combination of the results of the constituent analyses was performed essentially the same way for both the previous and the current analyses. The only differences are in the number of variables sampled and the number of observations in the sample.

1.4 Structure of the Analysis

The analysis of the Surry plant for NUREG-1150 is a level 3 probabilistic risk assessment composed of four constituent analyses:

1. Accident frequency analysis, which estimates the frequency of core damage for all significant initiating events;

2. Accident progression analysis, which determines the possible ways in which an accident could evolve given core damage;

3. Source term analysis, which estimates the source terms (i.e., environmental releases) for specific accident conditions; and

4. Consequence analysis, which estimates the health and economic impacts of the individual source terms.

Each of these analyses is a substantial undertaking in itself. By taking care to carefully define the interfaces between these individual analyses, the transfer of information is facilitated. At the completion of each constituent analysis, intermediate results are generated for presentation and interpretation. An overview of the assembly of these components into an integrated analysis is shown in Figure 1.2.

The NUREG-1150 plant studies are fully integrated probabilistic risk assessments in the sense that calculations leading to both risk and uncertainty in risk are carried through all four components of the individual plant studies. The frequency of the initiating event, the conditional probability of the paths leading to the consequence, and the value of the consequence itself can then be combined to obtain a risk measure. Measures of uncertainty in risk are obtained by repeating the calculation just indicated many times with different values for important parameters. This provides a distribution of risk estimates that is a measure of the uncertainty in risk.

It is important to recognize that a probabilistic risk assessment is a procedure for assembling and organizing information from many sources; the models actually used in the computational framework of a probabilistic risk assessment serve to organize this information, and as a result, are rarely as detailed as most of the models that are actually used in the original generation of this information. In order to capture the uncertainties, the first three of the four constituent analyses attempt to utilize all available sources of information for each analysis component, including

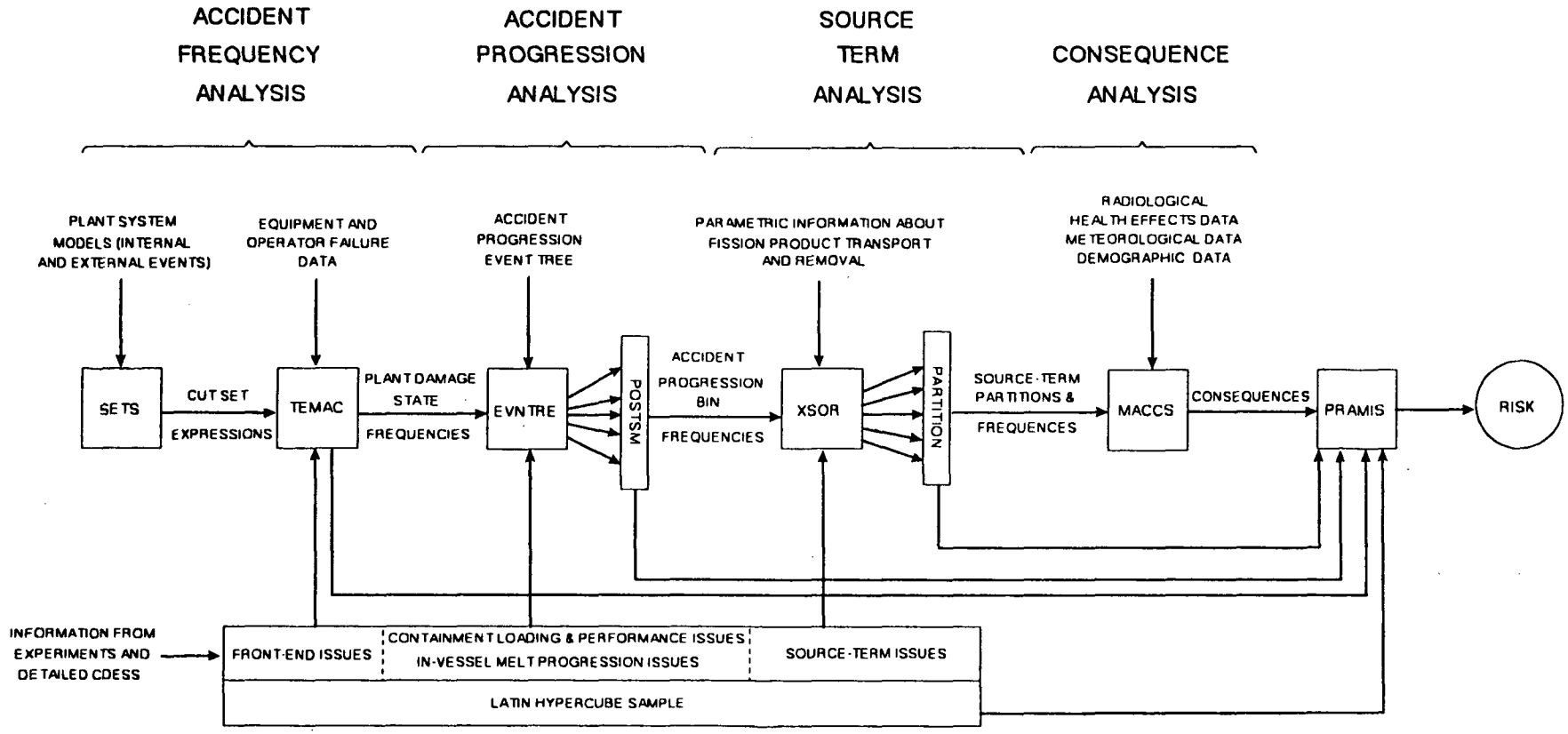


Figure 1.2. Overview of Integrated Plant Analysis in NUREG-1150.

past observational data, experimental data, mechanistic modeling and, as appropriate or necessary, expert judgment. This requires the use of relatively quick running models to assemble and manipulate the data developed for each analysis.

To facilitate both the conceptual description and the computational implementation of the NUREG-1150 analyses, a matrix representation[5,6] is used to show how the overall integrated analysis fits together and how the progression of an accident can be traced from initiating event to offsite consequences.

Accident Frequency Analysis. The accident frequency analysis uses event tree and fault tree techniques to investigate the manner in which various initiating events can lead to core damage. In initial detailed analyses, the SETS program[7] is used to combine experimental data, past observational data and modeling results into estimates of core damage frequency. The ultimate outcome of the initial accident frequency analysis for each plant is a group of minimal cut sets that lead to core damage. Detailed descriptions of the systems analyses for the individual plants are available elsewhere.[8,9,10,11,12] For the final integrated NUREG-1150 analysis for each plant, the group of risk-significant minimal cut sets is used as the systems model. In the integrated analysis, the TEMAC program[13,14] is used to evaluate the minimal cut sets. The minimal cut sets themselves are grouped into PDSs, where all minimal cut sets in a PDS provide a similar set of conditions for the subsequent accident progression analysis. Thus, the PDSs form the interface between the accident frequency analysis and the accident progression analysis.

With use of the transition matrix notation, the accident progression analysis may be represented by

$$\mathbf{fPDS} = \mathbf{fIE}\ \mathbf{P(IE \rightarrow PDS)}, \qquad \text{(Eq. 1.1)}$$

where **fPDS** is the vector of frequencies for the PDSs, **fIE** is the vector of frequencies for the initiating events, and **P(IE→PDS)** is the matrix of transition probabilities from initiating events to the PDSs. Specifically:

$\mathbf{fIE} = [fIE_1, \ldots, fIE_{nIE}]$,
fIE_i = frequency (yr^{-1}) for initiating event i,
nIE = number of initiating events,
$\mathbf{fPDS} = [fPDS_1, \ldots, fPDS_{nPDS}]$,
$fPDS_j$ = frequency (yr^{-1}) for plant damage state j,
nPDS = number of PDSs,

$$\mathbf{P(IE \rightarrow PDS)} = \begin{bmatrix} pPDS_{11} & \cdots & pPDS_{1,nPDS} \\ \vdots & & \vdots \\ pPDS_{nIE,1} & \cdots & pPDS_{nIE,nPDS} \end{bmatrix}$$

and

$pPDS_{ij}$ = probability that initiating event i will lead to plant damage state j.

The elements $pPDS_{ij}$ of **P(IE→PDS)** are conditional probabilities: given that initiating event i has occurred, $pPDS_{ij}$ is the probability that plant damage state j will also occur. The elements of **P(IE→PDS)** are determined by the analysis of the minimal cut sets with the TEMAC program. In turn, both the cut sets and the data used in their analysis come from earlier studies that draw on many sources of information. Thus, although the elements $pPDS_{ij}$ of **P(IE→PDS)** are represented as though they are single numbers, in practice these elements are functions of the many sources of information that went into the accident frequency analysis.

Accident Progression Analysis. The accident progression analysis uses event tree techniques to determine the possible ways in which an accident might evolve from each PDS. Specifically, a single event tree is developed for each plant and evaluated with the EVNTRE computer program.[15] The definition of each PDS provides enough information to define the initial conditions for the accident progression event tree (APET) analysis. Due to the large number of questions in the Surry APET and the fact that many of these questions have more than two outcomes, there are far too many paths through each tree to permit their individual consideration in subsequent source term and consequence analysis. Therefore, the paths through the trees are grouped into accident progression bins, where each bin is a group of paths through the event tree that define a similar set of conditions for source term analysis. The properties of each accident progression bin define the initial conditions for the estimation of the source term.

Past observations, experimental data, mechanistic code calculations, and expert judgment were used in the development and parameterization of the model for accident progression that is embodied in the APET. The transition matrix representation for the accident progression analysis is

$$\mathbf{fAPB} = \mathbf{fPDS}\ \mathbf{P(PDS \rightarrow APB)}, \qquad \text{(Eq. 1.2)}$$

where **fPDS** is the vector of frequencies for the PDSs defined in Eq. 1.1, **fAPB** is the vector of frequencies for the accident progression bins, and **P(PDS→APB)** is the matrix of transition probabilities from PDSs to accident progression bins. Specifically:

$$\mathbf{fAPB} = [fAPB_1, \ldots, fAPB_{nAPB}],$$

$fAPB_k$ = frequency (yr^{-1}) for accident progression bin k,

nAPB = number of accident progression bins,

$$\mathbf{P(PDS \rightarrow APB)} = \begin{bmatrix} pAPB_{11} & \cdots & pAPB_{1,nAPB} \\ \vdots & & \vdots \\ pAPB_{nPDS,1} & \cdots & pAPB_{nPDS,nAPB} \end{bmatrix}$$

and

$pAPB_{jk}$ = probability that plant damage state j will lead to accident progression bin k.

The properties of **fPDS** are given in conjunction with Eq. 1.1. The elements $pAPB_{jk}$ of **P(PDS→APB)** are determined in the accident progression analysis by evaluating the APET with EVNTRE for each PDS group.

Source Term Analysis. The source terms are calculated for each APB with a non-zero conditional probability by a fast-running parametric computer code entitled SURSOR. SURSOR is not a detailed mechanistic model and makes no pretense of modeling the fission product transport, physics, and chemistry from first principles. Instead, SURSOR integrates the results of many detailed codes and the conclusions of many experts. The experts, in turn, based many of their conclusions on the results of calculations with codes such as the Source Term Code Package,[16,17] MELCOR, and MAAP. Most of the parameters utilized calculating the fission product release fractions in SURSOR are sampled from distributions provided by an expert panel. Because of the large number of APBs, use of fast-executing code like SURSOR is absolutely necessary.

The number of APBs for which source terms are calculated is so large that it was not practical to perform a consequence calculation for every source term. That is, the consequence code, MACCS,[18,19,20] required so much computer time to calculate the consequences of a source term that the source terms had to be combined into source term groups. Each source term group is a collection of source terms that result in similar consequences. The frequency of the source term group is the sum of the frequencies of all the APBs which make up the group. The process of determining which APBs go to which source term group is denoted partitioning. It involves considering the potential of each source term group to cause early fatalities and latent cancer fatalities. Partitioning is a complex process; it is discussed in detail in Volume 1 of this report and in the User's Guide for the PARTITION Program.[21]

The transition matrix representation of the source term calculation and the grouping process is

$$\mathbf{fSTG} = \mathbf{fAPB}\ \mathbf{P(APB \rightarrow STG)} \qquad \text{(Eq. 1.3)}$$

where **fAPB** is the vector of frequencies for the accident progression bins defined in Eq. 1.2, **fSTG** is the vector of frequencies for the source term groups, and **P(APB→STG)** is the matrix of transition probabilities from accident progression bins to source term groups. Specifically,

$\mathbf{fSTG} = [fSTG_1, \ldots, fSTG_{nSTG}]$,

$fSTG_\ell$ = frequency (yr^{-1}) for source term group ℓ,

nSTG = number of source term groups,

$$\mathbf{P(APB \rightarrow STG)} = \begin{bmatrix} pSTG_{11} & \cdots & pSTG_{1,nSTG} \\ \vdots & & \vdots \\ pSTG_{nAPB,1} & \cdots & pSTG_{nAPB,nSTG} \end{bmatrix}$$

and

$pSTG_{k\ell}$ = probability that accident progression bin k will be assigned to source term group ℓ.

$$= \begin{cases} 1 & \text{if accident progression bin k is assigned to source term group } \ell \\ 0 & \text{otherwise.} \end{cases}$$

The properties of **fAPB** are given in conjunction with Eq. 1.2. Note that the source terms themselves do not appear in Eq. 1.4. The source terms are used only to assign an APB to a source term group. The consequences for each APB are computed from the average source term for the group to which the APB has been assigned.

<u>Consequence Analysis</u>. The consequence analysis is performed for each source term group by the MACCS program. The results for each source term group include estimates for both mean consequences and distributions of consequences. When these consequence results are combined with the frequencies for the source term groups, overall measures of risk are obtained. The consequence analysis differs from the preceding three constituent analyses in that uncertainties are not explicitly treated in the consequence analysis. That is, important values and parameters are determined from distributions by a sampling process in the accident frequency analysis, the accident progression analysis, and the source term analysis. This is not the case for the consequences in the analyses performed for NUREG-1150.

In the transition matrix notation, the risk may be expressed by

$$\mathbf{rC} = \mathbf{fSTG\ cSTG} \qquad \text{(Eq. 1.4)}$$

where **fSTG** is the vector of frequencies for the source term groups defined in Eq. 1.3, **rC** is the vector of risk measures, and **cSTG** is the matrix of mean consequence measures conditional on the occurrence of individual source term groups. Specifically,

$\mathbf{rC}$ = $[rC_1, \ldots, rC_{nC}]$,

rC_m = risk (consequence/yr) for consequence measure m,

nC = number of consequence measures,

$$\mathbf{cSTG} = \begin{bmatrix} cSTG_{11} & \cdots & cSTG_{1,nC} \\ \vdots & & \vdots \\ cSTG_{nSTG,1} & \cdots & cSTG_{nSTG,nC} \end{bmatrix}$$

and

$cSTG_{\ell m}$ = mean value (over weather) of consequence measure m conditional on the occurrence of source term group ℓ.

The properties of **fSTG** are given in conjunction with Eq. 1.3. The elements $cSTG_{\ell m}$ of **cSTG** are determined from consequence calculations with MACCS for individual source term groups.

<u>Computation of Risk</u>. Equations 1.1 through 1.4 can be combined to obtain the following expression for risk:

$$\mathbf{rC = fIE\ P(IE \rightarrow PDS)\ P(PDS \rightarrow APB)\ P(APB \rightarrow STG)\ cSTG.} \qquad \text{Eq.(1.5)}$$

This equation shows how each of the constituent analyses enters into the calculation of risk, starting from the frequencies of the initiating events and ending with the calculation of consequences. Evaluation of the expression in Eq. 1.5 is performed with the PRAMIS[22] and RISQUE codes.

The description of the complete risk calculation so far has focused on the computation of mean risk (consequences/year) because doing so makes the overall structure of the NUREG-1150 PRAs more easy to comprehend. The mean risk results are derived from the frequency of the initiating events, the conditional probabilities of the many ways that each accident may evolve and the probability of occurrence for each type of weather sequence at the time of an accident. The mean risk, then, is a summary risk measure.

More information is conveyed when distributions for consequence values are displayed. The form typically used for this is the complementary cumulative distribution fuction (CCDF). CCDFs are defined by pairs of values (c,f), where c is a consequence value and the f is the frequency with which c is exceeded. Figure 1.3 is an example of a CCDF. The construction of CCDFs is described in Volume 1 of this report. Each mean risk result is the outcome from reducing a curve of the form shown in Figure 1.3 to a single value. While the mean risk results are often useful for summaries or high-level comparisons, the CCDF is the more basic measure of risk because it displays the relationship between the size of the consequence and frequency exceedance. The nature of this relationship, i.e., that high consequence events are much less likely than low consequence events is lost when mean risk results alone are reported. This report utilizes both mean risk and CCDFs to report the risk results.

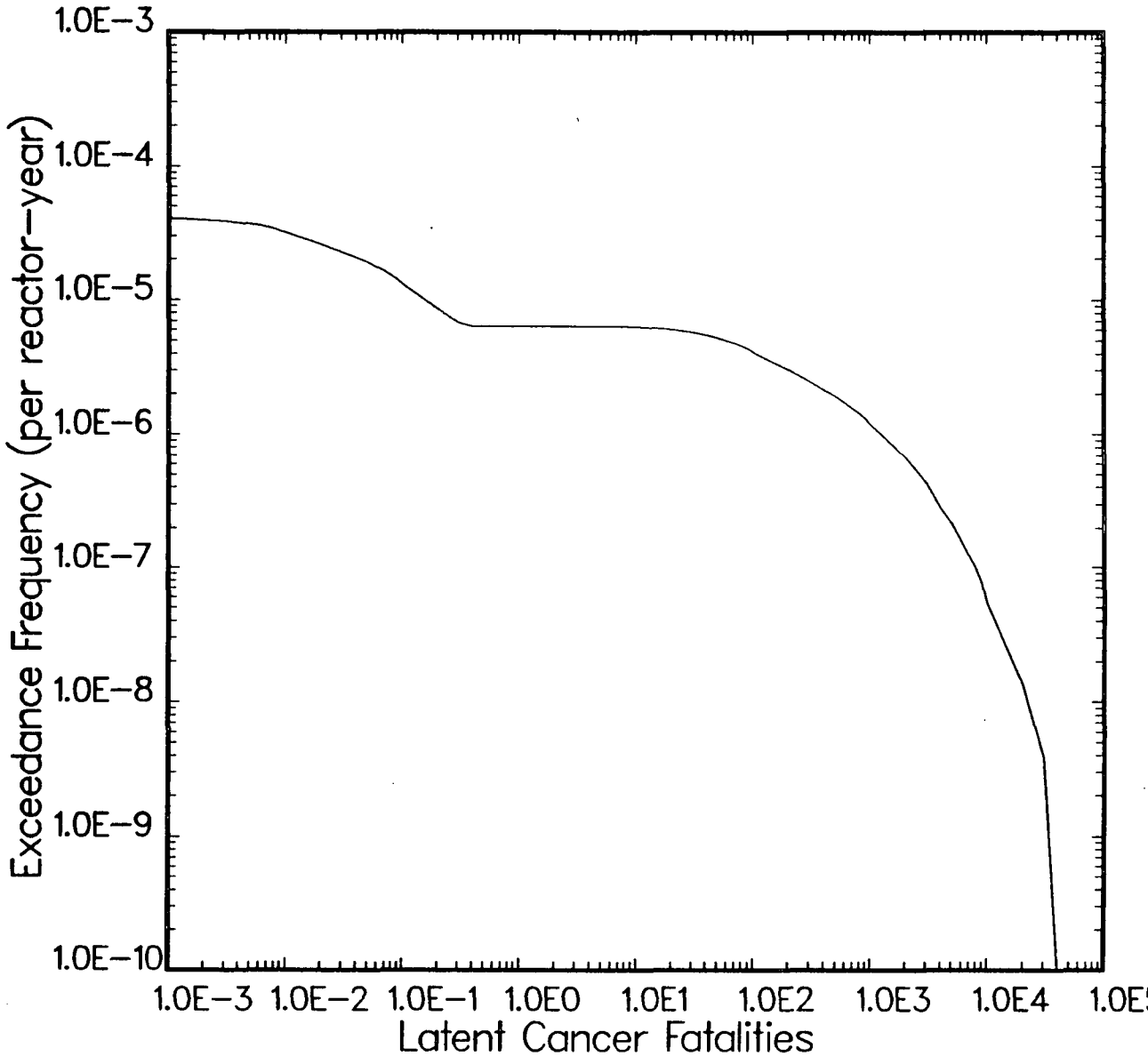


Figure 1.3. Example Risk CCDF.

Propagation of Uncertainty through the Analysis. The integrated NUREG-1150 analyses use Monte Carlo procedures as a basis for both uncertainty and the sensitivity analysis. This approach utilizes a sequence:

$$X_1,\ X_2,\ \ldots,\ X_{nV} \qquad \text{(Eq. 1.6)}$$

of potentially important variables, where nV is the number of variables selected for consideration. Most of these variables were considered by a panel of experts representing the NRC and its contractors, the academic world, and the nuclear industry. For each variable treated in this manner, two to six experts considered all the information at their disposal and provided a distribution for the variable. Formal decision analysis techniques[23] (also in Vol. 2 of this report) were used to obtain and record each expert's conclusions and to aggregate the assessments of the individual panel members into summary distribution for the variable. Thus, a sequence of distributions

$$D_1,\ D_2,\ \ldots,\ D_{nV}, \qquad \text{(Eq. 1.7)}$$

is obtained, where D_i is the distribution assigned to variable X_i.

From these distributions, a stratified Monte Carlo technique, Latin Hypercube Sampling,[24,25] is used to obtain the variable values that will actually be propagated through the integrated analysis. The result of generating a sample from the variables in Eq. 1.6 with the distributions in Eq. 1.7 is a sequence

$$\mathbf{S}_i = [X_{i1},\ X_{i2},\ \ldots,\ X_{i,nV}],\ i = 1,\ 2,\ \ldots,\ nLHS, \qquad \text{(Eq. 1.8)}$$

of sample elements, where X_{ij} is the value for variable X_j in sample element i and nLHS is the number of elements in the sample. The expression in Eq. 1.5 is then determined for each element of the sample. This creates a sequence of results of the form

$$\mathbf{rC}_i = \mathbf{fIE}_i\ \mathbf{P}_i\mathbf{(IE{\rightarrow}PDS)}\ \mathbf{P}_i\mathbf{(PDS{\rightarrow}APB)}\ \mathbf{P}_i\mathbf{(APB{\rightarrow}STG)}\ \mathbf{cSTG}, \qquad \text{(Eq. 1.9)}$$

where the subscript i is used to denote the evaluation of the expression in Eq. 1.5 with the ith sample element in Eq. 1.8. The uncertainty and sensitivity analyses in NUREG-1150 are based on the calculations summarized in Eq. 1.9. Since **P(IE→PDS)**, **P(PDS→APB)** and **P(APB→STG)** are based on results obtained with TEMAC, EVNTRE and SURSOR, determination of the expression in Eq. 1.9 requires a separate evaluation of the cut sets, the APET, and the source term model for each element or observation in the sample. The matrix **cSTG** in Eq. 1.9 is not subscripted because the NUREG-1150 analyses do not include consequence modeling uncertainty other than the stochastic variability due to weather conditions.

1.5 Organization of this Report

This report is published in seven volumes as described briefly in the Foreword. The first volume of NUREG/CR-4551 describes the methods used in the accident progression analysis, the source term analysis, and the consequence analysis, in addition to presenting the methods used to

assemble the results of these constituent analyses to determine risk and the uncertainty in risk. The second volume describes the results of convening expert panels to determine distributions for the variables thought to be the most important contributors to uncertainty in risk. Panels were formed to consider in-vessel processes, containment structural response, molten core-containment interactions, and source term issues. In addition to documenting the results of these panels for about 30 important parameters, Volume 2 includes supporting material used by these panels and presents the results of distributions that were determined by other means.

Volumes 3 through 6 present the results of the accident progression analysis, the source term analysis, and the consequence analysis, and the combined risk results for Surry, Peach Bottom, Sequoyah, and Grand Gulf, respectively. These analyses were performed by SNL. Volume 7 presents analogous results for Zion. The Zion analyses were performed by BNL.

This volume of NUREG/CR-4551, Volume 3, presents risk and constituent analysis results for Unit 1 of the Surry Power Station, operated by the Virginia Electric Power Company in southeastern Virginia. Part 1 of this volume presents the analysis and the results is some detail; Part 2 consists of appendices which contain further detail. Following a summary and an introduction, Chapter 2 of this volume presents the results of the accident progression analysis for internal initiating event, fires, and earthquakes. Chapter 3 presents the result of the source term analysis, and Chapter 4 gives the result of the consequence analysis. Chapter 5 summarizes the risk results, including the contributors to uncertainty in risk, for Surry, and Chapter 6 contains the insights and conclusions of the complete analysis.

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2. ANALYSIS OF THE ACCIDENT PROGRESSION

This chapter describes the analysis of the progression of the accident, starting from the uncovering of the top of active fuel (UTAF) and continuing for about 24 h or until the bulk of the radioactive material going to be released has been released. As the last barrier to the release of the fission products to the environment, the response of the containment to the stresses placed upon it by the degradation of the core and failure of the reactor vessel is an important part of this analysis. The main tool for performing the accident progression analysis is a large and complex event tree. The methods used in the accident progression analysis are presented in Volume 1, Part 1. The accident progression analysis starts with information received from the accident frequency analysis: frequencies and definitions of the plant damage states (PDSs). The results of the accident progression analysis are passed to the source term analysis and the risk analysis.

Section 2.1 reviews the plant features important to the accident progression analysis and the containment response. Section 2.2 summarizes the results of the accident frequency analysis, defines the PDSs, and presents their frequencies. Section 2.3 contains a brief description of the accident progression event tree (APET). A detailed description of the APET is contained in Appendix A. Section 2.4 describes the way in which the results of the evaluation of the APET are grouped together into bins. This grouping is necessary to reduce the information resulting from the APET evaluation to a manageable amount while still preserving the information required by the source term analysis. Section 2.5 presents the results of the accident progression analysis for internal initiators, fires, and earthquakes.

2.1 Surry Features Important to Accident Progression

The entire Surry plant was briefly described in Section 1.2 of this volume. This section provides more detail on the features important to the progression of a core degradation accident and the response of the containment to the stresses placed upon it. These features are:

- The containment structure;
- The maintenance of the containment atmosphere below ambient pressure when the plant is operating;
- The containment heat removal system;
- The service water canal; and
- The sump and cavity arrangement.

2.1.1 The Surry Containment Structure

The Surry containment is constructed of reinforced concrete; it has the shape of a cylinder topped by a hemispherical dome. The cylindrical portion of the containment sits on a basemat that is 10 ft thick. The wall of the cylinder is about 4.3 ft thick. The dome is about 2.6 ft thick.

The inner surface of the containment is a liner of welded steel plate, which forms the pressure boundary. Figure 1.1 shows a section through the Surry containment. The volume is 1,800,000 ft^3, and the design pressure is 45 psig. Due to conservatisms in design and construction, most estimates of the failure pressure are between two and three times the design pressure. The mean of the aggregate distribution for the failure pressure of the Surry containment provided by the Structural Response Expert Panel is 126 psig. The size and strength of the Surry containment mean that it can absorb a great deal of energy without failing.

2.1.2 Subatmospheric Containment During Operation

When the reactor is operating, the pressure inside the containment is kept at about 10 psia, about 5 psia below ambient atmospheric pressure. The implication of this is that it makes the probability of pre-existing leaks negligible. The vacuum pumps that keep the containment atmosphere below ambient pressure are limited in their capacity, so an open hatch or airlock would be quickly discovered even though the opening has an area of only a fraction of a square foot. The vacuum pumps would be unable to keep the pressure at 10 psia. The Technical Specifications prevent plant operation much above this pressure, so the rise in containment pressure would force the plant to be shut down until 10 psia could be maintained in the containment. The size of hole which would go unnoticed is so small that it may be ignored. The fact that the containment is maintained below ambient pressure also means that very few lines are normally open into the containment during normal operation; thus, the probability of isolation failure is low.

2.1.3 The Containment Heat Removal System

During normal operations, containment cooling is by fan coolers. These are not qualified for operation during severe accidents, and in any event, if the contents of the refueling water storage tank (RWST) are pumped into the containment, the fan coolers will be partially submerged. Further, the service water flow to the fan coolers is shut off when the containment is isolated. For these reasons, the fan coolers are not considered a viable means of containment heat removal in the Surry accident progression analysis. Emergency containment heat removal at Surry is only by the spray systems. The containment spray injection system has two trains. The pumps take suction from the RWST, and it can function only in the injection mode. There are two containment spray recirculation systems, each with two trains. Each of the four recirculation spray trains is completely separate from the other recirculation spray trains and from the containment spray injection system. Each containment spray recirculation train includes a heat exchanger that is cooled by the service water system. All four spray recirculation pumps take suction directly from the containment sump. One system has its pumps located inside the containment and the other has its pumps located outside the containment. The diversity and redundancy of the spray systems means that there are no significant accident sequences at Surry where the sprays are failed by hardware faults. If there is electric power available, and water in the sump, containment heat removal by the recirculation sprays is always available in the accident scenarios of interest.

2.1.4 Service Water Canal

Service water for cooling condensers, pumps, and heat exchangers is obtained by gravity flow from a service water canal which is elevated above the levels in the plants on which the pumps and condenser are located. This canal is continuously supplied with river water by electric pumps. If ac power is lost, the service water canal will drain in approximately 30 minutes. While the service water flow to many pumps can be shut off from the control room, the large lines to the condensers can be isolated only by manually closing a number of large valves outside the plant. The accident frequency analysts estimated that during a station blackout (SBO), these valves would not be closed in time to prevent the canal from draining. The implication of this unique service water arrangement is that when ac power is restored to the plant, emergency coolant injection cannot be restored to the core at once. The pumps are cooled by the service water system, and it takes on the order of 20 to 30 minutes to refill the canal and establish pump cooling. This means that to restore core cooling, power has to be restored about half an hour earlier at Surry than it would in a plant without a gravity-fed service water system.

2.1.5 Sump and Cavity Arrangement

There is no connection between the sump and the reactor cavity at a low elevation in the Surry containment. That is, the sump can be full when the reactor cavity is dry and the cavity can be full when the sump is dry. If the cavity is dry, the water in the sump is unavailable to mitigate the effects of vessel breach (VB) or to cool the core after VB. The only effective way to fill the reactor cavity is for the containment sprays to operate. The water falling inside the shield wall and in the refueling basin will drain into the reactor cavity. Overflow from the reactor cavity will drain to the sump. There is no overflow from the sump to the cavity. The sump is so large that, even with the entire RCS and the contents of the RWST in the sump, there is no overflow into the cavity. Because the sump and the cavity are not connected, the cavity is dry at VB in a number of accident scenarios at Surry in which it would not be dry if the sump and the cavity were connected at a low elevation. Whether the cavity is dry or contains water at VB has implications for the magnitude of the containment pressure rise at VB and whether core-concrete interaction (CCI) occurs.

The design of the cavity and the adjacent in-core instrumentation room (ICIR) is such that two containment failure modes important in some other plants are negligible at Surry. The seal table forms part of the ceiling of the ICIR. In some plants, the seal table is located between the crane wall and the containment wall. If high-pressure melt ejection (HPME) accompanies VB, it may fail the seal table and allow hot core debris to accumulate in the vicinity of the seal table. At Surry, the seal table is inside the crane wall, so this material cannot attack the containment pressure boundary. Were the seal table outside the crane wall, this material could attack and fail the steel liner. The other negligible failure mechanism at Surry is a direct impulse resulting from an ex-vessel steam explosions (EVSEs) at VB. In plants which have a direct water pathway from the reactor cavity to the containment wall, it is possible that the impulse from an EVSE could be transmitted in water to the containment wall and fail it. There is no such pathway at Surry.

2.2 Interface with the Core Damage Frequency Analysis

2.2.1 Definition of Plant Damage States

Information about the many different accidents that lead to core damage is passed from the accident frequency analysis to the accident progression analysis by means of PDSs. Because most of the accident sequences identified in the core damage frequency analysis will have accident progressions similar to other sequences, these sequences have been grouped together into PDSs. All the sequences in one PDS should behave similarly in the period following the UTAF. For the pressurized water reactors (PWRs), the PDS is denoted by a seven-letter indicator that defines seven characteristics that largely determine the initial and boundary conditions of the accident progression. More information about the accident sequences may be found in NUREG/CR-4550, Vol. 3, Part 1. The methods used in the accident frequency analysis are presented in NUREG/CR-4550, Volume 1.

Table 2.2-1 lists the seven characteristics used to define the PDSs for PWRs. Under each characteristic are given the possible values or attributes for that characteristic. For example, the first characteristic denotes the condition of the reactor cooling system (RCS) pressure boundary at the time core damage begins (assumed to be approximately when the top of active fuel [TAF] is uncovered). Table 2.2-1 shows that there are eight possibilities for this characteristic: T for transient or no break; A, S_1, S_2, and S_3 for the four sizes of break which do not bypass the containment; G and H for steam generator tube ruptures (SGTRs), and V for the large bypass pipe failure.

The first characteristic in the PDS is not necessarily an indication of the initiating event. It is an indicator of the RCS integrity at the time the core uncovers. That is, if the initiating event is a transient, say loss of offsite power (LOSP), but a reactor coolant pump (RCP) seal failure occurs before the onset of core degradation, then there is a small hole in the RCS pressure boundary at the time that core damage begins, which is the time the accident progression analysis begins. The PDS for this accident would begin with S_3 to reflect the fact that there is a small hole in the RCS when this analysis starts. It is the plant's condition at the onset of core damage that is important for the accident progression analysis, not what the original initiator may have been.

Thus, the first character in the PDS indicates the condition of the RCS at the onset of core degradation. As a holdover from the use of this character to indicate the original initiator, "T" is used to indicate no break (transient). An S_2 break is a break equivalent to a double-ended guillotine break of a pipe between 0.5 and 2 in. in diameter; an S_3 break is less a break of a pipe than 0.5 in. in diameter. An A break is a break of a pipe greater than 6 in. in diameter and an S_1 break is a break of a pipe between 2 and 6 in. in diameter. Both A and S_1 breaks are considered together in the accident progression analysis since both result in low pressure in the RCS. SGTRs are S_3 size. Almost all pump seal failures result in a leak area equivalent to an S_3 break. A stuck-open power-operated relief valve (PORV) is equivalent to an S_2 break. Event V is such

Table 2.2-1
PWR Plant Damage State Characteristics

1. **Status of RCS at Onset of Core Damage**
   T = no break (transient)
   A = large break in the RCS pressure boundary
   S_1 = medium break in the RCS pressure boundary
   S_2 = small break in the RCS pressure boundary
   S_3 = very small break in the RCS pressure boundary
   G = steam generator tube rupture (SGTR)
   H = SGTR with loss of secondary system integrity
   V = large break in an interfacing system

2. **Status of ECCS**
   B = operated in injection and now operating in recirculation
   I = operated in injection only
   R = not operating, but recoverable
   N = not operating, not recoverable
   L = LPIS available in both injection and recirculation modes

3. **Containment Heat Removal**
   Y = operating or operable if/when initiated
   R = not operating, but recoverable
   N = never operated, not recoverable
   S = sprays operable, but no CHR (no SW to HXs)

4. **AC Power**
   Y = available
   P = partially available
   R = not available, but recoverable
   N = not available, not recoverable

5. **Contents of RWST**
   Y = injected into containment
   R = not injected, but could be injected if power recovered
   N = not injected, cannot be injected in the future
   U = injected, but confined to upper compartment

6. **Heat Removal from the Steam Generators**
   X = at least one AFWS operating, SGs not depressurized
   Y = at least one AFWS operating, SGs depressurized
   S = S-AFWS failed at beginning, E-AFWS recoverable
   C = S-AFWS operated until battery depletion, E-AFWS recoverable, SGs not depressurized
   D = S-AFWS operated until battery depletion, E-AFWS recoverable, SGs depressurized
   N = no AFWS operating, no AFWS recoverable

7. **Cooling for Reactor Coolant Pump Seals**
   Y = operating
   R = not operating, but recoverable
   N = not operating, not recoverable

a well known and unique type of accident that the subsequent six characteristics are usually not written out.

The second characteristic concerns the status of the emergency core cooling system (ECCS). Recoverable means that the ECCS will operate if or when electric power is recovered. The value "L" for the second characteristic is used when the low-pressure injection system (LPIS) is available to inject when the core is uncovered but cannot because the RCS pressure is too high. "L" implies that HPIS is failed.

The letter "L" is chosen for the second characteristic, for example, for the S_2D_1 sequence. This is a small break with failure of the high-pressure injection (HPI) and it is placed in PDS S_2LYY-YYN. The low-pressure injection (LPI) pumps are operable, so if the operators recognize the situation and depressurize to allow injection by the LPIS there is no core damage. The only portion counted toward core damage is the small (about 2%) fraction where the operator does not recognize the situation and does not depressurize the primary system.

The use of the letter "B" for the second characteristic indicates that both the high-pressure injection system (HPIS) and the LPIS are operating but are unable to inject because the RCS pressure is too high. In sequence T_2LP, PDS TLYY-YNY, for example, the operators cannot open the PORVs and the auxiliary feedwater system (AFW) has failed. Thus bleed and feed is not possible using the HPIS, nor can the operators depressurize the system to use the LPIS. As in S_2LYY-YYN, a temperature-induced failure of the RCS pressure boundary or the sticking open of the PORVs or the SRVs will allow injection when the RCS pressure falls to the appropriate level.

The third characteristic concerns the status of containment heat removal (CHR). Recoverable means that the CHR systems will operate if or when electric power is recovered. The value "S" for the third characteristic is used when the sprays are available, but that there is no heat removal from the spray heat exchangers. Even if there is no heat removal, it is important to know if the sprays are operating because they reduce the aerosol concentrations in the containment atmosphere.

The fourth characteristic concerns the status of ac power. Recoverable means that power can be restored within the timeframe of the accident, roughly 24 h. Except for some seismic events and fire in the emergency switchgear room, electric power in the plant in general is always considered to be recoverable in those PDSs where it is not available. However, there are cases where an earthquake has failed motor control centers or switchgear although power is available at some levels in the plant, i.e., there is no SBO. The letter "P" is used to denote this situation. At the levels of interest (pumps and valves) this type of power loss is considered to be not recoverable.

The fifth characteristic concerns the status of the water in the RWST. It is important for the accident progression to know if the water from the RWST is inside the containment where it fills the sumps and the reactor cavity. The value "N" for this characteristic is used when some failure prevents the injection of the RWST, such as a seismic failure of the tank itself, or when the water from the RWST has been injected into the RCS but

has ended up outside the containment. This occurs in event V when the water is injected into the RCS but flows out through the break into the auxiliary building, and thus is not available inside the containment. The attribute "U" applies to PWRs with ice condenser containments and is not applicable to Surry.

The sixth characteristic concerns the heat removal from the steam generators (SGs). There are six possible values for this characteristic since the AFWS may operate for some time in a blackout accident, and the secondary system may or may not be depressurized by the operators. The following abbreviations are used in describing the sixth characteristic in Table 2.2-1:

E-AFWS = Electric-motor-driven auxiliary feedwater system; and
S-AFWS = Steam-turbine-driven auxiliary feedwater system.

The seventh characteristic concerns cooling for the reactor coolant pump (RCP) seals. Recoverable means that cooling will become available if or when electric power is recovered.

2.2.2 PDS Frequencies

This subsection presents the core damage frequencies for the PDSs and PDS groups. The accident frequency analyses for internal initiators, fires, and earthquakes were performed with more observations per sample than were the accident progression analysis and the subsequent analyses. As the samples were different in the random seed as well as the number of observations, the core damage frequencies differ slightly as is to be expected. This subsection lists these differences to facilitate the transition from the accident frequency analysis to the accident progression analysis. The internal initiators, fire initiators, and seismic initiators are considered in turn.

2.2.2.1 PDS Frequencies for Internal Initiators. Table 2.2-2 lists PDSs for Surry as placed into seven internally initiated PDS groups and gives their core damage frequencies from the sample of 200 observations used for the integrated risk analysis. The 25 internal initiated PDSs are all those which had mean frequencies above 1.0E-7/R-yr in the sample of 1000 observations used for the stand-alone accident frequency analysis. These 25 PDSs account for over 99% of the total mean core damage frequency (TMCDF) of 4.06E-5/yr. One PDS with a mean core damage frequency (MCDF) less than 1.0E-7/R-yr, GLYY-YXY in the ATWS PDS group, is listed in Table 2.2-2. When the list of cut sets and PDSs was finalized, this PDS had a MCDF slightly above 1.0E-7/R-yr. Last minute changes to the cut sets, the reduction in the sample size from the 1000 observations used for the stand-alone accident frequency analysis to 200 observations used for the integrated risk analysis, and the selection of a new seed for the sample selection changed all of the PDS frequencies somewhat. The MCDF for GLYY-YXY dropped to slightly below 1.0E-7/R-yr, but it was retained in the set of PDSs used in the integrated risk analysis.

Table 2.2-2
PDSs for Surry Internal Initiators

Group Number	Group Name	Mean CD Freq.(1) (1/R-yr)	Group % TMCD Freq.	PDSs	Mean CD Freq.(1) (1/R-yr)	%TMCD Freq.
1	Slow Blackout	2.2E-5	55.4	TRRR-RDY	1.0E-5	24.7
				S_3RRR-RDR	8.4E-6	20.7
				S_2RRR-RCR	2.0E-6	4.8
				TRRR-RDR	1.1E-6	2.7
				S_2RRR-RDR	7.0E-7	1.7
				S_3RRR-RCR	2.8E-7	0.7
2	LOCAs	6.1E-6	15.0	S_1IYY-YYN	1.7E-6	4.2
				S_1LYY-YYN	9.3E-7	2.3
				AIYY-YYN	8.5E-7	2.1
				ALYY-YYY	6.7E-7	1.6
				S_1NYY-YYN	6.1E-7	1.5
				S_3LYY-YYN	6.0E-7	1.5
				S_2LYY-YYN	4.5E-7	1.1
				ANYY-YYN	2.7E-7	0.7
3	Fast Blackout	5.4E-6	13.4	TRRR-RSR	5.4E-6	13.4
4	Event V	1.6E-6	4.1	V	1.6E-6	4.1
5	Transients	1.8E-6	4.3	TBYY-YNY	1.0E-6	2.6
				TLYY-YNY	7.1E-7	1.8
6	ATWS	1.4E-6	3.5	S_3NYY-YXN	7.5E-7	1.8
				TLYY-YXY	5.7E-7	1.4
				GLYY-YXY	9.0E-8	0.2
7	SGTRs	1.8E-6	4.4	HINY-NXY	1.4E-6	3.4
				GLYY-YXY	1.8E-7	0.4
				HINY-YXY	1.3E-7	0.3
				GLYY-YNY	1.0E-7	0.3
	Total	4.1E-5		Internal Initiators		

(1) Based on the sample of 200 observations used in the risk analysis.

Note that while Table 2.2-2 reports frequencies for the 25 PDSs, the accident frequencies actually used in the integrated risk analysis were those of the seven PDS groups. That is, the accident progression analysis was performed for each of the seven PDS groups individually. The 25 PDSs were used in determining the branching for some of the initialization questions in the APET, but the APET was not evaluated for each PDS separately.

The accident frequency analysis reports the PDS frequencies based on a sample size of 1000 (see Section 5 of NUREG/CR-4550, Vol. 3, Part 1). When considered as a separate entity, a great many variables could be sampled in the accident frequency analysis, and a sample size of 1000 was used. A sample this large was not feasible for the integrated risk analysis. Based on the results from the 1000-observation sample, those variables which were not important to the uncertainty in the core damage frequency were eliminated from the sampling, and the cut sets were re-evaluated using 200 observations for the integrated risk analysis. As some variation from sample-to-sample is observed even when the sample size and the variables sampled remain the same, there are variations between the 1000-observation sample used for the stand-alone accident frequency analysis and the 200-observation sample used for the integrated risk analysis. These differences are summarized in Table 2.2-3.

For each PDS group, the first line of Table 2.2-3 contains the 5th percentile, median, mean, and 95th percentile core damage frequencies for the 1000-observation sample used in the stand-alone accident frequency analysis. These values are taken from Table 5-5 of NUREG/CR-4550, Volume 3, Part 1. Samples containing 200 observations are used for the integrated risk analysis at Surry. The 5th percentile, median, mean, and 95th percentile core damage frequencies for first sample are shown on the second line of Table 2.2-3 for each PDS group. For Surry only, a second sample was drawn and run all the way through to risk. The same statistical measures are shown on the third line for this second sample for each PDS group.

The differences between distributions for core damage frequency for the three samples are within the statistical variation to be expected. Note that the fractional contributions of each PDS group to the MCDF in Table 2.2-2 are slightly different from those In Table 2.2-3. This is due to the fact that the group fractional contributions in Table 2.2-2 are based on the first sample of 200 observations, and the contributions in Table 2.2-3 are based on the sample of 1000 observations.

After all the risk calculations were completed and the results reported, it was determined that the cut sets used in the stand-alone accident frequency analysis were not exactly those used in the integrated risk analysis. A last-minute change to the cut sets did not get made for the cut sets used for the integrated risk analysis. The result is that the frequency for PDS TRRR-RSR, the only PDS in internal initiators Group 3, Fast SBO, was about 10% too low. Following Table 2.2-3 are listed the 5th percentile, median, mean, and 95th percentile core damage frequencies for TRRR-RSR for the 1000-observation sample used in the stand-alone accident frequency analysis, the 200-observation sample used in the risk analysis, and the 200 observation sample based on the revised cut sets used in the 1000-observation sample. The differences were not great enough to warrant rerunning the entire analysis.

Table 2.2-3
Comparison of PDS Core Damage Frequencies
for Surry Internal Initiators

PDSs	LHS Sample Size(1)	Core Damage Frequency (1/R-yr) 5%	Median	Mean	95%	% Mean TCD Freq.(2)
1	1000	6.1E-07	8.2E-06	2.2E-05	9.5E-05	54.6
Slow SBO	200	1.6E-06	1.1E-05	2.2E-05	6.4E-05	
	200 S2	1.4E-06	1.0E-05	2.4E-05	7.0E-05	
2	1000	1.2E-06	3.8E-06	6.0E-06	1.6E-05	14.7
LOCAs	200	1.2E-06	3.9E-06	6.1E-06	2.0E-05	
	200 S2	1.2E-06	3.7E-06	5.9E-06	1.8E-05	
3	1000	1.1E-07	1.7E-06	5.4E-06	2.3E-05	13.3
Fast SBO	200	1.2E-07	1.5E-06	5.4E-06	2.1E-05	
	200 S2	1.4E-07	1.5E-06	5.7E-06	2.3E-05	
4	1000	3.8E-11	4.9E-08	1.6E-06	5.3E-06	4.0
Event V	200	3.6E-11	4.9E-08	1.6E-06	8.2E-06	
	200 S2	3.6E-11	4.9E-08	1.6E-06	8.5E-06	
5	1000	7.2E-08	6.9E-07	2.1E-06	6.0E-06	4.8
Transients	200	1.1E-07	8.2E-07	1.8E-06	5.5E-06	
	200 S2	7.8E-08	8.0E-07	1.7E-06	5.2E-06	
6	1000	3.2E-08	4.2E-07	1.6E-06	5.9E-06	3.8
ATWS	200	2.9E-08	4.2E-07	1.4E-06	6.5E-06	
	200 S2	4.2E-08	4.0E-07	1.5E-06	5.6E-06	
7	1000	1.2E-07	7.4E-07	1.8E-06	6.0E-06	4.8
SGTR	200	4.5E-07	1.4E-06	1.8E-06	4.7E-06	
	200 S2	5.0E-07	1.4E-06	1.8E-06	4.4E-06	
Total	1000	6.6E-06	2.3E-05	4.0E-05	1.3E-04	
	200	9.8E-06	2.5E-05	4.1E-05	1.0E-04	
	200 S2	8.7E-06	2.6E-05	4.2E-05	1.2E-04	

(1) The accident frequency analysis used a Latin Hypercube Sampling (LHS) sample size of 1000. The accident progression analysis used an LHS sample size of 200; 200 S2 denotes the second sample of size 200.

(2) Percentages based on the LHS sample size of 1000.

Core Damage Frequency Distributions for TRRR-RSR

Distribution	5%	Median	Mean	95%
1000-Observation Sample	1.1E-7	1.7E-6	5.4E-6	2.3E-5
200-Observation Sample Used in Risk Analysis	1.2E-7	1.5E-6	5.4E-6	2.1E-5
Revised 200-Observation Sample	1.7E-7	1.8E-6	6.0E-6	2.3E-5

The differences are even less when all seven internally initiated PDS groups are considered.

Core Damage Frequency Distributions for
All Seven Internally Initiated PDS Groups

Distribution	5%	Median	Mean	95%
1000-Observation Sample	6.6E-6	2.3E-5	4.0E-5	1.3E-4
200-Observation Sample Used in Risk Analysis	9.8E-6	2.5E-5	4.1E-5	1.0E-4
Revised 200-Observation Sample	1.0E-5	2.6E-5	4.1E-5	1.0E-4

The seven PDS groups for internal initiators are discussed below. This is followed by presentation and discussion of the fire and seismic initiators.

PDS Group 1 consists of six slow blackout PDSs. In these accidents, off-site power is lost and the DGsfail to start or run. The steam-turbine-driven AFWS operates until the batteries are depleted. Without power for instruments and controls, the STD-AFWS eventually fails. Battery depletion is estimated to take about 4 h. During this time the RCP seals may fail or the PORVs may stick open. Thus the six PDSs in this group have the RCS in different states at the onset of core damage. In two of the PDSs in this group, the RCS is intact when the TAF is uncovered. Another two of the PDSs have S_3-size breaks (failures of the RCP seals), and the final two PDSs in this group have S_2-size breaks (stuck-open PORVs). The difference between the two "T" PDSs in Group 1 is whether there is cooling for the RCP seals. The difference between the two "S_3" PDSs and the two "S_2" PDSs is whether the secondary system is depressurized while the AFW is operating (before the core uncovers).

PDS Group 2 consists of seven loss-of-coolant accident (LOCA) PDSs. Four of the PDSs have an A-size break, and two of the PDSs have an S_1-size break, which are treated together and denoted "A" PDSs in this portion of the analysis. There is one PDS with an S_2-size break and one PDS with an S_3-size break. Four of the PDSs in this group have the LPIS operating. In PDS ALYY-YYY, the accumulators have failed and the LPIS is operating successfully (all trains). For an A break, the success criteria require

both accumulator injection and LPIS operation. Thus, even though the RCS pressure is low and the LPIS is injecting water successfully, core damage has been assumed. In PDS S_1LYY-YYY, HPIS has failed and the LPIS is operating successfully (all trains).

For an S_1 break, the success criteria require HPI early in the accident and LPIS operation later. In this PDS also, the RCS pressure is low and the LPIS is injecting water successfully, but core damage has been assumed since the success criteria have not been met. In PDS S_2LYY-YYY and S_3LYY-YYY, the break does not depressurize the RCS enough to allow LPI. Thus the accident will progress to vessel failure at pressure too high to allow LPI unless a large temperature-induced break occurs or the primary system is deliberately depressurized.

PDS Group 3 consists solely of TRRR-RSR--fast blackout. This accident is similar to PDS Group 1, except that the STD-AFW fails at the beginning. It proceeds to the onset of core damage before the RCP seals are likely to fail or the PORVs are likely to stick open.

Group 4 consists solely of Event V. This is a large break in low-pressure piping following the failure of the two check valves that isolate the low-pressure piping from the RCS. The break is outside containment in the auxiliary building, so the break both fails the RCS pressure boundary and bypasses the containment.

Internal PDS Group 5 consists of two PDSs that have failure of both AFW and Bleed and Feed. This PDS group is denoted Transients. In PDS TBYY-YNY, both LPIS and HPIS are available but the PORVs cannot be opened. The operators have failed to depressurize before the onset of core damage. In PDS TLYY-YNY, only LPIS is available. All AFW has failed and Bleed and Feed is not successful because the HPIS has failed. The operators have failed to depressurize before the onset of core damage in this PDS also.

As the operators have already failed to follow procedures and depressurize the system, no credit may be given for their depressurizing the RCS after the onset of core damage in PDS Group 5. Since there is RCP seal cooling and SGTRs are not very likely, the only effective means of depressurizing the RCS are the PORVs/SRVs sticking open or the failure of the hot leg/surge line. (Even though the PORVs cannot be opened from the control room, they may still open as part of their safety function. If they do not open at all, then the SRVs will open at a slightly higher pressure. The frequency of SRVs sticking open is assumed to be the same as for PORVs sticking open.) If the RCS pressure decreases to the high or intermediate range, the HPIS will, if not failed, inject. If the RCS pressure decreases to the low range, the LPIS will inject.

Group 6 contains the three ATWS PDSs. They differ in the status of the RCS at the time the core uncovers, whether the ECCS worked in the injection phase, and in whether cooling for the RCP seals is operating or failed. In this group also, the LPIS is available in some of the PDSs, and will inject if the RCS reaches low pressure.

PDS Group 7 consists of four PDSs that are initiated by SGTRs and which do not have scram failures. HINY-NXY is an SGTR with stuck-open SRVs in the secondary system. HINY-YXY is similar to HINY-NXY, but in addition has the RCS PORVs stuck open. GIYY-YNY has the RCS PORVs open since the operators are attempting to keep the core cooled by feed and bleed. GNYY-YXY has no unusual features. HINY-NXY has no possibility of the water from the RWST being injected into the containment; the HPIS pumps the water through the broken tube and out of the containment through the main steam line. In the other three PDSs, the sprays operate while there is still water in the RWST or in the sump, so the cavity is full when the TAF uncovers, or shortly thereafter.

In grouping the PDSs into the seven internally initiated groups shown in Table 2.2-2, no information is lost, nor are inappropriate assumptions made to facilitate this grouping. For example, all the breaks in PDS Group 2 are not treated as large (A) LOCAs simply because the majority of the group frequency is in the large LOCA PDSs. The appropriate division between large, small (S_2), and very small (S_3) LOCAs is made by using fractions for the branching ratios in Question 1 in the APET. By using fractional branch ratios in Question 1 and other places in the first twelve questions, placing the 25 PDSs into the seven PDS groups causes no loss of information.

The six PDSs left out of the accident progression analysis because their MCDFs fell below the cutoff of 1.0E-7/R-yr are:

PDS	MCDF
AINY-YYN	2.5E-8
ANNY-NYN	1.4E-9
S_1INY-YYN	5.0E-8
S_1NNY-NYN	2.7E-9
S_2NNY-NYN	2.7E-9
S_3NNY-NYN	3.5E-8

Their total MCDF is 1.1E-7/R-yr. Had they been included, they would all have been in PDS Group 2, LOCAs. This group has a MCDF of 5.9E-6/R-yr. The PDSs excluded do not have any features which would make the risk from them any higher than other PDSs retained in PDS Group 2. Furthermore, PDS Group 2 does not make a very large contribution to risk.

2.2.2.2 PDS Frequencies for Fire Initiators. Table 2.2-4 lists fire PDSs for Surry. There were only four PDSs, and they were all placed into a single Fire PDS group. Fire in the emergency switchgear room, S_3NNN-NDN, the dominant fire accident. The S_3 break in the RCS is an RCP seal failure due to the lack of seal cooling. The fire has failed the electrical power to all safety systems, so there is no way to replace the water lost through the RCP seals. The AFWS train driven by the steam-turbine pump operates until the batteries deplete, but this has little effect on the accident due to the pump seal failure. The S_3 break in the PDS due to fire in the auxiliary building, S_3NYY-NYN, is also an RCP seal failure due to the loss of cooling. All ECCS is failed, so there is no way to replace the water lost through the pump seals. AFWS and the containment sprays operate. PDS S_2NNY-NYY is due to a fire in the control room. All ECCS and sprays are

failed due to loss of control from the control room. Although the operators could take control of these systems from auxiliary control locations, core damage results because they failed to do so. The S_2 break is due to stuck-open PORVs. The fourth fire PDS results from fire in the cable vault and tunnel. The S_3 break is an RCP seal failure due to the loss of cooling. All ECCS and sprays are failed due to loss of control or motive power.

Table 2.2-4
PDSs for Surry Fire Initiators

Group Name	Mean CD Freq. (1/R-yr)	Fire Location	PDSs	Mean CD Freq. (1/R-yr)	% TMCD Freq.
FIRE	1.1E-5	Emergency Switchgear Room	S_3NNN-NDN	5.9E-6	54.3
		Auxiliary Building	S_3NYY-YYN	2.2E-6	20.0
		Cable Vault & Tunnel	S_3NNY-NYN	1.4E-6	13.0
		Control Room	S_2NNY-NXY	1.4E-6	12.7

Table 2.2-5 compares the core damage frequency distribution for the 1000-observation sample used in the fire core damage frequency analysis with the distribution for the 200-observation sample used in the integrated risk analysis. The stand-alone fire analysis included a fifth fire location, the room that houses the service water pumps for the charging pumps. As the mean value of the core damage frequency for this fire location was less than 1.0E-7/R-yr, it was not included in the integrated risk analysis. The differences between the means and medians of the two distributions are negligible. The differences at the extremes of the distribution are larger due to the elimination of the charging pump service water pump room location. The 1000-observation values are taken from Table 5.1 of NUREG/CR-4550, Volume 3, Part 3.

Table 2.2-5
Comparison of PDS Core Damage Frequencies
for Surry Fire Initiators

PDSs	LHS Sample Size(1)	Core Damage Frequency (1/R-yr) 5%	Median	Mean	95%
FIRE	1000	5.4E-7	8.3E-6	1.1E-5	3.8E-5
	200	2.3E-6	8.4E-6	1.1E-5	2.6E-5

(1) The accident frequency analysis used an LHS sample size of 1000. The accident progression analysis used an LHS sample size of 200.

After all the risk calculations were completed and the results reported, it was determined that the input to the LHS program for the 200-observation sample used for the integrated risk analysis was not the same as that used for the final fire runs made for the stand-alone accident frequency analysis. Instead, a preliminary version of the LHS fire input had been used for the integrated risk analysis. The main difference between the two was the use of gamma rather than lognormal distributions for the fire initiators. The LHS input for the 200-observation sample was revised to agree with that for the final 1000-observation sample, and TEMAC rerun with the corrected sample. Listed below are the 5th percentile, median, mean, and 95th percentile core damage frequencies for the 1000-observation sample, the 200-observation sample used in the integrated risk analysis, and the revised 200-observation sample. The differences were not great enough to warrant rerunning the fire risk analysis.

Core Damage Frequency Distributions for Fire

Distribution	5%	Median	Mean	95%
1000-Observation Sample	5.4E-7	8.3E-6	1.1E-5	3.8E-5
200-Observation Sample Used in Risk Analysis	2.3E-6	8.4E-6	1.1E-5	2.6E-5
Revised 200-Observation Sample	1.8E-6	8.6E-6	1.1E-5	2.8E-5

2.2.2.3 PDS Frequencies for Seismic Initiators. Table 2.2-6 lists PDSs for Surry as placed into three seismically initiated PDS groups. The seismic PDS frequencies were calculated for two different sets of hazard distributions; one generated by Lawrence Livermore National Laboratory (LLNL) and one generated by the Electric Power Research Institute (EPRI). More information on the differences between these two hazard distributions may be found in NUREG/CR-4550, Vol. 3, Part 3. Table 2.2-6 shows that the core damage frequency is almost an order of magnitude higher for the LLNL hazard distributions than it is for the EPRI hazard distributions. SBO accounts for a larger fraction of the core damage frequency when the LLNL rather than the EPRI hazard distributions are used.

Table 2.2-7 compares the core damage frequency distribution for the 4000-observation straight Monte Carlo sample used in the seismic core damage frequency analysis with the distribution for the 200-observation LHS sample used in the accident progression analysis and the subsequent analyses. Each of the three "EQ" PDS groups is divided into two subgroups. It was judged that the evacuation of the area around the reactor site would proceed differently for large earthquakes. Therefore, for each seismic group there is a high and a low acceleration subgroup. The dividing line between the two subgroups is a peak ground acceleration (PGA) of 0.6 g. The two subgroups must be kept separate in all the constituent analyses of the integrated risk analysis. Thus, Table 2.2-7 lists six seismic PDS groups. The differences between the 4000-observation sample distributions and the 200-observation sample distributions are of the magnitude to be expected considering the different sample sizes and the different random seed used, and are not significant.

Table 2.2-6
Plant Damage States for Surry Seismic Initiators
LLNL Hazard Distribution

Group Number	Group Name	Mean CD Freq.(1) (1/R-yr)	Group % TMCD Freq.	PDSs	Mean CD Freq.(1) (1/R-yr)	% TMCD Freq.
EQ 1	LOSP (No SBO)	9.1E-5	47.1	TNNY-NNY	3.9E-5	20.2
				TLNP-NNY	2.2E-5	11.4
				S_3NNY-NYN	1.7E-5	8.8
				TBYP-YNY	7.5E-6	3.9
				TLYP-YNY	5.3E-6	2.7
EQ 2	SBO	7.9E-5	41.1	TRRN-RNR	2.4E-5	12.4
				TRRN-RDR	1.5E-5	7.8
				S_3RRN-RDR	1.3E-5	6.7
				TNNN-NDN	8.3E-6	4.3
				ANNN-NNN	6.6E-6	3.4
				S_2RRN-RDR	5.1E-6	2.6
				ARRN-RDR	3.9E-6	2.0
				S_3NNN-NDN	3.4E-6	1.8
EQ 3	LOCAs	2.3E-5	11.9	S_2NNY-NYY	5.4E-6	2.8
				S_2LNP-NYY	5.0E-6	2.6
				ANNY-NYY	2.4E-6	1.2
				AINP-NYN	2.4E-6	1.2
				S_2LYP-YYY	1.7E-6	0.9
				AIYP-YYN	1.5E-6	0.8
				AIYP-YYY	1.3E-6	0.7
				S_1NNY-NYY	1.2E-6	0.6
				S_1LNP-NYY	9.5E-7	0.5
				S_1LYP-YYY	5.0E-7	0.3
				AIYY-YYY	4.2E-7	0.2
Total		1.9E-4		All Seismic Initiators based on the LLNL Hazard Distributions		

(1) Based on the sample of 200 observations used in the risk analysis.

Table 2.2-6 (continued)
Plant Damage States for Surry Seismic Initiators
EPRI Hazard Distribution

Group Number	Group Name	Mean CD Freq.(1) (1/R-yr)	Group % TMCD Freq.	PDSs	Mean CD Freq.(1) (1/R-yr)	% TMCD Freq.
EQ 1	LOSP (No SBO)	1.5E-5	53.7	TNNY-NNY	6.6E-6	23.6
				TLNP-NNY	2.6E-6	9.3
				S_3NNY-NYN	3.2E-6	11.4
				TBYP-YNY	1.8E-6	6.4
				TLYP-YNY	8.4E-7	3.0
EQ 2	SBO	9.4E-6	33.7	TRRN-RNR	2.5E-6	8.9
				TRRN-RDR	1.5E-6	5.4
				S_3RRN-RDR	2.4E-6	8.6
				TNNN-NDN	4.2E-7	1.5
				ANNN-NNN	3.8E-7	1.4
				S_2RRN-RDR	6.4E-7	2.3
				ARRN-RDR	5.0E-7	1.8
				S_3NNN-NDN	1.1E-6	3.9
EQ 3	LOCAs	3.5E-6	12.5	S_2NNY-NYY	8.1E-7	2.9
				S_2LNP-NYY	6.9E-7	2.5
				ANNY-NYY	4.8E-7	1.7
				AINP-NYN	3.6E-7	1.3
				S_2LYP-YYY	2.3E-7	0.8
				AIYP-YYN	3.1E-7	1.1
				AIYP-YYY	1.5E-7	0.5
				S_1NNY-NYY	1.7E-7	0.6
				S_1LNP-NYY	1.4E-7	0.5
				S_1LYP-YYY	5.0E-8	0.2
				AIYY-YYY	5.8E-8	0.2
Total		2.8E-5		All Seismic Initiators based on the EPRI Hazard Distributions		

(1) Based on the sample of 200 observations used in the risk analysis.

Table 2.2-7
Comparison of PDS Core Damage Frequencies
Surry: Internal Initiators
LLNL Hazard Distribution

PDSs	LHS Sample Size(1)	Core Damage Frequency (1/R-yr) 5%	Median	Mean	95%	% Mean TCD Freq.(2)
Peak Ground Acceleration > 0.6 g						
EQ 1	4000	1.4E-8	7.3E-7	8.3E-6	3.5E-5	
LOSP	200	9.1E-9	5.8E-7	9.4E-6	3.4E-5	5.0
EQ 2	4000	1.7E-8	7.7E-7	8.8E-6	3.9E-5	
SBO	200	2.2E-8	9.2E-7	1.1E-5	5.3E-5	5.8
EQ 3	4000	5.5E-9	5.4E-7	7.9E-6	3.4E-5	
LOCAs	200	9.5E-9	5.5E-7	7.5E-6	3.6E-5	4.0
Peak Ground Acceleration < 0.6 g						
EQ 1	4000	1.3E-7	7.2E-6	7.1E-5	3.5E-4	
LOSP	200	1.0E-7	6.2E-6	8.1E-5	3.5E-4	42.0
EQ 2	4000	1.2E-7	5.1E-6	5.4E-5	2.1E-4	
SBO	200	1.2E-7	5.8E-6	6.8E-5	2.9E-4	35.3
EQ 3	4000	1.1E-8	1.2E-6	1.5E-5	6.1E-5	
LOCAs	200	1.8E-8	1.1E-6	1.5E-5	7.3E-5	7.9
TOTAL	4000	4.5E-7	1.8E-5	1.7E-4	7.7E-4	
All PGA	200	5.3E-7	1.8E-5	1.9E-4	7.6E-4	

(1) The seismic accident frequency analysis used a Monte Carlo sample size of 4000. The accident progression analysis used an LHS sample size of 200.

(2) Percentages based on the LHS sample of 200 observations used in the integrated risk analysis.

Table 2.2-7 (continued)
Comparison of PDS Core Damage Frequencies
Surry: Seismic Initiators
EPRI Hazard Distribution

PDSs	LHS Sample Size(1)	Core Damage Frequency (1/R-yr) 5%	Median	Mean	95%	% Mean TCD Freq.(2)
Peak Ground Acceleration > 0.6 g						
EQ 1	4000	8.8E-9	2.0E-7	1.1E-6	4.4E-6	
LOSP	200	8.8E-9	2.5E-7	1.1E-6	4.9E-6	3.9
EQ 2	4000	1.1E-8	2.7E-7	1.3E-6	4.6E-5	
SBO	200	1.8E-8	3.2E-7	1.1E-6	4.7E-6	3.8
EQ 3	4000	3.9E-9	1.5E-7	9.4E-7	4.0E-6	
LOCAs	200	2.1E-9	2.0E-7	9.8E-7	5.5E-6	3.5
Peak Ground Acceleration < 0.6 g						
EQ 1	4000	9.3E-8	2.6E-7	1.3E-5	5.2E-5	
LOSP	200	9.6E-8	3.6E-6	1.4E-5	7.6E-5	49.9
EQ 2	4000	8.6E-8	2.0E-6	1.0E-5	3.9E-5	
SBO	200	1.3E-7	2.5E-6	8.4E-6	3.5E-5	29.9
EQ 3	4000	9.6E-9	3.8E-7	2.3E-6	9.6E-6	
LOCAs	200	5.3E-9	5.0E-7	2.5E-6	1.2E-5	8.9
TOTAL	4000	3.4E-7	7.0E-6	2.9E-5	1.3E-4	
Low PGA	200	3.7E-7	9.4E-6	2.8E-5	1.4E-4	

(1) The seismic accident frequency analysis used a Monte Carlo sample size of 4000. The accident progression analysis used an LHS sample size of 200.

(2) Percentages based on the LHS sample of 200 observations used in the integrated risk analysis.

2.2.3 High-Level Grouping of PDSs

To provide simpler, more easily understood summaries for NUREG-1150, the seven internally initiated PDS groups described above were further condensed into the following five groups:

1. Loss of Offsite Power (LOSP)
2. LOCAs
3. Transients
4. Bypass LOCAs
5. ATWS.

These five groups are denoted Summary-Groups or collapsed PDS Groups. The mapping from the seven groups described in the previous section into the five Summary-Groups used in the presentation of many of the results is given in Table 2.2-8. In combining two groups to form one super-group, frequency weighting by observation is employed. The percentages of the total MCDF given above provide only approximate weightings.

Table 2.2-8
Relationship Between PDS Groups and Summary-Groups

Summary-Group	% TMCDF	PDS Groups	% TMCDF
1. LOSP	66	1. Slow Blackout	55
		3. Fast Blackout	12
2. LOCAs	15	2. LOCAs	15
3. Bypass LOCAs	10	4. V	6
		7. SGTRs	4
4. Transients	5	5. Transients	5
5. ATWS	4	6. ATWS	4

2.2.4 Variables Sampled in the Accident Frequency Analysis

In the stand-alone accident frequency analysis for internal events, a large number of variables were sampled. (A list of these variables may be found in NUREG/CR-4550, Vol. 3, Part 1.) Only those variables found to be important to the uncertainty in the accident frequencies were selected for sampling in the integrated risk analysis. These variables are listed and defined in Table 2.2-9 (at the end of this subsection). For the regression analysis, identifiers of eight characters or less were required, and these are listed in the first column. Where these differ from the identifiers used in the fault trees, these identifiers are listed in the description in brackets. Generally, the eight-character identifiers have been selected to be as informative as possible to those not familiar with the conventions used in systems analysis. For example, while Event K is commonly used to

indicate the failure of the Reactor Protection System (RPS) to insert enough control rods to make the reactor subcritical, the identifier AU-SCRAM was chosen since it was felt that "auto scram" conveys more meaning to most readers than "K".

The second column in Table 2.2-9 gives the range of the distribution for the variable and the third column indicates the type of distribution used and its mean value. The entry "Experts" for the distribution indicates that the distribution came from the accident frequency analysis expert panel. The fourth and fifth columns in Table 2.2-9 show whether the variable is correlated with any other variable and the last column describes the variable. More complete descriptions and discussion of these variables may be found in the Surry accident frequency analysis report (NUREG/CR-4550, Vol. 3). This report also gives the source or the derivation of the distributions for all these variables.

Most of the variable distributions come from the generic accident sequence evaluation (ASEP) data base. Others were derived specifically for the Surry equipment using plant data. The distribution for the frequency of the LOSP initiating event was derived by combining data from all nuclear power plant sites with the historical experience at Surry, using the methods of NUREG/CR-5032. The distribution for the frequency of transient initiating events was derived from Surry data as described in NUREG/CR-3862. The distribution for the probability of failure to scram (AU-SCRAM, Event K) was derived from the information in NUREG-1000. The human error probability distributions were derived using the human reliability analysis (HRA) methodology as described in NUREG/CR-4772.

Failure of the RCP seals due to lack of cooling was sampled in the following manner in the accident frequency analysis: eight states were defined, and one of these states had a probability of 1.0 in each observation while the other seven states had a probability of 0.0. (When all the probability is assigned to one branch in every observation, the sampling is denoted zero-one sampling.) The eight RCP seal states are:

State	Total Leak Rate	Start Time	Probability	Fault Tree Identifier
1	750 gpm	90 min	0.535	RCP-LOCA-750-90M
2	467 gpm	150 min	0.120	RCP-LOCA-467-150
3	183 gpm	150 min	0.020	RCP-LOCA-183-150
4	183 gpm	210 min	0.015	RCP-LOCA-183-210
5	1440 gpm	90 min	0.005	RCP-LOCA-1440-90
6	183 gpm	90 min	0.010	RCP-LOCA-183-90
7	561 gpm	150 min	0.005	RCP-LOCA-561-150
8	Normal	N.A.	0.290	NO RCP SEAL LOCA

The probability for each state was determined by a special expert panel as described in NUREG/CR-4550, Volume 2. The use of this information in the Surry accident frequency analysis is described in more detail in NUREG/CR-4550, Volume 3. The last state represents success, i.e., no failure of the RCP seals. Design leakage through the seals is about 3 gpm/pump during normal operation, but non-failure leakage could be as high as 21 gpm/pump when there is no flow of cooling water to the seals. Leakage following

seal failure could be as high as 480 gpm/pump or 1440 gpm total. As there were 200 observations in the sample used to determine risk for Surry, state 1 (a total leak of 750 gpm from three pump seals starting at 90 minutes) had a probability of 1.0 for 107 observations and a probability of 0.0 for 93 observations. State 7 (561 gpm starting at 150 minutes) had a probability of 1.0 for only one observation. A random number generator was used to determine which state had the unity probability for which observation.

Only two accident frequency variables were correlated in the integrated analysis. As indicated in Table 2.2-9, DG-FRUN1 and DG-FRUN6 were correlated with each other since they represent failures to run for different times for the same equipment. The failures to run for the steam turbine-driven AFW pump (ATP-FR6 and ATP-FR24) should have been correlated for the same reason, but this correlation was omitted due to an oversight. Neither of the AFW pump failure-to-run variables was important in determining the uncertainty in risk, so the effect of omitting the correlation between them is not significant.

Table 2.2-10 (also at the end of this subsection) lists the variables sampled in the accident frequency analysis for fire initiators. Since the fire analysis considered random failures in addition to fire damage, these variables were sampled in addition to the variables sampled for the internal initiators. Although only four fire locations are presented in Table 2.2-4, there was a fifth fire location which was not discussed because its mean frequency was below the cutoff value of 1.0E-7/R-yr. However, two variables for this fire location, the room housing the service water pumps which cool the charging pumps, remained in the sample file and are listed in Table 2.2-10.

The variables sampled in the accident frequency analysis for seismic initiators are listed in NUREG/CR-4550, Vol. 3, Part 3. The variability in the hazard distribution is by far the major contributor to the variation in the seismic core damage frequency. Therefore, variables other than the hazard distribution were not considered in the regression analyses performed as part of the integrated risk analysis.

Table 2.2-9
Variables Sampled in the Accident Frequency Analysis for Internal Initiators

Variable	Range	Distribution	Correlation	Correlation With	Description
V-TRAIN	1.8E-13 1.5E-5	Experts Mean=5.5E-7	None		Initiating event: frequency(1/yr) of check valve failure in one of the LPIS trains.
IE-LOSP	2.6E-5 0.28	LOSP Data Mean=0.077	None		Initiating event: frequency (1/yr) of LOSP. [IE-T1]
IE-A	5.0E-5 0.0032	Lognormal Mean=5E-4	None		Initiating event: frequency (1/yr) of a large (dia. > 6 in.) break in the RCS (LOCA).
IE-S1	1.0E-4 0.0063	Lognormal Mean=0.001	None		Initiating event: frequency (1/yr) of an intermediate size (6 in. > dia. > 2 in.) LOCA.
IE-S2	1.0E-4 0.0063	Lognormal Mean=0.001	None		Initiating event: frequency (1/yr) of a small break (2 in. > dia. > 0.5 in.) in the RCS.
IE-S3	0.0013 0.082	Lognormal Mean=0.013	None		Initiating event: frequency (1/yr) of a very small (0.5 in. > dia.) break in the RCS (LOCA).
IE-T-ALL	0.67 41.6	Lognormal Mean = 6.6	None		Initiating event: frequency (1/yr) of all transients that require scram (Surry data). [IE-T]
IE-T-HIP	0.60 37.2	Lognormal Mean=5.9	None		Initiating event: frequency (1/yr) of all transients from high (>25%) power that require scram (Surry data). [IE-TN]
IE-LMFWS	0.096 5.9	Lognormal Mean=0.94	None		Initiating event: frequency (1/yr) of transients due to loss of the main feedwater system (Surry data).

Table 2.2-9 (continued)

Variable	Range	Distribution	Correlation	Correlation With	Description
IE-SGTR	0.001 0.063	Lognormal Mean=0.01	None		Initiating event: frequency (1/yr) of SGTRs (PWR data). [IE-T7]
IE-DCBUS	2.5E-5 0.14	Lognormal Mean=0.005	None		Initiating event: frequency (1/yr) for loss of a DC power buss. [IE-T5]
DG-FRUN1	9.9E-6 0.057	Lognormal Mean=0.002	Rank 1	DG-FRUN6	Probability that the diesel generator fails to run for 1 h, given that it starts.[DGN-FR-1HR]
DG-FRUN6	6.0E-5 0.34	Lognormal Mean=0.012	Rank 1	DG-FRUN1	Probability that the diesel generator fails to run for 6 h, given that it starts. [DGN-FR-6HR]
DG-FSTRT	0.0022 0.14	Lognormal Mean=0.022	None		Probability that the diesel generator fails to start, given a demand to start. [DGN-FS]
UNFV-MOD	1.8E-4 0.27	Lognormal Mean=0.014	None		Fraction of the time that the reactor operates with an unfavorable moderator temperature coefficient. [Z]
AU-SCRAM	1.8E-6 7.6E-4	Lognormal Mean=6E-5	None		Probability of failure of the RPS to automatically insert sufficient control rods to terminate the reaction. [K]
MN-SCRAM	0.017 1.0	Max. Entropy Mean=0.17	None		Probability of failure to effect manual scram due to operator error and hardware faults. [R]
AUTO-ACT	4.8E-5 0.020	Lognormal Mean=0.0016	None		Probability of failure of one train of an automatic actuation system (generic). [ACT-FA]

Table 2.2-9 (continued)

Variable	Range	Distribution	Correlation	Correlation With	Description
CCF-RWST	1.5E-6 0.0085	Lognormal Mean=3E-4	None		Probability of common cause failure of the recirculation mode transfer system due to miscalibration of the water level sensors in the RWST (human error). [RMT-CCF-FA-MSCAL]
BETA2MOV	0.0089 0.55	Lognormal Mean=0.088	None		Beta factor for common cause failure of two motor-operated valves (generic). [BETA-2MOV]
BETA-AFW	0.0057 0.35	Lognormal Mean=0.056	None		Beta factor for common cause failure of the AFWS motor-driven pumps (generic).
BETA-LPI	0.015 0.94	Lognormal Mean=0.15	None		Beta factor for common cause failure of the LPIS pumps (generic).
AFW-STMB	2.0E-8 0.0070	Lognormal Mean=1.0E-4	None		Probability of common cause failure of all AFWS due to steam binding (back leakage through check valves from MFWS). [CCF-LK-STMBD]
MDP-FSTR	1.5E-5 0.085	Lognormal Mean=0.003	None		Probability of failure to start (per demand) for motor-driven pumps for which specific plant data was not available (generic). [MDP-FS]
AFWMP-FS	6.4E-4 0.040	Lognormal Mean=0.0063	None		Probability of failure to start (per demand) for AFW motor-driven pumps (from Surry data). [AFW-MDP-FS-FW3B]

Table 2.2-9 (continued)

Variable	Range	Distribution	Correlation	Correlation With	Description
AFWTP-FS	5.5E-5 0.31	Lognormal Mean=0.011	None		Probability of failure to start (per demand) for AFW steam turbine-driven pump (from Surry data). [TDP-FS]
ATP-FR6	1.5E-4 0.85	Lognormal Mean=0.030	None		Probability of failure to run for 6 h for the AFW steam turbine-driven pump (generic). [TDP-FR-6HR]
ATP-FR24	0.01 1.0	Max. Entropy Mean=0.12	None		Probability of failure to run for 24 h for the AFW steam turbine-driven pump (generic). [TDP-FR-24HR]
PORV-BLK	0.0041 0.25	Lognormal Mean=0.040	None		Probability of failure to open (per demand) for the PORV block valves (MOVs). [PPS-MOV-FT]
LPRS-MOV	2.6E-5 0.15	Lognormal Mean=0.0052	None		Probability of failure (per demand) for the suction MOVs in the LPRS, due to hardware failures or plugging. [LPR-MOV-FT]
MOV-FT	1.5E-5 0.085	Lognormal Mean=0.003	None		Probability of failure to transfer (per demand) for motor-operated valves (generic).
MNV-PG1	4.1E-6 2.5E-4	Lognormal Mean=3.6E-5	None		Probability of failure due to plugging for manual valves that are flow-tested every month (generic). [XVM-PG-1MO]
MOV-PG3	1.0E-5 6.3E-4	Lognormal Mean=1.0E-4	None		Probability of failure due to MOVs that are flow-tested every 3 months (generic). [MOV-PG-3MO]

Table 2.2-9 (continued)

Variable	Range	Distribution	Correlation	Correlation With	Description
MOV-PG12	4.5E-5 0.0028	Lognormal Mean=4.4E-4	None		Probability of failure due to plugging forMOVs that are flow-tested every 12 months (generic). [MOV-PG-12MO]
AFW-OCC	1.5E-5 9.5E-4	Lognormal Mean=1.5E-4	None		Probability of common cause failure of AFWS due to an inadvertently open cross-connect to Unit 2 (flow diversion). [AFW-PSF-FC]
PORV-REC	1.5E-4 0.85	Lognormal Mean=0.030	None		Probability of failure of the pressurizer PORVs to reclose after opening (generic). [SOV-OO]
SSRVO-SB	0.030 1.0	Max. Entropy Mean=0.27	None		Probability of failure of an SG SRV to reclose within 1 h during SBO (faulted steam generator). [QS-SBO]
SSRVO-U2	0.016 1.0	Max. Entropy Mean=0.16	None		Probability of failure of a secondary system SRV at Unit 2 to reclose within 1 h during SBO at both units. [QS-UNIT2]
SOV-FT	1.0E-4 0.0063	Lognormal Mean=0.001	None		Probability of failure to transfer (per demand) for solenoid-operated valves (generic).
CKV-FT	1.0E-5 6.3E-4	Lognormal Mean=1E-4	None		Probability of failure to open (per demand) for check valves (generic).

Table 2.2-9 (continued)

Variable	Range	Distribution	Correlation	Correlation With	Description
HE-FDBLD	0.0071 0.71	Max. Entropy Mean=0.071	None		Probability of failure of the operator to initiate feed and bleed (human error - open PORVs, and start charging pump and align suction and discharge valves). [HPI-XHE-FO-FDBLD]
HE-PORVS	0.0044 0.44	Max. Entropy Mean=0.044	None		Probability of failure of the operator to initiate feed and bleed (human error; diagnose situation and open PORVs). [PPS-XHE-FO-PORVS]
HE-CST2	0.0065 0.65	Max. Entropy Mean=0.065	None		Probability of failure of the operator to align the AFWS suction to the backup CST during an SBO with a faulted SG. [AFW-XHE-FO-CST2]
HE-UNIT2	0.0036 0.36	Max. Entropy Mean=0.036	None		Probability of failure of the operator to provide AFW from Unit 2 via the cross-connect. [XHE-FO-UNIT2]
HE-SKILL	1.3E-5 0.077	Lognormal Mean=0.0026	None		Probability of human error for skill-based human errors (rudimentary actions performed from memory). [XHE-FO-SKILLBASE]
RCP-SL-F		Experts	None		Probability of RCP seal failure before the onset of core damage. [See text]

Table 2.2-10
Variables Sampled in the Accident Frequency Analysis for Fire Initiators

Variable	Range	Distribution	Correlation	Correlation With	Description
IE-AUXBL	0.027 0.16	Lognormal Mean=0.064	None		Initiating event - fire in auxiliary building. [AUXILIARY BLDG.]
AR-AUXBL	2.4E-4 0.0011	Max. Entropy Mean=4.8E-4	None		Area ratio in auxiliary building where critical damage occurred. [FA1]
SR-AUXBL	0.19 1.0	Max. Entropy Mean=0.30	None		Severity ratio for a large fire based on generic combustible fuel loading. [FS1]
FX-AUXBL	0.60 1.0	Max. Entropy Mean=0.87	None		Fraction of fires extinguished manually before critical damage occurred. [Q1TG]
HE-AUXBL	0.19 1.0	Max. Entropy Mean=0.26	None		Probability the operators fail to obtain HPI from Unit 2 to prevent RCP seal failure. [R1OP]
IE-CBLVT	3.0E-6 0.016	Lognormal Mean=0.0027	None		Initiating event - fire in cable vault and tunnel. [CABLE VAULT AND TUNNEL]
AR-CBLVT	0.012 0.047	Max. Entropy Mean=0.018	None		Area ratio in cable spreading room where critical damage occurred. [FA2]
SR-CBLVT	0.50 1.0	Max. Entropy Mean=0.90	None		Severity ratio for a large fire based on generic combustible fuel loading. [FS2]
FX-CBLVT	0.60 1.0	Max. Entropy Mean=0.87	None		Fraction of fires extinguished manually before critical damage occurred. [Q2TG]

Table 2.2-10 (continued)

Variable	Range	Distribution	Correlation	Correlation With	Description
XA-CBLVT	0.50 0.90	Max. Entropy Mean=0.70	None		Fraction of fires extinguished automatically before critical damage occurred. [QAUTO]
HE-CBLVT	0.0044 0.44	Max. Entropy Mean=0.044	None		Probability the operators fail to obtain HPI from Unit 2 to prevent RCP seal failure. [R2OP]
IE-CNTRM	1.2E-6 0.0074	Lognormal Mean=0.0011	None		Initiating event - fire in the control room. [CONTROL ROOM]
AR-CNTRM	2.4E-4 0.0011	Max Entropy Mean=4.8E-4	None		Area ratio of benchboard 1-1 to total cabinet area in the control room. [FA3]
HE-CNTRM	0.0074 0.74	Max. Entropy Mean=0.074	None		Probability the operators fail to from the auxiliary shutdown panel. [R3OP]
IE-ESWGR	0.027 0.16	Lognormal Mean=0.064	None		Initiating event - fire in emergency switchgear room. [ELECTRICAL SWITCHGEAR ROOM]
ARS-ESWG	0.020 0.099	Max. Entropy Mean = 0.039	None		Area ratio in emergency switchgear room for a small fire where critical damage occurred. [FA4]
SRS-ESWG	0.33 0.81	Max. Entropy Mean=0.70	None		Severity ratio for a small fire based on generic combustible fuel loading. [FS4]
ARL-ESWG	0.051 0.24	Max. Entropy Mean=0.10	None		Area ratio in emergency switchgear room for a large fire where critical damage occurred. [FA5]

Table 2.2-10 (continued)

Variable	Range	Distribution	Correlation	Correlation With	Description
SRL-ESWG	0.19 0.67	Max. Entropy Mean=0.30	None		Severity ratio for a large fire generic combustible fuel loading. [FS5]
FX-ESWGR	0.60 1.0	Max. Entropy Mean=0.87	None		Fraction of fires extinguished manually before critical damage occurred. [Q4TG]
IE-CPSWP		Lognormal Mean=0.0037	None		Initiating event - fire in charging pump service water pump room. [CHARGING PUMP SERVICE WATER PUMP ROOM]
FX-CPSWP	0.60 1.0	Max. Entropy Mean=0.87	None		Fraction of fires extinguished manually before critical damage occurred. [Q5TG]

2.3 Description of the Accident Progression Event Tree

This section describes the APET that is used to perform the accident progression analysis for Surry. The APET itself forms a high-level model of the accident progression. The APET is too large to be drawn out in a figure as smaller event trees usually are. Instead, the APET exists only as a computer input file. The APET is evaluated by the code EVNTRE, which is described elsewhere.[1]

The APET is not meant to be a substitute for detailed, mechanistic codes such as the STCP, CONTAIN, MELCOR, and MAAP. Rather, it is an integrating framework for synthesizing the results of these codes together with expert judgment on the strengths and weaknesses of the codes. The detailed, mechanistic codes require too much computer time to be run for all the possible accident progression paths. Therefore, the results from these codes are represented in the Surry APET, which can be evaluated very quickly. In this way, the full diversity of possible accident progressions can be considered and the uncertainty in the many phenomena involved can be included.

The following section contains a brief overview of the Surry APET. Details, including a complete listing of the APET and a discussion of each question, may be found in Appendix A of this volume. Section 2.3.2 is a summary of how the APET was quantified, that is, how the many numerical values for branching ratios and parameters were derived. Section 2.3.3 presents the variables that were sampled in the accident progression analysis for Surry.

2.3.1 Overview of the APET

The APET for Surry considers the progression of the accident from the time the TAF in the core is uncovered, which is assumed to be the onset of core damage through the CCI. Although the CCI may progress at ever slower rates for days, the end of this analysis has been arbitrarily set at 24 h. Except in very unusual accidents, almost all of the fission products that are going to be released from the containment will have been released by 24 h after the initiator.

While every effort has been made to make this a general event tree that can be applied to any large, dry containment, the cavity and sump arrangement at each plant is unique, and this tree was constructed for the Surry sump and cavity arrangement. Therefore, some revision of this tree will be required for plants with other sump and cavity configurations. The reactor cavity at Surry is not connected to the sump at or near the basemat elevation. The sump at Surry has a very large capacity, so no matter how much of the water in the RCS and RWST escapes into the Surry containment through a break, there will be no water in the cavity unless the sprays operate.

Table 2.3.1 lists the 71 questions in the Surry APET. There are seven time periods in this APET. To facilitate understanding of the APET and referencing between questions, each branch of every question is assigned a mnemonic abbreviation. The mnemonic branch abbreviations for most branches

start with a character or characters which indicate the time period of the question. The time periods used in the Surry APET, and their abbreviations, are:

B	Initial	Questions 1 through 14 determine the conditions at the beginning of the accident.
E	Early	Questions 15 through 31 concern the progression of the accident from the UTAF to just before VB. Questions 14 through 18 concern events or actions which may depressurize the RCS before breach. The possibility that core degradation may be arrested and VB prevented is considered in Question 23.
I	Intermediate	Questions 32 through 43 determine the progression of the accident immediately before, at, and immediately after VB, including the possibility of containment failure at, or immediately after, VB.
I2	Late Intermediate	Question 44 determines the status of the sprays shortly after VB, during the RCS release.
L	Late	Questions 45 through 55 determine the progression of the accident during the CCI.
L2	Very Late	Questions 56 through 64 determine the progression of the accident in the period following CCI, including the possibility of containment failure due to hydrogen combustion.
F	Final	Questions 65 through 71 determine the final status of the containment.

The clock time for each period varies depending upon the type of accident being modeled.

The Surry APET does not contain any questions to resolve core-vulnerable sequences, which are accidents that have failure of containment heat removal only. The continual deposition of decay heat in the containment by operation of the ECCS in the recirculation mode is predicted to lead to eventual containment failure in many hours or a few days. Containment failure, in turn, may lead to ECCS failure. The Surry PDSs with frequencies exceeding 1.0E-7/year did not contain any accidents of this type.

Although the fan coolers at Surry are not safety grade, and the accident progression analysis does not give any credit for their operation (although the accident frequency analysis does), this APET contains fan cooler questions. This is done to make this APET as applicable as possible to PWRs with large, dry containments that do have safety-grade fan coolers.

Containment failure due to hydrogen combustion in the period before vessel failure is not considered in the Surry APET. This possibility was included in the event tree used in the analysis performed for the previous draft of NUREG-1150, and no containment failures before vessel breach due to deflagrations were observed. Due to the size of the Surry containment, a considerable amount of hydrogen must be produced and mixed into the containment atmosphere to reach the minimum concentration for deflagrations. To reach the lower limit for deflagration in the absence of steam, hydrogen from oxidizing about one third of the zirconium in the Surry core must be released from the RCS. If the atmosphere is half steam, hydrogen from oxidizing about two thirds of the zirconium in the Surry core must be released from the RCS to reach the lower limit for deflagration. To cause a deflagration or a detonation capable of failing the Surry, the hydrogen must accumulate in the containment until concentrations well above the lower limit for deflagration are reached. If electric power is available during this period, the sprays will keep the steam concentration low and sparks from electrical equipment will cause ignition near the lower deflagrable limit. Thus, large hydrogen concentrations will not occur. If electric power is not available during this period, the sprays will not operate and the containment is likely to be inerted by the high steam concentration. Furthermore, in many of the accidents in which power is unavailable (SBOs), the RCS remains at high pressure and much of the hydrogen produced remains within the RCS until the vessel fails.

Hydrogen deflagrations are considered at vessel breach and after vessel breach in this analysis. The pressure rise at vessel breach was determined by a group of experts, the Containment Loads Panel. This pressure rise includes contributions from hydrogen combustion, RCS blowdown, direct containment heating, and ex-vessel steam explosions. The panel did not provide details about how much hydrogen is produced before vessel breach and how much is burned at vessel breach, so the amount of hydrogen remaining after vessel breach can only be approximated. If the containment does not fail at vessel breach, the APET determines if it fails later due to hydrogen deflagrations during or after CCI. Concentrations of hydrogen, oxygen, steam, and carbon dioxide in the containment atmosphere are computed by means of a "User Function" for the periods after vessel breach. The user function also calculates the pressure rise due to the late hydrogen burns.

In several places in the evaluation of the APET, a User Function is called. This is a FORTRAN function subprogram which is executed at that point in the evaluation of the APET. The user function allows computations to be carried out which are too complex to be treated directly in the event tree. The user function itself is listed in Appendix A.2, and the manipulations performed by the user function at each question that utilizes the user function are described in Appendix A.1. The user function is called to:

- Determine containment failure and the mode of failure **(Questions 43, 52, and 64)**;

- Compute the hydrogen concentration in the containment; determine if the containment atmosphere is flammable; and, if it is, determine the total pressure in the containment from a hydrogen burn **(Questions 51 and 63)**.

2.3.2 Overview of the APET Quantification

This section summarizes the ways in which the questions in the Surry APET were quantified and discusses these methods briefly. A detailed discussion of each question, which includes comments on its quantification, may be found in Appendix A.1.1.

In addition to the number and name of the question, Table 2.3-1 indicates if the question is sampled, and how the question is evaluated or quantified. In the sampling column, an entry of DS indicates that the sampling is from a distribution provided by one of the expert panels, or from the electric power recovery distribution. The item sampled may be either the branching ratios or the parameter defined at that question. For questions which are sampled and which were quantified internally, the entry ZO in the sampling column indicates that the question was sampled zero-one, and the entry SF means the questions were sampled with split fractions. The difference may be illustrated by a simple example. Consider a question that has two branches, and a uniform distribution from 0.0 to 1.0 for the probability for the first branch. If the sampling is zero-one, in half the observations, the probability for the first branch will be 1.0, and in the other half of the observations it will be 0.0. If the sampling is split fraction, the probability for the first branch for each observation is a random fractional value between 0.0 and 1.0. The average over all the fractions in the sample is 0.50. The implications of ZO or SF sampling are discussed in the methodology volume (Volume 1).

If the sampling column is blank, the branching ratios for that question, and the parameter values defined in that question, if any, are fixed. The branching ratios of the PDS questions change to indicate which PDS is being considered. Some of the branching ratios depend on the relative frequency of the PDSs, which make up the PDS group being considered. These branching ratios change for every sample observation, but may do so for some PDS groups and not for others. If the branching ratios change from observation-to-observation for any one of the seven PDS groups, SF is placed in the sampling column for the PDS questions.

The abbreviations in the quantification column of the Table 2.3-1 are given below, with the number of questions which have that type of quantification.

Type of Quantification	Number of Questions	Comments
PDS	11	Determined by the PDS
AcFrqAn	1	Determined in the accident frequency analysis
Other	4	See notes 1 through 4
Internal	17	Quantified internally in this analysis

Summary	17	The branch taken at this question follows directly from the branches taken at previous questions
ROSP	3	The probability of the recovery of offsite power is determined by distributions derived from the electric power recovery data for this plant
UFUN-Str.	3	Calculated in the User Function, using distributions from the Structural Expert Panel
UFUN-Int.	2	Calculated in the User Function, using an adiabatic pressure rise calculation determined internally
In-Vessel	5	Distributions from the In-Vessel Expert Panel
Loads	2	Distributions from the Containment Loads Expert Panel
Struct.	1	Distribution from the Structural Expert Panel
N.A.	5	Fan cooler questions not applicable to Surry

In some cases, a question may have more than one function, so the entry under Quantification in Table 2.3.1 can be only indicative. For example, Questions 43, 52, and 64 are listed as being quantified by the user function, based on distributions generated by the Structural Response Expert Panel. The actual situation is this: a portion of the user function is evaluated which determines whether the containment fails using the load pressure and the failure pressure. The load pressure is determined in Questions 39 and 40 based on aggregate distributions from the Containment Loads Expert Panel. The containment failure pressure is determined in Question 42 from the aggregate distribution from the Structural Response Expert Panel. If the failure pressure is lower than the load pressure, then the containment fails and the mode of failure is determined using the random number defined in Question 42 and a table of conditional failure mode probabilities contained in the user function. This table was also generated by the Structural Response Expert Panel. The sampling is indicated to be zero-one because one of the four branches of these questions always has a probability of 1.0, and the other three always have a probability of 0.0

Table 2.3-1
Questions in the Surry APET

Question Number	Question	Sampling	Quantification
1.	Size & location of RCS break when the core uncovers?	SF	PDS
2.	Has the reaction been brought under control?	SF	PDS
3.	For SGTR, are the secondary system SRVs stuck open?	SF	PDS
4.	Status of ECCS?	SF	PDS
5.	RCS depressurization by the operators?	SF	PDS
6.	Status of sprays?	SF	PDS
7.	Status of fan coolers?		N.A.
8.	Status of ac power?		PDS
9.	RWST injected into containment?	SF	PDS
10.	Heat removal from the steam generators?	SF	PDS
11.	Did the operators depressurize the secondary before the core uncovers?	SF	PDS
12.	Cooling for RCP seals?	SF	PDS
13.	Initial containment condition?		AcFrqAn
14.	Event V - break location under water?	SF	Note 1
15.	RCS pressure at the start of core degradation?		Summary
16.	Do the PORVs stick open?	SF	Note 2
17.	Temperature-induced RCP seal failure?	ZO	Note 3
18.	Is the RCS depressurized before breach by opening the pressurizer PORVs?		Internal
19.	Temperature-induced SGTR?	DS	In-Vessel
20.	Temperature-induced hot leg or surge line break?	DS	In-Vessel
21.	Is ac power available early?	SF	ROSP
22.	Rate of blowdown to containment?		Summary
23.	Vessel pressure just before vessel breach?	ZO	Internal
24.	Is core damage arrested? No vessel breach?	SF	Internal
25.	Early sprays?		Summary
26.	Early fan coolers?	N.A.	
27.	Early containment heat removal?		Summary

Table 2.3-1 (continued)

Question Number	Question	Sampling	Quantification
28.	Baseline containment pressure before VB?		Internal
29.	Time of accumulator discharge?		Summary
30.	Fraction of zirconium oxidized in-vessel during core degradation?	P	In-Vessel
31.	Amount of zirconium oxidized in-vessel during core degradation?		Summary
32.	Amount of water in the reactor cavity at vessel breach?		Summary
33.	Fraction of core released from the vessel at breach?	P	In-Vessel
34.	Amount of core released from the vessel at breach?		Summary
35.	Does an alpha event fail both vessel & containment?	SF	Note 4
36.	Type of vessel breach?	ZO	In-Vessel
37.	Does the vessel become a "Rocket" and fail the cont.?		Internal
38.	Size of hole in vessel (after ablation)?	ZO	Internal
39.	Total pressure rise at vessel breach? Large hole cases	P	Loads
40.	Total pressure rise at vessel breach? Small hole cases	P	Loads
41.	Does a significant ex-vessel steam explosion occur?		Internal
42.	Containment failure pressure?	P	Struct.
43.	Containment failure and type of failure?	ZO	UFUN-Str.
44.	Sprays after vessel breach?		Internal
45.	Is ac power available late?	SF	ROSP
46.	Late sprays?		Summary
47.	Late fan coolers?		N.A.
48.	Late containment heat removal?		Summary
49.	How much hydrogen burns at vessel breach?	SF	Internal
50.	Does late ignition occur?		Internal
51.	Resulting pressure in containment?		UFUN-Int.
52.	Containment failure and type of failure?	ZO	UFUN-Str.
53.	Amount of core available for CCI?		Summary
54.	Is the debris bed in a coolable configuration?		Internal

Table 2.3-1 (continued)

Question Number	Question	Sampling	Quantification
55.	Does prompt CCI occur?		Summary
56.	Is ac power available very late?	SF	ROSP
57.	Very late sprays?		Summary
58.	Very late fan coolers?		N.A.
59.	Very late containment heat removal?		Summary
60.	Does delayed CCI occur?		Summary
61.	How much hydrogen is produced during CCI?		Internal
62.	Does very late ignition occur?	P	Internal
63.	Resulting pressure in containment?		UFUN-Int.
64.	Containment failure and type of failure?	ZO	UFUN-Str.
65.	Sprays after very late CF?		Internal
66.	Fan coolers after very late CF?		N.A.
67.	Containment heat removal after very late CF		Summary
68.	Eventual basemat melt-through (BMT)?		Internal
69.	Eventual overpressure failure of containment?		Internal
70.	BMT before overpressure failure?		Internal
71.	Final containment condition?		Summary

Notes to Table 2.3-1

Note 1. Whether the location of the break in the low pressure piping would be under water in Event V at the time the core was uncovered was determined by a special panel which considered only this problem for the draft version of this analysis. As there was no new information available, there was no reason to change the conclusions reached by this group. See the discussion of Question 14 in Appendix A.1.1.

Note 2. There is little or no data on the failure rate of PORVs when passing gases at temperatures considerably in excess of their design temperature. The quantification was arrived at by discussions between the accident frequency analyst and the plant analyst. See the discussion of Question 16 in Appendix A.1.1.

Note 3. In the accident frequency analysis, a special panel was convened to consider the issue of the failure of RCP seals. The quantification of this question is not as detailed as that done in the accident frequency analysis, but relies on the information produced by this panel. See the discussion of Question 17 in Appendix A.1.1.

Note 4. The Alpha mode of vessel and containment failure was considered by the Steam Explosion Review Group a few years ago. The distribution used in this analysis is based on information contained in the report of this group. See the discussion of Question 35 in Appendix A.1.1.

Key to Abbreviations in Table 2.3-1

AcFrqAn	The quantification was performed as part of the Accident Frequency Analysis
DS	The branch probabilities are taken from a distribution; depending on the distribution the sampling may be SF or ZO.
Internal	The quantification was performed at Sandia National Laboratories by the plant analyst with the assistance of other members of the laboratory staff.
In-Vessel	This question was quantified by sampling from an aggregate distribution provided by the Expert Panel on In-Vessel Issues.
Loads	This question was quantified by sampling from an aggregate distribution provided by the Expert Panel on Containment Loads.
N.A.	Not Applicable.
P	A parameter is determined by sampling from a distribution, in most cases an aggregate distribution from an expert panel.
PDS	The quantification follows directly from the definition of the Plant Damage State.
ROSP	This question was quantified by sampling from a distribution derived from the offsite power recovery data for the plant.
SF	Split Fraction sampling - the branch probabilities are real numbers between zero and one.

Struct.	This question was quantified by sampling from an aggregate distribution provided by the Structural Response Expert Panel.
Summary	The quantification for this question follows directly from the branches taken at preceding questions, or the values of parameters defined in preceding questions.
UFUN-Str.	This question is quantified by the execution of a part of the User Function, using distributions from the Structural Response Expert Panel.
UFUN-Int.	This question is quantified by the execution of a part of the User Function, using an adiabatic calculation for the pressure rise due to hydrogen combustion.
ZO	Zero-One sampling - the branch probabilities are either 0.0 or 1.0.

2.3.3 Variables Sampled for the Accident Progression Analysis

About 50 variables were sampled for the accident progression analysis. That is, every time the APET was evaluated by EVNTRE, the original values of about 50 variables were replaced with values selected for the particular observation under consideration. These values were selected by the LHS program from distributions that were defined before the APET was evaluated. Most of these distributions were determined by expert panels. Table 2.3-2 lists the variables in the APET which were sampled for the accident progression analysis. Some of them are branch fractions; the others are parameter values for use in calculations performed while the APET is being evaluated.

In Table 2.3-2, the first column gives the variable abbreviation or identifier, and the question (and case if appropriate) in which the variable is used. The identifiers are limited to eight characters for the statistical package used to perform sensitivity studies. Where several variables are correlated, they are treated as one variable in the regression analysis (see section 3.3.1.10), but are different variables as far as the accident progression analysis and sampling process are concerned. Some of these variables in Table 2.3-2 have a number to distinguish the cases in the ninth position, which is dropped in the sensitivity analysis. For example, RCP-SL-P2 and RCP-SL-P3 are treated as one variable, RCP-SL-P, in the sensitivity analyses.

The second column gives the range of the distribution for the variable. An entry of "0.0/1.0" in this column indicates that the variable took on fractional values between 0.0 and 1.0. An entry of "Zero/One" in this column indicates that the variable was sampled Zero-One, i.e., it took on only the values 0.0 and 1.0. In each observation, one of these two values would be assigned.

The third column in Table 2.3-2 indicates the type of distribution used. For uniform distributions from 0.0 to 1.0, the mean is obvious and so is not listed. Otherwise, the mean is given, if appropriate. The entry "Experts" for the distribution indicates that the distribution came from an expert panel and the entry "Internal" distribution indicates that the distribution was determined internally by the project staff or others. (None of the distributions obtained by aggregating the conclusions of experts can be described succinctly in words. Plots of the aggregate expert distributions are contained in Volume 2 of this report. A listing of the input to the LHS program that contains many of these distributions in tabular form is given in Appendix E.) For Zero-One variables, an indication of the probability of each state is given in this column.

The fourth and fifth columns in Table 2.3-2 show whether the variable is correlated with any other. "Rank 1" indicates a rank correlation of 1.0. An "n" is used to indicate any integer. In the entry for RCP-SL-P2, RCP-SL-Pn in the "Correl. with" column indicates that RCP-SL-P2 is correlated with RCP-SL-P3 and RCP-SL-P4. For further information on each of the variables listed in the table, see the detailed discussion of the indicated APET question in Appendix A.

Most of the variables listed in Table 2.3-2 need no further comment. The RCS pressure at VB variables, RCSPR-VB2 and RCSPR-VB3 (Question 23), are sampled Zero-One. The distribution column gives the fraction of the time each of the pressure ranges is chosen. Low is below 200 psia, Im indicates the intermediate pressure range, from 200 to 600 psia. The high pressure range extends from 600 to 2000 psia, but is nominally about 1000 to 1500 psia. Setpoint pressure refers to the PORV and SRV settings, about 2500 psia.

RCP seal failure is considered both in the accident frequency analysis and in the accident progression analysis. The eight-character code is RCP-SL-F for RCP seal failures in the accident frequency analysis and RCP-SL-P for RCP seal failures in the accident progression analysis. These two variables should have been correlated with each other, but the ways in which seal failures were treated in the two constituent analyses were so different that this was not feasible.

Note that both the temperature-induced (T-I) hot leg failure variables (Question 20) and all the fraction of zirconium oxidized variables (Question 30) are correlated with each other as the experts concluded that the oxidation of a lot of zirconium before VB would result in high temperatures, which in turn, would make hot leg or surge line failure more likely. This reasoning included the T-I SGTR as well as the hot leg break, and it was intended that variable TI-SGTR would be correlated with TI-HOTLG and FR-ZROX. Due to an oversight, this correlation was omitted. As T-I SGTRs were very infrequent, the omission of this correlation was not significant.

The type of vessel failure variables (Question 36) are sampled Zero-One and the entries under "Distribution" indicate the probability of each type of vessel breach. HPME indicates ejection of the melt at high pressure through a hole that is small relative to the cross-section of the vessel. BtmHd indicates a gross failure of the entire bottom head of the vessel, and Pour indicates a slow release of the melt driven primarily by gravity. For the hole size (Question 38), large means greater than 0.4 m^2 (nominally 2.0 m^2) and small means smaller than 0.4 m^2 (nominally 0.1 m^2).

For the numerous pressure rise at VB variables (Questions 39 and 40), wet cavity means the cavity contains at least the accumulator water (depth about 4 ft) or that the cavity is full (depth about 14 ft). The fraction of the core ejected at VB (Question 33) was placed into three groups in Question 34. High fraction ejected means greater than 40%, medium fraction ejected means between 20 and 40%, and low fraction ejected means less than 20%.

The failure mode, as a function of failure pressure, was determined by the structural expert panel. The containment failure mode variable, CF-MODE (Question 42), is only a random variable used to determine the failure mode. The method used to select the failure mode for each observation is explained in Volume 1, and the results of the expert panel on the failure pressure and failure mode for Surry may be found in Volume 2. Additional information is contained in the discussion of Question 42 in Appendix A of this volume.

The final variable in Table 2.3-2 (Questions 21, 45, and 56) is used to select the probability that offsite power will be recovered in a specified time interval given that it was not recovered in a previous time interval. Distributions were developed for 12 cases, each with different start and end times, corresponding to different classes of accidents. See the discussions in Appendix A for the questions listed above. More detail on the methods for determining the probability of offsite power recovery may be found in the methodology volume of this report and NUREG/CR-4550. The variable POWERREC defines a quantile for these distributions and the associated recovery probabilities are used in the analysis.

Table 2.3-2
Variables Sampled in the Accident Progression Analysis for Internal Initiators

Variable Question & Case	Range	Distribution	Correlation	Correlated With	Description
V-UWATER Q14	0.70 1.0	Uniform Mean=0.85	None		Probability that the break location will be underwater when radioactive releases begin, given Event V.
PORV-OPN Q16 C1	0.0 1.0	Uniform	None		Probability that at least one PZR PORV or RCS SRV sticks open, given that the RCS is intact and the PORVs or SRVs are cycling.
RCP-SL-P2 Q17 C2	Zero One	Fail 0.71	Rank 1	RCP-SL-Pn	Probability of a T-I failure of the RCP seals,given core damage, RCS at setpoint pressure, and no cooling for the RCP seals.
RCP-SL-P3 Q17 C3	Zero One	Fail 0.65	Rank 1	RCP-SL-Pn	Probability of a T-I failure of the RCP seals given core damage, RCS at high pressure, and no cooling for the RCP seals.
RCP-SL-P4 Q17 C4	Zero One	Fail 0.60	Rank 1	RCP-SL-Pn	Probability of a T-I failure of the RCP seals, given core damage, RCS at intermediate or low pressure, and no cooling for the RCP seals.
TI-SGTR Q19 C1	0.0 0.12	Experts Mean=0.014	None		Probability of a T-I SGTR, given core damage, RCS at setpoint pressure, and no cooling for the steam generators.
TI-HOTLG1 Q20 C1	0.0 1.0	Experts Mean=0.77	Rank 1	TI-HOTLG2 FR-ZROXn	Probability of a T-I failure of the hot leg or surge line, given core damage, AFWS failure, and the RCS intact at setpoint pressure.

Table 2.3-2 (continued)

Variable Question & Case	Range	Distribution	Correlation	Correlated With	Description
TI-HOTLG2 Q20 C2	0.0 1.0	Experts Mean=0.035	Rank 1	TI-HOTLG1 FR-ZROXn	Probability of a T-I failure of the hot leg or surge line, given core damage, AFWS failure, and an S_3 break in the RCS.
RCSPR-VB2 Q23 C2	Zero One	0.20 Low 0.80 Im	Rank 1	RCSPR-VB3	RCS pressure just before vessel breach, given an initiating or induced S_2 break.
RCSPR-VB3 Q23 C3	Zero One	0.33 Low 0.34 Im 0.33 High	Rank 1	RCSPR-VB2	RCS pressure just before vessel breach, given an initiating or induced S_3 break.
CDARREST5 Q24 C5	0.80 1.0	Uniform	Rank 1	CDARRESTn	Probability that core damage can be arrested before VB, given the conditions of case 5. (Also used for case 8.)
CDARREST6 Q24 C6	0.0 1.0	Quadratic Mean=0.67	Rank 1	CDARRESTn	Probability that core damage can be arrested before VB, given the conditions of case 6.
CDARREST7 Q24 C7	0.0 1.0	Uniform	Rank 1	CDARRESTn	Probability that core damage can be arrested before VB, given the conditions of case 7.
FR-ZROX1 Q30 C1	0.0 1.3	Experts Mean=0.44	Rank 1	TI-HOTLGn FR-ZROXn	Fraction of equivalent core zirconium oxidized in-vessel given that the RCS is at setpoint pressure and the accumulators discharge before or after core melt.

Table 2.3-2 (continued)

Variable Question & Case	Range	Distribution	Correlation	Correlated With	Description
FR-ZROX2 Q30 C2	0.0 1.3	Experts Mean=0.50	Rank 1	TI-HOTLGn FR-ZROXn	Fraction of equivalent core zirconium oxidized in-vessel given that the RCS is at setpoint pressure and the accumulators discharge during core melt.
FR-ZROX3 Q30 C3	0.0 0.80	Experts Mean=0.32	Rank 1	TI-HOTLGn FR-ZROXn	Fraction of equivalent core zirconium oxidized in-vessel given that the RCS is at high pressure and the accumulators discharge before or after core melt.
FR-ZROX4 Q30 C4	0.0 0.85	Experts Mean=0.38	Rank 1	TI-HOTLGn FR-ZROXn	Fraction of equivalent core zirconium oxidized in-vessel given that the RCS is at high pressure and the accumulators discharge during core melt.
FR-ZROX5 Q30 C5	0.0 1.2	Experts Mean = 0.48	Rank 1	TI-HOTLGn FR-ZROXn	Fraction of equivalent core zirconium oxidized in-vessel given that the RCS is at intermediate pressure and the accumulators discharge before or after core melt.
FR-ZROX6 Q30 C6	0.0 1.2	Experts Mean=0.52	Rank 1	TI-HOTLGn FR-ZROXn	Fraction of equivalent core zirconium oxidized in-vessel given that the RCS is at intermediate pressure and the accumulators discharge during core melt.

Table 2.3-2 (continued)

Variable Question & Case	Range	Distribution	Correlation	Correlated With	Description
FR-ZROX7 Q30 C7	0.0 1.2	Experts Mean=0.45	Rank 1	TI-HOTLGn FR-ZROXn	Fraction of equivalent core zirconium oxidized given that the RCS is at low pressure and the accumulators discharge before core melt.
FR-HPME Q33	0.0 0.60	Experts Mean=0.30	None		Fraction of core which participates in HPME at VB.
VB-ALPHA Q35 C1	0.0 1.0	Experts Mean=.0091	None		Probability that an Alpha mode CF occurs,given that the RCS is at low pressure. (One tenth this value is utilized for case 2.)
TYPE-VB1 Q36 C2	Zero One	Experts HPME 0.79 BtmHd 0.08 Pour 0.13	Rank 1	TYPE-VB2	Type of VB given that the RCS is at setpoint pressure.
TYPE-VB2 Q36 C3	Zero One	Experts HPME 0.60 BtmHd 0.27 Pour 0.13	Rank 1	TYPE-VB1	Type of VB given that the RCS is at high pressure. (Also used for case 4.)
VBHOLSIZ Q38 C1	Zero One	0.1 Large 0.9 Small	None		Size of the hole in the vessel after ablation given high pressure melt ejection.
PRISE-LO Q39 C3	0.0 80 psi	Experts Mean=19	None		Pressure rise at VB given that the RCS is at low pressure or the mode of VB is Pour.

Table 2.3-2 (continued)

Variable Question & Case	Range	Distribution	Correlation	Correlated With	Description
PRISE-VB1 Q39 C5	6.5 165 psi	Experts Mean=67	Rank 1	PRISE-VBn	Pressure rise at VB given Im RCS pressure,high fraction ejected, large hole, wet cavity.
PRISE-VB2 Q39 C6	5.0 145 psi	Experts Mean=58	Rank 1	PRISE-VBn	Pressure rise at VB given Im RCS pressure, medium fract. ejected, large hole, wet cavity.
PRISE-VB3 Q39 C7	3.0 112 psi	Experts Mean=38	Rank 1	PRISE-VBn	Pressure rise at VB given Im RCS pressure, low fraction ejected, large hole, wet cavity.
PRISE-VB4 Q39 C8	11 185 psi	Experts Mean=90	Rank 1	PRISE-VBn	Pressure rise at VB given high or setpoint RCS pressure, high fraction ejected, large hole, dry cavity.
PRISE-VB5 Q39 C9	9.5 166 psi	Experts Mean = 75	Rank 1	PRISE-VBn	Pressure rise at VB given high or setpoint RCS pressure, medium fraction ejected, large hole, dry cavity.
PRISE-VB6 Q39 C10	5.5 123 psi	Experts Mean=47	Rank 1	PRISE-VBn	Pressure rise at VB given high or pressure, low fraction ejected, large hole, dry cavity.
PRISE-VB7 Q39 C11	9.0 180 psi	Experts Mean=77	Rank 1	PRISE-VBn	Pressure rise at VB given high or setpoint RCS pressure and a wet cavity or Im pressure and a dry cavity, high fraction ejected, large hole.

Table 2.3-2 (continued)

Variable Question & Case	Range	Distribution	Correlation	Correlated With	Description
PRISE-VB8 Q39 C12	8.0 160 psi	Experts Mean=65	Rank 1	PRISE-VBn	Pressure rise at VB given high or setpoint RCS pressure and a wet cavity or Im pressure and a dry cavity, medium fraction ejected, large hole.
PRISE-VB9 Q39 C13	5.0 120 psi	Experts Mean=42	Rank 1	PRISE-VBn	Pressure rise at VB given high or setpoint RCS pressure and a wet cavity or Im pressure and a dry cavity, low fraction ejected, large hole.
PRISE-VB10 Q40 C2	5.5 157 psi	Experts Mean=60	Rank 1	PRISE-VBn	Pressure rise at VB given Im RCS pressure, high fraction ejected, small hole, wet cavity.
PRISE-VB11 Q40 C3	4.5 135 psi	Experts Mean=49	Rank 1	PRISE-VBn	Pressure rise at VB given Im RCS pressure, medium fraction ejected small hole, wet cavity.
PRISE-VB12 Q40 C4	3.0 107 psi	Experts Mean=34	Rank 1	PRISE-VBn	Pressure rise at VB given Im RCS pressure, low fraction ejected, small hole, wet cavity.
PRISE-VB13 Q40 C5	8.0 160 psi	Experts Mean=75	Rank 1	PRISE-VBn	Pressure rise at VB given high or setpoint RCS pressure, high fraction ejected, small hole, dry cavity.
PRISE-VB14 Q40 C6	7.0 140 psi	Experts Mean=61	Rank 1	PRISE-VBn	Pressure rise at VB given high or setpoint RCS pressure, medium fraction ejected, small hole, dry cavity.

Table 2.3-2 (continued)

Variable Question & Case	Range	Distribution	Correlation	Correlated With	Description
PRISE-VB15 Q40 C7	4.4 108 psi	Experts Mean=40	Rank 1	PRISE-VBn	Pressure rise at VB given high or setpoint RCS pressure, low fraction ejected, small hole, dry cavity.
PRISE-VB16 Q40 C8	6.5 160 psi	Experts Mean=66	Rank 1	PRISE-VBn	Pressure rise at VB given high or setpoint RCS pressure and a wet cavity or Im pressure and a dry cavity, high fraction ejected, small hole.
PRISE-VB17 Q40 C9	6.0 136 psi	Experts Mean=55	Rank 1	PRISE-VBn	Pressure rise at VB given high or setpoint RCS pressure and a wet cavity or Im pressure and a dry cavity, medium fraction ejected, small hole.
PRISE-VB18 Q40 C10	3.6 110 psi	Experts Mean=37	Rank 1	PRISE-VBn	Pressure rise at VB given high or setpoint RCS pressure and a wet cavity or Im pressure and a dry cavity, low fraction ejected, small hole.
CF-PRES Q42	70 190 psig	Experts Mean=126	None		Containment failure pressure.
CF-MODE Q42	0.0 1.0	Uniform	None		Random number used to select containment failure mode.
HB-SCAL1 Q50, Q62	0.20 1.2	Internal Mean=0.72	None		Ratio of the expected pressure rise to the adiabatic pressure rise for a hydrogen burn resulting from rapid steam condensation.

Table 2.3-2 (continued)

Variable Question & Case	Range	Distribution	Correlation	Correlated With	Description
HB-SCAL2 Q62	0.10 1.0	Internal Mean=0.53	None		Ratio of the expected pressure rise to the adiabatic pressure rise for a hydrogen burn resulting from slow steam condensation.
POWERREC Q21, Q45, Q56			None		Variable used to select the probability that offsite power will be recovered in a specified time interval given that it was not recovered in a previous time interval.

2.4 Description of the Accident Progression Bins

As each path through the APET is evaluated, the result of that evaluation is stored by assigning it to an accident progression bin. This bin describes the evaluation in enough detail that a source term (release of radionuclides) can be calculated for it. The accident progression bins are the means by which information is passed from the accident progression analysis to the source term analysis. A bin is defined by specifying the attribute or value for each of eleven characteristics or quantities which define a certain feature of the evaluation of the APET. Section 2.4.1 describes the eleven characteristics, and the values that each characteristic can assume. A more detailed description of the binner, discussing each case in turn, is contained in Appendix A.1.3. The binner itself, which is expressed as a computer input file, is listed in Appendix A.1.4. Section 2.4.2 contains a discussion of rebinning, a process that takes place between evaluating the APET (in which binning takes place) and the source term analysis. Section 2.4.3 describes a reduced set of binning characteristics, which is used in presenting the results of evaluating the APET.

2.4.1 Description of the Bin Characteristics

The binning scheme for Surry uses eleven characteristics. That is, there are eleven types of information required to define a path through the APET. A bin is defined by specifying a letter for each of the eleven characteristics, where each letter for each characteristic has a meaning defined below. For a characteristic, the possible states are termed attributes. The Surry binning characteristics are:

Characteristic	Abbreviation	Description
1	CF-Time	Time of containment failure
2	Sprays	Periods in which sprays operate
3	CCI	Occurrence of CCIs
4	RCS-Pres	RCS pressure before vessel breach
5	VB-Mode	Mode of VB
6	SGTR	Steam generator tube rupture
7	Amt-CCI	Amount of core available for CCI
8	Zr-Ox	Fraction of Zirconium oxidized in-vessel
9	HPME	Fraction of the core in thr high pressure melt injection (HPME)
10	CF-Size	Size or type of containment failure
11	RCS-Hole	Number of large holes in the RCS after VB

Most of this information, organized in this manner, is needed by SURSOR to calculate the fission product source terms. Characteristic 5, Mode of Vessel Breach, is not used by SURSOR, but has been retained because it provides interesting output information about the APET outcome, or the paths taken through the APET. SURSOR obtains the information it needs concerning HPME from Characteristic 9, Fraction of the Core in HPME.

The remainder of this section consists of a listing of each attribute for each characteristic, followed by a brief description of each characteristic, and finally an explanation of an example bin.

Characteristic 1: Containment Failure Time

A - V-Dry	Event V, Break Location not Submerged
B - V-Wet	Event V, Break Location Submerged
C - Early-CF	Containment Failure before VB
D - CF-at-VB	Containment Failure at VB
E - Late-CF	Late Containment Failure (during the initial part of CCI, nominally a few hours after VB)
F - VLate-CF	Very Late Containment Failure (during the latter part of CCI, nominally 8 to 12 hours after VB)
G - Final-CF	Containment Failure in the Final Period (nominally about 24 h after VB)
H - No-CF	No Containment Failure

Characteristic 2 - Sprays

A - Sp-Early	The sprays operate only in the Early period.
B - Sp-E+I	The sprays operate only in the Early and Intermediate periods.
C - Sp-E+I+L	The sprays operate only in the Early, Intermediate, and Late periods.
D - SpAlways	The sprays Always operate during the periods of interest for fission product removal.
E - Sp-Late	The sprays operate only in the Late period.
F - Sp-L+VL	The sprays operate only in the Late and Very Late periods.

G - Sp-VL	The sprays operate only in the Very Late period.
H - Sp-Never	The sprays Never operate during the accident.
I - Sp-Final	The sprays operate only during the Final period, which is not of interest for fission product removal.

Characteristic 3 - Core-Concrete Interactions

A - Prmpt-Dry	CCI takes place promptly following VB. There is no overlying water pool to scrub the releases.
B - PrmptShlw	CCI takes place promptly following VB. There is a shallow (about 4.5 ft) overlying water pool to scrub the releases.
C - No-CCI	CCI does not take place.
D - PrmptDeep	CCI takes place promptly following VB. There is a deep (about 14 ft) overlying water pool to scrub the releases.
E - SDlyd-Dry	CCI takes place after a short delay. The debris bed is coolable, but the water in the cavity is not replenished. The delay is the time needed to boil off the accumulator water.
F - LDlyd-Dry	CCI takes place after a long delay. The debris bed is coolable, but the water in the cavity is not replenished. The delay is the time needed to boil off the water in a full cavity.

Characteristic 4 - RCS Pressure before Vessel Breach

A - SSPr	System Setpoint Pressure (2500 psia)
B - HiPr	High Pressure (1000 to 2000 psia)
C - ImPr	Intermediate Pressure (200 to 1000 psia)
D - LoPr	Low Pressure (less than 200 psia)

Characteristic 5 - Mode of Vessel Breach

A - VB-HPME	High Pressure Melt Ejection occurs - direct heating always occurs to some extent.
B - VB-Pour	The molten core Pours out of the vessel, driven primarily by the effects of gravity.
C - VB-BtmHd	Gross failure of a large portion of the Bottom Head of the vessel occurs, perhaps as a result of a circumferential failure.
D - Alpha	An Alpha mode failure occurs - resulting in containment failure as well as vessel failure.
E - Rocket	A Rocket mode failure occurs - resulting in containment failure as well as vessel failure.
F - No-VB	No VB occurs.

Characteristic 6 - Steam Generator Tube Rupture

A - SGTR	A SGTR occurs. The SRVs on the secondary system are not stuck open.
B - SGTR-SRVO	A SGTR occurs. The SRVs on the secondary system are stuck open.
C - No-SGTR	A SGTR does not occur.

Characteristic 7 - Amount of Core not in HPME available for CCI

A - Lrg-CCI	A CCI occurs and involves a Large Amount of the Core (70-100%).
B - Med-CCI	A CCI occurs and involves a Medium amount of the Core (30-70%).
C - Sml-CCI	A CCI occurs and involves a Small amount of the Core (0-30%).
D - No-CCI	No CCI occurs.

Characteristic 8 - Zirconium Oxidation

A - Lo-ZrOx	A Low amount of the core Zirconium was Oxidized in the vessel before VB. The implies a range from 0 to 40% oxidized, with a nominal value of 25%.
B - Hi-ZrOx	A High amount of the core Zirconium was Oxidized in the vessel prior to vessel breach. This implies that more than 40% of the Zirconium was oxidized, with a nominal value of 65%.

Characteristic 9 - High Pressure Melt Ejection (HPME)

A - Hi-HPME	A High fraction (> 40%) of the core was ejected under pressure from the vessel at failure.
B - Md-HPME	A Moderate fraction (20-40%) of the core was ejected under pressure from the vessel at failure.
C - Lo-HPME	A Low fraction (< 20%) of the core was ejected under pressure from the vessel at failure.
D - No-HPME	There was no HPME at vessel failure.

Characteristic 10 - Containment Failure Size

A - Cat-Rupt	The containment failed by catastrophic rupture, resulting in a very large hole and gross structural failure.
B - Rupture	The containment failed by the development of a large hole or rupture; nominal hole size is 7 ft^2.
C - Leak	The containment failed by the development of a small hole or a leak; nominal hole size is 0.1 ft^2.
D - BMT	The containment failed by BMT.
E - Bypass	The containment was bypassed by event V or an SGTR.
F - No-CF	The containment did not fail.

Characteristic 11 - Holes in the RCS

A - 1-Hole	There is only One large Hole in the RCS following VB, so there is no effective natural circulation through the RCS after breach.
B - 2-Holes	There are Two large Holes in the RCS following VB, so there will be effective natural circulation through the RCS after breach.

Characteristic 1 primarily concerns the time of containment failure. There are eight attributes. Five of these attributes concern the time of containment failure, two concern Event V, and one is for no containment failure. SGTRs are considered separately in Characteristic 6 since an SGTR can occur in addition to one of the modes of containment failure. SURSOR does not distinguish between Late and Very Late containment failure, so these two attributes are combined in the rebinner. BMT and eventual overpressure failure due to the inability to restore containment heat removal in the days following the accident are the failures that occur in the Final period.

Characteristic 2 concerns the periods in which the sprays operate. The division into the nine attributes is a straightforward sorting out of the various combinations of time periods. The final time period is of little consequence for the fission product release, but it must be included because there are cases where the sprays operate only in this period and, for each characteristic, the binner must have a location in which to place every outcome. As SURSOR does not distinguish between 'Sprays Never Operate', Attribute H, and 'Sprays Operate only in the Final Period', Attribute I, these two are combined in the rebinner for SURSOR.

Characteristic 3 concerns the CCIs. There are six possibilities which cover the meaningful combinations of prompt CCI, delayed CCI, and no CCI, with the amount of water in the cavity. The amount of water in the cavity may be divided into three cases. If the cavity was dry at VB and the accumulators discharge before breach, the cavity is dry at the start of CCI. If the cavity was dry at VB and the accumulators discharge at breach, the cavity will be about one quarter full. If the sprays operate before breach, then the cavity will be full (14 ft of water). (At Surry, the cavity can hold about 12,400 ft^3 of water.) The neutron shield tank has been ignored in this analysis. It contains 1600 ft^3 of water, and the walls are steel 1.5 in. thick (EPRI NP-4096, p. D-16). Although the supports may fail at or after vessel failure, there seems to be a good chance that the cylindrical tank (it surrounds the vessel) would wedge in place. The cavity and in-core instrumentation room together have a floor area of about 620 ft^2, so the neutron shield water would cover it to a depth of about 2.5 ft.

Characteristic 4 concerns the pressure in the reactor vessel before vessel breach; there are four levels. The pressures shown in parentheses below are approximate pressures just before VB. The RCS pressure during most of

the core degradation period may be less than this value except for SSPr where the reclosing of the PORVs will keep the system pressure at the setpoint value.

Characteristic 5 concerns the mode of vessel breach; there are six possibilities, including no VB. Direct heating of the containment always occurs to some extent if there is HPME, so there is no simple way to distinguish whether direct containment heating occurs.

Characteristic 6 concerns SGTR. There are only three possibilities: no SGTR, SGTR, and SGTR with the SRVs on the secondary system stuck open. SGTR is considered separately from the other containment failure modes since it can occur in addition to the other failure modes. That is, occurrence of an SGTR before VB does not preclude containment failure at VB or late containment failure. The SGTR creates a bypass of the containment which may have no removal mechanisms operating in the escape path, so it is important to treat it separately.

Characteristic 7 concerns how much of the core not in HPME that is available to participate in the CCI. The fractions 0.30 and 0.70 divide the range into three portions. The fourth attribute is no CCI. As SURSOR subtracts out the fraction of the core involved in HPME, when HPME occurs the fraction of the core available for CCI is always set to Large.

Characteristic 8 concerns the amount of the core zirconium which is oxidized in-vessel before vessel breach. There are two possible values for this characteristic: low and high. The demarcation point between the two ranges is 40%.

Characteristic 9 concerns the amount of the core involved in HPME; there are four attributes. The possible range is divided into three portions by 20% and 40%. No HPME is the fourth attribute.

Characteristic 10 concerns the size of the hole that results from containment failure or the type of containment failure. There are six attributes. The first three attributes concern failure of the containment wall above ground. BMT results in a release from the containment below ground. As SURSOR does not distinguish Final period leaks from BMT, they are combined in the rebinner. SURSOR determines whether the containment was bypassed from Characteristic 1 (Event V) and Characteristic 6 (SGTR), so the Bypass attribute is combined with No-CF in the rebinner.

Characteristic 11 concerns the number of large holes in the RCS after breach. The experts on the Source Term Expert Panel who provided distributions for revolatilization from the RCS surfaces after VB gave different distributions depending on whether an effective natural circulation flow would be set up within the vessel. A significant flow could be expected only if there were two large, effective holes in the RCS; for example the hole in the bottom head resulting from vessel failure and a large temperature-induced hole in the hot leg. SGTRs, failure of the RCP seals, and Event V's would not count as large effective holes since effective natural circulation through the RCS would not result in these cases. S_3-size holes are not considered large enough to result in effective natural circulation after vessel breach.

A typical bin might be GFADBCABDDB, which, using the information presented above, is:

G - Final-CF	Containment Failure in the Final Period
F - Sp-L+VL	Sprays only in the Late and Very Late periods.
A - Prmpt-Dry	Prompt CCI, Dry cavity
D - LoPr	Low Pressure in the RCS at vessel breach
B - VB-Pour	Core material Poured out of the vessel at breach
C - No-SGTR	No Steam Generator Tube Rupture
A - Lrg-CCI	A Large fraction of the core was available for CCI
B - Hi-ZrOx	A High fraction of the Zirconium was Oxidized in-vessel
D - No-HPME	No HPME
D - BMT	BMT
B - 2-Holes	Two Holes in the RCS.

2.4.2 Rebinning

The binning scheme used for the evaluation of the APET does not exactly match the input information required by SURSOR. The additional information in the initial binning is kept because it provides a better record of the outcomes of the APET evaluation. Therefore, there is a step between the evaluation of the APET and the evaluation of SURSOR known as "rebinning". In the rebinning, a few attributes in some characteristics are combined because there are no significant differences between them for calculating the fission product releases. Characteristic 5, Mode of VB, is not used by SURSOR, but is not eliminated in the rebinning. The information SURSOR requires about HPME is obtained from Characteristic 9.

In the rebinning for Surry, there are no changes for Characteristics 3, 4, 5, 6, 7, 8, 9, and 11. That is, for these eight characteristics, the information produced by the APET is exactly that used by SURSOR. For Characteristic 1, the Late-CF and VLate-CF, Attributes E and F, are combined into VLate-CF, Attribute E. Final-CF becomes Attribute F, and No-CF becomes Attribute G. For Characteristic 2, the two final attributes (H - Sp-Never, and I - Sp-Final) are combined into Attribute H, Sp-NonOp, since whether the sprays operate in the Final period does not affect the amount of fission products released. For Characteristic 10, the third and fourth attributes (C - Leak, and D - BMT) are combined into Attribute C (Leak) since SURSOR considers the radionuclides released from BMT to be the same as those released from a leak in this period. Also for Characteristic 10, the fifth and sixth attributes (E - Bypass and F - No-CF) are combined into a new Attribute D (No-CF) since the containment pressure boundary is not failed by a bypass and the releases from the bypass events (V and SGTR) are treated separately in SURSOR.
As rebinned, the listing of each attribute for each characteristic is as follows:

Characteristic 1 - Containment Failure Time (Rebinned)

A - V-Dry	Event V, Break Location not Submerged
B - V-Wet	Event V, Break Location Submerged

C - Early-CF Containment Failure before VB

D - CF-at-VB Containment Failure at VB

E - VLate-CF Late or Very Late Containment Failure (during CCI, nominally several hours after VB)

F - Final-CF Containment Failure in the Final Period (nominally about 24 h after VB)

G - No-CF No Containment Failure

Characteristic 2 - Sprays (Rebinned)

A - Sp-Early The sprays operate only in the Early period.

B - Sp-E+I The sprays operate only in the Early and Intermediate periods.

C - Sp-E+I+L The sprays operate only in the Early, Intermediate, and Late periods.

D - SpAlways The sprays Always operate during the periods of interest for fission product removal.

E - Sp-Late The sprays operate only in the Late period.

F - Sp-L+VL The sprays operate only in the Late and Very Late periods.

G - Sp-VL The sprays operate only in the Very Late period.

H - Sp-NonOp The sprays Never operate during the accident, or operate only during the Final period, which is not of interest for fission product removal.

Characteristic 3 - Core-Concrete Interactions (Rebinned)

A - Prmpt-Dry CCI takes place promptly following VB. There is no overlying water pool to scrub the releases.

B - PrmptShlw CCI takes place promptly following VB. There is a shallow (about 4.5 ft) overlying water pool to scrub the releases.

C - No-CCI CCI does not take place.

D - PrmptDeep CCI takes place promptly following VB. There is a deep (about 14 ft) overlying water pool to scrub the releases.

E - SDlyd-Dry CCI takes place after a short delay. The debris bed is coolable, but the water in the cavity is not replenished. The delay is the time needed to boil off the accumulator water.

F - LDlyd-Dry CCI takes place after a long delay. The debris bed is coolable, but the water in the cavity is not replenished. The delay is the time needed to boil off the water in a full cavity.

Characteristic 4 - RCS Pressure before Vessel Breach (Rebinned)

A - SSPr System Setpoint Pressure (2500 psia)

B - HiPr High Pressure (1000 to 2000 psia)

C - ImPr Intermediate Pressure (200 to 1000 psia)

D - LoPr Low Pressure (less than 200 psia)

Characteristic 5 - Mode of Vessel Breach (Rebinned)

A - VB-HPME HPME occurs - direct heating always occurs to some extent.

B - VB-Pour The molten core Pours out of the vessel, driven primarily by the effects of gravity.

C - VB-BtmHd Gross failure of a large portion of the Bottom Head of the vessel occurs, perhaps as a result of a circumferential failure.

D - Alpha An Alpha mode failure occurs resulting in containment failure as well as vessel failure.

E - Rocket A Rocket mode failure occurs resulting in containment failure as well as vessel failure.

F - No-VB No Vessel Breach occurs.

Characteristic 6 - Steam Generator Tube Rupture (Rebinned)

A - SGTR A SGTR occurs. The SRVs on the secondary system are not stuck open.

B - SGTR-SRVO A SGTR occurs. The SRVs on the secondary system are stuck open.

C - No-SGTR A SGTR does not occur.

Characteristic 7 - Amount of Core not in HPME available for CCI (Rebinned)

A - Lrg-CCI	A CCI occurs and involves a Large Amount of the Core (70-100%).
B - Med-CCI	A CCI occurs and involves a Medium amount of the Core (30-70%).
C - Sml-CCI	A CCI occurs and involves a Small amount of the Core (0-30%).
D - No-CCI	No CCI occurs.

Characteristic 8 - Zirconium Oxidation (Rebinned)

A - Lo-ZrOx	A Low amount of the core Zirconium was Oxidized in the vessel prior to vessel breach. The implies a range from 0 to 40% oxidized, with a nominal value of 25%.
B - Hi-ZrOx	A High amount of the core Zirconium was Oxidized in the vessel before VB. This implies that more than 40% of the zirconium was oxidized, with a nominal value of 65%.

Characteristic 9 - High Pressure Melt Ejection (HPME) (Rebinned)

A - Hi-HPME	A High fraction (> 40%) of the core was ejected under pressure from the vessel at failure.
B - Md-HPME	A Moderate fraction (20 to 40%) of the core was ejected under pressure from the vessel at failure.
C - Lo-HPME	A Low fraction (< 20%) of the core was ejected under pressure from the vessel at failure.
D - No-HPME	There was no HPME at vessel failure.

Characteristic 10 - Containment Failure Size (Rebinned)

A - Cat-Rupt	The containment failed by catastrophic rupture, resulting in a very large hole and gross structural failure.
B - Rupture	The containment failed by the development of a large hole or rupture; nominal hole size is 7 ft^2.
C - Leak	The containment failed by the development of a leak (nominal size 0.1 ft^2) or BMT.
D - No-CF	The containment did not fail. It may have been bypassed.

Characteristic 11 - Holes in the RCS (Rebinned)

A - 1-Hole	There is only One large Hole in the RCS following vessel breach, so there is no effective natural circulation through the RCS after breach.
B - 2-Holes	There are Two large Holes in the RCS following vessel breach, so there will be effective natural circulation through the RCS after breach.

In the rebinning process, bin GFADBCABDDB used as an example above becomes FFADBCABDCB since the rebinning affects first and tenth characteristics:

F - Final-CF	Containment Failure in the Final Period
F - Sp-L+VL	Sprays only in the Late and Very Late periods.
A - Prmpt-Dry	Prompt CCI, Dry cavity
D - LoPr	Low Pressure in the RCS at vessel breach
B - VB-Pour	Core material Poured out of the vessel at breach
C - No-SGTR	No Steam Generator Tube Rupture
A - Lrg-CCI	A Large fraction of the core was available for CCI
B - Hi-ZrOx	A High fraction of the Zirconium was Oxidized in-vessel
D - No-HPME	No HPME
C - Leak	Leak (includes BMT)
B - 2-Holes	Two Holes in the RCS.

2.4.3 Summary Bins for Presentation

For presentation purposes in NUREG-1150, a set of "summary" bins has been adopted. Instead of the 11 characteristics and thousands of possible bins that describe the evaluation of the APET in detail, the summary bins place the outcomes of the evaluation of the APET into a few, very general groups. The seven summary bins for Surry are:

VB, Early CF, Alpha
VB, Early CF, RCS Pressure > 200 psia
VB, Early CF, RCS Pressure < 200 psia
VB, Late CF
Bypass
VB, No CF
No VB.

This order is that used in displays. It has containment failure first, then Bypass, then no containment failure, and finally, no vessel breach. Containment failure is divided into four subsets, which are listed roughly in decreasing order of the severity of the resulting release.

In assigning bins to one of these summary bins, however, the summary bins must be considered in the following order:

Bypass
Alpha
No VB
Early CF
Late CF
No CF.

That is, if Bypass and Early CF both occur, the resulting bin is assigned to Bypass since Bypass occurs first in this list. The reason that the reduced bins must have a definite assignment priority is that all possible outcomes do not fit neatly into the seven reduced bins. There are certain combinations of events which can be put in different places in the reduced bins and there are other combinations of events which do not fit well in any of the reduced bins. None of these combinations are very frequent occurrences, but they have to be put in one of the seven reduced bins. The principle determining the reduced bin is that the release path which results in the highest offsite risk should determine the reduced bin. Thus the reduced bins reflect the logic used by SURSOR in calculating the source terms.

As an example, consider Event V followed by an Alpha mode failure of the vessel and containment. This results in Bypass and Early CF. Should this go in the Alpha reduced bin, or the Bypass reduced bin? By the priority list above, it is placed in the Bypass reduced bin. The reason is that almost all of the fission products released from the core before VB will have escaped to the auxiliary building through the bypass before VB. Thus this path determines most of the risk. Although SURSOR treats the CCI release as if all of it escapes through the ruptured containment, the early release is more important for determining offsite risk.

The placement in reduced bins of six other ambiguous combinations of events is discussed below.

Combination 1: Event V and B-Leak.

The fission product release from Event V with an isolation failure at the start of the accidents (as calculated by SURSOR) is very similar to the release from Event V without an isolation failure, and quite dissimilar to the releases from accidents with an isolation failures but no initial bypass of the containment. Therefore, this combination is placed in the Bypass reduced bin. The relative frequency of this combination is small since the probability of an isolation failure at Surry is 2E-4.

Combination 2: Event V and CF-at-VB.

This combination is analogous to the situation in which Event V is followed by an Alpha mode failure of the containment just discussed, except that the containment fails at VB for other reasons. It is also placed in the Bypass reduced bin.

Combination 3: SGTR and noVB.

In this scenario, vessel failure is avoided but there may be considerable core damage, and the fission products from the degradation of the core have an escape path to the environment through the secondary system. It is not possible in this analysis to determine how much core damage occurs before the arrest of the degradation process. For this combination of events, SURSOR calculates a SGTR release assuming that the degradation proceeds to the point of VB. If the core degradation is arrested very late, this is probably a reasonable assumption. Thus the SGTR and noVB combination is placed in the Bypass reduced bin. This combination is very infrequent; the three PDSs in the SGTR PDS group all have no ECCS operable, so the only PDS with an initiating SGTR that may have no VB is GLYY-YXY in the ATWS PDS group, which is less than 1% of the total mean core damage frequency. PDSs in which temperature-induced SGTRs occur may result in this combination of events, but temperature-induced SGTRs are very unlikely.

Combination 4: B-Leak and noVB

The combination of an isolation failure, no bypass, and the arrest of core damage before VB is a difficult combination to place in a reduced bin. There is at least some release of fission products to the containment during the core degradation process, either through the break or through the cycling PORVs. Some of this material will escape through the isolation failure. SURSOR calculates a release which is approximately half way (logarithmically) between the release from an isolation failure that is followed by VB and the release from an accident with no VB and no containment failure. Although most of the frequency in the No VB reduced bin represents noVB & noCF, the isolation failure and no VB combination fits better in the No VB reduced bin than it does in one of the VB and Early-CF reduced bins. The relative frequency of this combination is small since the probability of an isolation failure at Surry is 2E-4.

Combination 5: SGTR and CF-at-VB

SURSOR was designed to treat SGTRs in addition to other failures of the containment, so this combination of events poses no special problem for the source term calculation. As the SGTR largely determines the early release, and the early release is more important than the late release, this combinations is placed in the Bypass reduced bin. An Alpha mode failure is also a containment failure at vessel breach, so a SGTR followed by an Alpha event is also placed in the Bypass reduced bin.

Combination 6: SGTR and CF-Late

This combination of events is analogous to the previous one. Here the SGTR completely dominates the releases; there is no question that this combination should be placed in the Bypass reduced bin.

Thus, in assigning combinations of events in the APET to reduced bins, bypass failures (V and SGTR) take precedence no matter what else happens or doesn't happen. Alpha mode failures take precedence over other failure modes at VB, and over isolation failures. No VB is above Early CF in the priority list, so isolations failures are placed in the No VB reduced bin.

CF-at-VB with no VB is not possible, so that combination will not arise. The seven reduced bins may now be defined as follows:

Bypass — Includes Event V and SGTRs no matter what happens to the containment after the start of the accident; it also includes SGTRs that do not result in VB.

Alpha — Includes all accidents that have an Alpha mode failure of the vessel and the containment except those that follow Event V or an SGTR; it includes Alpha mode failures that follow isolation failures because the Alpha mode containment failure is of rupture size.

No VB — Includes all the accident progressions that avoid vessel failures except those which bypass the containment. Most of the bins placed in this reduced bin have no containment failure as well as no VB, bit it also includes bins in which the containment is not isolated at the start of the accident and the core is brought to a safe stable state before the vessel fails.

ECF-HiPr — Implies Early CF with the RCS above 200 psia when the vessel fails. Early CF here means at or before VB, so it includes isolation failures and seismic containment failures at the start of the accident as well as containment failure at VB. It does not include bins in which containment failure at VB follows Event V or an SGTR, or Alpha mode failures.

ECF-LoPr — Implies Early CF with the RCS below 200 psia when the vessel fails. It does not include bins in which containment failure at VB follows Event V or an SGTR, or Alpha mode failures.

Late-CF — Includes accidents in which the containment was not failed or bypassed before the onset of CCI and in which the vessel failed. The failure mechanisms are hydrogen combustion during CCI, BMT in several days, or eventual overpressure due to the failure to provide containment heat removal in the days following the accident.

VB-NoCF — Includes all the accidents not in one of the previous reduced bins. The vessel's lower head is penetrated by the core, but the containment does not fail and is not bypassed.

2.5 Results of the Accident Progression Analysis

This section presents the results of evaluating the APET. As evaluating the APET produces a number of accident progression bins (APBs), the discussion is primarily in terms of APBs. Some intermediate results are also presented. Sensitivity analyses are discussed as well.

Section 2.5.1 presents the results for the internal initiators. Section 2.5.2 discusses the sensitivity analyses run for the internal initiators. The accident progression analysis results for the fire initiators are presented in Section 2.5.3 and sensitivity analyses for fires are presented in Section 2.5.4. Seismic results are given in four sections. The basic results based on the LLNL hazard curve are presented in Section 2.5.5 and sensitivity analyses using the LLNL hazard curve are presented in Section 2.5.6. The seismic results based on the EPRI hazard curve are presented in Section 2.5.7 and sensitivity analyses utilizing the EPRI hazard curve are presented in Section 2.5.8.

The tables in this section contain only a very small portion of the output obtained by evaluating the APETs. Complete listings giving average bin conditional probabilities for each PDS group, and listings giving the bin probabilities for each PDS group for each observation are available on computer media by request.

2.5.1 Results for Internal Initiators

2.5.1.1 Results for PDS Group 1: Slow SBO. This PDS group consists of accidents in which all ac power is lost in the plant, but the steam turbine-driven AFWS operates for several hours. The operation of this system keeps the core covered and cooled as long as there is no water loss from the RCS. DC power is available until the batteries deplete. When the batteries deplete, control of the steam turbine-driven AFWS is lost and it fails.

This PDS group contains six PDSs: two have the RCS intact at UTAF, two have failure of the RCP seals before UTAF, and two have stuck-open PORVs before UTAF. In four of the six PDSs, the operators depressurized the secondary system before UTAF, and in two PDSs they did not. The PDSs in this group are listed in Table 2.2-2.

Table 2.5-1 lists the five most probable APBs for the PDS group, the five most probable APBs that have VB, and the five most probable APBs that have VB and early containment failure (CF). Most probable means most probable when the whole sample of 200 observations is considered; that is, the five most probable bins are the top five when ranked by mean probability conditional on the occurrence of the PDS group. In Table 2.5-1, the "Order" column gives the order of the bin when ranked by conditional probability. The "Prob." column lists mean APB probabilities conditional on the occurrence of the PDS group. That is, this table shows the results averaged over the 200 observations that form the sample. If Bin A occurred with a probability of 0.005 for each observation, its probability would be 0.005 in Table 2.5-1.

Table 2.5-1
Results of the Accident Progression Analysis for Surry
Internal Initiators--PDS Group 1: Slow SBO

Order	Bin	Prob.*	No. Occur.	CF Time	Sprays	CCI	RCS Pres.	VB Mode	Amt CCI	Zr Ox	HPME	CF Size
Five Most Probable Bins**												
1	HDCDFCDBDFB	0.171	121	No-CF	Always	No-CCI	LoPr	No-VB	No-CCI	Hi	No	No-CF
2	HDCDFCDADFB	0.145	113	No-CF	Always	No-CCI	LoPr	No-VB	No-CCI	Lo	No	No-CF
3	HDCDFCDADFA	0.046	41	No-CF	Always	No-CCI	LoPr	No-VB	No-CCI	Lo	No	No-CF
4	HDCCFCDBDFA	0.040	38	No-CF	Always	No-CCI	ImPr	No-VB	No-CCI	Hi	No	No-CF
5	HFADBCABDFA	0.038	33	No-CF	L+VL	PrmDry	LoPr	Pour	Large	Hi	No	No-CF
Five Most Probable Bins that have VB**												
5	HFADBCABDFA	0.038	33	No-CF	L+VL	PrmDry	LoPr	Pour	Large	Hi	No	No-CF
10	HFADBCAADFB	0.033	104	No-CF	L+VL	PrmDry	LoPr	Pour	Large	Lo	No	No-CF
14	HDCDBCDADFB	0.017	113	No-CF	Always	No-CCI	LoPr	Pour	No-CCI	Lo	No	No-CF
15	HDCDBCDBDFB	0.017	121	No-CF	Always	No-CCI	LoPr	Pour	No-CCI	Hi	No	No-CF
16	HGADBCABDFB	0.016	120	No-CF	VL	PrmDry	LoPr	Pour	Large	Hi	No	No-CF
Five Most Probable Bins that have VB and Early CF**												
64	DHADDCBADBB	0.0012	50	CFatVB	Never	PrmDry	LoPr	Alpha	Medium	Lo	No	Rupture
73	DHADDCBBDBB	0.0010	64	CFatVB	Never	PrmDry	LoPr	Alpha	Medium	Hi	No	Rupture
95	DFACACABACB	0.0007	1	CFatVB	L+VL	PrmDry	ImPr	HPME	Large	Hi	Hi	Leak
145	DFAAACAAABA	0.0004	4	CFatVB	L+VL	PrmDry	SSPr	HPME	Large	Lo	Hi	Rupture
172	DFADBCAADCB	0.0003	1	CFatVB	L+VL	PrmDry	LoPr	Pour	Large	Lo	No	Leak

* Mean probability conditional on the occurrence of the PDS.
** A listing of all bins, and a listing by observation are available on computer media.

If Bin B occurred with a probability of 1.00 for one observation and did not occur in the other 199 observations, its probability would also be 0.005. The column headed "No. Occur." gives the number of observations out of the 200 in the sample in which this APB occurred with a nonzero conditional probability.

The remaining nine columns in Table 2.5-1 explain 9 of the 11 characteristics in the APB indicator. The sixth characteristic, SGTR, has been omitted since none of the 100 most probable bins for this PDS group had T-I SGTR. The last characteristic, RCS-Hole, has also been omitted since it is of less interest than the others. The abbreviations for each APB characteristic are explained in Section 2.4 above.

The first part of Table 2.5-1 shows the first five bins when they are ranked in order by probability. Evaluation of the APET produced 1049 bins for the Slow SBO PDS group. To capture 95% of the probability, 138 bins are required. The four most probable bins have no VB and no CF. The five most probable bins capture 44% of the probability. The five most probable bins with VB all result in no CF, and all have the RCS at low pressure (less than 200 psia) at VB. Most of the APBs that result in VB and CF have BMT has the mode of CF. Note that each of the five most probable APBs and the five most probable APBs with VB occurred in at least one sixth of the observations in the sample. This is not the case with the five most probable APBs with both VB and early CF. Two of these bins occurred in only one sample, and another occurred in only four. This indicates that few observations in the sample may be large contributors to CF at VB, and thus to risk. Two of the five most probable APBs with both VB and early CF are Alpha mode failures of the containment, two are HPME and DCH failures, and the other is a low pressure Pour. Early CF means CF before or at VB. CF before VB is improbable at Surry, almost all early CFs are CF at VB. The strength of the containment led to the conclusion that CF before VB due to hydrogen combustion was negligible. The fact that the containment is maintained below atmospheric pressure during operation means that initial containment failures are unlikely for internal initiators.

In this PDS group, the probability of recovering offsite electrical power in time to arrest the core degradation process and avoid VB is about 0.62. More information concerning the methods used for determining the probability of the arrest of core damage for each case may be found in Appendix A.3.3.

Of the fraction of this PDS group which resulted in VB, most had the RCS at low pressure at VB. The fractions of this PDS group which are in the four pressure ranges at UTAF and just before VB (if it occurs) are:

	At UTAF	Just Before VB
SSPr (2500 psia)	0.54	0.06
HiPr (600 to 2000 psia)	0.13	0.10
ImPr (200 to 600 psia)	0.33	0.19
LoPr (< 200 psia)	0.00	0.65

The relative frequencies of the "T", "S_3", and "S_2" PDSs, in conjunction with whether the secondary system has been depressurized while the AFWS is operating, result in about half the PDS group being at the PORV setpoint pressure when the core uncovers (Question 15). Just before VB, the situation is quite different (Question 23). Five mechanisms for depressurizing the RCS are considered in the APET. Three of these are quite effective: RCP seal failures, PORVs sticking open, and temperature-induced hot leg (or surge line) failures. The result is that the probability of the accident continuing with the RCS pressure boundary intact from UTAF to VB is about 0.10. The determination of RCS pressure at VB is discussed further in Section 2.5.2.1.

The mean probability of CF at VB for this PDS group is only 0.008. Note that the 0.992 probability of no CF includes the 62% of the group that had core damage arrest and no VB. The mean probabilities of late and very late CFs due to hydrogen burns are 0.007 and 0.002, respectively. The mean probability of basemat melt-through (BMT) is about 0.07.

2.5.1.2 Results for PDS Group 2--LOCAs. This PDS group consists of accidents initiated by a break in the RCS pressure boundary. Three of the PDSs have A-size breaks, and three have S_1-breaks which are treated at A breaks in this analysis. There is one S_2 and one S_3 PDS in this group. These PDSs result in core damage because one or more of the ECCS required to respond does not operate. Four of the eight PDSs in this group have the LPIS operating but not injecting at UTAF. The PDSs in this group are listed in Table 2.2-2.

Table 2.5-2 lists the ten most probable APBs for this PDS group and the five most probable APBs that have VB and early containment failure (CF). The five most probable APBs that have VB are included in the ten most probable bins. Most probable means most probable based on the entire sample. Evaluation of the APET produced 216 bins for the LOCA PDS group. To capture 95% of the probability, 31 bins are required. The ten most probable bins capture 84% of the probability. Eight of the ten most probable bins have no CF, and four of them have no VB as well. The mode of CF for the two bins with CF is BMT. Most of the APBs that result in VB and CF have BMT have the mode of CF. Of the five most probable APBs with both VB and early CF, four are Alpha mode failures; the fifth is due to HPME and DCH. Only one of these APBs occurred in very few observations.

In the LOCA PDS group, the probability of arresting the core degradation process and avoiding VB is about 0.35. For two of the PDSs, the LPIS is operating at UTAF and the break (A or S_1) is large enough by itself to depressurize the RCS to the point where the LPIS may inject. These are core damage situations because the success criteria require the accumulators (A break) or HPIS (S_1 break) to function in addition to LPIS, and these systems failed. For two other PDSs, the LPIS is operating at UTAF, but the initiating break (S_2 or S_3) is not large enough to depressurize the RCS so the LPIS can inject. If a temperature-induced failure occurs after UTAF that is large enough to depressurize the RCS, then LPIS operation is likely to prevent VB by halting core degradation.

Table 2.5-2
Results of the Accident Progression Analysis for Surry
Internal Initiators--PDS Group 2: LOCAs

Order	Bin	Prob.*	No. Occur.	CF Time	Sprays	CCI	RCS Pres.	VB Mode	Amt CCI	Zr Ox	HPME	CF Size
Ten Most Probable Bins**												
1	HDCDFCDADFB	0.168	113	No-CF	Always	No-CCI	LoPr	No-VB	No-CCI	Lo	No	No-CF
2	HDCDBCDADFB	0.166	113	No-CF	Always	No-CCI	LoPr	Pour	No-CCI	Lo	No	No-CF
3	HDCDFCDBDFB	0.136	121	No-CF	Always	No-CCI	LoPr	No-VB	No-CCI	Hi	No	No-CF
4	HDCDBCDBDFB	0.131	121	No-CF	Always	No-CCI	LoPr	Pour	No-CCI	Hi	No	No-CF
5	HDDDBCAADFB	0.081	113	No-CF	Always	PrmDeep	LoPr	Pour	Large	Lo	No	No-CF
6	HDDDBCABDFB	0.064	121	No-CF	Always	PrmDeep	LoPr	Pour	Large	Hi	No	No-CF
7	HDCDFCDADFA	0.028	41	No-CF	Always	No-CCI	LoPr	No-VB	No-CCI	Lo	No	No-CF
8	GDDDBCAADDB	0.027	113	Final	Always	PrmDeep	LoPr	Pour	Large	Lo	No	BMT
9	GDDDBCABDDB	0.021	121	Final	Always	PrmDeep	LoPr	Pour	Large	Hi	No	BMT
10	HDCDFCDBDFA	0.020	33	No-CF	Always	No-CCI	LoPr	No-VB	No-CCI	Hi	No	No-CF
Five Most Probable Bins that have VB and Early CF**												
28	DAFDDCBBDBB	0.0024	70	CFatVB	Early	LDlyDry	LoPr	Alpha	Medium	Hi	No	Rupture
37	DAFDDCBADBB	0.0018	65	CFatVB	Early	LDlyDry	LoPr	Alpha	Medium	Lo	No	Rupture
69	DADDDCBBDBB	0.0004	52	CFatVB	Early	PrmDeep	LoPr	Alpha	Medium	Hi	No	Rupture
75	DDCBACDBACA	0.0003	1	CFatVB	Always	No-CCI	HiPr	HPME	No-CCI	Hi	Hi	Leak
77	DADDDCBADBB	0.0004	46	CFatVB	Early	PrmDeep	LoPr	Alpha	Medium	Lo	No	Rupture

* Mean probability conditional on the occurrence of the PDS.
** A listing of all bins, and a listing by observation are available on computer media.

The fractions of the LOCA PDS group which are in the four pressure ranges at UTAF and just before VB (if it occurs) are:

	At UTAF	Just Before VB
SSPr (2500 psia)	0.00	0.00
HiPr (600-2000 psia)	0.00	0.06
ImPr (200-600 psia)	0.19	0.06
LoPr (< 200 psia)	0.81	0.88

The five most frequent PDSs in this group are "A" or "S_1" PDSs, so it is not surprising that low pressure in the RCS is likely both at UTAF (Question 15) and at VB (Question 23).

The mean probability of CF at VB for this PDS group is only 0.006. Note that the 0.994 probability of no CF includes the 35% of the group that had core damage arrest and no VB. There are no late or very late CFs due to hydrogen burns for this PDS group. Electrical power is available all along, so ignition is expected shortly after a flammable concentration is reached. Burns at this concentration do not threaten the Surry containment. The mean probability of BMT is about 0.06.

2.5.1.3 Results for PDS Group 3--Fast SBO. This PDS group consists of accidents in which all ac power is lost in the plant and the steam turbine-driven AFWS fails at, or shortly after, the start of the accident. The Fast SBO PDS group consists of only one PDS, TRRR-RSR. Table 2.5-3 lists the five most probable APBs for the Fast SBO PDS group, the five most probable APBs that have VB, and the five most probable APBs that have VB and early containment failure (CF).

The first part of Table 2.5-3 shows the first five bins when they are ranked in order by probability. Evaluation of the APET produced 870 bins for the Fast SBO PDS group, of which 103 are required to capture 95% of the probability. The five most probable bins capture 45% of the probability. The five most probable bins capture 68% of the probability. They all have no CF, and three of them have no VB as well. Three of the five most probable bins that have VB have no CF; the other two have BMT. Most of the APBs that result in VB and CF have BMT as the mode of CF. Three the five most probable APBs with both VB and early CF are due to an Alpha mode event and the other two are due to HPME and DCH at VB. Two of these APBs occurred in only one observation in the sample.

In this PDS group, the probability of recovering offsite electrical power in time to arrest the core degradation process and avoid VB is about 0.51. More information concerning the methods used for determining the probability of the arrest of core damage for each case may be found in Appendix A.3.3.

Table 2.5-3
Results of the Accident Progression Analysis for Surry
Internal Initiators--PDS Group 3: Fast SBO

Order	Bin	Prob.*	No. Occur.	CF Time	Sprays	CCI	RCS Pres.	VB Mode	Amt CCI	Zr Ox	HPME	CF Size
Five Most Probable Bins**												
1	HDCDFCDBDFB	0.185	121	No-CF	Always	No-CCI	LoPr	No-VB	No-CCI	Hi	No	No-CF
2	HFADBCABDFB	0.095	120	No-CF	L+VL	PrmDry	LoPr	Pour	Large	Hi	No	No-CF
3	HDCDFCDADFB	0.083	113	No-CF	Always	No-CCI	LoPr	No-VB	No-CCI	Lo	No	No-CF
4	HFADBCAADFB	0.047	104	No-CF	L+VL	PrmDry	LoPr	Pour	Large	Lo	No	No-CF
5	HDCCFCDBDFA	0.042	38	No-CF	Always	No-CCI	ImPr	No-VB	No-CCI	Hi	No	No-CF
Five Most Probable Bins That Have VB**												
2	HFADBCABDFB	0.095	120	No-CF	L+VL	PrmDry	LoPr	Pour	Large	Hi	No	No-CF
4	HFADBCAADFB	0.047	104	No-CF	L+VL	PrmDry	LoPr	Pour	Large	Lo	No	No-CF
7	GFADBCABDDB	0.032	120	Final	L+VL	PrmDry	LoPr	Pour	Large	Hi	No	BMT
13	HFADBCAADFA	0.018	40	No-CF	L+VL	PrmDry	LoPr	Pour	Large	Lo	No	No-CF
14	GFADBCAADDB	0.016	104	Final	L+VL	PrmDry	LoPr	Pour	Large	Lo	No	BMT
Five Most Probable Bins that have VB and Early CF**												
45	DHADDCBBDBB	0.0027	64	CFatVB	Never	PrmDry	LoPr	Alpha	Medium	Hi	No	Rupture
71	DFACACABACB	0.0014	1	CFatVB	L+VL	PrmDry	ImPr	HPME	Large	Hi	Hi	Leak
111	DHADDCBADBB	0.0006	50	CFatVB	Never	PrmDry	LoPr	Alpha	Medium	Lo	No	Rupture
116	DFCBACDBBCA	0.0005	1	CFatVB	L+VL	No-CCI	HiPr	HPME	No-CCI	Hi	Md	Leak
168	DAFDDCBBDBB	0.0003	70	CFatVB	Early	LDlyDry	LoPr	Alpha	Medium	Hi	No	Rupture

* Mean probability conditional on the occurrence of the PDS.
** A listing of all bins, and a listing by observation are available on computer media.

Of the fraction of this PDS group which resulted in VB, most had the RCS at low pressure at VB. The fractions of this PDS group which are in the four pressure ranges at UTAF and just before VB (if it occurs) are:

	At UTAF	Just Before VB
SSPr (2500 psia)	1.00	0.03
HiPr (600-2000 psia)	0.00	0.12
ImPr (200-600 psia)	0.00	0.20
LoPr (< 200 psia)	0.00	0.66

As the only PDS in this group has the RCS intact at UTAF, the RCS is at the PORV setpoint pressure at that time (Question 15). Just before VB (Question 23), the probability of being at SSPr is only about 0.03. As discussed with regard to PDS Group 1, three of the five depressurization mechanisms considered in the APET are quite effective: RCP seal failures, PORVs sticking open, and temperature-induced hot leg (or surge line) failures. The result is that the probability of the accident continuing with the RCS pressure boundary intact from UTAF to VB is fairly small. The determination of RCS pressure at VB is discussed further in Sections 2.5.2.1 and 2.5.2.2.

The mean probability of CF at VB for this PDS group is only 0.007. Note that the 0.993 probability of no CF includes the 51% of the group that had core damage arrest and no VB. The mean probabilities of late and very late CFs due to hydrogen burns are 0.017 and 0.0005, respectively. The mean probability of BMT is about 0.09.

2.5.1.4 Results for PDS Group 4: Event V. This PDS group consists of accidents in which the check valves between the RCS and the LPIS fail, and then the LPIS piping, subjected to pressures much higher than those for which it was designed, also fails. This produces a path from the RCS to the auxiliary building, bypassing the containment, and is known as Event V. Experts considering the break location in the LPIS concluded that the probability was 0.85 that it would be low enough in the auxiliary building that the water from the RCS and the RWST, escaping through the break, would form a pool covering the break by the time when core degradation commenced.

Table 2.5-4 lists the eight most probable APBs for the V PDS Group. Evaluation of the APET produced 16 bins for this PDS group, of which eight are required to capture 95% of the probability. The four most probable bins capture 81% of the probability and all of them have the break location under water.

There is no possibility of avoiding VB or CCI in this PDS group. Due to the size of the containment bypass, containment failure is not of much interest.

Table 2.5-4
Results of the Accident Progression Analysis for Surry
Internal Initiators--PDS Group 4: Event V

Order	Bin	Prob.*	No. Occur.	CF Time	Sprays	CCI	RCS Pres.	VB Mode	Amt CCI	Zr Ox	HPME	CF Size
Eight Most Probable Bins**												
1	BHADBCAADEA	0.268	110	V-Wet	Never	PrmDry	LoPr	Pour	Large	Lo	No	Bypass
2	BHADBCABDEA	0.212	88	V-Wet	Never	PrmDry	LoPr	Pour	Large	Hi	No	Bypass
3	BHADBCAADDA	0.182	110	V-Wet	Never	PrmDry	LoPr	Pour	Large	Lo	No	BMT
4	BHADBCABDDA	0.144	88	V-Wet	Never	PrmDry	LoPr	Pour	Large	Hi	No	BMT
5	AHADBCAADEA	0.049	110	V-Dry	Never	PrmDry	LoPr	Pour	Large	Lo	No	Bypass
6	AHADBCABDEA	0.036	88	V-Dry	Never	PrmDry	LoPr	Pour	Large	Hi	No	Bypass
7	AHADBCAADDA	0.033	110	V-Dry	Never	PrmDry	LoPr	Pour	Large	Lo	No	BMT
8	AHADBCABDDA	0.024	88	V-Dry	Never	PrmDry	LoPr	Pour	Large	Hi	No	BMT

* Mean probability conditional on the occurrence of the PDS.
** A listing of all bins, and a listing by observation are available on computer media.

2.5.1.5 Results for PDS Group 5: Transients. This PDS group consists of accidents in which the RCS is intact but there is no way to remove heat from the core. The AFWS fails at the start of the accident; bleed and feed is ineffective because the HPIS fails or the PORVs cannot be opened. LPIS is available but the operators cannot open the PORVs or have failed to do so. The Transient PDS group consists of two PDSs, TBYY-YNY and TLYY-YNY. Table 2.5-5 lists the ten most probable APBs for the PDS group and the five most probable APBs that have VB and early CF. The five most probable APBs that have VB are included in the ten most probable bins. Most probable means most probable based on the entire sample. Evaluation of the APET produced 252 bins for the Transient PDS group, of which 21 are required to capture 95% of the probability.

The ten most probable bins capture 89% of the probability. They all have no CF, and the three most probable APBs have no VB as well. Six of the ten most probable bins have VB; three have Pour as the failure mode and three have HPME as the failure mode. Most of the APBs that result in VB and CF have BMT has the mode of CF. Of the five most probable APBs with both VB and early CF, two are due to an Alpha mode event, two are due to HPME and DCH at VB, and the fifth is due to gross failure of the lower head at the PORV setpoint pressure. Three of the five APBs occurred in only one observation out of 200.

In this PDS group, the probability of a temperature-induced failure of the RCS pressure boundary is quite high, almost 0.90. Since the LPIS is always operating for this PDS group, and HPIS is operating as well with a probability of 0.67, the probability of arresting the core degradation process and avoiding VB is high, about 0.77. More detail on the arrest of core damage may be found in Appendix A.3.

The fractions of this PDS group that are in the four pressure ranges at UTAF and just before VB (if it occurs) are:

	At UTAF	Just Before VB
SSPr (2500 psia)	1.00	0.12
HiPr (600-2000 psia)	0.00	0.002
ImPr (200-600 psia)	0.00	0.09
LoPr (< 200 psia)	0.00	0.79

As both PDSs in this group have the RCS intact at UTAF, the RCS is at the PORV setpoint pressure at that time (Question 15). Just before VB (Question 23), the probability of being at SSPr is only about 0.12. This probability is higher than PDS Group 3 (Fast SBO) because RCP seal cooling is available, thus rendering the failure of the pumps seals ineffective as a means of depressurization. The PORVs still function in their safety mode, so they may stick open even when hardware failures prevent their being opened from the control room. The two effective depressurization mechanisms for this PDS group are the PORVs sticking open and the temperature-induced hot leg (or surge line) failures. Deliberate opening of the PORVs by the operators is ineffective because they cannot open the PORVs or have already failed to do so. Temperature-induced SGTRs are very unlikely according to the expert panel. The determination of RCS pressure at VB is discussed further in Sections 2.5.2.1 and 2.5.2.2.

Table 2.5-5
Results of the Accident Progression Analysis for Surry
Internal Initiators--PDS Group 5: Transients

Order	Bin	Prob.*	No. Occur.	CF Time	Sprays	CCI	RCS Pres.	VB Mode	Amt CCI	Zr Ox	HPME	CF Size
Ten Most Probable Bins**												
1	HDCDFCDBDFB	0.501	121	No-CF	Always	No-CCI	LoPr	No-VB	No-CCI	Hi	No	No-CF
2	HDCDFCDADFB	0.207	113	No-CF	Always	No-CCI	LoPr	No-VB	No-CCI	Lo	No	No-CF
3	HDCCFCDBDFB	0.034	22	No-CF	Always	No-CCI	ImPr	No-VB	No-CCI	Hi	No	No-CF
4	HDCDBCDBDFB	0.032	121	No-CF	Always	No-CCI	LoPr	Pour	No-CCI	Hi	No	No-CF
5	HDCAACDACFA	0.026	24	No-CF	Always	No-CCI	SSPr	HPME	No-CCI	Lo	Lo	No-CF
6	HDCAACDABFA	0.025	30	No-CF	Always	No-CCI	SSPr	HPME	No-CCI	Lo	Md	No-CF
7	HDCAACDAAFA	0.021	25	No-CF	Always	No-CCI	SSPr	HPME	No-CCI	Lo	Hi	No-CF
8	HDCCFCDADFB	0.019	23	No-CF	Always	No-CCI	ImPr	No-VB	No-CCI	Lo	No	No-CF
9	HDDDBCABDFB	0.015	121	No-CF	Always	PrmDeep	LoPr	Pour	Large	Hi	No	No-CF
10	HDCDBCDADFB	0.013	113	No-CF	Always	No-CCI	LoPr	Pour	No-CCI	Lo	No	No-CF
Five Most Probable Bins that have VB and Early CF**												
45	DAFDDCBBDBB	0.0006	70	CFatVB	Early	LDlyDry	LoPr	Alpha	Medium	Hi	No	Rupture
48	DDCAACDAABA	0.0005	1	CFatVB	Always	No-CCI	SSPr	HPME	No-CCI	Lo	Hi	Rupture
64	DDCACCDABCA	0.0002	1	CFatVB	Always	No-CCI	SSPr	BtmHd	No-CCI	Lo	Md	Leak
72	DDDAACAAABA	0.0001	1	CFatVB	Always	PrmDeep	SSPr	HPME	Large	Lo	Hi	Rupture
75	DADDDCBBDBB	0.0001	52	CFatVB	Early	PrmDeep	LoPr	Alpha	Medium	Hi	No	Rupture

* Mean probability conditional on the occurrence of the PDS.
** A listing of all bins, and a listing by observation are available on computer media.

The mean probability of CF at VB for this PDS group is only 0.002. Note that the 0.998 probability of no CF includes the 0.77 of the group that had core damage arrest and no VB. There are no late or very late CFs due to hydrogen burns for this PDS group. Electrical power is available all along, so ignition is expected shortly after a flammable concentration is reached. Burns at this concentration do not threaten the Surry containment. The mean probability of BMT is about 0.013.

2.5.1.6 Results for PDS Group 6: ATWS. This PDS group consists of accidents in which neither control rod insertion nor boron injection bring the reaction under control shortly after the start of the accident. The core continues to generate large amounts of heat and steam until the water level drops far enough below TAF that the loss of the neutron moderating effect of the liquid water is lost for a substantial portion of the core. The ATWS PDS group consists of three PDSs, one with the RCS intact at UTAF, one with an S_3 break, and one with an SGTR. In all three situations, the PORVs will be open at UTAF due to the rate of steam generation in the core. The LPIS is operating but not injecting in the RCS intact and SGTR PDSs.

Table 2.5-6 lists the ten most probable APBs for the PDS group and the five most probable APBs that have VB and early CF or bypass. The five most probable APBs that have VB are included in the ten most probable bins. Most probable means most probable based on the entire sample. Evaluation of the APET produced 348 bins for the ATWS PDS group, of which 32 are required to capture 95% of the probability. Table 2.5-6 differs from the preceding tables in that the sprays characteristic has been omitted and the SGTR characteristic included. All the APBs for this PDS group have sprays all the time.

The ten most probable bins capture 78% of the probability. Seven of these APBs have no failure or bypass of the containment, two have SGTRs, and one has BMT in the final period. Four of the ten most probable bins have no VB. The two bins that have SGTRs have no VB, due to the operation of the LPIS throughout the accident. There may be a significant release in this accident since the core degradation may not be arrested until it is quite well advanced and a substantial portion of the fission products are released from the core. The last part of Table 2.5-6 shows the five most probable APBs with VB and early CF or bypass. These APBs all have SGTR and no CF; two of them occurred in only a few observations. Based on the mean core damage frequencies, 0.077 of this PDS group has an SGTR initiator, and so have containment bypass at the start of the accident. The most probable bin with CF at VB is 38th in order with a probability of 0.0016; the CF is due to an Alpha failure of both vessel and containment.

In this PDS group, the mean probability of arresting core degradation process and avoiding vessel breach is about 0.41. This comes from the operation of the LPIS following a temperature-induced break in the RCS. The water from the RWST injected by the LPIS contains enough boron to shut down the reaction should the core be in a configuration where continued reaction is possible.

Table 2.5-6
Results of the Accident Progression Analysis for Surry
Internal Initiators--PDS Group 6: ATWS

Order	Bin	Prob.*	No. Occur.	CF Time	Sprays	CCI	RCS Pres.	VB Mode	Amt CCI	Zr Ox	HPME	CF Size
Ten Most Probable Bins**												
1	HDCDFCDBDFB	0.223	121	No-CF	No-CCI	LoPr	No-VB	No	No-CCI	Hi	No	No-CF
2	HDCDBCDBDFB	0.136	121	No-CF	No-CCI	LoPr	Pour	No	No-CCI	Hi	No	No-CF
3	HDCDFCDADFB	0.128	113	No-CF	No-CCI	LoPr	No-VB	No	No-CCI	Lo	No	No-CF
4	HDCDBCDADFB	0.084	113	No-CF	No-CCI	LoPr	Pour	No	No-CCI	Lo	No	No-CF
5	HDDDBCABDFB	0.067	121	No-CF	PrmDeep	LoPr	Pour	No	Large	Hi	No	No-CF
6	HDDDBCAADFB	0.041	113	No-CF	PrmDeep	LoPr	Pour	No	Large	Lo	No	No-CF
7	HDCDFADBDEB	0.035	120	No-CF	No-CCI	LoPr	No-VB	SGTR	No-CCI	Hi	No	Bypass
8	HDCCACDBCFB	0.024	7	No-CF	No-CCI	ImPr	HPME	No	No-CCI	Hi	Lo	No-CF
9	GDDDBCABDDB	0.022	121	Final	PrmDeep	LoPr	Pour	No	Large	Hi	No	BMT
10	HDCDFADADEB	0.020	101	No-CF	No-CCI	LoPr	No-VB	SGTR	No-CCI	Lo	No	Bypass
Five Most Probable Bins that have VB and Early CF or Bypass**												
7	HDCDFADBDEB	0.035	120	No-CF	No-CCI	LoPr	No-VB	SGTR	No-CCI	Hi	No	Bypass
10	HDCDFADADEB	0.020	101	No-CF	No-CCI	LoPr	No-VB	SGTR	No-CCI	Lo	No	Bypass
32	HDCCBADBDEB	0.0026	6	No-CF	No-CCI	ImPr	Pour	SGTR	No-CCI	Hi	No	Bypass
34	HDCCAADBCEB	0.0024	7	No-CF	No-CCI	ImPr	HPME	SGTR	No-CCI	Hi	Lo	Bypass
35	HDCDBADBDEB	0.0022	118	No-CF	No-CCI	LoPr	Pour	SGTR	No-CCI	Hi	No	Bypass

* Mean probability conditional on the occurrence of the PDS.
** A listing of all bins, and a listing by observation are available on computer media.

The fractions of this PDS group that are in the four pressure ranges at UTAF and just before VB (if it occurs) are:

	At UTAF	Just Before VB
SSPr (2500 psia)	1.00	0.005
HiPr (600-2000 psia)	0.00	0.002
ImPr (200-600 psia)	0.00	0.19
LoPr (< 200 psia)	0.00	0.80

The RCS is at the PORV setpoint pressure at UTAF (Question 15) because the reaction has not been shut down and the steaming rate is high. Just before VB (Question 23), the probability of being at SSPr is only about 0.005. This probability is lower than in PDS Groups 1, 3, and 5 because the operators are allowed to deliberately open the PORVs in this PDS. In the human reliability analysis, it was judged that the operators would be too busy trying to bring the reaction under control before UTAF to consider opening the PORVs, and the PORVs would be kept open by the escaping steam in any event. Thus the effective depressurization mechanisms for this PDS group are: the PORVs sticking open, temperature-induced hot leg (or surge line) failures, and deliberate opening of the PORVs by the operators. Pump seal cooling is available in the one PDS where it would be effective (the "T" PDS where the RCS is intact), so failure of the pumps seals is ineffective as a means of depressurization for the ATWS PDS group. Temperature-induced SGTRs are very unlikely according to the expert panel.

The mean probability of CF at VB for this PDS group is only 0.003. Note that the 0.997 probability of no CF includes 0.41 that had core damage arrest and no VB. There are no late or very late CFs due to hydrogen burns for this PDS group. Electrical power is available all along, so ignition is expected shortly after a flammable concentration is reached. Burns at this concentration do not threaten the Surry containment. The mean probability of BMT is about 0.05.

2.5.1.7 Results for PDS Group 7: SGTRs. This PDS group consists of accidents in which the initiating event is the rupture of a steam generator tube. The reaction is shut down successfully. The SGTR PDS group includes two PDSs in which the RCS is depressurized using the two unaffected SGs according to procedures, and the SRVs on the main steam lines from the affected SG do not stick open. These accidents, denoted "G" SGTRs, are indicated by "SGTR" in Table 2.5-7. The most frequent and the least frequent PDSs in the SGTR PDS group are accidents in which the RCS is not depressurized according to procedures, and the SRVs on the main steam lines from the affected SG stick open. These accidents, denoted "H" SGTRs, are indicated by "SRVO" in Table 2.5-7. Like Table 2.5-6, Table 2.5-7 omits the sprays characteristic to show the SGTR characteristic. All the APBs for this PDS group have sprays all the time. Most of the fifteen most probable observations occurred in one sixth of the observations, or fewer.

Table 2.5-7
Results of the Accident Progression Analysis for Surry
Internal Initiators--PDS Group 7: SGTRs

Order	Bin	Prob.*	No. Occur.	CF Time	Sprays	CCI	RCS Pres.	VB Mode	Amt CCI	Zr Ox	HPME	CF Size
Fifteen Most Probable Bins**												
1	HHADBBAADEA	0.083	41	No-CF	PrmDry	LoPr	Pour	SRVO	Large	Lo	No	Bypass
2	GHADBBAADDA	0.057	41	Final	PrmDry	LoPr	Pour	SRVO	Large	Lo	No	BMT
3	HHADBBABDEA	0.052	25	No-CF	PrmDry	LoPr	Pour	SRVO	Large	Hi	No	Bypass
4	HHACABABBEA	0.042	15	No-CF	PrmDry	ImPr	HPME	SRVO	Large	Hi	Med	Bypass
5	GHADBBABDDA	0.036	25	Final	PrmDry	LoPr	Pour	SRVO	Large	Hi	No	BMT
6	HHBBBBAADEA	0.026	16	No-CF	PrmShl	HiPr	Pour	SRVO	Large	Lo	No	Bypass
7	HHACABAAAEA	0.022	8	No-CF	PrmDry	ImPr	HPME	SRVO	Large	Lo	Hi	Bypass
8	HHEBABAAAEA	0.022	9	No-CF	PrmDry	HiPr	HPME	SRVO	Large	Hi	Hi	Bypass
9	HDCDFADADEB	0.021	101	No-CF	PrmDry	LoPr	No-Vb	SGTR	No-CCI	Lo	No	Bypass
10	HDCDFADADEA	0.019	41	No-CF	PrmDry	LoPr	No-VB	SGTR	No-CCI	Lo	No	Bypass
11	GHBBBBAADDA	0.017	16	Final	PrmShl	HiPr	Pour	SRVO	Large	Lo	No	BMT
12	HHACABAACEA	0.017	8	No-CF	PrmDry	ImPr	HPME	SRVO	Large	Lo	Lo	Bypass
13	HHEBABAABEA	0.017	8	No-CF	SDlyDry	HiPr	HPME	SRVO	Large	Lo	Md	Bypass
14	HHEBABAACEA	0.017	9	No-CF	SDlyDry	HiPr	HPME	SRVO	Large	Lo	Lo	Bypass
15	HHACABAABEA	0.016	6	No-CF	PrmDry	ImPr	HPME	SRVO	Large	Lo	Md	Bypass

* Mean probability conditional on the occurrence of the PDS.
** A listing of all bins, and a listing by observation are available on computer media.

Evaluation of the APET produced 717 bins for the SGTR PDS group, of which 178 are required to capture 95% of the probability. Since all the APBs for this PDS group have bypass of the containment, Table 2.5-7 lists the 15 most probable APBs. They capture 46% of the probability. Only two of the 15 most probable bins have the SRVs reclosing; the other 13 bins result from the "H" SGTR accidents in which the secondary SRVs are stuck open. PDS HINY-NXY has a higher frequency than the other three PDSs in this group combined.

In this PDS group, the probability of avoiding vessel breach is about 0.06. No ECCS are operable in the "H" PDSs. The LPIS is operating in the two "G" PDSs, but there is an effective depressurization mechanism for only one of them. This mechanism is the deliberate opening of the PORVs. RCP seal cooling is available, so there are no seal failures. The RCS is not at the PORV setpoint pressure, so there is no possibility of the PORVs sticking open, T-I hot leg failures, or T-I SGTRs.

The fractions of this PDS group which are in the four pressure ranges at UTAF and just before VB (if it occurs) are:

	At UTAF	Just Before VB
SSPr (2500 psia)	0.00	0.00
HiPr (600-2000 psia)	1.00	0.30
ImPr (200-600 psia)	0.00	0.32
LoPr (< 200 psia)	0.00	0.39

As all four PDS in this group have an S_3-size SGTR at UTAF, the RCS pressure is in the High range at UTAF (Question 15). The four PDSs in this group are HINY-NXY, HINY-YXY, GLYY-YNY, and GLYY-YXY. In HINY-NXY and GLYY-YXY the operators failed to follow procedures and open the PORVs before UTAF, so no credit is given for their opening the PORVs after UTAF. In both HINY-YXY and GLYY-YNY the PORVs are open at UTAF as the operators are or were attempting to cool the core by bleed and feed. In HINY-YXY, the open PORVs serve only to reduce the RCS pressure before VB as no ECCS are available. In GLYY-YNY, the resulting pressure reduction in the RCS may allow the operating LPIS to inject water and arrest core damage before VB. PDSs HINY-YXY and GLYY-YNY are the least frequent of the four PDSs in the SGTR group. As discussed in Section 2.5.2.1, it was estimated that with an S_3-size break in the system, the low, intermediate, and high pressure ranges were equally likely at VB. The probabilities of these three pressure ranges given above vary somewhat from 0.33 due to the open PORVs just discussed.

For the "H" SGTRs, CF at VB is not particularly significant for risk as the bulk of the fission products escapes through the containment bypass. The MCDF of HINY-NXY is about 75% of the MCDF of the SGTR PDS group. For the group as a whole, the mean probability of CF at VB is about 0.03. There are no late or very late CFs due to hydrogen burns. The mean probability of BMT is about 0.27.

2.5.1.8 Core Damage Arrest and Avoidance of VB. It is possible to arrest the core damage process and avoid VB if ECCS injection is restored before the core degradation process has gone too far. Recovery of injection is due to one of two events. In the LOSP accidents, recovery of injection follows the restoration of offsite power. In other types of accidents, the ECCS is operating at UTAF but no injection is taking place because the RCS pressure is too high. Any break in the RCS pressure boundary that allows the RCS pressure to decrease to the point where the ECCS inject is likely to arrest the core degradation process. The break may be an initiating break or a temperature-induced break or other failure that occurs after UTAF.

PDS ALYY-YYY has the LPIS operating at UTAF. This is a core damage situation because the success criteria require the accumulators to operate in addition to the LPIS, and the accumulators fail. PDS S_1LYY-YYN also has the LPIS operating at UTAF; it is a core damage situation because the success criteria require the HPIS to operate in addition to the LPIS, and the HPIS fails. For both of these PDSs, the initiating break depressurizes the RCS sufficiently for the LPIS to inject. In PDS TLYY-YNY, the LPIS is also operating but the RCS is intact at UTAF. In this situation, injection will commence only if one of the five depressurization means considered in this analysis operates, and if the RCS is depressurized to a low enough level. In PDS TBYY-YNY. both LPIS and HPIS are operating, so it is not necessary that the RCS be depressurized to a low level. The five means of depressurizing the RCS after UTAF are:

1. PORVs or SRVs stick open;
2. T-I RCP seal failure;
3. Deliberate opening of the PORVs by the operators;
4. T-I SGTR; and
5. T-I hot leg or surge line failure.

Figure 2.5-1 shows the probability of halting the degradation of the core before the lower head of the vessel fails, thereby achieving a safe stable state with the vessel intact. For the LOSP collapsed PDS group, the distribution in Figure 2.5-1 reflects the distribution for offsite ac power recovery in the APET "early" period. To avoid a gap in the times for which power recovery is considered, the start of the APET "early" period is the end of the period for which recovery of offsite power was considered in the accident frequency analysis. This time is nominally the onset of core damage, but for some PDSs this time precedes the current estimates of the onset of core damage (UTAF) by a significant amount. The end of the APET "early" period is the expected time of VB. The estimated core damage states that different times in this period were used to determine the probability of core damage arrest for each PDS involved, as explained in Appendix A.1.1 (see the discussions of Questions 21 and 24) and in Appendix A.3.3.

For the ATWS, Transients, and LOCAs, the distributions for core damage arrest show the combined effects of RCS depressurization that allows ECCS injection in those PDSs which have ECCS operating at UTAF. The probability of core damage arrest is very high for Transients since one PDS in the group has LPIS operating and the other has both LPIS and HPIS operating.

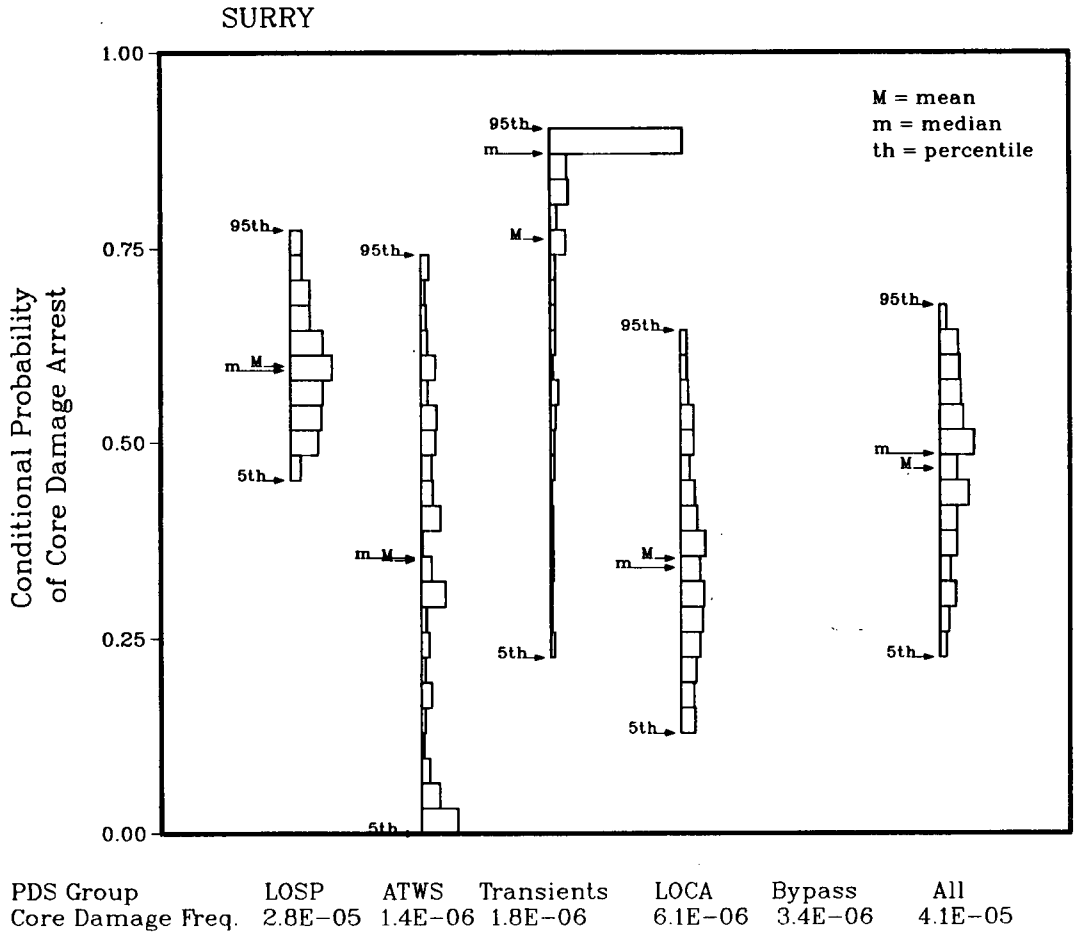


Figure 2.5-1. Probability of Core Damage Arrest--Internal.

As the probability of one or more of the depressurization mechanisms operating is high, so the probability of core damage arrest is high.

2.5.1.9 Early Containment Failure. For those accidents in which the containment is not bypassed, the offsite risk depends on the probability that the containment will fail before or at VB. There are four possibilities:

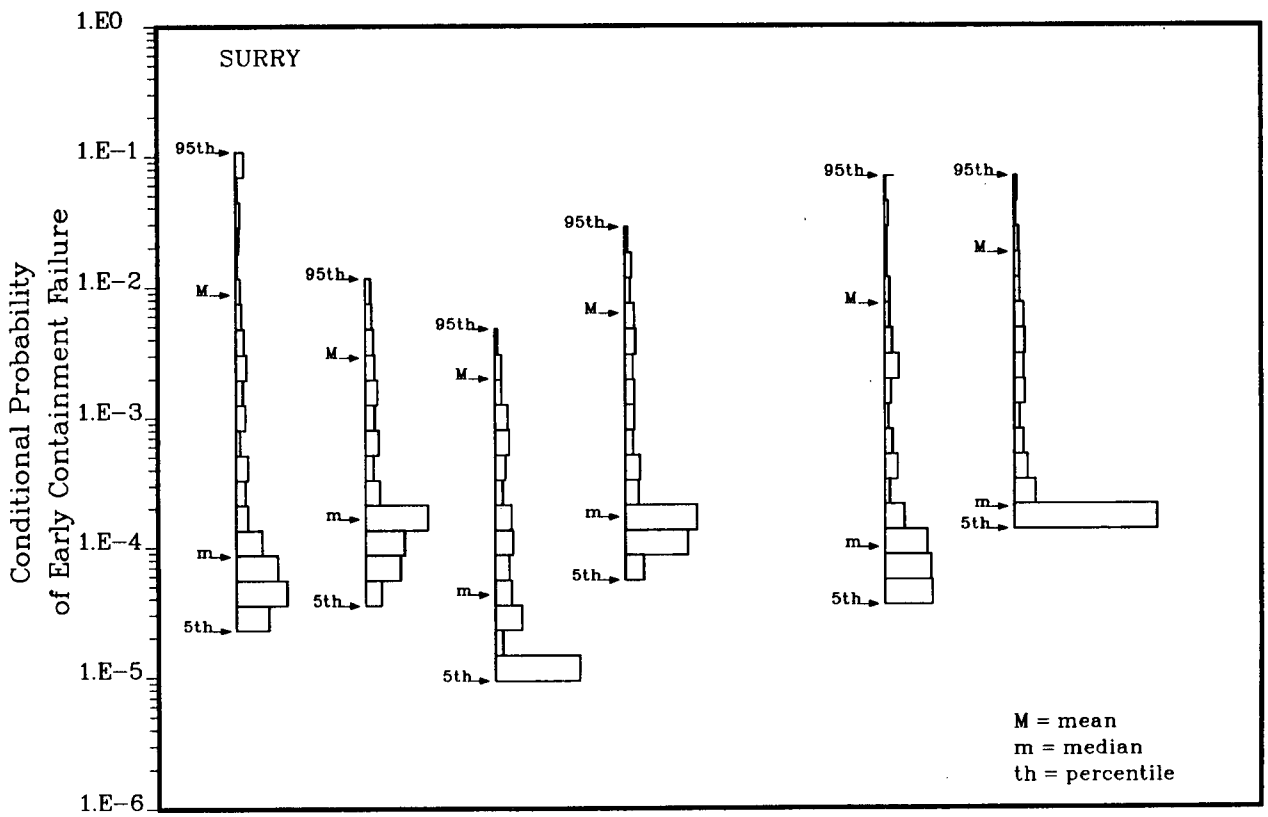
1. Pre-existing containment leak;
2. Isolation failure;
3. CF before VB due to hydrogen combustion; and
4. CF at VB due to the events at VB.

As the Surry containment is maintained about 5 psia below the ambient atmospheric pressure during operation, an unsealed hatch or an open vent line would be quickly discovered since the vacuum pumps could not keep the containment at the desired pressure. Thus the probability of a pre-existing leak at Surry is negligible. There are only two normally open

lines into the Surry containment, one to the vacuum pump and one to the sump pump. The failure of these two lines to isolate on demand is quite low.

Because the Surry containment was found to be quite strong by the structural experts who considered the issue, CF due to hydrogen burns before VB was not considered at Surry. It was estimated to be very unlikely that enough hydrogen would be generated in the vessel before VB to cause a pressure rise, when dispersed to the containment and ignited, that would threaten the Surry containment. This failure mode was included in the APET used for the analysis for Draft NUREG-1150, and no CFs before VB were found. The main risk for non-bypass accidents at Surry, then, comes from CF at VB. Almost all early CFs are CF at VB. As used in Figure 2.5-2, early CF means CF before, at VB, or immediately following VB.

Figure 2.5-2 shows the probability distribution for early CF at Surry. The probability is conditional on core damage. All the no VB probability, including a very small fraction that has isolation failures, is counted as no early CF (see Section 2.4.3). The conditional probability of early CF



PDS Group	SBO	ATWS	Transients	LOCAs	Bypass	All	Fire
Core Damage Freq.	2.8E-05	1.4E-06	1.8E-06	6.1E-06	3.4E-06	4.1E-05	1.1E-05

Figure 2.5-2. Probability of Early Containment Failure--Internal.

is particularly low for the Transient PDS group because the probability of core damage arrest is quite high. There is no histogram for the Bypass collapsed PDS group. When the containment function is bypassed by Event V or an SGTR, early CF ceases to be very important in determining the release of fission products and the offsite risk. Thus, the conditional probability of early CF was deliberately not plotted for the Bypass group. For accidents other than Bypass, the mean conditional probability of early CF is on the order of 0.01. This reflects the strength of the Surry containment relative the loads expected at VB and the probability that the vessel does not fail.

2.5.1.10 Summary. Figure 2.5-3 shows the mean distribution among the summary APSs for the summary PDS groups. Only mean values are shown, so Figure 2.5-3 gives no indication of the range of values encountered. The distribution for core damage arrest is shown in Figure 2.5-1, and the distribution for early (at or before VB) failure of the containment is shown in Figure 2.5-2. Nonetheless, Figure 2.5-3 gives a good idea of the relative likelihood of the possible results of the accident progression analysis. Except for the Bypass initiators, either no failure of the vessel (safe stable state) or no containment failure are by far the most

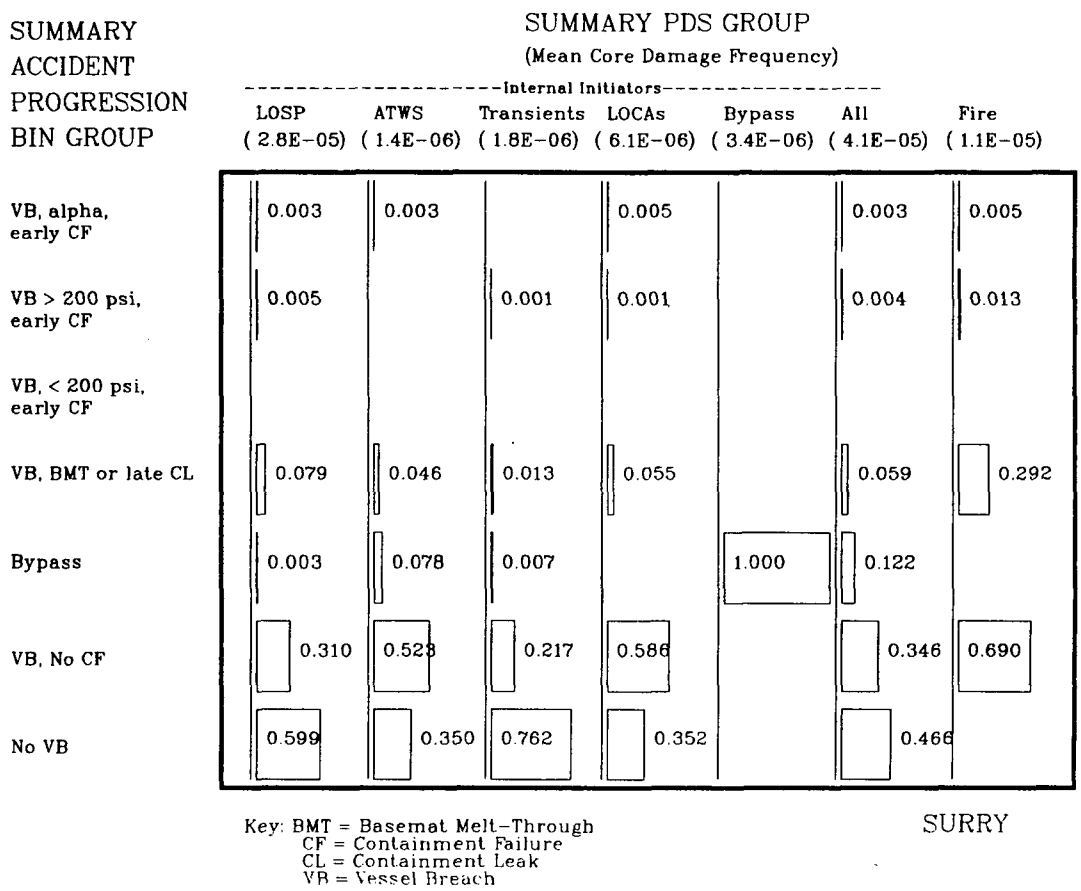


Figure 2.5-3. Mean Probability of APBs for PDSs--Internal and Fire.

likely outcomes. If VB is followed by CF, then a late failure is more likely than failure at or before VB. The late failure may be due to hydrogen ignition some hours after VB, but is more likely to be due to BMT. Early CF is fairly unlikely, as was indicated by Figure 2.5-2. This is largely due to the robust nature of the Surry containment. Figure 2.5-3 shows only the mean frequencies for the summary PDS groups and mean conditional probabilities for the summary APBs, where the mean is taken over all 200 observations in the sample. The core damage frequency of each PDS group is different for each observation. Figure 2.5-3A displays the range of mean core damage frequencies for the 200 observations for the seven PDS groups. The frequency range from the 5th percentile to the 95th percentile is about two or three orders of magnitude for all of the PDS groups APBs except Event V. The large range for Event V reflects the large uncertainty in the initiating event frequency for the interfacing system LOCA.

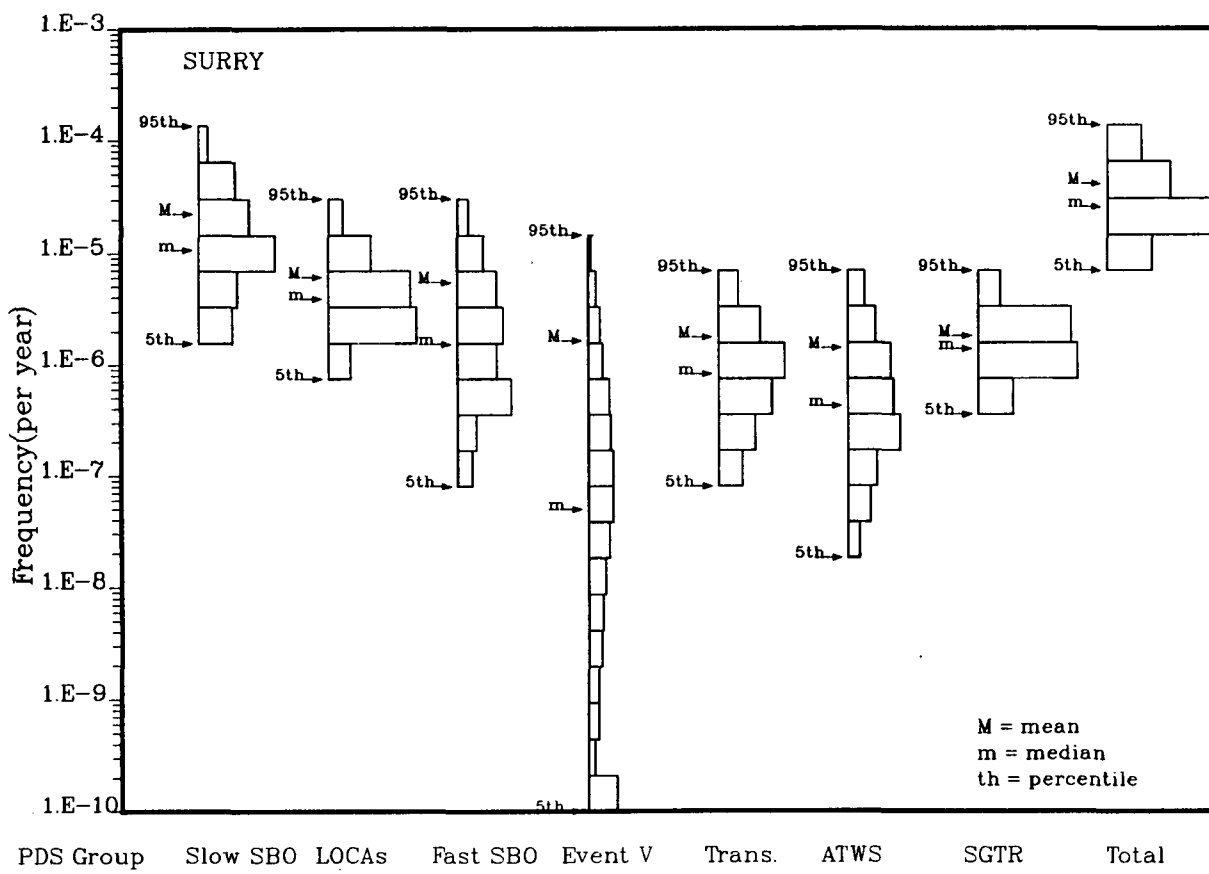


Figure 2.5.3A. Range of Mean Core Damage Frequencies for 200 Observations for Seven PDS Groups.

The mean conditional probability of each summary APB may be computed for each PDS group for each observation. When combined with the PDS group frequency, a frequency for each summary APB for each observation is obtained. The distribution of these values is displayed in Figure 2.5-3B. The 95th percentiles of the distributions for VB coincident with early containment failure (the first three distributions) all fall below 1.0E-6/year. The means are much greater than the medians for these distributions, indicating that the means are largely determined by a small number of observations with high frequencies of vessel breach followed by early CF. The Bypass summary APB includes both Event V and the SGTRs. The long low frequency 'tail' of the distribution for Event V in Figure 2.5-3A is lost when the interfacing system LOCA and SGTR frequencies are summed for presentation in Figure 2.5-3B.

The releases from accidents that result in VB and early CF are roughly comparable to releases from the most severe bypass accidents, and the releases

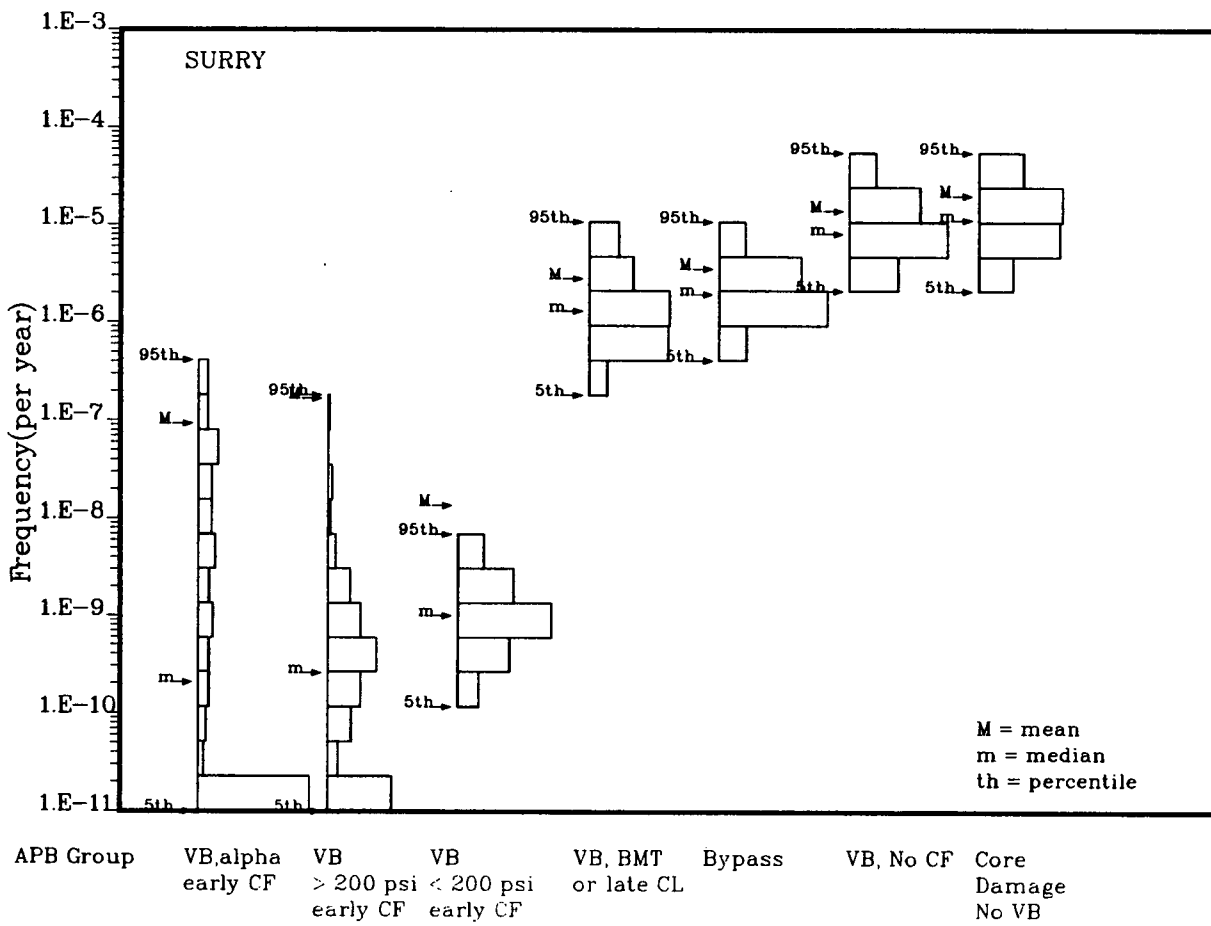


Figure 2.5.3B. Distribution of Frequencies for APB Groups.

from both of these types of accidents are much larger than non-bypass accidents in which the containment does not fail at all or fails some hours after vessel breach. Therefore, since Figure 2.5-3B shows that bypass accidents have a much higher frequency distribution than accidents with vessel breach and early CF, it may be inferred that the risk to the offsite population from internally initiated accidents at Surry is likely to be dominated by bypass accidents.

2.5.2 Sensitivity Analyses for Internal Initiators.

This section reports the results of three sensitivity analyses performed for the internally initiated accidents at Surry. The first explores the effects of changing the split between the pressure ranges for the RCS pressure at VB for S_3 breaks. The second sensitivity analysis concerned the elimination of temperature-induced SGTRs and hot leg failures. The third sensitivity analysis consisted of running a second sample of 200 observations.

2.5.2.1 Pressure at VB for S_2 and S_3 Breaks. The RCS pressure at VB is important because it largely determines the magnitude of the effects that accompany failure of the lower head. The pressure in the vessel just before breach may be considerably higher than the pressure during most of the core degradation process. A considerable amount of water is predicted to remain in the lower head until core slump. The steam generated at core slump repressurizes the RCS, at least temporarily. The pressure from core slump decreases at a rate determined by the size of the hole(s) in the RCS pressure boundary. For "T" PDSs, the PORVs reclose and keep the RCS at 2500 psia. For the "A" PDSs, the hole is so large and the depressurization so rapid that the RCS pressure is unquestionably low at VB. For situations with S_3 and S_2 breaks, the depressurization is slow enough that VB may occur while the pressure is quite high. Indeed, for small and very small breaks, the RCS pressure at breach depends directly upon the time between slump and breach.

The time between slump and breach varies considerably depending on the lower head failure mechanism postulated. Code predictions for the time between slump or collapse and breach range from a few minutes to over an hour. Not only is there uncertainty as to the time between slump and breach, but different mechanistic codes predict different peak pressures due to the slump and different pressure decay rates for the same size hole. Finally, each hole size represents a range of sizes, and the pressure decay rate varies considerably for holes within that range. As a result of these unknown and uncertain parameters, for S_3 and S_2 breaks, the RCS pressure at VB could not be assigned to a single pressure range. Indeed, even the division of the probability among the ranges was difficult. More information on this topic may be found in Volume 2, Part 6, of this report.

The division of the branch probability among the pressure ranges was determined by Sandia National Laboratories and Battelle Columbus Division. For situations with S_2 breaks, it was determined that the low pressure branch probability was 0.80 and the intermediate branch pressure was 0.20. For situations with S_3 breaks, the division of the probability used in the analyses was one third for each of the low, intermediate, and high pressure

branches. A sensitivity analysis was done for the S_3 breaks (Case 3 of Question 23) using probabilities of 0.47 for low pressure, 0.42 for intermediate pressure, and 0.11 for high pressure.

The high pressure range includes all pressures from 600 psia to 2000 psia, but most of the code results examined tended to have RCS pressure at VB that fell in the 1000 to 1400 psia range. The intermediate range is from 200 to 600 psia, and the low pressure range is below 200 psia. In summary, the branching probabilities for the base and sensitivity cases are:

Pressure Range	Sensitivity	Base
HiPr	0.11	0.333
ImPr	0.42	0.334
LoPr	0.47	0.333

Only the most frequent of the internally-initiated PDS groups was examined in detail. This group was Group 1, Slow SBO. This PDS group consists of six PDSs, two with no break in the RCS at UTAF, two with an S_3 break at UTAF, and two with an S_2 break at UTAF.

The changes from the base case to the sensitivity case were pronounced only for the high pressure branch in Question 23. The average branching ratios for a sample of 200 observations for the four pressure ranges were:

RCS Pressure at Vessel Breach (Q23)

Pressure Range	Sensitivity	Base
SSPr	0.055	0.055
HiPr	0.034	0.10
ImPr	0.21	0.19
LoPr	0.70	0.65

The realized splits for Case 3 of Question 23 were, for the three non-zero branches:

HiPr	0.10	0.32
ImPr	0.39	0.33
LoPr	0.51	0.35

These realized splits differ from the specified probabilities given above, but the variation is not unreasonable given that zero-one sampling was employed. (Zero-one sampling is discussed in Volume 1 of this report and under Questions 15 and 23 in Appendix A.1.1 of this volume.) The fraction of PDS Group 1 which has an initiating S_3 break (all RCP seal failures before UTAF) is 30.2%; at Question 23, 32.0% of this group of accidents went to Case 3. The difference mostly consists of "T" PDSs (RCS intact at UTAF) for which an RCP seal failure occurred after UTAF, but there were some T-I SGTRs as well. While the difference in the Case 3 splits is significant, as expected, the difference in the overall Question 23 branch probabilities is much less. Only two significant figures are given in these and all other tables, so the figures may not sum exactly to 1.00 due to roundoff.

It is interesting to see if the change in branch probabilities for the pressure at VB for S_3 breaks affected the type of VB. The realized branch probabilities were:

Type of Vessel Breach (Q35)

Pressure Range	Sensitivity	Base
PrEj	0.068	0.076
Pour	0.30	0.29
BtmHd	0.012	0.016
NoVB or α	0.62	0.62

The differences are not significant.

Whether the change in the branch probabilities for S_3 breaks had any effect on containment failure at VB is most important. The realized branch probabilities were:

Containment Failure at Vessel Breach (Q42)

Pressure Range	Sensitivity	Base
CtRp	0.0004	0.0004
Rupture	0.0039	0.0039
Leak	0.0029	0.0040
NoCF	0.99	0.99

The differences are not significant. The number of expected CFs resulting from VB at LoPr is essentially zero. While the number of expected failures for VB at HiPr is much larger, it is still small. And the fraction at HiPr at VB only changed from 3.3% to 10%.

The final question of interest for this sensitivity analysis is the last question in the APET:

Final Containment Condition (Q71)

Pressure Range	Sensitivity	Base
CtRp or Rupt	0.0068	0.0067
Leak	0.010	0.011
BMT	0.067	0.066
Bypass	0.0033	0.0033
NoCF	0.91	0.91

The differences are not significant. Given the results of the previous questions, this is to be expected.

2.5.2.2 No T-I SGTRs or Hot Leg Breaks. A sensitivity analysis was performed to determine the importance and the effects of the temperature-induced (T-I) hot leg (and surge line) breaks and the T-I SGTRs. These failures occur after the core melt and when the hydrogen and superheated

steam leaving the core have heated the hot leg, surge line, and steam generator inlet plenum to temperatures on the order of 1000 K. Aggregate cumulative failure probabilities for these phenomena were provided by the In-Vessel Expert Panel. Their conclusions were that these failures would occur only if the RCS was at the PORV setpoint pressure (about 2500 psia). The hot leg failures were judged to be relatively likely (mean failure probability about 0.70) while the SGTRs were estimated to be quite unlikely (mean failure probability about 0.015).

In the sensitivity analysis, these two T-I failures were eliminated completely. Note that the distributions used for the other three depressurization mechanisms were not altered in this sensitivity analysis. The deliberate opening of the PORVs is not a particularly effective means of depressurizing the RCS, but the sticking open of the PORVs and the failure of the RCP seals are effective.

Of the seven internally initiated PDS groups at Surry, three (LOCAs, Event V, and SGTRs) are completely unaffected by the elimination of the T-I hot leg failures and T-I SGTRs because the conditions for these events (RCS at PORV setpoint pressure) are not met. The other four PDS groups were evaluated in this sensitivity analysis, and the results for PDS Group 1, Slow SBO, will be discussed in some detail.

In the Surry APET, whether T-I SGTRs occur is Question 19, and whether T-I hot leg failures occur is Question 20. Thus, the base case (T-I failures as specified by the expert panel) and the sensitivity case (no T-I failures) are identical up through Question 18.

For slow blackouts, the mean RCS condition at the uncovering of the top of active fuel (UTAF) is:

No Break	0.541
S_3 Break	0.303
S_2 Break	0.156.

This is the condition of the RCS at the start of the accident progression analysis as determined by averaging the 200 observations in the sample. Question 15 determined the RCS pressure at UTAF. As the RCS pressure depends upon the state of the AFWS as well as the condition of the RCS, the mean division among the pressure levels for the Slow SBO PDS group at Question 15 does not exactly match the division among RCS states:

SSPr	0.541
HiPr	0.126
ImPr	0.333
LoPr	0.000.

where

SSPr = 2500 psia (PORV setpoint),
HiPr = roughly 1000 to 1400 psia, but perhaps as high as 2000 psia,
ImPr = 200 to 600 psia, and
LoPr = less than 200 psia.

The high pressure range includes all pressures from 600 psia to over 2000 psia, but the detailed mechanistic codes suggest that, during most of the core degradation process, the RCS pressure will be in the 1000 to 1400 psia range.

Question 16 is whether the PORVs stick open. The probability that the PORVs will stick open is 0.50 if they are cycling, that is, if there is no break in the RCS and it is at the PORV setpoint pressure (SSPr). Thus, half of the no break states become effective S_2 states at this point. Question 17 is whether the RCP seals fail. The mean failure fraction is 0.325, but most of these failures occur for states in which there is already an S_3 or S_2 break, and so have no effect. As there is no electric power, the operators are prevented from opening the PORVs in Question 18.

Question 19 concerns the T-I SGTR. No SGTRs were computed in the sensitivity case vs. 0.0033 in the base case. Question 20 concerns the T-I hot leg (or surge line) failure. No failures were computed in the sensitivity case vs. 0.197 in the base case.

Thus, at Question 23, which determines the pressure in the RCS just before VB, the mean division among the pressure levels is noticeably different for the two cases:

RCS Pressure at Vessel Breach (Q23)

Pressure Range	Sensitivity (No T-I Breaks)	Base (T-I Breaks)
SSPr	0.25	0.055
HiPr	0.10	0.10
ImPr	0.19	0.19
LoPr	0.46	0.65

These tables give results to only two significant figures, so roundoff may cause the column sums to differ slightly from exactly 1.00. Since the PORVs stick open half the time for the "T" PDSs, and the RCP seals fail about 60% to 70% of the time when there is no pump seal cooling, there are two effective means of depressurizing the RCS in the sensitivity case. About 60% of this PDS group has no pump seal cooling. The stuck-open PORVs question alone has converted half the No Break PDSs in the Slow SBO group to effective S_2 breaks. The base case has T-I hot leg breaks as well, and the difference is obvious. As expected, the T-I hot leg failures and SGTRs affect only the SSPr and LoPr pressure ranges since hot leg failures occur only when the RCS pressure is at the PORV setpoint value.

The fractions of the Slow SBO group that went to each case in Question 23 may also be of interest:

	Sensitivity (No T-I Breaks)	Base (T-I Breaks)
Case 1: A Breaks	0.000	0.197
Case 2: S_2 Breaks	0.428	0.428
Case 3: S_3 Breaks	0.327	0.320
Case 4: No Breaks	0.245	0.055

The effect of eliminating the T-I SGTRs is negligible, even in Question 23, but the effect of eliminating the T-I hot leg failures is to transfer about 20% of the Slow SBO group from LoPr to SSPr. The reason the fraction is not greater is that only 54% of the group is in the "No Break" category to begin with, and the stuck-open PORVs eliminate half of this category before the hot leg failure question is asked.

The type of vessel failure is determined in Question 36 of the Surry APET. The realized branching is:

Type of Vessel Breach (Q36)

Type of VB	Sensitivity (No T-I Breaks)	Base (T-I Breaks)
PrEj	0.14	0.076
Pour	0.22	0.29
BtmHd	0.025	0.016
NoVB or α	0.62	0.62

The differences are not larger because the probability is about 0.62 that offsite electric power and coolant injection is recovered before a large portion of the core is molten, and vessel failure is thus averted. It may be noted that the fraction for pressurized ejection is nearly doubled. Alpha mode failures account for only about 0.2% or 0.3% of the vessel failures.

If eliminating the T-I SGTRs and hot leg failures is to increase risk significantly, it must do so by increasing the fraction of containment failures at VB. This is determined in Question 43. The mean branch probabilities for the Slow SBO group are:

Containment Failure at Vessel Breach (Q43)

CF Mode	Sensitivity (No T-I Breaks)	Base (T-I Breaks)
Cat. Rupture	0.0005	0.0004
Rupture	0.0070	0.0039
Leak	0.0049	0.0040
NoCF	0.99	0.99

There are slightly more containment failures when the T-I RCS breaks are set to zero. The number of ruptures is nearly doubled, but the fraction is small in either case. The increase in the number of leaks is not as great.

Although 19% of the accident was transferred from LoPr at VB to SSPr at VB, the number of containment failures would not be expected to increase proportionally. In the first place, 62% of the accident goes to NoVB since power is recovered before the core melt has gone very far. And, of the portion of the accident shifted to SSPr, only a fraction will result in CF at VB since the load distributions provided by the Containment Loads Expert Panel are generally lower than the containment failure pressure distribution provided by the structural experts. This will be discussed in more detail below. The state of the containment at the end of the APET is summarized in the final question:

Final Containment Condition (Q71)

Condition	Sensitivity (No T-I Breaks)	Base (T-I Breaks)
Cat. Rupt. or Rupture	0.0095	0.0067
Leak	0.012	0.011
BMT	0.058	0.066
Bypass	0.00	0.0030
NoCF	0.92	0.91

The differences are not significant. Given the results of Question 43, this is to be expected.

Tables 2.5-8 through 2.5-11 summarize the results of the sensitivity analysis for the four internally initiated PDS groups for which the elimination of the T-I breaks have any effect. The Slow SBO group has already been discussed. The tables show the mean branch probabilities. The Fast SBO group results are similar to those for the Slow SBO group. The difference in CF at VB, the most important question for offsite risk, is discernible but not significant. For the Transient group, Table 2.5-10, the major difference is in the probability of core damage arrest and no vessel failure. The hot leg failure plays a very important role in depressurizing the RCS so that LPIS injection results. Furthermore, RCP seal cooling is operating in this PDS group, so the RCP seal failure mechanism is not effective. In spite of the large difference in the probability of the arrest of core degradation, the elimination of the T-I breaks does not make CF at VB likely. While the relative increase in the probability of CF at VB is large, the probability of CF at VB with no T-I breaks is still only about 0.016. For the ATWS PDS group, Table 2.5-11, the differences between the base and the sensitivity cases are not significant.

Both the base and sensitivity cases were carried through to risk. There were no significant differences between the two cases.

The following tables and discussion show that although the probability of SSPr at VB increased markedly when the T-I hot leg failures and SGTRs were eliminated, the increase in the probability of CF at VB was fairly small.

The reason for this is that for VB at SSPr, CF results only a small fraction of the time. This fact follows from the load and failure pressure distributions determined by the expert panels. The relationship of these distributions has been summarized in Table 2.5-12.

Table 2.5-8
Comparison of APET Results With and Without
T-I Hot Leg Breaks and SGTRs
PDS Group 1--Slow SBO

Fraction With RCS Pressure in Four Ranges:

	At UTAF	At VB Base Case	At VB No T-I Breaks
SSPr	0.541	0.055	0.245
HiPr	0.126	0.101	0.103
ImPr	0.333	0.190	0.191
LoPr	0.000	0.654	0.461

	Base Case	Sensitivity Case
Fraction With No Vb	0.618	0.618
Fraction With Alpha Mode Failure	0.0028	0.0022
Fraction With CF at VB Total	0.0083	0.0124
Cat. Rupture	0.0004	0.0005
Rupture	0.0039	0.0070
Leak	0.0040	0.0049
Fraction With VB, but No CF at VB	0.374	0.370
Fraction With CF--Late Burn	0.0072	0.0068
Fraction With CF--Very Late Burn	0.0024	0.0022
Fraction With the Following Final Containment Condition		
Rupture	0.0067	0.0095
Leak	0.0114	0.0120
BMT	0.0660	0.0577
Bypass	0.0030	0.0000
NoCF (& NoVB)	0.9130	0.9209

Table 2.5-9
Comparison of APET Results With and Without
T-I Hot Leg Breaks and SGTRs
PDS Group 3--Fast SBO

Fraction With RCS Pressure in Four Ranges:

	At UTAF	At VB Base Case	At VB No T-I Breaks
SSPr	1.000	0.029	0.150
HiPr	0.000	0.116	0.116
ImPr	0.000	0.198	0.197
LoPr	0.000	0.657	0.537

	Base Case	Sensitivity Case
Fraction With No VB	0.508	0.508
Fraction With Alpha Mode Failure	0.0038	0.0036
Fraction With CF at VB Total	0.0074	0.0130
Cat. Rupture	0.0000	0.0001
Rupture	0.0049	0.0089
Leak	0.0025	0.0040
Fraction With VB, but No CF at VB	0.484	0.479
CF--Late Burn	0.0166	0.0149
CF--Very Late Burn	0.0005	0.0006
Fraction With the Following Final Containment Condition		
Rupture	0.0070	0.0107
Leak	0.0179	0.0180
BMT	0.0870	0.0765
Bypass	0.0021	0.0000
NoCF (& NoVB)	0.8862	0.8948

Table 2.5-10
Comparison of APET Results with and without
T-I Hot Leg Breaks and SGTRs
PDS Group 5 -- Transients

Fraction With RCS Pressure in Four Ranges:

	At UTAF	At VB Base Case	At VB No T-I Breaks
SSPr	1.000	0.115	0.500
HiPr	0.000	0.002	0.000
ImPr	0.000	0.093	0.091
LoPr	0.000	0.790	0.409

	Base Case	Sensitivity Case
Fraction With No Vb	0.766	0.422
Fraction With Alpha Mode Failure	0.0009	0.0009
Fraction With CF at VB Total	0.0022	0.0165
Cat. Rupture	0.0000	0.0000
Rupture	0.0017	0.0108
Leak	0.0005	0.0057
Fraction With VB, but No CF at VB	0.232	0.562
Fraction With CF--Late Burn	0.00	0.00
Fraction With CF--Very Late Burn	0.00	0.00
Fraction With the Following Final Containment Condition		
Rupture	0.0016	0.0108
Leak	0.0008	0.0590
BMT	0.0130	0.0202
Bypass	0.0066	0.0000
NoCF (& NoVB)	0.9781	0.9631

Table 2.5-11
Comparison of APET Results with and without
T-I Hot Leg Breaks and SGTRs
PDS Group 6 -- ATWS

Fraction With RCS Pressure in Four Ranges:

	At UTAF	At VB Base Case	At VB No T-I Breaks
SSPr	1.000	0.005	0.025
HiPr	0.000	0.002	0.008
ImPr	0.000	0.191	0.198
LoPr	0.000	0.802	0.769

	Base Case	Sensitivity Case
Fraction With No VB	0.406	0.387
Fraction With Alpha Mode Failure	0.0029	0.0039
Fraction With CF at VB Total	0.0029	0.0039
Cat. Rupture	0.0000	0.0000
Rupture	0.0029	0.0033
Leak	0.0001	0.0006
Fraction With VB, but No CF at VB	0.591	0.609
Fraction With CF--Late Burn	0.00	0.00
Fraction With CF--Very Late Burn	0.00	0.00
Fraction With the Following Final Containment Condition		
Rupture	0.0029	0.0033
Leak	0.0003	0.0008
BMT	0.0472	0.0470
Bypass	0.0761	0.0754
NoCF (& NoVB)	0.8736	0.8736

Table 2.5-12
Probability of CF and Probability of Case
for CF at VB for Surry
PDS Group 1 -- Slow SBO

Case	Hole Size	RCS Pressure	Rx Cavity	Core Fraction Ejection	Prob. CF	Prob. Case Sens.	Prob. Case Base
1	Any	Lo	Any	Any	.0016	.220	.288
2	Large	Im	Wet	Large	.123	.0016	.0016
3	Large	Im	Wet	Medium	.071	.0016	.0016
4	Large	Im	Wet	Small	.012	.0009	.0009
5	Large	Hi	Dry	Large	.287	.0053	.0015
6	Large	Hi	Dry	Medium	.173	.0054	.0015
7	Large	Hi	Dry	Small	.022	.0094	.0045
8	Large	Hi	Wet	Large	.181	.0057	.0049
9	Large	Hi	Wet	Medium	.109	.0043	.0029
10	Large	Hi	Wet	Small	.014	.0058	.0052
11	Small	Im	Wet	Large	.081	.0034	.0034
12	Small	Im	Wet	Medium	.035	.0037	.0036
13	Small	Im	Wet	Small	.007	.0037	.0037
14	Small	Hi	Dry	Large	.152	.0212	.0093
15	Small	Hi	Dry	Medium	.073	.0269	.0082
16	Small	Hi	Dry	Small	.009	.0201	.0069
17	Small	Hi	Wet	Large	.095	.0109	.0084
18	Small	Hi	Wet	Medium	.043	.0192	.0151
19	Small	Hi	Wet	Small	.008	.0109	.0085

The pressure rise at vessel breach is determined in Questions 39 and 40 in the Surry APET. These two questions contain 19 non-trivial cases for pressure rise at VB; they have been numbered sequentially in Table 2.5-12. The pressure rise depends upon:

- The size of the hole in the vessel,
- The RCS pressure at VB,
- The presence or absence of water in the cavity, and
- The fraction of the core ejected at VB.

Columns 2 through 5 define these quantities for each case. The experts considered the HiPr and SSPr ranges to be the same for load purposes, so the "Hi" designation in the "RCS Pr," column in Table 2.5-12 means roughly 1500 to 2500 psia, although the range actually extends as low as 600 psia. The "Im" range is 200 to 600 psia, and the "Lo" range is less than 200 psia. There turned out to be no significant statistical differences

between the experts' aggregate pressure rise distributions for the Hi RCS pressure and wet cavity case and the Im RCS pressure and dry cavity case. So Cases 8, 9, 10, 17, 18, and 19 apply to intermediate pressure, dry cavity cases as well as the cases indicated.

The "Prob. CF" column in Table 2.5-12 gives the mean probability of CF if only that case is considered, i.e., if all the frequency went to that case. For example, if the APET were rigged so that Case 11 in Table 2.5-12 was always selected, then CF would be expected about 8% of the time. The values in this column were determined by comparing 10,000 random values from the containment failure distribution with 10,000 random values from each pressure rise distribution.

The comparison used to determine the mean CF probabilities was done in the following manner. The Structural Expert Panel provided an aggregate distribution for the probability of containment failure as a function of pressure, in psig. This was converted to psia by adding 14.7 psi to every point in the distribution. The Containment Loads Expert Panel provided aggregate distributions for pressure rise at VB for the 19 cases listed. These distributions were converted to absolute pressure by adding to them the baseline pressure in the containment before VB. The "no sprays" baseline pressures were used, which makes this comparison applicable to the SBO PDS groups (Groups 1 and 3). With no sprays operating, the baseline pressure is 26 psia for all breaks but the large breaks (A-size) and 37 psia for the large breaks. That is, 37 psia was added to the low pressure pressure rise distribution, and 26 psia to the other 18 pressure rise distributions. The absolute load and failure pressure curves were compared by selecting 10,000 pairs of random numbers between zero and one. One value from each pair determined a point on the failure curve, and the other determined a point on a load curve. If the load pressure exceeded the failure pressure, it was counted as a CF.

Note that for station blackouts, it is possible to have water in the cavity at VB if the power is restored before VB, but VB is not averted. In this situation, the sprays would have filled the cavity and reduced the baseline containment pressure to about ambient pressure. This comparison method overstates the CF probability for the "Wet" cases in Table 2.5-12. Examination of the "Prob. CF" column in Table 2.5-12 shows that the mean probability of CF at VB ranges from about 0.29 for the case with the highest pressure rise, Case 5, to less than 0.01 for Cases 13, 16, and 19. It remains to determine the probability of each of these 19 cases.

The "Prob. Case" columns in Table 2.5-12 give the fraction of PDS Group 1 (Slow SBO) that went to each case for the base run and for the sensitivity run in which the T-I hot leg breaks and SGTRs were eliminated. Note that the values in the "Prob. Case" columns only add up to about 0.38 since about 62% of the slow blackout PDS group had core damage arrest and no VB due to the recovery of offsite electric power. As small holes in the vessel are much more likely than large holes, only the small hole cases were selected with a probability over 0.01. As would be expected, Table 2.5-12 shows that eliminating the two T-I breaks decreased the fraction in the low pressure case and increased the fractions in the high pressure cases. The probability of the Slow SBO group going to the case with the

highest pressure rise, Case 5, is very low, less than 0.01 for both the base and sensitivity cases. The most probable case for the base case, Case 18, is about 10 times more probable than Case 5. The CF probability for Case 18 is 0.043. The most probable case for the sensitivity case, Case 15, is about five times more probable than Case 5. The CF probability for Case 15 is 0.073.

From Table 2.5-12 it may be seen why the increase in the fraction with SSPr at VB did not lead to a corresponding increase in the fraction with CF at VB. The load distributions and the failure distribution given by the experts are such that the more probable pressure rise cases result in CF probabilities on the order of 0.01 to 0.10 at Surry. If the entire fraction that went to VB in the Slow SBO PDS group went to Case 15, the CF probability would be 0.073 for the 38% that went to VB, resulting in an overall CF probability of 0.027. When the T-I hot leg and SGTR breaks were eliminated in the sensitivity analysis, for the Slow SBO group, the probability of CF at VB increased from 0.008 to 0.012. So the effective probability of CF at VB, conditional on VB, is considerably less than that for Case 15.

In summary, the effect of eliminating the T-I hot leg breaks and SGTRs is to increase the mean probability of PORV setpoint pressure at VB significantly. For the SBO PDS groups, this has little effect on the mean probability of CF at VB. For the Transient PDS group, eliminating the T-I breaks has a large effect on the mean probability of core damage arrest, but only a very small effect on the mean probability of CF at VB. When all PDS groups are considered, the effects of eliminating the T-I breaks on offsite risk are not discernible. The reason there is so little effect can be found in the containment failure pressure and containment load distributions determined by the expert panels. That is, Surry has a strong containment relative to the loads expected, and increasing the RCS pressure at VB does not increase the containment failure probability markedly.

2.5.2.3 Second Sample. To test the robustness of the sampling process, and to determine which means of displaying the results are subject to variation from sample to sample, a second sample of 200 observations was run all the way through to risk for the internal initiators at Surry. The analyses were identical except for the seed value used for the LHS program that generated the sample values.

Figure 2.5-4 shows the mean probabilities of the summary APBs for each summary PDS group for the second sample. It may be compared with Figure 2.5-3 which is the equivalent plot for the first sample. Although the results are not valid to three significant figures, three significant figures are shown so that the differences between the two samples may be discerned. The conditional probabilities for the collapsed APBs differ less than 0.01 from the first sample to the second. These differences are not significant. Indeed, the largest differences in this figure are in the mean core damage frequencies, which are determined in the accident frequency analysis, not here in the accident progression analysis. The results for PDS Group 1, Slow SBO, have been examined in detail. For the two samples, the mean branch probabilities for the question that determines the RCS pressure just before vessel failure are:

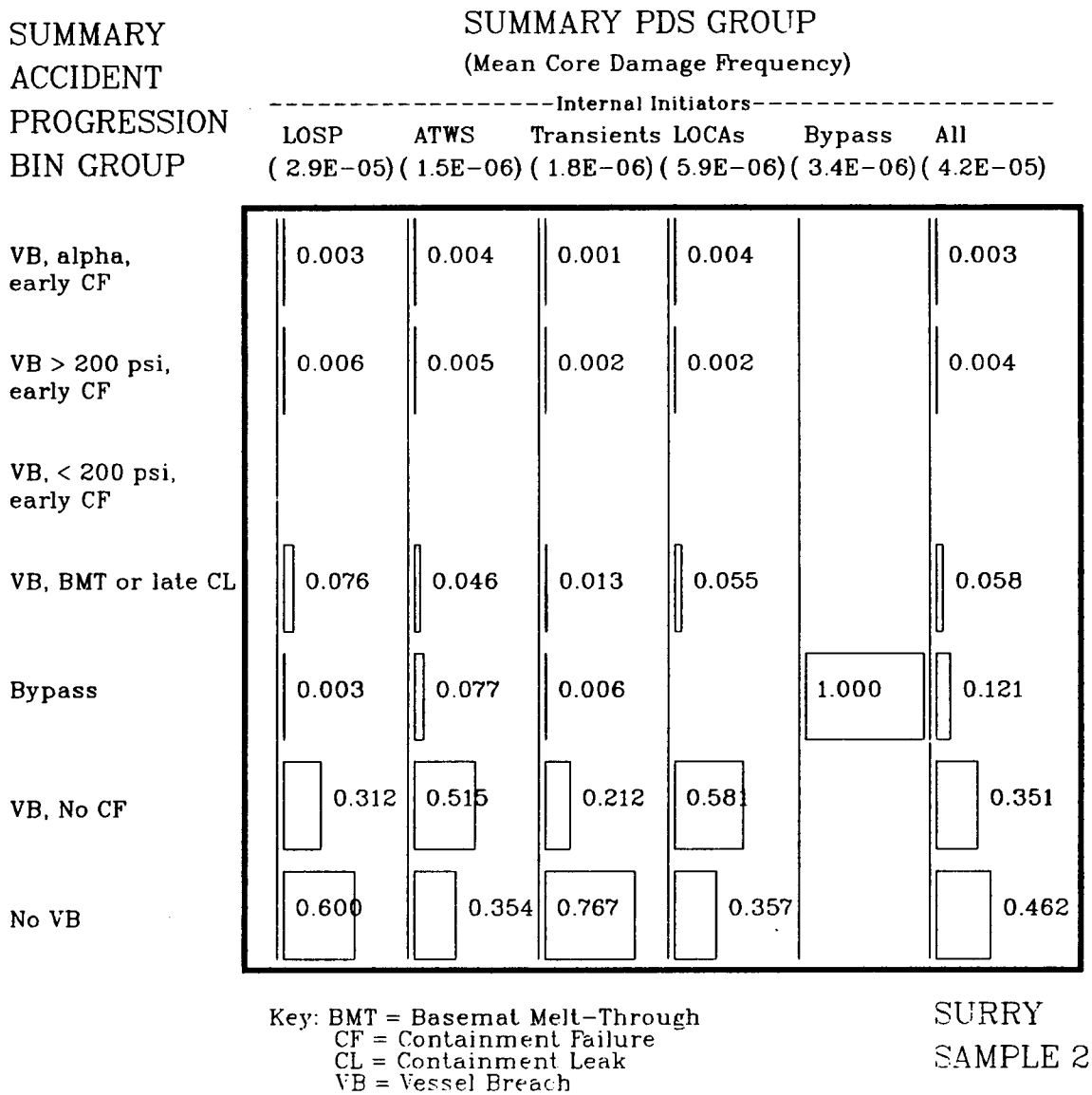


Figure 2.5-4. Mean Probability of APBs for PDSs--Internal Sample 2.

Question 23. Vessel Pressure Just Before Breach?

	Sample 1	Sample 2
Setpoint Pressure	0.0549	0.0523
High Pressure	0.1015	0.1166
Intermediate Pressure	0.1901	0.1866
Low Pressure	0.6536	0.6445

The differences between the samples are not significant. More significant figures are given than the accuracy of the analysis warrants so that the differences between the two samples are evident.

The mean probability of arresting the degradation of the core and avoiding VB is determined in Question 24; the probability is 0.6177 for Sample 1 and 0.6185 for Sample 2.

The mean branch probabilities for containment failure and the mode of failure at VB are:

Question 43. Containment Failure at Vessel Breach?

	Sample 1	Sample 2
Catastrophic Rupture	0.00043	0.00008
Rupture	0.00390	0.00629
Leak	0.00328	0.00228
No Failure	0.9917	0.9914

The differences are not significant.

The output bins for PDS Group 1, Slow SBO, were also examined. Some of the significant bins are listed in Table 2.5-13. Differences are evident only for mean probabilities below 0.01.

Distributions for various results were also examined and showed no significant differences between the two samples. The conclusion from running two samples is that the accident progression analysis appears to be very stable and reproducible.

Table 2.5-13
Comparison of Selected Bins for PDS Group 1, Slow SBO
for Two Samples for Surry

Sample 1		Sample 2		
Bin	Relative Frequency	Bin	Relative Frequency	Comments
HDC-DFC-DBD-FB	0.1713	HDC-DFC-DBD-FB	0.1709	Highest Freq. Bin, No VB, NoCF
HDC-DFC-DAD-FB	0.1446	HDC-DFC-DAD-FB	0.1448	2nd Highest Freq., No VB, NoCF
HDC-DFC-DAD-FA	0.0455	HDC-BFC-DAD-FA	0.0427	3rd Highest Freq., No VB, NoCF
GFA-DBC-ABD-DB	0.0125	GFA-DBC-ABD-DB	0.0125	Highest Freq. Bin with CF, BMT
EFA-DBC-AAD-CB	0.0029	EFA-DBC-ABD-CB	0.0015	Highest Frequency Bin with CF due to Late Burn
DHA-DDC-BAD-BB	0.0012	DHA-DDC-BBD-BB	0.0015	Highest Frequency Bin with CF at VB due to Alpha
DFA-CAC-ABA-CB	0.0007	DFA-CAC-AAA-BB	0.0008	Highest Frequency Bin with CF at VB due to DCH

2.5.3 Results for Fire Initiators

This PDS group consists of accidents initiated by fires. Fires were found to be important in four locations at Surry: the emergency switchgear room, the auxiliary building, the control room, and the cable vault and tunnel. Table 2.2-4 lists the mean CDFs for these four locations. The fires lead to core damage accidents by destroying the electric cables or switchgear necessary to power or control the ECCS. The coolant loss from the RCS is due to RCP seal failures in three of the four PDSs, and to stuck-open PORVs in the fourth PDS. The destruction caused by the fire is considered not to be reparable in the timeframe of interest; that is, there is no chance of recovering the ECCS, so there is no possibility of arresting the core degradation process and vessel failure is inevitable for the fire PDSs.

Table 2.5-14 lists the 10 most probable APBs for the PDS group and the five most probable APBs that have VB and early containment failure (CF). Since there is no possibility of core damage arrest for accidents initiated by fires, all the APBs have VB. So, the 10 most probable APBs are listed instead of the five most probable and the five most probable that have VB. Evaluation of the APET produced 754 bins for the Fire group. To capture 95% of the probability, 230 bins are required. Three of the 10 most probable bins have BMT; the other seven have no CF. The ten most probable bins capture 42% of the probability. Of the five most probable APBs with both VB and early CF, two have CF due to gross bottom head failure at intermediate pressure, two have CF due to an Alpha mode failure of both vessel and containment, and one has CF due to HPME and DCH with the RCS at high pressure. (Early CF means CF before or at VB.)

The fractions of the five PDS groups that are in the four pressure ranges at UTAF and just before VB (if it occurs) are:

	At UTAF	Just Before VB
SSPr (2500 psia)	0.0	0.0
HiPr (600 to 2000 psia)	0.14	0.15
ImPr (200 to 600 psia)	0.86	0.24
LoPr (< 200 psia)	0.00	0.61

The relative frequencies of the "S_3" and "S_2" PDSs, in conjunction with whether the secondary system has been depressurized while the AFWS is operating, result in over three-fourths of the Fire group being in the high pressure range when the core uncovers (Question 15). Just before VB, the situation is quite different (Question 23). Five mechanisms for depressurizing the RCS are considered in the APET. Only the deliberate opening of the PORVs by the operators is effective for the Fire PDSs. The determination of RCS pressure at VB was discussed in some detail in Section 2.5.2.1. See also the discussion of Question 23 in Appendix A.

Table 2.5-14
Results of the Accident Progression Analysis for Surry
Fire Initiators. PDS Group Fire

Order	Bin	Prob.*	No. Occur.	CF Time	Sprays	CCI	RCS Pres.	VB Mode	Amt CCI	Zr Ox	HPME	CF Size
Ten Most Probable Bins**												
1	HHADBCAADFB	0.079	114	No-CF	Never	PrmDry	LoPr	Pour	Large	Lo	No	No-CF
2	HHADBCABDFB	0.069	92	No-CF	Never	PrmDry	LoPr	Pour	Large	Hi	No	No-CF
3	GHADBCAADDB	0.054	114	Final	Never	PrmDry	LoPr	Pour	Large	Lo	No	BMT
4	HDCDBCDADFB	0.047	89	No-CF	Always	No-CCI	LoPr	Pour	No-CCI	Lo	No	No-CF
5	GHADBCABDDB	0.047	29	Final	Never	PrmDry	LoPr	Pour	Large	Hi	No	BMT
6	HDCDBCDBDFB	0.033	85	No-CF	Always	No-CCI	LoPr	Pour	No-CCI	Hi	No	No-CF
7	HHADBCAADFA	0.027	38	No-CF	Never	PrmDry	LoPr	Pour	Large	Lo	No	No-CF
8	HHADBCABDFA	0.025	28	No-CF	Never	PrmDry	LoPr	Pour	Large	Hi	No	No-CF
9	HHDDBCAADFB	0.023	82	No-CF	Always	PrmDeep	LoPr	Pour	Large	Lo	No	No-CF
10	GHADBCAADDA	0.019	38	Final	Never	PrmDry	LoPr	Pour	Large	Lo	No	BMT
Five Most Probable Bins that have VB and Early CF**												
62	DHACCCAABCA	0.0032	1	CFatVB	Never	PrmDry	ImPr	BtmHd	Large	Lo	Md	Leak
102	DHADDCBADBB	0.0018	54	CFatVB	Never	PrmDry	LoPr	Alpha	Medium	Lo	No	Rupture
119	DHACCCABACA	0.0014	1	CFatVB	Never	PrmDry	ImPr	BtmHd	Large	Hi	Hi	Leak
151	DHADDCBBDBB	0.0010	47	CFatVB	Never	PrmDry	LoPr	Alpha	Medium	Hi	No	Rupture
159	DDCBACDBACA	0.0009	1	CFatVB	Always	No-CCI	HiPr	HPME	No-CCI	Hi	Hi	Leak

* Mean probability conditional on the occurrence of the PDS.
** A listing of all bins, and a listing by observation are available on computer media.

The mean probability of CF at VB for this PDS group is 0.018. There are no late or very late CFs due to hydrogen burns for the Fire PDSs. Although power or control to the ECCS has been irreparably lost, normal station power is not failed. It was estimated that there would be enough sources of sparks in the containment in these situations to ignite the hydrogen present whenever a flammable concentration occurred. Deflagrations at the flammable limits are judged to be extremely unlikely to fail the Surry containment, so combustion events in these conditions are not considered. The mean probability of BMT is 0.26. As three of the four PDSs in this group have the sprays irreparably failed, it is possible that an overpressure failure of the containment may occur after several days due to the lack of CHR. As the Surry basemat is constructed of siliceous concrete, the cause of this CF is not primarily due to the generation of noncondensible gases by CCI, but results from the increase in the temperatures of the containment wall and atmosphere to the point where steam condensation on the walls ceases. Steam then behaves as a noncondensible gas. The mean probability of eventual overpressure CF is 0.03.

2.5.4 Sensitivity Analyses for Fire Initiators

No sensitivity analyses were performed for fire initiators at Surry.

2.5.5 Results for Seismic Initiators: LLNL Hazard Distribution

The seismic risk analysis was performed using two different seismic hazard distributions. This section reports the results using the hazard distribution developed by LLNL. Results based on the seismic hazard distribution developed by EPRI are presented in Section 2.5.7. The differences between these two distributions are discussed in NUREG/CR-4550, Vol. 3, Part 3.

The accidents initiated by earthquakes were analyzed in two groups. Those due to seisms with a maximum ground acceleration in excess of 0.6 g were denoted the high acceleration events. It was judged that the destruction in the general vicinity of the plant for those earthquakes would be so great that evacuation would be ineffective. For the low acceleration events, less than 0.6 g, it was estimated that evacuation would be possible, although perhaps more slowly than in emergencies without earthquakes.

2.5.5.1 Results for PDS Group EQ 1: LOSP (No SBO); High Acceleration, LLNL Hazard Distribution. This PDS group consists of accidents initiated by LOSP, but in which SBO does not result. The LOSP is due to the earthquake, but the DGs start and supply station power. There are five PDSs in this group as listed in Table 2.2-6. Four of them are similar to the internally initiated transients; AFWS fails at the start, and bleed and feed fails due to HPIS failures or PORV failures. Two of the four "T" (RCS intact) PDSs have LPIS operating, one has both LPIS and HPIS operating, and the fourth has no ECCS operable. The "S_3" PDS has an RCP seal failure and failure of all ECCS. Thus, in three of the five PDSs in the group, core damage arrest is possible if a T-I break after UTAF lowers the RCS pressure sufficiently. This PDS group consists of the fraction of these accidents due to seisms with a maximum ground acceleration exceeding 0.6 g.

Table 2.5-15 lists the 10 most probable APBs for this PDS group and the five most probable APBs that have VB and early CF. As the the five most probable APBs that have VB are contained in the ten most probable bins, these are listed instead of repeating many of the APBs. Evaluation of the APET produced 729 bins for the LOSP, high acceleration PDS group. To capture 95% of the probability, 70 bins are required. The 10n most probable bins capture 73% of the probability. Four of the 10 most probable bins have no VB; the other six have low pressure pour failures of the lower head. Two of the 10 most probable bins have BMT; the other eight have no CF. Of the five most probable APBs with both VB and early CF, two have CF due to an Alpha mode failure of both vessel and containment, and three have CF due to HPME and DCH with the RCS at high pressure.

Some of the PDSs in this group have ac electric power partially available in the plant. This is denoted by a "P" for the fourth PDS characteristic. This indication is used when seismic failures have rendered part or all of the ECCS, sprays, or AFWS inoperable but there is no SBO. The operability of these systems in these situations is indicated by the second, third, and seventh characteristics.

In the LOSP, high acceleration PDS group there is the possibility of arresting the core degradation process and avoiding VB since three of the PDSs have some ECCS operating at UTAF. If the RCS can be depressurized, injection by the ECCS may arrest core damage for these PDSs. The mean probabilities for this PDS group for the four pressure ranges at UTAF and just before VB (if it occurs) are:

	At UTAF	Just Before VB
SSPr (2500 psia)	0.934	0.012
HiPr (600 to 2000 psia)	0.0	0.002
ImPr (200 to 600 psia)	0.066	0.190
LoPr (< 200 psia)	0.0	0.796

Four of the five PDSs in this group are "T" PDSs, which have the RCS intact at the PORV setpoint pressure at UTAF (Question 15). These PDSs account for the high probability for SSPr at UTAF. At VB (Question 23), the probability is only about 0.01 that the RCS will be at that pressure. The Surry APET considers five mechanisms for depressurizing the RCS. Deliberate opening of the PORVs by the operators, the PORVs sticking open, and T-I hot leg breaks are effective for the LOSP, high acceleration PDS group. RCP seal failures are not important for this group since the four PDSs that do not have RCP seal failures at UTAF have seal cooling operating. In the seismic accident frequency analysis, it was judged that the operators would be too busy coping with the effects of the earthquake to open the PORVs before UTAF. Thus, they may do so afterwards since power is available unless the PORVs have failed closed (as they have in one PDS). Note that failures that prevent the PORVs from being opened from the control room do not prevent the PORVs from opening in their relief mode, and thus sticking open. The experts who considered T-I failures determined that hot leg failures were likely if the PCS was at the PORV setpoint pressure (about 2500 psi), while SGTRs were very unlikely. As the

Table 2.5-15
Results of the Accident Progression Analysis for Surry
Seismic Initiators. PDS Group EQ 1, LOSP (No SBO): High Acceleration,
LLNL Hazard Distribution

Order	Bin	Prob.*	No. Occur.	CF Time	Sprays	CCI	RCS Pres.	VB Mode	Amt CCI	Zr Ox	HPME	CF Size
Ten Most Probable Bins**												
1	HHCDFCDBDFB	0.192	123	No-CF	Never	No-CCI	LoPr	No-VB	No-CCI	Hi	No	No-CF
2	HHCDFCDADFB	0.117	111	No-CF	Never	No-CCI	LoPr	No-VB	No-CCI	Lo	No	No-CF
3	HHADBCABDFB	0.108	123	No-CF	Never	PrmDry	LoPr	Pour	Large	Hi	No	No-CF
4	GHADBCABDDB	0.073	123	Final	Never	PrmDry	LoPr	Pour	Large	Hi	No	BMT
5	HHADBCAADFB	0.072	112	No-CF	Never	PrmDry	LoPr	Pour	Large	Lo	No	No-CF
6	HDCDFCDBDFB	0.059	123	No-CF	Always	No-CCI	LoPr	No-VB	No-CCI	Hi	No	No-CF
7	GHADBCAADDB	0.049	112	Final	Never	PrmDry	LoPr	Pour	Large	Lo	No	BMT
8	HDCDFCDADFB	0.030	111	No-CF	Always	No-CCI	LoPr	No-VB	No-CCI	Lo	No	No-CF
9	HHACBCABDFB	0.017	8	No-CF	Never	PrmDry	ImPr	Pour	Large	Hi	No	No-CF
10	HDCDBCDBDFB	0.016	123	No-CF	Always	No-CCI	LoPr	Pour	No-CCI	Hi	No	No-CF
Five Most Probable Bins that have VB and Early CF**												
30	DHACACABACB	0.0037	1	CFatVB	Never	PrmDry	ImPr	HPME	Large	Hi	Hi	Leak
34	DHADDCBBDBB	0.0029	76	CFatVB	Never	PrmDry	LoPr	Alpha	Medium	Hi	No	Rupture
88	DHADDCBADBB	0.0005	71	CFatVB	Never	PrmDry	LoPr	Alpha	Medium	Lo	No	Rupture
112	DHFCACABACB	0.0004	1	CFatVB	Never	LDldDry	ImPr	HPME	Large	Hi	Hi	Leak
122	DHEAACAABCA	0.0003	2	CFatVB	Never	SDldDry	SSPr	HPME	Large	Lo	Md	Leak

* Mean probability conditional on the occurrence of the PDS.
** A listing of all bins, and a listing by observation are available on computer media.

deliberate depressurization and PORVs-stick-open questions are asked before the T-I hot leg break question, the probability is high that the RCS will be depressurized before the hot leg failures can occur.

Two of the five PDSs in this group have the LPIS operating at UTAF, and one had both LPIS and HPIS operating. For these PDSs, it is possible to arrest core damage and avoid vessel failure. Due to the depressurization of the RCS before VB, the mean probability of arresting the core degradation process and avoiding VB is about 0.40. The mean probability of having the LPIS operating at UTAF is about 0.55, but not all of the time will the open PORVs depressurize the RCS far enough and fast enough to allow LPIS injection in time to prevent VB. The probability that both LPIS and HPIS will be operating is small (about 0.016).

The mean probability of CF at VB for this PDS group is 0.009. There are no late or very late CFs due to hydrogen burns for the LOSP PDSs since power was available throughout the accident. The experts considering hydrogen ignition concluded that with electrical power available continuously, combustion would occur shortly after a flammable concentration of hydrogen was attained in the containment. Only deflagrations are possible at the flammable limits, and these are judged to be extremely unlikely to fail the Surry containment. Thus, late and very late CFs due to combustion when electrical power has been continuously available are not considered.

In the long term (several days), containment failures due to BMT or high pressures and temperatures in the containment are possible. The mean probability of BMT is 0.19 for the LOSP, high acceleration PDS group. BMT is only partially dependent upon the presence of containment heat removal (CHR). The long-term failure of the containment due to high pressures and temperatures is completely dependent upon CHR. That is, if CHR is operating, this mode of CF, usually denoted eventual overpressure, is not possible. As the three most probable PDSs of the five PDSs in this group have the sprays irreparably failed, eventual overpressure failure of the containment after several days is possible for this PDS group.

In most plants the basemat is composed of limestone concrete, so the attack of the basemat by the core debris will generate a large amount of noncondensible gases such as CO_2. The Surry basemat is constructed of siliceous concrete, so the eventual ovepressure CF at Surry is not primarily due to the generation of noncondensible gases by CCI. Instead, it results from the increase in the temperatures of the containment wall and atmosphere over several days. When the wall temperatures reach the point where steam condensation on the walls ceases, steam then behaves as a noncondensible gas and the pressure rises as steam is boiled off from the sump. The heat source is the decay products contained in the sump water. At Surry, this failure mechanism is estimated to take 5 or 6 days. While there is no question that this mechanism can eventually fail the containment, whether it will occur is primarily a function of whether CHR can be restored in this time period. The heat load after several days is not high, so almost any ad hoc means of heat removal from the containment, or a means of water addition, will suffice to prevent eventual overpressure failure. Therefore it was estimated to be very likely, even following an

earthquake, that CHR would be restored before the containment failed. The mean probability of eventual overpressure CF for the LOSP; high acceleration PDS group is thus fairly small, about 0.02.

2.5.5.2 Results for PDS Group EQ 2, SBO: High Acceleration, LLNL Hazard Distribution. This PDS group consists of accidents initiated by LOSP in which SBO follows. The LOSP is due to the earthquake, and the DGs fail to start due to seismic and random hardware failures. Due to the seismic failures in the electrical distribution system that may be expected, it was judged that offsite power would not be recovered within the timeframe of this analysis. Thus there is no chance of arresting core damage or avoiding VB in this PDS group. This PDS group consists of the fraction of these accidents due to seisms with a maximum ground acceleration exceeding 0.6 g.

There are eight PDSs in this group as listed in Table 2.2-6. Three of them are "T" (RCS intact) PDSs, two are "S_3" (very small break) PDSs, one is an "S_2" (small break) PDS, and two are "A" (large break) PDSs. The two "A" PDSs have failure of the SG or RCP pump supports coincident with the LOSP. These support failures are judged to place sufficient stress on the main steam line (MSL) penetrations that the containment fails. The failure mechanism envisaged is cracking of the welded steel pressure boundary where the penetration stiffener plate joins the thinner plate. It was estimated that the probability was 0.90 that the failure would be of leak size and 0.10 that the failure would be of rupture size. Only the two "A" PDSs in this group have these "time zero" CFs. In six of the eight PDS in this group, the AFWS operates until the batteries deplete. However, one of these six PDSs is an "A" PDS, and with a large break the operation of the AFWS is irrelevant.

Table 2.5-16 lists the ten most probable APBs for the PDS group and the five most probable APBs that have VB and early CF. In the "CF Time" column in Table 2.5-16, Early means at the start of the accident, and is used to distinguish "C" bins from "D" bins which have CF at VB. As the offsite consequences and risk are much the same whether the containment fails at time zero or at VB, when the APBs are grouped, or in general discussion, Early means at or before VB, and so would include the CFs at the start of the accident. (In analyses of other plants, the probability of CF before VB due to hydrogen combustion may not be negligible as it is at Surry. In these plants, there may be a significant chance of CF after UTAF and before VB for internal initiators.)

Since there is no possibility of core damage arrest for the seismic SBO PDS group, all the APBs have VB. So, the 10 most probable APBs are listed instead of the five most probable and the five most probable that have VB. Evaluation of the APET produced 490 bins for this group, of which, 109 are required to capture 95% of the probability. Two of the 10 most probable bins have CF at the start due to SG or RCP support failures, three have BMT, and the other five have no CF. The 10 most probable bins capture 61% of the probability. Of the five most probable APBs with both VB and early CF, four have CF at time zero; the fifth has CF at VB due to an Alpha mode event.

Table 2.5-16
Results of the Accident Progression Analysis for Surry
Seismic Initiators. PDS Group EQ 2, SBO: High Acceleration

Order	Bin	Prob.*	No. Occur.	CF Time	Sprays	CCI	RCS Pres.	VB Mode	Amt CCI	Zr Ox	HPME	CF Size
Ten Most Probable Bins**												
1	HHADBCABDFB	0.147	123	No-CF	Never	PrmDry	LoPr	Pour	Large	Hi	No	No-CF
2	GHADBCABDDB	0.100	123	Final	Never	PrmDry	LoPr	Pour	Large	Hi	No	BMT
3	HHADBCAADFB	0.094	112	No-CF	Never	PrmDry	LoPr	Pour	Large	Lo	No	No-CF
4	CHADBCAADCB	0.073	112	Early	Never	PrmDry	LoPr	Pour	Large	Lo	No	Leak
5	GHADBCAADDB	0.064	112	Final	Never	PrmDry	LoPr	Pour	Large	Lo	No	BMT
6	CHADBCABDCB	0.037	120	Early	Never	PrmDry	LoPr	Pour	Large	Hi	No	Leak
7	HHADBCAADFA	0.031	38	No-CF	Never	PrmDry	LoPr	Pour	Large	Lo	No	No-CF
8	HHADBCABDFA	0.025	33	No-CF	Never	PrmDry	LoPr	Pour	Large	Hi	No	No-CF
9	GHADBCAADDA	0.021	38	Final	Never	PrmDry	LoPr	Pour	Large	Lo	No	BMT
10	HHACACABBFA	0.019	16	No-CF	Never	PrmDry	ImPr	HPME	Large	Hi	Md	No-CF
Five Most Probable Bins that have VB and Early CF**												
4	CHADBCAADCB	0.073	112	Early	Never	PrmDry	LoPr	Pour	Large	Lo	No	Leak
6	CHADBCABDCB	0.037	120	Early	Never	PrmDry	LoPr	Pour	Large	Hi	No	Leak
17	CHADBCAADBB	0.0081	112	Early	Never	PrmDry	LoPr	Pour	Large	Lo	No	Rupture
27	DHADDCBBDBB	0.0053	76	CFatVB	Never	PrmDry	LoPr	Alpha	Medium	Hi	No	Rupture
39	CHADBCABDBB	0.0041	88	Early	Never	PrmDry	LoPr	Pour	Large	Hi	No	Rupture

* Mean probability conditional on the occurrence of the PDS.
** A listing of all bins, and a listing by observation are available on computer media.

In the SBO, high acceleration PDS group, there is no possibility of arresting the core degradation process and avoiding VB since offsite power is not recoverable in the time period considered in this analysis. The depressurization of the RCS during core melt serves only to reduce the loads placed upon the containment at VB. The mean probabilities for this PDS group for the four pressure ranges at UTAF and just before VB are:

	At UTAF	Just Before VB
SSPr (2500 psia)	0.67	0.02
HiPr (600 to 2000 psia)	0.0	0.11
ImPr (200 to 600 psia)	0.21	0.19
LoPr (< 200 psia)	0.12	0.68

Two of the three most probable PDSs in this group are "T" PDSs, so the RCS is intact at the PORV setpoint pressure at UTAF (Question 15) for these PDSs. In the two "S_3" PDSs, the AFWS operates until the batteries deplete and the secondary system is depressurized as well, so the RCS will not be in the high pressure range at UTAF for these PDSs. At VB (Question 23), the probability is only about 0.02 that the RCS will be at the system setpoint pressure. The Surry APET considers five mechanisms for depressurizing the RCS. RCP seal failures, the PORVs sticking open, and T-I hot leg breaks are effective for the SBO, high acceleration PDS group. RCP seal failures are important for this group since SBO causes a loss of seal cooling. Deliberate opening of the PORVs by the operators is prohibited by the procedures since there is no electric power.

The mean probability of CF at VB for this PDS group is 0.016. This is in addition to the 0.12 probability of CF at the start of the accident. If a rupture occurs at time zero, CF at VB is not considered since no further failure is possible. If a leak occurs at time zero, CF at VB is considered since the fast pressure rise at VB may convert the leak into a rupture or catastrophic rupture. As CF at VB itself is very unlikely, the conversion of a leak from the start into a rupture at VB is also highly unlikely.

There are no late CFs due to hydrogen burns for the LOSP PDSs since power is never recovered during this period. It is possible to have hydrogen burns in the very late period when the containment slowly cools off due to heat transfer to the containment, and enough steam condenses to de-inert the containment atmosphere. The mean probability of very late CF due to a burn is slightly less than 0.04.

The mean probability of BMT is 0.29 as sprays are not operable in the final period for this PDS group. This stems from the inability to recover offsite power when the LOSP is caused by an earthquake. The lack of sprays, and thus CHR, implies that an overpressure failure of the containment is possible several days after the start of the accident. As discussed in the previous subsection, this is unlikely to occur. The mean probability of eventual overpressure CF is less than 0.04 for the SBO--high acceleration PDS group.

2.5.5.3 Results for PDS Group EQ 3, LOCAs: High Acceleration, LLNL Hazard Distribution. This PDS group consists of accidents initiated by seismic pipe breaks. The failures in the ECCS required to respond to these breaks are partially seismic and partially random. There is no SBO, but some of the seismic failures are failures in the electrical distribution system, specifically in the parts that supply power to the ECCS, sprays, or AFWS. In these situations, the availability of electrical power, fourth PDS characteristic, is denoted by a "P". This PDS group consists of the fraction of these accidents due to seisms with a maximum ground acceleration exceeding 0.6 g.

There are 11 PDSs in this group as listed in Table 2.2-6. Three of them are "S_2" (small break) PDSs, three are "S_1" (intermediate break) PDSs, and the remaining five are "A" (large break) PDSs. The "A" PDSs are initiated by pipe breaks due to failures of the SG or RCP pump supports. These support failures are judged to place sufficient stress on the main steam line (MSL) penetrations that the containment fails by the formation of cracks around the penetration stiffener plates. The probability is 0.90 that the failure is a leak and 0.10 that the failure is a rupture. Only the "A" PDSs in this group have these "time zero" CFs. Two of the three "S_2" PDSs and two of the three "S_1" PDSs have the LPIS operating at UTAF. In the "S_1" PDSs, the RCS will depressurize enough due to the break alone that injection from the LPIS will commence. VB is unlikely in this situation. Sufficient depressurization from the S_2 breaks is not as certain. LPIS injection and the avoidance of VB is not as likely as for the S_1 breaks.

Table 2.5-17 lists the 15 most probable APBs for the PDS group. The overlap between the five most probable bins, the five most probable bins that have VB, and the five most probable APBs that have VB and early CF is so great that listing the 15 most probable bins provides more information. In the "CF Time" column in Table 2.5-17, Early means at the start of the accident, and is used to distinguish "C" bins from "D" bins which have CF at VB. When the APBs are grouped, or in general discussion, Early means at or before VB, and includes the CF at the start of the accident and CF at VB.

Evaluation of the APET produced 284 bins for this group, of which, 46 are required to capture 95% of the probability. The 15 most probable bins capture 75% of the probability. Six of the 15 most probable bins have CF at the start due to SG or RCP support failures; four have no VB and no CF, three have VB but no CF, and two have VB and BMT. The two most probable bins have no VB and No CF. They result from the PDSs with LPIS operating at UTAF.

In the LOCA, high acceleration PDS group there is the possibility of arresting the core degradation process and avoiding VB since four of the 11 PDSs in the group have the LPIS operating at UTAF. If the RCS can be depressurized sufficiently in a timely manner, injection by the LPIS may arrest core damage for these PDSs. The mean probabilities for this PDS group for the four pressure ranges at UTAF and just before VB (if it occurs) are:

Table 2.5-17
Results of the Accident Progression Analysis for Surry
Seismic Initiators. PDS Group EQ 3, LOCAs: High Acceleration,
LLNL Hazard Distribution

Order	Bin	Prob.*	No. Occur.	CF Time	Sprays	CCI	RCS Pres.	VB Mode	Amt CCI	Zr Ox	HPME	CF Size
Fifteen Most Probable Bins**												
1	HHCDFCDBDFB	0.110	123	No-CF	Never	No-CCI	LoPr	No-VB	No-CCI	Hi	No	No-CF
2	HHCDFCDADFB	0.107	111	No-CF	Never	No-CCI	LoPr	No-VB	No-CCI	Lo	No	No-CF
3	CHADBCAADCB	0.080	112	Early	Never	PrmDry	LoPr	Pour	Large	Lo	No	Leak
4	CHADBCABDCB	0.066	120	Early	Never	PrmDry	LoPr	Pour	Large	Hi	No	Leak
5	HHADBCAADFB	0.058	112	No-CF	Never	PrmDry	LoPr	Pour	Large	Lo	No	No-CF
6	HHADBCABDFB	0.050	123	No-CF	Never	PrmDry	LoPr	Pour	Large	Hi	No	No-CF
7	CDCDBCDADCB	0.045	112	Early	Always	No-CCI	LoPr	Pour	No-CCI	Lo	No	Leak
8	GHADBCAADDB	0.039	112	Final	Never	PrmDry	LoPr	Pour	Large	Lo	No	BMT
9	GHADBCABDDB	0.034	123	Final	Never	PrmDry	LoPr	Pour	Large	Hi	No	BMT
10	HDCDFCDBDFB	0.032	123	No-CF	Always	No-CCI	LoPr	No-VB	No-CCI	Hi	No	No-CF
11	CDCDBCDBDCB	0.030	95	Early	Always	No-CCI	LoPr	Pour	No-CCI	Hi	No	Leak
12	CDDDBCAADCB	0.030	112	Early	Always	PrmDeep	LoPr	Pour	Large	Lo	No	Leak
13	HDCDFCDADFB	0.026	111	No-CF	Always	No-CCI	LoPr	No-VB	No-CCI	Lo	No	No-CF
14	HDCDBCDADFB	0.020	112	No-CF	Always	No-CCI	LoPr	Pour	No-CCI	Lo	No	No-CF
15	CDDDBCABDCB	0.019	93	Early	Always	PrmDeep	LoPr	Pour	Large	Hi	No	Leak

* A listing of all bins, and a listing by observation are available on computer media.
** Mean probability conditional on the occurrence of the PDS.

	At UTAF	Just Before VB
SSPr (2500 psia)	0.0	0.0
HiPr (600 to 2000 psia)	0.0	0.0
ImPr (200 to 600 psia)	0.42	0.01
LoPr (< 200 psia)	0.58	0.99

As all of the PDSs in this group have an A, S_1, or S_2 break, the RCS pressure at UTAF (Question 15) is bound to be low or intermediate. The S_2 breaks comprise about 0.42 of this PDS group. As there is electric power available, and opening the PORVs is directed by the procedures when the core exit thermocouples show temperatures of 1200°F, it was estimated that the probability was 0.90 that the operators would open the PORVs in time to ensure the RCS was at low pressure by VB.

The mean probability of having the LPIS operating at UTAF is about 0.34 for the seismic LOCA PDS group. Four of the 11 PDSs in this group have the LPIS operating. For these PDS, it is likely that the RCS will depressurize sufficiently and quickly enough to allow LPIS injection in time to prevent VB. The mean probability of arresting the core degradation process and avoiding VB is just over 0.30.

The mean probability of CF at VB for this PDS group is 0.005. This is in addition to the 0.42 probability of CF at the start of the accident. This value is so large because five of the 11 PDSs in this group are "A" PDSs in which SG or RCP support failures at the time of earthquake fail the containment. If a rupture occurs at time zero, CF at VB is not considered since no further failure is possible. If a leak occurs at time zero, CF at VB is considered since the fast pressure rise at VB may convert the leak into a rupture or catastrophic rupture. As CF at VB itself is very unlikely, the conversion of a leak from the start into a rupture at VB is also highly unlikely.

There are no late or very late CFs due to hydrogen burns for the LOCA PDSs since power is continuously available. The hydrogen will burn when a flammable concentration is attained, which poses a negligible threat to the Surry containment. The mean probability of BMT is slightly less than 0.10. The sprays operate throughout the accident in five of the 11 PDSs in this group, and the sprays are irreparably failed in six of the 11 PDSs. The PDSs with failed sprays are more likely than those with operable sprays, so the mean probability for having no CHR is over 0.70. When CHR is not recovered in the long term, an overpressure failure of the containment is possible. As discussed in section 2.5.5.1, this is unlikely to occur. For the LOCA, high acceleration PDS group, the mean probability of eventual overpressure CF is 0.01.

2.5.5.4 Results for PDS Group EQ 1, LOSP (No SBO); Low Acceleration, LLNL Hazard Distribution. This PDS group consists of accidents initiated by LOSP, but in which SBO does not result. The LOSP is due to the earthquake, but the DGs start and supply station power. The five PDSs in this group are the same as those discussed in Section 2.5.5.1. This PDS group consists of the fraction of these accidents due to seisms with a maximum ground acceleration less than 0.6 g.

Table 2.5-18 lists the 10 most probable APBs for this PDS group and the five most probable APBs that have VB and early CF. As the five most probable APBs that have VB are contained in the 10 most probable bins, these are listed instead of repeating many of the APBs. Evaluation of the APET produced 803 bins for the LOSP, low acceleration PDS group. To capture 95% of the probability, 93 bins are required. The 10 most probable bins capture 71% of the probability. Four of the 10 most probable bins have no VB; the other six have low pressure pour failures of the lower head. Two of the 10 most probable bins have BMT; the other eight have no CF. Of the five most probable APBs with both VB and early CF, one has CF due to an Alpha mode failure of both vessel and containment, and four have CF due to HPME and DCH with the RCS at high pressure.

In the LOSP, low acceleration PDS group there is the possibility of arresting the core degradation process and avoiding VB since three of the PDSs have some ECCS operating at UTAF. If the RCS can be depressurized, injection by the ECCS may arrest core damage for these PDSs. The mean probabilities for this PDS group for the four pressure ranges at UTAF and just before VB (if it occurs) are:

	At UTAF	Just Before VB
SSPr (2500 psia)	0.80	0.025
HiPr (600 to 2000 psia)	0.0	0.007
ImPr (200 to 600 psia)	0.20	0.179
LoPr (< 200 psia)	0.0	0.789

Four of the five PDSs in this group are "T" PDSs, which have the RCS intact at the PORV setpoint pressure at UTAF (Question 15). These PDSs account for the high probability for SSPr at UTAF. At VB (Question 23), the probability is only about 0.025 that the RCS will be at that pressure. The effectiveness of the five mechanisms for depressurizing the RCS is the same for this PDS group as for the LOSP, high acceleration group (see Section 2.5.5.1).

Two of the five PDSs in this group have the LPIS operating at UTAF, and one had both LPIS and HPIS operating. For these PDSs, it is possible to arrest core damage and avoid vessel failure. Due to the depressurization of the RCS before VB, the mean probability of arresting the core degradation process and avoiding VB is about 0.38. The mean probability of having the LPIS operating at UTAF is about 0.51, but not all of the time will the open PORVs depressurize the RCS far enough and fast enough to allow LPIS injection in time to prevent VB. The probability that both LPIS and HPIS will be operating is about 0.15. If the HPIS is operating, any break at all will depressurize the RCS enough to allow injection. However, there is no assurance that this injection will occur soon enough or that enough water will be injected to prevent VB.

Table 2.5-18
Results of the Accident Progression Analysis for Surry
Seismic Initiators. PDS Group EQ 1, LOSP (No SBO): Low Acceleration,
LLNL Hazard Distribution

Order	Bin	Prob.*	No. Occur.	CF Time	Sprays	CCI	RCS Pres.	VB Mode	Amt CCI	Zr Ox	HPME	CF Size
Ten Most Probable Bins**												
1	HHCDFCDBDFB	0.148	123	No-CF	Never	No-CCI	LoPr	No-VB	No-CCI	Hi	No	No-CF
2	HHADBCABDFB	0.109	123	No-CF	Never	PrmDry	LoPr	Pour	Large	Hi	No	No-CF
3	HHCDFCDADFB	0.090	111	No-CF	Never	No-CCI	LoPr	No-VB	No-CCI	Lo	No	No-CF
4	HHADBCAADFB	0.080	112	No-CF	Never	PrmDry	LoPr	Pour	Large	Lo	No	No-CF
5	HDCDFCDBDFB	0.077	123	No-CF	Always	No-CCI	LoPr	No-VB	No-CCI	Hi	No	No-CF
6	GHADBCABDDB	0.074	123	Final	Never	PrmDry	LoPr	Pour	Large	Hi	No	BMT
7	GHADBCAADDB	0.055	112	Final	Never	PrmDry	LoPr	Pour	Large	Lo	No	BMT
8	HDCDFCDADFB	0.044	111	No-CF	Always	No-CCI	LoPr	No-VB	No-CCI	Lo	No	No-CF
9	HDCDBCDBDFB	0.018	123	No-CF	Always	No-CCI	LoPr	Pour	No-CCI	Hi	No	No-CF
10	HHACBCABDFB	0.012	8	No-CF	Never	PrmDry	ImPr	Pour	Large	Hi	No	No-CF
Five Most Probable Bins that have VB and Early CF**												
31	DHACACABACB	0.0039	1	CFatVB	Never	PrmDry	ImPr	HPME	Large	Hi	Hi	Leak
43	DHADDCBBDBB	0.0028	74	CFatVB	Never	PrmDry	LoPr	Alpha	Medium	Hi	No	Rupture
92	DHEAACAABCA	0.0007	2	CFatVB	Never	SDldDry	SSPr	HPME	Large	Lo	Md	Leak
114	DHEAACAAABA	0.0005	4	CFatVB	Never	SDldDry	SSPr	HPME	Large	Lo	Hi	Rupture
167	DHFCACABACB	0.0003	1	CFatVB	Never	LDldDry	ImPr	HPME	Large	Hi	Hi	Leak

* Mean probability conditional on the occurrence of the PDS.
** A listing of all bins, and a listing by observation are available on computer media.

The mean probability of CF at VB for this PDS group is 0.011. There are no late or very late CFs due to hydrogen burns for the LOSP PDSs since power is available throughout the accident. The mean probability of BMT is 0.19. The sprays are irreparably failed for the most probable three PDSs in this group. When CHR is not recovered in the long term, an overpressure failure of the containment is possible. As discussed in Section 2.5.5.1, this is unlikely to occur. The mean probability of eventual overpressure CF for the LOSP, low acceleration PDS group is 0.02.

2.5.5.5 Results for PDS Group EQ 2, SBO: Low Acceleration, LLNL Hazard Distribution. This PDS group consists of accidents initiated by LOSP in which SBO follows. The LOSP is due to the earthquake, and the DGs fail to start due to seismic and random hardware failures. There is no recovery of offsite power, and thus no chance of arresting core damage. The PDSs in this group are the same as those described in Section 2.5.5.2. This PDS group consists of the fraction of these accidents due to seisms with a maximum ground acceleration less than 0.6 g.

Table 2.5-19 lists the 10 most probable APBs for the PDS group and the five most probable APBs that have VB and early CF. In the "CF Time" column, Early means at the start of the accident, and is used to distinguish "C" bins from "D" bins which have CF at VB. Since there is no possibility of core damage arrest for the seismic SBO PDS group, all the APBs have VB. So, the 10 most probable APBs are listed instead of the five most probable and the five most probable that have VB. The 10 most probable bins capture 54% of the probability. Evaluation of the APET produced 492 bins for this group, of which, 112 are required to capture 95% of the probability. One of the 10 most probable bins has CF at the start due to SG or RCP support failures, four have BMT, and the other five have no CF. Of the five most probable APBs with both VB and early CF, four have CF at time zero; the fifth has CF at VB due to an Alpha mode event.

In the SBO, low acceleration PDS group there is no possibility of arresting the core degradation process and avoiding VB since offsite power is not recoverable in the time period considered in this analysis. The depressurization of the RCS during core melt serves only to reduce the loads placed upon the containment at VB. The mean probabilities for this PDS group for the four pressure ranges at UTAF and just before VB are:

	At UTAF	Just Before VB
SSPr (2500 psia)	0.56	0.01
HiPr (600 to 2000 psia)	0.0	0.18
ImPr (200 to 600 psia)	0.38	0.22
LoPr (< 200 psia)	0.06	0.59

Two of the three most probable PDSs in this group are "T" PDSs, so the RCS is intact at at the PORV setpoint pressure at UTAF (Question 15) for these PDSs. In the two "S_3" PDSs, the AFWS operates until the batteries deplete and the secondary system is depressurized as well, so there is no possibility that the RCS will be in the high pressure range at UTAF for these PDSs. At VB (Question 23), the probability is only about 0.01 that the RCS will be at the system setpoint pressure. The Surry APET considers five

Table 2.5-19
Results of the Accident Progression Analysis for Surry
Seismic Initiators. PDS Group EQ 2, SBO: Low Acceleration,
LLNL Hazard Distribution

Order	Bin	Prob.*	No. Occur.	CF Time	Sprays	CCI	RCS Pres.	VB Mode	Amt CCI	Zr Ox	HPME	CF Size
Ten Most Probable Bins**												
1	HHADBCABDFB	0.112	123	No-CF	Never	PrmDry	LoPr	Pour	Large	Hi	No	No-CF
2	HHADBCAADFB	0.080	112	No-CF	Never	PrmDry	LoPr	Pour	Large	Lo	No	No-CF
3	GHADBCABDDB	0.076	123	Final	Never	PrmDry	LoPr	Pour	Large	Hi	No	BMT
4	GHADBCAADDB	0.054	112	Final	Never	PrmDry	LoPr	Pour	Large	Lo	No	BMT
5	HHADBCAADFA	0.050	38	No-CF	Never	PrmDry	LoPr	Pour	Large	Lo	No	No-CF
6	HHADBCABDFA	0.039	33	No-CF	Never	PrmDry	LoPr	Pour	Large	Hi	No	No-CF
7	CHADBCAADCB	0.038	112	Early	Never	PrmDry	LoPr	Pour	Large	Lo	No	Leak
8	GHADBCAADDA	0.034	38	Final	Never	PrmDry	LoPr	Pour	Large	Lo	No	BMT
9	HHACACABBFA	0.032	16	No-CF	Never	PrmDry	ImPr	HPME	Large	Hi	Md	No-CF
10	GHADBCABDDA	0.026	33	Final	Never	PrmDry	LoPr	Pour	Large	Hi	No	BMT
Five Most Probable Bins that have VB and Early CF**												
7	CHADBCAADCB	0.038	112	Early	Never	PrmDry	LoPr	Pour	Large	Lo	No	Leak
11	CHADBCABDCB	0.017	120	Early	Never	PrmDry	LoPr	Pour	Large	Hi	No	Leak
44	CHADBCAADBB	0.0043	112	Early	Never	PrmDry	LoPr	Pour	Large	Lo	No	Rupture
46	DHADDCBBDBB	0.0042	74	CFatVB	Never	PrmDry	LoPr	Alpha	Medium	Hi	No	Rupture
55	DHABACABBCA	0.0035	1	CFatVB	Never	PrmDry	HiPr	HPME	Large	Hi	Md	Leak

* Mean probability conditional on the occurrence of the PDS.
** A listing of all bins, and a listing by observation are available on computer media.

mechanisms for depressurizing the RCS. RCP seal failures, the PORVs sticking open, and T-I hot leg breaks are effective for the SBO, low acceleration PDS group. RCP seal failures are important for this group since SBO causes a loss of seal cooling. Deliberate opening of the PORVs by the operators is prohibited by the procedures since there is no electric power.

The mean probability of CF at VB for this PDS group is 0.019. This is in addition to the 0.06 probability of CF at the start of the accident. If a rupture occurs at time zero, CF at VB is not considered since no further failure is possible. If a leak occurs at time zero, CF at VB is considered since the fast pressure rise at VB may convert the leak into a rupture or catastrophic rupture. As CF at VB itself is very unlikely, the conversion of a leak from the start into a rupture at VB is highly unlikely.

There are no late CFs due to hydrogen burns for the LOSP PDSs since power is never recovered during this period. It is possible to have hydrogen burns in the very late period when the containment slowly cools off due to heat transfer to the containment, and enough steam condenses to de-inert the containment atmosphere. The mean probability of very late CF due to a burn is slightly less than 0.04.

The mean probability of BMT is 0.30 for this PDS group. The lack of sprays, and thus CHR, for this PDS group implies that an overpressure failure of the containment may occur after several days. As discussed in Section 2.5.5.1, the Surry basemat is constructed of siliceous concrete and this is unlikely to occur. The mean probability of eventual overpressure CF is less than 0.04 for the SBO, low acceleration PDS group.

2.5.5.6 Results for PDS Group EQ 3, LOCAs: Low Acceleration, LLNL Hazard Distribution. This PDS group consists of accidents initiated by seismic pipe breaks. The failures in the ECCS required to respond to these breaks are partially seismic and partially random. There is no SBO, but some of the seismic failures are failures in the electrical distribution system, specifically in the parts that supply power to the ECCS, sprays, or AFWS. In these situations, the availability of electrical power, fourth PDS characteristic, is denoted by a "P". This PDS group consists of the fraction of these accidents due to seisms with a maximum ground acceleration less than 0.6 g. The 11 PDSs in this group are listed in Table 2.2-6 and discussed in Section 2.5.5.3

Table 2.5-20 lists the 15 most probable APBs for the PDS group. The overlap between the five most probable bins, the five most probable bins that have VB, and the five most probable APBs that have VB and early CF is so great that listing the 15 most probable bins provides more information. Evaluation of the APET produced 285 bins for this group, of which, 45 are required to capture 95% of the probability. The 15 most probable bins capture 78% of the probability. Five of the 15 most probable bins have CF at the start due to SG or RCP support failures; four have no VB and no CF, four have VB but no CF, and two have VB and BMT. The two most probable bins have no VB and No CF. They result from the PDSs with LPIS operating at UTAF.

Table 2.5-20
Results of the Accident Progression Analysis for Surry
Seismic Initiators. PDS Group EQ 3, LOCAs: Low Acceleration,
LLNL Hazard Distribution

Order	Bin	Prob.*	No. Occur.	CF Time	Sprays	CCI	RCS Pres.	VB Mode	Amt CCI	Zr Ox	HPME	CF Size
Fifteen Most Probable Bins**												
1	HHCDFCDBDFB	0.123	123	No-CF	Never	No-CCI	LoPr	No-VB	No-CCI	Hi	No	No-CF
2	HHCDFCDADFB	0.116	111	No-CF	Never	No-CCI	LoPr	No-VB	No-CCI	Lo	No	No-CF
3	CHADBCAADCB	0.080	112	Early	Never	PrmDry	LoPr	Pour	Large	Lo	No	Leak
4	HHADBCAADFB	0.076	112	No-CF	Never	PrmDry	LoPr	Pour	Large	Lo	No	No-CF
5	HHADBCABDFB	0.069	123	No-CF	Never	PrmDry	LoPr	Pour	Large	Hi	No	No-CF
6	CHADBCABDCB	0.063	120	Early	Never	PrmDry	LoPr	Pour	Large	Hi	No	Leak
7	GHADBCAADDB	0.052	112	Final	Never	PrmDry	LoPr	Pour	Large	Lo	No	BMT
8	GHADBCABDDB	0.047	123	Final	Never	PrmDry	LoPr	Pour	Large	Hi	No	BMT
9	CDCDBCDADCB	0.034	111	Early	Always	No-CCI	LoPr	Pour	No-CCI	Lo	No	Leak
10	HDCDFCDBDFB	0.025	123	No-CF	Always	No-CCI	LoPr	No-VB	No-CCI	Hi	No	No-CF
11	CDDDBCAADCB	0.022	111	Early	Always	PrmDeep	LoPr	Pour	Large	Lo	No	Leak
12	CDCDBCDBDCB	0.021	93	Early	Always	No-CCI	LoPr	Pour	No-CCI	Hi	No	Leak
13	HDCDFCDADFB	0.020	111	No-CF	Always	No-CCI	LoPr	No-VB	No-CCI	Lo	No	No-CF
14	HDCDBCDADFB	0.017	112	No-CF	Always	No-CCI	LoPr	Pour	No-CCI	Lo	No	No-CF
15	HDCDBCDBDFB	0.015	123	No-CF	Always	No-CCI	LoPr	Pour	No-CCI	Hi	No	No-CF

* Mean probability conditional on the occurrence of the PDS.
** A listing of all bins, and a listing by observation are available on computer media.

In the LOCA, low acceleration PDS group there is the possibility of arresting the core degradation process and avoiding VB since four of the 11 PDSs in the group have the LPIS operating at UTAF. If the RCS can be depressurized sufficiently in a timely manner, injection by the LPIS may arrest core damage for these PDSs. The mean probabilities for this PDS group for the four pressure ranges at UTAF and just before VB (if it occurs) are:

	At UTAF	Just Before VB
SSPr (2500 psia)	0.0	0.0
HiPr (600 to 2000 psia)	0.0	0.0
ImPr (200 to 600 psia)	0.51	0.01
LoPr (< 200 psia)	0.49	0.99

As all of the PDSs in this group have an A, S_1, or S_2 break, the RCS pressure at UTAF (Question 15) is bound to be low or intermediate. The S_2 breaks comprise about 0.51 of this PDS group. As there is electric power available, and opening the PORVs is directed by the procedures when the core exit thermocouples show temperatures of 1200°F, it was estimated that the probability was 0.90 that the operators would open the PORVs in time to ensure the RCS was at low pressure by VB.

The mean probability of having the LPIS operating at UTAF is about 0.34 for the seismic LOCA PDS group. Four of the 11 PDSs in this group have the LPIS operating. For these PDS, it is likely that the RCS will depressurize sufficiently and quickly enough to allow LPIS injection in time to prevent VB. The mean probability of arresting the core degradation process and avoiding VB is about 0.31.

The mean probability of CF at VB for this PDS group is 0.006. This is in addition to the 0.35 probability of CF at the start of the accident. This value is so large because five of the 11 PDSs in this group are "A" PDSs in which SG or RCP support failures at the time of earthquake fail the containment.

There are no late or very late CFs due to hydrogen burns for the LOCA PDSs since power is continuously available. The hydrogen will burn when a flammable concentration is attained, which poses a negligible threat to the Surry containment.

The mean probability of BMT is 0.12. The sprays operate throughout the accident in five of the 11 PDSs in this group, and the sprays are irreparably failed in six of the 11 PDSs. The PDSs with failed sprays are more likely than those with operable sprays, so the mean probability for having no CHR is over 0.78. When CHR is not recovered in the long term, an overpressure failure of the containment may occur after several days. As discussed in Section 2.5.5.1, this is unlikely to occur. For the LOCA, low acceleration PDS group, the mean probability of eventual overpressure CF is 0.01.

2.5.6 Sensitivity Analyses for Seismic Initiators: LLNL Hazard Distribution

To determine the effect of the initial failures of the containment due to failures of the SG and RCP supports, the integrated risk analysis using the LLNL hazard distribution was repeated without these induced seismic failures of the containment at the start of the accident. Except for the initial CFs, the removal of these CFs at the start of the accident has very little effect on the accident progression analysis. There are slightly more failures computed at VB since the probability of the containment being intact at VB increases, and the probabilities of BMT and late above-ground failures increase for the same reason.

Table 2.5-21 compares the results for CF at VB and for final CF with and without the initial failures of the containment for seismic PDS groups EQ 2 (SBO) and EQ 3 (LOCA). Initial seismic CFs occur only in the "A" PDSs, and as PDS group EQ 1 (LOSP, No SBO) contains no "A" PDSs, eliminating the initial seismic CFs has no effects on the APET results for this PDS group. The probability of initial CF does not go to zero in the sensitivity case because the isolation failures remain with a very low probability.

2.5.7 Results for Seismic Initiators: EPRI Hazard Distribution

The seismic risk analysis was performed using two different seismic hazard distributions. This section reports the results using the hazard distribution developed by EPRI. Results based on the seismic hazard distribution developed by LLNL were presented in Section 2.5.5. The differences between these two distributions are discussed in NUREG/CR-4550, Vol. 3, Part 3.

The accidents initiated by earthquakes were analyzed in two groups. Those due to seisms with a maximum ground acceleration in excess of 0.6 g were denoted the high acceleration events. It was judged that the destruction in the general vicinity of the plant for those earthquakes would be so great that evacuation would be ineffective. For the low acceleration events, less than 0.6 g, it was estimated that evacuation would be possible, although perhaps more slowly than in emergencies without earthquakes.

2.5.7.1 Results for PDS Group EQ 1, LOSP (No SBO): High Acceleration, EPRI Hazard Distribution. This PDS group consists of accidents initiated by LOSP, but in which SBO does not result. The LOSP is due to the earthquake, but the DGs start and supply station power. The five PDSs are discussed in Section 2.5.5.1. This PDS group consists of the fraction of these accidents due to seisms with a maximum ground acceleration exceeding 0.6 g.

Table 2.5-21
Comparison of the Accident Progression Analysis Results for Surry Seismic Initiators. With and Without Containment Failures at the Start of the Accident; LLNL Hazard Distribution

High Acceleration

Event	Probability of Event			
	Base Case - CF at t = 0		Sens. Case - No CF at t = 0	
	EQ 2 -SBO	EQ 3 LOCA	EQ 2 -SBO	EQ 3 LOCA
Initial CF	0.122	0.420	0.0002	0.0002
CF at VB	0.0156	0.0054	0.0158	0.0069
Late CF	0.0	0.0	0.0	0.0
Very Late CF	0.038	0.0	0.042	0.0
BMT	0.291	0.096	0.337	0.199
Eventual OP	0.036	0.010	0.041	0.020
No CF	0.496	0.472	0.564	0.774

Low Acceleration

Event	Probability of Event			
	Base Case - CF at t = 0		Sens. Case - No CF at t = 0	
	EQ 2 -SBO	EQ 3 LOCA	EQ 2 -SBO	EQ 3 LOCA
Initial CF	0.062	0.355	0.0002	0.0002
CF at VB	0.0189	0.0055	0.0190	0.0074
Late CF	0.0	0.0	0.0	0.0
Very Late CF	0.038	0.0	0.039	0.0
BMT	0.304	0.120	0.328	0.213
Eventual OP	0.038	0.013	0.041	0.022
No CF	0.538	0.509	0.572	0.757

Table 2.5-22 lists the 10 most probable APBs for this PDS group and the five most probable APBs that have VB and early CF. Evaluation of the APET produced 708 bins for the LOSP, high acceleration PDS group. To capture 95% of the probability, 63 bins are required. The 10 most probable bins capture 74% of the probability. Four of the 10 most probable bins have no VB; five have low pressure pour failures of the lower head; one has HPME. Two of the 10 most probable bins have BMT; the other eight have no CF. Of the five most probable APBs with both VB and early CF, three have CF due to an Alpha mode failure of both vessel and containment, and two have CF due to HPME and DCH with the RCS at high pressure.

In the LOSP, high acceleration PDS group, there is the possibility of arresting the core degradation process and avoiding VB since three of the PDSs have some ECCS operating at UTAF. If the RCS can be depressurized, injection by the ECCS may arrest core damage for these PDSs. The mean probabilities for this PDS group for the four pressure ranges at UTAF and just before VB (if it occurs) are:

	At UTAF	Just Before VB
SSPr (2500 psia)	0.932	0.011
HiPr (600 to 2000 psia)	0.0	0.003
ImPr (200 to 600 psia)	0.068	0.191
LoPr (< 200 psia)	0.0	0.796

Four of the five PDSs in this group are "T" PDSs, which have the RCS intact at the PORV setpoint pressure at UTAF (Question 15). These PDSs account for the high probability for SSPr at UTAF. At VB (Question 23), the probability is only about 0.025 that the RCS will be at that pressure. The effectiveness of the five mechanisms for depressurizing the RCS is the same for the EPRI hazard curve as for the LLNL hazard curve for this PDS group (see Section 2.5.5.1).

Two of the five PDS in this group have the LPIS operating at UTAF, and one had both LPIS and HPIS operating. For these PDSs, it is possible to arrest core damage and avoid vessel failure. Due to the depressurization of the RCS before VB, the mean probability of arresting the core degradation process and avoiding VB is about 0.36. The mean probability of having the LPIS operating at UTAF is about 0.51, but not all of the time will the open PORVs depressurize the RCS far enough and fast enough to allow LPIS injection in time to prevent VB. The probability that both LPIS and HPIS will be operating is negligible for the portion of this PDS group that has the peak ground acceleration above 0.6 g.

The mean probability of CF at VB for this PDS group is 0.011. There are no late or very late CFs due to hydrogen burns for the LOSP PDSs since power was available throughout the accident. The experts considering hydrogen ignition concluded that with electrical power available continuously, combustion would occur shortly after a flammable concentration of hydrogen was attained in the containment. Only deflagrations are possible at the flammable limits, and these are judged to be extremely unlikely to fail the Surry containment. Thus, late and very late CFs due to combustion when electrical power has been continuously available are not considered.

Table 2.5-22
Results of the Accident Progression Analysis for Surry
Seismic Initiators. PDS Group EQ 1, LOSP (No SBO): High Acceleration,
EPRI Hazard Distribution

Order	Bin	Prob.*	No. Occur.	CF Time	Sprays	CCI	RCS Pres.	VB Mode	Amt CCI	Zr Ox	HPME	CF Size
Ten Most Probable Bins**												
1	HHCDFCDBDFB	0.166	123	No-CF	Never	No-CCI	LoPr	No-VB	No-CCI	Hi	No	No-CF
2	HHADBCABDFB	0.139	123	No-CF	Never	PrmDry	LoPr	Pour	Large	Hi	No	No-CF
3	HHCDFCDADFB	0.130	112	No-CF	Never	No-CCI	LoPr	No-VB	No-CCI	Lo	No	No-CF
4	GHADBCABDDB	0.095	123	Final	Never	PrmDry	LoPr	Pour	Large	Hi	No	BMT
5	HHADBCAADFB	0.072	112	No-CF	Never	PrmDry	LoPr	Pour	Large	Lo	No	No-CF
6	GHADBCAADDB	0.049	112	Final	Never	PrmDry	LoPr	Pour	Large	Lo	No	BMT
7	HDCDFCDBDFB	0.036	123	No-CF	Always	No-CCI	LoPr	No-VB	No-CCI	Hi	No	No-CF
8	HDCDFCDADFB	0.026	112	No-CF	Always	No-CCI	LoPr	No-VB	No-CCI	Lo	No	No-CF
9	HHACBCABDFB	0.017	8	No-CF	Never	PrmDry	ImPr	Pour	Large	Hi	No	No-CF
10	HHACACABCFB	0.015	7	No-CF	Never	PrmDry	ImPr	HPME	Large	Hi	Lo	No-CF
Five Most Probable Bins that have VB and Early CF**												
24	DHADDCBBDBB	0.0043	72	CFatVB	Never	PrmDry	LoPr	Alpha	Medium	Hi	No	Rupture
25	DHACACABACB	0.0036	1	CFatVB	Never	PrmDry	ImPr	HPME	Large	Hi	Hi	Leak
88	DHADDCBADBB	0.0006	72	CFatVB	Never	PrmDry	LoPr	Alpha	Medium	Lo	No	Rupture
97	DHFCACABACB	0.0004	1	CFatVB	Never	LDldDry	ImPr	HPME	Large	Hi	Hi	Leak
102	DAFDDCBBDBB	0.0004	50	CFatVB	Never	LDldDry	LoPr	Alpha	Medium	Hi	No	Rupture

* Mean probability conditional on the occurrence of the PDS.
** A listing of all bins, and a listing by observation are available on computer media.

The mean probability of BMT is 0.21. The three most probable PDSs of the five PDSs in this group have the sprays irreparably failed. For the PDSs, the lack of CHR may cause an overpressure failure of the containment after several days. As discussed in Section 2.5.5.1, the Surry basemat is constructed of siliceous concrete and this is unlikely to occur. The mean probability of eventual overpressure CF for the LOSP, high acceleration PDS group is 0.025.

2.5.7.2 Results for PDS Group EQ 2, SBO: High Acceleration, EPRI Hazard Distribution. This PDS group consists of accidents initiated by LOSP in which SBO follows. The LOSP is due to the earthquake, and the DGs fail to start due to seismic and random hardware failures. Due to the seismic failures in the electrical distribution system that may be expected, it was judged that offsite power would not be recovered within the timeframe of this analysis. Thus there is no chance of arresting core damage or avoiding VB in this PDS group. The eight PDSs in this group are discussed in Section 2.5.5.2. This PDS group consists of the fraction of these accidents due to seisms with a maximum ground acceleration exceeding 0.6 g.

Table 2.5-23 lists the 10 most probable APBs for the PDS group and the five most probable APBs that have VB and early CF. In the "CF Time" column in Table 2.5-23, Early means at the start of the accident, and is used to distinguish "C" bins from "D" bins which have CF at VB. As the offsite consequences and risk are much the same whether the containment fails at time zero or at VB, when the APBs are grouped, or in general discussion, Early means at or before VB, and so would include the CFs at the start of the accident.

Since there is no possibility of core damage arrest for the seismic SBO PDS group, all the APBs have VB, so the 10 most probable APBs are listed. Evaluation of the APET produced 483 bins for this group, of which, 117 are required to capture 95% of the probability. Two of the 10 most probable bins have CF at the start due to SG or RCP support failures, three have BMT, and the other five have no CF. The 10 most probable bins capture 58% of the probability. Of the five most probable APBs with both VB and early CF, three have CF at time zero; one has CF at VB due to an Alpha mode event; and one has CF at VB due to HPME.

In the SBO, high acceleration PDS group there is no possibility of arresting the core degradation process and avoiding VB since offsite power is not recoverable in the time period considered in this analysis. The depressurization of the RCS during core melt serves only to reduce the loads placed upon the containment at VB. The mean probabilities for this PDS group for the four pressure ranges at UTAF and just before VB are:

	At UTAF	Just Before VB
SSPr (2500 psia)	0.60	0.02
HiPr (600 to 2000 psia)	0.0	0.13
ImPr (200 to 600 psia)	0.31	0.21
LoPr (< 200 psia)	0.09	0.64

Table 2.5-23
Results of the Accident Progression Analysis for Surry
Seismic Initiators. PDS Group EQ 2, SBO: High Acceleration,
EPRI Hazard Distribution

Order	Bin	Prob.*	No. Occur.	CF Time	Sprays	CCI	RCS Pres.	VB Mode	Amt CCI	Zr Ox	HPME	CF Size
Ten Most Probable Bins**												
1	HHADBCABDFB	0.125	123	No-CF	Never	PrmDry	LoPr	Pour	Large	Hi	No	No-CF
2	HHADBCAADFB	0.096	112	No-CF	Never	PrmDry	LoPr	Pour	Large	Lo	No	No-CF
3	GHADBCABDDB	0.085	123	Final	Never	PrmDry	LoPr	Pour	Large	Hi	No	BMT
4	GHADBCAADDB	0.065	112	Final	Never	PrmDry	LoPr	Pour	Large	Lo	No	BMT
5	HHADBCAADFA	0.045	38	No-CF	Never	PrmDry	LoPr	Pour	Large	Lo	No	No-CF
6	CHADBCAADCB	0.044	112	Early	Never	PrmDry	LoPr	Pour	Large	Lo	No	Leak
7	CHADBCABDCB	0.036	121	Early	Never	PrmDry	LoPr	Pour	Large	Hi	No	Leak
8	GHADBCAADDA	0.031	38	Final	Never	PrmDry	LoPr	Pour	Large	Lo	No	BMT
9	HHADBCABDFA	0.029	33	No-CF	Never	PrmDry	LoPr	Pour	Large	Hi	No	No-CF
10	HHACACABBFA	0.021	16	No-CF	Never	PrmDry	ImPr	HPME	Large	Hi	Md	No-CF
Five Most Probable Bins that have VB and Early CF**												
6	CHADBCAADCB	0.044	112	Early	Never	PrmDry	LoPr	Pour	Large	Lo	No	Leak
7	CHADBCABDCB	0.036	121	Early	Never	PrmDry	LoPr	Pour	Large	Hi	No	Leak
36	DHADDCBBDBB	0.0050	72	CFatVB	Never	PrmDry	LoPr	Alpha	Medium	Hi	No	Rupture
37	CHADBCAADBB	0.0049	112	Early	Never	PrmDry	LoPr	Pour	Large	Lo	No	Rupture
49	DHACACABACB	0.0040	1	CFatVB	Never	PrmDry	ImPr	HPME	Large	Hi	Hi	Leak

* Mean probability conditional on the occurrence of the PDS.
** A listing of all bins, and a listing by observation are available on computer media.

Two of the three most probable PDSs in this group are "T" PDSs, so the RCS is intact at the PORV setpoint pressure at UTAF (Question 15) for those PDSs. In the two "S_3" PDSs, the AFWS operates until the batteries deplete and the secondary system is depressurized as well, so the RCS will not be in the high pressure range at UTAF for those PDSs. At VB (Question 23), the probability is only about 0.02 that the RCS will be at the system setpoint pressure. The Surry APET considers five mechanisms for depressurizing the RCS as discussed in Section 2.5.5.2. Note that the fractions in each pressure range are not identical with those in Section 2.5.5.2. The relative frequencies of the "T", "S_3", "S_2", and "A" PDSs depend on the hazard distribution.

The mean probability of CF at VB for this PDS group is 0.019. This is in addition to the 0.09 probability of CF at the start of the accident. There are no late CFs due to hydrogen burns for the LOSP PDSs since power is never recovered during this period. It is possible to have hydrogen burns in the very late period when the containment slowly cools off due to heat transfer to the containment, and enough steam condenses to de-inert the containment atmosphere. The mean probability of very late CF due to a burn is slightly less than 0.04.

The mean probability of BMT is 0.30. The lack of sprays, and thus CHR, implies that an overpressure failure of the containment may occur after several days. As discussed in Section 2.5.5.1, this is unlikely to occur. The mean probability of eventual overpressure CF is less than 0.04 for the SBO, high acceleration PDS group.

2.5.7.3 Results for PDS Group EQ 3, LOCAs: High Acceleration, EPRI Hazard Distribution. This PDS group consists of accidents initiated by seismic pipe breaks. The failures in the ECCS required to respond to these breaks are partially seismic and partially random. There is no SBO, but some of the seismic failures are failures in the electrical distribution system, specifically in the parts that supply power to the ECCS, sprays, or AFWS. In these situations, the availability of electrical power, fourth PDS characteristic, is denoted by a "P". The 11 PDSs in this group are discussed in Section 2.5.5.3. This PDS group consists of the fraction of these accidents due to seisms with a maximum ground acceleration exceeding 0.6 g.

Table 2.5-24 lists the 15 most probable APBs for the PDS group. Evaluation of the APET produced 266 bins for this group, of which, 46 are required to capture 95% of the probability. The 15 most probable bins capture 76% of the probability. Six of the 15 most probable bins have CF at the start due to SG or RCP support failures; four have no VB and no CF, three have VB but no CF, and two have VB and BMT. The two most probable bins have no VB and no CF. They result from the PDSs with LPIS operating at UTAF.

In the LOCA, high acceleration PDS group there is the possibility of arresting the core degradation process and avoiding VB since four of the 11 PDSs in the group have the LPIS operating at UTAF.

Table 2.5-24
Results of the Accident Progression Analysis for Surry
Seismic Initiators. PDS Group EQ 3, LOCAs: High Acceleration,
EPRI Hazard Distribution

Order	Bin	Prob.*	No. Occur.	CF Time	Sprays	CCI	RCS Pres.	VB Mode	Amt CCI	Zr Ox	HPME	CF Size
Fifteen Most Probable Bins**												
1	HHCDFCDADFB	0.119	112	No-CF	Never	No-CCI	LoPr	No-VB	No-CCI	Lo	No	No-CF
2	HHCDFCDBDFB	0.108	123	No-CF	Never	No-CCI	LoPr	No-VB	No-CCI	Hi	No	No-CF
3	CHADBCAADCB	0.077	112	Early	Never	PrmDry	LoPr	Pour	Large	Lo	No	Leak
4	CHADBCABDCB	0.071	121	Early	Never	PrmDry	LoPr	Pour	Large	Hi	No	Leak
5	HHADBCAADFB	0.064	112	No-CF	Never	PrmDry	LoPr	Pour	Large	Lo	No	No-CF
6	HHADBCABDFB	0.060	123	No-CF	Never	PrmDry	LoPr	Pour	Large	Hi	No	No-CF
7	GHADBCAADDB	0.044	112	Final	Never	PrmDry	LoPr	Pour	Large	Lo	No	BMT
8	GHADBCABDDB	0.041	123	Final	Never	PrmDry	LoPr	Pour	Large	Hi	No	BMT
9	CDCDBCDADCB	0.036	111	Early	Always	No-CCI	LoPr	Pour	No-CCI	Lo	No	Leak
10	HDCDFCDADFB	0.034	112	No-CF	Always	No-CCI	LoPr	No-VB	No-CCI	Lo	No	No-CF
11	CDCDBCDBDCB	0.028	91	Early	Always	No-CCI	LoPr	Pour	No-CCI	Hi	No	Leak
12	CDDDBCAADCB	0.023	111	Early	Always	PrmDeep	LoPr	Pour	Large	Lo	No	Leak
13	HDCDFCDBDFB	0.023	123	No-CF	Always	No-CCI	LoPr	No-VB	No-CCI	Hi	No	No-CF
14	HDCDBCDADFB	0.018	112	No-CF	Always	No-CCI	LoPr	Pour	No-CCI	Lo	No	No-CF
15	CDDDBCABDCB	0.018	90	Early	Always	PrmDeep	LoPr	Pour	Large	Hi	No	Leak

* Mean probability conditional on the occurrence of the PDS.
** A listing of all bins, and a listing by observation are available on computer media.

If the RCS can be depressurized sufficiently in a timely manner, injection by the LPIS may arrest core damage for these PDSs. The mean probabilities for this PDS group for the four pressure ranges at UTAF and just before VB (if it occurs) are:

	At UTAF	Just Before VB
SSPr (2500 psia)	0.0	0.0
HiPr (600 to 2000 psia)	0.0	0.0
ImPr (200 to 600 psia)	0.44	0.01
LoPr (< 200 psia)	0.56	0.99

As all of the PDSs in this group have an A, S_1, or S_2 break, the RCS pressure at UTAF (Question 15) is bound to be low or intermediate. The S_2 breaks comprise 0.44 of this PDS group. As there is electric power available, and opening the PORVs is directed by the procedures when the core exit thermocouples show temperatures of 1200°F, it was estimated that the probability was 0.90 that the operators would open the PORVs in time to ensure the RCS was at low pressure by VB.

The mean probability of having the LPIS operating at UTAF is about 0.34 for the seismic LOCA PDS group. Four of the 11 PDSs in this group have the LPIS operating. For these PDSs, it is likely that the RCS will depressurize sufficiently and quickly enough to allow LPIS injection in time to prevent VB. The mean probability of arresting the core degradation process and avoiding VB is about 0.31.

The mean probability of CF at VB for this PDS group is 0.007. This is in addition to the 0.39 probability of CF at the start of the accident. This value is so large because five of the 11 PDSs in this group are "A" PDSs in which SG or RCP support failures at the time of earthquake fail the containment.

There are no late or very late CFs due to hydrogen burns for the LOCA PDSs since power is continuously available. The mean probability of BMT is 0.11. The sprays operate throughout the accident in five of the 11 PDSs in this group, and the sprays are irreparably failed in six of the 11 PDSs. The PDSs with failed sprays are more likely than those with operable sprays, so the mean probability for having no CHR is about 0.75. When CHR is not recovered in the long term, an overpressure failure of the containment may occur after several days. As discussed in Section 2.5.5.1, nonrecovery of CHR in a period on the order of five days was judged to be of low probability, even following an earthquake. Thus, for the LOCA, high acceleration PDS group the mean probability of eventual overpressure CF is 0.01.

2.5.7.4 Results for PDS Group EQ 1, LOSP (No SBO): Low Acceleration, EPRI Hazard Distribution. This PDS group consists of accidents initiated by LOSP, but in which SBO does not result. The LOSP is due to the earthquake, but the DGs start and supply station power. The five PDSs in this group are the same as those discussed in Section 2.5.5.1. This PDS group consists of the fraction of these accidents due to seisms with a maximum ground acceleration less than 0.6 g.

Table 2.5-25 lists the 10 most probable APBs for this PDS group and the five most probable APBs that have VB and early CF. Evaluation of the APET produced 789 bins for the LOSP, low acceleration PDS group. To capture 95% of the probability, 92 bins are required. The 10 most probable bins capture 71% of the probability. Four of the 10 most probable bins have no VB; five have low pressure pour failures of the lower head; and one has HPME. Two of the 10 most probable bins have BMT; the other eight have no CF. Of the five most probable APBs with both VB and early CF, three have CF due to an Alpha mode failure of both vessel and containment, and two have CF due to HPME and DCH with the RCS at high pressure.

In the LOSP, low acceleration PDS group, there is the possibility of arresting the core degradation process and avoiding VB since three of the PDS have some ECCS operating at UTAF. If the RCS can be depressurized, injection by the ECCS may arrest core damage for these PDSs. The mean probabilities for this PDS group for the four pressure ranges at UTAF and just before VB (if it occurs) are:

	At UTAF	Just Before VB
SSPr (2500 psia)	0.77	0.029
HiPr (600 to 2000 psia)	0.0	0.008
ImPr (200 to 600 psia)	0.23	0.179
LoPr (< 200 psia)	0.0	0.784

Four of the five PDSs in this group are "T" PDSs, which have the RCS intact at the PORV setpoint pressure at UTAF (Question 15). These PDSs account for the high probability for SSPr at UTAF. At VB (Question 23), the probability is only about 0.025 that the RCS will be at that pressure. The effectiveness of the five mechanisms for depressurizing the RCS is the same for this PDS group as for the LOSP - high acceleration group (see section 2.5.5.1).

Two of the five PDSs in this group have the LPIS operating at UTAF, and one had both LPIS and HPIS operating. For these PDSs, it is possible to arrest core damage and avoid vessel failure. Due to the depressurization of the RCS before VB, the mean probability of arresting the core degradation process and avoiding VB is about 0.34. The mean probability of having the LPIS operating at UTAF is about 0.31, but not all of the time will the open PORVs depressurize the RCS far enough and fast enough to allow LPIS injection in time to prevent VB. The probability that both LPIS and HPIS will be operating is about 0.15. If the HPIS is operating, any break at all will depressurize the RCS enough to allow injection. However, there is no assurance that this injection will occur soon enough, or that enough water will be injected, to prevent VB.

The mean probability of CF at VB for this PDS group is 0.012. There are no late or very late CFs due to hydrogen burns for the LOSP PDSs since power is available throughout the accident. The sprays are irreparably failed for the most probable three PDSs in this group. The mean probability of BMT is 0.21. The mean probability of eventual overpressure CF for the LOSP, low acceleration PDS group is 0.02.

Table 2.5-25
Results of the Accident Progression Analysis for Surry
Seismic Initiators. PDS Group EQ 1, LOSP (No SBO): Low Acceleration,
EPRI Hazard Distribution

Order	Bin	Prob.*	No. Occur.	CF Time	Sprays	CCI	RCS Pres.	VB Mode	Amt CCI	Zr Ox	HPME	CF Size
Ten Most Probable Bins**												
1	HHCDFCDBDFB	0.129	123	No-CF	Never	No-CCI	LoPr	No-VB	No-CCI	Hi	No	No-CF
2	HHADBCABDFB	0.129	123	No-CF	Never	PrmDry	LoPr	Pour	Large	Hi	No	No-CF
3	GHADBCABDDB	0.088	123	Final	Never	PrmDry	LoPr	Pour	Large	Hi	No	BMT
4	HHCDFCDADFB	0.086	112	No-CF	Never	No-CCI	LoPr	No-VB	No-CCI	Lo	No	No-CF
5	HHADBCAADFB	0.082	112	No-CF	Never	PrmDry	LoPr	Pour	Large	Lo	No	No-CF
6	HDCDFCDBDFB	0.059	123	No-CF	Always	No-CCI	LoPr	No-VB	No-CCI	Hi	No	No-CF
7	GHADBCAADDB	0.056	112	Final	Never	PrmDry	LoPr	Pour	Large	Lo	No	BMT
8	HDCDFCDADFB	0.047	112	No-CF	Always	No-CCI	LoPr	No-VB	No-CCI	Lo	No	No-CF
9	HDCDBCDBDFB	0.018	123	No-CF	Always	No-CCI	LoPr	Pour	No-CCI	Hi	No	No-CF
10	HHACACABCFB	0.013	7	No-CF	Never	PrmDry	ImPr	HPME	Large	Hi	Lo	No-CF
Five Most Probable Bins that have VB and Early CF**												
29	DHACACABACB	0.0041	1	CFatVB	Never	PrmDry	ImPr	HPME	Large	Hi	Hi	Leak
31	DHADDCBBDBB	0.0036	75	CFatVB	Never	PrmDry	LoPr	Alpha	Medium	Hi	No	Rupture
69	DHADDCBADBB	0.0012	72	CFatVB	Never	PrmDry	LoPr	Alpha	Medium	Lo	No	Rupture
106	DHEAACAAABA	0.0006	4	CFatVB	Never	SD1dDry	SSPr	HPME	Large	Lo	Hi	Rupture
126	DAFDDCBBDBB	0.0004	51	CFatVB	Early	LD1dDry	LoPr	Alpha	Medium	Hi	No	Rupture

* Mean probability conditional on the occurrence of the PDS.
** A listing of all bins, and a listing by observation are available on computer media.

2.5.7.5 Results for PDS Group EQ 2, SBO: Low Acceleration, EPRI Hazard Distribution. This PDS group consists of accidents initiated by LOSP in which SBO follows. The LOSP is due to the earthquake, and the DGs fail to start due to seismic and random hardware failures. There is no recovery of offsite power, and thus no chance of arresting core damage. The PDSs in this group are the same as those described in Section 2.5.5.2. This PDS group consists of the fraction of these accidents due to seisms with a maximum ground acceleration less than 0.6 g.

Table 2.5-26 lists the 10 most probable APBs for the PDS group and the five most probable APBs that have VB and early CF. In the "CF Time" column, Early means at the start of the accident, and is used to distinguish "C" bins from "D" bins which have CF at VB. Since there is no possibility of core damage arrest for the seismic SBO PDS group, all the APBs have VB. The 10 most probable bins capture 52% of the probability. Evaluation of the APET produced 478 bins for this group, of which, 119 are required to capture 95% of the probability. One of the 10 most probable bins has CF at the start due to SG or RCP support failures, four have BMT, and the other five have no CF. Of the five most probable APBs with both VB and early CF, two have CF at time zero; one has CF at VB due to an Alpha mode vent, one has CF at VB due to HPME at intermediate pressure, and one has CF at VB due to gross bottom head failure at intermediate pressure. The HPME failure of the vessel and the complete failure of the bottom head both result in DCH. In the HPME failure mode, the hole results from the melt-through of one or a few penetrations.

In the SBO, low acceleration PDS group there is no possibility of arresting the core degradation process and avoiding VB since offsite power is not recoverable in the time period considered in this analysis. The depressurization of the RCS during core melt serves only to reduce the loads placed upon the containment at VB. The mean probabilities for this PDS group for the four pressure ranges at UTAF and just before VB are:

	At UTAF	Just Before VB
SSPr (2500 psia)	0.53	0.02
HiPr (600 to 2000 psia)	0.0	0.18
ImPr (200 to 600 psia)	0.43	0.24
LoPr (< 200 psia)	0.04	0.57

Two of the three most probable PDSs in this group are "T" PDSs, so the RCS is intact at at the PORV setpoint pressure at UTAF (Question 15) for these PDSs. In the two "S_3" PDSs, the AFWS operates until the batteries deplete and the secondary system is depressurized as well, so the RCS will not be in the high pressure range at UTAF for these PDSs. At VB (Question 23), the probability is only about 0.02 that the RCS will be at the system setpoint pressure. The depressurization mechanisms are the same as those discussed in Section 2.5.5.2. Note that the fractions in each pressure range are not identical with those in Section 2.5.5.5. The relative frequencies of the "T", "S_3", "S_2", and "A" PDSs depend on the hazard distribution.

Table 2.5-26
Results of the Accident Progression Analysis for Surry
Seismic Initiators. PDS Group EQ 2, SBO: Low Acceleration,
EPRI Hazard Distribution

Order	Bin	Prob.*	No. Occur.	CF Time	Sprays	CCI	RCS Pres.	VB Mode	Amt CCI	Zr Ox	HPME	CF Size
Ten Most Probable Bins**												
1	HHADBCABDFB	0.101	123	No-CF	Never	PrmDry	LoPr	Pour	Large	Hi	No	No-CF
2	HHADBCAADFB	0.080	112	No-CF	Never	PrmDry	LoPr	Pour	Large	Lo	No	No-CF
3	GHADBCABDDB	0.068	123	Final	Never	PrmDry	LoPr	Pour	Large	Hi	No	BMT
4	HHADBCAADFA	0.060	38	No-CF	Never	PrmDry	LoPr	Pour	Large	Lo	No	No-CF
5	GHADBCAADDB	0.054	112	Final	Never	PrmDry	LoPr	Pour	Large	Lo	No	BMT
6	GHADBCAADDA	0.041	38	Final	Never	PrmDry	LoPr	Pour	Large	Lo	No	BMT
7	HHADBCABDFA	0.039	33	No-CF	Never	PrmDry	LoPr	Pour	Large	Hi	No	No-CF
8	HHACACABBFA	0.031	16	No-CF	Never	PrmDry	ImPr	HPME	Large	Hi	Md	No-CF
9	GHADBCABDDA	0.026	33	Final	Never	PrmDry	LoPr	Pour	Large	Hi	No	BMT
10	CHADBCAADCB	0.022	112	Early	Never	PrmDry	LoPr	Pour	Large	Lo	No	Leak
Five Most Probable Bins that have VB and Early CF**												
10	CHADBCAADCB	0.022	112	Early	Never	PrmDry	LoPr	Pour	Large	Lo	No	Leak
11	CHADBCABDCB	0.018	121	Early	Never	PrmDry	LoPr	Pour	Large	Hi	No	Leak
51	DHADDCBBDBB	0.0039	75	CFatVB	Never	PrmDry	LoPr	Alpha	Medium	Hi	No	Rupture
54	DHACACABACB	0.0038	1	CFatVB	Never	PrmDry	ImPr	HPME	Large	Hi	Hi	Leak
57	DHACCCAABCA	0.0034	1	CFatVB	Never	PrmDry	ImPr	BtmHd	Large	Lo	Md	Leak

* Mean probability conditional on the occurrence of the PDS.
** A listing of all bins, and a listing by observation are available on computer media.

The mean probability of CF at VB for this PDS group is 0.020. This is in addition to the 0.045 probability of CF at the start of the accident. There are no late CFs due to hydrogen burns for the LOSP PDSs since power is never recovered during this period. It is possible to have hydrogen burns in the very late period when the containment slowly cools off due to heat transfer to the containment, and enough steam condenses to de-inert the containment atmosphere. The mean probability of very late CF due to a burn is slightly less than 0.04. The mean probability of BMT is 0.31. The mean probability of eventual overpressure CF is less than 0.04 for the SBO, low acceleration PDS group.

2.5.7.6 Results for PDS Group EQ 3, LOCAs: Low Acceleration, EPRI Hazard Distribution. This PDS group consists of accidents initiated by seismic pipe breaks. The failures in the ECCS required to respond to these breaks are partially seismic and partially random. There is no SBO, but some of the seismic failures are failures in the electrical distribution system, specifically in the parts that supply power to the ECCS, sprays, or AFWS. In these situations, the availability of electrical power, fourth PDS characteristic, is denoted by a "P". This PDS group consists of the fraction of these accidents due to seisms with a maximum ground acceleration less than 0.6 g. The 11 PDSs in this group are discussed in Section 2.5.5.3

Table 2.5-27 lists the 15 most probable APBs for the PDS group. Evaluation of the APET produced 266 bins for this group, of which, 43 are required to capture 95% of the probability. The 15 most probable bins capture 80% of the probability. Six of the 15 most probable bins have CF at the start due to SG or RCP support failures; four have no VB and no CF, three have VB but no CF, and two have VB and BMT. The two most probable bins have no VB and no CF. They result from the PDSs with LPIS operating at UTAF.

In the LOCA, low acceleration PDS group there is the possibility of arresting the core degradation process and avoiding VB since four of the 11 PDSs in the group have the LPIS operating at UTAF. If the RCS can be depressurized sufficiently in a timely manner, injection by the LPIS may arrest core damage for these PDSs. The mean probabilities for this PDS group for the four pressure ranges at UTAF and just before VB (if it occurs) are:

	At UTAF	Just Before VB
SSPr (2500 psia)	0.0	0.0
HiPr (600 to 2000 psia)	0.0	0.0
ImPr (200 to 600 psia)	0.54	0.01
LoPr (< 200 psia)	0.46	0.99

As all of the PDSs in this group have an A, S_1, or S_2 break, the RCS pressure at UTAF (Question 15) is bound to be low or intermediate. The S_2 breaks comprise about 0.54 of this PDS group. As there is electric power available, and opening the PORVs is directed by the procedures when the core exit thermocouples show temperatures of 1200°F, it was estimated that the probability was 0.90 that the operators would open the PORVs in time to ensure the RCS was at low pressure by VB.

Table 2.5-27
Results of the Accident Progression Analysis for Surry
Seismic Initiators. PDS Group EQ 3, LOCAs: Low Acceleration,
EPRI Hazard Distribution

Order	Bin	Prob.*	No. Occur.	CF Time	Sprays	CCI	RCS Pres.	VB Mode	Amt CCI	Zr Ox	HPME	CF Size
Fifteen Most Probable Bins**												
1	HHCDFCDADFB	0.129	112	No-CF	Never	No-CCI	LoPr	No-VB	No-CCI	Lo	No	No-CF
2	HHCDFCDBDFB	0.118	123	No-CF	Never	No-CCI	LoPr	No-VB	No-CCI	Hi	No	No-CF
3	HHADBCAADFB	0.084	112	No-CF	Never	PrmDry	LoPr	Pour	Large	Lo	No	No-CF
4	HHADBCABDFB	0.080	123	No-CF	Never	PrmDry	LoPr	Pour	Large	Hi	No	No-CF
5	CHADBCAADCB	0.073	112	Early	Never	PrmDry	LoPr	Pour	Large	Lo	No	Leak
6	CHADBCABDCB	0.071	121	Early	Never	PrmDry	LoPr	Pour	Large	Hi	No	Leak
7	GHADBCAADDB	0.057	112	Final	Never	PrmDry	LoPr	Pour	Large	Lo	No	BMT
8	GHADBCABDDB	0.055	123	Final	Never	PrmDry	LoPr	Pour	Large	Hi	No	BMT
9	HDCDFCDADFB	0.026	112	No-CF	Always	No-CCI	LoPr	No-VB	No-CCI	Lo	No	No-CF
10	CDCDBCDADCB	0.026	111	Early	Always	No-CCI	LoPr	Pour	No-CCI	Lo	No	Leak
11	CDCDBCDBDCB	0.020	92	Early	Always	No-CCI	LoPr	Pour	No-CCI	Hi	No	Leak
12	CDDDBCAADCB	0.017	111	Early	Always	PrmDeep	LoPr	Pour	Large	Lo	No	Leak
13	HDCDFCDBDFB	0.017	123	No-CF	Always	No-CCI	LoPr	No-VB	No-CCI	Hi	No	No-CF
14	HDCDBCDADFB	0.015	112	No-CF	Always	No-CCI	LoPr	Pour	No-CCI	Lo	No	No-CF
15	CDDDBCABDCB	0.013	87	Early	Always	PrmDeep	LoPr	Pour	Large	Hi	No	Leak

* Mean probability conditional on the occurrence of the PDS.
** A listing of all bins, and a listing by observation are available on computer media.

The mean probability of having the LPIS operating at UTAF is about 0.34 for the seismic LOCA PDS group. Four of the 11 PDSs in this group have the LPIS operating. For these PDS, it is likely that the RCS will depressurize sufficiently and quickly enough to allow LPIS injection in time to prevent VB. The mean probability of arresting the core degradation process and avoiding VB is about 0.31.

The mean probability of CF at VB for this PDS group is 0.008. This is in addition to the 0.33 probability of CF at the start of the accident. This value is so large because five of the 11 PDSs in this group are "A" PDSs in which SG or RCP support failures at the time of earthquake fail the containment.

There are no late or very late CFs due to hydrogen burns for the LOCA PDSs since power is continuously available. The hydrogen will burn when a flammable concentration is attained, which poses a negligible threat to the Surry containment. The mean probability of BMT is 0.13. The sprays operate throughout the accident in five of the 11 PDSs in this group, and the sprays are irreparably failed in six of the 11 PDSs. The PDSs with failed sprays are more likely than those with operable sprays, so the mean probability for having no CHR is 0.81. When CHR is not recovered in the long term, an overpressure failure of the containment is possible after several days. As discussed in Section 2.5.5.1, the Surry basemat is constructed of siliceous concrete and this is unlikely to occur. For the LOCA, low acceleration PDS group the mean probability of eventual overpressure CF is 0.01.

2.5.8 Sensitivity Analyses for Seismic Initiators: EPRI Hazard Distribution

No sensitivity analyses that affected the accident progression analysis were performed for seismic initiators with the EPRI hazard distribution.

2.5.9 Comparison of Results for Seismic Initiators

Figure 2.5-5 summarizes the results of the accident progression analysis for the seismic initiators. The largest differences between the two hazard distributions are in the core damage frequencies. The mean core damage frequencies that result from using the EPRI hazard distributions are almost an order of magnitude lower than the mean core damage frequencies that result from using the LLNL hazard distributions. As the core damage frequency of a PDS group has no effect on the evaluation of the APET, the accident progression analysis results for the two hazard distributions are very similar. The differences are due to differences in the frequencies of the individual PDSs relative to other PDSs in the group.

Figure 2.5-5 shows the mean probability of the summary accident progression bins for the three PDS groups and both sets of seismic hazard distributions. Based on the mean probability, the majority of seismic core damage accidents result in either no vessel failure or no containment failures. There is no possibility of avoiding vessel failure for the SBO accidents because the damage to the switchyard is deemed to be not reparable within

the times of interest. The mean probability of early containment failure is on the order of 0.01 if the initial failures due to SG or RCP support failures are excluded. Initial CF occurs only for large breaks, so essentially all the low pressure early CFs are attributable to SG or RCP failures. If initial CFs are removed, the low pressure early CFs become negligible due to the strength of the Surry containment relative to the loads expected when the vessel fails at low pressures. The probability of late CF is relatively high for the SBO accidents because there is no long term recovery of containment heat removal as there is in the LOSP and LOCA accidents. The probability of late CF in the seismic accidents is higher than it is for internal initiators (see Figure 2.5-3) because many of the PDSs (including the most frequent ones) in the LOSP and LOCA groups have the sprays failed.

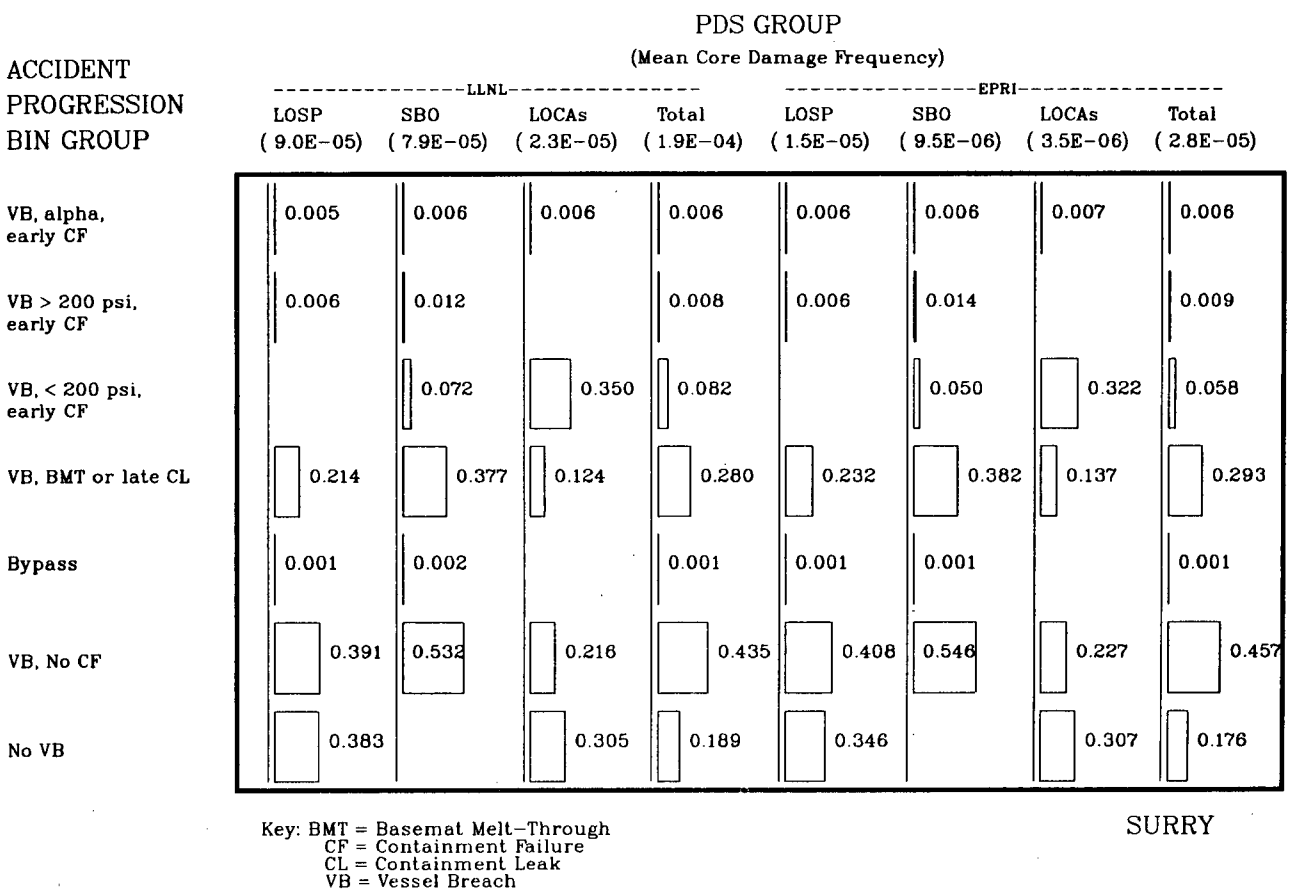


Figure 2.5-5. Mean Probabilities of APBs for PDSs--Seismic.

Figure 2.5-6 displays distribution of the probability of arresting the core melt process and avoiding failure of the lower head of the reactor vessel for the seismic initiators. No histogram is shown for the SBO PDS group as core damage arrest is not possible for this group. Inclusion of the SBO accidents in the total, however, accounts for the fact that the total distribution shows core damage arrest to be less likely than it is for either the LOSP or LOCA groups. The differences between the distributions for the hazard distributions are due to differences in the frequencies of the PDSs in which an injection system is operable relative to other PDSs in the group. The probability of core damage arrest for the seismic initiators is lower than it is for internal initiators (see Figure 2.5-1) because the frequencies of the PDSs with one or more injection systems operable are lower relative to the total frequency than they are for internal initiators.

Figure 2.5-7 presents distribution of the probability of early failure of the containment for the seismic initiators. Differences between the two sets of hazard distributions are minimal. The relatively high probabilities of early CF for the SBO and LOCAs groups reflect the initial failures of the containment due to SG and RCP support failures. The distributions for early CF for the seismic LOSP initiators are comparable to those for the internal LOSP initiators (see Figure 2.5-2).

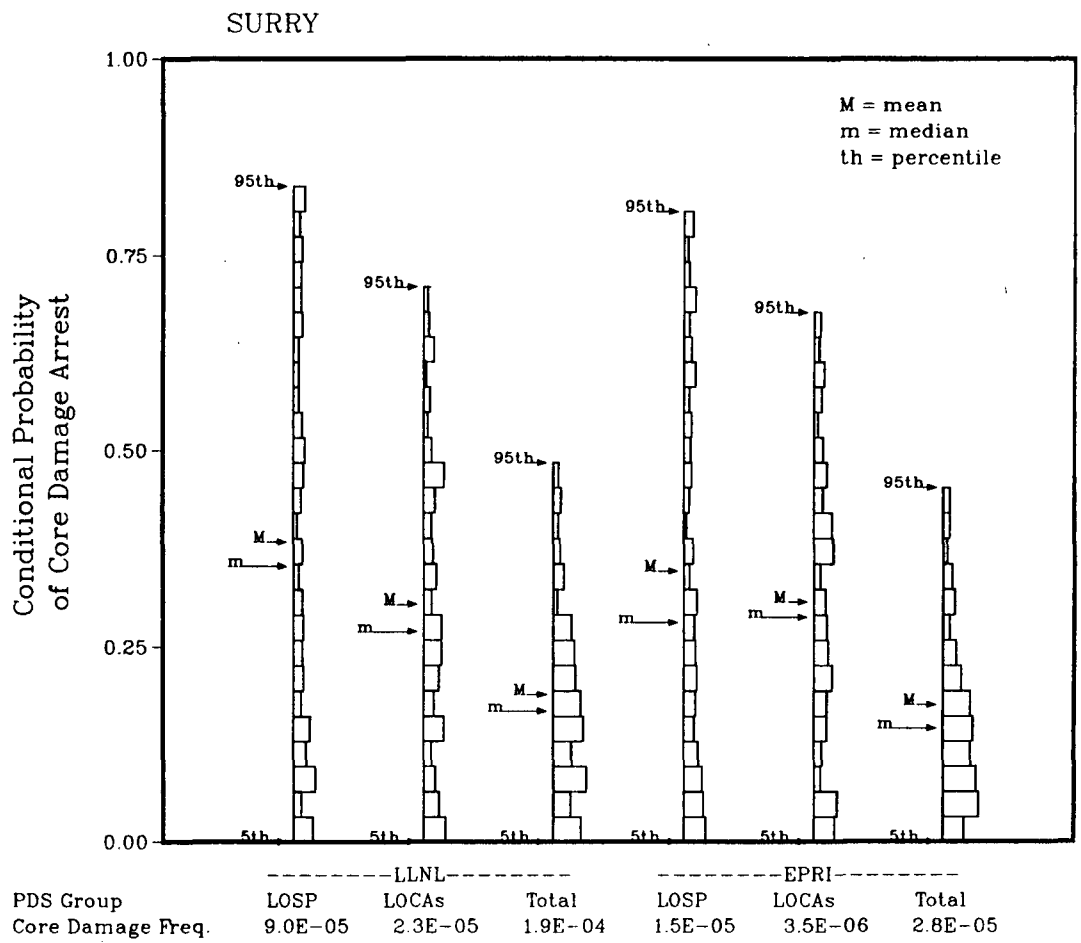
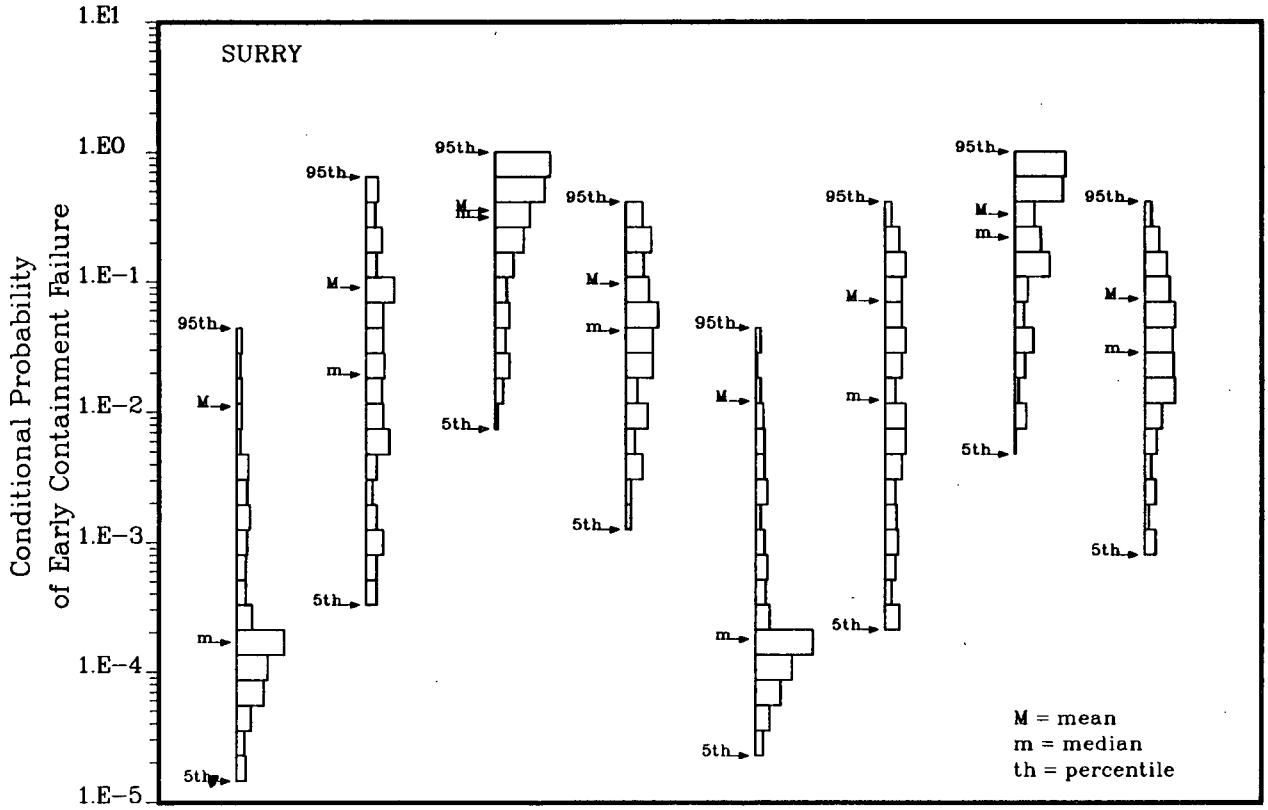


Figure 2.5-6. Probability of Core Damage Arrest--Seismic.



	LLNL				EPRI			
PDS Group	LOSP	SBO	LOCAs	Total	LOSP	SBO	LOCAs	Total
Core Damage Freq.	9.0E-05	7.9E-05	2.3E-05	1.9E-04	1.5E-05	9.5E-06	3.5E-06	2.8E-05

Figure 2.5-7. Probability of Early Containment Failure--Seismic.

2.6 Insights from the Accident Progression Analysis

For internal initiators, there is a good chance that non-bypass accidents will be arrested before vessel failure. The arrest of core damage is due to the recovery of offsite power or the reduction of RCS pressure to the point where a system operating at the onset of core damage can inject successfully. If core damage proceeds to failure of the lower head, the containment is unlikely to also fail at this time. This is partially due to the depressurization of the RCS before vessel failure, and partially due to the strength of the Surry containment relative to the loads expected. If the containment does fail, it is most likely to be BMT many hours after the breach of the vessel.

Depressurization of the RCS before the vessel fails is quite effective in reducing the loads placed upon the containment at vessel breach. The effective mechanisms, are temperature-induced failure of the hot leg or surge line, temperature-induced failure of the RCP seals, and the sticking open of the PORVs. All of these mechanisms are inadvertent and beyond the control of the operators. The apparent beneficial effects of depressurizing the RCS when lower head failure is imminent indicate that further investigation of depressurization may be warranted. The dependency of

containment integrity on failures that occur at unpredictable locations and at unpredictable times is somewhat unsettling. Analysis of the effects of increasing PORV capacity, providing the means to open the PORVs in blackout situations, and changing the procedures to remove the restricting conditions on deliberate depressurization might prove rewarding in decreasing the probability of early containment failure at PWRs with large, dry containments.

Another factor responsible for the low probability of early failure of the Surry containment is the strength of the containment relative to loads expected. For none of the 19 cases defined by the experts for pressure rise at vessel breach, was the mean of the pressure rise distribution less than 35 psi below the mean of the distribution for the failure pressure of the containment. For the case with the highest pressure rise, the mean probability of containment failure is on the order of 0.30, but this case is improbable. For the more probable cases with the RCS at pressures above 200 psi at low head failure, the mean probability of containment failure is on the order of 0.05. For vessel failure below 200 psi, the failure probability is about 0.002.

Although their core damage frequency is relatively low, the bypass accidents are important for internal initiators, specifically, Event V. This is due to the low probability of early containment failure for the more frequent accidents, SBO and LOCAs. The occurrence of Event V is a more likely way to defeat the containment function in a core melt situation than is an SBO or LOCA followed by CF at VB. Even though Event V creates a bypass of the containment, there is a mean probability of 0.85 that the break location in the interfacing low pressure piping will be covered by a water pool when the releases commence.

For fires, there is no possibility of core damage arrest as the initiating fire destroys the ability to provide control of motive power to the coolant injection systems. Early containment failure is unlikely, as for internal initiators, and there are no bypass initiators.

Early containment failure is also unlikely for the seismic initiators, except for the initial containment failures due to reactor coolant pump or steam generator support failures. There are no bypass initiators for the seismic accidents. Core damage arrest before VB is not possible in the seismic SBO accidents because the damage to the switchyard is judged to be to extensive to be repaired in the time frame of interest. Core damage arrest is possible in the LOSP and LOCA accidents, however. On the whole, about one sixth of the seismic core damage accidents are recovered before the vessel melts through. Core damage arrest is not as likely for seismic initiators as it is for internal initiators. This is due to the fact that the frequencies of the PDSs with one or more injection systems operable are lower relative to the total frequency for the seismic initiators than they are for internal initiators.

Except for the initial failures of the containment due to SG and RCP support failures, the probability of early CF is about 0.01 for the seismic initiators. The initial CF accidents are all large breaks in which the RCS will be at low pressure when the lower head fails. CF at VB is essentially

negligible for these accidents. Because of these initial failures of the containment, the probability of early CF is much higher for seismic initiators than it is for internal initiators. There are no bypass initiators for the seismic accidents, however. If bypass and early CF are considered together, then the seismic initiators have a lower probability of causing an accident with an open release path to the environment early in the accident. About one quarter of the seismic accidents have late failures of the containment. This is much higher than for internal initiators, and comes from the inability to recover offsite power for the SBO PDS group, and from the relatively high frequencies of PDSs in which the sprays are failed in the LOSP and LOCAs groups.

3. RADIOLOGICAL SOURCE TERM ANALYSIS

The source term is the information passed to the next analysis so that the offsite consequences can be calculated for each group of accident progression bins. The source term for a given bin consists of the release fractions for the nine radionuclide groups for the early release and for the late release, and additional information about the timing of the releases, the energy associated with the releases, and the height of the releases.

The source terms for Surry are generated by a relatively small parametric computer code: SURSOR. The aim of this model is not to calculate the behavior of the fission products from their basic chemical and physical properties and the flow and temperature conditions in the reactor and the containment. Instead, the purpose is to represent the results of the detailed codes that calculate the fission product behavior by application of the first principles of physics, chemistry, and thermodynamics.

A more complete discussion of the source term analysis, and of SURSOR in particular, may be found in NUREG/CR-5360.[a] The methods on which SURSOR is based are presented in NUREG/CR-4551, Volume 1, and the source term issues considered by the expert panels are described more fully in NUREG/CR-4551, Volume 2, Part 4.

Section 3.1 summarizes the features of the Surry plant that are important to the magnitude of the radionuclide release. Section 3.2 presents a brief overview of the SURSOR code, and Section 3.3 presents the results of the source term analysis. Section 3.4 discusses the partitioning of the thousands of source terms into groups for the consequence analysis. Section 3.5 concludes this section with a summary of the insights gained from the source term analysis.

3.1 Surry Features Important to the Source Term Analysis

The nuclear reactor of Surry Unit 1 is a three-loop pressurized water reactor (PWR) contained in a containment constructed of reinforced concrete with a welded steel liner forming the pressure boundary. Figure 1.1 shows a section through the Surry containment. More detail on the Surry plant in general is contained in Sections 1.2 and 2.1; this material is not repeated here.

The design pressure of the Surry containment is 45 psig, and the structural experts found the failure pressure to be generally between two and three times the design pressure. The relatively high failure pressure combined with the large size of the containment (5.1E4 m^3 = 1.8E6 ft^3) implies that the containment is relatively resistant to failure by the events at VB or by hydrogen combustion before or after VB. This was confirmed by the results of the accident progression analysis.

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[a] H.-N Jow, W. B. Murfin, and J. D. Johnson, "XSOR Codes User's Manual," NUREG/CR-5360, SAND89-0943, Sandia National Laboratories, (in preparation).

Two accident scenarios have been identified at Surry which bypass the containment. These accidents are Event V and steam generator tube ruptures (SGTRs). In Event V, the check valves which separate the low pressure injection system (LPIS) from the reactor coolant system (RCS) fail. The LPIS piping is not designed for full RCS pressure, and it fails outside the containment. This provides a direct pathway from the vessel to the auxiliary building. If the failure is at a low elevation, the water from the RCS escaping through the break and the water from the refueling water storage tank (RWST) pumped out the break by the LPIS will cover the break location so that there will be some scrubbing of the fission products released from the vessel. If the break location is not at a low elevation, there may be few effective removal mechanisms between the core and the environment, and releases could be quite high.

The magnitude of the source term from an SGTR accident depends on the integrity of the secondary system and the containment. If the integrity of both is maintained, the releases may be quite small. If the safety relif valves (SRVs) on the secondary system stick open, then a direct path from the vessel to the environment is created and the releases may be very high. If the SRVs on the secondary system do not stick open, then the releases depend on the time at which the containment fails (if at all) as in non-bypass accidents.

Emergency containment heat removal at Surry is by spray systems as described in Section 2.1.3. The sprays are quite effective in removing fission products from the containment atmosphere. The redundancy of the spray recirculation system means that there are no accident situations at Surry in which electric power is available and the sprays are failed due to hardware faults. There are some scenarios in which electric power is available but the sprays cannot operate due to lack of water in the sump, but these are all bypass accidents and spray operation has only a minor effect on the releases at best. Spray operation at and following VB is important in reducing the release if the containment fails after VB.

The pressure inside the Surry containment is maintained about 5 psia below ambient atmospheric pressure when the reactor is operating. This makes the existence of pre-existing leaks due to an open hatch or airlock negligible. The likelihood of isolation failure is also low, so, except for certain seismic events, the probability of a direct failure of the containment at the start of the accident is quite low.

There is no connection between the sump and the reactor cavity at a low elevation in the Surry containment as discussed in Section 2.1.5. Thus, the cavity is more often dry at VB than it would be if the sump and the cavity were connected. In general, a cavity full of water leads to less pressure rise at VB, and lower releases should the containment fail at VB, than a dry cavity. Further, a dry cavity makes core-concrete interaction (CCI) more likely, and the fission products release higher, than if the cavity is full of water.

In summary, the Surry containment is relatively robust, which reduces the likelihood of early containment failure. The sprays have a great deal of redundancy, and their operation in non-blackout sequences reduces the

releases from late containment failures (which are few in any event). In Event V and SGTRs in which the secondary systems SRVs are stuck open, the release path bypasses the containment.

3.2 Description of the SURSOR Code

This section describes the manner in which the source term is computed for each accident progression bin (APB). The source term is more than the fission product release fractions for each radionuclide class; it also contains information about the timing of the release, the height of the release, and the energy associated with the release. The next subsection presents a brief overview of the parametric model used to calculate the source terms. Section 3.2.2 discusses the model in some detail; a complete discussion of SURSOR may be found in Reference 1. Section 3.2.3 presents the variables sampled in the source term portion of this analysis.

3.2.1 Overview of the Parametric Model

SURSOR is a fast-running, parametric computer code used to calculate the source terms for each APB for each observation for Surry. As there are typically a few thousand bins for each observation, and 200 observations in the sample, the need for a source calculation method that requires a minimum of computer time for one evaluation is obvious. SURSOR is not designed to calculate the behavior of the fission products from their basic chemical and physical properties and the flow and temperature conditions in the reactor and the containment. The purpose of SURSOR is to provide a framework for integrating the results of the more detailed codes that do consider these quantities. Since many of the factors SURSOR utilizes to calculate the release fractions were determined by a panel of experts, the results of the detailed codes enter SURSOR "filtered" through the experts.

The 60 radionuclides (also referred to as isotopes, or fission products) considered in the consequence calculation are not dealt with individually in the source term calculation. Some different elements behave similarly enough both chemically and physically in the release path that they can be considered together. The sixty isotopes are placed in nine radionuclide classes as shown in Table 3.2-1. It is these nine classes which are treated individually in the source term analysis.

Table 3.2-1
Isotopes in Each Radionuclide Release Class

Release Class	Isotopes Included
1. Inert Gases	Kr-85, Kr-85M, Kr-87, Kr-88, Xe-133, Xe-135
2. Iodine	I-131, I-132, I-133, I-134, I-135
3. Cesium	Rb-86, Cs-134, Cs-136, Cs-137
4. Tellurium	Sb-127, Sb-129, Te-127, Te-127M, Te-129, Te-129M, Te-131M, Te-132

Table 3.2-1 (continued)

Release Class	Isotopes Included
5. Strontium	Sr-89, Sr-90, Sr-91, Sr-92
6. Ruthenium	Co-58, Co-60, Mo-99, Tc-99M, Ru-103, Ru-105, Ru-106, Rh-105
7. Lanthanum	Y-90, Y-91, Y-92, Y-93, Zr-95, Zr-97, Nb-95, La-140, La-141, La-142, Pr-143, Nd-147, Am-241, Cm-242, Cm-244
8. Cerium	Ce-141, Ce-143, Ce-144, Np-239, Pu-238, Pu-239, Pu-240, Pu-241
9. Barium	Ba-139, Ba-140

3.2.2 Description of SURSOR

Since the largest consequences generally result from accidents in which the containment fails before VB or about the time of VB, the nomenclature and structure of SURSOR reflects failure at VB. There is an early release which occurs before, at, or a few tens of minutes after VB, and there is a late release occurs several hours, after VB. In general, the early release is due to fission products that escape from the fuel while the core is still in the RCS, i.e., before vessel breach, and is often referred to as the RCS release. The late release is largely due to fission products that escape from the fuel during the CCI and is referred to as the CCI release. For situations where the containment fails many hours after vessel breach, the "early" release equation is still used, but the release is better termed the RCS release. After both releases are calculated in SURSOR, they are combined into the late release and the early release is set to zero. The late release includes not only fission products released from the core during CCI, but also material released from the fuel before VB which deposits in the RCS or the containment, and then is revolatilized after VB.

For radionuclide class i, the early or RCS release is calculated from the following equation:

ST(i) = [FCOR(i) * FVES(i) * FCONV(i) / DFE(i)] + DST(FDCH(i)).(Eq. 3.1)

And the late or CCI release is calculated from:

STL(i) = [(1-FCOR(i)) * FPART(i) * FCCI(i) * FCONC(i) / DFL(i)]
+ DLATE(FLATE(i)). (Eq. 3.2)

Both equations are valid for most APBs, but are not complete; there are additional terms, which are either small or apply only to certain types of accidents, that are not shown in this summary for reasons of expediency.

For example, some of the omitted terms concern releases from Event V and SGTR accidents. There is also an additional term, LATEI, that applies only for the iodine radionuclide class. The complete equations used are presented in NUREG/CR-5360. The FORTRAN listing of SURSOR is contained in Appendix B. The meaning of the terms in the equations above is as follows:

ST = fraction of the radionuclide in the core at the start of the accident that is released to the environment as part of the RCS release;

FCOR = fraction of the radionuclide in the core released to the vessel before VB;

FVES = fraction of the radionuclide released to the vessel that is subsequently released to the containment;

FCONV = fraction of the radionuclide in the containment from the RCS release that is released from the containment in the absence of any mitigating effects;

DFE = decontamination factor for RCS releases (sprays, etc.);

DST = fraction of core radionuclide released to the environment due to direct containment heating at vessel breach;

FDCH = fraction of radionuclide in the portion of the core involved in direct containment heating that is released to the containment at vessel breach;

STL = fraction of the radionuclide in the core at the start of the accident that is released to the environment as part of the CCI release;

FPART = fraction of the core which participates in the CCI;

FCCI = fraction of the radionuclide in the core material at the start of CCI which is subsequently released to the containment;

FCONC = fraction of the radionuclide in the containment from the CCI release that is released from the containment in the absence of any mitigating effects;

DFL = decontamination factor for late releases (sprays, etc.);

DLATE = fraction of core radionuclide released to the environment due to revolatilization from the RCS late in the accident; and

FLATE = fraction of core radionuclide remaining in the RCS which is revolatilized late in the accident.

Only the functional dependence of DLATE on FLATE, and of DST on FDCH, is indicated above, but DLATE and DST also depend on other factors such as FCOR. DST and DLATE are expressed as fractions of the initial core inventory like ST and STL. Complete expressions for DST and DLATE and an expanded discussion of them may be found in the XSOR document.

Figure 3.2-1 depicts the parametric equations schematically in terms of a flow diagram. Coming in from the left is all the radioactivity in any radionuclide class. The black arrows represent releases to the environment and the white arrows represent material retained in the RCS or in the containment. This figure is read as follows: the first division of the radioactive material is indicated by FCOR. The top branch, indicated by FCOR, represented the fraction released from the core before VB, and the lower branch, an amount 1-FCOR, represents the amount still in the RCS at VB. The FCOR branch is then split into that which leaves the RCS before or at VB, FVES, and that which is retained in the RCS past VB, 1-FVES. Of the material retained in the RCS at VB, a fraction FLATE is revolatilized later. Of the revolatilized fraction, a portion is removed by engineered removal mechanisms such as sprays, factor 1/DFL, and a another portion is removed by natural mechanisms such as deposition, factor FCONRL. The part of the revolatilized fraction that is not removed escapes to the environment, DLATE in the equation, as indicated by the top black arrow in Figure 3.2-1. FCONRL is the containment release fraction for the late revolatilization release, and is set equal to the FCONC value for tellurium.

When evaluated as part of the integrated risk analysis, SURSOR is run in the "sampling mode". That is, most of the factors in the release fraction equations are determined by sampling from distributions for that factor, and the value for each factor varies from observation to observation. Most of these distributions were provided by an expert panel.

The equations above contain 10 factors. Seven of them were considered by the Source Term Expert Panel. The other three were determined either by the expert panel for the previous draft of this report or internally. The eight issues considered by the Source Term Expert Panel are:

1. FCOR and FVES
2. Ice Condenser DF (not applicable to Surry)
3. FLATE
4. FCCI
5. FCONV and FCONC
6. LATEI (not utilized directly for PWRs)
7. Reactor Building DF (not applicable to PWRs)
8. DCH Releases (DST)

Three of these issues are not applicable to Surry. For each issue considered by the expert panel, the result is an aggregate distribution for the nine radionuclide release classes defined in Table 3.2-1. These distributions are not necessarily discrete. While the experts provided separate distributions for all nine classes for FCOR, for other factors, for example, they stated that classes 5 through 9 should be considered together as an aerosol class. Note that the distributions for the nine

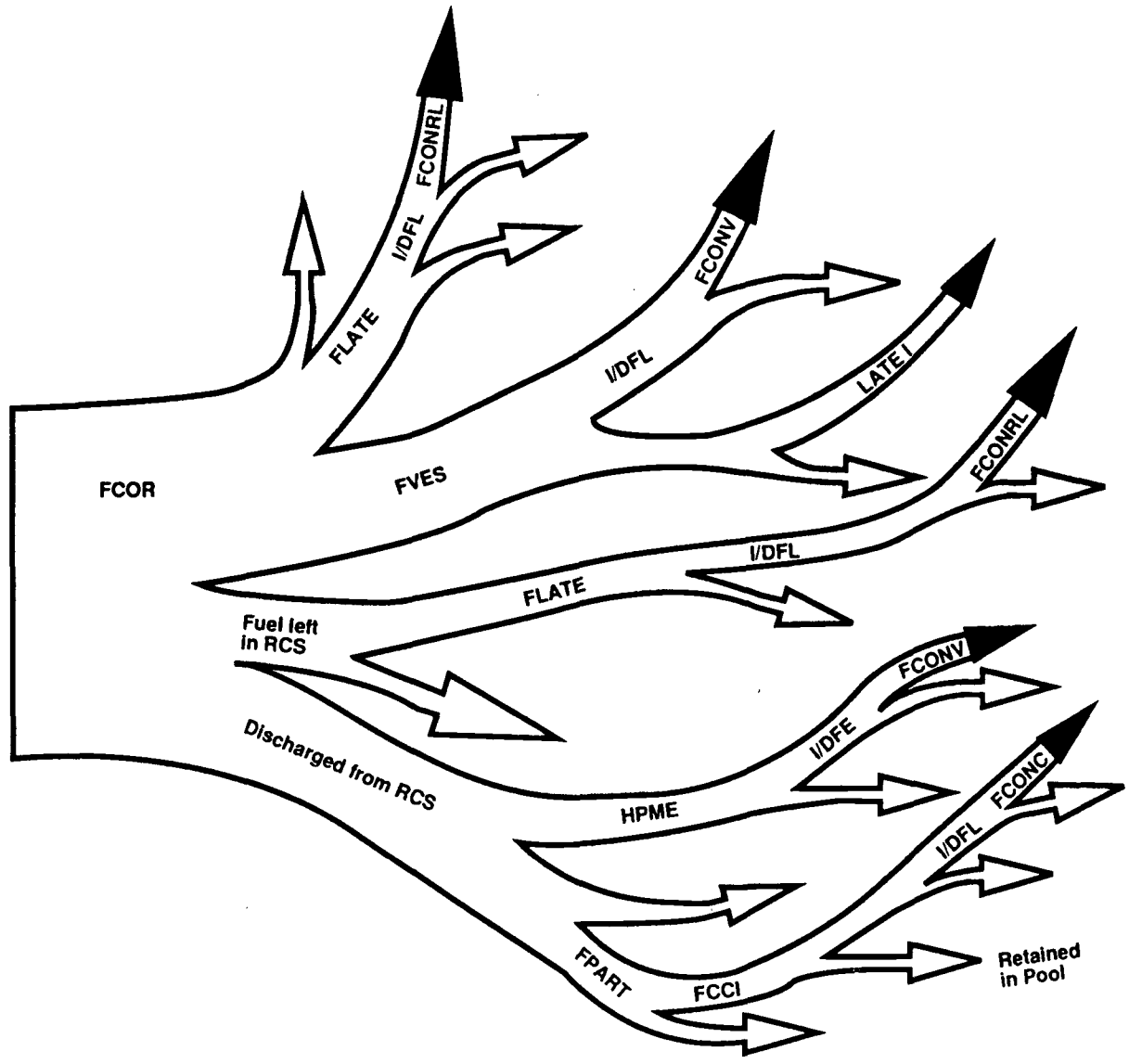


Figure 3.2-1. Blood Flow Diagram for SURSOR.

radionuclide classes are assumed to be completely correlated. That is, a single Latin Hypercube Sampling (LHS) variable applies to each factor in the release fraction equation, and it applies to the distributions for all nine radionuclide classes. For example, if the random number for FCOR is 0.777, the 77.7th percentile value is chosen from the iodine distribution, the cesium distribution, the tellurium distribution, etc. for FCOR.

Many of these factors in the equations above are determined directly by sampling from distributions provided by a panel of experts, see NUREG/CR-4551, Volume 2, Part 4. Other factors are derived from such values, and still others were determined internally, see NUREG/CR-4551, Volume 2, Part 6 and the XSOR document.[1] A brief discussion of each factor in the equations above follows.

FCOR is the fraction of the fission products released from the core to the vessel before vessel failure. The value used in each observation is obtained directly from the experts' aggregate distribution. There are separate distributions for each fission product group for high and low zirconium oxidation in vessel.

FVES is the fraction of the fission products released to the vessel that is subsequently released to the containment before or at vessel failure. As for FCOR, the value used in each observation is obtained directly from the experts' aggregate distribution, and there are separate distributions for each fission product group. There are four cases: RCS at system setpoint pressure, RCS at high or intermediate pressure, RCS at low pressure, and Event V.

FCONV is the fraction of the fission products in the containment from the RCS release that is released from the containment in the absence of mitigating factors such as sprays. The expert panel provided distributions for FCONV for four cases, each of which applies to all species except the noble gases. These cases apply to containment failure at or before VB, or within a few hours of VB. The four cases are: containment leak at or before VB--sprays operating, containment leak at or before VB--sprays not operating, containment rupture at or before VB, and very late containment rupture. Distributions for other levels and times of containment failure are derived in SURSOR from these four distributions. There is a fifth distribution which applies to Event V and which was determined internally. If the containment failure happens a day or more after the start of the accident, none of these distributions is used for FCONV. Because of the long time period for the engineered and natural removal processes to reduce the concentration of the fission products in the containment atmosphere, the fraction of the fission products released before or at VB remaining airborne at the time of containment failure is very small. This fraction was estimated internally to be 1.0E-6, and FCONV is set to that value for final period releases. (The exact value of 1.0E-6 is not important; any very small value would be satisfactory.) This value is used whether the release is due to above-ground failure or basemat melt-through (BMT). DFE is the decontamination factor for early releases. At Surry the containment sprays are the only mechanism that contribute to DFE for non-bypass accidents. For Event V, DFE reflects pool scrubbing if the break location is underwater. The Source Term Expert Panel concluded that the distributions

used for the spray decontamination factors (DF) were less important to determining offsite risk and the uncertainty in risk than whether the sprays were operating and other factors; so, the spray DF distributions (and the pool DF for Event V) were determined internally. There are two spray distributions which apply to the fission products released from the RCS before or at VB: the first applies when the con- tainment fails before or at VB and the RCS is at high pressure at VB; and the second applies when the containment fails after VB or when the con- tainment fails at VB but the RCS is at low pressure. Each distribution applies to all species except the noble gases. For failures of the con- tainment in the final period, the value from the distribution is multiplied by 10 to account for the very long period which the sprays have to wash particulate material out of the containment atmosphere.

DST is the fission product release (in fraction of the original core inventory) from the fine core debris particles that are rapidly spread throughout the containment in a direct containment heating (DCH) event at VB. The experts provided distributions for the fractions of the fission products that are released from the portion of the core involved in DCH for VB at high pressure (1000 to 2500 psia) and for VB at intermediate pressure (200 to 1000 psia). There are separate distributions for each fission product group (inert gases, iodine, cesium, etc.). These distributions are utilized only if the containment fails at (or within a few minutes of) vessel failure. For containment failures that occur hours after VB, it was internally estimated that the amount of fission products from DCH remaining in the atmosphere many hours after VB would be negligible.

FPART is the fraction of the core which participates in the CCI. The value of this factor is determined in the accident progression event tree (APET). There are three ranges of values. Five per cent of the core is estimated to remain in the vessel indefinitely and is not available to participate in CCI under any circumstances. SURSOR subtracts the amount of the core participating in DCH from the amount passed to it in Characteristic 7 of the accident progression bin.

FCCI is the fraction of the fission products present in the core material at the start of CCI that are released to the containment during CCI. The experts provided distributions for four cases that depended upon the fraction of the zirconium oxidized in-vessel and the presence or absence of water over the core debris during CCI. There are separate distributions for each fission product group.

FCONC is the fraction of the fission products released to the containment from the CCI that is released from the containment. The expert panel provided distributions for FCONC for five cases. There are separate distributions for each fission product group (inert gases, iodine, cesium, etc.). The five cases are the same as for FCONV. None of these cases is used for containment failure in the final period (after 24 h). Since containment failure occurs many hours after most of the fission products have been released from CCI, only a very small fraction of these fission products will still be in the containment atmosphere at the time of containment failure. This fraction was estimated internally to be on the order of 1.0E-4. The exact value is determined by utilizing the FCONC

distribution for Case 3, rupture before the onset of CCI. The ratio of the LHS value from the distribution to the median value of the distribution is multiplied by 1.0E-4 to obtain the value of FCONC used for final period containment failure. This value is used whether the release is due to aboveground failure or BMT.

DFL is the decontamination factor for late releases. At Surry, DFL can be due to either the containment sprays or a pool of water over the core debris during CCI. If both mechanisms are operable, only the larger DF is utilized. The pool scrubbing DF is obtained from a one of two internally determined distributions. One distribution applies to a full cavity and the other to a partially full cavity (accumulator water only). The procedure used to obtain the spray DF for the CCI release for final period CF is similar to that used to obtain the value for DFE (discussed above). As for DFE, if the containment fails in the final period, the value from the late CF spray distribution is multiplied by 10 to account for the very long time the sprays have to wash particulate material out of the containment atmosphere.

FLATE accounts for the release of radionuclides from the RCS late in the accident. Like DST, it is a fraction of the original core inventory. Fission products deposited in the RCS before VB may revert to a volatile form after the vessel fails and make their way to the environment. This term considers only revolatilization from the RCS. Revolatilization from the containment is considered to be significant only for iodine, and is discussed below (see LATEI). The expert panel provided distributions for the fraction of the radionuclides remaining in the RCS which are revolatilized. The amount remaining in the RCS is a function of FCOR, FVES, and other terms and is calculated in SURSOR. The experts concluded that whether there was effective natural circulation through the vessel was important in determining the amount of revolatilization. Thus, there are two cases: one large hole in the RCS, and two large large holes in the RCS. The experts provided separate distributions only for iodine, cesium, and tellurium. (Revolatilization is not possible for the inert gases as they would not deposit, and the experts concluded that it is negligible for radionuclide classes 5 through 9.) FLATE is computed in the following manner: the value from the experts' distributions is applied to the fraction of the radionuclide remaining in the RCS to obtain the fraction of the core inventory released to the containment by this mechanism. This is multiplied by the FCONC value for tellurium to determine the fraction that escapes to the environment. The tellurium value for FCONC is considered to be appropriate for revolatilized material since it, like tellurium, is slowly released over a long time period.

LATEI accounts for iodine in the containment which may assume a volatile form, such as methyl iodide, and be released late in the accident. The primary source of this iodine is the water in the reactor cavity and the containment sumps (which are separate at Surry). This term is added to the late release only for radionuclide class 2, iodine. The experts provided a distribution for the fraction of iodine in the containment which is converted to volatile forms. The method of calculating the amount of iodine remaining in the containment depends upon FCOR, FVES, FCCI, and other factors and is explained in the XSOR document.

No differentiation is made between the BMT and aboveground leaks in the final period. Even though the release point for BMT is underground, no allowance is made for attenuation or decontamination of the late fission product release. The BMT release is often dominated by the iodine release due to the LATEI term. The very slow passage of the gases through wet soil with a low driving pressure would undoubtedly result in some reduction in this release. This reduction could be quite large. Although giving no credit for removal in the wet soil is conservative, it is unimportant for the sample as a whole. The total releases from all the BMT failures of the containment are small compared to the releases from accidents and pathways in which the containment fails at or before vessel breach, or where the containment is bypassed.

3.2.3 Variables Sampled for the Source Term Analysis

The twelve variables sampled for the source term analysis are listed in Table 3.2-2 below. That is, when SURSOR was evaluated for all the bins generated by the APET evaluation for a given observation, all the sampled parameters in SURSOR had values chosen specifically for that observation.

Table 3.2-2
Variables Sampled in the Source Term Analysis

Variable	Description
FCOR	Fraction of each fission product group released from the core to the vessel before or at vessel breach. There are two cases: high and low zirconium oxidation.
FVES	Fraction of each fission product group released from the vessel to the containment before or at vessel breach. There are four cases: RCS at system setpoint pressure, RCS at high or intermediate pressure, RCS at low pressure, and Event V.
VDF	Decontamination factor for pool scrubbing for Event V when the break location is underwater at the time of the release. There is one distribution, which applies to all radionuclide classes except inert gases.
FCONV	Fraction of each fission product group in the containment from the RCS release that is released from the containment in the absence of mitigating factors such as sprays. There is one distribution for each case, which applies to all radionuclide classes except inert gases. There are five cases: containment leak at or before VB with sprays operating, containment leak at or before VB with sprays not operating, containment rupture at or before vessel breach, very late containment rupture, and Event V. Note that FCONV does not account for fission product removal by the sprays. The case differentiation on spray operation is to account for differences in containment atmosphere temperature and humidity between the two cases.

Table 3.2-2 (continued)

Variable	Description
FCCI	Fraction of each fission product group in the the core material at the start of CCIs that is released to the containment. There are four cases: low zirconium oxidation in the core and no overlying water, high zirconium oxidation in the core and no overlying water, low zirconium oxidation in the core with overlying water, and high zirconium oxidation in the core with overlying water.
FCONC	Fraction of each fission product group in the containment from the CCI release that is released from the containment in the absence of mitigating factors such as sprays. The five cases are the same as those for FCONV, but there are separate distributions for each radionuclide class.
SPRDF	Decontamination factor for sprays. Internal elicitation was used to develop a distribution for this variable which was used for all fission product groups except the noble gases. There is one distribution for each case, which applies to all radionuclide classes except inert gases. There are three cases: RCS release at high pressure and CF at VB, RCS releases not covered by the first case, and CCI releases.
LATEI	Fraction of the iodine deposited in the containment which is revolatilized and released to the environment late in the accident. This variable applies only to iodine.
FLATE	Fraction of the deposited amount of each fission product group in the RCS which revolatilized after VB and released to the containment. There are two cases: one large hole in the RCS, and two large holes in the RCS.
DST	Fraction of each fission product group in the the core material that becomes aerosol particles in a direct containment heating event at VB that is released to the containment. There are two cases: VB at high pressure (1000 to 2500 psia) and VB at intermediate pressure (200 to 1000 psia).
FISGFOSG	Fraction of each fission product group released from the reactor vessel to the steam generator, and from the steam generator to the environment, in a SGTR accident. There are two separate distributions, FISG and FOSG, each of which has two cases: SGTRs in which the secondary SRVs reclose, and SGTRs in which the secondary SRVs stick open.
POOL-DF	Decontamination factor for a pool of water overlying the core debris during CCI. There are two cases: a completely full (depth about 14 ft) cavity, and a partially full cavity (accumulator water only, depth about 4 ft).

These values were selected by the LHS program from distributions that were previously defined. Most of these distributions were determined by the expert panel on source terms.

The sampling process works somewhat differently for the source term analysis than it does for the accident progression analysis. In the source term analysis, LHS was used only to determine a random number between 0.0 and 1.0 for each variable to be sampled. The actual distributions are contained in a data file (listed in Appendix B) that is read by SURSOR before execution.

The variables selected by LHS are used to define quantiles in the parameter distributions; the values associated with these quantiles are used as parameter values in SURSOR. In use, the process works like this. Say LHS selects a value of 0.05 for FCOR for Observation 1. Referring to the data tables in Appendix B.2, it may be seen that, for low zirconium oxidation in-vessel, the 0.05 quantile values for FCOR are 0.18 for inert gases, 0.084 for iodine, 0.067 for cesium, etc. There is no correlation between any of the source term variables, but complete correlation within a variable. FCOR is not correlated with FVES, FCONV, or any other variable, but the values for the different cases and for the different radionuclide classes are completely correlated. That is, if the 0.05 quantile value is chosen for iodine for low zirconium oxidation, the 0.05 quantile value is also chosen for all the other radionuclide classes and for all values for high zirconium oxidation.

As all the source term variables are uniformly distributed from 0.0 to 1.0, and are uncorrelated, there are no columns for this information in Table 3.2-2 as there are in Table 2.3-2. There is a separate distribution for each radionuclide class for each variable in this table unless otherwise noted in the variable description. The different cases for each variable are noted in the description. Not all the cases considered by SURSOR are listed in Table 3.2-2; parameter values for other cases are determined internally in SURSOR, often from the values for the cases listed. For example, there is no distribution for FCONV for late leak. The value of FCONV for late leak is derived from the distribution for another case. (See the listing of Subroutine FCONVC in Appendix B.)

The variable identifiers given in Table 3.2-2 are used in several ways in the source term analysis. Consider the first variable in Table 3.2-2: FCOR. FCOR in the equation for fission product release is the actual fraction of each fission product group released from the core to the vessel before or at VB for the observation in question. But, FCOR is also used to refer to the experts' aggregate distributions from which the nine values (one for each radionuclide class or fission product group) for FCOR are chosen. Further, in the sampling process, FCOR is used to refer to the random number from the LHS which is used to select the values from these distributions. That is, as used in sampling, FCOR defines a quantile in these distributions. The release fractions associated with this quantile are used in SURSOR as the FCOR values. Thus, in Table 3.2-2, the end use of each variable is given although the actual sampled variable is a random number between 0.0 and 1.0 used to select an actual value.

Most of the twelve variables in Table 3.2-2 have been described more fully in the preceding section. The distributions for FCOR, FVES, FCONV, FCCI, FCONC, FLATE, and DST were provided by the Source Term Expert Panel. These distributions, the reasoning that led each expert to his conclusions, and the aggregation of the individual distributions are fully described in NUREG/CR-4551, Volume 2, Part 4. VDF, SPRDF, LATEI, FISG, FOSG, and DFSPL are discussed briefly below; the distributions for these source term factors and more discussion of them may be found in Appendix B.

The SGTR accidents with the secondary SRVs stuck open were not known to be significant to risk at Surry when the Source Term Expert Panel met for the last time. Therefore, a special ad hoc panel was convened to consider the factors FISG and FOSG. These factors are discussed briefly below; more detail may be found in NUREG/CR-4551, Volume 2, Part 6. The LATEI factor was considered by the expert panel for the BWRs, but the BWR distributions were not utilized directly for the PWRs as discussed in more detail in Appendix B of this report.

VDF is the decontamination factor used for Event V when the release location is underwater. These accidents are referred to as V-Wet accidents. For these types of accidents, SURSOR sets DFE to the value of VDF. The distribution for VDF was determined by the project staff. The range for VDF is from 1.6 to 5100; the median value is 6.2. VDF represents only scrubbing by passage through the pool of water overlying the break location. Any additional removal in the auxiliary building is accounted for by FCONV. The distribution for VDF is given in Appendix B.

SPRDF refers to both the spray decontamination factor for the RCS (vessel) release, DFSPV, and the CCI spray decontamination factor, DFSPC. There is only one value for each of these DFs; each DF applies to all radionuclide groups except the inert gases. Different spray distributions apply for CF at VB and for late CF. The value selected for DFSPC always is taken from the spray DF distribution for late CF. The value for DFSPV is taken from the early distribution for CF at VB, and from the spray DF distribution for late CF. However, the same random value between 0.0 and 1.0 from the LHS program is used to select both the RCS and CCI spray DF values. That is, the spray DF distributions are completely correlated. The spray DF distributions were determined by the project staff. For the RCS release with CF at VB, there are two distributions for the spray DF. One applies if the RCS was at high pressure before VB. In this case most of the RCS release will escape from the vessel just at VB, and the sprays will be very ineffective. The range of the spray DF distribution is from 1.0 (no effect) to 2.8; the median value is 1.6. For the RCS release with CF at VB with the RCS at low pressure before VB, much of the RCS release will have escaped from the vessel before VB, and the sprays will be very effective for that portion of the RCS release. The range of this spray DF distribution is from 2.3 to 2800; the median value is 40. The distribution for the CCI spray DF distribution ranges from 6.7 to 3200; the median value is 28. The complete distributions are contained in Appendix B.

LATEI refers to the evolution of iodine in volatile form from water in the containment late in the accident. Because of its volatile form (typically organic), this volatile iodine is all released to the environment as it is unaffected by all the removal mechanisms (pool scrubbing, sprays, deposi-

tion, etc.). The release fraction determined by LATEI applies to all the iodine released from the fuel and retained in the containment in aqueous solution, which is expected to be the bulk of the iodine released from the vessel and remaining in the containment. In Surry, this iodine would be expected to be contained in the water in the sump. The sump water does not play the same role in heat removal that the suppression pool does in the BWR, so the results of the expert panel (which apply to BWRs only) were not utilized directly. Instead, the distribution obtained specifically for PWRs in the first draft of this report was used. This is discussed further in Appendix B. The distribution used for LATEI ranges from 0.0 to 0.10; the median value is 0.05.

FISG and FOSG are the release fractions used for the RCS release for SGTR accidents. FISG is the fraction released from the core that enters the steam generator; and FOSG is the fraction entering the steam generator which is released from the steam generator to the environment. The actual equation used for the early or RCS release is:

$$ST(i) = [\ FCOR(i) * \{\ FISG(i) * FOSG(i) + [\ 1.0 - FISG(i)\ ] * FVES(i) * FCONV(i) / DFE(i)\ \}\ ] + DST(i). \qquad \text{(Eq. 3.3)}$$

As the material passing from the steam generator to the atmosphere bypasses the containment, the factors FCONV and DFE are not applied to this release path. For the SGTRs where the secondary system SRVs reclose, the distributions for FISG and FOSG were determined by the project staff. For the SGTRs where the secondary system SRVs stick open, the distributions for FISG and FOSG were determined by an ad hoc expert panel. The panel provided distributions for the product FISG * FOSG for iodine, cesium, tellurium, and aerosols. There is no retention in the SGs for the noble gases. Complete distributions for FISG and FOSG are listed in Appendix B.

DFPSL is the decontamination factor for the late pool scrubbing of the CCI release. This DF is applied when the core debris is not coolable and CCI takes place under water. There are two distributions: one applies for a shallow pool (approximately 4 ft deep) that results if only the accumulator water enters the cavity, and the other distribution applies when the sprays are (or were) operating and the cavity is full (14 ft deep). For both the shallow and deep pool distributions, one distribution applies to the iodine, cesium, barium, ruthenium, lanthanum, and cerium radionuclide classes, and another applies to the tellurium and strontium radionuclide classes. The distributions were determined by the NUREG-1150 project staff and are listed in Appendix B.

3.3 Results of Source Term Analysis

This section presents the results of computing the source terms for the APBs produced by evaluating the APET. The APET's evaluation produced a large number of APBs, so, as in Section 2.5, only more likely and more important APBs are discussed here. However, source terms were computed for all the APBs for each of the 200 observations in the sample. The source term is composed of release fractions for the nine radionuclide groups for an early and a late release as well as release timing, release height, and

release energy. As discussed above, the source terms are computed by a fast-running parametric computer code, SURSOR.

Section 3.3.1 presents the results for the internal initiators. Section 3.3.2 discusses the sensitivity analyses run for the internal initiators. The accident progression analysis results for the fire initiators are presented in Section 3.3.3 and sensitivity analyses for fires are presented in Section 3.3.4. The seismic results are given in four sections. The basic results based on the LLNL hazard curve are presented in Section 3.3.5 and sensitivity analyses utilizing the LLNL hazard curve are presented in Section 3.3.6. The seismic results based on the EPRI hazard curve are presented in Section 3.3.7 and sensitivity analyses utilizing the EPRI hazard curve are presented in Section 3.3.8.

The tables in this section present only a very small portion of the output obtained by computing source terms for each APB. More detailed results are contained in Appendix B, and complete listings are available on computer media by request.

3.3.1 Results for Internal Initiators

In a manner analogous to Section 2.5.1, the results of the source term analysis for internal initiators are presented for each PDS group.

3.3.1.1 Results for PDS Group 1: Slow SBO. As discussed in Section 2.5.1.1, this PDS group consists of accidents in which all ac power is lost in the plant, but the steam turbine-driven AFWS operates for several hours. When the batteries deplete, control of the steam turbine-driven AFWS is lost and it fails. This PDS group contains six PDSs: two have the RCS intact at UTAF, two have failure of the RCP seals before UTAF, and two have stuck-open PORVs before UTAF. In four of the six PDSs, the operators depressurized the secondary system before UTAF, and in two PDSs they did not. The PDSs in this group are listed in Table 2.2-2. VB is not inevitable for this PDS group as electric power may be recovered before the vessel fails. Small but nonzero releases are calculated by SURSOR in this case as fission products may escape to the containment through the PORVs or a temperature-induced break before the arrest of core damage. Even though the containment does not fail in core damage arrest cases, design basis leakage results in a very small release.

Table 2.5-1 lists the five most probable APBs for PDS Group 1, the five most probable APBs that have VB, and the five most probable APBs that have VB and early CF. Table 3.3-1 lists the mean source terms for these same APBs. Although the same bins are shown in both tables, and the structures of both tables are roughly analogous, there are some important differences in the nature of the material presented. First, Table 3.3-1 has two designators for each APB. The first designator is the APB definition initially produced in the analysis of the APET; the second designator is the rebinned definition which is used as input to SURSOR. Consider the first APB in Table 3.3-1: HDCDFCDBDFB. Following evaluation of the APET, it was rebinned to GDCDFCDBDDB as discussed in Section 2.4.2. The symbols used in these two representations for each APB are given in Sections 2.4.1 and 2.4.2.

The other difference between the nature of Tables 2.5-1 and 3.3-1 lies in the nature of the information presented. In Table 2.5-1, the bin itself was well defined, i.e., the characteristics of the bin did not vary from observation-to-observation. The only item in the table that varied from observation-to-observation was the probability of the occurrence of the bin itself. Thus, Table 2.5-1 lists a conditional probability averaged over the 200 observations in the sample. In Table 3.3-1, the bin is still well defined, but, as many of the factors that are utilized in calculating the fission product release vary from observation-to-observation, the source term for a specific bin varies with the observation. Thus, the entries in all columns in Table 3.3-1 except the Order and Bin columns represent averages over the 200 observations in the sample.

For example, consider the first APB in Table 3.3-1: GDCDFCDBDDB. Of the 200 observations in the sample, 121 had nonzero conditional probabilities for this bin. As source terms are not computed for zero-probability bins, there are 121 source terms associated with APB GDCDFCDBDDB. These 121 source terms were summed and then divided by 121 to produce the mean source term given in the first two lines of Table 3.3-1.

The five most probable APBs and the five most probable APBs with VB for PDS Group 1 did not have containment failure. As a result, the releases associated with these APBs are very small. When there is no containment failure, SURSOR describes releases with a single release segment rather than the two release segments used when there is containment failure. The five most probable APBs with VB and early containment failure have low conditional probabilities (see Table 2.5-1) but larger releases than the APBs without containment failure. The mean source terms in Table 3.3-1 can be used to compare the releases associated with specific APBs. However, as these mean source terms are typically not calculated over the same sample elements, fine distinctions between source terms associated with different APBs may be lost in the averaging process.

Table 3.3-1 presents mean source terms but does not contain any frequency information. In contrast, Figure 3.3-1 presents information on both source term size and frequency. Figure 3.3-1 summarizes the release fraction CCDFs for for the iodine, cesium, strontium, and lanthanum radionuclide classes. It indicates the frequency with which different values of the release fraction are exceeded, and displays the uncertainty in that frequency. The curves in Figure 3.3-1 are derived in the following manner: for each observation, evaluation of the APET produced a conditional probability for each APB. When multiplied by the frequency of the PDS group for that observation, a frequency for the APB is obtained. Calculation of the source term for the APB gives a total release fraction for each APB. When all the APBs are considered, a curve of exceedance frequency vs. release fraction can be plotted for each observation. Figure 3.3-1 is a summary presentation of these curves for the 200 observations in the sample.

Instead of placing all 200 curves on one figure, only four statistical measures are shown. These measures are generated by analyzing the curves in the vertical direction. For each release fraction on the abscissa, there are 200 values of the exceedance frequency (one for each sample

element). From these 200 values it is possible to calculate mean, median (50th quantile), 95th quantile and 5th quantile values. When this is done for each value of the release fraction, the curves in Figure 3.3-1 are obtained. Thus, Figure 3.3-1 provides information on the relationship between the size of the release fractions associated with PDS Group 1 and the frequency at which these release fractions are exceeded, as well as the variation in that relationship between the observations in the sample.

As an illustration of the information in Figure 3.3-1, the mean frequency (yr^{-1}) at which a release fraction of 10^{-6} is exceeded due to PDS Group 1 is 2×10^{-5}, 1×10^{-6}, 6×10^{-7} and 4×10^{-7} for the iodine, cesium, strontium and lanthanum release classes, respectively. For a release fraction of 0.1, the corresponding mean exceedance frequencies are 1×10^{-7}, 9×10^{-8}, 3×10^{-8} and $< 10^{-9}$, respectively. The three quantiles (i.e., the median, 95th and 5th) provide an indication of the spread between observations, which is often large. Typically, the mean curves reach a point where they drop very rapidly and move above the 95th quantile curve. This happens when the mean curve is dominated by a few large observations; this often occurs for large release fractions because only a few of the sample observations have nonzero exceedance frequencies for these large release fractions. Taken as a whole, the results in Figure 3.3-1 indicate that the occurrence of large source terms (e.g., release fractions ≥ 0.1) in conjunction with PDS Group 1 is very infrequent (less than 10^{-6} for iodine and cesium and less than 10^{-8} for Sr).

3.3.1.2 Results for PDS Group 2: LOCAs. This PDS group consists of accidents initiated by a break in the RCS pressure boundary, as discussed in Section 2.5.1.2. The breaks are of all (A, S_1, S_2, and S_3) sizes. in this group. These PDSs result in core damage because one or more of the ECCS required to respond does not operate. The PDSs in this group are listed in Table 2.2-2. Four of the eight PDSs have the LPIS operating but not injecting at UTAF, so the arrest of core damage before vessel failure is possible as discussed in Section 2.5.1.2. Even though the containment does not fail in these core damage arrest cases, design basis leakage results in small, but nonzero , releases.

Table 2.5-2 lists the 10 most probable APBs for this PDS group and the five most probable APBs that have VB and early containment failure (CF). The five most probable APBs that have VB are included in the 10 most probable bins. Table 3.3-2 lists the mean source terms for these same APBs. The source term consists of the release fractions, the release height and energy, and the times associated with the release. The release fractions give the early (RCS) and late (CCI) releases as fractions of the core inventory at the start of the accident. However, when there is no CF, or CF only in the final period due to BMT or overpressure, SURSOR sets the early release to zero and places the entire release into the late release portion. The three times (all in seconds) in Table 3.3-2 are the time the warning is given to evacuate the surrounding area, the time the release starts, and the duration of the release. The elevation of the release is given in meters, and the energy in watts.

Eight of the 10 most probable APBs for PDS Group 2 did not have containment failure and the releases associated with these APBs are extremely small. The other two of the 10 most probable APBs had BMT in the final period. The releases for these APBs are larger than those with no containment failure, but still quite small. The five most probable APBs with VB and early CF have lower conditional probabilities (see Table 2.5-2) but larger releases than the APBs without containment failure. As with the APBs for PDS Group 1 that have VB and CF at VB, some of these APBs give rise to source terms in which the mean release fractions for iodine and cesium exceed 0.10.

Figure 3.3-2 summarizes the release fraction CCDFs, and shows that the frequency at which iodine and cesium release fractions of 0.10 are exceeded are quite low, even at the 95th percentile. As would be expected, accidents that result in large releases are much more unlikely than those that result in small releases.

3.3.1.3 Results for PDS Group 3: Fast SBO. This PDS group consists of accidents in which all ac power is lost in the plant and the steam turbine-driven AFWS fails at, or shortly after, the start of the accident. As discussed in Section 2.5.1.3, the Fast SBO PDS group consists of only one PDS, TRRR-RSR. As in the Slow SBO PDS group, if offsite electrical power is recovered for a Fast SBO accident before the vessel fails, it may be possible to arrest the core degradation process and avoid vessel breach. Table 2.5-3 lists the five most probable APBs for the Fast SBO PDS group, the five most probable APBs that have VB, and the five most probable APBs that have VB and early containment failure (CF). Table 3.3-3 lists the mean source terms for these same APBs. The source term consists of the release fractions, the release height and energy, and the times associated with the release.

For the Fast SBO PDS group, the five most probable bins all have very low source terms. All five APBs have no CF, and three of them have no VB as well. Three of the five most probable bins that have VB have no CF; the other two have BMT. The release fractions for the APBs with BMT are low as the failure of the containment occurs only after many days and the release point below ground. Because of the nature of this type of CF, not much effort has been devoted to estimating their value and they may be much lower than shown. As discussed above, for no CF or CF in the final period, the early release is zero and the late release contains the entire amount estimated to pass to the atmosphere.

The five most probable Fast SBO APBs with VB and early CF have lower conditional probabilities (see Table 2.5-3) but larger releases than the APBs without containment failure. Some of these APBs give rise to source terms in which the mean release fractions for iodine and cesium exceed 0.10, but Figure 3.3-3 shows that the frequency at which iodine and cesium release fractions of 0.10 are exceeded are quite low, even at the 95th percentile.

3.3.1.4 Results for PDS Group 4: Event V. As discussed in Section 2.5.1.4, this PDS group consists of accidents in which the check valves between the RCS and the LPIS fail. Failure of the low pressure piping

produces a direct path from the RCS to the auxiliary building, bypassing the containment, and fails the LPIS as well. Experts considering the break location in the LPIS concluded that the probability was 0.85 that it would be low enough in the auxiliary building that the water from the RCS and the RWST, escaping through the break, would form a pool covering the break by the time when core degradation commenced. This pool can remove and retain a significant portion of the release. When the release is scrubbed by a water pool over the break location, the accident is termed V-Wet, and when there is no pool it is termed V-Dry. There is no possibility of avoiding VB or CCI in this PDS group. Due to the size of the containment bypass, containment failure is not of much interest.

Table 2.5-4 lists the eight most probable APBs for the V PDS Group and Table 3.3-4 lists the mean source terms for these same APBs. The source term consists of the release fractions, the release height and energy, and the times associated with the release. The four most probable bins are V-Wet and the next four are V-Dry. (The probability of the break location being under water is between 0.70 and 1.0.) The V-Wet release fractions are considerably lower than the V-Dry release fractions as expected.

The release fraction CCDF summary curves in Figure 3.3-4 shows that the frequency at which iodine and cesium release fractions of 0.10 are exceeded are below 10^{-6}/yr. Because this accident bypasses the containment, if it occurs the releases are likely to be substantial.

3.3.1.5 Results for PDS Group 5: Transients. This PDS group consists of accidents in which the RCS is intact but there is no way to remove heat from the core (see Section 2.5.1.5). The AFWS fails at the start of the accident; bleed and feed is ineffective. In PDS TBYY-YNY, HPIS and LPIS are available but the operators cannot open the PORVs from the control room or have failed to do so before the onset of core damage. In the other PDS in this group, TLYY-YNY, HPIS is failed but the LPIS is operable. In this PDS group, the probability of a temperature-induced failure of the RCS pressure boundary is quite high--almost 0.90. Since the LPIS is operating at the onset of core damage, the probability of arresting the core degradation process and avoiding VB is high.

Table 2.5-5 lists the 10 most probable APBs for the PDS group and the five most probable APBs that have VB and early CF. The five most probable APBs that have VB are included in the 10 most probable bins. Table 3.3-5 lists the mean source terms for these same 15 APBs. The 10 most probable bins all have no CF, and their release fractions are so low as to be negligible in an overall risk context.

The five most probable Transient APBs with VB and early CF have lower conditional probabilities (see Table 2.5-5) but larger releases than the APBs without containment failure. Some of these APBs give rise to source terms in which the mean release fractions for iodine and cesium exceed 0.10, but Figure 3.3-5 shows that the frequency at which iodine and cesium release fractions of 0.10 are exceeded are quite low, even at the 95th percentile.

3.3.1.6 Results for PDS Group 6: ATWS. This PDS group consists of accidents in which automatic control rod insertion fails to bring the nuclear reaction under control. The discussion in Section 2.5.1.6 points out that this PDS group consists of three PDSs, one with the RCS intact at UTAF, one with an S_3 break, and one with an SGTR. In all three situations, the PORVs will be open at UTAF due to the rate of steam generation in the core. The LPIS is operating but not injecting in the RCS-intact and SGTR PDSs. A temperature-induced break in the RCS, however, will allow the LPIS to inject successfully. The water from the RWST injected by the LPIS contains enough boron to shut down the reaction should the core be in a configuration where continued reaction is possible.

Table 2.5-6 lists the 10 most probable APBs for the PDS group and the five most probable APBs that have VB and early CF or bypass, and Table 3.3-6 lists the source terms calculated for these same 15 APBs. The six most probable bins have no failure of the containment and thus have very low releases. The seventh and tenth most probable bins have bypass of the containment (SGTR) and therefore have substantial releases although they have no VB due to the operation of the LPIS throughout the accident. Even in the absence of VB, SURSOR may calculate significant releases in these SGTR accidents since the core degradation may not be arrested until it is quite well advanced. By this time, a substantial portion of the fission products may have been released from the core. The five most probable APBs with VB and early CF or bypass all have SGTR and no CF. Whether the vessel fails or not does not have a large effect on the computed release fractions. Figure 3.3-6 shows that the frequency at which iodine and cesium release fractions of 0.10 are exceeded are fairly low for this PDS group in spite of the contribution from the SGTR initiators.

3.3.1.7 Results for PDS Group 7: SGTRs. As discussed in Section 2.5.1.7, this PDS group consists of accidents in which the initiating event is the rupture of a steam generator tube and the reaction is shut down successfully. In two of the PDSs in this group, the RCS is depressurized quickly using the two unaffected SGs according to procedures and the SRVs on the main steam lines from the affected SG do not stick open. These accidents, denoted "G" SGTRs, are indicated by "SGTR" in the SGTR column of Table 2.5-7. In the other two PDSs in the SGTR PDS group, the RCS is not depressurized in a timely fashion, and the SRVs on the main steam line from the affected SG stick open. These accidents, denoted "H" SGTRs, are indicated by "SRVO" in the SGTR column of Table 2.5-7. Since all the APBs for this PDS group have bypass of the containment, Table 2.5-7 lists the 15 most probable APBs. Only two of the 15 most probable bins have the SRVs reclosing; the other 13 bins result from the "H" SGTR accidents in which the secondary SRVs are stuck open. PDS HINY-NXY has a higher frequency than the other three PDSs in this group combined.

Table 3.3-7 lists the mean source terms for the same 15 APBs listed in Table 2.5-7. All the most probable APBs have fairly substantial release fractions. Note that the start of the release is about 14 h after the start of the accident for the "H" SGTRs. The evacuation warning time is estimated to be much earlier than this so there is time for the evacuation to be completed. Thus few early fatalities are to be expected in spite of the mean iodine release fractions over 0.10. Figure 3.3-7 shows that the

mean exceedance frequencies for which iodine and cesium release fractions of 0.10 are below 10^{-6}/yr. Because this accident bypasses the containment, if it occurs the releases are likely to be substantial.

3.3.1.8 Results for Summary Accident Progression Bins. The preceding seven subsections presented the source term results by PDS group. It is also possible to group the source terms in other ways. These other groupings are called summary APBs. These summary APBs generally group accidents by the cause and time of containment failure. The bypass accidents are treated separately.

Figure 3.3-8 shows the variation of the exceedance frequency with release fraction for the iodine, cesium, strontium, and lanthanum radionuclide classes for all the APBs which had an Alpha mode failure of the vessel and containment. (In an Alpha mode failure, an extremely energetic molten fuel-coolant interaction in the vessel fails the vessel and simultaneously generates a missile that fails the containment pressure boundary.) None of the APBs included in Figure 3.3-8 were initiated by a bypass event. Figure 3.3-8 shows that the frequency of a sizeable release from an Alpha event is quite low. The curves for iodine and cesium in this figure indicate that there is a great range in the frequency of the Alpha event itself, but that, if the event occurs, the release fraction is likely to exceed 0.01.

Figure 3.3-9 shows the variation of the exceedance frequency with release fraction for all the APBs in which the containment failed at VB with the RCS at high (> 200 psia) pressure at the time of VB. CF at VB with the vessel at high pressure indicates that direct containment heating (DCH) made a large contribution to the pressure rise in the containment at VB. Without a substantial pressure rise due to DCH, CF at VB is quite unlikely as CF due to hydrogen combustion and vessel blowdown alone is improbable. For each of the radionuclide classes, the mean curve lies above the 95th percentile curve. This indicates that the mean is largely determined by a few observations that have very large releases. Since the conditional probability of CF at VB due to DCH was found to be fairly low in the APET evaluation, this is not surprising.

Figure 3.3-10 shows the variation of the exceedance frequency with release fraction for all the APBs in which the containment failed at VB with the RCS at low (< 200 psia) pressure at the time of VB. CF at VB with the RCS at such low pressures is quite unlikely since the pressure contribution from DCH is negligible. Figure 3.3-10 shows that the frequencies of CF at VB with the RCS at low pressure are less than those for CF at VB with the RCS at high pressure. Neither Figure 3.3-9 nor Figure 3.3-10 include APBs due to bypass events (V or SGTR).

Figure 3.3-11 considers all the APBs in which the containment failed some hours or days after the vessel failed. Some of these failures are due to hydrogen burns a few hours after VB, or to eventual overpressure due to lack of containment heat removal, but most result from BMT. The figure shows that these types of CF are much more frequent than CF at VB, but that the release fractions are likely to be an order of magnitude or more lower.

Figures 3.3-12 and 3.3-13 show the variation of the exceedance frequency with release fraction for Event V. All the source terms for the V-Dry APBs were analyzed to produce Figure 3.3-12, while all the source terms for the V-Wet APBs were analyzed to produce Figure 3.3-13. As expected, the V-Dry release fractions are larger than the V-Wet release fractions due to the absence of the overlying water pool in the V-Dry accidents. The V-Dry releases are, however, about an order of magnitude less likely than the V-Wet releases.

Figures 3.3-14 and 3.3-15 consider all the APBs with SGTRs. Almost all these SGTRs are initiating events; there is a very small portion of these APBs that result from temperature-induced SGTRs following the onset of core damage. (The temperature-induced SGTRs are all "G: SGTRs, i.e., the secondary SRVs reclose.) As indicated by the discussion in subsection 2.5.1.6 and 3.3.1.6, the "H" SGTRs are both more likely and more deleterious than the normal "G" SGTRs.

3.3.1.9 Summary. When all the types of internally-initiated accidents at Surry are considered together, the exceedance frequency plots shown in Figure 3.3-16 are obtained. A plot is not shown for the noble gases since almost all of the noble gases (xenon and krypton) in the core are eventually released to the environment whether the containment fails or not. The mean frequency of exceeding a release fraction of 0.10 for iodine, cesium, and tellurium is on the order of 10^{-6}/year. The mean exceedance frequency for release of 0.10 of the core strontium is somewhat lower. The second sheet of Figure 3.3-16 shows the release fractions for ruthenium, lanthanum, cerium, and barium, which are often treated together as aerosol species. The mean frequency of exceeding a release fraction of 0.01 for these radionuclide classes is on the order of 10^{-6}/year. The releases for the barium class are slightly higher than those for the other three aerosol radionuclide classes.

3.3.1.10 Contributors to Uncertainty. Figure 3.3-16 provides information on the frequency at which release fractions of different sizes will be exceeded. Specifically, mean, median, 95th quantile, and 5th quantile values are given for the frequency at which release fractions will be exceeded. Thus, Figure 3.3-16 can be viewed as presenting uncertainty analysis results for exceedance frequencies. The underlying exceedance frequency curves that gave rise to these results are shown in Section B.3 of Appendix B.

As the curves in Figure 3.3-16 and in Appendix B.3 show, there is significant uncertainty in the frequency at which a release fraction will be exceeded. Due to the complexity of the underlying analysis and the concurrent variation of a large number of variables within this analysis, it is difficult to ascertain the cause of this uncertainty on the basis of a simple inspection of the results. However, numerical sensitivity analysis techniques provide a systematic way of investigating the observed variation in exceedance frequencies.

This section presents the results of using regression-based sensitivity analysis techniques to examine the variability associated with radionuclide releases to the environment. Two dependent variables will be considered

for individual radionuclide release classes. The first dependent variable is the annual release fraction (units: fraction/yr) for a radionuclide release class. This variable is the fraction of the inventory associated with a release class that is expected to be released each year. For a given sample element, this variable is obtained by multiplying the release fraction associated with each accident progression bin by the bin's frequency and then summing these products. This variable can be viewed as the result of reducing each of the curves in Figure B.3-1 to a single number. Further, this variable is analogous to the mean consequence results (units: consequence/yr) presented in Chapter 5.

The second dependent variable is the exceedance frequency associated with individual release fractions. As can be seen from the curves in Figure B.3-1, there are 200 exceedance frequencies (i.e., one for each sample element) associated with each release fraction for individual radionuclide release classes. For a given sample element, release fraction and radionuclide release class, the exceedance frequency is obtained by summing the frequencies of all accident progression bins that result in release fractions as large or larger than the one under consideration.

The uncertainty analysis techniques used in this study can be viewed as creating a mapping from analysis input to analysis results. The variables sampled in the generation of this mapping are presented in Tables 2.2-9, 2.3-2, and 3.2-2. For convenience, these variables are also summarized in Table 3.3-8 of this section. The variables listed in Table 3.3-8 are the independent variables in the sensitivity studies presented in this section. A series of correlated variables is represented by one variable. For example, although there are variables for three cases for core damage arrest, CDARREST, they are all correlated together (with a rank correlation of 1.0) and only one variable appears in the sensitivity analysis and in Table 3.3-8. The greatest collapse of this type is for the pressure rise at VB, variable PRISE-VB. The 18 variables for the cases other than low pressure have a rank correlation of 1.0 and appear as one variable in Table 3.3-8. Note that variable FR-ZROX from Table 2.3-2 does not appear in Table 3.3-8. FR-ZROX has a rank correlation of 1.0 with TI-HOTLG, so only one of these two variables appears in the sensitivity analysis. As TI-HOTLG appears in the APET before FR-ZROX, TI-HOTLG was chosen to represent both variables.

Sensitivity analysis results for annual release fractions are presented in Table 3.3-9. Specifically, this table contains the results of performing a stepwise regression on the annual release fraction for each radionuclide release class. This analysis was performed with the STEP program.[1] In the analysis, a variable was required to be significant at 0.02 α-level to enter a regression model and to remain significant at the 0.05 α-level to be retained in a regression model. Further, the behavior of the PRESS criterion[2] and individual R^2 values were considered in selecting the actual stopping points for the presented regressions. The PRESS criterion is used to assure that the selected regression model is not overfitting the data on which it is based. The analyses were tried with raw (i.e., untransformed) and rank-transformed data.[3] The analyses with rank-transformed data consistently performed as well as or better than the analyses with raw data. Therefore, Table 3.3-9 only presents the results of regression analyses performed with rank-transformed data.

Table 3.3-9 presents the results of a stepwise regression analysis for each radionuclide release class. For each release class, the variables are listed in the order that they entered the regression analysis. Further, the table also gives the standardized regression coefficients for the variables in the final regression model and the R^2 values that result with the entry of successive variables into the model. Variable importance is indicated by the order in which variables entered a regression, the change in R^2 values with the entry of successive variables, and the size of the standardized regression coefficients in the final regression model. Further, the tendency of a dependent variable to increase and decrease with an independent variable is indicated by a positive regression coefficient, and the tendency of a dependent variable to decrease when an independent variable increases is indicated by a negative regression coefficient.

Table 3.3-9 shows that the release rates for the more volatile radionuclide classes to be more affected by the variables that determine the accident frequency (e.g., V-TRAIN, IE-SGTR) and for the less volatile radionuclide classes to be more affected by the variables that determine the amounts released (e.g., FCOR, FISGFOSG). For the noble or inert gases, the first seven variables selected in the regression analysis are all related to the accident frequency, and the source term variables have a very small impact. This reflects the fact that all of the noble gases are released eventually in almost every core damage accident. Thus, it is the frequencies of the accidents themselves that are important. (DG-FSTRT, IE-LOSP, and DG-FRUN are important variables in determining the frequency of the SBOs.) The other extreme is ruthenium, where 85% of the variability is accounted for by FCOR and FISGFOSG. This pattern arises because the least volatile fission products are easily removed by both natural and engineered removal mechanisms. Thus the variability in the factors that determine the amount released are important. For iodine and cesium, the most important variables are FISGFOSG, IE-SGTR, V-TRAIN, and FCOR. This reflects the importance of the bypass accidents when the total amount released is the primary measure under consideration.

The fraction of the variability in the annual release rates which the regression models presented in Table 3.3-9 can explain ranges from 0.51 for the noble gases to 0.89 for ruthenium. For most of the radionuclide classes, the regression model accounts for 0.70 to 0.80 of the variability. There is a definite trend for the explained variability to increase as the volatility of the radionuclide class decreases. This implies that a less complex regression model is more suitable for these fission products, which in turn may be due to the importance of removal mechanisms in the RCS.

Nonlinear regression models were also utilized. By including cross-product variables in the regression analysis, the amount of the variability accounted for could be increased moderately for noble gases, iodine, cesium, and tellurium. The important product variables are V-INIT * FCOR, SG-INIT * FCOR * FISGFOSG, and DG-FSTRT * IE-LOSP. The product SG-INIT * FCOR * FISGFOSG is the first variable chosen for iodine, cesium and tellurium. For cesium and tellurium this variable alone accounts for 60% of the variability.

The results given in Table 3.3-9 come from a regression analysis of the annual release rates, which might also be denoted expected release fraction rates. Annual release rates are obtained by reducing each of the curves shown in Appendix B.3 to a single value with the units of fraction/year. Forming the annual release rates produces a single value for each observation and each radionuclide class which incorporates both the size and frequency of the release. Although this single number is useful, in forming it, all information about the relationship between size of the release and the frequency of the release is lost. The release fraction CCDFs shown in Appendix B.3 are more basic results than the annual release rates analyzed to produce Table 3.3-9.

Because of the importance of the release fraction CCDFs, a sensitivity analysis was performed to determine which variables controlled the frequency at which release fractions are exceeded. Partial rank correlation coefficients (PRCCs) were calculated between the sampled variables and the frequency at which release fractions are exceeded.[4]

A partial correlation coefficient (PCC) provides a measure of the strength of the linear relationship between two variables after the linear effects of all other variables in the analysis have been removed. A PCC close to 1.0 means that both variables increase and decrease together; a PCC close to -1.0 means that one variable increases while the other decreases; a PCC close to 0.0 means that there is little relationship between the behavior of the two variables. Conceptually, a PCC between two variables is obtained by constructing a regression model for the two variables. The PCC is then defined to be the positive square root of the R^2 value multiplied by the sign of the regression coefficient. Further, when the two variables under consideration are correlated with other variables in the analysis, a correction is made for this correlation before the regression model is constructed.[4] A PRCC instead of a PCC results when a PCC is calculated from rank-transformed data. The PRCC reduces the effects of nonlinearities and outliers relative to the PCC.

The PRCC analyses performed for Surry are based on the same data used to construct the mean and quantile curves for the radionuclide classes that are shown in Figure 3.3-16. The starting point is the family of 200 exceedance frequency curves shown in Appendix B.3. Each curve represents one observation in the sample; so for each release fraction on the abscissa there are 200 exceedance frequencies. For each value on the release fraction axis, the PCCSRC program[4] calculates the PRCCs between the exceedance frequency and the individual variables listed in Table 3.3-8. The results of this computation are presented as curves on a plot in which the abscissa is the release fraction and the ordinate is the value of the PRCC. Such curves are presented in Figures 3.3-17, 3.3-18, 3.3-19, and 3.3-20 for iodine, cesium, strontium, and lanthanum radionuclide classes. To reduce the number of curves plotted, a variable is included in these plots only if the maximum absolute value of its PRCC exceeds 0.50.

Figure 3.3-17 presents the results of the PRCC analysis for iodine. The curves for the important variables have been placed on two plots instead of one to make the results easier to read. For small release fractions, the

variability in the exceedance frequency is dominated by variables that determine the frequency of SBO accidents,; but for large release fractions, this variability is dominated by variables that determine the frequency of bypass accidents (V-TRAIN, IE-SGTR) and source term variables (FCOR, FISGFOSG, FCONV). The curves for all the PRCCs approach 0.0 as the release fraction approaches 1.0 because the exceedance frequencies approach 0.0 as the release fraction approach 1.0 for all observations in the sample. For some sample elements and for some radionuclide groups, the exceedance frequencies reach 0.0 for release fractions substantially below 1.0.

The bimodal form taken by the PRCC curve for LATEI in Figure 3.3-17 is very interesting. The high values of the PRCC for LATEI for release fractions between 3×10^{-6} and 3×10^{-4} coincide with the highest releases for no containment failure. (For no CF, there is a small release due to design basis leakage even though the containment remains intact.) The largest iodine releases for no containment failure are predominantly due to late revolatilization, since these releases are in volatile forms that are not affected by removal mechanisms. As a result, the uncertainty in the release fractions depends strongly on LATEI in this region. The low values of the PRCC for LATEI between 3×10^{-4} and 3×10^{-3} occur in a range in which very few releases occur. Iodine release fractions tend to be below 3×10^{-4} for no CF, and above 3×10^{-3} for CF. Iodine release fractions for late CF are usually between 3×10^{-3} and 10^{-1}, and iodine release fractions for bypass or early CF are usually between 10^{-2} and 1. Thus, the high values of the PRCC for LATEI between 3×10^{-3} and 10^{-1} coincide with the releases due to late containment failure. This agrees with the observation that iodine releases for late CF (late hydrogen burn, eventual overpressure, or BMT) are often dominated by the late revolatilization release.

Figure 3.3-18 presents the results of the PRCC analysis for the cesium radionuclide class. For small release fractions, the variability in the exceedance frequency is dominated by variables that determine the frequency of SBO (IE-LOSP, DG-FSTRT) and by variables that determine the frequency of bypass accidents (V-TRAIN, IE-SGTR). SPRDF is also important for the very lowest release fractions, since the sprays are very effective in reducing the size of the releases. The bypass initiator variables continue to be important in the middle range of the release fractions. For the highest release fractions, source term variables are the the most important.

Figure 3.3-19 presents the results of the PRCC analysis for Sr. For small release fractions, the variability in the exceedance frequency is dominated by variables that determine the frequency of bypass accidents (V-TRAIN, IE-SGTR). FCCI is also important for the very lowest release fractions. In contrast to the situation for iodine and cesium, none of the variables that determine the frequency of SBO (IE-LOSP, DG-FSTRT) are important for strontium. The source term variables FCOR and FCCI are the most important variables at the higher release fractions.

Figure 3.3-20 presents the PRCC results for the lanthanum radionuclide class. This figure looks much like that for strontium, but compressed to the left since the fission products in the lanthanum group are less volatile than strontium. For small release fractions, the variability in the exceedance frequency is dominated by bypass initiators; for large

release fractions FCOR and FCCI are the most important variables. The PRCC curves all drop to 0.0 at a release fraction of about 0.20 since that is the highest release fraction computed for the lanthanum group in any observation in the sample.

Plots similar to Figures 3.3-17, 3.3-18, 3.3-19, and 3.3-20 can also be generated for standardized rank regression coefficients (SRRCs). Since SRRCs are always less than PRCCs for uncorrelated variables, plots of PRCCs are more spread out and therefore easier to read. As PRCCs and SRRCs have the same intuitive, although not literal, interpretation, only plots of PRCCs have been prepared. Additional discussion of the relationship between PRCCs and SRRCs may be found in Reference 4.

3.3.2 Results of Second Sample for Internal Initiators

The probabilistic risk assessments in this report use Monte Carlo (i.e., Latin Hypercube)[5] techniques in the propagation of uncertainties. It is desirable to have an estimate of the sampling variability that results from propagating uncertainties in this manner. Unfortuntely, a theoretical basis does not exist for obtaining such an estimate for the use of Latin Hypercube Sampling in conjunction with an arbitrary model. However, it is possible to see the effects of the sampling process by performing an analysis with two independently generated samples and then comparing the results obtained with these two samples. This section presents such a comparison for source term results obtained in the analysis of internal initiators at Surry.

The source term results for internal initiators at Surry are summarized in Section 3.3.1.9. Specifically, Figure 3.3-16 gives mean, median, 5th quantile and 95th quantile curves for exceedance frequencies associated with individual release fractions. In turn, the curves in Figure 3.3-16 are summaries of the more detailed results in Figure B.3-1. The individual curves in Figure B.3-1 result from propagating a Latin Hypercube sample of size 200 through the probabilistic risk assessment for internal initiators. This sample is based on the variables in Table 3.3-8 (see also Tables 2.2-9, 2.3-2, and 3.2-2). Each curve in Figure B.3-1 is derived from a single element of the Latin Hypercube Sample, and as a result, the curves in Figure 3.3-16 provide a summary of the results obtained with the entire sample. Thus, examination of the effects of two independent samples on the curves in Figure 3.3-16 provides a way to investigate the impact of the sampling procedures being used.

To this end, a second sample of size 200 was generated (using the same variables as in the first sample) and then propagated through the analysis. This resulted in a second set of curves of the form shown in Figure B.3-1 and in a corresponding set of summary curves of the form shown in Figure 3.3-16. For ease of comparison, the original summary curves appearing in Figure 3.3-16 and the analogous summary curves generated with the second sample are plotted together in Figure 3.3-21.

The similarity of the corresponding curves in Figure 3.3-21 shows that very little uncertainty is being introduced into the analysis by the sampling process. Specifically, the median and mean curves are very similar; the 5th and 95th quantiles are also quite similar but show more variability than the median and mean curves. Overall, the median curve is most stable, although the mean curve is also quite stable, with this stability decreasing somewhat for larger release fractions. The 5th and 95th quantile curves are less stable than the median and mean curves because they are effectively determined by a smaller number of the sample elements. Similarly, the mean curve tends to be less stable for the larger release fractions because the exceedance frequencies for most sample elements are then zero and so the mean value is driven by a small number of nonzero values.

A stepwise regression on the annual release fraction was also performed for the second sample for internal initiators. Each radionuclide release class was analyzed with the STEP program[1] and results analogous to those in Table 3.3-9 were obtained. The analysis is described in Section 3.3.1.10 above. Table 3.3-10 compares the results of the stepwise regression analyses for the first and second sample for four radionuclide classes: noble gas, iodine, strontium, and lanthanum. As for Table 3.3-9, the analyses were performed with rank-transformed data.

Variable importance is indicated by the order in which variables entered a regression, the change in R^2 values with the entry of successive variables, and the size of the standardized regression coefficients in the final regression model. Table 3.3-10 shows that the larger contributors are similar in both samples. There is considerable variation between the samples for variables whose inclusion increases R^2 by only 0.02 or 0.01. The stepwise regression analysis accounts for more of the variablility for the volatile radionuclide classes for Sample 2 than it does for Sample 1. For all the radionuclide classes, the first four variables that enter the analysis for Sample 1 are the same as those for Sample 2, although the order may be different as in the results for noble gas in Table 3.3-10. The differences in the R^2 values due to the first four variables are pronounced only for noble gas and iodine. Cesium and tellurium are more like strontium is that the R^2 values for the first four variables for Sample 1 and Sample 2 are very close.

Based on the release fraction CCDFs, PRCCs were also calculated for Sample 2 and curves equivalent to those shown in Figures 3.3-17 through 3.3-20 were obtained. Figure 3.3-22 compares the PRCC curves for two representative variables for the iodine release fractions. The curves are quite similar. The reasons for the bimodal form taken by the PRCC curve for LATEI are discussed in Section 3.3.1.10. The bimodal form observed for Sample 1 is closely reproduced by Sample 2.

The PRCC results based on analysis of the CCDFs give generally closer agreement between the two samples than the stepwise regression results based on the mean annual release. This is due to the fact that much information is lost in forming the annual release values. The annual release value has contributions from the relatively frequent small releases as well as the very unlikely large releases. Figures 3.3-17 through 3.3-20

show that the variables which account for the most uncertainty for large releases are usually different than those that are the largest contributors for small releases. Therefore it is not surprising that the agreement between the two samples is closer for the PRCC curves based on the CCDFs than it is for the stepwise regression coefficients based on the annual release rates.

This comparison of results for two independent samples is continued in Section 5.1.2 where final risk results are compared. As in this section, the results for the two samples are very similar, indicating that little imprecision is being introduced into the analysis by the sampling process itself.

Table 3.3-1
Mean Source Terms for Surry
Internal Initiators. PDS Group 1: Slow SBO

Order	Bin	Warning Time (s)	Elevation (m)	Release Energy (W)	Release Start (s)	Release Duration (s)	Release Fractions								
							NG	I	Cs	Te	Sr	Ru	La	Ce	Ba
Five Most Probable Bins*															
1	HDCDFCDBDFB	2.2E+04	0.0E+00	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	GDCDFCDBDDB			0.0E+00	4.7E+04	8.6E+04	4.2E-03	4.5E-05	1.4E-09	7.1E-10	9.0E-11	3.1E-11	5.1E-12	2.0E-11	1.1E-10
2	HDCDFCDADFB	2.2E+04	0.0E+00	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	GDCDFCDADDB			0.0E+00	4.7E+04	8.6E+04	3.9E-03	3.9E-05	8.1E-10	3.2E-10	5.7E-11	1.1E-11	3.4E-12	1.5E-11	6.5E-11
3	HDCDFCDADFA	2.2E+04	0.0E+00	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	GDCDFCDADDA			0.0E+00	4.7E+04	8.6E+04	4.1E-03	3.7E-05	7.0E-10	2.5E-10	1.4E-11	5.3E-12	7.5E-13	2.5E-12	2.0E-11
4	HDCCFCDBDFA	2.2E+04	0.0E+00	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	GDCCFCDBDDA			0.0E+00	4.7E+04	8.6E+04	4.4E-03	3.5E-05	1.2E-09	6.1E-10	6.0E-11	2.3E-11	2.9E-12	9.7E-12	7.4E-11
5	HFADBCABDFA	2.2E+04	0.0E+00	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	GFADBCABDDA			0.0E+00	4.7E+04	8.6E+04	5.0E-03	1.9E-04	5.2E-09	3.2E-09	8.8E-10	7.5E-11	1.0E-10	1.2E-10	7.4E-10
Five Most Probable Bins That Have VB*															
5	HFADBCABDFA	2.2E+04	0.0E+00	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	GFADBCABDDA			0.0E+00	4.7E+04	8.6E+04	5.0E-03	1.9E-04	5.2E-09	3.2E-09	8.8E-10	7.5E-11	1.0E-10	1.2E-10	7.4E-10
10	HFADBCAADFB	2.2E+04	0.0E+00	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	GFADBCAADDB			0.0E+00	4.7E+04	8.6E+04	5.0E-03	1.8E-04	3.9E-09	2.3E-09	7.0E-10	3.0E-11	7.0E-11	9.8E-11	6.2E-10
14	HDCDBCDADFB	2.2E+04	0.0E+00	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	GDCDBCDADDB			0.0E+00	4.7E+04	8.6E+04	5.0E-03	7.9E-05	1.9E-09	7.7E-10	1.1E-10	2.2E-11	6.9E-12	3.0E-11	1.3E-10
15	HDCDBCDBDFB	2.2E+04	0.0E+00	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	GDCDBCDBDDB			0.0E+00	4.7E+04	8.6E+04	5.0E-03	9.1E-05	3.1E-09	1.5E-09	1.8E-10	6.1E-11	1.0E-11	4.0E-11	2.2E-10
16	HGADBCABDFB	2.2E+04	0.0E+00	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	GGADBCABDDB			0.0E+00	4.7E+04	8.6E+04	5.0E-03	1.6E-04	4.4E-09	2.5E-09	6.0E-10	6.8E-11	6.5E-11	9.3E-11	5.3E-10
Five Most Probable Bins That Have VB and Early CF*															
64	DHADDCBADBB	2.2E+04	1.0E+01	2.8E+07	2.8E+04	2.0E+02	8.8E-01	2.7E-01	2.4E-01	5.5E-02	1.5E-02	2.6E-03	1.0E-03	5.5E-03	1.6E-02
	DHADDCBADBB			1.6E+06	2.9E+04	2.2E+04	1.2E-01	5.4E-02	4.2E-02	1.0E-01	2.7E-02	1.2E-04	2.6E-03	2.8E-03	2.2E-02
73	DHADDCBBDBB	2.2E+04	1.0E+01	2.8E+07	2.8E+04	2.0E+02	9.1E-01	3.1E-01	2.8E-01	8.7E-02	1.9E-02	4.2E-03	1.3E-03	6.0E-03	2.1E-02
	DHADDCBBDBB			1.6E+06	2.9E+04	2.2E+04	9.3E-02	5.5E-02	4.3E-02	9.1E-02	2.7E-02	3.7E-04	3.0E-03	3.1E-03	2.0E-02
95	DFACACABACB	2.2E+04	1.0E+01	5.2E+05	2.8E+04	1.0E+03	7.5E-01	1.8E-01	1.7E-01	1.3E-01	1.1E-01	2.4E-02	1.3E-02	6.0E-02	1.1E-01
	DFACACABACB			1.6E+05	2.9E+04	2.2E+04	2.5E-01	7.9E-02	5.9E-02	4.3E-02	3.8E-02	8.0E-03	4.3E-03	2.0E-02	3.8E-02
145	DFAAACAAABA	2.2E+04	1.0E+01	2.8E+07	2.8E+04	2.0E+02	9.9E-01	1.1E-01	1.2E-01	3.4E-02	1.0E-02	1.5E-02	4.4E-03	4.3E-03	1.3E-02
	DFAAACAAABA			1.6E+05	2.9E+04	2.2E+04	7.6E-03	1.5E-02	1.7E-04	7.3E-03	5.1E-03	2.5E-05	5.9E-04	6.1E-04	4.3E-03
172	DFADBCAADCB	2.2E+04	1.0E+01	5.2E+05	2.8E+04	1.0E+03	7.2E-01	7.8E-03	4.7E-03	6.6E-04	7.8E-06	6.7E-11	6.7E-11	6.7E-11	1.3E-05
	DFADBCAADCB			1.6E+05	2.9E+04	2.2E+04	2.8E-01	8.2E-03	1.6E-03	2.9E-04	5.9E-06	2.3E-11	8.1E-08	1.1E-07	7.0E-06

* A listing of source terms for all bins is available on computer media

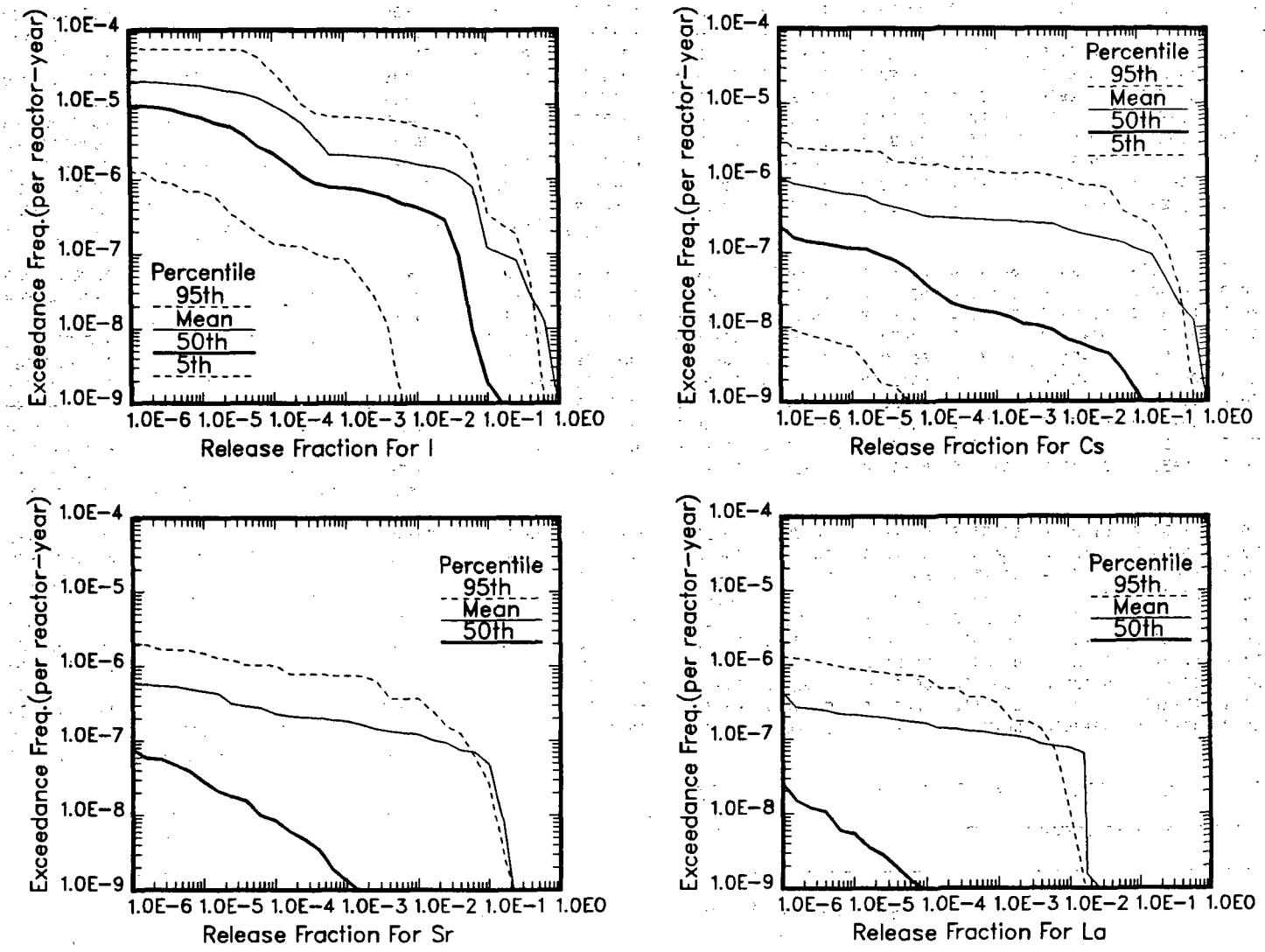


Figure 3.3-1. Exceedance Frequencies for Release Fractions for Surry Internal Initiators. PDS Group 1: Slow SBO

Table 3.3-2
Mean Source Terms for Surry
Internal Initiators. PDS Group 2: LOCAs

Order	Bin	Warning Time (s)	Elevation (m)	Release Energy (W)	Release Start (s)	Release Duration (s)	Release Fractions								
							NG	I	Cs	Te	Sr	Ru	La	Ce	Ba
Ten Most Probable Bins*															
1	HDCDFCDADFB	2.2E+04	0.0E+00	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	DCDFCDADDB			0.0E+00	4.7E+04	8.6E+04	3.9E-03	3.9E-05	8.1E-10	3.2E-10	5.7E-11	1.1E-11	3.4E-12	1.5E-11	6.5E-11
2	HDCDBCDADFB	2.2E+04	0.0E+00	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	GDCDBCDADDB			0.0E+00	4.7E+04	8.6E+04	5.0E-03	7.9E-05	1.9E-09	7.7E-10	1.1E-10	2.2E-11	6.9E-12	3.0E-11	1.3E-10
3	HDCDFCDBDFB	2.2E+04	0.0E+00	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	GDCDFCDBDDB			0.0E+00	4.7E+04	8.6E+04	4.2E-03	4.5E-05	1.4E-09	7.1E-10	9.0E-11	3.1E-11	5.1E-12	2.0E-11	1.1E-10
4	HDCDBCDBDFB	2.2E+04	0.0E+00	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	GDCDBCDBDDB			0.0E+00	4.7E+04	8.6E+04	5.0E-03	9.1E-05	3.1E-09	1.5E-09	1.8E-10	6.1E-11	1.0E-11	4.0E-11	2.2E-10
5	HDDDBCAADFB	2.2E+04	0.0E+00	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	GDDDBCAADDB			0.0E+00	4.7E+04	8.6E+04	5.0E-03	1.7E-04	3.2E-09	1.7E-09	4.5E-10	2.4E-11	4.4E-11	7.0E-11	3.8E-10
6	HDDDBCABDFB	2.2E+04	0.0E+00	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	GDDDBCABDDB			0.0E+00	4.7E+04	8.6E+04	5.0E-03	1.6E-04	4.0E-09	2.3E-09	4.4E-10	6.4E-11	5.3E-11	8.1E-11	4.1E-10
7	HDCDFCDADFA	2.2E+04	0.0E+00	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	GDCDFCDADDA			0.0E+00	4.7E+04	8.6E+04	4.1E-03	3.7E-05	7.0E-10	2.5E-10	1.4E-11	5.3E-12	7.5E-13	2.5E-12	2.0E-11
8	GDDDBCAADDB	2.2E+04	1.0E+01	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	FDDDBCAADCB			6.5E+03	1.3E+05	1.1E+04	1.0E+00	3.4E-02	1.4E-07	9.9E-08	3.1E-08	1.5E-10	3.3E-09	3.5E-09	2.3E-08
9	GDDDBCABDDB	2.2E+04	1.0E+01	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	FDDDBCABDCB			6.5E+03	1.3E+05	1.1E+04	1.0E+00	3.1E-02	1.1E-07	8.3E-08	2.2E-08	2.9E-10	3.0E-09	3.1E-09	1.6E-08
10	HDCDFCDBDFA	2.2E+04	0.0E+00	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	GDCDFCDBDDA			60E+00	4.7E+04	8.6E+04	4.3E-03	5.5E-05	1.7E-09	8.1E-10	7.1E-11	3.0E-11	3.4E-12	1.1E-11	9.0E-11
Five Most Probable Bins that have VB and Early CF*															
28	DAFDDCBBDBB	2.2E+04	1.0E+01	2.8E+06	2.8E+04	2.0E+02	8.3E-01	2.0E-02	1.7E-02	7.9E-03	1.2E-03	3.5E-04	7.8E-05	3.4E-04	1.4E-03
	DAFDDCBBDBB			1.6E+06	4.6E+04	2.2E+04	1.7E-01	1.4E-01	1.3E-01	9.0E-02	2.8E-02	3.7E-04	3.2E-03	3.2E-03	2.0E-02
37	DAFDDCBADBB	2.2E+04	1.0E+01	2.8E+06	2.8E+04	2.0E+02	7.6E-01	1.3E-02	9.4E-03	3.6E-03	7.1E-04	1.2E-04	4.1E-05	1.8E-04	7.9E-04
	DAFDDCBADBB			1.6E+06	4.6E+04	2.2E+04	2.4E-01	1.7E-01	1.6E-01	1.0E-01	3.0E-02	9.6E-05	2.8E-03	3.0E-03	2.4E-02
69	DADDDCBBDBB	2.2E+04	1.0E+01	2.8E+06	2.8E+04	2.0E+02	9.2E-01	3.0E-02	2.9E-02	8.1E-03	1.4E-03	3.5E-04	9.0E-05	4.0E-04	1.5E-03
	DADDDCBBDBB			1.6E+06	2.9E+04	2.2E+04	8.5E-02	6.1E-02	3.3E-02	2.4E-02	2.1E-03	3.2E-06	2.2E-04	2.3E-04	1.3E-03
75	DDCBACDBACA	2.2E+04	1.0E+01	5.2E+04	2.8E+04	1.1E+04	1.0E+00	8.3E-03	7.8E-03	4.1E-03	4.1E-03	6.0E-04	4.1E-04	2.2E-03	4.1E-03
	DDCBACDBACA			1.6E+05	1.0E+06	1.0E+06	0.0E+00	1.4E-02	3.3E-05	6.4E-05	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
77	DADDDCBADBB	2.2E+04	1.0E+01	2.8E+06	2.8E+04	2.0E+02	9.0E-01	2.3E-02	2.1E-02	3.4E-03	5.4E-04	9.6E-05	2.9E-05	1.3E-04	6.0E-04
	DADDDCBADBB			1.6E+06	2.9E+04	2.2E+04	9.7E-02	6.8E-02	4.2E-02	2.7E-02	1.6E-03	6.4E-06	1.6E-04	1.8E-04	1.2E-03

* A listing of source terms for all bins is available on computer media

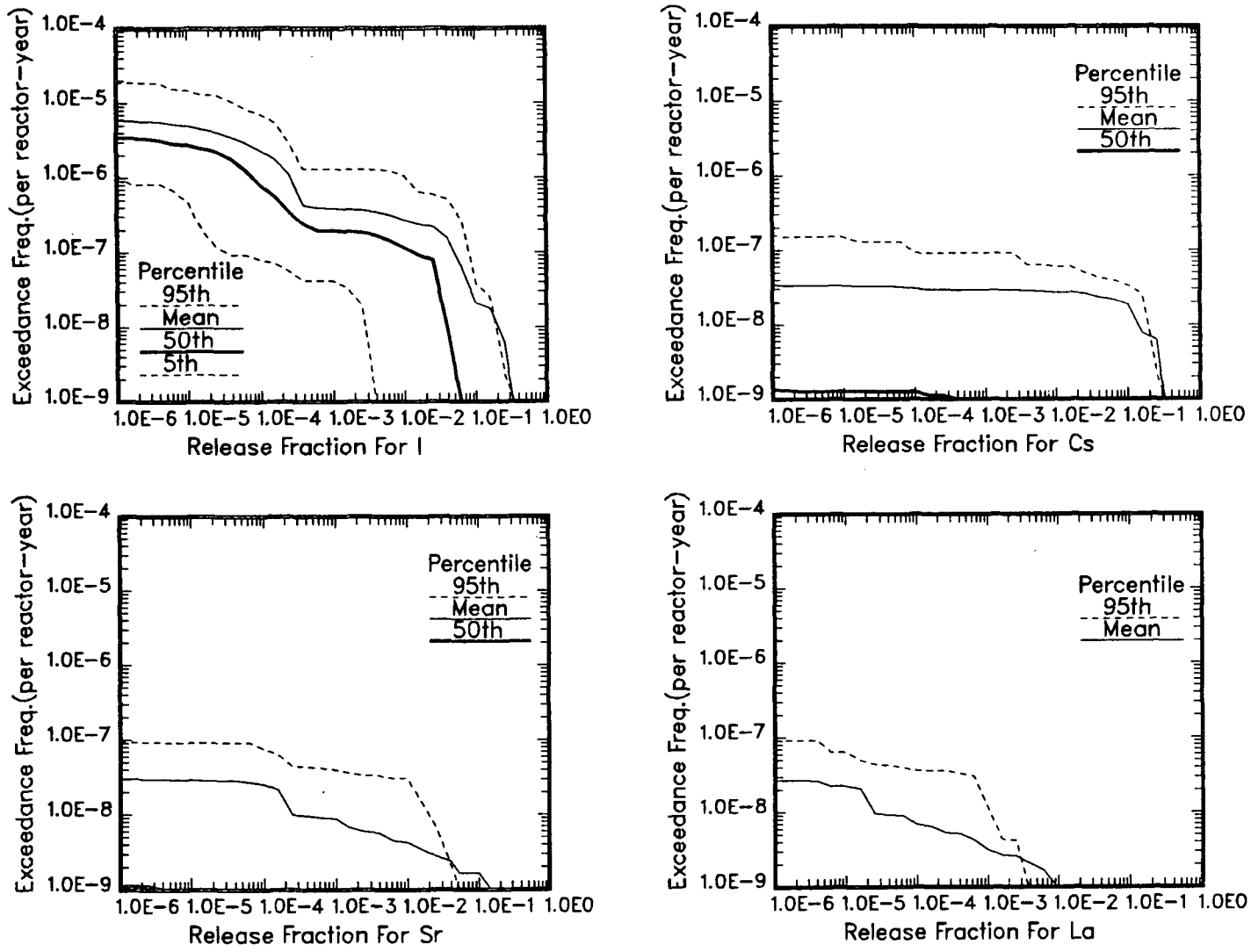


Figure 3.3-2. Exceedance Frequencies for Release Fractions for Surry Internal Initiators. PDS Group 2: LOCAs

Table 3.3-3
Mean Source Terms for Surry
Internal Initiators. PDS Group 3: Fast SBO

Order	Bin	Warning Time (s)	Elevation (m)	Release Energy (W)	Release Start (s)	Release Duration (s)	Release Fractions								
							NG	I	Cs	Te	Sr	Ru	La	Ce	Ba
Five Most Probable Bins*															
1	HDCDFCDBDFB	2.2E+04	0.0E+00	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	GDCDFCDBDDB			0.0E+00	4.7E+04	8.6E+04	4.2E-03	4.5E-05	1.4E-09	7.1E-10	9.0E-11	3.1E-11	5.1E-12	2.0E-11	1.1E-10
2	HFADBCABDFB	2.2E+04	0.0E+00	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	GFADBCABDDB			0.0E+00	4.7E+04	8.6E+04	5.0E-03	1.6E-04	4.4E-09	2.5E-09	6.0E-10	6.8E-11	6.5E-11	9.3E-11	5.3E-10
3	HDCDFCDADFB	2.2E+04	0.0E+00	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	GDCDFCDADDB			0.0E+00	4.7E+04	8.6E+04	3.9E-03	3.9E-05	8.1E-10	3.2E-10	5.7E-11	1.1E-11	3.4E-12	1.5E-11	6.5E-11
4	HFADBCAADFB	2.2E+04	0.0E+00	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	GFADBCAADDB			0.0E+00	4.7E+04	8.6E+04	5.0E-03	1.8E-04	3.9E-09	2.3E-09	7.0E-10	3.0E-11	7.0E-11	9.8E-11	6.2E-10
5	HDCCFCDBDFA	2.2E+04	0.0E+00	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	GDCCFCDBDDA			0.0E+00	4.7E+04	8.6E+04	4.4E-03	3.5E-05	1.2E-09	6.1E-10	6.0E-11	2.3E-11	2.9E-12	9.7E-12	7.4E-11
Five Most Probable Bins That Have VB*															
2	HFADBCABDFB	2.2E+04	0.0E+00	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	GFADBCABDDB			0.0E+00	4.7E+04	8.6E+04	5.0E-03	1.6E-04	4.4E-09	2.5E-09	6.0E-10	6.8E-11	6.5E-11	9.3E-11	5.3E-10
4	HFADBCAADFB	2.2E+04	0.0E+00	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	GFADBCAADDB			0.0E+00	4.7E+04	8.6E+04	5.0E-03	1.8E-04	3.9E-09	2.3E-09	7.0E-10	3.0E-11	7.0E-11	9.8E-11	6.2E-10
7	GFADBCABDDB	2.2E+04	1.0E+01	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	FFADBCABDCB			6.5E+03	1.3E+05	1.1E+04	1.0E+00	3.2E-02	1.5E-07	1.1E-07	3.7E-08	5.4E-10	4.3E-09	4.4E-09	2.8E-08
13	HFADBCAADFA	2.2E+04	0.0E+00	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	GFADBCAADDA			0.0E+00	4.7E+04	8.6E+04	5.0E-03	1.7E-04	3.6E-09	2.3E-09	8.0E-10	1.5E-11	7.9E-11	8.7E-11	6.7E-10
14	GFADBCAADDB	2.2E+04	1.0E+01	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	FFADBCAADCB			6.5E+03	1.3E+05	1.1E+04	1.0E+00	3.5E-02	2.0E-07	1.5E-07	5.2E-08	3.6E-10	5.5E-09	5.8E-09	4.3E-08
Five Most Probable Bins that have VB and Early CF*															
45	DHADDCBBDBB	2.2E+04	1.0E+01	2.8E+07	2.8E+04	2.0E+02	9.1E-01	3.1E-01	2.8E-01	8.7E-02	1.9E-02	4.2E-03	1.3E-03	6.0E-03	2.1E-02
	DHADDCBBDBB			1.6E+06	2.9E+04	2.2E+04	9.3E-02	5.5E-02	4.3E-02	9.1E-02	2.7E-02	3.7E-04	3.0E-03	3.1E-03	2.0E-02
71	DFACACABACB	2.2E+04	1.0E+01	5.2E+05	2.8E+04	1.0E+03	7.5E-01	1.8E-01	1.7E-01	1.3E-01	1.1E-01	2.4E-02	1.3E-02	6.0E-02	1.1E-01
	DFACACABACB			1.6E+05	2.9E+04	2.2E+04	2.5E-01	7.9E-02	5.9E-02	4.3E-02	3.8E-02	8.0E-03	4.3E-03	2.0E-02	3.8E-02
111	DHADDCBADBB	2.2E+04	1.0E+01	2.8E+07	2.8E+04	2.0E+02	8.8E-01	2.7E-01	2.4E-01	5.5E-02	1.5E-02	2.6E-03	1.0E-03	5.5E-03	1.6E-02
	DHADDCBADBB			1.6E+06	2.9E+04	2.2E+04	1.2E-01	5.4E-02	4.2E-02	1.0E-01	2.7E-02	1.2E-04	2.6E-03	2.8E-03	2.2E-02
116	DFCBACDBBCA	2.2E+04	1.0E+01	5.2E+05	2.8E+04	1.1E+04	6.6E-01	8.7E-02	9.7E-02	6.1E-03	1.0E-04	3.0E-04	1.0E-04	1.0E-04	1.1E-04
	DFCBACDBBCA			1.6E+05	1.0E+06	1.0E+06	3.4E-01	3.2E-03	4.8E-06	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
168	DAFDDCBBDBB	2.2E+04	1.0E+01	2.8E+06	2.8E+04	2.0E+02	8.3E-01	2.0E-02	1.7E-02	7.9E-03	1.2E-03	3.5E-04	7.8E-05	3.4E-04	1.4E-03
	DAFDDCBBDBB			1.6E+06	4.6E+04	2.2E+04	1.7E-01	1.4E-01	1.3E-01	9.0E-02	2.8E-02	3.7E-04	3.2E-03	3.2E-03	2.0E-02

* A listing of source terms for all bins is available on computer media

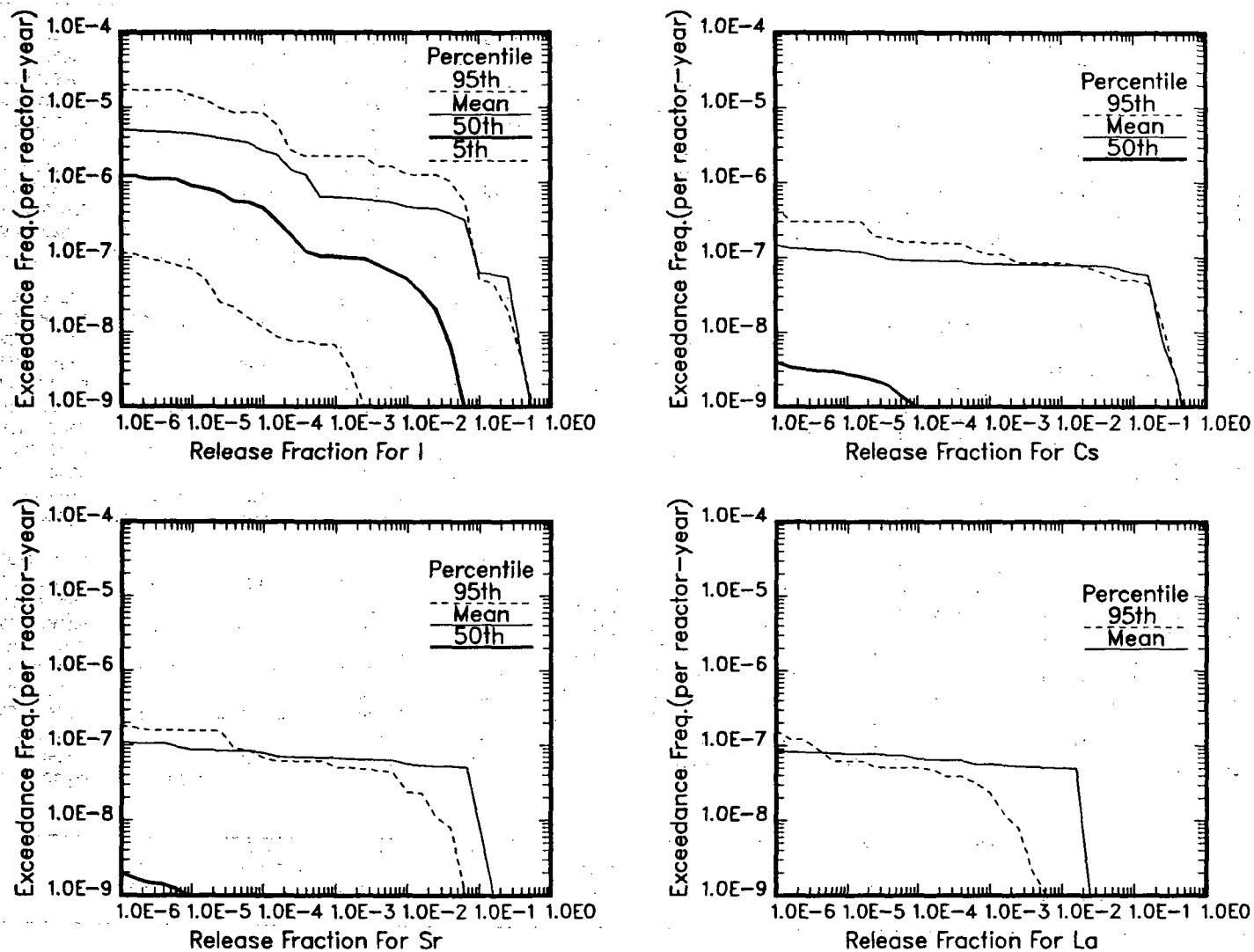


Figure 3.3-3. Exceedance Frequencies for Release Fractions for Surry Internal Initiators. PDS Group 3: Fast SBO

Table 3.3-4
Mean Source Terms for Surry
Internal Initiators. PDS Group 4: Event V

Order	Bin	Warning Time (s)	Elevation (m)	Release Energy (W)	Release Start (s)	Release Duration (s)	Release Fractions								
							NG	I	Cs	Te	Sr	Ru	La	Ce	Ba
Eight Most Probable Bins*															
1	BHADBCAADEA	1.3E+03	0.0E+00	1.9E+06	3.7E+03	1.8E+03	9.9E-01	7.0E-02	7.1E-02	9.4E-03	2.4E-03	4.3E-04	1.2E-04	5.5E-04	2.7E-03
	BHADBCAADDA			1.7E+05	1.0E+04	2.2E+04	1.1E-02	4.7E-02	7.6E-03	3.3E-02	1.1E-02	3.1E-04	1.3E-03	1.4E-03	9.3E-03
2	BHADBCABDEA	1.3E+03	0.0E+00	1.9E+06	3.7E+03	1.8E+03	9.9E-01	5.8E-02	5.9E-02	1.2E-02	3.0E-03	7.2E-04	2.0E-04	9.0E-04	3.3E-03
	BHADBCABDDA			1.7E+05	1.0E+04	2.2E+04	8.1E-03	4.4E-02	5.6E-03	2.5E-02	9.1E-03	1.5E-04	1.0E-03	1.0E-03	6.6E-03
3	BHADBCAADDA	1.3E+03	0.0E+00	1.9E+06	3.7E+03	1.8E+03	9.9E-01	5.5E-02	5.4E-02	9.4E-03	2.4E-03	4.3E-04	1.2E-04	5.5E-04	2.7E-03
	BHADBCAADCA			1.7E+05	1.0E+04	2.2E+04	1.1E-02	4.2E-02	4.5E-03	1.9E-02	6.8E-03	2.0E-04	8.5E-04	8.8E-04	5.8E-03
4	BHADBCABDDA	1.3E+03	0.0E+00	1.9E+06	3.7E+03	1.8E+03	9.9E-01	4.9E-02	4.9E-02	1.2E-02	3.0E-03	7.2E-04	2.0E-04	9.0E-04	3.3E-03
	BHADBCABDCA			1.7E+05	1.0E+04	2.2E+04	8.1E-03	3.9E-02	3.6E-03	1.5E-02	5.5E-03	7.8E-05	6.2E-04	6.2E-04	4.0E-03
5	AHADBCAADEA	1.3E+03	0.0E+00	3.7E+06	3.7E+03	1.8E+03	9.9E-01	3.4E-01	3.5E-01	4.4E-02	1.3E-02	2.3E-03	8.2E-04	3.9E-03	1.4E-02
	AHADBCAADDA			1.7E+05	1.0E+04	2.2E+04	1.1E-02	3.3E-02	7.6E-03	1.5E-01	5.8E-02	1.2E-03	6.8E-03	7.0E-03	4.8E-02
6	AHADBCABDEA	1.3E+03	0.0E+00	3.7E+06	3.7E+03	1.8E+03	9.9E-01	3.5E-01	3.5E-01	7.0E-02	1.5E-02	3.7E-03	9.9E-04	4.6E-03	1.6E-02
	AHADBCABDDA			1.7E+05	1.0E+04	2.2E+04	8.1E-03	3.0E-02	5.6E-03	1.3E-01	4.6E-02	5.0E-04	5.2E-03	5.2E-03	3.4E-02
7	AHADBCAADDA	1.3E+03	0.0E+00	3.7E+06	3.7E+03	1.8E+03	9.9E-01	2.7E-01	2.6E-01	4.4E-02	1.3E-02	2.3E-03	8.2E-04	3.9E-03	1.4E-02
	AHADBCAADCA			1.7E+05	1.0E+04	2.2E+04	1.1E-02	3.1E-02	4.5E-03	9.2E-02	3.7E-02	8.6E-04	4.5E-03	4.6E-03	3.1E-02
8	AHADBCABDDA	1.3E+03	0.0E+00	3.7E+06	3.7E+03	1.8E+03	9.9E-01	2.9E-01	2.9E-01	7.0E-02	1.5E-02	3.7E-03	9.9E-04	4.6E-03	1.6E-02
	AHADBCABDCA			1.7E+05	1.0E+04	2.2E+04	8.1E-03	2.8E-02	3.6E-03	7.8E-02	2.9E-02	2.7E-04	3.2E-03	3.3E-03	2.1E-02

* A listing of source terms for all bins is available on computer media

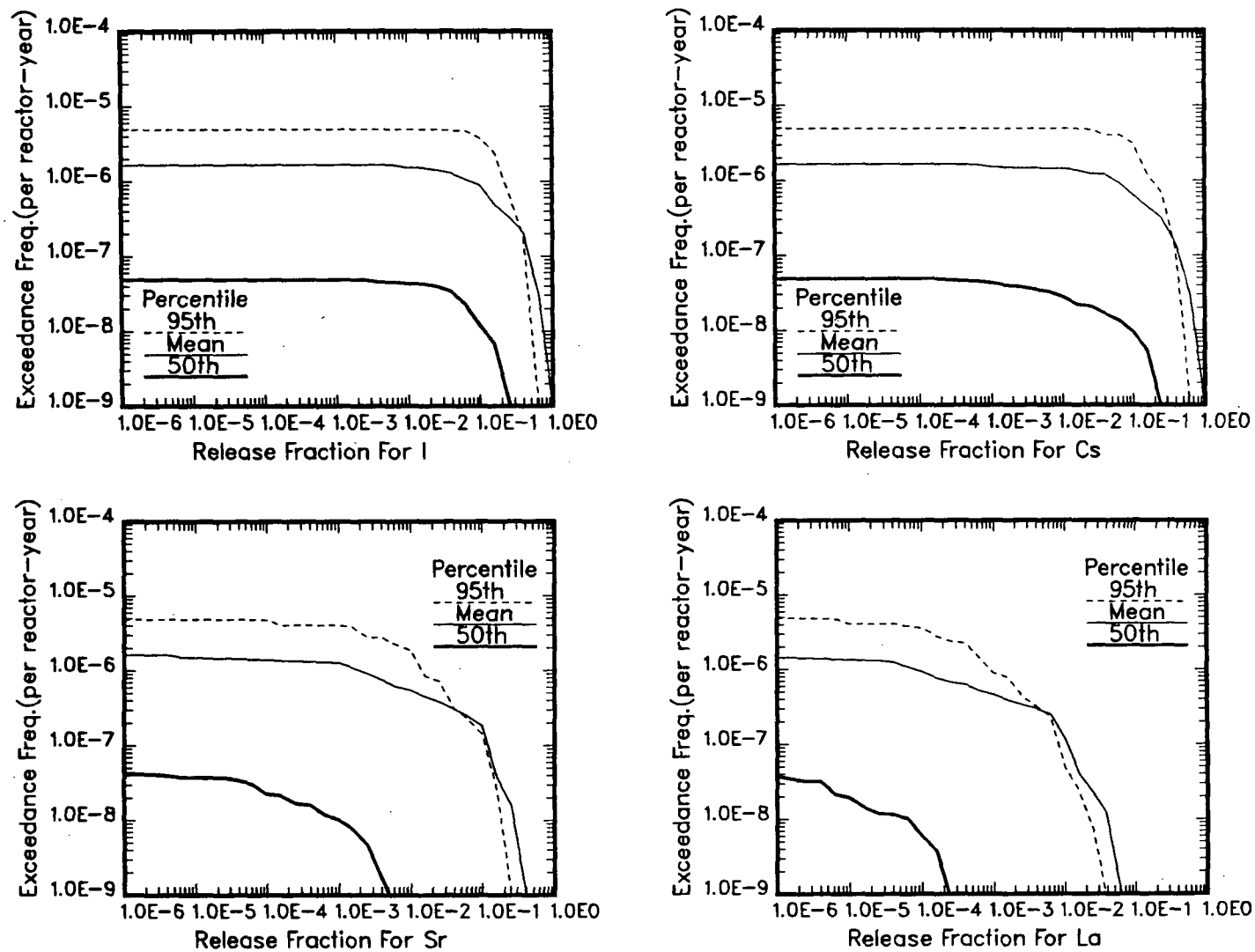


Figure 3.3-4. Exceedance Frequencies for Release Fractions for Surry Internal Initiators. PDS Group 4: Event V

Table 3.3-5
Mean Source Terms for Surry
Internal Initiators. PDS Group 5: Transients

Order	Bin	Warning Time (s)	Elevation (m)	Release Energy (W)	Release Start (s)	Release Duration (s)	Release Fractions								
							NG	I	Cs	Te	Sr	Ru	La	Ce	Ba
Ten Most Probable Bins*															
1	HDCDFCDBDFB	2.2E+04	0.0E+00	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	GDCDFCDBDDB			0.0E+00	4.7E+04	8.6E+04	4.2E-03	4.5E-05	1.4E-09	7.1E-10	9.0E-11	3.1E-11	5.1E-12	2.0E-11	1.1E-10
2	HDCDFCDADFB	2.2E+04	0.0E+00	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	GDCDFCDADDB			0.0E+00	4.7E+04	8.6E+04	3.9E-03	3.9E-05	8.1E-10	3.2E-10	5.7E-11	1.1E-11	3.4E-12	1.5E-11	6.5E-11
3	HDCCFCDBDFB	2.2E+04	0.0E+00	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	GDCCFCDBDDB			0.0E+00	4.7E+04	8.6E+04	4.2E-03	3.6E-05	1.4E-09	9.0E-10	1.8E-10	5.1E-11	1.1E-11	4.7E-11	2.1E-10
4	HDCDBCDBDFB	2.2E+04	0.0E+00	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	GDCDBCDBDDB			0.0E+00	4.7E+04	8.6E+04	5.0E-03	9.1E-05	3.1E-09	1.5E-09	1.8E-10	6.1E-11	1.0E-11	4.0E-11	2.2E-10
5	HDCAACDACFA	2.2E+04	0.0E+00	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	GDCAACDACDA			0.0E+00	4.7E+04	8.6E+04	5.0E-03	2.5E-05	6.4E-10	3.2E-10	1.7E-11	4.1E-12	8.2E-13	2.8E-12	2.2E-11
6	HDCAACDABFA	2.2E+04	0.0E+00	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	GDCAACDABDA			0.0E+00	4.7E+04	8.6E+04	5.0E-03	3.2E-05	7.9E-10	2.7E-10	5.9E-12	4.4E-12	3.2E-13	7.6E-13	1.1E-11
7	HDCAACDAAFA	2.2E+04	0.0E+00	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	GDCAACDAADA			0.0E+00	4.7E+04	8.6E+04	5.0E-03	2.9E-05	6.9E-10	2.2E-10	1.7E-11	3.4E-12	1.3E-12	6.0E-12	2.0E-11
8	HDCCFCDADFB	2.2E+04	0.0E+00	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	GDCCFCDADDB			0.0E+00	4.7E+04	8.6E+04	3.7E-03	3.0E-05	6.2E-10	2.2E-10	4.3E-11	7.1E-12	3.1E-12	1.4E-11	4.6E-11
9	HDDDBCABDFB	2.2E+04	0.0E+00	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	GDDDBCABDDB			0.0E+00	4.7E+04	8.6E+04	5.0E-03	1.6E-04	4.0E-09	2.3E-09	4.4E-10	6.4E-11	5.3E-11	8.1E-11	4.1E-10
10	HDCDBCDADFB	2.2E+04	0.0E+00	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	GDCDBCDADDB			0.0E+00	4.7E+04	8.6E+04	5.0E-03	7.9E-05	1.9E-09	7.7E-10	1.1E-10	2.2E-11	6.9E-12	3.0E-11	1.3E-10
Five Most Probable Bins That Have VB and Early CF*															
45	DAFDDCBBDBB	2.2E+04	1.0E+01	2.8E+06	2.8E+04	2.0E+02	8.3E-01	2.0E-02	1.7E-02	7.9E-03	1.2E-03	3.5E-04	7.8E-05	3.4E-04	1.4E-03
	DAFDDCBBDBB			1.6E+06	4.6E+04	2.2E+04	1.7E-01	1.4E-01	1.3E-01	9.0E-02	2.8E-02	3.7E-04	3.2E-03	3.2E-03	2.0E-02
48	DDCAACDAABA	2.2E+04	1.0E+01	2.8E+06	2.8E+04	2.0E+02	6.9E-01	1.7E-01	1.7E-01	2.3E-02	5.0E-04	2.6E-03	5.0E-04	5.0E-04	5.5E-04
	DDCAACDAABA			1.6E+05	1.0E+06	1.0E+06	3.1E-01	4.2E-03	4.8E-04	4.2E-05	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
64	DDCACCDABCA	2.2E+04	1.0E+01	5.2E+04	2.8E+04	1.1E+04	1.0E+00	1.1E-05	5.9E-06	2.5E-06	2.5E-06	6.5E-07	2.8E-07	2.4E-06	2.5E-06
	DDCACCDABCA			1.6E+05	1.0E+06	1.0E+06	0.0E+00	1.9E-03	3.4E-05	1.0E-05	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
72	DDDAACAAABA	2.2E+04	1.0E+01	2.8E+06	2.8E+04	2.0E+02	9.8E-01	1.9E-01	2.0E-01	2.3E-02	5.0E-04	2.6E-03	5.0E-04	5.0E-04	5.5E-04
	DDDAACAAABA			1.6E+05	2.9E+04	2.2E+04	2.5E-02	2.3E-02	4.8E-04	5.4E-03	6.2E-05	4.0E-11	5.4E-06	7.7E-06	5.2E-05
75	DADDDCBBDBB	2.2E+04	1.0E+01	2.8E+06	2.8E+04	2.0E+02	9.2E-01	3.0E-02	2.9E-02	8.1E-03	1.4E-03	3.5E-04	9.0E-05	4.0E-04	1.5E-03
	DADDDCBBDBB			1.6E+06	2.9E+04	2.2E+04	8.5E-02	6.1E-02	3.3E-02	2.4E-02	2.1E-03	3.2E-06	2.2E-04	2.3E-04	1.3E-03

* A listing of source terms for all bins is available on computer media

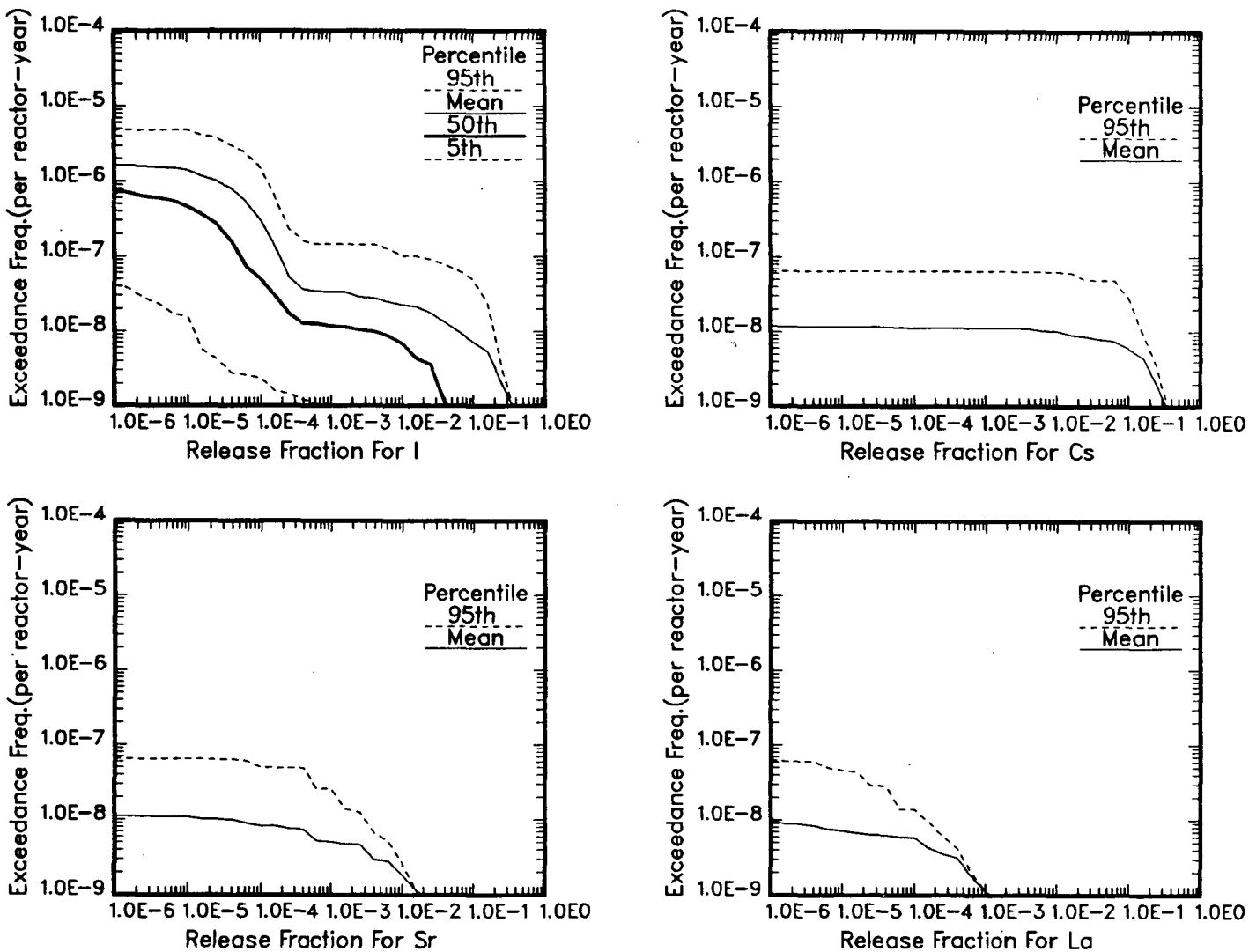


Figure 3.3-5. Exceedance Frequencies for Release Fractions for Surry Internal Initiators. PDS Group 5: Transients

Table 3.3-6
Mean Source Terms for Surry
Internal Initiators. PDS Group 6: ATWS

Order	Bin	Warning Time (s)	Elevation (m)	Release Energy (W)	Release Start (s)	Release Duration (s)	Release Fractions								
							NG	I	Cs	Te	Sr	Ru	La	Ce	Ba
Ten Most Probable Bins*															
1	HDCDFCDBDFB	2.2E+04	0.0E+00	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	GDCDFCDBDDB			0.0E+00	4.7E+04	8.6E+04	4.2E-03	4.5E-05	1.4E-09	7.1E-10	9.0E-11	3.1E-11	5.1E-12	2.0E-11	1.1E-10
2	HDCDBCDBDFB	2.2E+04	0.0E+00	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	GDCDBCDBDDB			0.0E+00	4.7E+04	8.6E+04	5.0E-03	9.1E-05	3.1E-09	1.5E-09	1.8E-10	6.1E-11	1.0E-11	4.0E-11	2.2E-10
3	HDCDFCDADFB	2.2E+04	0.0E+00	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	GDCDFCDADDB			0.0E+00	4.7E+04	8.6E+04	3.9E-03	3.9E-05	8.1E-10	3.2E-10	5.7E-11	1.1E-11	3.4E-12	1.5E-11	6.5E-11
4	HDCDBCDADFB	2.2E+04	0.0E+00	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	GDCDBCDADDB			0.0E+00	4.7E+04	8.6E+04	5.0E-03	7.9E-05	1.9E-09	7.7E-10	1.1E-10	2.2E-11	6.9E-12	3.0E-11	1.3E-10
5	HDDDBCABDFB	2.2E+04	0.0E+00	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	GDDDBCABDDB			0.0E+00	4.7E+04	8.6E+04	5.0E-03	1.6E-04	4.0E-09	2.3E-09	4.4E-10	6.4E-11	5.3E-11	8.1E-11	4.1E-10
6	HDDDBCAADFB	2.2E+04	0.0E+00	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	GDDDBCAADDB			0.0E+00	4.7E+04	8.6E+04	5.0E-03	1.7E-04	3.2E-09	1.7E-09	4.5E-10	2.4E-11	4.4E-11	7.0E-11	3.8E-10
7	HDCDFADBDEB	1.3E+04	1.0E+01	1.0E+06	2.0E+04	3.6E+03	3.8E-01	2.0E-01	1.8E-01	1.5E-01	1.5E-02	4.6E-03	7.2E-04	2.7E-03	1.7E-02
	GDCDFADBDDB			0.0E+00	1.0E+06	1.0E+06	0.0E+00	2.7E-05	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
8	HDCCACDBCFB	2.2E+04	0.0E+00	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	GDCCACDBCDB			0.0E+00	4.7E+04	8.6E+04	5.0E-03	9.6E-05	1.2E-09	4.7E-10	2.4E-11	1.1E-11	8.8E-13	2.8E-12	3.0E-11
9	GDDDBCABDDB	2.2E+04	1.0E+01	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	FDDDBCABDCB			6.5E+03	1.3E+05	1.1E+04	1.0E+00	3.1E-02	1.1E-07	8.3E-08	2.2E-08	2.9E-10	3.0E-09	3.1E-09	1.6E-08
10	HDCDFADADEB	1.3E+04	1.0E+01	1.0E+06	2.0E+04	3.6E+03	3.3E-01	1.5E-01	1.3E-01	1.2E-01	2.4E-02	4.5E-03	1.5E-03	7.4E-03	2.7E-02
	GDCDFADADDB			0.0E+00	1.0E+06	1.0E+06	0.0E+00	2.3E-05	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Five Most Probable Bins That Have VB and Early CF															
7	HDCDFADBDEB	1.3E+04	1.0E+01	1.0E+06	2.0E+04	3.6E+03	3.8E-01	2.0E-01	1.8E-01	1.5E-01	1.5E-02	4.6E-03	7.2E-04	2.7E-03	1.7E-02
	GDCDFADBDDB			0.0E+00	1.0E+06	1.0E+06	0.0E+00	2.7E-05	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
10	HDCDFADADEB	1.3E+04	1.0E+01	1.0E+06	2.0E+04	3.6E+03	3.3E-01	1.5E-01	1.3E-01	1.2E-01	2.4E-02	4.5E-03	1.5E-03	7.4E-03	2.7E-02
	GDCDFADADDB			0.0E+00	1.0E+06	1.0E+06	0.0E+00	2.3E-05	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
32	HDCCBADBDEB	1.3E+04	1.0E+01	1.0E+06	2.0E+04	3.6E+03	4.0E-01	2.4E-01	2.2E-01	2.2E-01	2.5E-02	1.0E-02	1.3E-03	4.2E-03	3.3E-02
	GDCCBADBDDB			0.0E+00	1.0E+06	1.0E+06	1.4E-03	3.6E-05	1.4E-10	1.5E-11	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
34	HDCCAADBCEB	1.3E+04	1.0E+01	1.0E+06	2.0E+04	3.6E+03	5.7E-01	3.7E-01	3.5E-01	2.6E-01	5.3E-02	1.2E-02	2.2E-03	8.5E-03	5.7E-02
	GDCCAADBCDB			0.0E+00	1.0E+06	1.0E+06	9.1E-04	3.8E-05	5.2E-11	1.7E-13	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
35	HDCDBADBDEB	1.3E+04	1.0E+01	1.0E+06	2.0E+04	3.6E+03	3.8E-01	2.0E-01	1.8E-01	1.5E-01	1.5E-02	4.6E-03	7.3E-04	2.8E-03	1.7E-02
	GDCDBADBDDB			0.0E+00	1.0E+06	1.0E+06	1.4E-03	2.7E-05	2.7E-10	6.2E-11	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00

* A listing of source terms for all bins is available on computer media

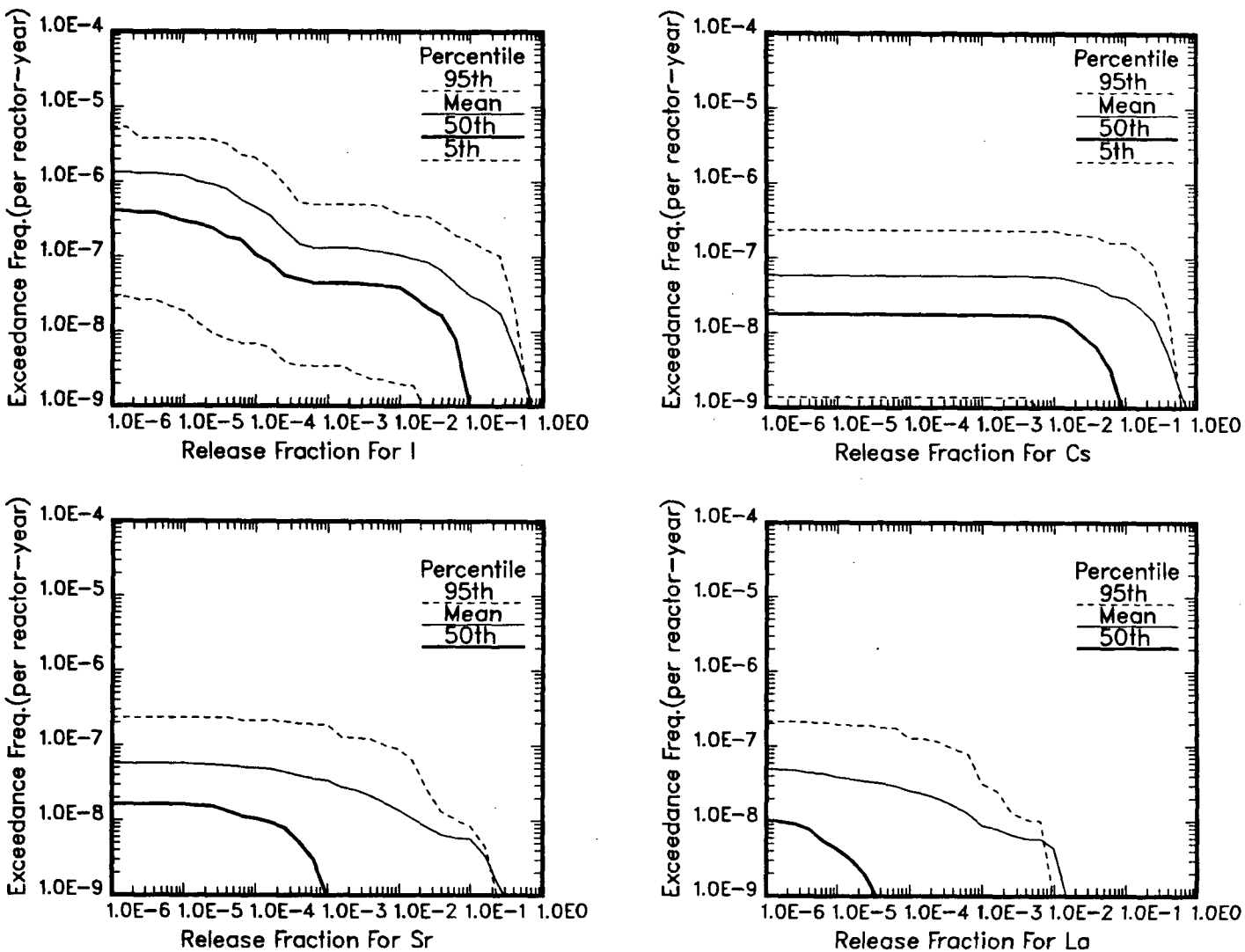


Figure 3.3-6. Exceedance Frequencies for Release Fractions for Surry Internal Initiators. PDS Group 6: ATWS

Table 3.3-7
Mean Source Terms for Surry
Internal Initiators. PDS Group 7: SGTRs

Order	Bin	Warning Time (s)	Elevation (m)	Release Energy (W)	Release Start (s)	Release Duration (s)	Release Fractions								
							NG	I	Cs	Te	Sr	Ru	La	Ce	Ba
Fifteen Most Probable Bins*															
1	HHADBBAADEA	3.6E+04	1.0E+01	1.0E+06	5.1E+04	1.0E+03	7.8E-01	1.9E-01	1.6E-01	6.8E-02	1.3E-02	2.7E-03	6.9E-04	2.7E-03	1.5E-02
	GHADBBAADDA			0.0E+00	5.2E+04	2.2E+04	3.9E-02	9.5E-03	8.2E-03	3.4E-03	6.5E-04	1.4E-04	3.5E-05	1.4E-04	7.7E-04
2	GHADBBAADDA	3.6E+04	1.0E+01	1.0E+06	5.1E+04	1.0E+03	9.4E-01	1.9E-01	1.6E-01	6.8E-02	1.3E-02	2.7E-03	6.9E-04	2.7E-03	1.5E-02
	FHADBBAADCA			0.0E+00	5.2E+04	1.1E+04	5.6E-02	3.8E-02	8.2E-03	3.4E-03	6.7E-04	1.4E-04	3.6E-05	1.4E-04	7.8E-04
3	HHADBBABDEA	3.6E+04	1.0E+01	1.0E+06	5.1E+04	1.0E+03	8.0E-01	2.6E-01	2.4E-01	1.0E-01	1.6E-02	4.2E-03	8.4E-04	3.4E-03	1.8E-02
	GHADBBABDDA			0.0E+00	5.2E+04	2.2E+04	4.0E-02	1.3E-02	1.2E-02	5.1E-03	8.1E-04	2.1E-04	4.2E-05	1.7E-04	9.0E-04
4	HHACABABBEA	3.6E+04	1.0E+01	1.0E+06	5.1E+04	1.0E+03	7.5E-01	1.9E-01	1.7E-01	7.0E-02	3.1E-03	1.9E-03	1.6E-04	5.5E-04	4.3E-03
	GHACABABBDA			0.0E+00	5.2E+04	2.2E+04	3.8E-02	9.5E-03	8.5E-03	3.5E-03	1.6E-04	9.3E-05	8.0E-06	2.8E-05	2.1E-04
5	GHADBBABDDA	3.6E+04	1.0E+01	1.0E+06	5.1E+04	1.0E+03	9.4E-01	2.6E-01	2.4E-01	1.0E-01	1.6E-02	4.2E-03	8.4E-04	3.4E-03	1.8E-02
	FHADBBABDCA			0.0E+00	5.2E+04	1.1E+04	5.5E-02	4.3E-02	1.2E-02	5.2E-03	8.2E-04	2.1E-04	4.4E-05	1.7E-04	9.1E-04
6	HHBBBBAADEA	3.6E+04	1.0E+01	1.0E+06	5.1E+04	1.0E+03	7.4E-01	1.7E-01	1.5E-01	8.3E-02	3.1E-02	5.2E-03	2.0E-03	8.5E-03	3.4E-02
	GHBBBBAADDA			0.0E+00	5.2E+04	2.2E+04	3.7E-02	8.7E-03	7.7E-03	4.2E-03	1.6E-03	2.6E-04	9.8E-05	4.2E-04	1.7E-03
7	HHACABAAAEA	3.6E+04	1.0E+01	1.0E+06	5.1E+04	1.0E+03	7.9E-01	2.5E-01	2.2E-01	9.3E-02	9.8E-03	3.1E-03	5.0E-04	1.6E-03	1.4E-02
	GHACABAAADA			0.0E+00	5.2E+04	2.2E+04	3.9E-02	1.2E-02	1.1E-02	4.6E-03	4.9E-04	1.6E-04	2.5E-05	8.2E-05	7.0E-04
8	HHEBABAAAEA	3.6E+04	1.0E+01	1.0E+06	5.1E+04	3.6E+03	5.4E-01	9.1E-02	7.6E-02	2.7E-02	2.3E-02	3.1E-03	2.0E-03	9.6E-03	2.3E-02
	GHEBABAAADA			0.0E+00	5.7E+04	2.2E+04	1.1E-04	1.2E-04	9.8E-09	1.7E-07	1.3E-08	1.0E-13	8.8E-10	9.3E-10	1.0E-08
9	HDCDFADADEB	1.3E+04	1.0E+01	1.0E+06	2.0E+04	3.6E+03	3.3E-01	1.5E-01	1.3E-01	1.2E-01	2.4E-02	4.5E-03	1.5E-03	7.4E-03	2.7E-02
	GDCDFADADDB			0.0E+00	1.0E+06	1.0E+06	0.0E+00	2.3E-05	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
10	HDCDFADADEA	1.3E+04	1.0E+01	1.0E+06	2.0E+04	3.6E+03	3.3E-01	1.4E-01	1.2E-01	1.0E-01	1.2E-02	2.6E-03	6.2E-04	2.4E-03	1.4E-02
	GDCDFADADDA			0.0E+00	1.0E+06	1.0E+06	0.0E+00	2.0E-05	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
11	GHBBBBAADDA	3.6E+04	1.0E+01	1.0E+06	5.1E+04	1.0E+03	9.4E-01	1.7E-01	1.5E-01	8.3E-02	3.1E-02	5.2E-03	2.0E-03	8.5E-03	3.4E-02
	FHBBBBAADCA			0.0E+00	5.2E+04	1.1E+04	5.8E-02	3.3E-02	7.7E-03	4.2E-03	1.6E-03	2.6E-04	9.8E-05	4.2E-04	1.7E-03
12	HHACABAACEA	3.6E+04	1.0E+01	1.0E+06	5.1E+04	1.0E+03	8.5E-01	2.4E-01	2.0E-01	7.4E-02	4.3E-03	2.0E-03	2.4E-04	6.9E-04	7.0E-03
	GHACABAACDA			0.0E+00	5.2E+04	2.2E+04	4.3E-02	1.2E-02	1.0E-02	3.7E-03	2.1E-04	1.0E-04	1.2E-05	3.5E-05	3.5E-04
13	HHEBABAABEA	3.6E+04	1.0E+01	1.0E+06	5.1E+04	3.6E+03	7.9E-01	1.8E-01	1.5E-01	4.2E-02	9.4E-04	4.9E-04	3.6E-05	6.8E-05	1.8E-03
	GHEBABAABDA			0.0E+00	5.7E+04	2.2E+04	5.2E-05	1.6E-04	1.4E-09	2.7E-07	1.3E-07	1.0E-09	1.5E-08	1.5E-08	1.1E-07
14	HHEBABAACEA	3.6E+04	1.0E+01	1.0E+06	5.1E+04	3.6E+03	9.5E-01	4.6E-01	4.1E-01	2.3E-01	8.0E-02	1.2E-02	4.0E-03	1.6E-02	8.6E-02
	GHEBABAACDA			0.0E+00	5.7E+04	2.2E+04	1.3E-05	1.0E-04	5.4E-09	2.6E-07	1.3E-07	1.5E-10	1.3E-08	1.3E-08	1.0E-07
15	HHACABAABEA	3.6E+04	1.0E+01	1.0E+06	5.1E+04	1.0E+03	7.8E-01	2.5E-01	2.3E-01	1.3E-01	9.7E-03	4.4E-03	5.7E-04	1.8E-03	1.5E-02
	GHACABAABDA			0.0E+00	5.2E+04	2.2E+04	3.9E-02	1.3E-02	1.1E-02	6.6E-03	4.9E-04	2.2E-04	2.8E-05	8.8E-05	7.7E-04

* A listing of source terms for all bins is available on computer media

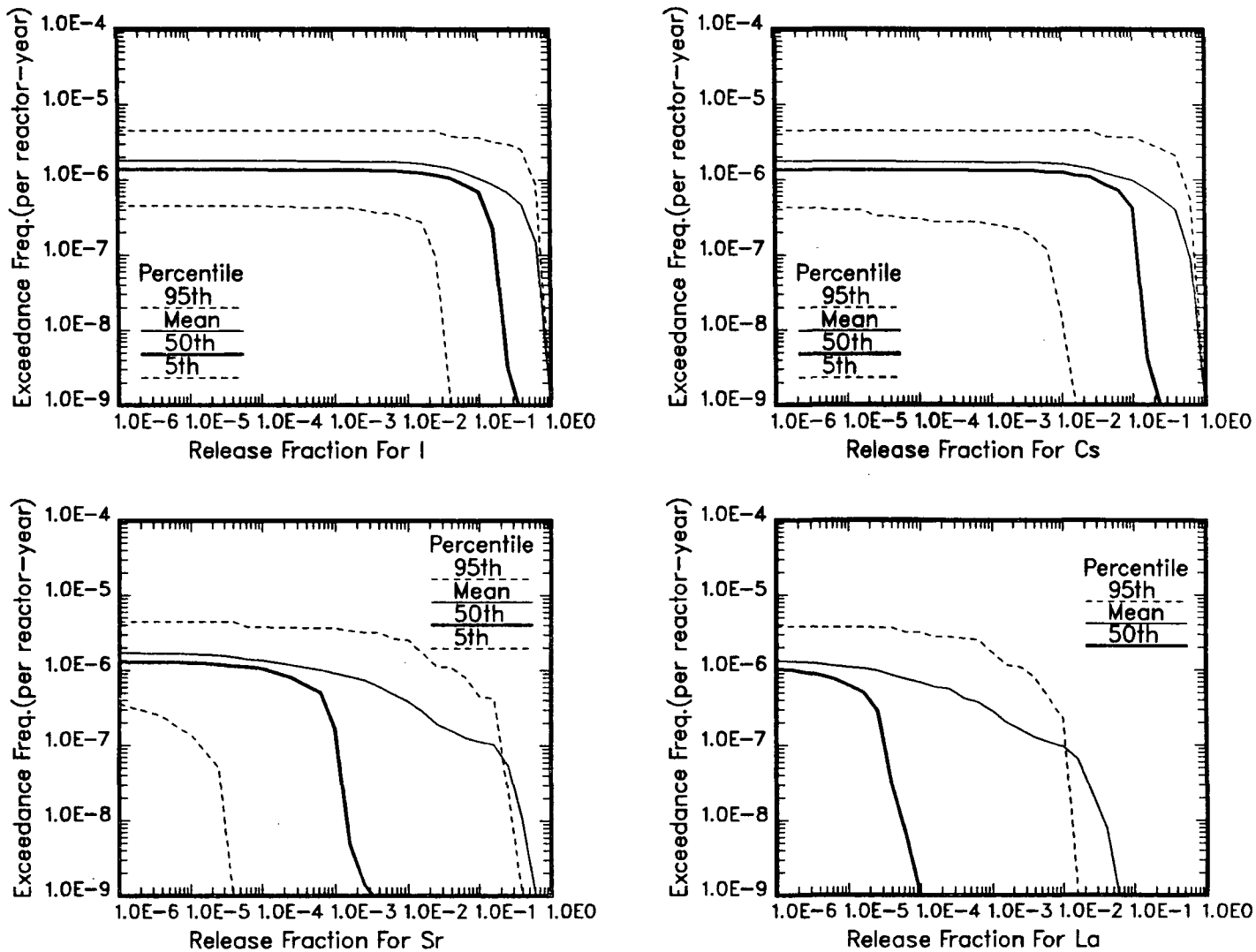


Figure 3.3-7. Exceedance Frequencies for Release Fractions for Surry Internal Initiators. PDS Group 7: SGTRs

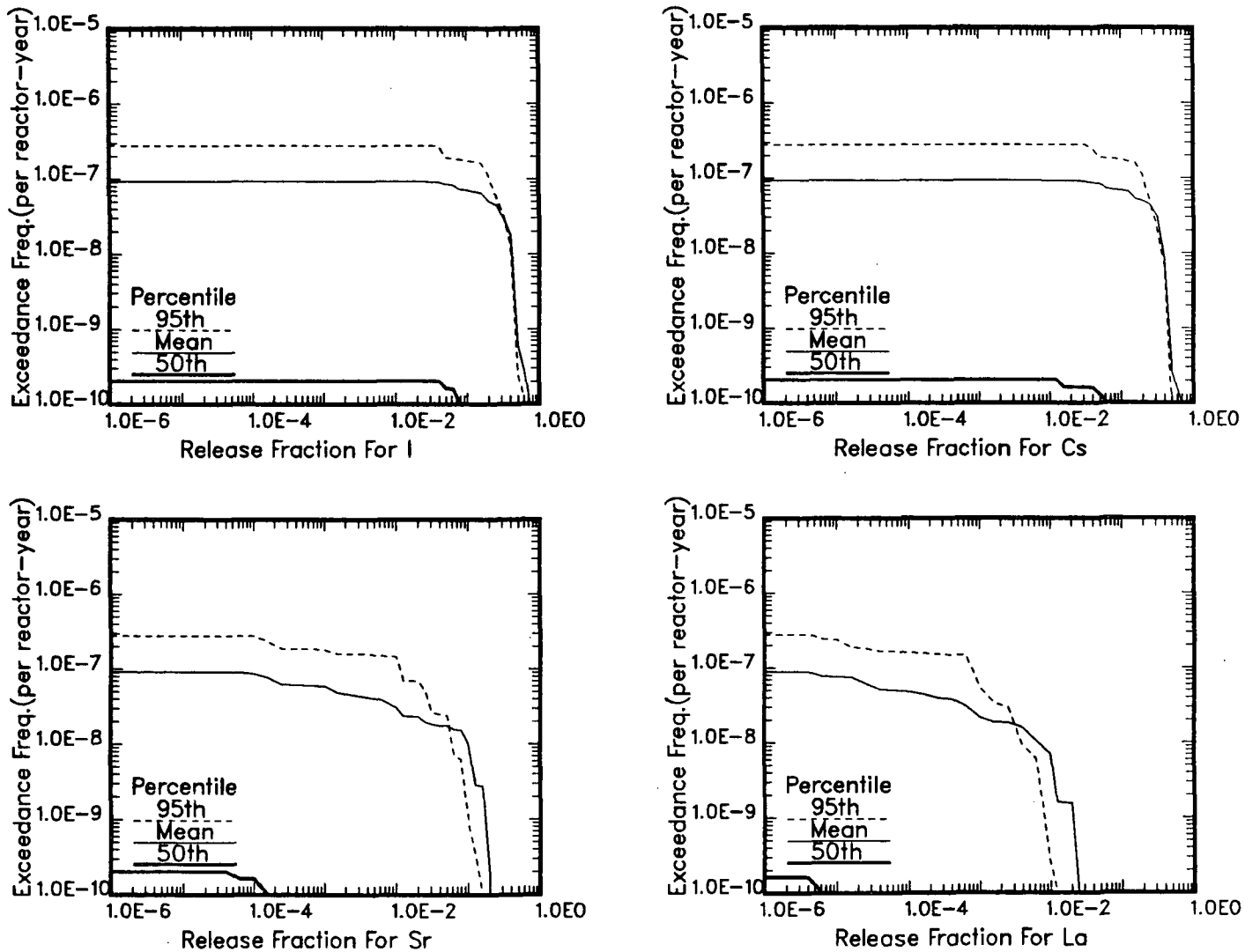


Figure 3.3-8. Exceedance Frequencies for Release Fractions for Surry Internal Initiators. Alpha Mode

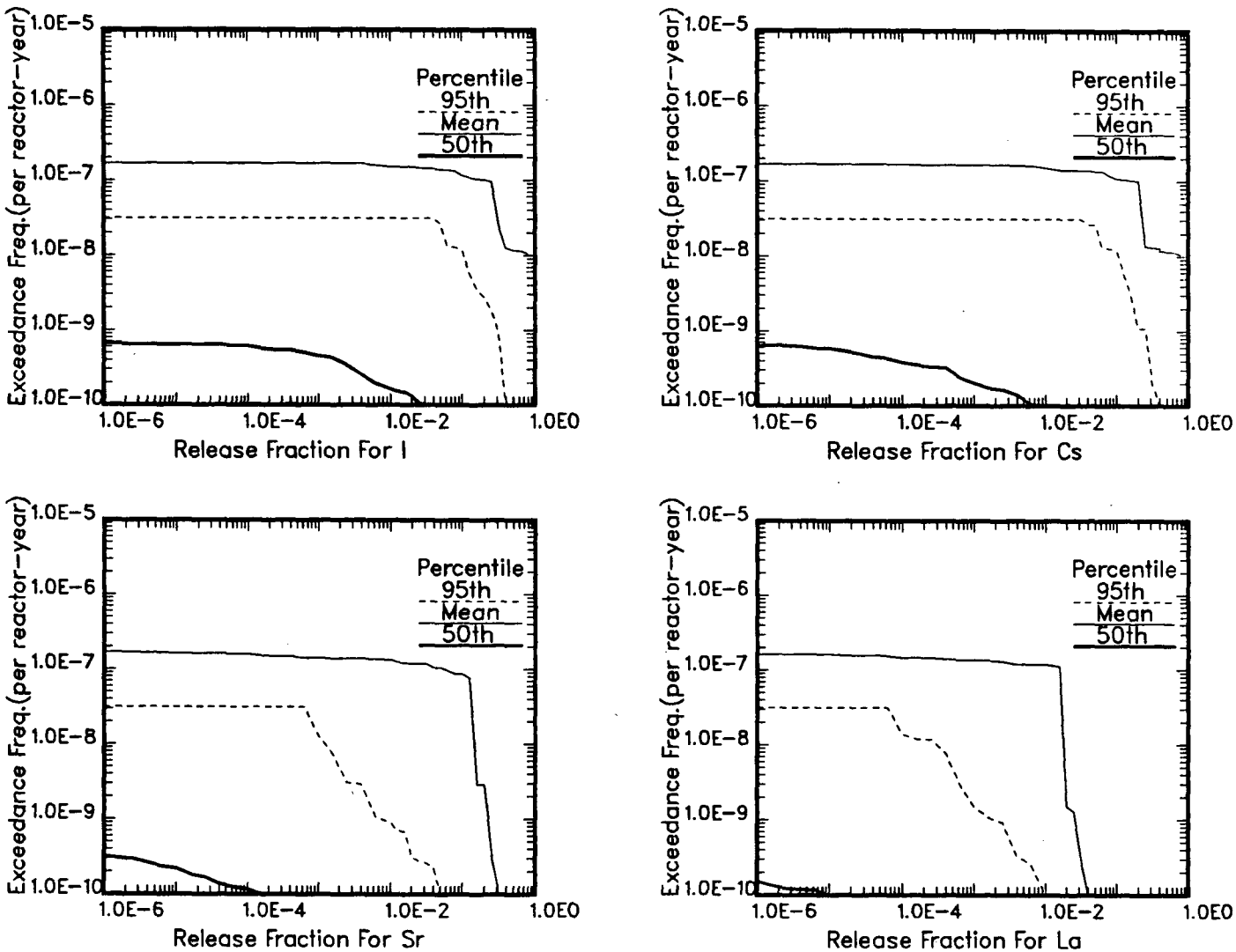


Figure 3.3-9. Exceedance Frequencies for Release Fractions for Surry Internal Initiators. Containment Failure at Vessel Breach with the RCS at High Pressure

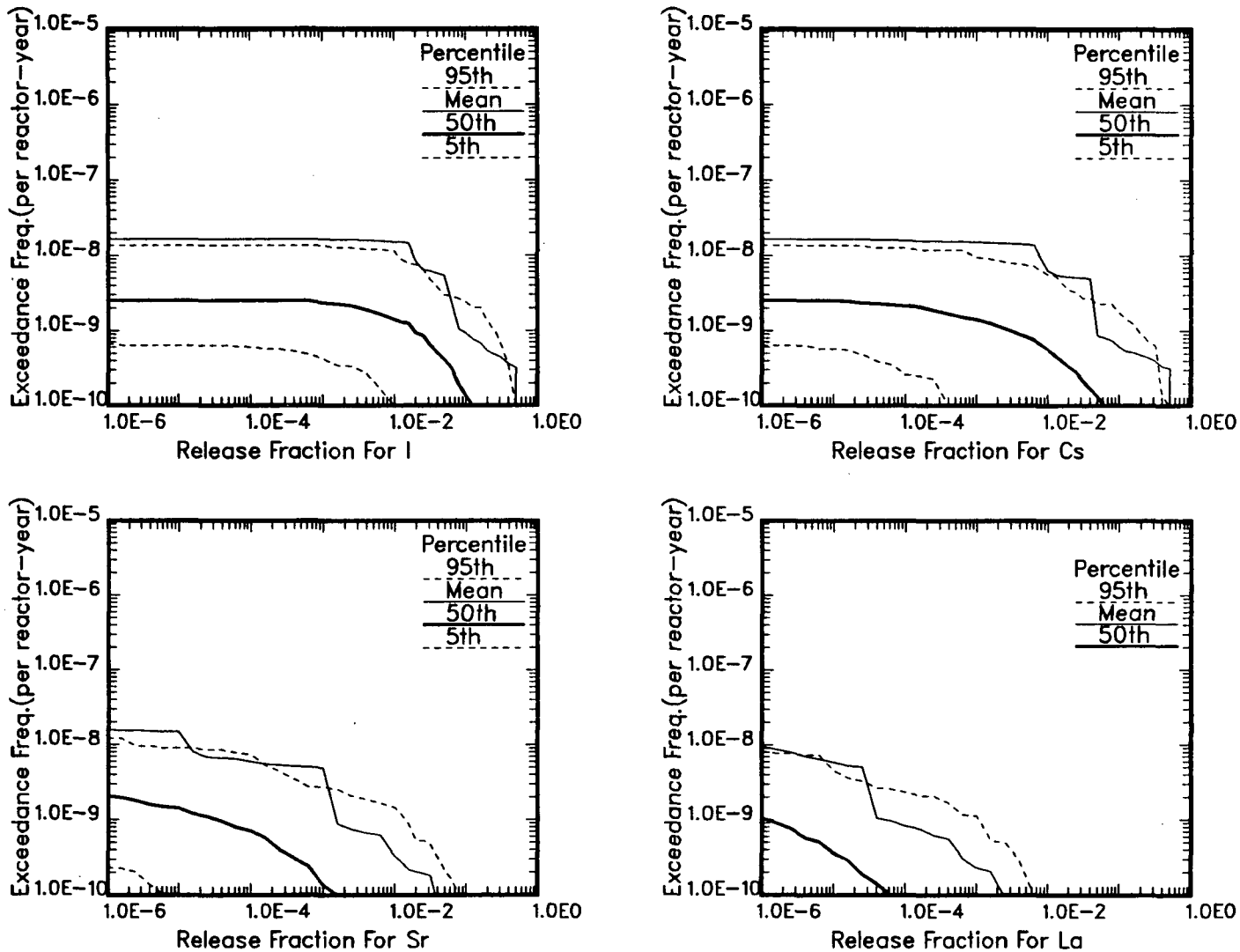


Figure 3.3-10. Exceedance Frequencies for Release Fractions for Surry Internal Initiators. Containment Failure at Vessel Breach with the RCS at Low Pressure

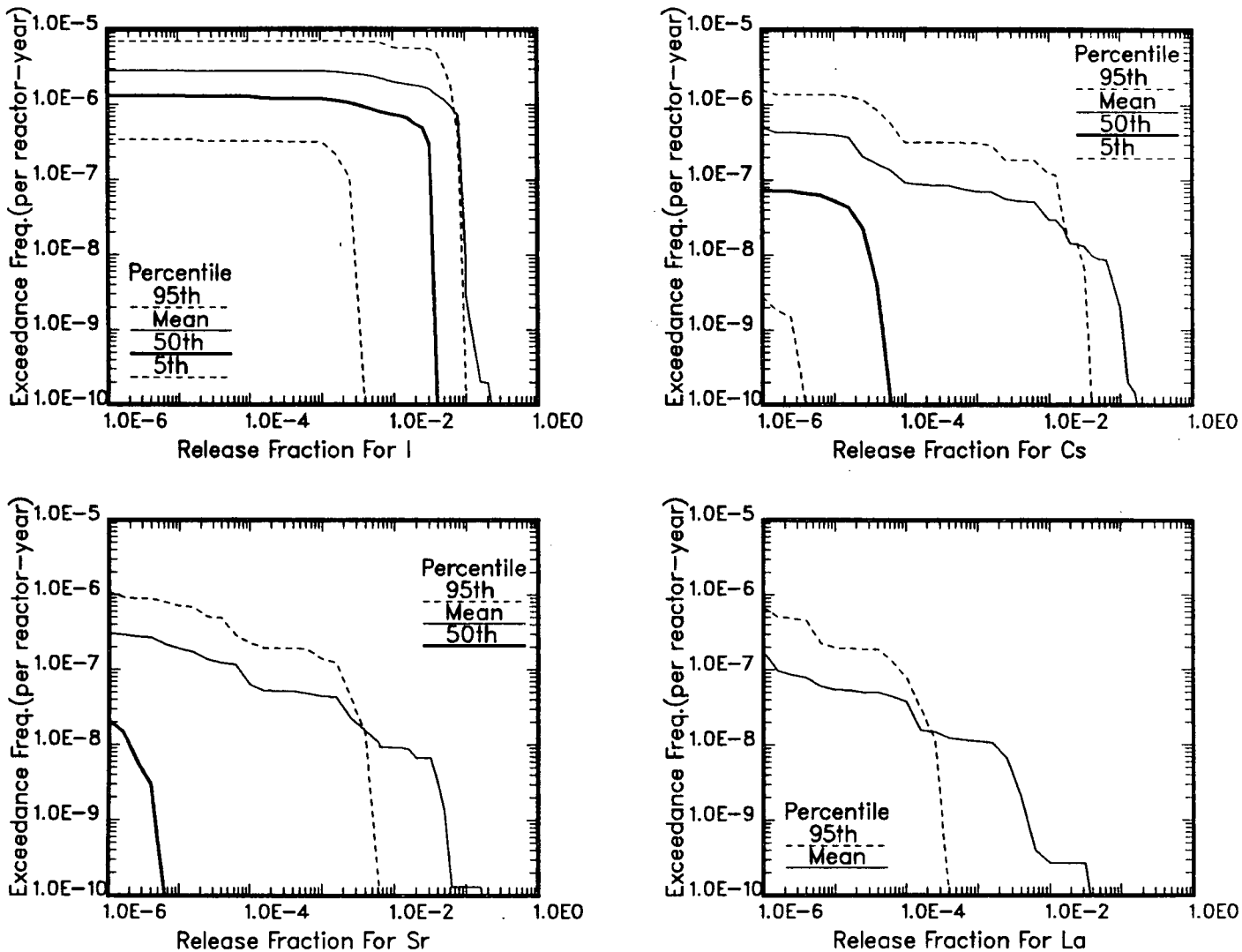


Figure 3.3-11. Exceedance Frequencies for Release Fractions for Surry Internal Initiators. Late Containment Failure

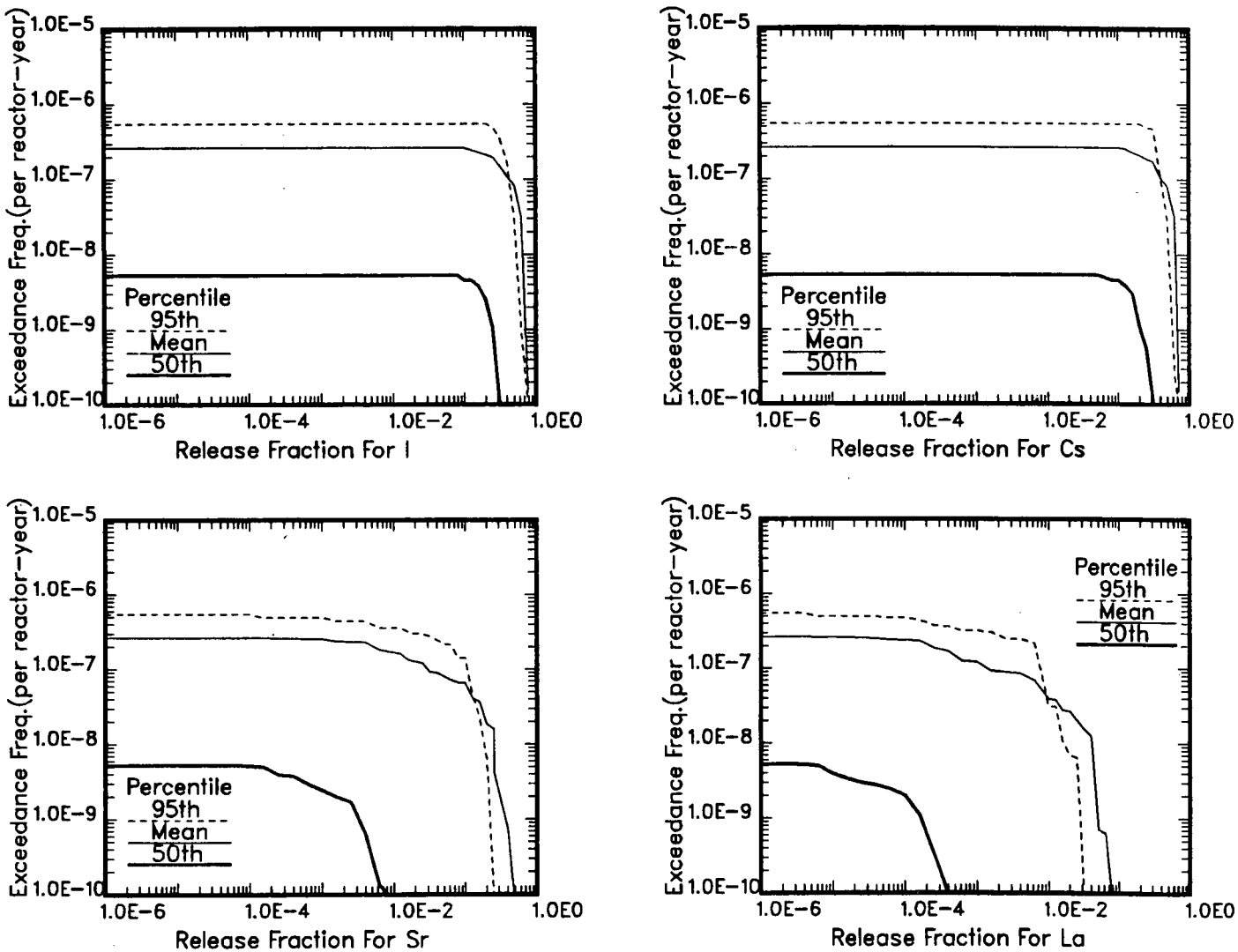


Figure 3.3-12. Exceedance Frequencies for Release Fractions for Surry Internal Initiators. V-Dry

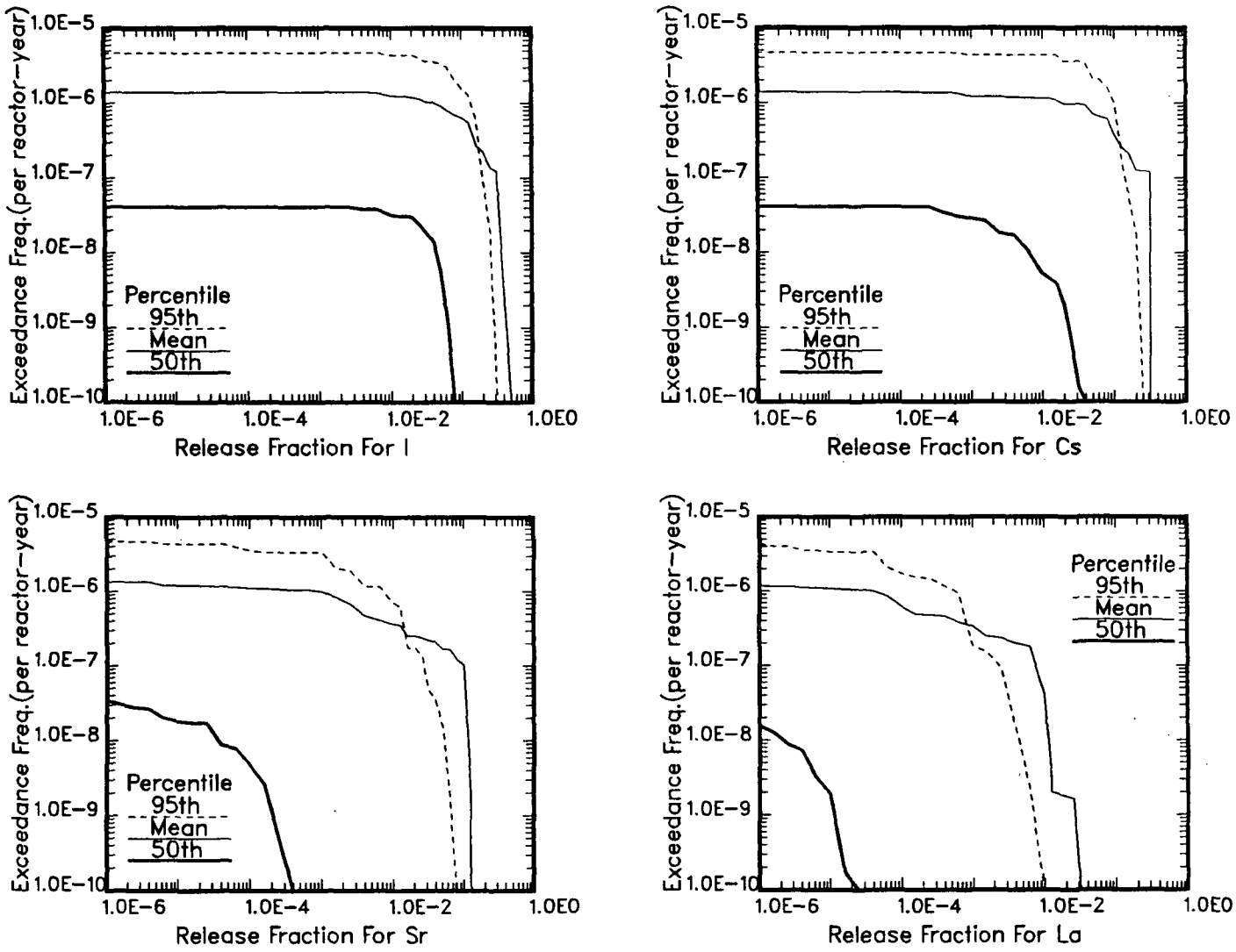


Figure 3.3-13. Exceedance Frequencies for Release Fractions for Surry Internal Initiators. V-Wet

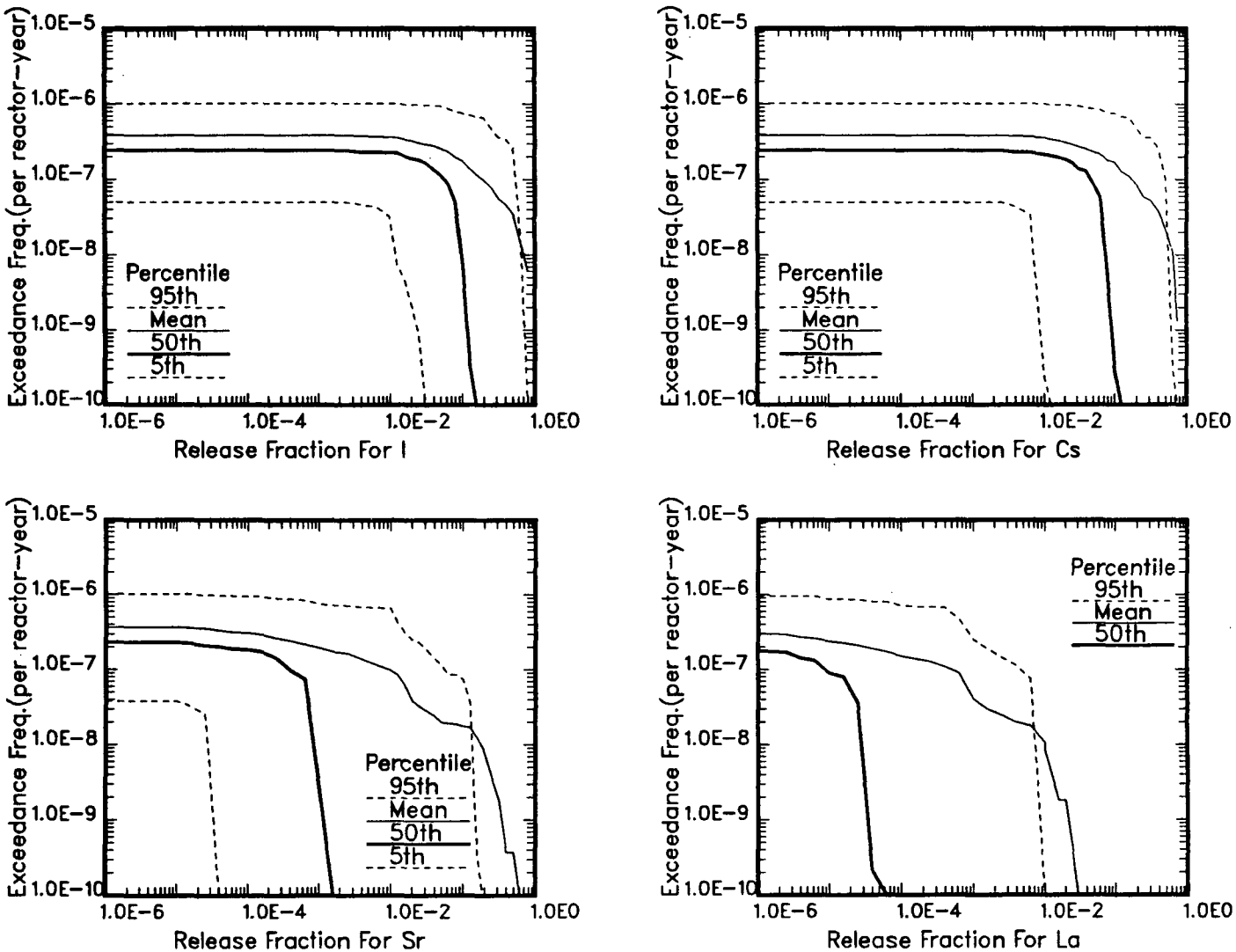


Figure 3.3-14. Exceedance Frequencies for Release Fractions for Surry Internal Initiators. "G" SGTRs (Secondary SRVs Reclosing

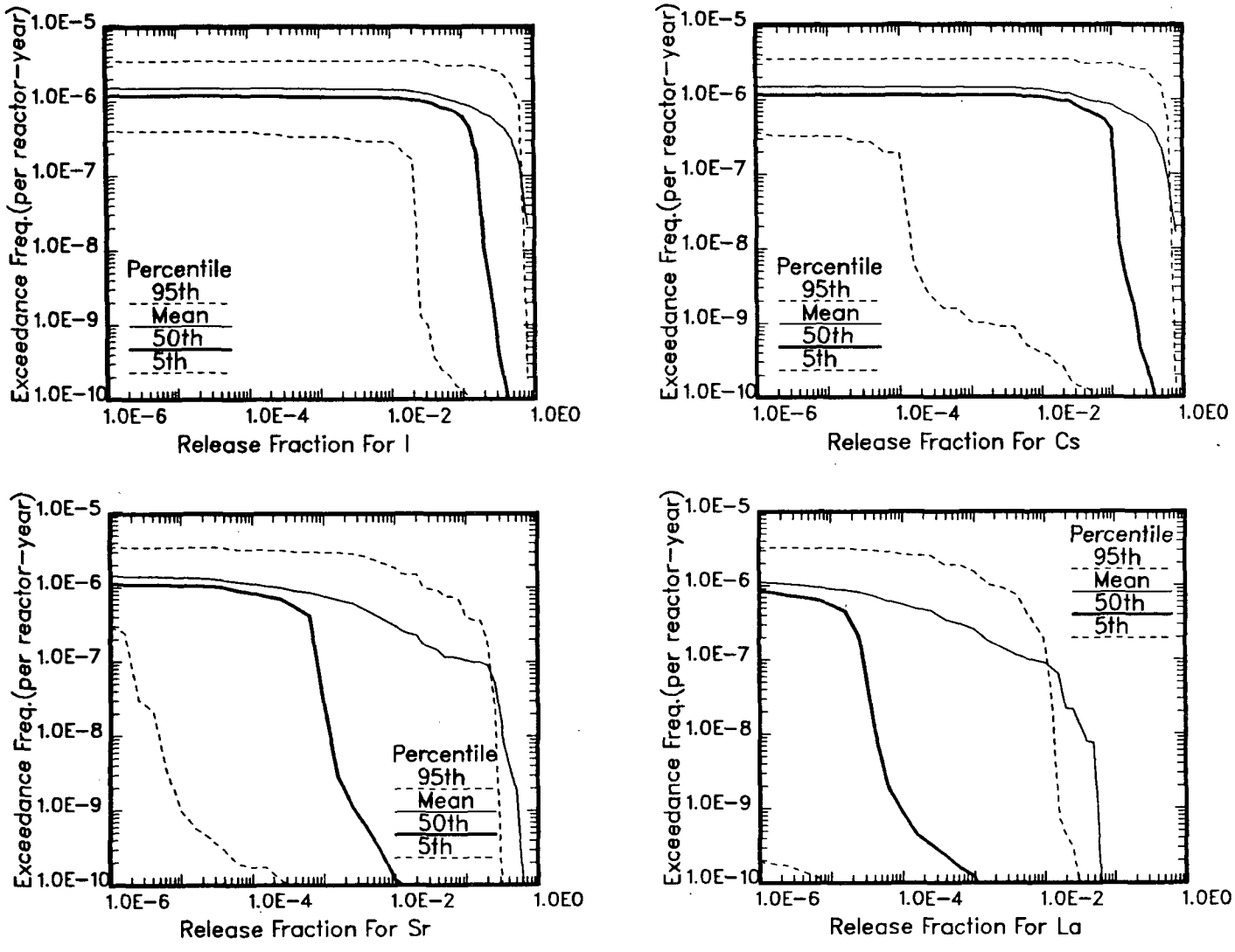


Figure 3.3-15. Exceedance Frequencies for Release Fractions for Surry Internal Initiators. "H" SGTRs (Secondary SRVs Stuck Open)

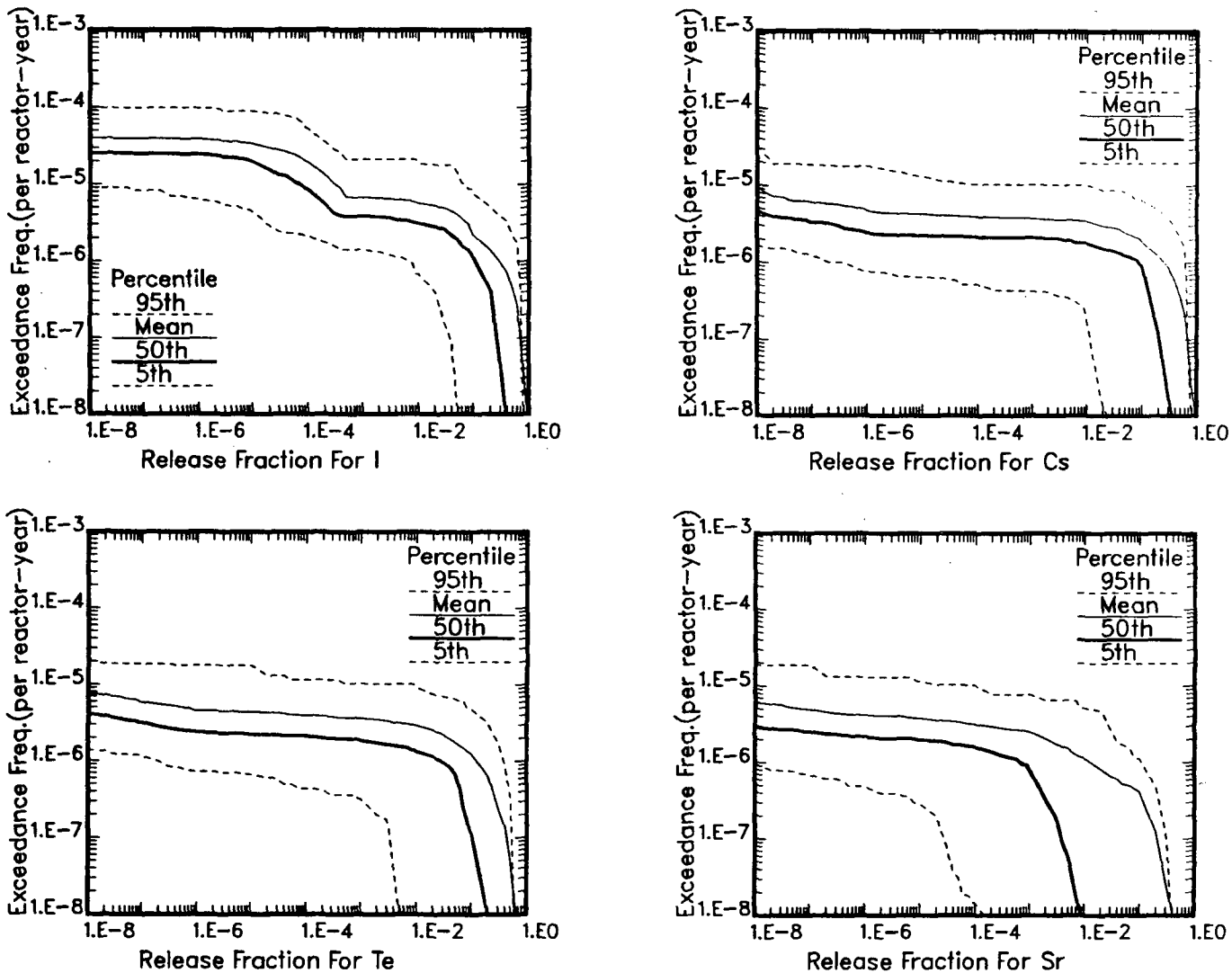


Figure 3.3-16. Exceedance Frequencies for Release Fractions for Surry: All Internal Initiators

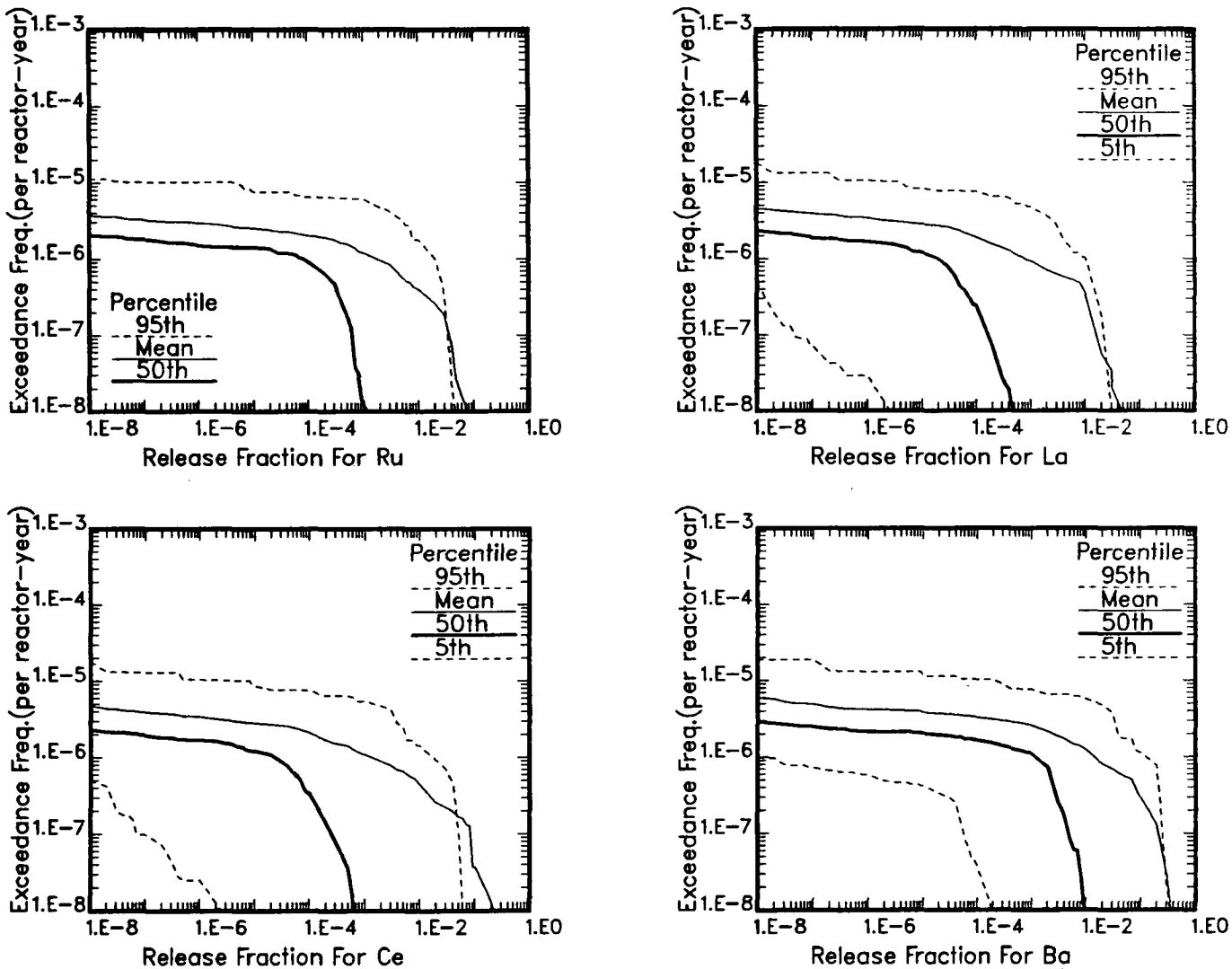


Figure 3.3-16. (continued)

Table 3.3-8
Summary of Variables Sampled
Surry: Internal Initiators

Variable	Analysis	Description
V-TRAIN	Acc. Freq.	IE - Interfacing System LOCA (Event V)
IE-LOSP	Acc. Freq.	IE - Loss of Offsite Power (LOSP)
IE-A	Acc. Freq.	IE - Large LOCA
IE-S1	Acc. Freq.	IE - Intermediate size LOCA
IE-S2	Acc. Freq.	IE - Small LOCA
IE-S3	Acc. Freq.	IE - Very small LOCA
IE-T-ALL	Acc. Freq.	IE - Transients that require scram
IE-T-HIP	Acc. Freq.	IE - Transients from high power that require scram
IE-LMFWS	Acc. Freq.	IE - Transients due to loss of main feedwater
IE-SGTR	Acc. Freq.	IE - Steam Generator Tube Rupture
IE-DCBUS	Acc. Freq.	IE - Loss of a DC power buss
DG-FRUN	Acc. Freq.	DG fails to run
DG-FSTRT	Acc. Freq.	DG fails to start
UNFV-MOD	Acc. Freq.	Unfavorable moderator temperature coefficient
AU-SCRAM	Acc. Freq.	RPS fails to scram reactor
MN-SCRAM	Acc. Freq.	Failure of manual scram
AUTO-ACT	Acc. Freq.	Failure of one train of an automatic actuation system
CCF-RWST	Acc. Freq.	CCF - miscalibration of RWST level sensors
BETA2MOV	Acc. Freq.	Beta factor for CCF of two motor-operated valves
BETA-AFW	Acc. Freq.	Beta factor for CCF of the AFWS motor-driven pumps
BETA-LPI	Acc. Freq.	Beta factor for CCF of the LPIS pumps
AFW-STMB	Acc. Freq.	CCF - all AFWS due to steam binding
MDP-FSTR	Acc. Freq.	Motor-driven pump fails to start (generic)
AFWMP-FS	Acc. Freq.	AFW motor-driven pump fails to start
AFWTP-FS	Acc. Freq.	AFW steam turbine-driven pump fails to start
ATP-FR6	Acc. Freq.	AFW turbine-driven pump fails to run for 6 hours
ATP-FR24	Acc. Freq.	AFW turbine-driven pump fails to run for 24 hours
PORV-BLK	Acc. Freq.	PORV block valves fail to open
LPRS-MOV	Acc. Freq.	LPRS suction MOVs fail to open
MOV-FT	Acc. Freq.	Motor-operated valve fails to transfer
MNV-PG1	Acc. Freq.	Plugging of manual valve flow tested every month
MOV-PG3	Acc. Freq.	Plugging of an MOV flow tested every 3 months
MOV-PG12	Acc. Freq.	Plugging of an MOV flow tested every 12 months
AFW-OCC	Acc. Freq.	CCF - open cross-connect to Unit 2 fails AFWS
PORV-REC	Acc. Freq.	Pressurizer PORV fails to reclose after opening
SSRVO-SB	Acc. Freq.	Secondary SRV fails to reclose during SBO
SSRVO-U2	Acc. Freq.	Secondary SRV fails to reclose during SBO at Unit 2

Table 3.3-8 (continued)

Variable	Analysis	Description
SOV-FT	Acc. Freq.	Solenoid-operated valve fails to transfer
CKV-FT	Acc. Freq.	Check valve fails to transfer
HE-FDBLD	Acc. Freq.	Operator error - feed and bleed (pumps and PORVs)
HE-PORVS	Acc. Freq.	Operator error - feed and bleed (PORVs only)
HE-CST2	Acc. Freq.	Operator error - align AFWS suction to backup CST
HE-UNIT2	Acc. Freq.	Operator error - cross-connect AFW from Unit 2
HE-SKILL	Acc. Freq.	Operator error - skill-based actions
RCP-SL-F	Acc. Freq.	T-I failure of the RCP seals before UTAF
V-UWATER	Acc. Prog.	Break location underwater for Event V
PORV-OPN	Acc. Prog.	A pressurizer PORV or RCS SRV sticks open
RCP-SL-P	Acc. Prog.	T-I failure of the RCP seals after UTAF
TI-SGTR	Acc. Prog.	T-I SGTR
TI-HOTLG	Acc. Prog.	T-I failure of the hot leg or surge line and fraction of equivalent core Zr oxidized in-vessel
RCSPR-VB	Acc. Prog.	RCS pressure just before vessel breach
CDARREST	Acc. Prog.	Arrest of core damage before VB
FR-HPME	Acc. Prog.	Fraction of core which participates in HPME
VB-ALPHA	Acc. Prog.	Probability of an Alpha mode CF
TYPE-VB	Acc. Prog.	Type of VB
VBHOLSIZ	Acc. Prog.	Size of the hole in the vessel after ablation
PRISE-LO	Acc. Prog.	Pressure rise at VB - RCS at low pressure or Pour
PRISE-VB	Acc. Prog.	Pressure rise at VB - RCS not at low pressure
CF-PRES	Acc. Prog.	Containment failure pressure
CF-MODE	Acc. Prog.	Random number used to select mode of CF
HB-SCAL	Acc. Prog.	Scale factor for pressure rise from a hydrogen burn
POWERREC	Acc. Prog.	Offsite power recovery
FCOR	Src. Term	Core Release Fraction
FVES	Src. Term	Vessel Release Fraction
VDF	Src. Term	Decontamination Factor for V Underwater Releases
FCONV	Src. Term	Containment RCS Release Fraction
FCCI	Src. Term	CCI Release Fraction
FCONC	Src. Term	Containment CCI Release Fraction
SPRDF	Src. Term	Spray Decontamination Factor (DFE & DFL)
LATEI	Src. Term	Late Release of Iodine from Water in Volatile Form
FLATE	Src. Term	Late Revolatilization from the RCS
DST	Src. Term	Direct Containment Heating Release Fraction
FISGFOSG	Src. Term	Release Fractions for SGTR Accidents
DFPSL	Src. Term	Decontamination Factor for Late Pool Scrubbing

Table 3.3-9
Summary of Rank Regression Analyses for
Annual Release Rates (fraction/yr)
for Internal Initiators

	Noble Gas			Iodine			Cesium		
STEP	VAR[a]	SRC[b]	R^{2c}	VAR	SRC	R^2	VAR	SRC	R^2
1	DG-FSTRT	0.35	0.13	FISGFOSG	0.54	0.28	FISGFOSG	0.59	0.36
2	IE-SGTR	0.27	0.21	IE-SGTR	0.34	0.39	FCOR	0.33	0.47
3	IE-LOSP	0.27	0.28	V-TRAIN	0.28	0.47	IE-SGTR	0.32	0.58
4	V-TRAIN	0.27	0.35	FCOR	0.25	0.52	V-TRAIN	0.30	0.67
5	DG-FRUN	0.26	0.42	LATEI	0.20	0.56			
6	LPR-MOV	0.17	0.45	PORV-BLK	0.17	0.58			
7	HE-UNIT2	-0.14	0.47	RCP-SL-F	-0.13	0.59			
8	FCOR	0.14	0.49	TYPE-VB	0.13	0.61			

	Tellurium			Strontium			Ruthenium		
STEP	VAR[a]	SRC[b]	R^{2c}	VAR	SRC	R^2	VAR	SRC	R^2
1	FCOR	0.51	0.29	FCOR	0.62	0.41	FCOR	0.84	0.74
2	FISGFOSG	0.50	0.53	FISGFOSG	0.35	0.52	FISGFOSG	0.33	0.85
3	V-TRAIN	0.30	0.62	FCCI	0.30	0.61	IE-SGTR	0.14	0.86
4	IE-SGTR	0.26	0.68	V-TRAIN	0.28	0.69	V-TRAIN	0.09	0.87
5	FCCI	0.12	0.70	IE-SGTR	0.14	0.71	FCCI	0.09	0.88
6	PORV-BLK	0.10	0.71	FDCH	-0.12	0.72	CF-PRES	-0.07	0.89
				VB-ALPHA	0.10	0.73			

Table 3.3-9 (continued)

	Lanthanum			Cerium			Barium		
STEP	VAR[a]	SRC[b]	R^2[c]	VAR	SRC	R^2	VAR	SRC	R^2
1	FCOR	0.62	0.42	FCOR	0.68	0.50	FCOR	0.64	0.44
2	FCCI	0.36	0.54	FCCI	0.32	0.60	FISGFOSG	0.39	0.58
3	V-TRAIN	0.28	0.62	FISGFOSG	0.27	0.66	V-TRAIN	0.26	0.64
4	FISGFOSG	0.28	0.69	V-TRAIN	0.25	0.72	FCCI	0.25	0.71
5	IE-SGTR	0.11	0.70	SPRDF	0.10	0.73	IE-SGTR	0.16	0.73
6	FDCH	-0.10	0.72	FDCH	-0.10	0.74	FDCH	-0.11	0.75
7	SPRDF	0.10	0.73				VB-ALPHA	0.09	0.76

[a] Variables listed in the order that they entered the regression analysis.
[b] Standardized regression coefficients (SRCs) in final regression model.
[c] R^2 values with the entry of successive variables into the regression model.

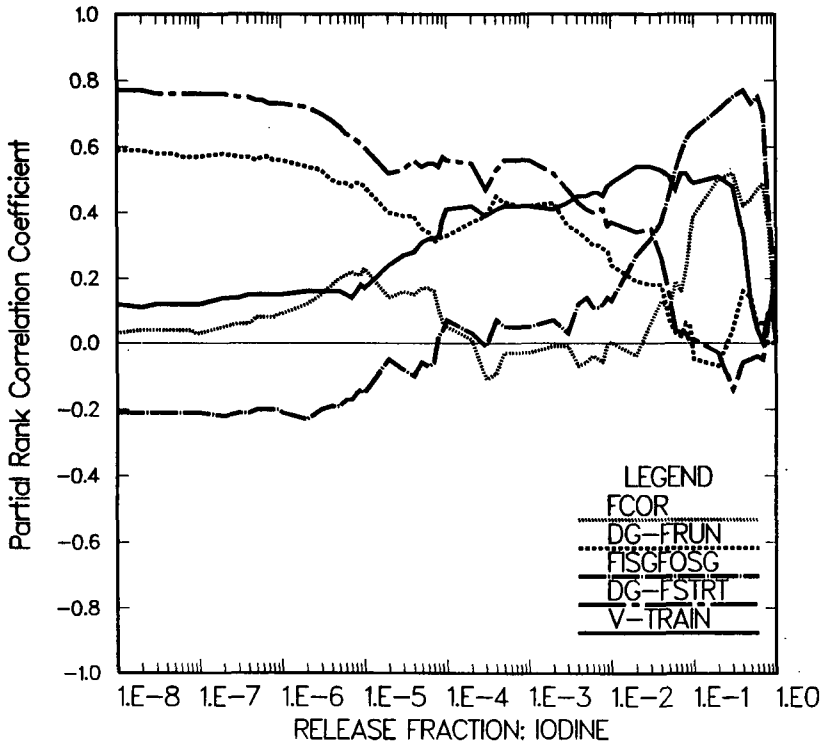
Table 3.3-10
Summary of Rank Regression Analyses for Annual Release Rates (fraction/yr) at Surry for Two Samples for Internal Initiators

	Noble Gas Sample 1			Noble Gas Sample 2			Iodine Sample 1			Iodine Sample 2		
Step	VAR[a]	SRC[b]	R^{2c}	VAR	SRC	R^2	VAR	SRC	R^2	VAR	SRC	R^2
1	DG-FSTRT	0.35	0.13	IE-SGTR	0.45	0.19	FISGFOSG	0.54	0.28	FISGFOSG	0.60	0.35
2	IE-SGTR	0.27	0.21	DG-FSTRT	0.39	0.35	IE-SGTR	0.34	0.39	IE-SGTR	0.39	0.51
3	IE-LOSP	0.27	0.28	V-TRAIN	0.29	0.43	V-TRAIN	0.28	0.47	V-TRAIN	0.26	0.57
4	V-TRAIN	0.27	0.35	IE-LOSP	0.25	0.49	FCOR	0.25	0.52	FCOR	0.24	0.63
5	DG-FRUN	0.26	0.42	POWERREC	-0.19	0.53	LATEI	0.20	0.56	DG-FSTRT	0.15	0.65
6	LPR-MOV	0.17	0.45	SSRVO-SB	0.19	0.56	PORV-BLK	0.17	0.58	LATEI	0.14	0.67
7	HE-UNIT2	-0.14	0.47	DG-FRUN	0.18	0.59	RCP-SL-F	-0.13	0.59	IE-LOSP	0.12	0.69
8	FCOR	0.14	0.49				TYPE-VB	0.13	0.61	V-UWATER	-0.17	0.70
9										AFW-STMB	-0.12	0.71
10										RCP-SL-F	0.11	0.73

Table 3.3-10 (continued)

	Strontium Sample 1			Strontium Sample 2			Lanthanum Sample 1			Lanthanum Sample 2		
Step	VAR[a]	SRC[b]	R^2[c]	VAR	SRC	R^2	VAR	SRC	R^2	VAR	SRC	R^2
1	FCOR	0.62	0.41	FCOR	0.64	0.40	FCOR	0.62	0.42	FCOR	0.61	0.39
2	FISGFOSG	0.35	0.52	FCCI	0.31	0.50	FCCI	0.37	0.54	FCCI	0.38	0.54
3	FCCI	0.30	0.61	V-TRAIN	0.32	0.60	V-TRAIN	0.29	0.62	V-TRAIN	0.33	0.63
4	V-TRAIN	0.28	0.69	FISGFOSG	0.27	0.67	FISGFOSG	0.28	0.69	FISGFOSG	0.17	0.66
5	IE-SGTR	0.14	0.71	IE-SGTR	0.15	0.70	IE-SGTR	0.11	0.70	VB-ALPHA	0.13	0.68
6	FDCH	-0.12	0.72	VB-ALPHA	0.15	0.72	FDCH	-0.10	0.72	RCP-SL-F	0.11	0.69
7	VB-ALPHA	0.10	0.73	ATP-FR6	-0.13	0.73	SPRDF	0.11	0.73	FCONC	0.10	0.70
8									0.73			
9									0.74			
10									0.75			
11									0.76			

[a] Variables listed in the order that they entered the regression analysis.
[b] Standardized regression coefficients (SRCs) in final regression model.
[c] R^2 values with the entry of successive variables into the regression model.



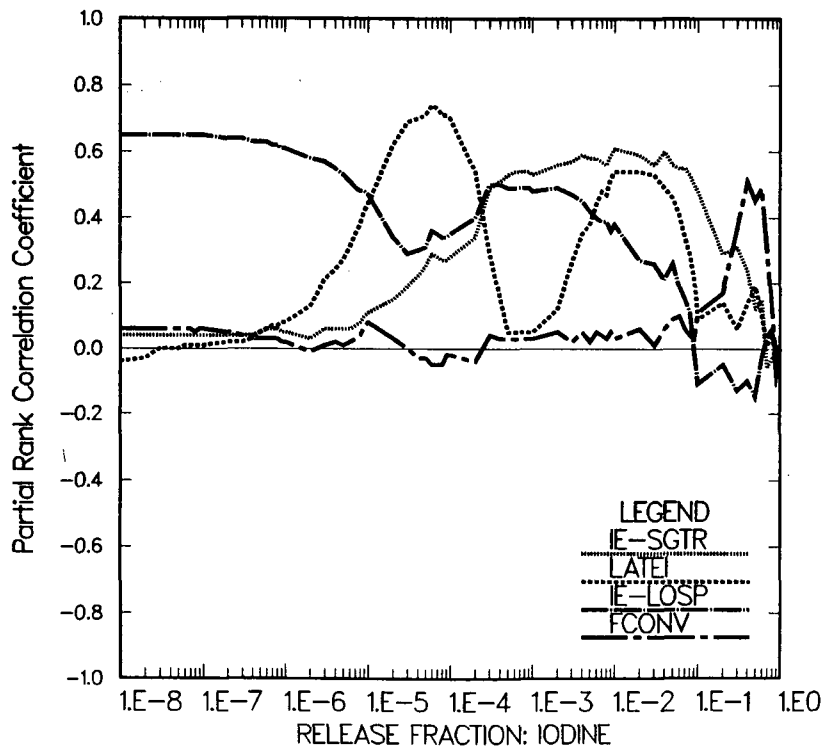
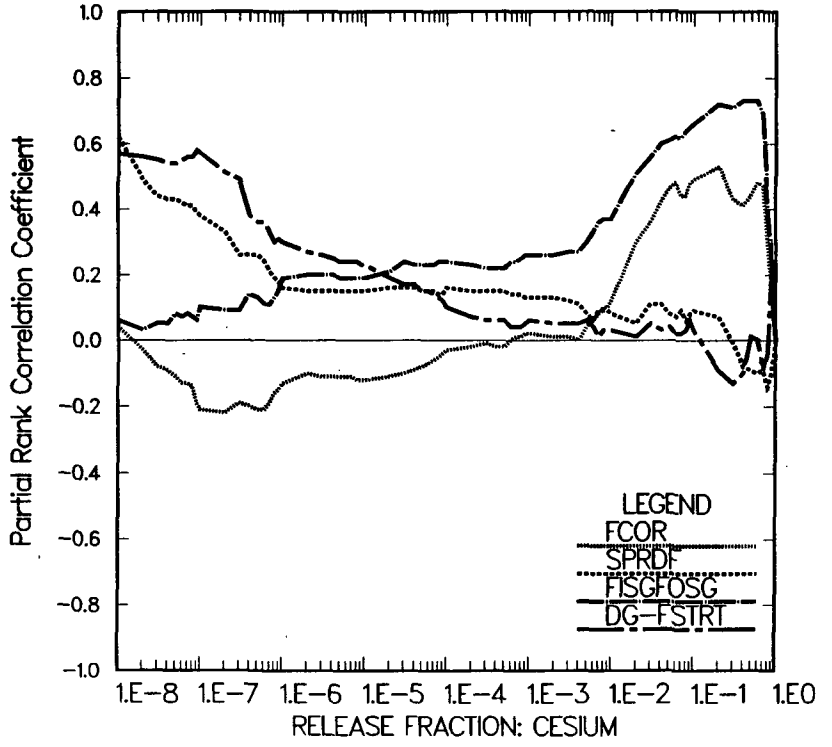


Figure 3.3-17. Partial Rank Correlation Coefficients for Exceedance Frequencies for Release Fractions for Surry Internal Initiators. Iodine



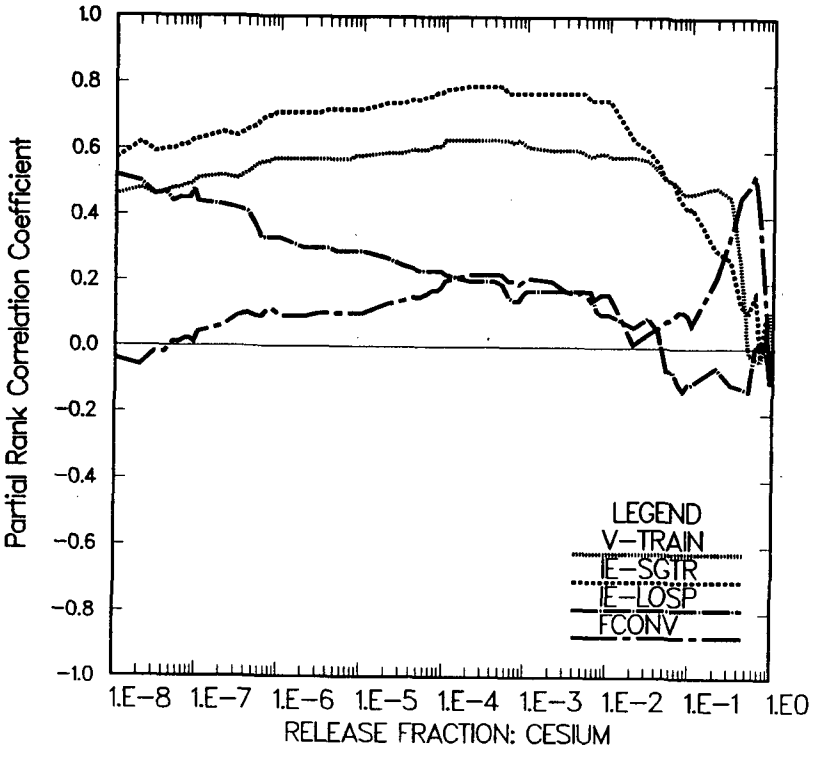


Figure 3.3-18. Partial Rank Correlation Coefficients for Exceedance Frequencies for Release Fractions for Surry Internal Initiators. Cesium

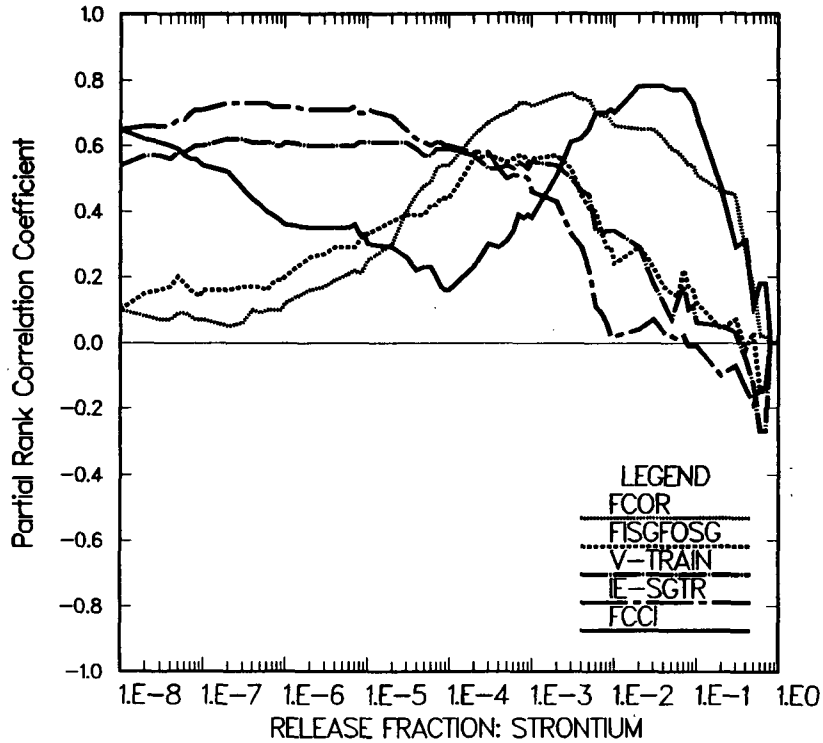


Figure 3.3-19. Partial Rank Correlation Coefficients for Exceedance Frequencies for Release Fractions for Surry Internal Initiators. Strontium

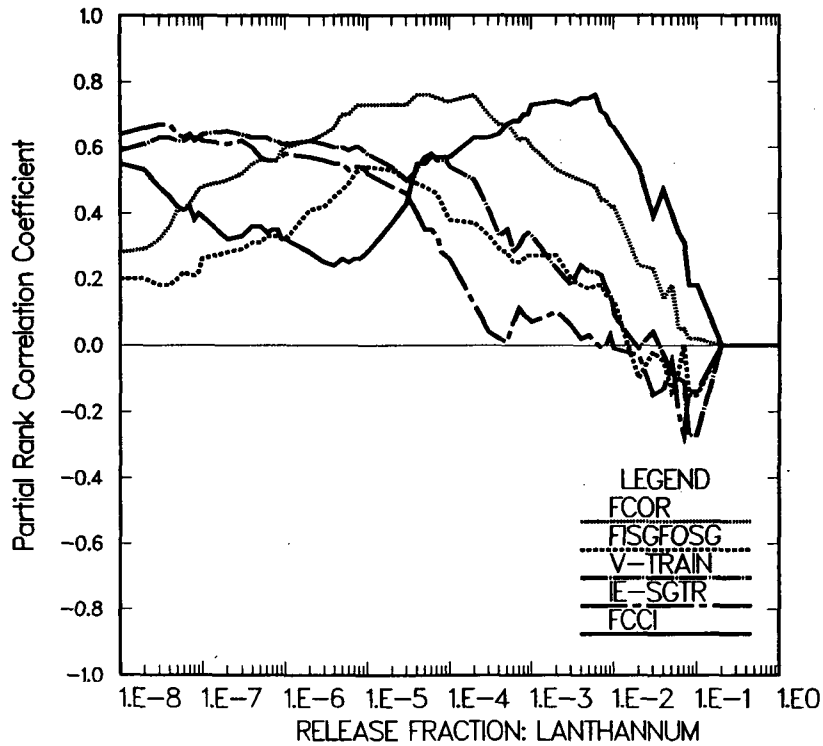


Figure 3.3-20. Partial Rank Correlation Coefficients for Exceedance Frequencies for Release Fractions for Surry Internal Initiators. Lanthanum

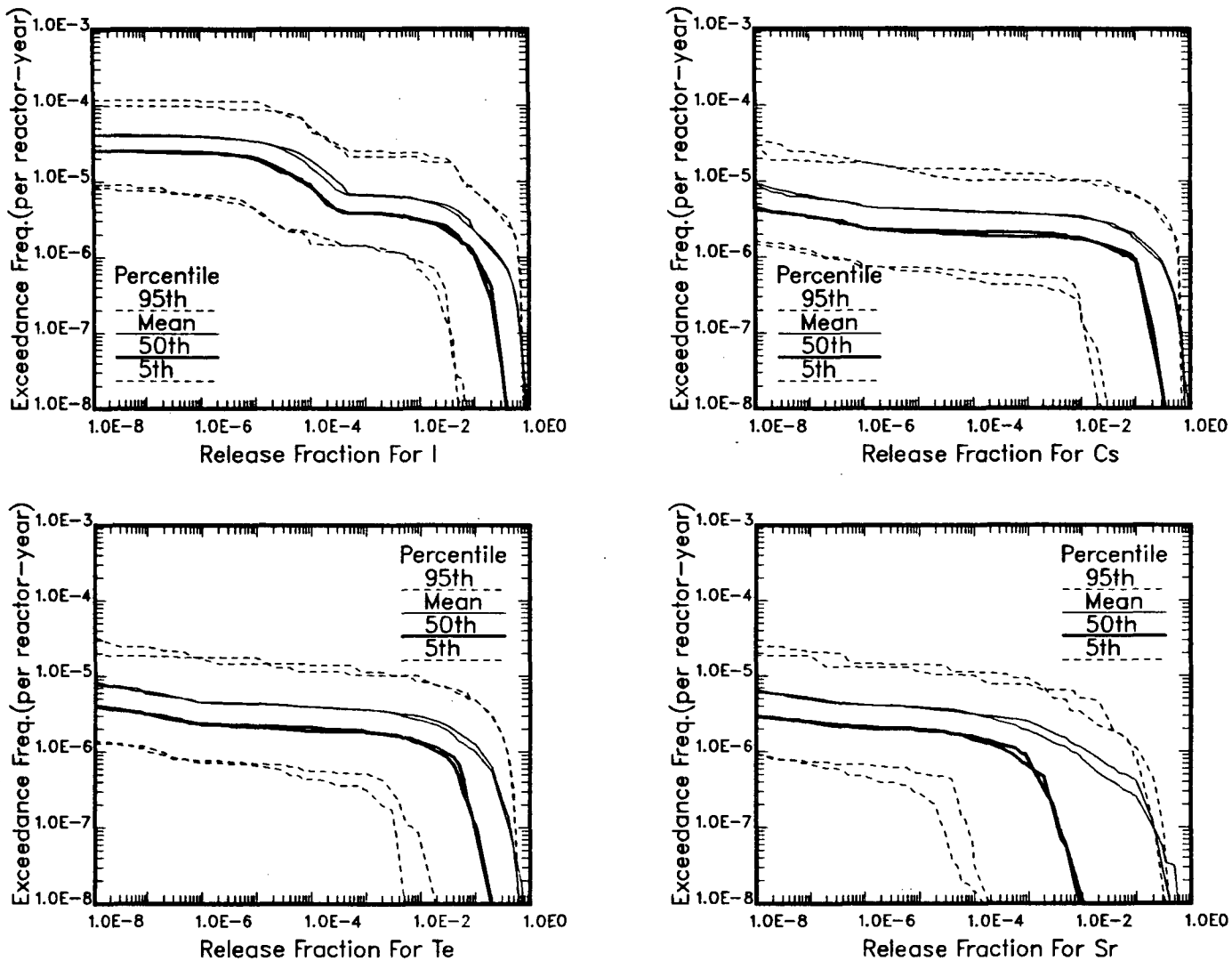


Figure 3.3-21. Comparison of Exceedance Frequencies for Two Independent Latin Hypercube Samples Surry Internal Initiators

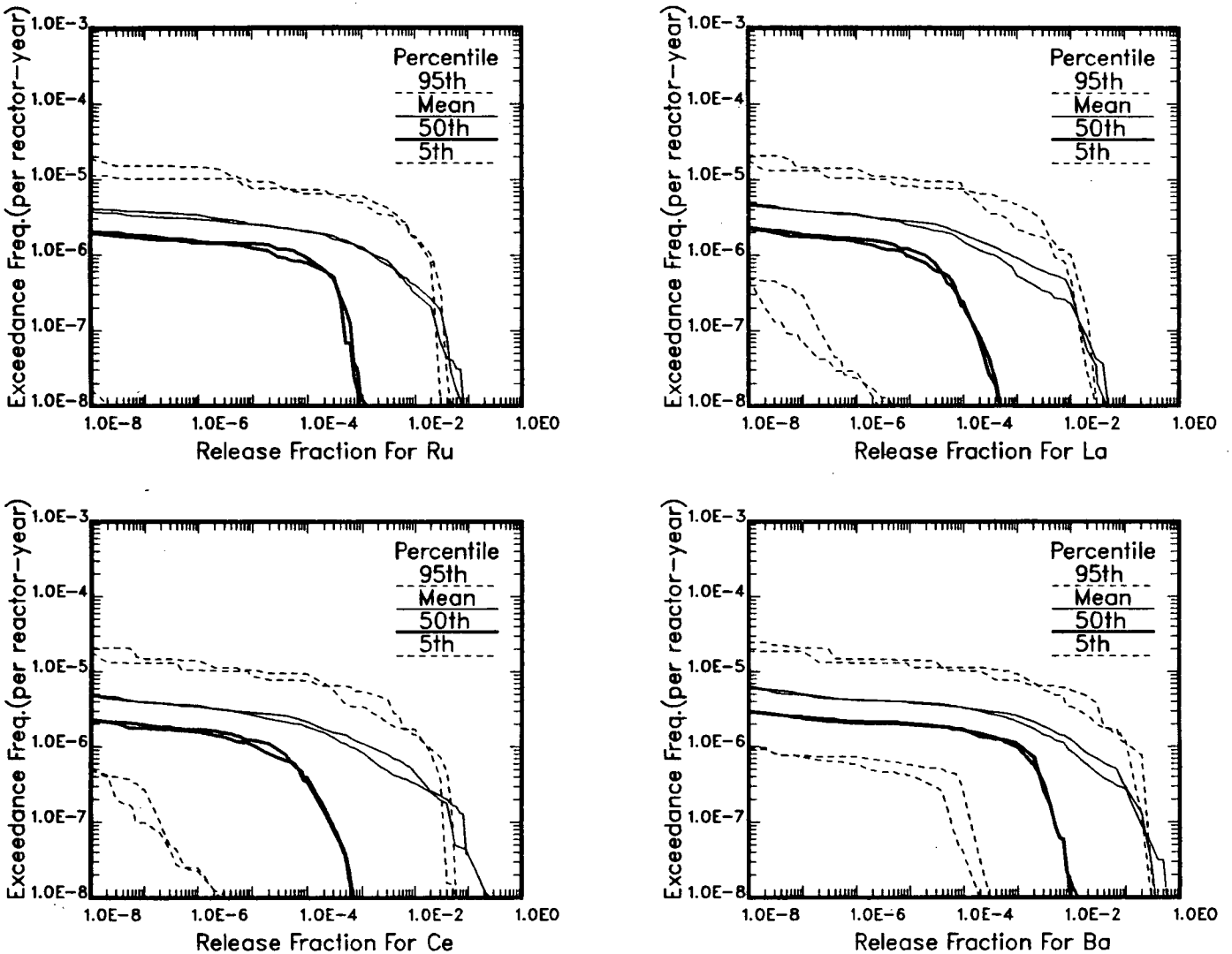
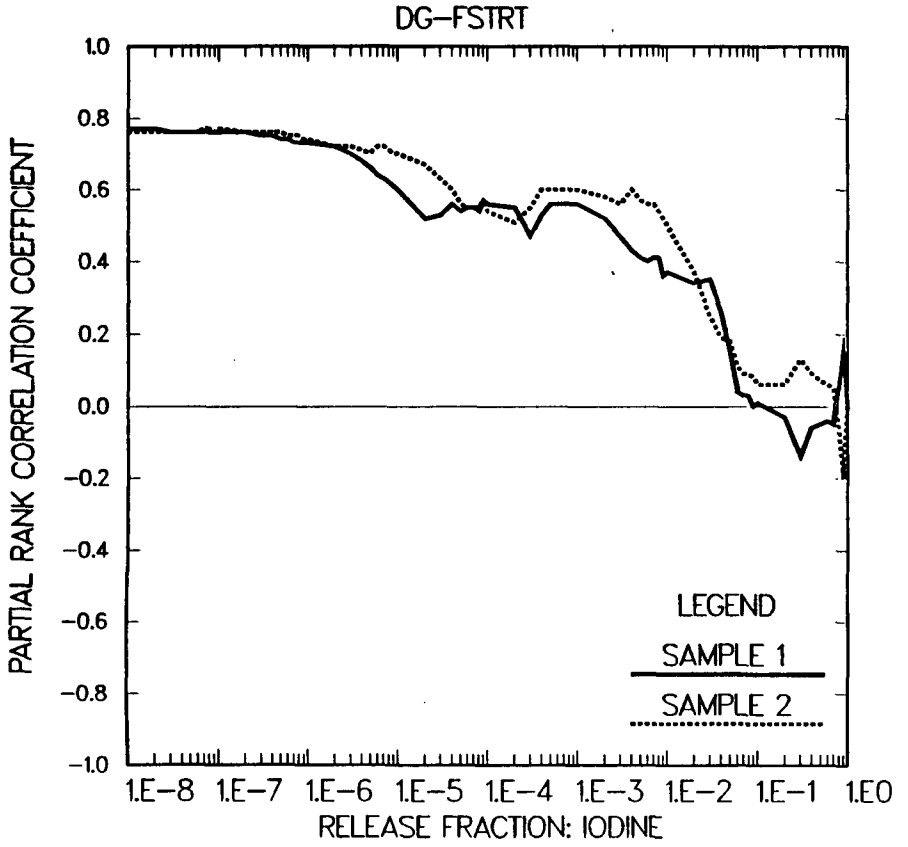


Figure 3.3-21. (continued)



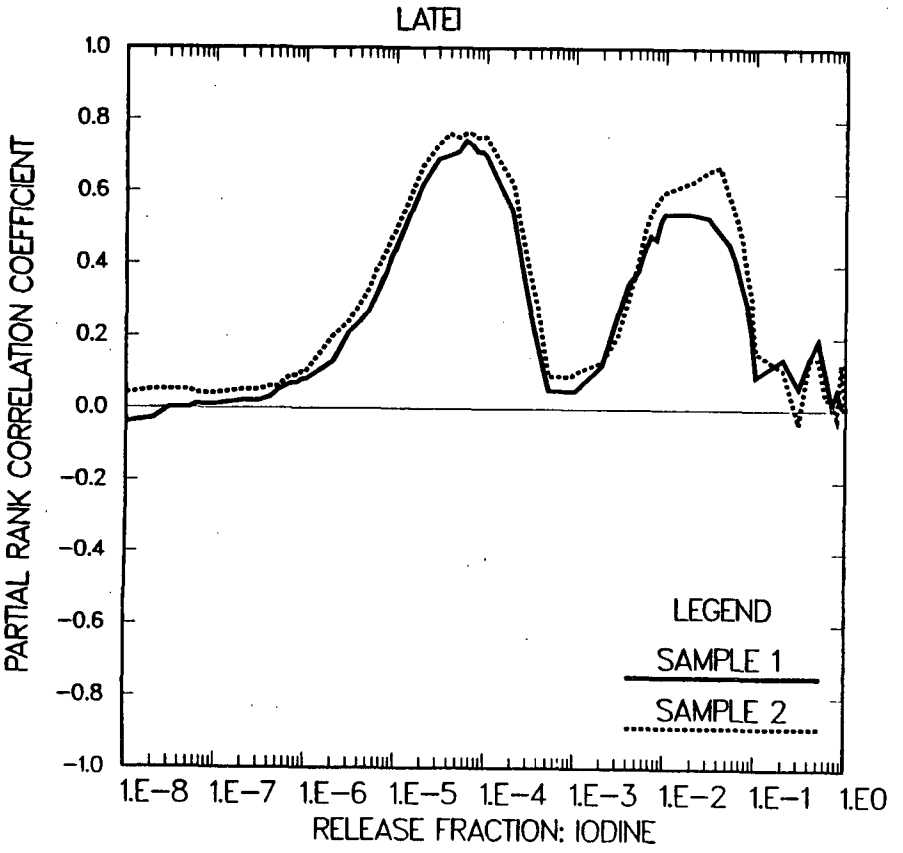


Figure 3.3-22. Comparison of two PRCC Curves for Two Representative Variables

3.3.3 Results for Fire Initiators

At Surry, fires were found to be important in the emergency switchgear room, the auxiliary building, the control room, and the cable vault and tunnel as discussed in Sections 2.2.2.2 and 2.5.3. Table 2.5-14 lists the 10 most probable APBs for the PDS group and the five most probable APBs that have VB and early containment failure (CF). Since there is no possibility of core damage arrest for the fire initiators, all the APBs have VB. Table 3.3-11 lists the mean source terms for the same APBs listed in Table 2.5-14. The structure of tables such as 3.3-11 is discussed in Section 3.3.1.1.

The 10 most probable fire APBs do not have aboveground containment failure. As a result, the releases associated with these APBs are very small. When there is no containment failure, SURSOR describes releases with a single release segment rather than the two release segments used when there is containment failure. Thus, the early release is zero for the 10 most probable bins in Table 3.3-11. The five most probable APBs with VB and early containment failure have low conditional probabilities (see Table 2.5-14) but larger releases than the APBs without containment failure. The mean source terms in Table 3.3-11 can be used to compare the releases associated with specific APBs. However, as these mean source terms are typically not calculated over the same sample elements, fine distinctions between source terms associated with different APBs may be lost in the averaging process.

Table 3.3-11 presents mean source terms but does not contain any frequency information. In contrast, Figure 3.3-23, which summarizes the release fraction CCDFs for for the I, Cs, Sr, and La radionuclide classes, presents information on both source term size and frequency. The derivation of the curves in Figure 3.3-23 is discussed in Section 3.3.1.1.

3.3.4 Sensitivity Analyses for Fire Initiators

No sensitivity analyses were performed for fire initiators at Surry.

3.3.5 Results for Seismic Initiators: LLNL Hazard Distribution

The seismic risk analysis was performed using two different seismic hazard distributions. This section concerns the source term results based on the hazard distribution developed by LLNL. Source term results based on the seismic hazard distribution developed by EPRI are presented in Section 3.3.7. The differences between these two distributions are discussed in NUREG/CR-4550, Vol. 3.[6]

The accidents initiated by earthquakes were analyzed in two groups. Those due to seisms with a maximum ground acceleration in excess of 0.6 g were denoted the high acceleration events. It was judged that the destruction in the general vicinity of the plant for those earthquakes would be so great that evacuation would be ineffective. For the low acceleration events, less than 0.6 g, it was estimated that evacuation would be possible, although perhaps more slowly than in emergencies without earthquakes.

The basic results of the source term analysis are the release fraction CCDFs for each observation in the sample. Figures 3.3-24 through 3.3-26 show four statistical measures of these release fraction CCDFs for the seismic PDS groups based on the LLNL hazard distribution. Results are shown for the iodine, cesium, strontium, and lanthanum radionuclide classes: both acceleration ranges are combined in these plots. Figure 3.3-27 contains the release fraction CCDFs for all three PDS groups and both acceleration ranges together for the LLNL hazard distribution.

3.3.5.1 Results for PDS Group EQ 1, LOSP (No SBO): High Acceleration, LLNL Hazard Distribution. This PDS group consists of accidents initiated by LOSP, but in which SBO does not result. The LOSP is due to the earthquake, but the DGs start and run, suppling station power. There are five PDSs in the seismic LOSP group as listed in Table 2.2-6, and discussed in Sections 2.2.2.3 and 2.5.5.1. This PDS group consists of the fraction of these accidents due to seisms with a peak ground acceleration (PGA) exceeding 0.6 g.

Table 2.5-15 lists the 10 most probable APBs for this PDS group and the five most probable APBs that have VB and early CF. Table 3.3-12 lists the mean source terms for these same APBs. The structure of tables such as Table 3.3-12 is discussed in Section 3.3.1.1. The release fractions are low for the 10 most probable bins because eight of them have no CF and the other two have BMT. Four of the five most probable bins with VB and early CF have iodine and cesium release fractions on the order of 0.30. These APBs have mean conditional probabilities (see Table 2.5-15) of 0.004 or less, however.

Table 3.3-12 presents mean source terms but does not contain any frequency information. In contrast, Figure 3.3-24 presents information on the frequency with which different values of the release fraction are exceeded, and displays the uncertainty in that frequency. This figure summarizes the LLNL seismic LOSP release fraction CCDFs for the iodine, cesium, strontium, and lanthanum radionuclide classes for both acceleration ranges. For a given release fraction, the exceedance frequency contribution from the high PGA group is roughly an order of magnitude lower than the contribution from the low PGA group. The interpretation and generation of figures such as Figure 3.3-24 is discussed in section 3.3.1.1.

3.3.5.2 Results for PDS Group EQ 2, SBO: High Acceleration, LLNL Hazard Distribution. This PDS group consists of accidents initiated by LOSP in which SBO follows. The LOSP is due to the earthquake, and the DGs fail to start due to seismic and random hardware failures. Due to the seismic failures in the electrical distribution system that may be expected, it was judged that offsite power would not be recovered within the timeframe of this analysis. Thus there is no chance of arresting core damage or avoiding VB in this PDS group. The two "A" PDSs in this group have large pipe breaks and initial CF due to failures of the SG or RCP pump supports that are coincident with the initiating LOSP. The eight PDSs in the SBO group are listed in Table 2.2-6 and discussed in Sections 2.2.2.3 and 2.5.5.2. This SBO PDS group consists of the fraction of these accidents due to seisms with a PGA exceeding 0.6 g.

Table 2.5-16 lists the 10 most probable APBs for the PDS group and the five most probable APBs that have VB and early CF. Table 3.3-13 lists the mean source terms for these same APBs. Two of the 10 most probable bins have initial failure of the containment due to SG or RCP support failures; for these bins (the 4th and 6th in order, first characteristic = C), the releases are much higher than for the others in the 10 most probable APBs. Of the other eight APBs, three have BMT, and the five have no CF. For the five most probable APBs with both VB and early CF, the iodine and cesium release fractions are in the range of 0.25 to 0.50. The total mean conditional probability (see Table 2.5-16) of these APBs is about 0.11. Figure 3.3-25 shows four statistical measures of the release fraction CCDFs for the iodine, cesium, strontium, and lanthanum radionuclide classes for the LLNL seismic SBO group for both acceleration ranges. For a given release fraction, the exceedance frequency contribution from the high PGA group is roughly a factor of 5 lower than the contribution from the low PGA group.

3.3.5.3 Results for PDS Group EQ 3, LOCAs: High Acceleration, LLNL Hazard Distribution. This PDS group consists of accidents initiated by seismic pipe breaks. The failures in the ECCS required to respond to these breaks are partially seismic and partially random. There is no SBO, but some of the seismic failures are in portions of the the electrical distribution system that supply power to the ECCS, sprays, or AFWS. There are 11 PDSs in this group as listed in Table 2.2-6 and discussed in Sections 2.2.2.3 and 2.5.5.3. The five "A" PDSs in this group have initial CF due to failures of the SG or RCP pump supports. This PDS group consists of the fraction of the seismic LOCA accidents due to earthquakes with a PGA exceeding 0.6 g.

Table 2.5-17 lists the fifteen most probable APBs for the PDS group, and Table 3.3-14 lists the mean source terms for these same APBs. The six APBs that have C as the first characteristic have initial CF. For these APBs the releases are much higher than for the others in the 15 most probable APBs. For the 3rd and 4th APBs, which have initial CF and the sprays inoperable, the release fractions are fairly high. For the 7th, 11th, 12th, and 15th APBs, which have initial CF and sprays operating, the release fractions are much lower. The mean conditional probabilities of the APBs are given in Table 2.5-17. The mean conditional probability of the most likely APB with initial CF is 0.80.

Figure 3.3-26 shows four statistical measures of the release fraction CCDFs for four radionuclide classes for the LLNL seismic LOCA group for both acceleration ranges. For a given release fraction, the exceedance frequency contribution from the high PGA group is roughly half the contribution from the low PGA group.

3.3.5.4 Results for PDS Group EQ 1, LOSP (No SBO): Low Acceleration, LLNL Hazard Distribution. This PDS group consists of seismic accidents initiated by LOSP, but in which SBO does not result, and in which the earthquake has a PGA less than 0.6 g. The five PDSs in this group are discussed in Sections 2.2.2.3 and 2.5.5.1. Similar PDSs with a PGA exceeding 0.6 g are discussed in Section 3.3.5.1. Table 2.5-18 lists the 10 most probable APBs for this PDS group and the five most probable APBs that have VB and early CF. Table 3.3-15 lists the mean source terms for

these same APBs. The release fractions are low for the 10 most probable bins because eight of them have no CF and the other two have BMT. Four of the five most probable bins with VB and early CF have iodine and cesium release fractions on the order of 0.30. These APBs have mean conditional probabilities (see Table 2.5-18) of 0.004 or less, however.

Figure 3.3-24 summarizes the release fraction CCDFs for the iodine, cesium, strontium, and lanthanum radionuclide classes LLNL seismic LOSP group for both acceleration ranges. For a given release fraction, the exceedance frequency contribution from the low PGA group is roughly an order of magnitude greater than the contribution from the high PGA group.

3.3.5.5 Results for PDS Group EQ 2, SBO: Low Acceleration, LLNL Hazard Distribution. This PDS group consists of seismic SBO accidents in which the earthquake has a PGA less than 0.6 g. The five PDSs in this group are discussed in Sections 2.2.2.3 and 2.5.5.2. Similar PDSs with a PGA exceeding 0.6 g are discussed in Section 3.3.5.2. Table 2.5-19 lists the 10 most probable APBs for the PDS group and the five most probable APBs that have VB and early CF. Table 3.3-16 lists the mean source terms for these same APBs. One of the 10 most probable bins has initial failure of the containment; for this bin (the 7th, first characteristic = C), the releases are much higher than for the other APBs in the 10 most probable APBs. The other nine most probable APBs have BMT or no CF, and so have relatively small release fractions. For the five most probable APBs with both VB and early CF, the iodine and cesium release fractions are in the range of 0.25 to 0.50. The total mean conditional probability (see Table 2.5-16) of these APBs is about 0.06.

Figure 3.3-25 shows four statistical measures of the release fraction CCDFs for the iodine, cesium, strontium, and lanthanum radionuclide classes for the LLNL seismic SBO group for both acceleration ranges. For a given release fraction, the exceedance frequency contribution from the low PGA group is roughly a factor of 5 higher than the contribution from the high PGA group.

3.3.5.6 Results for PDS Group EQ 3, LOCAs: Low Acceleration, LLNL Hazard Distribution. This PDS group consists of accidents initiated by seismic pipe breaks in which the earthquake has a PGA less than 0.6 g. The five PDSs in this group are discussed in Sections 2.2.2.3 and 2.5.5.3. Similar PDSs with a PGA exceeding 0.6 g are discussed in Section 3.3.5.3. Table 2.5-20 lists the 15 most probable APBs for the PDS group. Table 3.3-17 lists the mean source terms for these same APBs. The five APBs that have C as the first characteristic have initial CF. For these APBs the releases are much higher than for the other APBs in the 15 most probable APBs. For the 3rd and 6th APBs, which have initial CF and the sprays inoperable, the release fractions are fairly high. For the 9th, 11th, and 12th APBs, which have initial CF and sprays operating, the release fractions are much lower. The mean conditional probabilities of the APBs are given in Table 2.5-20. The mean conditional probability of the most likely APB with initial CF is 0.80.

Figure 3.3-26 shows four statistical measures of the release fraction CCDFs for four radionuclide classes for the LLNL seismic LOCA group for both

acceleration ranges. For a given release fraction, the exceedance frequency contribution from the low PGA group is roughly twice the contribution from the high PGA group.

3.3.6 Sensitivity Analyses for Seismic Initiators: LLNL Hazard Distribution

To determine the effect of the initial failures of the containment due to failures of the SG and RCP supports, the integrated risk analysis using the LLNL hazard distribution was repeated without these induced seismic failures of the containment at the start of the accident. Eliminating the initial failures of the containment does not eliminate the possibility of CF before VB since the isolation failures remain with a very low probability.

Elimination of the initial seismic CFs has no effect on the source term analysis as it only changes the conditional probabilities of the APBs, not the source terms computed for the APBs.

3.3.7 Results for Seismic Initiators: EPRI Hazard Distribution

The seismic risk analysis was performed using two different seismic hazard distributions. This section reports the results using the hazard distribution developed by EPRI. Results based on the seismic hazard distribution developed by LLNL are presented in Section 3.3.5. The differences between these two distributions are discussed in NUREG/CR-4550, Vol. 3, Part 3.[6]

The accidents initiated by earthquakes were analyzed in two groups. Those due to seisms with a maximum ground acceleration in excess of 0.6 g were denoted the high acceleration events. It was judged that the destruction in the general vicinity of the plant for those earthquakes would be so great that evacuation would be ineffective. For the low acceleration events, less than 0.6 g, it was estimated that evacuation would be possible, although perhaps more slowly than in emergencies without earthquakes.

Tables 3.3-18 through 3.3-23 give the mean source terms for the important APBs for the seismic analysis using the EPRI hazard distribution. These tables are analogous to Tables 3.3-17 through 3.3-22 for the LLNL hazard distribution. Tables 3.3-18 through 3.3-23 give the mean source terms for the APBs contained in Tables 2.5-22 through 2.5-27. Figures 3.3-28 through 3.3-30 show four statistical measures of the release fraction CCDFs for the seismic PDS groups based on the EPRI hazard distribution for the iodine, cesium, strontium, and lanthanum radionuclide classes. They are analogous to Figures 3.3-24 through 3.3-26 for the LLNL hazard distribution. Figure 3.3-31 contains the release fraction CCDFs for all three PDS groups and both acceleration ranges together for the EPRI hazard distribution.

The integrated risk analysis for the seismic initiators using the EPRI hazard distribution differs from the integrated risk analysis for the seismic initiators using the LLNL hazard distribution only in the distribution utilized for the relationship of the frequency and size of the initiating earthquakes in the accident frequency analysis. The different hazard distributions cause some differences in the relative probabilities of the PDSs in each group, and this in turn causes slight differences in

the results of the accident progression analysis. These differences may be assessed by comparing Tables 2.5-15 through 2.5-20 for the LLNL hazard distribution with Tables 2.5-22 through 2.5-25 for the EPRI hazard distribution. There are some changes in the order of the bins and their probabilities for the six comparable PDS groups. These differences are reflected in the source term analysis, and are generally the only significant differences between the two sesimic source term analyses. That is, identical or very similar source terms are computed for identical APBs; the only differences are in the conditional probabilities of these bins. This may be confirmed by comparing Tables 3.3-17 through 3.3-22 with Tables 3.3-18 through 3.3-23. Due to these similarities, the discussions of the source terms results in Section 3.3.5 are applicable here as well, and detailed discussion of each table and figure are not warranted.

3.3.8 Sensitivity Analyses for Seismic Initiators: EPRI Hazard Distribution

No sensitivity studies were performed for the sesimic initiators with the EPRI hazard distribution which affect the source term analysis.

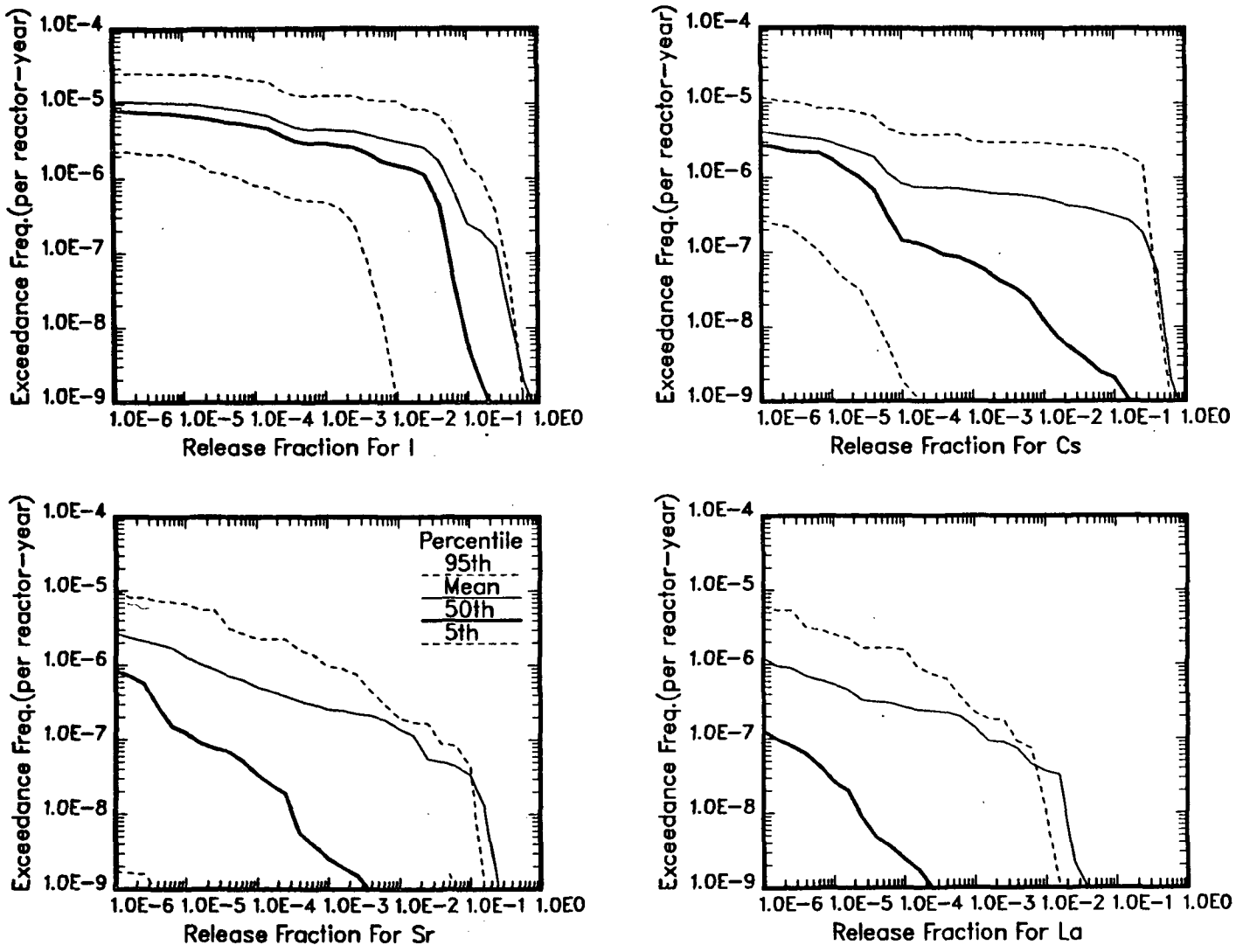


Figure 3.3-23. Release Fractions CCDFs for Fire Initiators

Table 3.3-11
Mean Source Terms for Surry
Fire Initiators

Order	Bin	Warning Time (s)	Elevation (m)	Release Energy (W)	Release Start (s)	Release Duration (s)	Release Fractions								
							NG	I	Cs	Te	Sr	Ru	La	Ce	Ba
Ten Most Probable Bins*															
1	HHADBCAADFB	2.2E+04	0.0E+00	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	GHADBCAADDB			0.0E+00	4.7E+04	8.6E+04	5.0E-03	1.7E-04	7.5E-07	4.7E-07	1.7E-07	8.7E-09	1.9E-08	2.6E-08	1.5E-07
2	HHADBCABDFB	2.2E+04	0.0E+00	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	GHADBCABDDB			0.0E+00	4.7E+04	8.6E+04	5.0E-03	1.6E-04	7.1E-07	4.4E-07	1.2E-07	8.0E-09	1.4E-08	1.8E-08	9.5E-0[illegible]
3	GHADBCAADDB	2.2E+04	1.0E+01	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	FHADBCAADCB			6.5E+04	1.3E+05	1.1E+04	1.0E+00	3.5E-02	4.6E-05	3.3E-05	1.2E-05	2.8E-07	1.5E-06	1.5E-06	1.0E-05
4	HDCDBCDADFB	2.2E+04	0.0E+00	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	GDCDBCDADDB			0.0E+00	4.7E+04	8.6E+04	5.0E-03	7.8E-05	1.8E-09	7.7E-10	1.2E-10	2.4E-11	6.8E-12	2.9E-11	1.4E-10
5	GHADBCABDDB	2.2E+04	1.0E+01	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	FHADBCABDCB			6.5E+04	1.3E+05	1.1E+04	1.0E+00	3.2E-02	3.4E-05	2.6E-05	8.6E-06	1.2E-07	9.7E-07	9.8E-07	6.3E-06
6	HDCDBCDBDFB	2.2E+04	0.0E+00	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	GDCDBCDBDDB			0.0E+00	4.7E+04	8.6E+04	5.0E-03	8.7E-05	3.1E-09	1.5E-09	1.2E-10	5.2E-11	6.0E-12	2.0E-11	1.6E-10
7	HHADBCAADFA	2.2E+04	0.0E+00	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	GHADBCAADDA			0.0E+00	4.7E+04	8.6E+04	5.0E-03	1.7E-04	6.7E-07	4.5E-07	1.4E-07	3.8E-09	1.4E-08	1.6E-08	1.2E-07
8	HHADBCABDFA	2.2E+04	0.0E+00	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	GHADBCABDDA			0.0E+00	4.7E+04	8.6E+04	5.0E-03	1.8E-04	7.2E-07	5.0E-07	1.4E-07	8.4E-09	1.6E-08	1.8E-08	1.2E-07
9	HHDDBCAADFB	2.2E+04	0.0E+00	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	GHDDBCAADDB			0.0E+00	4.7E+04	8.6E+04	5.0E-03	1.7E-04	3.6E-07	1.9E-07	3.7E-08	5.4E-09	3.2E-09	9.9E-09	3.8E-08
10	GHADBCAADDA	2.2E+04	1.0E+01	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	FHADBCAADCA			6.5E+04	1.3E+05	1.1E+04	1.0E+00	3.4E-02	4.1E-05	3.3E-05	1.1E-05	1.2E-07	1.2E-06	1.2E-06	9.0E-06
Five Most Probable Bins that have VB and Early CF*															
62	DHACCCAABCA	2.2E+04	1.0E+01	5.2E+05	2.8E+04	1.0E+03	7.5E-01	7.9E-03	5.3E-03	4.8E-03	5.0E-03	1.5E-03	6.1E-04	4.8E-03	5.0E-03
	DHACCCAABCA			1.6E+06	2.9E+04	2.2E+04	2.5E-01	3.7E-02	9.7E-03	4.0E-03	1.7E-03	5.2E-04	2.1E-04	1.6E-03	1.7E-03
102	DHADDCBADBB	2.2E+04	1.0E+01	2.8E+07	2.8E+04	2.0E+02	8.7E-01	2.6E-01	2.3E-01	4.9E-02	1.6E-02	2.6E-03	1.0E-03	5.3E-03	1.7E-02
	DHADDCBADBB			1.6E+06	2.9E+04	2.2E+04	1.3E-01	5.8E-02	4.5E-02	1.1E-01	3.2E-02	3.3E-04	3.2E-03	3.4E-03	2.6E-02
119	DHACCCABACA	2.2E+04	1.0E+01	5.2E+05	2.8E+04	1.0E+03	7.4E-01	9.4E-02	1.1E-01	5.0E-03	2.9E-04	1.1E-03	2.3E-04	2.3E-04	5.2E-04
	DHACCCABACA			1.6E+06	2.9E+04	2.2E+04	2.6E-01	7.4E-02	5.3E-02	3.1E-02	3.3E-04	3.8E-04	1.0E-04	7.9E-05	4.2E-04
151	DHADDCBBDBB	2.2E+04	1.0E+01	2.8E+07	2.8E+04	2.0E+02	9.1E-01	3.4E-01	3.2E-01	1.0E-01	2.1E-02	4.7E-03	1.5E-03	7.3E-03	2.3E-02
	DHADDCBBDBB			1.6E+06	2.9E+04	2.2E+04	9.1E-02	4.5E-02	3.3E-02	8.4E-02	2.8E-02	4.9E-04	3.3E-03	3.3E-03	2.1E-02
159	DDCBACDBACA	2.2E+04	1.0E+01	5.2E+04	2.8E+04	1.1E+04	1.0E+00	8.3E-03	7.8E-03	4.1E-03	4.1E-03	6.0E-04	4.1E-04	2.2E-03	4.1E-03
	DDCBACDBACA			1.6E+05	1.0E+06	1.0E+06	0.0E+00	1.4E-02	3.3E-05	6.4E-05	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00

* A listing of source terms for all bins is available on computer media

Table 3.3-12
Mean Source Terms for Surry
Seismic Initiators - PDS Group EQ 1 - LOSP (No SBO) - High Acceleration
LLNL Hazard Distribution

Order	Bin	Warning Time (s)	Elevation (m)	Release Energy (W)	Release Start (s)	Release Duration (s)	Release Fractions								
							NG	I	Cs	Te	Sr	Ru	La	Ce	Ba
Ten Most Probable Bins*															
1	HHCDFCDBDFB	2.2E+04	0.0E+00	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	GHCDFCDBDDB			0.0E+00	4.7E+04	8.6E+04	4.2E-03	4.6E-05	1.6E-07	7.4E-08	1.1E-08	3.0E-09	6.3E-10	2.7E-09	1.2E-08
2	HHCDFCDADFB	2.2E+04	0.0E+00	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	GHCDFCDADDB			0.0E+00	4.7E+04	8.6E+04	3.9E-03	3.8E-05	1.2E-07	5.5E-08	1.3E-08	2.4E-09	8.2E-10	4.0E-09	1.4E-08
3	HHADBCABDFB	2.2E+04	0.0E+00	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	GHADBCABDDB			0.0E+00	4.7E+04	8.6E+04	5.0E-03	1.6E-04	7.1E-07	4.4E-07	1.2E-07	8.1E-09	1.4E-08	1.8E-08	9.8E-08
4	GHADBCABDDB	2.2E+04	1.0E+01	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	FHADBCABDCB			6.5E+04	1.3E+05	1.1E+04	1.0E+00	3.1E-02	3.5E-05	2.6E-05	8.4E-06	1.3E-07	9.5E-07	9.6E-07	6.2E-06
5	HHADBCAADFB	2.2E+04	0.0E+00	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	GHADBCAADDB			0.0E+00	4.7E+04	8.6E+04	5.0E-03	1.7E-04	7.5E-07	4.6E-07	1.6E-07	8.9E-09	1.9E-08	2.6E-08	1.4E-07
6	HDCDFCDBDFB	2.2E+04	0.0E+00	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	GDCDFCDBDDB			0.0E+00	4.7E+04	8.6E+04	4.2E-03	4.6E-05	1.4E-09	7.1E-10	8.9E-11	3.0E-11	5.0E-12	2.0E-11	1.1E-10
7	GHADBCAADDB	2.2E+04	1.0E+01	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	FHADBCAADCB			6.5E+04	1.3E+05	1.1E+04	1.0E+00	3.5E-02	4.5E-05	3.2E-05	1.2E-05	2.8E-07	1.4E-06	1.5E-06	1.0E-05
8	HDCDFCDADFB	2.2E+04	0.0E+00	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	GDCDFCDADDB			0.0E+00	4.7E+04	8.6E+04	3.9E-03	3.8E-05	8.1E-10	3.2E-10	5.7E-11	1.1E-11	3.5E-12	1.5E-11	6.5E-11
9	HHACBCABDFB	2.2E+04	0.0E+00	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	GHACBCABDDB			0.0E+00	4.7E+04	8.6E+04	5.0E-03	1.2E-04	6.9E-07	4.7E-07	2.1E-07	2.2E-08	3.2E-08	3.5E-08	1.9E-07
10	HDCDBCDBDFB	2.2E+04	0.0E+00	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	GDCDBCDBDDB			0.0E+00	4.7E+04	8.6E+04	5.0E-03	9.1E-05	3.0E-09	1.5E-09	1.8E-10	6.1E-11	1.0E-11	3.9E-11	2.1E-10
Mean Source Terms for Five Most Probable Bins that have VB and Early CF*															
30	DHACACABACB	2.2E+04	1.0E+01	5.2E+05	2.8E+04	1.0E+03	7.5E-01	1.8E-01	1.7E-01	1.3E-01	1.1E-01	2.4E-02	1.3E-02	6.0E-02	1.1E-01
	DHACACABACB			1.6E+06	2.9E+04	2.2E+04	2.5E-01	7.9E-02	5.9E-02	4.4E-02	3.8E-02	8.0E-03	4.4E-03	2.0E-02	3.8E-02
34	DHADDCBBDBB	2.2E+04	1.0E+01	2.8E+07	2.8E+04	2.0E+02	9.1E-01	3.0E-01	2.7E-01	8.4E-02	1.8E-02	4.0E-03	1.2E-03	5.4E-03	2.0E-02
	DHADDCBBDBB			1.6E+06	2.9E+04	2.2E+04	8.8E-02	5.5E-02	4.3E-02	9.1E-02	2.7E-02	3.4E-04	3.0E-03	3.0E-03	2.0E-02
88	DHADDCBADBB	2.2E+04	1.0E+01	2.8E+07	2.8E+04	2.0E+02	8.8E-01	2.8E-01	2.5E-01	5.8E-02	1.6E-02	2.6E-03	9.8E-04	4.8E-03	1.7E-02
	DHADDCBADBB			1.6E+06	2.9E+04	2.2E+04	1.2E-01	5.4E-02	4.2E-02	1.0E-01	3.3E-02	4.2E-04	3.6E-03	3.8E-03	2.7E-02
112	DHFCACABACB	2.2E+04	1.0E+01	5.2E+05	2.8E+04	1.1E+04	1.0E+00	2.5E-01	2.3E-01	1.7E-01	1.5E-01	3.2E-02	1.7E-02	8.1E-02	1.5E-01
	DHFCACABACB			1.6E+06	4.6E+04	2.2E+04	0.0E+00	1.7E-02	5.4E-04	6.9E-04	0.0E+00	1.6E-05	8.3E-05	4.3E-05	0.0E+00
122	DHEAACAABCA	2.2E+04	1.0E+01	5.2E+05	2.8E+04	6.0E+03	8.8E-01	1.9E-02	2.7E-02	2.4E-03	1.5E-04	1.3E-04	2.9E-05	3.3E-05	2.3E-04
	DHEAACAABCA			1.6E+06	3.4E+04	2.2E+04	1.2E-01	3.3E-02	9.9E-03	2.2E-02	5.2E-04	1.8E-05	3.1E-05	3.6E-05	5.1E-04

* A listing of source terms for all bins is available on computer media

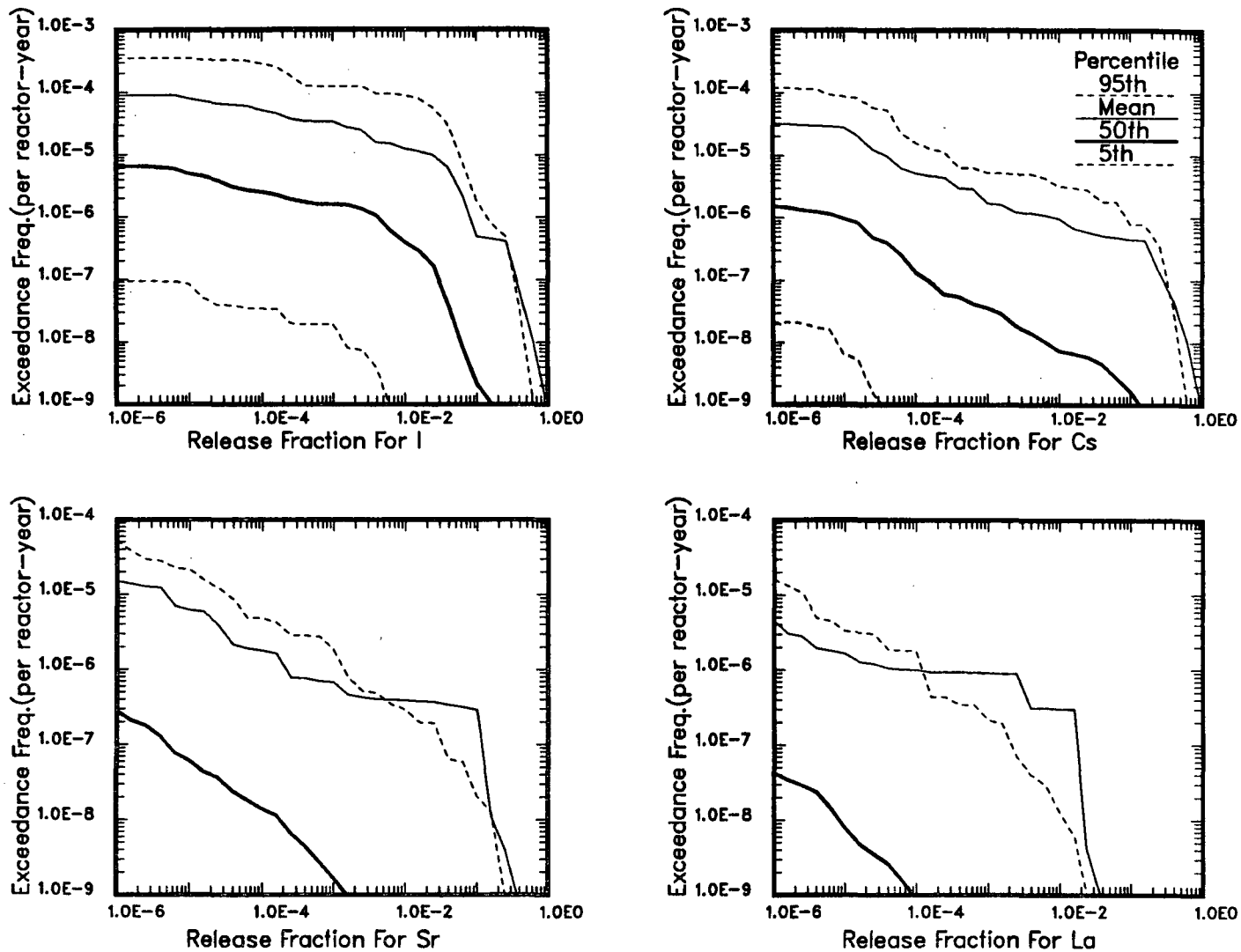


Figure 3.3-24. Release Fractions CCDFs for LLNL PDS EQ 1 LOSP--Hi PGA

Table 3.3-13
Mean Source Terms for Surry
Seismic Initiators - PDS Group EQ 2 - SBO - High Acceleration
LLNL Hazard Distribution

Order	Bin	Warning Time (s)	Elevation (m)	Release Energy (W)	Release Start (s)	Release Duration (s)	Release Fractions								
							NG	I	Cs	Te	Sr	Ru	La	Ce	Ba
Ten Most Probable Bins*															
1	HHADBCABDFB	2.2E+04	0.0E+00	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	GHADBCABDDB			0.0E+00	4.7E+04	8.6E+04	5.0E-03	1.6E-04	7.1E-07	4.4E-07	1.2E-07	8.1E-09	1.4E-08	1.8E-08	9.8E-08
2	GHADBCABDDB	2.2E+04	1.0E+01	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	FHADBCABDCB			6.5E+04	1.3E+05	1.1E+04	1.0E+00	3.1E-02	3.5E-05	2.6E-05	8.4E-06	1.3E-07	9.5E-07	9.6E-07	6.2E-06
3	HHADBCAADFB	2.2E+04	0.0E+00	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	GHADBCAADDB			0.0E+00	4.7E+04	8.6E+04	5.0E-03	1.7E-04	7.5E-07	4.6E-07	1.6E-07	8.9E-09	1.9E-08	2.6E-08	1.4E-07
4	CHADBCAADCB	2.2E+04	1.0E+01	5.2E+05	2.8E+04	1.0E+03	7.4E-01	1.5E-01	1.4E-01	3.0E-02	6.5E-03	1.2E-03	4.2E-04	2.0E-03	7.2E-03
	CHADBCAADCB			1.6E+06	2.9E+04	2.2E+04	2.6E-01	9.2E-02	6.3E-02	9.2E-02	3.5E-02	1.2E-03	4.0E-03	4.7E-03	3.0E-02
5	GHADBCAADDB	2.2E+04	1.0E+01	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	FHADBCAADCB			6.5E+04	1.3E+05	1.1E+04	1.0E+00	3.5E-02	4.5E-05	3.2E-05	1.2E-05	2.8E-07	1.4E-06	1.5E-06	1.0E-05
6	CHADBCABDCB	2.2E+04	1.0E+01	5.2E+05	2.8E+04	1.0E+03	7.4E-01	1.6E-01	1.5E-01	4.4E-02	7.1E-03	1.8E-03	4.5E-04	2.0E-03	7.9E-03
	CHADBCABDCB			1.6E+06	2.9E+04	2.2E+04	2.6E-01	9.3E-02	6.7E-02	8.4E-02	2.4E-02	7.8E-04	2.5E-03	3.0E-03	1.8E-02
7	HHADBCAADFA	2.2E+04	0.0E+00	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	GHADBCAADDA			0.0E+00	4.7E+04	8.6E+04	5.0E-03	1.7E-04	6.7E-07	4.5E-07	1.4E-07	3.8E-09	1.4E-08	1.6E-08	1.2E-07
8	HHADBCABDFA	2.2E+04	0.0E+00	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	GHADBCABDDA			0.0E+00	4.7E+04	8.6E+04	5.0E-03	1.9E-04	7.0E-07	4.8E-07	1.5E-07	8.0E-09	1.6E-08	1.9E-08	1.2E-07
9	GHADBCAADDA	2.2E+04	1.0E+01	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	FHADBCAADCA			6.5E+04	1.3E+05	1.1E+04	1.0E+00	3.4E-02	4.1E-05	3.3E-05	1.1E-05	1.2E-07	1.2E-06	1.2E-06	9.0E-06
10	HHACACABBFA	2.2E+04	0.0E+00	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	GHACACABBDA			0.0E+00	4.7E+04	8.6E+04	5.0E-03	1.1E-04	4.8E-07	3.3E-07	1.1E-07	5.1E-09	9.0E-09	1.3E-08	8.4E-08
Five Most Probable Bins that have VB and Early CF*															
4	CHADBCAADCB	2.2E+04	1.0E+01	5.2E+05	2.8E+04	1.0E+03	7.4E-01	1.5E-01	1.4E-01	3.0E-02	6.5E-03	1.2E-03	4.2E-04	2.0E-03	7.2E-03
	CHADBCAADCB			1.6E+06	2.9E+04	2.2E+04	2.6E-01	9.2E-02	6.3E-02	9.2E-02	3.5E-02	1.2E-03	4.0E-03	4.7E-03	3.0E-02
6	CHADBCABDCB	2.2E+04	1.0E+01	5.2E+05	2.8E+04	1.0E+03	7.4E-01	1.6E-01	1.5E-01	4.4E-02	7.1E-03	1.8E-03	4.5E-04	2.0E-03	7.9E-03
	CHADBCABDCB			1.6E+06	2.9E+04	2.2E+04	2.6E-01	9.3E-02	6.7E-02	8.4E-02	2.4E-02	7.8E-04	2.5E-03	3.0E-03	1.8E-02
17	CHADBCAADBB	2.2E+04	1.0E+01	2.8E+07	2.8E+04	2.0E+02	9.9E-01	4.3E-01	4.1E-01	7.7E-02	1.8E-02	3.3E-03	1.2E-03	5.7E-03	2.0E-02
	CHADBCAADBB			1.6E+06	2.9E+04	2.2E+04	1.1E-02	5.2E-02	4.0E-02	1.9E-01	7.1E-02	1.6E-03	8.5E-03	8.8E-03	6.0E-02
27	DHADDCBBDBB	2.2E+04	1.0E+01	2.8E+07	2.8E+04	2.0E+02	9.1E-01	3.0E-01	2.7E-01	8.4E-02	1.8E-02	4.0E-03	1.2E-03	5.4E-03	2.0E-02
	DHADDCBBDBB			1.6E+06	2.9E+04	2.2E+04	8.8E-02	5.5E-02	4.3E-02	9.1E-02	2.7E-02	3.4E-04	3.0E-03	3.0E-03	2.0E-02
39	CHADBCABDBB	2.2E+04	1.0E+01	2.8E+07	2.8E+04	2.0E+02	9.9E-01	4.5E-01	4.3E-01	1.2E-01	1.8E-02	4.9E-03	1.2E-03	5.2E-03	2.0E-02
	CHADBCABDBB			1.6E+06	2.9E+04	2.2E+04	8.1E-03	4.5E-02	3.3E-02	1.6E-01	5.6E-02	6.2E-04	6.3E-03	6.4E-03	4.1E-02

* A listing of source terms for all bins is available on computer media

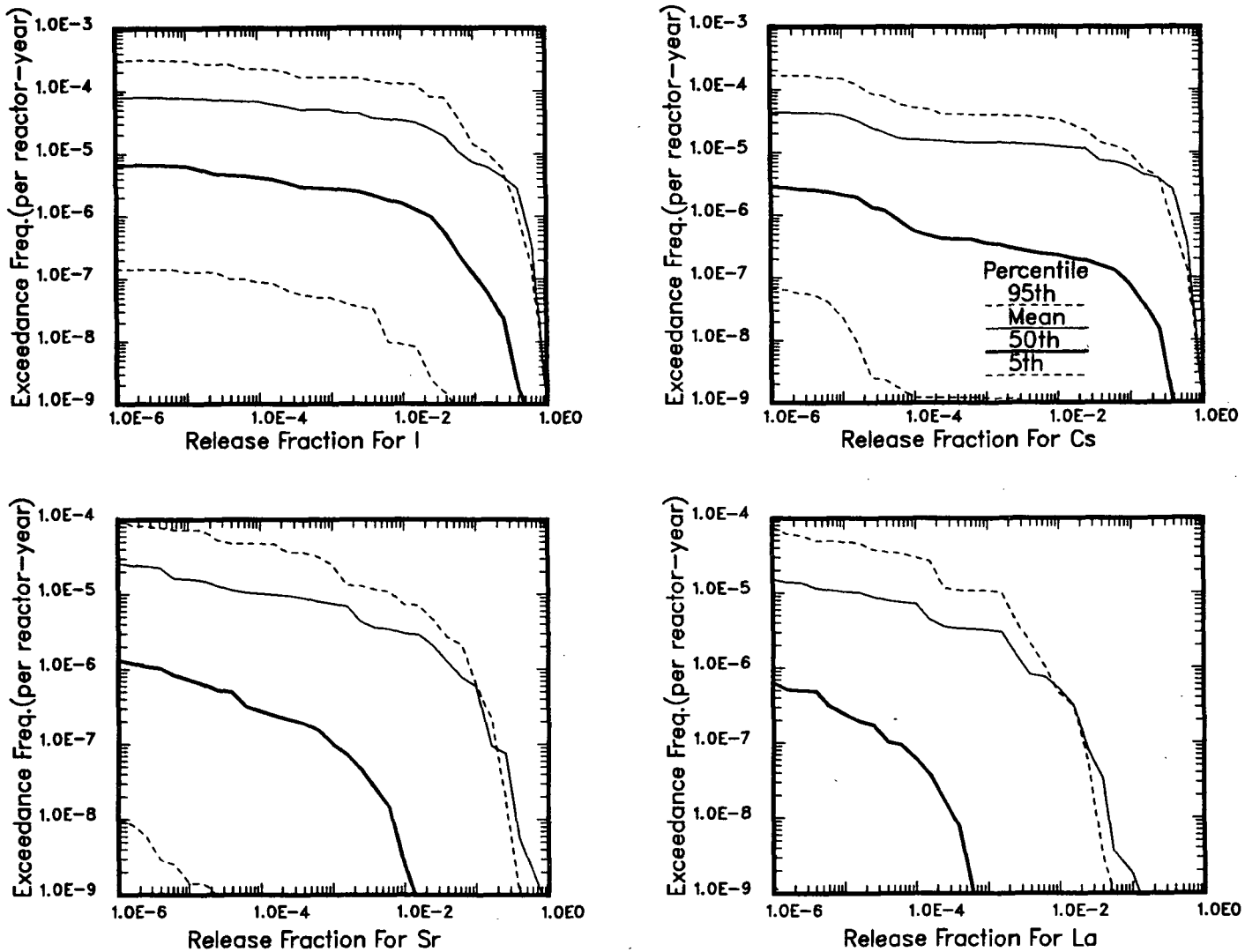


Figure 3.3-25. Release Fractions CCDFs for LLNL PDS EQ 2 SBO

Table 3.3-14
Mean Source Terms for Surry
Seismic Initiators - PDS Group EQ 3 - LOCAs - High Acceleration
LLNL Hazard Distribution

Order	Bin	Warning Time (s)	Elevation (m)	Release Energy (W)	Release Start (s)	Release Duration (s)	Release Fractions								
							NG	I	Cs	Te	Sr	Ru	La	Ce	Ba
Fifteen Most Probable Bins*															
1	HHCDFCDBDFB	2.2E+04	0.0E+00	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	GHCDFCDBDDB			0.0E+00	4.7E+04	8.6E+04	4.2E-03	4.6E-05	1.6E-07	7.4E-08	1.1E-08	3.0E-09	6.3E-10	2.7E-09	1.2E-08
2	HHCDFCDADFB	2.2E+04	0.0E+00	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	GHCDFCDADDB			0.0E+00	4.7E+04	8.6E+04	3.9E-03	3.8E-05	1.2E-07	5.5E-08	1.3E-08	2.4E-09	8.2E-10	4.0E-09	1.4E-08
3	CHADBCAADCB	2.2E+04	1.0E+01	5.2E+05	2.8E+04	1.0E+03	7.4E-01	1.5E-01	1.4E-01	3.0E-02	6.5E-03	1.2E-03	4.2E-04	2.0E-03	7.2E-03
	CHADBCAADCB			1.6E+06	2.9E+04	2.2E+04	2.6E-01	9.2E-02	6.3E-02	9.2E-02	3.5E-02	1.2E-03	4.0E-03	4.7E-03	3.0E-02
4	CHADBCABDCB	2.2E+04	1.0E+01	5.2E+05	2.8E+04	1.0E+03	7.4E-01	1.6E-01	1.5E-01	4.4E-02	7.1E-03	1.8E-03	4.5E-04	2.0E-03	7.9E-03
	CHADBCABDCB			1.6E+06	2.9E+04	2.2E+04	2.6E-01	9.3E-02	6.7E-02	8.4E-02	2.4E-02	7.8E-04	2.5E-03	3.0E-03	1.8E-02
5	HHADBCAADFB	2.2E+04	0.0E+00	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	GHADBCAADDB			0.0E+00	4.7E+04	8.6E+04	5.0E-03	1.7E-04	7.5E-07	4.6E-07	1.6E-07	8.9E-09	1.9E-08	2.6E-08	1.4E-07
6	HHADBCABDFB	2.2E+04	0.0E+00	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	GHADBCABDDB			0.0E+00	4.7E+04	8.6E+04	5.0E-03	1.6E-04	7.1E-07	4.4E-07	1.2E-07	8.1E-09	1.4E-08	1.8E-08	9.8E-08
7	CDCDBCDADCB	2.2E+04	1.0E+01	5.2E+04	2.8E+04	1.1E+04	7.8E-01	9.0E-03	6.5E-03	2.5E-03	4.0E-04	7.7E-05	2.4E-05	1.1E-04	4.5E-04
	CDCDBCDADCB			1.6E+05	1.0E+06	1.0E+06	2.2E-01	1.6E-02	8.0E-04	3.1E-04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
8	GHADBCAADDB	2.2E+04	1.0E+01	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	FHADBCAADCB			6.5E+04	1.3E+05	1.1E+04	1.0E+00	3.5E-02	4.5E-05	3.2E-05	1.2E-05	2.8E-07	1.4E-06	1.5E-06	1.0E-05
9	GHADBCABDDB	2.2E+04	1.0E+01	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	FHADBCABDCB			6.5E+04	1.3E+05	1.1E+04	1.0E+00	3.1E-02	3.5E-05	2.6E-05	8.4E-06	1.3E-07	9.5E-07	9.6E-07	6.2E-06
10	HDCDFCDBDFB	2.2E+04	0.0E+00	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	GDCDFCDBDDB			0.0E+00	4.7E+04	8.6E+04	4.2E-03	4.6E-05	1.4E-09	7.1E-10	8.9E-11	3.0E-11	5.0E-12	2.0E-11	1.1E-10
11	CDCDBCDBDCB	2.2E+04	1.0E+01	5.2E+04	2.8E+04	1.1E+04	8.3E-01	1.2E-02	1.0E-02	5.1E-03	7.9E-04	2.3E-04	5.0E-05	2.1E-04	9.2E-04
	CDCDBCDBDCB			1.6E+05	1.0E+06	1.0E+06	1.7E-01	1.9E-02	7.6E-04	2.0E-04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
12	CDDDBCAADCB	2.2E+04	1.0E+01	5.2E+04	2.8E+04	1.0E+03	7.4E-01	9.6E-03	8.3E-03	1.8E-03	3.0E-04	5.7E-05	1.8E-05	7.9E-05	3.4E-04
	CDDDBCAADCB			1.6E+05	2.9E+04	2.2E+04	2.6E-01	3.8E-02	3.6E-03	4.1E-03	1.3E-03	2.3E-05	1.3E-04	1.6E-04	1.0E-03
13	HDCDFCDADFB	2.2E+04	0.0E+00	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	GDCDFCDADDB			0.0E+00	4.7E+04	8.6E+04	3.9E-03	3.8E-05	8.1E-10	3.2E-10	5.7E-11	1.1E-11	3.5E-12	1.5E-11	6.5E-11
14	HDCDBCDADFB	2.2E+04	0.0E+00	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	GDCDBCDADDB			0.0E+00	4.7E+04	8.6E+04	5.0E-03	7.8E-05	1.9E-09	7.8E-10	1.1E-10	2.2E-11	6.9E-12	3.0E-11	1.3E-10
15	CDDDBCABDCB	2.2E+04	1.0E+01	5.2E+04	2.8E+04	1.0E+03	7.4E-01	1.1E-02	1.0E-02	3.8E-03	6.0E-04	1.8E-04	3.8E-05	1.6E-04	7.0E-04
	CDDDBCABDCB			1.6E+05	2.9E+04	2.2E+04	2.6E-01	3.6E-02	4.2E-03	4.1E-03	1.2E-03	6.6E-05	1.5E-04	1.9E-04	9.6E-04

* A listing of source terms for all bins is available on computer media

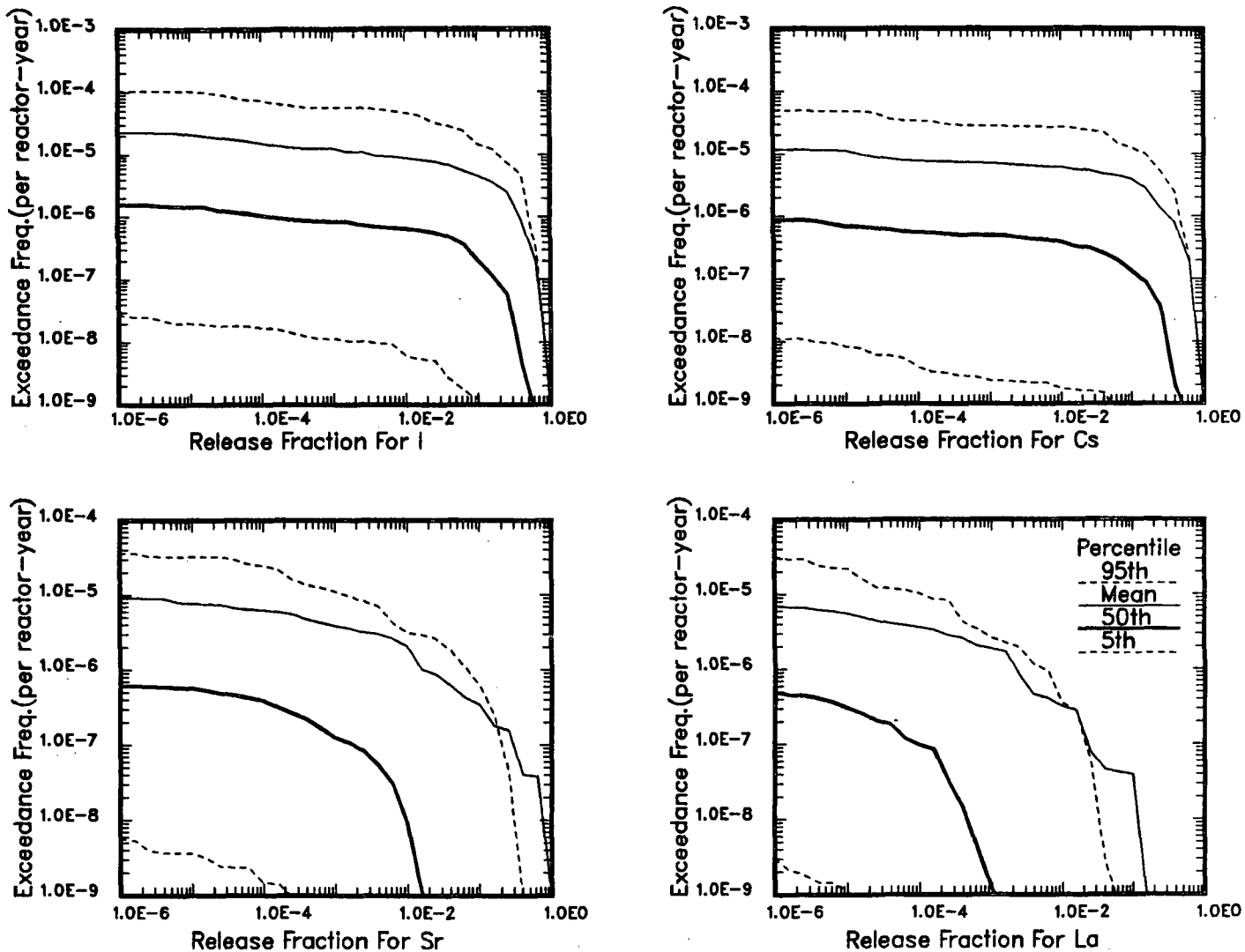


Figure 3.3-26. Release Fractions CCDFs for LLNL PDS EQ 3 LOCAs

Table 3.3-15
Mean Source Terms for Surry
Seismic Initiators - PDS Group EQ 1 - LOSP (No SBO) - Low Acceleration
LLNL Hazard Distribution

Order	Bin	Warning Time (s)	Elevation (m)	Release Energy (W)	Release Start (s)	Release Duration (s)	Release Fractions								
							NG	I	Cs	Te	Sr	Ru	La	Ce	Ba
Ten Most Probable Bins*															
1	HHCDFCDBDFB	2.2E+04	0.0E+00	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	GHCDFCDBDDB			0.0E+00	4.7E+04	8.6E+04	4.2E-03	4.6E-05	1.6E-07	7.4E-08	1.1E-08	3.0E-09	6.3E-10	2.7E-09	1.2E-08
2	HHADBCABDFB	2.2E+04	0.0E+00	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	GHADBCABDDB			0.0E+00	4.7E+04	8.6E+04	5.0E-03	1.6E-04	7.1E-07	4.4E-07	1.2E-07	8.1E-09	1.4E-08	1.8E-08	9.8E-08
3	HHCDFCDADFB	2.2E+04	0.0E+00	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	GHCDFCDADDB			0.0E+00	4.7E+04	8.6E+04	3.9E-03	3.8E-05	1.2E-07	5.5E-08	1.3E-08	2.4E-09	8.2E-10	4.0E-09	1.4E-08
4	HHADBCAADFB	2.2E+04	0.0E+00	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	GHADBCAADDB			0.0E+00	4.7E+04	8.6E+04	5.0E-03	1.7E-04	7.5E-07	4.6E-07	1.6E-07	8.9E-09	1.9E-08	2.6E-08	1.4E-07
5	HDCDFCDBDFB	2.2E+04	0.0E+00	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	GDCDFCDBDDB			0.0E+00	4.7E+04	8.6E+04	4.2E-03	4.6E-05	1.4E-09	7.1E-10	8.9E-11	3.0E-11	5.0E-12	2.0E-11	1.1E-10
6	GHADBCABDDB	2.2E+04	1.0E+01	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	FHADBCABDCB			6.5E+04	1.3E+05	1.1E+04	1.0E+00	3.1E-02	3.5E-05	2.6E-05	8.4E-06	1.3E-07	9.5E-07	9.6E-07	6.2E-06
7	GHADBCAADDB	2.2E+04	1.0E+01	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	FHADBCAADCB			6.5E+04	1.3E+05	1.1E+04	1.0E+00	3.5E-02	4.5E-05	3.2E-05	1.2E-05	2.8E-07	1.4E-06	1.5E-06	1.0E-05
8	HDCDFCDADFB	2.2E+04	0.0E+00	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	GDCDFCDADDB			0.0E+00	4.7E+04	8.6E+04	3.9E-03	3.8E-05	8.1E-10	3.2E-10	5.7E-11	1.1E-11	3.5E-12	1.5E-11	6.5E-11
9	HDCDBCDBDFB	2.2E+04	0.0E+00	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	GDCDBCDBDDB			0.0E+00	4.7E+04	8.6E+04	5.0E-03	9.1E-05	3.0E-09	1.5E-09	1.8E-10	6.1E-11	1.0E-11	3.9E-11	2.1E-10
10	HHACBCABDFB	2.2E+04	0.0E+00	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	GHACBCABDDB			0.0E+00	4.7E+04	8.6E+04	5.0E-03	1.2E-04	6.9E-07	4.7E-07	2.1E-07	2.2E-08	3.2E-08	3.5E-08	1.9E-07
Five Most Probable Bins that have VB and Early CF*															
31	DHACACABACB	2.2E+04	1.0E+01	5.2E+05	2.8E+04	1.0E+03	7.5E-01	1.8E-01	1.7E-01	1.3E-01	1.1E-01	2.4E-02	1.3E-02	6.0E-02	1.1E-01
	DHACACABACB			1.6E+06	2.9E+04	2.2E+04	2.5E-01	7.9E-02	5.9E-02	4.4E-02	3.8E-02	8.0E-03	4.4E-03	2.0E-02	3.8E-02
43	DHADDCBBDBB	2.2E+04	1.0E+01	2.8E+07	2.8E+04	2.0E+02	8.1E-01	3.0E-01	2.8E-01	8.6E-02	1.8E-02	4.1E-03	1.2E-03	5.5E-03	2.0E-02
	DHADDCBBDBB			1.6E+06	2.9E+04	2.2E+04	8.8E-02	5.5E-02	4.3E-02	8.9E-02	2.6E-02	3.5E-04	3.0E-03	3.0E-03	1.9E-02
92	DHEAACAABCA	2.2E+04	1.0E+01	5.2E+05	2.8E+04	6.0E+03	8.8E-01	1.9E-02	2.7E-02	2.4E-03	1.5E-04	1.3E-04	2.9E-05	3.3E-05	2.3E-04
	DHEAACAABCA			1.6E+06	3.4E+04	2.2E+04	1.2E-01	3.3E-02	9.9E-03	2.2E-02	5.2E-04	1.8E-05	3.1E-05	3.6E-05	5.1E-04
114	DHEAACAAABA	2.2E+04	1.0E+01	2.8E+07	2.8E+04	2.0E+02	9.9E-01	2.3E-01	2.6E-01	3.4E-02	1.0E-02	1.5E-02	4.4E-03	4.3E-03	1.3E-02
	DHEAACAAABA			1.6E+06	3.4E+04	2.2E+04	7.6E-03	3.4E-02	1.5E-02	1.3E-01	8.8E-02	3.8E-04	9.9E-03	1.0E-02	7.3E-02
167	DHFCACABACB	2.2E+04	1.0E+01	5.2E+05	2.8E+04	1.1E+04	1.0E+00	2.5E-01	2.3E-01	1.7E-01	1.5E-01	3.2E-02	1.7E-02	8.1E-02	1.5E-01
	DHFCACABACB			1.6E+06	4.6E+04	2.2E+04	0.0E+00	1.7E-02	5.4E-04	6.9E-04	0.0E+00	1.6E-05	8.3E-05	4.3E-05	0.0E+00

* A listing of source terms for all bins is available on computer media

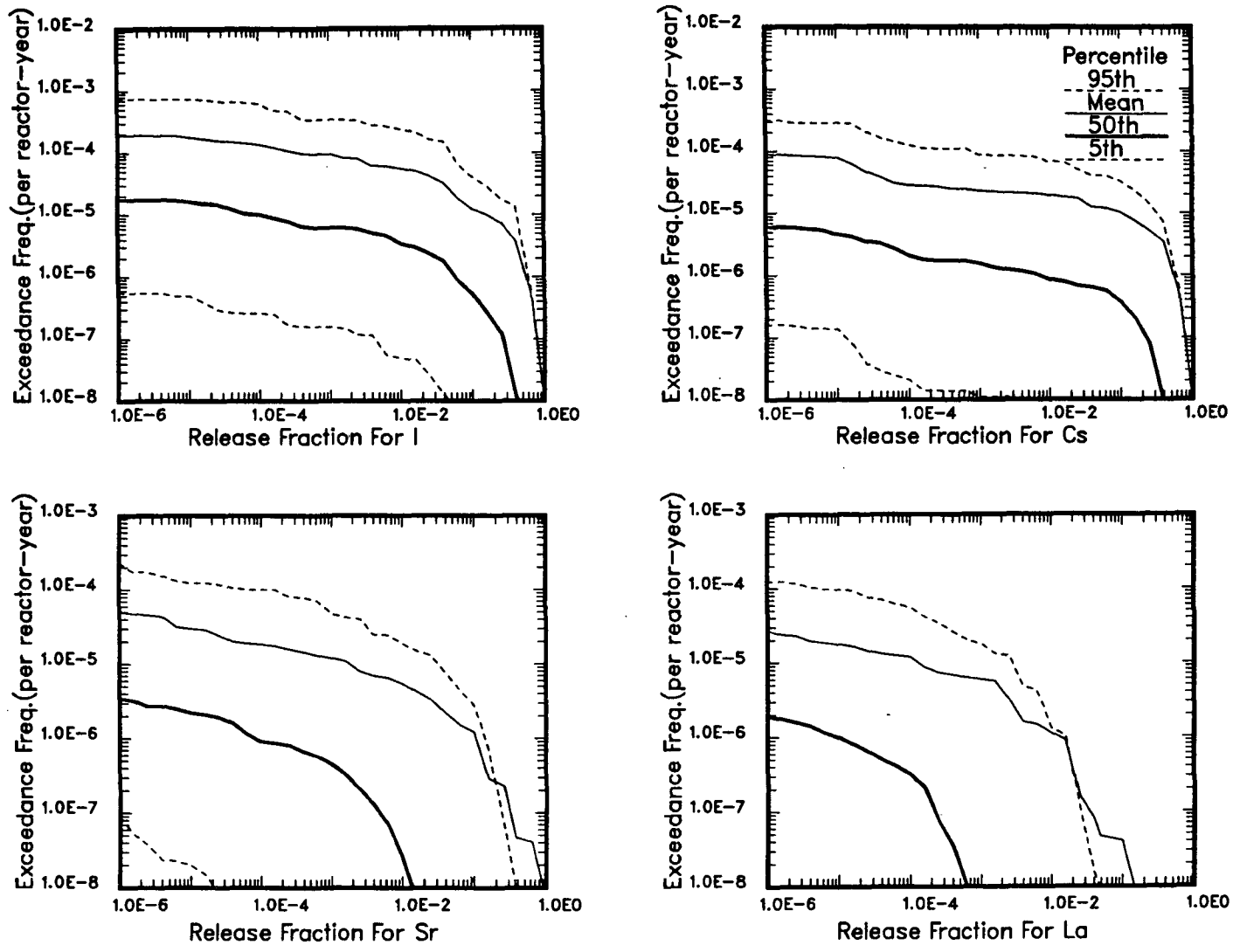


Figure 3.3-27. Release Fractions CCDFs for All LLNL & All PGA

Table 3.3-16
Mean Source Terms for Surry
Seismic Initiators - PDS Group EQ 2 - SBO - Low Acceleration
LLNL Hazard Distribution

Order	Bin	Warning Time (s)	Elevation (m)	Release Energy (W)	Release Start (s)	Release Duration (s)	Release Fractions								
							NG	I	Cs	Te	Sr	Ru	La	Ce	Ba
Ten Most Probable Bins*															
1	HHADBCABDFB	2.2E+04	0.0E+00	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	GHADBCABDDB			0.0E+00	4.7E+04	8.6E+04	5.0E-03	1.6E-04	7.1E-07	4.4E-07	1.2E-07	8.1E-09	1.4E-08	1.8E-08	9.8E-08
2	HHADBCAADFB	2.2E+04	0.0E+00	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	GHADBCAADDB			0.0E+00	4.7E+04	8.6E+04	5.0E-03	1.7E-04	7.5E-07	4.6E-07	1.6E-07	8.9E-09	1.9E-08	2.6E-08	1.4E-07
3	GHADBCABDDB	2.2E+04	1.0E+01	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	FHADBCABDCB			6.5E+04	1.3E+05	1.1E+04	1.0E+00	3.1E-02	3.5E-05	2.6E-05	8.4E-06	1.3E-07	9.5E-07	9.6E-07	6.2E-06
4	GHADBCAADDB	2.2E+04	1.0E+01	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	FHADBCAADCB			6.5E+04	1.3E+05	1.1E+04	1.0E+00	3.5E-02	4.5E-05	3.2E-05	1.2E-05	2.8E-07	1.4E-06	1.5E-06	1.0E-05
5	HHADBCAADFA	2.2E+04	0.0E+00	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	GHADBCAADDA			0.0E+00	4.7E+04	8.6E+04	5.0E-03	1.7E-04	6.7E-07	4.5E-07	1.4E-07	3.8E-09	1.4E-08	1.6E-08	1.2E-07
6	HHADBCABDFA	2.2E+04	0.0E+00	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	GHADBCABDDA			0.0E+00	4.7E+04	8.6E+04	5.0E-03	1.9E-04	7.0E-07	4.8E-07	1.5E-07	8.0E-09	1.6E-08	1.9E-08	1.2E-07
7	CHADBCAADCB	2.2E+04	1.0E+01	5.2E+05	2.8E+04	1.0E+03	7.4E-01	1.5E-01	1.4E-01	3.0E-02	6.5E-03	1.2E-03	4.2E-04	2.0E-03	7.2E-03
	CHADBCAADCB			1.6E+06	2.9E+04	2.2E+04	2.6E-01	9.2E-02	6.3E-02	9.2E-02	3.5E-02	1.2E-03	4.0E-03	4.7E-03	3.0E-02
8	GHADBCAADDA	2.2E+04	1.0E+01	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	FHADBCAADCA			6.5E+04	1.3E+05	1.1E+04	1.0E+00	3.4E-02	4.1E-05	3.3E-05	1.1E-05	1.2E-07	1.2E-06	1.2E-06	9.0E-06
9	HHACACABBFA	2.2E+04	0.0E+00	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	GHACACABBDA			0.0E+00	4.7E+04	8.6E+04	5.0E-03	1.1E-04	4.8E-07	3.3E-07	1.1E-07	5.1E-09	9.0E-09	1.3E-08	8.4E-08
10	GHADBCABDDA	2.2E+04	1.0E+01	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	FHADBCABDCA			6.5E+04	1.3E+05	1.1E+04	1.0E+00	3.7E-02	2.9E-05	2.8E-05	1.2E-05	2.6E-07	1.5E-06	1.5E-06	9.1E-06
Five Most Probable Bins that have VB and Early CF*															
7	CHADBCAADCB	2.2E+04	1.0E+01	5.2E+05	2.8E+04	1.0E+03	7.4E-01	1.5E-01	1.4E-01	3.0E-02	6.5E-03	1.2E-03	4.2E-04	2.0E-03	7.2E-03
	CHADBCAADCB			1.6E+06	2.9E+04	2.2E+04	2.6E-01	9.2E-02	6.3E-02	9.2E-02	3.5E-02	1.2E-03	4.0E-03	4.7E-03	3.0E-02
11	CHADBCABDCB	2.2E+04	1.0E+01	5.2E+05	2.8E+04	1.0E+03	7.4E-01	1.6E-01	1.5E-01	4.4E-02	7.1E-03	1.8E-03	4.5E-04	2.0E-03	7.9E-03
	CHADBCABDCB			1.6E+06	2.9E+04	2.2E+04	2.6E-01	9.3E-02	6.7E-02	8.4E-02	2.4E-02	7.8E-04	2.5E-03	3.0E-03	1.8E-02
44	CHADBCAADBB	2.2E+04	1.0E+01	2.8E+07	2.8E+04	2.0E+02	9.9E-01	4.3E-01	4.1E-01	7.7E-02	1.8E-02	3.3E-03	1.2E-03	5.7E-03	2.0E-02
	CHADBCAADBB			1.6E+06	2.9E+04	2.2E+04	1.1E-02	5.2E-02	4.0E-02	1.9E-01	7.1E-02	1.6E-03	8.5E-03	8.8E-03	6.0E-02
46	DHADDCBBDBB	2.2E+04	1.0E+01	2.8E+07	2.8E+04	2.0E+02	9.1E-01	3.0E-01	2.8E-01	8.6E-02	1.8E-02	4.1E-03	1.2E-03	5.5E-03	2.0E-02
	DHADDCBBDBB			1.6E+06	2.9E+04	2.2E+04	8.8E-02	5.5E-02	4.3E-02	8.9E-02	2.6E-02	3.5E-04	3.0E-03	3.0E-03	1.9E-02
55	DHABACABBCA	2.2E+04	1.0E+01	5.2E+05	2.8E+04	1.0E+03	7.3E-01	3.2E-01	3.7E-01	4.6E-03	7.7E-05	2.3E-04	7.5E-05	7.5E-05	8.3E-05
	DHABACABBCA			1.6E+06	2.9E+04	2.2E+04	2.7E-01	1.2E-01	1.3E-01	4.4E-01	2.4E-01	1.1E-03	3.0E-02	3.1E-02	1.8E-01

* A listing of source terms for all bins is available on computer media

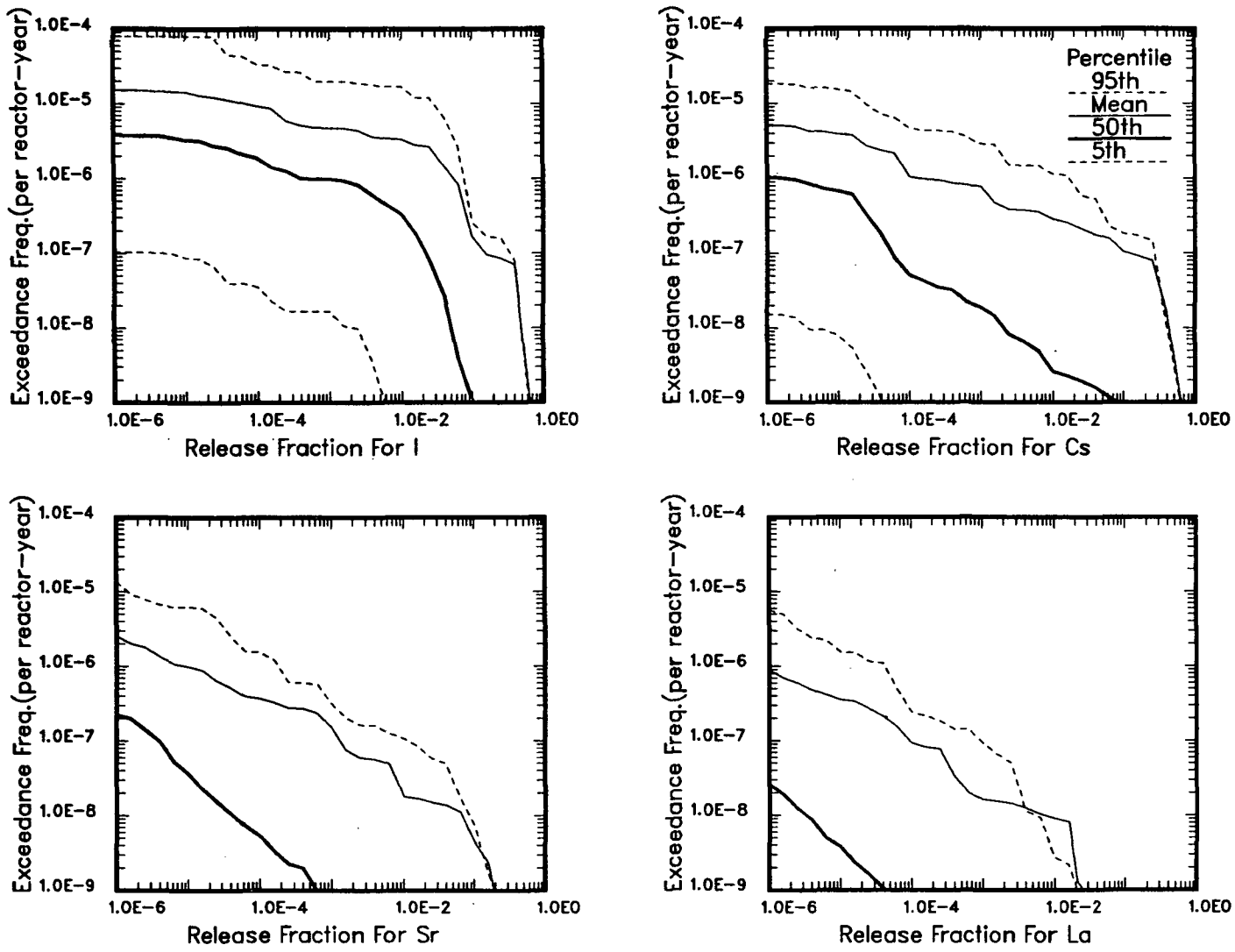


Figure 3.3-28. Release Fractions CCDF for EPRI PDS EQ 1 LOSP

Table 3.3-17
Mean Source Terms for Surry
Seismic Initiators - PDS Group EQ 3 - LOCAs - Low Acceleration
LLNL Hazard Distribution

Order	Bin	Warning Time (s)	Elevation (m)	Release Energy (W)	Release Start (s)	Release Duration (s)	Release Fractions								
							NG	I	Cs	Te	Sr	Ru	La	Ce	Ba
Fifteen Most Probable Bins*															
1	HHCDFCDBDFB	2.2E+04	0.0E+00	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	GHCDFCDBDDB			0.0E+00	4.7E+04	8.6E+04	4.2E-03	4.6E-05	1.6E-07	7.4E-08	1.1E-08	3.0E-09	6.3E-10	2.7E-09	1.2E-08
2	HHCDFCDADFB	2.2E+04	0.0E+00	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	GHCDFCDADDB			0.0E+00	4.7E+04	8.6E+04	3.9E-03	3.8E-05	1.2E-07	5.5E-08	1.3E-08	2.4E-09	8.2E-10	4.0E-09	1.4E-08
3	CHADBCAADCB	2.2E+04	1.0E+01	5.2E+05	2.8E+04	1.0E+03	7.4E-01	1.5E-01	1.4E-01	3.0E-02	6.5E-03	1.2E-03	4.2E-04	2.0E-03	7.2E-03
	CHADBCAADCB			1.6E+06	2.9E+04	2.2E+04	2.6E-01	9.2E-02	6.3E-02	9.2E-02	3.5E-02	1.2E-03	4.0E-03	4.7E-03	3.0E-02
4	HHADBCAADFB	2.2E+04	0.0E+00	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	GHADBCAADDB			0.0E+00	4.7E+04	8.6E+04	5.0E-03	1.7E-04	7.5E-07	4.6E-07	1.6E-07	8.9E-09	1.9E-08	2.6E-08	1.4E-07
5	HHADBCABDFB	2.2E+04	0.0E+00	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	GHADBCABDDB			0.0E+00	4.7E+04	8.6E+04	5.0E-03	1.6E-04	7.1E-07	4.4E-07	1.2E-07	8.1E-09	1.4E-08	1.8E-08	9.8E-08
6	CHADBCABDCB	2.2E+04	1.0E+01	5.2E+05	2.8E+04	1.0E+03	7.4E-01	1.6E-01	1.5E-01	4.4E-02	7.1E-03	1.8E-03	4.5E-04	2.0E-03	7.9E-03
	CHADBCABDCB			1.6E+06	2.9E+04	2.2E+04	2.6E-01	9.3E-02	6.7E-02	8.4E-02	2.4E-02	7.8E-04	2.5E-03	3.0E-03	1.8E-02
7	GHADBCAADDB	2.2E+04	1.0E+01	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	FHADBCAADCB			6.5E+04	1.3E+05	1.1E+04	1.0E+00	3.5E-02	4.5E-05	3.2E-05	1.2E-05	2.8E-07	1.4E-06	1.5E-06	1.0E-05
8	GHADBCABDDB	2.2E+04	1.0E+01	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	FHADBCABDCB			6.5E+04	1.3E+05	1.1E+04	1.0E+00	3.1E-02	3.5E-05	2.6E-05	8.4E-06	1.3E-07	9.5E-07	9.6E-07	6.2E-06
9	CDCDBCDADCB	2.2E+04	1.0E+01	5.2E+04	2.8E+04	1.1E+04	7.9E-01	9.0E-03	6.6E-03	2.5E-03	4.0E-04	7.7E-05	2.4E-05	1.1E-04	4.5E-04
	CDCDBCDADCB			1.6E+05	1.0E+06	1.0E+06	2.1E-01	1.6E-02	8.1E-04	3.1E-04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
10	HDCDFCDBDFB	2.2E+04	0.0E+00	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	GDCDFCDBDDB			0.0E+00	4.7E+04	8.6E+04	4.2E-03	4.6E-05	1.4E-09	7.1E-10	8.9E-11	3.0E-11	5.0E-12	2.0E-11	1.1E-10
11	CDDDBCAADCB	2.2E+04	1.0E+01	5.2E+04	2.8E+04	1.0E+03	7.4E-01	9.7E-03	8.4E-03	1.9E-03	3.0E-04	5.8E-05	1.8E-05	7.9E-05	3.4E-04
	CDDDBCAADCB			1.6E+05	2.9E+04	2.2E+04	2.6E-01	3.8E-02	3.6E-03	4.1E-03	1.4E-03	2.4E-05	1.4E-04	1.7E-04	1.1E-03
12	CDCDBCDBDCB	2.2E+04	1.0E+01	5.2E+04	2.8E+04	1.1E+04	8.3E-01	1.3E-02	1.1E-02	5.2E-03	7.7E-04	2.3E-04	4.9E-05	2.1E-04	9.0E-04
	CDCDBCDBDCB			1.6E+05	1.0E+06	1.0E+06	1.7E-01	1.8E-02	7.1E-04	2.0E-04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
13	HDCDFCDADFB	2.2E+04	0.0E+00	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	GDCDFCDADDB			0.0E+00	4.7E+04	8.6E+04	3.9E-03	3.8E-05	8.1E-10	3.2E-10	5.7E-11	1.1E-11	3.5E-12	1.5E-11	6.5E-11
14	HDCDBCDADFB	2.2E+04	0.0E+00	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	GDCDBCDADDB			0.0E+00	4.7E+04	8.6E+04	5.0E-03	7.8E-05	1.9E-09	7.8E-10	1.1E-10	2.2E-11	6.9E-12	3.0E-11	1.3E-10
15	HDCDBCDBDFB	2.2E+04	0.0E+00	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	GDCDBCDBDDB			0.0E+00	4.7E+04	8.6E+04	5.0E-03	9.1E-05	3.0E-09	1.5E-09	1.8E-10	6.1E-11	1.0E-11	3.9E-11	2.1E-10

* A listing of source terms for all bins is available on computer media

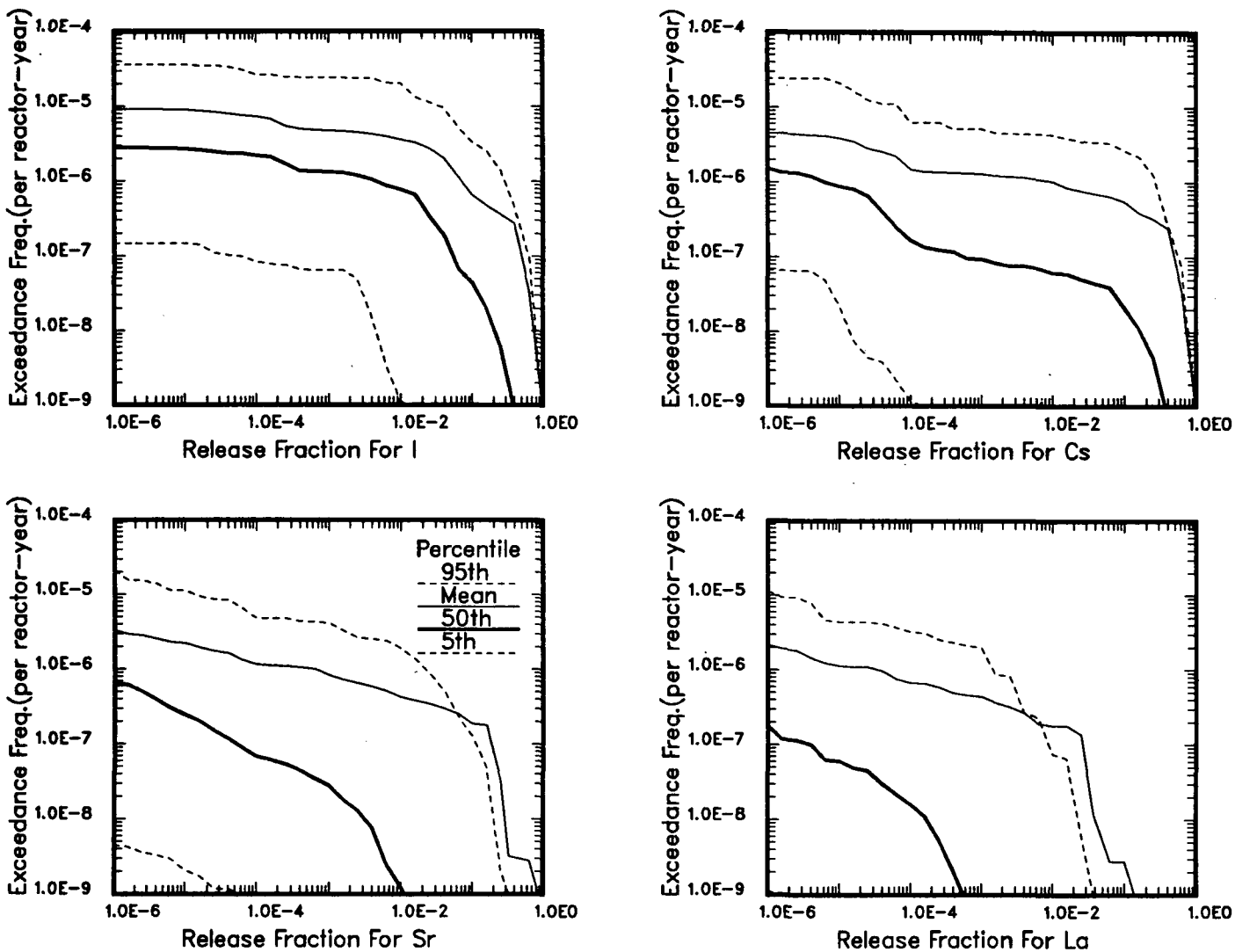


Figure 3.3-29. Release Fractions CCDF for EPRI PDS EQ 2 SBO

Table 3.3-18
Mean Source Terms for Surry
Seismic Initiators - PDS Group EQ 1 - LOSP (No SBO) - High Acceleration
EPRI Hazard Distribution

Order	Bin	Warning Time (s)	Elevation (m)	Release Energy (W)	Release Start (s)	Release Duration (s)	Release Fractions								
							NG	I	Cs	Te	Sr	Ru	La	Ce	Ba
Ten Most Probable Bins*															
1	HHCDFCDBDFB	2.2E+04	0.0E+00	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	GHCDFCDBDDB			0.0E+00	4.7E+04	8.6E+04	4.2E-03	4.6E-05	1.6E-07	7.4E-08	1.1E-08	3.0E-09	6.3E-10	2.7E-09	1.2E-08
2	HHADBCABDFB	2.2E+04	0.0E+00	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	GHADBCABDDB			0.0E+00	4.7E+04	8.6E+04	5.0E-03	1.6E-04	7.1E-07	4.4E-07	1.2E-07	8.1E-09	1.4E-08	1.8E-08	9.8E-08
3	HHCDFCDADFB	2.2E+04	0.0E+00	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	GHCDFCDADDB			0.0E+00	4.7E+04	8.6E+04	3.9E-03	3.9E-05	1.2E-07	5.6E-08	1.3E-08	2.4E-09	8.2E-10	4.0E-09	1.4E-08
4	GHADBCABDDB	2.2E+04	1.0E+01	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	FHADBCABDCB			6.5E+04	1.3E+05	1.1E+04	1.0E+00	3.1E-02	3.5E-05	2.6E-05	8.4E-06	1.3E-07	9.5E-07	9.6E-07	6.2E-06
5	HHADBCAADFB	2.2E+04	0.0E+00	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	GHADBCAADDB			0.0E+00	4.7E+04	8.6E+04	5.0E-03	1.7E-04	7.5E-07	4.6E-07	1.6E-07	8.9E-09	1.9E-08	2.6E-08	1.4E-07
6	GHADBCAADDB	2.2E+04	1.0E+01	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	FHADBCAADCB			6.5E+04	1.3E+05	1.1E+04	1.0E+00	3.5E-02	4.5E-05	3.2E-05	1.2E-05	2.8E-07	1.4E-06	1.5E-06	1.0E-05
7	HDCDFCDBDFB	2.2E+04	0.0E+00	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	GDCDFCDBDDB			0.0E+00	4.7E+04	8.6E+04	4.2E-03	4.6E-05	1.4E-09	7.1E-10	8.9E-11	3.0E-11	5.0E-12	2.0E-11	1.1E-10
8	HDCDFCDADFB	2.2E+04	0.0E+00	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	GDCDFCDADDB			0.0E+00	4.7E+04	8.6E+04	3.9E-03	3.9E-05	8.1E-10	3.2E-10	5.7E-11	1.1E-11	3.4E-12	1.5E-11	6.5E-11
9	HHACBCABDFB	2.2E+04	0.0E+00	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	GHACBCABDDB			0.0E+00	4.7E+04	8.6E+04	5.0E-03	1.2E-04	6.9E-07	4.7E-07	2.1E-07	2.2E-08	3.2E-08	3.5E-08	1.9E-07
10	HHACACABCFB	2.2E+04	0.0E+00	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	GHACACABCDB			0.0E+00	4.7E+04	8.6E+04	5.0E-03	1.4E-04	5.5E-07	2.9E-07	3.2E-08	3.7E-09	1.6E-09	2.8E-09	2.5E-08
Five Most Probable Bins that have VB and Early CF*															
24	DHADDCBBDBB	2.2E+04	1.0E+01	2.8E+07	2.8E+04	2.0E+02	9.1E-01	3.0E-01	2.8E-01	8.5E-02	1.9E-02	4.1E-03	1.2E-03	5.7E-03	2.0E-02
	DHADDCBBDBB			1.6E+06	2.9E+04	2.2E+04	9.1E-02	5.3E-02	4.1E-02	9.1E-02	2.7E-02	3.6E-04	3.1E-03	3.2E-03	2.0E-02
25	DHACACABACB	2.2E+04	1.0E+01	5.2E+05	2.8E+04	1.0E+03	7.5E-01	1.8E-01	1.7E-01	1.3E-01	1.1E-01	2.4E-02	1.3E-02	6.0E-02	1.1E-01
	DHACACABACB			1.6E+06	2.9E+04	2.2E+04	2.5E-01	7.9E-02	5.9E-02	4.4E-02	3.8E-02	8.0E-03	4.4E-03	2.0E-02	3.8E-02
88	DHADDCBADBB	2.2E+04	1.0E+01	2.8E+07	2.8E+04	2.0E+02	8.8E-01	2.7E-01	2.5E-01	5.7E-02	1.5E-02	2.6E-03	9.6E-04	4.8E-03	1.6E-02
	DHADDCBADBB			1.6E+06	2.9E+04	2.2E+04	1.2E-01	5.4E-02	4.2E-02	1.1E-01	3.7E-02	4.6E-04	4.0E-03	4.2E-03	3.0E-02
97	DHFCACABACB	2.2E+04	1.0E+01	5.2E+05	2.8E+04	1.1E+04	1.0E+00	2.5E-01	2.3E-01	1.7E-01	1.5E-01	3.2E-02	1.7E-02	8.1E-02	1.5E-01
	DHFCACABACB			1.6E+06	4.6E+04	2.2E+04	0.0E+00	1.7E-02	5.4E-04	6.9E-04	0.0E+00	1.6E-05	8.3E-05	4.3E-05	0.0E+00
102	DAFDDCBBDBB	2.2E+04	1.0E+01	2.8E+06	2.8E+04	2.0E+02	8.4E-01	2.1E-02	1.8E-02	8.1E-03	1.5E-03	3.7E-04	9.7E-05	4.4E-04	1.6E-03
	DAFDDCBBDBB			1.6E+06	4.6E+04	2.2E+04	1.6E-01	1.3E-01	1.2E-01	7.9E-02	2.4E-02	5.9E-05	2.3E-03	2.4E-03	1.6E-02

* A listing of source terms for all bins is available on computer media

Table 3.3-19
Mean Source Terms for Surry
Seismic Initiators - PDS Group EQ 2 - SBO - High Acceleration
EPRI Hazard Distribution

Order	Bin	Warning Time (s)	Elevation (m)	Release Energy (W)	Release Start (s)	Release Duration (s)	Release Fractions								
							NG	I	Cs	Te	Sr	Ru	La	Ce	Ba
Ten Most Probable Bins*															
1	HHADBCABDFB	2.2E+04	0.0E+00	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	GHADBCABDDB			0.0E+00	4.7E+04	8.6E+04	5.0E-03	1.6E-04	7.1E-07	4.4E-07	1.2E-07	8.1E-09	1.4E-08	1.8E-08	9.8E-08
2	HHADBCAADFB	2.2E+04	0.0E+00	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	GHADBCAADDB			0.0E+00	4.7E+04	8.6E+04	5.0E-03	1.7E-04	7.5E-07	4.6E-07	1.6E-07	8.9E-09	1.9E-08	2.6E-08	1.4E-07
3	GHADBCABDDB	2.2E+04	1.0E+01	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	FHADBCABDCB			6.5E+04	1.3E+05	1.1E+04	1.0E+00	3.1E-02	3.5E-05	2.6E-05	8.4E-06	1.3E-07	9.5E-07	9.6E-07	6.2E-06
4	GHADBCAADDB	2.2E+04	1.0E+01	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	FHADBCAADCB			6.5E+04	1.3E+05	1.1E+04	1.0E+00	3.5E-02	4.5E-05	3.2E-05	1.2E-05	2.8E-07	1.4E-06	1.5E-06	1.0E-05
5	HHADBCAADFA	2.2E+04	0.0E+00	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	GHADBCAADDA			0.0E+00	4.7E+04	8.6E+04	5.0E-03	1.7E-04	6.7E-07	4.5E-07	1.4E-07	3.8E-09	1.4E-08	1.6E-08	1.2E-07
6	CHADBCAADCB	2.2E+04	1.0E+01	5.2E+05	2.8E+04	1.0E+03	7.4E-01	1.5E-01	1.4E-01	3.0E-02	6.5E-03	1.2E-03	4.2E-04	2.0E-03	7.2E-03
	CHADBCAADCB			1.6E+06	2.9E+04	2.2E+04	2.6E-01	9.2E-02	6.3E-02	9.2E-02	3.5E-02	1.2E-03	4.0E-03	4.7E-03	3.0E-02
7	CHADBCABDCB	2.2E+04	1.0E+01	5.2E+05	2.8E+04	1.0E+03	7.4E-01	1.6E-01	1.5E-01	4.3E-02	7.1E-03	1.8E-03	4.5E-04	2.0E-03	7.8E-03
	CHADBCABDCB			1.6E+06	2.9E+04	2.2E+04	2.6E-01	9.2E-02	6.7E-02	8.3E-02	2.4E-02	7.7E-04	2.5E-03	3.0E-03	1.8E-02
8	GHADBCAADDA	2.2E+04	1.0E+01	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	FHADBCAADCA			6.5E+04	1.3E+05	1.1E+04	1.0E+00	3.4E-02	4.1E-05	3.3E-05	1.1E-05	1.2E-07	1.2E-06	1.2E-06	9.0E-06
9	HHADBCABDFA	2.2E+04	0.0E+00	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	GHADBCABDDA			0.0E+00	4.7E+04	8.6E+04	5.0E-03	1.9E-04	7.0E-07	4.8E-07	1.5E-07	8.0E-09	1.6E-08	1.9E-08	1.2E-07
10	HHACACABBFA	2.2E+04	0.0E+00	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	GHACACABBDA			0.0E+00	4.7E+04	8.6E+04	5.0E-03	1.1E-04	4.8E-07	3.3E-07	1.1E-07	5.1E-09	9.0E-09	1.3E-08	8.4E-08
Five Most Probable Bins that have VB and Early CF*															
6	CHADBCAADCB	2.2E+04	1.0E+01	5.2E+05	2.8E+04	1.0E+03	7.4E-01	1.5E-01	1.4E-01	3.0E-02	6.5E-03	1.2E-03	4.2E-04	2.0E-03	7.2E-03
	CHADBCAADCB			1.6E+06	2.9E+04	2.2E+04	2.6E-01	9.2E-02	6.3E-02	9.2E-02	3.5E-02	1.2E-03	4.0E-03	4.7E-03	3.0E-02
7	CHADBCABDCB	2.2E+04	1.0E+01	5.2E+05	2.8E+04	1.0E+03	7.4E-01	1.6E-01	1.5E-01	4.3E-02	7.1E-03	1.8E-03	4.5E-04	2.0E-03	7.8E-03
	CHADBCABDCB			1.6E+06	2.9E+04	2.2E+04	2.6E-01	9.2E-02	6.7E-02	8.3E-02	2.4E-02	7.7E-04	2.5E-03	3.0E-03	1.8E-02
36	DHADDCBBDBB	2.2E+04	1.0E+01	2.8E+07	2.8E+04	2.0E+02	9.1E-01	3.0E-01	2.8E-01	8.5E-02	1.9E-02	4.1E-03	1.2E-03	5.7E-03	2.0E-02
	DHADDCBBDBB			1.6E+06	2.9E+04	2.2E+04	9.1E-02	5.3E-02	4.1E-02	9.1E-02	2.7E-02	3.6E-04	3.1E-03	3.2E-03	2.0E-02
37	CHADBCAADBB	2.2E+04	1.0E+01	2.8E+07	2.8E+04	2.0E+02	9.9E-01	4.3E-01	4.1E-01	7.7E-02	1.8E-02	3.3E-03	1.2E-03	5.7E-03	2.0E-02
	CHADBCAADBB			1.6E+06	2.9E+04	2.2E+04	1.1E-02	5.2E-02	4.0E-02	1.9E-01	7.1E-02	1.6E-03	8.5E-03	8.8E-03	6.0E-02
49	DHACACABACB	2.2E+04	1.0E+01	5.2E+05	2.8E+04	1.0E+03	7.5E-01	1.8E-01	1.7E-01	1.3E-01	1.1E-01	2.4E-02	1.3E-02	6.0E-02	1.1E-01
	DHACACABACB			1.6E+06	2.9E+04	2.2E+04	2.5E-01	7.9E-02	5.9E-02	4.4E-02	3.8E-02	8.0E-03	4.4E-03	2.0E-02	3.8E-02

* A listing of source terms for all bins is available on computer media

Table 3.3-20
Mean Source Terms for Surry
Seismic Initiators - PDS Group EQ 3 - LOCAs - High Acceleration
EPRI Hazard Distribution

Order	Bin	Warning Time (s)	Elevation (m)	Release Energy (W)	Release Start (s)	Release Duration (s)	Release Fractions								
							NG	I	Cs	Te	Sr	Ru	La	Ce	Ba
Fifteen Most Probable Bins*															
1	HHCDFCDADFB	2.2E+04	0.0E+00	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	GHCDFCDADDB			0.0E+00	4.7E+04	8.6E+04	3.9E-03	3.9E-05	1.2E-07	5.6E-08	1.3E-08	2.4E-09	8.2E-10	4.0E-09	1.4E-08
2	HHCDFCDBDFB	2.2E+04	0.0E+00	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	GHCDFCDBDDB			0.0E+00	4.7E+04	8.6E+04	4.2E-03	4.6E-05	1.6E-07	7.4E-08	1.1E-08	3.0E-09	6.3E-10	2.7E-09	1.2E-08
3	CHADBCAADCB	2.2E+04	1.0E+01	5.2E+05	2.8E+04	1.0E+03	7.4E-01	1.5E-01	1.4E-01	3.0E-02	6.5E-03	1.2E-03	4.2E-04	2.0E-03	7.2E-03
	CHADBCAADCB			1.6E+06	2.9E+04	2.2E+04	2.6E-01	9.2E-02	6.3E-02	9.2E-02	3.5E-02	1.2E-03	4.0E-03	4.7E-03	3.0E-02
4	CHADBCABDCB	2.2E+04	1.0E+01	5.2E+05	2.8E+04	1.0E+03	7.4E-01	1.6E-01	1.5E-01	4.3E-02	7.1E-03	1.8E-03	4.5E-04	2.0E-03	7.8E-03
	CHADBCABDCB			1.6E+06	2.9E+04	2.2E+04	2.6E-01	9.2E-02	6.7E-02	8.3E-02	2.4E-02	7.7E-04	2.5E-03	3.0E-03	1.8E-02
5	HHADBCAADFB	2.2E+04	0.0E+00	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	GHADBCAADDB			0.0E+00	4.7E+04	8.6E+04	5.0E-03	1.7E-04	7.5E-07	4.6E-07	1.6E-07	8.9E-09	1.9E-08	2.6E-08	1.4E-07
6	HHADBCABDFB	2.2E+04	0.0E+00	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	GHADBCABDDB			0.0E+00	4.7E+04	8.6E+04	5.0E-03	1.6E-04	7.1E-07	4.4E-07	1.2E-07	8.1E-09	1.4E-08	1.8E-08	9.8E-08
7	GHADBCAADDB	2.2E+04	1.0E+01	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	FHADBCAADCB			6.5E+04	1.3E+05	1.1E+04	1.0E+00	3.5E-02	4.5E-05	3.2E-05	1.2E-05	2.8E-07	1.4E-06	1.5E-06	1.0E-05
8	GHADBCABDDB	2.2E+04	1.0E+01	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	FHADBCABDCB			6.5E+04	1.3E+05	1.1E+04	1.0E+00	3.1E-02	3.5E-05	2.6E-05	8.4E-06	1.3E-07	9.5E-07	9.6E-07	6.2E-06
9	CDCDBCDADCB	2.2E+04	1.0E+01	5.2E+04	2.8E+04	1.1E+04	7.9E-01	9.0E-03	6.6E-03	2.5E-03	4.0E-04	7.7E-05	2.4E-05	1.1E-04	4.5E-04
	CDCDBCDADCB			1.6E+05	1.0E+06	1.0E+06	2.1E-01	1.6E-02	8.1E-04	3.1E-04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
10	HDCDFCDADFB	2.2E+04	0.0E+00	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	GDCDFCDADDB			0.0E+00	4.7E+04	8.6E+04	3.9E-03	3.9E-05	8.1E-10	3.2E-10	5.7E-11	1.1E-11	3.4E-12	1.5E-11	6.5E-11
11	CDCDBCDBDCB	2.2E+04	1.0E+01	5.2E+04	2.8E+04	1.1E+04	8.3E-01	1.3E-02	1.1E-02	5.3E-03	7.8E-04	2.3E-04	5.0E-05	2.2E-04	9.2E-04
	CDCDBCDBDCB			1.6E+05	1.0E+06	1.0E+06	1.7E-01	1.8E-02	7.0E-04	2.1E-04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
12	CDDDBCAADCB	2.2E+04	1.0E+01	5.2E+04	2.8E+04	1.0E+03	7.4E-01	9.7E-03	8.4E-03	1.9E-03	3.0E-04	5.8E-05	1.8E-05	7.9E-05	3.4E-04
	CDDDBCAADCB			1.6E+05	2.9E+04	2.2E+04	2.6E-01	3.8E-02	3.7E-03	4.2E-03	1.4E-03	2.4E-05	1.4E-04	1.7E-04	1.1E-03
13	HDCDFCDBDFB	2.2E+04	0.0E+00	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	GDCDFCDBDDB			0.0E+00	4.7E+04	8.6E+04	4.2E-03	4.6E-05	1.4E-09	7.1E-10	8.9E-11	3.0E-11	5.0E-12	2.0E-11	1.1E-10
14	HDCDBCDADFB	2.2E+04	0.0E+00	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	GDCDBCDADDB			0.0E+00	4.7E+04	8.6E+04	5.0E-03	7.8E-05	1.9E-09	7.8E-10	1.1E-10	2.2E-11	6.9E-12	3.0E-11	1.3E-10
15	CDDDBCABDCB	2.2E+04	1.0E+01	5.2E+04	2.8E+04	1.0E+03	7.4E-01	1.2E-02	1.1E-02	4.0E-03	5.9E-04	1.8E-04	3.8E-05	1.6E-04	6.9E-04
	CDDDBCABDCB			1.6E+05	2.9E+04	2.2E+04	2.6E-01	3.5E-02	4.4E-03	4.1E-03	1.2E-03	6.7E-05	1.5E-04	1.9E-04	9.8E-04

* A listing of source terms for all bins is available on computer media

Table 3.3-21
Mean Source Terms for Surry
Seismic Initiators - PDS Group EQ 1 - LOSP (No SBO) - Low Acceleration
EPRI Hazard Distribution

Order	Bin	Warning Time (s)	Elevation (m)	Release Energy (W)	Release Start (s)	Release Duration (s)	Release Fractions								
							NG	I	Cs	Te	Sr	Ru	La	Ce	Ba
Ten Most Probable Bins*															
1	HHCDFCDBDFB	2.2E+04	0.0E+00	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	GHCDFCDBDDB			0.0E+00	4.7E+04	8.6E+04	4.2E-03	4.6E-05	1.6E-07	7.4E-08	1.1E-08	3.0E-09	6.3E-10	2.7E-09	1.2E-08
2	HHADBCABDFB	2.2E+04	0.0E+00	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	GHADBCABDDB			0.0E+00	4.7E+04	8.6E+04	5.0E-03	1.6E-04	7.1E-07	4.4E-07	1.2E-07	8.1E-09	1.4E-08	1.8E-08	9.8E-08
3	GHADBCABDDB	2.2E+04	1.0E+01	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	FHADBCABDCB			6.5E+04	1.3E+05	1.1E+04	1.0E+00	3.1E-02	3.5E-05	2.6E-05	8.4E-06	1.3E-07	9.5E-07	9.6E-07	6.2E-06
4	HHCDFCDADFB	2.2E+04	0.0E+00	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	GHCDFCDADDB			0.0E+00	4.7E+04	8.6E+04	3.9E-03	3.9E-05	1.2E-07	5.6E-08	1.3E-08	2.4E-09	8.2E-10	4.0E-09	1.4E-08
5	HHADBCAADFB	2.2E+04	0.0E+00	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	GHADBCAADDB			0.0E+00	4.7E+04	8.6E+04	5.0E-03	1.7E-04	7.5E-07	4.6E-07	1.6E-07	8.9E-09	1.9E-08	2.6E-08	1.4E-07
6	HDCDFCDBDFB	2.2E+04	0.0E+00	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	GDCDFCDBDDB			0.0E+00	4.7E+04	8.6E+04	4.2E-03	4.6E-05	1.4E-09	7.1E-10	8.9E-11	3.0E-11	5.0E-12	2.0E-11	1.1E-10
7	GHADBCAADDB	2.2E+04	1.0E+01	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	FHADBCAADCB			6.5E+04	1.3E+05	1.1E+04	1.0E+00	3.5E-02	4.5E-05	3.2E-05	1.2E-05	2.8E-07	1.4E-06	1.5E-06	1.0E-05
8	HDCDFCDADFB	2.2E+04	0.0E+00	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	GDCDFCDADDB			0.0E+00	4.7E+04	8.6E+04	3.9E-03	3.9E-05	8.1E-10	3.2E-10	5.7E-11	1.1E-11	3.4E-12	1.5E-11	6.5E-11
9	HDCDBCDBDFB	2.2E+04	0.0E+00	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	GDCDBCDBDDB			0.0E+00	4.7E+04	8.6E+04	5.0E-03	9.1E-05	3.0E-09	1.5E-09	1.8E-10	6.1E-11	1.0E-11	3.9E-11	2.1E-10
10	HHACACABCFB	2.2E+04	0.0E+00	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	GHACACABCDB			0.0E+00	4.7E+04	8.6E+04	5.0E-03	1.4E-04	5.5E-07	2.9E-07	3.2E-08	3.7E-09	1.6E-09	2.8E-09	2.5E-08
Five Most Probable Bins that have VB and Early CF*															
29	DHACACABACB	2.2E+04	1.0E+01	5.2E+05	2.8E+04	1.0E+03	7.5E-01	1.8E-01	1.7E-01	1.3E-01	1.1E-01	2.4E-02	1.3E-02	6.0E-02	1.1E-01
	DHACACABACB			1.6E+06	2.9E+04	2.2E+04	2.5E-01	7.9E-02	5.9E-02	4.4E-02	3.8E-02	8.0E-03	4.4E-03	2.0E-02	3.8E-02
31	DHADDCBBDBB	2.2E+04	1.0E+01	2.8E+07	2.8E+04	2.0E+02	9.1E-01	3.0E-01	2.8E-01	8.5E-02	1.8E-02	4.0E-03	1.2E-03	5.4E-03	2.0E-02
	DHADDCBBDBB			1.6E+06	2.9E+04	2.2E+04	8.9E-02	5.5E-02	4.3E-02	9.1E-02	2.6E-02	3.4E-04	3.0E-03	3.0E-03	1.9E-02
69	DHADDCBADBB	2.2E+04	1.0E+01	2.8E+07	2.8E+04	2.0E+02	8.8E-01	2.7E-01	2.5E-01	5.3E-02	1.5E-02	2.5E-03	9.6E-04	4.8E-03	1.6E-02
	DHADDCBADBB			1.6E+06	2.9E+04	2.2E+04	1.2E-01	5.5E-02	4.2E-02	1.1E-01	3.7E-02	4.6E-04	4.0E-03	4.2E-03	3.0E-02
106	DHEAACAAABA	2.2E+04	1.0E+01	2.8E+07	2.8E+04	2.0E+02	9.9E-01	2.3E-01	2.6E-01	3.4E-02	1.0E-02	1.5E-02	4.4E-03	4.3E-03	1.3E-02
	DHEAACAAABA			1.6E+06	3.4E+04	2.2E+04	7.6E-03	3.4E-02	1.5E-02	1.3E-01	8.8E-02	3.8E-04	9.9E-03	1.0E-02	7.3E-02
126	DAFDDCBBDBB	2.2E+04	1.0E+01	2.8E+06	2.8E+04	2.0E+02	8.4E-01	2.3E-02	2.0E-02	9.8E-03	1.5E-03	4.4E-04	1.0E-04	4.4E-04	1.8E-03
	DAFDDCBBDBB			1.6E+06	4.6E+04	2.2E+04	1.6E-01	1.4E-01	1.3E-01	8.1E-02	2.5E-02	6.1E-05	2.5E-03	2.6E-03	1.8E-02

* A listing of source terms for all bins is available on computer media

Table 3.3-22
Mean Source Terms for Surry
Seismic Initiators - PDS Group EQ 2 - SBO - Low Acceleration
EPRI Hazard Distribution

Order	Bin	Warning Time (s)	Elevation (m)	Release Energy (W)	Release Start (s)	Release Duration (s)	Release Fractions								
							NG	I	Cs	Te	Sr	Ru	La	Ce	Ba
Ten Most Probable Bins*															
1	HHADBCABDFB	2.2E+04	0.0E+00	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	GHADBCABDDB			0.0E+00	4.7E+04	8.6E+04	5.0E-03	1.6E-04	7.1E-07	4.4E-07	1.2E-07	8.1E-09	1.4E-08	1.8E-08	9.8E-08
2	HHADBCAADFB	2.2E+04	0.0E+00	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	GHADBCAADDB			0.0E+00	4.7E+04	8.6E+04	5.0E-03	1.7E-04	7.5E-07	4.6E-07	1.6E-07	8.9E-09	1.9E-08	2.6E-08	1.4E-07
3	GHADBCABDDB	2.2E+04	1.0E+01	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	FHADBCABDCB			6.5E+04	1.3E+05	1.1E+04	1.0E+00	3.1E-02	3.5E-05	2.6E-05	8.4E-06	1.3E-07	9.5E-07	9.6E-07	6.2E-06
4	HHADBCAADFA	2.2E+04	0.0E+00	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	GHADBCAADDA			0.0E+00	4.7E+04	8.6E+04	5.0E-03	1.7E-04	6.7E-07	4.5E-07	1.4E-07	3.8E-09	1.4E-08	1.6E-08	1.2E-07
5	GHADBCAADDB	2.2E+04	1.0E+01	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	FHADBCAADCB			6.5E+04	1.3E+05	1.1E+04	1.0E+00	3.5E-02	4.5E-05	3.2E-05	1.2E-05	2.8E-07	1.4E-06	1.5E-06	1.0E-05
6	GHADBCAADDA	2.2E+04	1.0E+01	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	FHADBCAADCA			6.5E+04	1.3E+05	1.1E+04	1.0E+00	3.4E-02	4.1E-05	3.3E-05	1.1E-05	1.2E-07	1.2E-06	1.2E-06	9.0E-06
7	HHADBCABDFA	2.2E+04	0.0E+00	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	GHADBCABDDA			0.0E+00	4.7E+04	8.6E+04	5.0E-03	1.9E-04	7.0E-07	4.8E-07	1.5E-07	8.0E-09	1.6E-08	1.9E-08	1.2E-07
8	HHACACABBFA	2.2E+04	0.0E+00	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	GHACACABBDA			0.0E+00	4.7E+04	8.6E+04	5.0E-03	1.1E-04	4.8E-07	3.3E-07	1.1E-07	5.1E-09	9.0E-09	1.3E-08	8.4E-08
9	GHADBCABDDA	2.2E+04	1.0E+01	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	FHADBCABDCA			6.5E+04	1.3E+05	1.1E+04	1.0E+00	3.7E-02	2.9E-05	2.8E-05	1.2E-05	2.6E-07	1.5E-06	1.5E-06	9.1E-06
10	CHADBCAADCB	2.2E+04	1.0E+01	5.2E+05	2.8E+04	1.0E+03	7.4E-01	1.5E-01	1.4E-01	3.0E-02	6.5E-03	1.2E-03	4.2E-04	2.0E-03	7.2E-03
	CHADBCAADCB			1.6E+06	2.9E+04	2.2E+04	2.6E-01	9.2E-02	6.3E-02	9.2E-02	3.5E-02	1.2E-03	4.0E-03	4.7E-03	3.0E-02
Five Most Probable Bins that have VB and Early CF*															
10	CHADBCAADCB	2.2E+04	1.0E+01	5.2E+05	2.8E+04	1.0E+03	7.4E-01	1.5E-01	1.4E-01	3.0E-02	6.5E-03	1.2E-03	4.2E-04	2.0E-03	7.2E-03
	CHADBCAADCB			1.6E+06	2.9E+04	2.2E+04	2.6E-01	9.2E-02	6.3E-02	9.2E-02	3.5E-02	1.2E-03	4.0E-03	4.7E-03	3.0E-02
11	CHADBCABDCB	2.2E+04	1.0E+01	5.2E+05	2.8E+04	1.0E+03	7.4E-01	1.6E-01	1.5E-01	4.3E-02	7.1E-03	1.8E-03	4.5E-04	2.0E-03	7.8E-03
	CHADBCABDCB			1.6E+06	2.9E+04	2.2E+04	2.6E-01	9.2E-02	6.7E-02	8.3E-02	2.4E-02	7.7E-04	2.5E-03	3.0E-03	1.8E-02
51	DHADDCBBDBB	2.2E+04	1.0E+01	2.8E+07	2.8E+04	2.0E+02	9.1E-01	3.0E-01	2.8E-01	8.5E-02	1.8E-02	4.0E-03	1.2E-03	5.4E-03	2.0E-02
	DHADDCBBDBB			1.6E+06	2.9E+04	2.2E+04	8.9E-02	5.5E-02	4.3E-02	9.1E-02	2.6E-02	3.4E-04	3.0E-03	3.0E-03	1.9E-02
54	DHACACABACB	2.2E+04	1.0E+01	5.2E+05	2.8E+04	1.0E+03	7.5E-01	1.8E-01	1.7E-01	1.3E-01	1.1E-01	2.4E-02	1.3E-02	6.0E-02	1.1E-01
	DHACACABACB			1.6E+06	2.9E+04	2.2E+04	2.5E-01	7.9E-02	5.9E-02	4.4E-02	3.8E-02	8.0E-03	4.4E-03	2.0E-02	3.8E-02
57	DHACCCAABCA	2.2E+04	1.0E+01	5.2E+05	2.8E+04	1.0E+03	7.5E-01	7.9E-03	5.3E-03	4.8E-03	5.0E-03	1.5E-03	6.1E-04	4.8E-03	5.0E-03
	DHACCCAABCA			1.6E+06	2.9E+04	2.2E+04	2.5E-01	3.7E-02	9.7E-03	4.0E-03	1.7E-03	5.2E-04	2.1E-04	1.6E-03	1.7E-03

* A listing of source terms for all bins is available on computer media

Table 3.3-23
Mean Source Terms for Surry
Seismic Initiators - PDS Group EQ 3 - LOCAs - Low Acceleration
EPRI Hazard Distribution

Order	Bin	Warning Time (s)	Elevation (m)	Release Energy (W)	Release Start (s)	Release Duration (s)	Release Fractions								
							NG	I	Cs	Te	Sr	Ru	La	Ce	Ba
Fifteen Most Probable Bins*															
1	HHCDFCDADFB	2.2E+04	0.0E+00	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	GHCDFCDADDB			0.0E+00	4.7E+04	8.6E+04	3.9E-03	3.9E-05	1.2E-07	5.6E-08	1.3E-08	2.4E-09	8.2E-10	4.0E-09	1.4E-08
2	HHCDFCDBDFB	2.2E+04	0.0E+00	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	GHCDFCDBDDB			0.0E+00	4.7E+04	8.6E+04	4.2E-03	4.6E-05	1.6E-07	7.4E-08	1.1E-08	3.0E-09	6.3E-10	2.7E-09	1.2E-08
3	HHADBCAADFB	2.2E+04	0.0E+00	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	GHADBCAADDB			0.0E+00	4.7E+04	8.6E+04	5.0E-03	1.7E-04	7.5E-07	4.6E-07	1.6E-07	8.9E-09	1.9E-08	2.6E-08	1.4E-07
4	HHADBCABDFB	2.2E+04	0.0E+00	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	GHADBCABDDB			0.0E+00	4.7E+04	8.6E+04	5.0E-03	1.6E-04	7.1E-07	4.4E-07	1.2E-07	8.1E-09	1.4E-08	1.8E-08	9.8E-08
5	CHADBCAADCB	2.2E+04	1.0E+01	5.2E+05	2.8E+04	1.0E+03	7.4E-01	1.5E-01	1.4E-01	3.0E-02	6.5E-03	1.2E-03	4.2E-04	2.0E-03	7.2E-03
	CHADBCAADCB			1.6E+06	2.9E+04	2.2E+04	2.6E-01	9.2E-02	6.3E-02	9.2E-02	3.5E-02	1.2E-03	4.0E-03	4.7E-03	3.0E-02
6	CHADBCABDCB	2.2E+04	1.0E+01	5.2E+05	2.8E+04	1.0E+03	7.4E-01	1.6E-01	1.5E-01	4.3E-02	7.1E-03	1.8E-03	4.5E-04	2.0E-03	7.8E-03
	CHADBCABDCB			1.6E+06	2.9E+04	2.2E+04	2.6E-01	9.2E-02	6.7E-02	8.3E-02	2.4E-02	7.7E-04	2.5E-03	3.0E-03	1.8E-02
7	GHADBCAADDB	2.2E+04	1.0E+01	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	FHADBCAADCB			6.5E+04	1.3E+05	1.1E+04	1.0E+00	3.5E-02	4.5E-05	3.2E-05	1.2E-05	2.8E-07	1.4E-06	1.5E-06	1.0E-05
8	GHADBCABDDB	2.2E+04	1.0E+01	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	FHADBCABDCB			6.5E+04	1.3E+05	1.1E+04	1.0E+00	3.1E-02	3.5E-05	2.6E-05	8.4E-06	1.3E-07	9.5E-07	9.6E-07	6.2E-06
9	HDCDFCDADFB	2.2E+04	0.0E+00	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	GDCDFCDADDB			0.0E+00	4.7E+04	8.6E+04	3.9E-03	3.9E-05	8.1E-10	3.2E-10	5.7E-11	1.1E-11	3.4E-12	1.5E-11	6.5E-11
10	CDCDBCDADCB	2.2E+04	1.0E+01	5.2E+04	2.8E+04	1.1E+04	7.9E-01	9.0E-03	6.6E-03	2.5E-03	4.0E-04	7.7E-05	2.4E-05	1.1E-04	4.5E-04
	CDCDBCDADCB			1.6E+05	1.0E+06	1.0E+06	2.1E-01	1.6E-02	8.1E-04	3.1E-04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
11	CDCDBCDBDCB	2.2E+04	1.0E+01	5.2E+04	2.8E+04	1.1E+04	8.3E-01	1.3E-02	1.1E-02	5.2E-03	7.7E-04	2.3E-04	5.0E-05	2.1E-04	9.1E-04
	CDCDBCDBDCB			1.6E+05	1.0E+06	1.0E+06	1.7E-01	1.9E-02	6.4E-04	1.8E-04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
12	CDDDBCAADCB	2.2E+04	1.0E+01	5.2E+04	2.8E+04	1.0E+03	7.4E-01	9.7E-03	8.4E-03	1.9E-03	3.0E-04	5.8E-05	1.8E-05	7.9E-05	3.4E-04
	CDDDBCAADCB			1.6E+05	2.9E+04	2.2E+04	2.6E-01	3.8E-02	3.7E-03	4.2E-03	1.4E-03	2.4E-05	1.4E-04	1.7E-04	1.1E-03
13	HDCDFCDBDFB	2.2E+04	0.0E+00	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	GDCDFCDBDDB			0.0E+00	4.7E+04	8.6E+04	4.2E-03	4.6E-05	1.4E-09	7.1E-10	8.9E-11	3.0E-11	5.0E-12	2.0E-11	1.1E-10
14	HDCDBCDADFB	2.2E+04	0.0E+00	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	GDCDBCDADDB			0.0E+00	4.7E+04	8.6E+04	5.0E-03	7.8E-05	1.9E-09	7.8E-10	1.1E-10	2.2E-11	6.9E-12	3.0E-11	1.3E-10
15	CDDDBCABDCB	2.2E+04	1.0E+01	5.2E+04	2.8E+04	1.0E+03	7.4E-01	1.2E-02	1.1E-02	4.1E-03	6.1E-04	1.8E-04	3.9E-05	1.7E-04	7.1E-04
	CDDDBCABDCB			1.6E+05	2.9E+04	2.2E+04	2.6E-01	3.6E-02	4.5E-03	4.2E-03	1.2E-03	6.2E-05	1.3E-04	1.8E-04	8.9E-04

* A listing of source terms for all bins is available on computer media

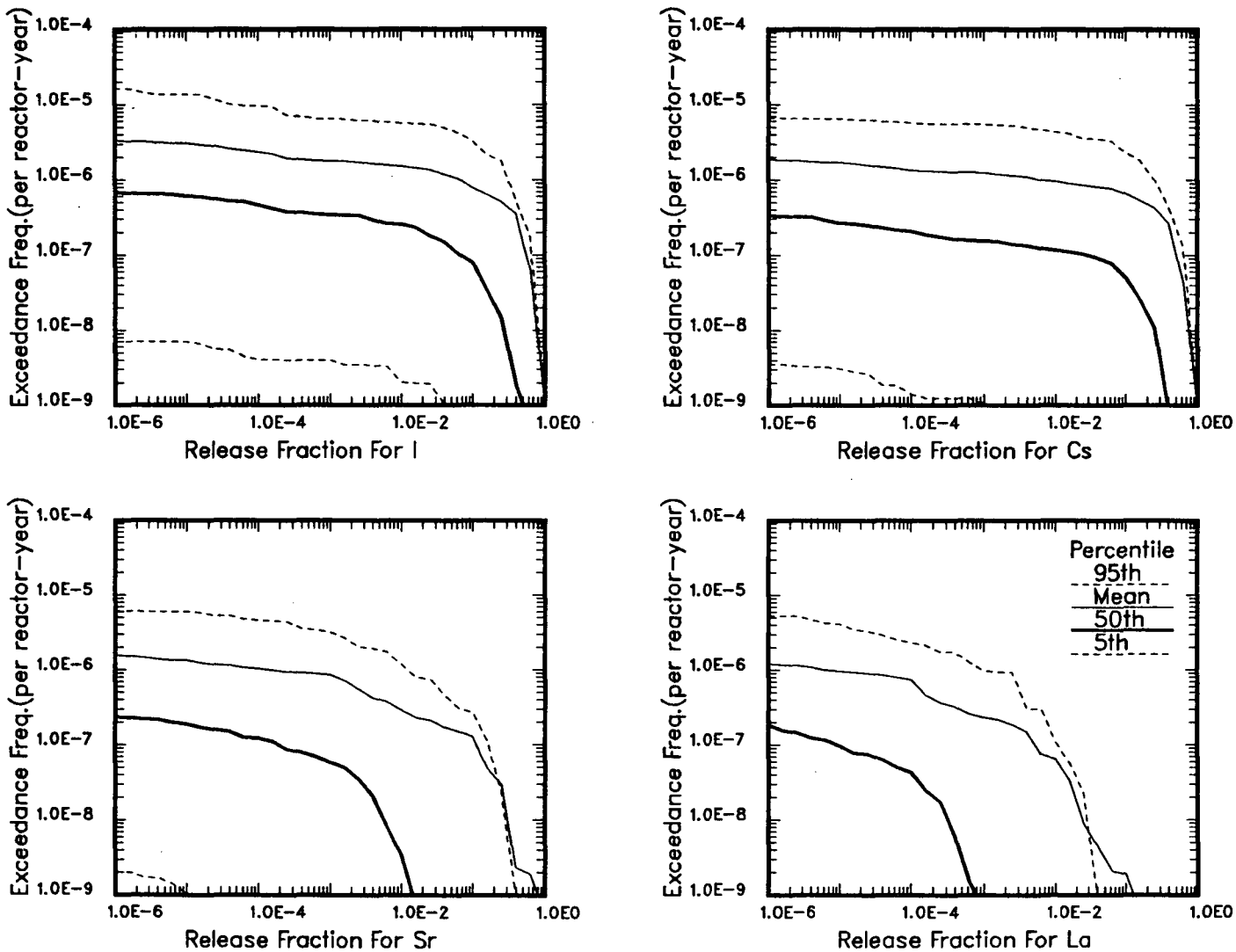


Figure 3.3-30. Release Fractions CCDF for EPRI PDS EQ 3 LOCAs

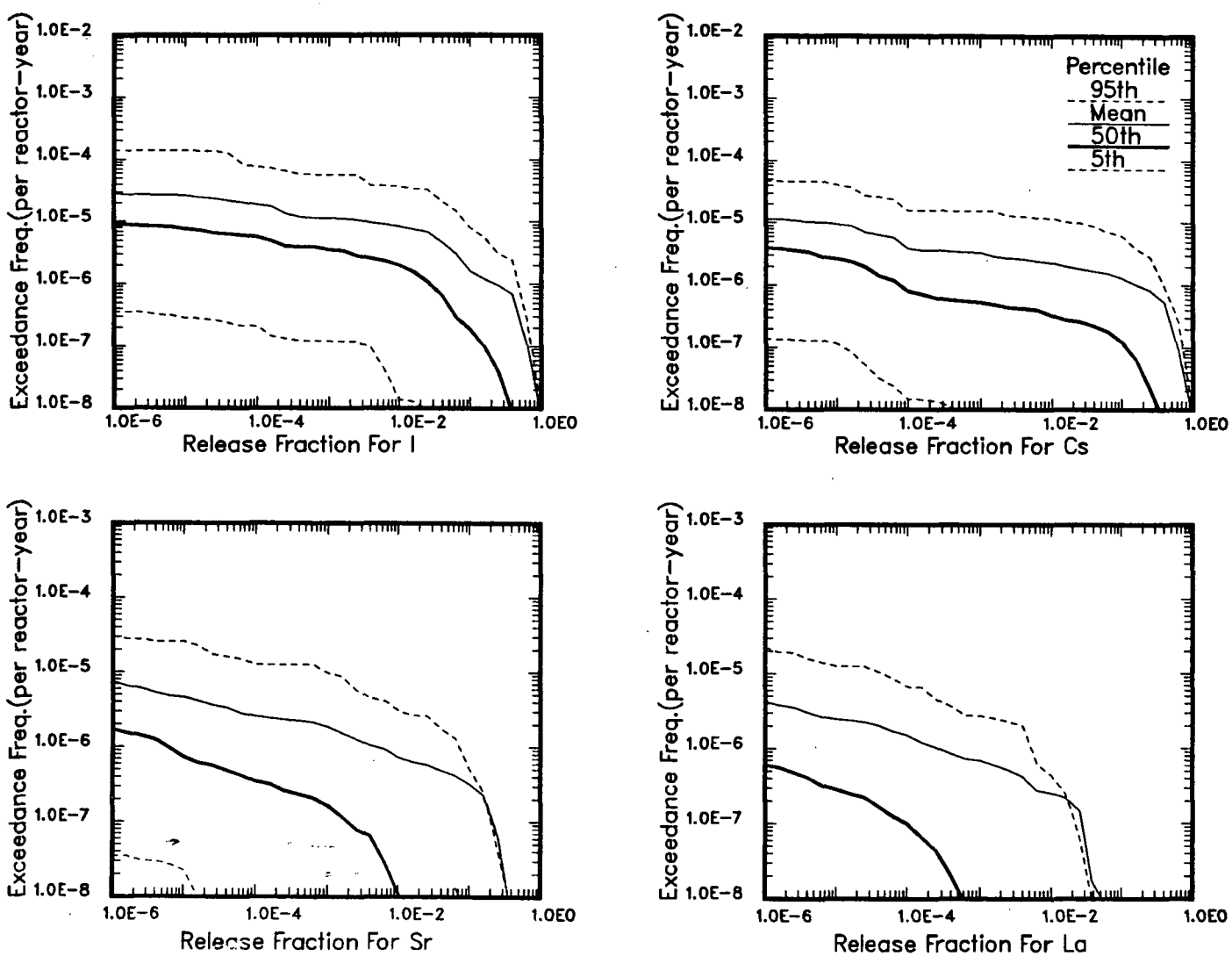


Figure 3.3-31. Release Fractions CCDF for All PDS and All PGA

3.4 Partitioning of the Source Terms for the Consequence Analysis

The first subsection discusses the partitioning process in some detail in the course of presenting the partitioning results for internal initiators. Partitioning results for fire initiators are given in Section 3.4.2. The results of partitioning the source terms for seismic initiators are presented in Sections 3.4.3 and 3.4.4 for the analyses utilizing the LLNL and EPRI hazard distributions, respectively.

3.4.1 Results for Internal Initiators

The accident progression analysis and the subsequent source term analysis resulted in the generation of 18,591 source terms for internal initiators. It is not computationally possible to perform a calculation with the MACCS consequence model[8] for each of these source terms. Therefore, the interface between the source term analysis and the consequence analysis is formed by grouping this large number of source terms into a much smaller number of source term groups. These groups are defined so that the source terms within them have similar properties and a frequency-weighted mean source term is determined for each group. Then, a single MACCS calculation is performed for each mean source term. This grouping of the source terms is performed with the PARTITION program,[7] and the process is referred to as "partitioning the source terms" or just "partitioning."

The partitioning process involves the following steps: definition of an early health effect weight (EH) for each source term, definition of a chronic health effect weight (CH) for each source term, subdivision (partitioning) of the source terms on the basis of EH and CH, a further subdivision on the basis of evacuation timing, and calculation of frequency-weighted mean source terms. The partitioning process is described in detail in NUREG/CR-4551, Vol. 1, and in the user's manual for the PARTITION program.[7] This section describes the details of the partitioning process for source terms generated in the source term analysis for internal initiators.

The early health effect weight EH is based on converting the radionuclide release associated with a source term into an equivalent I-131 release and then estimating the number of early fatalities that would result from this equivalent I-131 release. This estimated number of early fatalities is the early health effect weight EH. The relationship between early fatalities and equivalent I-131 releases is shown in Figure B.4-1 of Appendix B and is based on site-specific MACCS calculations for different-sized releases of I-131.

The chronic health effect weight CH is based on an assumed linear relationship between cancer fatalities due to a radionuclide and the amount of that radionuclide released. Specifically, a site-specific MACCS calculation is performed for a fixed release of each of the 60 radionuclides included in the NUREG-1150 consequence calculations. The results of these calculations and the assumed linear relationship between the amount released and cancer fatalities for each radionuclide are then used to estimate the total number of chronic fatalities associated with a source term. This estimated number of chronic fatalities is the chronic health effect weight CH. The results

of the MACCS calculations used in the determination of CH are shown in Table B.4-1 of Appendix B. Further, the input file for PARTITION containing the site-specific data used in the calculation of EH and CH is shown in Table B.4-2 of Appendix B.

The site-specific MACCS calculations that underlie the early and chronic health effect weights were performed with very conservative assumptions with respect to the energy and timing of the releases and also with respect to the emergency responses taken. As a result, these weights should be regarded as a measure of the potential of a source term to cause early and chronic fatalities rather than as an estimate of the fatalities that would actually result from a source term.

The partitioning process treats the cases for EH>0 and CH>0 and for EH=0 and CH>0 separately. Table 3.4-1 shows the division of the source terms into these two cases.

The case for EH>0 and CH>0 is treated first by PARTITION. As shown in Table 3.4-1, log CH ranges from 0.8769 to 4.7722 and log EH ranges from -0.9427 to 2.3320. Figure 3.4-1 shows a plot of the pairs (CH, EH) for the 6820 source terms for which both EH and CH are nonzero. The partitioning process is based on laying a grid on the (CH, EH) space shown in Figure 3.4-1 and then pooling cells that have either a small frequency or contain a small number of source terms. Specifically, the grid is selected so that the ratio between the maximum and minimum value for CH in any cell and also the ratio between the maximum and minimum value for EH in any cell will be less than a specified value. In this analysis, the maximum allowable ratio was selected to be 3.1, which resulted in a loguniform division of the range of CH into eight intervals and a similar division of the range of EH into seven intervals. The result of placing the selected grid on the (CH, EH) space is also shown in Figure 3.4-1.

Table 3.4-1
Summary of Early and Chronic Health Effect Weights
for Internal Initiators

	Number of Source Terms	Percent of Total Frequency
EH>0 and CH>0	6820	7.36
EH=0 and CH>0	11771	92.64
EH=0 and CH=0	0	0.00
Total	18591	100.00

For EH>0 and CH>0, Range LOG10(CH) = 0.8769 to 4.7722
Range LOG10(EH) = -0.9427 to 2.3320

For EH=0 and CH>0, Range LOG10(CH) = -4.1832 to 3.6797

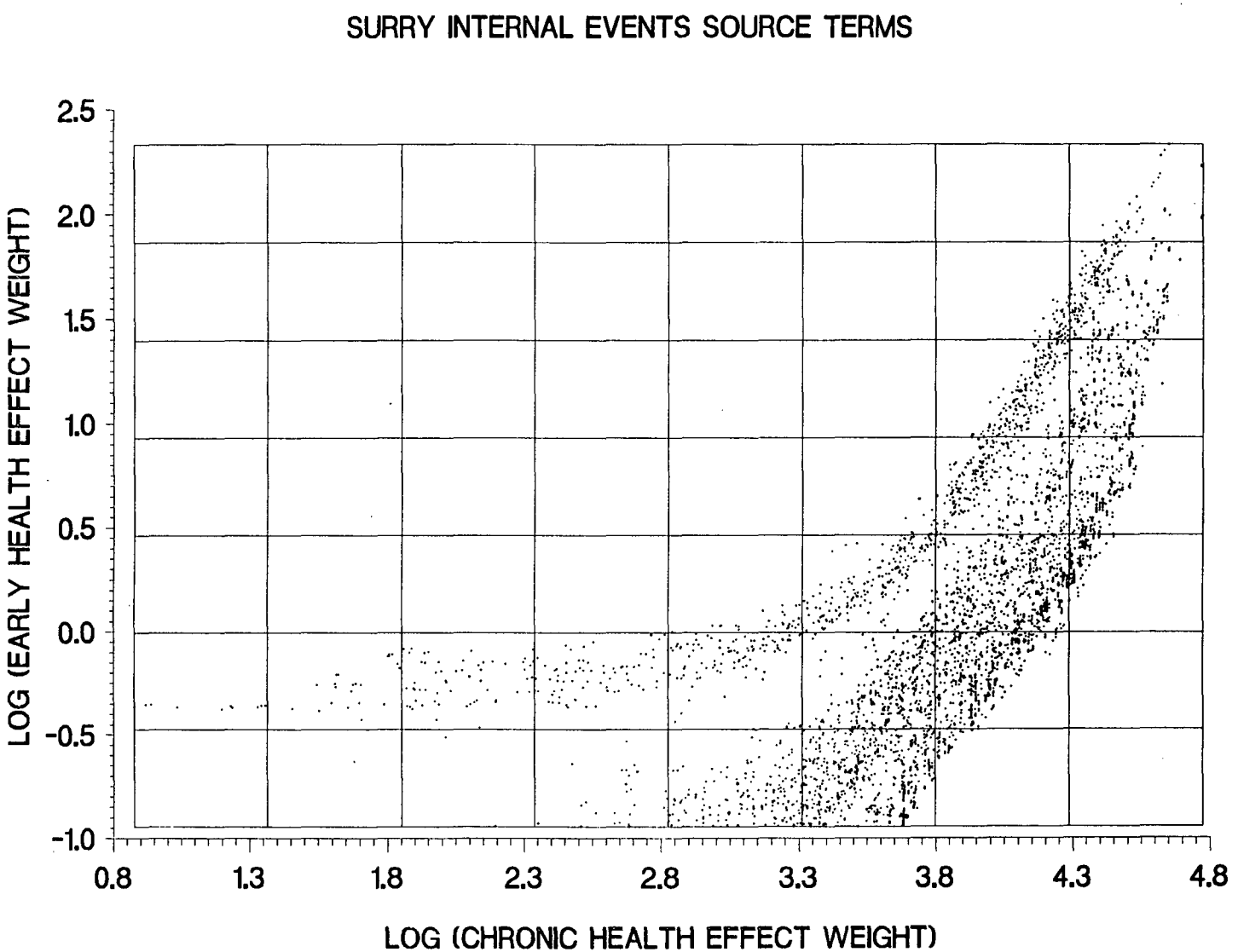


Figure 3.4-1. Distribution of Nonzero Early and Chronic Health Effect Weights for Internal Initiators

A summary of the partitioning process for EH>0 and CH>0 is given in Table 3.4-2. The table is divided into three parts. The first page is labeled "BEFORE PARTITIONING" and shows the distribution of the source terms before the partitioning process. As in Figure 3.4-1, the abscissa and ordinate correspond to CH and EH, respectively, with the ranges given in Table 3.4-1. The top plot shows the cell counts, and the bottom plot shows the fraction of the frequency in each cell. The second page of Table 3.4-2 is labeled "AFTER PARTITIONING" and shows the distribution of the source terms after the partitioning process. The partitioning process does not result in the loss of any source terms; rather, cells with a small number of source terms or a small frequency are pooled with other cells. Thus, the total number of source terms is not changed. The third page of this table is denoted "LABELING AFTER PARTITIONING" and shows the designators that will be used in the identification of source terms derived from the partitioning process.

A summary of the partitioning process for EH=0 and CH>0 is given in Table 3.4-3, which is structured analogously to Table 3.4-2 but has only one dimension instead of two. As indicated in Table 3.4-1, log(CH) ranges from -4.1832 to 3.6797. The cells shown in Table 3.4-3 are based on a loguniform division of the range of CH into six intervals.

At this point, the result of partitioning is 17 groups of source terms as shown in Tables 3.4-2 and 3.4-3. These source term groups are now further subdivided on the basis of evacuation timing. Specifically, each group of source terms is subdivided into three subgroups:

Subgroup 1: Evacuation starts at least 30 minutes before the release begins;

Subgroup 2: Evacuation starts between 30 minutes before and 1 hour after the release begins;

Subgroup 3: Evacuation starts more than 1 hour after the release begins.

This sorting of source terms is based on the warning time and the release start time associated with a source term and on the site-specific evacuation delay time. By definition, the evacuation delay is the time interval between the time the warning is given and the time the evacuation actually begins. The evacuation delay time for Surry is 2 h. Additional discussion of evacuation delay time is given in Volume 2, Part 7 of this report.

Once the source term groups shown in Tables 3.4-2 and 3.4-3 are sorted into subgroups on the basis of evacuation timing, a frequency-weighted mean source term is calculated for each populated subgroup. In the consequence analysis, a full MACCS calculation is performed for the mean source term for each source term subgroup. The mean source terms obtained in this analysis are shown in Table 3.4-4. This table contains frequency-weighted mean source terms for both the source term groups and subgroups. In the table, SUR-I and SUR-I-J are used to label the mean source terms derived from source term groups and subgroups, respectively, where iodine desig-

nates the source term group and J designates the source term subgroup. It is the source terms for the subgroups, SUR-I-J in Table 3.4-4, that are actually used for the risk calculations.

Although not parts of the source term definition, Table 3.4-4 also contains the mean frequency for the source term group, the conditional probability of the source term subgroups, and the mean value for the difference between the time at which release starts and the time at which evacuation starts (labeled dEVAC in the table). A positive value of dEVAC indicates that the evacuation starts before the release and a negative value of dEVAC indicates that the evacuation starts after the release. The mean frequency for a source term group is obtained by summing the frequencies of all source terms assigned to the group and then dividing by the sample size (200 in this analysis). The conditional probability of a subgroup is obtained by summing the frequencies of all source terms assigned to the subgroup and then dividing the resultant sum by the total frequency of all source terms in the associated source term group. Some source term subgroups are unpopulated; a mean source term does not appear for these subgroups in Table 3.4-4. To calculate the frequency-weighted mean source terms appearing in Table 3.4-4, each source term is weighted by the ratio between its frequency and the total frequency associated with the particular source term group or subgroup under consideration.

Source term groups SUR-01, SUR-02, SUR-03, SUR-05, SUR-06, and SUR-10 are dominated by Event V. Group SUR-14 is largely due to the "H" SGTRs. The other groups are composed of contributions from several different types of accidents. The dominant accident is reflected in the mean source term for the group. For SUR-01, Table 3.4-4 shows that almost all the probability is associated with the subgroup which has early release (at about 1 h), with evacuation starting after the release has commenced. For SUR-14, all the probability is in the first subgroup: the release starts very late and has the evacuation beginning hours before the start of the release. The highest release fractions are associated with group 10, as would be expected from Figure 3.4-1 and Table 3.4-2. The frequency for this group, however, is fairly low; relatively few source terms fall in the grid represented by group SUR-10, and they are not exceptionally frequent. The most likely source term groups are SUR-15 and SUR-16, which do not cause early fatalities and arise from accidents which do not result in bypass or early containment failure.

Table 3.4-2
Distribution of Source Terms with Nonzero Early Fatality and Chronic Fatality Weights for Internal Initiators

BEFORE PARTITIONING:

CELL COUNTS WITHIN THE GRID FOR A TOTAL COUNT OF 6820:

	1	2	3	4	5	6	7	8
1								86
2							50	456
3							224	531
4						12	440	386
5					28	222	1068	242
6	10	25	58	72	106	682	756	
7		1	3	51	262	964	85	

PERCENT OF FREQUENCY CONTAINED IN EACH CELL:

	1	2	3	4	5	6	7	8
1								1.64
2							3.18	6.17
3							2.48	4.34
4						0.07	9.28	4.04
5					0.86	24.49	7.37	3.53
6	0.18	4.89	1.19	1.80	7.06	2.74	5.74	
7		0.00	0.00	0.03	0.21	7.03	1.67	

Table 3.4-2 (continued)

AFTER PARTITIONING:

CELL COUNTS WITHIN THE GRID FOR A TOTAL COUNT OF 6820:

	1	2	3	4	5	6	7	8
1								86
2							50	456
3							224	531
4							446	386
5						303	1068	242
6		94			316		1246	
7						1372		

PERCENT OF FREQUENCY CONTAINED IN EACH CELL:

	1	2	3	4	5	6	7	8
1								1.64
2							3.18	6.17
3							2.48	4.34
4							9.32	4.04
5						25.22	7.37	3.53
6		6.16			9.24		7.82	
7						9.50		

Table 3.4-2 (continued)

LABELING AFTER PARTITIONING:

	1	2	3	4	5	6	7	8
1								SUR-10
2							SUR-05	SUR-11
3							SUR-06	SUR-12
4							SUR-07	SUR-13
5						SUR-03	SUR-08	SUR-14
6		SUR-01			SUR-02		SUR-09	
7						SUR-04		

Table 3.4-3
Distribution of Source Terms with Zero Early Fatality Weight and Nonzero Chronic Fatality Weight for Internal Initiators

BEFORE PARTITIONING:

CELL COUNTS WITHIN THE GRID FOR A TOTAL COUNT OF 11771:

	1	2	3	4	5	6
1	349	1553	2892	1599	2438	2940

PERCENT OF FREQUENCY CONTAINED IN EACH CELL:

	1	2	3	4	5	6
1	7.94	33.17	49.34	2.53	4.94	2.08

AFTER PARTITIONING:

CELL COUNTS WITHIN THE GRID FOR A TOTAL COUNT OF 11771:

	1	2	3	4	5	6
1		1902	3223		6646	

PERCENT OF FREQUENCY CONTAINED IN EACH CELL:

	1	2	3	4	5	6
1		41.11	49.84		9.05	

LABELING AFTER PARTITIONING:

	1	2	3	4	5	6
1		SUR-15	SUR-16		SUR-17	

Table 3.4-4
Mean Source Terms Resulting from Partitioning
for Internal Initiators--Surry

Source Term	Freq. (1/yr)	Cond. Prob.	Warn (s)	dEvac (s)	Elev (m)	Energy (W)	Start (s)	Dur (s)	Release Fractions								
									NG	I	Cs	Te	Sr	Ru	La	Ce	Ba
SUR-01	1.8E-07		1.3E+03	-4.8E+03	0.	1.8E+06	3.7E+03	1.8E+03	1.0E+00	7.4E-04	6.7E-04	2.2E-04	7.5E-06	3.5E-06	3.8E-07	1.3E-06	1.1E-05
						1.7E+05	1.0E+04	2.2E+04	4.2E-03	1.8E-02	2.6E-04	1.0E-04	2.0E-05	3.7E-07	2.6E-06	2.7E-06	1.7E-05
SUR-01-1		0.000															
SUR-01-2		0.002	1.3E+04	0.0E+00	10.	1.0E+06	2.0E+04	1.0E+03	8.0E-01	2.7E-03	3.7E-03	2.9E-03	1.8E-05	1.7E-07	8.5E-08	8.5E-08	3.6E-05
						0.0E+00	2.1E+04	1.1E+04	2.0E-01	5.1E-02	4.6E-04	3.6E-04	2.2E-06	2.1E-08	1.1E-08	1.1E-08	4.5E-06
SUR-01-3		0.998	1.3E+03	-4.8E+03	0.	1.8E+06	3.7E+03	1.8E+03	1.0E+00	7.3E-04	6.7E-04	2.1E-04	7.5E-06	3.5E-06	3.8E-07	1.3E-06	1.1E-05
						1.7E+05	1.0E+04	2.2E+04	3.7E-03	1.8E-02	2.6E-04	1.0E-04	2.0E-05	3.7E-07	2.6E-06	2.7E-06	1.7E-05
SUR-02	2.8E-07		2.4E+03	-4.6E+03	1.	3.1E+06	5.0E+03	1.7E+03	9.8E-01	1.3E-02	1.3E-02	1.7E-03	1.9E-03	2.3E-03	7.1E-04	6.9E-04	2.3E-03
						1.7E+05	1.1E+04	2.2E+04	2.2E-02	1.9E-02	2.3E-03	6.8E-03	1.6E-03	7.3E-06	1.4E-04	1.5E-04	1.3E-03
SUR-02-1		0.001	2.2E+04	1.8E+04	10.	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
						6.5E+05	4.7E+04	1.1E+04	1.0E+00	6.0E-02	1.2E-02	1.2E-01	3.0E-03	2.4E-05	1.9E-04	2.0E-04	1.8E-03
SUR-02-2		0.055	2.1E+04	-1.4E+03	10.	2.5E+07	2.7E+04	2.7E+02	9.8E-01	4.6E-03	6.9E-03	1.5E-02	3.3E-02	4.2E-02	1.3E-02	1.2E-02	3.9E-02
						1.5E+05	2.8E+04	2.1E+04	2.1E-02	6.6E-03	3.3E-04	3.6E-04	1.4E-04	2.5E-06	1.3E-05	1.5E-05	1.1E-04
SUR-02-3		0.945	1.3E+03	-4.8E+03	0.	1.9E+06	3.7E+03	1.8E+03	9.8E-01	1.4E-02	1.4E-02	9.4E-04	9.8E-05	3.4E-05	4.4E-06	1.5E-05	1.3E-04
						1.7E+05	1.0E+04	2.2E+04	2.1E-02	2.0E-02	2.4E-03	7.1E-03	1.7E-03	7.6E-06	1.5E-04	1.6E-04	1.3E-03
SUR-03	7.5E-07		1.8E+03	-4.7E+03	0.	2.5E+06	4.3E+03	1.8E+03	9.8E-01	7.2E-02	7.0E-02	1.2E-02	1.2E-03	1.3E-03	3.4E-04	3.7E-04	1.7E-03
						2.0E+05	1.2E+04	2.3E+04	1.9E-02	3.1E-02	3.8E-03	2.8E-02	1.2E-02	1.1E-04	1.4E-03	1.4E-03	9.4E-03
SUR-03-1		0.001	2.2E+04	1.8E+04	10.	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
						6.5E+05	4.7E+04	1.1E+04	1.0E+00	6.5E-02	3.1E-02	5.2E-01	2.5E-02	2.5E-02	4.0E-03	4.0E-03	2.2E-02
SUR-03-2		0.026	2.1E+04	-1.3E+03	10.	2.4E+07	2.7E+04	4.8E+02	9.4E-01	2.1E-02	2.7E-02	3.0E-02	3.4E-02	4.1E-02	1.3E-02	1.3E-02	4.1E-02
						1.4E+06	9.3E+04	8.6E+04	2.0E-02	7.6E-02	4.7E-02	6.0E-02	3.5E-02	2.5E-05	3.3E-03	3.5E-03	2.5E-02
SUR-03-3		0.973	1.3E+03	-4.8E+03	0.	2.0E+06	3.7E+03	1.8E+03	9.8E-01	7.4E-02	7.1E-02	1.1E-02	3.8E-04	2.7E-04	1.6E-05	3.8E-05	6.3E-04
						1.7E+05	1.0E+04	2.2E+04	1.7E-02	3.0E-02	2.6E-03	2.7E-02	1.1E-02	8.1E-05	1.3E-03	1.3E-03	8.9E-03
SUR-04	2.8E-07		3.0E+04	5.5E+03	10.	2.1E+06	4.2E+04	1.6E+03	7.5E-01	1.1E-01	9.3E-02	3.3E-02	2.5E-03	8.0E-04	1.1E-04	3.8E-04	3.3E-03
						1.8E+06	2.0E+05	1.7E+05	6.4E-02	2.6E-02	1.4E-02	5.8E-03	5.6E-04	2.8E-05	3.3E-05	4.3E-05	4.4E-04
SUR-04-1		0.700	3.6E+04	8.1E+03	10.	9.6E+05	5.1E+04	1.4E+03	8.5E-01	1.4E-01	1.1E-01	2.9E-02	1.8E-03	6.7E-04	7.8E-05	2.4E-04	2.6E-03
						2.4E+06	5.3E+04	1.7E+04	7.3E-02	2.2E-02	7.7E-03	4.1E-03	2.5E-04	3.2E-05	1.5E-05	2.3E-05	2.4E-04
SUR-04-2		0.300	1.6E+04	-5.4E+02	10.	4.7E+06	2.3E+04	2.1E+03	5.1E-01	5.6E-02	4.9E-02	4.2E-02	4.0E-03	1.1E-03	2.0E-04	7.2E-04	4.8E-03
						5.7E+05	5.4E+05	5.3E+05	4.4E-02	3.7E-02	2.8E-02	9.7E-03	1.3E-03	2.0E-05	7.6E-05	8.9E-05	9.0E-04
SUR-04-3		0.000															
SUR-05	9.5E-08		1.3E+03	-4.8E+03	0.	2.7E+06	3.8E+03	1.8E+03	9.9E-01	3.2E-01	3.3E-01	3.3E-02	2.8E-03	9.8E-04	2.1E-04	1.6E-03	3.3E-03
						1.7E+05	1.3E+04	2.4E+04	1.3E-02	2.9E-02	1.6E-03	2.2E-01	1.1E-01	4.7E-04	1.2E-02	1.2E-02	8.7E-02
SUR-05-1		0.000															
SUR-05-2		0.007	1.3E+04	0.0E+00	10.	1.0E+06	2.0E+04	1.9E+03	7.6E-01	1.6E-01	1.6E-01	3.1E-01	2.0E-01	5.2E-02	2.2E-02	1.9E-01	2.0E-01
						0.0E+00	3.8E+05	3.7E+05	2.4E-01	2.1E-02	1.4E-02	2.3E-02	1.5E-02	4.0E-03	1.7E-03	1.5E-02	1.5E-02
SUR-05-3		0.993	1.3E+03	-4.8E+03	0.	2.7E+06	3.6E+03	1.8E+03	9.9E-01	3.2E-01	3.3E-01	3.1E-02	1.4E-03	6.1E-04	5.5E-05	1.7E-04	1.9E-03
						1.7E+05	1.0E+04	2.2E+04	1.1E-02	2.9E-02	1.6E-03	2.2E-01	1.1E-01	4.5E-04	1.2E-02	1.2E-02	8.8E-02

Table 3.4-4 (continued)

Source Term	Freq. (1/yr)	Cond. Prob.	Warn (s)	dEvac (s)	Elev (m)	Energy (W)	Start (s)	Dur (s)	Release Fractions NG	I	Cs	Te	Sr	Ru	La	Ce	Ba
SUR-06	7.4E-08		2.0E+03	-4.5E+03	1.	3.2E+06	4.7E+03	1.9E+03	9.6E-01	2.9E-01	2.9E-01	4.5E-02	1.1E-02	2.1E-03	6.6E-04	3.6E-03	1.2E-02
						1.6E+05	6.7E+04	7.7E+04	2.2E-02	2.8E-02	5.1E-03	1.1E-01	3.3E-02	5.0E-04	3.8E-03	3.9E-03	2.6E-02
SUR-06-1		0.000															
SUR-06-2		0.062	1.3E+04	-1.2E+00	10.	1.0E+06	2.0E+04	3.4E+03	6.2E-01	3.4E-01	3.2E-01	3.4E-01	7.6E-02	1.7E-02	6.0E-03	4.0E-02	8.0E-02
						1.3E+03	9.2E+05	9.2E+05	8.3E-03	3.9E-03	3.3E-03	3.4E-03	2.8E-04	9.4E-05	1.9E-05	6.8E-05	3.2E-04
SUR-06-3		0.938	1.3E+03	-4.8E+03	0.	3.4E+06	3.7E+03	1.8E+03	9.8E-01	2.8E-01	2.9E-01	2.5E-02	7.1E-03	1.1E-03	3.0E-04	1.2E-03	7.5E-03
						1.7E+05	1.0E+04	2.2E+04	2.3E-02	2.9E-02	5.2E-03	1.2E-01	3.5E-02	5.3E-04	4.1E-03	4.2E-03	2.8E-02
SUR-07	2.8E-07		1.3E+04	-1.9E+03	5.	3.3E+06	1.9E+04	1.7E+03	8.9E-01	1.9E-01	1.9E-01	8.1E-02	6.4E-02	1.2E-02	6.5E-03	3.1E-02	6.4E-02
						2.4E+05	1.2E+05	1.1E+05	8.3E-02	5.2E-02	1.8E-02	4.8E-02	1.6E-02	2.2E-03	1.8E-03	6.1E-03	1.5E-02
SUR-07-1		0.118	3.6E+04	7.8E+03	10.	1.0E+06	5.1E+04	2.8E+03	9.9E-01	2.5E-01	2.4E-01	1.5E-01	2.0E-01	2.7E-02	1.7E-02	8.5E-02	2.0E-01
						0.0E+00	5.6E+04	1.9E+04	1.4E-02	1.6E-02	3.4E-03	2.3E-03	2.9E-03	3.8E-04	2.6E-04	1.2E-03	2.9E-03
SUR-07-2		0.405	2.1E+04	-1.2E+03	10.	5.4E+06	2.7E+04	1.2E+03	7.5E-01	2.2E-01	2.0E-01	1.4E-01	9.4E-02	2.1E-02	1.1E-02	5.0E-02	9.5E-02
						3.8E+05	2.6E+05	2.5E+05	1.8E-01	5.4E-02	4.0E-02	4.0E-02	3.1E-02	5.2E-03	3.5E-03	1.4E-02	2.9E-02
SUR-07-3		0.477	1.3E+03	-4.8E+03	0.	2.1E+06	3.7E+03	1.8E+03	9.8E-01	1.6E-01	1.6E-01	1.1E-02	3.9E-03	5.9E-04	1.8E-04	7.6E-04	4.1E-03
						1.7E+05	1.0E+04	2.2E+04	1.6E-02	6.0E-02	3.5E-03	6.7E-02	7.6E-03	1.7E-04	7.2E-04	7.5E-04	5.9E-03
SUR-08	2.2E-07		2.9E+04	4.6E+03	10.	3.9E+06	4.0E+04	1.8E+03	8.2E-01	3.3E-01	2.9E-01	1.3E-01	7.4E-03	3.2E-03	3.7E-04	1.1E-03	1.1E-02
						2.4E+05	2.3E+05	2.1E+05	5.4E-02	3.1E-02	2.4E-02	2.0E-02	2.5E-03	8.9E-05	2.1E-04	2.3E-04	1.9E-03
SUR-08-1		0.622	3.6E+04	7.8E+03	10.	1.0E+06	5.1E+04	1.7E+03	9.2E-01	3.9E-01	3.5E-01	1.2E-01	8.4E-03	3.5E-03	4.0E-04	1.2E-03	1.2E-02
						1.5E+04	5.4E+04	1.7E+04	3.6E-02	2.2E-02	1.3E-02	4.8E-03	3.3E-04	1.1E-04	1.9E-05	4.0E-05	4.2E-04
SUR-08-2		0.377	1.6E+04	-5.9E+02	10.	8.7E+06	2.3E+04	2.0E+03	6.4E-01	2.3E-01	2.1E-01	1.4E-01	5.7E-03	2.7E-03	3.3E-04	1.1E-03	8.3E-03
						6.2E+05	5.2E+05	5.2E+05	8.3E-02	4.5E-02	4.4E-02	4.4E-02	6.0E-03	5.8E-05	5.2E-04	5.5E-04	4.3E-03
SUR-08-3		0.001	1.3E+03	-4.8E+03	0.	2.4E+06	3.7E+03	1.8E+03	9.6E-01	1.1E-01	1.2E-01	1.0E-02	3.1E-04	1.5E-04	9.3E-06	1.9E-05	5.2E-04
						1.7E+05	1.0E+04	2.2E+04	3.7E-02	7.5E-02	3.8E-02	2.4E-02	8.2E-05	1.1E-09	5.4E-06	2.9E-06	9.6E-05
SUR-09	2.3E-07		2.9E+04	5.2E+03	10.	1.3E+06	4.1E+04	1.9E+03	7.5E-01	2.0E-01	1.8E-01	7.5E-02	6.5E-03	2.1E-03	3.9E-04	1.5E-03	8.7E-03
						5.6E+06	2.7E+05	2.4E+05	6.2E-02	2.7E-02	1.8E-02	7.2E-03	1.2E-03	7.3E-05	1.2E-04	1.6E-04	1.0E-03
SUR-09-1		0.666	3.6E+04	7.9E+03	10.	9.9E+05	5.1E+04	1.5E+03	9.0E-01	2.4E-01	2.1E-01	6.7E-02	6.7E-03	2.1E-03	4.1E-04	1.6E-03	8.9E-03
						8.2E+06	5.4E+04	1.7E+04	5.0E-02	2.0E-02	9.6E-03	4.7E-03	8.3E-04	9.2E-05	6.8E-05	1.3E-04	7.5E-04
SUR-09-2		0.334	1.5E+04	-3.6E+02	10.	1.9E+06	2.2E+04	2.6E+03	4.4E-01	1.1E-01	1.0E-01	8.9E-02	6.2E-03	1.9E-03	3.5E-04	1.2E-03	8.2E-03
						2.7E+05	6.9E+05	6.9E+05	8.7E-02	3.9E-02	3.5E-02	1.2E-02	2.0E-03	3.5E-05	2.1E-04	2.3E-04	1.5E-03
SUR-09-3		0.000															
SUR-10	4.9E-08		3.0E+03	-4.2E+03	1.	3.5E+06	6.0E+03	1.9E+03	9.9E-01	7.0E-01	6.5E-01	2.2E-01	3.8E-02	6.8E-03	1.8E-03	7.4E-03	4.1E-02
						1.6E+05	4.0E+04	4.9E+04	5.1E-03	9.8E-03	3.1E-03	1.3E-01	6.4E-02	5.1E-04	6.3E-03	6.7E-03	5.1E-02
SUR-10-1		0.037	3.6E+04	7.8E+03	10.	1.0E+06	5.1E+04	3.0E+03	9.9E-01	9.5E-01	9.4E-01	8.5E-01	5.5E-01	6.5E-02	2.8E-02	1.2E-01	5.5E-01
						0.0E+00	5.6E+04	1.7E+04	1.1E-02	1.1E-02	1.0E-02	9.4E-03	6.2E-03	7.3E-04	3.4E-04	1.3E-03	6.2E-03
SUR-10-2		0.035	1.3E+04	-2.3E+01	10.	1.4E+06	2.0E+04	3.1E+03	9.3E-01	8.2E-01	7.6E-01	7.9E-01	4.0E-01	6.4E-02	1.8E-02	7.5E-02	4.1E-01
						2.5E+04	8.0E+05	8.0E+05	2.0E-02	1.7E-02	1.6E-02	1.7E-02	8.0E-03	1.3E-03	3.7E-04	1.5E-03	8.4E-03
SUR-10-3		0.927	1.3E+03	-4.8E+03	0.	3.7E+06	3.7E+03	1.8E+03	1.0E+00	6.8E-01	6.4E-01	1.7E-01	4.2E-03	2.3E-03	1.6E-04	4.0E-04	6.8E-03
						1.7E+05	1.0E+04	2.2E+04	4.3E-03	9.5E-03	2.4E-03	1.4E-01	6.8E-02	4.7E-04	6.8E-03	7.1E-03	5.4E-02

Table 3.4-4 (continued)

Source Term	Freq. (1/yr)	Cond. Prob.	Warn (s)	dEvac (s)	Elev (m)	Energy (W)	Start (s)	Dur (s)	Release Fractions NG	I	Cs	Te	Sr	Ru	La	Ce	Ba
SUR-11	1.8E-07		8.8E+03	-2.3E+03		3.	3.4E+07	1.4E+04	1.9E+03	9.7E-01	5.0E-01	4.9E-01	1.9E-01	6.8E-02	1.4E-02	5.1E-03	2.5E-02
	7.2E-02																
						1.6E+05	1.1E+05	1.1E+05	8.6E-03	2.8E-02	5.3E-03	1.3E-01	4.8E-02	2.8E-04	4.2E-03	4.9E-03	3.7E-02
SUR-11-1		0.147	3.6E+04	7.8E+03	10.	1.0E+06	5.1E+04	2.4E+03	9.8E-01	6.1E-01	5.9E-01	4.2E-01	3.3E-01	6.1E-02	2.7E-02	1.4E-01	3.4E-01
						0.0E+00	5.5E+04	1.0E+04	2.4E-02	2.9E-02	2.1E-02	5.3E-02	2.8E-02	1.5E-03	3.1E-03	6.0E-03	2.5E-02
SUR-11-2		0.164	1.6E+04	-5.3E+02	10.	2.0E+08	2.3E+04	2.1E+03	8.6E-01	6.7E-01	6.3E-01	4.8E-01	7.8E-02	2.3E-02	4.6E-03	1.5E-02	8.8E-02
						2.6E+05	5.6E+05	5.5E+05	1.1E-02	7.5E-03	6.1E-03	1.4E-02	1.7E-03	3.1E-04	8.8E-05	2.8E-04	1.9E-03
SUR-11-3		0.689	1.3E+03	-4.8E+03	0.	2.7E+06	3.7E+03	1.8E+03	1.0E+00	4.4E-01	4.3E-01	7.8E-02	9.2E-03	2.3E-03	5.4E-04	2.3E-03	1.1E-02
						1.7E+05	1.0E+04	2.2E+04	4.7E-03	3.2E-02	1.8E-03	1.7E-01	6.4E-02	2.2E-05	5.4E-03	5.7E-03	4.8E-02
SUR-12	1.3E-07		3.1E+04	5.9E+03	10.	6.5E+06	4.5E+04	1.6E+03	9.4E-01	6.1E-01	5.7E-01	3.5E-01	9.3E-02	2.0E-02	5.6E-03	2.3E-02	1.1E-01
						1.1E+05	1.7E+05	1.4E+05	3.8E-02	3.5E-02	3.2E-02	3.6E-02	7.5E-03	7.3E-04	6.7E-04	1.3E-03	6.9E-03
SUR-12-1		0.775	3.6E+04	7.8E+03	10.	1.0E+06	5.1E+04	1.5E+03	9.6E-01	6.4E-01	6.0E-01	3.8E-01	1.1E-01	2.3E-02	6.8E-03	2.8E-02	1.3E-01
						0.0E+00	5.3E+04	1.6E+04	4.0E-02	3.0E-02	2.5E-02	2.1E-02	4.4E-03	8.9E-04	3.0E-04	1.0E-03	5.0E-03
SUR-12-2		0.225	1.6E+04	-4.9E+02	10.	2.5E+07	2.2E+04	2.3E+03	8.5E-01	5.0E-01	4.5E-01	2.6E-01	2.4E-02	8.1E-03	1.5E-03	5.3E-03	3.0E-02
						4.7E+05	5.8E+05	5.8E+05	3.4E-02	5.4E-02	5.8E-02	8.4E-02	1.8E-02	1.6E-04	1.9E-03	2.0E-03	1.3E-02
SUR-12-3		0.000	1.3E+03	-4.8E+03	0.	2.8E+06	3.7E+03	1.8E+03	9.1E-01	1.9E-01	2.0E-01	6.8E-03	3.4E-04	2.2E-04	2.0E-05	5.4E-05	6.9E-04
						1.7E+05	1.0E+04	2.2E+04	9.0E-02	3.1E-01	2.5E-01	2.2E-01	3.2E-03	3.3E-09	1.1E-04	1.3E-04	2.3E-03
SUR-13	1.2E-07		3.6E+04	7.7E+03	10.	1.1E+06	5.1E+04	1.7E+03	9.5E-01	5.9E-01	5.5E-01	2.8E-01	1.2E-02	9.2E-03	6.5E-04	1.7E-03	1.9E-02
						7.0E+03	6.0E+04	2.4E+04	3.8E-02	2.8E-02	2.1E-02	1.4E-02	1.3E-03	2.9E-04	9.9E-05	1.3E-04	1.2E-03
SUR-13-1		0.987	3.6E+04	7.8E+03	10.	1.0E+06	5.1E+04	1.7E+03	9.5E-01	5.9E-01	5.5E-01	2.8E-01	1.2E-02	9.3E-03	6.6E-04	1.7E-03	1.9E-02
						0.0E+00	5.4E+04	1.7E+04	3.8E-02	2.7E-02	2.0E-02	1.3E-02	1.3E-03	2.9E-04	9.0E-05	1.2E-04	1.2E-03
SUR-13-2		0.013	1.7E+04	-7.2E+02	10.	8.5E+06	2.4E+04	2.1E+03	8.5E-01	4.9E-01	4.5E-01	1.4E-01	3.0E-03	1.5E-03	1.4E-04	1.8E-04	4.6E-03
						5.5E+05	5.4E+05	5.3E+05	6.1E-02	5.5E-02	4.6E-02	6.0E-02	8.6E-03	1.9E-04	7.7E-04	7.9E-04	6.2E-03
SUR-13-3		0.000															
SUR-14	1.1E-07		3.6E+04	7.8E+03	10.	1.0E+06	5.1E+04	1.4E+03	9.3E-01	4.9E-01	4.4E-01	1.7E-01	5.2E-03	3.6E-03	2.5E-04	6.0E-04	9.3E-03
						2.1E+02	5.4E+04	1.7E+04	4.1E-02	2.7E-02	1.9E-02	7.5E-03	2.4E-04	1.6E-04	1.2E-05	2.8E-05	4.2E-04
SUR-14-1		1.000	3.6E+04	7.8E+03	10.	1.0E+06	5.1E+04	1.4E+03	9.3E-01	4.9E-01	4.4E-01	1.7E-01	5.2E-03	3.6E-03	2.5E-04	6.0E-04	9.3E-03
						0.0E+00	5.4E+04	1.7E+04	4.1E-02	2.7E-02	1.9E-02	7.5E-03	2.4E-04	1.6E-04	1.2E-05	2.8E-05	4.2E-04
SUR-14-2		0.000	2.2E+04	-1.5E+03	10.	2.8E+06	2.8E+04	2.0E+02	6.4E-01	7.1E-03	7.3E-03	1.4E-03	3.9E-05	1.6E-04	3.9E-05	3.9E-05	5.4E-05
						1.6E+06	4.6E+04	2.2E+04	3.6E-01	4.5E-01	4.6E-01	1.1E-01	2.7E-03	6.0E-09	1.2E-04	1.3E-04	2.1E-03
SUR-14-3		0.000															
SUR-15	1.5E-05		2.2E+04	1.7E+04	0.	1.1E-02	4.7E+04	2.2E-03	2.1E-08	9.5E-15	6.2E-15	5.7E-16	7.7E-18	2.4E-22	2.4E-22	2.4E-22	2.8E-17
						3.3E-02	4.7E+04	8.6E+04	4.1E-03	1.3E-05	1.6E-09	9.2E-10	2.3E-10	1.6E-11	2.0E-11	2.8E-11	1.9E-10
SUR-15-1		1.000	2.2E+04	1.7E+04	0.	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
						0.0E+00	4.7E+04	8.6E+04	4.1E-03	1.3E-05	1.6E-09	9.2E-10	2.3E-10	1.6E-11	2.0E-11	2.8E-11	1.9E-10
SUR-15-2		0.000	2.2E+04	-1.5E+03	10.	5.2E+04	2.8E+04	1.1E+04	1.0E-01	4.6E-08	3.0E-08	2.8E-09	3.8E-11	1.2E-15	1.2E-15	1.2E-15	1.3E-10
						1.6E+05	1.0E+06	1.0E+06	0.0E+00	2.2E-07	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
SUR-15-3		0.000															

Table 3.4-4 (continued)

Source Term	Freq. (1/yr)	Cond. Prob.	Warn (s)	dEvac (s)	Elev (m)	Energy (W)	Start (s)	Dur (s)	Release Fractions								
									NG	I	Cs	Te	Sr	Ru	La	Ce	Ba
SUR-16	1.9E-05		2.2E+04	1.7E+04	0.	1.8E+03	4.7E+04	3.1E+00	1.5E-03	1.4E-08	1.8E-09	7.1E-09	1.1E-09	2.5E-10	4.7E-11	1.7E-10	1.2E-09
						8.4E+01	4.8E+04	8.5E+04	1.6E-02	1.9E-04	3.5E-08	2.5E-08	6.5E-09	3.6E-10	6.4E-10	7.7E-10	5.1E-09
SUR-16-1		1.000	2.2E+04	1.7E+04	0.	1.8E+03	4.7E+04	2.8E+00	1.5E-03	1.3E-08	1.6E-09	7.0E-09	1.1E-09	2.5E-10	4.7E-11	1.7E-10	1.2E-09
						8.0E+01	4.8E+04	8.5E+04	1.6E-02	1.9E-04	3.5E-08	2.5E-08	6.5E-09	3.6E-10	6.4E-10	7.7E-10	5.1E-09
SUR-16-2		0.000	2.2E+04	-1.5E+03	10.	5.2E+04	2.8E+04	1.1E+04	5.8E-01	1.7E-05	9.2E-06	1.7E-06	5.9E-08	1.5E-08	2.1E-09	7.3E-09	8.4E-08
						1.6E+05	1.0E+06	1.0E+06	2.4E-02	5.2E-04	3.7E-07	5.9E-08	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
SUR-16-3		0.000															
SUR-17	3.4E-06		2.4E+04	1.5E+04	10.	2.4E+05	4.6E+04	5.1E+02	1.5E-01	8.5E-03	6.4E-03	1.8E-03	1.4E-04	3.3E-05	8.4E-06	3.5E-05	1.7E-04
						9.2E+05	1.5E+05	5.4E+04	7.7E-01	3.8E-02	5.1E-04	3.6E-04	6.1E-05	3.3E-06	5.0E-06	8.2E-06	5.0E-05
SUR-17-1		0.942	2.5E+04	1.6E+04	10.	1.9E+05	4.8E+04	3.3E+02	1.4E-01	7.3E-03	5.4E-03	1.2E-03	1.2E-04	2.3E-05	6.6E-06	2.8E-05	1.4E-04
						9.7E+05	1.1E+05	1.2E+04	8.1E-01	4.0E-02	3.9E-04	2.7E-04	4.9E-05	2.7E-06	4.2E-06	6.5E-06	4.1E-05
SUR-17-2		0.058	1.5E+04	-3.9E+02	10.	1.0E+06	2.2E+04	3.5E+03	3.0E-01	2.8E-02	2.3E-02	1.2E-02	5.3E-04	1.8E-04	3.7E-05	1.4E-04	6.6E-04
						1.5E+05	7.3E+05	7.3E+05	5.2E-02	5.3E-03	2.3E-03	1.8E-03	2.5E-04	1.4E-05	1.7E-05	3.6E-05	1.9E-04
SUR-17-3		0.000															

3.4.2 Results for Fire Initiators

This section presents the results of partitioning the source terms for fire initiators. The partitioning process, which is described in the preceding section, does not result in the loss of any source terms; rather, cells with a small number of source terms or a small frequency are pooled with other cells. The accident progression analysis and the subsequent source term analysis for fire accidents resulted in the generation of 6762 source terms. Table 3.4-5 shows the number of these source terms with EH>0 and CH>0 and the number with EH=0 and CH>0.

Table 3.4-5
Summary of Early and Chronic Health Effect Weights
for Fire Initiators

	Number of Source Terms	Percent of Total Frequency
EH>0 and CH>0	942	0.92
EH=0 and CH>0	5820	99.08
EH=0 and CH=0	0	0.00
Total	6762	100.00

For EH>0 and CH>0, Range LOG10(CH) = 2.8317 to 4.6534
Range LOG10(EH) = -0.9416 to 1.9923

For EH=0 and CH>0, Range LOG10(CH) = -3.1876 to 3.6169

Figure 3.4-2 shows a plot of the pairs (CH, EH) for the 942 source terms for which both EH and CH are nonzero. A summary of the partitioning process for EH>0 and CH>0 is given in Table 3.4-6. Only the percent of the frequency contained in each cell after partitioning and the labeling after partitioning are shown. A summary of the partitioning process for the 5820 source terms for which EH=0 and CH>0 is given in Table 3.4-7, which is structured analogously to Table 3.4-6 but has only one dimension instead of two.

The 15 groups of source terms that result from partitioning are further subdivided on the basis of evacuation timing into three subgroups as for internal initiators. Frequency-weighted mean source terms are calculated for each populated subgroup. The mean source terms obtained in this analysis are shown in Table 3.4-8. This table contains frequency-weighted mean source terms for both the source term groups and subgroups. In the table, SRF-I and SRF-I-J are used to label the mean source terms derived from source term groups and subgroups, respectively, where I designates the source term group and J designates the source term subgroup. It is the source terms for the subgroups, SRF-I-J in Table 3.4-8, that are actually used for the risk calculations. Table 3.4-8 is analogous to Table 3.4-4 for internal initiators.

Table 3.4-6
Distribution of Source Terms with Nonzero Early Fatality Weight and Nonzero Chronic Fatality Weight for Fire Initiators

PERCENT OF FREQUENCY CONTAINED IN EACH CELL AFTER PARTITIONING:

	1	2	3	4	5	6
1						0.02
2						2.34
3						
4					25.11	
5					8.03	
6				8.89	7.77	
7				5.24	3.80	
8			4.93	12.54		
9			21.32			

LABELING AFTER PARTITIONING:

	1	2	3	4	5	6
1						SRF-10
2						SRF-11
3						
4					SRF-06	
5					SRF-07	
6				SRF-03	SRF-08	
7				SRF-04	SRF-09	
8			SRF-01	SRF-05		
9			SRF-02			

Table 3.4-7
Distribution of Source Terms with Zero Early Fatality Weight and Nonzero Chronic Fatality Weight for Fire Initiators

PERCENT OF FREQUENCY CONTAINED IN EACH CELL AFTER PARTITIONING:

	1	2	3	4	5	6
1		41.04	28.12	16.32	14.53	

LABELING AFTER PARTITIONING:

	1	2	3	4	5	6
1		SRF-12	SRF-13	SRF-14	SRF-15	

Table 3.4-8
Mean Source Terms Resulting from Partitioning for Fire Initiators

Source Term	Freq. (1/yr)	Cond. Prob.	Warn (s)	dEvac (s)	Elev (m)	Energy (W)	Start (s)	Dur (s)	Release Fractions								
									NG	I	Cs	Te	Sr	Ru	La	Ce	Ba
SRF-01	4.9E-09		2.2E+04	-1.5E+03	10.	3.8E+06	2.8E+04	8.9E+02	7.8E-01	6.4E-02	5.9E-02	4.1E-03	3.8E-04	2.1E-04	3.7E-05	1.0E-04	4.7E-04
						1.6E+06	3.0E+04	2.2E+04	2.2E-01	5.0E-02	2.8E-02	4.3E-02	1.6E-03	3.7E-05	1.3E-04	1.5E-04	1.2E-03
SRF-01-1		0.000															
SRF-01-2		1.000	2.2E+04	-1.5E+03	10.	3.8E+06	2.8E+04	8.9E+02	7.8E-01	6.4E-02	5.9E-02	4.1E-03	3.8E-04	2.1E-04	3.7E-05	1.0E-04	4.7E-04
						1.6E+06	3.0E+04	2.2E+04	2.2E-01	5.0E-02	2.8E-02	4.3E-02	1.6E-03	3.7E-05	1.3E-04	1.5E-04	1.2E-03
SRF-01-3		0.000															
SRF-02	2.1E-08		2.2E+04	-1.5E+03	10.	2.7E+07	2.8E+04	2.1E+02	9.8E-01	4.1E-02	3.2E-02	7.1E-03	3.2E-04	2.1E-04	2.2E-05	6.1E-05	5.7E-04
						1.6E+06	3.0E+04	2.2E+04	1.5E-02	3.8E-02	2.7E-02	2.9E-02	1.0E-02	2.8E-06	6.5E-04	7.3E-04	7.4E-03
SRF-02-1		0.000															
SRF-02-2		1.000	2.2E+04	-1.5E+03	10.	2.7E+07	2.8E+04	2.1E+02	9.8E-01	4.1E-02	3.2E-02	7.1E-03	3.2E-04	2.1E-04	2.2E-05	6.1E-05	5.7E-04
						1.6E+06	3.0E+04	2.2E+04	1.5E-02	3.8E-02	2.7E-02	2.9E-02	1.0E-02	2.8E-06	6.5E-04	7.3E-04	7.4E-03
SRF-02-3		0.000															
SRF-03	8.9E-09		2.2E+04	-1.5E+03	10.	6.9E+06	2.8E+04	6.7E+03	9.2E-01	1.4E-01	1.3E-01	5.2E-02	4.6E-02	1.4E-02	6.3E-03	2.5E-02	4.6E-02
						1.6E+06	3.9E+04	2.2E+04	7.7E-02	2.4E-02	1.2E-02	2.8E-02	8.1E-03	7.6E-04	8.4E-04	1.8E-03	6.5E-03
SRF-03-1		0.000															
SRF-03-2		1.000	2.2E+04	-1.5E+03	10.	6.9E+06	2.8E+04	6.7E+03	9.2E-01	1.4E-01	1.3E-01	5.2E-02	4.6E-02	1.4E-02	6.3E-03	2.5E-02	4.6E-02
						1.6E+06	3.9E+04	2.2E+04	7.7E-02	2.4E-02	1.2E-02	2.8E-02	8.1E-03	7.6E-04	8.4E-04	1.8E-03	6.5E-03
SRF-03-3		0.000															
SRF-04	5.2E-09		2.2E+04	-1.5E+03	10.	2.4E+07	2.8E+04	2.7E+02	9.0E-01	1.5E-01	1.3E-01	1.1E-02	9.6E-04	3.6E-04	6.0E-05	1.7E-04	1.3E-03
						1.6E+06	3.1E+04	2.2E+04	9.9E-02	5.3E-02	4.3E-02	5.1E-02	8.4E-03	3.7E-05	5.7E-04	6.0E-04	5.3E-03
SRF-04-1		0.000															
SRF-04-2		1.000	2.2E+04	-1.5E+03	10.	2.4E+07	2.8E+04	2.7E+02	9.0E-01	1.5E-01	1.3E-01	1.1E-02	9.6E-04	3.6E-04	6.0E-05	1.7E-04	1.3E-03
						1.6E+06	3.1E+04	2.2E+04	9.9E-02	5.3E-02	4.3E-02	5.1E-02	8.4E-03	3.7E-05	5.7E-04	6.0E-04	5.3E-03
SRF-04-3		0.000															
SRF-05	1.3E-08		2.2E+04	-1.5E+03	10.	1.1E+06	2.8E+04	3.6E+03	7.9E-01	6.8E-02	7.6E-02	5.3E-03	3.0E-04	1.1E-03	2.4E-04	2.4E-04	5.4E-04
						1.6E+06	3.5E+04	2.2E+04	2.1E-01	1.0E-01	8.4E-02	3.1E-02	5.0E-04	2.5E-04	8.7E-05	6.6E-05	4.8E-04
SRF-05-1		0.000															
SRF-05-2		1.000	2.2E+04	-1.5E+03	10.	1.1E+06	2.8E+04	3.6E+03	7.9E-01	6.8E-02	7.6E-02	5.3E-03	3.0E-04	1.1E-03	2.4E-04	2.4E-04	5.4E-04
						1.6E+06	3.5E+04	2.2E+04	2.1E-01	1.0E-01	8.4E-02	3.1E-02	5.0E-04	2.5E-04	8.7E-05	6.6E-05	4.8E-04
SRF-05-3		0.000															
SRF-06	2.5E-08		2.2E+04	-1.5E+03	10.	1.3E+07	2.8E+04	2.6E+03	9.1E-01	2.2E-01	2.1E-01	1.3E-01	1.1E-01	2.7E-02	1.3E-02	5.9E-02	1.1E-01
						1.6E+06	3.3E+04	2.2E+04	9.5E-02	6.1E-02	5.0E-02	5.0E-02	1.9E-02	2.9E-03	2.4E-03	7.9E-03	1.7E-02
SRF-06-1		0.000															
SRF-06-2		1.000	2.2E+04	-1.5E+03	10.	1.3E+07	2.8E+04	2.6E+03	9.1E-01	2.2E-01	2.1E-01	1.3E-01	1.1E-01	2.7E-02	1.3E-02	5.9E-02	1.1E-01
						1.6E+06	3.3E+04	2.2E+04	9.5E-02	6.1E-02	5.0E-02	5.0E-02	1.9E-02	2.9E-03	2.4E-03	7.9E-03	1.7E-02
SRF-06-3		0.000															

Table 3.4-8 (continued)

Source Term	Freq. (1/yr)	Cond. Prob.	Warn (s)	dEvac (s)	Elev (m)	Energy (W)	Start (s)	Dur (s)	Release Fractions NG	I	Cs	Te	Sr	Ru	La	Ce	Ba
SRF-07	8.0E-09		2.2E+04	-1.5E+03	10.	2.5E+07	2.8E+04	2.2E+02	8.8E-01	3.2E-01	2.8E-01	4.7E-02	3.3E-03	7.3E-04	1.8E-04	9.0E-04	3.9E-03
						1.6E+06	3.2E+04	2.2E+04	1.2E-01	6.5E-02	5.7E-02	9.4E-02	2.9E-02	1.4E-04	3.2E-03	3.3E-03	2.2E-02
SRF-07-1		0.000															
SRF-07-2		1.000	2.2E+04	-1.5E+03	10.	2.5E+07	2.8E+04	2.2E+02	8.8E-01	3.2E-01	2.8E-01	4.7E-02	3.3E-03	7.3E-04	1.8E-04	9.0E-04	3.9E-03
						1.6E+06	3.2E+04	2.2E+04	1.2E-01	6.5E-02	5.7E-02	9.4E-02	2.9E-02	1.4E-04	3.2E-03	3.3E-03	2.2E-02
SRF-07-3		0.000															
SRF-08	7.8E-09		2.2E+04	-1.5E+03	10.	2.0E+07	2.8E+04	2.3E+02	7.5E-01	2.1E-01	2.1E-01	1.1E-02	1.4E-03	3.4E-04	8.1E-05	2.9E-04	1.7E-03
						1.6E+06	3.5E+04	2.2E+04	2.5E-01	1.3E-01	1.3E-01	1.2E-01	5.4E-03	1.8E-05	5.2E-04	5.3E-04	4.0E-03
SRF-08-1		0.000															
SRF-08-2		1.000	2.2E+04	-1.5E+03	10.	2.0E+07	2.8E+04	2.3E+02	7.5E-01	2.1E-01	2.1E-01	1.1E-02	1.4E-03	3.4E-04	8.1E-05	2.9E-04	1.7E-03
						1.6E+06	3.5E+04	2.2E+04	2.5E-01	1.3E-01	1.3E-01	1.2E-01	5.4E-03	1.8E-05	5.2E-04	5.3E-04	4.0E-03
SRF-08-3		0.000															
SRF-09	3.8E-09		2.2E+04	-1.5E+03	10.	1.1E+07	2.8E+04	2.1E+02	2.8E-01	3.6E-03	2.6E-03	4.2E-04	5.6E-06	1.3E-06	3.0E-07	3.0E-07	9.1E-06
						1.6E+06	4.6E+04	2.2E+04	7.2E-01	3.8E-01	3.8E-01	5.4E-02	3.5E-04	6.0E-10	1.2E-05	1.4E-05	3.2E-04
SRF-09-1		0.000															
SRF-09-2		1.000	2.2E+04	-1.5E+03	10.	1.1E+07	2.8E+04	2.1E+02	2.8E-01	3.6E-03	2.6E-03	4.2E-04	5.6E-06	1.3E-06	3.0E-07	3.0E-07	9.1E-06
						1.6E+06	4.6E+04	2.2E+04	7.2E-01	3.8E-01	3.8E-01	5.4E-02	3.5E-04	6.0E-10	1.2E-05	1.4E-05	3.2E-04
SRF-09-3		0.000															
SRF-10	2.1E-11		2.2E+04	-1.5E+03	10.	8.4E+06	2.8E+04	7.7E+02	8.2E-01	3.8E-01	4.0E-01	1.6E-01	1.3E-01	1.9E-02	1.3E-02	7.0E-02	1.3E-01
						1.6E+06	2.9E+04	2.2E+04	1.8E-01	8.5E-02	8.1E-02	4.2E-01	4.7E-01	4.3E-02	8.6E-02	8.6E-02	4.5E-01
SRF-10-1		0.000															
SRF-10-2		1.000	2.2E+04	-1.5E+03	10.	8.4E+06	2.8E+04	7.7E+02	8.2E-01	3.8E-01	4.0E-01	1.6E-01	1.3E-01	1.9E-02	1.3E-02	7.0E-02	1.3E-01
						1.6E+06	2.9E+04	2.2E+04	1.8E-01	8.5E-02	8.1E-02	4.2E-01	4.7E-01	4.3E-02	8.6E-02	8.6E-02	4.5E-01
SRF-10-3		0.000															
SRF-11	2.3E-09		2.2E+04	-1.5E+03	10.	4.4E+08	2.8E+04	2.0E+02	9.5E-01	7.8E-01	7.9E-01	3.3E-01	1.7E-02	1.8E-02	3.3E-03	5.9E-03	2.2E-02
						1.6E+06	2.9E+04	2.2E+04	5.1E-02	2.4E-02	2.4E-02	1.2E-01	4.6E-02	2.6E-04	5.7E-03	5.7E-03	3.5E-02
SRF-11-1		0.000															
SRF-11-2		1.000	2.2E+04	-1.5E+03	10.	4.4E+08	2.8E+04	2.0E+02	9.5E-01	7.8E-01	7.9E-01	3.3E-01	1.7E-02	1.8E-02	3.3E-03	5.9E-03	2.2E-02
						1.6E+06	2.9E+04	2.2E+04	5.1E-02	2.4E-02	2.4E-02	1.2E-01	4.6E-02	2.6E-04	5.7E-03	5.7E-03	3.5E-02
SRF-11-3		0.000															
SRF-12	4.4E-06		2.2E+04	1.8E+04	0.	2.9E-02	4.7E+04	6.0E-03	1.5E-07	1.8E-13	7.1E-14	6.3E-15	7.6E-17	1.1E-21	1.1E-21	1.1E-21	1.7E-16
						8.9E-02	4.7E+04	8.6E+04	5.0E-03	4.8E-05	2.9E-07	2.1E-07	6.6E-08	3.3E-09	7.1E-09	8.6E-09	5.5E-08
SRF-12-1		1.000	2.2E+04	1.8E+04	0.	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
						0.0E+00	4.7E+04	8.6E+04	5.0E-03	4.8E-05	2.9E-07	2.1E-07	6.6E-08	3.3E-09	7.1E-09	8.6E-09	5.5E-08
SRF-12-2		0.000	2.2E+04	-1.5E+03	10.	5.2E+04	2.8E+04	1.1E+04	2.7E-01	3.2E-07	1.3E-07	1.1E-08	1.4E-10	2.0E-15	2.0E-15	2.0E-15	3.1E-10
						1.6E+05	1.0E+06	1.0E+06	7.3E-01	2.6E-06	5.8E-07	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
SRF-12-3		0.000															

Table 3.4-8 (continued)

Source Term	Freq. (1/yr)	Cond. Prob.	Warn (s)	dEvac (s)	Elev (m)	Energy (W)	Start (s)	Dur (s)	Release Fractions								
									NG	I	Cs	Te	Sr	Ru	La	Ce	Ba
SRF-13	3.0E-06		2.2E+04	1.7E+04	1.	1.7E-01	4.7E+04	3.6E-02	2.0E-06	3.4E-11	1.6E-11	2.5E-12	3.8E-14	7.3E-15	5.3E-16	1.1E-15	8.3E-14
						4.1E+03	5.3E+04	8.1E+04	7.2E-02	2.9E-04	1.0E-06	7.8E-07	1.6E-07	8.4E-09	1.8E-08	2.2E-08	1.3E-07
SRF-13-1		1.000	2.2E+04	1.8E+04	1.	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
						4.1E+03	5.3E+04	8.1E+04	7.2E-02	2.9E-04	1.0E-06	7.8E-07	1.6E-07	8.4E-09	1.8E-08	2.2E-08	1.3E-07
SRF-13-2		0.000	2.2E+04	-1.5E+03	10.	5.2E+04	2.8E+04	1.1E+04	6.1E-01	1.0E-05	4.9E-06	7.5E-07	1.1E-08	2.2E-09	1.6E-10	3.4E-10	2.5E-08
						1.6E+05	1.0E+06	1.0E+06	3.9E-01	9.1E-04	3.5E-06	5.0E-07	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
SRF-13-3		0.000															
SRF-14	1.8E-06		2.2E+04	1.7E+04	10.	1.0E+02	4.7E+04	2.1E+01	2.0E-03	2.9E-07	2.0E-07	1.7E-07	1.8E-07	4.7E-08	2.0E-08	1.7E-07	1.8E-07
						6.2E+04	1.4E+05	1.3E+04	1.0E+00	1.2E-02	2.9E-05	2.6E-05	1.1E-05	3.2E-07	1.3E-06	1.3E-06	8.7E-06
SRF-14-1		0.998	2.2E+04	1.8E+04	10.	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
						6.2E+04	1.3E+05	1.1E+04	1.0E+00	1.2E-02	2.9E-05	2.6E-05	1.1E-05	3.2E-07	1.3E-06	1.3E-06	8.7E-06
SRF-14-2		0.002	2.2E+04	-1.5E+03	10.	5.2E+04	2.8E+04	1.1E+04	1.0E+00	1.5E-04	1.0E-04	8.8E-05	9.2E-05	2.4E-05	1.0E-05	8.7E-05	9.2E-05
						1.6E+05	1.0E+06	1.0E+06	4.0E-03	2.5E-02	2.9E-05	8.7E-06	3.7E-09	1.4E-10	1.7E-10	3.0E-10	2.7E-09
SRF-14-3		0.000															
SRF-15	1.6E-06		2.2E+04	1.7E+04	10.	1.5E+04	4.6E+04	1.5E+02	2.9E-02	2.7E-04	2.1E-04	1.4E-04	1.4E-04	3.8E-05	1.6E-05	1.2E-04	1.4E-04
						9.8E+04	1.4E+05	2.1E+04	9.7E-01	5.2E-02	2.9E-04	1.3E-04	4.8E-05	1.1E-05	5.7E-06	3.3E-05	4.5E-05
SRF-15-1		0.965	2.2E+04	1.8E+04	10.	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
						6.2E+04	1.3E+05	1.1E+04	1.0E+00	5.3E-02	4.0E-05	3.3E-05	1.1E-05	3.3E-07	1.4E-06	1.5E-06	9.4E-06
SRF-15-2		0.035	2.2E+04	-1.5E+03	10.	4.3E+05	2.8E+04	4.2E+03	8.3E-01	7.7E-03	5.9E-03	4.0E-03	4.0E-03	1.1E-03	4.7E-04	3.4E-03	4.0E-03
						1.1E+06	3.0E+05	2.9E+05	1.7E-01	2.9E-02	7.3E-03	2.9E-03	1.1E-03	2.9E-04	1.3E-04	9.1E-04	1.0E-03
SRF-15-3		0.000															

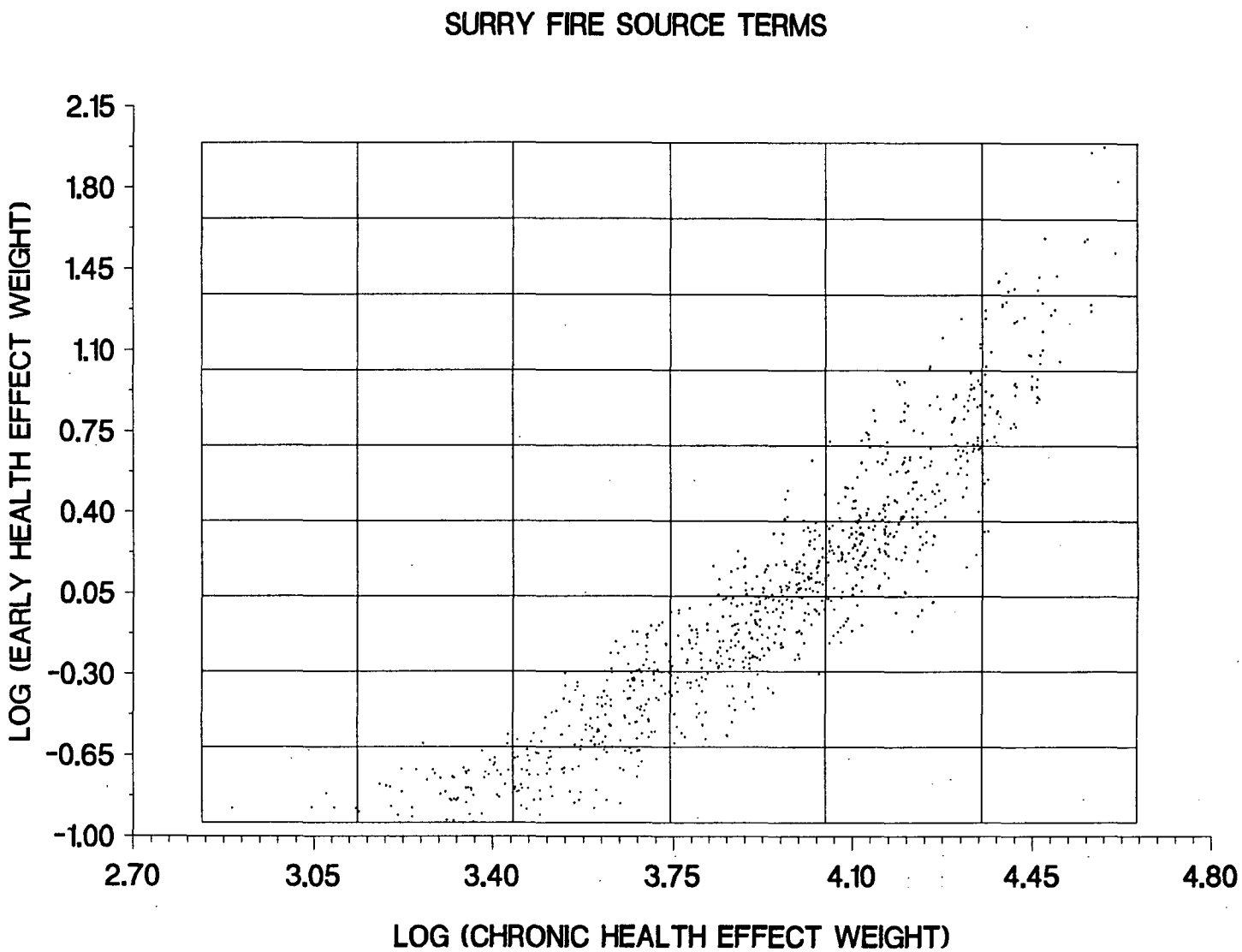


Figure 3.4-2. Partition Plot--Fire Initiator

3.4.3 Results for Seismic Initiators: LLNL Hazard Curve

This section presents the results of partitioning the source terms for seismic initiators based on the LLNL hazard distributions. The partitioning process is described in Section 3.4-1. The partitioning process does not result in the loss of any source terms; rather, cells with a small number of source terms or a small frequency are pooled with other cells. Because of differences in the evacuation of the surrounding population for large earthquakes, the accident progression, source term, and consequence analyses were performed separately for seisms with peak ground acceleration (PGA) over 0.6 g and for seisms with PGA less than 0.6 g. Thus, the partitioning of the high acceleration and low acceleration earthquakes was performed separately.

The accident progression analysis and the subsequent source term analysis for seismic initiators using the LLNL hazard distributions resulted in the generation of 11,775 source terms for high PGA and 11,967 source terms for low PGA. Table 3.4-9 shows the number of these source terms with EH>0 and CH>0 and the number with EH=0 and CH>0.

Table 3.4-9
Summary of Early and Chronic Health Effect Weights
for Seismic Initiators: LLNL Hazard Distributions

	Number of Source Terms	Percent of Total Frequency
PGA > 0.6 g		
EH>0 and CH>0	4193	14.60
EH=0 and CH>0	7582	85.40
EH=0 and CH=0	0	0.00
Total	11775	100.00

For EH>0 and CH>0, Range LOG10(CH) = 2.6696 to 4.7668
Range LOG10(EH) = -0.9423 to 2.2267

For EH=0 and CH>0, Range LOG10(CH) = -3.9650 to 3.9639

PGA < 0.6 g		
EH>0 and CH>0	4273	5.26
EH=0 and CH>0	7694	94.74
EH=0 and CH=0	0	0.00
Total	11967	100.00

For EH>0 and CH>0, Range LOG10(CH) = 2.6696 to 4.7668
Range LOG10(EH) = -0.9423 to 2.2274

For EH=0 and CH>0, Range LOG10(CH) = -3.9650 to 3.9639

Figure 3.4-3 shows plots of the pairs (CH, EH) for the source terms for both high and low acceleration for which both EH and CH are nonzero. A summary of the partitioning process for EH>0 and CH>0 is given in Table 3.4-10. Only the percent of the frequency contained in each cell after partitioning and the labeling after partitioning are shown. A summary of the partitioning process for the source terms for which EH=0 and CH>0 is given in Table 3.4-11, which is structured analogously to Table 3.4-10 but has only one dimension instead of two.

The groups of source terms that result from partitioning are further subdivided on the basis of evacuation timing. The three subgroups used are described in Section 3.4.1. Frequency-weighted mean source terms are calculated for each populated subgroup. The mean source terms obtained in this analysis are shown in Table 3.4-12. This table contains frequency-weighted mean source terms for both the source term groups and subgroups. SRH-I and SRH-I-J are used to label the mean source terms for high acceleration seisms derived from source term groups and subgroups, respectively, where I designates the source term group and J designates the source term subgroup. SRL-I and SRL-I-J are used similarly to label the mean source terms for low acceleration seisms. It is the source terms for the subgroups that are actually used for the risk calculations. Table 3.4-12 is analogous to Table 3.4-4 for internal initiators.

Table 3.4-10
Distribution of Source Terms with Nonzero Early Fatality and Chronic Fatality Weights for Seismic Initiators:
LLNL Hazard Distributions

PGA > 0.6 g

PERCENT OF FREQUENCY CONTAINED IN EACH CELL AFTER PARTITIONING:

	1	2	3	4	5	6
1						0.49
2						0.97
3					0.91	4.26
4					20.47	
5					16.32	
6				16.90	1.27	
7			6.66	16.52		
8		4.24	10.98			

Table 3.4-10 (continued)

LABELING AFTER PARTITIONING:

	1	2	3	4	5	6
1						SRH-10
2						SRH-11
3					SRH-06	SRH-12
4					SRH-07	
5					SRH-08	
6				SRH-04	SRH-09	
7			SRH-02	SRH-05		
8		SRH-01	SRH-03			

<u>PGA < 0.6 g</u>

PERCENT OF FREQUENCY CONTAINED IN EACH CELL AFTER PARTITIONING:

	1	2	3	4	5	6
1						0.38
2						0.87
3					0.84	4.09
4					25.04	
5				1.15	15.78	
6				14.04	1.44	
7			6.28	15.32		
8		4.46	10.32			

Table 3.4-10 (continued)

LABELING AFTER PARTITIONING:

	1	2	3	4	5	6
1						SRL-11
2						SRL-12
3					SRL-07	SRL-13
4					SRL-08	
5				SRL-04	SRL-09	
6				SRL-05	SRL-10	
7			SRL-02	SRL-06		
8		SRL-01	SRL-03			

Table 3.4-11
Distribution of Source Terms with Zero Early Fatality Weight and Nonzero Chronic Fatality Weight for Seismic Initiators:
LLNL Hazard Distributions

PGA > 0.6 g

PERCENT OF FREQUENCY CONTAINED IN EACH CELL AFTER PARTITIONING:

	1	2	3	4	5	6	7
1		13.39	54.39		28.41		3.81

LABELING AFTER PARTITIONING:

	1	2	3	4	5	6	7
1		SRH-13	SRH-14		SRH-15		SRH-16

Table 3.4-11 (continued)

PGA < 0.6 g

PERCENT OF FREQUENCY CONTAINED IN EACH CELL AFTER PARTITIONING:

	1	2	3	4	5	6	7
1			67.93		30.49		1.58

LABELING AFTER PARTITIONING:

	1	2	3	4	5	6	7
1			SRL-14		SRL-15		SRL-16

Table 3.4-12
Mean Source Terms Resulting from Partitioning for Seismic Initiators
LLNL Hazard Distributions: High PGA

Source Term	Freq. (1/yr)	Cond. Prob.	Warn (s)	dEvac (s)	Elev (m)	Energy (W)	Start (s)	Dur (s)	Release Fractions NG	I	Cs	Te	Sr	Ru	La	Ce	Ba
SRH-01	1.7E-07		2.2E+04	1.5E+03	10.	3.1E+05	3.5E+04	7.9E+02	4.9E-01	2.0E-02	1.5E-02	6.2E-03	4.4E-04	1.6E-04	2.3E-05	8.3E-05	6.1E-04
						5.8E+05	4.6E+04	2.9E+04	5.1E-01	6.3E-02	9.3E-03	4.4E-02	2.0E-03	7.4E-05	1.8E-04	2.0E-04	1.5E-03
SRH-01-1		0.356	2.2E+04	1.3E+04	10.	2.6E+04	4.6E+04	2.6E+01	1.9E-02	6.0E-04	5.7E-04	7.6E-04	9.9E-06	8.0E-06	2.6E-07	5.0E-07	1.4E-05
						6.3E+05	4.6E+04	1.1E+04	9.8E-01	5.8E-02	1.2E-02	1.1E-01	3.0E-03	3.0E-05	1.9E-04	2.0E-04	1.8E-03
SRH-01-2		0.000															
SRH-01-3		0.644	2.2E+04	-5.1E+03	10.	4.6E+05	2.8E+04	1.2E+03	7.5E-01	3.0E-02	2.3E-02	9.2E-03	6.8E-04	2.4E-04	3.6E-05	1.3E-04	9.4E-04
						5.6E+05	4.6E+04	3.9E+04	2.5E-01	6.6E-02	7.5E-03	5.9E-03	1.4E-03	9.8E-05	1.8E-04	2.0E-04	1.3E-03
SRH-02	2.7E-07		2.2E+04	-5.0E+03	10.	1.0E+06	2.8E+04	1.6E+03	7.6E-01	8.7E-02	6.7E-02	1.7E-02	1.5E-03	4.6E-04	6.7E-05	2.3E-04	1.9E-03
						3.8E+06	4.2E+04	3.4E+04	2.4E-01	5.7E-02	3.1E-02	4.8E-02	6.1E-03	1.4E-04	3.6E-04	4.3E-04	4.3E-03
SRH-02-1		0.000															
SRH-02-2		0.000															
SRH-02-3		1.000	2.2E+04	-5.0E+03	10.	1.0E+06	2.8E+04	1.6E+03	7.6E-01	8.7E-02	6.7E-02	1.7E-02	1.5E-03	4.6E-04	6.7E-05	2.3E-04	1.9E-03
						3.8E+06	4.2E+04	3.4E+04	2.4E-01	5.7E-02	3.1E-02	4.8E-02	6.1E-03	1.4E-04	3.6E-04	4.3E-04	4.3E-03
SRH-03	4.5E-07		2.2E+04	-4.9E+03	10.	7.8E+05	2.8E+04	2.5E+03	7.7E-01	5.9E-02	4.2E-02	1.5E-02	1.5E-03	5.2E-04	8.3E-05	2.7E-04	2.2E-03
						2.0E+06	1.4E+05	1.4E+05	2.3E-01	4.7E-02	3.3E-02	2.3E-02	8.1E-04	1.2E-04	4.2E-05	8.7E-05	8.5E-04
SRH-03-1		0.010	2.2E+04	1.4E+04	10.	1.8E+04	4.6E+04	3.7E+01	1.2E-02	1.2E-03	1.0E-03	5.0E-04	6.6E-06	7.7E-07	9.9E-08	1.6E-07	1.2E-05
						5.3E+07	4.9E+04	7.2E+03	9.9E-01	1.0E-01	8.2E-02	7.3E-02	1.5E-03	5.0E-05	6.7E-05	9.6E-05	1.2E-03
SRH-03-2		0.000															
SRH-03-3		0.990	2.2E+04	-5.1E+03	10.	7.9E+05	2.8E+04	2.5E+03	7.7E-01	5.9E-02	4.2E-02	1.5E-02	1.6E-03	5.2E-04	8.3E-05	2.7E-04	2.2E-03
						1.5E+06	1.5E+05	1.4E+05	2.2E-01	4.7E-02	3.3E-02	2.2E-02	8.0E-04	1.2E-04	4.2E-05	8.7E-05	8.5E-04
SRH-04	7.0E-07		2.2E+04	-4.8E+03	10.	1.7E+06	2.8E+04	2.2E+03	7.7E-01	1.7E-01	1.5E-01	5.7E-02	2.3E-03	1.4E-03	1.5E-04	4.1E-04	3.7E-03
						3.0E+06	6.9E+04	6.0E+04	2.3E-01	9.1E-02	4.3E-02	5.4E-02	1.1E-02	1.3E-03	1.1E-03	1.3E-03	9.2E-03
SRH-04-1		0.017	2.2E+04	1.3E+04	10.	2.3E+04	4.6E+04	5.1E+01	1.1E-02	3.6E-03	3.3E-03	3.6E-03	1.3E-04	8.1E-05	7.4E-06	2.1E-05	2.0E-04
						9.1E+07	5.5E+04	1.8E+04	9.8E-01	7.5E-02	5.3E-02	5.0E-01	3.3E-02	5.2E-02	6.0E-03	6.0E-03	3.1E-02
SRH-04-2		0.000															
SRH-04-3		0.983	2.2E+04	-5.1E+03	10.	1.8E+06	2.8E+04	2.2E+03	7.9E-01	1.7E-01	1.5E-01	5.8E-02	2.4E-03	1.4E-03	1.5E-04	4.2E-04	3.8E-03
						1.5E+06	7.0E+04	6.0E+04	2.1E-01	9.1E-02	4.3E-02	4.7E-02	1.0E-02	4.3E-04	1.1E-03	1.2E-03	8.8E-03
SRH-05	6.8E-07		2.2E+04	-5.0E+03	10.	7.2E+05	2.8E+04	2.5E+03	7.5E-01	1.2E-01	1.0E-01	2.7E-02	1.3E-03	3.6E-04	6.8E-05	2.0E-04	1.9E-03
						3.5E+06	5.5E+04	4.5E+04	2.4E-01	9.2E-02	3.7E-02	1.5E-02	7.3E-04	7.8E-05	4.2E-05	7.4E-05	7.9E-04
SRH-05-1		0.000															
SRH-05-2		0.000															
SRH-05-3		1.000	2.2E+04	-5.0E+03	10.	7.2E+05	2.8E+04	2.5E+03	7.5E-01	1.2E-01	1.0E-01	2.7E-02	1.3E-03	3.6E-04	6.8E-05	2.0E-04	1.9E-03
						3.5E+06	5.5E+04	4.5E+04	2.4E-01	9.2E-02	3.7E-02	1.5E-02	7.3E-04	7.8E-05	4.2E-05	7.4E-05	7.9E-04
SRH-06	3.8E-08		2.2E+04	-5.1E+03	10.	1.4E+07	2.8E+04	9.7E+02	9.2E-01	4.6E-01	4.3E-01	1.5E-01	7.8E-03	3.7E-03	4.5E-04	1.5E-03	1.1E-02
						1.3E+06	3.4E+04	2.5E+04	7.5E-02	9.5E-02	7.5E-02	1.4E-01	8.3E-02	2.5E-03	1.1E-02	1.2E-02	7.3E-02
SRH-06-1		0.000															

Table 3.4-12 (continued)

Source Term	Freq. (1/yr)	Cond. Prob.	Warn (s)	dEvac (s)	Elev (m)	Energy (W)	Start (s)	Dur (s)	Release Fractions NG	I	Cs	Te	Sr	Ru	La	Ce	Ba
SRH-06-2	0.026		1.3E+04	-3.6E+03	10.	1.0E+06	2.0E+04	1.4E+03	7.2E-01	5.0E-01	4.5E-01	4.5E-01	3.9E-02	1.8E-02	2.1E-03	7.1E-03	5.2E-02
						0.0E+00	1.2E+05	1.2E+05	7.6E-02	5.2E-02	4.6E-02	4.8E-02	4.4E-03	2.0E-03	2.3E-04	7.3E-04	5.8E-03
SRH-06-3		0.974	2.2E+04	-5.1E+03	10.	1.4E+07	2.8E+04	9.6E+02	9.3E-01	4.6E-01	4.3E-01	1.4E-01	7.0E-03	3.3E-03	4.1E-04	1.4E-03	1.0E-02
						1.3E+06	3.2E+04	2.2E+04	7.4E-02	9.6E-02	7.6E-02	1.4E-01	8.5E-02	2.5E-03	1.2E-02	1.2E-02	7.5E-02
SRH-07	8.4E-07		2.2E+04	-5.1E+03	10.	2.6E+06	2.8E+04	1.0E+03	7.7E-01	3.7E-01	3.4E-01	7.8E-02	1.6E-02	3.2E-03	1.5E-03	6.9E-03	1.7E-02
						1.5E+06	5.3E+04	4.6E+04	2.3E-01	1.3E-01	1.1E-01	1.0E-01	9.1E-03	8.4E-04	8.7E-04	2.4E-03	8.3E-03
SRH-07-1		0.000															
SRH-07-2		0.000															
SRH-07-3		1.000	2.2E+04	-5.1E+03	10.	2.6E+06	2.8E+04	1.0E+03	7.7E-01	3.7E-01	3.4E-01	7.8E-02	1.6E-02	3.2E-03	1.5E-03	6.9E-03	1.7E-02
						1.5E+06	5.3E+04	4.6E+04	2.3E-01	1.3E-01	1.1E-01	1.0E-01	9.1E-03	8.4E-04	8.7E-04	2.4E-03	8.3E-03
SRH-08	6.7E-07		2.2E+04	-5.1E+03	10.	6.0E+06	2.8E+04	1.3E+03	8.1E-01	2.6E-01	2.4E-01	5.4E-02	2.5E-03	8.3E-04	1.2E-04	3.8E-04	3.5E-03
						1.5E+06	5.2E+04	4.3E+04	1.9E-01	1.1E-01	7.9E-02	9.3E-02	2.1E-02	1.5E-04	1.5E-03	1.6E-03	1.5E-02
SRH-08-1		0.000															
SRH-08-2		0.000															
SRH-08-3		1.000	2.2E+04	-5.1E+03	10.	6.0E+06	2.8E+04	1.3E+03	8.1E-01	2.6E-01	2.4E-01	5.4E-02	2.5E-03	8.3E-04	1.2E-04	3.8E-04	3.5E-03
						1.5E+06	5.2E+04	4.3E+04	1.9E-01	1.1E-01	7.9E-02	9.3E-02	2.1E-02	1.5E-04	1.5E-03	1.6E-03	1.5E-02
SRH-09	5.2E-08		2.2E+04	-5.1E+03	10.	8.6E+06	2.8E+04	3.4E+03	8.1E-01	2.3E-01	2.0E-01	4.6E-02	4.9E-03	1.1E-03	2.2E-04	7.8E-04	6.0E-03
						1.4E+06	1.2E+05	1.1E+05	1.9E-01	1.1E-01	8.9E-02	6.1E-02	7.1E-03	4.2E-05	5.0E-04	5.5E-04	5.4E-03
SRH-09-1		0.000															
SRH-09-2		0.000															
SRH-09-3		1.000	2.2E+04	-5.1E+03	10.	8.6E+06	2.8E+04	3.4E+03	8.1E-01	2.3E-01	2.0E-01	4.6E-02	4.9E-03	1.1E-03	2.2E-04	7.8E-04	6.0E-03
						1.4E+06	1.2E+05	1.1E+05	1.9E-01	1.1E-01	8.9E-02	6.1E-02	7.1E-03	4.2E-05	5.0E-04	5.5E-04	5.4E-03
SRH-10	2.0E-08		2.2E+04	-5.1E+03	10.	8.5E+06	2.8E+04	2.5E+03	8.5E-01	3.9E-01	4.0E-01	4.6E-02	3.9E-03	8.3E-04	3.4E-04	1.7E-03	4.5E-03
						1.6E+06	3.3E+04	2.2E+04	1.5E-01	1.1E-01	1.2E-01	5.9E-01	6.0E-01	5.1E-02	1.1E-01	1.1E-01	5.7E-01
SRH-10-1		0.000															
SRH-10-2		0.000															
SRH-10-3		1.000	2.2E+04	-5.1E+03	10.	8.5E+06	2.8E+04	2.5E+03	8.5E-01	3.9E-01	4.0E-01	4.6E-02	3.9E-03	8.3E-04	3.4E-04	1.7E-03	4.5E-03
						1.6E+06	3.3E+04	2.2E+04	1.5E-01	1.1E-01	1.2E-01	5.9E-01	6.0E-01	5.1E-02	1.1E-01	1.1E-01	5.7E-01
SRH-11	4.0E-08		2.2E+04	-5.1E+03	10.	8.6E+06	2.8E+04	7.8E+02	8.1E-01	4.8E-01	4.7E-01	1.0E-01	5.9E-02	8.6E-03	5.1E-03	2.5E-02	6.0E-02
						1.6E+06	3.8E+04	3.0E+04	1.9E-01	1.6E-01	1.6E-01	4.2E-01	2.0E-01	5.5E-04	1.9E-02	2.1E-02	1.6E-01
SRH-11-1		0.000															
SRH-11-2		0.000															
SRH-11-3		1.000	2.2E+04	-5.1E+03	10.	8.6E+06	2.8E+04	7.8E+02	8.1E-01	4.8E-01	4.7E-01	1.0E-01	5.9E-02	8.6E-03	5.1E-03	2.5E-02	6.0E-02
						1.6E+06	3.8E+04	3.0E+04	1.9E-01	1.6E-01	1.6E-01	4.2E-01	2.0E-01	5.5E-04	1.9E-02	2.1E-02	1.6E-01

Table 3.4-12 (continued)

Source Term	Freq. (1/yr)	Cond. Prob.	Warn (s)	dEvac (s)	Elev (m)	Energy (W)	Start (s)	Dur (s)	Release Fractions NG	I	Cs	Te	Sr	Ru	La	Ce	Ba
SRH-12	1.8E-07		2.2E+04	-5.1E+03	10.	2.6E+07	2.8E+04	7.9E+02	9.7E-01	6.5E-01	6.3E-01	1.4E-01	3.2E-03	2.1E-03	1.4E-04	3.5E-04	5.7E-03
						1.6E+06	3.2E+04	2.3E+04	2.5E-02	5.0E-02	4.4E-02	2.2E-01	7.6E-02	4.9E-04	7.6E-03	8.0E-03	6.0E-02
SRH-12-1		0.000															
SRH-12-2		0.000															
SRH-12-3		1.000	2.2E+04	-5.1E+03	10.	2.6E+07	2.8E+04	7.9E+02	9.7E-01	6.5E-01	6.3E-01	1.4E-01	3.2E-03	2.1E-03	1.4E-04	3.5E-04	5.7E-03
						1.6E+06	3.2E+04	2.3E+04	2.5E-02	5.0E-02	4.4E-02	2.2E-01	7.6E-02	4.9E-04	7.6E-03	8.0E-03	6.0E-02
SRH-13	3.2E-06		2.2E+04	1.4E+04	0.	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
						0.0E+00	4.7E+04	8.6E+04	4.6E-03	9.5E-06	8.9E-08	3.8E-08	1.8E-09	6.9E-10	8.5E-11	2.0E-10	2.0E-09
SRH-13-1		1.000	2.2E+04	1.4E+04	0.	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
						0.0E+00	4.7E+04	8.6E+04	4.6E-03	9.5E-06	8.9E-08	3.8E-08	1.8E-09	6.9E-10	8.5E-11	2.0E-10	2.0E-09
SRH-13-2		0.000															
SRH-13-3		0.000															
SRH-14	1.3E-05		2.2E+04	1.4E+04	0.	5.0E+02	4.7E+04	8.1E+00	3.1E-04	1.0E-09	4.4E-10	7.2E-11	5.1E-12	1.3E-12	2.4E-13	7.9E-13	7.6E-12
						4.7E+02	4.8E+04	8.7E+04	7.7E-03	1.1E-04	5.2E-07	3.3E-07	7.2E-08	4.1E-09	7.7E-09	9.0E-09	6.2E-08
SRH-14-1		1.000	2.2E+04	1.4E+04	0.	5.0E+02	4.7E+04	8.1E+00	3.1E-04	1.0E-09	4.4E-10	7.2E-11	5.1E-12	1.3E-12	2.4E-13	7.9E-13	7.6E-12
						4.7E+02	4.8E+04	8.7E+04	7.7E-03	1.1E-04	5.2E-07	3.3E-07	7.2E-08	4.1E-09	7.7E-09	9.0E-09	6.2E-08
SRH-14-2		0.000															
SRH-14-3		0.000															
SRH-15	6.9E-06		2.2E+04	1.2E+04	10.	4.7E+03	4.6E+04	5.3E+02	5.5E-02	5.7E-05	4.5E-05	1.7E-05	1.4E-06	4.7E-07	7.2E-08	2.5E-07	2.0E-06
						7.4E+04	1.7E+05	5.7E+04	9.4E-01	2.5E-02	4.0E-05	5.7E-05	9.9E-06	2.0E-07	1.0E-06	1.1E-06	7.8E-06
SRH-15-1		0.926	2.2E+04	1.4E+04	10.	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
						6.6E+04	1.3E+05	1.1E+04	1.0E+00	2.5E-02	3.4E-05	5.3E-05	8.8E-06	1.4E-07	8.8E-07	9.3E-07	6.8E-06
SRH-15-2		0.000															
SRH-15-3		0.074	2.2E+04	-5.1E+03	10.	6.4E+04	2.8E+04	7.2E+03	7.4E-01	7.6E-04	6.1E-04	2.2E-04	1.9E-05	6.4E-06	9.7E-07	3.3E-06	2.7E-05
						1.7E+05	6.4E+05	6.4E+05	2.5E-01	2.0E-02	1.2E-04	1.0E-04	2.4E-05	9.7E-07	2.7E-06	3.0E-06	1.9E-05
SRH-16	9.2E-07		2.2E+04	-3.8E+01	10.	2.9E+05	3.3E+04	5.4E+03	6.0E-01	1.5E-02	1.2E-02	3.8E-03	1.8E-04	7.1E-05	9.4E-06	3.2E-05	2.6E-04
						4.5E+07	4.9E+05	4.8E+05	3.9E-01	3.5E-02	6.4E-03	7.6E-03	2.9E-03	5.2E-05	2.7E-04	2.9E-04	2.3E-03
SRH-16-1		0.269	2.2E+04	1.4E+04	10.	1.1E+04	4.7E+04	1.5E+01	1.2E-03	2.7E-04	2.5E-04	3.1E-04	4.0E-06	3.1E-06	1.0E-07	1.9E-07	5.8E-06
						1.6E+08	4.8E+04	1.4E+03	9.9E-01	5.3E-02	1.7E-02	2.3E-02	1.0E-02	1.7E-04	9.7E-04	1.0E-03	8.0E-03
SRH-16-2		0.000															
SRH-16-3		0.731	2.2E+04	-5.1E+03	10.	3.9E+05	2.8E+04	7.4E+03	8.2E-01	2.0E-02	1.6E-02	5.1E-03	2.4E-04	9.6E-05	1.3E-05	4.3E-05	3.6E-04
						4.6E+05	6.6E+05	6.5E+05	1.6E-01	2.9E-02	2.4E-03	1.9E-03	1.6E-04	9.9E-06	1.4E-05	1.7E-05	1.3E-04

Table 3.4-12 (continued)

Source Term	Freq. (1/yr)	Cond. Prob.	Warn (s)	dEvac (s)	Elev (m)	Energy (W)	Start (s)	Dur (s)	Release Fractions NG	I	Cs	Te	Sr	Ru	La	Ce	Ba
SRL-01	3.8E-07		2.2E+04	5.5E+03	10.	2.5E+05	3.8E+04	5.4E+02	3.3E-01	1.3E-02	1.0E-02	5.0E-03	3.3E-04	1.1E-04	1.7E-05	5.9E-05	4.5E-04
						6.0E+05	4.5E+04	2.2E+04	6.7E-01	5.9E-02	1.1E-02	6.6E-02	2.3E-03	6.7E-05	1.9E-04	2.1E-04	1.6E-03
SRL-01-1		0.552	2.2E+04	1.4E+04	10.	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
						6.5E+05	4.7E+04	1.1E+04	1.0E+00	6.0E-02	1.3E-02	1.1E-01	3.1E-03	3.5E-05	2.0E-04	2.1E-04	1.9E-03
SRL-01-2		0.044	1.3E+04	-3.6E+03	10.	1.0E+06	2.0E+04	1.0E+03	7.3E-01	2.3E-02	2.2E-02	3.0E-02	3.9E-04	3.1E-04	1.0E-05	1.9E-05	5.5E-04
						0.0E+00	2.1E+04	1.1E+04	2.7E-01	5.1E-03	2.7E-03	3.7E-03	5.1E-05	3.9E-05	1.4E-06	2.5E-06	7.1E-05
SRL-01-3		0.404	2.2E+04	-5.1E+03	10.	5.0E+05	2.8E+04	1.2E+03	7.5E-01	3.1E-02	2.3E-02	9.2E-03	7.7E-04	2.5E-04	4.0E-05	1.4E-04	1.0E-03
						6.1E+05	4.6E+04	3.8E+04	2.5E-01	6.4E-02	7.7E-03	6.1E-03	1.5E-03	1.1E-04	1.9E-04	2.2E-04	1.4E-03
SRL-02	5.4E-07		2.2E+04	-4.1E+03	10.	1.0E+06	2.9E+04	1.3E+03	7.2E-01	8.4E-02	6.5E-02	1.7E-02	1.4E-03	4.4E-04	6.4E-05	2.2E-04	1.8E-03
						3.6E+07	4.1E+04	3.1E+04	2.8E-01	5.7E-02	3.2E-02	4.9E-02	7.6E-03	1.5E-04	5.2E-04	5.9E-04	5.3E-03
SRL-02-1		0.050	2.2E+04	1.4E+04	10.	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
						7.0E+08	4.7E+04	1.0E+01	1.0E+00	7.6E-02	4.8E-02	9.9E-02	4.2E-02	4.4E-04	3.8E-03	4.0E-03	2.8E-02
SRL-02-2		0.014	1.3E+04	-3.6E+03	10.	1.0E+06	2.0E+04	1.8E+03	4.7E-01	1.0E-01	9.4E-02	5.1E-02	5.7E-04	2.3E-04	1.4E-05	2.1E-05	9.6E-04
						0.0E+00	2.2E+05	2.1E+05	9.8E-02	1.6E-02	1.0E-02	1.4E-02	2.1E-04	1.5E-05	1.7E-05	1.8E-05	2.1E-04
SRL-02-3		0.936	2.2E+04	-5.1E+03	10.	1.1E+06	2.8E+04	1.4E+03	7.6E-01	8.8E-02	6.8E-02	1.7E-02	1.5E-03	4.7E-04	6.8E-05	2.3E-04	1.9E-03
						1.6E+06	3.9E+04	3.0E+04	2.4E-01	5.7E-02	3.1E-02	4.7E-02	5.9E-03	1.4E-04	3.5E-04	4.2E-04	4.2E-03
SRL-03	8.9E-07		2.2E+04	-4.6E+03	10.	7.2E+05	2.8E+04	2.1E+03	7.5E-01	5.8E-02	4.1E-02	1.4E-02	1.5E-03	5.0E-04	8.0E-05	2.6E-04	2.1E-03
						2.8E+06	1.2E+05	1.1E+05	2.5E-01	4.9E-02	3.5E-02	2.5E-02	8.1E-04	1.3E-04	4.2E-05	8.9E-05	8.8E-04
SRL-03-1		0.025	2.2E+04	1.3E+04	10.	3.1E+04	4.6E+04	6.1E+01	2.1E-02	2.1E-03	1.7E-03	8.4E-04	1.1E-05	1.4E-06	1.8E-07	3.3E-07	2.0E-05
						5.1E+07	4.9E+04	7.9E+03	9.7E-01	1.0E-01	7.8E-02	7.1E-02	1.9E-03	5.2E-05	7.4E-05	1.1E-04	1.5E-03
SRL-03-2		0.000															
SRL-03-3		0.975	2.2E+04	-5.1E+03	10.	7.4E+05	2.8E+04	2.2E+03	7.7E-01	5.9E-02	4.2E-02	1.5E-02	1.5E-03	5.1E-04	8.2E-05	2.7E-04	2.2E-03
						1.5E+06	1.2E+05	1.1E+05	2.3E-01	4.8E-02	3.4E-02	2.3E-02	7.8E-04	1.3E-04	4.1E-05	8.9E-05	8.6E-04
SRL-04	9.9E-08		1.9E+04	5.6E+03	10.	1.0E+06	3.6E+04	1.2E+03	3.2E-01	9.8E-02	9.1E-02	8.1E-02	7.3E-03	2.0E-03	3.0E-04	1.1E-03	8.1E-03
						5.9E+05	7.6E+04	5.3E+04	5.9E-01	4.0E-02	2.3E-02	3.2E-01	2.5E-02	3.4E-02	4.1E-03	4.3E-03	2.3E-02
SRL-04-1		0.541	2.2E+04	1.4E+04	10.	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
						6.5E+05	4.7E+04	1.1E+04	1.0E+00	4.6E-02	2.8E-02	5.7E-01	3.9E-02	6.2E-02	7.2E-03	7.2E-03	3.7E-02
SRL-04-2		0.307	1.3E+04	-3.6E+03	10.	1.0E+06	2.0E+04	3.1E+03	6.5E-01	2.2E-01	2.2E-01	2.2E-01	3.8E-03	3.3E-03	1.1E-04	2.1E-04	5.5E-03
						0.0E+00	1.5E+05	1.4E+05	6.3E-02	1.6E-02	4.9E-03	5.0E-03	8.7E-05	7.3E-05	2.7E-06	5.1E-06	1.3E-04
SRL-04-3		0.153	2.2E+04	-5.1E+03	10.	4.6E+06	2.8E+04	1.9E+03	8.1E-01	1.9E-01	1.5E-01	8.3E-02	4.0E-02	6.8E-03	1.7E-03	7.0E-03	4.2E-02
						1.6E+06	3.3E+04	2.4E+04	1.9E-01	6.7E-02	4.3E-02	6.5E-02	2.4E-02	1.5E-03	1.7E-03	2.9E-03	2.1E-02
SRL-05	1.2E-06		2.2E+04	-5.0E+03	10.	2.5E+06	2.8E+04	1.9E+03	7.8E-01	1.6E-01	1.4E-01	5.4E-02	2.7E-03	1.8E-03	3.2E-04	5.9E-04	4.2E-03
						5.5E+06	6.1E+04	5.1E+04	2.2E-01	9.2E-02	4.5E-02	5.2E-02	1.1E-02	4.1E-04	1.1E-03	1.2E-03	9.1E-03
SRL-05-1		0.000															
SRL-05-2		0.000															
SRL-05-3		1.000	2.2E+04	-5.0E+03	10.	2.5E+06	2.8E+04	1.9E+03	7.8E-01	1.6E-01	1.4E-01	5.4E-02	2.7E-03	1.8E-03	3.2E-04	5.9E-04	4.2E-03
						5.5E+06	6.1E+04	5.1E+04	2.2E-01	9.2E-02	4.5E-02	5.2E-02	1.1E-02	4.1E-04	1.1E-03	1.2E-03	9.1E-03

Table 3.4-12 (continued)

Source Term	Freq. (1/yr)	Cond. Prob.	Warn (s)	dEvac (s)	Elev (m)	Energy (W)	Start (s)	Dur (s)	Release Fractions NG	I	Cs	Te	Sr	Ru	La	Ce	Ba
SRL-06	1.3E-06		2.2E+04	-4.7E+03	10.	8.1E+05	2.8E+04	2.1E+03	7.4E-01	1.2E-01	1.0E-01	2.6E-02	1.3E-03	4.5E-04	1.0E-04	2.1E-04	1.9E-03
						1.6E+07	4.9E+04	4.0E+04	2.6E-01	9.4E-02	3.9E-02	1.8E-02	1.4E-03	8.5E-05	1.0E-04	1.4E-04	1.2E-03
SRL-06-1		0.023	2.1E+04	1.2E+04	10.	9.1E+04	4.5E+04	1.4E+02	7.1E-02	1.1E-02	8.8E-03	5.3E-03	5.4E-05	1.3E-05	1.4E-06	1.9E-06	1.0E-04
						6.4E+08	4.7E+04	2.8E+03	9.3E-01	1.1E-01	1.1E-01	1.3E-01	3.4E-02	3.6E-04	3.2E-03	3.3E-03	2.3E-02
SRL-06-2		0.000															
SRL-06-3		0.977	2.2E+04	-5.1E+03	10.	8.2E+05	2.8E+04	2.1E+03	7.5E-01	1.2E-01	1.0E-01	2.6E-02	1.3E-03	4.6E-04	1.0E-04	2.2E-04	1.9E-03
						1.6E+06	4.9E+04	4.0E+04	2.5E-01	9.3E-02	3.7E-02	1.5E-02	6.0E-04	7.8E-05	3.3E-05	6.4E-05	7.0E-04
SRL-07	7.2E-08		2.1E+04	-4.8E+03	10.	1.3E+07	2.7E+04	9.9E+02	8.9E-01	4.4E-01	4.2E-01	1.8E-01	1.5E-02	6.4E-03	9.5E-04	3.8E-03	2.0E-02
						1.1E+06	5.5E+04	4.7E+04	7.2E-02	8.7E-02	6.8E-02	1.4E-01	9.1E-02	2.4E-03	1.2E-02	1.3E-02	8.0E-02
SRL-07-1		0.000															
SRL-07-2		0.176	1.3E+04	-3.6E+03	10.	1.0E+06	2.0E+04	1.6E+03	7.2E-01	4.9E-01	4.4E-01	4.7E-01	5.0E-02	2.1E-02	3.0E-03	1.3E-02	6.4E-02
						0.0E+00	1.7E+05	1.6E+05	7.7E-02	4.7E-02	4.2E-02	4.5E-02	4.8E-03	2.1E-03	2.9E-04	1.3E-03	6.1E-03
SRL-07-3		0.824	2.2E+04	-5.1E+03	10.	1.6E+07	2.8E+04	8.7E+02	9.3E-01	4.3E-01	4.1E-01	1.2E-01	8.1E-03	3.2E-03	5.2E-04	1.8E-03	1.1E-02
						1.3E+06	3.2E+04	2.2E+04	7.0E-02	9.5E-02	7.4E-02	1.7E-01	1.1E-01	2.4E-03	1.4E-02	1.5E-02	9.6E-02
SRL-08	2.2E-06		2.2E+04	-5.1E+03	10.	4.5E+06	2.8E+04	9.8E+02	7.8E-01	3.4E-01	3.2E-01	8.3E-02	3.2E-02	7.2E-03	3.5E-03	1.6E-02	3.2E-02
						1.6E+06	4.1E+04	3.4E+04	2.2E-01	1.2E-01	9.7E-02	9.6E-02	1.4E-02	1.5E-03	1.4E-03	4.3E-03	1.2E-02
SRL-08-1		0.000															
SRL-08-2		0.000															
SRL-08-3		1.000	2.2E+04	-5.1E+03	10.	4.5E+06	2.8E+04	9.8E+02	7.8E-01	3.4E-01	3.2E-01	8.3E-02	3.2E-02	7.2E-03	3.5E-03	1.6E-02	3.2E-02
						1.6E+06	4.1E+04	3.4E+04	2.2E-01	1.2E-01	9.7E-02	9.6E-02	1.4E-02	1.5E-03	1.4E-03	4.3E-03	1.2E-02
SRL-09	1.4E-06		2.2E+04	-5.1E+03	10.	7.0E+06	2.8E+04	1.1E+03	8.0E-01	2.6E-01	2.4E-01	5.0E-02	2.0E-03	7.0E-04	8.8E-05	2.7E-04	2.8E-03
						1.6E+06	4.2E+04	3.4E+04	2.0E-01	1.1E-01	7.9E-02	9.6E-02	2.2E-02	1.4E-04	1.6E-03	1.7E-03	1.6E-02
SRL-09-1		0.000															
SRL-09-2		0.000															
SRL-09-3		1.000	2.2E+04	-5.1E+03	10.	7.0E+06	2.8E+04	1.1E+03	8.0E-01	2.6E-01	2.4E-01	5.0E-02	2.0E-03	7.0E-04	8.8E-05	2.7E-04	2.8E-03
						1.6E+06	4.2E+04	3.4E+04	2.0E-01	1.1E-01	7.9E-02	9.6E-02	2.2E-02	1.4E-04	1.6E-03	1.7E-03	1.6E-02
SRL-10	1.2E-07		2.2E+04	-5.1E+03	10.	1.6E+07	2.8E+04	2.0E+03	8.6E-01	2.3E-01	2.2E-01	5.2E-02	5.1E-03	1.5E-03	2.6E-04	8.6E-04	7.2E-03
						1.5E+06	8.0E+04	6.9E+04	1.4E-01	8.9E-02	7.4E-02	5.5E-02	3.3E-03	1.2E-05	2.2E-04	2.4E-04	2.5E-03
SRL-10-1		0.000															
SRL-10-2		0.000															
SRL-10-3		1.000	2.2E+04	-5.1E+03	10.	1.6E+07	2.8E+04	2.0E+03	8.6E-01	2.3E-01	2.2E-01	5.2E-02	5.1E-03	1.5E-03	2.6E-04	8.6E-04	7.2E-03
						1.5E+06	8.0E+04	6.9E+04	1.4E-01	8.9E-02	7.4E-02	5.5E-02	3.3E-03	1.2E-05	2.2E-04	2.4E-04	2.5E-03
SRL-11	3.2E-08		2.2E+04	-5.1E+03	10.	9.3E+06	2.8E+04	2.2E+03	8.5E-01	4.0E-01	4.2E-01	5.0E-02	5.6E-03	1.1E-03	4.3E-04	2.1E-03	6.2E-03
						1.6E+06	3.5E+04	2.5E+04	1.5E-01	1.1E-01	1.1E-01	5.8E-01	5.9E-01	4.9E-02	1.0E-01	1.0E-01	5.6E-01
SRL-11-1		0.000															
SRL-11-2		0.000															

Table 3.4-12 (continued)

Source Term	Freq. (1/yr)	Cond. Prob.	Warn (s)	dEvac (s)	Elev (m)	Energy (W)	Start (s)	Dur (s)	Release Fractions								
									NG	I	Cs	Te	Sr	Ru	La	Ce	Ba
SRL-11-3		1.000	2.2E+04	-5.1E+03	10.	9.3E+06	2.8E+04	2.2E+03	8.5E-01	4.0E-01	4.2E-01	5.0E-02	5.6E-03	1.1E-03	4.3E-04	2.1E-03	6.2E-03
						1.6E+06	3.5E+04	2.5E+04	1.5E-01	1.1E-01	1.1E-01	5.8E-01	5.9E-01	4.9E-02	1.0E-01	1.0E-01	5.6E-01
SRL-12	7.5E-08		2.2E+04	-5.1E+03	10.	9.2E+06	2.8E+04	7.9E+02	8.2E-01	4.8E-01	4.7E-01	1.1E-01	6.4E-02	9.4E-03	5.5E-03	2.7E-02	6.5E-02
						1.6E+06	4.2E+04	3.4E+04	1.8E-01	1.6E-01	1.5E-01	4.0E-01	1.9E-01	4.9E-04	1.9E-02	2.0E-02	1.5E-01
SRL-12-1		0.000															
SRL-12-2		0.014	1.3E+04	-3.6E+03	10.	1.0E+06	2.0E+04	2.6E+03	9.2E-01	7.9E-01	7.4E-01	4.7E-01	1.4E-02	1.4E-02	6.9E-04	1.6E-03	2.2E-02
						0.0E+00	6.1E+05	6.1E+05	4.3E-02	3.8E-02	3.4E-02	2.2E-02	6.3E-04	6.4E-04	3.3E-05	7.8E-05	1.0E-03
SRL-12-3		0.986	2.2E+04	-5.1E+03	10.	9.3E+06	2.8E+04	7.6E+02	8.2E-01	4.8E-01	4.7E-01	1.1E-01	6.5E-02	9.3E-03	5.5E-03	2.7E-02	6.5E-02
						1.6E+06	3.4E+04	2.6E+04	1.8E-01	1.6E-01	1.6E-01	4.1E-01	1.9E-01	4.9E-04	1.9E-02	2.0E-02	1.5E-01
SRL-13	3.5E-07		2.2E+04	-5.1E+03	10.	2.5E+07	2.8E+04	7.0E+02	9.7E-01	6.6E-01	6.4E-01	1.4E-01	3.3E-03	2.0E-03	1.4E-04	3.2E-04	5.7E-03
						1.6E+06	3.6E+04	2.7E+04	2.5E-02	4.3E-02	3.6E-02	2.1E-01	6.9E-02	4.4E-04	6.9E-03	7.3E-03	5.5E-02
SRL-13-1		0.000															
SRL-13-2		0.030	1.3E+04	-3.6E+03	10.	1.0E+06	2.0E+04	2.7E+03	8.9E-01	6.1E-01	6.0E-01	3.5E-01	1.6E-02	8.7E-03	7.0E-04	2.1E-03	2.2E-02
						0.0E+00	2.1E+05	2.0E+05	5.3E-02	2.6E-02	2.2E-02	1.8E-02	1.5E-03	7.1E-04	7.8E-05	2.4E-04	2.0E-03
SRL-13-3		0.970	2.2E+04	-5.1E+03	10.	2.6E+07	2.8E+04	6.4E+02	9.8E-01	6.6E-01	6.4E-01	1.4E-01	2.9E-03	1.8E-03	1.2E-04	2.7E-04	5.2E-03
						1.6E+06	3.1E+04	2.2E+04	2.4E-02	4.3E-02	3.6E-02	2.2E-01	7.1E-02	4.3E-04	7.1E-03	7.5E-03	5.7E-02
SRL-14	1.1E-04		2.2E+04	1.4E+04	0.	8.8E+01	4.7E+04	1.2E+00	4.9E-05	1.6E-10	6.6E-11	1.1E-11	8.9E-13	2.4E-13	4.3E-14	1.4E-13	1.3E-12
						1.8E+02	4.7E+04	8.6E+04	6.9E-03	9.9E-05	4.7E-07	2.9E-07	6.3E-08	3.6E-09	6.5E-09	7.7E-09	5.4E-08
SRL-14-1		1.000	2.2E+04	1.4E+04	0.	8.8E+01	4.7E+04	1.2E+00	4.9E-05	1.6E-10	6.6E-11	1.1E-11	8.9E-13	2.4E-13	4.3E-14	1.4E-13	1.3E-12
						1.8E+02	4.7E+04	8.6E+04	6.9E-03	9.9E-05	4.7E-07	2.9E-07	6.3E-08	3.6E-09	6.5E-09	7.7E-09	5.4E-08
SRL-14-2		0.000															
SRL-14-3		0.000															
SRL-15	4.7E-05		2.2E+04	1.4E+04	10.	8.3E+02	4.7E+04	9.1E+01	9.4E-03	9.7E-06	7.7E-06	2.7E-06	2.3E-07	7.5E-08	1.1E-08	3.8E-08	3.1E-07
						6.8E+04	1.4E+05	1.9E+04	9.9E-01	2.5E-02	3.9E-05	7.4E-05	8.8E-06	1.9E-07	8.4E-07	9.1E-07	6.8E-06
SRL-15-1		0.987	2.2E+04	1.4E+04	10.	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
						6.7E+04	1.3E+05	1.1E+04	1.0E+00	2.5E-02	3.8E-05	7.3E-05	8.5E-06	1.8E-07	8.1E-07	8.8E-07	6.6E-06
SRL-15-2		0.000															
SRL-15-3		0.013	2.2E+04	-5.1E+03	10.	6.5E+04	2.8E+04	7.1E+03	7.4E-01	7.6E-04	6.0E-04	2.1E-04	1.8E-05	5.9E-06	8.8E-07	3.0E-06	2.4E-05
						1.8E+05	6.4E+05	6.3E+05	2.5E-01	2.0E-02	1.2E-04	1.1E-04	2.6E-05	1.0E-06	2.9E-06	3.3E-06	2.0E-05
SRL-16	2.5E-06		2.2E+04	6.7E+03	10.	1.8E+05	4.0E+04	2.7E+03	3.0E-01	8.0E-03	6.4E-03	2.3E-03	9.3E-05	4.1E-05	4.9E-06	1.6E-05	1.4E-04
						1.2E+08	2.6E+05	2.3E+05	6.8E-01	4.5E-02	1.1E-02	1.3E-02	5.3E-03	1.3E-04	5.2E-04	5.6E-04	4.2E-03
SRL-16-1		0.621	2.2E+04	1.4E+04	10.	0.0E+00	4.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
						1.9E+08	4.7E+04	3.2E+02	1.0E+00	5.6E-02	1.6E-02	2.0E-02	8.3E-03	2.0E-04	8.3E-04	8.9E-04	6.6E-03
SRL-16-2		0.016	1.3E+04	-3.6E+03	10.	1.0E+06	2.0E+04	2.0E+03	1.2E-01	2.5E-02	2.3E-02	3.0E-02	3.8E-04	3.1E-04	9.7E-06	1.8E-05	5.6E-04
						0.0E+00	2.9E+05	2.9E+05	1.6E-02	1.9E-03	1.7E-03	2.2E-03	2.8E-05	2.3E-05	7.3E-07	1.3E-06	4.1E-05
SRL-16-3		0.363	2.2E+04	-5.1E+03	10.	4.5E+05	2.8E+04	7.3E+03	8.2E-01	2.1E-02	1.7E-02	5.1E-03	2.4E-04	9.9E-05	1.3E-05	4.3E-05	3.6E-04
						5.4E+05	6.4E+05	6.3E+05	1.6E-01	2.8E-02	2.9E-03	2.4E-03	1.9E-04	1.3E-05	1.7E-05	2.1E-05	1.6E-04

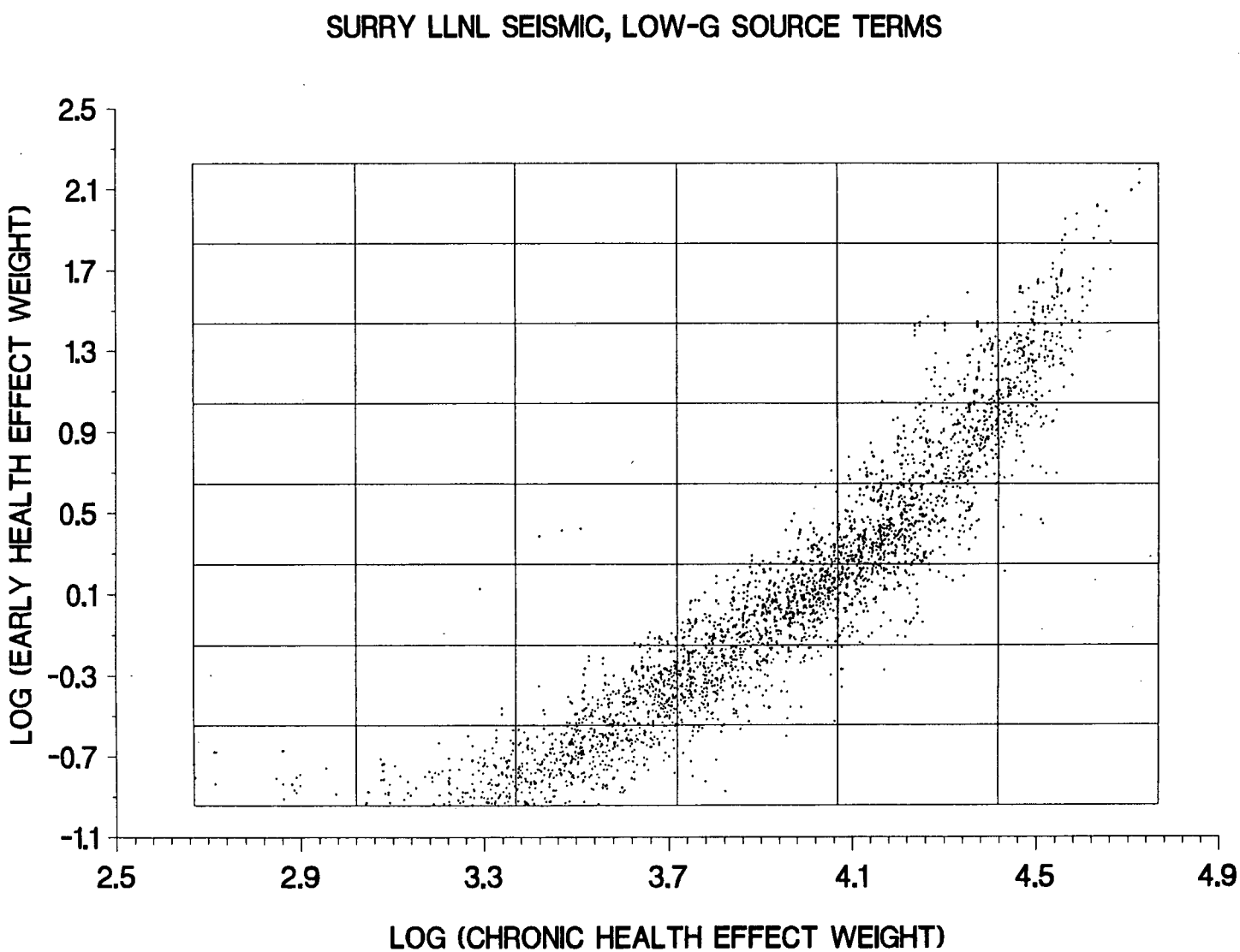


Figure 3.4-3. Partition Plot--Seismic LLNL Initiators

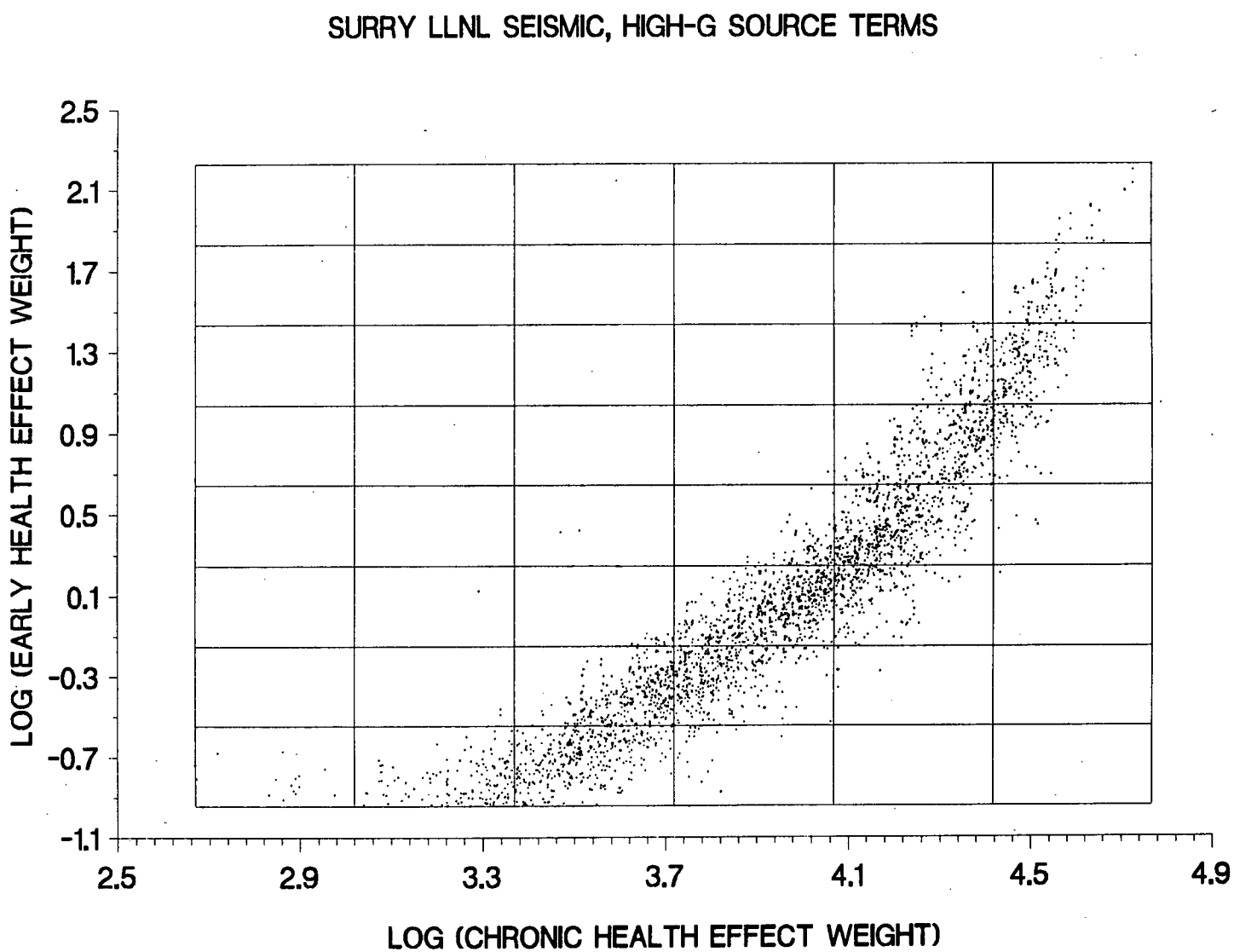


Figure 3.4-3. (continued)

3.4.4 Results for Seismic Initiators: EPRI Hazard Curve

This section presents the results of partitioning the source terms for seismic initiators based on the EPRI hazard distributions. The partitioning process, described in Section 3.4-1, does not result in the loss of any source terms; rather, cells with a small number of source terms or a small frequency are pooled with other cells. Because of differences in the evacuation of the surrounding population for large earthquakes, the accident progression, source term, and consequence analyses were performed separately for seisms with peak ground acceleration (PGA) over 0.6 g and for seisms with PGA less than 0.6 g. Thus, the partitioning of the high and low acceleration earthquakes was performed separately.

The accident progression analysis and the subsequent source term analysis for seismic initiators using the EPRI hazard distributions resulted in the generation of 11,400 source terms for high PGA and 11,774 source terms for low PGA. Table 3.4-13 shows the number of these source terms with EH>0 and CH>0 and the number with EH=0 and CH>0.

Table 3.4-13
Summary of Early and Chronic Health Effect Weights
for Seismic Initiators: EPRI Hazard Distributions

	Number of Source Terms	Percent of Total Frequency
PGA > 0.6 g		
EH>0 and CH>0	4072	12.31
EH=0 and CH>0	7328	87.69
EH=0 and CH=0	0	0.00
Total	11400	100.00
For EH>0 and CH>0, Range LOG10(CH) = 2.6697 to 4.7668		
Range LOG10(EH) = -0.9423 to 2.2303		
For EH=0 and CH>0, Range LOG10(CH) = -3.9650 to 3.9639		
PGA < 0.6 g		
EH>0 and CH>0	4162	5.03
EH=0 and CH>0	7612	94.97
EH=0 and CH=0	0	0.00
Total	11774	100.00
For EH>0 and CH>0, Range LOG10(CH) = 2.6697 to 4.7668		
Range LOG10(EH) = -0.9423 to 2.2359		
For EH=0 and CH>0, Range LOG10(CH) = -3.9650 to 3.9639		

Figure 3.4-4 shows plots of the pairs (CH, EH) for the source terms for both high and low acceleration for which both EH and CH are nonzero. A summary of the partitioning process for EH>0 and CH>0 is given in Table 3.4-14. Only the percent of the frequency contained in each cell after partitioning and the labeling after partitioning are shown. A summary of the partitioning process for the source terms for which EH=0 and CH>0 is given in Table 3.4-15.

The groups of source terms that result from partitioning are further subdivided on the basis of evacuation timing, using the same three subgroups as for internal initiators. Frequency-weighted mean source terms are calculated for each populated subgroup. The mean source terms obtained in this analysis are shown in Table 3.4-16. This table contains frequency-weighted mean source terms for both the source term groups and subgroups. SRE-I and SRE-I-J are used to label the mean source terms for EPRI high acceleration seisms derived from source term groups and subgroups, respectively, where I designates the source term group and J designates the source term subgroup. SRD-I and SRD-I-J are used similarly to label the mean source terms for EPRI low acceleration seisms. The risk calculations use only the subgroup source terms. Table 3.4-16 is analogous to Table 3.4-4 for internal initiators.

Table 3.4-14
Distribution of Source Terms with Nonzero Early Fatality and Chronic Fatality Weights for Seismic Initiators: EPRI Hazard Distributions

PGA > 0.6 g

PERCENT OF FREQUENCY CONTAINED IN EACH CELL AFTER PARTITIONING:

	1	2	3	4	5	6
1						0.35
2						4.43
3						4.26
4					7.24	2.67
5					12.40	
6				6.32	20.68	
7				11.25		
8			9.37	8.25		
9			12.79			

LABELING AFTER PARTITIONING:

	1	2	3	4	5	6
1						SRE-09
2						SRE-10
3						SRE-11
4					SRE-06	SRE-12
5					SRE-07	
6				SRE-03	SRE-08	
7				SRE-04		
8			SRE-01	SRE-05		
9			SRE-02			

Table 3.4-14 (continued)

PGA < 0.6 g

PERCENT OF FREQUENCY CONTAINED IN EACH CELL AFTER PARTITIONING:

	1	2	3	4	5	6
1						0.28
2						3.01
3						10.00
4					9.06	
5					9.15	
6				5.35	20.70	
7				11.68		
8			11.43	7.20		
9			12.13			

LABELING AFTER PARTITIONING:

	1	2	3	4	5	6
1						SRD-09
2						SRD-10
3						SRD-11
4					SRD-06	
5					SRD-07	
6				SRD-03	SRD-08	
7				SRD-04		
8			SRD-01	SRD-05		
9			SRD-02			

Table 3.4-15
Distribution of Source Terms with Zero Early Fatality Weight and Nonzero Chronic Fatality Weight for Seismic Initiators:
EPRI Hazard Distributions

PGA > 0.6 g

PERCENT OF FREQUENCY CONTAINED IN EACH CELL AFTER PARTITIONING:

	1	2	3	4	5	6	7	8
1			39.00	32.02		28.98		

LABELING AFTER PARTITIONING:

	1	2	3	4	5	6	7	8
1			SRE-13	SRE-14		SRE-15		

PGA < 0.6 g

PERCENT OF FREQUENCY CONTAINED IN EACH CELL AFTER PARTITIONING:

	1	2	3	4	5	6	7	8
1			40.16	33.12		26.72		

LABELING AFTER PARTITIONING:

	1	2	3	4	5	6	7	8
1			SRD-12	SRD-13		SRD-14		
	1	2	3	4	5	6	7	

Table 3.4-16
Mean Source Terms Resulting from Partitioning for Seismic Initiators
EPRI Hazard Distributions: High PGA (continued)

Source Term	Freq. (1/yr)	Cond. Prob.	Warn (s)	dEvac (s)	Elev (m)	Energy (W)	Start (s)	Dur (s)	Release Fractions								
									NG	I	Cs	Te	Sr	Ru	La	Ce	Ba
SRE-01	3.7E-08		2.2E+04	-4.6E+03	10.	1.7E+06	2.8E+04	1.3E+03	7.4E-01	8.2E-02	6.3E-02	1.2E-02	1.0E-03	3.0E-04	4.9E-05	1.8E-04	1.3E-03
						2.1E+07	4.2E+04	3.3E+04	2.6E-01	6.6E-02	2.9E-02	3.4E-02	3.7E-03	9.6E-05	2.7E-04	3.2E-04	2.8E-03
SRE-01-1		0.028	2.2E+04	1.4E+04	10.	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
						6.9E+08	4.7E+04	1.1E+02	1.0E+00	7.6E-02	4.9E-02	9.9E-02	4.2E-02	4.4E-04	3.8E-03	3.9E-03	2.8E-02
SRE-01-2		0.002	1.3E+04	-3.6E+03	10.	1.0E+06	2.0E+04	1.5E+03	6.1E-01	8.6E-02	7.2E-02	5.2E-02	1.3E-03	6.9E-04	6.1E-05	1.7E-04	2.0E-03
						0.0E+00	2.0E+05	1.9E+05	1.9E-01	4.0E-02	6.5E-03	3.7E-03	8.3E-05	2.2E-05	2.8E-06	7.8E-06	1.3E-04
SRE-01-3		0.970	2.2E+04	-5.1E+03	10.	1.7E+06	2.8E+04	1.3E+03	7.6E-01	8.4E-02	6.5E-02	1.3E-02	1.0E-03	3.1E-04	5.1E-05	1.8E-04	1.3E-03
						1.5E+06	4.1E+04	3.3E+04	2.4E-01	6.6E-02	2.8E-02	3.2E-02	2.6E-03	8.6E-05	1.7E-04	2.1E-04	2.1E-03
SRE-02	5.1E-08		2.2E+04	-1.5E+03	10.	1.3E+06	2.8E+04	2.5E+03	6.1E-01	3.6E-02	3.0E-02	4.8E-03	5.3E-04	1.3E-04	2.6E-05	9.9E-05	6.4E-04
						4.4E+06	9.4E+04	8.0E+04	3.8E-01	6.8E-02	2.9E-02	2.9E-02	4.3E-03	1.2E-05	3.6E-04	3.8E-04	3.1E-03
SRE-02-1		0.187	2.2E+04	1.4E+04	10.	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
						1.7E+07	4.7E+04	5.8E+03	1.0E+00	9.8E-02	4.9E-02	7.2E-02	2.0E-03	1.6E-05	1.1E-04	1.2E-04	1.3E-03
SRE-02-2		0.006	1.3E+04	-3.6E+03	10.	1.0E+06	2.0E+04	1.3E+03	6.9E-01	3.2E-02	2.5E-02	1.2E-02	3.0E-04	5.0E-05	1.0E-05	3.3E-05	4.4E-04
						0.0E+00	9.0E+04	8.2E+04	1.4E-01	2.8E-02	2.3E-03	1.0E-03	2.2E-05	2.5E-06	6.8E-07	1.9E-06	3.3E-05
SRE-02-3		0.807	2.2E+04	-5.1E+03	10.	1.3E+06	2.8E+04	2.5E+03	7.5E-01	4.4E-02	3.7E-02	5.9E-03	6.6E-04	1.7E-04	3.3E-05	1.2E-04	7.9E-04
						1.5E+06	1.1E+05	9.7E+04	2.4E-01	6.2E-02	2.5E-02	2.0E-02	4.8E-03	1.1E-05	4.2E-04	4.4E-04	3.5E-03
SRE-03	2.5E-08		2.2E+04	-4.4E+03	10.	2.3E+06	2.8E+04	1.6E+03	7.2E-01	1.3E-01	1.1E-01	4.0E-02	1.6E-02	2.5E-03	9.1E-04	3.9E-03	1.7E-02
						1.5E+06	6.7E+04	5.7E+04	2.8E-01	1.0E-01	7.5E-02	1.0E-01	3.3E-02	3.2E-03	3.8E-03	4.6E-03	2.7E-02
SRE-03-1		0.037	2.2E+04	1.4E+04	10.	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
						6.5E+05	4.7E+04	1.1E+04	1.0E+00	4.6E-02	2.9E-02	5.7E-01	3.9E-02	6.3E-02	7.2E-03	7.2E-03	3.7E-02
SRE-03-2		0.004	1.3E+04	-3.6E+03	10.	1.0E+06	2.0E+04	1.9E+03	6.3E-01	2.0E-01	2.0E-01	2.0E-01	4.5E-03	3.1E-03	1.7E-04	4.3E-04	6.5E-03
						0.0E+00	2.8E+04	2.3E+04	1.1E-01	2.5E-02	1.5E-02	1.5E-02	3.9E-04	2.4E-04	1.6E-05	4.3E-05	5.5E-04
SRE-03-3		0.959	2.2E+04	-5.1E+03	10.	2.3E+06	2.8E+04	1.6E+03	7.4E-01	1.3E-01	1.1E-01	4.1E-02	1.7E-02	2.6E-03	9.4E-04	4.1E-03	1.7E-02
						1.6E+06	6.8E+04	5.9E+04	2.6E-01	1.0E-01	7.7E-02	8.6E-02	3.3E-02	9.1E-04	3.7E-03	4.5E-03	2.6E-02
SRE-04	4.5E-08		2.2E+04	-9.8E+02	10.	4.5E+06	2.8E+04	2.5E+03	5.9E-01	9.1E-02	7.9E-02	1.4E-02	1.6E-03	6.8E-04	1.5E-04	3.6E-04	2.0E-03
						4.2E+07	6.1E+04	4.4E+04	4.1E-01	1.1E-01	7.2E-02	1.2E-01	1.3E-02	2.3E-04	1.1E-03	1.2E-03	9.5E-03
SRE-04-1		0.216	2.2E+04	1.4E+04	10.	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
						1.9E+08	4.7E+04	4.1E+03	1.0E+00	1.3E-01	1.1E-01	3.0E-01	1.8E-02	5.0E-04	1.7E-03	1.8E-03	1.3E-02
SRE-04-2		0.008	1.3E+04	-3.6E+03	10.	1.0E+06	2.0E+04	1.1E+03	6.9E-01	1.0E-01	9.9E-02	4.9E-02	1.5E-03	7.2E-04	7.0E-05	2.0E-04	2.0E-03
						0.0E+00	4.1E+04	3.2E+04	2.5E-01	3.3E-02	1.7E-02	3.7E-02	7.0E-04	8.0E-05	5.8E-05	7.6E-05	6.6E-04
SRE-04-3		0.776	2.2E+04	-5.1E+03	10.	4.6E+06	2.8E+04	2.6E+03	7.6E-01	1.2E-01	1.0E-01	1.8E-02	2.1E-03	8.6E-04	2.0E-04	4.6E-04	2.6E-03
						1.5E+06	6.5E+04	5.5E+04	2.4E-01	1.0E-01	6.2E-02	7.1E-02	1.1E-02	1.6E-04	9.1E-04	1.0E-03	8.7E-03
SRE-05	3.3E-08		2.2E+04	-5.1E+03	10.	1.0E+06	2.8E+04	2.9E+03	6.8E-01	9.2E-02	7.8E-02	2.5E-02	1.9E-03	5.6E-04	1.0E-04	4.2E-04	2.2E-03
						1.5E+06	9.9E+04	8.9E+04	3.1E-01	7.3E-02	4.5E-02	2.8E-02	2.6E-03	1.6E-04	1.9E-04	2.9E-04	2.1E-03
SRE-05-1		0.000															
SRE-05-2		0.005	1.3E+04	-3.6E+03	10.	1.0E+06	2.0E+04	2.2E+03	3.3E-01	1.1E-01	1.1E-01	9.9E-02	1.4E-03	1.2E-03	3.9E-05	7.0E-05	2.1E-03
						0.0E+00	4.3E+05	4.3E+05	2.2E-02	7.2E-03	7.3E-03	6.5E-03	9.1E-05	8.0E-05	2.5E-06	4.6E-06	1.3E-04

Table 3.4-16 (continued)

Source Term	Freq. (1/yr)	Cond. Prob.	Warn (s)	dEvac (s)	Elev (m)	Energy (W)	Start (s)	Dur (s)	Release Fractions NG	I	Cs	Te	Sr	Ru	La	Ce	Ba
SRE-05-3	0.995	2.2E+04		-5.1E+03	10.	1.0E+06	2.8E+04	2.9E+03	6.8E-01	9.2E-02	7.8E-02	2.4E-02	1.9E-03	5.6E-04	1.0E-04	4.2E-04	2.2E-03
						1.5E+06	9.8E+04	8.7E+04	3.1E-01	7.4E-02	4.5E-02	2.8E-02	2.6E-03	1.6E-04	1.9E-04	2.9E-04	2.1E-03
SRE-06	2.9E-08		2.2E+04	-5.1E+03	10.	5.9E+06	2.8E+04	1.4E+03	8.1E-01	3.0E-01	2.7E-01	1.4E-01	4.5E-02	9.0E-03	2.8E-03	1.3E-02	4.8E-02
						1.6E+06	3.4E+04	2.5E+04	1.9E-01	1.5E-01	1.4E-01	1.6E-01	4.8E-02	2.3E-03	4.1E-03	6.1E-03	3.7E-02
SRE-06-1		0.000															
SRE-06-2		0.000	1.3E+04	-3.6E+03	10.	1.0E+06	2.0E+04	1.0E+03	6.6E-01	3.6E-01	3.2E-01	3.2E-01	7.6E-03	7.9E-03	4.6E-04	1.1E-03	1.3E-02
						0.0E+00	2.1E+04	1.8E+04	1.1E-01	5.5E-02	4.6E-02	5.1E-02	4.6E-03	9.9E-04	3.9E-04	4.8E-04	4.1E-03
SRE-06-3		1.000	2.2E+04	-5.1E+03	10.	5.9E+06	2.8E+04	1.4E+03	8.1E-01	3.0E-01	2.7E-01	1.4E-01	4.5E-02	9.0E-03	2.8E-03	1.3E-02	4.8E-02
						1.6E+06	3.4E+04	2.5E+04	1.9E-01	1.5E-01	1.4E-01	1.6E-01	4.8E-02	2.3E-03	4.1E-03	6.1E-03	3.7E-02
SRE-07	4.9E-08		2.2E+04	-5.1E+03	10.	5.9E+06	2.8E+04	2.6E+03	8.3E-01	2.9E-01	2.8E-01	9.9E-02	4.3E-02	5.6E-03	2.0E-03	8.5E-03	4.4E-02
						1.6E+06	4.5E+04	3.4E+04	1.7E-01	1.1E-01	6.9E-02	9.9E-02	1.7E-02	9.7E-04	1.1E-03	2.3E-03	1.5E-02
SRE-07-1		0.000															
SRE-07-2		0.000	1.3E+04	-3.6E+03	10.	1.0E+06	2.0E+04	2.9E+03	8.0E-01	4.0E-01	3.2E-01	1.2E-01	1.9E-03	4.4E-04	4.0E-05	5.2E-05	3.2E-03
						0.0E+00	3.8E+05	3.7E+05	5.4E-02	2.0E-02	1.2E-02	7.5E-03	1.5E-04	1.7E-05	4.9E-06	4.1E-06	1.8E-04
SRE-07-3		1.000	2.2E+04	-5.1E+03	10.	5.9E+06	2.8E+04	2.6E+03	8.3E-01	2.9E-01	2.8E-01	9.9E-02	4.3E-02	5.6E-03	2.0E-03	8.5E-03	4.4E-02
						1.6E+06	4.5E+04	3.4E+04	1.7E-01	1.1E-01	6.9E-02	9.9E-02	1.7E-02	9.7E-04	1.1E-03	2.3E-03	1.5E-02
SRE-08	8.2E-08		2.2E+04	-5.1E+03	10.	6.2E+06	2.8E+04	1.6E+03	7.6E-01	2.8E-01	2.7E-01	2.3E-02	9.5E-04	3.9E-04	3.9E-05	1.2E-04	1.4E-03
						1.6E+06	4.0E+04	3.1E+04	2.4E-01	1.3E-01	1.1E-01	1.1E-01	3.3E-03	7.1E-05	2.6E-04	2.8E-04	2.7E-03
SRE-08-1		0.000															
SRE-08-2		0.000															
SRE-08-3		1.000	2.2E+04	-5.1E+03	10.	6.2E+06	2.8E+04	1.6E+03	7.6E-01	2.8E-01	2.7E-01	2.3E-02	9.5E-04	3.9E-04	3.9E-05	1.2E-04	1.4E-03
						1.6E+06	4.0E+04	3.1E+04	2.4E-01	1.3E-01	1.1E-01	1.1E-01	3.3E-03	7.1E-05	2.6E-04	2.8E-04	2.7E-03
SRE-09	1.4E-09		2.2E+04	-5.1E+03	10.	4.0E+06	2.8E+04	1.6E+03	7.9E-01	3.1E-01	3.4E-01	4.0E-02	1.2E-03	5.2E-04	4.9E-05	1.5E-04	1.8E-03
						1.6E+06	3.0E+04	2.2E+04	2.1E-01	1.2E-01	1.2E-01	5.9E-01	6.7E-01	6.2E-02	1.2E-01	1.2E-01	6.4E-01
SRE-09-1		0.000															
SRE-09-2		0.001	1.3E+04	-3.6E+03	10.	1.0E+06	2.0E+04	3.1E+03	9.4E-01	8.0E-01	7.3E-01	7.8E-01	3.5E-01	6.3E-02	1.5E-02	5.8E-02	3.7E-01
						0.0E+00	7.2E+04	6.5E+04	2.5E-02	2.0E-02	1.8E-02	1.9E-02	8.9E-03	1.5E-03	3.9E-04	1.6E-03	9.3E-03
SRE-09-3		0.999	2.2E+04	-5.1E+03	10.	4.0E+06	2.8E+04	1.6E+03	7.9E-01	3.1E-01	3.4E-01	3.9E-02	9.0E-04	4.7E-04	3.6E-05	1.0E-04	1.4E-03
						1.6E+06	3.0E+04	2.2E+04	2.1E-01	1.2E-01	1.2E-01	5.9E-01	6.7E-01	6.2E-02	1.2E-01	1.2E-01	6.4E-01
SRE-10	1.8E-08		2.2E+04	-5.1E+03	10.	1.1E+07	2.8E+04	4.6E+02	9.2E-01	5.7E-01	5.7E-01	3.0E-01	1.6E-01	2.0E-02	7.7E-03	3.3E-02	1.6E-01
						1.1E+06	2.2E+05	2.1E+05	8.5E-02	8.1E-02	7.1E-02	2.3E-01	1.1E-01	1.5E-04	1.1E-02	1.2E-02	8.8E-02
SRE-10-1		0.000															
SRE-10-2		0.000	1.3E+04	-3.6E+03	10.	1.0E+06	2.0E+04	2.3E+03	9.0E-01	7.4E-01	6.9E-01	4.6E-01	2.8E-02	1.7E-02	2.4E-03	1.7E-02	3.5E-02
						0.0E+00	5.0E+05	4.9E+05	6.9E-02	5.1E-02	4.6E-02	2.8E-02	2.6E-03	1.2E-03	2.5E-04	2.0E-03	3.0E-03
SRE-10-3		1.000	2.2E+04	-5.1E+03	10.	1.1E+07	2.8E+04	4.6E+02	9.2E-01	5.7E-01	5.7E-01	3.0E-01	1.6E-01	2.0E-02	7.7E-03	3.3E-02	1.6E-01
						1.1E+06	2.2E+05	2.1E+05	8.5E-02	8.1E-02	7.1E-02	2.3E-01	1.1E-01	1.5E-04	1.1E-02	1.2E-02	8.8E-02

Table 3.4-16 (continued)

Source Term	Freq. (1/yr)	Cond. Prob.	Warn (s)	dEvac (s)	Elev (m)	Energy (W)	Start (s)	Dur (s)	Release Fractions								
									NG	I	Cs	Te	Sr	Ru	La	Ce	Ba
SRE-11	1.7E-08		2.2E+04	-5.1E+03	10.	7.1E+06	2.8E+04	1.8E+03	8.2E-01	4.1E-01	4.5E-01	4.7E-02	4.6E-03	1.7E-03	3.3E-04	1.4E-03	5.5E-03
						1.5E+06	4.8E+04	3.9E+04	1.8E-01	9.0E-02	8.8E-02	3.9E-01	1.9E-01	1.0E-03	2.4E-02	2.4E-02	1.5E-01
SRE-11-1		0.000															
SRE-11-2		0.007	1.3E+04	-3.6E+03	10.	1.0E+06	2.0E+04	1.4E+03	7.6E-01	3.5E-01	3.3E-01	3.4E-01	1.1E-01	3.1E-02	1.1E-02	9.4E-02	1.1E-01
						0.0E+00	5.8E+04	5.2E+04	1.7E-01	4.0E-02	3.2E-02	3.5E-02	1.2E-02	3.6E-03	1.3E-03	1.1E-02	1.3E-02
SRE-11-3		0.993	2.2E+04	-5.1E+03	10.	7.1E+06	2.8E+04	1.8E+03	8.2E-01	4.1E-01	4.5E-01	4.5E-02	3.9E-03	1.5E-03	2.5E-04	7.8E-04	4.8E-03
						1.6E+06	4.8E+04	3.9E+04	1.8E-01	9.0E-02	8.9E-02	3.9E-01	1.9E-01	1.0E-03	2.4E-02	2.4E-02	1.5E-01
SRE-12	1.1E-08		2.2E+04	-5.1E+03	10.	2.0E+07	2.8E+04	1.3E+03	9.0E-01	5.7E-01	5.7E-01	7.8E-02	1.7E-03	1.2E-03	4.3E-05	8.3E-05	2.5E-03
						1.6E+06	3.2E+04	2.2E+04	1.0E-01	9.7E-02	8.6E-02	2.0E-01	1.5E-02	2.4E-04	1.1E-03	1.1E-03	1.0E-02
SRE-12-1		0.000															
SRE-12-2		0.000	1.3E+04	-3.6E+03	10.	1.0E+06	2.0E+04	3.6E+03	8.1E-01	5.7E-01	5.3E-01	3.8E-01	8.6E-03	7.8E-03	3.0E-04	6.0E-04	1.3E-02
						0.0E+00	6.0E+05	5.9E+05	2.8E-04	3.6E-05	4.7E-09	1.1E-07	5.0E-08	4.0E-12	3.2E-09	3.3E-09	3.0E-08
SRE-12-3		1.000	2.2E+04	-5.1E+03	10.	2.0E+07	2.8E+04	1.3E+03	9.0E-01	5.7E-01	5.7E-01	7.7E-02	1.7E-03	1.2E-03	4.3E-05	8.3E-05	2.5E-03
						1.6E+06	3.2E+04	2.2E+04	1.0E-01	9.7E-02	8.6E-02	2.0E-01	1.5E-02	2.4E-04	1.1E-03	1.1E-03	1.0E-02
SRE-13	1.1E-06		2.2E+04	1.4E+04	0.	5.2E+04	2.8E+04	1.1E+04	1.0E-04	9.1E-10	3.4E-10	2.9E-11	3.5E-13	3.6E-18	3.6E-18	3.6E-18	6.6E-13
						1.0E+02	4.8E+04	8.7E+04	5.0E-03	3.4E-05	2.3E-07	1.5E-07	4.7E-08	3.4E-09	4.8E-09	6.7E-09	3.9E-08
SRE-13-1		0.999	2.2E+04	1.4E+04	0.	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
						0.0E+00	4.7E+04	8.6E+04	4.5E-03	3.4E-05	2.3E-07	1.5E-07	4.7E-08	3.4E-09	4.8E-09	6.7E-09	3.9E-08
SRE-13-2		0.000															
SRE-13-3		0.001	2.2E+04	-5.1E+03	10.	5.2E+04	2.8E+04	1.1E+04	1.5E-01	1.4E-06	5.2E-07	4.5E-08	5.3E-10	5.5E-15	5.5E-15	5.5E-15	1.0E-09
						1.6E+05	1.0E+06	1.0E+06	8.4E-01	5.4E-06	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
SRE-14	9.0E-07		2.2E+04	1.3E+04	2.	1.9E+05	2.8E+04	1.0E+04	5.1E-03	4.1E-07	3.0E-07	4.4E-08	7.2E-10	7.2E-11	1.3E-11	4.3E-11	1.3E-09
						1.4E+04	8.0E+04	9.4E+04	1.7E-01	5.5E-04	3.5E-06	3.3E-06	1.1E-06	7.2E-09	8.9E-08	9.5E-08	7.2E-07
SRE-14-1		0.979	2.2E+04	1.4E+04	2.	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
						9.8E+03	6.0E+04	7.5E+04	1.6E-01	4.8E-04	3.5E-06	3.3E-06	1.1E-06	7.4E-09	9.1E-08	9.7E-08	7.4E-07
SRE-14-2		0.000															
SRE-14-3		0.021	2.2E+04	-5.1E+03	10.	1.9E+05	2.8E+04	1.0E+04	2.4E-01	1.9E-05	1.4E-05	2.1E-06	3.4E-08	3.4E-09	6.1E-10	2.0E-09	6.1E-08
						2.2E+05	9.7E+05	9.7E+05	7.4E-01	3.8E-03	4.4E-06	3.1E-06	1.4E-08	7.5E-14	4.4E-10	7.0E-10	1.0E-08
SRE-15	8.2E-07		2.2E+04	9.7E+03	10.	3.1E+05	2.8E+04	5.8E+03	1.6E-01	1.8E-03	1.4E-03	5.1E-04	1.8E-04	2.6E-05	9.3E-06	4.2E-05	1.8E-04
						2.7E+06	2.1E+05	1.2E+05	8.3E-01	3.8E-02	1.2E-03	1.4E-03	1.4E-04	1.1E-05	1.2E-05	2.0E-05	1.2E-04
SRE-15-1		0.777	2.2E+04	1.4E+04	10.	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
						3.4E+06	1.3E+05	1.0E+04	1.0E+00	3.7E-02	5.7E-04	1.1E-03	8.5E-05	9.6E-06	8.7E-06	1.3E-05	7.3E-05
SRE-15-2		0.001	1.3E+04	-3.6E+03	10.	1.0E+06	2.0E+04	1.9E+03	1.5E-01	1.6E-02	1.2E-02	4.8E-03	4.2E-05	8.0E-06	4.5E-07	6.9E-07	6.9E-05
						0.0E+00	5.1E+04	4.9E+04	1.8E-02	3.9E-03	9.0E-04	3.9E-04	4.8E-06	8.0E-07	1.6E-07	2.0E-07	6.9E-06
SRE-15-3		0.222	2.2E+04	-5.1E+03	10.	3.0E+05	2.8E+04	5.8E+03	7.3E-01	8.1E-03	6.5E-03	2.3E-03	8.1E-04	1.2E-04	4.2E-05	1.9E-04	8.3E-04
						4.5E+05	5.0E+05	4.9E+05	2.5E-01	4.2E-02	3.4E-03	2.3E-03	3.4E-04	1.6E-05	2.3E-05	4.6E-05	2.8E-04

Table 3.4-16 (continued)

Source Term	Freq. (1/yr)	Cond. Prob.	Warn (s)	dEvac (s)	Elev (m)	Energy (W)	Start (s)	Dur (s)	Release Fractions NG	I	Cs	Te	Sr	Ru	La	Ce	Ba
SRD-01	1.4E-07		2.2E+04	-4.0E+03	10.	1.3E+06	2.8E+04	1.1E+03	7.1E-01	7.0E-02	5.9E-02	7.8E-03	5.5E-04	1.9E-04	3.0E-05	9.9E-05	7.0E-04
						4.2E+07	3.7E+04	2.7E+04	2.9E-01	6.2E-02	2.9E-02	4.1E-02	4.2E-03	7.8E-05	3.5E-04	3.8E-04	3.1E-03
SRD-01-1		0.058	2.2E+04	1.4E+04	10.	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
						7.0E+08	4.7E+04	5.4E+01	1.0E+00	7.6E-02	4.9E-02	9.9E-02	4.2E-02	4.4E-04	3.8E-03	4.0E-03	2.8E-02
SRD-01-2		0.005	1.3E+04	-3.6E+03	10.	1.0E+06	2.0E+04	2.2E+03	5.4E-01	9.7E-02	8.3E-02	6.7E-02	1.9E-03	1.0E-03	9.5E-05	2.7E-04	2.8E-03
						0.0E+00	4.4E+05	4.4E+05	1.2E-01	2.4E-02	4.3E-03	2.7E-03	8.0E-05	2.6E-05	3.3E-06	9.8E-06	1.2E-04
SRD-01-3		0.937	2.2E+04	-5.1E+03	10.	1.3E+06	2.8E+04	1.1E+03	7.5E-01	7.5E-02	6.3E-02	7.9E-03	5.7E-04	2.0E-04	3.2E-05	1.0E-04	7.3E-04
						1.6E+06	3.4E+04	2.7E+04	2.5E-01	6.1E-02	2.8E-02	3.8E-02	2.0E-03	5.6E-05	1.3E-04	1.6E-04	1.6E-03
SRD-02	1.5E-07		2.2E+04	2.8E+03	10.	1.5E+06	2.8E+04	2.2E+03	4.4E-01	2.5E-02	2.1E-02	3.2E-03	3.2E-04	8.4E-05	1.7E-05	5.9E-05	3.9E-04
						8.2E+06	7.3E+04	5.1E+04	5.6E-01	7.5E-02	3.4E-02	4.1E-02	3.7E-03	1.4E-05	2.9E-04	3.1E-04	2.6E-03
SRD-02-1		0.415	2.2E+04	1.4E+04	10.	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
						1.8E+07	4.7E+04	5.6E+03	1.0E+00	9.6E-02	5.0E-02	7.3E-02	2.1E-03	1.6E-05	1.1E-04	1.2E-04	1.4E-03
SRD-02-2		0.018	1.3E+04	-3.6E+03	10.	1.0E+06	2.0E+04	1.4E+03	6.9E-01	3.2E-02	2.5E-02	1.2E-02	4.3E-04	7.7E-05	1.7E-05	5.7E-05	6.0E-04
						0.0E+00	1.1E+05	1.0E+05	1.4E-01	2.8E-02	2.1E-03	9.9E-04	2.7E-05	4.0E-06	9.9E-07	3.1E-06	3.9E-05
SRD-02-3		0.568	2.2E+04	-5.1E+03	10.	1.6E+06	2.8E+04	2.2E+03	7.5E-01	4.4E-02	3.7E-02	5.2E-03	5.4E-04	1.5E-04	2.9E-05	1.0E-04	6.6E-04
						1.5E+06	9.1E+04	8.3E+04	2.4E-01	6.1E-02	2.4E-02	2.0E-02	5.0E-03	1.2E-05	4.3E-04	4.6E-04	3.6E-03
SRD-03	6.8E-08		2.2E+04	-2.9E+03	10.	2.2E+06	2.8E+04	1.5E+03	6.6E-01	1.2E-01	1.0E-01	3.9E-02	1.5E-02	2.4E-03	8.5E-04	3.7E-03	1.6E-02
						1.4E+06	6.1E+04	5.0E+04	3.3E-01	9.4E-02	6.9E-02	1.4E-01	3.1E-02	7.9E-03	3.7E-03	4.5E-03	2.6E-02
SRD-03-1		0.113	2.2E+04	1.4E+04	10.	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
						6.5E+05	4.7E+04	1.1E+04	1.0E+00	4.4E-02	2.7E-02	5.7E-01	3.9E-02	6.3E-02	7.2E-03	7.2E-03	3.7E-02
SRD-03-2		0.020	1.3E+04	-3.6E+03	10.	1.0E+06	2.0E+04	2.2E+03	5.8E-01	2.0E-01	1.9E-01	2.1E-01	5.7E-03	3.8E-03	2.5E-04	6.8E-04	8.2E-03
						0.0E+00	2.6E+05	2.5E+05	8.4E-02	2.0E-02	1.2E-02	1.3E-02	3.2E-04	2.1E-04	1.4E-05	3.6E-05	4.7E-04
SRD-03-3		0.867	2.2E+04	-5.1E+03	10.	2.2E+06	2.8E+04	1.5E+03	7.5E-01	1.4E-01	1.1E-01	4.1E-02	1.7E-02	2.7E-03	9.8E-04	4.2E-03	1.8E-02
						1.6E+06	5.9E+04	5.1E+04	2.5E-01	1.0E-01	7.6E-02	8.8E-02	3.1E-02	9.2E-04	3.3E-03	4.3E-03	2.5E-02
SRD-04	1.5E-07		2.2E+04	2.1E+03	10.	7.6E+06	2.8E+04	1.9E+03	4.9E-01	7.2E-02	6.3E-02	1.3E-02	2.4E-03	2.1E-03	6.0E-04	7.3E-04	3.0E-03
						9.2E+07	5.3E+04	3.1E+04	5.1E-01	1.1E-01	7.6E-02	1.5E-01	1.5E-02	2.7E-04	1.4E-03	1.5E-03	1.1E-02
SRD-04-1		0.375	2.2E+04	1.4E+04	10.	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
						2.4E+08	4.7E+04	3.4E+03	1.0E+00	1.3E-01	1.1E-01	2.8E-01	2.1E-02	4.7E-04	1.9E-03	2.0E-03	1.4E-02
SRD-04-2		0.027	1.3E+04	-3.6E+03	10.	1.0E+06	2.0E+04	1.5E+03	6.5E-01	1.1E-01	1.0E-01	6.7E-02	1.8E-03	1.1E-03	9.0E-05	2.5E-04	2.6E-03
						0.0E+00	1.5E+05	1.4E+05	2.1E-01	2.7E-02	1.5E-02	2.9E-02	5.2E-04	7.2E-05	4.3E-05	5.5E-05	5.0E-04
SRD-04-3		0.598	2.2E+04	-5.1E+03	10.	7.9E+06	2.8E+04	1.9E+03	7.9E-01	1.2E-01	1.0E-01	1.8E-02	4.0E-03	3.5E-03	9.9E-04	1.2E-03	4.9E-03
						1.5E+06	5.3E+04	4.3E+04	2.1E-01	9.5E-02	5.6E-02	6.7E-02	1.3E-02	1.6E-04	1.1E-03	1.2E-03	9.7E-03
SRD-05	9.1E-08		2.2E+04	-5.1E+03	10.	1.2E+06	2.8E+04	2.1E+03	7.1E-01	9.2E-02	8.2E-02	2.4E-02	1.8E-03	5.6E-04	1.0E-04	4.0E-04	2.0E-03
						1.5E+06	1.1E+05	1.0E+05	2.7E-01	6.8E-02	4.2E-02	2.5E-02	2.4E-03	1.6E-04	2.2E-04	3.1E-04	2.0E-03
SRD-05-1		0.000															
SRD-05-2		0.018	1.3E+04	-3.6E+03	10.	1.0E+06	2.0E+04	1.8E+03	3.2E-01	1.1E-01	1.1E-01	9.8E-02	1.4E-03	1.2E-03	3.8E-05	6.9E-05	2.0E-03
						0.0E+00	3.1E+05	3.1E+05	2.8E-02	9.0E-03	9.2E-03	8.2E-03	1.1E-04	1.0E-04	3.2E-06	5.8E-06	1.7E-04

Table 3.4-16 (continued)

Source Term	Freq. (1/yr)	Cond. Prob.	Warn (s)	dEvac (s)	Elev (m)	Energy (W)	Start (s)	Dur (s)	Release Fractions NG	I	Cs	Te	Sr	Ru	La	Ce	Ba
SRD-05-3		0.982	2.2E+04	-5.1E+03	10.	1.2E+06	2.8E+04	2.1E+03	7.2E-01	9.2E-02	8.1E-02	2.3E-02	1.8E-03	5.5E-04	1.1E-04	4.1E-04	2.0E-03
						1.5E+06	1.1E+05	9.8E+04	2.8E-01	6.9E-02	4.3E-02	2.6E-02	2.5E-03	1.6E-04	2.2E-04	3.2E-04	2.0E-03
SRD-06	1.1E-07		2.2E+04	-5.1E+03	10.	1.2E+07	2.8E+04	1.1E+03	8.5E-01	3.5E-01	3.2E-01	1.2E-01	4.0E-02	7.4E-03	2.5E-03	1.1E-02	4.3E-02
						1.6E+06	3.1E+04	2.3E+04	1.5E-01	1.5E-01	1.5E-01	1.8E-01	3.6E-02	1.6E-03	3.0E-03	4.4E-03	2.7E-02
SRD-06-1		0.000															
SRD-06-2		0.000	1.3E+04	-3.6E+03	10.	1.0E+06	2.0E+04	1.1E+03	6.5E-01	3.5E-01	3.1E-01	3.4E-01	1.4E-02	9.0E-03	8.8E-04	3.0E-03	1.9E-02
						0.0E+00	5.6E+04	5.4E+04	1.0E-01	4.8E-02	4.0E-02	4.4E-02	2.3E-03	1.0E-03	1.8E-04	2.7E-04	2.5E-03
SRD-06-3		1.000	2.2E+04	-5.1E+03	10.	1.2E+07	2.8E+04	1.1E+03	8.5E-01	3.5E-01	3.2E-01	1.2E-01	4.0E-02	7.4E-03	2.5E-03	1.1E-02	4.3E-02
						1.6E+06	3.1E+04	2.3E+04	1.5E-01	1.5E-01	1.5E-01	1.8E-01	3.6E-02	1.6E-03	3.0E-03	4.4E-03	2.7E-02
SRD-07	1.2E-07		2.2E+04	-5.1E+03	10.	8.2E+06	2.8E+04	2.1E+03	8.3E-01	3.1E-01	3.1E-01	8.7E-02	3.7E-02	5.1E-03	1.8E-03	7.3E-03	3.7E-02
						1.6E+06	4.0E+04	3.0E+04	1.7E-01	1.0E-01	6.8E-02	1.1E-01	1.7E-02	8.8E-04	1.3E-03	2.3E-03	1.5E-02
SRD-07-1		0.000															
SRD-07-2		0.001	1.3E+04	-3.6E+03	10.	1.0E+06	2.0E+04	2.9E+03	8.0E-01	3.9E-01	3.3E-01	1.3E-01	2.1E-03	5.3E-04	6.0E-05	1.6E-04	3.4E-03
						0.0E+00	2.3E+05	2.2E+05	7.9E-02	2.4E-02	1.5E-02	1.1E-02	1.9E-04	1.9E-05	7.5E-06	4.9E-06	2.2E-04
SRD-07-3		0.999	2.2E+04	-5.1E+03	10.	8.3E+06	2.8E+04	2.1E+03	8.3E-01	3.1E-01	3.1E-01	8.7E-02	3.7E-02	5.1E-03	1.8E-03	7.3E-03	3.7E-02
						1.6E+06	4.0E+04	3.0E+04	1.7E-01	1.0E-01	6.8E-02	1.1E-01	1.7E-02	8.8E-04	1.3E-03	2.3E-03	1.5E-02
SRD-08	2.6E-07		2.2E+04	-5.1E+03	10.	1.2E+07	2.8E+04	1.0E+03	8.0E-01	3.2E-01	2.9E-01	3.3E-02	1.2E-03	4.4E-04	4.3E-05	1.2E-04	1.7E-03
						1.6E+06	3.5E+04	2.6E+04	2.0E-01	1.0E-01	8.5E-02	9.2E-02	3.0E-03	5.8E-05	2.3E-04	2.5E-04	2.5E-03
SRD-08-1		0.000															
SRD-08-2		0.000	1.3E+04	-3.6E+03	10.	1.0E+06	2.0E+04	3.6E+03	8.1E-01	3.2E-01	3.2E-01	1.2E-01	1.6E-03	4.4E-04	2.3E-05	3.0E-05	2.5E-03
						0.0E+00	2.6E+04	2.0E+02	1.9E-01	3.0E-02	1.8E-02	2.4E-02	1.9E-04	6.4E-10	1.7E-05	1.3E-07	2.2E-04
SRD-08-3		1.000	2.2E+04	-5.1E+03	10.	1.2E+07	2.8E+04	1.0E+03	8.0E-01	3.2E-01	2.9E-01	3.3E-02	1.2E-03	4.4E-04	4.3E-05	1.2E-04	1.7E-03
						1.6E+06	3.5E+04	2.6E+04	2.0E-01	1.0E-01	8.5E-02	9.2E-02	3.0E-03	5.8E-05	2.3E-04	2.5E-04	2.5E-03
SRD-09	3.5E-09		2.2E+04	-5.1E+03	10.	4.0E+06	2.8E+04	1.4E+03	7.8E-01	3.2E-01	3.4E-01	4.2E-02	2.3E-03	7.0E-04	9.7E-05	3.5E-04	2.9E-03
						1.6E+06	3.0E+04	2.2E+04	2.2E-01	1.1E-01	1.1E-01	5.9E-01	6.7E-01	6.2E-02	1.2E-01	1.2E-01	6.4E-01
SRD-09-1		0.000															
SRD-09-2		0.004	1.3E+04	-3.6E+03	10.	1.0E+06	2.0E+04	2.9E+03	9.3E-01	8.0E-01	7.3E-01	7.8E-01	3.6E-01	6.3E-02	1.6E-02	6.3E-02	3.8E-01
						0.0E+00	4.7E+04	4.0E+04	3.1E-02	2.6E-02	2.4E-02	2.4E-02	1.3E-02	2.0E-03	6.0E-04	2.5E-03	1.3E-02
SRD-09-3		0.996	2.2E+04	-5.1E+03	10.	4.0E+06	2.8E+04	1.4E+03	7.8E-01	3.1E-01	3.4E-01	3.9E-02	9.2E-04	4.7E-04	3.8E-05	1.1E-04	1.5E-03
						1.6E+06	3.0E+04	2.2E+04	2.2E-01	1.1E-01	1.1E-01	5.9E-01	6.7E-01	6.2E-02	1.2E-01	1.2E-01	6.4E-01
SRD-10	3.8E-08		2.2E+04	-5.1E+03	10.	1.1E+07	2.8E+04	5.3E+02	8.9E-01	5.6E-01	5.6E-01	2.5E-01	1.2E-01	1.6E-02	6.0E-03	2.6E-02	1.2E-01
						1.3E+06	1.6E+05	1.5E+05	1.1E-01	9.5E-02	8.7E-02	2.9E-01	1.4E-01	1.8E-04	1.4E-02	1.5E-02	1.1E-01
SRD-10-1		0.000															
SRD-10-2		0.000	1.3E+04	-3.6E+03	10.	1.0E+06	2.0E+04	2.2E+03	9.0E-01	7.6E-01	7.1E-01	4.6E-01	2.0E-02	1.5E-02	1.4E-03	8.2E-03	2.7E-02
						0.0E+00	4.7E+05	4.7E+05	6.4E-02	5.3E-02	4.7E-02	2.9E-02	1.6E-03	1.0E-03	1.4E-04	9.3E-04	2.1E-03

Table 3.4-16 (continued)

Source Term	Freq. (1/yr)	Cond. Prob.	Warn (s)	dEvac (s)	Elev (m)	Energy (W)	Start (s)	Dur (s)	Release Fractions NG	I	Cs	Te	Sr	Ru	La	Ce	Ba
SRD-10-3	1.000		2.2E+04	-5.1E+03	10.	1.1E+07	2.8E+04	5.3E+02	8.9E-01	5.6E-01	5.6E-01	2.5E-01	1.2E-01	1.6E-02	6.0E-03	2.6E-02	1.2E-01
						1.3E+06	1.6E+05	1.5E+05	1.1E-01	9.5E-02	8.7E-02	2.9E-01	1.4E-01	1.8E-04	1.4E-02	1.5E-02	1.1E-01
SRD-11	1.3E-07		2.2E+04	-5.1E+03	10.	3.0E+06	2.8E+04	1.7E+03	7.7E-01	3.5E-01	4.0E-01	2.2E-02	2.1E-03	9.2E-04	2.2E-04	9.8E-04	2.5E-03
						1.6E+06	3.5E+04	2.7E+04	2.3E-01	1.0E-01	1.1E-01	4.2E-01	2.2E-01	1.1E-03	2.8E-02	2.8E-02	1.7E-01
SRD-11-1		0.000															
SRD-11-2		0.013	1.3E+04	-3.6E+03	10.	1.0E+06	2.0E+04	1.9E+03	7.8E-01	4.6E-01	4.3E-01	3.5E-01	6.3E-02	2.0E-02	6.1E-03	5.0E-02	6.8E-02
						0.0E+00	1.9E+05	1.8E+05	1.1E-01	3.6E-02	3.0E-02	2.8E-02	6.6E-03	2.1E-03	6.9E-04	5.7E-03	7.0E-03
SRD-11-3		0.987	2.2E+04	-5.1E+03	10.	3.0E+06	2.8E+04	1.7E+03	7.7E-01	3.5E-01	4.0E-01	1.8E-02	1.4E-03	6.8E-04	1.5E-04	3.6E-04	1.7E-03
						1.6E+06	3.3E+04	2.5E+04	2.3E-01	1.1E-01	1.1E-01	4.3E-01	2.3E-01	1.1E-03	2.8E-02	2.8E-02	1.7E-01
SRD-12	9.6E-06		2.2E+04	1.4E+04	0.	5.2E+04	2.8E+04	1.1E+04	1.7E-05	1.5E-10	5.6E-11	4.8E-12	5.8E-14	5.9E-19	5.9E-19	5.9E-19	1.1E-13
						1.7E+01	4.7E+04	8.6E+04	4.6E-03	3.7E-05	2.4E-07	1.6E-07	4.5E-08	3.2E-09	4.6E-09	6.4E-09	3.8E-08
SRD-12-1		1.000	2.2E+04	1.4E+04	0.	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
						0.0E+00	4.7E+04	8.6E+04	4.5E-03	3.7E-05	2.4E-07	1.6E-07	4.5E-08	3.2E-09	4.6E-09	6.4E-09	3.8E-08
SRD-12-2		0.000															
SRD-12-3		0.000	2.2E+04	-5.1E+03	10.	5.2E+04	2.8E+04	1.1E+04	1.5E-01	1.4E-06	5.2E-07	4.5E-08	5.3E-10	5.5E-15	5.5E-15	5.5E-15	1.0E-09
						1.6E+05	1.0E+06	1.0E+06	8.4E-01	5.4E-06	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
SRD-13	7.9E-06		2.2E+04	1.4E+04	2.	2.3E+05	2.8E+04	1.1E+04	8.8E-04	7.2E-08	5.3E-08	8.0E-09	1.4E-10	1.6E-11	3.1E-12	1.2E-11	2.5E-10
						1.1E+04	6.4E+04	7.8E+04	1.6E-01	4.8E-04	3.7E-06	3.7E-06	9.5E-07	3.7E-09	8.2E-08	8.7E-08	6.8E-07
SRD-13-1		0.996	2.2E+04	1.4E+04	2.	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
						9.9E+03	6.0E+04	7.5E+04	1.6E-01	4.6E-04	3.7E-06	3.7E-06	9.6E-07	3.7E-09	8.2E-08	8.7E-08	6.8E-07
SRD-13-2		0.000															
SRD-13-3		0.004	2.2E+04	-5.1E+03	10.	2.3E+05	2.8E+04	1.1E+04	2.3E-01	1.9E-05	1.4E-05	2.1E-06	3.8E-08	4.3E-09	8.1E-10	3.1E-09	6.5E-08
						2.3E+05	1.0E+06	1.0E+06	7.5E-01	3.8E-03	4.4E-06	2.9E-06	7.8E-10	9.6E-17	2.4E-11	3.8E-11	5.6E-10
SRD-14	6.4E-06		2.2E+04	1.3E+04	10.	4.1E+05	2.8E+04	5.3E+03	3.6E-02	4.9E-04	4.0E-04	1.3E-04	4.1E-05	7.2E-06	2.6E-06	1.4E-05	4.2E-05
						2.9E+06	1.5E+05	3.2E+04	9.6E-01	3.7E-02	7.4E-04	1.5E-03	1.3E-04	1.6E-05	1.3E-05	2.1E-05	1.1E-04
SRD-14-1		0.949	2.2E+04	1.4E+04	10.	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
						3.0E+06	1.3E+05	1.0E+04	1.0E+00	3.6E-02	5.7E-04	1.4E-03	1.1E-04	1.5E-05	1.2E-05	1.8E-05	9.7E-05
SRD-14-2		0.002	1.3E+04	-3.6E+03	10.	1.0E+06	2.0E+04	2.1E+03	1.4E-01	1.7E-02	1.3E-02	5.2E-03	4.5E-05	9.3E-06	6.2E-07	9.0E-07	7.9E-05
						0.0E+00	1.8E+05	1.8E+05	1.7E-02	3.2E-03	8.6E-04	3.8E-04	5.0E-06	9.2E-07	1.9E-07	2.3E-07	7.1E-06
SRD-14-3		0.049	2.2E+04	-5.1E+03	10.	3.9E+05	2.8E+04	5.4E+03	7.3E-01	9.3E-03	7.6E-03	2.4E-03	8.3E-04	1.5E-04	5.3E-05	2.8E-04	8.6E-04
						5.9E+05	4.4E+05	4.4E+05	2.5E-01	4.1E-02	3.9E-03	3.4E-03	4.2E-04	2.8E-05	3.0E-05	8.6E-05	3.5E-04

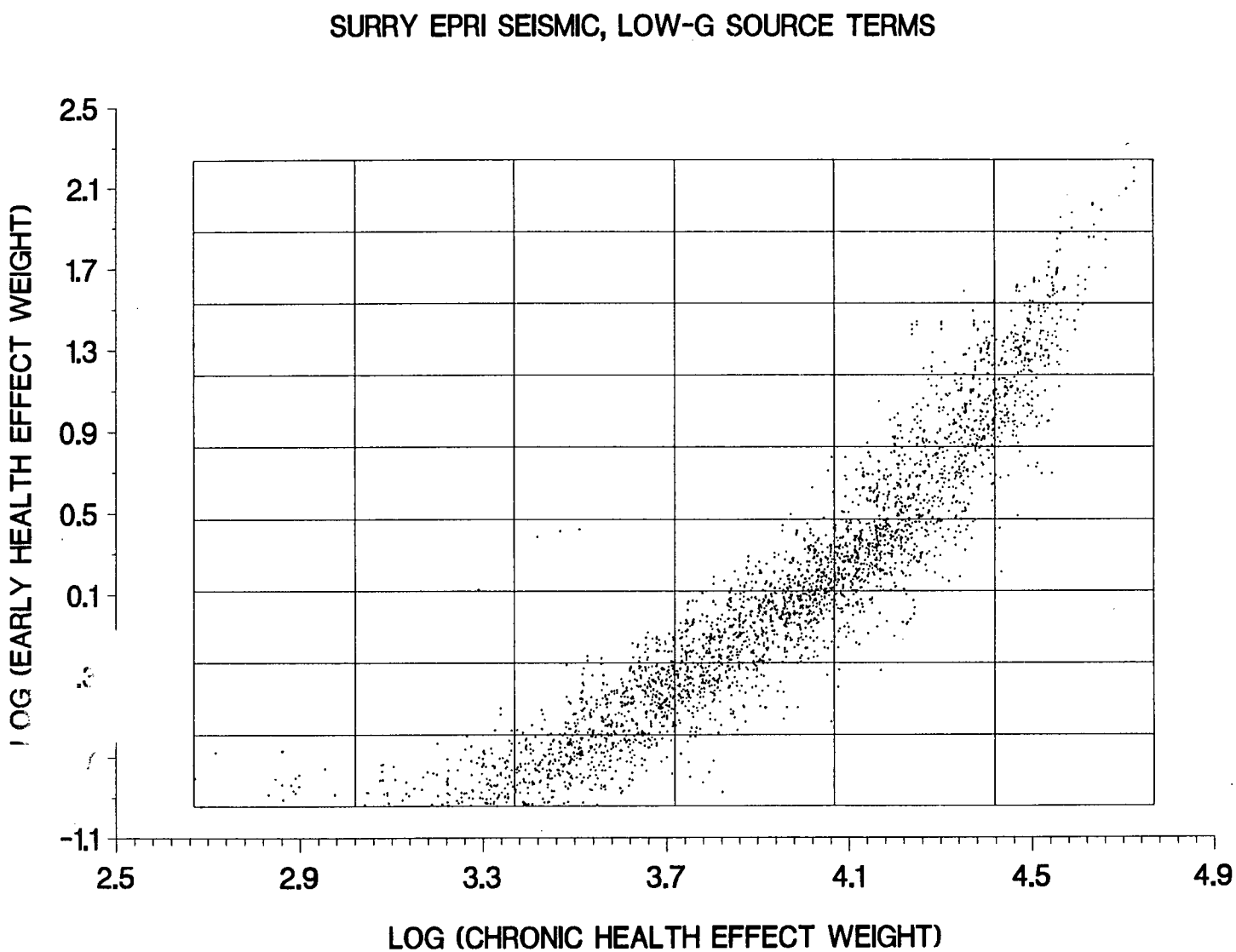


Figure 3.4-4. Partition Plot--EPRI Initiators

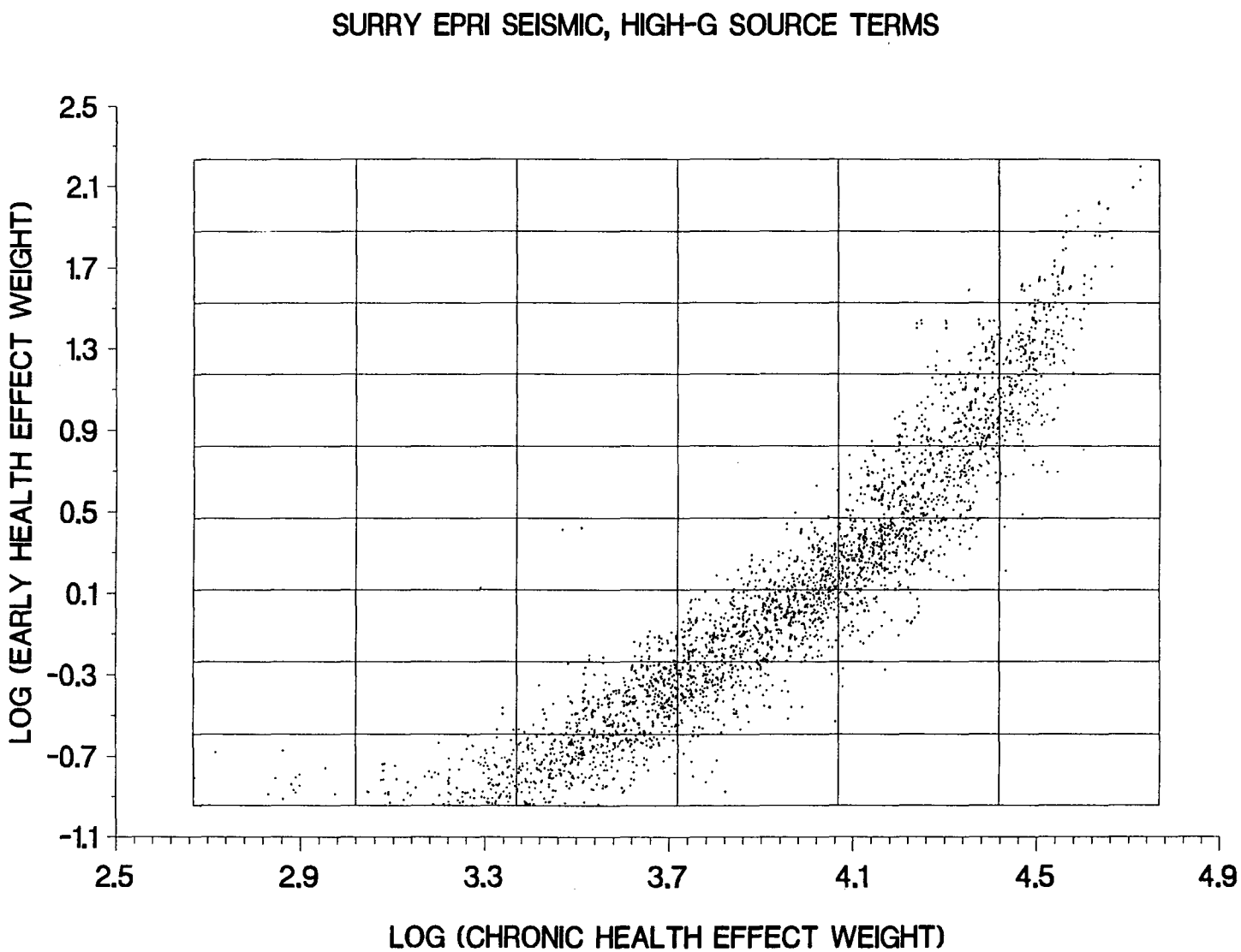


Figure 3.4-4. (continued)

3.5 Insights from the Source Term Analysis

The range in the release fractions calculated for similar accidents is large--typically two orders of magnitude for the more volatile radionuclide classes--and four orders of magnitude of more for the less volatile radionuclides. In general, the higher release fractions are of the same magnitude as those found in the RSS, but the bulk of the distribution is lower than the release fractions found by the RSS. While iodine and cesium release fractions exceeding 0.10 are possible for many different types of accidents, they are very unlikely for most types. Only for Event V with the break location not submerged and the SGTRs in which the secondary SRVs stick open is there a good chance that the release fractions for iodine and cesium will be about 0.10 or higher.

3.6 References

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4. CONSEQUENCE ANALYSIS

Offsite consequences were calculated with MACCS[1,2,3] for each of the source term groups defined in the partitioning process. This code has been in use for some time and will not be described in any detail. Although the variables thought to be the largest contributors to the uncertainty in risk were sampled from distributions in the accident frequency analysis, the accident progression analysis, and the source term analysis, there was no analogous treatment of uncertainties in the consequence analysis. Variability in the weather was fully accounted for, but the uncertainty in other parameters such as the dry deposition speed or the evacuation rate was not considered.

4.1 Description of the Consequence Analysis

Offsite consequences were calculated with MACCS for each of the source term groups defined in the partitioning process. MACCS tracks the dispersion of the radioactive material in the atmosphere from the plant and computes its its deposition on the ground. MACCS then calculates the effects of this radioactivity on the population and the environment. Doses and the ensuing health effects from 60 radionuclides are computed for the following pathways: immersion or cloudshine, inhalation from the plume, groundshine, deposition on the skin, inhalation of resuspended ground contamination, ingestion of contaminated water and ingestion of contaminated food.

MACCS treats atmospheric dispersion by the use of multiple, straight-line Gaussian plumes. Each plume can have a different direction, duration, and initial radionuclide concentration. Cross-wind dispersion is treated by a multi-step function. Dry and wet deposition are treated as independent processes. The weather variability is treated by means of a stratified sampling process.

For early exposure, the following pathways are considered: immersion or cloudshine, inhalation from the plume, groundshine, deposition on the skin, and inhalation of resuspended ground contamination. Skin deposition and inhalation of resuspended ground contamination have generally not been considered in previous consequence models. For the long-term exposure, MACCS considers following four pathways: groundshine, inhalation of resuspended ground contamination, ingestion of contaminated water and ingestion of contaminated food. The direct exposure pathways, groundshine, and inhalation of resuspended ground contamination, produce doses in the population living in the area surrounding the plant. The indirect exposure pathways, ingestion of contaminated water and food, produce doses in those who ingest food or water emanating from the area around the accident site. The contamination of water bodies is estimated for the washoff of land-deposited material as well as direct deposition. The food pathway model includes direct deposition onto crop and uptake from the soil.

Both short-term and long-term mitigative measures are modeled in MACCS. Short-term actions include evacuation, sheltering and emergency relocation out of the emergency planing zone. Long-term actions include later relocation and restrictions on land use and crop disposition. Relocation and land decontamination, interdiction, and condemnation are based on

projected long-term doses from groundshine and inhalation of resuspended radioactivity. The disposal of agricultural products is based on the products' contamination levels and the removal of farmland from crop production is based on ground contamination criteria.

The health effects models link the dose received by an organ to predicted morbidity or mortality. The models used in MACCS calculate both short-term and long-term effects for a number of organs.

The MACCS consequence model calculates a large number of different consequence measures. Results for the following six consequence measures are given in this report: early fatalities, total latent cancer fatalities, population dose within 50 miles, population dose for the entire region, early fatality risk within 1 mile, and latent cancer fatality risk within 10 miles. These consequence measures are described in Table 4.1-1. For the analyses performed for NUREG-1150, 99.5% of the population evacuates and 0.5% of the population does not evacuate and continues normal activity. Details of the methods used to incorporate the consequence results for the source term groups into the integrated risk analysis are given in Volume 1 of this report.

4.2 MACCS Input for Surry

The values of most MACCS input parameters (e.g., aerosol dry deposition velocity, health effects model parameter values, food pathway transfer factors) do not depend on site characteristics. For those parameters that do depend on site characteristics (e.g., evacuation speed, shielding factors, farmland usage), the methods used to calculate the parameters are essentially the same for all sites. Because the methods used to develop input parameter values for the MACCS NUREG-1150 analyses and the parameter values developed using those methods are documented in Volume 2, Part 7 of this report, only a small portion of the MACCS input is presented here.

Table 4.2-1 lists the MACCS input parameters that have strong site dependencies and presents the values of these parameters used in the MACCS calculations for the Surry site. The evacuation delay period begins when general emergency conditions occur and ends when the general public starts to evacuate; non-farm wealth includes personal, business, and public property; and the farmland fractions do not add to one because not all farmland is under cultivation. In addition to the site specific data presented in Table 4.2-1, the Surry MACCS calculations used one year of meteorological data from the Surry site and regional population data developed from the 1980 census tapes. The following table gives the population within certain distances of the plant as summarized from the MACCS demographic input.

Table 4.1-1
Definition of Consequence Analysis Results

Variable	Definition
Early fatalities	Number of fatalities occurring within 1 year of the accident.
Total latent cancer fatalities	Number of latent cancer fatalities due to both early and chronic exposure.
Population dose within 50 miles	Population dose, expressed in effective dose equivalents for whole body exposure (person-rem), due to early and chronic exposure pathways within 50 miles of the reactor. Due to the nature of the chronic pathways models, the actual exposure due to food and water consumption may take place beyond 50 miles.
Population dose within entire region	Population dose, expressed in effective dose equivalents for whole body exposure (person-rem), due to early and chronic exposure pathways within the entire region.
Individual early fatality risk within one mile	The probability of dying within one year for an individual within one mile of the exclusion boundary (i.e., Σ (ef/pop)p, where ef is the number of early fatalities, pop is the population size, p is the weather condition probability, and the summation is over all weather conditions).
Individual latent cancer risk within 10 miles	The probability of dying from cancer due to the accident for an individual within 10 miles of the plant (i.e., Σ (cf/pop)p, where cf is the number of cancer fatalities due to direct exposure in the resident population, pop is the population size, p is the weather condition probability, and the summation is over all weather conditions; chronic exposure does not include ingestion but does include integrated groundshine and inhalation exposure from $t = 0$ to $t = \infty$).

Distance From Plant (km)	Distance From Plant (miles)	Population
1.6	1.0	9
4.8	3.0	354
16.1	10.0	73,411
48.3	30.0	593,504
160.9	100.0	2,825,702
563.3	350.0	53,947,736
1609.3	1000.0	155,943,904

There is considerable variation in the sector populations (out to 1000 miles) as well. The NNE and WNW sectors have populations of about 25 million, while the ENE sector has a population of only about 30,000.

The evacuation parameters for the seismic risk analyses differed from those for the analysis for internal initiators. It was estimated that for earthquakes with PGAs greater than 0.6 g there would be no effective evacuation and many structures would be uninhabitable. Thus, the population in the emergency response zone is modeled as being outdoors for the first 24 h and then relocating at 24 h. For earthquakes with PGAs less than 0.6 g, it was judged that evacuation would be possible, but that it would start later and proceed at a slower pace than an evacuation for an internal initiator. Thus, for seisms with PGAs less than 0.6 g, the delay time is 3.0 hours (1.5 times the normal delay time) and the evacuation speed is 0.9 m/s (half the normal evacuation speed). This is referred to as degraded evacuation for low acceleration earthquakes.

Table 4.2-2 lists the shielding factors for the Surry consequence analysis. One set of shielding factors was used for internal and fire initiators, and two sets were used for the seismic initiators. The MACCS code considers three different portions of the population or cohorts during the emergency phase of an accident. The appropriate shielding factors are applied according to the response of the people to the declared emergency. The evacuate and take shelter shielding factors apply only during the emergency phase of the consequence calculation. The normal activity shielding factors apply to all those who are not actively evacuating or taking shelter. Thus, the normal activity shielding factors apply to individuals before they begin evacuating or taking shelter, to individuals who choose not to evacuate or take shelter, and to everyone outside the emergency response zone. Furthermore, the normal activity shielding factors are used for all exposure calculations after the emergency phase of the accident, that is, for the chronic exposure computations.

For seismic initiators, the shielding parameters are modified in addition to the evacuation parameters. For the inhalation and skin pathways, it was estimated that buildings would offer no effective protection following an earthquake because of broken windows. The effectiveness of being indoors is reduced for groundshine as well because the broken windows allow deposition within buildings.

Table 4.2-1
Site Specific Input Data for Surry MACCS Calculations

Parameter	
Reactor Power Level (MWt)	2441
Containment Height (m)	50
Containment Width (m)	40
Exclusion Zone Distance (km)	0.52
Evacuation Delay (h)	2.0
Evacuation Speed (m/s)	1.8
Farmland Fractions by Crop Categories	
Pasture	0.41
Stored Forage	0.13
Grains	0.21
Green Leafy Vegetables	0.002
Legumes and Seeds	0.15
Roots and Tubers	0.003
Other Food Crops	0.004
Non-Farm Wealth ($/person)	84,000
Farm Wealth	
Value ($/hectare)	2613
Fraction in Improvements	0.25

For internal and fire initiators, and for low acceleration (PGA < 0.6 g) seismic initiators, the three cohorts treated by MACCS are: (1) those who evacuate; (2) those who continue normal activities; and (3) those who take shelter. Exposure to each cohort is calculated using the shielding factors shown in Table 4.2-2. The risk results reported for these initiators are based on the judgment that 99.5% of the population in the emergency response zone would evacuate and the other 0.5% would continue normal activities. The sheltering cohort is not utilized for these initiators.

For high acceleration (PGA > 0.6 g) seismic initiators, the cohorts are different. It is desired that the exposure be calculated as if everyone in the emergency response zone remains outdoors for 24 h after the earthquake which initiates the accident, and then relocates. This was accomplished within the structure of MACCS by placing everyone in the emergency response zone in the "shelter" cohort, and setting the shelter shielding factors to values appropriate for people outdoors. (The normal activities cohort could not be used to represent the population outdoors within the emergency response zone because a hot spot relocation criterion is applied to this

Table 4.2-2
Shielding Factors Used for Surry MACCS Calculations

Radiation Pathway	Population Response		
	Evacuate	Normal Activity	Take Shelter
Internal and Fire Initiators			
Cloudshine	1.0	0.75	0.60
Groundshine	0.5	0.33	0.20
Inhalation	1.0	0.41	0.33
Skin	1.0	0.41	0.33
Seismic Initiators (PGA < 0.6 g)			
Cloudshine	1.0	0.75	0.60
Groundshine	0.5	0.50	0.40
Inhalation	1.0	1.0	1.0
Skin	1.0	1.0	1.0
Seismic Initiators (PGA > 0.6 g)			
Cloudshine	N.A.	0.75	1.0
Groundshine	N.A.	0.33	0.7
Inhalation	N.A.	0.41	1.0
Skin	N.A.	0.41	1.0

N.A. = Not Applicable

cohort at 12 h, and because the normal activity shielding factors are also utilized outside the emergency response zone and for the chronic exposure calculations.) MACCS calculations were performed for emergency response zones with radii of 5, 10, and 20 miles. The results reported in this volume use the results for an emergency response zone of 10 miles radius. That is, the consequence calculation for high acceleration seismic initiators uses the shielding factors shown in the shelter column of Table 4.2-2 for the population within 10 miles of the plant for the first 24 h, and uses the shielding factors shown in the normal activity column for the people farther than 10 miles from the plant and for all chronic exposures.

The normal activity shielding factors are used in the chronic exposure calculations for all initiators. The entries in Table 4.2-2 show that this results in less chronic exposure shielding for the low acceleration seismic initiators than for the other initiators. As groundshine dominates the chronic exposure pathways, the use of 0.5 for the groundshine shielding factor yields a chronic exposure estimate about 50% higher than that which would have been obtained using a shielding factor of 0.33 for the low acceleration seismic initiators. As the earthquake damage will be limited to a few tens of miles and will be limited in time as well, the use of chronic exposure shielding factors for seismic initiators that are different from the normal chronic exposure shielding factors is difficult to justify. If the study were to be repeated in the future, the approach used for low acceleration seismic initiators would be discarded and the method used for high acceleration earthquakes would be modified to treat low acceleration events by the adoption of an earlier relocation time.

4.3 Results of MACCS Consequence Calculations

The results given in this section are conditional on the occurrence of a release. That is, given that a release takes place, with release fractions and other characteristics as defined by one of the source term groups, then the consequences reported in this section are calculated. The tables and figures in this section contain no information about the frequency with which these consequences may be expected. Information about the frequencies of consequences of various magnitudes is contained in the risk results (Chapter 5).

4.3.1 Results for Internal Initiators

The integration of the NUREG-1150 probabilistic risk assessments uses the results of the MACCS consequence calculations in two forms. In the first form, a single mean (over weather variation) result is reported for each consequence measure. This produces a nSTG x nC matrix of mean consequence measures, where nSTG is the number of source term groups and nC is the number of consequence measures under consideration. For internal initiators at Surry, nSTG = 52 and nC = 6. The resultant 52 x 6 matrix of mean consequence measures is shown in Table 4.3-1. The source terms that give rise to these mean consequence measures are given in Table 3.4-4. Some of the cases indicated in Table 3.4-4 have a zero frequency and no consequence results are reported for these cases in Table 4.3-1. The mean consequence measures in Table 4.3-1 are used by PRAMIS[5] and RISQUE in the calculation of the mean risk results for internal initiators at Surry. An early

fatality consequence value less than 1.0 may be interpreted as the probability of obtaining one death. The population dose is the effective dose equivalent to the whole body for the population in the region indicated.

Table C.1-1 in Appendix C provides a breakdown of mean consequence results between individuals who evacuate, continue normal activities, and actively shelter; information on the division of results between early and chronic exposure is also given. In addition to the six consequence measures which are reported in the text of this report, Table C.1-1 contains results for early injuries (prodromal vomiting), economic cost, and individual early fatality risk at 1 mile. [Note that individual early fatality risk <u>at</u> one mile is distinct from individual early fatality risk <u>within</u> one mile. The risk at one mile (listed in Appendix C only) is for a hypothetical individual at that distance. The risk within one mile (reported in the text) uses the actual residence distances for all people living within one mile of the plant. Only if there are no people living within one mile of the plant is the calculation made assuming that a hypothetical person is located exactly one mile from the plant.]

In the second form, a complementary cumulative distribution function (CCDF) is used for each consequence measure. Conditional on the occurrence of a source term, each of these CCDFs gives the probability that individual consequence values will be exceeded due to the uncertainty in the weather conditions that exist at the time of an accident. These CCDFs are given in Figure 4.3-1. Each frame in this figure displays the CCDFs for a single consequence measure for all the subgroup source terms (SUR-I-J) in Table 3.4-4 which have a non-zero frequency. The CCDFs were generated using the estimate that 99.5% of the population evacuates and 0.5% of the population continues normal activities. Each of the mean consequence results in Table 4.3-1 is the result of reducing one of the CCDFs in Figure 4.3-1 to a single number. The CCDFs in Figure 4.3-1 will subsequently be used to create CCDFs for risk, with the PRPOST code, which is described in Volume 1 of this report. The CCDFs for risk are presented in the next chapter; they relate consequence values with the frequency at which these values are exceeded.

Table 4.3-1
Mean Consequence Results for Internal Initiators
(Population Doses in Sv)

Source Term	Early Fatal-ities	Total Lat. Cancer Fatalities	Pop. Dose Within 50 mi	Pop. Dose Entire Region	Individual Early Fat. Risk, 1 mi.	Individual Lat. Can. Fatality Fat. Risk 10 mi.
SUR-01-1	-----	-----	-----	-----	-----	-----
SUR-01-2	9.35E-5	9.31E+1	2.33E+3	5.73E+3	4.64E-6	6.52E-5
SUR-01-3	3.87E-2	3.90E+1	1.24E+3	2.24E+3	1.31E-3	1.42E-4
SUR-02-1	5.70E-4	2.43E+2	5.22E+3	1.46E+4	2.45E-5	8.38E-5
SUR-02-2	5.68E-1	7.67E+2	1.13E+4	4.42E+4	3.82E-3	1.48E-3
SUR-02-3	4.94E-2	2.72E+2	5.82E+3	1.61E+4	1.65E-3	2.28E-4
SUR-03-1	1.16E-2	6.89E+2	1.15E+4	4.19E+4	1.60E-4	1.12E-4
SUR-03-2	4.20E-1	1.59E+3	2.26E+4	9.60E+4	4.51E-3	1.54E-3
SUR-03-3	1.57E-1	7.94E+2	1.13E+4	4.78E+4	4.37E-3	3.62E-4
SUR-04-1	6.80E-4	1.04E+3	1.04E+4	6.13E+4	2.59E-5	1.17E-4
SUR-04-2	2.11E-4	9.37E+2	1.45E+4	5.55E+4	1.02E-5	2.86E-4
SUR-04-3	-----	-----	-----	-----	-----	-----
SUR-05-1	-----	-----	-----	-----	-----	-----
SUR-05-2	2.86E+0	3.61E+3	5.15E+4	1.92E+5	2.97E-2	3.99E-3
SUR-05-3	1.83E+0	2.56E+3	2.62E+4	1.58E+5	1.60E-2	8.91E-4
SUR-06-1	-----	-----	-----	-----	-----	-----
SUR-06-2	9.24E-2	2.42E+3	2.42E+4	1.44E+5	2.16E-3	7.47E-4
SUR-06-3	1.49E+0	2.19E+3	2.15E+4	1.32E+5	1.34E-2	9.67E-4
SUR-07-1	6.55E-2	2.38E+3	2.76E+4	1.42E+5	1.96E-4	1.13E-4
SUR-07-2	3.38E+0	2.83E+3	3.43E+4	1.67E+5	3.73E-2	2.72E-3
SUR-07-3	5.03E-1	1.40E+3	1.46E+4	8.30E+4	8.97E-3	5.96E-4
SUR-08-1	7.75E-3	2.20E+3	1.68E+4	1.31E+5	1.09E-4	1.32E-4
SUR-08-2	2.64E-2	2.27E+3	2.14E+4	1.34E+5	1.22E-3	3.72E-4
SUR-08-3	2.35E-1	1.44E+3	1.61E+4	8.43E+4	5.57E-3	5.11E-4
SUR-09-1	3.08E-3	1.66E+3	1.36E+4	9.83E+4	6.75E-5	1.21E-4
SUR-09-2	1.97E-3	1.35E+3	1.74E+4	7.97E+4	6.00E-5	3.06E-4
SUR-09-3	-----	-----	-----	-----	-----	-----

Table 4.3-1 (continued)

Source Term	Early Fatal-ities	Total Lat. Cancer Fatalities	Pop. Dose Within 50 mi	Pop. Dose Entire Region	Individual Early Fat. Risk, 1 mi.	Individual Lat. Can. Fatality Fat. Risk 10 mi.
SUR-10-1	8.38E-1	4.78E+3	4.78E+4	2.73E+5	2.62E-4	1.59E-4
SUR-10-2	2.44E+0	4.51E+3	4.66E+4	2.60E+5	2.25E-2	1.85E-3
SUR-10-3	1.19E+1	3.67E+3	3.34E+4	2.21E+5	2.90E-2	1.83E-3
SUR-11-1	3.57E-1	4.30E+3	4.56E+4	2.45E+5	2.55E-4	1.60E-4
SUR-11-2	3.23E-1	4.95E+3	2.77E+4	2.96E+5	7.48E-5	6.97E-4
SUR-11-3	4.03E+0	2.92E+3	2.78E+4	1.76E+5	2.23E-2	1.52E-3
SUR-12-1	1.18E-1	3.38E+3	2.69E+4	2.03E+5	1.88E-4	1.47E-4
SUR-12-2	6.28E-2	3.93E+3	3.01E+4	2.35E+5	1.54E-3	5.73E-4
SUR-12-3	4.65E-1	3.23E+3	2.67E+4	1.91E+5	8.08E-3	6.16E-4
SUR-13-1	2.93E-2	3.00E+3	2.15E+4	1.78E+5	1.56E-4	1.52E-4
SUR-13-2	1.26E-1	3.50E+3	2.68E+4	2.08E+5	5.37E-3	4.38E-4
SUR-13-3	-----	-----	-----	-----	-----	-----
SUR-14-1	1.33E-2	2.65E+3	1.88E+4	1.57E+5	1.28E-4	1.50E-4
SUR-14-2	6.78E-4	3.16E+3	2.23E+4	1.86E+5	2.51E-5	2.03E-4
SUR-14-3	-----	-----	-----	-----	-----	-----
SUR-15-1	0.00E+0	1.01E-2	4.28E-1	8.90E-1	0.00E+0	2.41E-9
SUR-15-2	0.00E+0	1.59E-1	3.10E+0	9.09E+0	0.00E+0	8.28E-8
SUR-15-3	-----	-----	-----	-----	-----	-----
SUR-16-1	0.00E+0	9.36E-2	4.28E+0	8.93E+0	0.00E+0	3.57E-8
SUR-16-2	0.00E+0	1.40E+0	3.75E+1	8.84E+1	0.00E+0	1.12E-6
SUR-16-3	-----	-----	-----	-----	-----	-----
SUR-17-1	0.00E+0	1.13E+2	2.66E+3	6.94E+3	0.00E+0	7.60E-5
SUR-17-2	2.89E-5	3.63E+2	6.71E+3	2.13E+4	1.44E-6	1.66E-4
SUR-17-3	-----	-----	-----	-----	-----	-----
SUR-18	0.00E+0	0.00E+0	0.00E+0	0.00E+0	0.00E+0	0.00E+0

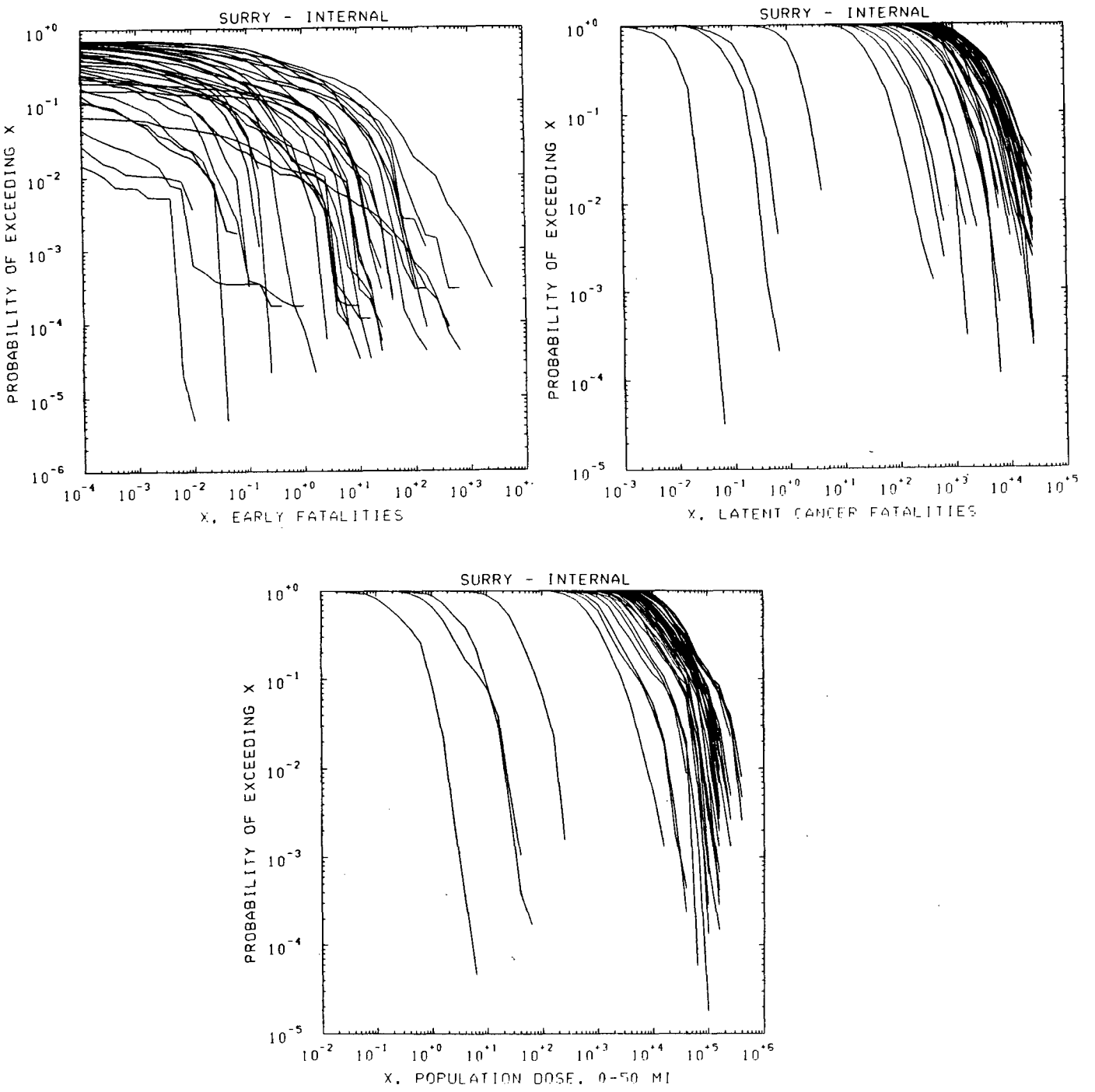


Figure 4.3-1. Consequences Conditional on Source Terms
Surry: Internal Initiators

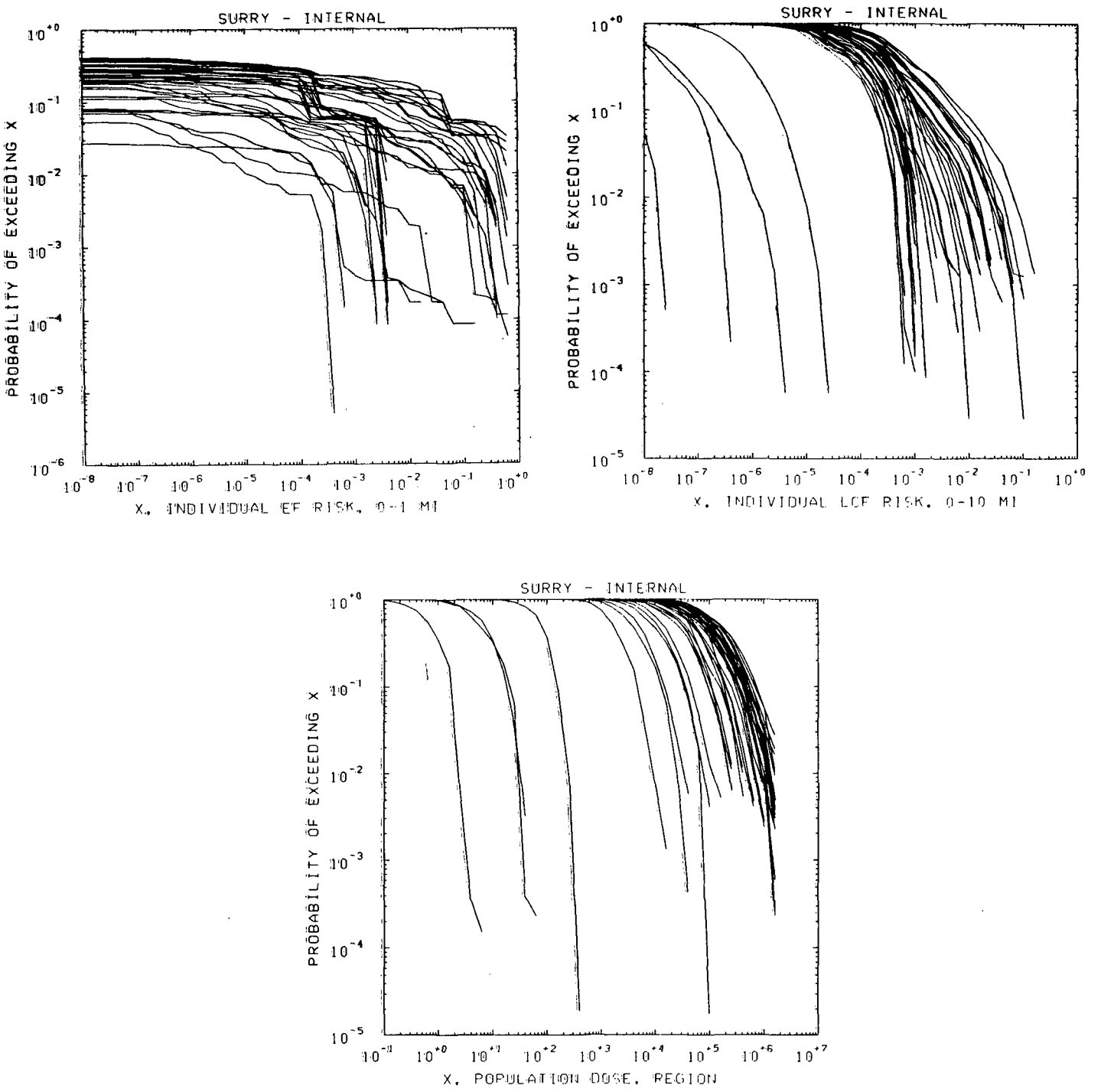


Figure 4.3-1. (continued)

4.3.2 Results for Fire Initiators

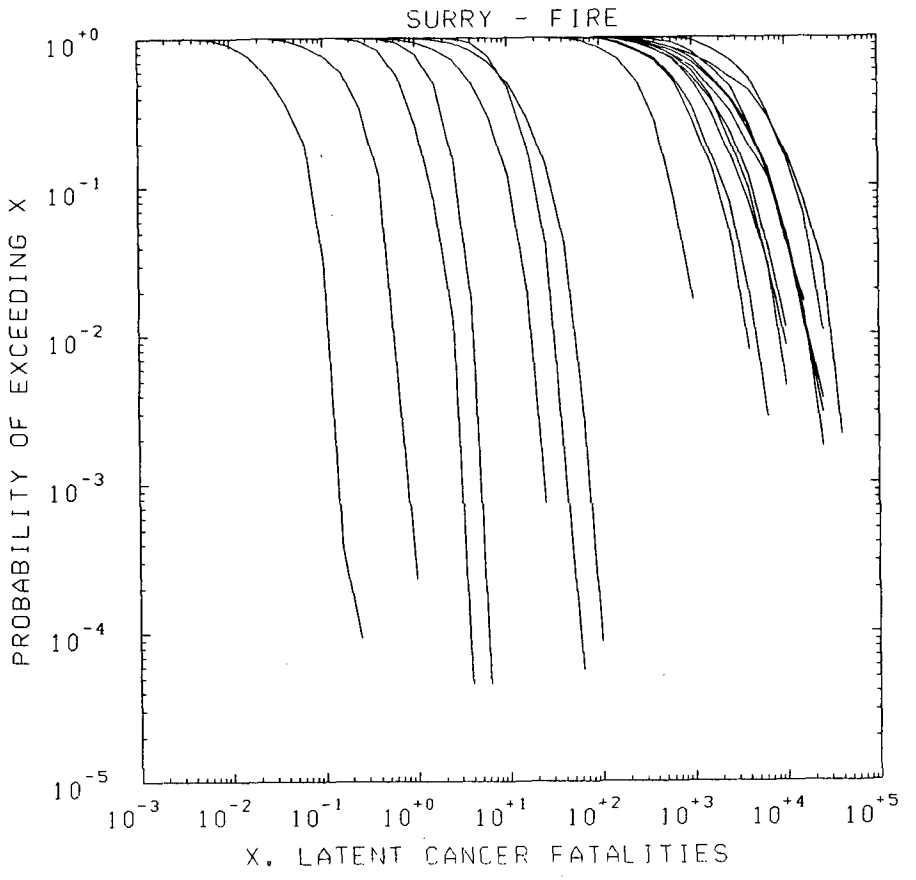
Figure 4.3-2 contains the CCDFs for each source term subgroup for the fire initiators. There is a curve in these plots for each subgroup source term (SRF-I-J) in Table 3.4-8 which has a non-zero frequency. Table 4.3-2 contains the mean consequence results for these same source term subgroups. As for internal initiators, 99.5% of the population evacuates and 0.5% continues normal activities. Each of the mean consequence results in Table 4.3-2 is the result of reducing one of the CCDFs in Figure 4.3-2 to a single number.

4.3.3 Results for Seismic Initiators: LLNL Hazard Curve

Figures 4.3-3 and 4.3-4 contain the CCDFs for each source term subgroup for the seismic initiators using the LLNL hazard distributions. There is a curve in these plots for each subgroup source term in Table 3.4-12 which has a non-zero frequency. Tables 4.3-3 and 4.3-4 contain the mean consequence results for the source terms in Tables 3.4-12 for low and high PGA earthquakes, respectively. The source terms designated SRL-I-J arise from earthquakes with PGAs less than 0.6 g, and the source terms designated SRH-I-J arise from earthquakes with PGAs greater than 0.6 g. For low PGA seisms, 99.5% of the population evacuates (although later and more slowly than if there were no earthquake) and 0.5% continues normal activities. For high PGA seisms, there is no evacuation. The population that would have evacuated is relocated 24 hours after the accident.

4.3.4 Results for Seismic Initiators: EPRI Hazard Curve

Figures 4.3-5 and 4.3-6 contain the CCDFs for each source term subgroup for the seismic initiators using the LLNL hazard distributions. There is a curve in these plots for each subgroup source term in Table 3.4-16 which has a non-zero frequency. Tables 4.3-5 and 4.3-6 contain the mean consequence results for the source terms in Tables 3.4-16 for low and high PGA earthquakes, respectively. The source terms designated SRD-I-J arise from earthquakes with PGAs less than 0.6 g, and the source terms designated SRE-I-J arise from earthquakes with PGAs greater than 0.6 g. For low PGA seisms, 99.5% of the population evacuates (although later and more slowly than if there were no earthquake) and 0.5% continues normal activities. For high PGA seisms, there is no evacuation. The population that would have evacuated is relocated 24 h after the accident.



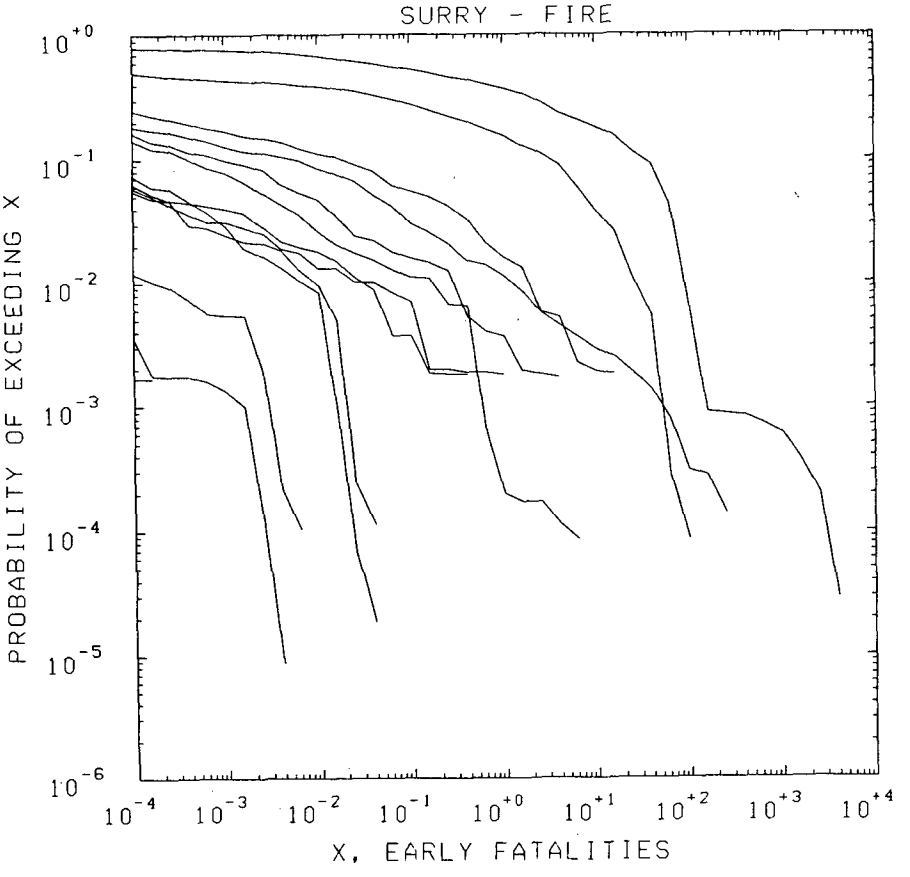


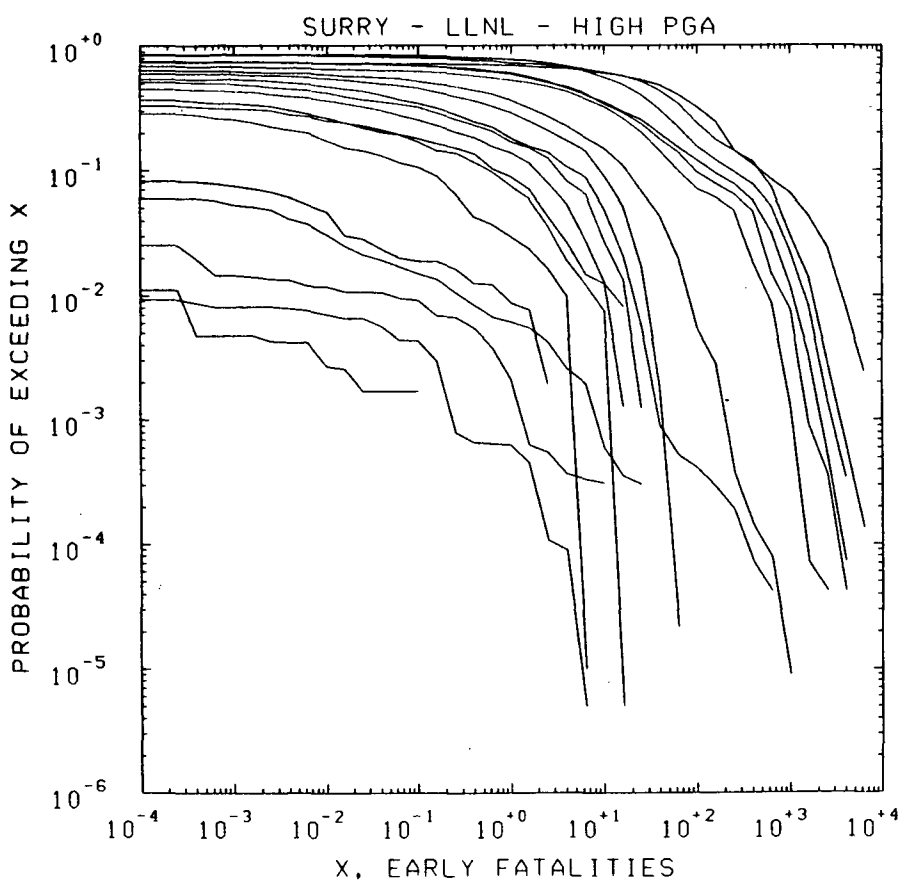
Figure 4.3-2. Consequences Conditional on Source Terms Surry: Fire Initiators

Table 4.3-2
Mean Consequence Results for Fire Initiators
(Population Doses in Sv)

Source Term	Early Fatal-ities	Total Lat. Cancer Fatalities	Pop. Dose 50 mi	Pop. Dose Entire Region	Early Fat. Risk, 1 mi.	Lat. Can Fatality 10 mi.
SRF-01-1	-----	-----	-----	-----	-----	-----
SRF-01-2	3.47E-03	9.98E+02	1.31E+04	5.89E+04	1.58E-04	2.59E-04
SRF-01-3	-----	-----	-----	-----	-----	-----
SRF-02-1	-----	-----	-----	-----	-----	-----
SRF-02-2	2.92E-06	8.52E+02	1.21E+04	5.11E+04	1.45E-07	2.54E-04
SRF-02-3	-----	-----	-----	-----	-----	-----
SRF-03-1	-----	-----	-----	-----	-----	-----
SRF-03-2	5.31E-03	1.78E+03	2.14E+04	1.09E+05	2.54E-04	4.60E-04
SRF-03-3	-----	-----	-----	-----	-----	-----
SRF-04-1	-----	-----	-----	-----	-----	-----
SRF-04-2	1.59E-03	1.85E+03	1.60E+04	1.10E+05	1.79E-05	3.00E-04
SRF-04-3	-----	-----	-----	-----	-----	-----
SRF-05-1	-----	-----	-----	-----	-----	-----
SRF-05-2	1.97E-04	1.57E+03	1.76E+04	9.20E+04	9.23E-06	2.18E-04
SRF-05-3	-----	-----	-----	-----	-----	-----
SRF-06-1	-----	-----	-----	-----	-----	-----
SRF-06-2	1.45E+00	3.27E+03	3.65E+04	1.91E+05	2.45E-02	2.45E-03
SRF-06-3	-----	-----	-----	-----	-----	-----
SRF-07-1	-----	-----	-----	-----	-----	-----
SRF-07-2	9.35E-02	2.99E+03	2.21E+04	1.80E+05	8.64E-04	4.90E-04
SRF-07-3	-----	-----	-----	-----	-----	-----
SRF-08-1	-----	-----	-----	-----	-----	-----
SRF-08-2	1.51E-02	3.10E+03	2.25E+04	1.84E+05	1.67E-04	3.32E-04
SRF-08-3	-----	-----	-----	-----	-----	-----
SRF-09-1	-----	-----	-----	-----	-----	-----
SRF-09-2	2.47E-04	2.73E+03	1.90E+04	1.60E+05	1.20E-05	1.74E-04
SRF-09-3	-----	-----	-----	-----	-----	-----

Table 4.3-2 (continued)

Source Term	Early Fatal-ities	Total Lat. Cancer Fatalities	Pop. Dose 50 mi	Pop. Dose Entire Region	Early Fat. Risk, 1 mi.	Lat. Can Fatality 10 mi.
SRF-10-1	-----	-----	-----	-----	-----	-----
SRF-10-2	9.79E+00	5.81E+03	7.04E+04	3.31E+05	3.13E-02	4.89E-03
SRF-10-3	-----	-----	-----	-----	-----	-----
SRF-11-1	-----	-----	-----	-----	-----	-----
SRF-11-2	2.00E-01	5.61E+03	2.94E+04	3.36E+05	6.11E-05	8.32E-04
SRF-11-3	-----	-----	-----	-----	-----	-----
SRF-12-1	0.00E+00	3.73E-02	1.69E+00	3.16E+00	0.00E+00	2.55E-08
SRF-12-2	0.00E+00	8.03E-01	1.39E+01	4.70E+01	0.00E+00	2.60E-07
SRF-12-3	-----	-----	-----	-----	-----	-----
SRF-13-1	0.00E+00	2.18E-01	7.58E+00	1.77E+01	0.00E+00	1.12E-07
SRF-13-2	1.31E-08	1.69E+00	4.32E+01	1.10E+02	6.55E-10	1.19E-06
SRF-13-3	-----	-----	-----	-----	-----	-----
SRF-14-1	0.00E+00	5.17E+00	1.69E+02	4.27E+02	0.00E+00	3.94E-06
SRF-14-2	4.43E-07	1.10E+01	3.91E+02	8.26E+02	2.21E-08	1.68E-05
SRF-14-3	-----	-----	-----	-----	-----	-----
SRF-15-1	0.00E+00	1.37E+01	5.33E+02	1.19E+03	0.00E+00	1.13E-05
SRF-15-2	1.57E-05	3.09E+02	6.78E+03	1.93E+04	7.84E-07	1.72E-04
SRF-15-3	-----	-----	-----	-----	-----	-----
SRF-16	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00



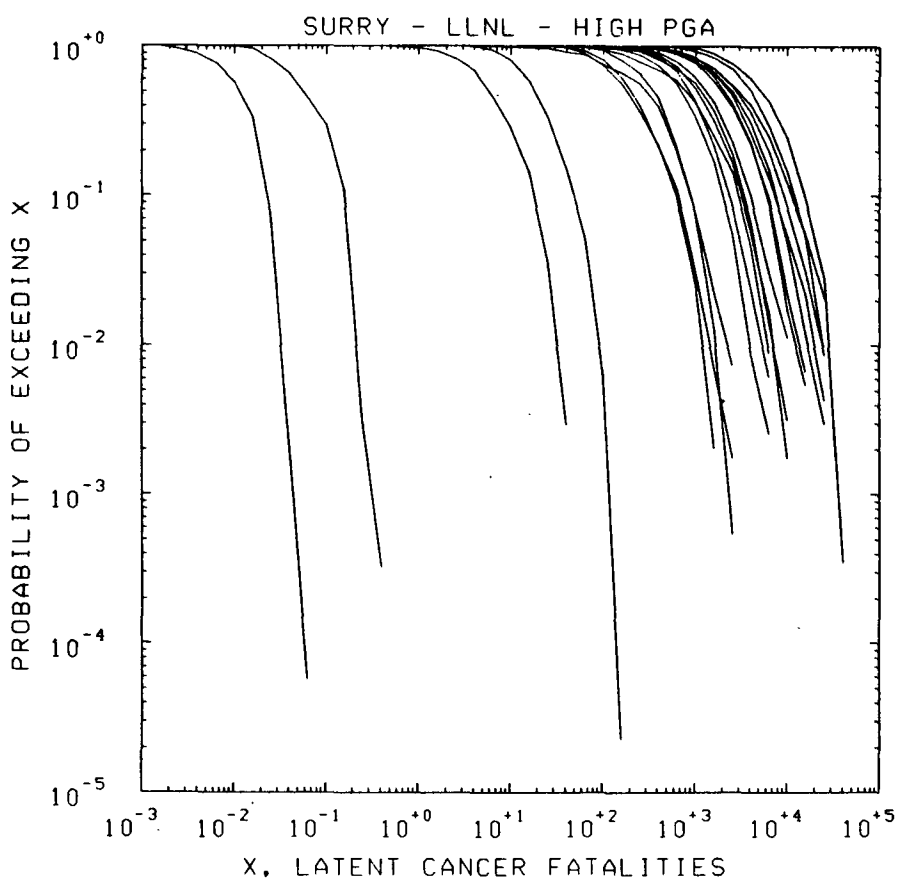
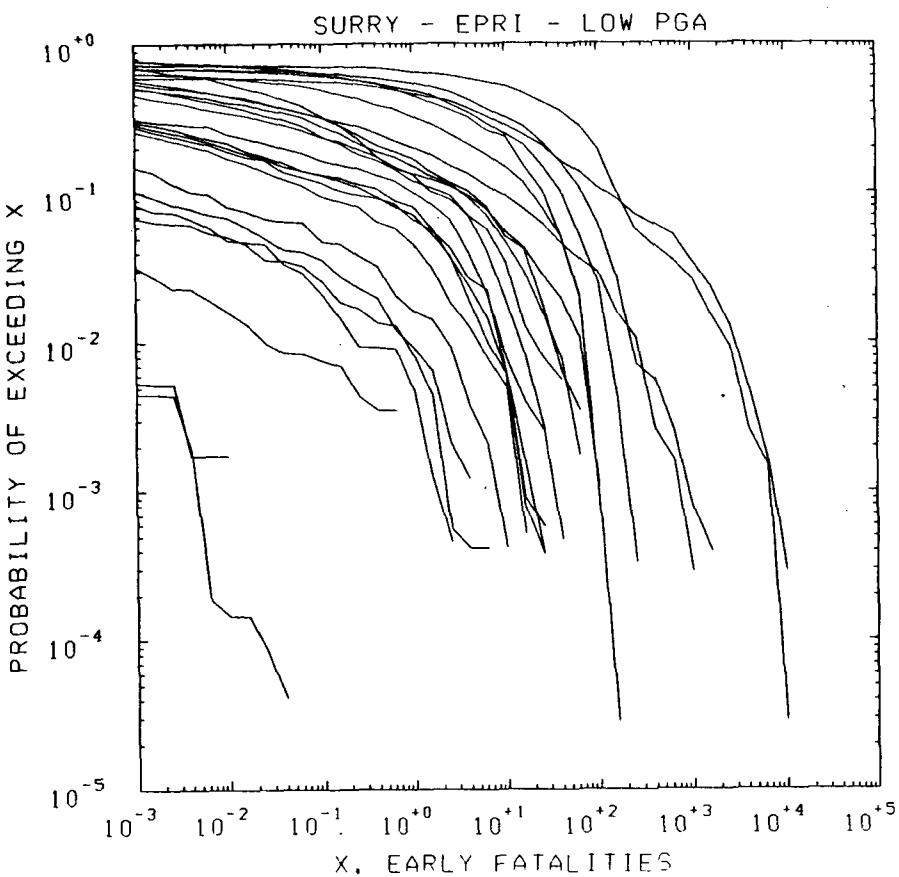


Figure 4.3-3. Consequences Conditional on Source Terms
Surry: Seismic Initiators; LLNL Hazard Distributions, Low PGA



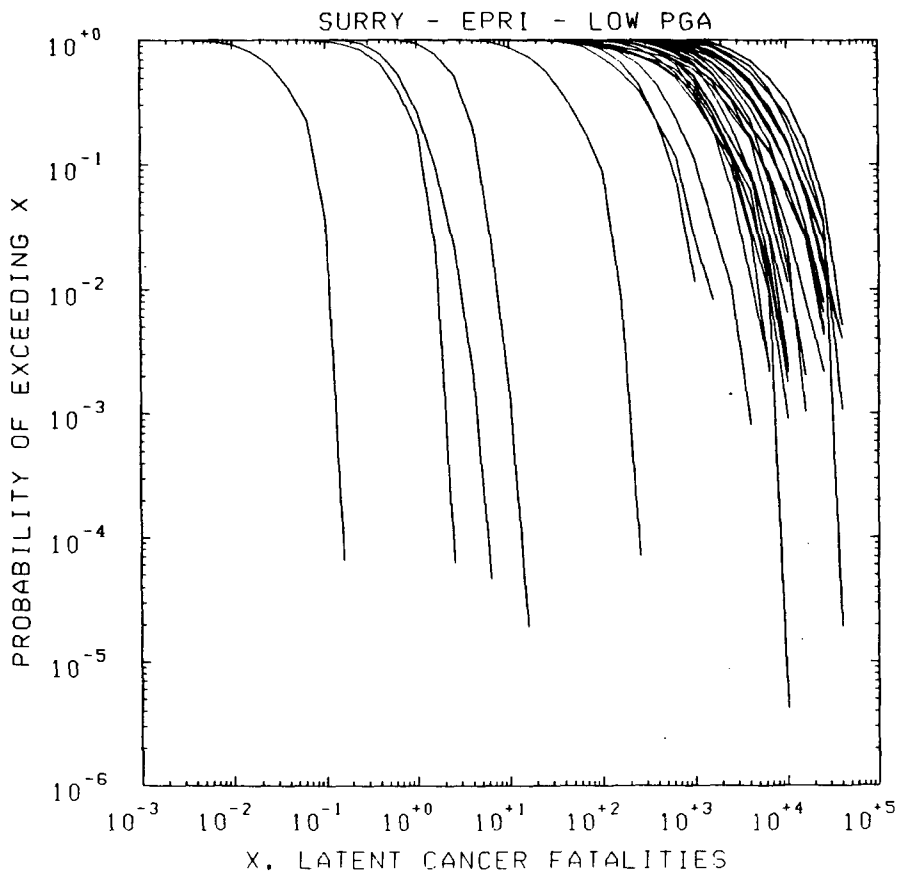


Figure 4.3-4. Consequences Conditional on Source Terms
Surry: Seismic Initiators; LLNL Hazard Distributions, High PGA

Table 4.3-3
Mean Consequence Results for Seismic Initiators
LLNL Hazard Distributions; Low PGA
(Population Doses in Sv)

Source Term	Early Fatal-ities	Total Lat. Cancer Fatalities	Pop. Dose 50 mi	Pop. Dose Entire Region	Early Fat. Risk, 1 mi.	Lat. Can Fatality 10 mi.
SRL-01-1	1.62E-03	3.52E+02	7.45E+03	2.13E+04	5.30E-05	1.16E-04
SRL-01-2	3.17E-02	4.56E+02	8.17E+03	2.66E+04	1.17E-03	3.06E-04
SRL-01-3	8.29E-03	5.99E+02	1.13E+04	3.64E+04	3.91E-04	3.51E-04
SRL-02-1	4.81E-04	1.32E+03	9.32E+03	8.61E+04	1.87E-06	7.17E-05
SRL-02-2	1.63E-01	1.36E+03	1.61E+04	8.02E+04	5.90E-03	5.33E-04
SRL-02-3	7.08E-02	1.42E+03	1.95E+04	8.50E+04	2.95E-03	6.02E-04
SRL-03-1	2.25E-05	1.53E+03	1.24E+04	9.06E+04	1.03E-06	1.15E-04
SRL-03-2	-----	-----	-----	-----	-----	-----
SRL-03-3	3.28E-02	1.25E+03	1.84E+04	7.42E+04	1.60E-03	5.09E-04
SRL-04-1	3.82E-02	1.35E+03	1.87E+04	7.73E+04	2.52E-04	1.08E-04
SRL-04-2	1.33E+00	2.42E+03	2.27E+04	1.41E+05	2.47E-02	1.18E-03
SRL-04-3	2.00E+00	2.84E+03	3.51E+04	1.67E+05	1.54E-02	3.33E-03
SRL-05-1	-----	-----	-----	-----	-----	-----
SRL-05-2	-----	-----	-----	-----	-----	-----
SRL-05-3	1.99E-01	2.54E+03	2.82E+04	1.53E+05	7.13E-03	1.04E-03
SRL-06-1	8.80E-04	2.35E+03	1.41E+04	1.45E+05	3.42E-06	1.23E-04
SRL-06-2	-----	-----	-----	-----	-----	-----
SRL-06-3	1.34E-01	1.87E+03	2.21E+04	1.11E+05	5.82E-03	6.43E-04
SRL-07-1	-----	-----	-----	-----	-----	-----
SRL-07-2	1.30E+01	4.78E+03	5.35E+04	2.69E+05	4.18E-02	6.52E-03
SRL-07-3	3.89E+00	5.40E+03	5.18E+04	3.26E+05	8.02E-03	3.39E-03
SRL-08-1	-----	-----	-----	-----	-----	-----
SRL-08-2	-----	-----	-----	-----	-----	-----
SRL-08-3	1.08E+01	4.91E+03	5.34E+04	2.81E+05	2.36E-02	6.70E-03
SRL-09-1	-----	-----	-----	-----	-----	-----
SRL-09-2	-----	-----	-----	-----	-----	-----
SRL-09-3	3.68E-01	3.76E+03	3.40E+04	2.25E+05	4.71E-03	1.46E-03

Table 4.3-3 (continued)

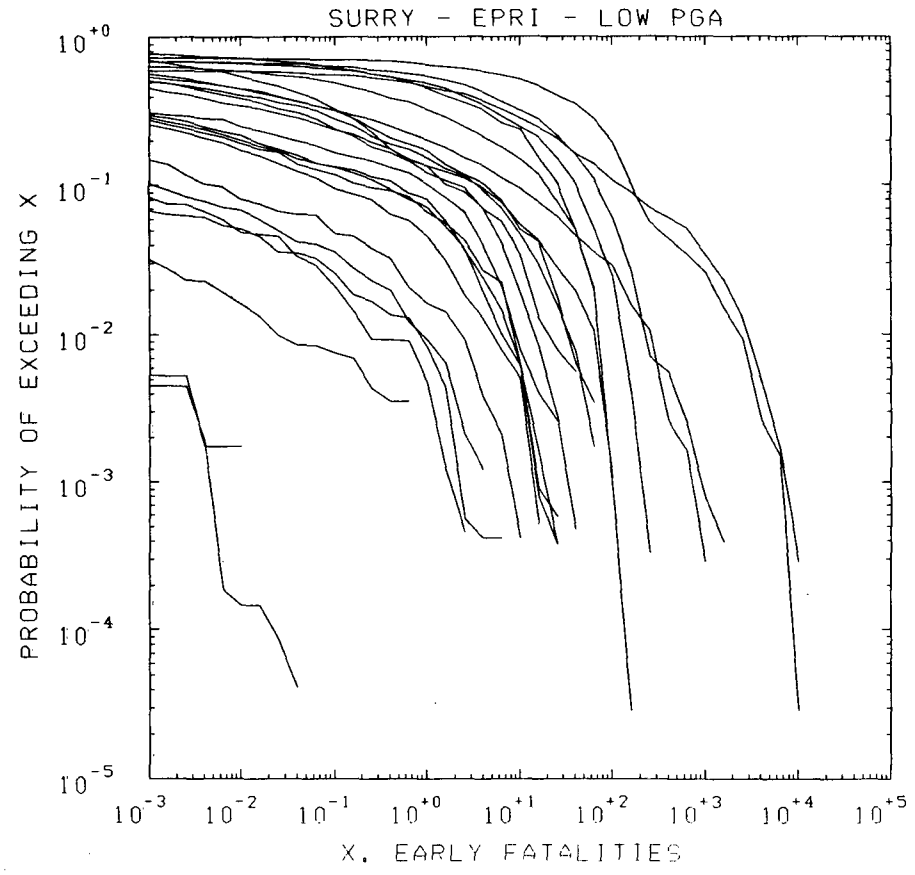
Source Term	Early Fatal-ities	Total Lat. Cancer Fatalities	Pop. Dose 50 mi	Pop. Dose Entire Region	Early Fat. Risk, 1 mi.	Lat. Can Fatality 10 mi.
SRL-10-1	-----	-----	-----	-----	-----	-----
SRL-10-2	-----	-----	-----	-----	-----	-----
SRL-10-3	6.25E-02	3.83E+03	3.33E+04	2.27E+05	1.62E-03	1.31E-03
SRL-11-1	-----	-----	-----	-----	-----	-----
SRL-11-2	-----	-----	-----	-----	-----	-----
SRL-11-3	1.72E+00	8.97E+03	1.06E+05	4.95E+05	1.00E-02	3.87E-03
SRL-12-1	-----	-----	-----	-----	-----	-----
SRL-12-2	1.02E+01	5.29E+03	5.12E+04	3.09E+05	4.48E-02	4.01E-03
SRL-12-3	7.01E+01	7.33E+03	8.79E+04	4.18E+05	2.11E-02	9.92E-03
SRL-13-1	-----	-----	-----	-----	-----	-----
SRL-13-2	6.49E+00	4.73E+03	4.29E+04	2.77E+05	4.08E-02	3.17E-03
SRL-13-3	1.25E+01	5.77E+03	5.11E+04	3.48E+05	7.10E-03	3.53E-03
SRL-14-1	0.00E+00	8.26E-02	3.90E+00	7.20E+00	0.00E+00	6.80E-08
SRL-14-2	-----	-----	-----	-----	-----	-----
SRL-14-3	-----	-----	-----	-----	-----	-----
SRL-15-1	0.00E+00	1.21E+01	5.05E+02	1.06E+03	0.00E+00	1.01E-05
SRL-15-2	-----	-----	-----	-----	-----	-----
SRL-15-3	3.87E-05	3.13E+01	1.06E+03	2.02E+03	1.94E-06	6.85E-05
SRL-16-1	4.86E-06	5.04E+02	6.38E+03	3.24E+04	1.32E-07	4.83E-05
SRL-16-2	5.77E-03	4.78E+02	8.56E+03	2.79E+04	2.87E-04	2.71E-04
SRL-16-3	4.91E-05	3.99E+02	8.34E+03	2.38E+04	2.46E-06	2.38E-04
SRL-17	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Table 4.3-4
Mean Consequence Results for Seismic Initiators
LLNL Hazard Distributions; High PGA
(Population Doses in Sv)

Source Term	Early Fatal-ities	Total Lat. Cancer Fatalities	Pop. Dose 50 mi	Pop. Dose Entire Region	Early Fat. Risk, 1 mi.	Lat. Can Fatality 10 mi.
SRH-01-1	4.43E-01	2.74E+02	6.41E+03	1.62E+04	1.36E-02	3.81E-04
SRH-01-2	-----	-----	-----	-----	-----	-----
SRH-01-3	1.18E-01	4.63E+02	9.27E+03	2.78E+04	4.92E-03	3.46E-04
SRH-02-1	-----	-----	-----	-----	-----	-----
SRH-02-2	-----	-----	-----	-----	-----	-----
SRH-02-3	6.53E-01	1.17E+03	1.76E+04	6.91E+04	1.51E-02	7.98E-04
SRH-03-1	9.24E-03	1.21E+03	1.11E+04	7.15E+04	4.24E-04	3.14E-04
SRH-03-2	-----	-----	-----	-----	-----	-----
SRH-03-3	3.16E-01	9.66E+02	1.47E+04	5.65E+04	9.80E-03	4.91E-04
SRH-04-1	3.77E-02	1.58E+03	1.97E+04	9.14E+04	8.73E-04	1.63E-03
SRH-04-2	-----	-----	-----	-----	-----	-----
SRH-04-3	2.53E+00	1.87E+03	2.23E+04	1.11E+05	2.58E-02	1.11E-03
SRH-05-1	-----	-----	-----	-----	-----	-----
SRH-05-2	-----	-----	-----	-----	-----	-----
SRH-05-3	1.10E+00	1.50E+03	1.91E+04	8.83E+04	2.02E-02	7.24E-04
SRH-06-1	-----	-----	-----	-----	-----	-----
SRH-06-2	1.47E+02	3.45E+03	4.02E+04	2.00E+05	5.11E-02	4.36E-03
SRH-06-3	5.34E+01	4.23E+03	4.25E+04	2.47E+05	4.78E-02	5.51E-03
SRH-07-1	-----	-----	-----	-----	-----	-----
SRH-07-2	-----	-----	-----	-----	-----	-----
SRH-07-3	3.40E+01	3.56E+03	3.76E+04	2.08E+05	3.39E-02	3.30E-03
SRH-08-1	-----	-----	-----	-----	-----	-----
SRH-08-2	-----	-----	-----	-----	-----	-----
SRH-08-3	6.02E+00	2.81E+03	2.89E+04	1.66E+05	2.21E-02	1.69E-03
SRH-09-1	-----	-----	-----	-----	-----	-----
SRH-09-2	-----	-----	-----	-----	-----	-----
SRH-09-3	1.57E+00	2.82E+03	2.75E+04	1.65E+05	1.28E-02	1.26E-03

Table 4.3-4 (continued)

Source Term	Early Fatal-ities	Total Lat. Cancer Fatalities	Pop. Dose 50 mi	Pop. Dose Entire Region	Early Fat. Risk, 1 mi.	Lat. Can Fatality 10 mi.
SRH-10-1	-----	-----	-----	-----	-----	-----
SRH-10-2	-----	-----	-----	-----	-----	-----
SRH-10-3	2.49E+02	7.24E+03	1.12E+05	3.90E+05	8.73E-02	2.30E-02
SRH-11-1	-----	-----	-----	-----	-----	-----
SRH-11-2	-----	-----	-----	-----	-----	-----
SRH-11-3	1.01E+02	5.53E+03	7.05E+04	3.12E+05	7.79E-02	1.24E-02
SRH-12-1	-----	-----	-----	-----	-----	-----
SRH-12-2	-----	-----	-----	-----	-----	-----
SRH-12-3	6.97E+01	4.94E+03	4.26E+04	2.91E+05	4.19E-02	4.73E-03
SRH-13-1	0.00E+00	1.28E-02	4.87E-01	9.74E-01	0.00E+00	1.20E-08
SRH-13-2	-----	-----	-----	-----	-----	-----
SRH-13-3	-----	-----	-----	-----	-----	-----
SRH-14-1	0.00E+00	7.53E-02	3.57E+00	6.63E+00	0.00E+00	8.32E-08
SRH-14-2	-----	-----	-----	-----	-----	-----
SRH-14-3	-----	-----	-----	-----	-----	-----
SRH-15-1	0.00E+00	8.16E+00	2.87E+02	7.02E+02	0.00E+00	6.39E-06
SRH-15-2	-----	-----	-----	-----	-----	-----
SRH-15-3	2.34E-04	2.42E+01	7.60E+02	1.53E+03	1.17E-05	5.03E-05
SRH-16-1	2.10E-03	3.91E+02	5.59E+03	2.48E+04	6.60E-05	1.19E-04
SRH-16-2	-----	-----	-----	-----	-----	-----
SRH-16-3	2.30E-02	2.99E+02	6.33E+03	1.76E+04	1.14E-03	2.20E-04
SRH-17	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00



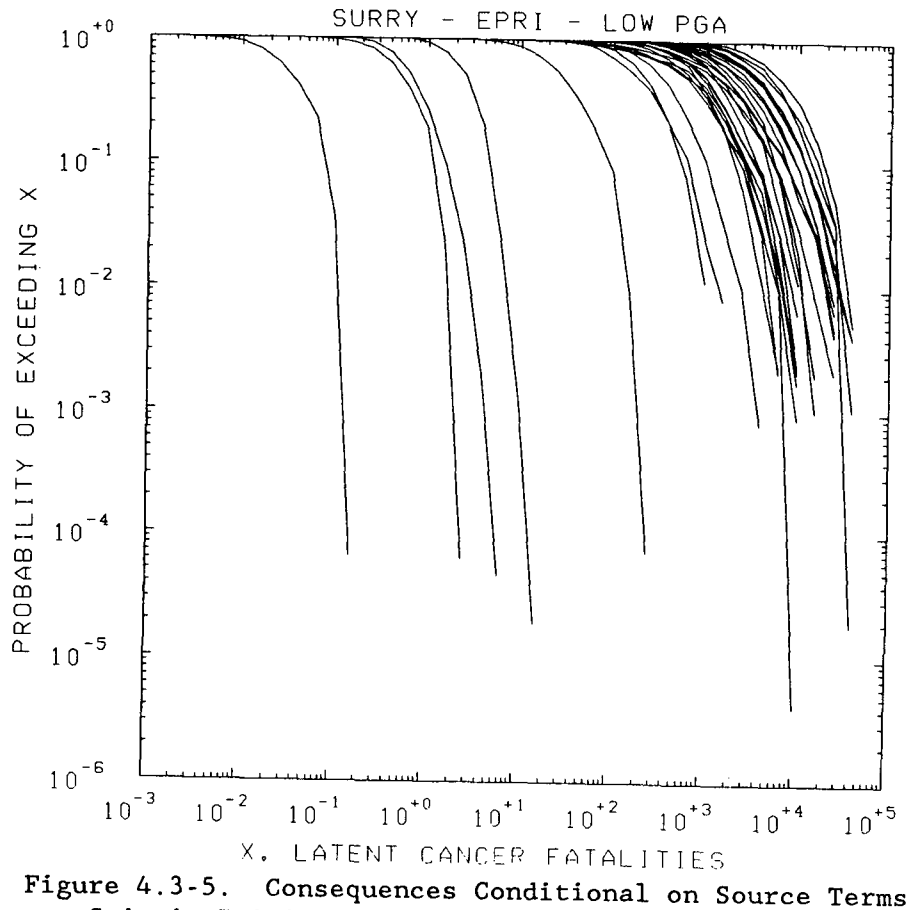
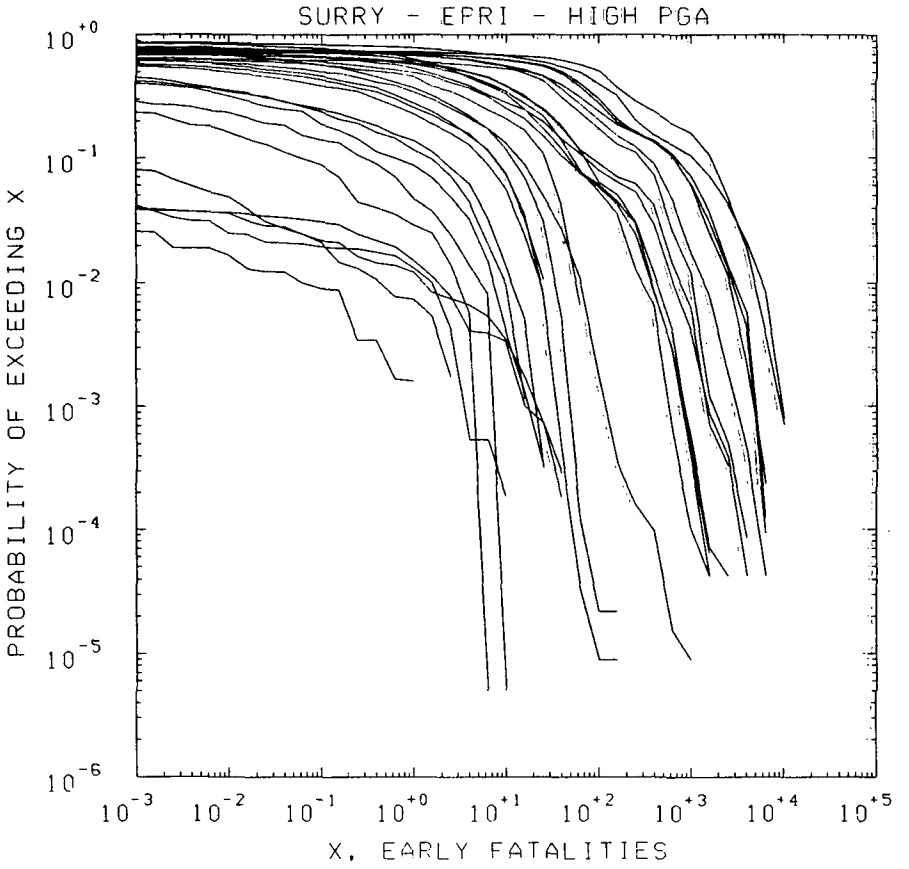


Figure 4.3-5. Consequences Conditional on Source Terms
Surry: Seismic Initiators; EPRI Hazard Distributions, Low PGA



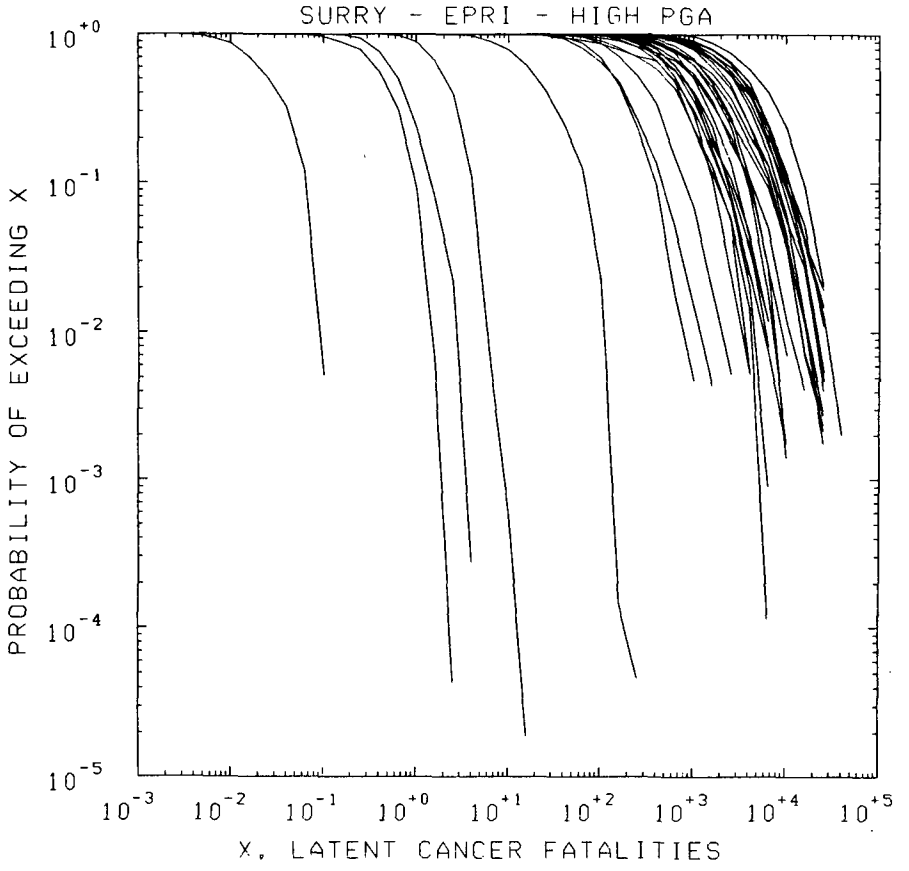


Figure 4.3-6. Consequences Conditional on Source Terms Surry: Seismic Initiators; EPRI Hazard Distributions, High PGA

Table 4.3-5
Mean Consequence Results for Seismic Initiators
EPRI Hazard Distributions--Low PGA
(Population Doses in Sv)

Source Term	Early Fatal-ities	Total Lat. Cancer Fatalities	Pop. Dose 50 mi	Pop. Dose Entire Region	Early Fat. Risk, 1 mi.	Lat. Can Fatality 10 mi.
SRD-01-1	0.00E+00	1.22E+03	8.93E+03	7.95E+04	0.00E+00	7.97E-05
SRD-01-2	1.98E-01	1.15E+03	1.43E+04	6.75E+04	6.75E-03	5.57E-04
SRD-01-3	3.38E-02	1.33E+03	1.83E+04	7.93E+04	1.43E-03	5.07E-04
SRD-02-1	0.00E+00	9.82E+02	1.07E+04	5.83E+04	0.00E+00	1.08E-04
SRD-02-2	1.41E-02	4.91E+02	9.24E+03	2.93E+04	5.81E-04	2.97E-04
SRD-02-3	3.45E-03	1.06E+03	1.69E+04	6.40E+04	1.71E-04	4.15E-04
SRD-03-1	0.00E+00	1.11E+03	1.54E+04	6.83E+04	0.00E+00	9.90E-05
SRD-03-2	1.65E+00	2.35E+03	2.44E+04	1.37E+05	2.05E-02	1.41E-03
SRD-03-3	5.25E-01	2.71E+03	3.24E+04	1.63E+05	1.08E-02	2.03E-03
SRD-04-1	0.00E+00	2.16E+03	1.42E+04	1.30E+05	0.00E+00	1.27E-04
SRD-04-2	3.50E-01	1.54E+03	1.80E+04	9.05E+04	8.24E-03	7.17E-04
SRD-04-3	2.40E-02	2.33E+03	2.65E+04	1.39E+05	9.31E-04	1.08E-03
SRD-05-1	-----	-----	-----	-----	-----	-----
SRD-05-2	3.10E-01	1.51E+03	1.74E+04	8.83E+04	8.81E-03	7.01E-04
SRD-05-3	7.30E-02	1.76E+03	2.28E+04	1.04E+05	3.35E-03	6.23E-04
SRD-06-1	-----	-----	-----	-----	-----	-----
SRD-06-2	5.77E+00	3.55E+03	3.87E+04	2.04E+05	3.12E-02	3.42E-03
SRD-06-3	9.17E+00	5.44E+03	5.44E+04	3.15E+05	1.29E-02	5.83E-03
SRD-07-1	-----	-----	-----	-----	-----	-----
SRD-07-2	1.82E+00	3.09E+03	2.94E+04	1.84E+05	2.70E-02	1.28E-03
SRD-07-3	2.46E+00	4.27E+03	4.34E+04	2.51E+05	1.15E-02	3.61E-03
SRD-08-1	-----	-----	-----	-----	-----	-----
SRD-08-2	1.10E+00	2.96E+03	2.49E+04	1.76E+05	2.51E-02	9.99E-04
SRD-08-3	3.63E-01	4.15E+03	3.56E+04	2.47E+05	3.96E-03	1.53E-03
SRD-09-1	-----	-----	-----	-----	-----	-----
SRD-09-2	1.14E+02	7.08E+03	9.94E+04	3.61E+05	5.79E-02	1.47E-02
SRD-09-3	7.54E+00	8.97E+03	1.16E+05	4.64E+05	5.34E-02	8.13E-03

Table 4.3-5 (continued)

Source Term	Early Fatal-ities	Total Lat. Cancer Fatalities	Pop. Dose 50 mi	Pop. Dose Entire Region	Early Fat. Risk, 1 mi.	Lat. Can Fatality 10 mi.
SRD-10-1	-----	-----	-----	-----	-----	-----
SRD-10-2	1.20E+01	5.47E+03	5.59E+04	3.16E+05	4.44E-02	5.22E-03
SRD-10-3	1.22E+02	7.10E+03	8.41E+04	4.15E+05	2.33E-02	1.01E-02
SRD-11-1	-----	-----	-----	-----	-----	-----
SRD-11-2	2.30E+01	5.50E+03	7.17E+04	2.93E+05	4.67E-02	1.16E-02
SRD-11-3	8.54E-01	5.50E+03	5.87E+04	3.32E+05	1.35E-02	2.17E-03
SRD-12-1	0.00E+00	4.06E-02	1.98E+00	3.42E+00	0.00E+00	3.12E-08
SRD-12-2	-----	-----	-----	-----	-----	-----
SRD-12-3	0.00E+00	8.17E-01	1.74E+01	4.71E+01	0.00E+00	1.77E-06
SRD-13-1	0.00E+00	6.13E-01	2.15E+01	4.71E+01	0.00E+00	4.79E-07
SRD-13-2	-----	-----	-----	-----	-----	-----
SRD-13-3	0.00E+00	2.83E+00	1.00E+02	2.13E+02	0.00E+00	5.58E-06
SRD-14-1	0.00E+00	3.94E+01	1.36E+03	2.86E+03	0.00E+00	3.04E-05
SRD-14-2	2.93E-05	2.82E+02	5.83E+03	1.67E+04	1.47E-06	1.75E-04
SRD-14-3	1.90E-05	2.81E+02	6.86E+03	1.72E+04	9.51E-07	1.98E-04
SRD-15	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Table 4.3-6
Mean Consequence Results for Seismic Initiators
EPRI Hazard Distributions--High PGA
(Population Doses in Sv)

Source Term	Early Fatal-ities	Total Lat. Cancer Fatalities	Pop. Dose 50 mi	Pop. Dose Entire Region	Early Fat. Risk, 1 mi.	Lat. Can Fatality 10 mi.
SRE-01-1	9.48E-02	9.04E+02	8.06E+03	5.78E+04	1.08E-03	1.32E-04
SRE-01-2	1.68E+00	8.37E+02	1.24E+04	4.89E+04	2.33E-02	6.48E-04
SRE-01-3	5.28E-01	1.09E+03	1.64E+04	6.42E+04	1.32E-02	7.06E-04
SRE-02-1	3.58E-02	7.71E+02	9.93E+03	4.53E+04	1.63E-03	3.77E-04
SRE-02-2	2.05E-01	3.84E+02	7.33E+03	2.26E+04	6.90E-03	2.83E-04
SRE-02-3	9.88E-02	8.28E+02	1.45E+04	4.92E+04	4.28E-03	3.99E-04
SRE-03-1	7.07E+00	1.09E+03	1.95E+04	5.47E+04	4.56E-02	4.61E-03
SRE-03-2	2.28E+01	1.81E+03	2.04E+04	1.04E+05	4.42E-02	1.77E-03
SRE-03-3	2.09E+00	2.01E+03	2.57E+04	1.20E+05	2.34E-02	1.91E-03
SRE-04-1	1.04E-01	1.61E+03	1.29E+04	9.55E+04	2.01E-03	4.37E-04
SRE-04-2	2.13E+00	1.17E+03	1.53E+04	6.83E+04	2.67E-02	8.13E-04
SRE-04-3	3.83E-01	1.78E+03	2.21E+04	1.05E+05	9.48E-03	8.43E-04
SRE-05-1	-----	-----	-----	-----	-----	-----
SRE-05-2	3.48E+00	1.13E+03	1.42E+04	6.56E+04	3.03E-02	8.92E-04
SRE-05-3	7.02E-01	1.37E+03	1.91E+04	8.02E+04	1.62E-02	6.34E-04
SRE-06-1	-----	-----	-----	-----	-----	-----
SRE-06-2	8.66E+01	2.65E+03	2.87E+04	1.54E+05	5.53E-02	2.84E-03
SRE-06-3	4.92E+01	3.72E+03	4.46E+04	2.13E+05	5.67E-02	6.30E-03
SRE-07-1	-----	-----	-----	-----	-----	-----
SRE-07-2	3.00E+01	2.42E+03	2.47E+04	1.42E+05	4.60E-02	1.82E-03
SRE-07-3	2.38E+01	3.18E+03	3.59E+04	1.84E+05	3.75E-02	4.17E-03
SRE-08-1	-----	-----	-----	-----	-----	-----
SRE-08-2	-----	-----	-----	-----	-----	-----
SRE-08-3	4.75E+00	3.18E+03	2.99E+04	1.87E+05	3.16E-02	1.69E-03
SRE-09-1	-----	-----	-----	-----	-----	-----
SRE-09-2	4.91E+02	4.94E+03	8.07E+04	2.89E+05	6.28E-02	9.87E-03
SRE-09-3	3.82E+02	7.02E+03	1.24E+05	3.72E+05	1.01E-01	2.57E-02

Table 4.3-6 (continued)

Source Term	Early Fatal-ities	Total Lat. Cancer Fatalities	Pop. Dose 50 mi	Pop. Dose Entire Region	Early Fat. Risk, 1 mi.	Lat. Can Fatality 10 mi.
SRE-10-1	-----	-----	-----	-----	-----	-----
SRE-10-2	2.04E+02	4.35E+03	5.06E+04	2.54E+05	5.53E-02	5.65E-03
SRE-10-3	2.12E+02	5.02E+03	6.11E+04	3.03E+05	3.12E-02	6.21E-03
SRE-11-1	-----	-----	-----	-----	-----	-----
SRE-11-2	2.10E+02	4.20E+03	7.37E+04	2.25E+05	5.56E-02	1.37E-02
SRE-11-3	2.44E+01	4.58E+03	4.85E+04	2.70E+05	6.30E-02	6.16E-03
SRE-12-1	-----	-----	-----	-----	-----	-----
SRE-12-2	1.11E+02	3.07E+03	3.07E+04	1.79E+05	5.47E-02	3.14E-03
SRE-12-3	4.06E+01	4.63E+03	3.86E+04	2.73E+05	3.97E-02	2.95E-03
SRE-13-1	0.00E+00	3.21E-02	1.56E+00	2.69E+00	0.00E+00	3.09E-08
SRE-13-2	-----	-----	-----	-----	-----	-----
SRE-13-3	0.00E+00	7.77E-01	1.60E+01	4.50E+01	0.00E+00	1.54E-06
SRE-14-1	0.00E+00	5.14E-01	1.71E+01	3.92E+01	0.00E+00	4.61E-07
SRE-14-2	-----	-----	-----	-----	-----	-----
SRE-14-3	0.00E+00	2.34E+00	7.50E+01	1.72E+02	0.00E+00	4.26E-06
SRE-15-1	0.00E+00	2.91E+01	8.93E+02	2.03E+03	0.00E+00	3.01E-05
SRE-15-2	1.87E-02	2.13E+02	4.54E+03	1.24E+04	9.28E-04	1.57E-04
SRE-15-3	4.69E-03	1.89E+02	4.51E+03	1.13E+04	2.34E-04	1.63E-04
SRE-16	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

4.4 References

1. D. I. Chanin, J. L. Sprung, L. T. Ritchie, and H.-N. Jow, "MELCOR Accident Consequence Code System (MACCS): User's Guide," NUREG/CR-4691, SAND86-1562, Vol. 1, Sandia National Laboratories, February 1990.

2. H.-N. Jow, J. L. Sprung, J. A. Rollstin, and D. I. Chanin, "MELCOR Accident Consequence Code System (MACCS): Model Description," NUREG/CR-4691, SAND86-1562, Vol. 2, Sandia National Laboratories, February 1990.

3. J. A. Rollstin, D. I. Chanin, and H.-N. Jow, "MELCOR Accident Consequence Code System (MACCS): Programmer's Reference Manual," NUREG/CR-4691, SAND86-1562, Vol. 3, Sandia National Laboratories, February 1990.

4. R. L. Iman, J. D. Johnson, and J. C. Helton, "A User's Guide for the Probabilistic Risk Assessment Model Integration System (PRAMIS)," NUREG/CR-5262, SAND88-3093, Sandia National Laboratories, May 1990.

5. SURRY RISK RESULTS

This section gives the results of the integrated risk analysis for the Surry plant. Section 5.1 gives the risk results for internal initiators; Section 5.2 presents the results for risk due to fires. Seismic risk was computed using two different sets of hazard distributions. Results of the integrated risk analysis based on the LLNL hazard distributions are given in Section 5.3. Results of the integrated risk analysis based on the EPRI hazard distributions are presented in Section 5.4. The two seismic risk estimates are compared in Section 5.5.

Risk is determined by bringing together the results of four constituent analyses: the accident frequency, accident progression, source term, and consequence analyses. The phrase integrated risk analysis is used to refer to the combined result when all four analyses are combined. The way in which these analyses contribute to risk analysis is summarized in Section 1.4 of this volume. More detail on the methods used in calculating risk can be found in Volume 1.

The figures in this section present only a very small portion of the total risk output available. Detailed listings of results are available on computer media by request.

5.1 Results for Internal Initiators

This section describes the results of the integrated risk analysis for internal initiators at the Surry plant. Section 5.1.1 is a discussion of basic risk results for internal initiators. A second sample for internal initiators, which is just as valid as the first sample, was run completely through the integrated risk analysis. The results of this second sample and its implications are discussed in Section 5.1.2. Section 5.1.3 is concerned with the types of accidents and plant features which are important in determining the risk from internal initiators at Surry. Finally, Section 5.1.4 constitutes the results of the regression analysis performed to determine the important contributors to the uncertainty in risk due to internal initiators.

5.1.1 Risk Results

Figure 5.1-1 shows the basic results of the integrated risk analysis for internal initiators at Surry. This figure shows the complementary cumulative distribution functions (CCDFs) for early fatalities, latent cancer fatalities, population dose within 50 miles, population dose within the entire region, individual risk of early fatality within one mile of the site boundary, and individual risk of latent cancer fatality within 10 miles. The CCDFs display the relationship between the frequency of the consequence and the magnitude of the consequence. As there are 200 observations in the sample for Surry, the actual risk results at the most basic level are 200 CCDFs for each consequence measure. Plots showing these 200 curves are contained in Appendix D; only four statistical measures of the 200 curves are shown in Figure 5.1-1. These measures are generated by analyzing the plots in the vertical direction. For each

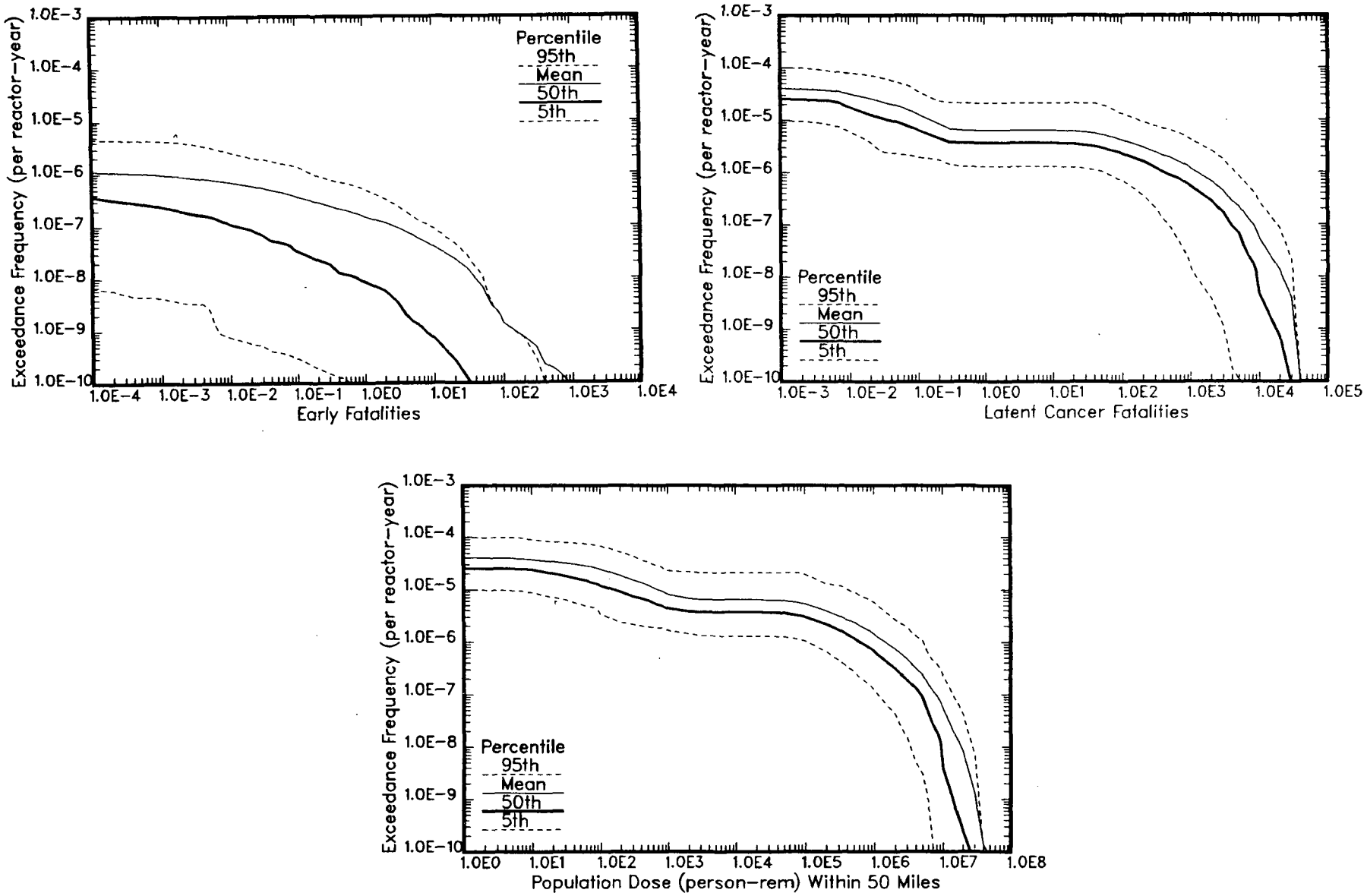
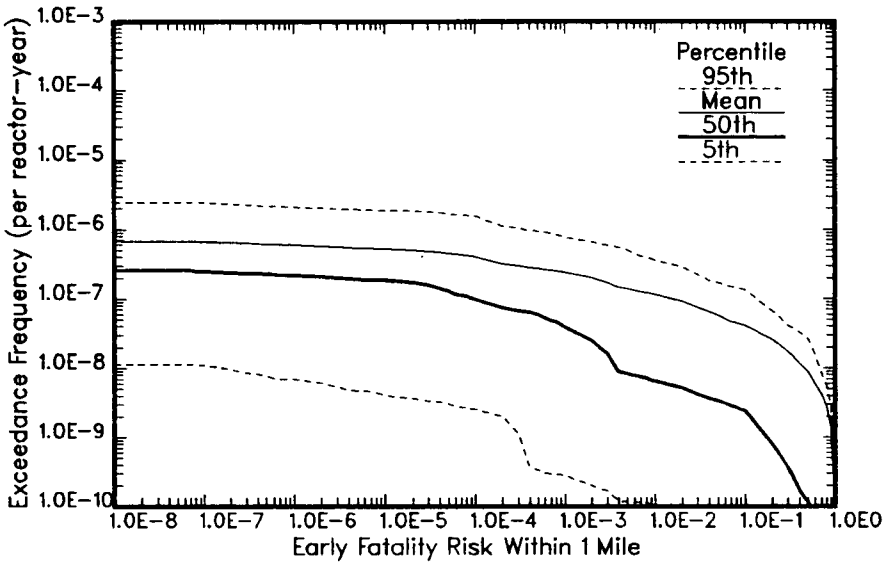
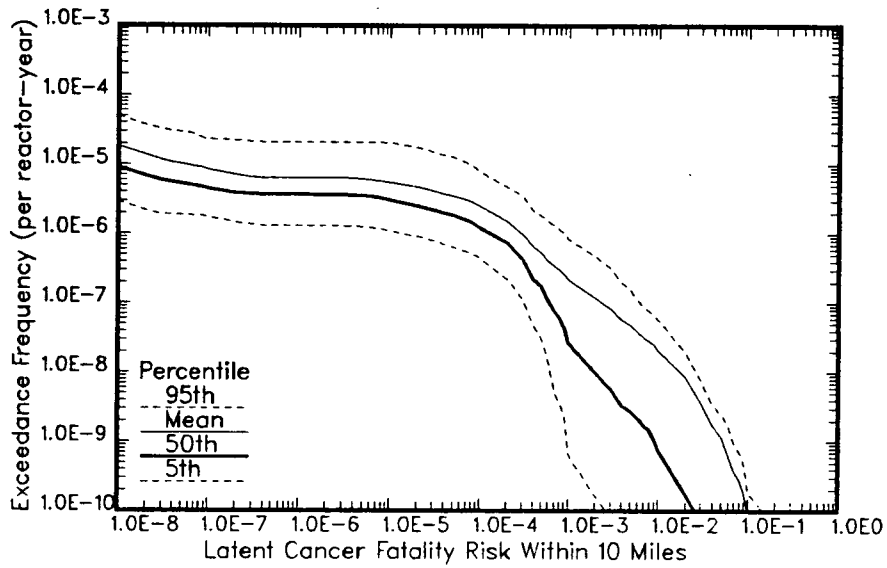


Figure 5.1-1. Exceedance Frequencies for Risk Surry: All Internal Initiators





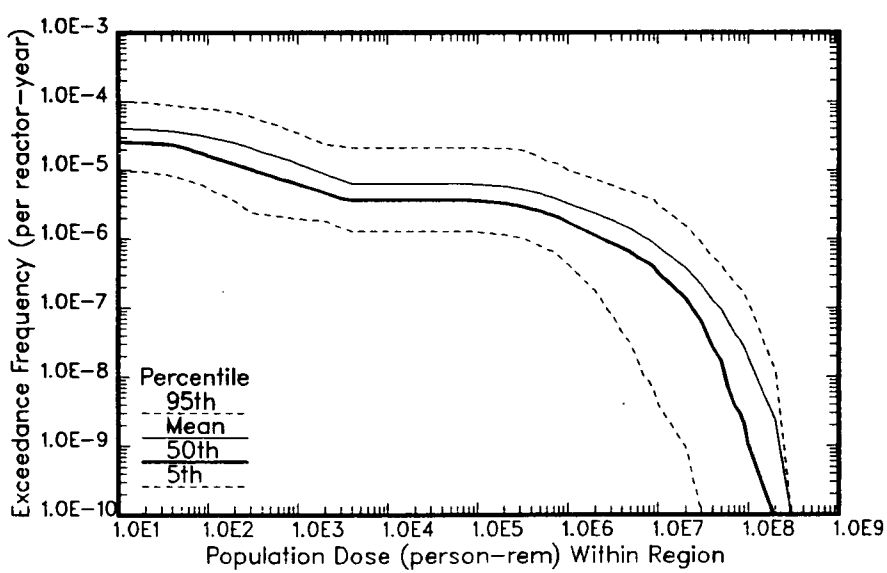


Figure 5.1-1. (continued)

consequence value on the abscissa, there are 200 values of the exceedance frequency (one for each observation or sample element) and from these 200 values the mean, median, 95th percentile, and 5th percentile values are calculated. When this is done for each value of the consequence measure, the curves in Figure 5.1-1 are obtained. Thus, Figure 5.1-1 gives the relationship between the magnitude of the consequence and the frequency at which the consequence is exceeded, as well as the variation in that relationship. The percentile curves in Figure 5.1-1 and similar figures can be read from either axis; however, the mean curve is only valid when read from the abscissa.

Although the abscissa in the last two plots in Figure 5.1-1 is labeled "Risk", this reflects historical usage and is not really correct. The x-axis in these plots actually represents conditional probability: specifically, the probability that an individual, randomly located in the spatial interval according to the population distribution, will die given that the accident occurs. The ordinate gives the frequency of an accident that produces a conditional probability that exceeds the value on the abscissa. A true risk measure does not result until the curves in the last two plots of Figure 5.1-1 are reduced to single values.

The curves for latent cancer fatalities in Figure 5.1-1 are relatively flat from 0.2 to 80 fatalities. This means that latent cancer fatalities in this range are very unlikely. Any type of containment failure or bypass is likely to lead to more than 80 delayed fatalities. If the containment does not fail, the eventual release of the noble gases (xenon and krypton) from the containment due to design basis leakage will probably cause less than 0.2 latent cancer fatalities.

The variation from the 5th to the 95th percentiles indicates the uncertainty in the risk estimates due to uncertainty in the basic parameters in the three sampled constituent analyses (the accident frequency, accident progression, and source term analyses). The variation along a curve in Figure 5.1-1 (or along one of the individual curves in Appendix D) is indicative of the variation in risk due to different types of accidents and due to different weather conditions at the time of the accident. Thus the individual curves in Appendix D can be viewed as representing stochastic variability (i.e., the effects of probabilistic events in which it is possible for the accident to develop in more than one way) and the variability between curves can be seen as representing the effects of imprecisely known parameters and processes that are mostly nonstochastic. As the magnitude of the consequence measure increases, the mean curve typically approaches or exceeds the 95th percentile curve. This results when the mean is dominated by a few large observations, which often happens for large values of the consequences because only a few observations have nonzero exceedance frequencies for these large consequences.

Figure 5.1-1 shows the following mean and median exceedance frequencies for fixed values of early fatalities (EF) and latent cancer fatalities (LCF):

	Exceedance Frequency (1/R-yr)	
Consequence	Mean	Median
1 EF	2E-7	1E-8
100 EF	2E-9	< 1E-10
100 LCF	4E-6	2E-6
10,000 LCF	5E-8	1E-8

Although the latent cancer fatality values mentioned above may appear large, they must be considered in perspective; the calculated latent cancer fatalities occur throughout the entire region and over several decades. Between 400,000 to 500,000 deaths due to cancer occur every year in the U.S. The population within 350 miles of the plant is about 54 million and the population within 1000 miles of the plant is about 156 million. When spread over two or three decades, even tens of thousands of additional latent cancer fatalities are statistically indistinguishable from the general background morbidity due to malignant neoplasms in such a large population.

Although the CCDF for each observation conveys the most information about risk, a single number may be generated for each consequence measure for each observation. This value, denoted annual risk, is determined by summing the product of the frequencies and consequences for all the points that are used to construct the CCDF for each observation in the sample. The construction of annual risk has the effect of averaging over the different weather states and includes contributions from all the different types of accidents that can occur. Since the complete analysis consisted of a sample of 200 observations, there are 200 values of annual risk for each consequence measure. These 200 values may be ordered and plotted as histograms, which is done in Figure 5.1-2. The same four statistical measures utilized above are shown on these plots as well. Note that considerable information has been lost in going from the CCDFs in Appendix D to the histograms of annual values in Figure 5.1-2; the relationship between the size of the consequence and its frequency has been sacrificed to obtain a single value for risk for each observation.

The plots in Figure 5.1-2 show the variation in the annual risk for six consequence measures. Where the mean is close to the 95th percentile, it may be inferred that a relatively small number of observations dominate the mean value. This is more likely to occur for the early fatality consequence measures than for the latent cancer fatality or population dose consequence measures due to the threshold effect for early fatalities. In essence, Figure 5.1-2 shows the probability density functions of the logarithms of the consequence measures. Equivalent density functions could be generated for the consequence measures themselves, but would appear quite different due to the change in scale. Another alternative, but equivalent display, for the results in Figure 5.1-2 would be to use cumulative distribution functions.

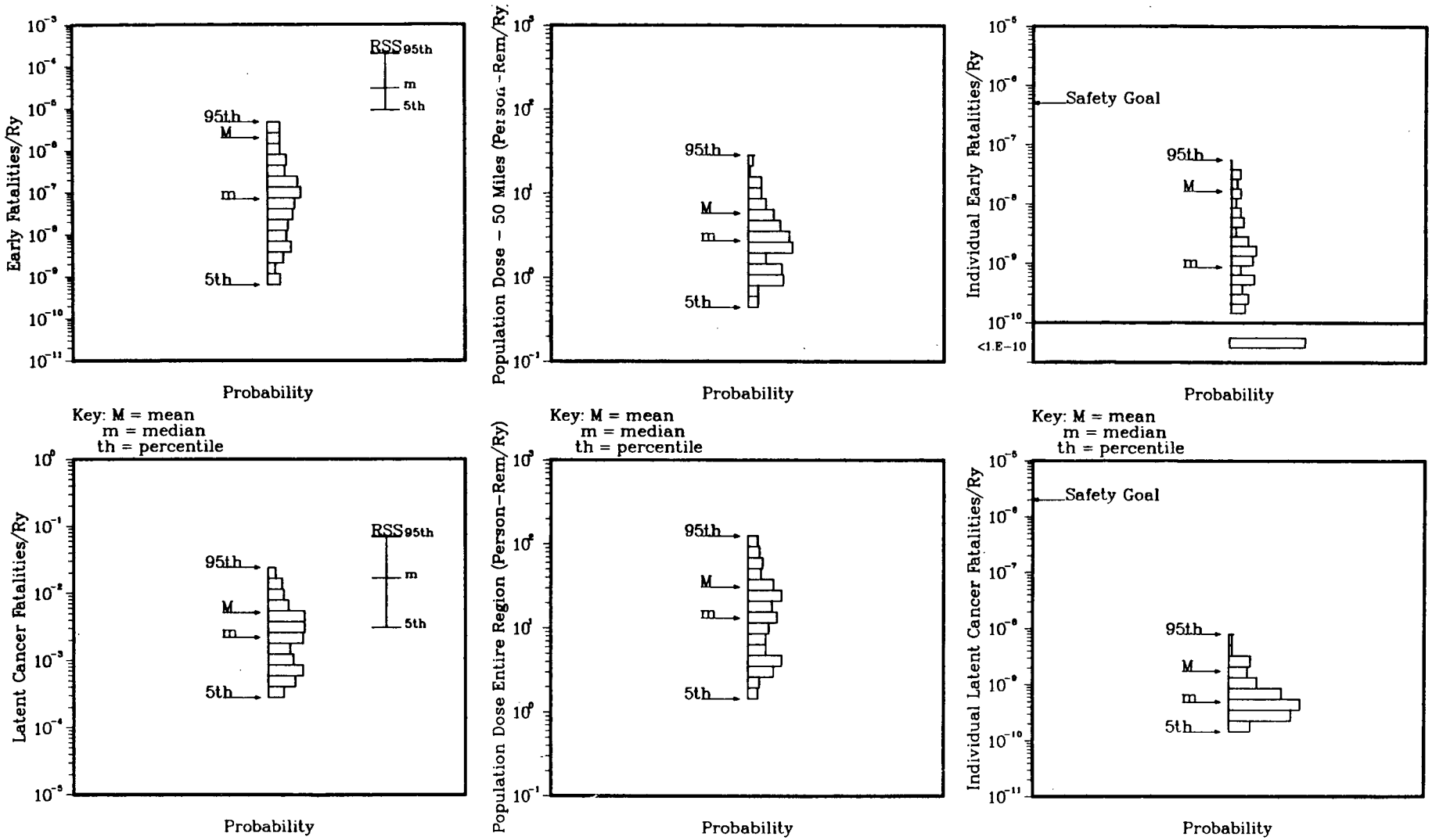


Figure 5.1-2. Distributions of Annual Risk. Surry: All Internal Initiators

For early fatalities and latent cancer fatalities, the results of this study may be compared with those of the Reactor Safety Study (RSS).[1] For early fatalities, Figure 5.1-2 shows that almost the entire distribution is below the lower end of the RSS distribution. The median value for this study is about two orders of magnitude below the median for the RSS. (The RSS did not report mean values.) For latent cancer fatalities, the 5th percentile of the RSS distribution falls between the mean and median of the current distribution. The median value for this study is about one order of magnitude below the median for the RSS.

These decreases in risk are greater than the decrease in the core damage frequency. The RSS reported a point estimate value of 4.6E-5/R-yr. For the integrated risk analysis, the median and mean of the core damage frequency distribution are 2.5E-5/R-yr and 4.1E-5/R-yr, respectively. (The median and mean value of the CDF are slightly different in the integrated risk analysis than in the stand-alone accident frequency analysis for reasons discussed in Section 2.2.) Thus, the bulk of the decrease in the risk at Surry compared to the RSS comes from our improved understanding of how reactor accidents progress, and how much of the fission product inventory will be released in the course of an accident.

The safety goals are expressed in terms of mean individual fatality risks, which is really an individual's probability of becoming a casualty of a reactor accident in a given year. The individual early fatality risk within one mile is the frequency (per year) that a person living within one mile of the site boundary will die within a year due to the accident. The entire population within one mile is considered to obtain an average value. The individual latent cancer fatality risk within 10 miles is the frequency (per year) that a person living within 10 miles of the plant will die many years later from cancer due to radiation exposure received from the accident. The entire population within 10 miles is considered to obtain an average value. A single value for individual fatality risk for each observation is obtained by reducing the CCDF for each observation to a single value. The density distribution of these 200 values is plotted in the last two frames of Figure 5.1-2. Although the values are really frequencies, they are so small that they are essentially probabilities that an individual will become a casualty of a reactor accident in a given year. The plots for individual risk in Figure 5.1-2 show that both internally initiated risk distributions for Surry fall well below the safety goal.

A single measure of risk for the entire sample may be obtained by taking the average value from the histograms in Figure 5.1-2. This measure of risk is commonly called mean risk, although it is actually the average of the annual risk, or the mean value of the mean risk. The mean risk values for the six consequence measures reported here are displayed in Figure 5.1-2. The important contributors to mean risk are considered in subsection 5.1.3.

One of the main factors accounting for the low values for early fatality risk at Surry is the strength of the containment. Estimates of failure pressure have increased over the years; the median and mean values of the distribution for the failure pressure of the Surry containment for this analysis are about 126 psig. Although the pressure rise at VB now contains

the contributions from direct heating of the containment, the addition of this mechanism has been more than offset by the mechanisms considered that lead to depressurization of the RCS before failure of the vessel. The RCS depressurization mechanisms included are: T-I failure of the hot leg or surge line, PORVs sticking open, T-I RCP seal failure, T-I SGTR, and deliberate opening of the PORVs by the operators. Only the first three of these mechanisms are very effective, but this was sufficient to ensure that only a small fraction of the accidents that were at full system pressure at the onset of core damage were still at that pressure at vessel breach. Reducing the RCS pressure at vessel breach, of course, reduces the loads placed on the containment at vessel breach, and thus reduces the probability of CF.

Another change in the analysis which has reduced the probability of CF at vessel breach, and thus the early fatality risk, is the consideration of arresting the core damage process before vessel failure and achieving a safe, stable state as at TMI-2. Obtaining sufficient ECCI after the onset of core damage may come about through the recovery of offsite power, or the depressurization of the RCS to the point where injection by systems operating at the onset of core damage commences. A significant fraction of the time, the accidents in the most likely three PDS groups (Slow SBO, LOCAs, and Fast SBO, comprising about 85% of the MCDF) result in arrest of the core damage process and no vessel breach. In the portion of these accidents that do continue to vessel breach, the RCS is usually at low or intermediate pressure, and the chances of CF at VB are low.

In summary, the risk of early fatalities at Surry is low because the most likely CD accidents, SBO and LOCA, rarely lead to CF at vessel breach. Early fatality risk is dominated by Event V, as will be seen in subsection 5.1.3, and the frequency of Event V is fairly low.

Latent cancer fatality risk at Surry is also fairly low. For this risk measure, an early release is not very important. Sizeable releases from the most likely CD accidents, SBO and LOCA, are relatively unlikely. CF at VB is improbable, and late CF is neither likely nor does it produce a large release. The risk of latent cancer fatalities is largely due to Event V and SGTRs with the secondary SRVs stuck open, and both these accidents have frequencies on the order of 1E-6/R-yr.

5.1.2 Second Sample

To determine the reproducibility of the integrated risk analyses performed for NUREG-1150, a second sample was run through the entire integrated risk analysis for Surry. The second sample is just as valid as the first sample, and differs from the first sample only in the fact that a different random seed was used in the Latin Hypercube Sampling (LHS) program. Therefore, differences in the results between the two samples are an indication of the robustness of the analysis methods.

Figure 5.1-3 displays the statistical measures of the CCDFs for both samples. Considering the range of the distributions, as indicated by the distance between the 5th and the 95th percentile curves, the agreement between the two samples is remarkably good. As the family of CCDFs is the

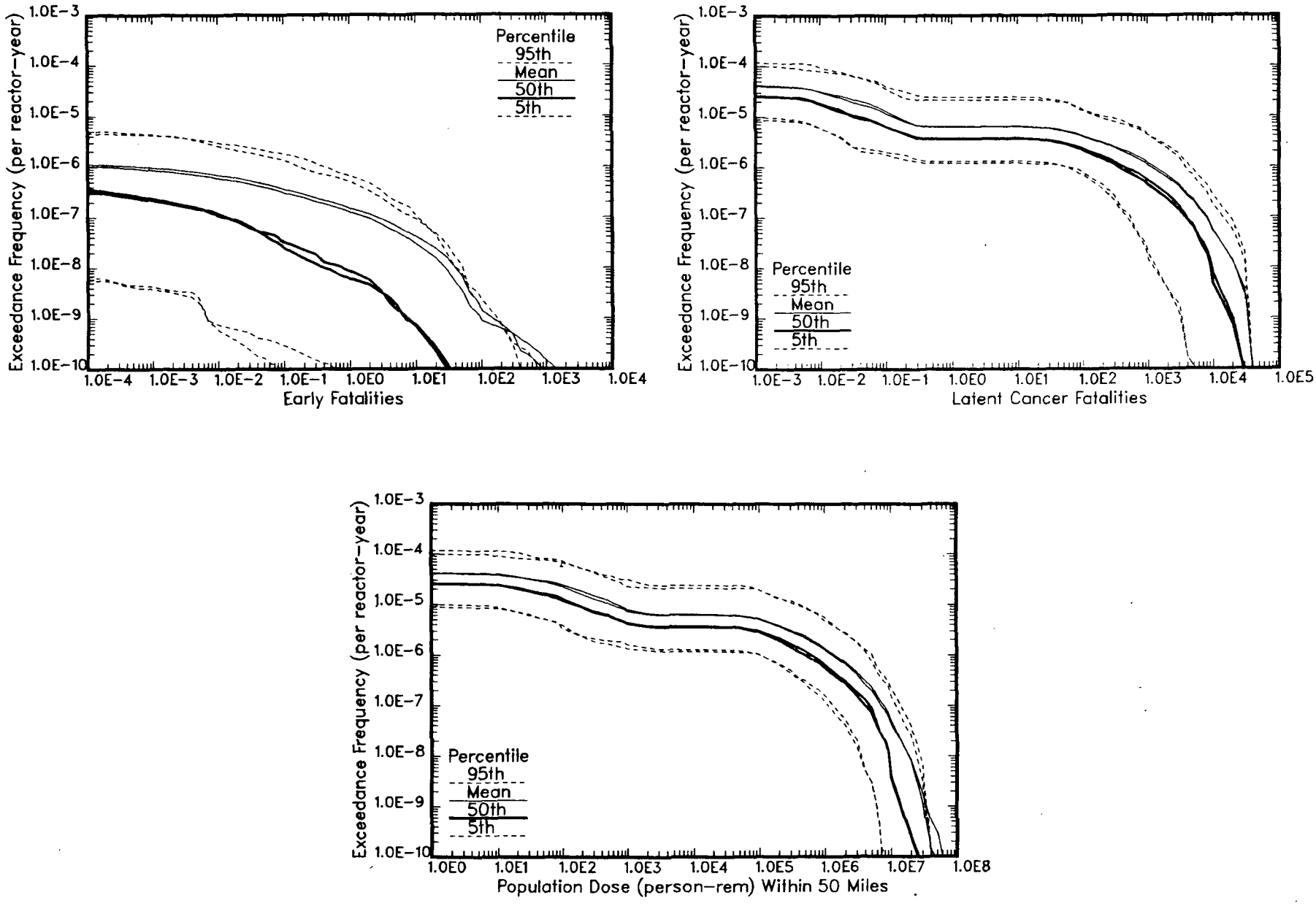
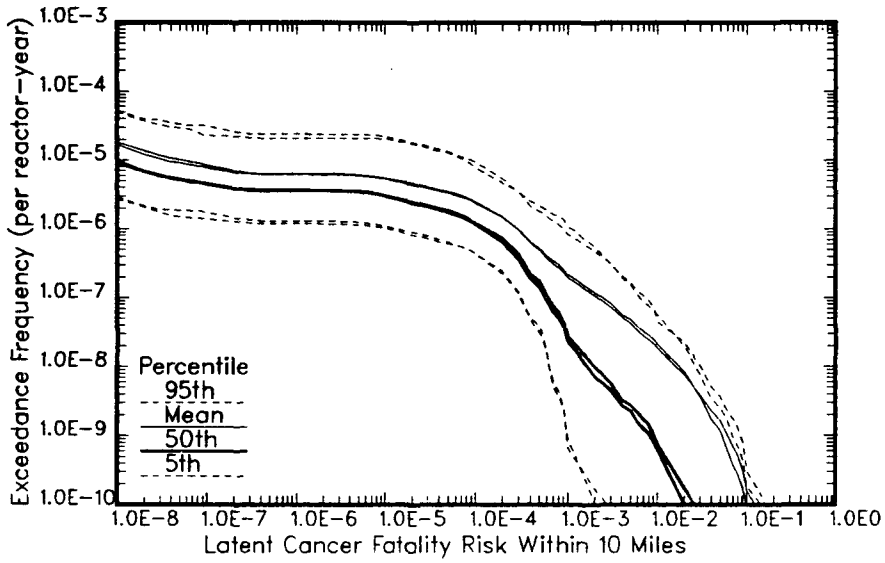
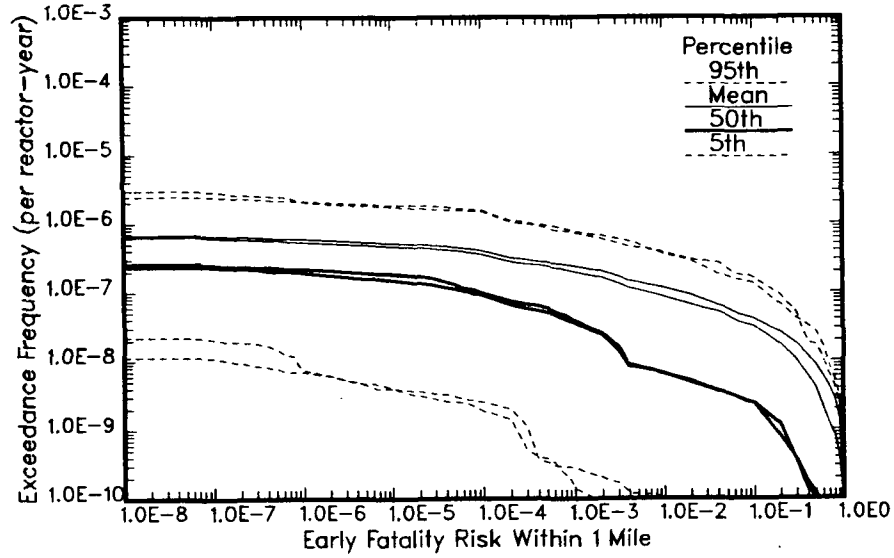


Figure 5.1-3. Comparison of the Exceedance Frequencies for Risk Surry: Two Samples for Internal Initiators





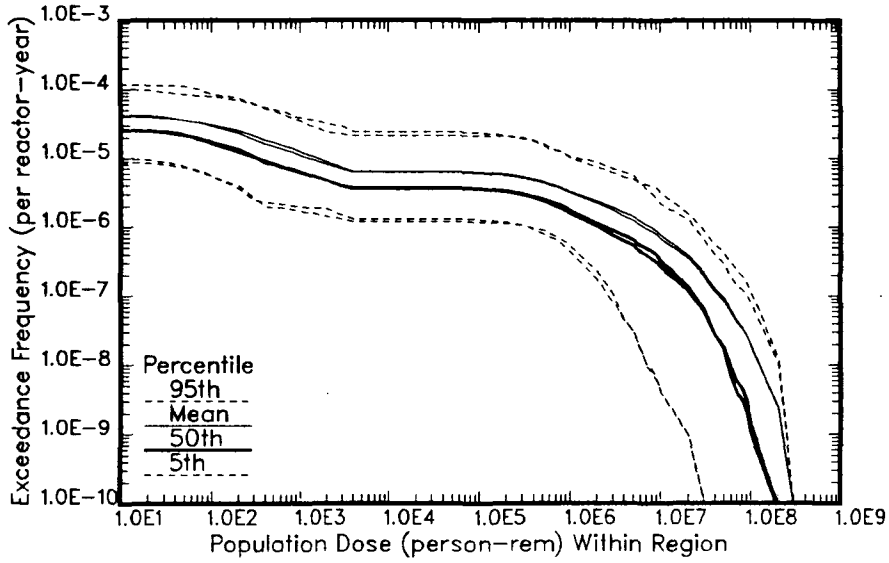


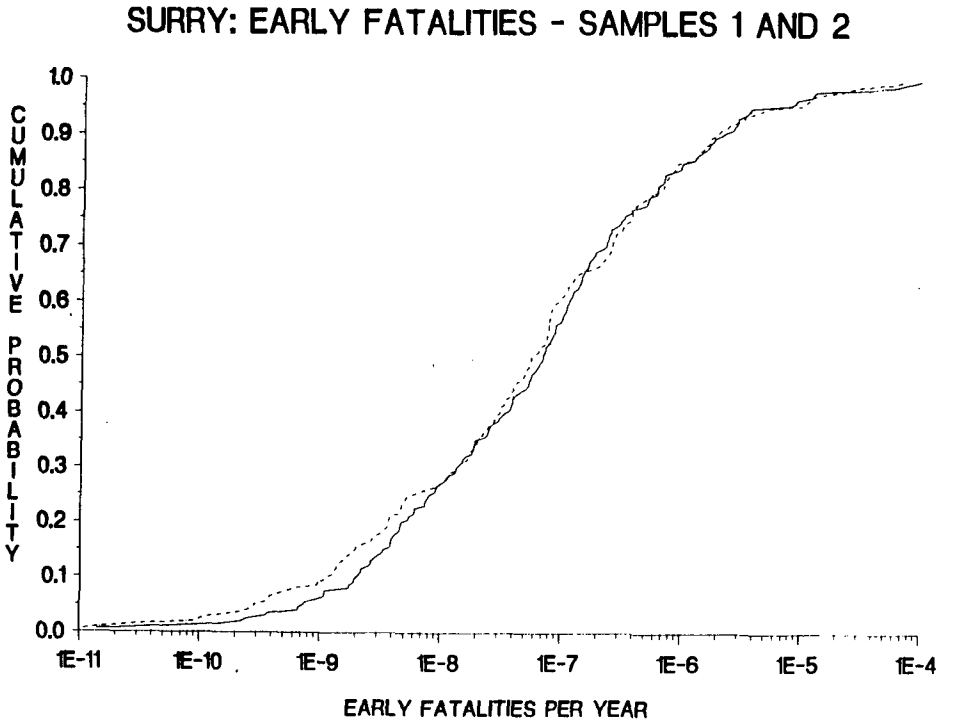
Figure 5.1-3. (continued)

most basic measure of risk, this agreement indicates that the methods used for this integrated risk analysis are sound.

Table 5.1-1 presents four statistical measures of the distributions of core damage frequency and annual risk for both samples. Figure 5.1-4 contains cumulative distribution plots for annual risk for early fatalities and latent cancer fatalities. Figure 5.1-4 shows that there is remarkably good agreement over the entire curve, while Table 5.1-1 shows that differences are apparent at some points. Differences between the samples at the extremes of the distributions are not surprising since the extremes are determined by a relatively few observations. The median value is generally more stable between the samples than is the mean. The mean value, often determined by a relatively few observations also, shows some variation between samples.

Table 5.1-1
Distributions for Annual Risk at Surry due to Internal Initiators
(All values per reactor-year)
(Population doses in person-rem)

Risk Measure	Sample	5th%tile	Median	Mean	95th%tile
Core Damage	1	9.8E-6	2.5E-5	4.1E-5	1.0E-4
	2	8.7E-6	2.6E-5	4.2E-5	1.2E-4
Early Fatalities	1	7.6E-10	7.0E-8	2.0E-6	5.4E-6
	2	3.2E-10	5.8E-8	1.6E-6	7.2E-6
Latent Cancer Fat.	1	3.1E-4	2.2E-3	5.2E-3	1.9E-2
	2	3.5E-4	2.9E-3	4.8E-3	1.8E-2
Population Dose 50 mi.	1	5.9E-1	2.7E 0	5.8E 0	2.5E+1
	2	6.9E-1	2.3E 0	5.3E 0	2.2E+1
Population Dose Entire Region	1	1.9E 0	1.3E+1	3.1E+1	1.2E+2
	2	2.1E 0	1.2E+1	2.8E+1	1.0E+2
Ind. Early Fat. Risk 1 mile	1	1.4E-11	8.7E-10	1.6E-8	4.9E-8
	2	6.3E-12	7.9E-10	1.1E-8	6.1E-8
Ind. L. C. Fatalities Risk--10 miles	1	1.6E-10	4.9E-10	1.7E-9	8.1E-9
	2	1.6E-10	4.5E-10	1.6E-9	7.1E-9



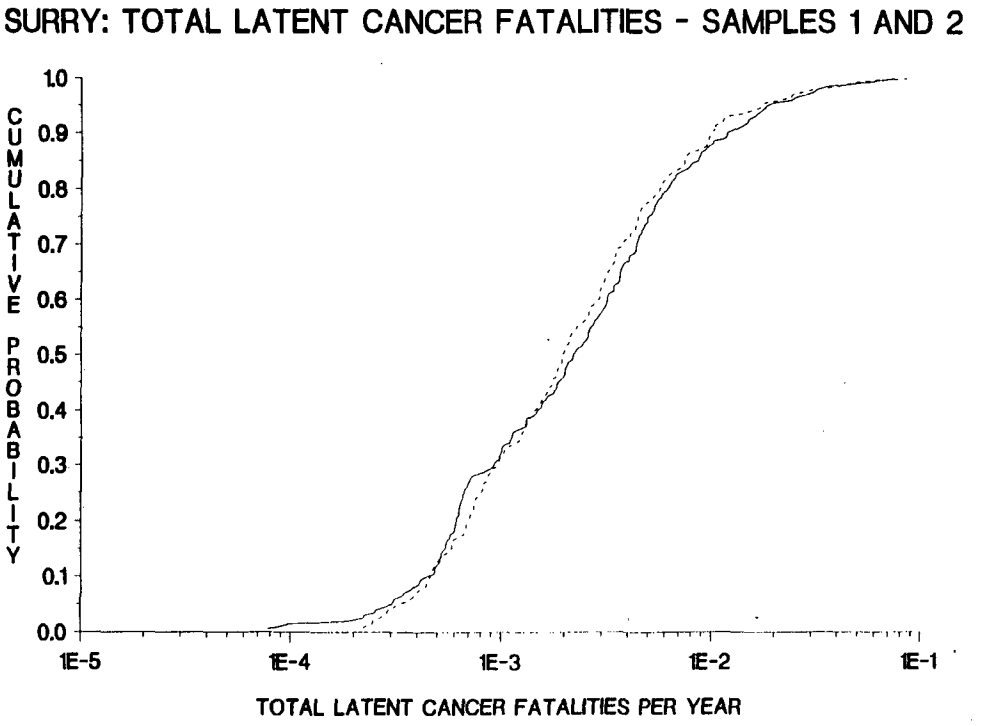


Figure 5.1-4. Comparison of the Cumulative Distributions for Annual Risk; Surry: Two Samples for Internal Initiators

5.1.3 Contributors to Risk

There exist two distinct ways to calculate contribution to risk. To facilitate their definition, the following quantities are introduced:

rC_j = risk (units: consequences/R-yr) for consequence measure j,

rC_{ij} = value for rC_j obtained for observation i,

rC_{jk} = risk (units: consequences/R-yr) for consequence measure j due to PDS group k,

rC_{ijk} = value for rC_{jk} obtained for observation i, and

nLHS = number of observations in the Latin Hypercube Sample.

The notation used here is similar to that used in Section 1.4 The value of nLHS is 200 for Surry. The risk rC_{ij} is the jth element of the vector $\mathbf{rC}_i$ in Equation (1.9) of Section 1.4. The risk rC_{ijk} is the jth element of the vector $\mathbf{rC}_i$ when the frequencies of all the PDS groups except group k in the vector $\mathbf{fPDS}_i$ are set to zero. The vector $\mathbf{fPDS}_i$ is equal to the product $\mathbf{fIE}_i\ \mathbf{P}_i(\mathbf{IE \rightarrow PDS})$.

The result of the first method for computing contribution to risk is denoted the fractional contribution to mean risk and abbreviated FCMR. The contribution of PDS group k to the risk for consequence measure j, $FCMR_{jk}$, is defined as the ratio of the annual risk due to PDS group k to the total annual risk. That is, $FCMR_{jk}$ is defined by

$$FCMR_{jk} = E(\ rC_{jk}\ )\ /\ E(\ rC_j\ ),$$

where E(x) represents the annual value of x. Computationally, $FCMR_{jk}$ is found by use of the relation

$$FCMR_{jk} = [\ \Sigma\ rC_{ijk}\ /\ nLHS\ ]\ /\ [\ \Sigma\ rC_{ij}\ /\ nLHS\ ]$$

$$= \Sigma\ rC_{ijk}\ /\ \Sigma\ rC_{ij},$$

where the summations are from i = 1 to i = nLHS.

The result of the second method for computing contribution to risk is denoted the mean fractional contribution to risk and abbreviated MFCR. The contribution of PDS group k to the risk for consequence measure j, $FCMR_{jk}$, is defined as the annual value of ratio of the risk due to PDS group k to the total risk. That is:

$$MFCR_{jk} = E(\ rC_{jk}\ /\ rC_j\ ).$$

Computationally, $MFCR_{jk}$ is found by use of the relation

$$MFCR_{jk} = \Sigma\ (\ rC_{ijk}\ /\ rC_{ij}\ )\ /\ nLHS,$$

where the summation again is from i = 1 to i = nLHS.

For FCMR the averaging over the observations is done before the ratio of group risk to total risk is formed; for MFCR the averaging over the observations is done after the ratio of group risk to total risk is formed.

Table 5.1-2 gives the values of FCMR and MFCR for the five summary PDS groups used for reporting results in NUREG-1150. These measures are shown for both samples to give an indication of the reproducibility of these values. Results of computing the contributions to mean risk by the two methods are given below for the two samples for early fatalities and latent cancer fatalities for the four PDS groups which make the largest contributions to risk.

Contributors (percent) to Annual Early Fatality Risk at Surry Internal Initiators:

	Sample 1		Sample 2	
PDS Group	FCMR	MFCR	FCMR	MFCR
Slow SBO	8.6	7.7	15.6	7.3
Fast SBO	8.6	1.3	13.9	1.7
Event V	77.3	57.4	62.6	64.0
SGTR	4.1	29.0	6.9	22.3

Contributors (percent) to Annual Latent Cancer Fatality Risk at Surry Internal Initiators:

	Sample 1		Sample 2	
PDS Group	FCMR	MFCR	FCMR	MFCR
Slow SBO	10.9	15.2	14.6	14.9
Fast SBO	4.6	3.6	8.6	3.9
Event V	34.3	15.9	25.5	15.8
SGTR	46.5	57.0	47.0	56.8

The variations between the samples and between the two methods of computing contribution to risk are higher for early fatalities than for latent cancer fatalities because of the threshold effect involved in determining the number of early fatalities. The variations between samples are higher for FCMR than for MFCR, indicating that MFCR is a more robust measure of the risk results than FCMR.

Pie charts for these two risk measures for both methods of computing the contribution to risk are shown in Figure 5.1-5 for both samples. The differences are readily apparent when this method of displaying the results is utilized, and suggest the level of confidence that these results warrant.

Table 5.1-2
Fractional PDS Contributions (in percent) to Annual
Risk at Surry Due to Internal Initiators

Summary PDS Group	Sample	Method	Core Damage	Early Fatalities	Latent Cancer Fatalities	Population Dose 50 miles	Population Dose Region	Ind. E. F. Risk-1 mile	Ind. L.C.F. Risk-10 mile
LOSP	1	FCMR	68.8	17.1	15.5	20.9	15.5	22.7	29.8
	2	FCMR	69.7	29.4	23.2	24.6	23.3	24.0	36.4
	1	MFCR	55.3	9.1	18.8	22.2	18.9	11.9	25.7
	2	MFCR	54.5	9.1	18.7	21.9	18.8	10.9	24.9
ATWS	1	FCMR	3.5	1.4	2.0	2.1	2.0	1.8	2.4
	2	FCMR	3.6	0.7	2.2	2.4	2.2	1.2	2.1
	1	MFCR	5.0	3.7	3.6	3.7	3.6	3.8	4.8
	2	MFCR	5.1	2.9	3.5	3.7	3.5	3.6	4.4
Transients	1	FCMR	4.3	0.05	0.4	0.4	0.4	0.08	0.3
	2	FCMR	4.2	0.1	0.4	0.5	0.4	0.2	0.4
	1	MFCR	6.7	0.3	0.8	0.9	0.8	0.4	0.9
	2	MFCR	6.7	0.6	1.0	1.1	1.0	0.6	1.1
LOCAs	1	FCMR	15.0	0.03	1.3	2.3	1.4	0.06	2.0
	2	FCMR	14.2	0.2	1.7	2.6	1.7	0.4	2.2
	1	MFCR	21.2	0.6	4.0	5.0	4.1	0.9	5.8
	2	MFCR	22.0	1.2	4.2	5.3	4.2	1.6	6.1
Bypass	1	FCMR	8.5	81.4	80.8	74.3	80.7	75.4	65.5
	2	FCMR	8.2	69.6	72.5	69.8	72.5	74.3	58.9
	1	MFCR	11.8	86.3	72.8	68.3	72.6	83.0	62.8
	2	MFCR	11.7	86.2	72.6	68.0	72.5	83.2	63.5

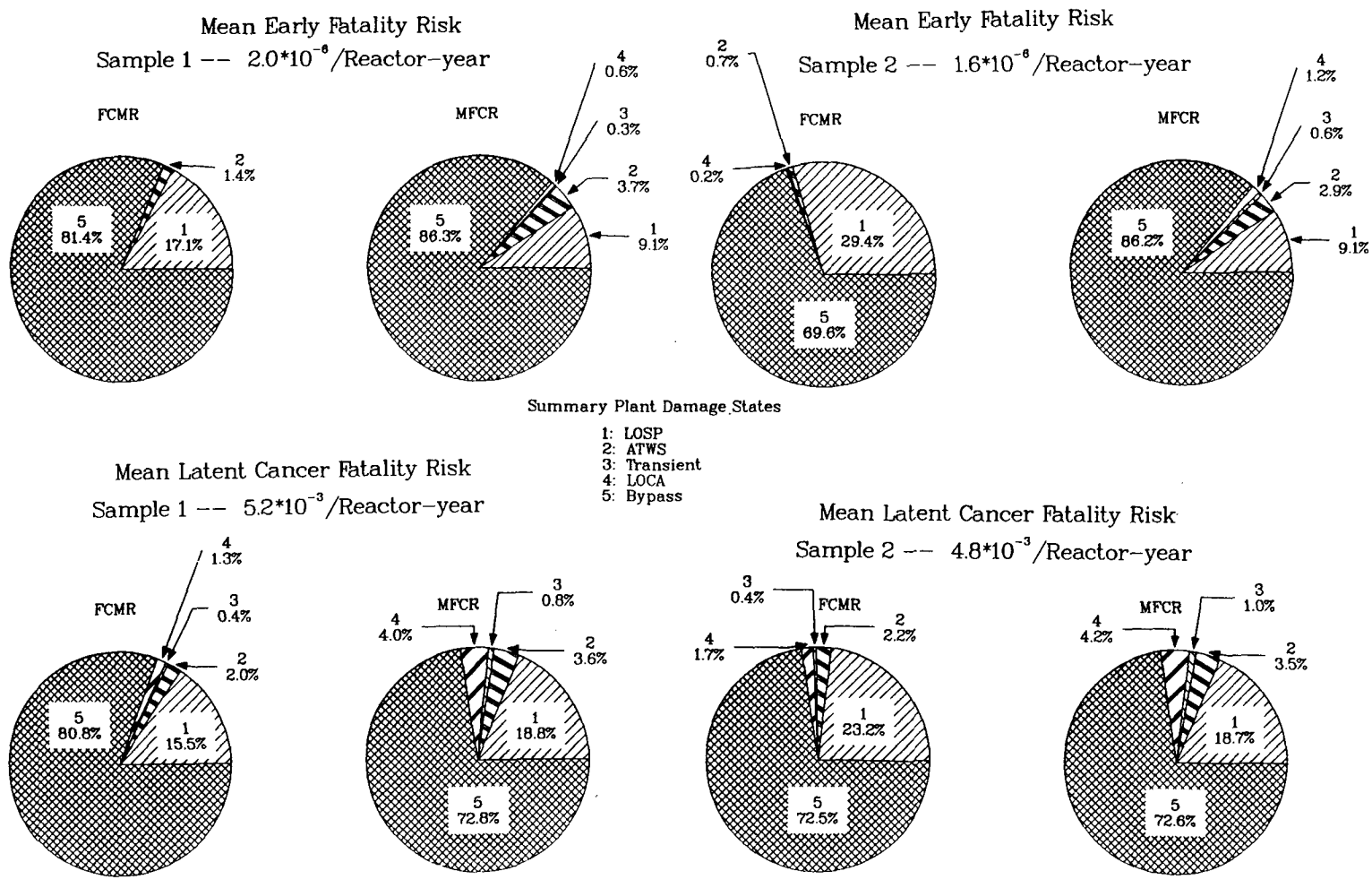


Figure 5.1-5. Fractional PDS Contributions to Annual Risk; Surry: Internal Initiators
MFCR = Mean Fractional Contribution to Risk;
FCMR = Fractional Contribution to Mean Risk.

Both methods of computing the contributions to risk are conceptually valid, and the second sample is as valid as the first, so the conclusion is clear: contributors to mean risk can only be interpreted in a very broad sense. That is, it is valid to say that Event V is the major contributor to mean early fatality risk at Surry, or that Event V contributes on the order of 2/3 to 3/4 of the mean risk at Surry. It is not valid to state that Event V contributes 77.3% of the early fatality risk at Surry.

The contributions of the summary accident progression bins (APBs) to mean risk can also be computed in two ways. Table 5.1-3 and Figure 5.1-6 display the results of these calculations. As indicated above, the bypass accidents account for most of the risk. How much Alpha mode CF, early CF with the RCS above 200 psia at vessel breach, and late CF contribute to mean risk depends markedly on which method of calculating the contributions to mean risk is used. The results using the MFCR approach show much less variation from Samples 1 to 2 than the results obtained with the FCMR method.

The FCMR measure of the contribution to mean risk is less stable than the MFCR measure because the annual risk for each observation is typically dominated by a few APBs which have both high frequency and high source terms and the mean risk is dominated by a few observations which have very large values of annual risk. The bulk of the mean risk is contributed by about 10 observations. While the sample as a whole is reproducible, the 10 or so observations that control mean risk are generally not reproducible. Since it is the exact nature of these 10 (approximately) observations that determine the contributors to mean risk, it is not surprising that FCMR is not a robust measure of the entire risk analysis.

Both FCMR and MFCR are conceptually valid methods of computing the contributions to mean risk. However, given the overall structure of the PRAs performed for NUREG-1150, MFCR is the more appropriate measure. The analysis performed for each observation in the sample can be viewed as a complete PRA. In a single observation, each sampled variable has a fixed value representing one possible value for an imprecisely known quantity. Each observation yields an estimate for the ratio rC_{jk}/rC_j (the fractional contribution of PDS group k to the risk for consequence measure j) based on an internally consistent set of assumptions. Taken as a whole, the sample produces a distribution for fractional contributions to risk.

For the contributions of the seven PDS groups, these distributions are summarized in Figure 5.1-7, which shows "box and whisker" plots for early fatalities and latent cancer fatalities for both samples for internal initiators. The box encloses the middle half of the distribution (from the 25th percentile to the 75th percentile) and the vertical line within the box indicates the median value. The mean value is indicated by the large dot. The vertical bar at the end of the line on the right indicates the minimum of two values: (1) maximum value; and (2) a value that is greater than the 75th percentile by 1.5 times the difference between the 75th percentile and the 25th percentile. In a similar manner, the bar at the end of the line on the left is the maximum of the minimum value, and a value that is less than the 25th percentile by 1.5 times the difference between the 75th percentile and the 25th percentile.

Table 5.1-3
Fractional APB Contributions (in percent) to Annual
Risk at Surry Due to Internal Initiators

Summary Accident Progression Bin	Sample	Method	Early Fatalities	Latent Cancer Fatalities	Population Dose Dose 50 miles	Population Dose Region	Ind. E. F. Risk-1 mile	Ind. L.C.F. Risk-10 mile
VB, Early CF Alpha mode	1	FCMR	1.0	3.1	3.0	3.1	1.6	2.5
	2	FCMR	10.9	7.8	6.2	7.8	9.4	10.8
	1	MFCR	4.5	3.4	2.8	3.4	6.8	2.9
	2	MFCR	7.5	3.7	2.9	3.7	9.0	3.3
VB, Early CF RCS > 200 psi	1	FCMR	15.8	7.1	7.3	7.0	20.7	17.2
	2	FCMR	16.9	9.5	7.5	9.5	13.3	15.6
	1	MFCR	2.0	2.0	2.1	2.0	2.3	2.5
	2	MFCR	1.8	1.7	1.7	1.7	2.0	2.1
VB, Early CF RCS < 200 psi	1	FCMR	0.01	0.1	0.2	0.1	0.02	0.1
	2	FCMR	0.01	0.04	0.05	0.03	0.01	0.04
	1	MFCR	0.4	0.4	0.4	0.4	0.9	0.4
	2	MFCR	0.2	0.08	0.08	0.08	0.4	0.1
VB, Late CF or BMT	1	FCMR	0.0	5.8	12.1	6.0	0.0	11.4
	2	FCMR	0.0	6.2	12.4	6.3	0.0	10.5
	1	MFCR	0.4	16.2	21.4	16.5	0.7	25.1
	2	MFCR	0.07	16.6	21.8	16.8	0.1	24.8
Bypass of Containment	1	FCMR	83.2	83.8	77.2	83.7	77.7	68.7
	2	FCMR	72.2	76.4	73.7	76.3	77.3	63.1
	1	MFCR	92.7	77.7	73.1	77.5	89.3	69.0
	2	MFCR	90.4	77.8	73.2	77.6	88.5	69.5
VB, No CF	1	FCMR	0.0	0.01	0.06	0.02	0.0	0.02
	2	FCMR	0.0	0.01	0.06	0.02	0.0	0.01
	1	MFCR	0.0	0.04	0.1	0.06	0.0	0.04
	2	MFCR	0.0	0.04	0.1	0.07	0.0	0.04
No VB	1	FCMR	0.0	0.04	0.1	0.05	0.0	0.05
	2	FCMR	0.0	0.04	0.1	0.05	0.0	0.05
	1	MFCR	0.0	0.1	0.2	0.1	0.01	0.1
	2	MFCR	0.01	0.1	0.2	0.1	0.02	0.1

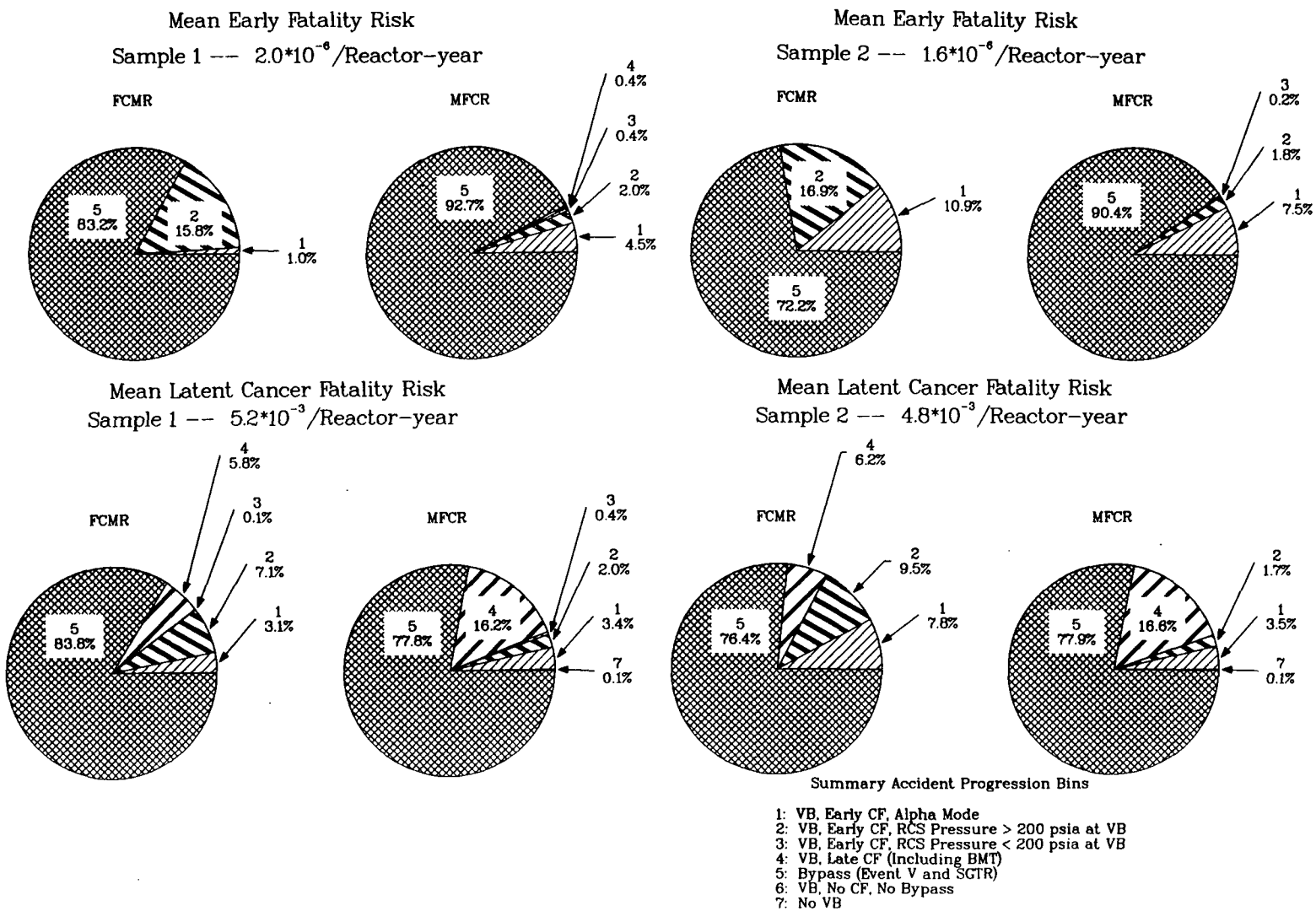


Figure 5.1-6. Fractional APB Contributions to Annual Risk. Surry: Internal Initiators
MFCR = Mean Fractional Contribution to Risk.
FCMR = Fractional Contribution to Mean Risk

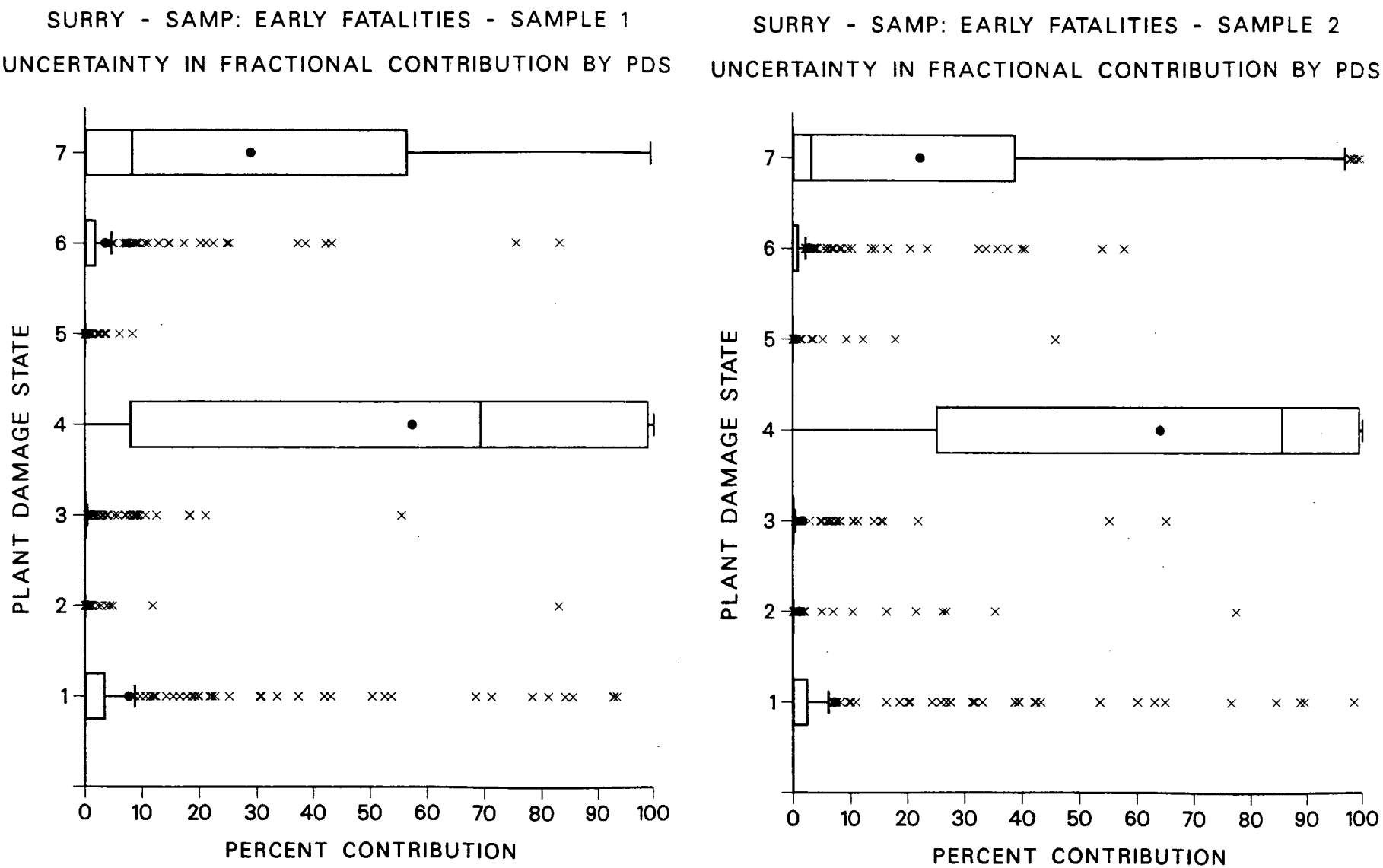
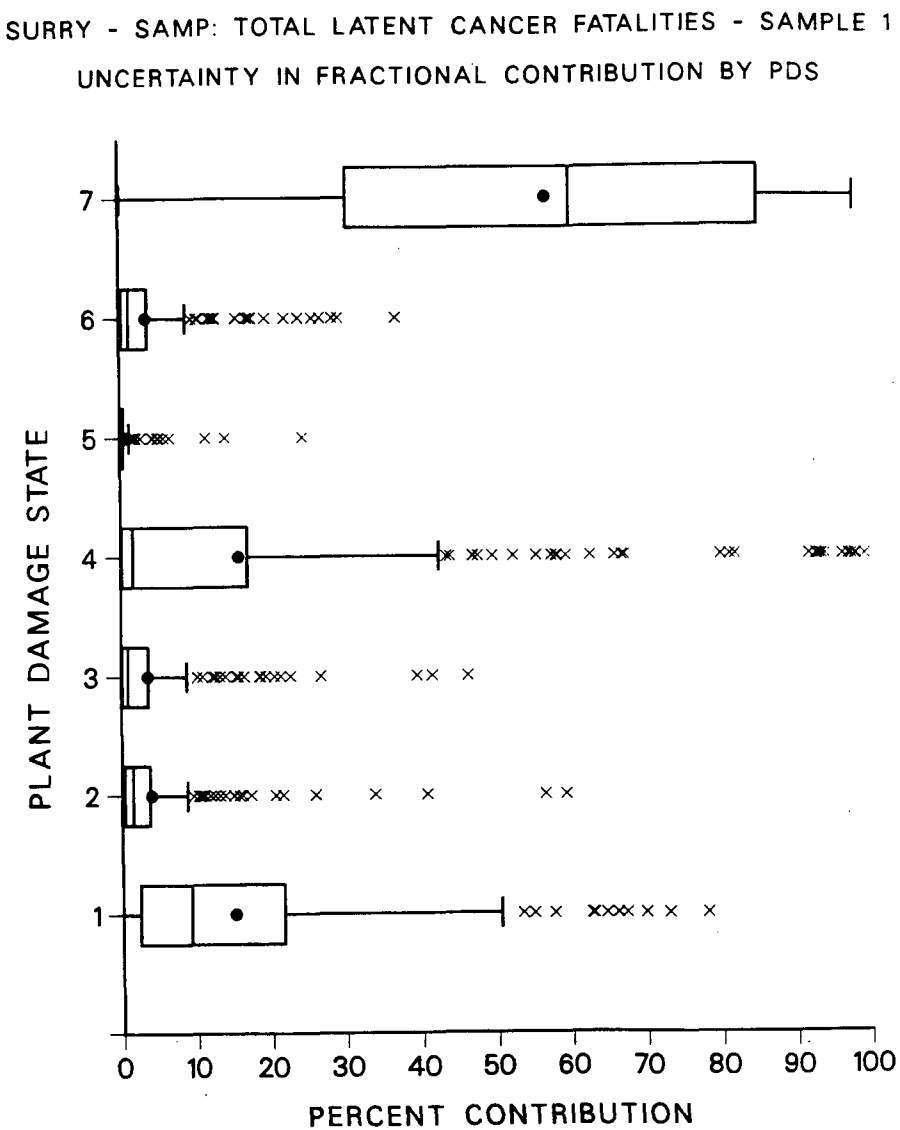


Figure 5.1-7. Distributions for Fractional PDS Contributions to Annual Risk
Surry: Internal Initiators
(1=Slow SBO; 2=LOCAs; 3=Fast SBO; 4=Event V; 5=Transients; 6=ATWS; 7=SGTR)



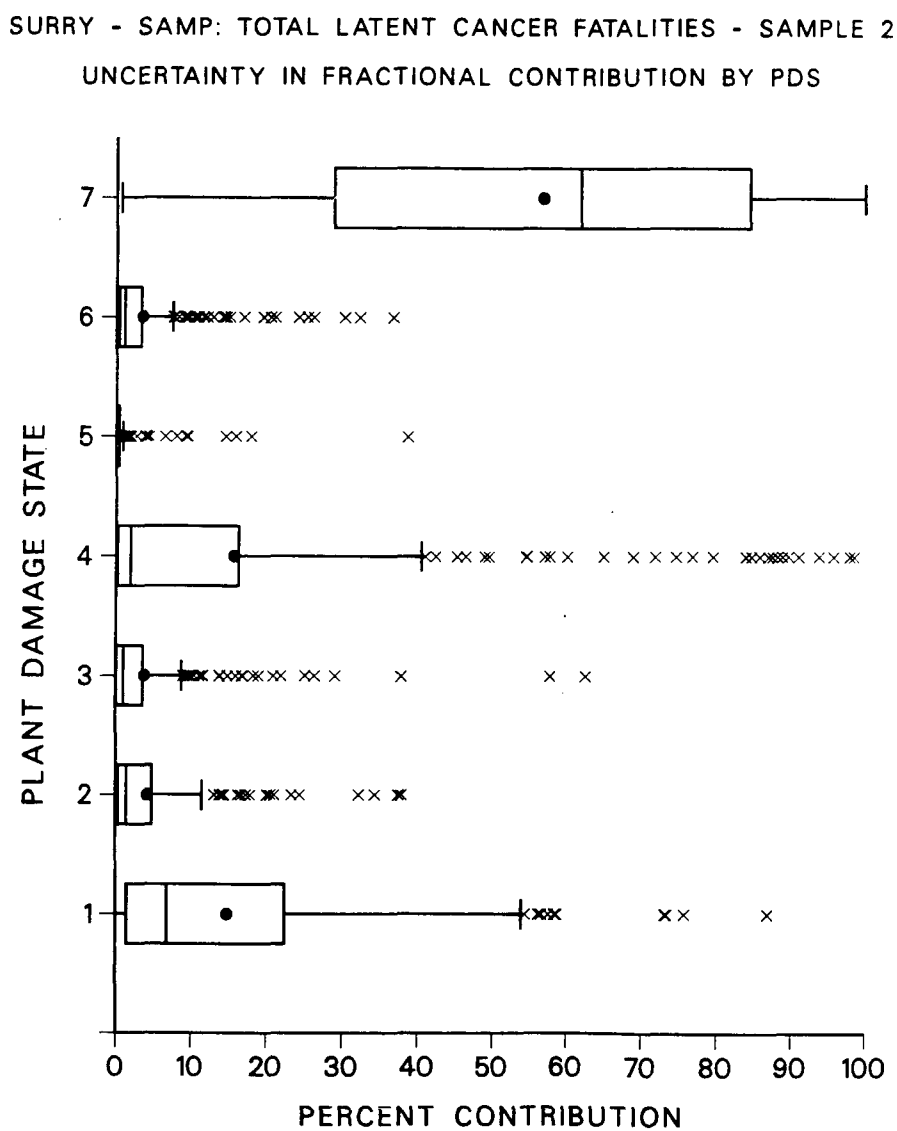


Figure 5.1-7. (continued)

Points that fall outside these bars are indicated by x's. In symmetric distributions these values would be considered outliers.

Figure 5.1-7 shows that the differences between the two samples are not great when complete distributions are considered. The MFCR values are the annual or mean values of the distributions shown in Figure 5.1-7. That is, the large dots in Figure 5.1-7 are the MFCR values in the tables above. As such, MFCR results from averaging over the the sampled variables and is thus consistent with other annual values reported in this study. That is, for other quantities, a single value is obtained for each observation in the sample, and distributions and means are reported for these values. Thus, the calculation of MFCR is consistent with the manner in which mean risk values are calculated. The FMCR results are not consistent with this pattern of obtaining a complete result for each observation and then analyzing the distribution of results.

This is an appropriate place to remind the reader of a caveat made elsewhere in this report: a mean value is a summary measure and information is lost in generating it. Thus, considerable caution should be used in drawing conclusions solely from mean values. A mean is obtained by reducing an entire distribution to a single number. For example, the MFCR values for PDS groups come from reducing each of the distributions in Figure 5.1-7 to a single number. Figure 5.1-7 shows that a PDS group may contribute almost 100% of the risk for some observations even though the group's mean contribution is quite low.

Even though the measures for determining the contributors to mean risk are only approximate, the types of accidents that are the largest contributors to offsite risk at Surry are clear. For the two consequence measures that depend on a large early release, early fatalities and individual risk of early fatality within one mile, the risk is dominated by Event V. As discussed in Subsection 5.1.1, the probability of CF at VB is low for the most frequent CD accidents (SBO and LOCA) due to the strength of the containment, core damage arrest before vessel breach, and RCS depressurization. As a result, SBO and LOCA accidents rarely lead to large, early releases. The SGTR accidents that lead to large releases, the "H" SGTRs with stuck-open secondary SRVs, are very lengthy accidents. Therefore, although the releases from the "H" SGTR accidents are large, they occur after the evacuation is complete and cause relatively few early fatalities. Thus, Event V accounts for most of the large, early releases, and most of the early fatality risk.

For the four consequence measures that depend primarily on the total amount of radioactivity released (population dose within 50 miles, population dose within the entire region, latent cancer fatalities, and individual risk of latent cancer fatality within 10 miles), the risk is dominated by Event V and SGTRs. The SGTRs contribute more than Event V, and most of this contribution comes from the "H" SGTRs (secondary SRVs stuck open).

Although the "H" SGTR accident is unlikely (MCDF about 1.0E-6/R-yr), there is a direct open path from the reactor vessel to the environment throughout the accident. SGTRs were not considered as initiators in the previous version of this analysis[2], so the "H" SGTRs are "new" accidents for the

NUREG-1150 PWR analyses. Thus, their importance to the latent cancer fatality risk was unrecognized at the time the expert panel on source term issues was meeting. After the contribution of the "H" SGTRs was evident, an ad hoc expert panel was convened to consider releases from "H" SGTR accidents (see NUREG-4551 Volume 2, Part 6). This panel concluded that there would be few effective removal mechanisms operating in the release path through the steam generator and the secondary system safety valves. Thus, the release fractions are high for this accident. Since the onset of core damage occurs about 10 h after the start of the accident for "H" SGTRs, the evacuation is complete before the releases commence; thus, "H" SGTRs do not dominate the early fatality risk. However, the "H" SGTR accidents are the largest contributor to latent cancer fatality risk.

5.1.4 Contributors to Uncertainty

Figure 5.1-1 provides information on the frequency at which values for individual consequence measures will be exceeded. Specifically, mean, median, 5th percentile, and 95th percentile values are shown for these exceedance frequencies. Thus, Figure 5.1-1 can be viewed as presenting uncertainty analysis results for the risk at Surry due to internal initiators. The underlying exceedance frequency curves (CCDFs) for Figure 5.1-1 are contained in Appendix D.

As the curves in Figure 5.1-1 and in Appendix D show, there is significant uncertainty in the frequency at which a given consequence value will be exceeded. Due to the complexity of the underlying analysis and the concurrent variation of a large number of variables within this analysis, it is difficult to ascertain the cause of this uncertainty on the basis of a simple inspection of the results. However, numerical sensitivity analysis techniques provide a systematic way of investigating the observed variation in exceedance frequencies.

This section presents the results of using regression-based sensitivity analysis techniques to examine the variability in the consequences of internally initiated accidents at Surry. Two dependent variables will be considered. The first dependent variable is the risk (units: consequences/year) for each consequence measure. For a given observation in the sample, this variable is obtained by multiplying the each consequence value by its frequency and then summing these products. This variable can be viewed as the result of reducing each of the curves in Figure D.1 to a single number.

The second dependent variable is the exceedance frequency associated with individual consequence values. As can be seen from the curves in Figure D.1, there are 200 exceedance frequency curves (i.e., one for each observation) associated with each consequence measure. For a given sample element and consequence value, the exceedance frequency is obtained by summing the frequencies of all consequence values as large or larger than the one under consideration.

The uncertainty analysis techniques used in this study can be viewed as creating a mapping from analysis input to analysis results. The variables sampled in the generation of this mapping are presented in Tables 2.2-9,

2.3-2, and 3.2-1. For convenience, these variables are also summarized in Table 3.3.1-8 of section 3.3.1. The variables listed in Table 3.3.1-8 are the independent variables in the sensitivity studies presented in this section. As explained in subsection 3.3.1.10, a series of correlated variables is represented by one variable. For example, FR-ZROX has a rank correlation of 1.0 with TI-HOTLG, so only one of these two variables (TI-HOTLG) is included in the sensitivity analysis.

Sensitivity analysis results for the six consequence measures used to express risk are presented in Table 5.1-4. This table contains the results of performing a stepwise regression on the risk as expressed by: early fatalities, latent cancer fatalities, population dose within 50 miles, population dose within the entire region, individual risk of early fatality within 1 mile, and individual risk of latent cancer fatality within 10 miles. The analysis for these variables was performed with the STEP program.[3] In the analysis, a variable was required to be significant at 0.02 α-level to enter a regression model and to remain significant at the 0.05 α-level to be retained in a regression model. Further, the behavior of the PRESS criterion[4] and individual R^2 values were considered in selecting the actual stopping points for the presented regressions. The PRESS criterion is used to ensure that the selected regression model is not overfitting the data on which it is based. The analyses were tried with raw (i.e., untransformed) and rank-transformed[5] data. The analyses with rank-transformed data consistently performed as well as or better than the analyses with raw data. Therefore, Table 5.1-4 only presents the results of regression analyses performed with rank-transformed data.

For each consequence measure, Table 5.1-4 lists the variables in the order that they entered the regression analysis, gives the standardized regression coefficients for the variables in the final regression model, and shows the R^2 values that result with the entry of successive variables into the model. Variable importance is indicated by the order in which variables entered a regression, the change in R^2 values with the entry of successive variables, and the size of the standardized regression coefficients in the final regression model. Further, the tendency of a dependent variable to increase and decrease with an independent variable is indicated by a positive regression coefficient, and the tendency of a dependent variable to decrease when an independent variable increases is indicated by a negative regression coefficient.

Table 5.1-4 shows that the uncertainty in all the measures of risk is dominated by the uncertainty in variables that determine the frequency of bypass accidents and the release fractions for bypass accidents. V-TRAIN is the initiating event frequency for Event V (interfacing system LOCA) and IE-SGTR is the initiating event frequency for SGTRs. FCOR is the fractional release from the reactor core to the vessel, and applies to all types of accidents. FISGFOSG is the release fraction from the vessel to the environment for SGTRs. These four variables, or three of them, are the largest contributors to the variability for each measure of risk.

Table 5.1-4
Summary of Rank Regression Analyses for
Annual Risk at Surry for Internal Initiators

	Early Fatalities			Latent Cancer Fatalities			Population Dose--50 miles		
Step	VAR[a]	SRC[b]	R^{2c}	VAR	SRC	R^2	VAR	SRC	R^2
1	V-TRAIN	0.69	0.46	FISGFOSG	0.50	0.26	FISGFOSG	0.42	0.18
2	FISGFOSG	0.29	0.56	FCOR	0.35	0.38	IE-SGTR	0.36	0.30
3	FCOR	0.23	0.61	IE-SGTR	0.32	0.49	V-TRAIN	0.32	0.41
4	VB-ALPHA	0.16	0.63	V-TRAIN	0.31	0.58	FCOR	0.28	0.49
5	FDCH	-0.13	0.65						
6	FCONV	0.12	0.67						
7	FCCI	0.12	0.68						
8	FCONC	0.10	0.69						
9	FLATE	0.11	0.70						
10	LATEI	0.11	0.71						
11	IE-LMFWS	0.10	0.72						

[a] Variables listed in the order that they entered the regression analysis.

[b] Standardized regression coefficients (SRCs) in final regression model.

[c] R^2 values with the entry of successive variables into the regression model.

Table 5.1-4 (continued)

	Population Dose Entire Region			Individual Early Fatality Risk--1 mile			Individual Latent Cancer Fat. Risk-1 mi.		
Step	VAR[a]	SRC[b]	R^{2c}	VAR	SRC	R^2	VAR	SRC	R^2
1	FISGFOSG	0.50	0.26	V-TRAIN	0.76	0.58	V-TRAIN	0.44	0.18
2	FCOR	0.35	0.38	FISGFOSG	0.24	0.64	IE-SGTR	0.32	0.28
3	IE-SGTR	0.32	0.48	FCOR	0.19	0.67	FISGFOSG	0.23	0.34
4	V-TRAIN	0.31	0.58	IE-SGTR	0.13	0.69	IE-LOSP	0.19	0.38
5				VB-ALPHA	0.12	0.70	LATEI	0.16	0.40
6				FLATE	0.12	0.72	DG-FSTRT	0.16	0.43
7				FDCH	-0.12	0.73	FCOR	0.16	0.45
8				LATEI	0.11	0.74			

[a] Variables listed in the order that they entered the regression analysis.

[b] Standardized regression coefficients (SRCs) in final regression model.

[c] R^2 values with the entry of successive variables into the regression model.

The regression analyses for early fatalities and individual risk of early fatality within 1 mile are relatively successful as they account for about 75% of the observed variability. The regression analyses for the other four consequence measures are less successful as they are able to account for only 50 to 60% of the variability. By including product variables in the regression analysis, the amount of the variability accounted for can be increased moderately for some of the risk measures. The product variables considered are:

V-INIT * FCOR,
SGTR-INIT * FCOR * FISGFOSG,
SGTR-INIT * FISGFOSG,
IE-LOSP * DG-FRUN,
IE-LOSP * DG-FRUN * FCOR,
IE-LOSP * DG-FSTRT, and
IE-LOSP * DG-FSTRT * FCOR.

The product variables were first formed and then rank-transformed. To some extent, this obscures the importance of pointer variables such a FCOR. The greatest improvements in the model R^2 values from including product variables were for latent cancer fatalities and the population doses. Table 5.1-5 presents the regression results for latent cancer fatalities and the population dose within 50 miles. The regression results for the population dose within the region are identical to those for latent cancer fatalities. The addition of cross-products to the regression model did not produce significantly better results (as measured by R^2 values) for early fatalities or either of the individual risk measures.

A stepwise regression on the annual risk measures was also performed for the second sample for internal initiators. Table 5.1-6 compares the results of the stepwise regression analyses for the first and second sample for early fatalities and latent cancer fatalities. As in the analysis performed for the first sample (see Table 5.1-4), the analysis was performed with rank-transformed data. Table 5.1-6 shows that the larger contributors are similar in both samples. There is considerable variation between the samples for variables whose inclusion increases R^2 by only 0.02 or 0.01. The stepwise regression analysis accounts for more of the variability for the risk measures related to total population dose for Sample 2 than it does for Sample 1.

The analysis results given in Tables 5.1-4 through 5.1-6 are based on reducing each of the curves shown in Appendix D to a single value with the units of consequence/year. While this simplifies the analysis and produces a single variable which incorporates both the consequence magnitude and frequency, information about the relationship between magnitude and frequency is lost in computing this single number. The risk CCDFs shown in Appendix D are more basic results than the risk values analyzed to produce Tables 5.1-4 and 5.1-5.

Table 5.1-5
Rank Regression Summaries for
Annual Risk at Surry for Internal Initiators
Using Product Variables

	Latent Cancer Fatalities			Population Dose--50 mi.		
Step	VAR[a]	SRC[b]	R^{2c}	VAR	SRC	R^2
1	SG-I*FCOR*FSG[d]	0.63	0.51	SG-I*FCOR*FSG	0.48	0.41
2	V-INIT	0.28	0.59	V-INIT	0.31	0.49
3	DG-FS*LOSP[e]	0.14	0.61	DG-FS*LOSP	0.20	0.53
4	FISGFOSG	0.15	0.62	LPRS-MOV	0.15	0.56
5	SSRVO-SB	0.11	0.64	SG-I*FSG[f]	0.20	0.57

[a] Variables listed in the order that they entered the regression analysis.

[b] Standardized regression coefficients (SRCs) in final regression model.

[c] R^2 values with the entry of successive variables into the regression model.

[d] SG-I*FCOR*FSG = SGTR-INT * FCOR * FISGFOSG

[e] DG-FS*LOSP = DG-FSTRT * IE-LOSP

[f] SG-I*FSG = SGTR-INT * FISGFOSG

Table 5.1-6
Summary of Rank Regression Analyses for Annual Risk at Surry
for Two Samples for Internal Initiators

	Early Fatalities Sample 1			Early Fatalities Sample 2			Latent Cancer Fatalities Sample 1			Latent Cancer Fatalities Sample 2		
STEP	VAR[a]	SRC[b]	R^2[c]	VAR	SRC	R^2	VAR	SRC	R^2	VAR	SRC	R^2
1	V-TRAIN	0.69	0.46	V-TRAIN	0.71	0.51	FISGFOSG	0.50	0.26	FISGFOSG	0.52	0.26
2	FISGFOSG	0.29	0.56	FISGFOSG	0.33	0.62	FCOR	0.35	0.38	IE-SGTR	0.36	0.39
3	FCOR	0.23	0.61	FCOR	0.20	0.65	IE-SGTR	0.32	0.49	FCOR	0.33	0.50
4	VB-ALPHA	0.16	0.63	FCONC	0.13	0.67	V-TRAIN	0.31	0.58	V-TRAIN	0.30	0.59
5	FDCH	-0.13	0.65	FCCI	0.13	0.69				DG-FSTRT	0.16	0.62
6	FCONV	0.12	0.67	FCONV	0.11	0.70				IE-LOSP	0.14	0.63
7	FCCI	0.12	0.68	LPRS-MOV	-0.11	0.71						
8	FCONC	0.69	0.10	TI-SGTR	0.11	0.72						
9	FLATE	0.70	0.11	HB-SCAL	-0.11	0.73						
10	LATEI	0.71	0.11									

[a] Variables listed in the order that they entered the regression analysis.
[b] Standardized regression coefficients (SRCs) in final regression model.
[c] R^2 values with the entry of successive variables into the regression model.

Because of the importance of the risk CCDFs, a sensitivity analysis was performed to determine which variables controlled the frequencies at which the consequence values are exceeded. Partial rank correlation coefficients (PRCCs) were calculated between the sampled variables and the frequency at which consequence values are exceeded.[6] PRCCs are discussed in subsection 3.3.1.10.

The PRCC analyses performed for Surry are based on the same data used to construct the mean and quantile curves for the consequence measures shown in Figure 5.1-1. The starting point is the family of 200 exceedance frequency curves shown in Appendix D. Each curve represents one observation in the sample; so for each consequence value on the abscissa there are 200 exceedance frequencies. For each value on the consequence axis, the PCCSRC program[5] calculates the PRCCs between the exceedance frequency and the individual variables listed in Table 3.3.1-8. The results of this computation are presented as curves in which the abscissa is the consequence value and the ordinate is the value of the PRCC. Such curves are presented in Figures 5.1-8 through 5.1-13. To reduce the number of curves plotted, a variable is included in these plots only if the maximum absolute value of its PRCC exceeds 0.50.

Figure 5.1-8 illustrates the results of the PRCC analysis for early fatalities. For most of the risk range, the three most important contributors to the variability in early fatality risk are V-TRAIN, FCOR, and FISGFOSG. For the very largest risk values, FCONV and FCONC are the largest contributors. For the very largest values of risk, all the PRCCs tend toward 0.0. This is because the exceedance frequencies eventually reach zero; then is no variability to analyze.

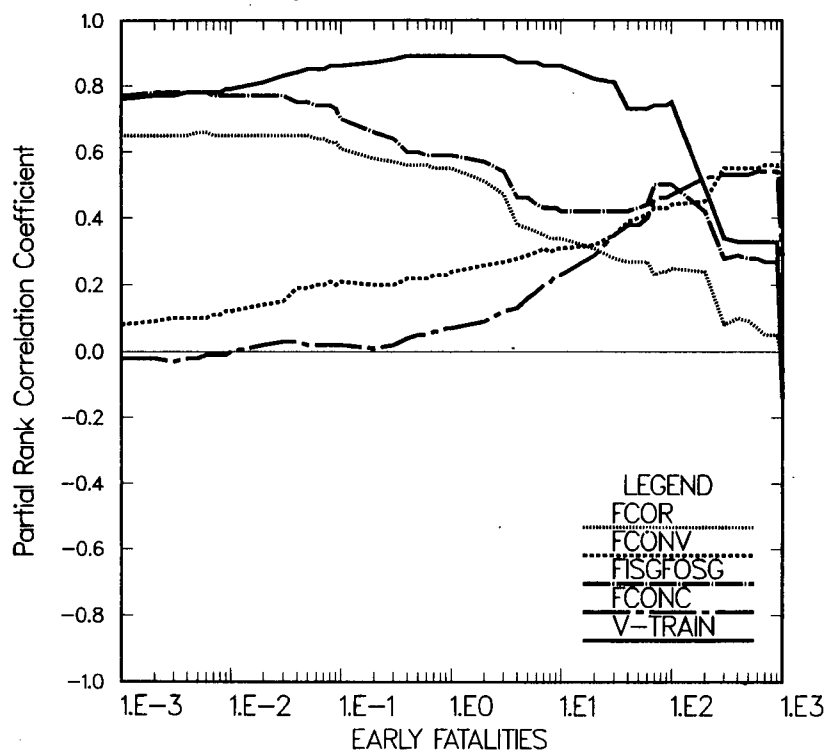
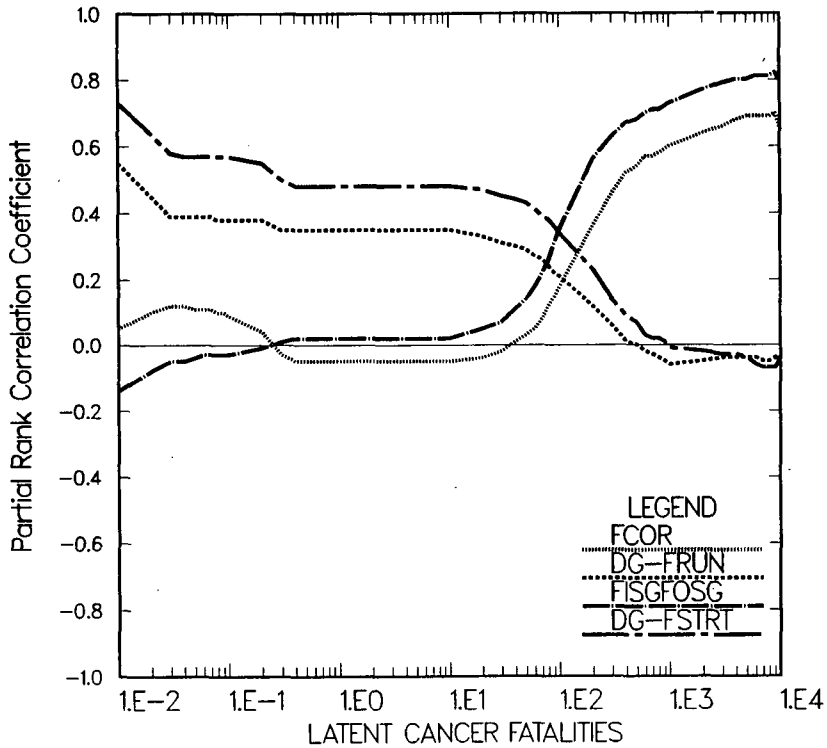


Figure 5.1-8. Partial Rank Correlation Coefficients for Exceedance Frequencies for Early Fatality Risk



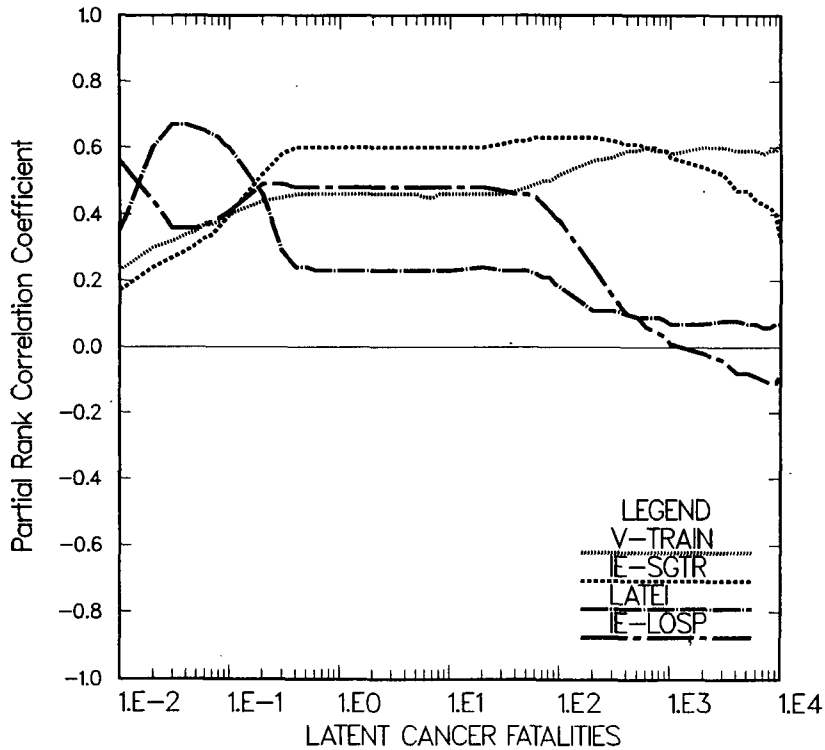
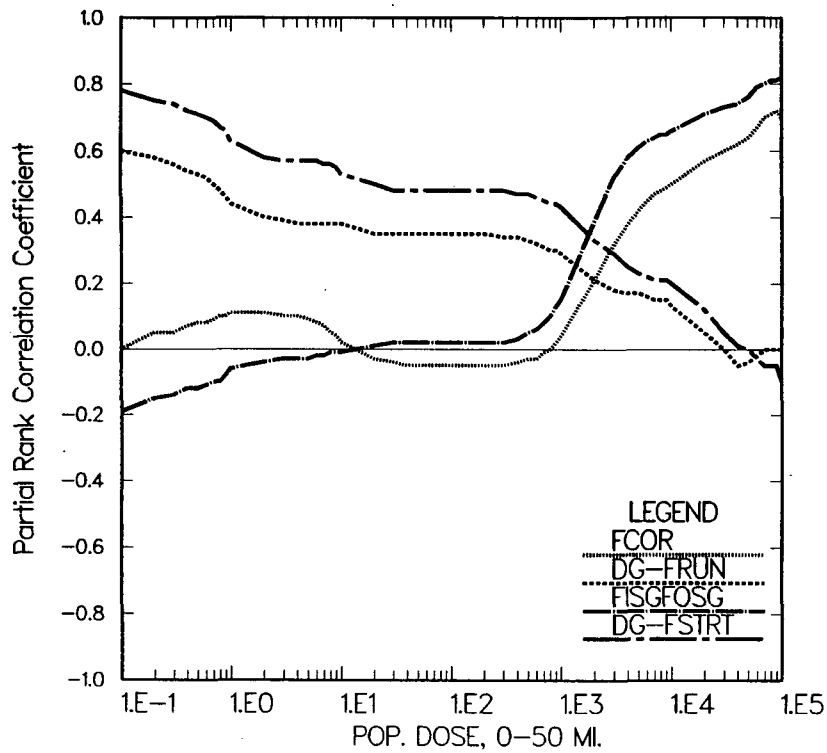


Figure 5.1-9. Partial Rank Correlation Coefficients for Exceedance Frequencies for Latent Cancer Fatality Risk Surry: Internal Initiators



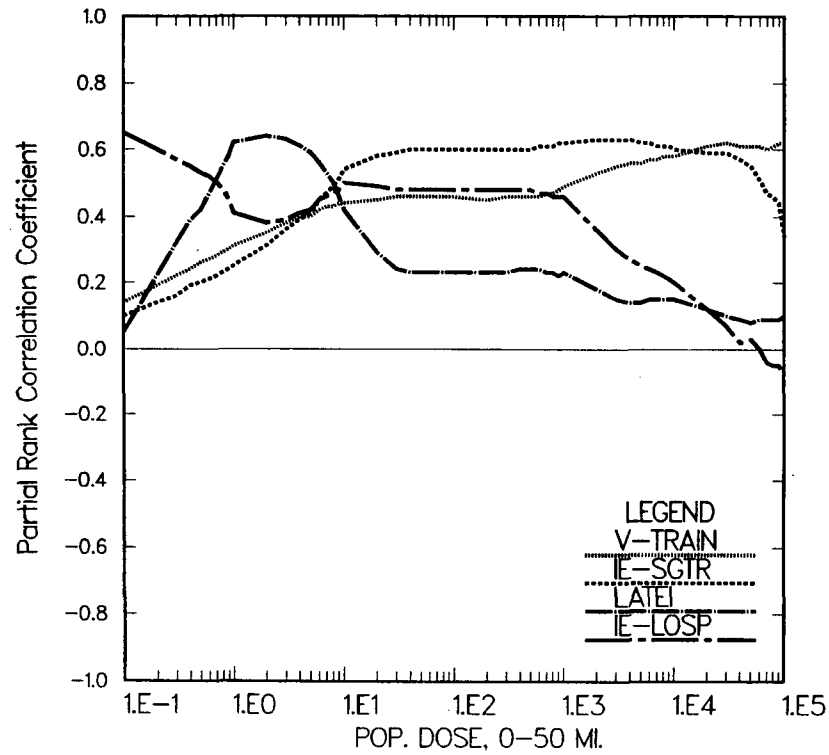
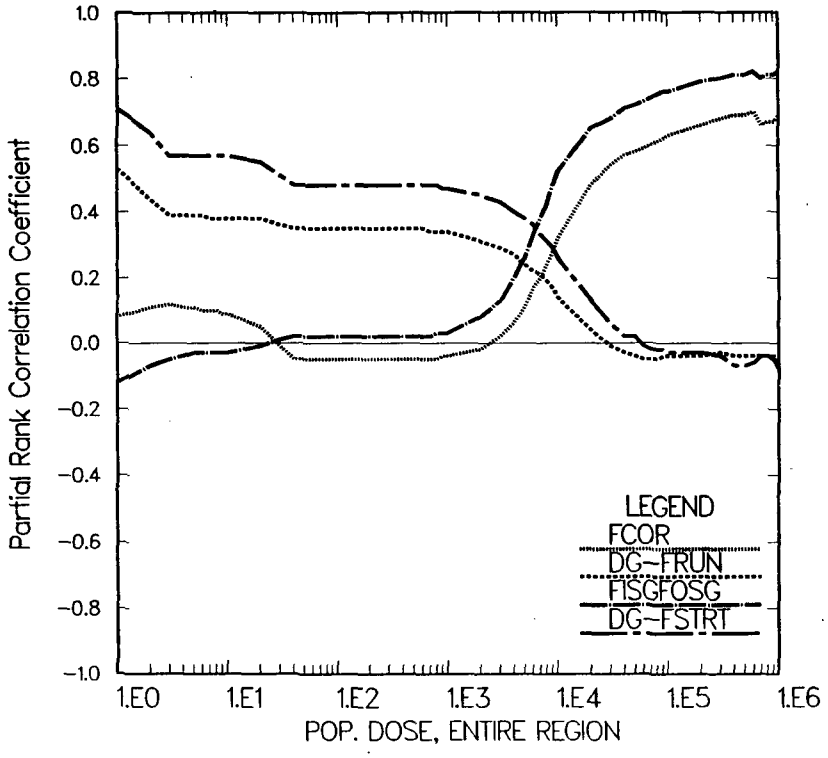


Figure 5.1-10. Partial Rank Correlation Coefficients for Exceedance Frequencies for Population Dose within 50 Miles Surry: Internal Initiators



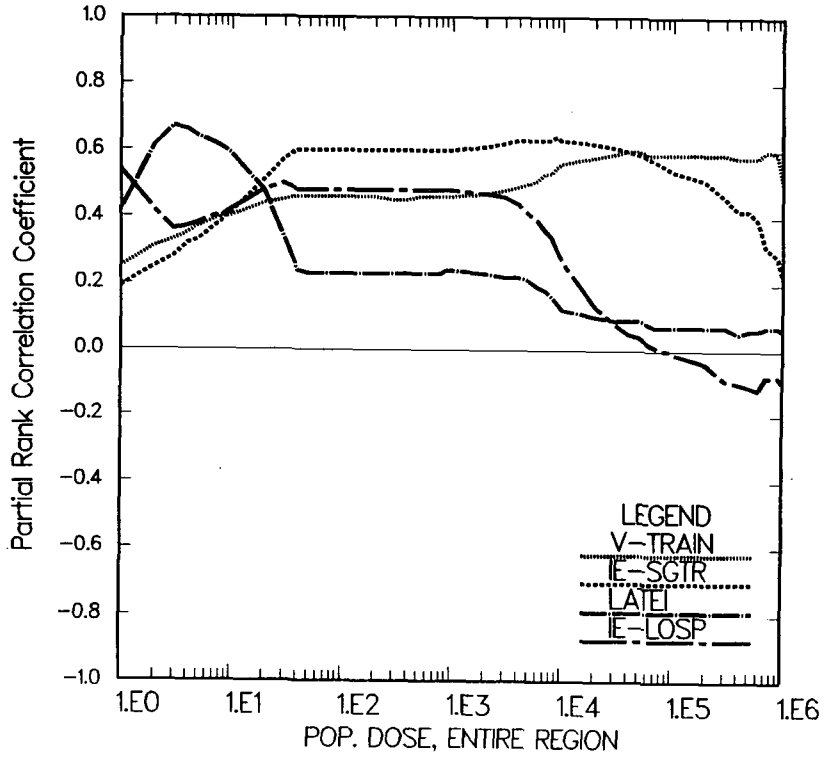


Figure 5.1-11. Partial Rank Correlation Coefficients for Exceedance Frequencies for Population Dose for the Entire Region Surry: Internal Initiators

Figure 5.1-9 presents the results of the PRCC analysis for latent cancer fatalities. For smallest risk values, the variability in the exceedance frequency is dominated by variables that determine the frequency of SBO (IE-LOSP, DG-FSTRT, DG-FRUN) and by the late revolatilization of iodine. For intermediate numbers of latent cancer fatalities, IE-LOSP, DG-FSTRT, and DG-FRUN continue to be important, but the bypass initiator variables IE-SGTR and V-TRAIN are also important contributors to uncertainty. For the highest risk values, IE-SGTR and V-TRAIN are joined by source term variables FCOR and FISGFOSG in dominating the variability.

The PRCCs do not all drop to zero for large values of latent cancer fatalities as they did for early fatalities. As may be seen in the CCDF plots in Appendix D, the exceedance frequencies for 10,000 latent cancer fatalities do not drop to zero for most observations in the sample as they do for 1000 early fatalities.

Figures 5.1-10 and 5.1-11 illustrate the results of the PRCC analysis for population dose within 50 miles and population dose within the entire region. The results are very similar to those in Figure 5.1-9 for latent cancer fatalities. This results because the number of latent cancer fatalities is a linear function of the population dose. Thus, variables affect latent cancer fatalities and both population dose risk measures similarly.

Figure 5.1-12 presents the results of the PRCC analysis for early fatality risk within one mile. The four variables that make significant contributions to the uncertainty in this risk measure are V-TRAIN, FCOR, FISGFOSG, and IE-SGTR. For the larger risk values, V-TRAIN dominates. To deliver a fatal dose to an individual, the release must be early and large, and the wind must be blowing toward the individual selected. Thus, the early fatality risk within one mile depends on the frequency of large release fractions and wind direction probabilities.

Figure 5.1-13 presents the results of the PRCC analysis for latent cancer fatality risk within 10 miles. For the smaller values of latent cancer fatality risk within 10 miles, the uncertainty is dominated by V-TRAIN, DG-FSRT, and IE-SGTR. V-TRAIN and IE-SGTR are the bypass initiating event frequencies. In the 10^{-3} to 10^{-2} range, V-TRAIN, FCOR, and FISGFOSG are the largest contributors to the uncertainty. For the very highest values, the frequency of the alpha mode simultaneous failure of the vessel and containment is the largest contributor.

PRCCs based on the release fraction CCDFs were also calculated for Sample 2 and curves equivalent to those shown in Figures 3.3-17 through 3.3-20 were obtained. Figure 5.1-14 compares the PRCC curves for two representative variables for early fatalities. The curves are quite similar. The agreement between the samples is best for the consequence values for which the variable makes a large contribution to the uncertainty. The differen between the samples at the highest consequence values are to be expected since the very largest consequences have nonzero exceedance frequencies for only a few observations.

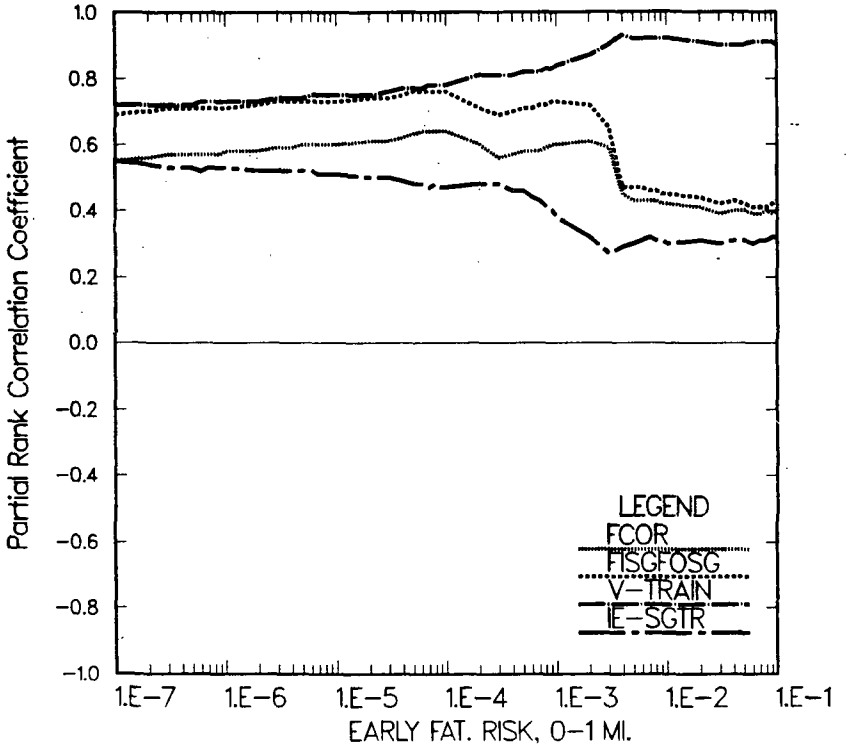
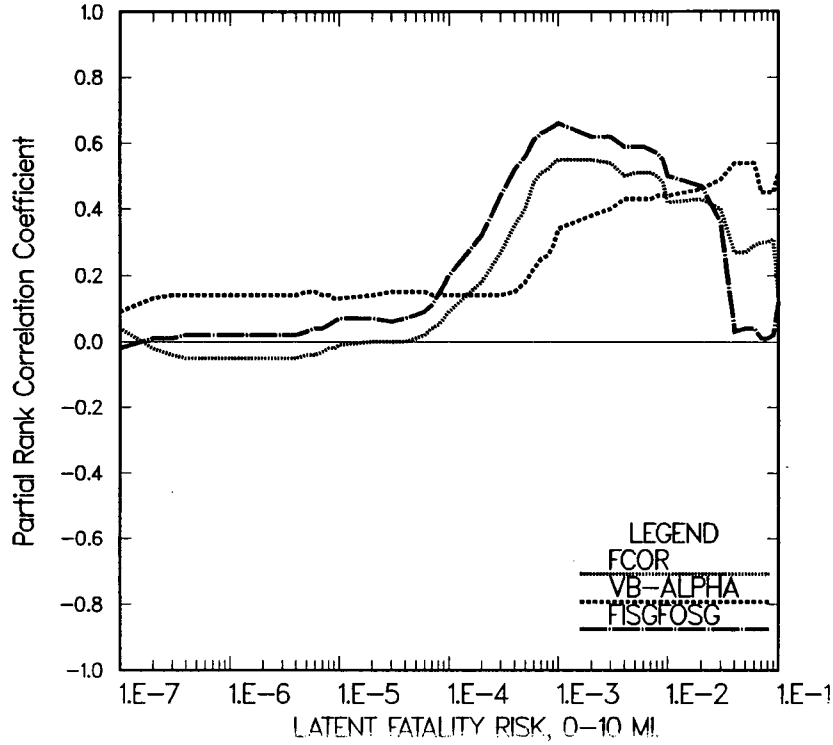


Figure 5.1-12. Partial Rank Correlation Coefficients for Exceedance Frequencies for Individual Early Fatality Risk within One Mile Surry: Internal Initiators

The PRCC results based on analysis of the CCDFs give generally closer agreement between the two samples than the stepwise regression results based on the mean risk. This is due to the fact that much information is lost in forming the mean risk. The mean risk has contributions from the relatively frequent small consequences as well as the very unlikely large consequences. Figures 5.1-8 through 5.1-13 show that the variables which account for the most uncertainty for large consequences are usually different than those that are the largest contributors for small consequences. Therefore it is not surprising that the agreement between the two samples is closer for the PRCC curves based on the CCDFs than it is for the stepwise regression coefficients based on mean risk. The stepwise regression analyses show the contributions of variables that are smaller contributors to uncertainty than those considered in the PRCC analysis. As would be expected, there is less agreement between the results for the two samples for these small contributors.

Overall, considering all six measures of risk, the largest contributors to the uncertainty are the bypass initiating events, V-TRAIN and IE-SGTR, and the source term variables FCOR and FISGFOSG. FISGFOSG applies only to SGTR accidents. For some of the lower values, the variables IE-LOSP, DG-FSTRT, and DG-FRUN, which contribute to the frequency of station blackout, are important.



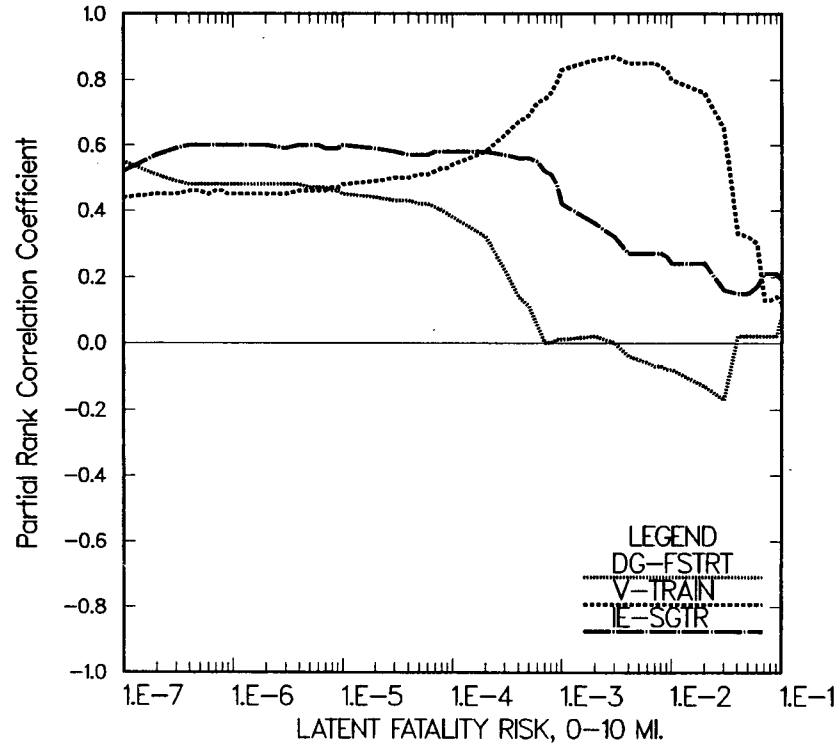
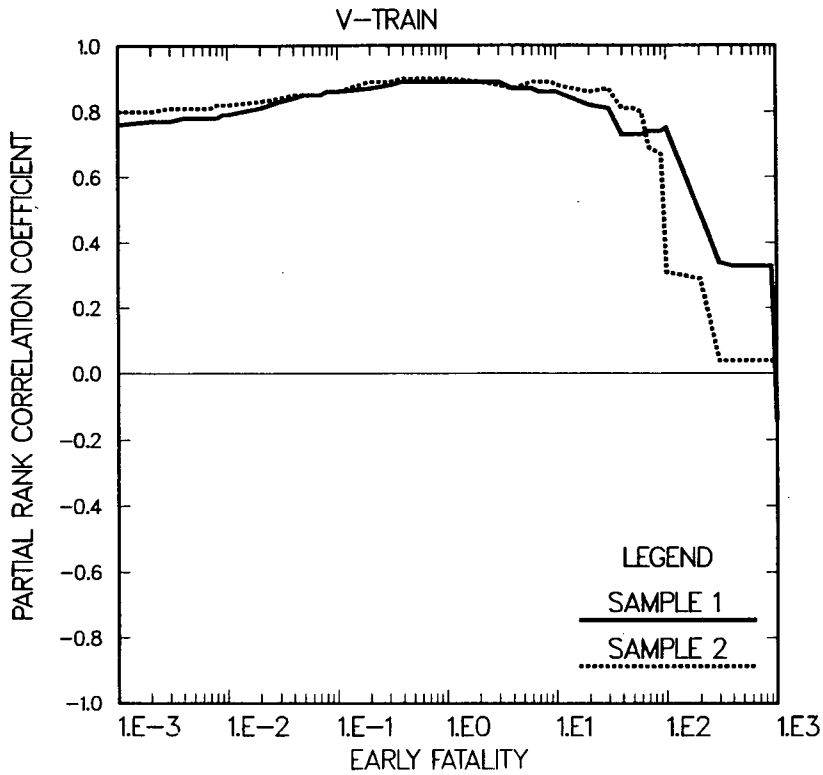


Figure 5.1-13. Partial Rank Correlation Coefficients for Exceedance Frequencies for Individual Latent Cancer Fatality Risk within 10 Miles Surry: Internal Initiators



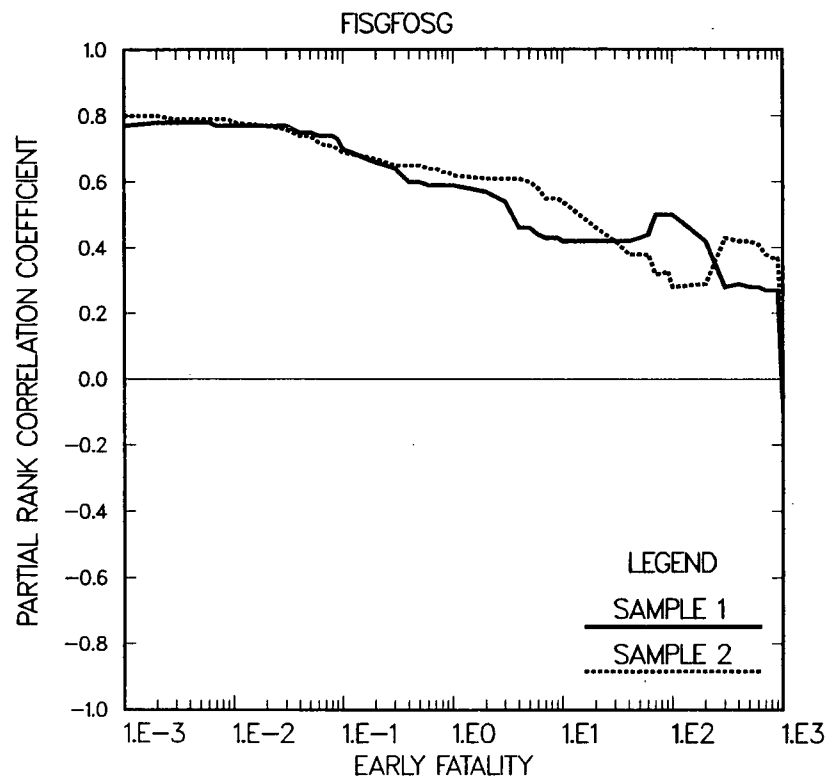


Figure 5.1-14. Comparison of Partial Rank Correlation Coefficient Curves for Two Representative Variables Surry: Internal Initiators.

5.2 Results for Fire Initiators

This section presents the results of the integrated risk analysis for fire initiators at the Surry plant. As the risk due to fires at Surry is low compared to the risk from internal initiators, no analyses analogous to those for internal initiators were performed to determine the types of fire accidents that are the largest contributors to risk, or to determine the important contributors to the uncertainty in risk due to fires.

Figure 5.2-1 shows the basic results of the integrated risk analysis for fire initiators at Surry. The CCDFs indicate that the risk from fire is well below the risk from internal initiators. The distributions for annual risk are summarized in Table 5.2-1 and Figure 5.2-2. When comparing the fire risk results with the internally initiated results shown in Table 5.1-1 and Figure 5.1-2, note that different scales had to be used for the fire-initiated plots to show complete distributions. The annual risk at Surry due to fires is an order of magnitude or more below that due to internal initiators.

While the mean core damage frequency due to fires is about one fourth of the mean core damage frequency due to internal initiators, the risk is considerably lower relative to the risk from internal initiators. This is due to the low probability of early failure of the containment and the absence of containment bypass events among the fire initiators. Much of the risk for internal initiators is due to Event V or SGTRs which create an early bypass of the containment. The only way to bypass the containment for fire initiators is for a temperature-induced SGTR to occur. However, the expert panel concluded that this was very unlikely unless the containment was at full system pressure. All the fire PDSs include RCP seal failures or stuck-open PORVs, so the RCS is never at full system pressure during core melts that result from fires.

Failure of the containment due to the pressure rise that accompanies melt-through of the lower head is not likely for fire initiators. As discussed above for internal initiators, the structural expert panel provided a distribution for the failure pressure of the containment that lies generally above the distributions for loads at vessel failure determined by the Containment Loads Expert Panel.

There is only one PDS group for fire initiators, so an analysis of the contributors to mean risk by PDS group is not meaningful. The calculation of the contributions of the summary APBs to mean risk gives the following results:

Contributors (percent) to Annual Risk Due to Fire Initiators at Surry:

	Early Fatalities		Latent Cancer Fatalities	
Summary APB	FCMR	MFCR	FCMR	MFCR
VB, Early CF, Alpha Mode	15.7	41.2	38.1	21.7
VB, Early CF, RCS > 200 psia	83.4	20.2	49.8	6.0
VB, Early CF, RCS < 200 psia	0.9	38.6	0.8	4.8
VB, Late CF (Including BMT)	0.0	0.0	11.1	65.5
VB, No CF	0.0	0.0	0.3	2.0

As there are no bypass accidents among the fire initiators, early fatality risk is almost entirely due to early containment failure as would be expected. Whether Alpha mode failures or failures due to the pressure rise at VB when the RCS is at high pressure is more important depends upon the method used to compute the contribution to risk. Similarly, whether late failures of the containment are important to the latent cancer fatality risk depends upon the method used. Although Alpha mode and HPME/DCH failures of the containment are important contributors to the risk due to fires, the risk due to fires is very low. When the risk due to internal initiators is considered in addition to the risk from fires, Alpha mode and HPME/DCH failures of the containment are not the dominant contributors to risk at Surry.

Table 5.2-1
Distributions for Annual Risk at Surry Due to Fire Initiators
(All values per reactor-year)
(Population doses in person-rem)

Risk Measure	5th %tile	Median	Mean	95th %tile
Core Damage	2.3E-6	8.3E-6	1.1E-5	2.5E-5
Early Fatalities	1.1E-14	3.0E-11	3.8E-8	2.8E-8
Latent Cancer Fatalities	3.2E-6	3.6E-5	2.7E-4	6.1E-4
Population Dose--50 miles	1.0E-2	1.0E-1	3.7E-1	1.1E 0
Population Dose--Entire Region	2.6E-2	2.8E-1	1.7E 0	4.3E 0
Ind. Early Fat. Risk--1 mile	5.3E-16	4.3E-13	6.3E-10	2.2E-10
Ind. L. C. Fat. Risk--10 miles	2.4E-12	2.1E-11	1.2E-10	2.5E-10

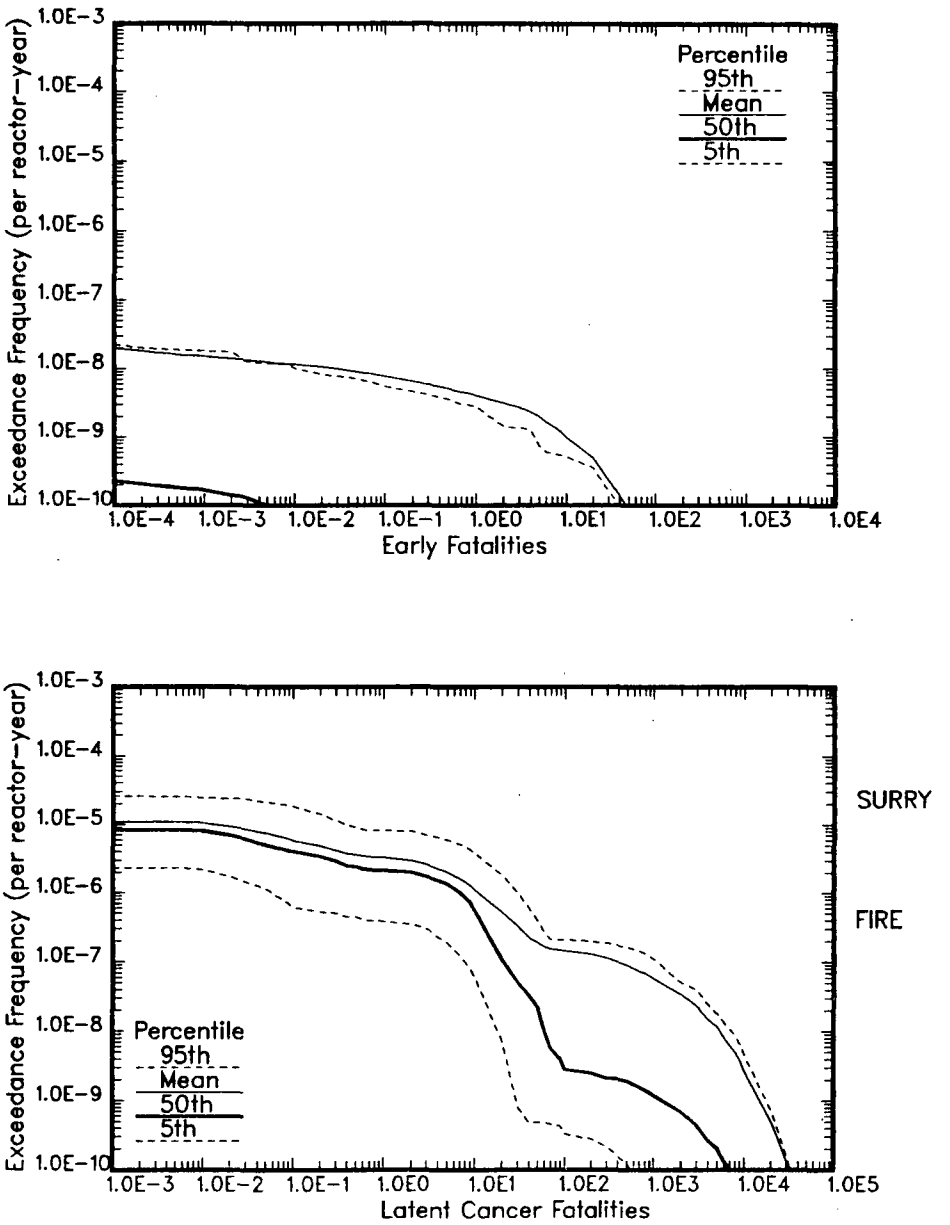
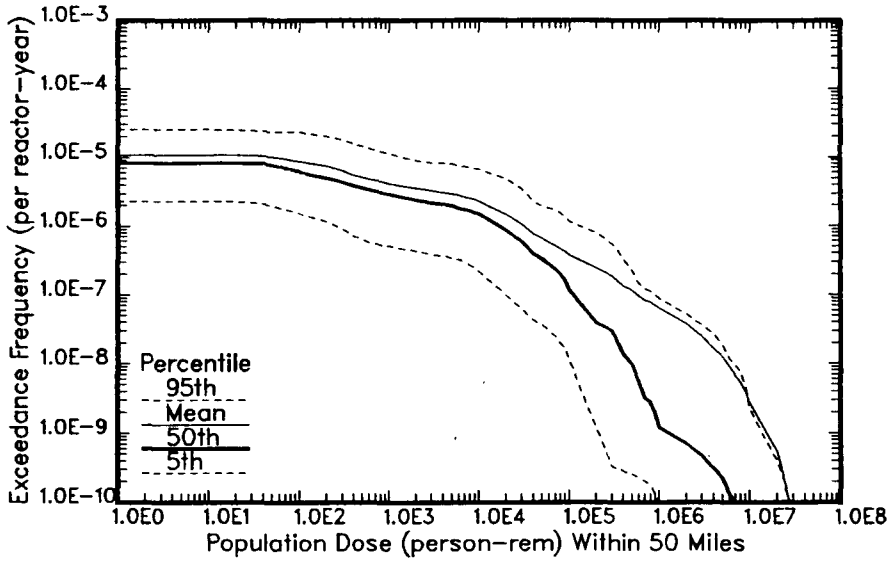


Figure 5.2-1. Exceedance Frequencies for Risk. Surry: Fire Initiators



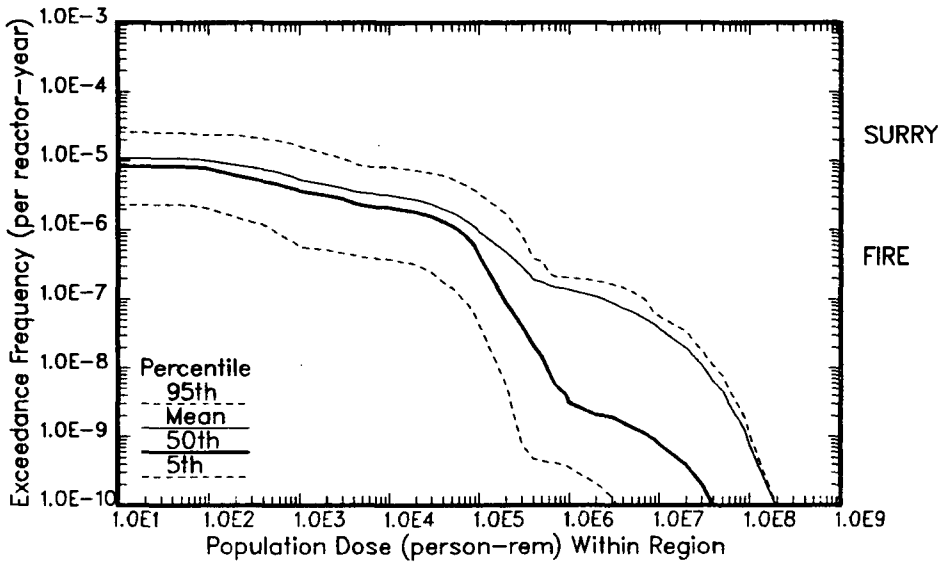
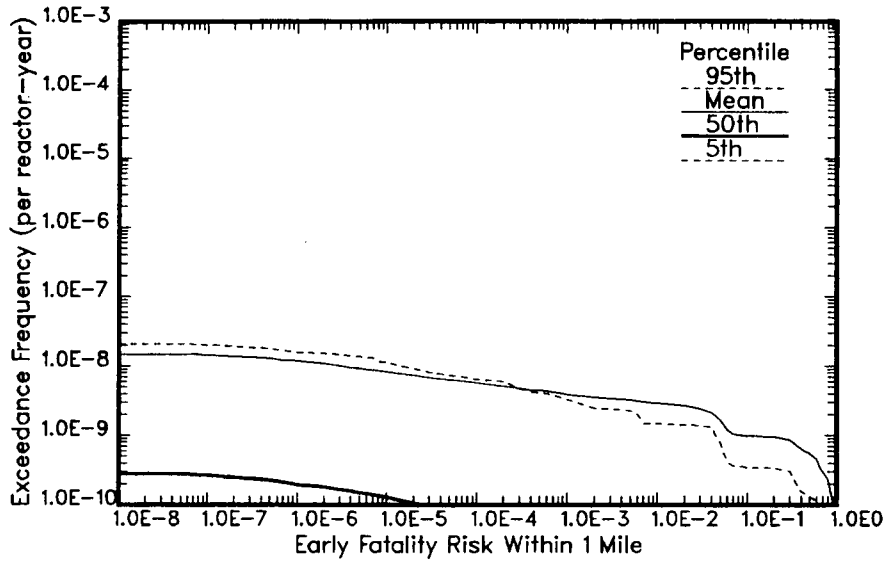


Figure 5.2-1. (continued)



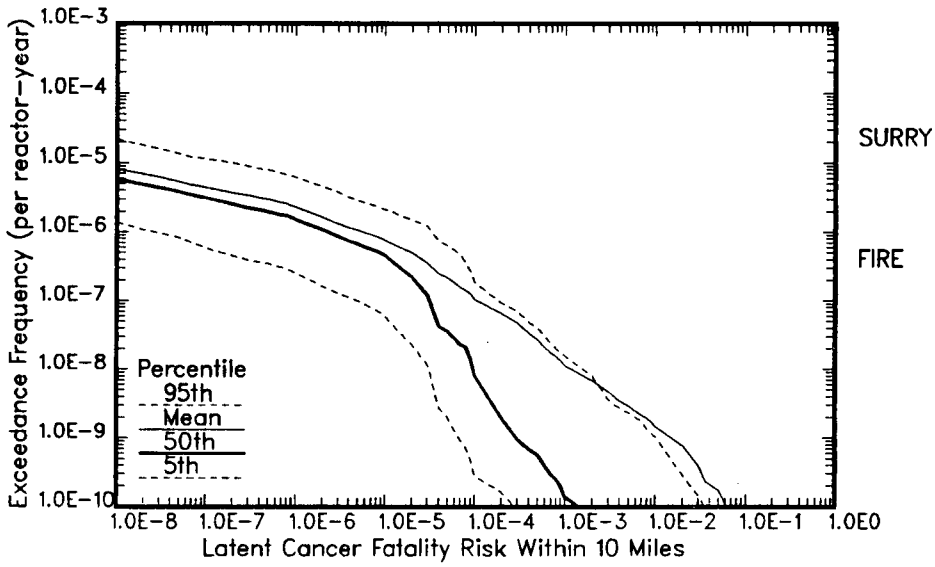


Figure 5.2-1. (continued)

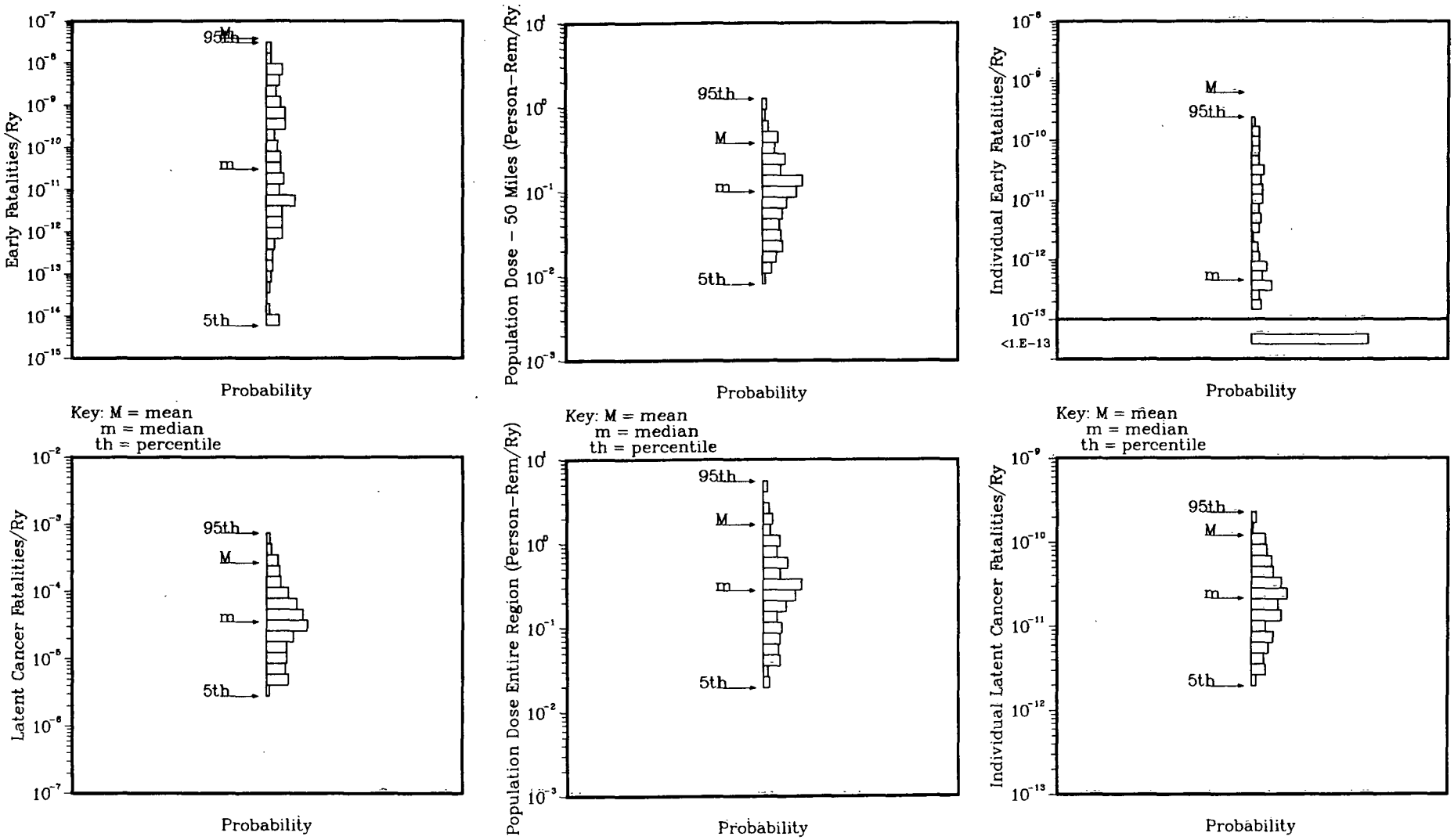


Figure 5.2-2. Distributions of Annual Risk. Surry: Fire Initiators

5.3 Results for Seismic Initiators: LLNL Hazard Curve

This section deals with the results of the integrated risk analysis for seismic initiators at the Surry plant utilizing the LLNL hazard distributions. Section 5.3.1 presents the basic risk results and Section 5.3.2 presents the results of the sensitivity cases that were run using the LLNL hazard distributions. The types of accidents and plant features which are important in determining the seismic risk, and the variables which are important contributors to the uncertainty in risk are discussed in Section 5.5, where the results based on both hazard distributions are treated together.

5.3.1 Risk Results

Figure 5.3-1 shows the four statistical measures of the CCDFs for risk for seismic initiators at Surry using the LLNL hazard distributions. The methods for deriving the four statistical measures of the family of CCDFs are described in Section 5.1.1. Figure 5.3-1 shows the following mean and median exceedance frequencies for fixed values of early fatalities (EF) and latent cancer fatalities (LCF):

	Exceedance Frequency (1/R-yr)	
Consequence	Mean	Median
1 EF	2E-6	7E-8
100 EF	2E-7	1E-9
100 LCF	2E-5	1E-6
10,000 LCF	6E-7	1E-8

The histograms of annual risk are shown in Figure 5.3-2. The relationship between the size of the consequence and its frequency in Figure 5.3-1 has been lost in computing the annual risk for each observation which are plotted in Figure 5.3-2.

The risk due to seismic initiators using the LLNL hazard distributions is compared with that from internal initiators and that from earthquakes based on the EPRI hazard distributions in Section 5.5. The risk using the LLNL seismic hazard distribution is larger than the risk due to internal initiators. There are three main reasons for this. First, the LLNL seismic core damage frequency distribution is higher than the internal initiator core damage frequency distribution. Second, there is no evacuation for earthquakes with peak ground accelerations (PGAs) greater than 0.6 g, and the evacuation is degraded (see Section 4.3.3) for earthquakes with PGAs less than 0.6 g. Third, the seismic "A" (large break) PDSs have concomitant initial failures of the containment. While there are no bypass events among the seismic initiators, the "A" PDSs play the same role, that is, they are accidents in which vessel failure is assured and in which the containment function is defeated at the start of the accident. Figure 2.5-5 shows that, based on mean values, initial containment failures occur for about 8% of the seismic accidents when the LLNL hazard distributions are used, while bypass accidents account for about 12% of the internally initiated accidents.

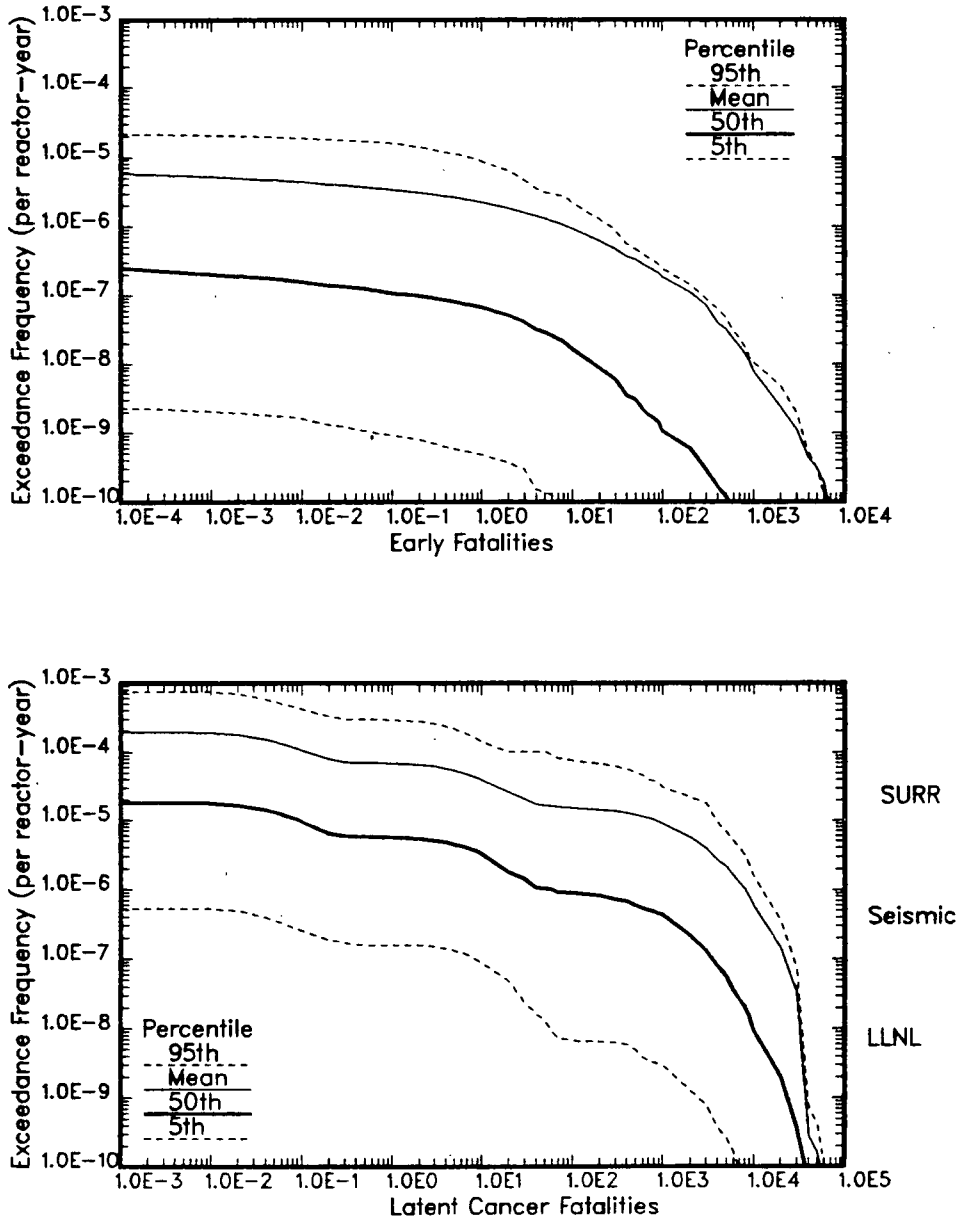
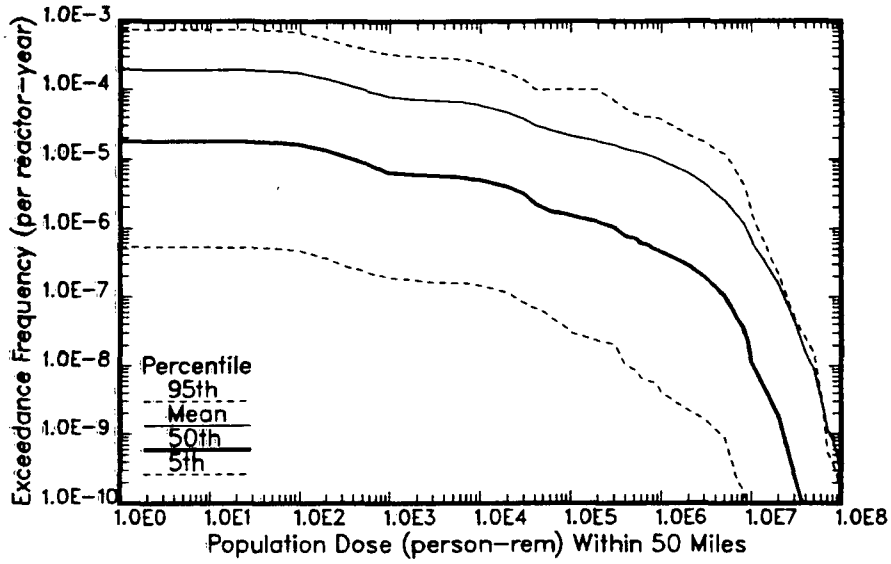


Figure 5.3-1. Exceedance Frequencies for Risk.
Surry: Seismic Initiators
LLNL Hazard Distributions



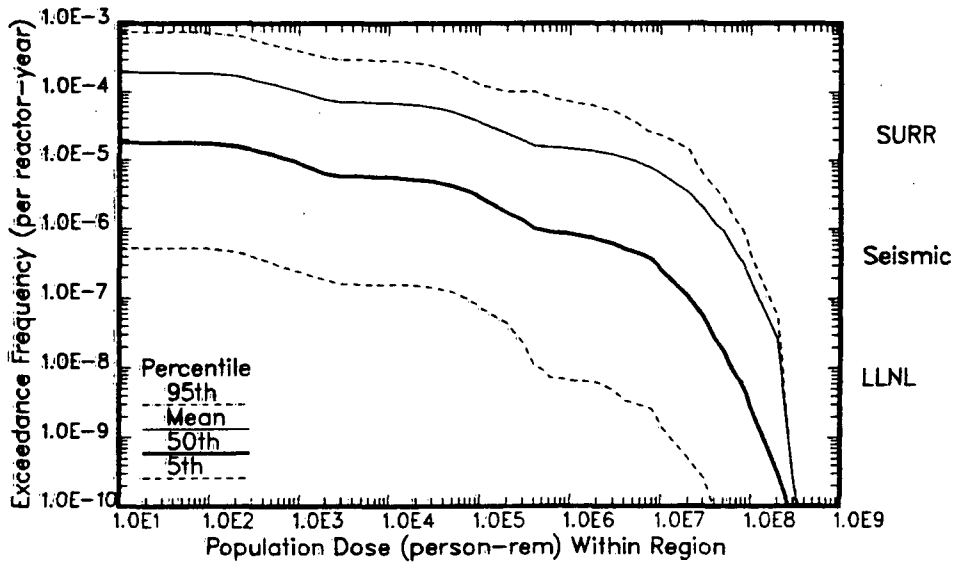
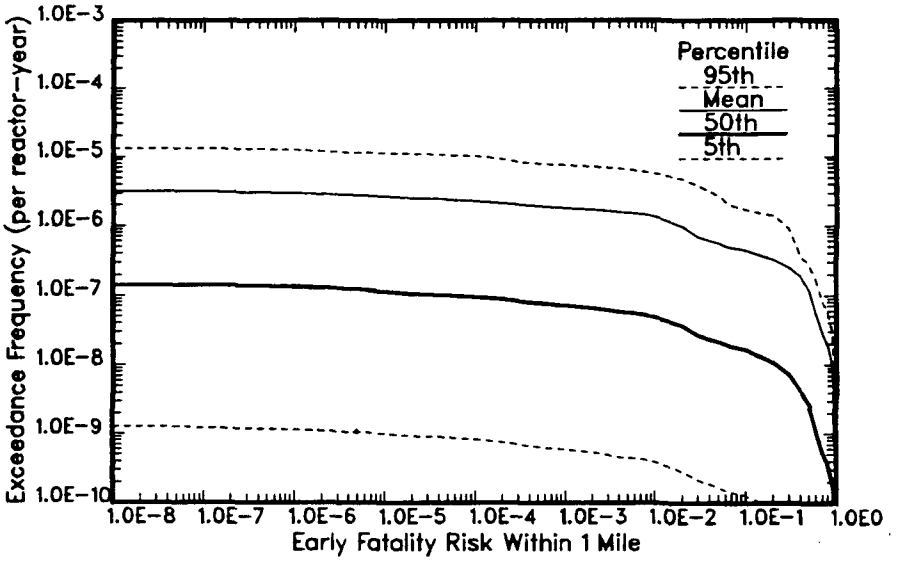


Figure 5.3-1. (continued)



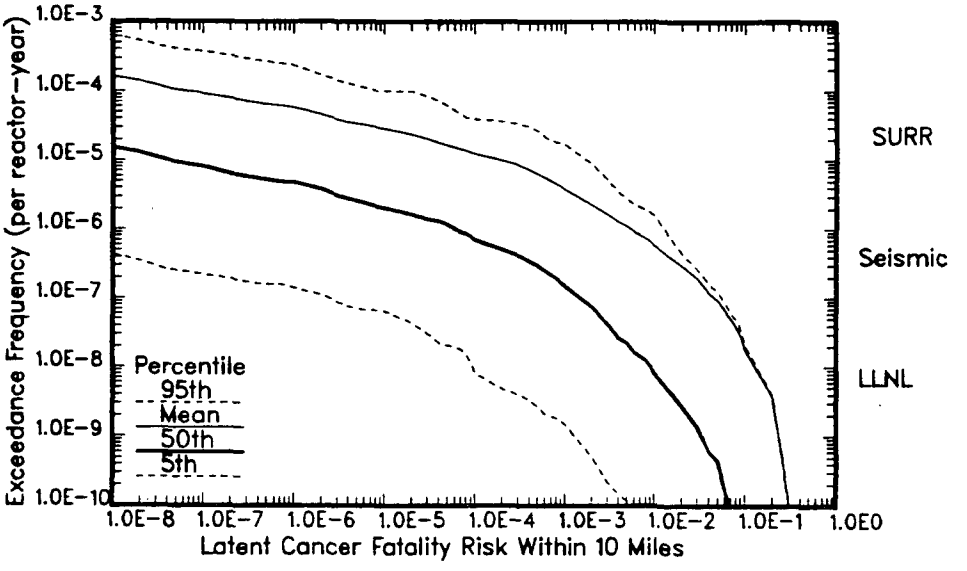


Figure 5.3-1. (continued)

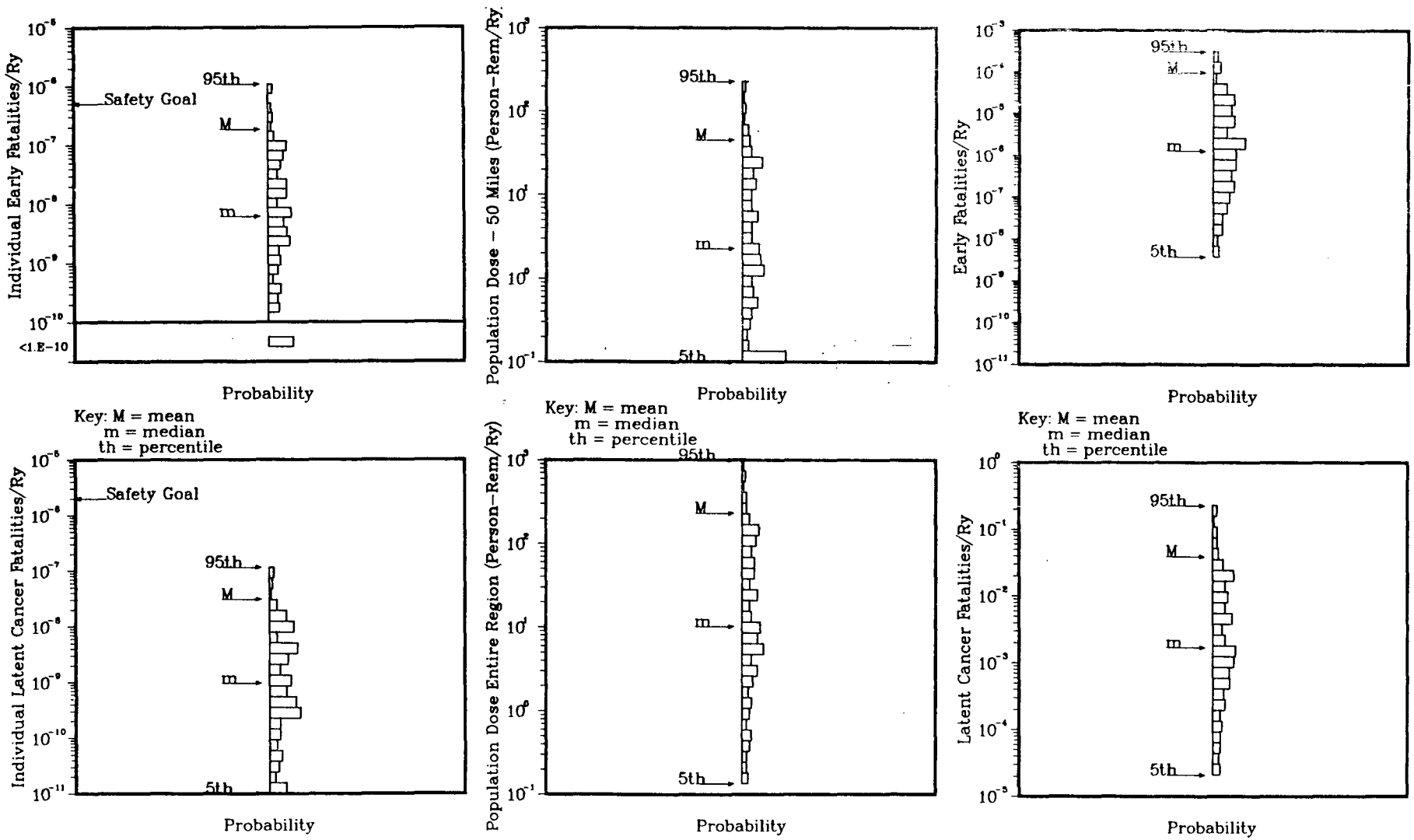


Figure 5.3-2. Distributions of Annual Risk. Surry: Seismic Initiators
LLNL Hazard Distributions

The safety goals are written in terms of mean individual fatality risks, that is, in terms of the annual probability that an individual will die as a result of a reactor accident. As shown in Figure 5.3-2, the means fall well below the safety goal for the LLNL seismic hazard distributions for Surry for both individual early fatality risk and for individual latent cancer fatality risk.

A single measure of risk for the entire sample is given by the mean value from the histograms in Figure 5.3-2. This measure of risk is commonly called mean risk. The mean risk values for the six consequence measures for seismic initiators using the LLNL hazard distributions are displayed in Figure 5.3-2. The important contributors to mean risk are discussed in Section 5.5.

5.3.2 Results of Sensitivity Analyses

Two sensitivity analyses, or ceteris paribus studies, were made using the LLNL hazard distribution. In the first one, the initial failures of the containment due to the failures of the supports for the SGs and RCPs were eliminated. That is, the initial CFs that accompanied the "A" PDSs in the base case did not occur in the sensitivity case. Table 5.3-1 compares the distributions of annual risk for six consequence measures with and without the initial CFs. As would be expected, the risk declines markedly when the initial CFs are eliminated. The reductions are largest for early fatalities and individual early fatality risk within one mile. Initial failure of the containment due to collapse of the SG or RCP supports is the main cause of early CFs for seismic initiators, so it is not surprising that early fatalities decrease when this failure mode is eliminated. Assuming these initial CFs do not occur also reduces the population dose and latent cancer fatality distributions.

Table 5.3-2 shows that eliminating the initial CFs due to SG and RCP support failures has a large effect on the fractions that each PDS group contributes to the mean risk. The FCMR and MFCR methods of measuring the contribution to mean risk are explained in Section 5.1.3. With initial CFs, the LOSP (No SBO) group is only a small contributor because it contains no "A" PDSs, and has no initial CFs. Without initial CFs, the LOSP (No SBO) group is a much larger contributor to risk. With initial CFs, the high PGA SBO and LOCA groups are disproportionately high contributors to early fatalities. This occurs because the "A" PDSs are larger contributors to the group core damage frequency (CDF) for strong earthquakes than they are for weak earthquakes. Large accelerations are required to fail the SG or RCP supports. The SBO group tends to contribute more to risk than to the mean CDF because there is no chance of core damage arrest for the SBO seismic initiators.

The seismic risk analysis without initial CFs was also performed assuming that 10% of the affected population would be killed in the earthquake itself for the earthquakes with PGA > 0.6 g, and therefore would be unavialable to be counted as reactor accident casualties. This had the effect of reducing the early fatalities and the individual early fatality risk within one mile distributions slightly. For example, with this assumption the

mean early fatalities dropped from 6.7E-5/R-yr to 6.6E-5/R-yr. The reductions are not larger because the bulk of the risk does not come from the earthquakes with PGA > 0.6 g.

The other sensitivity analysis was to divide the range of ground acceleration into three regions. That is, instead of dividing each seismic PDS group into subgroups with PGA > 0.6 g and PGA < 0.6 g, each group was divided into three subgroups:

PGA > 0.6 g,
0.3 g < PGA < 0.6 g, and
PGA < 0.3 g.

Table 5.3-1
Distributions for Annual Risk at Surry Due to Seismic Initiators
LLNL Hazard Distributions
(All values per reactor-year)
(Population doses in person-rem)

Risk Measure	Initial CFs	5th %ile	Median	Mean	95th %ile
Core Damage	Yes	5.3E-7	1.8E-5	1.9E-4	7.4E-4
	No	5.3E-7	1.8E-5	1.9E-4	7.4E-4
Early Fatalities	Yes	5.5E-9	1.3E-6	9.3E-5	2.0E-4
	No	5.0E-12	2.8E-8	6.7E-5	2.6E-5
Latent Cancer Fatalities	Yes	2.4E-5	1.7E-3	3.9E-2	1.9E-1
	No	7.1E-6	3.0E-4	7.2E-3	2.1E-2
Population Dose 50 miles	Yes	4.0E-2	2.3E 0	4.5E+1	2.3E+2
	No	2.0E-2	7.5E-1	1.4E+1	4.5E+1
Population Dose Entire Region	Yes	1.5E-1	1.0E+1	2.3E+2	1.1E+3
	No	4.9E-2	2.0E 0	4.3E+1	1.4E+2
Ind. Early Fat. Risk: 1 mile	Yes	5.0E-11	6.2E-9	1.8E-7	9.5E-7
	No	9.7E-14	5.9E-11	2.1E-8	2.8E-8
Ind. L. C. Fat. Risk: 10 miles	Yes	1.4E-11	9.7E-10	3.1E-8	1.2E-7
	No	6.6E-12	3.1E-10	1.2E-8	2.8E-8

Table 5.3-2
Fractional PDS Contributions (in percent) to Annual
Risk at Surry Due to Seismic Initiators
LLNL Hazard Distributions

		FCMR			MFCR		
PDS Group	PGA	Core Damage	Initial CF	No Init. CF	Core Damage	Initial CF	No Init. CF
Early Fatalities							
LOSP (No SBO)	Low	42.1	3.4	41.5	38.9	2.5	23.7
SBO	Low	35.2	25.4	47.7	37.5	12.1	33.8
LOCAs	Low	7.9	8.0	0.7	9.2	12.8	5.7
LOSP (No SBO)	High	4.9	1.3	4.8	4.2	1.5	9.8
SBO	High	5.9	39.8	5.1	5.5	25.1	20.2
LOCAs	High	3.9	22.1	0.3	4.7	46.0	6.8
Latent Cancer Fatalities							
LOSP (No SBO)	Low	42.1	5.6	40.7	38.9	8.4	31.3
SBO	Low	35.2	47.4	46.6	37.5	35.4	49.3
LOCAs	Low	7.9	21.4	3.1	9.2	32.1	7.5
LOSP (No SBO)	High	4.9	0.4	3.0	4.2	0.5	2.4
SBO	High	5.9	14.9	5.3	5.5	8.4	6.5
LOCAs	High	3.9	10.3	1.2	4.7	15.2	3.0

The main change in this sensitivity case is that normal evacuation takes place for earthquakes with PGA < 0.3 g. In the base case, the evacuation proceeded with 1.5 times the normal delay and half the normal speed for all earthquakes with PGA < 0.6 g. In this sensitivity case, this degraded evacuation applies only for earthquakes with PGA between 0.3 g and 0.6 g.

Because the cut sets had to be broken up further, and a different random seed used in the LHS program, the core damage frequency distribution changed as shown in Table 5.3-3. The mean and 95th percentile decreased while the 5th percentile and median increased, indicating a distribution with less spread than the base case. For most risk measures, Table 5.3-3 shows that the means decreased slightly while the medians increased somewhat. This reflects the more compact core damage frequency distribution. Table 5.3-4 shows that the seisms with PGAs below 0.3 are minimal contributors to the risk as expected.

Table 5.3-3
Distributions for Annual Risk at Surry Due to Seismic Initiators
LLNL Hazard Distributions
(All values per reactor-year)
(Population doses in person-rem)

Risk Measure	PGA Subgroups	5th %ile	Median	Mean	95th %ile
Core Damage	2	5.3E-7	1.8E-5	1.9E-4	7.4E-4
	3	2.7E-6	4.0E-5	1.3E-4	5.5E-4
Early Fatalities	2	5.5E-9	1.3E-6	9.3E-5	2.0E-4
	3	1.5E-8	2.3E-6	8.6E-5	3.6E-4
Latent Cancer Fatalities	2	2.4E-5	1.7E-3	3.9E-2	1.9E-1
	3	1.1E-4	3.6E-3	2.9E-2	1.8E-1
Population Dose 50 miles	2	4.0E-2	2.3E 0	4.5E+1	2.3E+2
	3	1.9E-1	5.9E 0	3.3E+1	1.9E+2
Population Dose Entire Region	2	1.5E-1	1.0E+1	2.3E+2	1.1E+3
	3	6.7E-1	2.2E+1	1.7E+2	1.0E+3
Ind. Early Fat. Risk--1 mile	2	5.0E-11	6.2E-9	1.8E-7	9.5E-7
	3	1.9E-10	1.2E-8	1.4E-7	7.0E-7
Ind. L. C. Fat. Risk--10 miles	2	1.4E-11	9.7E-10	3.1E-8	1.2E-7
	3	8.0E-11	2.2E-9	1.8E-8	1.1E-7

Table 5.3-4
Fractional PDS Contributions (in percent) to Annual
Risk at Surry Due to Seismic Initiators
LLNL Hazard Distributions--Three PGA Subgroups

		Early Fatalities		Latent Cancer Fatalities	
PDS Group	PGA	FCMR	MFCR	FCMR	MFCR
LOSP (No SBO)	Low	0.0	0.2	1.7	2.2
SBO	Low	0.2	0.6	4.8	4.8
LOCAs	Low	0.0	0.2	1.4	1.1
LOSP (No SBO)	Medium	0.4	2.5	4.8	6.2
SBO	Medium	14.5	11.7	22.1	20.7
LOCAs	Medium	13.1	17.5	30.3	25.9
LOSP (No SBO)	High	2.5	1.9	0.7	1.7
SBO	High	42.3	24.5	20.3	15.2
LOCAs	High	27.0	40.9	13.9	22.2

5.4 Results for Seismic Initiators: EPRI Hazard Curve

This section presents the results of the integrated risk analysis for seismic initiators at the Surry plant utilizing the EPRI hazard distributions. Section 5.4.1 presents the basic risk results and Section 5.4.2 presents the results of the sensitivity case that was run using the EPRI hazard distributions. The types of accidents and plant features which are important in determining the seismic risk, and the variables which are important contributors to the uncertainty in risk are discussed in Section 5.5, where the results based on both hazard distributions are treated together.

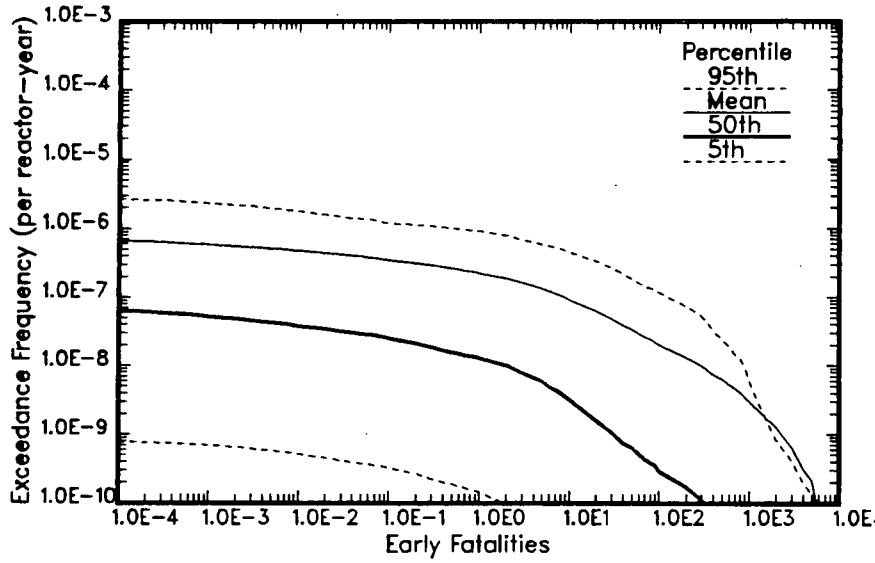
5.4.1 Risk Results

Figure 5.4-1 shows the four statistical measures of the CCDFs for risk for seismic initiators at Surry using the EPRI hazard distributions. The methods for deriving the four statistical measures of the family of CCDFs are described in Section 5.1.1. Figure 5.4-1 shows the following mean and median exceedance frequencies for fixed values of early fatalities (EF) and latent cancer fatalities (LCF):

	Exceedance Frequency (1/R-yr)	
Consequence	Mean	Median
1 EF	2E-7	1E-8
100 EF	2E-8	3E-10
100 LCF	6E-7	5E-7
10,000 LCF	1E-8	4E-9

The histograms of annual risk are shown in Figure 5.4-2. The relationship between the size of the consequence and its frequency in Figure 5.4-1 has been lost in computing the annual values for risk for each observation.

The risk due to seismic initiators using the EPRI hazard distributions is generally about the same magnitude as the risk due to internal initiators. The EPRI seismic core damage frequency distribution is slightly lower than the internal initiator core damage frequency distribution. But, there is no evacuation for earthquakes with peak ground accelerations (PGAs) greater than 0.6 g, and the evacuation is degraded (see Section 4.3.3) for earthquakes with PGAs less than 0.6 g. While there are no bypass events among the seismic initiators, the "A" PDSs play the same role due to their initial containment failures. In both Event V and the seismic "A" PDSs, vessel failure is assured and the containment function is defeated at the start of the accident. Figure 2.5-5 shows that initial containment failures occur on the average for about 6% of the seismic accidents when the EPRI hazard distributions are used, while bypass accidents account for about 12% of the internally initiated accidents.



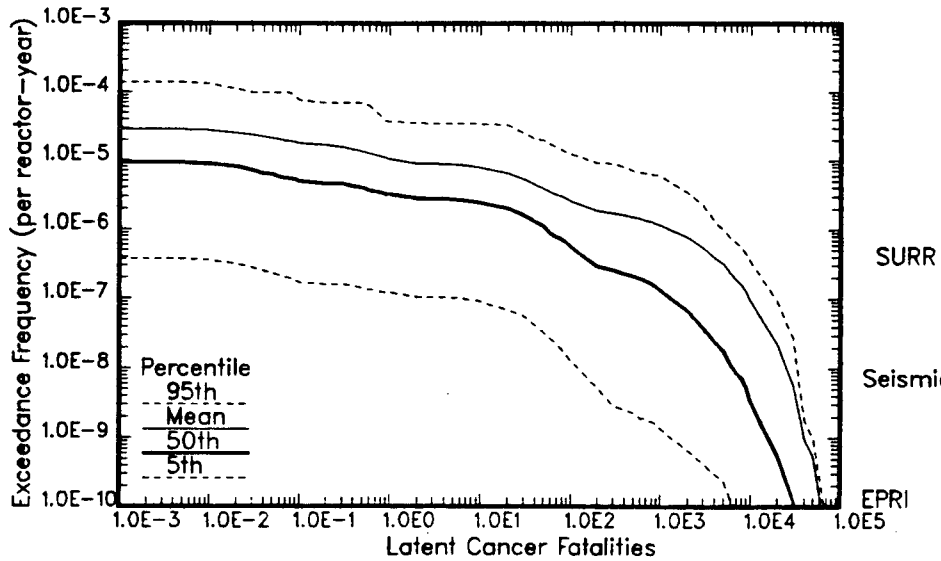
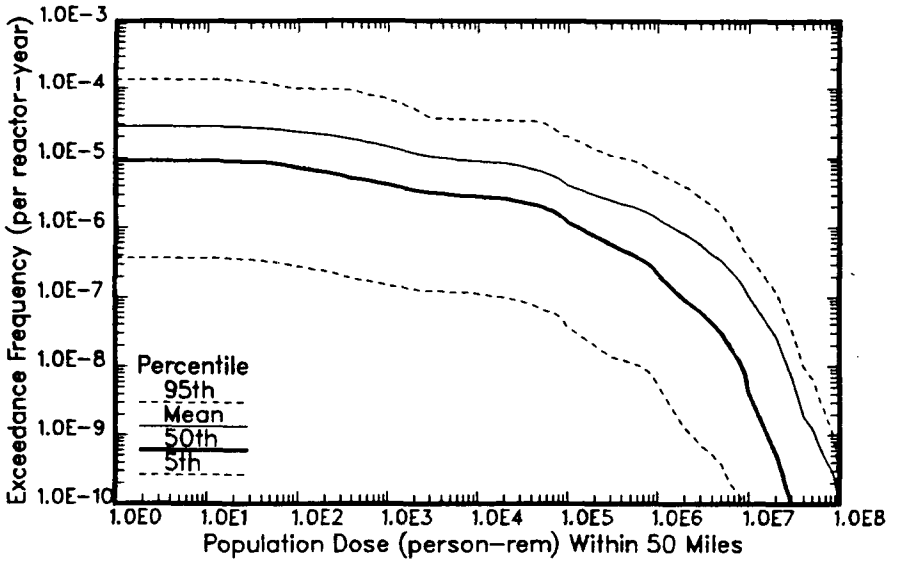


Figure 5.4-1. Exceedance Frequencies for Risk.
Surry: Seismic Initiators; EPRI Hazard Distributions



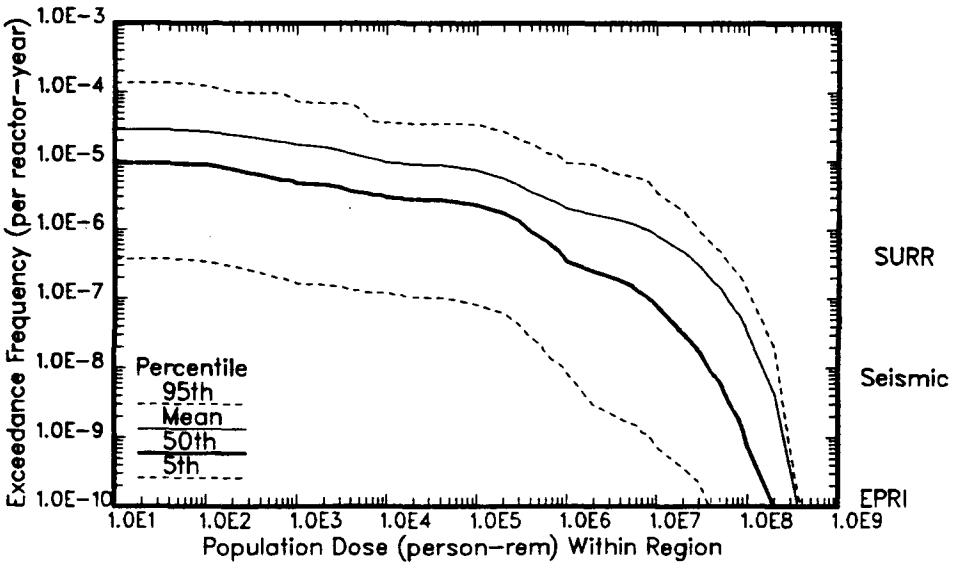
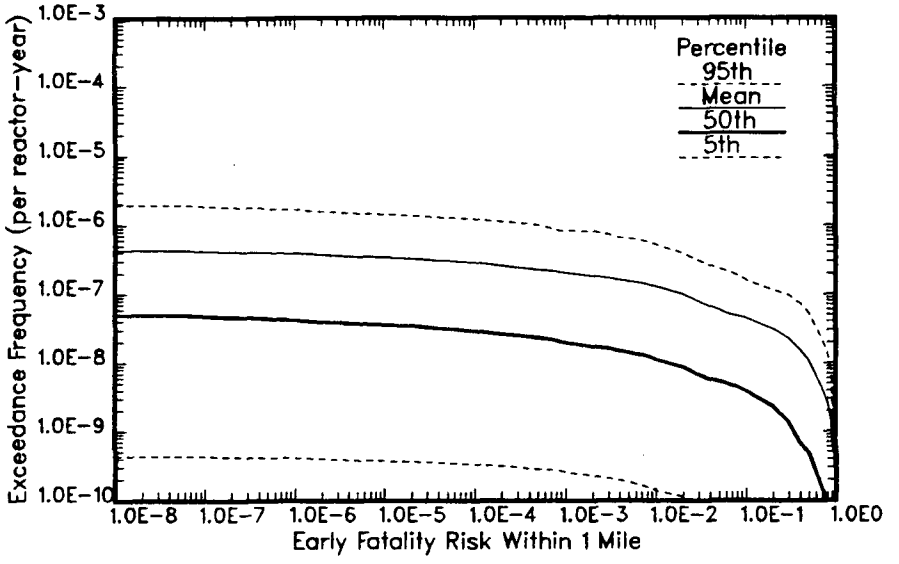


Figure 5.4-1. (continued)



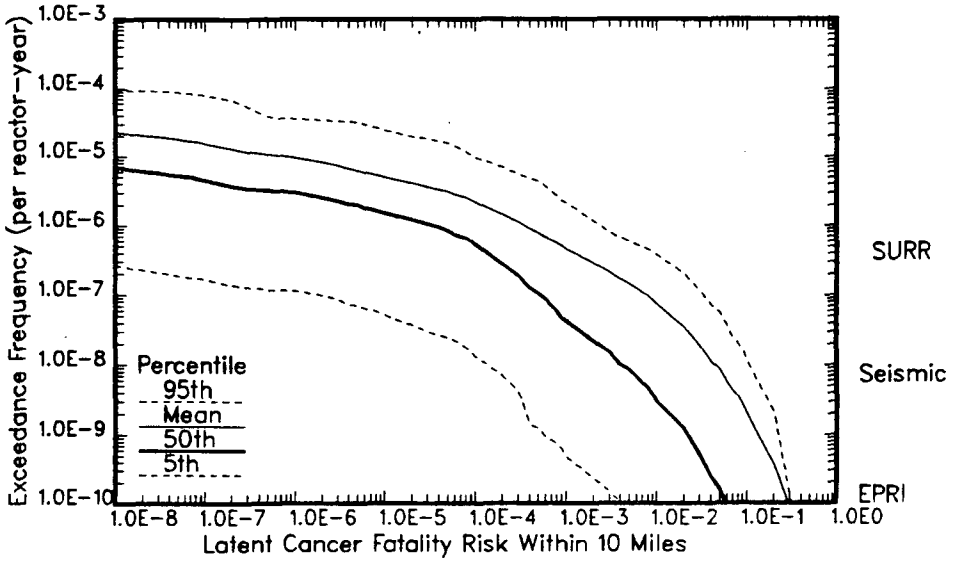


Figure 5.4-1. (continued)

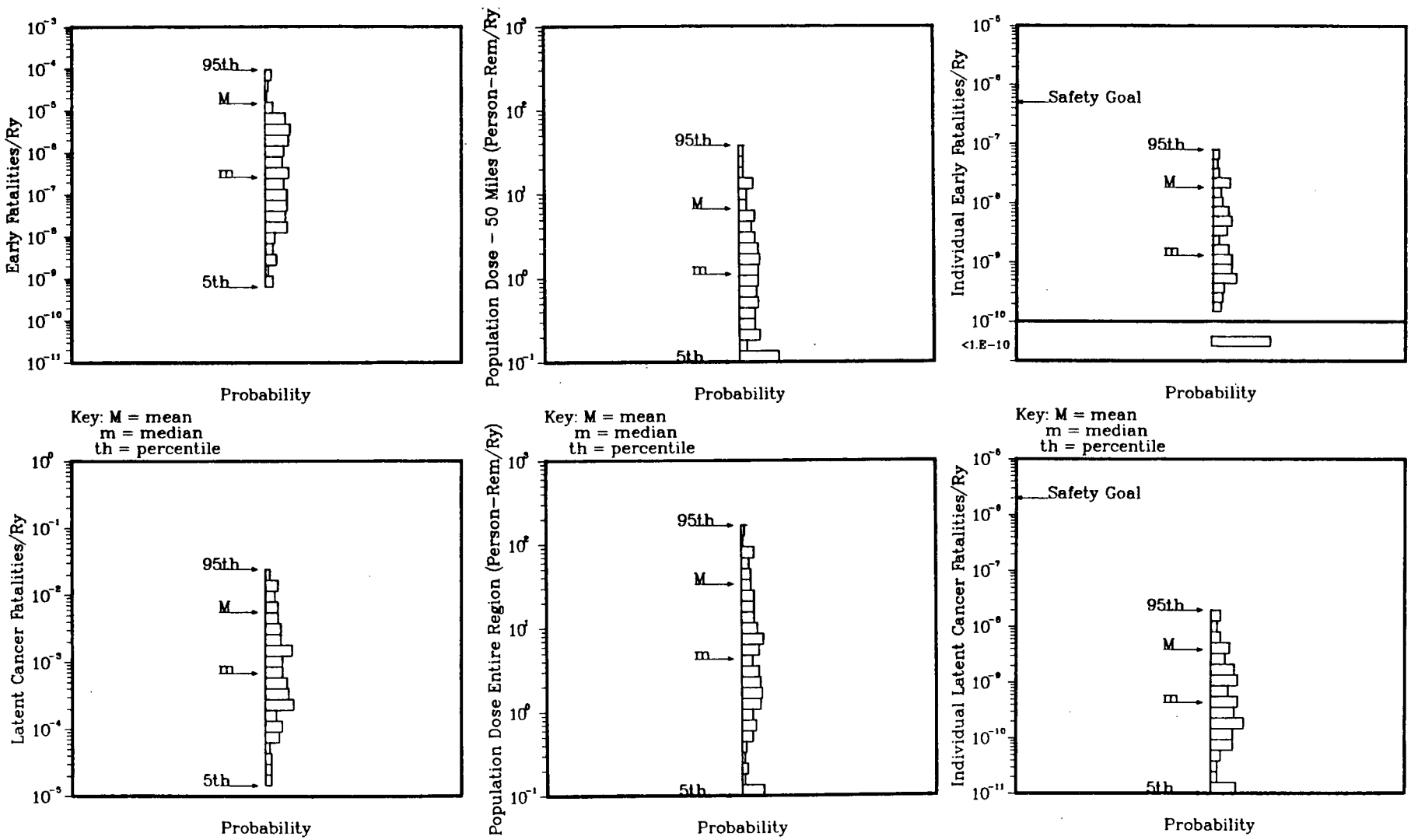


Figure 5.4-2. Distributions of Annual Risk. Surry: Seismic Initiators; EPRI Hazard Distributions

The safety goals are written in terms of individual fatality risks, that is, in terms of the annual probability that an individual will die as a result of the accident. The distributions based on the EPRI seismic hazard distributions for both individual early fatality risk and individual latent cancer fatality risk lie below the safety goal.

5.4.2 Results of Sensitivity Analyses

One sensitivity analysis, or ceteris paribus study, was made using the EPRI hazard distribution. In this study, the degraded evacuation parameters used in the base case for earthquakes with PGA < 0.6 g were replaced with the normal evacuation parameters used in the absence of earthquakes. Table 5.4-1 compares the distributions of annual risk for six consequence measures with degraded and normal evacuation for the low PGA earthquakes. The risk declines by about 50% when normal evacuation is substituted for the degraded evacuation. Table 5.4-2 shows that normal evacuation for the low PGA seisms has the effect of eliminating almost all the early fatalities due to the low PGA earthquakes. The effects of evacuation timing and speed on the contributors to mean risk are not as pronounced for the risk measures such as latent cancer fatalities which depend on the total population dose.

Table 5.4-1
Distributions for Annual Risk at Surry Due to Seismic Initiators
EPRI Hazard Distributions
(All values per reactor-year)
(Population doses in person-rem)

Risk Measure	Evacuation PGA < 0.6 g	5th %ile	Median	Mean	95th %ile
Core Damage	Degr.	3.7E-7	9.3E-6	2.8E-5	1.4E-4
	Normal	3.7E-7	9.3E-6	2.8E-5	1.4E-4
Early Fatalities	Degr.	1.1E-9	2.6E-7	1.4E-5	7.5E-5
	Normal	7.4E-10	1.6E-7	8.2E-6	3.9E-5
Latent Cancer Fatalities	Degr.	1.7E-5	6.9E-4	5.6E-3	2.6E-2
	Normal	7.4E-6	2.8E-4	1.5E-3	7.2E-3
Population Dose - 50 miles	Degr.	2.9E-2	1.1E 0	6.7E 0	3.7E+1
	Normal	1.8E-2	6.1E-1	2.3E 0	1.2E+1
Population Dose - Entire Region	Degr.	1.1E-1	4.3E 0	3.4E+1	1.6E+2
	Normal	4.9E-2	1.8E 0	9.4E 0	4.4E+1
Ind. Early Fat. Risk - 1 mile	Degr.	1.6E-11	1.3E-9	1.8E-8	8.8E-8
	Normal	1.1E-11	9.5E-10	1.0E-8	4.4E-8
Ind. L. C. Fat. Risk - 10 miles	Degr.	1.1E-11	4.3E-10	3.8E-9	1.6E-8
	Normal	5.5.-12	1.9E-10	1.2E-9	5.6E-9

Table 5.4-2
Fractional PDS Contributions (in percent) to Annual
Risk at Surry Due to Seismic Initiators
EPRI Hazard Distributions

		FCMR			MFCR		
PDS Group	PGA	Core Damage	Degr. Evac.	Normal Evac.	Core Damage	Degr. Evac.	Normal Evac.
Early Fatalities							
LOSP (No SBO)	Low	50.5	0.9	0.0	43.4	4.1	0.4
SBO	Low	29.4	22.1	0.0	36.6	11.6	0.1
LOCAs	Low	8.7	20.5	0.0	8.6	12.4	0.0
LOSP (No SBO)	High	4.0	0.5	0.8	3.4	2.4	4.2
SBO	High	3.9	22.0	39.0	4.5	26.5	37.5
LOCAs	High	3.5	34.0	60.2	3.4	43.1	57.8
Latent Cancer Fatalities							
LOSP (No SBO)	Low	50.5	10.3	9.6	43.4	14.7	19.3
SBO	Low	29.4	37.0	20.7	36.6	36.8	25.0
LOCAs	Low	8.7	33.9	0.8	8.6	30.2	1.8
LOSP (No SBO)	High	4.0	0.5	1.7	3.4	0.7	1.8
SBO	High	3.9	6.1	22.3	4.5	6.4	19.7
LOCAs	High	3.5	12.3	44.9	3.4	11.1	32.4

5.5 Comparison of Results for Seismic Initiators

This section briefly compares the results of the integrated risk analysis for seismic initiators at the Surry plant utilizing the two different hazard distributions. The use of the LLNL hazard distributions in the accident frequency analysis results in larger estimates of risk than use of the EPRI hazard distributions. This may be seen by comparing the CCDFs in Figure 5.3-1 with those in Figure 5.4-1, or by comparing the histograms for annual risk in Figure 5.3-2 with those in Figure 5.4-2. Very generally speaking, the risk from the seismic initiators based on the EPRI hazard distributions is comparable to that from internal initiators, while the risk from the seismic initiators based on the LLNL hazard distributions is higher than that from internal initiators. The distance from the 5th percentile curve to the 95th percentile curve for the seismic initiators is typically an order of magnitude greater than it is for the internal initiators (see Figure 5.1-1). This is due to the great uncertainty in the seismic hazard distributions.

The following mean and median exceedance frequencies for fixed values of early fatalities (EF) and latent cancer fatalities (LCF) may be found from Figures 5.1-1, 5.3-1, and 5.4-1:

	Exceedance Frequency (1/R-yr)					
	Internal		Seismic - LLNL		Seismic - EPRI	
Consequence	Mean	Median	Mean	Median	Mean	Median
1 EF	2E-7	1E-8	2E-6	7E-8	2E-7	1E-8
100 EF	2E-9	< 1E-10	2E-7	1E-9	2E-8	3E-10
100 LCF	4E-6	2E-6	2E-5	1E-6	6E-7	5E-7
10,000 LCF	5E-8	1E-8	6E-7	1E-8	1E-8	4E-9

For all four fixed consequence values, the exceedance frequency based on the LLNL hazard distributions is greater than the exceedance frequency from internal initiators if the mean CCDF is used, but is comparable with the exceedance frequency from internal initiators if the median CCDF is used. The exceedance frequency based on the EPRI hazard distributions is of the same magnitude or less than the exceedance frequency from internal initiators depending on whether the mean or median CCDF is used.

Table 5.5-1 lists four statistical measures of the annual risk for both seismic hazard distributions. The mean and 95th percentile values of the core damage frequency computed using the LLNL hazard distributions are about six times the equivalent values computed using the EPRI hazard distributions. There is less difference when the 5th percentile or the median values are compared. The large differences in the upper portions of the core damage frequency distributions cause differences of the same order of magnitude in the seismic offsite risk. Comparing the mean values for the early fatalities, latent cancer fatalities, population dose within 50 miles, and population dose within the region, the values based on the LLNL hazard distributions are about six times the corresponding values based on the EPRI hazard distributions. For the individual fatality risk measures, the differences are larger, about an order of magnitude. The lower distributions for annual risk that result from using the EPRI hazard distributions are largely due to the lower core damage frequency distribution. Distributions for annual risk for internal initiators for both samples are contained in Table 5.1-1 for comparison.

When the histograms for annual risk for seismic initiators (Figures 5.3-2 and 5.4-2) are compared with those for internal initiators (Figure 5.1-2), two differences are obvious. First, the results based on the LLNL hazard distributions lie generally above the equivalent distributions for internal initiators. This is to be expected given the higher core damage frequency distribution for the LLNL hazard distributions. For most of the risk measures, the EPRI risk distributions are generally similar in to the distributions for internal initiators. Second, the seismic risk distributions are wider than the risk distributions for internal initiators. This is mostly due to the large uncertainty in the seismic hazard itself.

Table 5.5-2 compares the contributors to mean risk for the two seismic hazard distributions, both for the summary PDS groups LOSP and LOCA, and for the high and low acceleration groups. Based on the FCMR method of calculating the contributions to mean risk, using the EPRI hazard distributions the LOCAs contribute more to the mean risk for all risk measures than they do using the LLNL hazard distribution. Based on the MFCR method, however, this difference is not apparent.

Table 5.5-3 compares the contributions to mean risk from the summary APBs for the two seismic hazard distributions. The summary bin which accounts for most of the risk, for all risk measures, is that in which the containment fails early with the RCS at low pressure. As discussed above, almost all the risk in this bin is due to containment failures at the time of the earthquake caused by failures of the RCP or SG supports. Most of the risk not attributable to the early CF, low pressure bin may be traced to the Alpha mode bin, the early CF, high pressure bin, or the late CF bin. As would be expected, the late CF bin is a negligible contributor to early fatality risk. Although there are no bypass initiators among the seismic core damage accidents, the expert panel on in-vessel processes concluded that temperature-induced SGTRs were possible, but very unlikely. These SGTRs account for the risk contributions in the bypass summary bin.

Table 5.5-1
Distributions for Annual Risk at Surry Due to Seismic Initiators
(All values per reactor-year)
(Population doses in person-rem)

Risk Measure	Hazard Distrib.	5th %ile	Median	Mean	95th %ile
Core Damage	LLNL	5.3E-7	1.8E-5	1.9E-4	7.4E-4
	EPRI	3.7E-7	9.3E-6	2.8E-5	1.4E-4
Early Fatalities	LLNL	5.5E-9	1.3E-6	9.3E-5	2.0E-4
	EPRI	1.1E-9	2.6E-7	1.4E-5	7.5E-5
Latent Cancer Fatalities	LLNL	2.4E-5	1.7E-3	3.9E-2	1.9E-1
	EPRI	1.7E-5	6.9E-4	5.6E-3	2.6E-2
Population Dose 50 miles	LLNL	4.0E-2	2.3E 0	4.5E+1	2.3E+2
	EPRI	2.9E-2	1.1E 0	6.7E 0	3.7E+1
Population Dose Entire Region	LLNL	1.5E-1	1.0E+1	2.3E+2	1.1E+3
	EPRI	1.1E-1	4.3E 0	3.4E+1	1.6E+2
Ind. Early Fat. Risk--1 mile	LLNL	5.0E-11	6.2E-9	1.8E-7	9.5E-7
	EPRI	1.6E-11	1.3E-9	1.8E-8	8.8E-8
Ind. L. C. Fat. Risk--10 miles	LLNL	1.4E-11	9.7E-10	3.1E-8	1.2E-7
	EPRI	1.1E-11	4.3E-10	3.8E-9	1.6E-8

Table 5.5-2
Fractional PDS Contributions (in percent) to Annual
Risk at Surry Due to Seismic Initiators

Summary PDS Group	Hazard Dist.	Method	Core Damage	Early Fatalities	Latent Cancer Fatalities	Population Dose 50 miles	Population Dose Region	Ind. E. F. Risk-1 mile	Ind. L.C.F. 10 miles
LOSP	LLNL	FCMR	88.2	69.8	68.3	67.7	68.3	66.1	73.8
		MFCR	86.0	41.2	52.7	57.0	54.1	42.7	51.8
	EPRI	FCMR	87.8	45.5	53.8	56.7	54.3	46.1	51.4
		MFCR	87.9	44.5	58.6	64.2	59.7	45.5	59.1
LOCA	LLNL	FCMR	11.8	30.2	31.7	32.3	31.7	33.9	26.2
		MFCR	14.0	58.8	47.3	43.0	45.9	57.3	48.2
	EPRI	FCMR	12.2	54.5	46.2	43.3	45.7	53.9	48.6
		MFCR	12.1	55.5	41.4	35.8	40.3	54.5	40.9
Low PGA	LLNL	FCMR	85.3	36.8	74.4	74.2	74.6	45.4	74.0
		MFCR	85.6	27.4	75.9	76.9	76.5	37.9	71.3
	EPRI	FCMR	88.7	43.5	81.2	80.9	81.5	43.4	73.9
		MFCR	88.7	28.0	81.7	83.0	82.3	36.8	77.2
High PGA	LLNL	FCMR	14.7	63.2	25.6	25.8	25.4	54.6	26.0
		MFCR	14.4	72.6	24.1	23.1	23.5	62.1	28.7
	EPRI	FCMR	11.3	56.5	18.8	19.1	18.5	56.6	26.1
		MFCR	11.3	72.0	18.3	17.0	17.7	63.2	22.8

Table 5.5-3
Fractional APB Contributions (in percent) to Annual
Risk at Surry Due to Seismic Initiators

Summary Accident Progression	Hazard Dist.	Method	Early Fatalities	Latent Cancer Fatalities	Population Dose Dose 50 miles	Population Dose Region	Ind. E. F. Risk-1 mile	Ind. L.C.F. Risk-10 mile
VB, Early CF Alpha mode	LLNL	FCMR	1.7	3.2	2.8	3.2	2.2	3.1
	LLNL	MFCR	6.2	7.1	5.8	6.9	7.1	6.6
	EPRI	FCMR	3.4	11.6	9.0	11.5	7.7	9.7
	EPRI	MFCR	7.6	7.6	5.5	7.3	8.6	6.9
VB, Early CF RCS > 200 psi	LLNL	FCMR	7.2	6.5	6.1	6.3	6.9	10.6
	LLNL	MFCR	2.7	2.9	2.7	2.8	3.0	3.0
	EPRI	FCMR	3.6	16.2	14.9	16.2	15.2	12.1
	EPRI	MFCR	1.9	2.5	2.3	2.4	2.5	2.2
VB, Early CF RCS < 200 psi	LLNL	FCMR	90.4	83.9	80.0	83.2	88.4	82.8
	LLNL	MFCR	88.2	70.1	62.2	67.9	84.0	70.9
	EPRI	FCMR	92.3	62.4	58.5	61.5	75.1	70.8
	EPRI	MFCR	84.7	61.3	50.6	59.4	81.8	59.5
VB, Late CF or BMT	LLNL	FCMR	0.04	4.7	9.1	5.6	0.5	2.3
	LLNL	MFCR	0.09	14.5	24.0	17.1	0.9	14.6
	EPRI	FCMR	0.06	8.6	16.0	9.6	0.4	6.0
	EPRI	MFCR	0.1	24.1	37.3	26.5	0.6	26.7
Bypass of Containment	LLNL	FCMR	0.6	0.7	0.6	0.7	1.1	0.6
	LLNL	MFCR	2.1	2.8	2.4	2.7	2.5	2.5
	EPRI	FCMR	0.5	0.5	0.6	0.5	0.1	0.8
	EPRI	MFCR	5.2	2.6	2.0	2.5	5.2	2.9
VB, No CF	LLNL	FCMR	0.0	0.01	0.06	0.02	0.0	0.01
	LLNL	MFCR	0.0	0.09	0.2	0.1	0.0	0.1
	EPRI	FCMR	0.0	0.07	0.2	0.1	0.0	0.09
	EPRI	MFCR	0.0	0.3	0.5	0.3	0.0	0.3
No VB	LLNL	FCMR	0.1	1.0	1.3	1.0	0.9	0.6
	LLNL	MFCR	0.8	2.5	2.7	2.5	2.5	2.3
	EPRI	FCMR	0.09	0.6	0.8	0.6	0.5	0.5
	EPRI	MFCR	0.5	1.6	1.8	1.6	1.3	1.5

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6. INSIGHTS AND CONCLUSIONS

Core Damage Arrest. The inclusion of the possibility of arresting the core degradation process before vessel failure is an important feature of this analysis. For internal initiators, there is a good chance that non-bypass accidents will be arrested before vessel failure. This may be due to the recovery of offsite power or the reduction of RCS pressure to the point where an operable system can inject. The arrest of core damage before VB plays an important part in reducing the risk due to the most frequent types of internal accidents: SBOs and LOCAs. For fires, there is no possibility of core damage arrest as the initiating fire destroys the ability to provide control or motive power to the coolant injection systems. For accidents initiated by earthquakes, core damage arrest is not possible in the SBO accidents as the switchyard is destroyed. The fraction of accidents that do not progress to vessel failure in the LOSP (No SBO) and LOCA groups is significant, however.

Depressurization of the RCS. Depressurization of the RCS before the vessel fails is important in reducing the loads placed upon the containment at VB and in arresting core damage before vessel breach. For accidents in which the RCS is at the PORV setpoint pressure during core degradation, the effective mechanisms for pressure reduction are temperature-induced failure of the hot leg or surge line, temperature-induced failure of the RCP seals, and the sticking open of the PORVs. All of these mechanisms are inadvertent and beyond the control of the operators. The apparent beneficial effects of reducing the pressure in the RCS when lower head failure is imminent indicate that further investigation of depressurization may be warranted. The dependency of the probability of containment failure on RCS pressure boundary failures that occur at unpredictable locations and at unpredictable times is somewhat unsettling. Studies of the effects of increasing PORV capacity, providing the means to open the PORVs in blackout situations, and changing the procedures to remove restrictive conditions on deliberate RCS pressure reduction might prove rewarding in decreasing the probability of early containment failure at PWRs.

Containment Failure. If a core damage accident proceeds to the point where the lower head of the reactor vessel fails, the containment is unlikely to fail at this time. This is partially due to the depressurization of the RCS before vessel failure and partially due to the strength of the Surry containment relative to the loads expected. If the containment does fail, it is most likely to fail many hours after vessel breach. The mode and time of failure depends upon the availability of containment heat removal (CHR). If CHR is recovered within a day or so, basemat meltthrough is the most probable failure mode. If CHR is not recovered within many days, an overpressure failure about a week after the start of the accident is the likely mode.

Bypass Accidents. Bypass accidents dominate the risks that depend on a large early release as well as those which are functions of the total release. Event V is the accident most likely to result in a large, early release for internal initiators. SGTRs are also important contributors to

large releases, but most of the large releases due to SGTRs occur many hours after the start of the accident. The most important SGTRs are those in which the SRVs on the secondary system stick open. Although the bypass accidents are not the most frequent types of internal accidents, the low probability of CF, especially early CF, for the non-bypass accidents results in the large contributions of the bypass accidents to risk.

Fission Product Releases. There is considerable uncertainty in the release fractions for all types of accidents. For most accidents, the central portions of the release fraction distributions are below most release fraction estimates of several years ago. While the upper portions of the release fraction distributions are comparable with the values of the RSS, many of these distributions now extend to release fractions that are several orders of magnitude lower than those of the RSS.

Comparison with the RSS. The distributions for annual risk resulting from the current analysis of the offsite risk from internally initiated accidents at the Surry nuclear power plant are lower than those found about 15 years ago in the RSS. For early fatalities, the 95th percentile of the current distribution lies below the 5th percentile of the RSS distribution. For latent cancer fatalities, the 95th percentile of the current distribution is slightly greater than the median of the RSS distribution. The most frequent accidents, SBOs and LOCAs, are unlikely to result in early containment failure. This is due to a number of factors, including: consideration of core damage arrest, higher estimates of the containment failure pressure, reduced estimates of the pressure rise at vessel breach, and lower release fractions for many accidents.

Uncertainty in Risk. Considerable uncertainty is associated with the risk estimates produced in this analysis. The largest contributors to this uncertainty are the frequencies of the initiating events, especially for the bypass and seismic initiators, and the uncertainty in some of the parameters that determine the magnitude of the fission product release to the environment. The distributions for annual risk resulting from this analysis are much wider than those from the RSS. The additional uncertainty is all in the direction of lower risk. Propagation of the uncertainties in the accident frequency, accident progression, and source term analyses through to risk allows the uncertainty to be quantitatively calculated and displayed.

Risk from Fire. The risk due to fires at Surry is lower that that from internal initiators or earthquakes. While there is no chance of core damage arrest due to disruption of ECCS control or motive power, the fire core damage frequency is about one fourth that for internal initiators, there are no bypass initiators, and the probability of early containment failure is small.

Risk from Earthquakes. The offsite risk at Surry due to earthquakes depends very strongly on the set of hazard distributions utilized in the accident frequency analysis. If the LLNL hazard distributions are used, the upper portions of the annual risk distributions are about an order of magnitude higher than the risk distributions from internal initiators. If the EPRI hazard distributions are used, the annual risk distributions are roughly comparable with the risk distributions from internal initiators.

Much of the offsite seismic risk is attributable to initial containment failures due to the reactor coolant pump or steam generator support failures that accompany the large "A" LOCAs. Containment failure at VB is relatively unlikely for the seismic initiators.

Comparison with the Safety Goals. The mean risk falls well below the safety goals for internal, fire, and seismic initiators. For internal and fire initiators, even the 95th percentile value for annual risk falls more than an order of magnitude below the safety goal. For the seismic initiators, mean values for individual latent cancer fatality risk are more than an order of magnitude below the safety goal for both the LLNL and EPRI hazard distributions. For the probability of an individual early fatality from seismic initiators using the EPRI hazard distributions, mean value is about an order of magnitude below the safety goal. If the LLNL hazard distributions are used, the mean value of the probability of an individual early fatality is about one third the safety goal.

DISTRIBUTION:

Frank Abbey
U. K. Atomic Energy Authority
Wigshaw Lane, Culcheth
Warrington, Cheshire, WA3 4NE
ENGLAND

Kiyoharu Abe
Department of Reactor Safety Research
Nuclear Safety Research Center
ToKai Research Establishment
JAERI
Tokai-mura, Naga-gun
Ibaraki-ken,
JAPAN

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Nuclear Engineering Division
Cekmece Nuclear Research and Training Centre
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Istanbul
TURKEY

Bharat Agrawal
USNRC-RES/AEB
MS: NL/N-344

Kiyoto Aizawa
Safety Research Group
Reactor Research and Development Project
PNC
9-13m 1-Chome Akasaka
Minatu-Ku
Tokyo
JAPAN

Oguz Akalin
Ontario Hydro
700 University Avenue
Toronto, Ontario
CANADA M5G 1X6

David Aldrich
Science Applications International Corporation
1710 Goodridge Drive
McLean, VA 22102

Agustin Alonso
University Politecnica De Madrid
J Gutierrez Abascal, 2
28006 Madrid
SPAIN

Christopher Amos
Science Applications International Corporation
2109 Air Park Road SE
Albuquerque, NM 87106

Richard C. Anoba
Project Engr., Corp. Nuclear Safety
Carolina Power and Light Co.
P. O. Box 1551
Raleigh, NC 27602

George Apostolakis
UCLA
Boelter Hall, Room 5532
Los Angeles, CA 90024

James W. Ashkar
Boston Edison Company
800 Boylston Street
Boston, MA 02199

Donald H. Ashton
Bechtel Power Corporation
P.O. Box 2166
Houston, TX 77252-2166

J. de Assuncao
Cabinete de Proteccao e Seguranca Nuclear
Secretario de Estado de Energia
Ministerio da Industria
av. da Republica, 45-6°
1000 Lisbon
PORTUGAL

Mark Averett
Florida Power Corporation
P.O. Box 14042
St. Petersburg, FL 33733

Raymond O. Bagley
Northeast Utilities
P.O. Box 270
Hartford, CT 06141-0270

Juan Bagues
Consejo de Seguridad Nucleare
Sarangela de la Cruz 3
28020 Madrid
SPAIN

George F. Bailey
Washington Public Power Supply System
P. O. Box 968
Richland, WA 99352

H. Bairiot
Belgonucleaire S A
Rue de Champ de Mars 25
B-1050 Brussels
BELGIUM

Louis Baker
Reactor Analysis and Safety Division
Building 207
Argonne National Laboratory
9700 South Cass Avenue
Argonne, IL 60439

H-P. Balfanz
TUV-Norddeutschland
Grosse Bahnstrasse 31,
2000 Hamburg 54
FEDERAL REPUBLIC OF GERMANY

Patrick Baranowsky
USNRC-NRR/OEAB
MS: 11E-22

H. Bargmann
Dept. de Mecanique
Inst. de Machines Hydrauliques et de Mecaniques des Fluides
Ecole Polytechnique de Lausanne
CH-1003 Lausanne
M.E. (ECUBLENS)
CH. 1015 Lausanne
SWITZERLAND

Robert A. Bari
Brookhaven National Laboratory
Building 130
Upton, NY 11973

Richard Barrett
USNRC-NRR/PRAB
MS: 10A-2

Kenneth S. Baskin
S. California Edison Company
P.O. Box 800
Rosemead, CA 91770

J. Basselier
Belgonucleaire S A
Rue du Champ de Mars 25, B-1050
Brussels
BELGIUM

Werner Bastl
Gesellschaft Fur Reaktorsicherheit
Forschungsgelande
D-8046 Garching
FEDERAL REPUBLIC OF GERMANY

Anton Bayer
BGA/ISH/ZDB
Postfach 1108
D-8042 Neuherberg
FEDERAL REPUBLIC OF GERMANY

Ronald Bayer
Virginia Electric Power Co.
P. O. Box 26666
Richmond, VA 23261

Eric S. Beckjord
Director
USNRC-RES
MS: NL/S-007

Bruce B. Beckley
Public Service Company
P.O. Box 330
Manchester, NH 03105

William Beckner
USNRC-RES/SAIB
MS: NL/S-324

Robert M. Bernero
Director
USNRC-NMSS
MS: 6A-4

Ronald Berryman [2]
Virginia Electric Power Co.
P. O. Box 26666
Richmond, VA 23261

Robert C. Bertucio
NUS Corporation
1301 S. Central Ave, Suite 202
Kent, WA 98032

John H. Bickel
EG&G Idaho
P.O. Box 1625
Idaho Falls, ID 83415

Peter Bieniarz
Risk Management Association
2309 Dietz Farm Road, NW
Albuquerque, NM 87107

Adolf Birkhofer
Gesellschaft Fur Reaktorsicherheit
Forschungsgelande
D-8046 Garching
FEDERAL REPUBLIC OF GERMANY

James Blackburn
Illinois Dept. of Nuclear Safety
1035 Outer Park Drive
Springfield, IL 62704

Dennis C. Bley
Pickard, Lowe & Garrick, Inc.
2260 University Drive
Newport Beach, CA 92660

Roger M. Blond
Science Applications Int. Corp.
20030 Century Blvd., Suite 201
Germantown, MD 20874

Simon Board
Central Electricity Generating
Board
Technology and Planning Research
Division
Berkeley Nuclear Laboratory
Berkeley Gloucestershire, GL139PB
UNITED KINGDOM

Mario V. Bonace
Northeast Utilities Service Company
P.O. Box 270
Hartford, CT 06101

Gary J. Boyd
Safety and Reliability Optimization
Services
9724 Kingston Pike, Suite 102
Knoxville, TN 37922

Robert J. Breen
Electric Power Research Institute
3412 Hillview Avenue
Palo Alto, CA 94303

Charles Brinkman
Combustion Engineering
7910 Woodmont Avenue
Bethesda, MD 20814

K. J. Brinkmann
Netherlands Energy Res. Fdtn.
P.O. Box 1
1755ZG Petten NH
NETHERLANDS

Allan R. Brown
Manager, Nuclear Systems and
Safety Department
Ontario Hydro
700 University Ave.
Toronto, Ontario M5G1X6
CANADA

Robert G. Brown
TENERA L.P.
1340 Saratoga-Sunnyvale Rd.
Suite 206
San Jose, CA 95129

Sharon Brown
EI Services
1851 So. Central Place, Suite 201
Kent, WA 98031

Ben Buchbinder
NASA, Code QS
600 Maryland Ave. SW
Washington, DC 20546

R. H. Buchholz
Nutech
6835 Via Del Oro
San Jose, CA 95119

Robert J. Budnitz
Future Resources Associates
734 Alameda
Berkeley, CA 94707

Gary R. Burdick
USNRC-RES/DSR
MS: NL/S-007

Arthur J. Buslik
USNRC-RES/PRAB
MS: NL/S-372

M. Bustraan
Netherlands Energy Res. Fdtn.
P.O. Box 1
1755ZG Petten NH
NETHERLANDS

Nigel E. Buttery
Central Electricity Generating
Board
Booths Hall
Chelford Road, Knutsford
Cheshire, WA168QG
UNITED KINGDOM

Jose I. Calvo Molins
Probabilistic Safety Analysis
Group
Consejo de Seguridad Nuclear
Sor Angela de la Cruz 3, Pl. 6
28020 Madrid
SPAIN

J. F. Campbell
Nuclear Installations Inspectorate
St. Peters House
Balliol Road, Bootle
Merseyside, L20 3LZ
UNITED KINGDOM

Kenneth S. Canady
Duke Power Company
422 S. Church Street
Charlotte, NC 28217

Lennart Carlsson
IAEA A-1400
Wagramerstrasse 5
P.O. Box 100
Vienna, 22
AUSTRIA

Annick Carnino
Electricite de France
32 Rue de Monceau 8EME
Paris, F5008
FRANCE

G. Caropreso
Dept. for Envir. Protect. & Hlth.
ENEA Cre Casaccia
Via Anguillarese, 301
00100 Roma
ITALY

James C. Carter, III
TENERA L.P.
Advantage Place
308 North Peters Road
Suite 280
Knoxville, TN 37922

Eric Cazzoli
Brookhaven National Laboratory
Building 130
Upton, NY 11973

John G. Cesare
SERI
Director Nuclear Licensing
5360 I-55 North
Jackson, MS 39211

S. Chakraborty
Radiation Protection Section
Div. De La Securite Des Inst. Nuc.
5303 Wurenlingen
SWITZERLAND

Sen-I Chang
Institute of Nuclear Energy
Research
P.O. Box 3
Lungtan, 325
TAIWAN

J. R. Chapman
Yankee Atomic Electric Company
1671 Worcester Road
Framingham, MA 01701

Robert F. Christie
Tennessee Valley Authority
400 W. Summit Hill Avenue, W10D190
Knoxville, TN 37902

T. Cianciolo
BWR Assistant Director
ENEA DISP TX612167 ENEUR
Rome
ITALY

Thomas Cochran
Natural Resources Defense Council
1350 New York Ave. NW, Suite 300
Washington, D.C. 20005

Frank Coffman
USNRC-RES/HFB
MS: NL/N-316

Larry Conradi
NUS Corporation
16835 W. Bernardo Drive
Suite 202
San Diego, CA 92127

Peter Cooper
U.K. Atomic Energy Authority
Wigshaw Lane, Culcheth
Warrington, Cheshire, WA3 4NE
UNITED KINGDOM

C. Allin Cornell
110 Coquito Way
Portola Valley, CA 94025

Michael Corradini
University of Wisconsin
1500 Johnson Drive
Madison, WI 53706

E. R. Corran
Nuclear Technology Division
ANSTO Research Establishment
Lucas Heights Research Laboratories
Private Mail Bag 7
Menai, NSW 2234
AUSTRALIA

James Costello
USNRC-RES/SSEB
MS: NL/S-217A

George R. Crane
1570 E. Hobble Creek Dr.
Springville, UT 84663

Mat Crawford
SERI
5360 I-55 North
Jackson, MS 39211

Michael C. Cullingford
Nuclear Safety Division
IAEA
Wagramerstrasse, 5
P.O. Box 100
A-1400 Vienna
AUSTRIA

Garth Cummings
Lawrence Livermore Laboratory
L-91, Box 808
Livermore, CA 94526

Mark A. Cunningham
USNRC-RES/PRAB
MS: NL/S-372

James J. Curry
7135 Salem Park Circle
Mechanicsburg, PA 17055

Peter Cybulskis
Battelle Columbus Division
505 King Avenue
Columbus, OH 43201

Peter R. Davis
PRD Consulting
1935 Sabin Drive
Idaho Falls, ID 83401

Jose E. DeCarlos
Consejo de Seguridad Nuclear
Sor Angela de la Cruz 3, Pl. 8
28016 Madrid
SPAIN

M. Marc Decreton
Department Technologie
CEN/SCK
Boeretang 200
B-2400 Mol
BELGIUM

Richard S. Denning
Battelle Columbus Division
505 King Avenue
Columbus, OH 43201

Vernon Denny
Science Applications Int. Corp.
5150 El Camino Real, Suite 3
Los Altos, CA 94303

J. Devooget
Faculte des Sciences Appliques
Universite Libre de Bruxelles
av. Franklin Roosevelt
B-1050 Bruxelles
BELGIUM

R. A. Diederich
Supervising Engineer
Environmental Branch
Philadelphia Electric Co.
2301 Market St.
Philadelphia, PA 19101

Raymond DiSalvo
Battelle Columbus Division
505 King Avenue
Columbus, OH 43201

Mary T. Drouin
Science Applications International
Corporation
2109 Air Park Road S.E.
Albuquerque, NM 87106

Andrzej Drozd
Stone and Webster
Engineering Corp.
243 Summer Street
Boston, MA 02107

N. W. Edwards
NUTECH
145 Martinville Lane
San Jose, CA 95119

Ward Edwards
Social Sciences Research Institute
University of Southern California
Los Angeles, CA 90089-1111

Joachim Ehrhardt
Kernforschungszentrum Karlsruhe/INR
Postfach 3640
D-7500 Karlsruhe 1
FEDERAL REPUBLIC OF GERMANY

Adel A. El-Bassioni
USNRC-NRR/PRAB
MS: 10A-2

J. Mark Elliott
International Energy Associates,
Ltd., Suite 600
600 New Hampshire Ave., NW
Washington, DC 20037

Farouk Eltawila
USNRC-RES/AEB
MS: NL/N-344

Mike Epstein
Fauske and Associates
P. O. Box 1625
16W070 West 83rd Street
Burr Ridge, IL 60521

Malcolm L. Ernst
USNRC-RGN II

F. R. Farmer
The Long Wood, Lyons Lane
Appleton, Warrington
WA4 5ND
UNITED KINGDOM

P. Fehrenback
Atomic Energy of Canada, Ltd.
Chalk River Nuclear Laboratories
Chalk River Ontario, K0J1P0
CANADA

P. Ficara
ENEA Cre Casaccia
Department for Thermal Reactors
Via Anguillarese, 301
00100 ROMA
ITALY

A. Fiege
Kernforschungszentrum
Postfach 3640
D-7500 Karlsruhe
FEDERAL REPUBLIC OF GERMANY

John Flack
USNRC-RES/SAIB
MS: NLS-324

George F. Flanagan
Oak Ridge National Laboratory
P.O. Box Y
Oak Ridge, TN 37831

Karl N. Fleming
Pickard, Lowe & Garrick, Inc.
2260 University Drive
Newport Beach, CA 92660

Terry Foppe
Rocky Flats Plant
P. O. Box 464, Building T886A
Golden, CO 80402-0464

Joseph R. Fragola
Science Applications International
Corporation
274 Madison Avenue
New York, NY 10016

Wiktor Frid
Swedish Nuclear Power Inspectorate
Division of Reactor Technology
P. O. Box 27106
S-102 52 Stockholm
SWEDEN

James Fulford
NUS Corporation
910 Clopper Road
Gaithersburg, MD 20878

Urho Fulkkinen
Technical Research Centre of
Finland
Electrical Engineering Laboratory
Otakaari 7 B
SF-02150 Espoo 15
FINLAND

J. B. Fussell
JBF Associates, Inc.
1630 Downtown West Boulevard
Knoxville, TN 37919

John Garrick
Pickard, Lowe & Garrick, Inc.
2260 University Drive
Newport Beach, CA 92660

John Gaunt
British Embassy
3100 Massachusetts Avenue, NW
Washington, DC 20008

Jim Gieseke
Battelle Columbus Division
505 King Avenue
Columbus, OH 43201

Frank P. Gillespie
USNRC-NRR/PMAS
MS: 12G-18

Ted Ginsburg
Department of Nuclear Energy
Building 820
Brookhaven National Laboratory
Upton, NY 11973

James C. Glynn
USNRC-RES/PRAB
MS: NL/S-372

P. Govaerts
Departement de la Surete Nucleaire
Association Vincotte
avenue du Roi 157
B-1060 Bruxelles
BELGIUM

George Greene
Building 820M
Brookhaven National Laboratory
Upton, NY 11973

Carrie Grimshaw
Brookhaven National Laboratory
Building 130
Upton, NY 11973

H. J. Van Grol
Energy Technology Division
Energieonderzoek Centrum Nederland
Westerduinweg 3
Postbus 1
NL-1755 Petten ZG
NETHERLANDS

Sergio Guarro
Lawrence Livermore Laboratories
P. O. Box 808
Livermore, CA 94550

Sigfried Hagen
Kernforschungzentrum Karlsruhe
P. O. Box 3640
D-7500 Karlsruhe 1
FEDERAL REPUBLIC OF GERMANY

L. Hammar
Statens Karnkraftinspektion
P.O. Box 27106
S-10252 Stockholm
SWEDEN

Stephen Hanauer
Technical Analysis Corp.
6723 Whittier Avenue
Suite 202
McLean, VA 22101

Brad Hardin
USNRC-RES/TRAB
MS: NL/S-169

R. J. Hardwich, Jr.
Virginia Electric Power Co.
P.O. Box 26666
Richmond, Va 23261

Michael R. Haynes
UKAEA Harwell Laboratory
Oxfordshire
Didcot, Oxon., OX11 ORA
ENGLAND

Michael J. Hazzan
Stone & Webster
3 Executive Campus
Cherry Hill, NJ 08034

A. Hedgran
Royal Institute of Technology
Nuclear Safety Department
Bunellvagen 60
10044 Stockholm
SWEDEN

Sharif Heger
UNM Chemical and Nuclear
Engineering Department
Farris Engineering
Room 209
Albuquerque, NM 87131

Jon C. Helton
Dept. of Mathematics
Arizona State University
Tempe, AZ 85287

Robert E. Henry
Fauske and Associates, Inc.
16W070 West 83rd Street
Burr Ridge, IL 60521

P. M. Herttrich
Federal Ministry for the
Environment, Preservation of
Nature and Reactor Safety
Husarenstrasse 30
Postfach 120629
D-5300 Bonn 1
FEDERAL REPUBLIC OF GERMANY

F. Heuser
Giesellschaft Fur Reaktorsicherheit
Forschurgsgelande
D-8046 Garching
FEDERAL REPUBLIC OF GERMANY

E. F. Hicken
Giesellschaft Fur Reaktorsicherheit
Forschungsgelande
D-8046 Garching
FEDERAL REPUBLIC OF GERMANY

D. J. Higson
Radiological Support Group
Nuclear Safety Bureau
Australian Nuclear Science and
Technology Organisation
P.O. Box 153
Rosebery, NSW 2018
AUSTRALIA

Daniel Hirsch
University of California
A. Stevenson Program on
Nuclear Policy
Santa Cruz, CA 95064

H. Hirschmann
Hauptabteilung Sicherheit und
Umwelt
Swiss Federal Institute for
Reactor Research (EIR)
CH-5303 Wurenlingen
SWITZERLAND

Mike Hitchler
Westinghouse Electric Corp.
Savanna River Site
Aiken, SC 29808

Richard Hobbins
EG&G Idaho
P. O. Box 1625
Idaho Falls, ID 83415

Steven Hodge
Oak Ridge National Laboratory
P.O. Box Y
Oak Ridge, TN 37831

Lars Hoegberg
Office of Regulation and Research
Swedish Nuclear Power Inspectorate
P. O. Box 27106
S-102 52 Stockholm
SWEDEN

Lars Hoeghort
IAEA A-1400
Wagranerstraase 5
P.O. Box 100
Vienna, 22
AUSTRIA

Edward Hofer
Giesellschaft Fur Reaktorsicherheit
Forschurgsgelande
D-8046 Garching
FEDERAL REPUBLIC OF GERMANY

Peter Hoffmann
Kernforschingszentrum Karlsruhe
Institute for Material
Und Festkorperforsching I
Postfach 3640
D-7500 Karlsruhe 1
FEDERAL REPUBLIC OF GERMANY

N. J. Holloway
UKAEA Safety and Reliability
Directorate
Wigshaw Lane, Culcheth
Warrington, Cheshire, WA34NE
UNITED KINGDOM

Stephen C. Hora
University of Hawaii at Hilo
Division of Business Administration
and Economics
College of Arts and Sciences
Hilo, HI 96720-4091

J. Peter Hoseman
Swiss Federal Institute for
Reactor Research
CH-5303, Wurenlingen
SWITZERLAND

Thomas C. Houghton
KMC, Inc.
1747 Pennsylvania Avenue, NW
Washington, DC 20006

Dean Houston
USNRC-ACRS
MS: P-315

Der Yu Hsia
Taiwan Atomic Energy Council
67, Lane 144, Keelung Rd.
Sec. 4
Taipei
TAIWAN

Alejandro Huerta-Bahena
National Commission on Nuclear
Safety and Safeguards (CNSNS)
Insurgentes Sur N. 1776
Col. Florida
C. P. 04230 Mexico, D.F.
MEXICO

Kenneth Hughey [2]
SERI
5360 I-55 North
Jackson, MS 39211

Won-Guk Hwang
Kzunghee University
Yongin-Kun
Kyunggi-Do 170-23
KOREA

Michio Ichikawa
Japan Atomic Energy Research
Institute
Dept. of Fuel Safety Research
Tokai-Mura, Naka-Gun
Ibaraki-Ken, 319-1
JAPAN

Sanford Israel
USNRC-AEOD/ROAB
MS: MNBB-9715

Krishna R. Iyengar
Louisiana Power and Light
200 A Huey P. Long Avenue
Gretna, LA 70053

Jerry E. Jackson
USNRC-RES
MS: NL/S-302

R. E. Jaquith
Combustion Engineering, Inc.
1000 Prospect Hill Road
M/C 9490-2405
Windsor, CT 06095

S. E. Jensen
Exxon Nuclear Company
2101 Horn Rapids Road
Richland, WA 99352

Kjell Johannson
Studsvik Energiteknik AB
S-611 82, Nykoping
SWEDEN

Richard John
SSM, Room 102
927 W. 35th Place
USC, University Park
Los Angeles, CA 90089-0021

D. H. Johnson
Pickard, Lowe & Garrick, Inc.
2260 University Drive
Newport Beach, CA 92660

W. Reed Johnson
Department of Nuclear Engineering
University of Virginia
Reactor Facility
Charlottesville, VA 22901

Jeffery Julius
NUS Corporation
1301 S. Central Ave, Suite 202
Kent, WA 98032

H. R. Jun
Korea Adv. Energy Research Inst.
P.O. Box 7, Daeduk Danju
Chungnam 300-31
KOREA

Peter Kafka
Gesellschaft Fur Reaktorsicherheit
Forschungsgelande
D-8046 Garching
FEDERAL REPUBLIC OF GERMANY

Geoffrey D. Kaiser
Science Application Int. Corp.
1710 Goodridge Drive
McLean, VA 22102

William Kastenberg
UCLA
Boelter Hall, Room 5532
Los Angeles, CA 90024

Walter Kato
Brookhaven National Laboratory
Associated Universities, Inc.
Upton, NY 11973

M. S. Kazimi
MIT, 24-219
Cambridge, MA 02139

Ralph L. Keeney
101 Lombard Street
Suite 704W
San Francisco, CA 94111

Henry Kendall
Executive Director
Union of Concerned Scientists
Cambridge, MA

Frank King
Ontario Hydro
700 University Avenue
Bldg. H11 G5
Toronto
CANADA M5G1X6

Oliver D. Kingsley, Jr.
Tennessee Valley Authority
1101 Market Street
GN-38A Lookout Place
Chattanooga, TN 37402

Stephen R. Kinnersly
Winfrith Atomic Energy
Establishment
Reactor Systems Analysis Division
Winfrith, Dorchester
Dorset DT2 8DH
ENGLAND

Ryohel Kiyose
University of Tokyo
Dept. of Nuclear Engineering
7-3-1 Hongo Bunkyo
Tokyo 113
JAPAN

George Klopp
Commonwealth Edison Company
P.O. Box 767, Room 35W
Chicago, IL 60690

Klaus Koberlein
Gesellschaft Fur Reaktorsicherheit
Forschungsgelande
D-8046 Garching
FEDERAL REPUBLIC OF GERMANY

E. Kohn
Atomic Energy Canada Ltd.
Candu Operations
Mississauga
Ontario, L5K 1B2
CANADA

Alan M. Kolaczkowski
Science Applications International
Corporation
2109 Air Park Road, S.E.
Albuquerque, NM 87106

S. Kondo
Department of Nuclear Engineering
Facility of Engineering
University of Tokyo
3-1, Hongo 7, Bunkyo-ku
Tokyo
JAPAN

Herbert J. C. Kouts
Brookhaven National Laboratory
Building 179C
Upton, NY 11973

Thomas Kress
Oak Ridge National Laboratory
P.O. Box Y
Oak Ridge, TN 37831

W. Kroger
Institut fur Nukleare
Sicherheitsforschung
Kernforschungsanlage Julich GmbH
Postfach 1913
D-5170 Julich 1
FEDERAL REPUBLIC OF GERMANY

Greg Krueger [3]
Philadelphia Electric Co.
2301 Market St.
Philadelphia, PA 19101

Bernhard Kuczera
Kernforschungzentrum Karlsruhe
LWR Safety Project Group (PRS)
P. O. Box 3640
D-7500 Karlsruhe 1
FEDERAL REPUBLIC OF GERMANY

Jeffrey L. LaChance
Science Applications International
Corporation
2109 Air Park Road S.E.
Albuquerque, NM 87106

H. Larsen
Riso National Laboratory
Postbox 49
DK-4000 Roskilde
DENMARK

Wang L. Lau
Tennessee Valley Authority
400 West Summit Hill Avenue
Knoxville, TN 37902

Timothy J. Leahy
EI Services
1851 South Central Place, Suite 201
Kent, WA 98031

John C. Lee
University of Michigan
North Campus
Dept. of Nuclear Engineering
Ann Arbor, MI 48109

Tim Lee
USNRC-RES/RPSB
MS: NL/N-353

Mark T. Leonard
Science Applications International Corporation
2109 Air Park Road, SE
Albuquerque, NM 87106

Leo LeSage
Director, Applied Physics Div.
Argonne National Laboratory
Building 208, 9700 South Cass Ave.
Argonne, IL 60439

Milton Levenson
Bechtel Western Power Company
50 Beale St.
San Francisco, CA 94119

Librarian
NUMARC/USCEA
1776 I Street NW, Suite 400
Washington, DC 80006

Eng Lin
Taiwan Power Company
242, Roosevelt Rd., Sec. 3
Taipei
TAIWAN

N. J. Liparulo
Westinghouse Electric Corp.
P. O. Box 355
Pittsburgh, PA 15230

Y. H. (Ben) Liu
Department of Mechanical Engineering
University of Minnesota
Minneapolis, MN 55455

Bo Liwnang
IAEA A-1400
Swedish Nuclear Power Inspectorate
P.O. Box 27106
S-102 52 Stockholm
SWEDEN

J. P. Longworth
Central Electric Generating Board
Berkeley Gloucester
GL13 9PB
UNITED KINGDOM

Walter Lowenstein
Electric Power Research Institute
3412 Hillview Avenue
P. O. Box 10412
Palo Alto, CA 94303

William J. Luckas
Brookhaven National Laboratory
Building 130
Upton, NY 11973

Hans Ludewig
Brookhaven National Laboratory
Building 130
Upton, NY 11973

Robert J. Lutz, Jr.
Westinghouse Electric Corporation
Monroeville Energy Center
EC-E-371, P. O. Box 355
Pittsburgh, PA 15230-0355

Phillip E. MacDonald
EG&G Idaho, Inc.
P.O. Box 1625
Idaho Falls, ID 83415

Jim Mackenzie
World Resources Institute
1735 New York Ave. NW
Washington, DC 20006

Richard D. Fowler
Idaho Nat. Engineering Laboratory
P.O. Box 1625
Idaho Falls, ID 83415

A. P. Malinauskas
Oak Ridge National Laboratory
P.O. Box Y
Oak Ridge, TN 37831

Giuseppe Mancini
Commission European Comm.
CEC-JRC Eraton
Ispra Varese
ITALY

Lasse Mattila
Technical Research Centre of Finland
Lonnrotinkatu 37, P. O. Box 169
SF-00181 Helsinki 18
FINLAND

Roger J. Mattson
SCIENTECH Inc.
11821 Parklawn Dr.
Rockville, MD 20852

Donald McPherson
USNRC-NRR/DONRR
MS: 12G-18

Jim Metcalf
Stone and Webster Engineering Corporation
245 Summer St.
Boston, MA 02107

Mary Meyer
A-1, MS F600
Los Alamos National Laboratory
Los Alamos, NM 87545

Ralph Meyer
USNRC-RES/AEB
MS: NL/N-344

Charles Miller
8 Hastings Rd.
Momsey, NY 10952

Joseph Miller
Gulf States Utilities
P. O. Box 220
St. Francisville, LA 70775

William Mims
Tennessee Valley Authority
400 West Summit Hill Drive.
W10D199C-K
Knoxville, TN 37902

Jocelyn Mitchell
USNRC-RES/SAIB
MS: NL/S-324

Kam Mohktarian
CBI Na-Con Inc.
800 Jorie Blvd.
Oak Brook, IL 60521

James Moody
P.O. Box 641
Rye, NH 03870

S. Mori
Nuclear Safety Division
OECD Nuclear Energy Agency
38 Blvd. Suchet
75016 Paris
FRANCE

Walter B. Murfin
P.O. Box 550
Mesquite, NM 88048

Joseph A. Murphy
USNRC-RES/DSR
MS: NL/S-007

V. I. Nath
Safety Branch
Safety Engineering Group
Sheridan Park Research Community
Mississauga, Ontario L5K 1B2
CANADA

Susan J. Niemczyk
1545 18th St. NW, #112
Washington, DC 20036

Pradyot K. Niyogi
USDOE-Office of Nuclear Safety
Washington, DC 20545

Paul North
EG&G Idaho, Inc.
P. O. Box 1625
Idaho Falls, ID 83415

Edward P. O'Donnell
Ebasco Services, Inc.
2 World Trade Center, 89th Floor
New York, NY 10048

David Okrent
UCLA
Boelter Hall, Room 5532
Los Angeles, CA 90024

Robert L. Olson
Tennessee Valley Authority
400 West Summit Hill Rd.
Knoxville, TN 37902

Simon Ostrach
Case Western Reserve University
418 Glenman Bldg.
Cleveland, OH 44106

D. Paddleford
Westinghouse Electric Corporation
Savanna River Site
Aiken, SC 29808

Robert L. Palla, Jr.
USNRC-NRR/PRAB
MS: 10A-2

Chang K. Park
Brookhaven National Laboratory
Building 130
Upton, NY 11973

Michael C. Parker
Illinois Department of Nuclear
Safety
1035 Outer Park Dr.
Springfield, IL 62704

Gareth Parry
NUS Corporation
910 Clopper Road
Gaithersburg, MD 20878

J. Pelce
Departement de Surete Nucleaire
IPSN
Centre d'Estudes Nucleaires du CEA
B.P. no. 6, Cedex
F-92260 Fontenay-aux-Roses
FRANCE

G. Petrangeli
ENEA Nuclear Energy ALT Disp
Via V. Brancati, 48
00144 Rome
ITALY

Marty Plys
Fauske and Associates
16W070 West 83rd St.
Burr Ridge, IL 60521

Mike Podowski
Department of Nuclear Engineering
and Engineering Physics
RPI
Troy, NY 12180-3590

Robert D. Pollard
Union of Concerned Scientists
1616 P Street, NW, Suite 310
Washington, DC 20036

R. Potter
UK Atomic Energy Authority
Winfrith, Dorchester
Dorset, DT2 8DH
UNITED KINGDOM

William T. Pratt
Brookhaven National Laboratory
Building 130
Upton, NY 11973

M. Preat
Chef du Service Surete Nucleaire et
Assurance Qualite
TRACTEBEL
Bd. du Regent 8
B-100 Bruxells
BELGIUM

David Pyatt
USDOE
MS: EH-332
Washington, DC 20545

William Raisin
NUMAEC
1726 M St. NW
Suite 904
Washington, DC 20036

Joe Rashid
ANATECH Research Corp.
3344 N. Torrey Pines Ct.
Suite 1320
La Jolla, CA 90237

Dale M. Rasmuson
USNRC-RES/PRAB
MS: NL/S-372

Ingvard Rasmussen
Riso National Laboratory
Postbox 49
DK-4000, Roskilde
DENMARK

Norman C. Rasmussen
Massachusetts Institute of
Technology
77 Massachusetts Avenue
Cambridge, MA 02139

John W. Reed
Jack R. Benjamin & Associates, Inc.
444 Castro St., Suite 501
Mountain View, CA 94041

David B. Rhodes
Atomic Energy of Canada, Ltd.
Chalk River Nuclear Laboratories
Chalk River, Ontario K0J1P0
CANADA

Dennis Richardon
Westinghouse Electric Corporation
P.O. Box 355
Pittsburgh, PA 15230

Doug Richeard
Virginia Electric Power Co.
P.O.Box 26666
Richmond, VA 23261

Robert Ritzman
Electric Power Research Institute
3412 Hillview Avenue
Palo Alto, CA 94304

Richard Robinson
USNRC-RES/PRAB
MS: NL/S-372

Jack E. Rosenthal
USNRC-AEOD/ROAB
MS: MNBB-9715

Denwood F. Ross
USNRC-RES
MS: NL/S-007

Frank Rowsome
9532 Fern Hollow Way
Gaithersburg, MD 20879

Wayne Russell
SERI
5360 I-55 North
Jackson, MS 39211

Jorma V. Sandberg
Finnish Ctr. Rad. Nucl. and Safety
Department of Nuclear Safety
P.O. Box 268
SF-00101 Helsinki
FINLAND

G. Saponaro
ENEA Nuclear Engineering Alt.
Zia V Brancati 4B
00144 ROME
ITALY

M. Sarran
United Engineers
P. O. Box 8223
30 S 17th Street
Philadelphia, PA 19101

Marty Sattison
EG&G Idaho
P. O. Box 1625
Idaho Falls, ID 83415

George D. Sauter
Electric Power Research Institute
3412 Hillview Avenue
Palo Alto, CA 94303

Jorge Schulz
Bechtel Western Power Corporation
50 Beale Street
San Francisco, CA 94119

B. R. Sehgal
Electric Power Research Institute
3412 Hillview Avenue
Palo Alto, CA 94303

Subir Sen
Bechtel Power Corp.
15740 Shady Grove Road
Location 1A-7
Gaithersburg, MD 20877

S. Serra
Ente Nazionale per l'Energia
Electtrica (ENEL)
via G. B. Martini 3
Rome
ITALY

Bonnie J. Shapiro
Science Applications International
Corporation
360 Bay Street
Suite 200
Augusta, GA 30901

H. Shapiro
Licensing and Risk Branch
Atomic Energy of Canada Ltd.
Sheridan Park Research Community
Mississauga, Ontario L5K 1B2
CANADA

Dave Sharp
Westinghouse Savannah River Co.
Building 773-41A, P. O. Box 616
Aiken, SC 29802

John Sherman
Tennessee Environmental Council
1719 West End Avenue, Suite 227
Nashville, TN 37203

Brian Sheron
USNRC-RES/DSR
MS: NL/N-007

Rick Sherry
JAYCOR
P. O. Box 85154
San Diego, CA 92138

Steven C. Sholly
MHB Technical Associates
1723 Hamilton Avenue, Suite K
San Jose, CA 95125

Louis M. Shotkin
USNRC-RES/RPSB
MS: NL/N-353

M. Siebertz
Chef de la Section Surete' des
Reacteurs
CEN/SCK
Boeretang, 200
B-2400 Mol
BELGIUM

Melvin Silberberg
USNRC-RES/DE/WNB
MS: NL/S-260

Gary Smith
SERI
5360 I-55 North
Jackson, MS 39211

Gary L. Smith
Westinghouse Electric Corporation
Hanford Site
Box 1970
Richland, WA 99352

Lanny N. Smith
Science Applications International
Corporation
2109 Air Park Road SE
Albuquerque, NM 87106

K. Soda
Japan Atomic Energy Res. Inst.
Tokai-Mura Naka-Gun
Ibaraki-Ken 319-11
JAPAN

David Sommers
Virginia Electric Power Company
P. O. Box 26666
Richmond, VA 23261

Herschel Spector
New York Power Authority
123 Main Street
White Plains, NY 10601

Themis P. Speis
USNRC-RES
MS: NL/S-007

Klaus B. Stadie
OECD-NEA, 38 Bld. Suchet
75016 Paris
FRANCE

John Stetkar
Pickard, Lowe & Garrick, Inc.
2216 University Drive
Newport Beach, CA 92660

Wayne L. Stiede
Commonwealth Edison Company
P.O. Box 767
Chicago, IL 60690

William Stratton
Stratton & Associates
2 Acoma Lane
Los Alamos, NM 87544

Soo-Pong Suk
Korea Advanced Energy Research Institute
P. O. Box 7
Daeduk Danji, Chungnam 300-31
KOREA

W. P. Sullivan
GE Nuclear Energy
175 Curtner Ave., M/C 789
San Jose, CA 95125

Tony Taig
U.K. Atomic Energy Authority
Wigshaw Lane, Culcheth
Warrington, Cheshire, WA3 4NE
UNITED KINGDOM

John Taylor
Electric Power Research Institute
3412 Hillview Avenue
Palo Alto, CA 94303

Harry Teague
U.K. Atomic Energy Authority
Wigshaw Lane, Culcheth
Warrington, Cheshire, WA3 4NE
UNITED KINGDOM

Technical Library
Electric Power Research Institute
P.O. Box 10412
Palo Alto, CA 94304

Mark I. Temme
General Electric, Inc.
P.O. Box 3508
Sunnyvale, CA 94088

T. G. Theofanous
University of California, S.B.
Department of Chemical and Nuclear Engineering
Santa Barbara, CA 93106

David Teolis
Westinghouse-Bettis Atomic Power Laboratory
P. O. Box 79, ZAP 34N
West Mifflin, PA 15122-0079

Ashok C. Thadani
USNRC-NRR/SAD
MS: 7E-4

Garry Thomas
L-499 (Bldg. 490)
Lawrence Livermore National Laboratory
7000 East Ave.
P.O. Box 808
Livermore, CA 94550

Gordon Thompson
Institute for Research and Security Studies
27 Ellworth Avenue
Cambridge, MA 02139

Grant Thompson
League of Women Voters
1730 M. Street, NW
Washington, DC 20036

Arthur Tingle
Brookhaven National Laboratory
Building 130
Upton, NY 11973

Rich Toland
United Engineers and Construction
30 S. 17th St., MS 4V7
Philadelphia, PA 19101

Brian J. R. Tolley
DG/XII/D/1
Commission of the European Communities
Rue de la Loi, 200
B-1049 Brussels
BELGIUM

David R. Torgerson
Atomic Energy of Canada Ltd.
Whiteshell Nuclear
Research Establishment
Pinawa, Manitoba, ROE 1LO
CANADA

Alfred F. Torri
Pickard, Lowe & Garrick, Inc.
191 Calle Magdalena, Suite 290
Encinitas, CA 92024

Klau Trambauer
Gesellschaft Fur Reaktorsicherheit
Forschungsgelande
D-8046 Garching
FERERAL REPUBLIC OF GERMANY

Nicholas Tsoulfanidis
Nuclear Engineering Dept.
University of Missouri-Rolla
Rolla, MO 65401-0249

Chao-Chin Tung
c/o H.B. Bengelsdorf
ERC Environmental Services Co.
P. O. Box 10130
Fairfax, VA 22030

Brian D. Turland
UKAEA Culham Laboratory
Abingdon, Oxon OX14 3DB
ENGLAND

Takeo Uga
Japan Institute of Nuclear Safety
Nuclear Power Engineering Test
Center
3-6-2, Toranomon
Minato-ku, Tokyo 108
JAPAN

Stephen D. Unwin
Battelle Columbus Division
505 King Avenue
Columbus, OH 43201

A. Valeri
DISP
ENEA
Via Vitaliano Brancati, 48
I-00144 Rome
ITALY

Harold VanderMolen
USNRC-RES/PRAB
MS: NL/S-372

G. Bruce Varnado
ERC International
1717 Louisiana Blvd. NE, Suite 202
Albuquerque, NM 87110

Jussi K. Vaurio
Imatran Voima Oy
Loviisa NPS
SF-07900 Loviisa
FINLAND

William E. Vesely
Science Applications International
Corporation
2929 Kenny Road, Suite 245
Columbus, OH 43221

J. I. Villadoniga Tallon
Div. of Analysis and Assessment
Consejo de Seguridad Nuclear
c/ Sor Angela de la Cruz, 3
28020 Madrid
SPAIN

Willem F. Vinck
Kapellestract 25
1980
Tervuren
BELGIUM

R. Virolainen
Office of Systems Integration
Finnish Centre for Radiation and
Nuclear Safety
Department of Nuclear Safety
P.O. Box 268
Kumpulantie 7
SF-00520 Helsinki
FINLAND

Raymond Viskanta
School of Mechanical Engineering
Purdue University
West Lafayette, IN 47907

S. Visweswaran
General Electric Company
175 Curtner Avenue
San Jose, CA 95125

Truong Vo
Pacific Northwest Laboratory
Battelle Blvd.
Richland, WA 99352

Richard Vogel
Electric Power Research Institute
P. O. Box 10412
Palo Alto, CA 94303

G. Volta
Engineering Division
CEC Joint Research Centre
CP No. 1
I-21020 Ispra (Varese)
ITALY

Ian B. Wall
Electric Power Research Institute
3412 Hillview Avenue
Palo Alto, CA 94303

Adolf Walser
Sargent and Lundy Engineers
55 E. Monroe Street
Chicago, IL 60603

Edward Warman
Stone & Webster Engineering Corp.
P.O. Box 2325
Boston, MA 02107

Norman Weber
Sargent & Lundy Co.
55 E. Monroe Street
Chicago, IL 60603

Lois Webster
American Nuclear Society
555 N. Kensington Avenue
La Grange Park, IL 60525

Wolfgang Werner
Gesellschaft Fur Reaktorsicherheit
Forschungsgelande
D-8046 Garching
FEDERAL REPUBLIC OF GERMANY

Don Wesley
IMPELL
1651 East 4th Street
Suite 210
Santa Ana, CA 92701

Detlof von Winterfeldt
Institute of Safety and Systems Management
University of Southern California
Los Angeles, CA 90089-0021

Pat Worthington
USNRC-RES/AEB
MS: NL/N-344

John Wreathall
Science Applications International Corporation
2929 Kenny Road, Suite 245
Columbus, OH 43221

D. J. Wren
Atomic Energy of Canada Ltd.
Whiteshell Nuclear Research Establishment
Pinawa, Manitoba, ROE 1LO
CANADA

Roger Wyrick
Inst. for Nuclear Power Operations
1100 Circle 75 Parkway, Suite 1500
Atlanta, GA 30339

Kun-Joong Yoo
Korea Advanced Energy Research Institute
P. O. Box 7
Daeduk Danji, Chungnam 300-31
KOREA

Faith Young
Energy People, Inc.
Dixou Springs, TN 37057

Jonathan Young
R. Lynette and Associates
15042 Northeast 40th St.
Suite 206
Redmond, WA 98052

C. Zaffiro
Division of Safety Studies
Directorate for Nuclear Safety and Health Protection
Ente Nazionale Energie Alternative
Via Vitaliano Brancati, 48
I-00144 Rome
ITALY

Mike Zentner
Westinghouse Hanford Co.
P. O. Box 1970
Richland, WA 99352

X. Zikidis
Greek Atomic Energy Commission
Agia Paraskevi, Attiki
Athens
GREECE

Bernhard Zuczera
Kernforschungszentrum
Postfach 3640
D-7500 Karlsruhe
FEDERAL REPUBLIC OF GERMANY

1521 J. R. Weatherby
3141 S. A. Landenberger [5]
3151 W. I. Klein
5214 D. B. Clauss
6344 E. D. Gorham
6001 D. D. Carlson
6001 R. J. Breeding
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8524 J. A. Wackerly

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Roger J. Breeding
Jon C. Helton
Walter B. Murfin
Lanny N. Smith

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Sandia National Laboratories
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Division of Systems Research
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11. ABSTRACT *(200 words or less)*

In support of the Nuclear Regulatory Commission's (NRC's) assessment of the risk from severe accidents at commercial nuclear power plants in the U.S. reported in NUREG-1150, the Severe Accident Risk Reduction Program (SARRP) has completed a revised calculation of the risk to the general public from severe accidents at the Surry Power Station, Unit 1. This power plant, located in southeastern Virginia, is operated by the Virginia Electric Power Corp.

The emphasis in this risk analysis was not on determining a "so-called" point estimate of risk. Rather, it was to determine the distribution of risk, and to discover the uncertainties that account for the breadth of this distribution. Off-site risk initation by events, both internal to the power station and external to the power station were assessed.

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