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# **Drywell Debris Transport Study**

Final Report

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#### Abstract

This report describes results of the drywell debris transport study. The objective of the study is to develop a methodology for estimating fraction of LOCA generated fibrous insulation debris that would be transported from the location of their generation in the drywell to the suppression pool. The study decomposed the problem into several components that were amenable to resolution by the knowledge base that can be developed from separate effects experiments, analytical modeling, and engineering calculations. Experiments and analytical studies were undertaken to compile the necessary knowledge base on debris transport during blowdown, washdown of debris by ECCS water flow, and debris sedimentation on the drywell floor. Logic charts were used to link both experimental and analytical results. The results of the study were used to delineate plant features and transport phenomena that dominate debris transport in the BWR drywell. A separate logic chart was developed for each postulated accident scenario and generic plant type analyzed. The logic charts can be modified to take into account effects of the plant-specific features. The overall method is comprehensible to engineers who are not experts in the subject of debris transport. Also, it is sufficiently flexible that new evidence and assumptions, related to debris size and distribution, can be easily accommodated.

# **Table of Contents**

\_\_\_\_

					Page
Abs	tract .				iii
Exe	cutive S	Summary			ix
Ack	nowled	lgments			xiii
Acr	onyms				xiv
1	Intro	luction .		•••••	1-1
	1.1 1.2 1.3	Backgro Progran Referen	ound and Ol o Overview ces	bjectives	1-1 1-2 1-4
2	Meth	odology	Overview		2-1
	2.1	Debris 7 2.1.1 2.1.2	Fransport Pa Blowdown Washdown	athways	2-1 2-4 2-9
	2.2 2.3 2.4 2.5	Debris S Identifie Debris 7 2.4.1 2.4.2 2.4.3 2.4.4 Referen	Size Consid cation of Co Fransport F Plant Desi Selection ECCS Thr Drywell S ces	lerations ontrolling Phenomena and Plant Features	2-17 2-17 2-17 2-29 2-29 2-29 2-29 2-29 2-29
3	Cont	rolling Pł	enomena a	nd Plant Features	3-1
	3.1	Control 3.1.1 3.1.2 3.1.3	ling Plant F Effect of I Vent and I Duration of	Features Floor Gratings Drywell Floor Design of Unthrottled ECCS Operation	3-1 3-1 3-1 3-5
	3.2	Domina 3.2.1 3.2.2 3.2.3	ant Transpo Small Del Large Del Large Car	ort Processes	3-5 3-5 3-5 3-8
	3.3	Referer	nces		3-8
4	Quar	ntification	of Logic C	Charts	4-1
	4.1	Main S	team Line F	Break Logic Chart	4-1
		4.1.1	Debris Ge 4.1.1.1 4.1.1.2 4.1.1.3	eneration Key Findings Upper Bound Estimates Central Estimates	4-1 4-4 4-6 4-6

# Contents (continued)

Page

		4.1.2	Distribution at the End of Blowdown44.1.2.1Key Findings44.1.2.2Upper Bound Estimates4-4.1.2.3Central Estimates4-	-6 -7 11 13
		4.1.3	Erosion and Washdown4-14.1.3.1Key Findings4.1.3.2Upper Bound4.1.3.3Central Estimate4-1	18 18 18 18
		4.1.4	Drywell Floor Pool Transport4-14.1.4.1Key Findings4-14.1.4.2Upper Bound4-14.1.4.3Central Estimate4-2	19 19 19 23
		4.1.5	Results of Quantification4-24.1.5.1Upper Bound4-24.1.5.2Central Estimate4-2	23 23 23
	4.2	Recircu	ation Line Break	23
		4.2.1	Debris Classification4-24.2.1.1Key Findings4-24.2.1.2Upper Bound4-34.2.1.3Central Estimates4-3	27 27 30 30
		4.2.2	Distribution at the End of Blowdown4-34.2.2.1Key Findings4-34.2.2.2Upper Bound Estimates4-34.2.2.3Central Estimates4-3	50 50 51 51
		4.2.3	Erosion and Washdown4-34.2.3.1Key Findings4.2.3.2Upper Bound4.2.3.3Central Estimate4-3	51 53 53
		4.2.4	Drywell Floor Pool         4-3           4.2.4.1         Upper Bound         4-3           4.2.4.2         Central Estimate         4-3	13 13 16
		4.2.5	Results of Quantification4-34.2.5.1Upper Bound4-34.2.5.2Central Estimate4-3	6 6 6
	4.3	Referen	ces 4-3	6
5	Appl	ication of	the Study Results	-1
	5.1 5.2 5.3	Integrat Deviatio Referen	on of Debris Generation Data	1 2 4
App	endix .	A Co	npilation of Debris Transport Study Logic Charts	-1

# **FIGURES**

\_\_\_\_

<b>E-1</b>	Postulated debris transport pathways and experiments/analyses conducted to compile the necessary knowledge base	x
1-1	Programmatic overview of the drywell debris transport study	1-3
2-1	Postulated debris transport pathways in a Mark I BWR	2-2
2-2	Transport pathways in a BWR	2-3
2-3	Data gathered to evaluate drywell debris transport during blowdown (short-term) phase	2-13
2-4	Data gathered to evaluate drywell debris transport during washdown (long-term) phase	2-14
2-5	A photograph of small size insulation debris produced in air-jet tests	2-21
2-6	A photograph of large size insulation debris produced in air-jet tests	2-21
2-7	A photograph of large canvassed debris produced in air-jet tests	2-22
2-8	A photograph of shredded canvas debris produced in air-jet tests	2-22
2-9	Generic logic chart used for quantification of debris transport	2-25
2-10	Accident scenarios analyzed in the study	2-28
3-1	Typical small debris deposition on wet gratings observed in the experiments	3-2
3-2	Capture of large debris on dry/wet gratings	3-3
3-3	Capture of small debris around simulation Mark II vent	3-4
3-4	Erosion of large debris trapped on floor grating by water flow	3-6
3-5	Erosion as a function of time for large pieces trapped on floor grating	3-7
4-1	Logic chart for upper bound estimate of transport factor for a MSLB scenario	4-2
4-2	Logic chart for central estimate of transport factor for a MSLB scenario	4-3
4-3	Blowdown data corresponding to a postulated main steam line break in a BWR/4 plant.	4-5
4-4	MELCOR predictions for drywell thermal hydraulics response following a MSLB	4-8
4-5	CFD code predictions for quasi-steady flow patterns that exist in the drywell following a MSLB	4-9
4-6	Liquid film build-up on drywell structures due to steam condensation	4-12
4-7	Secondary logic tree used to evaluate upper bound debris distribution after blowdown	4-14
4-8	Efficiency for capture of small debris by floor grating	4-15
4-9	Secondary logic tree used to obtain the central estimate for debris distribution after blowdown	4-16
4-10	Structure capture fraction	4-17
4-11	Flow velocities at overflow level for containment spray pool in Mark I	4-20
4-12	Specific kinetic energies for containment spray pool in Mark I	4-21
4-13	Logic chart for upper bound estimate of transport factor for a RLB scenario	4-25
4-14	Logic chart for central estimate of transport factor for a RLB scenario	4-26
4-15	Blowdown data corresponding to a postulated recirculation line break in a BWR/4	4-28
4-16	Expansion of high speed water jet in a region with structural impediments	4-29
4-17	Logic used to estimate distribution at the end of blowdown	4-32
4-18	Flow velocities at overflow level for full recirculation flow from broken pipe in Mark I	4-34
4-19	Specific kinetic energies for full recirculation flow from broken pipe in Mark I	4-35
5-1	Upper bound logic chart with BWROG size distribution data	5-6
5-2	Central estimate logic chart with BWROG site distribution data	5-7
5-3	Effect of upper floor grating on upper bound estimate of debris distribution after blowdown	5-8
5-4	Effect of upper grating on central estimate debris distribution after blowdown	5-9
5-5	Upper bound logic tree for debris transport in a Mark I drywell with one floor grating	5-10
5-6	Central estimate logic tree for debris transport in a Mark I drywell with one floor grating	5-11

Page

# TABLES

-----

2-1	Overview of separate effects test program	2-7
2-2	Overview of integrated experimental program	2-11
2-3	Overview of washdown experimental program	2-15
2-4	Overview of CFD simulation of transport in drywell pool	2-19
2-5	Debris classification	2-23
4-1	Upper bound estimate of debris transport fractions for a MSLB scenario	4-22
4-2	Central estimate of debris transport fractions for a MSLB scenario	4-24
4-3	Upper bound estimate of debris transport fractions for a RLB scenario	4-37
4-4	Central estimate of debris transport fractions for a RLB scenario	4-38
5-1	Debris size distribution data used in example 1	5-2
5-2	Upper bound estimates for debris transport based on BWROG size distribution data	5-3
5-3	Central estimate for debris transport based on BWROG size distribution data	5-4
5-4	Center and upper bound estimates for debris transport factors based on BWROG size	
	distribution data	5-5
5-5	Upper bound transport factors for debris transport in a Mark I drywell with one floor grating	5-12
5-6	Central estimate transport factors for debris transport in a Mark I drywell with one floor grating	5-13

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#### **Executive Summary**

A loss of coolant accident (LOCA) in a boiling water reactor (BWR) would destroy fibrous insulation blankets and generate fibrous debris in a region close to the break referred to as the zone of influence (ZOI). This debris would be carried away from the zone of influence by high velocity steam flow, in the case of a main steam line break (MSLB), and by steam-water mixtures, in the case of a recirculation line break (RLB). The debris entrained by the vapor flow would be transported across the drywell volume through floor gratings to the drywell floor where it enters the vent pipes (or downcomers). However, the drywell presents numerous impediments to such transport in the form of I-beams, floor gratings, pipes, instrument panels, etc., where the debris may become attached or trapped. The remaining debris would be transported to the suppression pool during blowdown phase, within minutes after a LOCA.

Following blowdown, water would be introduced into the drywell by break overflow or drywell sprays. Water from the drywell sprays covers 100% of the drywell structures located underneath the sprays, whereas water from break flow spreads over a limited cross-section of the drywell located directly beneath the break. In both cases, as the water cascades down from the location of its introduction it would washdown (i.e., re-entrain or erode) some of the debris captured on (or trapped by) the drywell structures during blowdown. The washed down debris would be brought to the drywell floor where water accumulates to form a pool until the water level rises above the vent or downcomer entrance. The pool height and the pool flow dynamics, including turbulence levels are highly plantspecific, controlled by such features as the water flow rate, height from which water falls into the pool, vent pipe offset and type of structures located close to the floor. Depending on the pool dynamics, the debris brought to the floor may remain in suspension or may sediment. The fraction that remains in suspension will ultimately be transported to the vents (or downcomers) as the water flows into them.

As shown in Figure E-1, debris transport is a complex process occurring over two distinct phases: blowdown and washdown. The objective of the drywell debris transport study (DDTS) is to investigate debris transport using a bounding analysis approach to estimate the fraction of the debris transported by blowdown and washdown processes and to identify important phenomena and plant features that control or dominate debris transport. The results of the DDTS would form the basis by which NRC can judge the accuracy of the debris transport factors used in the utility strainer blockage analyses.

SEA undertook the DDTS in September 1996. The first step of the DDTS was to perform an end-to-end scoping calculation to understand the thermal and hydraulic conditions that would govern debris transport. Based on these calculations, the overall transport problem was decomposed into several components that were amenable to resolution by the knowledge base that can be developed from separate effects experiments, analytical modeling and engineering calculations. The calculations also identified vital data necessary to quantify transport. Experiments and analytical studies were undertaken to compile the necessary knowledge base on debris transport during blowdown, washdown of debris by ECCS water flow, and debris sedimentation on the drywell floor. In particular, three experiments were designed and conducted as part of this study. The first two experiments studied inertial capture of fibrous insulation fragments during air-borne transport on typical drywell structures. The third experiment studied washdown of debris previously deposited on various drywell structures by break overflow and containment sprays. In addition, detailed CFD simulations were used to determine flow patterns that would likely exist on the drywell floor during ECCS recirculation and the likelihood of debris sedimentation under these conditions. The study relied primarily on this knowledge base to quantify importance of each transport pathway. Although analytical tools (e.g., MELCOR and RELAP) were used in the study, their usage was limited to gathering information regarding selected aspects of the overall problem.

The results of the study were used to delineate plant features and transport phenomena that dominate debris transport in the BWR drywell. Three such plant features were identified: (1) number and arrangement of gratings with respect to the break, (2) duration of unthrottled ECCS flow, and (3) vent and drywell floor design. Experimental data clearly illustrated that during blowdown, the drywell



Figure E-1. Postulated debris transport pathways and experiments/analyses conducted to compile the necessary knowledge base.

floor gratings provide the largest potential for capture of both small and large debris, with capture efficiencies between 15% and 30% for small debris and 100% for large debris. The small pieces captured on gratings can be easily re-entrained by ECCS water flow during washdown. The only mechanism available for washdown of large pieces is erosion, which was found to be a constant rate process. Therefore, time assumed for unthrottled operation of ECCS plays a key role in determining the fraction of large pieces that would be washed down. Although vents may provide an effective location for capture during blowdown, the captured debris may become re-entrained by the drywell pool flow dynamics. Typically, higher flow velocities and turbulence levels characterize pools formed as a result of break over flow. Sedimentation of small or large debris in such pools is unlikely. On the other hand, sedimentation is likely in the pools formed by containment sprays.

A simplified logic chart method was chosen to link both experimental and analytical results. A separate logic chart was developed for each postulated accident scenario and generic plant type analyzed. A total of twenty accident scenarios covering three plant types (Mark I, II and III), two break types (MSLB and RLB) and a variety of assumptions regarding ECCS response were analyzed. For each scenario two types of transport factors were obtained. The upper bound estimates were obtained by compounding bounding estimates for the effect of each transport pathway. It is extremely unlikely that transport following a LOCA would exceed upper bound estimates. The central estimates are judged to be a more realistic representation of debris transport.

The study estimates that a large fraction of small debris and large debris produced below the lowest grating would be transported to the vents. However, only a small fraction of the large debris generated above the lowest grating would be transported. No transport pathways were identified for canvas covered large pieces. The total fraction of debris transported depends strongly on the assumed size distribution of the debris and the location of the break. Table E-1 presents upper bound and central estimates for the transport factor corresponding to each accident scenario analyzed for a postulated LOCA in the mid-region of the drywell assuming BWROG recommended debris size distribution.

Transport factor estimates presented in Table E-1 were obtained based on an assumed set of generic plant features (e.g. floor gratings). Plant specific usage of these factor should be subject to a review to assure that all plant features were properly modeled in this study. If necessary, the logic charts provided in this study can be easily modified to account for plant-specific features, such as number and arrangement of floor gratings. Also, they are sufficiently flexible to accommodate new evidence and assumptions related to debris size and distribution.

	Central Estimate			Upper Bound Estimate			
Containment/Break	Small Large D		Debris	Small	Large Debris		
	Debris	Above	Below	Debris	Above	Below	
		Grating	Grating		Grating	Grating	
Mark I							
Main Steam Line Break	0.52	0.01	0.90	1.0	0.05	1.0	
Recirculation Line Break	0.86	0.02	0.94	1.0	0.30	1.0	
Mark II	· · · · · · · · · · · · · · · · · · ·						
Main Steam Line Break	0.74	0.01	0.90	1.0	0.05	1.0	
Recirculation Line Break	0.89	0.02	0.95	1.0	0.30	1.0	
Mark III							
Main Steam Line Break	0.55	0	0.90	0.93	0.03	1.0	
Recirculation Line Break	0.72	0.01	0.90	1.0	0.30	1.0	

 Table E-1. Upper bound and central estimates for transport factor associated with a postulated LOCA in the mid-region of the drywell using BWROG size distribution.

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#### ACRONYMS

ARL	Alden Research Laboratory Inc.
BWR	Boiling water reactor
BWROG	Boiling Water Reactor's Owners Group
CEESI	Colorado Engineering Experiment Station
CFD	Computational fluid dynamics
DDTS	Drywell debris transport study
ECCS	Emergency core cooling system
GPM	Gallons per minute
LOCA	Loss of coolant accident
MSL	Mean steam line
MSLB	Main steam line break
NRC	U.S. Nuclear Regulatory Commission
PIRT	Phenomena Identification and Ranking Table
PP&L	Pennsylvania Power and Light Company
PVC	Polyvinyl chloride
RLB	Recirculation line break
SEA	Science and Engineering Associates, Inc.
ZOI	Zone of influence

# **1. Introduction**

# 1.1 Background and Objectives

In 1993, the U.S. Nuclear Regulatory Commission (NRC) initiated an evaluation of the potential of loss of coolant accident (LOCA) generated debris to block boiling water reactor (BWR) suction strainers and prevent the emergency core cooling systems (ECCS) from performing their long-term cooling function [Ref. 1.1]. In 1995, Science and Engineering Associates, Inc. (SEA) completed the NUREG/CR-6224 study, which analyzed that potential for a reference plant. The study concluded that LOCA generated debris have a high likelihood of accumulating on the ECCS suction strainers following a LOCA event, and that this accumulation could cause excessive head loss, disabling the ECCS pumps within a short duration [Ref. 1.2]. NUREG/CR-6224 postulated that insulation debris generated in the drywell would be transported to the wetwell over two phases: (1) blowdown phase, during which steam/gas flow would entrain and transport debris to the suppression pool; and (2) washdown phase, where water flowing out of the break and/or containment sprays will transport a fraction of the remaining debris. The NUREG/CR-6224 analyses reasoned that the congested layout closer to the gratings would offer a large surface area for debris retention. This formed the basis for dividing the reference plant containment into three regions (High-, Mid-, and Low- Regions) with reference to the two gratings, and for assuming that the fraction of debris transported to the suppression pool would vary depending on the region in which it was generated<sup>1</sup>. However, due to the lack of directly applicable experimental or analytical data, this fraction, termed the transport factor, was estimated based on engineering judgement derived from the analysis of the Barseback-2 event data [Ref. 1.2 and 1.3]. The transport factors used for the reference plant in the NUREG/CR-6224 analyses varied from 0.25 to 0.75, depending on the location of the break with respect to the floor gratings. The NUREG/CR-6224 study did not identify methods by which transport factors can be estimated for other BWR plants.

<sup>1</sup> Because debris generated by breaks located in the high region will have to pass through two floor gratings, a smaller fraction of them will be transported.

The NRC concluded that any engineering judgement based on a scarce set of experimental data would be associated with large uncertainties, and therefore, NUREG/CR-6224 transport factors could not be defended either as a 'best-estimate' or a 'reasonable upper-bound estimate'. As a result, while formulating the Regulatory Guide 1.82, Rev. 2, NRC recommended usage of 100% debris transport<sup>2</sup> unless lower transport factors could be justified through analyses or experiments [Ref. 1.4].

The industry and vendors, represented by the Boiling Water Reactors Owner's Group (BWROG), have cited the Barsebäck-2 event data and the ABB Karlshamn data to argue that transport factors chosen in the NUREG/CR-6224 study are unrealistically large [Ref. 1.3 and 1.5]. The BWROG suggested that deposition will likely occur on all free surfaces not just gratings as assumed in the NUREG/CR-6224 study, and therefore, transport fractions in the range of 0.10 to 0.25 are more realistic [Ref. 1.6]. The BWROG pointed out that usage of overly conservative NUREG/CR-6224 transport factors might preclude several solutions that are otherwise sound and cost-effective. They proposed a small scale test program to study debris retention by selected drywell structures (e.g., gratings) and to compile data, which can then be used to derive the appropriate plant-specific transport factors. Individual licensees were expected to apply these derived transport factors to estimate the quantity of debris transported to the suppression pool [Ref. 1.7]. A reliable knowledge base would be necessary to judge the appropriateness of individual licensee assumptions. The need for such knowledge base was also expressed by CSNI/PWG International Task Group [Ref. 1.3], which pointed out that drywell transport is the least understood aspect of the BWR ECCS strainer issue.

In response to this need, NRC initiated a study, referred to as drywell debris transport study (DDTS) to investigate debris transport in BWR drywells using a bounding analysis approach. This bounding analysis was to estimate the fraction of debris transported from the drywell to the suppression pool during blowdown and washdown phases of a postulated LOCA scenario in BWRs. The focus of the DDTS is to provide a

<sup>&</sup>lt;sup>2</sup> For solutions based on active strainers, 100% transport should be assumed during blowdown which typically lasts a few hundred seconds.

description of the important phenomena and plant features that control and/or dominate debris transport during blowdown and washdown, and the relative importance of each phenomenon as a function of the debris size. The results of the DDTS should provide reasonable engineering insights that can be used to judge the appropriateness of debris transport factor estimates used in the utility strainer blockage analyses. The auxiliary guidance provided by NRC included:

- The study will focus on fibrous debris only.
- The focus should not be to develop a comprehensive predictive tool that can be readily applied to plant types and scenarios. Instead, the study should integrate experimental and analytical results in such a way that an engineer familiar with nuclear plants, but not necessarily an expert in strainer blockage issues, can comprehend and apply the results.
- The study should use "conservative" assumptions, if data is unavailable and can not be generated within the allocated resources or within schedule.

In parallel, the NRC assembled a Phenomena Identification and Ranking Table (PIRT) panel to review the scope of the DDTS, rank the phenomena of importance, and advise the NRC on the methods used to analyze each phenomenon [Ref. 1.8].

# 1.2 Program Overview and Report Outline

SEA undertook the DDTS with subcontractor support from Alden Research Laboratory, Inc. (ARL) in July 1996. From the onset the study focused on identifying important transport pathways and phenomena that control or dominate the mode of transport. The first step of the DDTS was to undertake an end-to-end scoping calculation to understand the thermal and hydraulic mechanisms that govern debris transport and their relative importance. The study also identified vital data needs to accomplish the overall objectives. A series of experiments were designed and conducted to address the data needs related to inertial capture on drywell structures and washdown of debris by ECCS flow. Also, detailed CFD simulations were undertaken to determine likely flow patterns that exist on the drywell floor and likelihood of debris sedimentation. The DDTS relied primarily on this database to quantify the importance of each transport pathway.<sup>3</sup> Analytical tools (e.g., computational fluid dynamics codes and MELCOR) were used as needed either during experiment design to establish thermalhydraulics conditions to be simulated in the experiments, or in the post-experimental stage to scale the experimental data to plant conditions. In all cases, analytical tools were used within their specified range of applicability and then benchmarked against experimental data whenever necessary. Figure 1-1 provides an overview of the DDTS.

A simplified logic chart method was chosen to integrate experimental data and analytical results such that rationale used to derive the transport factors would be tractable and easily comprehended. A separate logic chart was developed for each accident scenario and each plant type to accommodate differences in plant conditions that control transport. The logic and rationale used to quantify the logic tree are summarized in this report, including a brief phenomenological description of debris transport in BWR drywells. This report also summarizes the phenomena and plant features that were determined to dominate or control debris transport. Finally, this report provides an example on how the study results can be applied to a particular BWR plant.

As noted above, the logic tree quantification relied mainly on the experimental data obtained as part of the DDTS. To this end, a total of three experiments were designed and conducted as part of this study. The first two experiments focused on studying inertial capture of debris on typical drywell structures during airborne transport. The third experiment studied washdown of debris previously deposited on various drywell structures by break overflow and containment sprays. The experiments are described in detail in NUREG/CR-6369, Supplement 1, "Drywell Debris Transport Study: Experimental Work" [Ref. 1.9].

In addition, the study relied on analytical models to quantify phenomena that were: (a) previously studied experimentally by other investigators [Ref. 1.9] or (b) amenable to be simulated using existing codes

<sup>&</sup>lt;sup>3</sup> Such an approach was determined to provide the best option for judging appropriateness of plant-specific assumptions. The PIRT panel input was used to revise some of the elements of the experimental program.



Figure 1-1. Programmatic overview of the drywell debris transport study.

codes (e.g., Computational Fluid Dynamics code) to an adequate degree of accuracy. In the former case analytical models were used to scale the data from past test facilities to BWR drywells. In the latter case, analytical models were directly used to quantify the impact of selected transport phenomena. These analytical models are summarized in NUREG/CR-6369, Supplement 2, "Drywell Debris Transport Study: Analytical Work." [Ref. 1.10]

## **1.3 References**

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# 2. Methodology Overview

#### 2.1 Debris Transport Pathways

A LOCA in a BWR would destroy fibrous insulation blankets and generates fibrous debris in a region surrounding the break, referred to as the zone of influence (ZOI) or the break region [Ref 2.1]. This debris would be carried away from the break region by high velocity steam flow, in the case of a main steam line break (MSLB), and by steam-water mixtures, in the case of a recirculation line break (RLB). However, the BWR drywell presents numerous structural impediments to such a transport in the form of I-beams, columns, pipes, floor gratings, instrument panels, etc. Some of these structures will be wet due to steam condensing on their relatively cool surfaces and deposition of water droplets that are produced by the jet expansion process. Some fibrous debris could adhere to such structures located outside the break region in spite of the high steam velocities, which act to shear them away from the structures. In addition, some fraction of the debris would enter enclosures (e.g., reactor cavity) and become trapped. Finally, an additional fraction of debris would be deposited at the vent (or downcomer) entrance on the drywell floor. The remaining debris would be transported by the blowdown flows to the vents (or downcomer)<sup>1</sup>, and subsequently to the suppression pool.

Figure 2-1a and 2-1b illustrates the physical processes that govern debris transport through drywell during blowdown. As shown here, during and after blowdown debris would traverse over most regions of the containment and depending on the local flow and structural surface conditions, they can be captured in different regions of the containment. Following blowdown, water would be introduced into the drywell by break overflow or drywell sprays<sup>2</sup>. Water flow from the containment sprays cover nearly 100% of the region located underneath the sprays (see Figure 2-1b). On the other hand, overflow from the break spreads over a small cross section of the drywell located directly beneath the break. In both cases, as the water cascades down from the location of its introduction it may washdown (i.e., re-entrain or erode) debris

previously deposited on structures located in its path. Potential for transport by washdown would be minimal for debris deposited on structures located above the containment sprays (referred to hereafter as Structures-Above) or in enclosures, since they would not be subject to any water flow (with the exception of condensate drainage which is minimal). On the other hand, washdown potential would be largest for the structures located directly underneath the break (referred to as *Structures-Below*) that would be subjected to break flow (≈25, 000 GPM) and containment spray flow (≈4500 GPM). Debris located on these structures could be eroded in addition to simply being re-entrained. For other structures (referred to as Structures-Other), washdown potential would be moderate as they would be subject to containment sprays only.

The washed down debris would be brought down to the drywell floor where water accumulates to form a pool until the water level rises above the vent entrance (see Figure 2-1b). The pool height and the flow dynamics, including the turbulence levels, are highly plant-specific, controlled by such features as the water flow rate, height from which water falls into the pool, vent pipe offset from the floor and type of structures located close to the floor. Depending on the pool dynamics, the debris brought down by water may remain in suspension or may settle down. The pool dynamics may also re-suspend some of the debris previously deposited on the drywell floor (e.g. near vent entrances). The pool height and flow dynamics within the pool are highly plant-specific. The fraction that remains in suspension would be transported to the vents as the water overflows into them.

Figure 2-2 delineates the transport pathways and the close coupling that exists between blowdown and washdown transport processes described above. The quantity of debris advected to the vents due to the combined effects of these pathways can be expressed as [Ref. 2.1]:

$$\mathbf{V}_{\text{pool}}^{i} = \mathbf{F}^{i} \bullet \mathbf{V}_{\text{gen}}^{i} \tag{2-1}$$

<sup>&</sup>lt;sup>1</sup> This study assumes that all of the debris entering the vents would be transported to the suppression pool.

<sup>&</sup>lt;sup>2</sup> Type and duration of water flow are plant specific. In some scenarios water may not enter the drywell.

#### Methodology Overview



Figure 2-1. Postulated debris transport pathways in a Mark I BWR.



Figure 2-2. Transport pathways in a BWR.

where,

V <sup>i</sup> gen	is the volume of i <sup>th</sup> size fibrous debris generated in the drywell break region (ft <sup>3</sup> )
V <sup>i</sup> pool	is the volume of i <sup>th</sup> size fibrous debris

F<sup>i</sup> is the drywell debris transport factor for the i<sup>th</sup> size debris.

The objective of this study is to estimate F<sup>i</sup> for three different types of BWR drywell designs (Mark I, II and III) and for several postulated accident scenarios.

As shown in Figures 2-1 and 2-2, transport occurs over two distinct phases of accident progression, the blowdown phase and the washdown phase. Hence,  $F^i$  can be expressed as:

$$\mathbf{F}^{i} = \mathbf{F}^{i}_{bid} + \mathbf{F}^{i}_{wd} \tag{2-2}$$

 $F^{i}_{bd}$  and  $F^{i}_{wd}$  are blowdown and washdown transport factors, respectively. The blowdown transport factor can be decomposed as follows:

$$F_{bd}^{i} = (1 - X_{en}^{1} - X_{sa}^{i} - X_{sb}^{i} - X_{so}^{i} - X_{df}^{i}$$
 (2-3)

Where, X<sup>i</sup><sub>en</sub>, X<sup>i</sup><sub>sa</sub>, X<sup>i</sup><sub>sb</sub>, X<sup>i</sup><sub>so</sub> and X<sup>i</sup><sub>sf</sub> are fractions of generated debris deposited on (or trapped by) *enclosures, structures-above, structures-break, structures-other* and *drywell floor*, respectively. On the other hand, the fraction transported during long-term washdown phase, F<sup>i</sup><sub>wd</sub>, can be expressed as:

$$\mathbf{F}_{wd}^{i} = \mathbf{F}_{Floor}^{i} \bullet \mathbf{Z}^{i}$$
(2-4)

 $F^{i}_{Floor}$  is the fraction of the generated debris that would reach the drywell floor and  $Z^{i}$  is the fraction of that debris that remains in suspension and is ultimately transported to the vents.  $F^{i}_{Floor}$  can be further expressed as:

$$F_{Floor}^{i} = X_{sa}^{i} \bullet Y_{sa}^{i} + X_{sb}^{i} \bullet Y_{sb}^{i} + X_{so}^{i} \bullet Y_{so}^{i} + X_{df}^{i}$$
(2-5)

Y<sup>i</sup><sub>sa</sub>, Y<sup>i</sup><sub>sb</sub>, and Y<sup>i</sup><sub>so</sub> are the fractions of i<sup>th</sup> size debris previously deposited on *structures-above*, *structuresbreak* and *structures-other* that would be washed down. Thus, the problem of estimating the total transport factor, F<sup>i</sup>, can be seen to be decomposed into the following parts:

- Estimate fractions of the fibrous debris deposited on (or trapped by) enclosures, structures-above, structures-below, structures-other, and drywell floor (i.e., X<sup>i</sup><sub>enc</sub>, X<sup>i</sup><sub>sa</sub>, X<sup>i</sup><sub>sb</sub>, X<sup>i</sup><sub>so</sub>, and X<sup>i</sup><sub>df</sub>). These fractions are referred to as capture fractions hereafter. The remaining fraction (F<sup>i</sup><sub>bd</sub>) will be advected to vents during short-term blowdown.
- 2. Estimate fractions of the debris deposited on (or trapped by) each structural class that would be washed down during long-term ECCS recirculation phase (i.e., Y<sup>i</sup><sub>sa</sub>, Y<sup>i</sup><sub>sb</sub>, and Y<sup>i</sup><sub>so</sub>). These fractions are referred to as washdown fractions. This fraction of the debris previously deposited on the structures during blowdown would reach the drywell pool, where as the remainder will remain permanently on the structures.
- Estimate fraction of the debris reaching the suppression pool that would remain in suspension and would be advected to the vents during longterm ECCS recirculation phase (Z<sup>i</sup>). The remainder will settle down on the drywell floor.

Decomposing the problem into these three parts avoids the need for conducting integrated analyses that tend to be very complex. Such decomposition also allows for designing experiments and conducting analyses specifically applicable to each part.

#### 2.1.1 Blowdown Transport (Short-term)

Transport of debris from the break region to the vents by blowdown flow is referred to as blowdown transport or short-term transport.<sup>3</sup> This transport is controlled strongly by the transport medium (i.e., the continuum that entrains debris particles). Depending on the break type (i.e., main steam line break or recirculation line break), a fraction of the generated debris would be transported by the steam flow and the remaining fraction would be transported by the water component. For example, in the case of a main steam line break, the break effluent is primarily steam with equilibrium quality greater than 0.9, and void fraction close to 1. As a result, blowdown debris transport in this case is driven entirely by bulk movements of the gaseous phase. In the case of a recirculation line break,

<sup>&</sup>lt;sup>3</sup> This is because blowdown transport occurs over a short time scale (within minutes) after a LOCA.

large quantities of water is introduced into the containment. In this case, a fraction of the debris would be entrained by the steam flow, whereas the remaining fraction is carried by the water component. Section 4 presents the rationale used to partition the debris according to the medium in which it is transported.

#### **Transport by the Gaseous Phase**

Estimation of the capture fractions (i.e.,  $X_{enc}^{i}$ ,  $X_{sa}^{i}$ ,  $X_{sb}^{i}$ ,  $X_{so}^{i}$ , and  $X_{df}^{i}$ ) associated with vapor phase transport requires information related to the following quantities:

- 1. The fraction of the generated debris carried into the *enclosures*, *structures-above*, *structures-break*, *structures-other* and *drywell floor*.
- 2. Efficiency (or effectiveness) of the structures located in each of those regions to trap or capture debris.

The fraction of debris transported into each region depends on the bulk flow patterns established in the drywell as a result of blowdown from the break and the relief provided by the vent pipes. A variety of analyses, including MELCOR<sup>4</sup> and CFD calculations, were performed to predict drywell flow patterns following postulated recirculation and main steam line breaks [Ref. 2.2 and 2.3]. Break blowdown flow velocity, temperature and quality, required as input to these calculations, were obtained based on RELAP simulation of BWR/4 plants. Additional input related to structural layout and bulk porosity was gathered from detailed surveys of Mark I and Mark II drywells [Ref. 2.2]. Results of these calculations coupled with engineering judgments<sup>5</sup> were used to estimate the fractions of debris advected into each region of the drywell. Section 4 summarizes the important results of these analyses and how they were used.

The results of the analyses concluded that high gas velocities (25-100 ft/s) outside the break region would entrain and transport insulation debris through the drywell unless it is trapped (or

captured) by structures located upstream<sup>6</sup>. Inertia will cause the fibrous debris to impact structural objects located in fibrous pathway. The majority of the time, these structural impediments will be wet due to steam condensation and water droplet deposition on their surfaces. However, it was not clear if the debris particles thus impacting the structures would adhere to those surfaces or be sheared off by the high gaseous velocities. Debris larger than the clearance (4" x 1½") in the floor grating would be trapped on the floor grating. It was not known if such pieces would remain on the gratings or be forced through the gratings by gaseous flow later on. Two experiments were conducted to gain a basic understanding of capture on drywell structures:

- 1. The separate effects tests focused on measuring removal efficiency of isolated structural elements placed in a test channel and subjected to plug flow of air intermixed with debris particles of known size. The structures were wet by water sprays to the desired wetness covering a wide range of conditions anticipated in the drywell. The debris were injected uniformly into the flow stream by a debris injection gun. The structures examined included the Mark II vent pipe, pipes, I-beam, and floor grating. A brief overview of the test program and its results are summarized in Table 2-1. The experiments also studied potential for degradation of large insulation pieces that are trapped on structures, such as floor gratings, when subjected to remaining blowdown flow at a velocity of 150 ft/s.
- 2. The integrated effects tests were conducted in which insulation debris generated by 1100 psi jet from a 4" nozzle were transported over structural elements assembled to the prototypical congestion level. In these tests, an aged insulation blanket was mounted on a target pipe located in the center-line of the jet expanding from the nozzle. The debris were then allowed to be transported across the structural region. A comprehensive survey of BWR containments was used to design this structural region, which is 20 ft long. Full scale structures such as I-beams, pipes, floor gratings, and Mark I vents were simulated. The measured

<sup>&</sup>lt;sup>4</sup> MELCOR was used primarily to estimate time taken for vent clearing in Mark I and Mark II drywells and to establish appropriate boundary conditions for CFD analyses. <sup>5</sup> Engineering judgements were necessitated by the fact that all these analyses (including MELCOR and CFD simulations) sought several simplifying assumptions to minimize computational effort.

<sup>&</sup>lt;sup>6</sup> Larger partially torn insulation blankets will become de-entrained under the influence of gravity. They are not included in the following discussions.



# Table 2-1. Overview of separate effects test program.

## **Objective**

•Determine capture efficiency of an isolated structural element to capture a given size insulation debris being transported by plug flow of air. Examine the impact of congestion on capture efficiency. Examine effect of wetness and flow velocity.

#### Test Method

•For each test, assemble structures in the channel and establish desired flow velocity. Wet the structures by turning on the sprays. Inject selected size debris into the flow. Measure fraction of debris captured on structures.

#### **Experimental Parameters**

•4ft x 4ft channel with fine misters to introduce wetness. Gun for debris injection. •Structures simulated: I-beams, Pipes (1-ft to 2-ft), Gratings, and Mark II Vents

•Flow Velocity: 25 - 150 ft/s; Wetness: Dry to Draining film. •Insulation Size: Small & Medium; Shape: Irregular; Wetness: Dry



#### **Grating Capture Efficiency**

#### **Final Results and Conclusions**

•Dry structures do not capture small debris. Wetness effect reaches a plateau. •Velocity has insignificant effect.

•Debris size effects capture fraction for gratings. Insignificant effect on other structures capture efficiency.

•Grating have the largest efficiency for capture (10-30%). Other drywell structures have much lower capture efficiency (10%).

•Congestion lowers capture efficiency.

•Erosion of large pieces when subjected to 150-175 ft/s air flow (mixed with droplets) is minimal. Limitations

•Data for low debris mass loading compared to anticipated plant conditions (1-2 lbm/100 ft<sup>2</sup> vs 4-10 lbm/ft<sup>2</sup>) •Structures could not be assembled to the required levels of congestion. •Debris sizes experimented are smaller than desired.

#### Methodology Overview





capture efficiencies were compared with separate effects tests (after properly scaling them). Table 2-2 presents an overview of the experimental program and important findings. These experiments were designed to be more prototypical of BWR conditions following a LOCA.

The experimental program is described in detail in NUREG/CR-6369, Supplement 1 [Ref. 2.4]. The program provided a knowledge base that can be used to judge the effectiveness of various structures to capture debris as a function of structured wetness, flow velocity, and debris size. This knowledge base was coupled together with analytical models and engineering judgment to estimate fraction of the airborne debris deposited on various structures. Figure 2-3 summarizes all of the data gathered and used to quantify  $X_{ien}^i$ ,  $X_{iso}^i$ ,  $X_{iso}^i$ ,  $X_{idf}^i$ .

#### Transport by Liquid Phase

A fraction of the generated debris would be entrained and transported by water flow during the early stages of a postulated recirculation line break. CFD calculations have shown that due to drag imparted by the surrounding structures, break water spreads over a limited cross-section of the drywell [Ref. 2.3]. If it is assumed that water spreads over a quarter of the drywell cross-section, the resulting flow (approximately 50-200 GPM/ft<sup>2</sup>) will impart sufficient drag on the debris located in its pathway and transport them to the drywell floor<sup>7</sup>. The only exception will be pieces larger than the grating clearance of 4"x1.5" which will become trapped on the gratings. As a result, a simple model was used to quantify short term capture fractions (i.e., Xiend,  $X_{sa}^{i}, X_{sb}^{i}, X_{so}^{i}$  and  $X_{df}^{i}$  associated with liquid phase transport.

#### 2.1.2 Washdown Transport (Long-term)

#### Structural Washdown

Transport of debris deposited at different locations in the drywell by ECCS water flow occurs over a long-term (up to hours). If the debris is loosely attached to the structures, it may simply be reentrained and carried to the bottom of the drywell. If the debris is trapped, it may erode with time when subjected to water, with the secondary debris generated by erosion brought to the drywell floor. In order to estimate structural washdown fractions (i.e., Y<sup>i</sup><sub>sa</sub>, Y<sup>i</sup><sub>sb</sub> and Y<sup>i</sup><sub>so</sub>), knowledge of the following phenomena is necessary:

- 1. Distribution of debris in the drywell at the end of blowdown,
- 2. Type of debris and its mode of attachment to the structures<sup>8</sup>,
- 3. Assumptions related to ECCS operation (i.e., ECCS response), and
- 4. Potential for washdown and erosion for each debris size as a function of water flow to which it is subjected, duration of exposure and the structure to which it was attached.

As shown in Figure 2-4, distribution of debris at the end of blowdown, type of debris and their mode of attachment were determined from analyses described in Section 2.1.1. Utility Final Safety Analysis Reports (UFSAR), Emergency Operating Procedures (EOP) and simple engineering analyses were used to determine the duration of flow and the location of flow. Finally, experiments were conducted to determine if pieces of various size debris located on drywell structures could be washed down or eroded down when subjected to water flow. Table 2-3 provides an overview of this test program conducted at SEA. These analyses and experiments were coupled together to derive  $Y^i_{sa}$ ,  $Y^i_{sb}$  and  $Y^i_{so}$  in Section 4 for each accident scenario.

#### Sedimentation in the Drywell Pool

The ECCS flow and the washdown debris would be transported to the drywell floor (see Figure 2-1), where they form a pool whose depth depends on the vent-pipe offset height. Transport of debris in the drywell pool depends to a large extent on the pool flow-dynamics, pool turbulence levels, debris characteristics and drywell floor layout. The pool flow-dynamics would be controlled by the amount of water added and the height from which it falls into the pool. The DDTS relied on CFD simulation of flow on the drywell pool to predict pool flowdynamics corresponding to containment sprays and break overflow [Ref 2.2]. PP&L flume test data [Ref. 2.5] were used to determine flow conditions that

<sup>&</sup>lt;sup>7</sup> This conclusion was further verified by the tests described in the following sections.

<sup>&</sup>lt;sup>\*</sup> For example small debris are loosely attached to the structures and could be easily washed down. Large debris cannot be easily washed down from the floor gratings where they are trapped



# Test Setup Used in the Integrated Experimental Program



**Insulation Blanket Mounting** 

Table 2-2. Overview of integrated experimental program.

#### **Objective**:

Determine Fibrous Insulation Debris Capture Fractions on typical drywell structures assembled to the congestions prototypical of BWR drywells. Use BWR survey to determine prototypical congestion levels.

#### Test Method:

Debris Generation and subsequent transport by dispersing 1100 psi air jet over warm (90 °F) pre-wet structures. Determine capture efficiency as function of debris size, flow velocity and structural wetness.

#### **Experimental Parameters:**

•Prototypical structures assembled to the desired congestion level over 20 ft length based on survey of BWR drywells. •Structures tested: I-Beams, Pipes, Gratings, and Mark I vent pipe entrance/jet plate. •Bulk flow velocities: 25-50 ft/s. Local flow velocities up to 70 ft/s •Wetness: Dry, partially dry and wet structures. Dry insulation. · Size: Small to Large (including canvassed)



# Grating Capture Efficiency for Small Debris

#### **Final Results and Conclusions**







Figure 2-3. Data gathered to evaluate drywell debris transport during blowdown (short-term) phase.



Figure 2-4. Data gathered to evaluate drywell debris transport during washdown (long-term) phase.

#### Table 2-3. Overview of Washdown Experimental Program



#### **Objectives:**

•Obtain experimental data to estimate fraction of insulation initially captured on floor grating that would be eroded and transported by water flow typical of break overflow and containment sprays •Confirm trends of data reported by previous investigators.

#### **Test Method**:

Place debris of known size and mass on the grating and subject it to desired water flow rate over a pre-determined duration. Measure the fraction of insulation eroded.

#### **Test Parameters:**

•2-ftx2-ft test section with clear viewing glass where insulation is located on mock-up grating and pipes •Flow velocities from 20 to 175 GPM typical of spray and break flows. Water at room temperature. •Insulation pieces generated by air jet experiments. Aged fiber-glass insulation. •Size: Small, Medium and Large, including canvassed pieces.



#### **Final Results and Conclusions**

•Significant Fraction of Small and Medium pieces on gratings would be washed down by break and/or containment sprays flows.

•Erosion of large pieces is time dependent for break flow (see Figure). It is negligible for sprays.

•Secondary debris generated by erosion are very small and float at residual turbulence.

·Canvassed insulation pieces do not erode.

#### Methodology Overview

would be necessary to entrain different size debris. The information from these two steps was coupled to evaluate the potential for transport of small and large debris in Mark I, II and III drywell pools formed by drywell sprays and break overflow. Table 2-4 provides an overview of the analyses conducted and the important findings. Details of these analyses are documented in NUREG/CR-6369, Supplement 2 [Ref. 2.2].

# 2.2 Debris Size Considerations

From the onset, the study was designed to identify dominant transport pathways and the associated transport fractions as a function of the size of the debris. Such an approach was necessitated by the fact that debris size distribution that is universally applicable to plant conditions and accident scenarios is not available. On the other hand, there is consensus that the debris can be broadly divided into three size classes: small', large, and largecanvassed, according to their relative size and pathways available for their transport. Figures 2-5, 2-6, 2-7, and 2-8 are the photographic images of the typical small, large, and large-canvassed pieces studied. All experiments and analyses were designed to compile a knowledge base for all three size groups. Based on the insights gained from these experiments, the larger pieces are further divided into two groups according to the location of their generation with respect to the lowest major floor grating: large-above and large-below. This classification reflects fundamentally different pathways associated with each size group. Table 2-5 provides a brief description of the debris, their geometrical range and associated transport pathway. As noted in Table 2-5, the large-canvassed pieces were found to be "non-transportable" and hence were screened out from further analysis.

# 2.3 Identification of Controlling Phenomena and Plant Features

Experimental data were analyzed together with information related to expected plant conditions to

identify controlling phenomena and plant features. The study suggests that the number and arrangement of floor gratings, duration of ECCS flow, and drywell floor layout (including vent design) are the key plant features that control transport. Another parameter that can significantly influence transport fraction is the debris size distribution. The most important transport pathways are:

- Advection of small debris during blowdown,
- Advection of large debris generated below lowest floor grating during blowdown, and
- Erosion of large debris captured on gratings, and
- Gravitational settling of debris in drywell pools when subjected to containment spray.

Section 3.0 provides further details on these pathways.

# 2.4 Debris Transport Factor Quantification

As evident from the previous discussion, the fibrous debris transport is a complex process involving several competing phenomena. Development of a comprehensive "best-estimate" predictive tool that accounts for each phenomenon mechanistically was beyond the scope of this study<sup>10</sup>. Instead, the study decomposed the problem and studied each transport pathway shown in Figure 2-2 independently. The experimental data and analytical predictions compiled for each transport pathway were integrated together using simplified logic trees. These logic charts were structured based on insights gained regarding important transport pathways for each debris size category. Figure 2-9 presents a generic logic tree used to quantify debris transport, including definitions of various terms. As shown in Figure 2-9, the logic chart decomposes the problem into five independent steps: LOCA Type; Debris Classification, Distribution after blowdown, Erosion and Washdown; and Sedimentation in drywell pool. The first column describes the accident being analyzed. This information sets the boundary conditions for all the subsequent steps. The second column specifies the size distribution data through the use of size fractions ( $\eta 1$ ,  $\eta 2$ ,  $\eta 3$ , and  $\eta 4$ ) defined as the mass fraction of the debris belonging to size classes small, large-above, large-below and large-

<sup>&</sup>lt;sup>°</sup> It should be noted that, initially, efforts were made to further classify small debris into sub-groups fines, small and medium consistent with NUREG.CR-6224 study [Ref. 2.1]. However, a decision was made to collapse them into a single group called small because: a) fines, small and medium pieces have very similar transport pathways and b) existing debris size distribution data does not differentiate these three size groups [Ref. 2.3].

<sup>&</sup>lt;sup>10</sup> Also, see NRC guidance listed in Section 1.



**CFD Simulation of Mark I Flow Patterns** 



Figure 2-5. A photograph of small size insulation debris produced in air-jet tests.



Figure 2-6. A Photograph of Large Size Insulation Debris Produced in Air-Jet Tests



Figure 2-7. A Photograph of Large Canvassed Debris Produced in Air-Jet Tests



Figure 2-8. A Photograph of Shredded Canvassed Debris Produced in Air-Jet Tests

#### Methodology Overview

Debris Type	Dimensions	NUREG/CR-6224 Terminology		Transport Characteristics
Small (Figure 2-5)	<6″ x 4″	Classes 2-6	• • • •	Smaller than (≈equal to) grating clearance. Will be forced through gratings Gravitation settling negligible Vent capture unlikely Pool turbulence can keep them in suspension Washdown by sprays and break flow
Large (Figure 2-6)	> 6"x4"	6+	• • •	Unlikely to be forced through grating even at flow velocities >200 ft/s. No washdown by sprays Erosion by break flow Capture at vents
Large- Canvassed (Figure 2-7)	>6"x4" covered with canvas	"Non- transportable"	•	Transport unlikely No pathway for transport identified
Canvas Fragment (Figure 2-8)	1"x1" to 3"x3"	Not considered	•	Same as small

#### Table 2-5. Debris classification.

LOCA Type	Debris Classification	Distribution After Blowdown	Erosion and Washdown	Drywell Floor Pool	Path ID.	Fraction	Final Location
		Advected to Vents	I	•	1	F <sub>1</sub>	Vents
MARKI		(1-X <sub>en</sub> -X <sub>d</sub> r-X <sub>sa</sub> -X <sub>sb</sub> -X <sub>so</sub> Enclosures	)\$		2	F <sub>2</sub>	Enclosures
DUMMY SH	EET	X <sub>m</sub> s		Waterborne	3	F.	Vents
MSLBREAM	C C C C C C C C C C C C C C C C C C C			Z <sup>8</sup>		3	
ECCS UNTH	ROTTLED	Drywell Floor X <sub>a</sub> <sup>3</sup>		Sediment	4	F₄	Floor
SPRAYS OP	ERATED	ŭ		L			
				Waterborne	5	Fs	Vents
FIBROUS IN	SULATION		Condensate Drainage	Z <sup>s</sup>			
		Structures-Above	Y 5 58	Sediment	6	F <sub>6</sub>	Floor
	Small Pieces	X <sub>58</sub> 3	Adheres		7	F,	Structures-Above
	η <sub>1</sub> =1.0			Waterborne	8	F <sub>8</sub>	Vents
			Break Flow/Spravs	Zs			
		Otrasta Danata	Y <sub>sb</sub> <sup>3</sup>	Sediment	9	F <sub>9</sub>	Floor
		Structures-Break	Adheres		10	F <sub>10</sub>	Structures-Break
		-	<b>.</b>	Waterborne	11	F.,	Vents
			Smap/Condenate	Zs			
			Y manual Sprays/Condensate	Sediment	12	F <sub>12</sub>	Floor
		Structures-Other	Adheres		13	F.,,	Structures-Other
		180		Waterborne	14		Vante
				Zs	14	' 14	Vents
			Break Flow/Sprays	Sediment	15	F.,	Floor
		Structures-Break	A dheres		16	i	Structures Brook
		A <sub>sb</sub> <sup>ist</sup>	Adheres		10	<b>1</b> 8	Structures-Break
				Waterborne	17	F <sub>17</sub>	Vents
	Large-Above	1	Sprays/Condensate		10	F	Floor
	η <sub>2</sub> =1.0	Structures-Other	Y so	Sediment	10	' 18	FIOOT
M SL Break		X <sub>so</sub> la	Adheres		19	F <sub>19</sub>	Structures-Other
1.00		Advected to Vent			20	F <sub>20</sub>	Vents
		(1-X <sub>en</sub> -X <sub>af</sub> -X <sub>sb</sub> -X <sub>so</sub> ) <sup>o</sup> Enclosures			21	F <sub>21</sub>	Enclosures
	Large-Below	X <sub>en</sub> te		Waterborne	22	F_	Vents
	13-1.0			Z			
		Drywell Floor X <sub>et</sub> lb		Sediment	23	F <sub>23</sub>	Floor
		ŭ		P			
				Waterborne	24	F <sub>24</sub>	Vents
			Sprays/Condensate	Z			
		Structures Break	Y sb	Sediment	25	F <sub>25</sub>	Floor
		X <sub>sb</sub> b	Adheres		26	F 28	Structures-Break
				Waterborne	27	F <sub>27</sub>	Vents
			Sprave /Condenants	Z			
				1	28	F <sub>28</sub>	Floor
		Structures-Other	Adheres		29	F∞	Structures-Other
		~` <b>s</b> o	L	. <u> </u>			Character 1
	ucanvassed η <sub>4</sub> =1.0				30 Total	Γ <sub>30</sub>	Structures/Floor
	·4					$= - (F_1:F_{30})$	

#### **Location Definitions**

Structures- Above: Drywell Structures Located above Spray Heads. Washdown by condensate drainage only.

Structures- Break: Drywell Structures Located in the quardrant underneath the break. Washdown by break overflow and spray (if applicable).

Structures- Other: Drywell Structures Located below sprays but not underneath the break. Spray washdown.

**Enclosures**: Enclosed volumes where debris may enter and become trapped. Not subject to washdown.

Drywell Floor: Vents and bends at the drywell floor.

#### **Transport Factors Estimated**

Factor	Formula	Explanation
F <sup>s</sup>	$(F_1+F_3+F_5+F_8+F_{11})/\eta_1$	Fraction of Small Debris Transported
F <sup>la</sup>	$(F_{14}+F_{17})/\eta_2$	Fraction of Large-Above Debris
		Transported
F <sup>ib</sup>	$(F_{20}+F_{22}+F_{24}+F_{27})/\eta_3$	Fraction of Large-Below Debris
		Transported
F <sup>Large</sup>	$(\eta_2 F^{la} + \eta_3 F^{lb})/(\eta_2 + \eta_3)$	Fraction of All Large Debris
		Transported
F <sup>trans</sup>	$(\eta_1 F^{s} + \eta_2 F^{la} + \eta_3 F^{lb})/(\eta_1 + \eta_2 + \eta_3)$	Fraction of Transportable Debris
		Transported
F <sup>201</sup>	$(\eta F^{s}+\eta_{2}F^{la}+\eta_{3}F^{lb})$	Fraction of All Insulation in the ZOI
		Transported

Logic Chart Heading	Explanation	-
LOCA Scenario	A description of the scenario being quantified. (see Figure 2-10)	All assumptions based on a gene
Debris Classification	See Size definitions above.	BWROG data is
Distribution after blowdown	Where is the debris located at the end of blowdown? What fraction onstructures-above, -break, etc.?	Removal efficient advection model
Erosion and Washdown	What fraction of the debris previously deposited on various drywell structures would be washed down or will be eroded over time?	Spray flow and b Experimental dat debris and erosid
Drywell Floor Pool	What fraction of the debris reaching the drywell pool will be transported?	CFD simulations turbulence levels with experimenta

# **Size Definitions:**

Small Pieces: Insulation debris small enough to pass through grating clearence (see Table 2-4). Large-Above: Large insulation pieces generated above lowest grating. Large-Below: Large Insulation Pieces generated below the lowest grating

Canvassed: Large Insulation Pieces covered and protected by canvas lining.

#### **Rationale Used for Quantification**

related to systems response and time scales were eric BWR Plant. Particular plant response may vary.

used as an example to derive  $\eta_1$ ,  $\eta_2$ ,  $\eta_3$  and  $\eta_4$ .

cy from experiments was coupled with a simplified was used.

break overflow were assumed to cause washdown. ata was used to estimate washdown fractions for small on rates for large debris.

s of drywell floor pool was used to determine residual and flow patterns. This information was then coupled al data to obtain the fraction of debris transported.

#### Methodology Overview

example was provided to illustrate how such information can be folded-in to calculate a single transport factor that can be used to estimate the quantity of debris reaching the suppression pool, provided the quantity of insulation contained in the zone of influence is known.

The next three steps allow the user to enter data regarding inertial capture of debris on drywell structures located in various regions of the drywell, the fraction of that debris that would be eroded and washed down by water flow, and subsequently, the potential for sedimentation of debris on the drywell floor. Data on capture fractions  $(X_{isen}^{i}, X_{idf}^{i}, X_{isa}^{i}, X_{isb}^{i} \text{ and } X_{iso}^{i})$ , washdown fractions 1.  $(Y_{isa}^{i}, Y_{isb}^{i}, \text{and } Y_{iso}^{i})$ , and drywell pool transport fraction (Z<sup>i</sup>) applicable to each postulated accident scenario were derived and entered in these three columns. Section 2.1 provides definitions of each term, with the rationale for their quantification provided in Section 4. The entries under heading 'Fractions' were obtained simply by multiplying the branch fractions associated with that particular pathway. The fractions whose final 2. location is vents were then added to calculate the transport factor for the accident scenario being evaluated. Six different types of transport factors were derived from this study:

- F<sup>i</sup> Fraction of small debris transported to the vents
   F<sup>la</sup> Fraction of large-above debris transported to the vents
- F<sup>lb</sup> Fraction of large-below debris transported to the vents

 $F^{\text{large}}$  Fraction of all large debris transported to the vents, defined as  $(\eta 2 \bullet F^{\text{la}} + \eta 3 \bullet F^{\text{lb}})/(\eta 2 + \eta 3)$ 

 $F^{trans}$  Fraction of 'transportable debris' transported to the vents, defined as  $(\eta 1 \bullet F^s + \eta 2 \bullet F^{la} + \eta 3 \bullet F^{lb})/(\eta 1 + \eta 2 + \eta 3)$ 

 $F^{ZOI}$  Fraction of all the debris contained in the ZOI that would be transported to the vents, defined as  $(\eta \mathbf{1} \cdot \mathbf{F}^{s} + \eta \mathbf{2} \cdot \mathbf{F}^{la} + \eta \mathbf{3} \cdot \mathbf{F}^{lb})$ 

These six transport factors were derived for each accident scenario. The calculated transport factors were found to be a strong function of the accident scenario assumed. A separate logic tree was developed for each accident scenario that analyzed impact of variations in the following parameters:

- Plant Design
- Break Type and Location
- ECCS Throttling
- Containment Spray Operation

Figure 2-10 provides a complete spectrum of accident scenarios analyzed in the present study

For each of the twenty (20) scenarios analyzed (see Figure 2-10), two types of estimates for debris transport fractions were obtained:

- <u>Upper Bound Estimate</u>. These estimates were obtained by compounding bounding estimates for each individual logic-tree branch. It is unlikely that actual drywell transport factor in a BWR following a LOCA would be greater than the upper bound estimate. The upper bound estimates can be treated as generic estimates that will most likely bound all accident scenarios and operating conditions for that plant type.
- <u>Central Estimate</u>. These estimates were obtained by compounding more realistic estimates for each individual branch. The central estimates are judged to be closer to reality, but without the assurance that they can not be exceeded under any accident condition. Central estimates should be applied on a plant-specific basis after assuring that actual plant systems behavior is consistent with the accident scenarios analyzed and that the underlying modeling assumptions are representative of the particular plant.

Appendix-A contains a complete listing of all the logic trees developed in this study. In addition, Section 4 describes the quantification process in detail by considering logic trees developed for two postulated breaks. Section 5 provides an example of how the results of the present study can be integrated with the debris size distribution data to estimate combined generation-transport factor.

As discussed above, a total of 20 accident scenarios were analyzed as part of the DDTS (see Figure 2-10), which considered variations in the following parameters (or plant data).
Initiating Event	Plant Design	Type of Break	Throttle ECCS Flow	Operate Containment Sprays
Chart of LOCA Scen in Debris Trans	narios Analyzed sport Study	Main Steam Line Break	Yes (Steaming)	Operated Intermittently Not Opreated
	Mark I Containment		No (Full Flow < 1 Hr.)	Operated Intermittently Not Opreated
		Recirculation Line Break	Yes (Full Flow < 1 Hr)	Operated Intermittently Not Opreated
		The Break	No (Full Flow < 3 Hr)	Operated Intermittently
		Main Steam Line Break	Yes (Steaming)	Operated Intermittently Not Opreated
Scenarios Analyzed	 Mark II Containment		No (Full Flow < 1 hr.)	Operated Intermittently Not Opreated
			Yes (Full Flow < 1 Hr)	Operated Intermittently Not Opreated
		·	No (Full Flow < 3 hr.)	Operated Intermittently Not Opreated
		Main Steam Line Break	No (Full Flow < 1 hr.)	·····
	Mark III Containment	Recirculation Line Break	Yes (Full Flow < 1 Hr) No (Full Flow < 3 hr.)	

Figure 2-10. Accident scenarios analyzed in the study.

#### 2.4.1 Plant Design

Drywell transport factors were derived for all three types of drywell designs: Mark I, II, and III. Plant features that are most common<sup>11</sup> were used to define generic design of each containment type. For example, each containment type was assumed to contain two levels of contiguous floor gratings<sup>12</sup>. Major differences between these containment types as modeled in the study pertained to vent arrangement and ECCS flow rates. These differences were found to significantly impact debris transport during washdown. Other differences between plant types were found to be of secondary importance (e.g., containment volume, structural congestion level) and hence were modeled generically.

#### 2.4.2 Selection of Break Type and Location For each containment type, two breaks were analyzed:

- 1. A double ended guillotine break in the main steam line with full separation of broken ends in the mid-region of the drywell
- A double ended guillotine break in the recirculation line with full separation of broken ends in the mid-region of the drywell

Breaks can occur in the main steam lines, recirculation lines or feedwater lines, all of which are pressurized during normal operation. In this study, breaks in feedwater line were screened out as they were found to have been bounded by postulated breaks in the recirculation lines.

The location of an arbitrarily postulated main steam line (MSL) breaks may vary from the top of the containment where the MSL enters the biological shield to the mid-region where the MSL exits the drywell. Recirculation line break locations can vary from the bottom of the drywell (close to the drywell floor) to the mid-region where the recirculation flow enters/exits the pressure vessel. Examination of drywell piping layout would demonstrate that breaks located in the mid-region of the drywell will subject more target pipes (i.e., insulated primary pipes) to higher pressures than the breaks postulated in either extremes of the drywell. Therefore, it is very likely that breaks located in the mid-region of the containment would generate substantially more debris than other postulated locations. As a result, the study focused on the breaks postulated in the mid-region of the drywell<sup>13</sup>.

#### 2.4.3 ECCS Throttling

In addition to ECCS flow rate, duration of unthrottled ECCS flow also impacts overall debris transport fraction. Transport fractions were derived for throttled and unthrottled conditions. While using the results, it should be noted that throttled ECCS operation is the most likely scenario, and unthrottled conditions occur only because of either an operator error or instrument malfunction.

For a MSLB, throttled conditions assume that the operator throttles ECCS flow after the reactor core is refilled, but before the pressure vessel is completely filled and water starts to overflow through the break. Unthrottled condition, on the other hand, assume that the operator does not throttle ECCS flow and lets it overflow through the broken pipe for an hour after a LOCA. Similarly, in the case of a recirculation line break, throttled condition corresponds to throttling ECCS flow one hour after a LOCA and unthrottled condition assumes continuous operation of ECCS at full flow for three hours.

#### 2.4.4 Drywell Spray Operation

Drywell spray operation in the majority of drywells is a manual function, initiated as a response to high containment pressure and/or high containment temperature. Typically, containment sprays are turned on after ECCS flow is throttled, and are operated intermittently for up to 30 minutes at a drywell time. Some of the containment designs do not possess sprays. For Mark I and II designs, the impact of intermittent operation was quantified assuming 30-minute operation. Mark III containments either do not possess drywell sprays, or are not likely to operate them.

#### 2.5 References

2.1 Zigler et al., "Parametric Study of the Potential for BWR ECCS Strainer Blockage due to LOCA

<sup>&</sup>lt;sup>11</sup> A comprehensive survey of BWR drywells was used to identify most common plant features for each plant type with special emphasis on number and arrangement of floor gratings. <sup>12</sup> Survey indicates that several Mark II drywells contain more than two levels of grating, whereas several Mark Is contain only one grating. Such plant-specific variations can be easily accommodated by modifying appropriate logic trees, as shown in Section 5.

 $<sup>^{13}</sup>$  However, the logic charts were structured to accommodate breaks in other regions of the drywell by simply varying  $\eta_2$  and  $\eta_3$ .

Generated Debris," NUREG / CR-6224, Science and Engineering Associated, Inc., 1995.

- 2.2 D. V. Rao and C. J. Shaffer, "Drywell Debris Transport Study: Calculational Work Final Report," NUREG / CR-6369, Supplement 2, Science and Engineering Associates, Inc., 1997.
- 2.3 K. Williams, "Simulation of a BWR Drywell Flow in Response to a Recirculation –Line LOCA using a Computational Fluid Dynamics (CFD) Code," FSS Report: RX-96-05, Flow Simulation Services, Inc., 1996.
- 2.4 D. V. Rao et al, "Drywell Debris Transport Study: Experimental Work Final Report," NUREG / CR-6369, Supplement 1, Science and Engineering Associates, Inc., 1997.
- 2.5 P. Murthy and M. Padmanabhan, "ECCS Strainer Model Study: Transport and Experimental Studies in a Laboratory Flume," Report 31-94/M216F, Alden Research Laboratory, Inc. 1994.

One of the objectives of the DDTS is to identify physical phenomena/processes and plant features that control and dominate insulation debris transport in the BWR drywell. Experimental data were used to draw the necessary insights.

# 3.1 Controlling Plant Features

Three plant features that control debris transport are: (1) number and arrangement of gratings with respect to the break, (2) vent and drywell floor design, and (3) duration of unthrottled ECCS flow.

## 3.1.1 Effect of Floor Gratings

Experimental data clearly illustrate that drywell floor gratings provide the largest potential for capture of both small and large debris. Figure 3-1 illustrates capture of small debris on wet floor gratings. The measured capture efficiencies varied between 15% and 30% for small debris depending on the flow velocity and relative wetness. But a large fraction of the captured small pieces will be washed down within 30 minutes by containment sprays or within few minutes by break overflow; no washdown is expected in the case of condensate drainage.

In the case of large pieces, the floor grating possesses a capture efficiency of 100%. Figure 3-2 illustrates the capture of large debris on grating. As shown here, the large debris are captured on the surface and cannot be forced through the grating by either blowdown flow or washdown flow. The only mechanism available for its transport is erosion by ECCS flow.

Credit for capture on floor grating should be given subject to the following considerations:

 <u>Capture of small pieces is only possible if the</u> <u>grating surface is wet</u>. Experiments demonstrated that capture efficiency of gratings for small debris are small (6%) if the grating surfaces are not wet<sup>1</sup>.

- 2. <u>If floor gratings do not cover the entire flow cross-</u> section they may not be as effective at debris <u>capture</u>. A survey of the plants suggest that typically one or two floor gratings exist in each plant. In some cases, they cover only a small fraction of the flow cross section and would allow debris to bypass. Other examples include large open holes in the gratings designed to accommodate control valves and piping runs. In all such cases care must be taken to ensure that gratings still provide an effective geometry for capturing debris.
- 3. <u>Combined effects of blowdown and washdown</u> <u>should be considered</u>. For example, smaller debris captured on the grating during blowdown can be washed down by sprays and break flow.

## 3.1.2 Vent and Drywell Floor Design

Experiments were conducted to study the effectiveness of the vents to capture debris. In Figure 3-3, the test setup used to simulate Mark II vents is shown. As shown here, the captured debris was deposited around the vent on the floor or vent plate. These experiments showed that capture at the vents is a significant contributor for removal of small, and large pieces; with an efficiency of 10-15% for small and greater than 30% for large pieces.<sup>2</sup>. However, in order to take credit for debris capture at the vents, the analyst must carefully consider combined effects of blowdown and washdown (i.e., pieces deposited during blowdown may become re-suspended and transported during washdown depending on the hydrodynamic conditions that exit in the pool during washdown phase).

A pool of water that formed on the drywell floor may provide an area where debris might settle during washdown. Analyses conducted as part of the study suggest that significant debris retention might be possible in the pools formed during spray operation. On the other hand, the potential for debris settling is low in pools formed of break overflow because such pools are associated with higher flow velocities and

<sup>&</sup>lt;sup>1</sup> In the case of dry grating, filtration of small pieces by large pieces already deposited on grating is also a possible mechanism for debris removal. At the concentration of present interest its contribution is minimal.

<sup>&</sup>lt;sup>2</sup> In case of recirculation line break potential for debris capture at vents during blowdown could be higher. However, these pieces may become resuspended and advected during washdown.



Figure 3-1. Typical small debris deposition on wet gratings observed in the experiments.



Figure 3-2. Capture of large debris on dry/wet gratings. (The piece is being subjected to 150 ft/s air flow.)



Figure 3-3. Capture of small debris around simulated Mark II vent.

drywell floor can be very effective at retaining debris on the drywell. Further discussions are provided in Section 4 with details provided in NUREG/CR-6369, Supplement 2 [Ref. 3.1].

## 3.1.3 Duration of Unthrottled ECCS Operation

Assumptions related to duration of ECCS operation at full flow following a LOCA play a vital role in debris transport. Figure 3-4 presents photographic illustration of large debris erosion by break flow. Also shown in Figure 3-5, erosion was found to be a constant rate process [Ref. 3.2]. If the ECCS is allowed to operate at full flow for several hours after a LOCA, it is likely that a large fraction of insulation will be eroded and transported to the suppression pool. As a result, the debris transport factor may vary considerably depending on the assumptions related to ECCS operation. In view of this variability, results of the present study were expressed as a function of assumed ECCS response following LOCA. The analyst should select most appropriate accident scenario applicable to the plant under consideration.

# 3.2 Dominant Transport Processes

The following physical processes/phenomena were determined to be controlling transport.

## 3.2.1 Small Debris

Table 2-5 and Figure 2-5 presented a description of small debris. Typically, a majority of this debris is smaller than the grating clearances and can readily pass through them. Analyses and experiments suggest that small debris possess low gravitational velocities (1-3 ft/s in air STP), and tend to stay fully suspended at airflow velocities higher than 10 ft/s (see Section 2.4.1 of Ref. 3.2). The processes that dominate transport of small debris are: advection, inertial capture, washdown and pool hydrodynamics. During blowdown the gratings are the most likely locations for debris capture, followed by other structural congestion, vents and drywell floor. For Mark I and III containments, the most

dominant transport pathways for small debris are:

- 1. Advection during blowdown by steam/water mixtures
- 2. Washdown of pieces previously deposited due to inertial capture by break flow and subsequent advection to vents.

For Mark II containments, the dominant transport mechanisms are slightly different:

- 1. Advection during blowdown by steam/water mixtures
- 2. Washdown of pieces previously deposited due to inertial capture by spray flow and subsequent advection to vents.
- 3. Washdown of pieces previously deposited due to inertial capture by break flow and subsequent advection to vents.

Other transport pathways were found to be of secondary of importance.

## 3.2.2 Large Debris

Experiments were conducted to study if large pieces would be forced through the grating clearances due to: (a) exposure to high velocity steam flow, (b) exposure to high velocity two-phase jet flow typical of recirculation line break, or (c) prolonged exposure to break/spray water flow. The results suggest that large pieces  $(1/8^{th} \text{ or higher in thickness})$  exposed for several minutes to  $150 \text{ ft/s}^3$  airflow neither erode nor are forced through the grating, although pressure drop across the pieces is as large as 0.5 - 1 psi<sup>4</sup>. Finally, washdown experiments documented in Ref. 3.2 also revealed that potential for large pieces being forced through when subjected to break or spray water flow is negligible. Once again substantial erosion might occur over time. For these pieces the most dominant transport pathways are

- 1. Advection of large debris generated below the lowest grating
- 2. Erosion of large debris by break flow and subsequent transport, and
- Advection of large pieces through discontinuities in the floor gratings.

<sup>&</sup>lt;sup>3</sup> Note that flow velocity of 150 ft/s corresponds to a situation in which blowdown flow from a main steam line break flows through 1/8<sup>th</sup> of the drywell cross-section

<sup>&</sup>lt;sup>4</sup> To maximize pressure drop, fine water droplets were added to the airflow.



(a) Before Exposure to Water



(b) After Exposure to Water

Figure 3-4. Erosion of large debris trapped on floor grating by water flow.



# Figure 3-5. Erosion as a function of time for large pieces trapped on floor grating. (Flow is $\cong$ 50 GPM/ft<sup>2</sup>)

## 3.2.3 Large-Canvassed

The study concluded that transport of large canvassed pieces is unlikely either by advection or by erosion. Therefore, these pieces were classified as "non-transportable."

## 3.3 References

- 3.1 D. V. Rao and C. J. Shaffer, "Drywell Debris Transport Study: Calculational Work Final Report," NUREG / CR-6369, Supplement 2, Science and Engineering Associates, Inc., 1997.
- 3.2 D. V. Rao et al, "Drywell Debris Transport Study: Experimental Work Final Report," NUREG / CR-6369, Supplement 1, Science and Engineering Associates, Inc., 1997
- 3.3 NEDO-32686, "Utility Resolution Guidance for ECCS Suction Strainer Blockage," Boiling Water Reactor Owners' Group, 1996.

# 4. Quantification of Logic Charts

Logic charts were used to integrate analytical predictions and experimental data related to debris generation, blowdown transport, washdown and erosion, and drywell floor transport. A separate logic chart was developed for each of the twenty postulated LOCA scenarios in BWR Mark I, II and III containments to properly account for scenariospecific variations in the thermal and hydraulic conditions that exist in the drywell. Appendix A presents a complete listing of all the logic charts developed in this study. In this section, two accident sequences are analyzed in detail to illustrate the methodology and delineate various approaches used to account for the effect of each physical process.

Debris transport in the drywell is a complex process involving several coupled phenomena. Mechanistic modeling of such a process is not practical. Where necessary, reasonable approximations' were sought to de-couple the problem into separate steps that would enable the use of simple models in place of detailed mechanistic models that would otherwise have to be developed. Resulting first-order models were intentionally configured to provide conservative estimates for each step of the coupled problem. Such conservative estimates were then compounded to obtain the upper bound estimate for debris transport. More realistic central estimates were obtained by refining some of the underlying assumptions to more accurately reflect the expected plant conditions. Accordingly, an upper-bound and a central estimate logic tree was developed for each scenario. The rationale used for each approximation in the analyses is described below. Section 2 may be consulted for definitions of various terms used below.

# 4.1 Main Steam Line Break Logic Chart

The accident scenario analyzed here is a postulated MSLB in a Mark I drywell. The break was assumed to be in the mid-region of the containment where it is likely to generate the maximum amount of debris. In this scenario, it was assumed that the operator would throttle the ECCS after recovering the

pressure vessel level, but before any significant water spillage from the broken end. Also, it was assumed that the operator would initiate the containment sprays and would run them for thirty minutes in response to elevated containment pressure and temperature. In the reference plant being analyzed, the drywell vents are offset from the floor by 18-inches resulting in a drywell floor pool capable of holding 8000 gallons of water before significant overflow into the vents. The drywell has two gratings, both covering 100% of the flow crosssectional area with no significant chances for debris to bypass the gratings. The drywell free-volume is 120,000 ft<sup>3</sup>, with 41% of it above the top grating, 37% between the two gratings and 22% below the lower grating. Typical drywell structures occupy the volume above, below and between the gratings. No plant specific features were considered. For example, this plant has large air handling units located close to the vent entrances, which would provide large surface area for debris deposition, but their ability to capture debris was ignored.

Figures 4-1 and 4-2 present the logic charts developed to deduce upper bound and central estimates, respectively, for the transport factor. Consistent with postulated debris transport pathways (see Figure 2-2), these charts de-couple the overall problem into four sequential (but independent) processes: debris generation, distribution after blowdown, erosion and washdown, and transport via the drywell floor pool. A series of analyses and experiments were undertaken to develop necessary understanding regarding each of these processes. The following sections describe important findings related to each process and how they were utilized to derive upper bound and central estimates.

#### 4.1.1 Debris Generation

The debris generation data provide boundary conditions for all the subsequent processes. The scoping analyses [Ref. 4.1] have shown that debris transport is influenced most by the following parameters related to debris generation: a) duration of debris generation, b) location of debris generation, c) medium of transport, d) debris wetness, and e) size

<sup>&</sup>lt;sup>1</sup> Analytical models and experimental data were used to assure that all approximations are defensible and that they provide conservative (if not accurate) representation of the phenomena of interest.

## Quantification of Logic Charts

LOCA Type (Section 4.1)	Debris Classification (Section 4.1.1)	Distribution After Blowdown (Section 4.1.2)	Erosion and Washdown (Section 4.1.3)	Drywell Floor Pool (Section 4.1.4)	Path No.	Fraction (Section 4.1.5)	Final Location
	l	Advected to Vents			1	1.958E-01	Vents
MARK I		0.89 Enclosures		······	2	0.000E+00	Enclosures
UPPER BOUND		0.00			,	0.000 - 100	Vente
MSL BREAK		D		0.00	3	0.000E+00	vents
ECCS THROTT	LED	0.00		Sediment	4	0.000E+00	Floor
SPRAYS OPERA	TED			1.00			
	TION			Waterborne	5	0.000E+00	Vents
FIBROUS INSUL	LATION		Condensate Drainage	0.10			
		St	0.10	Sediment	6	0.000E+00	Floor
	Small Pieces	Structures-Above	Adheres	0.90	7	0.000E+00	Structures-Above
	0.22		0.90				••
				Waterborne	8	6.600E-04	Vents
			Sprays/Condensate	0.10			
		Structures Break	1.00	Sediment	9	5.940E-03	Floor
		0.03	Adheres	0.90	10	0.000E+00	Structures-Break
		0.05	0.00				
				Waterborne	11	1.760E-03	Vents
			Sprays/Condensate	0.10			
		Stratures Other	1.00	Sediment	12	1.584E-02	Floor
		0.08	Adheres	0.90	13	0.000E+00	Structures-Other
			0.00				
				Waterborne	14	1.500E-03	vents
	1		Sprays/Condensate				
		Structures Break	0.02	Sediment	15	0.000E+00	Floor
		0.25	Adheres	0.00	16	7.350E-02	Structures-Break
			0.98	W	17	4 5005 02	Vanta
					17	4.300E-03	vents
	Large-Above		Sprays/Condensate				
	0.30	Structures_Other	0.02	Sediment	18	0.000E+00	Floor
		0.75	Adheres	0.00	19	2.205E-01	Structures-Other
MSL Break		Advected to Vent	0.98		20	8.000E-02	Vents
1.00	1	1.00				0.0001-02	,
1	1	Enclosures			21	0.000E+00	Enclosures
	Large-Below	0.00		Waterborne	22	0.000E+00	Vents
	0.00			0.00			
		Drywell Floor		i Sediment	21	0.000E+00	Floor
		0.00		1.00	2.2	0.0000100	11001
				W		0.0005.000	V
				waterborne	24	0.000E+00	v ents
			Sprays/Condensate				
		Structures Break	0.02	Sediment	25	0.000E+00	Floor
		0.00	Adheres	1.00	26	0.000E+00	Structures-Break
			0.98	Waterborne	27	0.0005+00	Vonto
				waterborne	21	0.0008+00	y ents
	1		Sprays/Condensate				 
		Structures-Other	0.02	[Sediment	28	0.000E+00	Floor
		0.00	Adheres	1.00	29	0.000E+00	Structures-Other
	Comment		0.98		20	4 000 - 01	Structures/Eleon
1	0.40				50	4.000E-01	Suuciares/Floof

note: Fractions are normalized to each debris class



LOCA Type (Section 4.1)	Debris Classification (Section 4.1.1)	Distribution After Blowdown (Section 4.1.2)	Erosion and Washdown (Section 4.1.3)	Drywell Floor Pool (Section 4.1.4)	Path No.	Fraction (Section 4.1.5)	Final Location
		Advected to Vents		**************************************	1	1.144E-01	Vents
MARK I		0.52 Enclosures	· · · · · · · · · · · · · · · · · · ·	1	2 0007 01		
CENTRAL ESTI	MATE	0.01			2	2.2008-03	Enclosures
MSL BREAK				Waterborne	3	0.000E+00	Vents
		Drywell Floor		0.00			
ECCS THROTTI	LED	0.01		Sediment	4	2.200E-03	Floor
SPRAYS OPERA	TED	Í		1.00			
FIBROUS INSUL	ATION			Waterborne	5	8.800E-07	Vents
			Condensate Drainage	0.01			
		Structures-Above	0.01	Sediment	6	8.712E-05	Floor
	Small Pieces	0.04	Adheres	0.33	7	8.712E-03	Structures-Above
	0.22		0.99	Waterborne	8	1 100E-04	Vante
				0.01			7 this
			Sprays/Condensate	Sediment	Q	1.089E-02	Floor
	÷	Structures-Break		0.99		1.0092-02	FIOO
		0.10	Adheres 0 50		10	1.100E-02	Structures-Break
			0.00	Waterborne	11	3.520E-04	Vents
			Sprays/Condensate	0.01			
			0.50	Sediment	12	3.485E-02	Floor
		0.32	Adheres	0.99	13	3 520E-02	Structures-Other
			0.50				Suddares-Outer
			I	Waterborne	14	5.100E-04	Vents
		,	Sprays/Condensate	1.00			
		Structures-Break	0.01	Sediment	15	0.000E+00	Floor
		0.15	Adheres		16	5.049E-02	Structures-Break
			0.99	Waterborne	17	2.890E-03	Vents
	Lorge About			1.00			
	0.34	Γ	0.01	Sediment	18	0.000E+00	Floor
	l	Structures-Other	i dharaa	0.00			
MSL Break		0.85 L	0.99	<u>.</u>	19	2.861E-01	Structures-Other
1.00	r	Advected to Vent			20	3.600E-02	Vents
		Enclosures			21	4.000E-04	Enclosures
	Large-Below	0.01		Waterborne	22	0.000E100	
	0.04		ſ	0.00		0.0002+00	y ents
		Drywell Floor 0.04		Sediment	23	1.600E-03	Floor
			Ľ	1.00	23	1.000E-05	rioù
			,	Waterborne	24	0.000E+00	Vente
				0.00		0.0001100	venis
		5	Sprays/Condensate	Sediment	25	4 000E-06	Floor
	1	Structures-Break		1.00		4.0002-00	11001
	1	0.01	Adheres		26	3.960E-04	Structures-Break
		· · · · · · · · · · · · · · · · · · ·		Waterborne	27	0.000E+00	Vents
		5	Sprays/Condensate	0.00			
	l.		0.01	Sediment	28	1.600E-05	Floor
	E	0.04	Adheres	1.00	29	1.584E-03	Structures-Other
	anvasced	L (	0.99				Su uciui es-Olifei
	140				30	4.000E-01	Structures/Floor

note: Fractions are normalized to each debris class



distribution of generated debris. Debris size classification information was explicitly used in Figures 4-1 and 4-2 under the "debris classification" heading. Information gathered on the other three processes was used in the latter part of the logic tree quantification.

#### 4.1.1.1 Key Findings

Figure 2-3 provides an overview of various analyses performed to develop basic understanding of debris generation by steam jets in a BWR drywell. These analyses included:

- RELAP calculations to estimate break flow, including its thermodynamic state, as a function of time,
- CFD calculations to draw insights related to deflection of gaseous jets by typical drywell structures located in its path,
- Review of experimental data related to debris generation by expanding air jets, and
- Review of limited experimental data on debris generation by steam jets.

In addition, two bench-top experiments were conducted to draw insights related to debris wetness following a postulated main steam line break. NUREG/CR-6369, Supplement 2 documents some of these calculations and their results in detail. Important conclusions of these analyses are as follows:

Debris generation occurs within seconds after LOCA. The duration of debris generation is important to determine the thermal and hydraulic conditions to which the debris is subjected during its transport. Debris generation was known to be strongly dependent on the flow dynamic pressure at the target pipe [Ref. 4.3]. The dynamic pressure, defined as  $\rho v^2/2g_{,,}$  is dependent on the flow velocity and pressure at the break plane (i.e., higher flow velocities and pressure at the nozzle would translate into higher dynamic pressure at the target). As shown in Figure 4-3, the steam flow velocity at the break exit plane remains nearly sonic for the first twenty seconds, although it decreases slightly from 900 ft/s to 800 ft/s. During the same time, however, the fluid density decreases rapidly due to reduction in the vessel pressure from 1050 psi to 300 psi. As a result, the dynamic pressure on a target located in the close vicinity of the break falls rapidly with time, decreasing to a third of its initial value within the first five seconds. Because, debris generation is directly proportional to the jet dynamic pressure [Ref. 4.2], it can be concluded that majority of the debris would be generated within the first five seconds. For the sake of simplicity, it is reasonable to assume that debris generation occurs instantaneously after a LOCA<sup>2</sup>.

- 2. Debris generation is limited to a zone of influence surrounding the break. Further destruction or degradation of the debris outside the zone of influence is negligible. This approximation is vital to de-couple the problem that would enable modeling debris transport independent of debris generation<sup>3</sup>. Analytical efforts were undertaken to study jet expansion in the zone of influence, when subjected to structural congestion typical of the drywell midregion. These studies found that the same processes that generate debris from the target pipes would also deflect and diffuse the jet within the zone of influence. Therefore, at the exit of the zone of influence<sup>4</sup> the flow velocities would be in the range of 50-100 ft/s. Flow velocities in the remainder of the drywell are in the range of 30-45 ft/s, with the exception of the neck region where flow velocities as high as 100 ft/s are possible. Experiments were conducted to study if gas velocities as high as 150 ft/s can cause any damage to debris [Ref. 4.3, Section 2, Tests 41 through 44]. These tests have shown that no damage would be expected in the region outside the zone of influence.
- 3. Steam is the medium of transport. Medium of transport affects pathways available for transport. For example, debris entrained by steam would be distributed through out the drywell. On the other hand, water-borne debris would be carried downward to the drywell floor without interaction with a majority of drywell structures. Calculations were undertaken to determine the constituents of the break flow and draw conclusions related to the medium of transport. As shown in Figure 4-3, these calculations suggest that a primarily dry

<sup>&</sup>lt;sup>2</sup> Sensitivity analyses suggest that transport factors are weakly dependent on this assumption. It was found to result in a slightly conservative estimate of debris transport factor.

<sup>&</sup>lt;sup>3</sup> If such an approximation is invalid, then more complex modeling effort integrating debris generation and transport would be necessary.

<sup>&</sup>lt;sup>4</sup>The zone of influence tends to be hemispherical for a postulated single-ended MSLB in a congested region.



Figure 4-3. Blowdown data corresponding to a postulated main steam line break in a BWR/4 plant.

steam jet expands into the containment with an equilibrium quality at the stagnation point greater than 0.8 over the first twenty seconds. The corresponding equilibrium void fraction is 0.99. Therefore, it is very likely that debris are entrained and transported through the drywell by steam continuum, with suspended water droplet field.

- 4. The debris would be nearly dry. Wet debris tends to be heavier (i.e., higher inertia) and will be more likely to impact the structural impediments in their path and adhere to them. Two bench-top experiments were conducted as part of this study (Ref. 4.4) to establish likely debris wetness following a MSLB. In the first one, the fiberglass insulation fragments of different size were held stationary and were continually exposed to up to 2 minutes of steam flowing across it. In the second test, a small-scale steam jet from an industrial boiler was used to fragment the aged insulation blanket. In both cases, debris weight was measured while they were wet and after they were completely dried. A maximum increase in weight of 20% was noted in these tests with all the condensed water film on the outer surface; the bulk of the fragment volume was essentially dry. Such a slight increase is unlikely to effect transport or capture. Therefore, it is reasonable to assume that debris would be dry. Note that this assumption minimizes the potential for debris capture in the drywell.
- 5. Debris size distribution is uncertain. Typical sizes of the debris as they exit the zone of influence and the mass of debris belonging to each size group are vital components necessary to estimate overall transport factor. Existing data suggest that generated debris can be generally characterized as small, large and large-canvassed. Past experiments have provided some data that can be used to derive debris size distribution typical of main steam line breaks (see Section 5). However, any such effort would be associated with large uncertainties. No attempts were made as part of this study to develop applicable debris size distribution.

#### 4.1.1.2 Upper Bound Estimates

Sizes of the debris as they exit the zone of influence are a crucial input necessary to determine applicable

transport pathways. Existing experimental data suggest that fibrous insulation debris can be broadly classified into three size groups, small, large and large-canvassed. Also, experiments conducted as part of this study established that gratings are effective at capturing all the large debris transported to them by steam or water flow. Hence, it is likely that large debris generated above the lowest grating would follow substantially different pathways compared to those generated below. To accommodate these differences, the large debris were further divided into two groups: large-above and large-below. The focus of this study was to obtain transport factors for each of these debris sizes (i.e., small, large-above, large-below, and large canvassed). To meet this objective, a value of 1.0 was assigned for  $\eta_{12}$   $\eta_{22}$   $\eta_{32}$ and  $\eta_4$  in Figure 4-1. Such a choice automatically normalizes values under the heading "Fractions" to each size class (i.e., all fractions belonging to each size class add up to 1.0). Section 5 describes how the actual size distribution data, if available for the particular scenario of interest, can be used to calculate the overall transport factor (F<sup>ZOI</sup>).

#### 4.1.1.3 Central Estimates

Same approach as above.

#### 4.1.2 Distribution at the End of Blowdown

The objective of this step was to estimate where the debris would be located at the end of blowdown. The allowable final locations are *vents* (*suppression pool*), *enclosures*, *structures-above*, *structures-break*, *structures-other* and *drywell floor*. As the initial (or boundary) condition, it was assumed that dry debris exits the zone of influence, and that, due to high flow velocities, debris deposition is negligible within the zone of influence. Finally, it was assumed that all of the debris is entrained and transported by steam flow. During transport outside the zone of influence the debris would not undergo further destruction or reattachment.

Subject to these conditions, the fraction of debris advected to vents during blowdown can be expressed as:

$$\mathbf{F}_{bd}^{i} = \left(1 - \mathbf{X}_{en}^{i} - \mathbf{X}_{sa}^{i} - \mathbf{X}_{sb}^{i} - \mathbf{X}_{so}^{i} - \mathbf{X}_{df}^{i}\right)$$

Where,  $F^{i}_{bd}$  is the blowdown transport factor for i<sup>th</sup> size debris, and  $X^{i}_{en}$ ,  $X^{i}_{sa}$ ,  $X^{i}_{sb}$ ,  $X^{i}_{so}$ , and  $X^{i}_{df}$  are

capture fractions associated with *enclosures*, *structures-above*, *structures-break*, *structures-other*, and *drywell floor*, respectively. Each of these individual fractions are the product of the fraction of debris carried into that region by gas flow and the efficiency of the structures in that region to capture  $i^{th}$  size debris. Analyses and experiments were conducted to draw insights related to both these phenomena.

#### 4.1.2.1 Key Findings

An analytical approach was adopted to estimate the quantity of debris being carried into each region of the containment. For this purpose, CFD simulation of the drywell was undertaken to determine likely bulk flow patterns that would exist in the drywell following a LOCA. These CFD calculations utilized break flow estimates from RELAP simulations as a boundary condition. To minimize computational effort, the actual drywell structures were not modeled. Instead, porous media with a pressure drop approximated structural impediments to flow. The resulting bulk flow patterns were utilized to draw conclusions related to debris movement.

In addition, experiments were conducted to study capture efficiencies associated with drywell structures assembled to prototypical congestion levels. Experimental data were obtained for a wide range of conditions determined to be representative of drywell thermal and hydraulic conditions corresponding to different accident scenarios. These experiments clearly established that structural wetness plays a vital role in deposition. Hence, further analytical efforts were devoted to draw insights related to the build-up of water film on drywell structures. Based on all these analyses, the following conclusions were drawn related to debris transport outside the zone of influence:

 Debris becomes intermixed with the containment atmosphere. Immediately after LOCA (t ≈0 s), vent flow is minimal due to large frictional losses at the vent entrance and presence of water in the down-comers<sup>5</sup>. During this time (< 1.0 second after LOCA), the break flow is primarily used to pressurize the containment. CFD simulations suggest that strong recirculating flow patterns exist in the drywell during this short interval, leading to nearly uniform concentration of debris within the drywell. This finding was used to set the initial conditions for transport (i.e., uniform concentration of small debris in the drywell at t=0 s).

- 2. Vents clear shortly after LOCA. Debris advection to suppression pool commences once the vents clear. Several MELCOR<sup>6</sup> analyses were conducted to estimate time taken for vent clearance in Mark I and Mark II containments (see Figure 4-4) [Ref. 4.6]. For the smallest of the operating BWR drywells (free-volume  $\approx 125,000 \text{ ft}^3$ ), vents were predicted to be cleared in 0.5 seconds after assuming that no condensation occurs in the drywell (either on structures or due to isentropic jet expansion). For an average size drywell (140,000 ft<sup>3</sup>) coupled with more realistic estimates of steam condensation, vents were cleared at 0.8 seconds. After vents cleared, the drywell was maintained at a quasi-steady pressure of 45 psia for about 30 seconds. As shown in Figure 4-4, during this quasi-steady state, the flow rate closely follows the breakflow shown in Figure 4-3.
- 3. Moderate flow velocities and relatively simpler bulk flow patterns drive debris transport outside the zone of influence. Figure 4-5 illustrates typical bulk flow patterns expected in the drywell following MSLB [Ref. 4.5]. This corresponds to the case in which direction of the break flow is horizontal and the vents are cleared at 0 seconds. Several such runs with different break orientations were used to draw insights related to likely flow patterns that would exist in the drywell following a LOCA. These calculations suggest that flow velocities in the majority of the drywell would be in the range of 25-45 ft/s, with the exception of the neck region where they may as high as 100 ft/s. The bulk flow patterns would cause continuous mixing of the debris with drywell atmosphere. It is likely that at any given time mass of debris advected to vents can be approximated by a simple volume turnover model.
- 4. Debris advection by blowdown flow occurs on a short time scale. Analyses have shown that the

<sup>&</sup>lt;sup>5</sup> In Mark I and II drywells, down-comers would be occupied by water slug 4-6 ft in height.

<sup>&</sup>lt;sup>6</sup> MELCOR was used because it already has a detailed vent model.



Quantification of Logic Charts

Figure 4-4. MELCOR predictions for drywell thermal hydraulics response following a MSLB.

4-8



Figure 4-5. CFD code predictions for quasi-steady flow patterns that exist in the drywell following a MSLB.

rate at which debris is advected from the drywell is a product of the concentration in the drywell and the volumetric flow rate. For fully mixed flow conditions, assuming debris generation at 0 seconds and no removal from the flow, the fraction of generated debris that would be advected during t seconds can be calculated from the mass conservation equation as:

$$F(t) = (M_{o} - M(t)) / M_{o} \equiv 1 - e^{-(t - T_{vent})/\tau}$$
(4-1)

where,

F(t)	=	fraction of initial inventory
		transported in t seconds.
Mo	=	= debris mass inventory in the
		drywell at t=0,
М	=	debris mass inventory in the
		drywell at t,
T <sub>vent</sub>	=	time required to clear
		vents/downcomers (0.5 –1.0 s
		for Mark I)
τ	=	turnover time <sup><math>7</math></sup> (3.4, 4.2 and 5.4
		seconds, for Mark I, II and III)

For a Mark I drywell ( $T_{vent} = 0.75 \text{ s}$  and  $\tau = 3.4 \text{ s}$ ), the transport factor is 0.40, 0.71, 0.93 and 0.98 corresponding to t=2.5, 5, 10, and 15 seconds, respectively. Therefore, the debris that remains in suspension would be advected to the vents by blowdown flow within the first 15 seconds. During these first 15 seconds, the containment conditions remain quasi-steady. Hence, it is not necessary to undertake a transient debris transport analysis. This conclusion was used to simplify transport models significantly.

Potential for gravitational settling of debris is negligible. Gravitational settling is one mechanism by which debris can be removed from the flow. For quiescent flow, debris terminal velocity<sup>8</sup> is a good indicator of the

potential for debris removal by this mechanism. In a turbulent flow (such as that expected in the drywell), the flow turbulence can reduce likelihood of debris falling out due to gravitational settling. It has long been known that gravitational settling is negligible if the root-mean-square turbulent velocity is higher than the terminal velocity of the suspended particle. The CFD calculations were undertaken to estimate turbulent kinetic energy (which is a measure of the RMS velocity) in different regions of the drywell as a function of time. These calculations suggested that turbulent kinetic energy in the bulk of the containment atmosphere following a MSLB is greater than 24 joules/kg. Corresponding turbulence root-mean-square velocity is approximately 21 ft/s, which is far in excess of the debris fragments terminal velocity of 2-5 ft/s. Therefore, it can be concluded that containment flow dynamics and turbulence levels would be sufficient to keep debris in suspension. This conclusion is further validated by separate effects tests (Ref. 4.3, Section 2.4.1). Also note that neglecting gravitational settling results in higher transport.

- 5. A fraction of the generated debris would be captured by structures. Experiments conducted at similar operating conditions clearly demonstrated that small and large debris would be captured on gratings and other drywell structures. The fraction captured was found to be a strong function of the structural wetness, and types of structures located in each region.
- 7. Structural wetness varies with time. Experiments and analyses have shown that small and large debris possess enough inertia to impact the structures as they are carried across them by bulk gas movement. If the structures are dry, however, the debris will not adhere to them. On the other hand, wet structures can be effective at removing debris from the flow stream. Therefore, considerable analytical effort was undertaken to study various means by which drywell structures would become wet. Condensation of steam on relatively cool drywell structures and water droplet

<sup>&</sup>lt;sup>7</sup> Turn over time is defined as the ratio of "mass of drywell atmosphere at 45 psia corresponding to quasi-steady condition (lb.)" to "break flow rate (lb./s)".

<sup>\*</sup> Terminal velocity is a measure of particle inertia and is equal to its gravitational settling velocity in quiescent air (or water). Usually a particle will remain in suspension if its terminal velocity is much lower than the flow root-mean-square velocity.

deposition<sup>9</sup> on drywell structures were identified as two mechanisms that would wet outer surfaces of the structures. MELCOR calculations were used to estimate water film buildup on the structures due to steam condensation alone. As shown in Figure 4-6, condensation occurs rather quickly with water film building up to 75 µm within the first second. Also, it would take approximately

2 seconds for the liquid film thickness to reach a saturated state<sup>10</sup>. Liquid film buildup would likely be faster than shown in Figure 4-5 due to water droplet deposition, which was not considered in the MELCOR analyses. This information was used during the design of experiments described in Ref. 4.2. In these experiments, the capture data was obtained for all three possible surface conditions: dry, wet ( $\approx$  75-µm water film) and saturated ( $\approx$  150-µm water film).

#### 4.1.2.2 Upper Bound Estimates

As evident from the discussions above, several uncertainties exist in the predictions related to vital thermal-hydraulic phenomena, including vent clearance time and structural wetness. The upper bound transport factors were obtained by assuming "worst-case" T/H response.

#### Transport of Small Debris

Figure 4-7 illustrates the logic used to predict distribution of *small* debris in the drywell at the end of blowdown. It is based on the following assumptions:

- 1. Debris is generated instantaneously after the LOCA (t=0 sec)
- 2. Vents are cleared of water and quasi-steady venting starts at 0.5 s after LOCA ( $T_{vent} = 0.5$  s). The most likely time for vent clearing would be closer to 0.8 s. On the other hand, it would not be lower than 0.5 s, which represents the worst case.

- 3. All structures would be dry for the first two seconds. This assumption is very conservative considering that MELCOR calculations suggested that the film thickness on majority of structures due to steam condensation alone would be as high as 75  $\mu$ m within the first second (see Figure 4-6). Even higher thicknesses are likely if film buildup due to water droplet deposition is considered.
- 4. No capture of small debris during the first 2 seconds. Tests have shown that dry pipes and I-beams would not capture small debris. On the other hand, the dry gratings would have capture efficiency of approximately 6% [Ref. 2.4]. To be conservative, however, it was assumed that no deposition occurs on any structures during the first 2 seconds.
- Approximately 35% of the small debris would be advected to the vents within the first two seconds. Subject to above assumptions, the fraction of small debris advected to vents can be estimated as

$$F_{2sec}^{s} = 1 - \exp(-(2 - T_{vent})/\tau)$$
 (4.2)

Using  $T_{vent} = 0.5$  s and  $\tau = 3.4$  s,  $F_{2sec}^{s}$  is estimated to be 0.35, which is the value used in Figure 4-7 for the fraction of debris transported in the first two seconds. The remaining 65% of the debris would be uniformly distributed in the drywell at the 2-second mark.

- 6. Debris contained in the upper region at the end of 2 seconds will pass through two gratings, while the debris contained in the middle region goes through one grating. The debris contained in the lower region does not go through any gratings. This picture of transport is consistent with the bulk flow patterns expected in the drywell following a MSLB (see Figure 4-5).
- 7. Ratios of the drywell volume contained above the highest grating (upper region), between the two gratings (middle region) and below the lowest grating (lower region) are 0.41, 0.37 and 0.22, respectively. These values were obtained by proportioning the drywell inventory according to the volume of each region.
- Debris would be captured at the floor gratings with an efficiency of 15%. Capture of debris on structures other than gratings is negligible (including vents). Figure 4-8 illustrates the measured capture efficiency of the floor gratings

 $<sup>^{\</sup>circ}$  Water droplets are introduced into the containment when the steam jet over expands (shocks) in the containment. The wave stability calculations suggest that these droplets will likely be in the range of 10-20  $\mu$ m in diameter.

<sup>&</sup>lt;sup>10</sup> Saturation condition corresponds to a situation in which addition of water by condensation is off-set by film drainage by gravitational and entrainment mechanisms.



Figure 4-6. Liquid film build-up on drywell structures due to steam condensation.

commonly employed in BWR drywells. Measured capture efficiency for wet gratings varied between 15-35%, with a mean value of 25%. In the present calculation, a capture efficiency of 15% was assumed. The remaining 85% would be transported downwards. These split fractions (0.15 and 0.85) were used to quantify each subsequent branch in Figure 4-7.

As shown in Figure 4-7, the upper bound identifies four pathways for transport of **small** debris to the vents during blowdown:

- 1. Advection of 35% of the small debris generated during first two seconds when the drywell structures are dry,
- 2. Advection of 100% of the debris contained in the lower region of the drywell at the end of 2 seconds,
- 3. Advection of 85% of the debris contained in the middle region at the end of 2 seconds, and
- 4. Advection of 72.25% of the debris contained in the upper region of the drywell after accounting for capture at both gratings.

Together these pathways resulted in transport of 89% of the small debris to the vents during blowdown. The remainder (11%) was deposited on the floor gratings located below the spray heads. Assuming uniform flow conditions, a quarter of this captured debris was assumed to be on the grating located directly underneath the break (*structures-break*) and the remaining 75% is assumed to have been on the rest of the grating (*structures-other*). Thus a value of 0.03 and 0.08 were used for  $X_{sb}^{s}$  and  $X_{so}^{s}$  in Figure 4-1. The remaining factors ( $X_{sm}^{s}$ ,  $X_{sm}^{s}$ , and  $X_{sd}^{s}$ ) were assigned 0.

#### Transport of Large Debris

Advection of 100% of the *large-below* debris to the vents was assumed. This assumption is supported by CEESI tests in which large debris pieces (1.5 ft. x 1.5 ft.) were transported horizontally up to 50 feet. Factors  $X_{en}^i$ ,  $X_{sa}^i$ ,  $X_{sb}^i$ ,  $X_{so}^i$ , and  $X_{df}^i$  were assigned a value of zero signifying no capture of *large-below* debris in the drywell.

It is assumed that all the *large-above* debris would be captured on the gratings. <u>Implicitly, it was assumed</u> that floor grating covers the entire flow cross-section without allowing any chance for bypass. A quarter of this captured debris was assumed to be on the grating located directly underneath the break (*structures-break*) and the remaining 75% is assumed to have been on the rest of the grating (*structures-other*). Thus a value of 0.75 and 0.25 were used for  $X^{i}_{so}$  and  $X^{i}_{sb}$  in Figure 4-1. The remaining factors ( $X^{i}_{en}$ ,  $X^{i}_{sa}$ , and  $X^{i}_{df}$ ) were assigned 0.

#### 4.1.2.3 Central Estimates

The central estimates were based on assumptions that were judged to be more representative (or realistic) of debris transport in the drywell. As discussed below, even the central estimates possess a certain margin of conservatism.

#### Transport of Small Debris

The rationale used for deriving the central estimate of debris distribution at the end of blowdown is illustrated in Figure 4-9. The fundamental differences between central estimate and upper bound estimate are as follows:

- 1. Vents clear of water at 0.75 s after LOCA. The sensitivity analyses suggested that 0.75 seconds is more representative of the Mark I and II Drywells.
- 2. Before the vents clear, 10% of the small debris would be captured on the two gratings together. These values were obtained by combining the CFD calculation results with the experimental data. The CFD runs suggested that a debris particle generated at the break location and carried by steam flow without slip would pass through at least two gratings within the first 0.75 seconds. For conditions typical of this 0.75 seconds (low structural wetness and high velocities), a single grating capture fraction of 6-9% was measured in the separate effects tests (Ref. 4.3, Section 2, Test 26). For two successive gratings estimated capture efficiency is 12 to 18%. However, a value of 10% was used in this study, which is conservative.
- 3. Drywell structures contained in upper, middle and lower regions (other than the gratings) will remove 10% of the debris passing through them. The structural assemblies in the upper, middle and lower regions were found to have combined surface area for deposition larger than the structures used in the CEESI facility for which a capture efficiency of 10% was measured (see Figure 4-10). Note that structures used in the CEESI testing were selected based on a survey of

Initiating Event	Surface Wetting	Distribution in Drywell	Interaction with Upper Grating	Interaction with Lower Grating	Interaction with Vent Structures and Floor	Path	Fraction	To Vent	Location of Debris
	Incomplete			l		1	3.5000E-01	×	Transported Into Vent Downcomers
				Goes by	Goes by 1.00	2	1.9255E-01	X	Transported Into Vent Downcomers
		OUND ESTIMATE	Goes By	0.85	Captured	3	0.0000E00		Deposited onto Floor Near Vents
Small Pieces 1.00	-	Upper Region 0.41	0.85	Captured 0.15		4	3.3979E-02		Structures Below Spray Heads
			Captured 0.15			5	3.9975E-02		Structures Below Spray Heads
				Goes By 1.	Goes By 1.00	- 6	2.0443E-01	X	Transported Into Vent Downcmers
	Complete 0.65	Middle Region		0.85	Captured	7	0.0000E00		
		0.37		Captured 0.15		- 8	3.6075E-02		
		Lower Region				9	1.4300E-01	X	Trasported Into Vent Downcomer
		0.22			Captured	- 10	0.0000E00		Deposited onto Floor Near Vents

Figure 4-7. Secondary logic tree used to evaluate upper bound debris distribution after blowdown.



Figure 4-8. Efficiency for capture of small debris by floor grating.

Debris Size Classification	Distribution at Time of Vent Clearance	Distribution in Drywell	Interaction with Structures in Upper Region	Interation with Upper Grating	Interaction with Structures in Middle Region	Interaction with Lower Grating	Interaction with Structures in Lower Region	Interaction with Vent Structures and Floor	Path	Fraction	To Vent	Location of Debris
	Structures (A	bove)							1	2.0000E-02		Structures Above Spray
	0.02 Structures (B	lelow)							2	8.0000E-02		Structures Below Spray
	0.08 Enclosures								3	1.0000E-02		Enclosures
	0.01						Goes By	Goes By	4	1.4814E-01	X	Transported Into Vent Downcomers
		BWR MARK I				Goes By	0.90	Captured 0.01	5	1.4963E-03		Deposited onto Floor Near Vents
	CE	NTRAL ESTIMA	TE		Goes By	0.75	Captured 0.10	ed	6	1.6626E-02		Structures Below Spray Heads
Small Pieces	Goes By			Captured 0.25				7	5.5419E-02		Structures Below Spray Heads	
1.00	Goes By Cap				Captured 0.10				- 8	2.4631E-02		Structures Below Spray Heads
		Upper Region	0.00	Captured					ø	8.2103E-02		Structures Below Spray Heads
	0.41		Captured (Ab	ove)				·····	10	1.8245E-02		Structures Above Spray Heads
			Captured (Be	Captured (Below)						1.8245E-02		Structures Below Spray Heads
		0.00					Goes By	Goes By	12	1.9805E-01	X	Transported Into Vent Downcomers
						Goes By	0.90	Captured 0.01	- 13	2.0005E-03		Deposited onto Floor Near Vents
	Airborne 0.89	1			Goes By	0.75	Captured 0.10		14	2.2228E-02		Structures Below Spray Heads
		Middle Region			-	Captured 0.25			15	7.4092E-02		Structures Below Spray Heads
		0.37	Captured 0.10				16	3.2930E-02		Structures Below Spray Heads		
							Goes By Goes By 0 99		17	1.7446E-01	X	Transported Into Vent Downcomers
		Lower Region					0.90	Captured 0.01	18	1.7622E-03		Deposited onto Floor Near Vents
		0.22					Captured 0,10		19	1.9580E-02		Structures Below Spray Heads

Page 1 - 1

Figure 4-9. Secondary logic tree used to obtain the central estimate for debris distribution after blowdown.

Quantification of Logic Charts



structures that exist in various regions of the BWR drywell. Also, the debris residence in the structural region of CEESI is much smaller than that expected in the BWR drywell. Thus direct use of CEESI data is reasonable, although it may underestimate capture. *Each grating removes an additional 25% of the debris passing through them.* As shown in Figure 4-8 above, central estimate for grating capture efficiency is 25%.

- 4. *Vents capture 1% of the debris.* In the CEESI tests, Mark I vents were found to be ineffective at capturing small debris, irrespective of structural and debris wetness.
- 5. *Enclosures trap 1% of the debris.* It is likely that a fraction of the debris would enter the enclosures (e.g., reactor cavity) where they would become trapped. Based on engineering judgment this fraction was assumed to be 0.01.

Subject to above assumptions, it is estimated that approximately 52% of the small debris would be transported to the vents. The remaining debris would be distributed in the drywell as follows: 1% on *enclosures*  $(X_{en}^{s})$ , 1% on *drywell floor or vents*  $(X_{dp}^{s})$ , 4% on *structures-above*  $(X_{ss}^{s})$ , 10% on *structures-break*  $(X_{sp}^{s})$ , and 32% on *structures-other*  $(X_{sp}^{s})$ .

#### Transport of Large Debris

Advection of 90% of the large-below debris is assumed. The remaining 10% would be trapped in the enclosures or on drywell structures such as support cables.<sup>11</sup> A nominal 1% was assumed to enter the enclosures and the remaining 9% on structures or drywell floor. These estimates were judged to be conservative, but necessitated by the lack of experimental data

Central estimates are also based on the assumption that 100% of the large-above debris would be captured on the gratings. However, it is assumed that only 15% would be trapped on the grating directly below the break. This division is based on the insight gained by CEESI integrated effects tests where the majority of large pieces were blown away from the break area by the flow velocity. Therefore,

<sup>&</sup>lt;sup>11</sup> Experiments have shown that support cables and small diameter pipes normal to the flow provide ideal locations for large debris to wrap around.

a higher fraction is expected to be on the grating away from the break as compared to below the break.

## 4.1.3 Erosion and Washdown

This step addresses potential for re-entrainment of small debris and erosion of large debris by containment sprays. As shown in Figure 2-2, debris deposited on structure-break and structures-other would be subject to water flow which may erode and/or wash them down to the drywell floor. Reentrainment refers to the process by which small pieces of insulation debris loosely attached to the drywell structures would be entrained and carried by cascading water flow. Erosion refers to the process by which water would erode primarily large insulation pieces trapped on structures (thus not available for entrainment). This step relies on the outcome of the previous step to determine the quantity and the type of debris that would be located on each structure. The ECCS flow rates and the drywell layout information were coupled to calculate the water flow impinging on each structure. Experiments were conducted to evaluate potential for washdown and erosion of debris corresponding to these conditions.

#### 4.1.3.1 Key Findings

For the accident scenario of present interest, break overflow is not expected, as it was assumed that the operator would throttle the flow upon recovering vessel level. Debris deposited on *structures-break* and *structures-other* would be subjected to containment spray flow of 4500 GPM distributed across the drywell cross-section for thirty minutes. Corresponding to those flow conditions, washdown data were obtained for small and large debris [Ref. 4.3]. The data suggest that the containment sprays will washdown the majority of the small debris located on structures subjected to spray flow. The experiments also established that the spray water would not result in significant erosion of large pieces.

Small debris deposited on *structures-above* would be subjected to condensate drainage. No experimental data were obtained for such cases. Instead engineering judgment was used to estimate washdown by condensate drainage.

#### 4.1.3.2 Upper Bound

The upper bound estimate was obtained based on the following assumptions:

- 1. In thirty minutes, the containment sprays would wash down 100% of the small debris deposited on structures. At the end of blowdown, approximately 11% of the small debris are retained on the floor gratings, which would be exposed to containment spray flow for thirty minutes. Experimental data obtained for similar conditions suggest that sprays would washdown 100% of the debris deposited on pipes and 40-50% debris deposited on gratings. Nevertheless, a washdown factor of 1.0 was used for structuresother and structures-break in Figure 4-1.
- 2. The containment sprays would washdown 2% of the large debris. Experimental data suggest that sprays would erode a maximum of 2% of the large debris. A washdown factor of 0.02 was used for large-above captured on *structures-other* and *structures-break* in Figure 4-1.
- 3. The condensate drainage will transport 10% of small debris<sup>12</sup>. CEESI experience suggests that very little (if any) debris would be transported by condensate drainage. Directly applicable experimental data is non-existent. To be conservative, a small debris washdown fraction of 0.10 was assigned to *structures-above*.

Thus the upper bound was based on a value of 1.0 for  $Y_{so}^{s}$  and  $Y_{sb}^{s}$ , and 0.1 for  $Y_{sa}^{s}$ . Also, a value of 0.02 was used for  $Y_{so}^{1}$  and  $Y_{sb}^{1}$ .

#### 4.1.3.3 Central Estimate

Central estimates were obtained based on the following assumptions:

1. In thirty minutes, the containment sprays would wash down 50% of the small debris deposited on structures by inertial deposition. Experimental data suggest that sprays would washdown 100% of the debris deposited on pipes and 40-50% debris deposited on gratings. However, not all the debris would be subjected to sprays. Both the Barsebäck-2 event and the CEESI experiments demonstrate that large structures located above can prevent washdown of debris deposited on

 $<sup>^{12}</sup>$  In this particular case no debris were deposited on the *structureabove* as shown in Figure 4-1 and explained in Section 4.1.2.2.

smaller structures underneath, and also debris deposited on drywell walls will not likely be washed down. A washdown transport factor of 0.5 was used for small debris deposited on *structures-break* and *structures-other*.

- 2. The containment sprays would washdown 1% of the large debris. Experimental data suggest that, sprays would washdown a maximum of 2% of the large debris. A more realistic washdown transport factor of 0.01 was used for large debris deposited on *structures-break* and *structures-other*.
- 3. The condensate drainage will transport 1% of small debris. This estimate is based on engineering judgment and was applied for small debris deposited on structures-above.

The central estimate was derived using a value of 0.5 for  $Y_{so}^{s}$  and  $Y_{sb}^{s}$ , and 0.01 for  $Y_{sa}^{s}$ . In addition, a value of 0.01 was used for  $Y_{so}^{1}$  and  $Y_{sb}^{1}$ .

## 4.1.4 Drywell Floor Pool Transport

The quantity of debris reaching the drywell floor as a result of blowdown and washdown are given by  $F_{Floor}^{i} = X_{sa}^{i} \bullet Y_{sa}^{i} + X_{sb}^{i} \bullet Y_{sb}^{i} + X_{so}^{i} \bullet Y_{so}^{i} + X_{df}^{i}$ (2.5)

The objective of this final step is to evaluate what fraction of this quantity will be transported to the vents when subjected to flow dynamics established by containment spray flow.

The analyses have shown that deep water pools formed on the Mark I drywell floor due to containment spray water accumulation would allow the debris particles to settle down (Ref. 4.4). The objective of this step is to estimate what fraction of debris would be transported to the vents versus what fraction would settle down. Detailed CFD simulations of the water flow on the drywell floor were coupled with experimental data [Ref. 4.6] to draw necessary insights.

#### 4.1.4.1 Key Findings

Drywell pool forms as a result of accumulation of containment spray flow on the drywell floor before it fills up and starts to overflow into the vents. For the Mark I containment being modeled, the containment spray flow rate is approximately 4500 GPM and the drywell pool capacity is approximately

8000 gallons. The vents are offset from the floor by approximately 18 inches. The sprays were assumed to add water to the entire cross-section of the drywell floor. Computational fluid dynamics calculations were undertaken to predict flow patterns and turbulence levels that exist in the drywell pool as a result of containment sprays (see Figures 4-11 and 4-12). Several sensitivity analyses were conducted to study the impact of plant-specific variations in various parameters, such as ECCS flow rate, presence of structures and vent-pipe offset height (i.e., height of the vent pipes compared to drywell floor). These sensitivity analyses demonstrated that during containment spray operation, low flow velocities (< 0.05 ft/s) and low turbulence levels (turbulence kinetic energy<sup>13</sup>  $< 10^4$  ft<sup>2</sup>/s<sup>2</sup>) characterize the bulk of the Mark I drywell pool. The flow dynamics may be slightly more turbulent over a small region closer to the vent entrance. Past experiments have shown that small and large debris would settle down under such flow conditions [Ref. 4.6]. Also the flow would not resuspend debris deposited previously on the drywell floor. Therefore, for this scenario it is very likely that a major fraction of the debris would settle down.

#### 4.1.4.2 Upper Bound

Upper bound was obtained subject to the following assumptions:

- 1. Small debris deposited in the bulk of the drywell would settle down (or sediment). The flow patterns were determined to be quiescent and thus would allow for debris sedimentation.
- 2. Small debris deposited in a small region close to the vent entrance will be transported. As shown in Figure 4-11 and 4-12, turbulence levels are slightly higher in the close proximity of the vents. Small debris<sup>14</sup> brought into this region by spray water flow would likely enter the vents before they settle down. Under this approximation, about 10% of the debris brought down by the sprays were estimated to enter the vents. Hence, a value of 0.1 was used for pool transport factor (Z\*) in Figure 4-1.

 $<sup>^{13}</sup>$  Turbulence kinetic energy is an indicator of residual pool turbulence and is expressed as ½  $U^2_{\rm rms}$ ; where  $U_{\rm rms}$  is the root-mean-square velocity of the flow.

<sup>&</sup>lt;sup>14</sup> Small debris has a settling velocity of 0.05 ft/s and would take 40 seconds to settle down in an 18-inch deep pool. During the same time, debris would travel 18-inches or more horizontally. Thus debris deposited in a circular region 18-inches in radius extending from the vent entrance may be transported into the vents.





DEBRIS TRANSPORT RESULTS								
Plant Design:	MARKI							
Estimate:	UPPER BOUND			FIBROUS I	NSULATION	ł.		
Break:	MSL BREA	K						
ECCS:	ECCS THR	OTTLED						
Sprays:	SPRAYS O	PERATED						
TREE QUANTIFICAT	ION							
Debris Classification	Vents	Enclosures	Floor	Structures Above	Structures Break	Structures Other	Transport Fraction	
Small Pieces	9.010E-01	0.000E+00	9.900E-02	0.000E+00	0.000E+00	0.000E+00	0.9010	
Large Pieces-Above	2.000E-02	0	0.000E+00	0	2.450E-01	7.350E-01	0.0200	
Large Pieces-Below	1.000E+00	0.000E+00	0.000E+00	0	0.000E+00	0.000E+00	1.0000	
FINAL DISTRIBUTIO	NS (Horizon	tal)						
Debris Classification	Debris Classification Vents		Floor	Structures Above	Structures Break	Structures Other		
Small Pieces	90.10%	0.00%	9.90%	0.00%	0.00%	0.00%		
Large Pieces-Above	2.00%	0%	0.00%	0%	24.50%	73.50%		
Large Pieces-Below	100.00%	0.00%	0.00%	0%	0.00%	0.00%		
		Debri	s Transpor	t Fractions				
				All large, all debris and all zone of influence are described in Section 5.				
Sm	all Debris	Large Above Gratings	Large Belo Gratings	w All Large	Debris All	Debris A	All Zone-of- Influence	

 Table 4-1. Upper bound estimate of debris transport reactions for a MSLB scenario.

- 3. Eroded component of the large pieces will be transported to vents by spray flow. Experiments have shown that secondary debris from erosion of large debris tended to be individual fibers (or small clumps) that would be maintained in suspension at very low velocities. A pool transport factor of 1.0 was used for erosions brought down by the containment spray flow.
- 4. Large and small pieces previously deposited on the drywell floor will not be re-entrained. Experimental data have confirmed this assumption for drywell floor pool flows typical of those established by containment sprays. (Note that some of the large pieces that are dry may become suspended for a short duration while air is trapped in the insulation, but the potential transport was estimated to be minimal for this scenario.)

#### 4.1.4.3 Central Estimate

In the central estimate, a more rigorous approach was used to estimate the potential for small debris settling in a region closer to the vent entrance. In particular, CFD calculations were carried out to examine the movement of debris deposited in the pool at different locations. These calculations suggest that nearly all the debris would settle down irrespective of the location of its introduction. This finding was used to lower transport factor for small debris ( $Z^{s}$ ) from 0.1 to 0.01. The other two assumptions regarding erosion and re-entrainment were retained.

## 4.1.5 Results of Quantification

The branch-split factors used for each step are shown in Figure 4-1 and 4-2. Successive numbers were multiplied to obtain the fractions of debris transported by each pathway. These fractions are shown under heading "Fractions" in Figures 4-1 and 4-2. Fractions associated with those pathways that ended with vents being the "Final Location" were added together to calculate the transport factor for each class of debris  $F^s$ ,  $F^{la}$ , and  $F^{lb}$ . Tables 4-1 and 4-2 provide the estimated transport factors as functions of debris size.

#### 4.1.5.1 Upper Bound

Two dominant pathways were identified for debris transport during blowdown:

- 1. Advection of small debris by steam, and
- 2. Advection of large debris generated below the lowest grating (i.e., *large-below*) by steam.

As shown in Table 4-1, together they contributed towards transport of 90% of *small* and 100% of *largebelow* debris during blowdown. In Figure 4-1, both these two pathways were highlighted as a measure of their importance.

Four additional transport pathways contribute towards transport during washdown. These pathways pertain to washdown and subsequent transport of *small* and *large-above* debris deposited on *structures-break* and *structures-other* by containment sprays. As shown in Figure 4-1, their contribution is minimal.

#### 4.1.5.2 Central Estimate

Dominant pathways identified in the central estimate are same as those identified above, i.e.,

- 1. Advection of small debris by steam, and
- 2. Advection of *large-below* debris by steam.

However, as shown in Table 4-2, their contribution is considerably smaller compared to the upper bound. Only 52% of small debris are transported to the vents with all of it occurring during blowdown.

# 4.2 Recirculation Line Break

The accident scenario considered is a postulated recirculation line break (RLB) in the mid-region of a Mark I drywell. It is assumed that the operator would throttle the ECCS one-hour after the accident. Until that point, the ECCS make-up flow of 25, 000 GPM was assumed to spill through the break into the drywell. The spillage accumulates on the drywell floor, until the water level exceeds 18-inches at which point water overflows into the vents. The drywell is assumed to have same geometrical characteristics analyzed in Section 4.1. Figures 4-13 and 4-14 are the logic charts developed to estimate upper bound and central estimate of the transport factor.

	,	DEBRIS	TRANSPO	RT RESULT	8		
Plant Design:	MARKI						
Estimate:	ESTIMATE		FIBROUS I	NSULATION	N		
Break:	ιК						
ECCS:	ECCS THR	OTTLED					
Sprays:	SPRAYS C	PERATED					
TREE QUANTIFICAT	ION						
Debris Classification	Vents	Enclosures	Floor	Structures Above	Structures Break	Structures Other	Transport Fraction
Small Pieces	5.221E-01	1.000E-02	2.183E-01	3.960E-02	5.000E-02	1.600E-01	0.5221
Large Pieces-Above	1.000E-02	0	0.000E+00	0	1.485E-01	8.415E-01	0.0100
Large Pieces-Below	9.000E-01	1.000E-02	4.050E-02	0	9.900E-03	3.960E-02	0.9000
FINAL DISTRIBUTIO	NS (Horizon	tal)					
Debris Classification	Vents	Enclosures	Floor	Structures Above	Structures Break	Structures Other	
Small Pieces	52.21%	1.00%	21.83%	3.96%	5.00%	16.00%	
Large Pieces-Above	1.00%	0%	0.00%	0%	14.85%	84.15%	
Large Pieces-Below	90.00%	1.00%	4.05%	0%	0.99%	3.96%	-
· · ·			•				-
				6-0009 PL			
		Debris	s Transport	Fractions			
1.000					***		
0.750				<u> </u>			
L 07 500							
ਬ.500 ੲ				A11.1	arge all de	bris and a	11
				7000	of influen	ce are	
0.250				decor	ihed in Se	ection 5	
0.000					<u>.</u>		
Small Debris	Large At Grating	xove Larg gs Gr	e Below A atings	Il Large Debris	All Debri	s All Zo Influ	one-of- ience
				1		······	

## Table 4-2. Central estimate of debris transport fractions for a MSLB scenario

Quantification of Logic Charts

LOCA Type (Section 4.1)	Debris Classification (Section 4.1.1)	Distribution After Blowdown (Section	Erosion and Washdown (Section 4.1.3)	Drywell Floor Pool (Section 4.1.4)	Path No.	Fraction (Section 4.1.5)	Final Location
		Advected to Vents	I		1	0.000E+00	Vents
MARK I		0.00 Enclosures			2	0.000E+00	Enclosures
UPPER BOUND		0.00		Waterborne	2	2 200E-01	Vente
RL BREAK		Danuall Floor		1.00		2,2002-01	vents
ECCS THROTTLE	)	1.00	<u></u> _	Sediment	4	0.000E+00	Floor
NO SPD AVS				0.00			
NO SERATS				Waterborne	5	0.000E+00	Vents
FIBROUS INSULAT	TION		Condensate Drainage	1.00			
		S	0.10	Sediment	6	0.000E+00	Floor
	Small Pieces	0.00	Adheres	0.00	7	0.000E+00	Structures-Above
	0.22		0.90	Wotorborne	2	0.000E+00	Vents
				1.00	0	0.0002+00	v ents
			Recirculation Flow	Sadimant	0	0.000E+00	Floor
		Structures-Break	1.00	0.00		0.0002100	11001
		0.00	Adheres		10	0.000E+00	Structures-Break
			0.00	Waterborne	11	0.000E+00	Vents
			Condensate Drainage	1.00			
			0.10	Sediment	12	0.000E+00	Floor
		Structures-Other	Adheres	0.00	13	0.000E+00	Structures-Other
		0.00	0.90			2 (00E 02	
				Waterborne	14	3.600E-02	vents
			Recirculation Flow			1	
		Structures-Break	0.12	Sediment	15	0.000E+00	Floor
		1.00	Adheres		16	2.640E-01	Structures-Break
			0.88	Waterborne	17	0.000E+00	Vents
			Que de conte Desimore	1.00			
	Large-Above	ļ	0.00	Sediment	18	0.000E+00	Floor
	0.50	Structures-Other		0.00	10	0.0005.000	Structures Other
RL Break		0.00	1.00		19	0.0002+00	Structures-Other
1.00		Advected to Vent			20	8.000E-02	Vents
		1.00 Enclosures			21	0.000E+00	Enclosures
	Large-Below	0.00		Waterborne	22	0.000E+00	Vents
	0.08			1.00			
		Drywell Floor		Sediment	23	0.000E+00	Floor
				0.00			
		1 1 1		Waterborne	24	0.000E+00	Vents
				1.00	t		
			Recirculation Flow	Sediment	25	0.000E+00	Floor
		Structures-Break		0.00		0.0005.000	Ctourt and Decels
		0.00	Adheres 0.00		26	0.000£+00	Structures-Break
			-	Waterborne	27	0.000E+00	Vents
			Condensate Drainage	1,00			
		Structures Other	0.00	Sediment	28	0.000E+00	Floor
		0.00	Adheres	0.00	29	0.000E+00	Structures-Other
	Canvassed		1.00		30	4.000E-01	Structures/Floor
	0.40						

note: Fractions are normalized to each debris class

Figure 4-13. Logic chart for upper bound estimate of transport factor for a RLB scenario.
## Quantification of Logic Charts

LOCA Type	Debris Classification	Distribution After	Erosion and Washdown	Drywell Floor Pool	Path	Fraction (Section	
(Section 4.1)	(Section 4.1.1)	4.1.2)	(Section 4.1.3)	(Section 4.1.4)	No.	4.1.5)	Final Location
MARKI		Advected to Vents			1	1.012E-01	Vents
		Enclosures			2	2.200E-03	Enclosures
CENTRAL ESTIM	ATE	0.01		Waterborne	3	4.400E-02	Vents
RL BREAK		Drywell Floor		1.00			
ECCS THROTTLE	D	0.20		Sediment	4	0.000E+00	Floor
NO SPRAYS				0.00			
FIRROUS INSULA	TION			Waterborne	5	4.400E-05	Vents
I BROOD INSULATION			Condensate Drainage	1.00			
		Structures-Above	0.01	Sediment 0.00	6	0.000E+00	Floor
	Small Pieces	0.02	Adheres		7	4.356E-03	Structures-Above
	0.22		0.99	Waterborne	8	1.760E-02	Vents
			Recirculation Flow	1.00			
		Structures-Break	1.00	Sediment	9	0.000E+00	Floor
		0.08	Adheres	0.00	10	0.000E+00	Structures-Break
			0.00	Waterborne	11	5.060E-04	Vents
			Condensate Drainage	1.00			
			0.01	Sediment	12	0.000E+00	Floor
	1	Structures-Other 0.23	Adheres	0.00	13	5.009E-02	Structures-Other
			0.99	Waterborne	14	4 0805 02	
				1.00	14	4.080E-03	Vents
			Recirculation Flow 0.08	Sediment	15	0.000E+00	Floor
	1	Structures-Break	Adheres	0.00	16	4 602E 02	Starten Dard
		0.15	0.92		10	4.692E-02	Structures-Break
			1	Waterborne	17	0.000E+00	Vents
	Large-Above		Condensate Drainage	Sodimont	10	0.0005.100	51
	0.34	Structures-Other	0.00	0.00	18	0.000E+00	Floor
RL Break		0.85	Adheres		19	2.890E-01	Structures-Other
1,00		Advected to Vent			20	3.600E-02	Vents
		Enclosures			21	4.000E-04	Enclosures
	0.04	0.01		Waterborne	22	1.440E-03	Vents
		Drywell Floor		0.90			
		0.04		Sediment	23	1.600E-04	Floor
				0.10			
				Waterborne	24	2.000E-04	Vents
			Recirculation Flow	1.00			
		Structures-Break	0.50	Sediment 0.00	25	0.000E+00	Floor
		0.01	Adheres		26	2.000E-04	Structures-Break
			0.50	Waterborne	27	0.000E+00	Vents
			Condensate Drainage	1.00			
		Structures-Other	0.00	Sediment	28	0.000E+00	Floor
	L	0.04	Adheres	0.00	29	1.600E-03	Structures-Other
	Canvassed	•	1.00		30	4 000F-01	Structures/Floor
	0.40				50		Su uctures r'100r

note: Fractions are normalized to each debris class



Similar to the previous case, the overall transport problem is decomposed into four independent processes: debris generation, distribution at the end of blowdown, washdown and erosion and drywell pool transport. The fundamental differences between this and the previous MSLB scenario are:

- 1. Debris generation occurs due to two-phase blowdown, instead of steam as in the case of main steam line break,
- 2. A portion of the debris would be transported by the water component of the blowdown flow,
- 3. Break overflow introduces a large quantity of water which has the potential to erode large pieces of insulation located on floor gratings, and
- 4. The drywell pool would likely to be more turbulent.

Several analyses were conducted to quantify the impact of these differences on debris transport. Figures 2-3 and 2-4 summarized the analyses undertaken in this study.

## 4.2.1 Debris Classification

As in the previous case, data is gathered regarding the following parameters related to debris generation: a) duration of debris generation, b) location of debris generation, c) debris wetness, d) medium of transport, and e) size distribution of debris.

### 4.2.1.1 Key Findings

Debris generation by the recirculation break is expected to be different from the MSLB by the fact that blowdown initially consists of water, followed by two-phase mixtures in the later stage of accident progression. Insights relating to jet expansion and potential for debris generation were drawn from the following investigations:

- 1. CSQ simulation of two-phase jet expansion from various stagnation conditions (pressure and sub-cooling) and loads impinged by such an expansion [Ref. 4.7], and
- 2. Experimental study of two-phase jet expansion [Ref. 4.8].

These analyses were augmented by a series of hand calculations, as necessary, to apply their results to

the present study. Important conclusions of these analyses are as follows:

1. Debris generation occurs over a prolonged period after LOCA. Calculations suggest that mainly water at a flow rate of approximately 25000 lb/s exits the nozzle initially (stagnation static quality < 0.02 and void-fraction < 50% for the first 5 seconds) (See Figure 4-15). The corresponding nozzle flow velocity is on the order of 30-100 ft/s. As shown in Figure 4-16, the liquid effluent forms an approximately spherically shape within the piping region as a result of flashing and jet deflection [Ref. 4.5 and 4.8]. Also it decelerates significantly within a short region due to structural drag. Typically such jets are expected to destroy debris contained in a spherical region no larger than 3 to 5 nozzle-diameters in radius [Ref. 4.9]. Debris generated during this phase will likely be entrained and transported by water component as it cascades down to the drywell floor.

> Later on substantial flashing occurs within the broken pipe, resulting in increased flow quality at the nozzle. After about 20 seconds, as shown in Figure 4-15, the break flow consists of a steam continuum (void fraction > 0.90) with suspended liquid water droplets (quality > 35%). Steam flow at velocities up to 800 ft/s penetrates the piping region. Due to low structural drag, high velocities are maintained over a region extending up to 10 nozzlediameters [Ref. 4.2 and 4.5]. Debris generated during this phase will likely be entrained by steam and transported through the drywell in a manner similar to that for the main steam line break.

2. A fraction of the debris (≈80%) would be transported by steam, with the remaining (≈20%) transported by water. As a result of a recirculation line break, debris could be generated in a spherical region extending up to 10 nozzle-diameters in radius [Ref. 4.2]. However, as described above, insulation contained in the close proximity of the break (< 5 nozzle-diameters) will be generated within the first five seconds and will be transported by water. The remainder will be generated later into accident (t> 20 s) and will be transported by steam continuum.



Figure 4-15. Blowdown data corresponding to a postulated recirculation line break in a BWR/4.



- 3. Several plant layouts were used to estimate the relative fractions of debris transported by water versus steam. Based on these analyses, it is concluded that no larger than 20% of the total generated debris would be transported by water, with the remaining 80% being transported by steam. These fractions were used to derive the central estimates for the transport factor. On the other hand, the upper bound transport factor was derived assuming that 100% of the debris would be entrained by water.
- 4. The debris and the structures would be wet (nearly saturated). As shown in Figure 4-15, the water component of the blowdown flow is as high as 5000 lb/s even during the later stages of the accident (water component = M(1-x)). Therefore, it is very likely that all structures and debris would be wet.
- 5. *Debris size distribution is uncertain.* There are no existing data on types of debris generated by recirculation line breaks. It is assumed that the debris can be broadly divided into the same three groups, small, large and largecanvassed.

### 4.2.1.2 Upper Bound

The debris was divided into four groups depending on their size and location of generation. They are *small, large-above, large-below* and *large-canvassed*. Once again, a value of 1.0 was used for  $\eta_1$ ,  $\eta_2$ ,  $\eta_3$ , and  $\eta_4$ . The focus of the study is to estimate transport factors for each debris size.

### 4.2.1.3 Central Estimate

Same as Section 4.2.1.2.

### 4.2.2 Distribution at the End of Blowdown

This step addresses transport of small and large pieces by water and steam components. As the boundary condition, it is assumed that small, large and large-canvassed pieces exit the zone of influence, and will not degrade any further during their transport outside the zone of influence. The debris would be wet and would be generated over a longer period. The objective of this step was to estimate where the debris would be located at the end of blowdown.

### 4.2.2.1 Key Findings

The key findings related to debris transport during recirculation line break are:

- Small debris entrained by water will be deposited in the drywell pool instantaneously. As previously noted, break flow consists mainly of water during the first 5 seconds. Assuming that water spreads uniformly over a quarter of the drywell cross-section, the average flow rates exceed 200 GPM/ft<sup>2</sup>. Experiments have shown that such high water flow will entrain and transport all the small debris. Hence, it is likely that all small debris initially entrained by water would cascade with the break flow down to the drywell pool.
- Advection by water medium would also occur over a 2. short time scale with nearly 100% of debris transported. Calculations suggest that break liquid effluent would form a pool on the floor and could flow into the vents within 4 to 5 seconds. For most Mark I drywells, one to two pool turnovers are expected during blowdown. Assuming two turnovers, it can be easily shown that approximately 85% of the debris would be advected to the vents during blowdown. This transport would be augmented by the ECCS recirculation flow of 25, 000 GPM, which would be added to the pool after blowdown. During this time it is likely that the pool would be highly turbulent due to phenomena such as sloshing, flashing and flow dynamics. Therefore, it is unlikely that any debris, irrespective of its size, would settle in the pool.
- 3. Advection by steam resembles transport by MSLB. The bulk flow patterns in the drywell volume during later stages of RLB blowdown were predicted by approximating the break flow to be single-phase steam<sup>15</sup>. These analyses suggest that steam bulk flow patterns in the containment are similar to the previous predictions for main steam line break, although they are less severe. Approximating them by steam flow patterns resulting from a MSLB is conservative.

<sup>&</sup>lt;sup>15</sup> This assumption ignores the interfacial momentum transfer between steam and water. Therefore, it is likely to result in higher steam velocities, which maximizes the potential for transport.

### 4.2.2.2 Upper Bound Estimates

The model assumes that 100% of the small debris would be entrained by the liquid medium and be transported to the drywell floor instantaneously. Depending on the drywell pool capacity and break flow, all or a fraction of the debris would be transported to the vents during blowdown itself. In this analysis it was assumed that 100% of the small debris are located in the drywell pool at the end of blowdown. This assumption has no impact on the overall outcome since break overflow results in transport of nearly 100% of this debris.

It is estimated that 100% of the large debris produced above the lowest grating will be trapped directly beneath the break on the floor grating. This estimate is a direct result of the assumption that all debris would be entrained and transported by water as it cascades down.

Finally, all of the large-debris generated below the lowest grating will be transported into the drywell pool by water.

### 4.2.2.3 Central Estimates

Figure 4-17 illustrates the logic used to estimate the capture fractions for small debris. The rationale used for quantification of important steps is as follows:

- Approximately 20% of the small debris would be entrained and transported by water to the drywell floor. Additional 1% of the debris may be captured in the enclosures. Experiments have shown that all of the small debris entrained by water would be carried to the drywell structures. A small quantity of debris may enter enclosures such as the reactor cavity where they will be captured either during steam-borne advection or during water-borne advection. A value of 1% was used to represent this fraction trapped in the enclosures.
- 2. Remaining 79% of the small debris would be transported similarly to a MSLB described in Section 4.1.2.2. The important steps are as follows:
  - a) The debris becomes inter-mixed with the drywell volume, with 41% of it above the upper grating, 37% between

two gratings and 22% below the lowest grating.

- b) The debris contained above the upper grating would be deposited on 1) structures in the upper region, 2) upper grating, 3) structures in the mid-region, 4) lower grating, 5) structures in the lower region and 6) vents. Structures will remove debris with an efficiency of 10%, where as the gratings have an efficiency of 25%.
- c) The debris contained between the two gratings would be deposited on
  1) structures in the mid-region, 2) lower grating, 3) structures in the lower region and 4) vents.
- d) The debris contained below the lower grating would be deposited on 1) structures in the lower region and 2) vents.
- 3. For large debris generated below the lowest grating (*large-below*), same distribution as main steam line break was used: 90% advected to vents, 1% in enclosures, 4% deposited at the vent entrances, and 5% captured on structures such as support cables. Of the 5% captured on structures, it is assumes that 25% would be located directly beneath the break and the remaining 75% distributed over the rest of the drywell.
- 4. All large-above, debris would be captured on the lower grating. It is assumed that 25% of that debris would be on structures-break, where as 75% would be on *structures-other*.

### 4.2.3 Erosion and Washdown

In this scenario, water is introduced into the containment as a result of break overflow for a period of one-hour, at a rate of 25, 000 GPM. As it cascades down the drywell structures, water spreads over a cross-section as large as one-fourth of the drywell cross-section. Corresponding water flow is nearly 50 GPM/ft<sup>2</sup> at the lower grating. Debris deposited underneath the break, but in the break quadrant, will be subjected these high water flows. Experiments were conducted to study the impact of these large quantities of water on fibrous insulation transport. The findings of these experiments are summarized below.

Debris Size	Initial
Classification	Distribution
	Enclosuros
	0.01 Waterborne
	0.20

Debris Size Classification	Initial Distribution	Distribution in Drywell	Interaction with Structures in Upper Region	Interation with Upper Grating	Interaction with Structures ir Middle Region	Interaction with Lower Grating	Interaction with Structures in Lower Region	Interaction with Vent Structures and Floor	Path	Fraction	To Vent	Location of Debris
	Enclosures								- 1	1.0000E-02		Enclosures Drywell Floor
	Waterborne						Goes By	Goes By 0.99	- 2 - 3	1.3149E-01	x	Transported Into Vent Downcomers
	Recir	culation Line			Goes By	Goes By 0.75	0.90 Captured	Captured 0.01	- 4	1.3282E-03		Deposited onto Floor Near Vents Structures Below Spray Heads
				Goes By	0.90	Captured	0.10		- 6	4.9192E-02		Structures Below Spray Heads
Small Pieces		TIMATE	Goes By 0.90	0.75	Captured 0.10				7	2.1863E-02		Structures Below Spray Heads Structures Below Spray
		Upper Region	Captured (A	Captured 0.25 Above)					- 8	1.6195E-02		Heads Structures Above Spray
		0.41	0.05 Captured (E	Below)			<u></u>		- 10	1.6195E-02		Structures Below Spray Heads
			0.05				Goes By	Goes By	- 11	1.7580E-01	х	Transported Into Vent Downcomers
						Goes By	0.90	Captured 0.01	12	1.7757E-03		Deposited onto Floor Nea Vents
	Airborne	4			Goes By	0.75	Captured		- 13	1.9730E-02		Structures Below Spray Heads
	0.79	Middle Regio	on	<u> </u>	0.90	Captured			- 14	6.5768E-02		Structures Below Spray Heads
		0.37			Captured				15	2.9230E-02		Structures Below Spray Heads
		r			0.10		Goes By	Goes By	16	1.5486E-01	X	Transported Into Vent Downcomers
		Lower Regio	n				0.90	Captured 0.01	17	1.5642E-03		Deposited onto Floor Nea Vents
		0.22					Captured 0.10		- 18	1.7380E-02		Structures Below Spray Heads

4-32

NUREG/CR-6369

### 4.2.3.1 Key Findings

- All small debris located in the quadrant in which break is located will be re-entrained and washed down to the drywell floor. Experiments conducted as part of the present study [Ref. 4.3] clearly established that recirculating ECCS flow will washdown small debris deposited previously on pipes, I-beams or gratings.
- 2. Large debris will not be forced through the gratings. They would be eroded gradually at a constant rate. Experiments were conducted to specifically address if large debris would be forced through gratings when subjected water flows typical of recirculating ECCS flow. In these experiments, pieces as thin as 1/8 inch were exposed to water flow of approximately 50 GPM/ft<sup>2</sup>. The pieces were not forced through the grating instantaneously (or on a short-time scale). Instead they were eroded over a longer time scale (see Figures 3-3 and 3-5).
- 3. *Erosions resemble small clumps of individual fibers.* Once again experimental data were used to draw this conclusion.

### 4.2.3.2 Upper Bound

For this scenario all small debris were transported to the drywell floor during blowdown. Therefore, structural washdown of small debris is not important.

Erosion of *large-above* debris captured on gratings during blowdown is the only mechanism considered in the upper bound. Based on experimental data shown in Figure 3-5, it is estimated that about 12% of that debris would be eroded when subjected to one hour of ECCS flow. Note that 12% value assumed is an upper bound for the erosion measured in the experiments (including experimental uncertainties). The washdown may be lower if the operator throttles ECCS flow well before one hour.

### 4.2.3.3 Central Estimate

Experiments have shown that 100% of the small debris deposited on structures and gratings will be washed down by break flow across them. As a result, it was assumed that all small debris

previously deposited on structures-break would be transported to the drywell pool as a result of washdown. Other drywell structures would not be subject to water flow other than condensate drainage. A transport fraction of 0.01 was assigned to quantify small quantities of debris that may be transported by condensate drainage.

Erosion of *large-above* debris deposited on *structures-break* was estimated to be 8% based on the experimental data, assuming that insulation would be subjected to 1-hr of ECCS recirculation flow of 25,000 GPM.

The water flow may break loose a fraction of the *large-below* debris trapped by structures below the lowest grating. No experimental data was available to quantify this effect. It was assumed that 50% of such debris are knocked down by the flow and brought to the drywell pool.

### 4.2.4 Drywell Floor Pool

A drywell pool forms as a result of accumulation of break overflow on the drywell floor before it fills up and spills into the vents. For a small BWR/4 reactor with Mark I containment, the unthrottled break overflow rate is approximately 25000 GPM and the drywell pool capacity is approximately 8000 gallons. The vents are offset from the floor by approximately 18 inches. It is assumed that structures located between the break and the drywell would distribute the flow over a quarter of the drywell cross-section. CFD calculations were undertaken to predict flow patterns and turbulence levels that exist in the drywell pool as a result of break overflow (see Figures 4-18 and 4-19). Several sensitivity analyses were conducted to study the impact of plant-specific variations in various parameters, such as ECCS flow rate, presence of structures and vent-pipe offset height (i.e., height of the vent pipes compared to drywell floor). These sensitivity analyses demonstrated that during unthrottled ECCS operation, high flow velocities (< 0.5-1 ft/s) and high turbulence levels characterize the bulk of the drywell pool. Past experiments have shown that at these flow conditions small and large debris would be maintained in suspension [Ref. 4.6].

### 4.2.4.1 Upper Bound

It was assumed that both small and large debris would be maintained in suspension and transported to the vents. No sedimentation is likely. Mark I — Recirculatic 25000 GPM Flow Focu Viewed From Above

**Quantification of Logic Charts** 



Pressure Backgrou lbf/ft2

Figure 4-18. Flow veloc

NUREG/CR-6369

# Mark I — Recirculation 25000 GPM Flow Focu



Figure 4-19. Specific kine

### 4.2.4.2 Central Estimate

The central estimate also assumed that 100% of the small debris deposited previously in the drywell pool or brought to the pool by break overflow would be transported during the ECCS recirculation phase. However, it assumed that only 90% of the large debris would be transported. The remaining 10% would settle down in the wake regions of the drywell structures.

### 4.2.5 Results of Quantification

Tables 4-3 and 4-4 present estimated transport factors as functions of debris size.

### 4.2.5.1 Upper Bound

Two pathways dominate transport by recirculation line break:

- 1. Water-borne advection of small debris.
- 2. Water-borne advection of large-below debris.

The other significant pathway for transport is erosion of large-above pieces and subsequent transport by break overflow. Together these pathways contribute towards transport of all small and large-below debris, and approximately 12% of the large-above debris.

#### 4.2.5.2 Central Estimate

The dominant pathways for transport are:

- 1. Air-borne advection of small debris,
- 2. Water-borne advection of small debris,
- 3. Air-borne advection of large-below debris, and
- 4. Washdown and subsequent transport of small debris by break overflow.

Together these pathways resulted in transport of 75% of small debris and90% of the large-below debris. Only 2% of the large-above debris were transported.

### 4.3 References

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- 4.2 Boiling Water Reactor Owners' Group, "Utility Resolution Guidance for ECCS Suction Strainer Blockage," NEDO-32686, 1996
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- 4.4 D. V. Rao, et al., "Drywell Debris Transport Study: Analytical Work, "NUREG/CR-6369, Supplement 2, Science and Engineering Associates, Inc., SEA 97-3105-A:16, September 1997.
- 4.5 K. Williams, "Simulation of a BWR Drywell Flow in Response to a Recirculation –Line LOCA using a Computational Fluid Dynamics (CFD) Code," FSS Report: RX-96-05, Flow Simulation Services, Inc., 1996.
- 4.6 P. Murthy and M. Padmanabhan, "ECCS Strainer Model Study: Transport and Experimental Studies in a Laboratory Flume," Report 31-94/M216F, Alden Research Laboratory, Inc. 1994.
- 4.7 G. G. Weigand, et al., "Two-Phase Jet Loads," NUREG/cR-2913, Sandia National Laboratories, SAND 82-1935, January 1983.
- Electric Power Research Institute, "Two-Phase Jet Modeling and Data Comparison," EPRI NP-4362, S. Levy Incorporated, March 1986.
- 4.9 W. W. Durgin and J. Noreika, "the Susceptibility of Fibrous Insulation Pillows to Debris Formation Under Exposure to Energetic Jet Flow," NUREG/CR-3170, Alden Research Laboratory, Inc., 1983.

		DEBRIS	TRANSPO	RT RESULT	S	:			
Plant Design:	MARK I								
Estimate:	UPPER BO	UND		FIBROUS INSULATION					
Break:	RL BREAK	ζ							
ECCS:	ECCS THR	OTTLED							
Sprays:	NO SPRAY	íS							
TREE QUANTIFICATION									
Debris Classification	Vents	Enclosures	Floor	Structures Above	Structures Break	Structures Other	Transport Fraction		
Small Pieces	1.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	1.0000		
Large Pieces-Above	1.200E-01	0	0.000E+00	0	8.800E-01	0.000E+00	0.1200		
Large Pieces-Below	1.000E+00	0.000E+00	0.000E+00	0	0.000E+00	0.000E+00	1.0000		
FINAL DISTRIBUTIO	NS (Horizon	tal)							
				Structures	Structures	Structures			
Debris Classification	Vents	Enclosures	Floor	Above	Break	Other			
Small Pieces	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%			
Large Pieces-Above	12.00%	0%	0.00%	0%	88.00%	0.00%			
Large Pieces-Below	100.00%	0.00%	0.00%	0%	0.00%	0.00%			
	<u></u>	Debris	Transport	Fractions					
1.250									
1.000									
e 0.750			_						
actic									
Ĕ 0.500									
0.250									
0.200									
0.000   Small De	ebris Larg Gi	e Above ratings	Large Below Gratings	All Large D	ebris All I	Debris A	All Zone-of- Influence		

# Table 4-3. Upper bound estimate of debris transport fractions for a RLB scenario.

		DEBRIS	TRANSPO	RT RESULT	S		
Plant Design:	MARK I						
Estimate:	CENTRAL	ESTIMATE		<b>FIBROUS</b>	NSULATIO	N	
Break:	RL BREAK	K					
ECCS:	ECCS THR	OTTLED					
Sprays:	NO SPRAY	íS					
TREE QUANTIFICAT	ION						
Debris Classification	Vents	Enclosures	Floor	Structures Above	Structures Break	Structures Other	Transport Fraction
Small Pieces	7.425E-01	1.000E-02	0.000E+00	1.980E-02	0.000E+00	2.277E-01	0.7425
Large Pieces-Above	1.200E-02	0	0.000E+00	0	1.380E-01	8.500E-01	0.0120
Large Pieces-Below	9.410E-01	1.000E-02	4.000E-03	0	5.000E-03	4.000E-02	0.9410
FINAL DISTRIBUTIO	NS (Horizon	tal)					
Debris Classification	Vents	Enclosures	Floor	Structures Above	Structures Break	Structures Other	
Small Pieces	74.25%	1.00%	0.00%	1.98%	0.00%	22.77%	
Large Pieces-Above	1.20%	0%	0.00%	0%	13.80%	85.00%	
Large Pieces-Below	94.10%	1.00%	0.40%	0%	0.50%	4.00%	
· · · · · · · · · · · · · · · · · · ·							
		Debri	s Transport	Fractions			
1.000	. <u></u>				· · · · · ·		
0.750							
E E							
		<u> </u>				<u></u> .	
0.250	· · · · ·						
			đ.			,	
0.000 + Small	Debris La	rge Above Gratings	Large Below Gratings	All Large	Debris A	ll Debris	All Zone-of- influence
							-

# Table 4-4. Central estimate of debris transport fractions for a RLB scenario.

# 5. Application Of The Study Results

The ultimate objective of this study was to provide a tractable method by which an analyst could estimate the total quantity of fibrous debris reaching the suppression pool, or for NRC to judge applicability of licensee calculation of debris transport. The logic charts presented in Section 4 provide only part of the information necessary to meet this objective. Other information required to accomplish this objective includes debris size distribution and differences between the plant geometry assumed to develop the logic charts and the actual plant features. This section provides an approach by which logic charts can be coupled with this additional information to estimate quantity of debris transported to the suppression pool.

# 5.1 Integration of Debris Generation Data

The logic charts provided in Section 4 can be used to estimate fractions of each debris size that would be transported to the suppression pool due to combined effects of blowdown and washdown transport. In order to estimate the total quantity of debris transported to the suppression pool, these fractions have to be weighted with the size distribution data as shown below:

$$Q_{\text{pool}} = \left( \eta_1 \bullet F^s + \eta_3 \bullet F^{1-b} + \eta_4 \bullet F^{1-c} \right) \bullet Q_{\text{ZOI}}$$
$$\equiv F^{\text{ZOI}} \bullet Q_{\text{ZOI}}$$

where

Q <sub>pool</sub>	is the quantity of debris reaching the
	suppression pool (ft <sup>3</sup> )
Q <sub>ZOI</sub>	is the quantity of insulation contained in
	the zone of influence (ft <sup>3</sup> )
$\eta_i$	is the fraction of Q <sub>ZOI</sub> destroyed into
	<u>small</u> pieces
η <sub>2</sub>	is the fraction of Q <sub>ZOI</sub> destroyed into
	large pieces, but generated above the
	lowest floor grating
η3	is the fraction of Q <sub>ZOI1</sub> destroyed into
	large pieces, but generated below the
	lowest floor grating
$\eta_4$	is the fraction of Q <sub>ZOI</sub> destroyed into
	large pieces covered in <u>canvass</u>

FZOI is the weighted average transport factor that can be applied to the ZOI. This is very similar to the transport factors proposed by the BWROG [Ref. 5.1]

From the onset, the study did not focus on developing the size distribution fractions applicable to each plant type and postulated scenario. Instead, the study focused on developing a flexible method by which the analyst can easily input the size distribution fractions deemed applicable to the particular scenario being analyzed. To meet this objective, the logic charts were configured such that applicable size distribution data (i.e.,  $\eta_1$ ,  $\eta_2$ ,  $\eta_3$ , and  $\eta_4$ ) can be directly entered into them and the resulting values under the heading 'Fractions' can be summed to calculate F<sup>ZOI</sup>.

To demonstrate this further, consider that a plant wishes to use the BWROG recommended debris size distribution listed in Table 5-1 and estimate the quantity of debris transported to the suppression pool for the accident scenario described in Section 4.1. For the break under consideration, the plant layout (Ref. 5.1) suggests that 90% of the large debris would be generated above the lowest grating, with the remainder generated below the lowest grating. For the upper bound, however, the licensee estimates that 20% of the large debris is generated below the lowest grating, instead of the 10% used in the central estimate. Assume that accident scenario and the plant geometry under consideration is same as that described in Section 4.1.

As shown in Table 5-1, for the central estimate, the size distribution fractions,  $\eta_1$ ,  $\eta_2$ ,  $\eta_3$ , and  $\eta_4$ , are equal to 0.22, 0.342 (0.38 x 0.9), 0.038 (0.38 x 0.1), and 0.4. Similarly, for the upper bound estimate,  $\eta_1$ ,  $\eta_2$ ,  $\eta_3$ , and  $\eta_4$  are equal to 0.22, 0.304 (0.38 x 0.8), 0.076 (0.38 x 0.2), and 0.4. The logic charts displayed in Figures 5-1 and 5-2 were obtained from Figure 4-1 and 4-2, respectively, by entering the upper bound and central estimates for  $\eta_1$ ,  $\eta_2$ ,  $\eta_3$ , and  $\eta_{44}$  in place of 1.0. Quantification results for these two charts are shown in Table 5-2 and 5-3. As shown in these tables, the upper bound estimate is 0.154. Table 5-4 provides similar estimates for all the LOCA scenarios

### Table 5-1. Debris size distribution data used in example 1 Reference 5.1.

Debris Classification	Upper Bound	Central Estimate
Small Pieces	0.22	0.22
Large Pieces	0.38	0.38
Canvassed	0.40	0.40

#### BWROG Distribution of Generated Debris

#### Location of Large Pieces Relative to Lowest Grating

Debris Classification	Upper Bound	Central Estimate
Large Above	0.8	0.9
Large Below	0.2	0.1

#### Distribution for Logic Chart Quantification

Debris Classification	Upper Bound	Central Estimate
Small Pieces $(\eta_i)$	0.22	0.22
Large Pieces $(\eta_2)$	0.30	0.34
Large Pieces – Below $(\eta_3)$	0.08	0.04
Canvassed (η₄)	0.40	0.40

postulated in this study. As shown in this table, the upper bound estimates for F<sup>ZOI</sup> for a Mark I MSLB between 0.28 and 0.31 depending on the scenario considered. For a recirculation line break, F<sup>ZOI</sup> upper bound reached up to 0.4. Variations between Mark I, II, and III are not significant because the study assumed that all the containment types contain two floor gratings and other plant features that are similar.

In this example, the BWROG size distribution data was used to demonstrate the ease with which such data (if judged to be applicable) can be integrated into the logic charts. Its use should not be perceived as an unconditional endorsement of its applicability to a variety of breaks. The analyst must judge its applicability and, if not applicable, derive applicable plant-, break- and insulation-specific size distribution data for use.

# 5.2 Deviations from the Assumed Generic Plant Geometry

As described in Section 4, all the logic charts presented thus far have been based on certain assumptions related to plant geometry. Direct use of the transport factors presented in Table 5-4. Appendix-A is only justified if the plant being analyzed is similar to the assumed plant geometry. If not, any variations should be carefully considered to derive applicable transport factors. To demonstrate how such variations can be accommodated, consider a Mark I plant with one floor grating instead of two floor gratings as assumed in the present case. For this case, assume the same size distribution as that used in the example above.

This deviation can be seen to affect distribution after blowdown in Figures 5-1 and 5-2. Note that these fractions were obtained by assuming two gratings as shown in Figures 4-7 and 4-8. Retention at the upper grating can be eliminated by setting capture efficiency in both cases to be 0.0, instead of 0.15 used in Figure 4-7 and 0.25 used in Figure 4-8. As shown in Figures 5-3 and 5-4, this change results in transport of a higher fraction of debris to the vents during blowdown. Figures 5-5 and 5-6 present resulting logic trees for the overall accident scenario, with the quantification results presented in Tables 5-5 and 5-6. These tables, when compared to Tables 5-1 and 5-2, clearly illustrate that a larger fraction of the small debris would be transported if the plant were to have a single grating.

DEBRIS TRANSPORT RESULTS											
Plant Design:	MARK I										
Estimate:	UPPER BC	OUND		FIBROUS	INSULATIO	N					
Break:	MSL BREA	4K									
ECCS:	ECCS THF	ROTTLED									
Sprays:	SPRAYS O	PERATED									
TREE QUANTIFICA	TION										
Debris Classification	Vents	Enclosures	Floor	Structures Above	Structures Break	Structures Other	Transport Fraction				
Small Pieces	1.982E-01	0.000E+00	2.178E-02	0.000E+00	0.000E+00	0.000E+00	0.9010				
Large Pieces-Above	6.000E-03	0	0.000E+00	0	7.350E-02	2.205E-01	0.0200				
Large Pieces-Below	8.000E-02	0.000E+00	0.000E+00	0	0.000E+00	0.000E+00	1.0000				
All Large Pieces	8.600E-02	0.000E+00	0.000E+00	0	7.350E-02	2.205E-01	0.2263				
All Debris	2.842E-01	0.000E+00	2.178E-02	0.000E+00	7.350E-02	2.205E-01	0.4737				
All Zone-of-Influence							0.2842				
FINAL DISTRIBUTI	ONS (Horizo	ntal)									
		<b>.</b> .		Structures	Structures	Structures					
Debris Classification	Vents	Enclosures	Floor	Above	Break	Other					
Small Pieces	90.10%	0.00%	9.90%	0.00%	0.00%	0.00%					
Large Pieces-Above 2.00%		0%	0.00%	0%	24.50%	73.50%					
Large Pieces-Below 100.00%		0.00%	0.00%	0%	0.00%	0.00%					
All Large Pieces 22.63% (		0.00%	0.00%	0%	19.34%	58.03%					
All Debris	All Debris 47.37% 0.00%		3.63%	0.00%	12.25%	36.75%					
RELATIVE CONTR	IBUTIONS (	(Vertical)									
Debris Classification	Vents	Enclosures	Floor	Structures	Structures	Structures					
Debris Classification	vents	Enclosures	11001	Above	Break	Other					
Small Pieces	69.74%	N/A	100.00%	N/A	0.00%	0.00%					
Large Pieces-Above	2.11%	N/A	0.00%	N/A	100.00%	100.00%					
Large Pieces-Below	28.15%	N/A	0.00%	N/A	0.00%	0.00%					
All Large Pieces	30.26%	N/A	0.00%	N/A	100.00%	100.00%					
1.250		Debris	Transport	Fractions							
1.000											
0.250 0.000											
Small Del	oris Large Gra	e Above atings	Large Below Gratings	All Large De	bris All D	ebris A	All Zone-of- Influence				

 Table 5-2. Upper bound estimates for debris transport based on BWROG size distribution data.

<b></b>		DEBRI	S TRANSPO	ORT RESUL	TS		·
Plant Design:	MARKI				15		
Estimate:	CENTRAI	ESTIMATI	5	FIBROUS	INSULATIC	NN	
Break:	MSL BRE	AK		TIDROOD	INSULATIC		
ECCS:	ECCS THI	ROTTLED					
Sprays:	SPRAYS C	PERATED					
TREE QUANTIFICA	TION						
Debris Classification	Vents	Enclosures	Floor	Structures Above	Structures Break	Structures Other	Transport Fraction
Small Pieces	1.149E-01	2.200E-03	4.803E-02	8.712E-03	1.100E-02	3.520E-02	0.5221
Large Pieces-Above	3.400E-03	0	0.000E+00	0	5.049E-02	2.861E-01	0.0100
Large Pieces-Below	3.600E-02	4.000E-04	1.620E-03	0	3.960E-04	1.584E-03	0.9000
All Large Pieces	3.940E-02	4.000E-04	1.620E-03	0	5.089E-02	2.877E-01	0.1037
All Debris	1.543E-01	2.600E-03	4.965E-02	8.712E-03	6.189E-02	3.229E-01	0.2571
All Zone-of-Influence							0.1543
FINAL DISTRIBUTIO	ONS (Horizo	ntal)					
Debris Classification	Vents	Enclosures	Floor	Structures Above	Structures Break	Structures	
Small Pieces	52.21%	1.00%	21.83%	3.96%	5.00%	16.00%	
Large Pieces-Above	1.00%	0%	0.00%	0%	14.85%	84.15%	
Large Pieces-Below	90.00%	1.00%	4.05%	0%	0.99%	3.96%	
All Large Pieces	10.37%	0.11%	0.43%	0%	13.39%	75.71%	
All Debris	25.71%	0.43%	8.27%	1.45%	10.31%	53.82%	
RELATIVE CONTR	BUTIONS (	Vertical)					
Debris Classification	Vents	Enclosures	Floor	Structures Above	Structures Break	Structures	
Small Pieces	74.46%	84.62%	96.74%	100.00%	17.77%	10.90%	
Large Pieces-Above	2.20%	0%	0.00%	0%	81.59%	88.61%	
Large Pieces-Below	23.34%	15.38%	3.26%	0%	0.64%	0.49%	
All Large Pieces	25.54%	15.38%	3.26%	0%	82.23%	89.10%	
1.000		Debris	Transport I	ractions			
0.750							
Small Debr	is Large Grat	Above La ings	arge Below Gratings	All Large Deb	ris All De	ebris All II	Zone-of- nfluence

Table 5-3. Central estimate for debris transport based on BWROG size distribution data.

DEBRIS TRANSPORT FRACTIONS														
Break	ECCS	Sprays	Small		Large Above		Large Below		All Large		All Debris		All ZOI	
2.04.1			Central	UB	Central	UB	Central	UB	Central	UB	Central	UB	Central	UB
Mark I														
Main Steam Line	Steaming	Not Used	0.52	0.89	0.00	0.00	0.90	1.00	0.09	0.21	0.25	0.46	0.15	0.28
Main Steam Line	Steaming	Operated	0.52	0.90	0.01	0.02	0.90	1.00	0.10	0.23	0.26	0.47	0.15	0.28
Main Steam Line	Full < 1 Hr	Not Used	0.63	0.93	0.01	0.03	0.94	1.00	0.11	0.23	0.30	0.49	0.18	0.29
Main Steam Line	Full < 1 Hr	Operated	0.79	1.00	0.02	0.05	0.94	1.00	0.12	0.25	0.36	0.53	0.22	0.31
Recirculation Line	Full < 1 Hr	Not Used	0.74	1.00	0.01	0.12	0.94	1.00	0.11	0.31	0.34	0.56	0.21	0.34
Recirculation Line	Full < 1 Hr	Operated	0.86	1.00	0.02	0.12	0.94	1.00	0.12	0.31	0.39	0.56	0.23	0.34
Recirculation Line	Full < 3 Hr	Not Used	0.74	1.00	0.04	0.30	0.94	1.00	0.14	0.45	0.36	0.65	0.21	0.39
Recirculation Line	Full < 3 Hr	Operated	0.86	1.00	0.05	0.30	0.94	1.00	0.14	0.45	0.40	0.65	0.24	0.39
Mark II													┞───┥	
Main Steam Line	Steaming	Not Used	0.55	0.89	0.00	0.00	0.90	1.00	0.09	0.21	0.26	0.46	0.16	0.28
Main Steam Line	Steaming	Operated	0.74	1.00	0.01	0.02	0.90	1.00	0.10	0.23	0.34	0.51	0.20	0.31
Main Steam Line	Full < 1 Hr	Not Used	0.70	0.95	0.01	0.03	0.95	1.00	0.11	0.23	0.33	0.50	0.20	0.30
Main Steam Line	Full < 1 Hr	Operated	0.83	1.00	0.02	0.05	0.95	1.00	0.12	0.25	0.38	0.52	0.23	0.31
Recirculation Line	Full < 1 Hr	Not Used	0.80	1.00	0.01	0.12	0.95	1.00	0.11	0.31	0.36	0.56	0.22	0.34
Recirculation Line	Full < 1 Hr	Operated	0.89	1.00	0.02	0.12	0.95	1.00	0.12	0.31	0.40	0.56	0.24	0.34
Recirculation Line	Full < 3 Hr	Not Used	0.80	1.00	0.04	0.30	0.95	1.00	0.14	0.45	0.38	0.65	0.23	0.39
Recirculation Line	Full < 3 Hr	Operated	0.89	1.00	0.05	0.30	0.95	1.00	0.14	0.45	0.42	0.65	0.25	0.39
Mark III	Ī									ļ				
Main Steam Line	Steaming	N/A	0.55	0.89	0.00	0.00	0.90	1.00	0.09	0.21	0.26	0.46	0.16	0.28
Main Steam Line	Full < 1 Hr	N/A	0.64	0.93	0.01	0.03	0.90	1.00	0.11	0.23	0.30	0.49	0.18	0.29
Recirculation Line	Full < 1 Hr	N/A	0.72	1.00	0.01	0.12	0.90	1.00	0.11	0.31	0.33	0.56	0.20	0.34
Recirculation Line	Full < 3 Hr	N/A	0.72	1.00	0.04	0.30	0.90	1.00	0.13	0.45	0.35	0.65	0.21	0.39

Table 5-4. Central and upper bound estimates for debris transport factors based on BWROG size distribution data.

# Application of the Study Results

LOCA Type	Debris Classification	Distribution After Blowdown	Erosion and Washdow	n Drywell Floor Pool	Path No	Fraction	Final Location
MARKI		Advected to Vents			1	1.958E-01	Vents
LIPPER POUNT		0.89 Enclosures			2	0.000E+00	Enclosures
MOL DDD I V	,	0.00		Waterborne	3	0.000E+00	Vents
MSL BREAK		Drywell Floor		0.00			
ECCS THROTT	LED	0.00		Sediment	4	0.000E+00	Floor
SPRAYS OPER.	ATED			1.00			
FIBROUS INSU	LATION			0.10	5	0.000E+00	Vents
			Condensate Drainage	Sediment	6	0.000E+00	Floor
	Small Pieces	Structures-Above	Adheres	0.90	7	0.000E+00	Structures-Above
	0.22		0.90	Waterborne	8	6 600E 04	Vanta
			Sprays/Condensate	0.10		0.000E-04	vents
		Structures_Break	1.00	Sediment	9	5.940E-03	Floor
		0.03	Adheres	0.90	10	0.000E+00	Structures-Break
			0.00	Waterborne	11	1.760E-03	Vents
			Sprays/Condensate	0.10			
		Structures-Other	1.00	Sediment	12	1.584E-02	Floor
	1	0.08	Adheres		13	0.000E+00	Structures-Other
			0.00	Waterborne	14	1.500E-03	Vents
			Sprays/Condensate	1.00			
	5	Structures-Break	0.02	0.00	15	0.000E+00	Floor
	C C C C C C C C C C C C C C C C C C C	0.25	Adheres 0.98		16	7.350E-02	Structures-Break
				Waterborne	17	4.500E-03	Vents
	Large-Above 0.30		Sprays/Condensate	Sediment	19	0.000E1.00	
	Le contra le contra en contra le co	Structures-Other	Adheres	0.00	10	0.00012+00	Floor
MSL Break		Advected to Vent	0.98	·····	19	2.205E-01	Structures-Other
1.00	Ē	1.00			20	8.000E-02	Vents
1	Large-Below 0	Enclosures			21	0.000E+00	Enclosures
C	0.08			Waterborne	22	0.000E+00	Vents
	L	Drywell Floor		Sediment	22	0.0005.00	
	-		!	1.00	25	0.000E+00	Floor
				Waterborne	24	0.000E+00	Vents
			Sprays/Condensate	0.00			
	s	tructures-Break	0.02	Sediment	25	0.000E+00	Floor
			Adheres		26	0.000E+00	Structures-Break
			ŕ	Waterborne	27	0.000E+00	Vents
			Sprays/Condensate				
	S	tructures-Other		1.00	28	0.000E+00	Floor
	0.	.00 14	Aaneres		29	0.000E+00	Structures-Other
. <u></u> 0	.40				30 Total	4.000E-01	Structures/Floor

Figure 5-1. Upper bound logic chart with BWKOG size distribution data.

LOCA Type	Debris Classification	Distribution After Blowdown	Erosion and Washdown	Drywell Floor Pool	Path No.	Fraction	Final Location
		Advected to Vents			1	1.144E-01	Vents
MARK I		0.52 Enclosures			2	2.200E-03	Enclosures
CENTRAL EST	IMATE	0.01		Waterborne	3	0.000E+00	Vents
MSL BREAK		D		0.00			
ECCS THROTT	LED	0.01		Sediment	4	2.200E-03	Floor
SPRAYS OPER	ATED			1.00			
FIRBOUG INCO	I ATION			Waterborne	5	8.800E-07	Vents
FIBROUS INSU	LATION		Condensate Drainage	0.01			
		Structures-Above	0.01	0.99	6	8.712E-05	Floor
	Small Pieces	0.04	Adheres		7	8.712E-03	Structures-Above
	0.22		0.99	Waterborne	8	1.100E-04	Vents
			Sprays/Condensate	0.01			
		Structures-Break	0.50	Sediment	9	1.089E-02	Floor
		0.10	Adheres		10	1.100E-02	Structures-Break
			0.50	Waterborne	11	3.520E-04	Vents
			Sprays/Condensate	0.01			
		Structures Other	0.50	Sediment	12	3.485E-02	Floor
		0.32	Adheres	0.99	13	3.520E-02	Structures-Other
			0.50	Waterborne	14	5.100E-04	Vents
			Snmuc/Condensate	1.00			
	1		0.01	Sediment	15	0.000E+00	Floor
		Structures-Break	Adheres	0.00	16	5.049E-02	Structures-Break
			0.99	Waterborne	17	2.890E-03	Vents
			S-muc/Condonate	1.00			
	0.34		0.01	Sediment	18	0.000E+00	Floor
		Structures-Other	Adheres	0.00	19	2.861E-01	Structures-Other
MSL Break	4	Advected to Vent	0.99		20	3.600E-02	Vents
1.00		0.90			1	4 0005 04	Enclosures
	Large-Below	Enclosures 0.01			21	4.000E-04	Enclosules
]	0.04			Waterborne	22	0.000E+00	Vents
		Dryweil Floor		Sediment	73	L 600E-03	Floor
		0.04		1.00		1.0001 05	
				Waterborne	24	0.000E+00	Vents
			Sprays/Condensate	0.00			
			0.01	Sediment	25	4.000E-06	Floor
1		0.01	Adheres	1.00	26	3.960E-04	Structures-Break
			0.99	Waterborne	27	0.000E+00	Vents
			Samue/Condensate	0.00			
			0.01	Sediment	28	1.600E-05	Floor
		Structures-Other 0.04	Adheres	1.00	29	1.584E-03	Structures-Other
	Canvassed		0.99	·	- 30	4.000E-01	Structures/Floor
1	0.40		· · · · · · · · · · · · · · · · · · ·		Total	1.000E+00	

Figure 5-2. Central estimate logic chart with BWROG size distribution data.

### Application of the Study Results

Initiating Event	Surface Wetting	Distribution in Drywell	Interaction with Upper Grating	Interaction with Lower Grating	Interaction with Vent Structures and Floor	Path	Fraction	To Vent	Location of Debris
	Incomplete				<u> </u>	- 1	3.5000E-01	x	Transported Into Vent Downcomers
		OUND ESTIMAT	Ē	Goes by	Goes by 1.00	2	2.2653E-01	Х	Transported Into Vent Downcomers
			Goes By	0.85	Captured	3	0.0000E00		Deposited onto Floor Near Vents
Small Pieces		Upper Region 0.41	-	Captured0.15		4	3.9975E-02		Structures Below Spray Heads
			Captured			5	0.0000E00		Structures Below Spray Heads
	Complete			Goes By	Goes By 1.00	6	2.0443E-01	Х	Transported Into Vent Downcmers
	0.65	Middle Region		0.85	Captured	7	0.0000E00		
		0.57		Captured 0.15		8	3.6075E-02		
		Lower Region			Goes by 1.00	9	1.4300E-01	Х	Trasported Into Vent Downcomer
		0.22			Captured	10	0.0000E00		Deposited onto Floor Near Vents

Figure 5-3. Effect of upper floor grating on upper bound estimate of debris distribution after blowdown.

Debris Size Classification	Distribution at Time of Vent Clearance	Distribution in Drywell	Interaction with Structures in Upper Region	Interation with Upper Grating	Interaction with Structures in Middle Region	Interaction with Lower Grating	Interaction with Structures in Lower Region	Interaction with Vent Structures and Floor	Path	Fraction	To Vent	Location of Debris
	Structures (A 0.02	bove)				• •			1	2.0000E-02		Structures Above Spray Heads
	Structures (E 0.08	elow)							2	8.0000E-02		Structures Below Spray Heads
	Enclosures 0.01								3	1.0000E-02		Enclosures
							Goes By	Goes By 0.99	4	1.9751E-01	X	Transported Into Vent Downcomers
						Goes By	0.90	Captured 0.01	5	1.9951E-03		Deposited onto Floor Near Vents
	CE	NTRAL ESTIMAT	ſE		Goes By 0.90	0.10	Captured 0.10		6	2.2168E-02		Structures Below Spray Heads
Small Pieces	<b></b>			Goes By 1.00		Captured 0.25			7	7.3892E-02		Structures Below Spray Heads
1.00			Goes By 0.90		Captured 0.10				8	3.2841E-02		Structures Below Spray Heads
		Upper Region	l	Captured		. <u></u>			9	0.0000E00		Structures Below Spray Heads
		0.41	Captured (Ab 0.05	ove)					10	1.8245E-02		Structures Above Spray Heads
			Captured (Be 0.05	low)					11	1.8245E-02		Structures Below Spray Heads
							Goes By	Goes By 0.99	12	1.9805E-01	X	Transported Into Vent Downcomers
	A :					Goes By	0.90	Captured 0.01	13	2.0005E-03		Deposited onto Floor Near Vents
	0.89				Goes By 0.90	0.75	Captured 0.10		14	2.2228E-02		Structures Below Spray Heads
		Middle Region 0.37				Captured 0.25			15	7.4092E-02		Structures Below Spray Heads
					Captured 0.10				16	3.2930E-02		Structures Below Spray Heads
							Goes By	Goes By 0.99	17	1.7446E-01	X	Transported Into Vent Downcomers
		Lower Region					0.90	Captured 0.01	18	1.7622E-03		Deposited onto Floor Near Vents
		V.22					Captured 0.10		19	1.9580E-02		Structures Below Spray Heads

Figure 5-4. Effect of upper grating on central estimate of debris distribution after blowdown.



Application of the Study Results



LOCA Туре	Debris Classification	Distribution After Blowdown	Erosion and Washdown	Drywell Floor Pool	Path No.	Fraction	Final Location
		Advected to Vents			1	1.254E-01	Vents
MARK I		0.57 Enclosures			2	2.200E-03	Enclosures
CENTRAL EST	IMATE	0.01		Waterborne	3	0.000E+00	Vents
MSL BREAK		Drovell Floor		0.00			
ECCS THROTT	LED	0.01		Sediment	4	2.200E-03	Floor
SPRAYS OPER	ATED			Waterborne	5	8.800F-07	Vents
FIBROUS INSU	LATION		Condemaste Delles	0.01			
NO UPPER GR	ATING	Cu	0.01	Sediment	6	8.712E-05	Floor
	Small Pieces	Structures-Above	Adheres	0.99	7	8.712E-03	Structures-Above
Į	0.22		0.99	Waterborne	8	9.900E-05	Vents
1	ļ		Sprays/Condensate	0.01		0 0015 00	Floor
		Structures-Break	0.50	Sediment 0.99	9	9.801E-03	rioor
		0.09	Adheres 0.50		10	9.900E-03	Structures-Break
				Waterborne 0.01	11	3.080E-04	Vents
			Sprays/Condensate	Sediment	12	3.049E-02	Floor
		Structures-Other	Adheres	0.99	13	3.080E-02	Structures-Other
I		0.20	0.50	Waterborne	14	5.100E-04	Vents
			Snraue/Condensate	1.00			
		Observation D	0.01	Sediment	15	0.000E+00	Floor
		O.15	Adheres	0.00	16	5.049E-02	Structures-Break
Í		1	0.99	Waterborne	17	2.890E-03	Vents
1	Large-Above	]	Sprays/Condensate	1.00		0.0005 - 00	Floor
	0.34	Structures-Other	0.01	0.00	18	0.000E+00	Structures Out
MSL Break		0.85	Adheres 0.99		19	2.801E-01	Vante
1.00	1	Advected to Vent 0.90	<b></b>		20	3.00012-0Z	· · ·
	Large-Below	Enclosures 0.01		<u> </u>	21	4.000E-04	Enclosures
1	0.04	<b>1</b>		Waterborne 0.00	22	0.000E+00	Vents
1		Drywell Floor 0.04		Sediment	23	1.600E-03	Floor
1				1.00			
				Waterborne 0.00	24	0.000E+00	Vents
			Sprays/Condensate	Sediment	25	4.000E-06	Floor
		Structures-Break	Adheres	1.00	26	3.960E-04	Structures-Break
		0.01	0.99	Waterborne	27	0.000E+00	Vents
1			Spraue/Condensate	0.00	·		
		Characterize Out-	0.01	Sediment	28	1.600E-05	Floor
		0.04	Adheres	1.00	29	1.584E-03	Structures-Other
1	Canvassed		U.99		30	4.000E-01	Structures/Floor
	3.10				' L'otal	1 LUCOE+UN	

Figure 5-6. Central estimate logic tree for debris transport in a Mark I drywell with one floor grating.

DEBRIS TRANSPORT RESULTS										
Plant Design:	MARK I									
Estimate:	UPPER BO	UND		<b>FIBROUS</b> I	INSULATIO	N				
Break:	MSL BREA	ĸ								
ECCS:	ECCS THE	ROTTLED								
Sprays:	SPRAYS O	PERATED								
TREE QUANTIFICA	TION									
Debris Classification	Vents	Enclosures	Floor	Structures Above	Structures Break	Structures Other	Transport Fraction			
Small Pieces	2.042E-01	0.000E+00	1.584E-02	0.000E+00	0.000E+00	0.000E+00	0.9280			
Large Pieces-Above	6.000E-03	0	0.000E+00	0	7.350E-02	2.205E-01	0.0200			
Large Pieces-Below	8.000E-02	0.000E+00	0.000E+00	0	0.000E+00	0.000E+00	1.0000			
All Large Pieces	8.600E-02	0.000E+00	0.000E+00	0	7.350E-02	2.205E-01	0.2263			
All Debris	2.902E-01	0.000E+00	1.584E-02	0.000E+00	7.350E-02	2.205E-01	0.4836			
All Zone-of-Influence							0.2902			
FINAL DISTRIBUTIO	ONS (Horizo	ntal)								
Debuis Classification	Vonto	Enclosures	Floor	Structures	Structures	Structures				
Debris Classification	vents	Enclosures	FIOOF	Above	Break	Other				
Small Pieces	92.80%	0.00%	7.20%	0.00%	0.00%	0.00%				
Large Pieces-Above	2.00%	0%	0.00%	0%	24.50%	73.50%				
Large Pieces-Below	100.00%	0.00%	0.00%	0%	0.00%	0.00%				
All Large Pieces	22.63%	0.00%	0.00%	0%	19.34%	58.03%				
All Debris	48.36%	0.00%	2.64%	0.00%	12.25%	36.75%				
RELATIVE CONTR	IBUTIONS (	Vertical)								
Debris Classification	Vents	Enclosures	Floor	Structures	Structures	Structures				
Small Pieces	70.36%	N/A	100.00%	N/A	0.00%	0.00%				
Large Pieces-Above	2 07%	N/A	0.00%	N/A	100.00%	100.00%				
Large Pieces-Below	27 57%	N/A	0.00%	N/A	0.00%	0.00%				
All Large Pieces	29.64%	N/A	0.00%	N/A	100.00%	100.00%				
1.250		Debris	Transport	Fractions			]			
1.000 5 0.750 0.500 0.250 0.000 Small Det	pris Large	e Above	Large Below	H Large De	bris All D	Pebris A	All Zone-of-			
	Gra	atings	Gratings	<u>j</u>			Influence			

Table 5-5. Upper bound transport factors for debris transport in a Mark I drywell with one floor grating.

 Table 5-6. Central estimate transport factors for debris transport in a Mark I drywell with one floor grating.

DEBRIS TRANSPORT RESULTS									
Plant Design:	MARK I						o		
Estimate:	CENTRAL	ESTIMATE	Ì	FIBROUS	INSULATIO	N	i i i i i i i i i i i i i i i i i i i		
Break:	MSL BREA	AK		TEROUS					
ECCS:	ECCS THE	ROTTLED							
Sprays:	SPRAYS O	PERATED							
TREE QUANTIFICA	TION								
Debris Classification	Vents	Enclosures	Floor	Structures Above	Structures Break	Structures Other	Transport Fraction		
Small Pieces	1.258E-01	2.200E-03	4.258E-02	-02 8.712E-03 9.90		3.080E-02	0.5719		
Large Pieces-Above	3.400E-03	0	0.000E+00	0	5.049E-02	2.861E-01	0.0100		
Large Pieces-Below	3.600E-02	4.000E-04	1.620E-03	0	3.960E-04	1.584E-03	0.9000		
All Large Pieces	3.940E-02	4.000E-04	1.620E-03	0	5.089E-02	2.877E-01	0.1037		
All Debris	1.652E-01	2.600E-03	4.420E-02	8.712E-03	6.079E-02	3.185E-01	0.2753		
All Zone-of-Influence							0.1652		
FINAL DISTRIBUTIO	ONS (Horizo	ntal)							
			_	Structures	Structures	Structures			
Debris Classification	Vents	Enclosures	Floor	Above	Break	Other			
Small Pieces	57.19%	1.00%	19.35%	3.96%	4.50%	14.00%			
Large Pieces-Above	0%	0.00%	0%	14.85%	84.15%				
Large Pieces-Below	90.00%	1.00%	4.05%	0%	0.99%	3.96%			
All Large Pieces	10.37%	0.11%	0.43%	0%	13.39%	75.71%			
All Debris	27.53%	0.43%	7.37%	1.45%	10.13%	53.08%			
RELATIVE CONTR	IBUTIONS (	Vertical)							
Debris Classification	Vents	Enclosures	Floor	Structures Above	Structures Break	Structures Other			
Small Pieces	76 15%	84 62%	96 33%	100.00%	16.29%	9.67%			
Large Pieces-Above	2.06%	0%	0.00%	0%	83.06%	89.83%			
Large Pieces-Below	21.79%	15.38%	3.67%	0%	0.65%	0.50%			
All Large Pieces	23.85%	15.38%	3.67%	0%	83.71%	90.33%			
1.000		Debris	Transport	Fractions					
0.750									
0.250 0.000 Small Deb	ris Large	Above L	arge Below	All Large Det	oris All D	ebris Al	I Zone-of-		
	Gra	tings	Gratings			1	nfluence		

Application of the Study Results

A variety of deviations from assumed plant geometries can be analyzed by simply altering appropriate branch ratios, including assumptions related to operation of containment sprays, break overflow duration and drywell floor design.

# **5.3 References**

- 5.1 NEDO-32686, "Utility Resolution Guidance for ECCS Suction Strainer Blockage," Boiling Water Reactor Owners' Group, 1996.
- 5.2 U.S. Nuclear Regulatory Commission, "Water Sources for Long-Term Recirculation Cooling Following a Loss of Coolant Accident," Regulatory Guide 1.82, Rev. 2, 1995.
- 5.3 Zigler et al., "Parametric Study of the Potential for BWR ECCS Strainer Blockage Due to LOCA Generated DEBRIS," NUREG/CR-6224, Science and Engineering Associates, Inc., 1995.
- 5.4 D. V. Rao et al, "Drywell Debris Transport Study: Experimental Work," NUREG / CR-6369, Supplement 1, Science and Engineering Associates, Inc., 1997

Appendix A

**Compilation of Debris Transport Study Logic Charts** 

### A.1 INTRODUCTION

The drywell debris transport problem was decomposed into several components that were amenable to resolution by the available knowledge base including small-scale experiments, analytical modeling and engineering calculations, and by engineering judgments. Then the solutions to the individual components were linked together into a comprehensive study using logic charts the represented the overall transport process. A separate chart was created for each accident scenario and each plant design analyzed but only selected logic charts were presented in the main document of this report. This appendix provides, in Sections A.3 and A.4, a complete compilation of the charts for the reader desiring detailed information. The quantification results for all the charts are presented in Section A.2.

The structure of the logic chart, which was identical for each of the scenarios and plant design studied, was explained in the main document (see Figure 2-9). To summarize, the charts decomposes the overall transport problem into those transport processes associated with primary system blowdown, subsequent erosion and washdown of the insulation debris deposited onto structures during the blowdown period, and the water pool forming on the drywell floor. The chart further treated small debris separately from large debris generated above any grating and large debris generated below the lowest grating. The relative concentrations of small and large debris were essentially an unknown to this study and their determination was not a study objective. Therefore, the results are reported by debris size classification and then combined with debris generation data from an outside source to illustrate how this data can be used to determine overall debris transport fractions. The first sheet of each logic charts contains the actual structure of the chart while the second sheet contained the tabulated results for that chart. The identification of the accident scenario and the plant design is found in the upper left corner of each sheet.

The logic chart structure (first sheet) begins at the left side and then progresses from left to right as the insulation debris was postulated to move through the various transport processes. The structures resulted in a total of 30 separate debris transport pathways with the fraction of the initial debris following each pathway and its final location noted in the right two columns. Note that that sum of the fractions adds to one.

Three tables of quantification results are shown on each of the second sheets along with a graphical presentation of the transport fractions. The first of these three tables shows a summation of the debris fraction sorted by debris type and their final locations. The fractions of debris transported into the downcomer vents are shown in the column at the right. For example, the transport fraction for small debris in the right column was the predicted fraction of the debris in the form of small pieces that was transported into the vent downcomers. The debris classifications in the first table are further illustrated in Table A-1.

<b>Debris Classification</b>	Basis for Quantification
Small Pieces	Only small pieces of debris
Large Pieces-Above	Only large debris generated above any grating.
Large Pieces-Below	Only large debris generated below the lowest grating.
All Large Pieces	The combination of both large pieces-above, and large pieces-below.
All Debris	The combination of small pieces, large pieces-above, and large pieces-below.
All Zone-of-Influence	All insulation contained in the zone-of-influence including canvassed debris and intact insulation still on the pipes.

Table A-1: Basis for	· Quantification of	Debris Trans	port by Debris	Classification
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The second and third of these tables contains the same information as the first table but the information is expressed in percentages. In the second table, the percentages were based on the total fractions for that debris classification (horizontal) and in the third table, the percentages were based on the total fractions for a particular final location (vertical).

### A.2 COMPILATION OF RESULTS

The final quantification results are shown in Tables A-2 and A-3, and Figure A-1 through A-6. Table A-2 lists the debris transport fractions sorted by debris classification and scenario. Table A-3 shows the relative contribution each debris classification made to the total debris transported into the downcomer vents, i.e., the percentages for small, large-above, and large-below add to 100%. Figure A-1 shows the transport fractions for small debris alone in a bar chart for each scenario for the Mark I design. Figure A-2 shows the transport fractions combined with a debris generation size distribution, i.e., fraction of all insulation located in the total zone-of-influence that transported into the vent downcomers for a Mark I design. The other figures, Figures A-3 through A-6, show similar results for the Mark II and III designs

# Table A-2: Debris Transport Fractions

	DEBRIS TRANSPORT FRACTIONS													
Brook	FCCS	Sprays	Sma	lli	Large A	/pove	Large B	elow	All La	rge	All De	bris	All ZC	)I
Digan			Central	UB	Central	UB	Central	UB	Central	UB	Central	UB	Central	UB
Mark I							ļ		┞───┼		<b></b>			0.00
Main Steam Line	Steaming	Not Used	0.52	0.89	0.00	0.00	0.90	1.00	0.09	0.21	0.25	0.46	0.15	0.28
Main Steam Line	Steaming	Operated	0.52	0.90	0.01	0.02	0.90	1.00	0.10	0.23	0.26	0.47	0.15	0.28
Main Steam Line	Full < 1 Hr	Not Used	0.63	0.93	0.01	0.03	0.94	1.00	0.11	0.23	0.30	0.49	0.18	0.29
Main Steam Line	Full < 1 Hr	Operated	0.79	1.00	0.02	0.05	0.94	1.00	0.12	0.25	0.36	0.53	0.22	0.31
Recirculation Line	Full < 1 Hr	Not Used	0.74	1.00	0.01	0.12	0.94	1.00	0.11	0.31	0.34	0.56	0.21	0.34
Recirculation Line	Full < 1 Hr	Operated	0.86	1.00	0.02	0.12	0.94	1.00	0.12	0.31	0.39	0.56	0.23	0.34
Recirculation Line	Full < 3 Hr	Not Used	0.74	1.00	0.04	0.30	0.94	1.00	0.14	0.45	0.36	0.65	0.21	0.39
Recirculation Line	Full < 3 Hr	Operated	0.86	1.00	0.05	0.30	0.94	1.00	0.14	0.45	0.40	0.65	0.24	0.39
Mark II								!		·				
Main Steam Line	Steaming	Not Used	0.55	0.89	0.00	0.00	0.90	1.00	0.09	0.21	0.26	0.46	0.16	0.28
Main Steam Line	Steaming	Operated	0.74	1.00	0.01	0.02	0.90	1.00	0.10	0.23	0.34	0.51	0.20	0.31
Main Steam Line	Full < 1 Hr	Not Used	0.70	0.95	0.01	0.03	0.95	1.00	0.11	0.23	0.33	0.50	0.20	0.30
Main Steam Line	Full < 1 Hr	Operated	0.83	1.00	0.02	0.05	0.95	1.00	0.12	0.25	0.38	0.52	0.23	0.31
Recirculation Line	Full < 1 Hr	Not Used	0.80	1.00	0.01	0.12	0.95	1.00	0.11	0.31	0.36	0.56	0.22	0.34
Recirculation Line	Full < 1 Hr	Operated	0.89	1.00	0.02	0.12	0.95	1.00	0.12	0.31	0.40	0.56	0.24	0.34
Recirculation Line	Full < 3 Hr	Not Used	0.80	1.00	0.04	0.30	0.95	1.00	0.14	0.45	0.38	0.65	0.23	0.39
Recirculation Line	Full < 3 Hr	Operated	0.89	1.00	0.05	0.30	0.95	1.00	0.14	0.45	0.42	0.65	0.25	0.39
Mark III	1	1	T							L	Į	<b></b>		ļ
Main Steam Line	Steaming	N/A	0.55	0.89	0.00	0.00	0.90	1.00	0.09	0.21	0.26	0.46	0.16	0.28
Main Steam Line	Full < 1 Hr	N/A	0.64	0.93	0.01	0.03	0.90	1.00	0.11	0.23	0.30	0.49	0.18	0.29
Recirculation Line	Full < 1 Hr	N/A	0.72	1.00	0.01	0.12	0.90	1.00	0.11	0.31	0.33	0.56	0.20	0.34
Recirculation Line	Full < 3 Hr	N/A	0.72	1.00	0.04	0.30	0.90	1.00	0.13	0.45	0.35	0.65	0.21	0.39

A--3

RELATIVE CONTRIBUTIONS TO TRANSPORT TO VENTS													
Break	ECCS	Sprays	Small	1	Large Abc	ove	Large Bel	ow .	All Large				
		-	Central	UB	Central	UB	Central	UB	Central	UB			
Mark I									<u> </u>				
Main Steam Line	Steaming	Not Used	76%	71%	0%	0%	24%	29%	24%	29%			
Main Steam Line	Steaming	Operated	74%	70%	2%	2%	23%	28%	26%	30%			
Main Steam Line	Fuli < 1 Hr	Not Used	77%	70%	2%	3%	21%	27%	23%	30%			
Main Steam Line	Full < 1 Hr	Operated	80%	70%	3%	4%	17%	26%	20%	30%			
Recirculation Line	Full < 1 Hr	Not Used	80%	65%	2%	11%	18%	24%	20%	35%			
Recirculation Line	Full < 1 Hr	Operated	81%	65%	3%	11%	16%	24%	19%	35%			
Recirculation Line	Full < 3 Hr	Not Used	76%	56%	6%	23%	18%	21%	24%	44%			
Recirculation Line	Full < 3 Hr	Operated	78%	56%	7%	23%	16%	21%	22%	44%			
Mark II			·										
Main Steam Line	Steaming	Not Used	77%	71%	0%	0%	23%	29%	23%	29%			
Main Steam Line	Steaming	Operated	80%	72%	2%	2%	18%	26%	20%	28%			
Main Steam Line	Full < 1 Hr	Not Used	79%	70%	2%	3%	19%	27%	21%	30%			
Main Steam Line	Fuli < 1 Hr	Operated	80%	70%	3%	4%	17%	26%	20%	30%			
Recirculation Line	Full < 1 Hr	Not Used	81%	65%	2%	11%	17%	24%	19%	35%			
Recirculation Line	Full < 1 Hr	Operated	81%	65%	3%	11%	16%	24%	19%	35%			
Recirculation Line	Full < 3 Hr	Not Used	77%	56%	6%	23%	17%	21%	23%	44%			
Recirculation Line	Full < 3 Hr	Operated	78%	56%	7%	23%	15%	21%	22%	44%			
Mark III										L			
Main Steam Line	Steaming	N/A	77%	71%	0%	0%	23%	29%	23%	29%			
Main Steam Line	Full < 1 Hr	N/A	78%	70%	2%	3%	20%	27%	22%	30%			
Recirculation Line	Full < 1 Hr	N/A	80%	65%	2%	11%	18%	24%	20%	35%			
Recirculation Line	Full < 3 Hr	N/A	76%	56%	7%	23%	17%	21%	24%	44%			

# Table A-3: Relative Contributions to Transport into Vents



Appendix A

LOCA Scenario

Figure A-1: Mark I Transport Fractions for Small Debris

# Mark I Combined Generation and Transport Fractions



LOCA Scenario

Figure A-2: Mark I Combined Generation and Transport Fractions

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LOCA Scenario

Figure A-3: Mark II Transport Fractions for Small Debris

# Mark II Combined Generation and Transport Fractions



LOCA Scenario

Figure A-4: Mark II Combined Generation and Transport Fractions

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**LOCA Scenarios** 

Figure A-5: Mark III Transport Fractions for Small Debris

# Mark III Combined Generation and Transport Fractions



**LOCA Scenarios** 

Figure A-6: Mark III Combined Generation and Transport Fraction

NUREG/CR-6369

#### A.3 LOGIC CHARTS FOR CENTRAL ESTIMATES

The logic charts for the central debris transport estimates are presented here and the corresponding upper bound estimates are presented on Section A.4.

#### A.3.1 Mark I

This section contains the central estimate logic charts for the Mark I design.

#### A.3.1.1 Main Steam Line Break

The central estimate logic charts for the main steam line breaks are presented here, then the charts for the recirculation line breaks are presented in Section A.3.1.2

LOCA Type	Debris Classification	Distribution After Blowdown	Erosion and Washdown	Drywell Floor Pool	Path No.	Fraction	Final Location
MARKI		Advected to Vents			1	1.144E-01	Vents
CENTRAL EST	IMATE	0.52 Enclosures			2	2.200E-03	Enclosures
MSL BREAK		0.01		Waterborne	3	0.000E+00	Vents
FCCS THEOTT	TED	Drywell Floor		0.00			_
NO SPRAVS		0.01		1.00	4	2.200E-03	Floor
FIRROUS INSU	LATION			Waterborne	5	0.000E+00	Vents
FIBROUS INSU	LATION		Condensate Drainage	0.00			
	Small Pieces	Structures-Above	0.01 Adheres	1.00		8.800E-05	Charles Alexan
	0.22	0.04	0.99	Watathama	,	0.0005.00	Structures-Above
			Condensate Devinage	0.00	0	0.000E+00	Vents
		Structures Break	0.01	Sediment	9	2.200E-04	Floor
		0.10	Adheres	1.00	10	2.178E-02	Structures-Break
			0.99	Waterborne	11	0.000E+00	Vents
			Condensate Drainage	0.00	12	70405.04	Flore
		Structures-Other	10.01	1.00	12	7.040E-04	Floor
		0.32	0.99	Watarhama	13	0.000E+02	Structures-Other
			Condensate Deninage	0.00	14	0.0002+00	vents
		- Structures-Break	0.00	Sediment	15	0.000E+00	Floor
		0.15	Adheres	1.00	16	5.100E-02	Structures-Break
			1.00	Waterborne	17	0.000E+00	Vents
	Large-Above		Condensate Drainage	Sediment	18	0.0005+00	Floor
	0.54	Structures-Other	Adheres	1.00	19	2 890F-01	Structures_Other
MSL Break		Advected to Vent	1.00		20	3.600E-02	· Vents
		0.90 Enclosures			21	4 000E-04	Fuclosures
	Large-Below	0.01		Waterborne	27	0.000E+00	Vente
		Drywell Floor		0.00		0.0002.00	7 (114)
		0.04		Sediment	23	1.600E-03	Floor
				Waterborne	24	0.000E+00	Vents
			Condensate Drainage	0.00		0.0002.00	
		Structures-Break	0.00	Sediment	25	0.000E+00	Floor
		0.01	Adheres		26	4.000E-04	Structures-Break
				Waterborne	27	0.000E+00	Vents
			Condensate Drainage 0.00	Sediment	28	0.000E+00	Floor
		Structures-Other 0.04	Adheres	1.00	29	1.600E-03	Structures-Other
	Canvassed		1.00		30	4,000E-01	Structures/Floor
	0.40		·····	····	Total	1.000E+00	

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#### DEBRIS TRANSPORT RESULTS MARK I **Plant Design:** FIBROUS INSULATION **CENTRAL ESTIMATE Estimate: Break:** MSL BREAK ECCS: ECCS THROTTLED NO SPRAYS Sprays: TREE QUANTIFICATION Structures Structures Structures Transport **Debris Classification** Vents Enclosures Floor Above Break Other Fraction Small Pieces 1.144E-01 2.200E-03 3.212E-03 8.712E-03 2.178E-02 6.970E-02 0.5200 0.000E+00 0.000E+00 0 5.100E-02 2.890E-01 0.0000 Large Pieces-Above 0 Large Pieces-Below 3.600E-02 4.000E-04 1.600E-03 0 4.000E-04 1.600E-03 0.9000 0.0947 All Large Pieces 3.600E-02 4.000E-04 1.600E-03 0 5.140E-02 2.906E-01 4.812E-03 8.712E-03 7.318E-02 3.603E-01 0.2507 All Debris 1.504E-01 2.600E-03 All Zone-of-Influence 0.1504 **FINAL DISTRIBUTIONS (Horizontal)** Structures Structures Structures Enclosures **Debris Classification** Vents Floor Above Break Other 3.96% 9.90% 52.00% 1.00% 1.46% 31.68% Small Pieces 0% 0.00% 0% 15.00% 85.00% Large Pieces-Above 0.00% 4.00% 4.00% 0% 1.00% Large Pieces-Below 90.00% 1.00% 9.47% 0.11% 0.42% 0% 13.53% 76.47% All Large Pieces 1.45% 12.20% 60.05% 0.43% 0.80% All Debris 25.07% **RELATIVE CONTRIBUTIONS (Vertical)** Structures Structures Structures Enclosures Floor **Debris Classification** Vents Above Break Other 29.76% 66.75% 100.00% 19.34% 76.06% 84.62% Small Pieces 0.00% 0% 69.69% 80.21% Large Pieces-Above 0.00% 0% 0.44% 23.94% 15.38% 33.25% 0% 0.55% Large Pieces-Below 33.25% 0% 70.24% 80.66% All Large Pieces 23.94% 15.38% **Debris Transport Fractions**



LOCA Type	Debris Classification	Distribution After Blowdown	Erosion and Washdown	Drywell Floor Pool	Path No.	Fraction	Final Location
		Advected to Vents			1	1.144E-01	Vents
MARK I		0.52 Enclosures	-		2	2.200E-03	Enclosures
CENTRAL EST	IMATE	0.01		Waterhome	2	0.000E+00	Vonte
MSL BREAK				0.00		0.000±+00	venus
ECCS THROTT	LED	Drywell Floor		i Sediment	4	2.200E-03	Floor
SPRAYS OPER	ATED			1.00			
				Waterborne	5	8.800E-07	Vents
FIBROUS INSU	LATION		Condensate Drainage	0.01			
		Structures_Above	0.01	Sediment	6	8.712E-05	Floor
	Small Pieces	0.04	Adheres	0.99	7	8.712E-03	Structures-Above
	0.22		0.99	Waterborne	8	1.100E-04	Vents
			Spravs/Condensate	0.01			
			0.50	Sediment	9	1.089E-02	Floor
		Structures-Break	Adheres	0.99	10	1.100E-02	Structures-Break
			0.50	Waterborne	11	3.520E-04	Vents
			Same Condensate	0.01			
			0.50	Sediment	12	3.485E-02	Floor
		Structures-Other 0.32	Adheres	0.99	13	3.520E-02	Structures-Other
		0.22	0.50	Waterborne	14	5 100E-04	Vents
				1.00	14	5.1001-04	
			Sprays/Condensate	Sediment	15	0.000E+00	Floor
		Structures-Break	Adheres	0.00	16	5 049E-02	Structures_Break
		0.15	0.99			0.000000	
				1.00	17	2.890E-03	Vents
	Large-Above	4	Sprays/Condensate	Sediment	18	0.000E+00	Floor
	0.24	Structures-Other		0.00	10	2.0(15.0)	Structure Other
MSL Break		0.85	0.99		19	2.8012-01	Subcures-Oliei
1.00		Advected to Vent			20	3.600E-02	Vents
	Large-Below	Enclosures			21	4.000E-04	Enclosures
	0.04	0.01		Waterborne	22	0.000E+00	Vents
		Drywell Floor		0.00			
		0.04		Sediment	23	1.600E-03	Floor
				1.00			
				Waterborne	24	0.000E+00	Vents
			Sprays/Condensate	Sediment	25	4.000E-06	Floor
		Structures-Break	0.01	1.00	26	1.000E.04	Sharehand Breek
		0.01	0.99		20	3.900E-04	Stuctures-Break
				Waterborne	27	0.000E+00	Vents
1			Sprays/Condensate	Sadimont	10	1.6007-05	Floor
		Structures-Other	0.01	1.00	28	1.0002-03	F IOOI
		0.04	Adheres		29	1.584E-03	Structures-Other
	Canvassed				30	4.000E-01	Structures/Floor
1	0.40				i lotal	1 1.000E+00	

		DEBRIS	S TRANSPO	RT RESULT	S		
Plant Design:	MARK I						
Estimate:	CENTRAL	ESTIMATE		FIBROUS I	NSULATIO	N	
Break:	MSL BREA	ιK					
ECCS:	ECCS THR	OTTLED					
Sprays:	SPRAYS O	PERATED					
TREE QUANTIFICA	TION						
Debris Classification	Vents	Enclosures	Floor	Structures Above	Structures Break	Structures Other	Transport Fraction
Small Pieces	1.149E-01	2.200E-03	4.803E-02	8.712E-03	1.100E-02	3.520E-02	0.5221
Large Pieces-Above	3.400E-03	0	0.000E+00	0	5.049E-02	2.861E-01	0.0100
Large Pieces-Below	3.600E-02	4.000E-04	1.620E-03	0	3.960E-04	1.584E-03	0.9000
All Large Pieces	3.940E-02	4.000E-04	1.620E-03	0	5.089E-02	2.877E-01	0.1037
All Debris	1.543E-01	2.600E-03	4.965E-02	8.712E-03	6.189E-02	3.229E-01	0.2571
All Zone-of-Influence							0.1543
FINAL DISTRIBUTI	ONS (Horizo	ntal)					
	Manda	Englacemen	Floor	Structures	Structures	Structures	
Debris Classification	vents	Enclosures	Floor	Above	Break	Other	
Small Pieces	52.21%	1.00%	21.83%	3.96%	5.00%	16.00%	
Large Pieces-Above	1.00%	0%	0.00%	0%	14.85%	84.15%	
Large Pieces-Below	90.00%	1.00%	4.05%	0%	0.99%	3.96%	
All Large Pieces	10.37%	0.11%	0.43%	0%	13.39%	75.71%	
All Debris	25.71%	0.43%	8.27%	1.45%	10.31%	53.82%	
RELATIVE CONTR	<b>IBUTIONS</b>	(Vertical)					
	Viente	Fralesures	Floor	Structures	Structures	Structures	
Debris Classification	v ents	Enclosures	FIOOF	Above	Break	Other	
Small Pieces	74.46%	84.62%	96.74%	100.00%	17.77%	10.90%	
Large Pieces-Above	2.20%	0%	0.00%	0%	81.59%	88.61%	
Large Pieces-Below	23.34%	15.38%	3.26%	0%	0.64%	0.49%	
All Large Pieces	25.54%	15.38%	3.26%	0%	82.23%	89.10%	
1.000		Debris	s Transport	Fractions			
0.750							
0.750							
L L							
0.250							
0.000							
Small Debris	s Large A Gratir	Above La ligs G	rge Below Gratings	All Large Debri	s All Deb	ris All. Infl	Zone-of- luence

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LOCA Type	Debris Classification	Distribution After Blowdown	Erosion and Washdown	Drywell Floor Pool	Path No.	Fraction	Final Location
		Advected to Vents			1	1.144E-01	Vents
MARK I		0.52 Enclosume			2	2 200E 01	<b>F</b>
CENTRAL EST	IMATE	0.01				2.200E-03	Enclosures
MSI DDEAK				Waterborne	3	2.200E-03	Vents
NISL BREAK		Drywell Floor		1.00			
NOT THROTTI	LED	0.01	• • • • • • • • • •	Sediment	4	0.000E+00	Floor
NO SPRAYS				0.00			
TIDDOUG INSU				Waterborne	5	8.800E-05	Vents
FIDROUS INSU	LATION		Condensate Drainage	1.00			
		Charles Allessa	0.01	Sediment	6	0.000E+00	Floor
	Small Pieces	0.04	Adheres	0.00	7	8.712E-03	Structures-Above
	0.22		0.99	Watashasa		3 300 5 03	N
				1.00	•	2.2001-02	vents
			Recirculation Flow	(D. 3)		0.0007.00	~
		Structures-Break	1.00	0.00	9	0.000E+00	Floor
		0.10	Adheres	*****	10	0.000E+00	Structures-Break
			0.00	Waterborne	11	7.040E-04	Vents
			Condensate Dminage	1.00			
			0.01	Sediment	12	0.000E+00	Floor
		Structures-Other	Adheres	0.00	13	6.0705.00	Structures Other
		0.32	0.99		15	0.9701-02	Sullciules-Oulei
				Waterborne	14	4.080E-03	Vents
			Recirculation Flow	1.00			
		Structures-Break	0.08	Sediment	15	0.000E+00	Floor
		0.15	Adheres	0.00	16	4.692E-02	Structures-Break
			0.92	Waterborne	17	0.000F+00	Vents
				1.00		0.0001100	vena
	Large-Above		Condensate Drainage	Sediment	18	0.000E+00	Floor
	0.54	Structures-Other	0.00	0.00		0.0001100	11001
MSL Break		0.85	Adheres		19	2.890E-01	Structures-Other
1.00	1	Advected to Vent			20	3.600E-02	Vents
		0.90 Enclosures			21	4.000E-04	Enclosures
	Large-Below	0.01					
	0.04			Waterborne	22	1.440E-03	Vents
		Drywell Floor			_		
		0.04		0.10	23	1.600E-04	Floor
1							
				1.00	24	2.000E-04	Vents
			Recirculation Flow	C-diment	26	0.0005.00	<b>m</b>
		Structures-Break	0.50	0.00		0.000E+00	PIOUR
		0.01	Adheres		26	2.000E-04	Structures-Break
			0.50	Waterborne	27	0.000E+00	Vents
			Condensate Dminage	1.00			
			0.00	Sediment	28	0.000E+00	Floor
		Structures-Other	Adheres	0.00	20	1 6005 03	Structures Other
		0.04	1.00		- 27	1.000E-03	
	Canvassed				30 Tatal	4.000E-01	Structures/Floor
1	V.TV				10041	1.0000+00	

		DEBRIS	TRANSPO	RT RESULT	S		
Plant Design:	MARK I						
Estimate:	CENTRAL	ESTIMATE	ſ	FIBROUS I	NSULATIO	N	
Break:	MSL BREA	K					
ECCS:	NOT THRO	OTTLED					
Sprays:	NO SPRAY	'S					
TDEE OUANTIEICA	TION						
Debris Classification	Vents	Enclosures	Floor	Structures Above	Structures Break	Structures Other	Transport Fraction
Small Pieces	1 394E-01	2.200E-03	0.000E+00	8.712E-03	0.000E+00	6.970E-02	0.6336
Large Pieces-Above	4 080E-03	0	0.000E+00	0	4.692E-02	2.890E-01	0.0120
Large Pieces-Relow	3 764E-02	4.000E-04	1.600E-04	0	2.000E-04	1.600E-03	0.9410
All Large Pieces	4.172E-02	4.000E-04	1.600E-04	0	4.712E-02	2.906E-01	0.1098
All Debris	1.811E-01	2.600E-03	1.600E-04	8.712E-03	4.712E-02	3.603E-01	0.3019
All Zone-of-Influence	1.0112 01						0.1811
EINAL DISTRICTION	ONS (Horizo)	ntal)					
FINAL DISTRIBUTI				Structures	Structures	Structures	
Debris Classification	Vents	Enclosures	Floor	Above	Break	Other	
Small Dieces	63 36%	1.00%	0.00%	3.96%	0.00%	31.68%	
Jarge Pieces_Above	1 20%	0%	0.00%	0%	13.80%	85.00%	
Large Pieces-Below	94 10%	1.00%	0.40%	0%	0.50%	4.00%	
All Large Pieces	10.98%	0.11%	0.04%	0%	12.40%	76.47%	
All Debris	30.19%	0.43%	0.03%	1.45%	7.85%	60.05%	
DELATIVE CONTR	TRUTIONS	(Vertical)					
RELATIVE CONTR				Structures	Structures	Structures	
Debris Classification	Vents	Enclosures	Floor	Above	Break	Other	
Small Pieces	76.96%	84.62%	0.00%	100.00%	0.00%	19.34%	
Large Pieces-Above	2.25%	0%	0.00%	0%	99.58%	80.21%	
Large Pieces-Below	20.78%	15.38%	100.00%	0%	0.42%	0.44%	
All Large Pieces	23.04%	15.38%	100.00%	0%	100.00%	80.66%	
1.000		Debri	s Transport	Fractions			
0.750							
0.250 0.250							20 m + 12 + 1
0.000						Debris	All Zone-of-
Small D	eons Lar G	ge Above Fratings	Gratings	ni Laiye L		20010	Influence

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LOCA Type	Debris Classification	Distribution After Blowdown	Erosion and Washdow	n Drywell Floor Pool	Path No.	Fraction	Final Location
MARK 1	i	Advected to Vents			1	1.144E-01	Vents
CENTRAL EST	IMATE	Enclosures			2	2.200E-03	Enclosures
MSL BREAK		0.01		Waterborne	3	2.200E-03	Vents
NOT THROTTI	LED	Drywell Floor					
SPRAYS OPER	ATED	0.01		0.00	- 4	0.000E+00	Floor
FIBROUS INSU	LATION	с. 1		Waterborne	5	8.800E-05	Vents
			Condensate Drainage	Sediment	6	0.0005400	
	Small Pieces	Structures-Above 0.04	Adheres	0.00	7	8.712E-03	Structures-Above
	0.22		0.99	Waterborne	8	2.200E-02	Vents
			Recirculation Flow	1.00			
		Structures-Break	1.00	Sediment	9	0.000E+00	Floor
		0.10	Adheres 0.00	***************************************	10	0.000E+00	Structures-Break
				Waterborne	11	3.520E-02	Vents
		1	Sprays/Condensate 0.50	Sediment	12	0.000E+00	Floor
		Structures-Other 0.32	Adheres	0.00	13	3.520E-02	Structures-Other
			0.50	Waterborne	14	4.080E-03	Vents
			Recirculation Flow	1.00			
	1	Structures-Break	0.08	Sediment 0.00	15	0.000E+00	Floor
		0.15	Adheres 0.92		16	4.692E-02	Structures-Break
				Waterborne 1.00	17	2.890E-03	Vents
	Large-Above 0.34	[	Sprays/Condensate 0.01	Sediment	18	0.000E+00	Floor
MSI Break		0.85	Adheres	0.00	19	2.861E-01	Structures-Other
1.00	/	Advected to Vent	0.99		20	3.600E-02	Vents
	C F	).90 Enclosures			21	4.000E-04	Enclosures
	0.04	).01		Waterborne	22	1.440E-03	Vents
	I	Drywell Floor		0.90			
	0	1.04	ļ	Sediment 0.10	23	1.600E-04	Floor
				Waterborne	24	2.000E-04	Vents
		F	Recirculation Flow	1.00			
	s	tructures-Break	0.50	Sediment	25	0.000E+00	Floor
	0	<u>م</u> 0	.50		26	2.000E-04	Structures-Break
		~		1.00	27	1.600E-05	Vents
		o Tructures_Other	.01	Sediment	28	0.000E+00	Floor
	0.	04 A	Adheres		29	1.584E-03	Structures-Other
c	Canvassed		.yy		30	4.000E-01	Structures/Floor
······································					Total	1.000E+00	

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		DEBRIS	TRANSPO	RT RESULT	S	, <u></u>	
Plant Design:	MARK I						
Estimate:	CENTRAL	ESTIMATE		FIBROUS I	NSULATIO	N	
Break:	MSL BREA	K					
ECCS:	NOT THRO	DTTLED					
Sprays:	SPRAYS O	PERATED					
TREE QUANTIFICA	TION						
Debris Classification	Vents	Enclosures	Floor	Structures Above	Structures Break	Structures Other	Transport Fraction
Small Pieces	1.739E-01	2.200E-03	0.000E+00	8.712E-03	0.000E+00	3.520E-02	0.7904
Large Pieces-Above	6.970E-03	0	0.000E+00	0	4.692E-02	2.861E-01	0.0205
Large Pieces-Below	3.766E-02	4.000E-04	1.600E-04	0	2.000E-04	1.584E-03	0.9414
All Large Pieces	4.463E-02	4.000E-04	1.600E-04	0	4.712E-02	2.877E-01	0.1174
All Debris	2.185E-01	2.600E-03	1.600E-04	8.712E-03	4.712E-02	3.229E-01	0.3642
All Zone-of-Influence							0.2185
FINAL DISTRIBUTIO	ONS (Horizo	ntal)				Ci i i	
Debris Classification	Vents	Enclosures	Floor	Structures Above	Structures Break	Other	
Small Pieces	79.04%	1.00%	0.00%	3.96%	0.00%	16.00%	
Large Pieces-Above	2.05%	0%	0.00%	0%	13.80%	84.15%	
Large Pieces-Below	94.14%	1.00%	0.40%	0%	0.50%	3.96%	
All Large Pieces	11.74%	0.11%	0.04%	0%	12.40%	75.71%	
All Debris	36.42%	0.43%	0.03%	1.45%	7.85%	53.82%	
RELATIVE CONTR	BUTIONS	(Vertical)					
Debris Classification	Vents	Enclosures	Floor	Structures Above	Structures Break	Structures Other	
Small Pieces	79.58%	84.62%	0.00%	100.00%	0.00%	10.90%	
Large Pieces-Above	3.19%	0%	0.00%	0%	99.58%	88.61%	
Large Pieces-Below	17.23%	15.38%	100.00%	0%	0.42%	0.49%	
All Large Pieces	20.42%	15.38%	100.00%	0%	100.00%	89.10%	
1.000		Debri	s Transport	Fractions		1977 - 148 - 1978 - 147 - 148 - 149 - 149 - 149 - 149 - 149 - 149 - 149 - 149 - 149 - 149 - 149 - 149 - 149 - 1	
0.750							

All Zone-of-

Influence

.

All Debris

Large Below Gratings All Large Debris

Large Above Gratings

Laction Fraction

0.250

0.000 -

Small Debris

### A.3.1.2 Recirculation Line Break

This section contains central estimate logic charts for Mark I recirculation line break scenarios.

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LOCA Type	Debris Classification	Distribution After Blowdown	Erosion and Washdown	Drywell Floor Pool	Path No.	Fraction	Final Location
MADYI		Advected to Vents		·····	1	1.012E-01	Vents
MAKN I	13.6 4 715	0.46 Enclosures			2	2.200E-03	Enclosures
CENTRAL EST	IMATE	0.01		Waterborne	3	4.400E-02	Vents
RL BREAK		Dryweil Floor		1.00			
ECCS THROTT	TLED	0.20		Sediment	4	0.000E+00	Floor
NO SPRAYS				Waterborne	5	4 400 8-05	Ventr
FIBROUS INSU	LATION		Condensate Drainage	1.00			venus
		Structures-Above	0.01	Sediment	6	0.000E+00	Floor
	Small Pieces 0.22	0.02	Adheres 0.99		7	4.356E-03	Structures-Above
				Waterborne	8	1.760E-02	Vents
			Recirculation Flow	Sediment	9	0.000E+00	Floor
		Structures-Break	Adheres	0.00	10	0.000 E+00	Shuahama Davala
		0.08	0.00		10	0.0002700	Sunctures-Break
				Waterborne 1.00	11	5.060E-04	Vents
			0.01	Sediment	12	0.000E+00	Floor
		0.23	Adheres	0.00	13	5.009E-02	Structures-Other
			0.99	Waterborne	14	4.080E-03	Vents
			Recimulation Flow	1.00			
		Structure Devel	0.08	Sediment	15	0.000E+00	Floor
		0.15	Adheres	0.00	16	4.692E-02	Structures-Break
			0.92	Waterborne	17	0.000E+00	Vents
	Large-Above		Condensate Drainage	1.00			
	0.34	Structures-Other	0.00	Sediment 0.00	18	0.000E+00	Floor
RL Break		0.85	Adheres 1.00		19	2.890E-01	Structures-Other
1.00		Advected to Vent			20	3.600E-02	Vents
	Large-Below	Enclosures			21	4.000E-04	Enclosures
	0.04	0.01		Waterborne	22	1.440E-03	Vents
		Drywell Floor		Sediment	23	1.600F-04	Floor
		0.04		0.10		1.000 01	11001
				Waterborne	24	2.000E-04	Vents
			Recirculation Flow	Sediment	25	0.000E+00	Floor
		Structures-Break 0.01	Adheres	0.00	26	2.000E-04	Structures-Break
			0.50	Waterborne	27	0.000E+00	Vents
			Condensate Drainage	1.00			
		Structures-Other	0.00	Sediment	28	0.000E+00	Floor
		0.04	Adheres	v.w	29	1.600E-03	Structures-Other
	Canvassed		1.00		30	4.000E-01	Structures/Floor
L	0.40				Total	1.000E+00	

		DEBRI	S TRANSPO	RT RESULT	rs		
Plant Design:	MARK I					-	
Estimate:	CENTRAL	ESTIMATE		FIBROUS	INSULATIO	N	
Break:	RL BREAK	K					
ECCS:	ECCS THE	ROTTLED					
Sprays:	NO SPRAY	/S					
TREE QUANTIFICA	TION						
Debris Classification	Vents	Enclosures	Floor	Structures Above	Structures Break	Structures Other	Transport Fraction
Small Pieces	1.634E-01	2.200E-03	0.000E+00	4.356E-03	0.000E+00	5.009E-02	0.7425
Large Pieces-Above	4.080E-03	0	0.000E+00	0	4.692E-02	2.890E-01	0.0120
Large Pieces-Below	3.764E-02	4.000E-04	1.600E-04	0	2.000E-04	1.600E-03	0.9410
All Large Pieces	4.172E-02	4.000E-04	1.600E-04	0	4.712E-02	2.906E-01	0.1098
All Debris	2.051E-01	2.600E-03	1.600E-04	4.356E-03	4.712E-02	3.407E-01	0.3418
All Zone-of-Influence							0.2051
FINAL DISTRIBUTIO	ONS (Horizo	ntal)					
Debris Classification	Vents	Enclosures	Floor	Structures Above	Structures Break	Structures Other	
Small Pieces	74.25%	1.00%	0.00%	1.98%	0.00%	22.77%	
Large Pieces-Above	1.20%	0%	0.00%	0%	13.80%	85.00%	
Large Pieces-Below	94.10%	1.00%	0.40%	0%	0.50%	4.00%	
All Large Pieces	10.98%	0.11%	0.04%	0%	12.40%	76.47%	
All Debris	34.18%	0.43%	0.03%	0.73%	7.85%	56.78%	
RELATIVE CONTR	IBUTIONS (	Vertical)					
Debris Classification	Vents	Enclosures	Floor	Structures Above	Structures Break	Structures Other	
Small Pieces	79.66%	84.62%	0.00%	100.00%	0.00%	14.70%	
Large Pieces-Above	1.99%	0%	0.00%	0%	99.58%	84.83%	
Large Pieces-Below	18.35%	15.38%	100.00%	0%	0.42%	0.47%	
All Large Pieces	20.34%	15.38%	100.00%	0%	100.00%	85.30%	
1.000		Debris	Transport	Fractions			
0.750							
U.500							
0.250							
Small Del	bris Larg Gra	e Above atings	Large Below Gratings	All Large De	ebris All [	Debris /	All Zone-of- Influence

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LOCA Type	Debris Classification	Blowdown	Erosion and Washdown	Drywell Floor Pool	No.	Fraction	Final Locatio
MARKI		Advected to Vents			1	1.012E-01	Vents
MANN I		0.46 Enclosures			2	2.200E-03	Enclosures
CENTRAL EST	ГІМАТЕ	0.01		Waterborne	-	4 400 5 03	
RL BREAK				1.00		4.400E-02	Vents
FCCS TUDOT		Drywell Floor		C. Parts			_
ECCS INKOI	ILED	0.20		0.00	4	0.000E+00	Floor
SPRAYS OPER	LATED			Waterborne	£	4 4005 05	V
FIBROUS INSU	ULATION			1.00	J	4.400E-03	vents
			Condensate Drainage	Sediment	6	0.00015+00	Floor
	C 11 D'	Structures-Above		0.00		0.0002.00	riou
	Small Pieces	0.02	Adheres	· · · · · · · · · · · · · · · · · · ·	7	4.356E-03	Structures-Abc
			0.77	Waterborne	8	1.760E-02	Vents
			Recirculation Flow	1.00			
		Sharatuma Devalt	1.00	Sediment	9	0.000E+00	Floor
		0.08	iAdheres	0.00	10	0.000E+00	Structures-Bre
			0.00	Waterborne		2 520E 01	Vart
				1.00		2.3306-02	venus
			Sprays/Condensate	iSediment	12	0.0005+00	Floor
		Structures-Other	0.50	0.00	12	0.000£+00	F1001
		0.23	Adheres	·····	13	2.530E-02	Structures-Oth
			0.50	Waterborne	14	4.080E-03	Vents
			Recirculation Flow	1.00			
			0.08	Sediment	15	0.000E+00	Floor
		0.15	Adheres	0.00	16	4.692E-02	Structures-Bre
			0.92	W7-41		0.0007.00	
				1.00	- 17	2.890E-03	Vents
	Large-Above		Sprays/Condensate	Sadiment	10	0.000	<b>Fi</b> ana
		Structures-Other	0.01	0.00	10	0.000E+00	ritor
RL Break		0.85	Adheres		19	2.861E-01	Structures-Oth
1.00		Advected to Vent	0.33		20	3.600E-02	Vents
		0.90 Enclosures			21	4.000E-04	Enclosures
	Large-Below	0.01					
	0.04			0.90	22	1.440E-03	Vents
		Drywell Floor		6		1 (007 0)	-
		0.04		0.10	23	1.600E-04	Floor
				Waterhome	24	2 000 E 04	Vorte
				1.00		2.0000-04	venus
			Recirculation Flow	Sediment	25	0.0008+00	Floor
		Structures-Break	0.50	0.00		0.00001.00	
		0.01	Adheres		26	2.000E-04	Structures-Brea
	1			Waterborne	27	1.600E-05	Vents
			Sprays/Condensate	1.00			
			0.01	Sediment	28	0.000E+00	Floor
		Structures-Other 0.04	Adheres	0.00	29	1.584E-03	Structures-Othe
			0.99				
	Canvassed				30	4.000E-01	Structures/Floc

		DEBRIS	S TRANSPO	RT RESULT	rs.		
Plant Design:	MARK I						
Estimate:	CENTRAL	ESTIMATE		FIBROUS	INSULATIO	N	
Break:	RL BREAK	ζ					
ECCS:	ECCS THE	OTTLED					
Sprays:	SPRAYS O	PERATED					
TREE QUANTIFICA	TION						
Debris Classification	Vents	Enclosures	Floor	Structures Above	Structures Break	Structures Other	Transport Fraction
Small Pieces	1.881E-01	2.200E-03	0.000E+00	4.356E-03	0.000E+00	2.530E-02	0.8552
Large Pieces-Above	6.970E-03	0	0.000E+00	0	4.692E-02	2.861E-01	0.0205
Large Pieces-Below	3.766E-02	4.000E-04	1.600E-04	0	2.000E-04	1.584E-03	0.9414
All Large Pieces	4.463E-02	4.000E-04	1.600E-04	0	4.712E-02	2.877E-01	0.1174
All Debris	2.328E-01	2.600E-03	1.600E-04	4.356E-03	4.712E-02	3.130E-01	0.3880
All Zone-of-Influence							0.2328
FINAL DISTRIBUTIO	ONS (Horizo	ntal)					
Debris Classification	Vents	Enclosures	Floor	Structures Above	Structures Break	Structures Other	
Small Pieces	85.52%	1.00%	0.00%	1.98%	0.00%	11.50%	
Large Pieces-Above	2.05%	0%	0.00%	0%	13.80%	84.15%	
Large Pieces-Below	94.14%	1.00%	0.40%	0%	0.50%	3.96%	
All Large Pieces	11.74%	0.11%	0.04%	0%	12.40%	75.71%	
All Debris	38.80%	0.43%	0.03%	0.73%	7.85%	52.17%	
RELATIVE CONTR	IBUTIONS (	Vertical)					
Debris Classification	Vents	Enclosures	Floor	Structures Above	Structures Break	Structures Other	
Small Pieces	80.83%	84.62%	0.00%	100.00%	0.00%	8.08%	
Large Pieces-Above	2.99%	0%	0.00%	0%	99.58%	91.41%	
Large Pieces-Below	16.18%	15.38%	100.00%	0%	0.42%	0.51%	
All Large Pieces	19.17%	15.38%	100.00%	0%	100.00%	91.92%	



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MARK I CENTRAL EST RL BREAK		on Blowdown	ter Erosion and Wash	down Drywell Floor Poo	A Path No.	Fraction	Final Location
CENTRAL EST RL BREAK		Advected to Vents			1	1.012Ė-01	Vents
CENTRAL ES		Enclosures			2	2 2005 02	
RL BREAK	TIMATE	0.01		······································		2.200E-03	Enclosures
				Waterborne	3	4.400E-02	Vents
NOT THROTT	1.50	Drywell Floor		1.00			
		0.20	_	Sediment	4	0.000E+00	Floor
NO SPRAYS				0.00			
FIBROUS INSL	JLATION			Waterborne	5	4.400E-05	Vents
			Condensate Drainage	1.00			
		Structures-Above	0.01	Sediment	6	0.000E+00	Floor
	Small Pieces	0.02	Adheres	0.00	7	4.356E-03	Structures-Above
	0.22		0.99	Waterborne			
				1.00		1.760E-02	Vents
			Recirculation Flow				
		Structures-Break	1.00	0.00	- 9	0.000E+00	Floor
		0.08	Adheres	****	10	0.000E+00	Structures-Break
			0.00	Waterborne	11	5.060E-04	Vente
			Condenante During a	1.00		0.0001204	Venis
			0.01	Sediment	12	0.000E+00	Floor
		Structures-Other	A dhama	0.00		0.0001.00	Pioor
		0.25	0.99	· · · · · · · · · · · · · · · · · · ·	13	5.009E-02	Structures-Other
				Waterborne	14	1.377E-02	Vents
			Recirculation Flow	1.00			
		Structures Break	0.27	Sediment	15	0.000E+00	Floor
		0.15	Adheres	0.00	16	1 7727 00	0
			0.73		10	3.725E-02	Structures-Break
				Waterborne	17	0.000E+00	Vents
	Large-Above		Condensate Drainage				
ľ		Structures-Other	0.00	Sediment	18	0.000E+00	Floor
Break		0.85	Adheres		19	2.890E-01	Structures-Other
0		Advected to Vent	1.00		20	3 600 E 02	
		0.90				5.0002-02	venus
I	Large-Below	0.01			21	4.000E-04	Enclosures
C	0.04			Waterborne	22	1.440E-03	Vents
		Drywell Floor		0.90			
		0.04		Sediment	23	1.600E-04	Floor
				0.10			
				Waterborne	24	2.000E-04	Vents
				1.00			
			Recirculation Flow				
		_	Recirculation Flow	Sediment	25	0.000E+00	Floor
		Structures-Break	Recirculation Flow	Sediment 0.00	25	0.000E+00	Floor
	5	Structures-Break 0.01	Recirculation Flow 0.50 Adheres 0.50	Sediment 0.00	25 26	0.000E+00 2.000E-04	Floor Structures-Break
		Structures-Break	Recirculation Flow 0.50 Adheres 0.50	Sediment 0.00 Waterborne	25 26 27	0.000E+00 2.000E-04 0.000E+00	Floor Structures-Break Vents
	5	Structures-Break	Recirculation Flow 0.50 Adheres 0.50 Condensate Drainage	Sediment 0.00 Waterborne 1.00	25 26 27	0.000E+00 2.000E-04 0.000E+00	Floor Structures-Break Vents
		Structures-Break	Recirculation Flow 0.50 Adheres 0.50 Condensate Drainage 0.00	Sediment 0.00 Waterborne 1.00 Sediment	25 26 27 28	0.000E+00 2.000E-04 0.000E+00 0.000E+00	Floor Structures-Break Vents Floor
	s	Structures-Break 0.01 Structures-Other 0.04	Recirculation Flow 0.50 Adheres 0.50 Condensate Drainage 0.00 Adheres	Sediment 0.00 Waterborne 1.00 Sediment 0.00	25 26 27 28 29	0.000E+00 2.000E-04 0.000E+00 0.000E+00	Floor Structures-Break Vents Floor
	s o anvassed	Structures-Break 0.01 Structures-Other 0.04	Recirculation Flow 0.50 Adheres 0.50 Condensate Drainage 0.00 Adheres 1.00	Sediment 0.00 Waterborne 1.00 Sediment 0.00	25 26 27 28 29	0.000E+00 2.000E-04 0.000E+00 0.000E+00 1.600E-03	Floor Structures-Break Vents Floor Structures-Other

<b></b>		DEDDI		DT DESID 7					
	r	DEBRIN	S I KANSPU	KI KESULI					
Plant Design:	MARKI								
Estimate:	CENTRAL	ESTIMATE		FIBROUS INSULATION					
Break:	RL BREAK	٢							
ECCS:	NOT THR	OTTLED							
Sprays:	NO SPRAY	/S							
TREE QUANTIFICATION									
Debris Classification	Vents	Enclosures	Floor	Structures Above	Structures Break	Structures Other	Transport Fraction		
Small Pieces	1.634E-01	2.200E-03	0.000E+00	4.356E-03	0.000E+00	5.009E-02	0.7425		
Large Pieces-Above	1.377E-02	0	0.000E+00	0	3.723E-02	2.890E-01	0.0405		
Large Pieces-Below	3.764E-02	4.000E-04	1.600E-04	0	2.000E-04	1.600E-03	0.9410		
All Large Pieces	5.141E-02	4.000E-04	1.600E-04	0	3.743E-02	2.906E-01	0.1353		
All Debris	2.148E-01	2.600E-03	1.600E-04	4.356E-03	0.3579				
All Zone-of-Influence									
FINAL DISTRIBUTIO	ONS (Horizo	ntal)							
Debris Classification	Vents	Enclosures	Floor	Structures Above	Structures Break	Structures Other			
Small Pieces	74.25%	1.00%	0.00%	1.98%	0.00%	22.77%			
Large Pieces-Above	4.05%	0%	0.00%	0%	10.95%	85.00%			
Large Pieces-Below	94.10%	1.00%	0.40%	0%	0.50%	4.00%			
All Large Pieces	13.53%	0.11%	0.04%	0%	9.85%	76.47%			
All Debris	35.79%	0.43%	0.03%	0.73%	6.24%	56.78%			
RELATIVE CONTR	IBUTIONS (	Vertical)							
Dobrio Classification	Vonto	Engloguros	Floor	Structures	Structures	Structures			
Debris Classification	v ents	Enclosures	L100L	Above	Break	Other			
Small Pieces	76.06%	84.62%	0.00%	100.00%	0.00%	14.70%			
Large Pieces-Above	6.41%	0%	0.00%	0%	99.47%	84.83%			
Large Pieces-Below	17.53%	15.38%	100.00%	0%	0.53%	0.47%			
All Large Pieces	23.94%	15.38%	100.00%	0%	100.00%	85.30%			



LOCA Type	Debris Classification	Distribution After Blowdown	Erosion and Washdown	Drywell Floor Pool	Path No	Fraction	Final Location
	· · · · · · · · · · · · · · · · · · ·	Advected to Vents			1	1.012E-01	Vents
MARK I		0.46 Enclosures			2	2.200E-03	Enclosures
CENTRAL EST	IMATE	0.01		Waterhome	3	4 400 5 02	Vente
RL BREAK				1.00		4.4002-02	Vents
NOT THROTTI	LED	0.20		Sediment	4	0.000E+00	Floor
SPRAYS OPER	ATED			0.00			
FIRPOUS INSU	LATION			Waterborne	5	4.400E-05	Vents
	LATION		Condensate Drainage	1.00			
		Structures-Above	0.01	Sediment 0.00	6	0.000E+00	Floor
	Small Pieces	0.02	Adheres		7	4.356E-03	Structures-Above
	0.22		0.99	Waterborne	8	1.760E-02	Vents
			Recirculation Flow	1.00			
		Structures-Break	1.00	Sediment 0.00	9	0.000E+00	Floor
		0.08	Adheres	• # \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \	10	0.000E+00	Structures-Break
			0.00	Waterborne	11	2.530E-02	Vents
			Sprays/Condensate	1.00			
		Structures-Other	0.50	Sediment 0.00	12	0.000E+00	Floor
		0.23	Adheres		13	2.530E-02	Structures-Other
			0.50	Waterborne	14	1.377E-02	Vents
			Recirculation Flow	1.00			
		Structures-Break	0.27	Sediment 0.00	15	0.000E+00	Floor
		0.15	Adheres		16	3.723E-02	Structures-Break
			0.75	Waterborne	17	2.890E-03	Vents
	Large-Above		Sprays/Condensate	1.00			
	0.34	Structures-Other	0.01	Sediment 0.00	18	0.000E+00	Floor
RL Break		0.85	Adheres		19	2.861E-01	Structures-Other
1.00		Advected to Vent			20	3.600E-02	Vents
	Large Deleus	Enclosures			21	4.000E-04	Enclosures
	0.04	0.01		Waterborne	22	1.440E-03	Vents
		Drywell Floor		0.90			
		0.04		Sediment	23	1.600E-04	Floor
				0.10			
				1.00		2.000E-04	Yents
			Recirculation Flow	Sediment	25	0.000E+00	Floor
		Structures-Break	Adheres	0.00	26	2.000E-04	Structures-Break
			0.50	Waterhome	17	1 600 E 05	Vante
				1.00	41	1.000E-03	Y CILI3
			Sprays/Condensate 0.01	Sediment	28	0.000E+00	Floor
		Structures-Other 0.04	Adheres	0.00	29	1.584E-03	Structures-Other
	Canvasced		0.99		20	4 000 = 01	Structures/Elaca
	0.40	·			Total	1.000E+00	Juntimes 4001

· · · · · · · · · · · · · · · · · · ·		DEBRIS	TRANSPO	RT RESULT	S	· · ·	
Plant Design:	MARKI						
Estimate:	CENTRAL	ESTIMATE		FIBROUS	NSULATIO	N	
Break:	RL BREAK	<				-	
ECCS:	NOT THR	- OTTLED					
Sprays:	SPRAYS O	PERATED					
TREE QUANTIFICATION							
Debris Classification Vents Enclosures			Floor	Structures Above	Structures Break	Structures Other	Transport Fraction
Small Pieces	1.881E-01	2.200E-03	0.000E+00	4.356E-03	0.000E+00	2.530E-02	0.8552
Large Pieces-Above	1.666E-02	0	0.000E+00	0	3.723E-02	2.861E-01	0.0490
Large Pieces-Below	3.766E-02	4.000E-04	1.600E-04	0	2.000E-04	1.584E-03	0.9414
All Large Pieces	5.432E-02	4.000E-04	1.600E-04	0	3.743E-02	2.877E-01	0.1429
All Debris	2.425E-01	2.600E-03	1.600E-04	4.356E-03	3.743E-02	3.130E-01	0.4041
All Zone-of-Influence							0.2425
FINAL DISTRIBUTIO	ONS (Horizo	ntal)					
Debris Classification	Vents	Enclosures	Floor	Structures Above	Structures Break	Structures Other	
Small Pieces	85.52%	1.00%	0.00%	1.98%	0.00%	11.50%	
Large Pieces-Above	4.90%	0%	0.00%	0%	10.95%	84.15%	
Large Pieces-Below	94.14%	1.00%	0.40%	0%	0.50%	3.96%	
All Large Pieces	14.29%	0.11%	0.04%	0%	9.85%	75.71%	
All Debris	40.41%	0.43%	0.03%	0.73%	6.24%	52.17%	
RELATIVE CONTR	IBUTIONS (	Vertical)					
Debris Classification	Vents	Enclosures	Floor	Structures Above	Structures Break	Structures Other	
Small Pieces	77.60%	84.62%	0.00%	100.00%	0.00%	8.08%	
Large Pieces-Above	6.87%	0%	0.00%	0%	99.47%	91.41%	
Large Pieces-Below	15.53%	15.38%	100.00%	0%	0.53%	0.51%	
All Large Pieces	22.40%	15.38%	100.00%	0%	100.00%	91.92%	
		Debris	Transport	Fractions			



#### A.3.2 Mark II

This section contains the central estimate logic charts for the Mark II design.

#### A.3.2.1 Main Steam Line Break

The central estimate logic charts for the main steam line breaks are presented here, then the charts for the recirculation line breaks are presented in Section A.3.2.2.

LOCA Type	Debris Classificatio	Distribution After Blowdown	Erosion and Washdo	own Drywell Floor Po	pol Path	Fraction	Final Location
MARK II		Advected to Vents			1	1.210E-01	Vents
in 2 Mar II		0.55 Enclosures					
CENTRAL ES	ГІМАТЕ	0.01			2	2.200E-03	Enclosures
MSL BREAK				Waterborne	3	0.000E+00	Vents
ECCS THROT	TLED	Drywell Floor					
		0.06		Sediment	4	1.320E-02	Floor
NO SPRAYS							
FIBROUS INSU	JLATION			Waterborne		0.000E+00	Vents
			Condensate Drainage	- Cardimond			
	Small Pieces	Structures-Above	0.01	1.00		6.600E-05	Floor
	0.22	0.03	Adheres		7	6.534E-03	Structures-Above
	l			Waterborne	8	0.000E+00	Vents
			Condensate Drainage	0.00			
		Structures-Break	0.01	Sediment	9	1.980E-04	Floor
		0.09	Adheres	1.00	10	1.960E-02	Structures Basels
			0.99	Watachana		1.5002-02	Su uciules-Break
				0.00		0.000E+00	Vents
		12	Condensate Drainage	Sediment	12	6 7305 04	
		Structures-Other	A dhama	1.00	12	3.7208-04	Floor
		0.20	0.99		13	5.663E-02	Structures-Other
				Waterborne	14	0.000E+00	Vents
			Condensate Drainage	0.00			
		Structures-Break	0.00	Sediment	15	0.000E+00	Floor
		0.15	Adheres	1.00	16	5.100E-02	Structures-Break
			1.00	Waterborne	17	0.000E+00	
	Large-Above		Condensate Drainage	0.00		0.0002100	Y ends
	0.34		0.00	Sediment	18	0.000E+00	Floor
	L	0.85	Adheres	1.00	10	2 9005 01	
1SL Break		Advected to Vent	1.00		19	2.890E-01	Structures-Other
	F	0.90			20	3.600E-02	Vents
1	arge-Below	Enclosures			21	4.000E-04	Enclosures
C	0.04			Waterborne	22	0.000E+00	Vente
	I	Drywell Floor		0.00			
	c	0.04		Sediment	23	1.600E-03	Floor
				1.00			
				Waterborne	24	0.000E+00	Vents
1		(	Condensate Drainage	0.00			
	s	Bructures-Break	0.00	Sediment	25	0.000E+00	Floor
	o	.01	Adheres	1.00	26	4.000E-04	Structures-Break
		1	.00	Waterborne	27	0.0005+00	
	Ì	,	ondonast- D	0.00		0.0002+00	Vents
	1	lo	.00	Sediment	28	0.0005+00	Floor
	SI	tructures-Other	dheres	1.00		5.000L100	r100r
	u.	1	.00		29	1.600E-03	Structures-Other
0.	40				30	4.000E-01	Structures/Floor
					Total	1.000E+00	

·												
		DEBRIS	TRANSPO	RT RESULT	S							
Plant Design:	MARK II											
Estimate:	CENTRAL	ESTIMATE		<b>FIBROUS</b> I	NSULATIO	N						
Break:	MSL BREA	K										
ECCS:	ECCS THR	OTTLED										
Sprays:	NO SPRAY	'S										
TREE QUANTIFICA	TION											
Debris Classification	Vents	Enclosures	Floor	Structures Above	Structures Break	Structures Other	Transport Fraction					
Small Pieces	1.210E-01	2.200E-03	1.404E-02	6.534E-03	1.960E-02	5.663E-02	0.5500					
Large Pieces-Above	0.000E+00	0	0.000E+00	0	5.100E-02	2.890E-01	0.0000					
Large Pieces-Below	3.600E-02	4.000E-04	1.600E-03	0	4.000E-04	1.600E-03	0.9000					
All Large Pieces	3.600E-02	4.000E-04	1.600E-03	0	5.140E-02	2.906E-01	0.0947					
All Debris	1.570E-01	2.600E-03	1.564E-02	6.534E-03	7.100E-02	3.472E-01	0.2617					
All Zone-of-Influence							0.1570					
FINAL DISTRIBUTIO	ntal)											
THOSE DISTRIBUTS				Structures	Structures	Structures						
Debris Classification	Vents	Enclosures	Floor	Above	Break	Other						
Small Pieces	55.00%	1.00%	6.38%	2.97%	8.91%	25.74%						
Large Pieces-Above	0.00%	0%	0.00%	0%	15.00%	85.00%						
Large Pieces-Below	90.00%	1.00%	4.00%	0%	1.00%	4.00%						
All Large Pieces	9.47%	0.11%	0.42%	0%	13.53%	76.47%						
All Debris	26.17%	0.43%	2.61%	1.09%	11.83%	57.87%						
DELATIVE CONTR	BUTIONS	(Vertical)										
RELATIVE CONTR				Structures	Structures	Structures						
Debris Classification	Vents	Enclosures	Floor	Above	Break	Other						
Small Pieces	77.07%	84.62%	89.77%	100.00%	27.61%	16.31%						
Large Pieces-Above	0.00%	0%	0.00%	0%	71.83%	83.23%						
Large Pieces-Below	22.93%	15.38%	10.23%	0%	0.56%	0.46%						
All Large Pieces	22.93%	15.38%	10.23%	0%	72.39%	83.69%						
Debris Transport Fractions												
1.000												





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LOCA Type	Debris Classification	Distribution After Blowdown	Erosion and Washdown	n Drywell Floor Pool	Path No.	Fraction	Final Location
MARK II		Advected to Vents			1	1.210E-01	Vents
CENTRAL EST	ኘትለልጥም	Enclosures			2	2.200E-03	Enclosures
LETINAL EST	INIATE	0.01		Waterborne	3	6.600E-03	Vents
MSL BREAK		Drywell Floor		0.50			
ECCS THROTT	LED	0.06		Sediment	4	6.600E-03	Floor
SPRAYS OPER	ATED			Waterborne	5	5.0405.05	
FIBROUS INSU	LATION		Condensate Drainage	0.90		5.9402-05	Vents
		Structures, Above	0.01	Sediment	6	6.600E-06	Floor
	Small Pieces	0.03	Adheres	0.10	7	6.534E-03	Structures-Above
	0.22		0.99	Waterborne	8	8.910E-03	Vents
			Sprays/Condensate	0.90			
		Structures-Break	0.50	Sediment	9	9.900E-04	Floor
		0.09	Adheres		10	9.900E-03	Structures-Break
			0.50	Waterborne	11	2.574E-02	Vents
			Sprays/Condensate	0.90			
		Structures-Other	0.50	Sediment 0.10	12	2.860E-03	Floor
		0.26	Adheres 0.50		13	2.860E-02	Structures-Other
				Waterborne	14	5.100E-04	Vents
		r	Sprays/Condensate	1.00 Sediment			
	r	Structures-Break	0.01	0.00	15	0.000E+00	Floor
	1	0.15	Adheres 0.99		16	5.049E-02	Structures-Break
			1	Waterborne	17	2.890E-03	Vents
	Large-Above	r.	Sprays/Condensate	Sodiment	10	0.0007.00	
		Structures-Other	6.01 ·	0.00	18	0.000E+00	Floor
MSL Break	(		0.99		19	2.861E-01	Structures-Other
1.00		).90			20	3.600E-02	Vents
1	Large-Below	Enclosures	7.7 is		21	4.000E-04	Enclosures
1	0.04		r	Waterborne	22	0.000E+00	Vents
	I	Drywell Floor		0.00			
		1.04	ł	Sediment 1.00	23	1.600E-03	Floor
				Waterborne	24	0.000E+00	Vents
		s	Sprays/Condensate	0.00			
1	s	Structures_Break	0.01	Sediment	25	4.000E-06	Floor
	0	.01	Adheres	1.00	26	3.960E-04	Structures-Break
		0	),99	Waterborne	27	0.000E+00	Vents
		S	prays/Condensate	0.00			
	s	tructures-Other	0.01	Sediment	28	1.600E-05	Floor
	0.	.04	Adheres		29	1.584E-03	Structures-Other
C	Canvassed	0			30	4.000E-01	Structures/Floor
	.40				Total	1.000E+00	

· · · · · · · · · · · · · · · · · · ·		DEBRIS	TRANSPO	RT RESULT	S		
Plant Design:	MARK II						
Estimate:	CENTRAL	ESTIMATE		FIBROUS I	NSULATIO	N	
Break:	MSL BREA	K					
ECCS:	ECCS THR	OTTLED					
Sprays:	SPRAYS O	PERATED					
TREE OLIANTIEICA	TION						
TREE QUARTIERCA				Structures	Structures	Structures	Transport
Debris Classification	Vents	Enclosures	Floor	Above	Break	Other	Fraction
Small Pieces	1.623E-01	2.200E-03	1.046E-02	6.534E-03	9.900E-03	2.860E-02	0.7378
Large Pieces-Above	3.400E-03	0	0.000E+00	0	5.049E-02	2.861E-01	0.0100
Large Pieces-Below	3.600E-02	4.000E-04	1.620E-03	0	3.960E-04	1.584E-03	0.9000
All Large Pieces	3.940E-02	4.000E-04	1.620E-03	0	5.089E-02	2.877E-01	0.1037
All Debris	2.017E-01	2.600E-03	1.208E-02	6.534E-03	6.079E-02	3.163E-01	0.3362
All Zone-of-Influence							0.2017
ETNAL DISTRICTO	ONS (Horizo)	ntal)					
FINAL DISTRIBUT				Structures	Structures	Structures	
Debris Classification	Vents	Enclosures	Floor	Above	Break	Other	
Small Pieces	73,78%	1.00%	4.75%	2.97%	4.50%	13.00%	
Large Pieces-Above	1.00%	0%	0.00%	0%	14.85%	84.15%	
Large Pieces-Below	90.00%	1.00%	4.05%	0% 0.99% 3.96%			
All Large Pieces	10.37%	0.11%	0.43%	0%			
All Debris	33.62%	0.43%	2.01%	1.09%	10.13%	52.72%	
RELATIVE CONTR	BUTIONS	(Vertical)					
	<b></b>	Ì	_	Structures	Structures	Structures	
Debris Classification	Vents	Enclosures	Floor	Above	Break	Other	
Small Pieces	80.47%	84.62%	86.59%	100.00%	16.29%	9.04%	
Large Pieces-Above	1.69%	0%	0.00%	0%	83.06%	90.46%	
Large Pieces-Below	17.85%	15.38%	13.41%	0%	0.65%	0.50%	
All Large Pieces	19.53%	15.38%	13.41%	0%	83.71%	90.96%	
		Debri	s Transport	Fractions			
1.000	<u> </u>						
0.750							
uo							
ថ្ម 0.500				<u> </u>			
Ē					5.0		
0.250							
				Alexandra and a			
0.000			Bull y d				
Small D	ebris Lar G	ge Above ratings	Large Below Gratings	All Large D	Xebris All	Debris	All Zone-of-

LOCA Type	Debris Classification	Distribution After Blowdown	Erosion and Washdow	n Drywell Floor Pool	Path No.	Fraction	Final Location
MARK II		Advected to Vents			1	1.210E-01	Vents
		0.55 Enciosures			2	2.200E-03	Enclosures
CENTRAL EST	IMATE	0.01 Waterborne			3	1.3205-02	Venta
MSL BREAK		Drawell Floor					, cuta
NOT THROTTI	LED	0.06	· · · · · · · · · · · · · · · · · · ·	Sediment	4	0.000E+00	Floor
NO SPRAYS				0.00			
FIBROUS INSU	LATION			Waterborne	5	6.600E-05	Vents
			Condensate Drainage	1.00			
	Small Disease	Structures-Above	0.01	0.00	6	0.000E+00	Floor
	0.22	0.03	Adheres		7	6.534E-03	Structures-Above
				Waterborne	8	1.980E-02	Vents
			Recirculation Flow	1.00			
		Structures-Break	1.00	Sediment 0.00	9	0.000E+00	Floor
		0.09	Adheres		10	0.000E+00	Structures-Break
			0.00	Waterborne	11	5.720E-04	Vents
			Condensate Drainage	1.00			
		Structures-Other	0.01	Sediment 0.00	12	0.000E+00	Floor
		0.26	Adheres		13	5.663E-02	Structures-Other
			0.77	Waterborne	14	4.080E-03	Vents
			Recirculation Flow	1.00			
		Structures-Break	0.08	Sediment	15	0.000E+00	Floor
		0.15	Adheres		16	4.692E-02	Structures-Break
			0.92	Waterborne	17	0.000E+00	Vents
	Large-Above		Condensate Drainage	1.00			
	0.34	Structures-Other	0.00	Sediment	18	0.000E+00	Floor
MSL Break		0.85	Adheres		19	2.890E-01	Structures-Other
1.00	ľ	Advected to Vent	1.00		20	3.600E-02	Vents
	Lorno Doloui	Enclosures			21	4.000E-04	Enclosures
	0.04	0.01		Waterborne	22	1.600E-03	Vents
	1	Drvwell Floor		1.00			
	C	0.04		Sediment	23	0.000E+00	Floor
				0.00			
				Waterborne	24	2.000E-04	Vents
		1 17	Recirculation Flow	Radimunt		0.0007.00	·
	5	Structures-Break		0.00		0.000E+00	Floor
	C	).01	Adheres 0.50		26	2.000E-04	Structures-Break
				Waterborne	27	0.000E+00	Vents
		(	Condensate Drainage				
	s	tructures-Other	0.00	0.00	28	0.000E+00	Floor
	0	.04	Adheres		29	1.600E-03	Structures-Other
	Canvassed				30	4.000E-01	Structures/Floor
	/				Total	1.000E+00	

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DEBRIS TRANSPORT RESULTS									
Plant Design:	MARK II								
Estimate:	CENTRAL	ESTIMATE		FIBROUS I	NSULATIO	N			
Break:	MSL BREA	к							
ECCS:	NOT THRO	OTTLED							
Sprays:	NO SPRAY	′S							
TREE OUANTIEICA	TION								
INEE QUANTIERCA				Ct	C4	St.	7 <b>7</b>		
Debris Classification	Vents	Enclosures	Floor	Above	Break	Other	Fraction		
Small Pieces	1.546E-01	2.200E-03	0.000E+00	6.534E-03	0.000E+00	5.663E-02	0.7029		
Large Pieces-Above	4.080E-03	0	0.000E+00	0	4.692E-02	2.890E-01	0.0120		
Large Pieces-Below	3.780E-02	4.000E-04	0.000E+00	0	2.000E-04	1.600E-03	0.9450		
All Large Pieces	4.188E-02	4.000E-04	0.000E+00	0	4.712E-02	2.906E-01	0.1102		
All Debris	1.965E-01	2.600E-03	0.000E+00	6.534E-03	4.712E-02	3.472E-01	0.3275		
All Zone-of-Influence							0.1965		
FINAL DISTRIBUTIO	)NS (Horizo	ntal)							
	<u>`</u>	,	_	Structures	Structures	Structures			
Debris Classification	Vents	Enclosures	Floor	Above	Break	Other			
Small Pieces	70.29%	1.00%	0.00%	2.97%	0.00%	25.74%			
Large Pieces-Above	1.20%	0%	0.00%	0%	13.80%	85.00%			
Large Pieces-Below	94.50%	1.00%	0.00%	0%	0.50%	4.00%			
All Large Pieces	11.02%	0.11%	0.00%	0%	12.40%	76.47%			
All Debris	32.75%	0.43%	0.00%	1.09%	7.85%	57.87%			
RELATIVE CONTR	<b>IBUTIONS</b> (	Vertical)							
		,		Structures	Structures	Structures			
Debris Classification	Vents	Enclosures	Floor	Above	Break	Other			
Small Pieces	78.69%	84.62%	N/A	100.00%	0.00%	16.31%			
Large Pieces-Above	2.08%	0%	N/A	0%	99.58%	83.23%			
Large Pieces-Below	19.23%	15.38%	N/A	0%	0.42%	0.46%			
All Large Pieces	21.31%	15.38%	N/A	0%	100.00%	83.69%			
Debris Transport Fractions									
1.000									
0.750									
500									
1.100 Lange			5 M						
0.250							See and see a		
0.000									

All Zone-of-

Influence

All Debris

Large Below Gratings All Large Debris

Large Above Gratings

Small Debris

LOCA Type	Debris Classification	Distribution After Blowdown	Erosion and Washdown	Drywell Floor Pool	Path No.	Fraction	Final Location
MARK II		Advected to Vents			1	1.210E-01	Vents
		0.55 Enclosures			2	2.200E-03	Enclosures
CENTRAL EST	IMATE	0.01		Waterborne	3	1.320E-02	Vents
MSL BREAK		Desuell Floor					
NOT THROTTI	LED	0.06		Sediment	4	0.000E+00	Floor
SPRAYS OPER	ATED			0.00			
FIBROUS INSU	LATION			Waterborne	5	6.600E-05	Vents
			Condensate Drainage	1.00			
		Structures-Above	0.01	Sediment	6	0.000E+00	Floor
	Small Pieces	0.03	Adheres		7	6.534E-03	Structures-Above
	0.22		0.99	Waterborne	8	1.980E-02	Vents
			Recirculation Flow	1.00			
		Structures-Break	1.00	Sediment	9	0.000E+00	Floor
		0.09	Adheres	0.00	10	0.000E+00	Structures-Break
			0.00	Waterborne	11	2.860E-02	Vents
			Sprays/Condensate	1.00			
		Structures_Other	0.50	Sediment	12	0.000E+00	Floor
		0.26	Adheres	0.00	13	2.860E-02	Structures-Other
			0.50	Waterborne	14	4.080E-03	Vents
			Projection Flour	1.00			
			0.08	Sediment	15	0.000E+00	Floor
		Structures-Break	Adheres	0.00	16	4.692E-02	Structures-Break
			0.92	Waterhame	17	3 0005 03	
				1.00	17	2.890E-03	Vents
	Large-Above 0.34		Sprays/Condensate	Sediment	18	0.000E+00	Floor
		Structures-Other	Adheres	0.00	10	2 861 8 01	Structures Other
MSL Break		Advanted to Vant	0.99		- 15	2.6012-01	Sudelules-Olikei
1.00		0.90			20	3.600E-02	Vents
	Large-Below	Enclosures			21	4.000E-04	Enclosures
	0.04	0.01		Waterborne	22	1.600E-03	Vents
		Drywell Floor		1.00			
		0.04		Sediment	23	0.000E+00	Floor
				Weterland			
				1.00	24	2.000E-04	Vents
		1	Recirculation Flow	Sediment	25	0.000E+00	Floor
		Structures-Break	à dharas	0.00	26	2 0005 04	Structure David
		0.01	0.50		20	2.0002-04	Structures-Break
			1	Waterborne	27	1.600E-05	Vents
			Sprays/Condensate	Sadiment	70	0.0007+00	171.0
		Structures-Other	0.01	0.00	28	0.000E+00	Floor
		0.04	Adheres 0.99		29	1.584E-03	Structures-Other
	Canvassed	······			30	4.000E-01	Structures/Floor
	0.40				Tota	1.000E+00	

<u> </u>		DEBRIS	5 TRANSPO	RT RESULT			
Plant Design:	MARK II						
Estimate:	CENTRAL	ESTIMATE		FIBROUS	NSULATIO	N	
Break:	MSL BREA	K					
ECCS:	NOT THR	OTTLED					
Sprays:	SPRAYS O	PERATED					
TREE QUANTIFICA	TION						
Debris Classification	Vents	Enclosures	Floor	Structures Above	Structures Break	Structures Other	Transport Fraction
Small Pieces	1.827E-01	2.200E-03	0.000E+00	6.534E-03	0.000E+00	2.860E-02	0.8303
Large Pieces-Above	6.970E-03	0	0.000E+00	0	4.692E-02	2.861E-01	0.0205
Large Pieces-Below	3.782E-02	4.000E-04	0.000E+00	0	2.000E-04	1.584E-03	0.9454
All Large Pieces	4.479E-02	4.000E-04	0.000E+00	0	4.712E-02	2.877E-01	0.1179
All Debris	2.275E-01	2.600E-03	0.000E+00	6.534E-03	4.712E-02	3.163E-01	0.3791
All Zone-of-Influence							0.2275
FINAL DISTRIBUTIO	ONS (Horizo)	ntal)					
Debris Classification	Vents	Enclosures	Floor	Structures	Structures	Structures	
				Above	Break	Other	
Small Pieces	83.03%	1.00%	0.00%	2.97%	0.00%	13.00%	
Large Pieces-Above	2.05%	0%	0.00%	0%	13.80%	84.15%	
Large Pieces-Below	94.54%	1.00%	0.00%	0%	0.50%	3.96%	
All Large Pieces	11.79%	0.11%	0.00%	0%	12.40%	75.71%	
All Debris	37.91%	0.43%	0.00%	1.09%	/.85%	52.72%	
RELATIVE CONTR	<b>BUTIONS</b> (	Vertical)					
Debris Classification	Vents	Enclosures	Floor	Structures	Structures	Structures	
	00.210/	94 (20)		AD0ve	Break	Other	
Small Pieces	80.31%	84.62%	N/A	100.00%	0.00%	9.04%	
Large Pieces-Above	3.06%	0%	N/A	0%	99.58%	90.46%	
Large Pieces-Below	10.63%	15.38%	N/A	0%	0.42%	0.50%	
All Large Pieces	19.69%	15.38%	N/A	0%	100.00%	90.90%	
		Debris	Transport	Fractions			
1.000							
	•						
0.750						·	
E E							
<del>g</del> 0.500							
Fra					10.010		
0.250							
0.200			a an				
0.000				f francist	K		An Alexand

All Zone-of-

Influence

All Debris

Large Below Gratings

All Large Debris

Large Above

Gratings

Small Debris

## A.3.2.2 Recirculation Line Break

This section contains central estimate logic charts for Mark II recirculation line break scenarios.

LOCA Type	Debris Classification	Distribution After Blowdown	Erosion and Washdowr	n Drywell Floor Pool	Path No.	Fraction	Final Location
MARK II		Advected to Vents		·····	1	1.078E-01	Vents
OPERAL DOT		Enclosures			2	2.200E-03	Enclosures
CENTRAL EST	IMATE	0.01 Waterborne			3	5.500E-02	Vents
RL BREAK		Drywell Floor		1.00			
ECCS THROTT	LED	0.25		Sediment	4	0.000E+00	Floor
NO SPRAYS				0.00			
FIBROUS INSU	LATION			Waterborne	5	2.200E-05	Vents
			Condensate Drainage	1.00			
	Concil Disease	Structures-Above	0.01	0.00	0	0.000E+00	Floor
	Small Pieces	0.01	Adheres		7	2.178E-03	Structures-Above
				Waterborne	8	1.320E-02	Vents
			Recirculation Flow	1.00			
		Structures-Break	1.00	0.00	9	0.000E+00	Floor
		0.06	Adheres		10	0.000E+00	Structures-Break
				Waterborne	11	3.960E-04	Vents
			Condensate Drainage	1.00			
		Structures-Other	0.01	0.00	12	0.000E+00	Floor
		0.18	Adheres		13	3.920E-02	Structures-Other
			0.33	Waterborne	14	4.080E-03	Vents
			Recirculation Flow	1.00			
		Structures-Break	0.08	Sediment	15	0.000E+00	Floor
		0.15	Adheres		16	4.692E-02	Structures-Break
			0.92	Waterborne	17	0.000E+00	Vents
	Large-Above		Condensate Drainage	1.00			
	0.34	Structures-Other	0.00	Sediment	18	0.000E+00	Floor
RL Break		0.85	Adheres	0.00	19	2.890E-01	Structures-Other
1.00		Advected to Vent	1.00		20	3.600E-02	Vents
		0.90 Enclosures			21	4.000E-04	Enclosures
	Large-Below 0.04	0.01		Waterborne	22	1.600E-03	Vents
		Drywell Floor		1.00			
		0.04		Sediment	23	0.000E+00	Floor
				0.00			
				Waterborne	24	2.000E-04	Vents
			Recirculation Flow	Sadiment	25	0.0007.00	
		Structures-Break	0.50	0.00		0.0002+00	Fioor
		0.01	Adheres 0.50		26	2.000E-04	Structures-Break
			:	Waterborne	27	0.000E+00	Vents
			Condensate Drainage	Sodiment	20	0.000 5 .00	
		Structures-Other	0.00	0.00	28	U.UO0E+00	Floor
	· · ·	0.04	Adheres 1.00		29	1.600E-03	Structures-Other
l l	Canvassed				30	4.000E-01	Structures/Floor
	V.TV				Iotal	LOOOE+00	

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DEBRIS TRANSPORT RESULTS								
Plant Design:	MARKI							
Estimate:	CENTRAL	ESTIMATE		ETBROUS INSULATION				
Break:	RL BREAK	<		12.1000		<b>-</b>		
ECCS:	ECCS THR	OTTLED						
Sprays:	NO SPRAYS							
IKEL QUANTIFICA				<b>G</b> 4	<u>Standard</u>	C.L.	T	
Debris Classification	Vents	Enclosures	Floor	Above	Break	Other	Fraction	
Small Pieces	1.764E-01	2.200E-03	0.000E+00	2.178E-03	0.000E+00	3.920E-02	0.8019	
Large Pieces-Above	4.080E-03	0	0.000E+00	0	4.692E-02	2.890E-01	0.0120	
Large Pieces-Below	3.780E-02	4.000E-04	0.000E+00	0	2.000E-04	1.600E-03	0.9450	
All Large Pieces	4.188E-02	4.000E-04	0.000E+00	0	4.712E-02	2.906E-01	0.1102	
All Debris	2.183E-01	2.600E-03	0.000E+00	2.178E-03	4.712E-02	3.298E-01	0.3638	
All Zone-of-Influence							0.2183	
FINAL DISTRIBUTIONS (Horizontal)								
	Vents	Enclosures	Floor	Structures	Structures	Structures		
Debris Classification				Above	Break	Other		
Small Pieces	80.19%	1.00%	0.00%	0.99%	0.00%	17.82%		
Large Pieces-Above	1.20%	0%	0.00%	0%	13.80%	85.00%		
Large Pieces-Below	94.50%	1.00%	0.00%	0%	0.50%	4.00%		
All Large Pieces	11.02%	0.11%	0.00%	0%	12.40%	76.47%		
All Debris	36.38%	0.43%	0.00%	0.36%	7.85%	54.97%		
RELATIVE CONTRIBUTIONS (Vertical)								
	Vents	Enclosures	Floor	Structures	Structures	Structures		
Debris Classification				Above	Break	Other		
Small Pieces	80.82%	84.62%	N/A	100.00%	0.00%	11.89%		
Large Pieces-Above	1.87%	0%	N/A	0%	99.58%	87.63%		
Large Pieces-Below	17.32%	15.38%	N/A	0%	0.42%	0.49%		
All Large Pieces	19.18%	15.38%	N/A	0%	100.00%	88.11%		



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1000 - 7	<b>D</b> 1 1 <b>C</b> 1 <b>C</b>	Distribution After		1	Dath	T	T
LOCA Type	Debris Classification	Blowdown	Erosion and Washdown	Drywell Floor Pool	No.	Fraction	Final Location
		Advected to Vents			1	1.078E-01	Vents
MAKK II		0.49 Enclosures			2	2.200E-03	Enclosures
CENTRAL ESTIMATE		0.01		Waterhome		6 5000 cm	
RL BREAK		_		1.00		5.500E-02	Vents
ECCS THROT	TLED	Drywell Floor		Cadimant			
		0.25		0.00	4	0.000E+00	Floor
SFRATS OFEN	CATED			Waterborne	5	2 200E-05	Vents
FIBROUS INSULATION			0.1	1.00		2.2001-05	vents
			0.01	Sediment	6	0.000E+00	Floor
	Small Pieces	Structures-Above	Adheres	0.00	7	3 1795 03	Eterne Al
	0.22	0.01	0.99			2.1782-03	Structures-Above
				Waterborne	8	1.320E-02	Vents
			Recirculation Flow	1.00			
		Structures-Break	1.00	Sediment	9	0.000E+00	Floor
		0.06	Adheres		10	0.000E+00	Structures-Break
			0.00	Waterborne	11	1.980E-02	Vents
			Sprays/Condensate	1.00			
			0.50	Sediment	12	0.000E+00	Floor
		0.18	Adheres	0.00	13	1.980E-02	Structures-Other
			0.50	117-a- 1 -			
				1.00	14	4.080E-03	Vents
			Recirculation Flow	<b>C</b> - 1 <sup>1</sup>		0.0007.00	_
		Structures-Break	0.08	0.00	15	0.000E+00	Floor
		0.15	Adheres		16	4.692E-02	Structures-Break
			0.92	Waterborne	17	2.890E-03	Vents
	Large-Above		Sprays/Condensate	1.00			
	0.34	Structures Other	0.01	Sediment	18	0.000E+00	Floor
		0.85	Adheres	0.00	19	2.861E-01	Structures-Other
L Break		Advected to Vent	0.99		20	3.600 F-02	Vente
		0.90				5.00012-02	¥ CIIIS
	Large-Below	Enclosures 0.01	·····		21	4.000E-04	Enclosures
	0.04			Waterborne	22	1.600E-03	Vents
		Drywell Floor		1.00			
		0.04		Sediment	23	0.000E+00	Floor
				0.00			
			ŗ	Waterborne	24	2.000E-04	Vents
			Recirculation Flow	1.00			
		Structures-Break	0.50	Sediment	25	0.000E+00	Floor
:		0.01	Adheres		26	2.000E-04	Structures-Break
			0.50	Waterborne	27	1.600E-05	Vents
			Sprays/Condensate	1.00			
			0.01	Sediment	28	0.000E+00	Floor
		Structures-Other	Adheres	0.00	20	1 5845 02	Structures Othe
	2		0.99		27	1.364E-03	autures-Other
i	0.40		····		30 Tetri	4.000E-01	Structures/Floor
	V.40				Total	1.000E+00	

DEBRIS TRANSPORT RESULTS								
Plant Design:	MARK II							
Estimate:	CENTRAL	ESTIMATE		FIBROUS INSULATION				
Break:	RL BREAK							
ECCS:	ECCS THR	OTTLED						
Sprays:	SPRAYS O	PERATED						
TREE QUANTIFICATION								
Debris Classification	Vents	Enclosures	Floor	Structures Above	Structures Break	Structures Other	Transport Fraction	
Small Pieces	1.958E-01	2.200E-03	0.000E+00	2.178E-03	0.000E+00	1.980E-02	0.8901	
Large Pieces-Above	6.970E-03	0	0.000E+00	0	4.692E-02	2.861E-01	0.0205	
Large Pieces-Below	3.782E-02	4.000E-04	0.000E+00	0	2.000E-04	1.584E-03	0.9454	
All Large Pieces	4.479E-02	4.000E-04	0.000E+00	0	4.712E-02	2.877E-01	0.1179	
All Debris	2.406E-01	2.600E-03	0.000E+00	2.178E-03	4.712E-02	3.075E-01	0.4010	
All Zone-of-Influence							0.2406	
FINAL DISTRIBUTIO	ONS (Horizo	ntal)						
				Structures	Structures	Structures		
Debris Classification	Vents	Enclosures	Floor	Above	Break	Other		
Small Pieces	89.01%	1.00%	0.00%	0.99%	0.00%	9.00%		
Large Pieces-Above	2.05%	0%	0.00%	0%	13.80%	84.15%		
Large Pieces-Below	94.54%	1.00%	0.00%	0%	0.50%	3.96%		
All Large Pieces	11.79%	0.11%	0.00%	0%	12.40%	75.71%		
All Debris	40.10%	0.43%	0.00%	0.36%	7.85%	51.25%		
RELATIVE CONTRIBUTIONS (Vertical)								
Debris Classification	Vente	Enclosures	Floor	Structures	Structures	Structures		
Debris Classification	v ents		11001	Above	Break	Other		
Small Pieces	81.39%	84.62%	N/A	100.00%	0.00%	6.44%		
Large Pieces-Above	2.90%	0%	N/A	0%	99.58%	93.05%		
Large Pieces-Below	15.72%	15.38%	N/A	0%	0.42%	0.52%		
All Large Pieces	18.61%	15.38%	N/A	0%	100.00%	93.36%		
Debris Transport Fractions								
0.750								
0.000								
Small Debris Large Above Large Below All Large Debris All Debris All Zone-of- Gratings Gratings Influence								

LOCA Type	Debris Classification	Distribution After Blowdown	Erosion and Washdown	Drywell Floor Pool	Path No.	Fraction	Final Location
		Advected to Vents			1	1.078E-01	Vents
MARK II		0.49 Enclosures		2	2.200E-03	Enclosures	
CENTRAL ESTIMATE		0.01		Waterborne	3	5.5008-02	Vents
RL BREAK		Drywell Floor		1.00		5.0001-01	·
NOT THROTTLED		0.25		Sediment	4	0.000E+00	Floor
NO SPRAYS				0.00			
FIBROUS INSU	LATION			Waterborne	5	2.200E-05	Vents
			Condensate Drainage	Sediment	6	0.0008-000	Floor
	Small Pieces	Structures-Above	Adheres	0.00	7	2 1785 03	Structures About
	0.22	0.01	0.99			2.1780-03	Sinicillies-Above
				Waterborne		1.320E-02	Vents
			Recirculation Flow	Sediment	9	0.000E+00	Floor
		Structures-Break	Adheme	0.00	10	0.0005100	Charter Paul
		0.06	0.00		10	0.0002+00	Structures-Break
				Waterborne	11	3.960E-04	Vents
			Condensate Drainage	Sediment	12	0.000E+00	Floor
		Structures-Other	Adheres	0.00	13	3 0205 02	Structures Other
		0.18	0.99	Watachana	1.5	1.2775.02	Jude luies-Ouki
			i	1.00	14	1.3776-02	Vents
			Recirculation Flow	Sediment	15	0.000E+00	Floor
		Structures-Break	Adheres	0.00	16	3 723E_02	Structures_Break
		0.15	0.73	Watashasaa		0.000E100	Vest
				1.00		0.000£+00	v ents
	Large-Above		Condensate Drainage	Sediment	18	0.000E+00	Floor
		Structures-Other	Adheres	0.00	19	2.890E-01	Structures-Other
RL Break		Advected to Vent	1.00	······································	20	3.600E-02	Vents
1.00		0.90				4 0007 04	Escleaures
	Large-Below	0.01			21	4.0002-04	Enclosures
	0.04			Waterborne 1.00	22	1.600E-03	Vents
		Drywell Floor 0.04		Sediment	23	0.000E+00	Floor
				0.00			
				Waterborne	24	2.000E-04	Vents
			Recirculation Flow	1.00			
		Structures-Break	0.50	Sediment 0.00	25	0.000E+00	Floor
		0.01	Adheres		26	2.000E-04	Structures-Break
				Waterborne	27	0.000E+00	Vents
			Condensate Drainage	1.00		0.0007.00	
		Structures-Other	0.00	Sedument 0.00	28	0.000E+00	Floor
		0.04	Adheres		29	1.600E-03	Structures-Other
	Canvassed				30	4.000E-01	Structures/Floor
	. 0.40				Total	1.000E+00	

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DEBRIS TRANSPORT RESULTS								
Plant Design:	MARK II							
Estimate:	CENTRAL	ESTIMATE	FIBROUS INSULATION					
Break:	RL BREAK							
ECCS:	NOT THRO	DTTLED						
Sprays:	NO SPRAY	S						
TREE QUANTIFICA	TION							
Debris Classification	Vents	Enclosures	Floor	Structures Above	Structures Break	Structures Other	Transport Fraction	
Small Pieces	1.764E-01	2.200E-03	0.000E+00	2.178E-03	0.000E+00	3.920E-02	0.8019	
Large Pieces-Above	1.377E-02	0	0.000E+00	0	3.723E-02	2.890E-01	0.0405	
Large Pieces-Below	3.780E-02	4.000E-04	0.000E+00	0	2.000E-04	1.600E-03	0.9450	
All Large Pieces	5.157E-02	4.000E-04	0.000E+00	0	3.743E-02	2.906E-01	0.1357	
All Debris	2.280E-01	2.600E-03	0.000E+00	2.178E-03	3.743E-02	3.298E-01	0.3800	
All Zone-of-Influence							0.2280	
FINAL DISTRIBUTIONS (Horizontal)								
Debris Classification	Vents	Enclosures	Floor	Structures Above	Structures Break	Structures Other		
Small Pieces	80.19%	1.00%	0.00%	0.99%	0.00%	17.82%		
Large Pieces-Above	4.05%	0%	0.00%	0%	10.95%	85.00%		
Large Pieces-Below	94.50%	1.00%	0.00%	0%	0.50%	4.00%		
All Large Pieces	13.57%	0.11%	0.00%	0%	9.85%	76.47%		
All Debris	38.00%	0.43%	0.00%	0.36%	6.24%	54.97%		
RELATIVE CONTRIBUTIONS (Vertical)								
Debris Classification	Vents	Enclosures	Floor	Structures Above	Structures Break	Structures Other		
Small Pieces	77.38%	84.62%	N/A	100.00%	0.00%	11.89%		
Large Pieces-Above	6.04%	0%	N/A	0%	99.47%	87.63%		
Large Pieces-Below	16.58%	15.38%	N/A	0%	0.53%	0.49%		
All Large Pieces	22.62%	15.38%	N/A	0%	100.00%	88.11%		
Debris Transport Fractions								


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LOCA Type	Debris Classification	Distribution After Blowdown	Erosion and Washdown	Drywell Floor Pool	Path No.	Fraction	Final Location
		Advected to Vents			1	1.078E-01	Vents
MARK II		0.49 Enclosures			2	2.200E-03	Enclosures
CENTRAL EST	IMATE	0.01		Waterborne	3	5.500E-02	Vents
RL BREAK		Drywell Floor					
NOT THROTTI	ED	0.25		Sediment	4	0.000E+00	Floor
SPRAYS OPER	ATED			U.co	_	2 2 2 2 2 2	
FIBROUS INSU	LATION		Condensate Deninage	1.00	5	2.200E-05	Vents
		Structures-Above	0.01	Sediment	6	0.000E+00	Floor
	Small Pieces	0.01	Adheres	0.00	7	2.178E-03	Structures-Above
	0.22		0.99	Waterborne	8	1.320E-02	Vents
			Recirculation Flow	1.00			
		Structures-Break	1.00	Sediment 0.00	9	0.000E+00	Floor
		0.06	Adheres		10	0.000E+00	Structures-Break
			0.00	Waterborne	11	1.980E-02	Vents
			Sprays/Condensate	Sediment	12	0.0008+00	Floor
		Structures-Other	Adheres	0.00	13	1.980E-02	Structures Other
		0.13	0.50	Waterborne	14	1 377F-07	Vente
			Recipulation Flow	1.00		1.5772-02	T CILS
		Structures_Break	0.27	Sediment	15	0.000E+00	Floor
		0.15	Adheres	0.00	16	3.723E-02	Structures-Break
			0.73	Waterborne	17	2.890E-03	Vents
	Large-Above		Sprays/Condensate	1.00			
	0.34	Structures-Other	0.01	Sediment 0.00	18	0.000E+00	Floor
RL, Break		0.85	Adheres 0.99		19	2.861E-01	Structures-Other
1.00		Advected to Vent			20	3.600E-02	Vents
	Large-Below	Enclosures	· · · · · · · · · · · · · · · · · · ·		21	4.000E-04	Enclosures
	0.04	0.01		Waterborne	22	1.600E-03	Vents
		Drywell Floor		1.00			
		0.04		Sediment 0.00	23	0.000E+00	Floor
				Waterborne	24	2.000E-04	Vents
			Recirculation Flow	1.00			
		Structures-Break	0.50	Sediment 0.00	25	0.000E+00	Floor
		0.01	Adheres 0.50		26	2.000E-04	Structures-Break
			1	Waterborne	27	1.600E-05	Vents
			Sprays/Condensate	Sediment	28	0.0005+00	Floor
		Structures-Other 0.04	Adheres	0.00	29	1.584E-03	Structures-Other
	Canvassed		0.99		30	4.000F-01	Structures/Floor
	0.40				Total	1.000E+00	54 4644 65 1 1001

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DEBRIS TRANSPORT RESULTS											
Plant Design:	MARK II										
Estimate:	CENTRAL	ESTIMATE		FIBROUS I	NSULATIO	N					
Break:	RL BREAK										
ECCS:	NOT THRO	OTTLED									
Sprays:	SPRAYS O	PERATED									
TREE QUANTIFICA	TION										
Debris Classification	Vents	Enclosures	Floor	Structures Above	Structures Break	Structures Other	Transport Fraction				
Small Pieces	1.958E-01	2.200E-03	0.000E+00	2.178E-03	0.000E+00	1.980E-02	0.8901				
Large Pieces-Above	1.666E-02	0	0.000E+00	0	3.723E-02	2.861E-01	0.0490				
Large Pieces-Below	3.782E-02	4.000E-04	0.000E+00	0	2.000E-04	1.584E-03	0.9454				
All Large Pieces	5.448E-02	4.000E-04	0.000E+00	0	3.743E-02	2.877E-01	0.1434				
All Debris	2.503E-01	2.600E-03	0.000E+00	2.178E-03	3.743E-02	3.075E-01	0.4172				
All Zone-of-Influence							0.2503				
FINAL DISTRIBUTI	ONS (Horizo	ntal)									
			<b>T</b> 71	Structures	Structures	Structures					
Debris Classification	Vents	Enclosures	Floor	Above	Break	Other					
Small Pieces	89.01%	1.00%	0.00%	0.99%	0.00%	9.00%					
Large Pieces-Above	4.90%	0%	0,00%	0%	10.95%	84.15%					
Large Pieces-Below	94.54%	1.00%	0.00%	0%	0.50%	3.96%					
All Large Pieces	14.34%	0.11%	0.00%	0%	9.85%	75.71%					
All Debris	41.72%	0.43%	0.00%	0.36%	6.24%	51.25%					
RELATIVE CONTR	IBUTIONS	(Vertical)									
				Structures	Structures	Structures					
Debris Classification	Vents	Enclosures	Floor	Above	Break	Other					
Small Pieces	78.24%	84.62%	N/A	100.00%	0.00%	6.44%					
Large Pieces-Above	6.66%	0%	N/A	0%	99.47%	93.05%					
Large Pieces-Below	15.11%	15.38%	N/A	0%	0.53%	0.52%					
All Large Pieces	21.76%	15.38%	N/A	0%	100.00%	93.56%					
		Debris	s Transport	Fractions							
1.000											
0.750											
<u><u><u></u><u></u><u></u><u></u><u></u><u></u><u></u><u></u><u></u><u></u><u></u><u></u><u></u><u></u><u></u><u></u><u></u><u></u></u></u>											
Fra					8000 80	astur potk Nationalia Nationalia					
0.250							5-10-10-10-10-10-10-10-10-10-10-10-10-10-				
				Real Products							
Small D	ebris Lar G	ge Above ratings	Large Below Gratings	All Large D	ebris All	Debris	All Zone-of- Influence				

## A.3.3 Mark III

This section contains the central estimate logic charts for the Mark III design.

### A.3.3.1 Main Steam Line Break

The central estimate logic charts for the main steam line breaks are presented here, then the charts for the recirculation line breaks are presented in Section A.3.3.2

Adveted to Verais         I         L1056-01         Verais           CENTRAL ESTIMATE         0.01         Watchme         0         0.000+00         Verait           MSL BREAK         Downell Floor         0.0         0.000+00         Verait         0.000+00         Verait           ECCS THROTTLED         0.01         Sectores         1.00         0         0.000+00         Verait           NO SPRAVS         0.01         Sectores         0.000+00         Verait         0.000+00         Verait           PIBROUSI INSULATION         Ondersite Drininge         0.000         0.000+00         Verait         0.000+00         Verait           Small Pices         0.00         Org         Waterborne         0         6.0000+00         Verait           0.01         Sametres-Alove         0.00         Verait         0.000+00         Verait           0.02         Org         Waterborne         1.0         6.0000+00         Verait           0.02         Org         Waterborne         1.0         0.000+00         Verait           0.03         Org         Verait         1.0         0.000+00         Verait           0.04         Org         0.000+00         1.1         0.0000	LOCA Type	Debris Classification	Distribution After Blowdown	Erosion and Washdow	n Drywell Floor Pool	Path No.	Fraction	Final Location
CENTRAL ESTIMATE         Discloses         2         2 20263         Pindomes           MSL BREAK         Dyvell Fjoor         3         0.0000-00         Vers           NO SPRAVS         Divell Fjoor         4         2.0000-00         Vers           FIBROUS INSULATION         Divell Fjoor         1.00         -         5         0.0000-00         Vers           Small Preces         Dio3         Adners         1.00         7         6.5348-00         Structures-Above           001         Sinctures-Above         0.00         0.00         7         6.5348-00         Structures-Above           002         Operations         1.00         7         6.5348-00         Structures-Above           003         Operations         1.00         7         6.5348-00         Structures-Above           0.00         Operations         0.00         1.00         2.2080-04         Ploor           0.01         Adneres         1.00         7         6.5348-00         Structures-Above           0.02         Operations         1.0         0.000E+00         Vers         0.000E+00         Vers           0.01         Adneres         1.00         1.0         6.000E+00         Floor <t< td=""><td>MARK III</td><td></td><td>Advected to Vents</td><td></td><td></td><td>1</td><td>1.210E-01</td><td>Vents</td></t<>	MARK III		Advected to Vents			1	1.210E-01	Vents
Name         0.01         Watchers         0         0.000E-00         Van           MSL BREAK         Dywell Floor         0.01         6.000E-00         Ploor         900E-00         Van           CCS TIRGUTLED         0.01         1.00         4         2.200E-00         Vends           FIBROUS INSULATION         Sectioner         5         0.000E+00         Vends           Soull Preces         Distances-Above         0.00         90         Vanchore         8         0.000E+00         Vends           0.01         1.00         1.0         7         6.534E-01         Structures-Above           0.02         0.99         Watchore         8         0.000E+00         Vends           0.02         0.99         Watchore         8         0.000E+00         Vends           0.01         1.00         10         2.178E-02         Structures-Above           0.02         Structures-Other         1.00         11         0.000E+00         Vends           0.01         Adhres         1.00         12         6.000E+00         Floor           0.02         Structures-Other         0.00         Vends         0.000E+00         Floor           0.02	CENTRAL EST	IMATE	Enciosures			2	2.200E-03	Enclosures
Mat. DEXAX         Doyaell Floor         0.00         4         2.200E-03         Ploor           BCCS THROTTLED         0.0         -         Sediment         4         2.200E-03         Ploor           NO SPRAYS         -         -         Sediment         6         6.000E-00         Vents           FIBROIS INSULATION         -         -         -         6.000E-00         Vents           Small Pices         0.03         -         -         6.000E+00         Vents           0.02         -	MEL DODAY		Waterborne			3	0.000E+00	Vents
ECCS TRROTTLED         0.01         Sectors         4         2.200E-03         Ploor           NO SPRAYS         1.00         5         0.00E+00         Vern           FIBROUS INSULATION         Condensate Drainage         5         0.00E+00         Vern           Small Prees         0.03         0.01         Schement         6         6.600E-05         Fiber           0.02         0.03         0.01         Schement         6         6.000E+00         Vern           0.02         0.03         0.07         7         6.514E-03         Structures-Above         0.00         Vern         0.00E+00         Vern	MOL BREAK		Drywell Floor		0.00			
NO SPRAYS FIBROUS INSULATION FIB	ECCS THROTT	LED	0.01		Sediment	4	2.200E-03	Floor
FIBROUS DSULATION         Condensate Drainage (00)         Section         Southers/ (00)         Southers/ (00) <thsouthers <br="">(00)         Southers/ (00)         So</thsouthers>	NO SPRAYS				Waterhome		0.0007.00	
Small Pieces         Structures-Above         Condensate Drange Advers         Sciences         Floor           0.22         0.3         0.97         4         0.000E+00         Vents           0.21         0.3         0.97         4         0.000E+00         Vents           0.22         0.01         3climent         9         2.200E-04         Floor           0.01         3climent         9         2.200E-04         Floor           0.01         3climent         9         2.200E-04         Floor           0.01         3climent         1.0         2.178E-02         Structures-Dreak           0.01         3climent         1.0         2.178E-02         Structures-Dreak           0.01         3climent         1.0         2.000E+00         Vents           0.03         Adheres         1.0         1.0         0.000E+00         Vents           0.30         Adheres         1.0         1.5         0.000E+00         Vents           0.30         Adheres         1.0         1.5         0.000E+00         Vents           0.31         1.00         Vents         1.00         Vents         1.00         Vents           0.40         0.00<	FIBROUS INSU	LATION			0.00	,	0.000E+00	Vents
Small Pieces         Structures-Above 0.03         Adheres         1.00         7         6.5345.00         Structures-Above 0.00           0.22         0.33         0.99         Waterborne         8         0.0005+00         Vents           0.03         Condensate Drainage         0.00         2.2005.04         Floor           0.10         Adheres         1.00         0         2.1786.02         Structures-Break           0.10         Adheres         1.00         10         2.1786.02         Structures-Other           0.10         Adheres         1.00         11         0.0005+00         Vents           0.10         Condensate Drainage         Scientent         12         6.6005-04         Floor           0.10         0.39         Waterborne         14         0.0005+00         Vents           0.30         Condensate Drainage         5cientent         15         0.0005+00         Vents           0.34         Condensate Drainage         5cientent         16         5.1006.02         Structures-Other           0.35         Adheres         1.00         Waterborne         12         0.0005+00         Vents           0.34         Structures-Other         1.00         Waterborne				0.01	Sediment	6	6.600E-05	Floor
VSL Break         0.92         Waterborne         8         0.000E+00         Vents           0.01         0.01         0.01         0.01         2.200E-04         Floor           0.10         0.10         0.10         2.178E-02         Structures-Break         0.00         Vents           0.10         0.10         0.10         0.10         2.178E-02         Structures-Break         0.00         Vents           0.10         0.00         0.01         0.00         2.178E-02         Structures-Other         0.00         Vents           0.00         0.01         0.00         0.01         0.00         Vents         0.00         Vents           0.00         0.01         0.00         90         Waterborne         14         0.000E+00         Vents           0.00         0.01         Underes         1.00         16         5.100E-02         Structures-Other         1.00         16         5.100E-02         Structures-Other           0.01         Large-Above         0.01         Vents         0.00         16         5.100E-02         Structures-Other           0.02         Condemate Drainage         0.00         Vents         0.00         Vents           0.03<		Small Pieces	Structures-Above	Adheres	1.00	7	6.534E-03	Structures-Above
VSL Brack         Structures-Break         Condensate Drainage         0.00         0         0.000         0         Venia           VSL Break         0.01         0.02         Watehome         11         0.000E+00         Venia           VSL Break         0.01         0.99         Watehome         11         0.000E+00         Venia           0.01         0.99         Watehome         11         0.000E+00         Venia           0.03         0.99         Watehome         12         6.600E+04         Floor           0.03         0.99         Watehome         13         6.534E+02         Structures-Other           0.30         0.99         Watehome         13         6.534E+02         Structures-Other           0.30         0.99         Watehome         15         0.000E+00         Venia           0.34         Structures-Drainage         1.00         16         5.100E+02         Structures-Other           0.34         Structures-Other         1.00         18         0.000E+00         Floor           0.34         Structures-Other         1.00         18         0.000E+00         Floor           0.34         Structures-Other         1.00         12 <t< td=""><td></td><td>0.22</td><td></td><td>0.99</td><td>Waterborne</td><td>8</td><td>0.000E+00</td><td>Vente</td></t<>		0.22		0.99	Waterborne	8	0.000E+00	Vente
MSL Break         Large-Above         Structures-Break         Out         Condensate Drainage         Sciencest         9         2.00E-04         Floor           MSL Break         0.10         Adheres         1.00         10         2.178E-02         Structures-Break           MSL Break         0.10         Adheres         1.00         13         6.534E-02         Structures-Other           0.30         Adheres         1.00         13         6.534E-02         Structures-Other           0.30         Adheres         1.00         13         6.534E-02         Structures-Other           0.30         Adheres         1.00         14         0.000E+00         Veats           0.01         Adheres         1.00         15         0.000E+00         Veats           0.02         Structures-Other         0.00         1.00         16         5.100E-02         Structures-Drake           0.03         Adheres         1.00         16         5.100E-02         Structures-Other           0.04         Structures-Other         1.00         16         5.100E-02         Veats           0.04         Structures-Other         1.00         22         0.00E+00         Veats           0.04				Condensate Designage	0.00		0.00012700	¥ CIII3
MSL Break         0.10         Adheres         1.00         10         2.178E-02         Structures-Break           0.10         0.99         Waterborne         11         0.000E+00         Vents           0.00         Sedment         12         6.000E+00         Vents           0.00         Adheres         1.00         13         6.534E-02         Structures-Other           0.30         Adheres         1.00         13         6.534E-02         Structures-Other           0.30         Adheres         1.00         14         0.000E+00         Vents           0.30         Condensate Drainage         50.00         Vents         50.00         Vents           0.00         Structures-Other         1.00         16         5.100E-02         Structures-Dreak           0.15         Adheres         1.00         Waterborne         17         0.000E+00         Floor           0.04         Structures-Other         1.00         Waterborne         18         0.000E+00         Floor           0.04         Structures-Other         1.00         12         3.600E+00         Floor           0.05         Structures-Other         1.00         12         0.000E+00         Vents			Charter D	0.01	Sediment	9	2.200E-04	Floor
MSL Break         0.99         Waterborne         11         0.000E+00         Vents           0.00         001         Sciment         12         6.600E+04         Floor           0.30         Afteres         1.00         13         6.534E+02         Structures-Other           0.30         Afteres         1.00         13         6.534E+02         Structures-Other           0.30         Afteres         1.00         13         6.534E+02         Structures-Other           0.30         Afteres         1.00         16         5.100E+00         Vents           0.00         Condensate Drainage         6.000         Condensate Drainage         10.0         Vents           0.01         Afteres         1.00         Waterborne         17         0.000E+00         Vents           0.03         Structures-Other         1.00         Waterborne         17         0.000E+00         Vents           0.04         Structures-Other         1.00         20         3.600E+02         Vents           0.05         Exclosures         1.00         20         3.600E+02         Vents           0.04         O11         Waterborne         21         4.000E+03         Floor			0.10	Adheres	1.00	10	2.178E-02	Structures-Break
MSL Break         Condensate Drainage         0.00         1         0.0000-00         Vens           0.00         0.0         0.0         0.0         0.0         0.0000-00         Vens           0.00         0.0         0.0         0.0         0.0         0.0000-00         Vens           0.00         0.0         0.0         0.0         0.0000-00         Vens           0.00         0.00         0.0000-00         Vens         0.0000-00         Vens           0.00         0.00         0.0000-00         Vens         0.0000-00         Vens           0.00         0.00         16         5.100E-02         Structures-Dther         0.00           0.00         1.00         Waterborne         17         0.0000-00         Vents           0.00         1.00         Waterborne         18         0.0000-00         Vents           0.00         0.00         1.00         20         3.660E-02         Vents           0.00         0.01         Waterborne         22         0.0000-00         Vents           0.04         0.01         Waterborne         23         1.600E-03         Floor           0.00         0.00         1.00				0.99	Waterborne	11	0.000E+00	Vante
Visit Break         Structures-Other         Outerstance Datage         Sediment         12         6.600E-04         Floor           0.30         Adheres         1.00         13         6.534E-02         Structures-Other           0.30         0.30         Operating         0.00         14         0.000E+00         Veata           0.00         0.00         Condenate Drainage         0.00         16         5.100E-02         Structures-Break           0.15         Adheres         1.00         16         5.100E-02         Structures-Break           0.34         Structures-Other         1.00         Waterborne         17         0.000E+00         Vents           0.34         Structures-Other         1.00         Waterborne         18         0.000E+00         Floor           0.34         Structures-Other         1.00         Structures-Other         1.00         Vents         Structures-Other           0.35         Adheres         1.00         20         3.600E+00         Floor           0.34         Structures-Other         1.00         21         4.000E-04         Enclosures           0.04         Option         Condenate Drainage         21         4.000E-04         Enclosures				Condensate Designage	0.00		V.VVETU	¥ € B (3
MSL Break         Structures-Other         Adheres         1.00         13         6.534E-02         Structures-Other           0.30         0.30         Materborne         14         0.000E+00         Venta           0.00         0.00         Structures-Break         1.00         16         5.100E-02         Structures-Break           0.15         Adheres         1.00         Waterborne         17         0.000E+00         Venta           0.34         Structures-Other         1.00         Waterborne         17         0.000E+00         Venta           0.34         Structures-Other         1.00         Waterborne         18         0.000E+00         Ploor           0.35         Adheres         1.00         Venta         1.00         Venta           0.04         Structures-Other         1.00         1.00         Venta         1.00         Venta           0.04         Other         1.00         20         3.600E-02         Venta           0.05         Advected to Vent         1.00         20         3.600E-02         Venta           0.06         0.01         Waterborne         21         4.000E-04         Enclosures           0.04         Drywell Floor				0.01	Sediment	12	6.600E-04	Floor
VSL Break         0.59         Waterborne         14         0.000E+00         Venta           0.00         0.00         Structures-Break         0.00         16         5.100E-02         Structures-Break           0.15         1.00         Waterborne         17         0.000E+00         Venta           0.34         Ordensate Drainage         0.00         Venta         18         0.000E+00         Venta           0.34         Structures-Other         1.00         Waterborne         17         0.000E+00         Floor           0.34         Structures-Other         1.00         Waterborne         18         0.000E+00         Floor           0.34         Structures-Other         1.00         1.00         18         0.000E+00         Floor           0.34         Structures-Other         1.00         1.00         20         3.600E-02         Vents           1.00         0.01         Waterborne         22         0.000E+00         Vents         1.00         Vents           0.04         O.04         Enclosures         1.00         23         1.600E-03         Floor           0.04         O.04         Ediment         23         1.600E+00         Floor			Structures-Other 0.30	Adheres	1.00	13	6.534E-02	Structures-Other
VSL Break         Structures-Break         Condensate Drainage (0.00         100         115         0.000E+00         Floor           0.34         0.15         Adheres         1.00         Waterborne         17         0.000E+00         Vents           0.34         Structures-Other         1.00         Waterborne         17         0.000E+00         Floor           0.34         Structures-Other         1.00         Waterborne         17         0.000E+00         Floor           0.35         Adheres         1.00         19         2.890E-01         Structures-Other           0.00         0.01         Waterborne         20         3.600E-02         Vents           0.04         0.01         Waterborne         21         4.000E-04         Enclosures           0.04         0.01         Waterborne         22         0.000E+00         Vents           0.04         O.01         Waterborne         22         0.000E+00         Vents           0.04         O.04         Enclosures         0.00         Vents         0.00           0.04         O.04         Enclosures         1.00         24         0.000E+00         Vents           0.00         0.01         Adheres				0.99	Waterborne	14	0.000E+00	Vents
MSL Break         Structures-Break         Structures-Other				Condensate Drainage	0.00			
MSL Break         I.00         16         5.100E-02         Structures-Break           0.15         Adheres         1.00         17         0.000E+00         Vents           0.34         Sinctures-Other         0.00         Sediment         18         0.000E+00         Floor           0.34         Sinctures-Other         1.00         19         2.890E-01         Structures-Other           0.35         Adheres         1.00         19         2.890E-01         Structures-Other           1.00         0.03         Adheres         1.00         20         3.600E-02         Vents           0.00         Discures         1.00         19         2.890E-01         Structures-Other           0.00         Discures         1.00         20         3.600E-02         Vents           0.04         Discures         1.00         21         4.000E-04         Enclosures           0.04         Discures-Discures         22         0.000E+00         Vents           0.04         Discures-Discures         24         0.000E+00         Vents           0.00         Condensate Drainage         0.00         Structures-Break         1.00         25         0.000E+00         Vents			Shuahuna D1-	0.00	Sediment	15	0.000E+00	Floor
Large-Above         1.00         Waterhome         17         0.000E+00         Vents           0.34         Structures-Other         0.00         Sediment         18         0.000E+00         Floor           0.34         Structures-Other         0.00         Sediment         18         0.000E+00         Floor           0.00         Advected to Vent         1.00         19         2.890E-01         Structures-Other           0.00         Enclosures         1.00         20         3.600E-02         Vents           0.01         Waterhome         21         4.000E-04         Enclosures           0.04         Drywell Floor         0.00         2         0.000E+00         Vents           0.04         Structures-Break         0.00         Waterhome         24         0.000E+00         Vents           0.01         Materhome         24         0.000E+00         Vents         0.00         Vents           0.04         Drywell Floor         1.00         26         4.000E-04         Structures-Break           0.01         Adieres         1.00         26         4.000E-04         Structures-Break           0.01         Adieres         1.00         28         0.000E+00		1	0.15	Adheres	1.00	16	5.100E-02	Structures-Break
Large-Above         Condensate Drainage         0.00         1.00         Floor           0.34         Structures-Other         0.00         1.00         19         2.890E-01         Structures-Other           0.85         Adheres         1.00         19         2.890E-01         Structures-Other           1.00         Advected to Vent         1.00         20         3.660E-02         Vents           1.00         D.90         Enclosures         21         4.000E-04         Enclosures           1.00         0.01         Waterborne         22         0.000E+00         Vents           0.04         Drywell Floor         0.00         Sediment         23         1.600E+03         Floor           0.04         Condensate Drainage         0.00         Vents         0.00         Vents         0.00         Vents           0.04         Condensate Drainage         0.00         Vents         1.00         Vents           0.01         Adheres         1.00         25         0.000E+00         Vents           0.04         Adheres         1.00         26         0.000E+00         Floor           1.00         Waterborne         27         0.000E+00         Floor				1.00	Waterborne	17	0.000E+00	Vents
0.34         Structures-Other         0.00         Sediment         18         0.000E+00         Floor           0.85         Adheres         1.00         19         2.890E-01         Structures-Other           0.00         Large-Below         0.01         20         3.600E-02         Vents           0.04         Drywell Floor         21         4.000E-04         Enclosures           0.04         Drywell Floor         0.00         23         1.600E-03         Floor           0.04         Drywell Floor         0.00         Sediment         23         1.600E-03         Floor           0.04         Drywell Floor         0.00         Sediment         23         1.600E-03         Floor           0.04         Drywell Floor         0.00         Sediment         25         0.000E+00         Vents           0.00         Structures-Break         1.00         Sediment         25         0.000E+00         Floor           1.00         Materborne         27         0.000E+00         Floor         1.00           0.01         Adheres         1.00         26         4.000E-04         Structures-Break           1.00         Structures-Other         0.00         1.00		Large-Above		Condensate Drainage	0.00			
MSL Break         Adheres         1.00         19         2.890E-01         Structures-Other           1.00         0.85         Adheres         20         3.600E-02         Vents           0.090         Enclosures         21         4.000E-04         Enclosures           0.04         Drywell Floor         22         0.000E+00         Vents           0.04         Drywell Floor         5ediment         23         1.600E-04         Floor           0.04         Condensate Drainage         0.00         Vents         0.00         Vents           0.00         Structures-Break         1.00         24         0.000E+00         Vents           0.01         Adheres         1.00         25         0.000E+00         Vents           0.04         Adheres         1.00         25         0.000E+00         Vents           0.01         Adheres         1.00         26         4.000E+04         Structures-Break           0.01         Adheres         1.00         26         4.000E+00         Vents           0.02         O.04         Adheres         29         1.600E+03         Structures-Other           0.04         Adheres         1.00         29		0.34	Structures_Other	0.00	Sediment	18	0.000E+00	Floor
1.00         Advected to Vent         1.00         20         3.600E-02         Vents           Large-Below         0.01         Waterborne         21         4.000E-04         Enclosures           0.04         Drywell Floor         0.00         Sediment         23         1.600E-02         Vents           0.04         Drywell Floor         0.00         Vents         Ploor	MSL Break	Ľ	0.85	Adheres	1.00	19	2.890E-01	Structures-Other
Large-Below         0.00         21         4.000E-04         Enclosures           0.04         Drywell Floor         0.00         0.00         Vents         0.00         Vents           0.04         Drywell Floor         0.00         Sediment         23         1.600E-03         Floor           0.04         Sediment         23         1.600E-03         Floor         Vents           0.04         Sediment         23         0.000E+00         Vents           0.00         Sediment         23         0.000E+00         Vents           0.00         Sediment         25         0.000E+00         Floor           1.00         Structures-Break         1.00         26         4.000E-04         Structures-Break           0.01         Adheres         1.00         26         4.000E-04         Structures-Break           1.00         Vents         0.00         Sediment         28         0.000E+00         Vents           0.04         Adheres         1.00         29         1.600E-03         Structures/Floor           0.04         Adheres         1.00         29         1.600E-03         Structures/Floor	1.00		Advected to Vent	1.00		20	3.600E-02	Vents
Large-Below         0.01         Waterborne         22         0.000E+00         Vents           0.04         Drywell Floor         0.00         Sediment         23         1.600E+03         Floor           0.04         Sediment         23         1.600E+03         Floor         Floor           0.04         Sediment         23         1.600E+03         Floor         Floor           0.04         Sediment         23         0.000E+00         Vents         Floor           0.00         Sediment         25         0.000E+00         Floor         Floor           0.00         Sediment         25         0.000E+00         Floor         Floor           0.01         Adheres         1.00         26         4.000E+04         Structures-Break           0.01         Structures-Other         0.00         Sediment         28         0.000E+00         Floor           0.02         Structures-Other         1.00         Sediment         28         0.000E+00         Floor           0.04         Adheres         1.00         29         1.600E-03         Structures-Other           0.04         Adheres         30         4.000E+01         Structures/Floor			0.90 Enclosures			21	4.000E-04	Enclosures
Drywell Floor         0.00         22         0.000E+00         Vents           0.04         Sediment         23         1.600E+00         Vents           0.04         Naterborne         24         0.000E+00         Vents           0.00         Waterborne         24         0.000E+00         Vents           0.00         Structures-Break         0.00         Sediment         25         0.000E+00         Floor           0.01         Adheres         1.00         26         4.000E+00         Vents           0.00         Condensate Drainage         0.00         26         4.000E+00         Vents           0.01         Adheres         1.00         28         0.000E+00         Vents           0.00         Structures-Other         1.00         28         0.000E+00         Floor           1.00         Waterborne         27         0.000E+00         Floor           0.04         Adheres         1.00         29         1.600E+03         Structures-Other           0.04         Adheres         30         4.000E+01         Structures/Floor		Large-Below 0.04	0.01		Waterborne	27	0.000E+00	Varia
Lorywen ruon         Sediment         23         1.600E-03         Floor           0.04         Naterborne         24         0.000E+00         Vents           0.00         Waterborne         24         0.000E+00         Vents           0.00         Structures-Break         0.00         Sediment         25         0.000E+00         Floor           Structures-Break         0.00         Sediment         26         4.000E-04         Structures-Break           0.01         Adheres         1.00         26         4.000E+00         Vents           0.00         Sediment         27         0.000E+00         Vents           0.00         Sediment         28         0.000E+00         Vents           0.00         Sediment         28         0.000E+00         Floor           1.00         0.00         Sediment         28         0.000E+00         Floor           0.04         Adheres         1.00         29         1.600E-03         Structures-Other           1.00         30         4.000E-01         Structures/Floor         30			Drawell Floor		0.00	- 22	V.UUE700	venta
I.00         Vaterborne         24         0.000E+00         Vents           Vaterborne         0.00         Sediment         25         0.000E+00         Floor           Structures-Break         0.00         Sediment         25         0.000E+00         Floor           0.01         Adheres         1.00         26         4.000E-04         Structures-Break           0.01         Adheres         1.00         26         4.000E+00         Vents           0.00         Structures-Other         0.00         Sediment         28         0.000E+00         Vents           0.04         Adheres         1.00         29         1.600E-03         Structures-Other           1.00         30         4.000E-01         Structures/Floor			0.04		Sediment	23	1.600E-03	Floor
Vaterborne     24     0.000E+00     Vents       0.00     Condensate Drainage     0.00     Sediment     25     0.000E+00     Floor       0.01     Adheres     1.00     26     4.000E-04     Structures-Break       1.00     Waterborne     27     0.000E+00     Vents       0.01     Materborne     27     0.000E+00     Vents       0.00     Structures-Other     0.00     Sediment     28     0.000E+00     Vents       0.04     Adheres     1.00     29     1.600E-03     Structures-Other       1.00     30     4.000E-01     Structures-Other					1.00			
Outersate Drainage     Outersate Dra					Waterborne	24	0.000E+00	Vents
Structures-Break         0.00         pseument         25         0.000E+00         Floor           0.01         Adheres         1.00         26         4.000E-04         Structures-Break           1.00         Waterborne         27         0.000E+00         Vents           0.00         Condensate Drainage         0.00         Sediment         28         0.000E+00         Vents           0.00         Structures-Other         1.00         Sediment         28         0.000E+00         Floor           0.04         Adheres         1.00         29         1.600E-03         Structures-Other           0.04         Adheres         30         4.000E-01         Structures/Floor           0.40         Taxet         1.00         1.00         Structures/Floor			ŕ	Condensate Drainage	Sadimant	~	0.000	_
0.01         Adheres         26         4.000E-04         Structures-Break           1.00         Waterborne         27         0.000E+00         Vents           0.00         Condensate Drainage         0.00         28         0.000E+00         Floor           0.04         Adheres         1.00         29         1.600E-03         Structures-Other           0.04         1.00         30         4.000E-01         Structures/Floor		2	Structures-Break		1.00	25	0.000E+00	Floor
Waterborne     27     0.000E+00     Vents       0.00     Condensate Drainage     0.00     Sediment     28     0.000E+00     Floor       Structures-Other       0.04     Adheres     1.00     29     1.600E-03     Structures-Other       1.00     30     4.000E-01     Structures/Floor		C	0.01	Adheres 1.00		26	4.000E-04	Structures-Break
Condensate Drainage     Condensate Drainage     Condensate Drainage       0.00     Sediment     28     0.000E+00     Floor       0.04     Adheres     1.00     29     1.600E-03     Structures-Other       1.00     30     4.000E-01     Structures/Floor       0.40     Taral     1.00     1.00				1	Waterborne	27	0.000E+00	Vents
Structures-Other         10.00         rscament         28         0.000E+00         Floor           0.04         Adheres         1.00         29         1.600E-03         Structures-Other           Canvassed         1.00         30         4.000E-01         Structures/Floor           0.40         Tapel         1.00E-03         Structures/Floor			ť	Condensate Drainage	Sediment	30	0.000	
0.04     [Adheres]     29     1.600E-03     Structures-Other       Canvassed     30     4.000E-01     Structures/Floor       0.40     Taml     1.000E-00     Structures/Floor			Structures-Other	0.00	1.00	28	0.000E+00	Floor
Canvassed         30         4.000E-01         Structures/Floor           0.40         Tame         1.000E+00		(	).04	Adheres		29	1.600E-03	Structures-Other
		Canvassed		<u> </u>		30 Total	4.000E-01	Structures/Floor

		DEBRIS	S TRANSPO	RT RESULT	s		
Plant Design:	MARK III						
Estimate:	CENTRAL	ESTIMATE		FIBROUS	INSULATIO	N	
Break:	MSL BREA	ĸ					
ECCS:	ECCS THE	OTTLED					
Sprays:	NO SPRAY	'S					
TREE OUANTIFICA	TION						
				Structures	Structures	Structures	Transport
Debris Classification	Vents	Enclosures	Floor	Above	Break	Other	Fraction
Small Pieces	1.210E-01	2.200E-03	3.146E-03	6.534E-03	2.178E-02	6.534E-02	0.5500
Large Pieces-Above	0.000E+00	0	0.000E+00	0	5.100E-02	2.890E-01	0.0000
Large Pieces-Below	3.600E-02	4.000E-04	1.600E-03	0	4.000E-04	1.600E-03	0.9000
All Large Pieces	3.600E-02	4.000E-04	1.600E-03	0	5.140E-02	2.906E-01	0.0947
All Debris	1.570E-01	2.600E-03	4.746E-03	6.534E-03	7.318E-02	3.559E-01	0.2617
All Zone-of-Influence							0.1570
FINAL DISTRIBUTIO	)NS (Horizo)	ntal)					
THUAL DISTRIBUTE				Structures	Structures	Structures	
Debris Classification	Vents	Enclosures	Floor	Above	Break	Other	
Small Pieces	55.00%	1.00%	1.43%	2.97%	9.90%	29.70%	
Large Pieces-Above	0.00%	0%	0.00%	0%	15.00%	85.00%	
Large Pieces-Below	90.00%	1.00%	4.00%	0%	1.00%	4.00%	
All Large Pieces	9.47%	0.11%	0.42%	0%	13.53%	76.47%	
All Debris	26.17%	0.43%	0.79%	1.09%	12.20%	59.32%	
RELATIVE CONTR	IBUTIONS (	Vertical)					
		( ci deui)		Structures	Structures	Structures	
Debris Classification	Vents	Enclosures	Floor	Above	Break	Other	
Small Pieces	77.07%	84.62%	66.29%	100.00%	29.76%	18.36%	
Large Pieces-Above	0.00%	0%	0.00%	0%	69.69%	81.19%	
Large Pieces-Below	22.93%	15.38%	33.71%	0%	0.55%	0.45%	
All Large Pieces	22.93%	15.38%	33.71%	0%	70.24%	81.64%	
		Debris	Transport	Fractions			
1.000							
0.750				<u> </u>			· · · · · · · · · · · · · · · · · · ·
c l							
ਿੱਚ 0.500	ļ						
Fra							
0.250				<u>.</u> .			
				<u>教徒</u> (14)			
0.000	a		Reefer estimates	Beach to the control		indexate:	River Stand over

All Zone-of-

Influence

All Debris

Large Below

Gratings

All Large Debris

Large Above

Gratings

Small Debris

۰.

LOCA Type	Debris Classification	Distribution After Blowdown	Erosion and Washdown	Drywell Floor Pool	Path No.	Fraction	Final Location
14.0.		Advected to Vents			1	1.210E-01	Vents
MARK III		0.55 Enclosures				3 3005 03	Englis
CENTRAL EST	TIMATE	0.01				2.200E-03	Enclosures
				Waterborne	3	1.760E-03	Vents
MSL BREAK		Danuall Electro		0.80			
NOT THROTT	LED	Drywell Floor		Sediment	4	4.4006-04	Floor
				0.20	<u> </u>	1.10012-04	11001
NO SPRAYS							
FIBROUS INSI	LATION			Waterborne	5	5.280E-05	Vents
			Condensate Drainage	0.80			
			0.01	Sediment	6	1.320E-05	Floor
	Smail Pieces	Structures-Above	Adheres	0.20	7	6 534F-03	Structures, Abou
	0.22	0.03	0.99		·	0.0042-00	Sudduites-Above
				Waterborne	8	1.760E-02	Vents
			Recirculation Flow	0.80			
			1.00	Sediment	9	4.400E-03	Floor
		Structures-Break		0.20			
		0.10	Adheres		10	0.000E+00	Structures-Break
			0.00	Waterborne	11	5.280E-04	Venta
				0.80		0.2005 04	, cuta
			Condensate Drainage				
		Structures-Other	0.01	Sediment	12	1.320E-04	Floor
		0.30	Adheres	0.20	13	6.534E-02	Structures-Other
			0.99				
				Waterborne	14	4.080E-03	Vents
			Recirculation Flow	1.00			
			0.08	Sediment	15	0.000E+00	Floor
		Structures-Break	Adhenes	0.00	16	4 6975 07	Structures Brook
		0.15	0.92	· · · · · · · · · · · · · · · · · · ·	- 10	4.0321402	Subcules-Dicak
				Waterborne	17	0.000E+00	Vents
	Large-Above		Condensate Duning as	1.00			
	0.34		10.00	Sediment	18	0.000E+00	Floor
		Structures-Other		0.00			
ASL Break		0.85	Adheres		19	2.890E-01	Structures-Other
.00	4	Advected to Vent	1.00		20	3.600E-02	Vents
		0.90					
	I ame-Below	Enclosures			21	4.000E-04	Enclosures
	0.04	0.01		Waterborne	22	0.000E+00	Vents
				0.00		0.0002/00	· cata
		Drywell Floor					
		0.04		Sediment	23	1.600E-03	Floor
				1.00			
				Waterborne	24	0.000E+00	Vents
			Perimulation Flow	0.00	ĺ		
			n so	Sediment	25	2.000E-04	Floor
		Structures-Break		1.00			
		0.01	Adheres		26	2.000E-04	Structures-Break
			0.50	Waterborne	27	0.00017+00	Vente
			1	0.00		0.0002700	+ CULS
			Condensate Drainage				
		Structures Other	0.00	Sediment	28	0.000E+00	Floor
	- -	0.04	Adheres	1.00	29	1.600E-03	Structures_Other
		515 T	1.00	· · · · · · · · · · · · · · · · · · ·		1.0001-03	Gauciales-Oalel
	Canvassed				30	4.000E-01	Structures/Floor
	0.40				Total	1.000E+00	

ſ	DEBRIS TRANSPORT RESULTS									
Plant Design:	MARK III									
Estimate:	CENTRAL	ESTIMATE		FIBROUS	INSULATIO	N				
Break:	MSL BREA	АК								
ECCS:	NOT THR	OTTLED								
Sprays:	NO SPRAY	(S								
TREE QUANTIFICATION										
Debris Classification	Vents	Enclosures	Floor	Structures Above	Structures Break	Structures Other	Transport Fraction			
Small Pieces	1.409E-01	2.200E-03	4.985E-03	6.534E-03	0.000E+00	6.534E-02	0.6406			
Large Pieces-Above	4.080E-03	0	0.000E+00	0	4.692E-02	2.890E-01	0.0120			
Large Pieces-Below	3.600E-02	4.000E-04	1.800E-03	0	2.000E-04	1.600E-03	0.9000			
All Large Pieces	4.008E-02	4.000E-04	1.800E-03	0	4.712E-02	2.906E-01	0.1055			
All Debris	1.810E-01	2.600E-03	6.785E-03	6.534E-03	4.712E-02	3.559E-01	0.3017			
All Zone-of-Influence							0.1810			
FINAL DISTRIBUTIO	FINAL DISTRIBUTIONS (Horizontal)									
Debris Classification	Vents	Enclosures	Floor	Structures Above	Structures Break	Structures Other				
Small Pieces	64.06%	1.00%	2.27%	2.97%	0.00%	29.70%				
Large Pieces-Above	1.20%	0%	0.00%	0%	13.80%	85.00%				
Large Pieces-Below	90.00%	1.00%	4.50%	0%	0.50%	4.00%				
All Large Pieces	10.55%	0.11%	0.47%	0%	12.40%	76.47%				
All Debris	30.17%	0.43%	1.13%	1.09%	7.85%	59.32%				
RELATIVE CONTR	IBUTIONS (	Vertical)								
Debris Classification	Vents	Enclosures	Floor	Structures Above	Structures Break	Structures Other				
Small Pieces	77.86%	84.62%	73.47%	100.00%	0.00%	18.36%				
Large Pieces-Above	2.25%	0%	0.00%	0%	99.58%	81.19%				
Large Pieces-Below	19.89%	15.38%	26.53%	0%	0.42%	0.45%				
All Large Pieces	22.14%	15.38%	26.53%	0%	100.00%	81.64%				
Debris Transport Fractions										



0.750

Fraction 605.0

0.250

0.000 -

# A.3.3.2 Recirculation Line Break

This section contains central estimate logic charts for Mark III recirculation line break scenarios.

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LOCA Type	Debris Classification	Distribution After Blowdown	Erosion and Washdown	Drywell Floor Pool	Path No.	Fraction	Final Location
		Advected to Vents		•	1	1.078E-01	Vents
MARK III		0.49 Enclosures			2	2.200E-03	Enclosures
CENTRAL EST	IMATE	0.01	Waterborne	3	3.696E-02	Vents	
RL BREAK				0.80			
ECCS THROTT	TLED	0.21		Sediment	4	9.240E-03	Floor
NO SPRAYS				0.20			
EIRDOUS INSU	I ATION			Waterborne	5	1.760E-05	Vents
FIDROUS INSU	LAHON		Condensate Drainage	0.80			
		Structures-Above	0.01	Sediment 0.20	6	4.400E-06	Floor
	Small Pieces	0.01	Adheres		7	2.178E-03	Structures-Above
	0.22		0.99	Waterborne	8	1.232E-02	Vents
			Recirculation Flow	0.80			
		Structures-Break	1.00	Sediment	9	3.080E-03	Floor
		0.07	Adheres	0.20	10	0.000E+00	Structures-Break
			0.00	Waterborne	11	3.696E-04	Vents
			Condensate Drainage	0.80			
		Structures_Other	0.01	Sediment	12	9.240E-05	Floor
		0.21	Adheres	0.20	13	4.574E-02	Structures-Other
			0.99	Waterborne	14	4.080E-03	Vents
			Recirculation Flow	1.00			
			0.08	Sediment	15	0.000E+00	Floor
		0.15	Adheres	0.00	16	4.692E-02	Structures-Break
			0.92	Waterborne	17	0.000E+00	Vents
	Large-Above		Condensate Drainage	1.00			
	0.34		0.00	Sediment	18	0.000E+00	Floor
		0.85	Adheres	0.00	19	2.890E-01	Structures-Other
RL Break		Advected to Vent	1.00		20	3.600E-02	Vents
1.00		0.90 Englasuma				4 0005 04	Faclasses
ļ	Large-Below	0.01			21	4.000E-04	Enclosures
	0.04			Waterborne 0,00	22	0.000E+00	Vents
		Drywell Floor		Sediment	23	1.600E-03	Floor
		0.04		1.00		1.0002 03	
				Waterbome	24	0.000E+00	Vents
			Recirculation Flow	0.00			
		Structures Break	0.50	Sediment	25	2.000E-04	Floor
		0.01	Adheres	1.00	26	2.000E-04	Structures-Break
1			0.50	Waterborne	27	0.000E+00	Vents
			Condensate Drainage	0.00			
		0	0.00	Sediment	28	0.000E+00	Floor
		Structures-Other 0.04	Adheres	1.00	29	1.600E-03	Structures-Other
	Canvassed		1.00		30	4.000F-01	Structures/Floor
	0.40				Total	1.000E+00	04,00,00,0071,1004

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DEBRIS TRANSPORT RESULTS									
Plant Design:	MARK III								
Estimate:	CENTRAL	ESTIMATE		<b>FIBROUS</b>	NSULATIO	N			
Break:	RL BREAK	ζ							
ECCS:	ECCS THR	OTTLED							
Sprays:	NO SPRAY	/S							
TREE QUANTIFICA	TION								
Debris Classification	Vents	Enclosures	Floor	Structures Above	Structures Break	Structures Other	Transport Fraction		
Small Pieces	1.575E-01	2.200E-03	1.242E-02	2.178E-03	0.000E+00	4.574E-02	0.7158		
Large Pieces-Above	4.080E-03	0	0.000E+00	0	4.692E-02	2.890E-01	0.0120		
Large Pieces-Below	3.600E-02	4.000E-04	1.800E-03	0	2.000E-04	1.600E-03	0.9000		
All Large Pieces	4.008E-02	4.000E-04	1.800E-03	0	4.712E-02	2.906E-01	0.1055		
All Debris	1.975E-01	2.600E-03	1.422E-02	2.178E-03	4.712E-02	3.363E-01	0.3292		
All Zone-of-Influence							0.1975		
FINAL DISTRIBUTIO	ONS (Horizoi	ntal)							
Debris Classification	Vents	Enclosures	Floor	Structures Above	Structures Break	Structures Other			
Small Pieces	71.58%	1.00%	5.64%	0.99%	0.00%	20.79%			
Large Pieces-Above	1.20%	0%	0.00%	0%	13.80%	85.00%			
Large Pieces-Below	90.00%	1.00%	4.50%	0%	0.50%	4.00%			
All Large Pieces	10.55%	0.11%	0.47%	0%	12.40%	76.47%			
All Debris	32.92%	0.43%	2.37%	0.36%	7.85%	56.06%			
RELATIVE CONTR	IBUTIONS (	Vertical)							
Dobris Classification	Vents	Fuctosures	Floor	Structures	Structures	Structures			
	Y CI163	Enclosures	1.1001	Above	Break	Other			
Small Pieces	79.71%	84.62%	87.34%	100.00%	0.00%	13.60%			
Large Pieces-Above	2.07%	0%	0.00%	0%	99.58%	85.93%			
Large Pieces-Below	18.22%	15.38%	12.66%	0%	0.42%	0.48%			
All Large Pieces	20.29%	15.38%	12.66%	0%	100.00%	86.40%			



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LOCA Type	Debris Classification	Distribution After Blowdown	Erosion and Washdown	Drywell Floor Pool	Path No.	Fraction	Final Location
MARK III		Advected to Vents			1	1.078E-01	Vents
CENTRAL PET	13 <i>4</i> 4 772	Enclosures			2	2.200E-03	Enclosures
CENTRAL EST	INCA I E	0.01		Waterborne	3	3.696E-02	Vents
RL BREAK		Drywell Floor		0.80			
NOT THROTTI	LED	0.21		Sediment	4	9.240E-03	Floor
NO SPRAYS				0.20			
FIBROUS INSU	LATION			Waterborne	5	1.760E-05	Vents
			Condensate Drainage	Gadimant.			
	Small Disease	Structures-Above	0.01	0.20	0	4.400E-06	Floor
	0.22	0.01	Adheres		7	2.178E-03	Structures-Above
				Waterborne	8	1.232E-02	Vents
			Recirculation Flow	0.80			
1		Structures-Break	1.00	Sediment 0.20	9	3.080E-03	Floor
		0.07	Adheres		10	0.000E+00	Structures-Break
			0.00	Waterborne	11	3.696E-04	Vents
			Condensate Drainage	0.80			
		Structures-Other	0.01	Sediment	12	9.240E-05	Floor
		0.21	Adheres		13	4.574E-02	Structures-Other
			0.99	Waterborne	14	1.377E-02	Vents
			Recirculation Flow	1.00			
		Structures, Break	0.27	Sediment	15	0.000E+00	Floor
		0.15	Adheres	0.00	16	3.723E-02	Structures-Break
			0.73	Waterborne	17	0.000E+00	Vents
	Large-Above		Condensate Drainage	1.00			
	0.34	Structure Other	0.00	Sediment	18	0.000E+00	Floor
		0.85	Adheres	0.00	19	2.890E-01	Structures-Other
RL Break		Advected to Vent	1.00		20	3.600E-02	Vents
		0.90 Finalocumo	······································			4 000E 04	Enclosures
	Large-Below	0.01				4.000£-04	Enclosures
	0.04			Waterborne	22	0.000E+00	Vents
		Drywell Floor		Sediment	23	1.600E-03	Floor
		0.04		1.00			
				Waterborne	24	0.000E+00	Vents
			Recirculation Flow	0.00			
		Structure Brook	0.50	Sediment	25	2.000E-04	Floor
		0.01	Adheres	1.00	26	2.000E-04	Structures-Break
			0.50	Waterborne	27	0.000E+00	Vents
			Condensate Drainage	0.00			
			0.00	Sediment	28	0.000E+00	Floor
		Structures-Other 0.04	Adheres	1.00	29	1.600E-03	Structures-Other
	Canvaccad	-	1.00		30	4 0005-01	Structures/Floor
[	0.40	·····			Total	1.000E+00	Structures/FI001

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		DEBRIS	5 TRANSPO	RT RESULT	ïS		
Plant Design:	MARK III						
Estimate:	CENTRAL	ESTIMATE		FIBROUS I	INSULATIO	N	
Break:	RL BREAK	ζ.					
ECCS:	NOT THRO	OTTLED					
Sprays:	NO SPRAY	(S					
TREE QUANTIFICA	TION						
Debris Classification	Vents	Enclosures	Floor	Structures Above	Structures Break	Structures Other	Transport Fraction
Small Pieces	1.575E-01	2.200E-03	1.242E-02	2.178E-03	0.000E+00	4.574E-02	0.7158
Large Pieces-Above	1.377E-02	0	0.000E+00	0	3.723E-02	2.890E-01	0.0405
Large Pieces-Below	3.600E-02	4.000E-04	1.800E-03	0	2.000E-04	1.600E-03	0.9000
All Large Pieces	4.977E-02	4.000E-04	1.800E-03	0	3.743E-02	2.906E-01	0.1310
All Debris	2.072E-01	2.600E-03	1.422E-02	2.178E-03	3.743E-02	3.363E-01	0.3454
All Zone-of-Influence							0.2072
FINAL DISTRIBUTI	ONS (Horizo	ntal)					
	<b>T</b> 7 4	The state of the s	Floor	Structures	Structures	Structures	
Debris Classification	vents	Enclosures	FIOOF	Above	Break	Other	
Small Pieces	71.58%	1.00%	5.64%	0.99%	0.00%	20.79%	
Large Pieces-Above	4.05%	0%	0.00%	0%	10.95%	85.00%	
Large Pieces-Below	90.00%	1.00%	4.50%	0%	0.50%	4.00%	
All Large Pieces	13.10%	0.11%	0.47%	0%	9.85%	76.47%	
All Debris	34.54%	0.43%	2.37%	0.36%	6.24%	56.06%	
RELATIVE CONTR	BUTIONS	(Vertical)					
Debris Classification	Vents	Enclosures	Floor	Structures Above	Structures Break	Structures Other	
Small Pieces	75.98%	84.62%	87.34%	100.00%	0.00%	13.60%	
Large Pieces-Above	6.64%	0%	0.00%	0%	99.47%	85.93%	
Large Pieces-Below	17.37%	15.38%	12.66%	0%	0.53%	0.48%	
All Large Pieces	24.02%	15.38%	12.66%	0%	100.00%	86.40%	



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## A.4 LOGIC CHARTS FOR UPPER BOUND ESTIMATES

The logic charts for the upper bound debris transport estimates are presented here .

### A.4.1 Mark I

This section contains the upper bound estimate logic charts for the Mark I design.

#### A.4.1.1 Main Steam Line Break

The upper bound estimate logic charts for the main steam line breaks are presented here, then the charts for the recirculation line breaks are presented in Section A.4.1.2.

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LOCA Type	Debris Classification	Distribution After Blowdown	Erosion and Washdow	n Drywell Floor Pool	Path	Fraction	Final Location
		Advected to Vents			1	1.958E-01	Vents
MARK I		0.89 Enclosures					
UPPER BOUND		0.00	****			0.000E+00	Enclosures
MSL BREAK		Waterborne			3	0.000E+00	Vents
ECCS THROTT	LED	Drywell Floor					
		0.00		1.00	- 4	0.000E+00	Floor
NU SPRAYS				Waterborne	5	0.000E+00	Vente
FIBROUS INSU	LATION		Condenante Desire	0.00	-	0.000100	Venis
		-	0.10	Sediment	6	0.000E+00	Floor
	Small Pieces	Structures-Above	Adheres	1.00	7	0.0005+00	Structure About
	0.22		0.90	********************	•	0.00012100	Succures-Above
				Waterborne	- 8	0.000E+00	Vents
			Condensate Drainage	Sediment	0	6 600E 04	-
		Structures-Break	0.10	1.00	- · · ·	0.000E-04	Floor
		0.03	Adheres 0.90		10	5.940E-03	Structures-Break
				Waterborne	11	0.000E+00	Vents
			Condensate Drainage	0.00			
		Structures-Other	0.10	Sediment	12	1.760E-03	Floor
	L	0.08	Adheres	1.00	13	1.584E-02	Structures-Other
			0.90	Waterborne	14	0.000E+00	Vents
			Condensate Drainage	0.00			
			0.00	Sediment	15	0.000E+00	Floor
	1	0.25	Adheres	1.00	16	7.500E-02	Structures-Break
		-	1.00	117-1			of items of the
				0.00	17	0.000E+00	Vents
	0.30	:	Condensate Drainage	Sediment	18	0.000E+00	Floor
	1	Structures-Other	4. <b>H</b> earan	1.00		0.0002100	Picor
MSL Break	i	J.75 [	1.00		19	2.250E-01	Structures-Other
1.00	, F	Advected to Vent			20	8.000E-02	Vents
1	arge-Below	Enclosures			21	0.000E+00	Enclosures
.(	0.08	3.00		Waterborne	22	0.000E+00	Vents
	i II	Drywell Floor		0.00			
		0.00		Sediment	23	0.000E+00	Floor
				1.00			
				Waterborne	24	0.000E+00	Vents
			Condensate Drainage	0.00			
	s	Structures-Break	0.00	Sediment	25	0.000E+00	Floor
	0	0.00	Adheres		26	0.000E+00	Structures-Break
	1		1.00	Waterborne	27	0.000E+00	Vents
		(	Condensate Drainage	0.00			
			0.00	Sediment	28	0.000E+00	Floor
	iS 0	.00	Adheres	1.00	29	0.000E+00	Structures-Other
, in the second s	anvassed	<b>6</b> 1	1.00			10000	
	.40				JU Total	4.000E-01	Structures/Floor

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DEBRIS TRANSPORT RESULTS											
Plant Design:	MARK I										
Estimate:	UPPER BO	UND		FIBROUS I	NSULATIO	N					
Break:	MSL BREA	К									
ECCS:	ECCS THR	OTTLED									
Sprays:	NO SPRAY	S	Ų								
TREE QUANTIFICATION											
Debris Classification	Vents	Enclosures	Floor	Structures Above	Structures Break	Structures Other	Transport Fraction				
Small Pieces	1.958E-01	0.000E+00	2.420E-03	0.000E+00	5.940E-03	1.584E-02	0.8900				
Large Pieces-Above	0.000E+00	0	0.000E+00	0	7.500E-02	2.250E-01	0.0000				
Large Pieces-Below	8.000E-02	0.000E+00	0.000E+00	0	0.000E+00	0.000E+00	1.0000				
All Large Pieces	8.000E-02	0.000E+00	0.000E+00	0	7.500E-02	2.250E-01	0.2105				
All Debris	2.758E-01	0.000E+00	2.420E-03	0.000E+00	8.094E-02	2.408E-01	0.4597				
All Zone-of-Influence							0.2758				
FINAL DISTRIBUTIO	ONS (Horizo	ntal)									
				Structures	Structures	Structures					
Debris Classification	Vents	Enclosures	Floor	Above	Break	Other					
Small Pieces	89.00%	0.00%	1.10%	0.00%	2.70%	7.20%					
Large Pieces-Above	0.00%	0%	0.00%	0%	25.00%	75.00%					
Large Pieces-Below	100.00%	0.00%	0.00%	0%	0.00%	0.00%					
All Large Pieces	21.05%	0.00%	0.00%	0%	19.74%	59.21%					
All Debris	45.97%	0.00%	0.40%	0.00%	13.49%	40.14%					
RELATIVE CONTE	IBUTIONS	(Vertical)									
Debris Classification	Vents	Enclosures	Floor	Structures Above	Structures Break	Structures Other					
Small Pieces	70.99%	N/A	100.00%	N/A	7.34%	6.58%					
Large Pieces-Above	0.00%	N/A	0.00%	N/A	92.66%	93.42%					
Large Pieces-Below	29.01%	N/A	0.00%	N/A	0.00%	0.00%					
All Large Pieces	29.01%	N/A	0.00%	N/A_	92.66%	93.42%					
		Debri	s Transpor	Fractions							



LOCATI	e Deuris Classificatio	Blowdown	Erosion and Washdow	n Drywell Floor Pool	No.	Fraction	Final Loca
MARK I		Advected to Vents			1	1.958E-01	Vents
UPPER ROU	ND	Enclosures		***	2	0.000E+00	Enclosure
		0.00		Waterborne	3	0.000E+00	Ventr
MSL BREAK	<u>c</u>	Drywell Floor		0.00	•	0.0001.00	Vents
ECCS THRO	TTLED	0.00	환하 같 때 은 한 산 때 말은 드 것 때 된 식 날 다 모은 수	Sediment	4	0.000E+00	Floor
SPRAYS OPP	ERATED			1.00			
FIBROUS IN	SULATION			Waterborne	5	0.000E+00	Vents
			Condensate Drainage				
	Small Pieces	Structures-Above		0.90	6	0.000E+00	Floor
	0.22	0.00	0.90		7	0.000E+00	Structures-Al
				Waterborne	8	6.600E-04	Vents
			Sprays/Condensate	0.10			
		Structures-Break	1.00	Sediment 0.90	9	5.940E-03	Floor
		0.03	Adheres		10	0.000E+00	Structures-Br
			0.00	Waterborne	11	1.760E-03	Vents
			Sprays/Condensate	0.10			
		Structures-Other	1.00	Sediment	12	1.584E-02	Floor
		0.08	Adheres	V.JU	13	0.000E+00	Structures-Ot
			0.00	Waterborne	14	1.500E-03	Vents
			Sprays/Condensate	1.00			
		Structures-Break	0.02	Sediment	15	0.000E+00	Floor
		0.25	Adheres	0.00	16	7.350E-02	Structures-Bre
			0.98	Waterborne	17	4.500E-03	Vents
	Large-Above		Sprays/Condensate	1.00			
	0.30	Structure Other	0.02	Sediment	18	0.000E+00	Floor
191 Decel		0.75	Adheres	0.00	19	2.205E-01	Structures-Oth
.00	-	Advected to Vent	0.98		20	8,0005-07	Vente
		1.00 Enclosures				0.0002.02	V CALS
	Large-Below	0.00			21	0.000E+00	Enclosures
	0.08		1	Waterborne	22	0.000E+00	Vents
		Drywell Floor	           	Sediment	22	0.0005.00	~
		0.00	į	1.00		0.000E+00	Floor
				Waterborne	24	0.000E+00	Vents
			Sprays/Condensate	0.00			
			0.02	Sediment	25	0.000E+00	Floor
		0.00	Adheres	1.00	26	0.000E+00	Structures-Brez
			0.98	Waterborne	27	0.0005+00	Vat
			Samue (Can do units	0.00		0.0005700	vents
		1	0.02	Sediment	28	0.000E+00	Floor
		Structures-Other 0.00	Adheres	1.00	29	0.00015+00	Structure Orl
	Canvassed	L. (	0.98			0.00012700	Su unites-Othe
	0.40		·····		30 Total	4.000E-01	Structures/Floo

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DEBRIS TRANSPORT RESULTS											
Plant Design:	MARK I										
Estimate:	UPPER BO	UND		FIBROUS I	NSULATIO	N					
Break:	MSL BREA	K									
ECCS:	ECCS THR	OTTLED									
Sprays:	SPRAYS O	PERATED									
TREE QUANTIFICATION											
Debris Classification	Vents	Enclosures	Floor	Structures Above	Structures Break	Structures Other	Transport Fraction				
Small Pieces	1.982E-01	0.000E+00	2.178E-02	0.000E+00	0.000E+00	0.000E+00	0.9010				
Large Pieces-Above	6.000E-03	0	0.000E+00	0	7.350E-02	2.205E-01	0.0200				
Large Pieces-Below	8.000E-02	0.000E+00	0.000E+00	0	0.000E+00	0.000E+00	1.0000				
All Large Pieces	8.600E-02	0.000E+00	0.000E+00	0	7.350E-02	2.205E-01	0.2263				
All Debris	2.842E-01	0.000E+00	2.178E-02	0.000E+00	7.350E-02	2.205E-01	0.4737				
All Zone-of-Influence							0.2842				
FINAL DISTRIBUTIONS (Horizontal)											
			Heer	Structures	Structures	Structures					
Debris Classification	Vents	Enciosures	Floor	Above	Break	Other					
Debris Classification	<b>Vents</b> 90.10%	0.00%	9.90%	Above 0.00%	Break 0.00%	0.00%					
Debris Classification Small Pieces Large Pieces-Above	Vents 90.10% 2.00%	0.00%	9.90% 0.00%	Above 0.00% 0%	Break 0.00% 24.50%	Other           0.00%           73.50%					
Debris Classification Small Pieces Large Pieces-Above Large Pieces-Below	Vents           90.10%           2.00%           100.00%	0.00% 0% 0.00%	9.90% 0.00% 0.00%	Above 0.00% 0% 0%	Break 0.00% 24.50% 0.00%	Other           0.00%           73.50%           0.00%					
Debris Classification Small Pieces Large Pieces-Above Large Pieces-Below All Large Pieces	Vents 90.10% 2.00% 100.00% 22.63%	Enclosures           0.00%           0%           0.00%	9.90% 0.00% 0.00% 0.00%	Above 0.00% 0% 0%	Break 0.00% 24.50% 0.00% 19.34%	Other           0.00%           73.50%           0.00%           58.03%					
Debris Classification Small Pieces Large Pieces-Above Large Pieces-Below All Large Pieces All Debris	Vents 90.10% 2.00% 100.00% 22.63% 47.37%	Enclosures           0.00%           0%           0.00%           0.00%           0.00%	9.90% 0.00% 0.00% 0.00% 3.63%	Above 0.00% 0% 0% 0% 0% 0.00%	Break           0.00%           24.50%           0.00%           19.34%           12.25%	Other           0.00%           73.50%           0.00%           58.03%           36.75%					
Debris Classification Small Pieces Large Pieces-Above Large Pieces-Below All Large Pieces All Debris BEL ATIVE CONTR	Vents 90.10% 2.00% 100.00% 22.63% 47.37%	Enciosures 0.00% 0.00% 0.00% 0.00% (Vertical)	9.90% 0.00% 0.00% 0.00% 3.63%	Above           0.00%           0%           0%           0%           0%	Break           0.00%           24.50%           0.00%           19.34%           12.25%	Other           0.00%           73.50%           0.00%           58.03%           36.75%					
Debris Classification Small Pieces Large Pieces-Above Large Pieces-Below All Large Pieces All Debris RELATIVE CONTR Debris Classification	Vents           90.10%           2.00%           100.00%           22.63%           47.37%           UBUTIONS           Vents	Enciosures 0.00% 0.00% 0.00% 0.00% (Vertical) Enclosures	9.90% 0.00% 0.00% 0.00% 3.63% Floor	Above 0.00% 0% 0% 0% 0% Structures Above	Break           0.00%           24.50%           0.00%           19.34%           12.25%           Structures           Break	Other           0.00%           73.50%           0.00%           58.03%           36.75%           Structures           Other					
Debris Classification Small Pieces Large Pieces-Above Large Pieces-Below All Large Pieces All Debris RELATIVE CONTE Debris Classification Small Pieces	Vents           90.10%           2.00%           100.00%           22.63%           47.37%           IBUTIONS           Vents           69.74%	0.00%           0%           0.00%           0.00%           0.00%           0.00%           0.00%           0.00%           Description           Enclosures           N/A	9.90% 0.00% 0.00% 3.63% Floor 100.00%	Above           0.00%           0%           0%           0%           0%           Structures           Above           N/A	Break           0.00%           24.50%           0.00%           19.34%           12.25%           Structures           Break           0.00%	Other           0.00%           73.50%           0.00%           58.03%           36.75%           Structures           Other           0.00%					
Debris Classification         Small Pieces         Large Pieces-Above         Large Pieces-Below         All Large Pieces         All Debris         RELATIVE CONTR         Debris Classification         Small Pieces         Large Pieces-Above	Vents           90.10%           2.00%           100.00%           22.63%           47.37%           UBUTIONS           Vents           69.74%           2.11%	Enclosures           0.00%           0%           0.00%           0.00%           0.00%           0.00%           0.00%           0.00%           0.00%           0.00%           0.00%           0.00%           0.00%           0.00%           0.00%           0.00%           0.00%           0.00%           0.00%           0.00%	9.90%         0.00%         0.00%         3.63%         Floor         100.00%         0.00%	Above           0.00%           0%	Break           0.00%           24.50%           0.00%           19.34%           12.25%           Structures           Break           0.00%           100.00%	Other           0.00%           73.50%           0.00%           58.03%           36.75%           Structures           Other           0.00%           100.00%					
Debris Classification         Small Pieces         Large Pieces-Above         Large Pieces-Below         All Large Pieces         All Debris         RELATIVE CONTR         Debris Classification         Small Pieces         Large Pieces-Above         Large Pieces-Below	Vents           90.10%           2.00%           100.00%           22.63%           47.37%           UBUTIONS           Vents           69.74%           2.11%           28.15%	Enclosures 0.00% 0.00% 0.00% 0.00% (Vertical) Enclosures N/A N/A N/A	9.90%         0.00%         0.00%         3.63%         Floor         100.00%         0.00%	Above           0.00%           0%           0%           0%           0%           Structures           Above           N/A           N/A           N/A	Break           0.00%           24.50%           0.00%           19.34%           12.25%           Structures           Break           0.00%           100.00%           0.00%	Other           0.00%           73.50%           0.00%           58.03%           36.75%           Structures           Other           0.00%           100.00%           0.00%					
Debris Classification         Small Pieces         Large Pieces-Above         Large Pieces-Below         All Large Pieces         All Debris         RELATIVE CONTR         Debris Classification         Small Pieces         Large Pieces-Above         Large Pieces-Below         All Large Pieces-Below         All Large Pieces-Below	Vents           90.10%           2.00%           100.00%           22.63%           47.37%           UBUTIONS           Vents           69.74%           2.11%           28.15%           30.26%	0.00%           0%           0.00%           0.00%           0.00%           0.00%           0.00%           0.00%           0.00%           0.00%           0.00%           0.00%           0.00%           0.00%           0.00%           0.00%           Vertical)           Enclosures           N/A           N/A           N/A           N/A	9.90%         0.00%         0.00%         3.63%         Floor         100.00%         0.00%         0.00%	Above           0.00%           0%           0%           0%           0%           0%           N/A           N/A           N/A           N/A	Break           0.00%           24.50%           0.00%           19.34%           12.25%           Structures           Break           0.00%           100.00%           0.00%	Other           0.00%           73.50%           0.00%           58.03%           36.75%           Structures           0.00%           100.00%           100.00%           100.00%					



LOCA Type	Debris Classificati	on Distribution Afte Blowdown	r Erosion and Washe	iown Dryweil Floor	Pool Pa	th Fraction	Einal Locati
MARK I		Advected to Vents			N	0.	Vent
		0.89 Enclosures					Vents
UPPER BOUN	D	0.00			2	0.000E+00	Enclosures
MSL BREAK				Waterborne	3	0.000E+00	Vents
		Drywell Floor		1.00			
NOT THROTT	LED	0.00	: 약 은 약 은 약 은 쪽 별 은 와 상 수 약 은 약 은 즉 약	Sediment	4	0.000E+00	Floor
NO SPRAYS				0.00	*====		11001
FIBROUS INSL	<b>JLATION</b>	1		Waterborne	5	0.000E+00	Vente
			Condensate Drainage	1.00			Vents
		Structures Albana	0.10	Sediment	6	0.000E+00	Floor
	Small Pieces	0.00	Adheres	0.00	7	0.000	
	0.22	7	0.90			0.000E+00	Structures-Abo
				Waterborne	8	6.600E-03	Vents
			Recirculation Flow	1.00			
		Structures-Break	1.00	Sediment	9	0.000E+00	Floor
		0.03	Adheres	0.00	10	0.000E+00	Structures Beer
			0.00				Sudchifes-Brea
				1.00	11	1.760E-03	Vents
			Condensate Drainage				
		Structures-Other	0.10	0.00	12	0.000E+00	Floor
		0.08	Adheres		13	1.584E-02	Structures-Othe
			0.90	Waterborne	14	9 000E 01	
			Recipulation Flow	1.00		2.00012-03	Vents
		_	0.12	Sediment	15	0.000E+00	
	1	Structures-Break	Adheme	0.00		0.0002100	Floor
			0.88	<u> </u>	16	6.600E-02	Structures-Break
1				Waterborne	17	0.000E+00	Vents
Ľ	arge-Above		Condensate Drainage	1.00			
0	0.30	Structures_Other	0.00	Sediment	18	0.000E+00	Floor
Break	L	0.75	Adheres	0.00	19	2 2505 01	<u> </u>
Dicak		Advected to Vent	1.00			2.2306-01	Structures-Other
		1.00		·····	20	8.000E-02	Vents
L	arge-Below	Enclosures			21	0.000E+00	Enclosures
0.	.08	5.00		Waterborne	22	0.000 8+00	
	i II	Drywell Floor		1.00		0.000£+00	Vents
	10	0.00		!Sediment	22	0.00017 - 00	_
	1			0.00		0.0002+00	Floor
				Waterborne	24	0.0005.100	
			Desirus de la sur	Waterborne	24	0.000E+00	Vents
		ŗ	Recirculation Flow	Waterborne . 1.00 Sediment	24	0.000E+00	Vents
	S (S	Instance-Break	Recirculation Flow	Waterborne 1.00 Sediment 0.00	24 25	0.000E+00 0.000E+00	Vents Floor
	S	tructures-Break	Recirculation Flow 1.00 Adheres 2.00	Waterborne 1.00 Sediment 0.00	24 25 26	0.000E+00 0.000E+00 0.000E+00	Vents Floor Structures-Break
	S	tructures-Break	Recirculation Flow 1.00 Adheres 0.00	Waterborne 1.00 Sediment 0.00 Waterborne	24 25 26 27	0.000E+00 0.000E+00 0.000E+00 0.000E+00	Vents Floor Structures-Break Vents
	s	tructures-Break	Recirculation Flow 1.00 Adheres 2.00 Condensate Drainage	Waterborne 1.00 Sediment 0.00 Waterborne 1.00	24 25 26 27	0.000E+00 0.000E+00 0.000E+00 0.000E+00	Vents Floor Structures-Break Vents
	S	itructures-Break	Recirculation Flow 1.00 Adheres 0.00 Condensate Drainage	Waterborne 1.00 Sediment 0.00 Waterborne 1.00 Sediment	24 25 26 27 28	0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00	Vents Floor Structures-Break Vents
	S 0 0.	itructures-Break	Recirculation Flow 1.00 Adheres 0.00 Condensate Drainage 1.00 Adheres	Waterborne 1.00 Sediment 0.00 Waterborne 1.00 Sediment 0.00	24 25 26 27 28	0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00	Vents Floor Structures-Break Vents Floor
	S 0, 0,	itructures-Break	Recirculation Flow 1.00 Adheres 0.00 Condensate Drainage 0.00 Adheres .00	Waterborne 1.00 Sediment 0.00 Waterborne 1.00 Sediment 0.00	24 25 26 27 28 29	0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00	Vents Floor Structures-Break Vents Floor Structures-Other

·· ·												
		DEBRIS	5 TRANSPO	RT RESULI	S							
Plant Design:	MARKI											
Estimate:	UPPER BO	UND		FIBROUS I	NSULATIO	N						
Break:	MSL BREA	K										
ECCS:	NOT THR	OTTLED										
Sprays:	NO SPRAY	'S										
TREE QUANTIFICA	TION											
Debris Classification	Vents	Enclosures	Floor	Structures Above	Structures Break	Structures Other	Transport Fraction					
Small Pieces	2.042E-01	0.000E+00	0.000E+00	0.000E+00	0.000E+00	1.584E-02	0.9280					
Large Pieces-Above	9.000E-03	0	0.000E+00	0	6.600E-02	2.250E-01	0.0300					
Large Pieces-Below	8.000E-02	0.000E+00	0.000E+00	0	0.000E+00	0.000E+00	1.0000					
All Large Pieces	8.900E-02	0.000E+00	0.000E+00	0	6.600E-02	2.250E-01	0.2342					
All Debris	2.932E-01	0.000E+00	0.000E+00	0.000E+00	6.600E-02	2.408E-01	0.4886					
All Zone-of-Influence							0.2932					
FINAL DISTRIBUTIONS (Horizontal)												
Debris Classification	Vents	Enclosures	Floor	Structures	Structures	Structures						
Small Diagon	02 808/	0.00%	0.00%	AD076	0.00%	7 20%						
Small Pieces	3 000/	0.0076	0.00%	0.0078	22 00%	75.00%						
Large Pieces-Above	100.00%	0.00%	0.00%	0%	0.00%	0.00%						
All Large Pieces	23 42%	0.00%	0.00%	0%	17 37%	59 21%						
All Debris	48 86%	0.00%	0.00%	0.00%	11.00%	40 14%						
All Deolis	40.0070	0.0070	0.0070	0.0070	11.0070	40.1470						
RELATIVE CONTR	<b>IBUTIONS</b> (	Vertical)										
Debris Classification	Vente	Enclosures	Floor	Structures	Structures	Structures						
Debris Classification	Venus	Enclosures	11001	Above	Break	Other						
Small Pieces	69.64%	N/A	N/A	N/A	0.00%	6.58%						
Large Pieces-Above	3.07%	N/A	N/A	N/A	100.00%	93.42%						
Large Pieces-Below	27.29%	N/A	N/A	N/A	0.00%	0.00%						
All Large Pieces	30.36%	N/A	N/A	N/A	100.00%	93.42%						



LOCA Type	Debris Classification	Distribution After Blowdown	Erosion and Washdown	Drywell Floor Pool	Path No.	Fraction	Final Location
		Advected to Vents			1	1.958E-01	Vents
MARK I		0.89 Enclosures			2	0.000E+00	Enclosures
UPPER BOUND	)	0.00				0.0002.00	
MSL BREAK				Waterborne	3	0.000E+00	Vents
		Drywell Floor					
NOT THROTT	LED	0.00		Sediment	4	0.000E+00	Floor
SPRAYS OPER	ATED						
FIBROUS INSU	LATION			Waterborne	5	0.000E+00	Vents
			Condensate Drainage			0.0005.000	
		Structures-Above	0.10	0.00	0	0.000E+00	FIOOF
	Small Pieces	0.00	Adheres		7	0.000E+00	Structures-Above
	0.22		0.90	Waterborne	8	6.600E-03	Vents
			Recipulation Flow	1.00			
			1.00	Sediment	9	0.000E+00	Floor
		Structures-Break	A dheres	0.00	10	0.000E+00	Structures-Break
		0.03	0.00			0.000£100	Succuresbicar
				Waterborne	11	1.760E-02	Vents
			Sprays/Condensate	1.00			_
		Structures-Other	1.00	Sediment	12	0.000E+00	Floor
		0.08	Adheres	****	13	0.000E+00	Structures-Other
			0.00	Waterborne	14	9.000E-03	Vents
				1.00			
			Recirculation Flow	Sediment	15	0.000E+00	Floor
		Structures-Break		0.00		( (005.00	
		0.25	Adheres 0.88		16	6.600E-02	Structures-Break
				Waterborne	17	4.500E-03	Vents
	Large-Above		Sprays/Condensate	1.00			· .
	0.30	Charles Only a	0.02	Sediment	18	0.000E+00	Floor
		0.75	Adheres	0.00	19	2.205E-01	Structures-Other
MSL Break	4	Advected to Vent	0.98		20	8.000E-02	Vents
1.00		1.00				0.0002.02	
1	I arge-Below	Enclosures			21	0.000E+00	Enclosures
	0.08			Waterborne	22	0.000E+00	Vents
		Drywell Floor		1.00			
		0.00	****	Sediment	23	0.000E+00	Floor
		1		0.00			
				Waterborne	24	0.000E+00	Vents
		1	Recirculation Flow	1.00			
			1.00	Sediment	25	0.000E+00	Floor
		Structures-Break	Adheres	0.00	26	0.000E+00	Structures-Break
			0.00	Matachama	27	0.000.5100	Vente
				valeroome	21	U.UUVETUV	¥ €113
			Sprays/Condensate	i Sediment	10	0.0005-00	Floor
		Structures-Other	0.02	0.00	25	0.0002400	rioor
		0.00	Adheres		29	0.000E+00	Structures-Other
1	Canvassed		0.98		30	4.000E-01	Structures/Floor
	0.40	· · · · · · · · · · · · · · · · · · ·			Total	1.000E+00	

		DEBRIS	5 TRANSPO	RT RESULI	S		
Plant Design:	MARK I						
Estimate:	UPPER BO	UND		FIBROUS I	NSULATIO	N	
Break:	MSL BREA	K					
ECCS:	NOT THR	OTTLED					
Sprays:	SPRAYS O	PERATED					
TREE QUANTIFICA	TION						
Debris Classification	Vents	Enclosures	Floor	Structures Above	Structures Break	Structures Other	Transport Fraction
Small Pieces	2.200E-01	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	1.0000
Large Pieces-Above	1.350E-02	0	0.000E+00	0	6.600E-02	2.205E-01	0.0450
Large Pieces-Below	8.000E-02	0.000E+00	0.000E+00	0	0.000E+00	0.000E+00	1.0000
All Large Pieces	9.350E-02	0.000E+00	0.000E+00	0	6.600E-02	2.205E-01	0.2461
All Debris	3.135E-01	0.000E+00	0.000E+00	0.000E+00	6.600E-02	2.205E-01	0.5225
All Zone-of-Influence							0.3135
FINAL DISTRIBUTIO	ONS (Horizo	ntal)					
			1	Structures	Structures	Structures	
Debris Classification	Vents	Enclosures	Floor	Above	Break	Other	
Small Pieces	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	
Large Pieces-Above	4.50%	0%	0.00%	0%	22.00%	73.50%	
Large Pieces-Below	100.00%	0.00%	0.00%	0%	0.00%	0.00%	
All Large Pieces	24.61%	0.00%	0.00%	0%	17.37%	58.03%	
All Debris	52.25%	0.00%	0.00%	0.00%	11.00%	36.75%	
RELATIVE CONTR	IBUTIONS (	Vertical)					
Debris Classification	Vents	Enclosures	Floor	Structures Above	Structures Break	Structures Other	
Small Pieces	70.18%	N/A	N/A	N/A	0.00%	0.00%	
Large Pieces-Above	4.31%	N/A	N/A	N/A	100.00%	100.00%	
Large Pieces-Below	25.52%	N/A	N/A	N/A	0.00%	0.00%	
All Large Pieces	29.82%	N/A	N/A	N/A	100.00%	100.00%	



# A.4.1.2 Recirculation Line Break

This section contains upper bound estimate logic charts for Mark I recirculation line break scenarios.

LOCA Type	Debris Classification	Distribution After Blowdown	Erosion and Washdown	Drywell Floor Pool	Path No.	Fraction	Final Location
		Advected to Vents	****	- ビ 속 속 수 산 성 중 중 중 중 중 중 중 중 중 중 중 중 중 중 중 중 중 중	1	0.000E+00	Vents
MARKI		0.00 Enclosures	***		2	0.000E+00	Enclosures
UPPER BOUND	)	0.00		Waterborne	3	2.200E-01	Vents
RL BREAK		Drywell Floor		1.00			
ECCS THROTT	LED	1.00		Sediment	4	0.000E+00	Floor
NO SPRAYS				Waterhome	5	0.0005+00	Vorte
FIBROUS INSU	LATION		Condensate Desires of	1.00		0.000£+00	vents
		Shutter them	0.10	Sediment	6	0.000E+00	Floor
	Small Pieces	0.00	Adheres	0.00	7	0.000E+00	Structures-Above
	0.22		0.90	Waterborne	8	0.000E+00	Vents
			Recirculation Flow	1.00			
		Structures-Break	1.00	Sediment 0.00	9	0.000E+00	Floor
		0.00	Adheres 0.00		10	0.000E+00	Structures-Break
				Waterborne	11	0.000E+00	Vents
		1	Condensate Drainage	Sediment	12	0.000E+00	Floor
		Structures-Other 0.00	Adheres	0.00	13	0.000E+00	Structures-Other
			0.90	Waterborne	14	3.600E-02	Vents
			Recirculation Flow	1.00			
		Structures-Break	0.12	Sediment	15	0.000E+00	Floor
		1.00	Adheres	0.00	16	2.640E-01	Structures-Break
			0.88	Waterborne	17	0.000E+00	Vents
	Large-Above		Condensate Drainage	1.00	10	0.000171.00	Eleca.
	0.30	Structures-Other	0.00	0.00	18	0.000±+00	Pitor
RL Break		0.00	Adheres 1:00	***	19	0.000E+00	Structures-Other
1.00		Advected to Vent			20	8.000E-02	Vents
	Large-Below	Enclosures	***		21	0.000E+00	Enclosures
	0.08			Waterborne	22	0.000E+00	Vents
		Drywell Floor		Sediment	23	0.000E+00	Floor
				0.00			
				Waterborne	24	0.000E+00	Vents
			Recirculation Flow	Sediment	25	0.000E+00	Floor
		Structures-Break	Adheres	0.00	26	0.000E+00	Structures-Break
			0.00	Waterborne	27	0.000E+00	Vents
			Condensate Drainage	1.00			
		Charles College	0.00	Sediment	28	0.000E+00	Floor
		0.00	Adheres	0.00	29	0.000E+00	Structures-Other
	Canvassed		1.00		30	4.000E-01	Structures/Floor
1	0.40				Total	1.000E+00	

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NUREG/CR-6369

······································	DEBRIS TRANSPORT RESULTS										
Plant Design:	MARK I										
Estimate:	UPPER BO	UND		FIBROUS I	NSULATIO	N					
Break:	RL BREAK	ζ.									
ECCS:	ECCS THR	OTTLED									
Sprays:	NO SPRAY	7S									
TREE QUANTIFICA	TION										
Debris Classification	Vents	Enclosures	Floor	Structures Above	Structures Break	Structures Other	Transport Fraction				
Small Pieces	2.200E-01	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	1.0000				
Large Pieces-Above	3.600E-02	0	0.000E+00	0	2.640E-01	0.000E+00	0.1200				
Large Pieces-Below	8.000E-02	0.000E+00	0.000E+00	0	0.000E+00	0.000E+00	1.0000				
All Large Pieces	1.160E-01	0.000E+00	0.000E+00	0	2.640E-01	0.000E+00	0.3053				
All Debris	3.360E-01	0.000E+00	0.000E+00	0.000E+00	2.640E-01	0.000E+00	0.5600				
All Zone-of-Influence							0.3360				
FINAL DISTRIBUTIO	ONS (Horizo	ntal)									
Debris Classification	Vents	Enclosures	Floor	Structures Above	Structures Break	Structures Other					
Small Pieces	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%					
Large Pieces-Above	12.00%	0%	0.00%	0%	88.00%	0.00%					
Large Pieces-Below	100.00%	0.00%	0.00%	0%	0.00%	0.00%					
All Large Pieces	30.53%	0.00%	0.00%	0%	69.47%	0.00%					
All Debris	56.00%	0.00%	0.00%	0.00%	44.00%	0.00%					
RELATIVE CONTR	IBUTIONS	(Vertical)									
Debris Classification	Vents	Enclosures	Floor	Structures Above	Structures Break	Structures Other					
Small Pieces	65.48%	N/A	N/A	N/A	0.00%	N/A					
Large Pieces-Above	10.71%	N/A	N/A	N/A	100.00%	N/A					
Large Pieces-Below	23.81%	N/A	N/A	N/A	0.00%	N/A					
All Large Pieces	34.52%	N/A	N/A	N/A	100.00%	N/A					



LOCA Type	Debris Classification	Distribution After Blowdown	Erosion and Washdow	wn Dryweil Floor Poo	Path	Fraction	Final Location
		Advected to Vents			11	0.000E+00	Varte
MARKI		0.00 Enclosume		- 김 은 부 등 은 너 가 지 도 한 다 은 국 해 준 은 수 도 :	••	0.0002100	vents
UPPER BOUNI	)	0.00	· 프 프 프 프 프 프 프 프 프 프 프 프 프 프 프 프 프 프 프		2	0.000E+00	Enclosures
RL BREAK				Waterborne	3	2.200E-01	Vents
		Drywell Floor		1.00			
ECCS THROTT	TLED	1.00		Sediment	4	0.000E+00	Floor
SPRAYS OPER	ATED			0.00			
				Waterborne	5	0.000E+00	Vonte
FIBROUS INSU	LATION		Condensate Desires	1.00			Vends
			0.10	Sediment	6	0.000E+00	Floor
	Small Pieces	Structures-Above	A charac	0.00			11001
	0.22	0.00	0.90			0.000E+00	Structures-Above
				Waterborne	8	0.000E+00	Vents
			Recirculation Flow	1.00			
		Share D. 1	1.00	Sediment	9	0.000E+00	Floor
		Structures-Break	Adheres	0.00	10	0.0005.000	
			0.00		- 10	0.000E+00	Structures-Break
				Waterborne	11	0.000E+00	Vents
			Sprays/Condensate	1.00			
		Structures-Other	1.00	Sediment	12	0.000E+00	Floor
		0.00	Adheres	0.00	13	0.000E+00	Structures-Other
			0.00	Waterborne	·		
				1.00	14	3.600E-02	Vents
			Recirculation Flow				3
		Structures-Break	0.12	Sediment	15	0.000E+00	Floor
		1.00	Adheres	0.00	16	2.640E-01	Structures-Break
			0.88	Waterborne	17	0.000	<b>T</b> 7 .
	arme Above			1.00	17	0.000£+00	Vents
	0.30		Sprays/Condensate	Sediment	10	0.0007.00	-
	j J	Structures-Other	0.02	0.00	10	0.000E+00	Floor
L Break	4	0.00	Adheres		19	0.000E+00	Structures-Other
00	_	Advected to Vent	0.98		20	8.000E-02	Vents
		1.00 Enclosures					
L.	arge-Below	0.00		*****************	21	0.000E+00	Enclosures
C	0.08			Waterborne	22	0.000E+00	Vents
	la la	Drywell Floor		1.00			
		).00		Sediment	23	0.000E+00	Floor
				0.00			
				Waterborne	24	0.000E+00	Vents
			Recirculation Flow	1.00			
		[	1.00	Sediment	25	0.000E+00	Floor
		0.00	Adheres	0.00	26	0.000E+00	Strandard Decal
1		ļ. ļ	0.00		20	0.0002700	Suructures-Break
			:	Waterborne	27	0.000E+00	Vents
		5	Sprays/Condensate	1.00			
		tructures_Other	0.02	Sediment	28	0.000E+00	Floor
	0	.00 !/	Adheres	0.00	29	0.000E+00	Structures_Other
	anvassed	- (	).98				Sa wates Otter
0.	40				30 Tetr1	4.000E-01	Structures/Floor
					LOGAL	< 1.0 K (M-4-0) (C) }	

DEBRIS TRANSPORT RESULTS											
Plant Design:	MARK I										
Estimate:	UPPER BO	UND		FIBROUS I	NSULATIO	N					
Break:	RL BREAK	<u> </u>				- · · · · · · · · · · · · · · · · · · ·					
ECCS:	ECCS THE	OTTLED									
Sprays:	SPRAYS O	PERATED									
TOFF OLIANTEELCA	TION										
TREE QUANTIFICATION			<u>.</u>	G4 4	G4 4	The second secon					
Debris Classification	Vents	Enclosures	Floor	Structures Above	Structures Break	Structures Other	Transport Fraction				
Small Pieces	2.200E-01	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	1.0000				
Large Pieces-Above	3.600E-02	0	0.000E+00	0	2.640E-01	0.000E+00	0.1200				
Large Pieces-Below	8.000E-02	0.000E+00	0.000E+00	0	0.000E+00	0.000E+00	1.0000				
All Large Pieces	1.160E-01	0.000E+00	0.000E+00	0	2.640E-01	0.000E+00	0.3053				
All Debris	3.360E-01	0.000E+00	0.000E+00	0.000E+00	2.640E-01	0.000E+00	0.5600				
All Zone-of-Influence							0.3360				
ETNAL DISTRIBUTIONS (Horizontal)											
	<u> </u>	<u>,</u>	_	Structures	Structures	Structures					
Debris Classification	l Vents	Enclosures	l Hloor I								
		Linciosanos	11001	Above	Break	Other					
Small Pieces	100.00%	0.00%	0.00%	<b>Above</b> 0.00%	<b>Break</b> 0.00%	<b>Other</b> 0.00%					
Small Pieces Large Pieces-Above	100.00% 12.00%	0.00%	0.00%	Above 0.00% 0%	Break 0.00% 88.00%	Other 0.00% 0.00%					
Small Pieces Large Pieces-Above Large Pieces-Below	100.00% 12.00% 100.00%	0.00% 0% 0.00%	0.00%	Above 0.00% 0% 0%	Break 0.00% 88.00% 0.00%	Other           0.00%           0.00%           0.00%					
Small Pieces Large Pieces-Above Large Pieces-Below All Large Pieces	100.00% 12.00% 100.00% 30.53%	0.00% 0% 0.00% 0.00%	0.00% 0.00% 0.00% 0.00%	Above 0.00% 0% 0%	Break 0.00% 88.00% 0.00% 69.47%	Other           0.00%           0.00%           0.00%					
Small Pieces Large Pieces-Above Large Pieces-Below All Large Pieces All Debris	100.00% 12.00% 100.00% 30.53% 56.00%	0.00% 0% 0.00% 0.00%	0.00% 0.00% 0.00% 0.00%	Above           0.00%           0%           0%           0%           0%	Break           0.00%           88.00%           0.00%           69.47%           44.00%	Other           0.00%           0.00%           0.00%           0.00%           0.00%					
Small Pieces Large Pieces-Above Large Pieces-Below All Large Pieces All Debris RELATIVE CONTR	100.00% 12.00% 100.00% 30.53% 56.00%	0.00% 0% 0.00% 0.00% 0.00% Vertical)	0.00% 0.00% 0.00% 0.00% 0.00%	Above           0.00%           0%           0%           0%           0%	Break           0.00%           88.00%           0.00%           69.47%           44.00%	Other           0.00%           0.00%           0.00%           0.00%           0.00%					
Small Pieces Large Pieces-Above Large Pieces-Below All Large Pieces All Debris RELATIVE CONTR	100.00% 12.00% 100.00% 30.53% 56.00%	0.00% 0% 0.00% 0.00% 0.00% (Vertical)	0.00% 0.00% 0.00% 0.00% 0.00%	Above 0.00% 0% 0% 0.00% Structures	Break           0.00%           88.00%           0.00%           69.47%           44.00%           Structures	Other 0.00% 0.00% 0.00% 0.00% Structures					
Small Pieces Large Pieces-Above Large Pieces-Below All Large Pieces All Debris RELATIVE CONTR Debris Classification	100.00% 12.00% 100.00% 30.53% 56.00% IBUTIONS Vents	0.00% 0% 0.00% 0.00% 0.00% Vertical) Enclosures	0.00% 0.00% 0.00% 0.00% Floor	Above 0.00% 0% 0% 0.00% Structures Above	Break           0.00%           88.00%           0.00%           69.47%           44.00%           Structures           Break	Other 0.00% 0.00% 0.00% 0.00% Structures Other					
Small Pieces Large Pieces-Above Large Pieces-Below All Large Pieces All Debris RELATIVE CONTR Debris Classification Small Pieces	100.00% 12.00% 100.00% 30.53% 56.00% BUTIONS Vents 65.48%	0.00% 0% 0.00% 0.00% 0.00% (Vertical) Enclosures N/A	0.00% 0.00% 0.00% 0.00% 0.00% Floor	Above 0.00% 0% 0% 0% 0% Structures Above N/A	Break           0.00%           88.00%           0.00%           69.47%           44.00%           Structures           Break           0.00%	Other 0.00% 0.00% 0.00% 0.00% Structures Other N/A					
Small Pieces Large Pieces-Above Large Pieces-Below All Large Pieces All Debris <b>RELATIVE CONTR</b> <b>Debris Classification</b> Small Pieces Large Pieces-Above	100.00% 12.00% 100.00% 30.53% 56.00% IBUTIONS Vents 65.48% 10.71%	0.00% 0% 0.00% 0.00% 0.00% Vertical) Enclosures N/A N/A	0.00%           0.00%           0.00%           0.00%           0.00%           0.00%           0.00%           N/A	Above           0.00%           0%           0%           0%           0%           0%           Structures           Above           N/A           N/A	Break           0.00%           88.00%           0.00%           69.47%           44.00%           Structures           Break           0.00%           100.00%	Other 0.00% 0.00% 0.00% 0.00% Structures Other N/A N/A					
Small Pieces         Large Pieces-Above         Large Pieces-Below         All Large Pieces         All Debris         RELATIVE CONTR         Debris Classification         Small Pieces         Large Pieces-Above         Large Pieces-Below	100.00%           12.00%           100.00%           30.53%           56.00%           IBUTIONS           Vents           65.48%           10.71%           23.81%	0.00% 0% 0.00% 0.00% (Vertical) Enclosures N/A N/A N/A	0.00%           0.00%           0.00%           0.00%           0.00%           0.00%           0.00%           N/A           N/A           N/A	Above           0.00%           0%           0%           0%           0%           0%           N/A           N/A           N/A	Break           0.00%           88.00%           0.00%           69.47%           44.00%           Structures           Break           0.00%           100.00%           0.00%	Other 0.00% 0.00% 0.00% 0.00% Structures Other N/A N/A N/A					



LOCA Type	Debris Classification	Distribution After Blowdown	Erosion and Washdov	vn Drywell Floor Poo	l Patt No.	Fraction	Final Location
MARK I		Advected to Vents		,	l	0.000E+00	Vents
TOPED BOUND		Enclosures			2	0.000E+00	Fuclosumer
OTTER BOUND		0.00		Waterborne	3	2 2005 01	Enclosures
RL BREAK		Drywell Floor		1.00		2.200E-01	Vents
NOT THROTTL	ED	1.00		Sediment	4	0.000E+00	T
NO SPRAYS				0.00		0.0002.00	Floor
FIBROUS INSUT	ATION			Waterborne	5	0.000E+00	Vents
	ALION		Condensate Drainage	1.00			
		Structures-Above	0.10	Sediment	6	0.000E+00	Floor
5	Small Pieces	0.00	Adheres	0.00	7	0.000E+00	Structures-Above
	.22		0.90	Waterborne		0.0007.00	
[			Desire lation 51	1.00		0.000E+00	Vents
			1.00	Sediment	9	0.000E+00	Floor
1		Structures-Break	Adheres	0.00	-		11001
			0.00		10	0.000E+00	Structures-Break
				Waterborne	11	0.000E+00	Vents
			Condensate Drainage				
	l l	Structures-Other	0.10	0.00	12	0.000E+00	Floor
		0.00	Adheres		13	0.000E+00	Structures-Other
				Waterborne	14	9.000E-02	Vents
			Recirculation Flow	1.00			
	:	Structures-Break	0.30	Sediment	15	0.000E+00	Floor
		1.00	Adheres	0.00	16	2.100E-01	Structures-Break
	1		0.70	Waterborne	17	0.0005.00	
La	irge-Above		Condensate Dminage	1.00		0.000£+00	Vents
0.:	30		0.00	Sediment	18	0.000E+00	Floor
		Structures-Other	Adheres	0.00	10	0.0007.00	
Break	ļ	Advected to Vent	1.00		- 19	0.000E+00	Structures-Other
Č I	1	.00			20	8.000E-02	Vents
La	rge-Below 0	Enclosures	******		21	0.000E+00	Enclosures
0.0	8			Waterborne	22	0.000E+00	Vents
	I	Drywell Floor		1.00			
	0	.00		Sediment	23	0.000E+00	Floor
				0.00			
			ī	Waterborne	24	0.000E+00	Vents
		I I	Recirculation Flow	1.00			
	SI	tructures-Break	1.00	Sediment 0.00	25	0.000E+00	Floor
	0.	.00	Adheres		26	0.000E+00	Structures-Break
		ŭ		Waterborne	27	0.000E+00	Vents
	1	c	Condensate Drainage	1.00			
	C+		.00	Sediment	28	0.000E+00	Floor
	0.0	00 A	dheres	0.00	29	0.000E+00	Structures Other
Can	vassed	1	.00		+	0.0001100	suructures-Other
0.40	)		······································		30 Total	4.000E-01	Structures/Floor

Plant Design:	MARKI						
	TALCARGE &						
Estimate:	UPPER BO	UND		FIBROUS I	NSULATIO	N	
Break:	RL BREAK						
ECCS:	NOT THRO	OTTLED					
Sprays:	NO SPRAY	S					
TREE QUANTIFICAT	FION						
Debris Classification	Vents	Enclosures	Floor	Structures Above	Structures Break	Structures Other	Transport Fraction
Small Pieces	2.200E-01	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	1.0000
Large Pieces-Above	9.000E-02	0	0.000E+00	0	2.100E-01	0.000E+00	0.3000
Large Pieces-Below	8.000E-02	0.000E+00	0.000E+00	0	0.000E+00	0.000E+00	1.0000
All Large Pieces	1.700E-01	0.000E+00	0.000E+00	0	2.100E-01	0.000E+00	0.4474
All Debris	3.900E-01	0.000E+00	0.000E+00	0.000E+00	2.100E-01	0.000E+00	0.6500
All Zone-of-Influence							0.3900
FINAL DISTRIBUTIO	NS (Horizo)	ntal)					
Debris Classification	Vonte	Fnelosures	Floor	Structures	Structures	Structures	
Depris Classification	v ents	Enclosules	11001	Above	Break	Other	
Small Pieces	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	
Large Pieces-Above	30.00%	0%	0.00%	0%	70.00%	0.00%	
Large Pieces-Below	100.00%	0.00%	0.00%	0%	0.00%	0.00%	
All Large Pieces	44.74%	0.00%	0.00%	0%	55.26%	0.00%	
All Debris	65.00%	0.00%	0.00%	0.00%	35.00%	0.00%	
RELATIVE CONTRI	<b>IBUTIONS</b> (	(Vertical)					
Debris Classification	Vents	Enclosures	Floor	Structures Above	Structures Break	Structures Other	
Small Diegen	56 / 10/	N/A	N/A	N/A	0.00%	N/A	
Jarga Diagon Above	23 08%		N/A	N/A	100.00%	N/A	
Large Pieces Below	20.51%	N/A	N/A	N/A	0.00%	N/A	
All Large Pieces	43.59%	N/A	N/A	N/A	100.00%	N/A	



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LOCA Type	Debris Classification	Distribution After Blowdown	Erosion and Washdown	Drywell Floor Pool	Path No.	Fraction	Final Location
MADE		Advected to Vents			1	0.000E+00	Venta
MARKI		0.00 Enclosures			2	0.000F+00	Enclosures
UPPER BOUND		0.00				V.VIJETOU	CARLOSUES
DI BOFAK				Waterborne	3	2.200E-01	Vents
		Drywell Floor		1.00			
NOT THROTTI	LED	1.00		Sediment	4	0.000E+00	Floor
SPRAYS OPER	ATED			0.00			
EIRBOUG INCU				Waterborne	5	0.000E+00	Vents
FIBROUS 1150	LATION		Condensate Drainage	1.00			
		Character 11	0.10	Sediment	6	0.000E+00	Floor
	Small Pieces	0.00	Adheres	0.00	7	0.000E+00	Structures-Above
	0.22	,	0.90				
				Waterborne	8	0.000E+00	Vents
		1 4 2	Recirculation Flow	1.00			
		i Structures-Break	1.00	Sediment	9	0.000E+00	Floor
		0.00	Adheres	0.00	10	0.000E+00	Structures-Break
			0.00	Waterborne	1.	0.0007.00	
				1.00	- 11	0.000E+00	Vents
			Sprays/Condensate	C. Harris			_
		Structures-Other	1.00	0.00	12	0.000E+00	Floor
		0.00	Adheres		13	0.000E+00	Structures-Other
			0.00	Waterborne	14	9.000E-02	Vents
			<b>B</b> ( 1) ( <b>B</b>	1.00			
			Recirculation Flow	Sediment	15	0.0006+00	Floor
		Structures-Break	0.50	0.00		0.00012700	11001
		1.00	Adheres		16	2.100E-01	Structures-Break
			0.70	Waterborne	17	0.000E+00	Vents
	l arge-Above		Sprave/Condensate	1.00			
	0.30		0.02	Sediment	18	0.000E+00	Floor
		Structures-Other	1 1 1 1	0.00			
RL Break		0.00	0.98		19	0.000E+00	Structures-Other
1.00		Advected to Vent			20	8.000E-02	Vents
		1.00 Enclosures			21	0.000E+00	Faclosumes
	Large-Below	0.00				0.0001.00	
	0.08			Waterborne	22	0.000E+00	Vents
		Drywell Floor		1.00			
		0.00		Sediment	23	0.000E+00	Floor
				0.00			
				Waterborne	24	0.000E+00	Vents
			Recirculation Flow	1.00			
			1.00	Sediment	25	0.000E+00	Floor
		Structures-Break	Adheres	0.00	26	0.000E+00	Structures-Break
			0.00			0.00011.00	Su do un CS-Di CAA
			:	Waterborne	27	0.000E+00	Vents
			Sprays/Condensate	1.00			
		Structure Other	0.02	Sediment	28	0.000E+00	Floor
		0.00	Adheres	0.00	29	0.000E+00	Structures-Other
	Comment		0.98				
	Canvassed				30	4.000E-01	Structures/Floor

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······	<del></del>	DEBRIS	TRANSPO	RT RESULT	S		
Plant Design:	MARK I						
Estimate:	UPPER BO	UND		N			
Break:	RL BREAK	ζ.					
ECCS:	NOT THRO	DTTLED					
Sprays: SPRAYS OPERATED							
TREE QUANTIFICATION							
Debris Classification	Vents	Enclosures	Floor	Structures Above	Structures Break	Structures Other	Transport Fraction
Small Pieces	2.200E-01	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	1.0000
Large Pieces-Above	9.000E-02	0	0.000E+00	0	2.100E-01	0.000E+00	0.3000
Large Pieces-Below	8.000E-02	0.000E+00	0.000E+00	0	0.000E+00	0.000E+00	1.0000
All Large Pieces	1.700E-01	0.000E+00	0.000E+00	0	2.100E-01	0.000E+00	0.4474
All Debris	3.900E-01	0.000E+00	0.000E+00	0.000E+00	2.100E-01	0.000E+00	0.6500
All Zone-of-Influence						0.3900	
FINAL DISTRIBUTIO	FINAL DISTRIBUTIONS (Horizontal)						
				Structures Structures Structur		Structures	
Debris Classification	Vents	Enclosures	Floor	Above	Break	Other	
Small Pieces	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	
Large Pieces-Above	30.00%	0%	0.00%	0%	70.00%	0.00%	
Large Pieces-Below	100.00%	0.00%	0.00%	0%	0.00%	0.00%	
All Large Pieces	44.74%	0.00%	0.00%	0%	55.26%	0.00%	
All Debris	65.00%	0.00%	0.00%	0.00%	35.00%	0.00%	
RELATIVE CONTR	BUTIONS	(Vertical)					
Debris Classification	Vents	Enclosures	Floor	Structures Above	Structures Break	Structures Other	
Small Pieces	56.41%	N/A	N/A	N/A	0.00%	N/A	
Large Pieces-Above	23.08%	N/A	N/A	N/A	100.00%	N/A	
Large Pieces-Below	20.51%	N/A	N/A	N/A	0.00%	N/A	
All Large Pieces	43.59%	N/A	N/A	N/A	100.00%	N/A	
		Debri	s Transport	Fractions			



## A.4.2 Mark II

This section contains the upper bound estimate logic charts for the Mark II design.

### A.4.2.1 Main Steam Line Break

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The upper bound estimate logic charts for the main steam line breaks are presented here, then the charts for the recirculation line breaks are presented in Section A.4.2.2.

LOCA Type	Debris Classification	Distribution After Blowdown	Erosion and Washdown	Drywell Floor Pool	Path No.	Fraction	Final Location
MARK II		Advected to Vents		-	.1	1.958E-01	Vents
		0.89 Enclosures			2	0.000E+00	Enclosures
UPPER BOUND		0.00		Waterhome	1	0.0007.00	
MSL BREAK				0.00		0.0002+00	Vents
ECCS THROTT	LED	0.03		Sediment	4	6.600E-03	Floor
NO SPRAYS				1.00	1		
FIRROUS INSU	LATION			Waterborne	5	0.000E+00	Vents
1 1010000 11:00	Lation		Condensate Drainage	0.00			
		Structures-Above	0.10	Sediment	6	0.000E+00	Floor
1	Small Pieces	0.00	Adheres	1.00	7	0.000E+00	Structures-Above
	0.22		0.90	Waterborne	8	0.000E+00	Vents
			Condensate Drainage	0.00			
	-	Stranstrume Develo	0.10	Sediment	9	4.400E-04	Floor
		0.02	Adheres	1.00	10	3.960E-03	Structures-Break
			0.90	Waterborne	11	0.0005+00	Vanta
				0.00		0.0002+00	vents
			0.10	Sediment	12	1.320E-03	Floor
		Structures-Other 0.06	Adheres	1.00	13	1 188E_02	Structures Other
			0.90		13	1.1882-02	Schenner Scher
			i	0.00	14	0.000E+00	Vents
			Condensate Drainage	Sediment	15	0.000E+00	
		Structures-Break	0.00	1.00	1.5	0.000±+00	Floor
		0.25	Adheres		16	7.500E-02	Structures-Break
			:	Waterborne	17	0.000E+00	Vents
	Large-Above		Condensate Drainage	0.00			
	0.30	Structures-Other	0.00	Sediment	18	0.000E+00	Floor
ASL Break		0.75	Adheres		19	2.250E-01	Structures-Other
.00		Advected to Vent	1.00		20	8.000E-02	Vents
	1	1.00 Enclosures			21	0.000E+00	Enclosures
	0.08	0.00		Waterborne	22	0.000E+00	Vente
	1	Drywell Floor	ĺ	0.00			
	1	0.00		Sediment	23	0.000E+00	Floor
				1.00			
			ŕ	Waterborne	24	0.000E+00	Vents
	1		Condensate Drainage	0.00	Ì		
		Structures-Break	0.00	Sediment	25	0.000E+00	Floor
	1 1 1	0.00	Adheres		26	0.000E+00	Structures-Break
			1.00	Waterborne	27	0.000E+00	Vents
			Condensate Drainage	0.00			
		Structures Other	0.00	Sediment	28	0.000E+00	Floor
		0.00	Adheres	1.00	29	0.000E+00	Structures-Other
	Canvassed	•	1.00		20	4 000 5 01	Strangt
	).40				Total	1.000E+00	Structures/Floor

DEBRIS TRANSPORT RESULTS									
Plant Design:	MARK II								
Estimate:	UPPER BOUND								
Break:	MSL BREA	K		1 BROOD I					
ECCS:	ECCS THR	OTTLED							
Sprays:	NO SPRAY	'S							
TREE QUANTIFICATION									
Debris Classification	Vents	Enclosures	Floor	Structures Above	Structures Break	Structures Other	Transport Fraction		
Small Pieces	1.958E-01	0.000E+00	8.360E-03	0.000E+00	3.960E-03	1.188E-02	0.8900		
Large Pieces-Above	0.000E+00	0	0.000E+00	0	7.500E-02	2.250E-01	0.0000		
Large Pieces-Below	8.000E-02	0.000E+00	0.000E+00	0	0.000E+00	0.000E+00	1.0000		
All Large Pieces	8.000E-02	0.000E+00	0.000E+00	0	7.500E-02	2.250E-01	0.2105		
All Debris	2.758E-01	0.000E+00	8.360E-03	0.000E+00	7.896E-02	2.369E-01	0.4597		
All Zone-of-Influence							0.2758		
FINAL DISTRIBUTIONS (Horizontal)									
Debris Classification	Vents	Enclosures	Floor	Structures Above	Structures Break	Structures Other			
Small Pieces	89.00%	0.00%	3.80%	0.00%	1.80%	5.40%			
Large Pieces-Above	0.00%	0%	0.00%	0%	25.00%	75.00%			
Large Pieces-Below	100.00%	0.00%	0.00%	0%	0.00%	0.00%			
All Large Pieces	21.05%	0.00%	0.00%	0%	19.74%	59.21%			
All Debris	45.97%	0.00%	1.39%	0.00%	13.16%	39.48%			
RELATIVE CONTR	IBUTIONS (	Vertical)							
Debris Classification Vents Enclosures		Floor	Structures Above	Structures Break	Structures Other				
Small Pieces	70.99%	N/A	100.00%	N/A	5.02%	5.02%			
Large Pieces-Above	0.00%	N/A	0.00%	N/A	94.98%	94.98%			
Large Pieces-Below	29.01%	N/A	0.00%	N/A	0.00%	0.00%			
All Large Pieces	29.01%	N/A	0.00%	N/A	94.98%	94.98%			
1.250		Debris	Transport	Fractions					



LOCA Type	Debris Classification	Distribution After Blowdown	Erosion and Washdown	Drywell Floor Pool	Path No.	Fraction	Final Location
		Advected to Vents			1	1.958E-01	Venta
MARK II		0.89 Enclosures			,	0.0005+00	Enclosure
UPPER BOUND		0.00		1366 W W W W W W W W W W W W W W W W W W		0.000E+00	Enclosures
MEL DDEAK				Waterborne	3	6.600E-03	Vents
		Drywell Floor		1.00			
ECCS THROTT	TLED	0.03		Sediment	4	0.000E+00	Floor
SPRAYS OPER	ATED			0.00			
EDDOUG INCU				Waterborne	5	0.000E+00	Vents
FIBRUUS INSU	LATION		Condensate Drainage	1.00			
			0.10	Sediment	6	0.000E+00	Floor
	Small Pieces	Structures-Above	Adheres	0.00	7	0.000E+00	Structures-Above
	0.22	0.00	0.90	*******			
				Waterborne	8	4.400E-03	Vents
			Sprays/Condensate	1.00			
		Structure Presk	1.00	Sediment	9	0.000E+00	Floor
		0.02	Adheres	0.00	10	0.000E+00	Structures-Break
			0.00	Waterborne	11	1 130 5 03	Nents
				1.00		1.3202-02	vents
			Sprays/Condensate				_
		Structures-Other	1.00	0.00	12	0.000E+00	Floor
		0.06	Adheres		13	0.000E+00	Structures-Other
			0.00	Waterborne	14	1.500E-03	Vents
				1.00			
			Sprays/Condensate	Sediment	15	0.000E+00	Floor
		Structures-Break	0.02	0.00			
	ł	0.25	Adheres		16	7.350E-02	Structures-Break
			0.90	Waterborne	17	4.500E-03	Vents
	Large-Above		Sprays/Condensate	1.00			
	0.30		0.02	Sediment	18	0.000E+00	Floor
		Structures-Other	Adheres	0.00	19	2 205E-01	Structures_Other
ASL Break	l		0.98			2.2052 01	
.00		Advected to Vent			20	8.000E-02	Vents
		Enclosures			21	0.000E+00	Enclosures
	Large-Below	0.00		Waterhome	22	0.000 E+00	Vonte
	0.00			0.00		0.00012100	venis
		Drywell Floor		Sediment	22	0.000 E+00	Floor
		0.00		1.00	23	0.000£+00	FIOOT
				Metal	~	0.0005.00	*7- 4-
				0.10	24	0.000E+00	Vents
			Sprays/Condensate				_
	-	Structures-Break	0.02	Sediment	25	0.000E+00	Floor
		0.00	Adheres	*== = = = = = = = = = = = = = = = = = =	26	0.000E+00	Structures-Break
			0.98	Waterborne	27	0.000E+00	Vents
		F 1 2		0.10			·
			Sprays/Condensate	Sediment	28	0.0005+00	Floor
		Structures-Other	0.04	0.90	20	0.0005100	11001
	1	0.00	Adheres		29	0.000E+00	Structures-Other
	Canvassed		0.98		30	4.000E-01	Structures/Floor
	0.40				Total	1.000E+00	

· · · · · · · · · · · · · · · · · · ·											
DEBRIS TRANSPORT RESULTS											
Plant Design:	MARK II										
Estimate:	UPPER BO	UND		<b>FIBROUS</b> I	NSULATIO	N					
Break:	MSL BREA	K									
ECCS:	CCS: ECCS THROTTLED										
Sprays:	SPRAYS O	PERATED									
TREE QUANTIFICA	TION										
Debris Classification	Vonts	Fuclosures	Floor	Structures	Structures	Structures	Transport				
Debits Classification	V CIILS	Enclosules	FIGUI	Above	Break	Other	Fraction				
Small Pieces	2.200E-01	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	1.0000				
Large Pieces-Above	6.000E-03	0	0.000E+00	0	7.350E-02	2.205E-01	0.0200				
Large Pieces-Below	8.000E-02	0.000E+00	0.000E+00	0	0.000E+00	0.000E+00	1.0000				
All Large Pieces	8.600E-02	0.000E+00	0.000E+00	0	7.350E-02	2.205E-01	0.2263				
All Debris	3.060E-01	0.000E+00	0.000E+00	0.000E+00	7.350E-02	2.205E-01	0.5100				
All Zone-of-Influence							0.3060				
FINAL DISTRIBUTIO	ONS (Horizon	ntal)									
Dubaia Classification	Viento	<b>F</b> actoria	Eleen	Structures	Structures	Structures					
Debris Classification	vents	Enclosures	Floor	Above	Break	Other					
Small Pieces	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%					
Large Pieces-Above	2.00%	0%	0.00%	0%	24.50%	73.50%					
Large Pieces-Below	100.00%	0.00%	0.00%	0%	0.00%	0.00%					
All Large Pieces	22.63%	0.00%	0.00%	0%	19.34%	58.03%					
All Debris	51.00%	0.00%	0.00%	0.00%	12.25%	36.75%					
RELATIVE CONTR	IBUTIONS (	Vertical)									
Debris Classification	Vents	Enclosures	Floor	Structures Above	Structures Break	Structures Other					
Small Pieces	71.90%	N/A	N/A	N/A	0.00%	0.00%					
Large Pieces-Above	1.96%	N/A	N/A	N/A	100.00%	100.00%					
Large Pieces-Below	26.14%	N/A	N/A	N/A	0.00%	0.00%					



LOCA Ty	pe Debris Classificat	tion Distribution Aft Blowdown	er Erosion and Wash	down Drywell Floor Po	ol Pati No.	h Fraction	Final Location
MARK II		Advected to Vents			1	1.958E-01	Vents
		0.89 Enclosures					
UPPER BOI	UND	0.00			2	0.000E+00	Enclosures
MSL BREAT	к			Waterborne	3	6.600E-03	Vente
		Drywell Floor		1.00			· · cuis
NOT THRO	TTLED	0.03	······································	Sediment	4	0.000000	_
NO SPRAYS	5			0.00		0.0002+00	Floor
				Waterhome			
FIBROUS IN	NSULATION			1.00		0.000E+00	Vents
			Condensate Drainage				
	Small Diana	Structures-Above		0.00	- 6	0.000E+00	Floor
	0 22	0.00	Adheres		7	0.000E+00	Structures-Above
			0.90	Watertome			
				1.00		4.400E-03	Vents
			Recirculation Flow	Sectionent			
		Structures-Break	1.00	0.00	9	0.000E+00	Floor
		0.02	Adheres		10	0.000E+00	Structures-Break
			0.00	Waterborne	11	1 2205 02	
				1.00	11	1.320E-03	Vents
		1	Condensate Drainage	Sadiment			
		Structures-Other	0.10	0.00	- 12	0.000E+00	Floor
		0.06	Adheres		13	1.188E-02	Structures-Other
		0.90	Waterhome				
			1.00	14	9.000E-03	Vents	
			Recirculation Flow				1
		Structures-Break	10.12	0.00	15	0.000E+00	Floor
		0.25	Adheres		16	6.600E-02	Structures-Break
			0.88	Waterborne	17	0.0007.00	
	arve-Above			1.00		0.0002+00	Vents
	0.30	4	Condensate Drainage				4
		Structures-Other	0.00	0.00	18	0.000E+00	Floor
SL Break		0.75	Adheres		19	2.250E-01	Structures-Other
x	1	Advected to Vent	1.00		20	8.000E 01	
		1.00 Englosum				0.00012-02	vents
	Large-Below	0.00			21	0.000E+00	Enclosures
	0.08			Waterborne	22	0.000E+00	Vonte
		Drywell Floor		1.00			vents
		0.00	****	Sediment	12	0.0005.00	_
				0.00		0.000E+00	Floor
		1 1 1		Watachama	.		
				1.00	24	0.000E+00	Vents
			Recirculation Flow				
		Structures-Break	1.00	Sediment	25	0.000E+00	Floor
		0.00	Adheres	5.00	26	0.000E+00	Structures-Break
			0.00	Waterberg			
				waterborne	27	0.000E+00	Vents
			Condensate Drainage				
	1		0.00	Sediment	28	0.000E+00	Floor
		Structures-Other	i				
		Structures-Other 0.00	Adheres	0.00	29	0.000F+00	Structures Out
	Canvassed	Structures-Other 0.00	Adheres 1.00	0.00	29	0.000E+00	Structures-Other
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	NC DY Y	DEDRI					
Plant Design:	MARK II					37	
Estimate:	UPPER BO	UND		FIBROUS I	NSULATIO	N	
Break:	MSL BREA	<u>K</u>					
ECCS:	NOT THR	DTTLED					
Sprays:	NO SPRAY	/S					
TREE QUANTIFICA	TION						
Debuis Clearification	Vonta	Enclosures	Floor	Structures	Structures	Structures	Transport
Debris Classification	vents	Eliciosures	LIOOI	Above	Break	Other	Fraction
Small Pieces	2.081E-01	0.000E+00	0.000E+00	0.000E+00	0.000E+00	1.188E-02	0.9460
Large Pieces-Above	9.000E-03	0	0.000E+00	0	6.600E-02	2.250E-01	0.0300
Large Pieces-Below	8.000E-02	0.000E+00	0.000E+00	0	0.000E+00	0.000E+00	1.0000
All Large Pieces	8.900E-02	0.000E+00	0.000E+00	0	6.600E-02	2.250E-01	0.2342
All Debris	2.971E-01	0.000E+00	0.000E+00	0.000E+00	6.600E-02	2.369E-01	0.4952
All Zone-of-Influence							0.2971
FINAL DISTRIBUTIO	ONS (Horizo	ntal)					
			171	Structures	Structures	Structures	
Debris Classification	Vents	Enclosures	Floor	Above	Break	Other	
Small Pieces	94.60%	0.00%	0.00%	0.00%	0.00%	5.40%	
Large Pieces-Above	3.00%	0%	0.00%	0%	22.00%	75.00%	
Large Pieces-Below	100.00%	0.00%	0.00%	0%	0.00%	0.00%	
All Large Pieces	23.42%	0.00%	0.00%	0%	17.37%	59.21%	
All Debris	49.52%	0.00%	0.00%	0.00%	11.00%	39.48%	
RELATIVE CONTR	BUTIONS	(Vertical)					
Debris Classification	Vents	Enclosures	Floor	Structures	Structures	Structures	
			27/1	ADOVE	Break	Ciner 5 020/	
Small Pieces	70.05%	N/A	N/A	N/A	0.00%	5.02%	
		N1/A	E NI/A	N/A	100.00%	94.98%	
Large Pieces-Above	3.03%	IN/A	IN/A	1011		2.000/	
Large Pieces-Above Large Pieces-Below	3.03% 26.93%	N/A N/A	N/A N/A	N/A	0.00%	0.00%	
Large Pieces-Above Large Pieces-Below All Large Pieces	3.03% 26.93% 29.95%	N/A N/A N/A	N/A N/A	N/A N/A	0.00% 100.00%	0.00% 94.98%	

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LOCA Type	Debris Classification	Distribution After Blowdown	Erosion and Washdown	Drywell Floor Pool	Path No.	Fraction	Final Location
		Advected to Vents			1	1.958E-01	Vents
MARK II		0.89 Enclosur <del>es</del>			2	0.000E+00	Enclosures
UPPER BOUND	)	0.00		Watanhama		6 6005 02	1/1-14
MSL BREAK				1.00	3	0.000E-03	vents
NOT THROTTI	LED	0.03		Sediment	4	0.000E+00	Floor
SPRAYS OPER	ATED			0.00			
FIBROUS INSU	LATION			Waterborne	5	0.000E+00	Vents
			Condensate Drainage	Sediment	6	0.000E+00	Floor
	Small Pieces	Structures-Above	Adheres	0.00	7	0.000E+00	Structures_Above
	0.22	0.00	0.90			0.0002.00	Sulatures Above
				1.00	8	4.400E-03	Vents
			Recirculation Flow	Sediment	9	0.000E+00	Floor
		Structures-Break	1.00	0.00			
		0.02	Adheres		10	0.000E+00	Structures-Break
				Waterborne	11	1.320E-02	Vents
			Sprays/Condensate			0.0007.00	
		Structures-Other	1.00	0.00	12	0.000E+00	Floor
		0.06	Adheres 0.00	****	13	0.000E+00	Structures-Other
				Waterborne	14	9.000E-03	Vents
			Recirculation Flow	1.00			
		Structures-Break	0.12	Sediment 0.00	15	0.000E+00	Floor
		0.25	Adheres		16	6.600E-02	Structures-Break
			0.00	Waterborne	17	4.500E-03	Vents
	Large-Above		Sprays/Condensate	1.00			
	0.30	Structures-Other	0.02	Sediment 0.00	18	0.000E+00	Floor
MSL Break		0.75	Adheres		19	2.205E-01	Structures-Other
1.00		Advected to Vent			20	8.000E-02	Vents
	I away Dalawa	1.00 Enclosures			21	0.000E+00	Enclosures
	0.08	0.00		Waterborne	22	0.000E+00	Vents
		Drywell Floor		1.00			
		0.00		Sediment	23	0.000E+00	Floor
				Waterborne	24	0.0005+00	Vents
		1		1.00		0.000£100	venus
			Recirculation Flow	Sediment	25	0.000E+00	Floor
		Structures-Break	Adheres	0.00	26	0.000E+00	Structures-Break
			0.00	Waterborne	27	0.000E+00	Vents
			Same (Cond	1.00	~.		
			oprays/Condensate	Sediment	28	0.000E+00	Floor
		Structures-Other 0.00	Adheres	0.00	29	0.000E+00	Structures-Other
	Canvassed		0.98		30	4.000E-01	Structures/Floor
	0.40				Total	1.000E+00	

		DEBRIS	TRANSPO	RT RESULT	S		
Plant Design:	MARK II						
Estimate:	UPPER BO	UND		FIBROUS I	NSULATIO	N	
Break:	MSL BREA	K					
ECCS:	NOT THRO	OTTLED					
Sprays:	SPRAYS O	PERATED					
TREE QUANTIFICA	TION						
Debris Classification	Vents	Enclosures	Floor	Structures Above	Structures Break	Structures Other	Transport Fraction
Small Pieces	2.200E-01	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	1.0000
Large Pieces-Above	1.350E-02	0	0.000E+00	0	6.600E-02	2.205E-01	0.0450
Large Pieces-Below	8.000E-02	0.000E+00	0.000E+00	0	0.000E+00	0.000E+00	1.0000
All Large Pieces	9.350E-02	0.000E+00	0.000E+00	0	6.600E-02	2.205E-01	0.2461
All Debris	3.135E-01	0.000E+00	0.000E+00	0.000E+00	6.600E-02	2.205E-01	0.5225
All Zone-of-Influence							0.3135
FINAL DISTRIBUTIO	ONS (Horizo	ntal)					
Debris Classification	Vents	Enclosures	Floor	Structures Above	Structures Break	Structures Other	
Small Pieces	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	
Large Pieces-Above	4.50%	0%	0.00%	0%	22.00%	73.50%	
Large Pieces-Below	100.00%	0.00%	0.00%	0%	0.00%	0.00%	
All Large Pieces	24.61%	0.00%	0.00%	0%	17.37%	58.03%	
All Debris	52.25%	0.00%	0.00%	0.00%	11.00%	36.75%	
RELATIVE CONTR	<b>IBUTIONS</b>	Vertical)					
Debris Classification	Vents	Enclosures	Floor	Structures Above	Structures Break	Structures Other	
Small Pieces	70.18%	N/A	N/A	N/A	0.00%	0.00%	
Large Pieces-Above	4.31%	N/A	N/A	N/A	100.00%	100.00%	
Large Pieces-Below	25.52%	N/A	N/A	N/A	0.00%	0.00%	
All Large Pieces	29.82%	N/A	N/A	N/A	100.00%	100.00%	
		Debris	s Transport	Fractions			
1.250							<b>]</b> [
1.000							

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# A.4.2.2 Recirculation Line Break

This section contains upper bound estimate logic charts for Mark II recirculation line break scenarios.

LOCA Type	Debris Classification	Distribution After Blowdown	Erosion and Washdown	Drywell Floor Pool	Path No.	Fraction	Final Location
		Advected to Vents			1	0.000E+00	Vents
MARK II		0.00 Enclosures			2	0.000E+00	Enclosures
UPPER BOUND	)	0.00		Waterborne	1	2 200E-01	Vente
RL BREAK		Descell Floor		1.00		2.20015-01	
ECCS THROTT	TLED	1.00	· · · · ·	Sediment	4	0.000E+00	Floor
NO SPRAYS				0.00			
FIBROUS INSU	LATION			Waterborne	5	0.000E+00	Vents
			Condensate Drainage	Sediment	6	0.000E+00	Floor
	Small Pieces	Structures-Above	Adheres	0.00	7	0.000E+00	Structures-Above
	0.22		0.90	Waterhome	8	0.000E+00	Vente
		1		1.00		0.0001.00	· cuts
			Recirculation Flow	Sediment	9	0.000E+00	Floor
		Structures-Break	Adheres	0.00	10	0.000E+00	Structures-Break
			0.00	Waterborne	11	0.000E+00	Vents
			Condensate Drainage	1.00			
		Sharahara Othan	0.10	Sediment	12	0.000E+00	Floor
		0.00	Adheres	0.00	13	0.000E+00	Structures-Other
			0.90	Waterborne	14	3.600E-02	Vents
			Recirculation Flow	1.00			
		Structures-Break	0.12	Sediment	15	0.000E+00	Floor
		1.00	Adheres		16	2.640E-01	Structures-Break
			0.88	Waterborne	17	0.000E+00	Vents
	Large-Above		Condensate Drainage	1.00			
	0.30	Structures-Other	0.00	Sediment 0.00	18	0.000E+00	Floor
RL Break		0.00	Adheres 1.00		19	0.000E+00	Structures-Other
1.00		Advected to Vent			20	8.000E-02	Vents
	Large-Below	Enclosures			21	0.000E+00	Enclosures
	0.08			Waterborne	22	0.000E+00	Vents
		Drywell Floor		Sadiment		0.0005.00	171 and
		0.00		0.00	23	V.UUE+UU	F 100T
				Waterborne	24	0.000E+00	Vents
		) 	Recirculation Flow	1.00			
		Structures-Break	1.00	Sediment 0.00	25	0.000E+00	Floor
		0.00	Adheres	*****************	26	0.000E+00	Structures-Break
			v.00	Waterborne	27	0.000E+00	Vents
			Condensate Drainage	1.00	20	0.0007.000	Flaar
		Structures-Other	0.00	0.00	28	0.000E+00	r:00r
		0.00	Adheres		29	0.000E+00	Structures-Other
	Canvassed 0.40				30 Total	4.000E-01 1.000E+00	Structures/Floor

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				<u>.</u>			
		DEBRIS	TRANSPO	RT RESULT	S		
Plant Design:	MARK II						
Estimate:	UPPER BO	UND		FIBROUS I	<b>NSULATIO</b>	N	
Break:	RL BREAK	ζ					
ECCS:	ECCS THR	OTILED					
Sprays:	NO SPRAY	S					
TREE QUANTIFICA	TION						
Debris Classification	Vents	Enclosures	Floor	Structures Above	Structures Break	Structures Other	Transport Fraction
Small Pieces	2.200E-01	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	1.0000
Large Pieces-Above	3.600E-02	0	0.000E+00	0	2.640E-01	0.000E+00	0.1200
Large Pieces-Below	8.000E-02	0.000E+00	0.000E+00	0	0.000E+00	0.000E+00	1.0000
All Large Pieces	1.160E-01	0.000E+00	0.000E+00	0	2.640E-01	0.000E+00	0.3053
All Debris	3.360E-01	0.000E+00	0.000E+00	0.000E+00	2.640E-01	0.000E+00	0.5600
All Zone-of-Influence							0.3360
FINAL DISTRIBUTIO	ONS (Horizo	ntal)					
	N7	<b>F</b> eedawara	Heer	Structures	Structures	Structures	
Debris Classification	vents	Enclosures	<b>F1001</b>	Above	Break	Other	
Small Pieces	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	
Large Pieces-Above	12.00%	0%	0.00%	0%	88.00%	0.00%	
Large Pieces-Below	100.00%	0.00%	0.00%	0%	0.00%	0.00%	
All Large Pieces	30.53%	0.00%	0.00%	0%	69.47%	0.00%	
All Debris	56.00%	0.00%	0.00%	0.00%	44.00%	0.00%	
RELATIVE CONTR	BUTIONS	(Vertical)					
Debris Classification	Vents	Enclosures	Floor	Structures Above	Structures Break	Structures Other	
Small Pieces	65.48%	N/A	N/A	N/A	0.00%	N/A	
Large Pieces-Above	10.71%	N/A	N/A	N/A	100.00%	N/A	
Large Pieces-Below	23.81%	N/A	N/A	N/A	0.00%	N/A	
All Large Pieces	34.52%	N/A	N/A	N/A	100.00%	N/A	



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LOCA Type	Debris Classification	Distribution After Blowdown	Erosion and Washdown	Drywell Floor Pool	Path No.	Fraction	Final Location
		Advected to Vents			1	0.000E+00	Vents
MARK II		0.00 Enclosur <del>e</del> s			2	0.000E+00	Enclosures
UPPER BOUND	)	0.00		Waterborne	3	2 200E-01	Vente
RL BREAK		Drywell Floor		1.00			
ECCS THROTT	LED	1.00		Sediment	4	0.000E+00	Floor
SPRAYS OPER	ATED			Waterborne	5	0.000E+00	Vents
FIBROUS INSU	LATION		Condensate Drainage	1.00			
		Structures-Above	0.10	Sediment 0.00	6	0.000E+00	Floor
	Small Pieces 0.22	0.00	Adheres 0.90		7	0.000E+00	Structures-Above
		1 1 1		Waterborne	8	0.000E+00	Vents
			Recirculation Flow	Sediment	9	0.000E+00	Floor
		Structures-Break	Adheres	0.00	10	0.000F+00	Structures-Break
		0.00	0.00			0.0002.00	Structure Struck
			Snow (Condensate	1.00		0.000E+00	Vents
		Structures-Other	1.00	Sediment	12	0.000E+00	Floor
		0.00	Adheres		13	0.000E+00	Structures-Other
			0.00	Waterborne	14	3.600E-02	Vents
			Recirculation Flow	1.00	15	0.000E+00	Floor
-		Structures-Break	0.12	0.00	15	2.6405.03	Structures Brook
		1.00	0.88		10	2.0401-01	Su de dires-Break
	Large Above		Snraw/Condensate	1.00	17	0.000E+00	Vents
	0.30	Structures_Other	0.02	Sediment	18	0.000E+00	Floor
Di Dunala		0.00	Adheres	v.w	19	0.000E+00	Structures-Other
RL Break 1.00	1	Advected to Vent	0.98		20	8.000E-02	Vents
	I ame Below	1.00 Enclosures	****		21	0.000E+00	Enclosures
	0.08	0.00		Waterborne	22	0.000E+00	Vents
		Drywell Floor 0.00		Sediment	23	0.000E+00	Floor
		1 1 2 2 1 1		0.00 Waterborne	24	0.000E+00	Vents
			Recirculation Flow	1.00 Sediment	25	0.000E+00	Floor
		Structures-Break 0.00	Adheres	0.00	26	0.000E+00	Structures-Break
			0.00	Waterborne	27	0.000E+00	Vents
		5 7 7 7 7	Sprays/Condensate	1.00 Sediment	28	0.000E+00	Floor
		Structures-Other 0.00	Adheres	0.00	29	0.000E+00	Structures-Other
	Canvassed		0.98		30	4.000E-01	Structures/Floor
L	0.40				Total	1.000E+00	

		DEBRIS	TRANSPO	RT RESULT	s			
Plant Design:	MARK II	1						
Estimate.	UPPER BO	UND		FIBROUS I	NSULATIO	N		
Break	RL BREAK							
FCCS:	ECCS THR	OTTLED						
Sprave:	SPRAYS O	PERATED						
Spi ays.								
TREE QUANTIFICA	TION		<b>`</b>					
Debris Classification	Vents	Enclosures	Floor	Structures Above	Structures Break	Structures Other	Transport Fraction	
Small Pieces	2.200E-01	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	1.0000	
Large Pieces-Above	3.600E-02	0	0.000E+00	0	2.640E-01	0.000E+00	0.1200	
Large Pieces-Below	8.000E-02	0.000E+00	0.000E+00	0	0.000E+00	0.000E+00	1.0000	
All Large Pieces	1.160E-01	0.000E+00	0.000E+00	0	2.640E-01	0.000E+00	0.3053	
All Debris	3.360E-01	0.000E+00	0.000E+00	0.000E+00	2.640E-01	0.000E+00	0.5600	
All Zone-of-Influence							0.3360	
FINAL DISTRIBUTIO	ONS (Horizo)	ntal)						
		· · · · · · · · · · · · · · · · · · ·		Structures	Structures	Structures		
Debris Classification	Vents	Enclosures	Floor	Above	Break	Other		
Small Pieces	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%		
Large Pieces-Above	12.00%	0%	0.00%	0%	88.00%	0.00%		
Large Pieces-Below	100.00%	0.00%	0.00%	0%	0.00%	0.00%		
All Large Pieces	30.53%	0.00%	0.00%	0%	69.47%	0.00%		
All Debris	56.00%	0.00%	0.00%	0.00%	44.00%	0.00%		
RELATIVE CONTR	BUTIONS	(Vertical)						
	1			Structures	Structures	Structures		
Debris Classification	Vents	Enclosures	Floor	Above	Break	Other		
Small Pieces	65.48%	N/A	N/A	N/A	0.00%	N/A		
Large Pieces-Above	10.71%	N/A	N/A	N/A	100.00%	N/A		
Large Pieces-Below	23.81%	N/A	N/A	N/A	0.00%	N/A		
All Large Pieces	34.52%	N/A	N/A	N/A	100.00%	N/A		
Debris Transport Fractions								
1.000				<u></u>		<u></u>		
			1. A A A A A A A A A A A A A A A A A A A					

All Zone-of-

Influence

All Large Debris

All Debris

Large Below Gratings

Large Above Gratings

0.750 Eraction 0.500

0.250

0.000 -

Small Debris

LOCA Type	Debris Classificatio	Distribution Aft Blowdown	er Erosion and Wash	down Drywell Fl	oor Pool	Path No.	Fraction	Final Locati
MARK II		Advected to Vents				1	0.000E+00	) Vents
		Enclosures				1	0.0005.00	
UPPER BOUND	•	0.00		***********		·	0.000E+00	Enclosures
RL BREAK				Waterborne		3	2.200E-01	Vents
OT THROTTI	.ED	Drywell Floor		1.00				
10.000		1.00		Sediment		4	0.000E+00	Floor
O SPRAYS		1		0.00	:			
IBROUS INSU	LATION			Waterborne		5	0.000E+00	Vents
			Condensate Drainage					
		Structures-Above	0.10	Sediment		6	0.000E+00	Floor
,	Small Pieces	0.00	Adheres	0.00		7	0.000E+00	Structures-Abo
	0.22		0.90	Waterhome				
				1.00		8	0.000E+00	Vents
			Recirculation Flow					
		Structures-Break	1.00	0.00		_9	0.000E+00	Floor
		0.00	Adheres			10	0.000E+00	Structures-Brea
			0.00	Waterborne			0.000E+00	
		1	Condemonto Desíanos	1.00			0.0002700	Vents
			0.10	Sediment		12	0.0005+00	
		Structures-Other		0.00			0.00000000	Floor
		0.00	0.90			13	0.000E+00	Structures-Othe
				Waterborne		14	9.000E-02	Vents
			Recirculation Flow	1.00				
		Structures-Break	0.30	Sediment		15	0.000E+00	Floor
	1	1.00	Adheres	0.00		16	2 1005 01	
			0.70				2.1008-01	Structures-Breal
				Waterborne		17	0.000E+00	Vents
0	arge-Above		Condensate Drainage			ĺ		
		Structures-Other	10.00	Sediment		18	0.000E+00	Floor
Break	(	0.00	Adheres			19	0.000E+00	Structures-Other
	4	Advected to Vent	1.00			20	9 000 5 07	
		1.00					3.000E-02	Vents
La	urge-Below			*****		21	0.000E+00	Enclosures
0.0	8			Waterborne		22	0.000E+00	Vents
	I	Dryweil Floor		1.00				
	0	.00		Sediment		23	0.000E+00	Floor
				0.00				
	[			Waterborne		24	0.000E+00	Vente
			Recirculation Flow	1.00				
			1.00	Sediment		25	0.000E+00	Floor
	0	fructures-Break	Adhenes	0.00				11001
	0.		0.00			26	0.000E+00	Structures-Break
				Waterborne		27	0.000E+00	Vents
	i i		C ondensate Drainage	1.00				
		nichines_Othe=	0.00	Sediment		28	0.000E+00	Floor
	0,0	00	Adheres	0.00			0.00011.00	
Car	vassed	ł	1.00	****		., .	0.000E+00	Structures-Other
					3	0	4.000E-01	Structures/Floor

		DEBRIS	TRANSPO	RT RESULT	S		
Plant Design:	MARK II						
Estimate:	UPPER BO	UND		FIBROUS I	NSULATIO	N	
Break:	RL BREAK	ζ.					
ECCS:	NOT THRO	OTTLED					
Sprays:	NO SPRAY	/S					
TREE QUANTIFICATION							
Debris Classification	Vents	Enclosures	Floor	Structures Above	Structures Break	Structures Other	Transport Fraction
Small Pieces	2.200E-01	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	1.0000
Large Pieces-Above	9.000E-02	0	0.000E+00	0	2.100E-01	0.000E+00	0.3000
Large Pieces-Below	8.000E-02	0.000E+00	0.000E+00	0	0.000E+00	0.000E+00	1.0000
All Large Pieces	1.700E-01	0.000E+00	0.000E+00	0	2.100E-01	0.000E+00	0.4474
All Debris	3.900E-01	0.000E+00	0.000E+00	0.000E+00	2.100E-01	0.000E+00	0.6500
All Zone-of-Influence							0.3900
FINAL DISTRIBUTIO	ONS (Horizo	ntal)					
Debris Classification	Vents	Enclosures	Floor	Structures Above	Structures Break	Structures Other	
Small Pieces	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	
Large Pieces-Above	30.00%	0%	0.00%	0%	70.00%	0.00%	
Large Pieces-Below	100.00%	0.00%	0.00%	0%	0.00%	0.00%	
All Large Pieces	44.74%	0.00%	0.00%	0%	55.26%	0.00%	
All Debris	65.00%	0.00%	0.00%	0.00%	35.00%	0.00%	
RELATIVE CONTR	IBUTIONS	(Vertical)					
Debris Classification	Vents	Enclosures	Floor	Structures Above	Structures Break	Structures Other	
Small Pieces	56.41%	N/A	N/A	N/A	0.00%	N/A	
Large Pieces-Above	23.08%	N/A	N/A	N/A	100.00%	N/A	
Large Pieces-Below	20.51%	N/A	N/A	N/A	0.00%	N/A	



LOCA Type	Debris Classification	Distribution After Blowdown	Erosion and Washdown	Dryweil Floor Pool	Path	Fraction	Final Location
		Advected to Vents			1	0.000E+00	Vents
MARK II		0.00 Enclosures			2	0.0005+00	Enclosures
UPPER BOUND	)	0.00	# * * * * * * * = = = = # # # # * * * *	Watanka ana		0.000E100	Literosures
RL BREAK				1.00	3	2-200E-01	Vents
NOT THROTTI	ED	Drywell Floor		Sediment	4	0.000E+00	Floor
SPRAYS OPER	ATED			0.00			
				Waterborne	5	0.000E+00	Vents
FIBROUS INSU	LATION		Condensate Drainage	1.00			
		Structures-Above	0.10	Sediment	6	0.000E+00	Floor
	Small Pieces	0.00	Adheres		7	0.000E+00	Structures-Above
	0.22		0.90	Waterborne	8	0.000E+00	Vents
			Recipculation Flow	1.00			-
		Standard Durali	1.00	Sediment	9	0.000E+00	Floor
		0.00	Adheres	0.00	10	0.000E+00	Structures-Break
			0.00	Waterborne	11	0.000E+00	Vents
			Spraig/Condensate	1.00			
			1.00	Sediment	12.	0.000E+00	Floor
		Structures-Other 0.00	Adheres	0.00	13	0.000E+00	Structures-Other
			0.00	Waterborne	14	9.000F-02	Vents
			Perimutation Flow	1.00			
			0.30	Sediment	15	0.000E+00	Floor
		Structures-Break	Adheres	0.00	16	2.100E-01	Structures-Break
			0.70			0.000E.00	
				1.00	17	0.000E+00	Vents
	Large-Above		Sprays/Condensate	Sediment	18	0.000E+00	Floor
		Structures-Other	A dheres	0.00	10	0.000E+00	Straughtering Other
L, Break		A drugsted to Mant	0.98		19	0.000,5+00	Structures-Other
.00		1.00	· · · · · · · · · · · · · · · · · · ·		20	8.000E-0Z	Vents
	Large-Below	Enclosures			21	0.000E+00	Enclosures
	0.08	5.00		Waterborne	22	0.000E+00	Vents
		Drywell Floor		1.00			
		0.00		Sediment	23	0.000E+00	Floor
				Wetertaun		0.00051.00	<b>.</b>
			Ī	1.00		0.000E+00	vents
			Recirculation Flow	Sediment	25	0.000E+00	Floor
		Structures-Break	l l l A dhenes	0.00	16	0.0005+00	Structures Decale
			0.00			0.000100	Ju us un co-Dicak
			ſ	Waterborne 1.00	27	0.000E+00	Vents
			Sprays/Condensate	Sediment	28	0.0005+00	Floor
		Structures-Other		0.00	- 20	0.0002700	rioor
		0.00	0.98		29	0.000E+00	Structures-Other
	Canvassed				30	4.000E-01	Structures/Floor

		DEBRIS	TRANSPO	RT RESULT	s	· · · · · · · · · · · · · · · · · · ·	
Plant Design:	MARK II		· · · · · · · · · · · · · · · · · · ·				
Estimate:	UPPER BO	UND		FIBROUS I	NSULATIO	N	
Break:	<b>RL BREAK</b>	ζ					
ECCS:	NOT THRO	OTTLED					
Sprays:	SPRAYS O	PERATED					
TREE QUANTIFICA	TION						
Debris Classification	Vents	Enclosures	Floor	Structures Above	Structures Break	Structures Other	Transport Fraction
Small Pieces	2.200E-01	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	1.0000
Large Pieces-Above	9.000E-02	0	0.000E+00	0	2.100E-01	0.000E+00	0.3000
Large Pieces-Below	8.000E-02	0.000E+00	0.000E+00	0	0.000E+00	0.000E+00	1.0000
All Large Pieces	1.700E-01	0.000E+00	0.000E+00	0	2.100E-01	0.000E+00	0.4474
All Debris	3.900E-01	0.000E+00	0.000E+00	0.000E+00	2.100E-01	0.000E+00	0.6500
All Zone-of-Influence							0.3900
FINAL DISTRIBUTIO	ONS (Horizo	ntal)					
Debris Classification	Vents	Enclosures	Floor	Structures Above	Structures Break	Structures Other	
Small Pieces	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	
Large Pieces-Above	30.00%	0%	0.00%	0%	70.00%	0.00%	
Large Pieces-Below	100.00%	0.00%	0.00%	0%	0.00%	0.00%	
All Large Pieces	44.74%	0.00%	0.00%	0%	55.26%	0.00%	
All Debris	65.00%	0.00%	0.00%	0.00%	35.00%	0.00%	
RELATIVE CONTR	IBUTIONS (	Vertical)					
Debris Classification	Vents	Enclosures	Floor	Structures Above	Structures Break	Structures Other	
Small Pieces	56.41%	N/A	N/A	N/A	0.00%	N/A	
Large Pieces-Above	23.08%	N/A	N/A	N/A	100.00%	N/A	
Large Pieces-Below	20.51%	N/A	N/A	N/A	0.00%	N/A	
All Large Pieces	43.59%	N/A	N/A	N/A	100.00%	N/A	
1.250		Debris	: Transport	Fractions			
1.000							



# A.4.3 Mark III

This section contains the upper bound estimate logic charts for the Mark III design.

#### A.4.3.1 Main Steam Line Break

The upper bound estimate logic charts for the main steam line breaks are presented here, then the charts for the recirculation line breaks are presented in Section A.4.3.2.

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LOCA Type	Debris Classification	Distribution After Blowdown	Erosion and Washdown	Drywell Floor Pool	Path No.	Fraction	Final Location
		Advected to Vents			1	1.958E-01	Vents
MARK III		0.89 Enclosures			2	0.000E+00	Enclosures
UPPER BOUND	)	0.00	# 바 바 바 맨 중 명 중 명 중 도 도 드 바 년 위 당 중 방 동	****			•
MSL BREAK				Waterborne	3	0.000E+00	Vents
ECCS THROT	FLED	Dryweil Floor		Sediment	4	0.000E+00	Floor
NO SPRAVS				1.00			
				Waterborne	5	0.000E+00	Vents
FIBROUS INSU	JLATION		Condensate Drainage	0.00			
		Structures-Above	0.10	Sediment 1.00	6	0.000E+00	Floor
	Small Pieces	0.00	Adheres		7	0.000E+00	Structures-Above
	··		0.90	Waterborne	8	0.000E+00	Vents
			Condensate Drainage	10.00			
		Structures-Break	0.10	Sediment 1.00	9	6.600E-04	Floor
		0.03	Adheres		10	5.940E-03	Structures-Break
			0.90	Waterborne	11	0.000E+00	Vents
			Condensate Drainage	0.00			
		Structures-Other	0.10	Sediment 1.00	12	1.760E-03	Floor
		0.08	Adheres	- <u></u>	13	1.584E-02	Structures-Other
			0.90	Waterborne	14	0.000E+00	Vents
			Condensate Drainage	0.00			
		Structures-Break	0.00	Sediment	15	0.000E+00	Floor
		0.25	Adheres		16	7.500E-02	Structures-Break
				Waterborne	17	0.000E+00	Vents
	Large-Above		Condensate Drainage			0.000	
	0.30	Structures-Other	0.00	1.00	18	0.000E+00	Floor
MSL Break		0.75	Adheres	·····	19	2.250E-01	Structures-Other
1.00		Advected to Vent			20	8.000E-02	Vents
	I ame-Below	Enciosures			21	0.000E+00	Enclosures
	0.08	0.00		Waterborne	22	0.000E+00	Vents
		Drywell Floor		0.00			
		0.00		Sediment	23	0.000E+00	Floor
				Waterhome	74	0.0005+00	Vente
				0.00		0.0002700	
			Condensate Drainage	Sediment	25	0.000E+00	Floor
		Structures-Break	Adheres	1.00	26	0.000E+00	Structures-Break
			1.00	Waterborne	27	0.000E+00	Vents
			Condensate During an	0.00			
			0.00	Sediment	28	0.000E+00	Floor
		Structures-Other 0.00	Adheres	1.00	29	0.000E+00	Structures-Other
	Canvassed		1.00		30	4,000F-01	Structures/Floor
	0.40				Total	1,000E+00	

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		DEBRIS	TRANSPO	RT RESULT	s		
Plant Design:	MARK III						
Estimate:	UPPER BO	UND		N			
Break:	MSL BREA	K					
ECCS:	ECCS THR	OTTLED					
Sprays:	NO SPRAY	'S					
TREE QUANTIFICATION							
Debris Classification	Vents	Enclosures	Floor	Structures Above	Structures Break	Structures Other	Transport Fraction
Small Pieces	1.958E-01	0.000E+00	2.420E-03	0.000E+00	5.940E-03	1.584E-02	0.8900
Large Pieces-Above	0.000E+00	0	0.000E+00	0	7.500E-02	2.250E-01	0.0000
Large Pieces-Below	8.000E-02	0.000E+00	0.000E+00	0	0.000E+00	0.000E+00	1.0000
All Large Pieces	8.000E-02	0.000E+00	0.000E+00	0	7.500E-02	2.250E-01	0.2105
All Debris	2.758E-01	0.000E+00	2.420E-03	0.000E+00	8.094E-02	2.408E-01	0.4597
All Zone-of-Influence							0.2758
FINAL DISTRIBUTIONS (Horizontal)							
	Vanta	Englagung	Floor	Structures	Structures	Structures	
Debris Classification	vents	Enclosures	r 100r	Above	Break	Other	
Small Pieces	89.00%	0.00%	1.10%	0.00%	2.70%	7.20%	
Large Pieces-Above	0.00%	0%	0.00%	0%	25.00%	75.00%	
Large Pieces-Below	100.00%	0.00%	0.00%	0%	0.00%	0.00%	
All Large Pieces	21.05%	0.00%	0.00%	0%	19.74%	59.21%	
All Debris	45.97%	0.00%	0.40%	0.00%	13.49%	40.14%	
RELATIVE CONTR	IBUTIONS (	Vertical)					
Debris Classification	Vents	Enclosures	Floor	Structures Above	Structures Break	Structures Other	
Small Pieces	70.99%	N/A	100.00%	N/A	7.34%	6.58%	
Large Pieces-Above	0.00%	N/A	0.00%	N/A	92.66%	93.42%	
Large Pieces-Below	29.01%	N/A	0.00%	N/A	0.00%	0.00%	
All Large Pieces	29.01%	N/A	0.00%	N/A	92.66%	93.42%	



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LOCA Type	Debris Classification	Distribution After Blowdown	Erosion and Washdown	Drywell Floor Pool	Path No.	Fraction	Final Location
		Advected to Vents			1	1.958E-01	Vents
MARK III		0.89 Enciosur <del>e</del> s			2	0.000E+00	Enclosures
UPPER BOUND	)	0.00 Waterborne				0.000E+00	Vents
MSL BREAK		Drywell Floor		1.00			
NOT THROTTI	LED	0.00		Sediment	4	0.000E+00	Floor
NO SPRAYS				Waterborne	5	0.00015+00	Vante
FIBROUS INSU	LATION		Condensate Desinage	1.00		0.000 ET00	venus
		Structures-Above	0.10	Sediment	6	0.000E+00	Floor
	Small Pieces	0.00	Adheres	0.00	7	0.000E+00	Structures-Above
	0.22		0.90	Waterborne	8	6.600E-03	Vents
			Recirculation Flow	1.00		0.0007.00	-
		Structures-Break	1.00	0.00	9	0.000£+00	Ficor
		0.03	Adheres		10	0.000E+00	Structures-Break
				Waterborne	11	1.760E-03	Vents
			Condensate Drainage	Sediment	12	0.000E+00	Floor
		Structures-Other	Adheres	0.00	13	1.584E-02	Structures-Other
		0.08	0.90	Waterborne	14	9.0005-03	Vente
			Pagingulation Flow	1.00		2.0002-03	· · · · · ·
		Structures Dreak	0.12	Sediment	15	0.000E+00	Floor
		0.25	Adheres	0.00	16	6.600E-02	Structures-Break
			0.88	Waterborne	17	0.000E+00	Vents
	Large-Above	-	Condensate Drainage	1.00 Sediment	18	0.000E+00	Floor
		Structures-Other 0.75	Adheres	0.00	19	2.250E-01	Structures-Other
MSL Break		Advected to Vent	1.00		20	8.000E-02	Vents
		1.00 Enclosures			21	0.000E+00	Enclosures
	Large-Below 0.08	0.00		Waterborne	22	0.000E+00	Vents
		Drywell Floor		0.10 Sediment	23	0.000E+00	Floor
				0.90			
				Waterborne	24	0.000E+00	Venta
			Recirculation Flow	Sediment	25	0.000E+00	Floor
		Structures-Break 0.00	Adheres	0.90	26	0.000E+00	Structures-Break
			0.00	Waterborne	27	0.000E+00	Vents
		   	Condensate Drainage	0.10			
		Structures-Other	0.00	Sediment 0.90	28	0.000E+00	Floor
		0.00	Adheres 1.00	**********	29	0.000E+00	Structures-Other
	Canvassed				30 Total	4.000E-01	Structures/Floor

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. <u> </u>		DEBRIS	TRANSPO	RT RESULT	S		
Plant Design:	MARK III						
Estimate:	UPPER BOUND			FIBROUS I	NSULATIO	N	
Break:	MSL BREA	K					
ECCS:	NOT THRO	OTTLED			0		
Sprays:	NO SPRAY	'S					
TREE QUANTIFICATION							
Debris Classification	Vents	Enclosures	Floor	Structures Above	Structures Break	Structures Other	Transport Fraction
Small Pieces	2.042E-01	0.000E+00	0.000E+00	0.000E+00	0.000E+00	1.584E-02	0.9280
Large Pieces-Above	9.000E-03	0	0.000E+00	0	6.600E-02	2.250E-01	0.0300
Large Pieces-Below	8.000E-02	0.000E+00	0.000E+00	0	0.000E+00	0.000E+00	1.0000
All Large Pieces	8.900E-02	0.000E+00	0.000E+00	0	6.600E-02	2.250E-01	0.2342
All Debris	2.932E-01	0.000E+00	0.000E+00	0.000E+00	6.600E-02	2.408E-01	0.4886
All Zone-of-Influence							0.2932
FINAL DISTRIBUTIO	ONS (Horizo	ntal)					
Debuie Classification	Vonte	Enclosures	Floor	Structures	Structures	Structures	
Debris Classification	vents	Eliciosules	TIOUI	Above	Break	Other	
Small Pieces	92.80%	0.00%	0.00%	0.00%	0.00%	7.20%	
Large Pieces-Above	3.00%	0%	0.00%	0%	22.00%	75.00%	
Large Pieces-Below	100.00%	0.00%	0.00%	0%	0.00%	0.00%	
All Large Pieces	23.42%	0.00%	0.00%	0%	17.37%	59.21%	
All Debris	48.86%	0.00%	0.00%	0.00%	11.00%	40.14%	
RELATIVE CONTRIBUTIONS (Vertical)							
Debris Classification	Vents	Enclosures	Floor	Structures Above	Structures Break	Structures Other	
Small Pieces	69.64%	N/A	N/A	N/A	0.00%	6.58%	
Large Pieces-Above	3.07%	N/A	N/A	N/A	100.00%	93.42%	
T D' Dalam	07.000/	NI/A	N/A	N/A	0.00%	0.00%	
Large Pieces-Below	27.29%	IN/A	10/1	1			
All Large Pieces	30.36%	N/A N/A	N/A	N/A	100.00%	93.42%	



### A.4.3.2 Recirculation Line Break

This section contains the upper bound estimate logic charts for Mark III recirculation line break scenarios.

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LOCA Type	Debris Classification	Distribution After Blowdown	Erosion and Washdown	Drywell Floor Pool	Path No.	Fraction	Final Location
MADYIN		Advected to Vents			1	0.000E+00	Vents
MARK III		0.00 Enclosures			2	0.000E+00	Enclosures
UPPER BOUND	)	0.00		``````````````````````````````````````			
RL BREAK				1 00	د	2.200 <u>E</u> -01	Vents
		Drywell Floor		1.00			
ECCS THROT	TLED	1.00		Sediment	4	0.000E+00	Floor
NO SPRAYS				0.00			
FIBROUS INSU	ILATION			Waterborne	5	0.000E+00	Vents
			Condensate Drainage	1.00			
		Structures-Above	0.10	Sediment	6	0.000E+00	Floor
	Small Pieces	0.00	Adheres	0.00	7	0.000E+00	Structures-Above
	0.22		0.90	Waterborne	8	0.000E+00	Vente
				1.00		0.0001.00	, venus
		1	Recirculation Flow	i Sediment	0	0.000E+00	Floor
		Structures-Break	1.00	0.00		0.0001.00	11001
		0.00	Adheres	~~~~~~~~~~~~~~~~~~	10	0.000E+00	Structures-Break
			0.00	Waterborne	11	0.000E+00	Vents
			Condensate Dening on	1.00			
			0.10	Sediment	12	0.000E+00	Floor
		Structures-Other		0.00	12	0.0007.00	Charles Other
		0.00	0.90		13	0.000£+00	Structures-Other
				Waterborne	14	3.600E-02	Vents
			Recirculation Flow	1.00			
		Structures_Break	0.12	Sediment	15	0.000E+00	Floor
		1.00	Adheres	0.00	16	2.640E-01	Structures-Break
			0.88	Watarboma	17	0.000E+00	Vonte
				1.00		0.00000100	¥ CULS
	Large-Above		Condensate Drainage	i Sodimant	10	0.000E+00	Floor
	0.30	Structures-Other	0.00	0.00	18	0.000£+00	FIOO
RI Break		0.00	Adheres		19	0.000E+00	Structures-Other
1.00	4	Advected to Vent	1.00		20	8.000E-02	Vents
		1.00 Englogung			11	0.000E+00	Engloguma
	Large-Below	0.00				0.0001-00	Eliciostics
	0.08			Waterborne	22	0.000E+00	Vents
		Drywell Floor		0.10			
		0.00		Sediment	23	0.000E+00	Floor
				0.90			
				Waterborne	24	0.000E+00	Vents
			Recirculation Flow	0.10			
			1.00	Sediment	25	0.000E+00	Floor
		0.00	Adheres	0.90	26	0.000E+00	Structures-Break
l			0.00	Watahana	. 74	0.0005100	Ve-t-
				o.10	21	0.0002+00	¥ dats
			Condensate Drainage			0.0007	-
		Structures-Other	0.00	0.90	28	0.000E+00	Floor
		0.00	Adheres		29	0.000E+00	Structures-Other
	Canvassed		1.00		30	4,000E-01	Structures/Floor
1	0.40		<u> </u>		Total	1.000E+00	

DEBRIS TRANSPORT RESULTS							
Plant Design:	MARK III						
Estimate:	UPPER BO	UND		FIBROUS I	NSULATIO	N	
Break:	RL BREAK	(					
ECCS:	ECCS THR	OTTLED					
Sprays:	NO SPRAY	'S					
TREE QUANTIFICATION							
Debris Classification	Vents	Enclosures	Floor	Structures Above	Structures Break	Structures Other	Transport Fraction
Small Pieces	2.200E-01	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	1.0000
Large Pieces-Above	3.600E-02	0	0.000E+00	0	2.640E-01	0.000E+00	0.1200
Large Pieces-Below	8.000E-02	0.000E+00	0.000E+00	0	0.000E+00	0.000E+00	1.0000
All Large Pieces	1.160E-01	0.000E+00	0.000E+00	0	2.640E-01	0.000E+00	0.3053
All Debris	3.360E-01	0.000E+00	0.000E+00	0.000E+00	2.640E-01	0.000E+00	0.5600
All Zone-of-Influence							0.3360
FINAL DISTRIBUTIONS (Horizontal)							
Debris Classification	Vents	Enclosures	Floor	Structures Above	Structures Break	Structures Other	
Small Pieces	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	
Large Pieces-Above	12.00%	0%	0.00%	0%	88.00%	0.00%	
Large Pieces-Below	100.00%	0.00%	0.00%	0%	0.00%	0.00%	
All Large Pieces	30.53%	0.00%	0.00%	0%	69.47%	0.00%	
All Debris	56.00%	0.00%	0.00%	0.00%	44.00%	0.00%	
RELATIVE CONTR	<b>IBUTIONS</b>	Vertical)					
Debris Classification	Vents	Enclosures	Floor	Structures Above	Structures Break	Structures Other	
Small Pieces	65.48%	N/A	N/A	N/A	0.00%	N/A	
Large Pieces-Above	10.71%	N/A	N/A	N/A	100.00%	N/A	
Large Pieces-Below	23.81%	N/A	N/A	N/A	0.00%	N/A	
All Large Pieces	34.52%	N/A	N/A	N/A	100.00%	N/A	
Debris Transport Fractions							



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LOCA Type	Debris Classification	Distribution After Blowdown	Erosion and Washdown	Drywell Floor Pool	Path No.	Fraction	Final Location
		Advected to Vents			1	0.000E+00	Vents
MARK III		0.00 Enclosures			2	0.000E+00	Enclosures
UPPER BOUND	)	0.00	· 중 약 약 약 약 약 한 한 한 한 한 한 약 약 약 약 약 약 약 약	*********			
DEAK				Waterborne	3	2.200E-01	Vents
U BREAK		Dryweil Floor		1.00			
OT THROTT	LED	1.00		Sediment	4	0.000E+00	Floor
O SUD AVE				0.00			
O SPRATS				Waterborne	5	0.000E+00	Vents
TIBROUS INSU	LATION			1.00			
			Condensate Drainage	Sediment	6	0.000E+00	Floor
		Structures-Above	0.10	0.00		0.000100	Pioo
	Small Pieces	0.00	Adheres		7	0.000E+00	Structures-Above
	0.22		0.90	Waterborne	8	0.0008+00	Vente
				11.00		0.0002.00	
			Recirculation Flow				_
		i Structures, Break	1.00	Sediment	9	0.000E+00	Floor
		10.00	Adheres	0.00	10	0.000E+00	Structures-Break
			0.00		·		
				Waterborne	11	0.000E+00	Vents
			Condensate Drainage	1.00			
			0.10	Sediment	12	0.000E+00	Floor
		Structures-Other	Adheres	0.00	13	0.000F+00	Structures_Other
		0.00	0.90		- 15	0.0001.00	Saletator Cale
				Waterborne	14	9.000E-02	Vents
			Recirculation Flow	1.00			
			0.30	Sediment	15	0.000E+00	Floor
		Structures-Break		0.00			
		1.00	Adheres		16	2.100E-01	Structures-Break
			0.70	Waterborne	17	0.000E+00	Vents
			0 ) · • • • ·	1.00			
	Large-Above	Ą	Condensate Drainage	- Sediment	18	0.000E+00	Floor
	0.30	Structures-Other	10.00	0.00	10	0.0002100	
		0.00	Adheres		19	0.000E+00	Structures-Other
L. Break		Advected to Vent	1.00		20	8.000E-02	Vents
.00		1.00	·····		-		
		Enclosures			21	0.000E+00	Enclosures
	Large-Below	0.00		Waterborne	22	0.000E+00	Vents
	1.00			0.10	·		
		Drywell Floor		L Sadimant	22	0.0005.00	Floor-
		0.00		0.90	43	0.0002400	FIOOF
				Waterborne	24	0.000E+00	Vents
			Recirculation Flow	0.10			
			1.00	Sediment	25	0.000E+00	Floor
		Structures-Break	i A dhanna	0.90	74	0.000E+00	Structures Dess-
		0.00	i Adheres	و من من من من من خر الله في من خر أن الله في الله من من من من من من من الله الله	20	U.U.U.ETW	Suuciales-Dieak
				Waterborne	27	0.000E+00	Vents
			Condensate Dellare	0.10			
			Condensate Drainage	Sediment	28	0.000E+00	Floor
		Structures-Other	0.00	0.90		0.0000.00	
	1	0.00	Adheres		29	0.000E+00	Structures-Other
	Composed		1.00		20	4 000 0 01	Structures/Floor
	0.40				Total	1.000E+00	Sciances Floor
	VITY.					MYXXXX YV .	

DEBRIS TRANSPORT RESULTS							
Plant Design:	MARK III						
Estimate:	UPPER BO	UND		N			
Break:	RL BREAK						
ECCS:	NOT THR	OTTLED					
Sprays:	NO SPRAY	'S					
TREE QUANTIFICATION							
Debris Classification	Vents	Enclosures	Floor	Structures Above	Structures Break	Structures Other	Transport Fraction
Small Pieces	2.200E-01	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	1.0000
Large Pieces-Above	9.000E-02	0	0.000E+00	0	2.100E-01	0.000E+00	0.3000
Large Pieces-Below	8.000E-02	0.000E+00	0.000E+00	0	0.000E+00	0.000E+00	1.0000
All Large Pieces	1.700E-01	0.000E+00	0.000E+00	0	2.100E-01	0.000E+00	0.4474
All Debris	3.900E-01	0.000E+00	0.000E+00	0.000E+00	2.100E-01	0.000E+00	0.6500
All Zone-of-Influence							0.3900
FINAL DISTRIBUTIONS (Horizontal)							
Dahaia Chamification	Vonto	Freloguros	Floor	Structures	Structures	Structures	
Debris Classification	vents	Enclosures	FIGUE	Above	Break	Other	
Small Pieces	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	
Large Pieces-Above	30.00%	0%	0.00%	0%	70.00%	0.00%	
Large Pieces-Below	100.00%	0.00%	0.00%	0%	0.00%	0.00%	
All Large Pieces	44.74%	0.00%	0.00%	0%	55.26%	0.00%	
All Debris	65.00%	0.00%	0.00%	0.00%	35.00%	0.00%	
All Debris RELATIVE CONTR	65.00%	0.00% (Vertical)	0.00%	0.00%	35.00%	0.00%	
All Debris RELATIVE CONTR Debris Classification	65.00% IBUTIONS Vents	0.00% (Vertical) Enclosures	0.00% Floor	0.00% Structures Above	35.00% Structures Break	0.00% Structures Other	
All Debris RELATIVE CONTR Debris Classification Small Pieces	65.00% IBUTIONS Vents 56.41%	0.00% (Vertical) Enclosures N/A	0.00% Floor N/A	0.00% Structures Above N/A	35.00% Structures Break 0.00%	0.00% Structures Other N/A	
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All Debris <b>RELATIVE CONTR</b> <b>Debris Classification</b> Small Pieces Large Pieces-Above Large Pieces-Below All Large Pieces	65.00% <b>IBUTIONS</b> Vents 56.41% 23.08% 20.51% 43.59%	0.00% (Vertical) Enclosures N/A N/A N/A N/A	0.00% Floor N/A N/A N/A	0.00% Structures Above N/A N/A N/A N/A	35.00% Structures Break 0.00% 100.00% 0.00%	0.00% Structures Other N/A N/A N/A N/A	



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