NUREG/CR-6369, Vol. 1
SEA 97-3105-A:14

Drywell Debris Transport Study

Final Report

Science and Engineering Associates, Inc.

U.S. Nuclear Regulatory Commission
Office of Nuclear Regulatory Research
Washington, DC 20555-0001

AVAILABILITY NOTICE

Availability of Reference Materials Cited in NRC Publications

NRC publications in the NUREG series, NRC regulations, and *Title 10, Energy,* of the *Code of Federal Regulations,* may be purchased from one of the following sources:

1. The Superintendent of Documents
   U.S. Government Printing Office
   P.O. Box 37082
   Washington, DC 20402-9328
   <http://www.access.gpo.gov/su_docs>
   202-512-1800

2. The National Technical Information Service
   Springfield, VA 22161-0002
   <http://www.ntis.gov/ordernow>
   703-487-4650

The NUREG series comprises (1) brochures (NUREG/BR-XXXX), (2) proceedings of conferences (NUREG/CP-XXXX), (3) reports resulting from international agreements (NUREG/IA-XXXX), (4) technical and administrative reports and books [(NUREG-XXXX) or (NUREG/CR-XXXX)], and (5) compilations of legal decisions and orders of the Commission and Atomic and Safety Licensing Boards and of Office Directors' decisions under Section 2.206 of NRC's regulations (NUREG-XXXX).

A single copy of each NRC draft report is available free, to the extent of supply, upon written request as follows:

Address: Office of the Chief Information Officer
Reproduction and Distribution
Services Section
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001
E-mail: <DISTRIBUTION@nrc.gov>
Facsimile: 301-415-2289

A portion of NRC regulatory and technical information is available at NRC's World Wide Web site:

<http://www.nrc.gov>

All NRC documents released to the public are available for inspection or copying for a fee, in paper, microfiche, or, in some cases, diskette, from the Public Document Room (PDR):

NRC Public Document Room
2120 L Street, N.W., Lower Level
Washington, DC 20555-0001
<http://www.nrc.gov/NRC/PDR/pdr1.htm>
1-800-397-4209 or locally 202-634-3273

Microfiche of most NRC documents made publicly available since January 1981 may be found in the Local Public Document Rooms (LPDRs) located in the vicinity of nuclear power plants. The locations of the LPDRs may be obtained from the PDR (see previous paragraph) or through:

<http://www.nrc.gov/NRC/NUREGS/SR1350/V9/lpdr/html>

Publicly released documents include, to name a few, NUREG-series reports; *Federal Register* notices; applicant, licensee, and vendor documents and correspondence; NRC correspondence and internal memoranda; bulletins and information notices; inspection and investigation reports; licensee event reports; and Commission papers and their attachments.

Documents available from public and special technical libraries include all open literature items, such as books, journal articles, and transactions, *Federal Register* notices, Federal and State legislation, and congressional reports. Such documents as theses, dissertations, foreign reports and translations, and non-NRC conference proceedings may be purchased from their sponsoring organization.

Copies of industry codes and standards used in a substantive manner in the NRC regulatory process are maintained at the NRC Library, Two White Flint North, 11545 Rockville Pike, Rockville, MD 20852-2738. These standards are available in the library for reference use by the public. Codes and standards are usually copyrighted and may be purchased from the originating organization or, if they are American National Standards, from—

American National Standards Institute
11 West 42nd Street
New York, NY 10036-8002
<http://www.ansi.org>
212-642-4900

NUREG/CR-6369, Vol. 1
SEA 97-3105-A:14

Drywell Debris Transport Study

Final Report

Manuscript Completed: February 1998
Date Published: September 1999

Prepared by
D. V. Rao, C. Shaffer, E. Haskin

Science and Engineering Associates, Inc.
6100 Uptown Blvd. NE
Albuquerque, NM 87110

Prepared for
Division of Engineering Technology
Office of Nuclear Regulatory Research
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001
NRC Job Code W6325

NUREG/CR-6369, Volume 1, has been reproduced from the best available copy. Some of the pages in this publication were intentionally omittted.

For sale by the U.S. Government Printing Office
Superintendent of Documents, Mail Stop: SSOP, Washington, DC 20402-9328
ISBN 0-16-050193-8

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

Contents (continued)

Page

FIGURES

Page

TABLES

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 plant-specific, 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

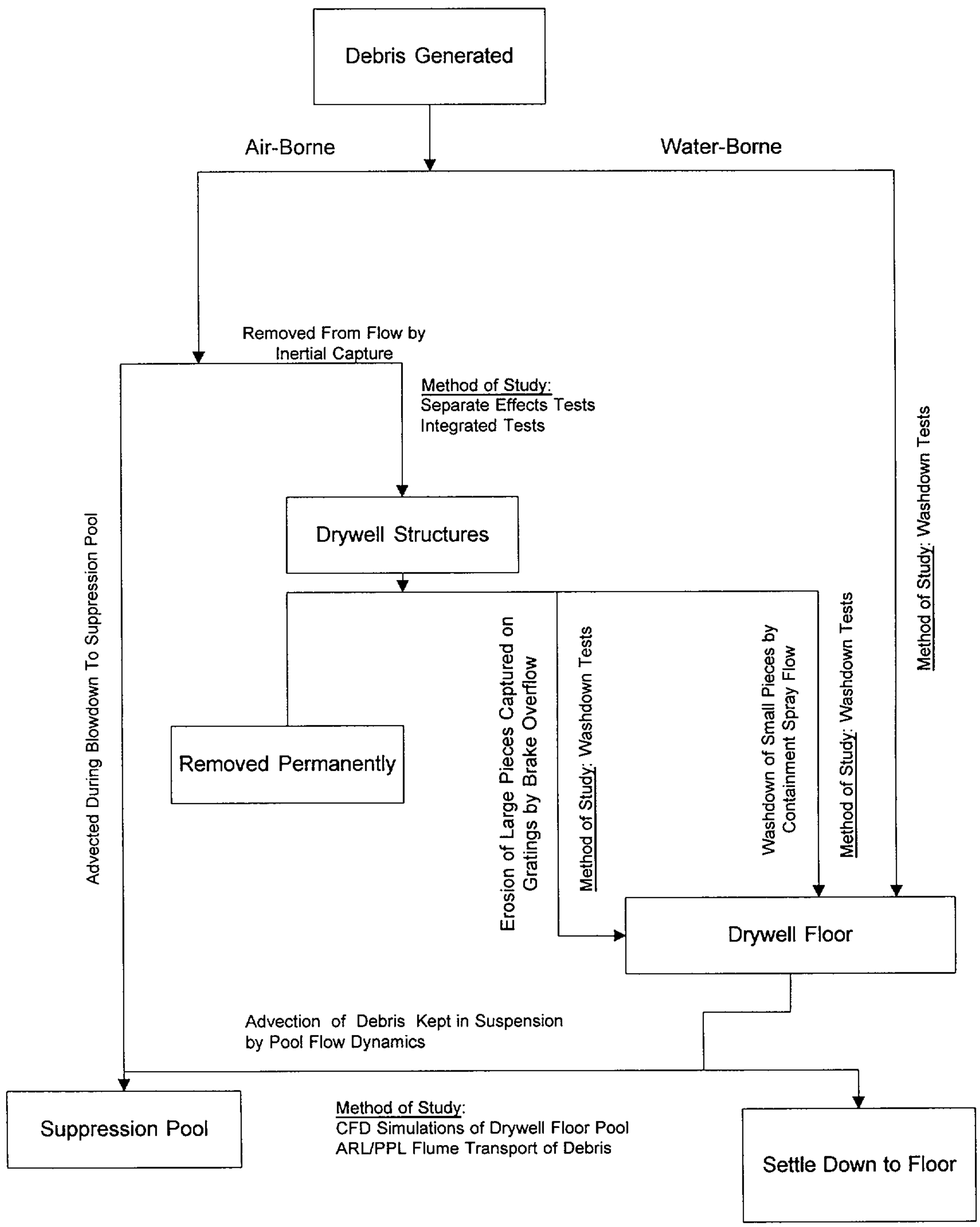


Figure E-1. Postulated debris transport pathways and experiments/analyses conducted to compile the necessary knowledge base.

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 ot 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.

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.

	Central Estimate			Upper Bound Estimate		
Containment/Break	**Small Debris**	**Large Debris Above Grating**	**Large Debris Below Grating**	**Small Debris**	**Large Debris Above Grating**	**Large Debris Below 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

Acknowledgements

The authors would like to acknowledge contributions of numerous individuals and several organizations. First, the study could not have been completed without the technical and management support from the US Nuclear Regulatory Commission. Mr. Michael Marshall (NRC/RES) is the NRC task manager for the drywell debris transport study and provided critical technical direction at different times, participated in the experiments, and performed an in depth review of the results. Mr. Robert Elliott (NRC/NRR) and Mr. Aleck Serkiz provided valuable regulatory viewpoint and historical perspective, respectively.

Several SEA staff members provided key technical assistance at critical junctures. Ms. Jane Brideau was responsible for program management and technical report preparation. Mr. Frank Sciacca provided valuable help during Phase 1 study, including design of the experimental program. Mr. Brian Carpenter and Mr. David Cremer played a key role in designing and conducting CEESI experiments, without whose hard work the tests could not have been conducted on time or within budget. Similarly, Ms. Kami Burr and Mr. Jerry Stockton were responsible for the design of washdown experiments and Mr. Kirk Weingardt was solely responsible for conducting the experiments and drying the insulation. Ms. Rose Flores and Janice Johnston is responsible for typing and producing this report.

Mr. George Hecker who participated in this study since its inception led the experimental efforts at ARL; with assistance from Dr. Mahadevan Padmanabhan and Mr. Phil Stacey. Authors would like to express sincere gratitude to them.

The authors also received valuable input from the Phenomena Identification and Ranking Table (PIRT) Panel members: Drs. Ken Williams, Mark Leonard, Brent Boyack, Lothar Wolf, and Gary Wilson. They played an important role during experimental program design and methodology development.

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[1]. 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.

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[2] 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

[1] 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.

[2] 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.[3] Analytical tools (e.g., computational fluid dynamics codes and MELCOR) were used as needed either during experiment design to establish thermal-hydraulics 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

[3] 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.

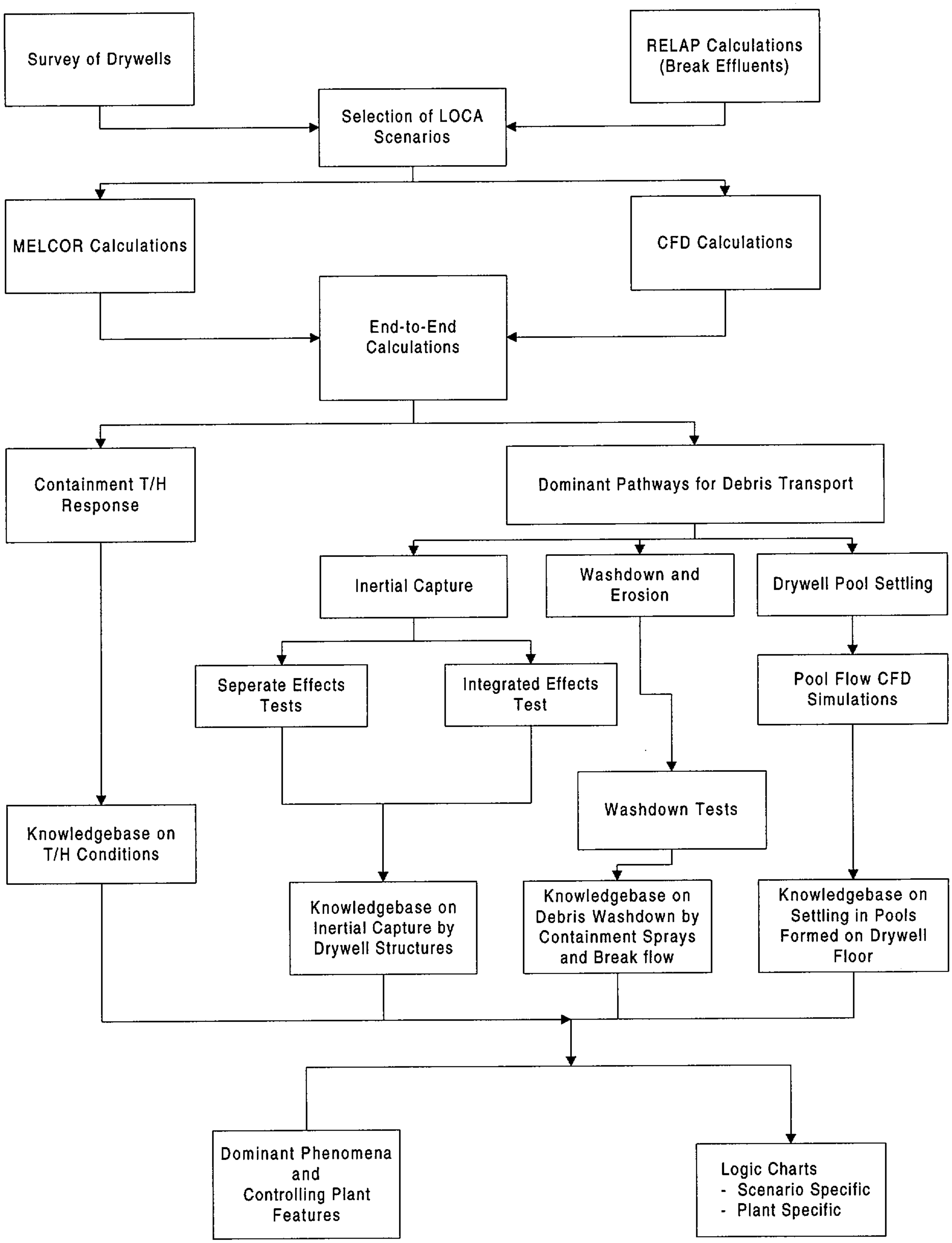


Figure 1-1. Programmatic overview of the drywell debris transport study.

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

1.1 US Nuclear Regulatory Commission, "Potential for Loss of Emergency Core Cooling Function Due to a Combination of Operational and Post-LOCA Debris in Containment," Information Notice 93-94, 1993.

1.2 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.

1.3 International Task Group, "Knowledge Base for Emergency Core Cooling System Recirculation Reliability," NEA/CSNI/R(95)," 1996.

1.4 US Nuclear Regulatory Commission, "Water Sources for Long Term Recirculation Cooling Following a Loss of Coolant Accident," Regulatory Guide, 1.82, Rev. 2, 1995.

1.5 "Karlsham Tests, 1992. Test Report. Steam Blast on Insulation Objects," Report: RVE 92-205, ABB Atom, 1992.

1.6 R. A. Pinelli, "BWR Owner's Group Comments on August 1994 Draft Report NUREG/CR-6224," BWROG-94158, 1994.

1.7 T. A. Green, "Preliminary Design Consideration for ECCS Suction Strainer Debris Loading and Head Loss," OG97-025-161, GE Nuclear Energy, 1996.

1.8 G. Wilson, et al., "BWR Drywell Debris Transport Phenomena Identification and Ranking Table (PIRT)," Final Report, INEL/EXT-97-00984, Lockheed martin Idaho Technologies Co., Idaho Falls, ID, September 1997.

1.9 Rao, et al., "Drywell Debris Transport Study: Experimental Work," NUREG/CR-6369, Supplement 1, SEA 97-3510-A:15, September 1997.

1.10 Rao, et al., "Drywell Debris Transport Study: Analytical Work," NUREG/CR-6369, Supplement 2, SEA 97-3510-A:16, September 1997.

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)[1], 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[2]. 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]:

$$V^{i}_{pool} = F^{i} \bullet V^{i}_{gen} \qquad (2\text{-}1)$$

[1] This study assumes that all of the debris entering the vents would be transported to the suppression pool.

[2] Type and duration of water flow are plant specific. In some scenarios water may not enter the drywell.

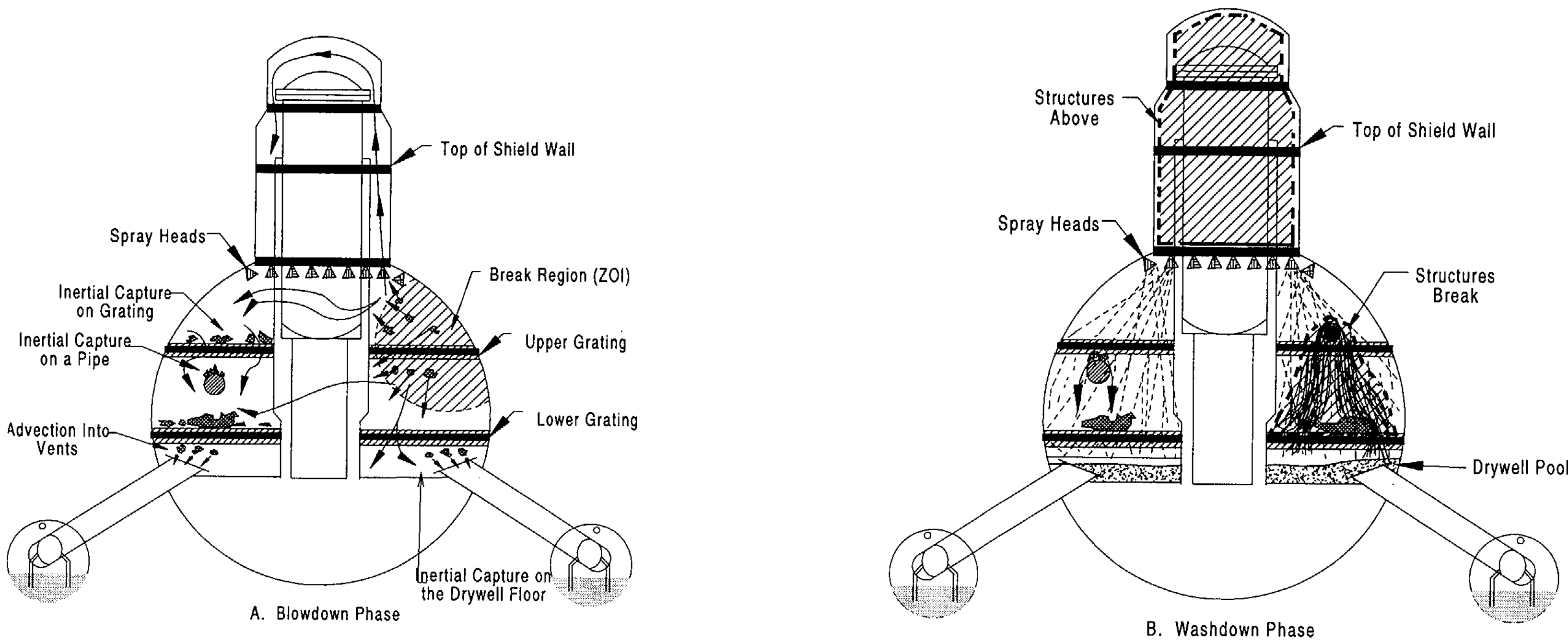


Figure 2-1. Postulated debris transport pathways in a Mark I BWR.

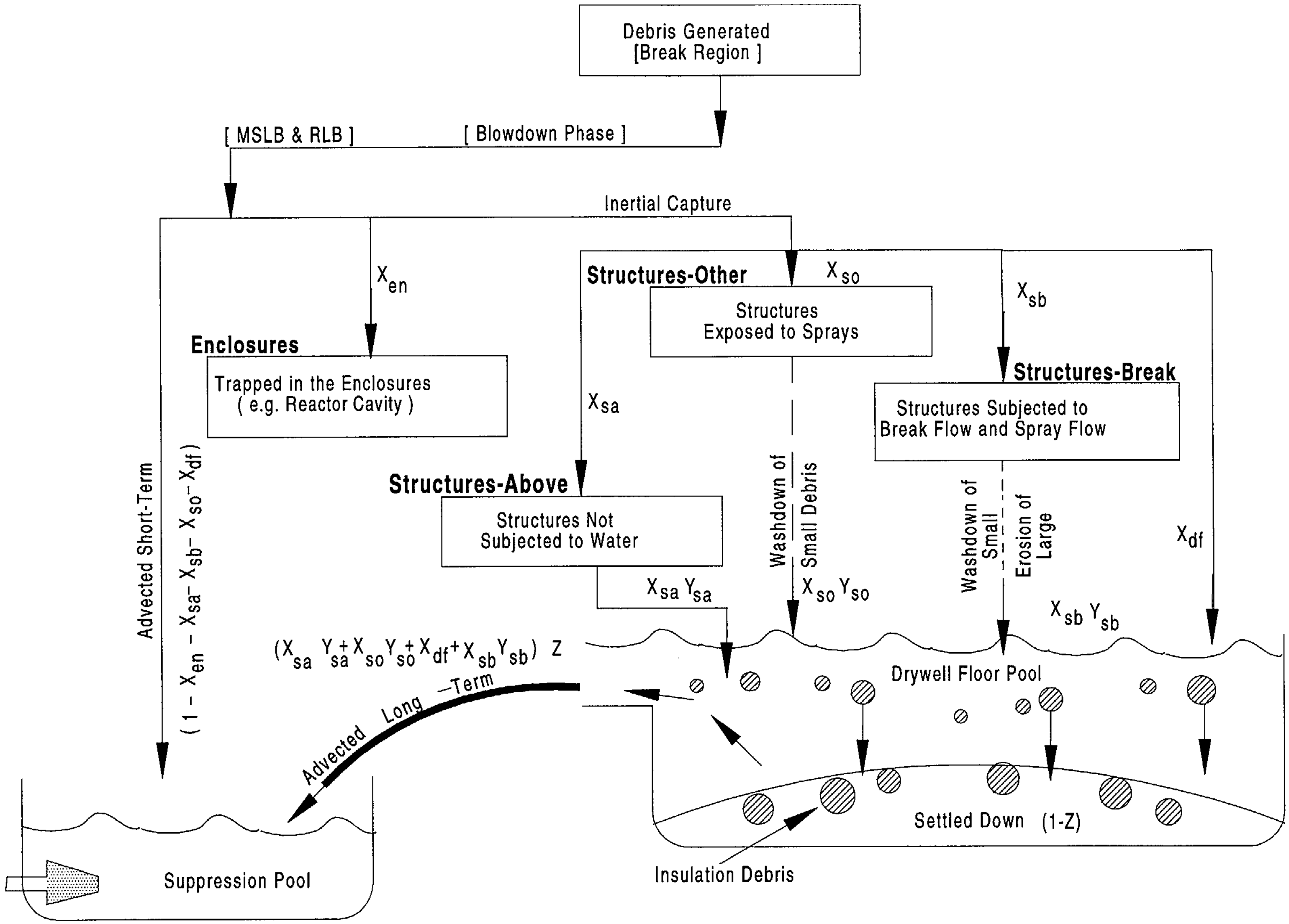


Figure 2-2. Transport pathways in a BWR.

where,

V^i_{gen} is the volume of i^{th} size fibrous debris generated in the drywell break region (ft^3)

V^i_{pool} is the volume of i^{th} size fibrous debris transported to the suppression pool (ft^3)

F^i is the drywell debris transport factor for the i^{th} size debris.

The objective of this study is to estimate F^i 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:

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

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

$$F^i_{bd} = (1 - X^1_{en} - X^i_{sa} - X^i_{sb} - X^i_{so} - X^i_{df} \tag{2-3}$$

Where, X^i_{en}, X^i_{sa}, X^i_{sb} , X^i_{so} and X^i_{sf} 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^i_{wd}, can be expressed as:

$$F^i_{wd} = F^i_{Floor} \bullet Z^i \tag{2-4}$$

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:

$$F^i_{Floor} = X^i_{sa} \bullet Y^i_{sa} + X^i_{sb} \bullet Y^i_{sb} + X^i_{so} \bullet Y^i_{so} + X^i_{df} \tag{2-5}$$

Y^i_{sa}, Y^i_{sb} , and Y^i_{so} are the fractions of i^{th} size debris previously deposited on *structures-above, structures-break* and *structures-other* that would be washed down. Thus, the problem of estimating the total transport factor, F^i, can be seen to be decomposed into the following parts:

1. Estimate fractions of the fibrous debris deposited on (or trapped by) enclosures, structures-above, structures-below, structures-other, and drywell floor (i.e., X^i_{enc}, X^i_{sa} , X^i_{sb} , X^i_{so} and X^i_{df}). These fractions are referred to as capture fractions hereafter. The remaining fraction (F^i_{bd}) 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^i_{sa}, Y^i_{sb} , and Y^i_{so}). 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.
3. Estimate fraction of the debris reaching the suppression pool that would remain in suspension and would be advected to the vents during long-term ECCS recirculation phase (Z^i). 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.[3] 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,

[3] 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^i_{enc}, X^i_{sa}, X^i_{sb}, X^i_{so}, and X^i_{df}) 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[4] 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[5] 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[6]. 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

[4] 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.
[5] Engineering judgements were necessitated by the fact that all these analyses (including MELCOR and CFD simulations) sought several simplifying assumptions to minimize computational effort.

[6] Larger partially torn insulation blankets will become de-entrained under the influence of gravity. They are not included in the following discussions.

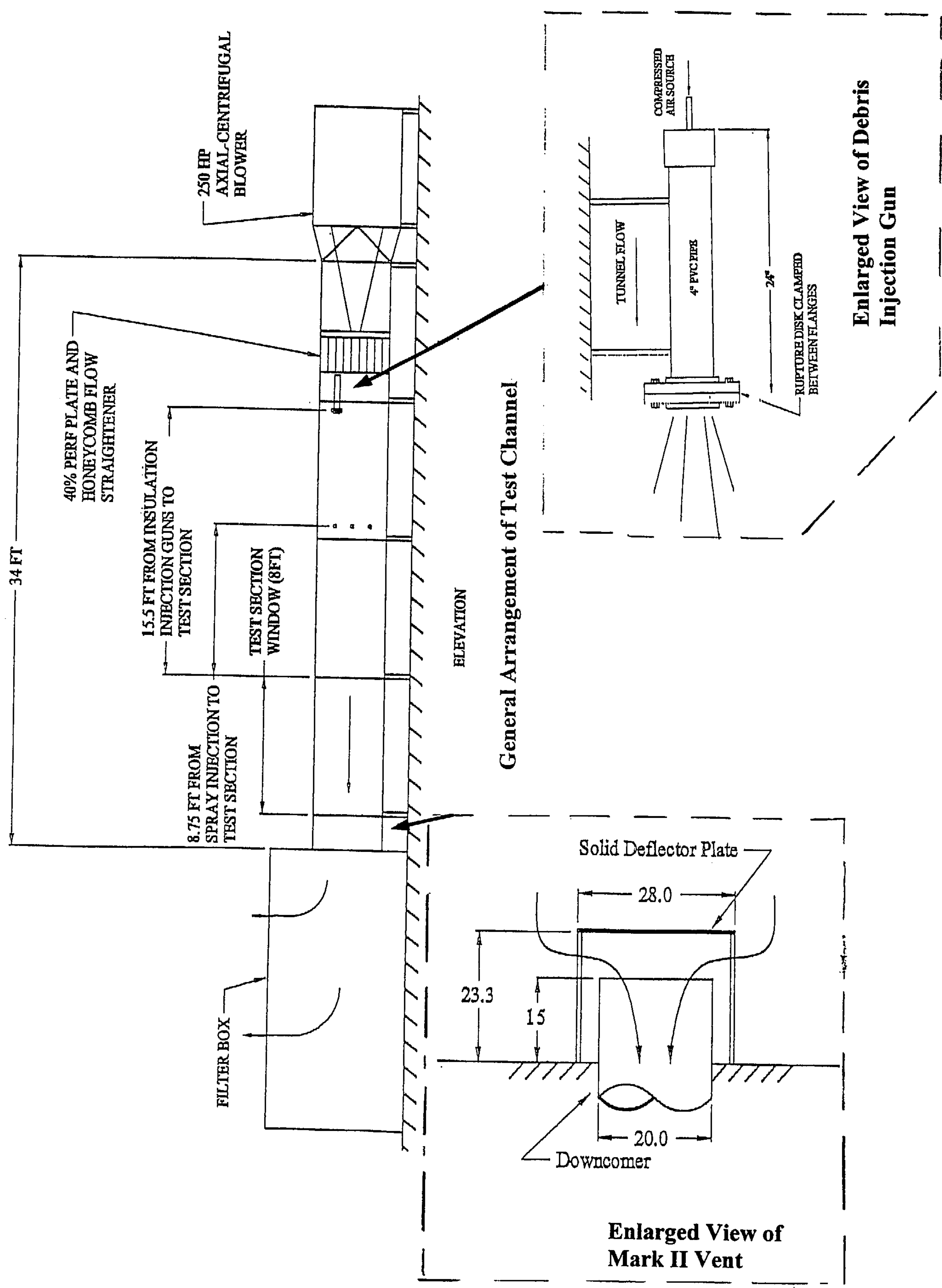


Table 2-1. Overview of separate effects test program.

Objective

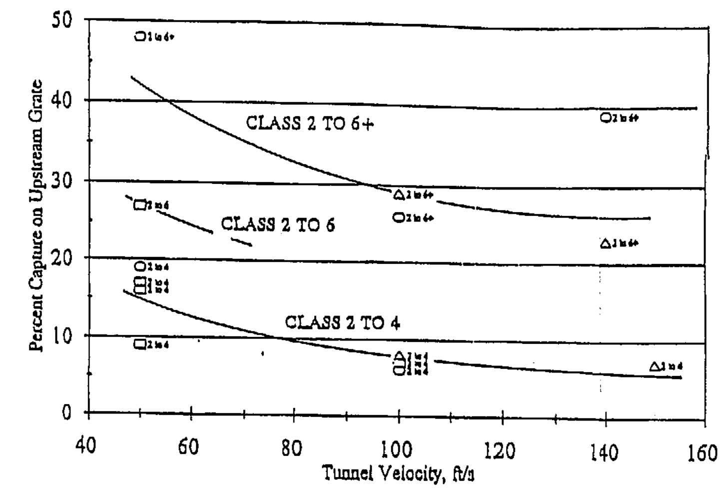
•Determine capture efficiency of an isolated structural element to capture a given size insulation debris being transported by plug flow of air. Examine the impact of congestion on capture efficiency. Examine effect of wetness and flow velocity.

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^2 vs 4-10 lbm/ft^2)
•Structures could not be assembled to the required levels of congestion.
•Debris sizes experimented are smaller than desired.

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 air-borne debris deposited on various structures. Figure 2-3 summarizes all of the data gathered and used to quantify X^i_{en}, X^i_{sa}, X^i_{sb},X^i_{so} and X^i_{df}.

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^2) will impart sufficient drag on the debris located in its pathway and transport them to the drywell floor[7]. 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., X^i_{end}, X^i_{sa}, X^i_{sb} , X^i_{so} and X^i_{df}) 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 re-entrained 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^i_{sa}, Y^i_{sb} and Y^i_{so}), 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[8],
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.

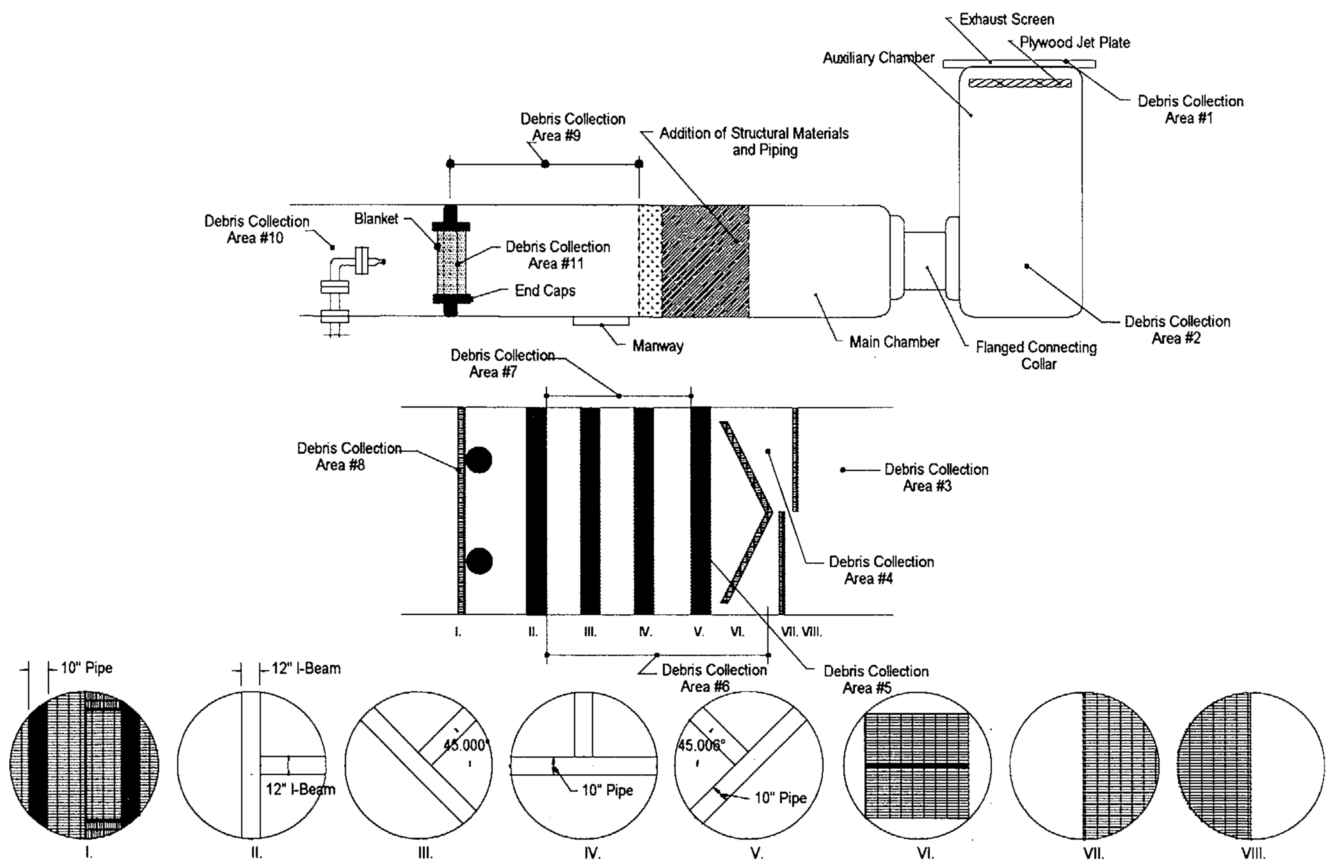
As shown in Figure 2-4, distribution of debris at the end of blowdown, type of debris and their mode of attachment were determined from analyses described in Section 2.1.1. Utility Final Safety Analysis Reports (UFSAR), Emergency Operating Procedures (EOP) and simple engineering analyses were used to 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

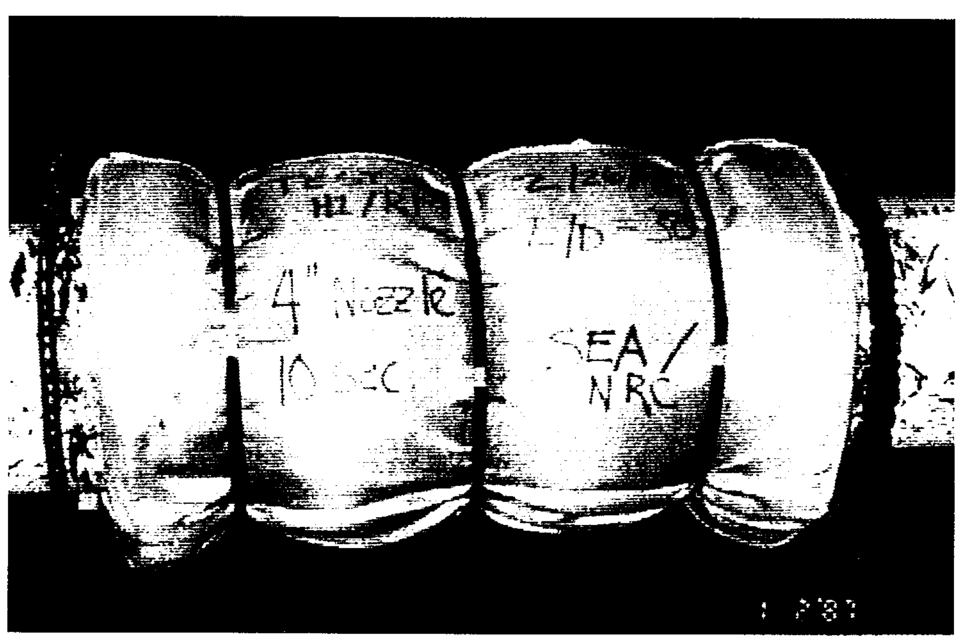
The ECCS flow and the washdown debris would be transported to the drywell floor (see Figure 2-1), where they form a pool whose depth depends on the vent-pipe offset height. Transport of debris in the drywell pool depends to a large extent on the pool flow-dynamics, pool turbulence levels, debris characteristics 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 flow-dynamics 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

[7] This conclusion was further verified by the tests described in the following sections.

[8] 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:

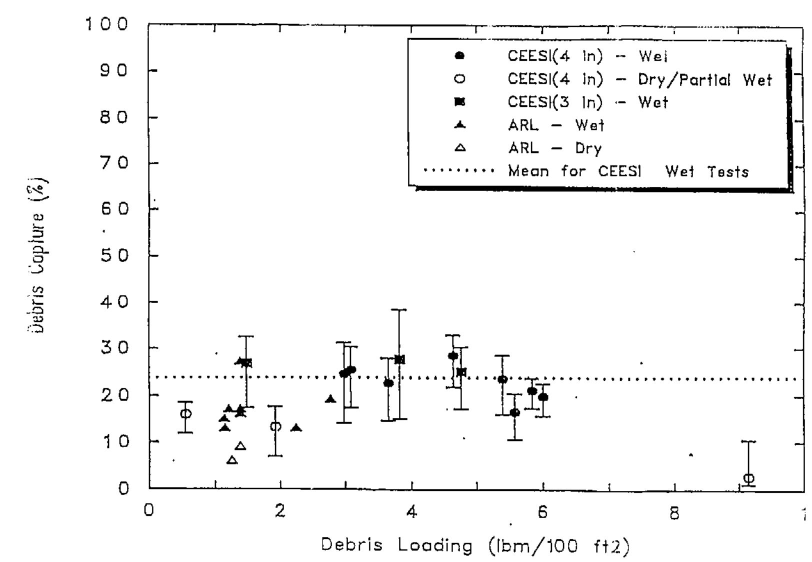
Determine Fibrous Insulation Debris Capture Fractions on typical drywell structures assembled to the congestions prototypical of BWR drywells. Use BWR survey to determine prototypical congestion levels.

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

- Mean capture fractions for Small Debris on wet structures
    - structural assemblies of desired congestion level over 20-ft transport path = 10% (wet) and 0% (dry)
    - gratings= 24% (wet) and 0% (dry)
    - Vent pipe entrance: 15% (wet) and 0% (dry)
- 100% capture of large pieces on gratings.
- Data in good agreement with ARL data for gratings and structures

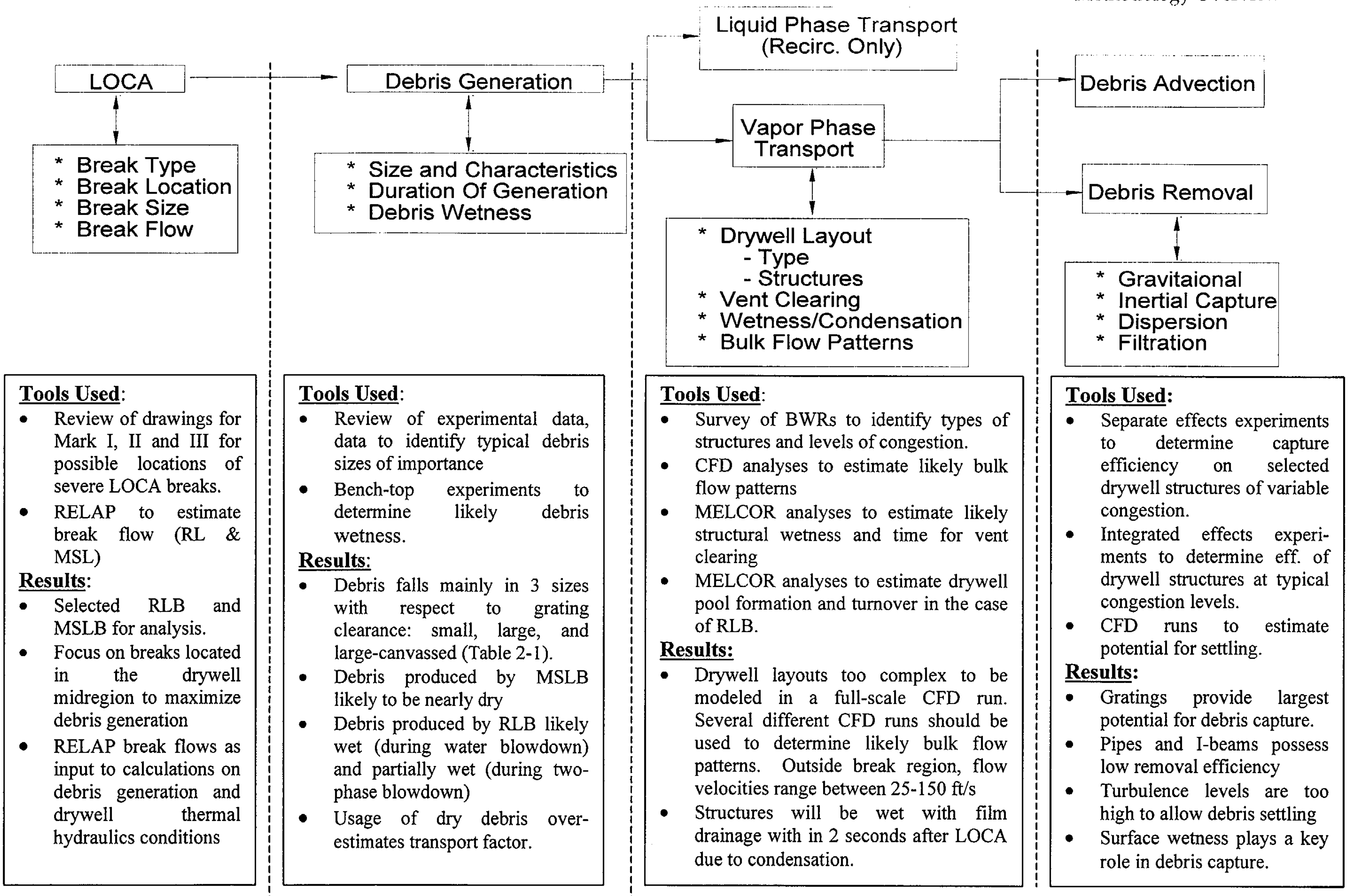
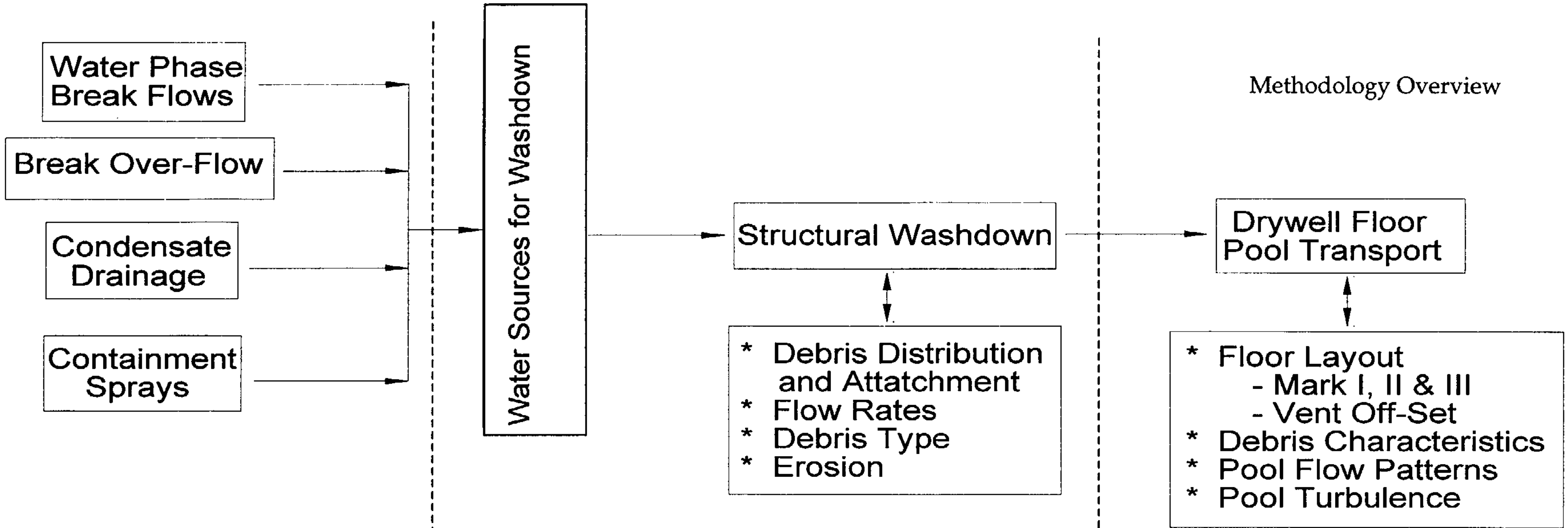


Figure 2-3. Data gathered to evaluate drywell debris transport during blowdown (short-term) phase.



Tools Used:

- RELAP Runs to estimate water-phase blowdown.
- FSAR and EOP review to identify sources of water in postulated accident scenarios. Flow rates and duration critical.

Results:

- Break blowdown water not sufficient to overflow Mark III drywell pool.
- Systems response strongly dependent on accident scenario and operator action. Assume conservative numbers to bound significant plant-specific variations.
- Break overflow unlikely following MSLB
- Containment spray unlikely after RLB.

Tools Used:

- Input from Blowdown calculations to estimate debris distribution at the end of blowdown.
- Engineering judgements and CFD runs for flow distribution on various structures
- BWROG experimental data on debris size. Enhanced with NRC experiments.
- NRC washdown experiments for structural washdown of small pieces and erosion of large debris.

Results:

- Assume that break overflow uniformly spreads over the structures located in the quadrant in which break is located.
- The containment sprays can washdown large fraction of small debris on gratings.
- The condensate drainage has little impact on transport.
- Break flow can washdown small debris and erodes large debris. Erosion time-dependent.

Tools Used:

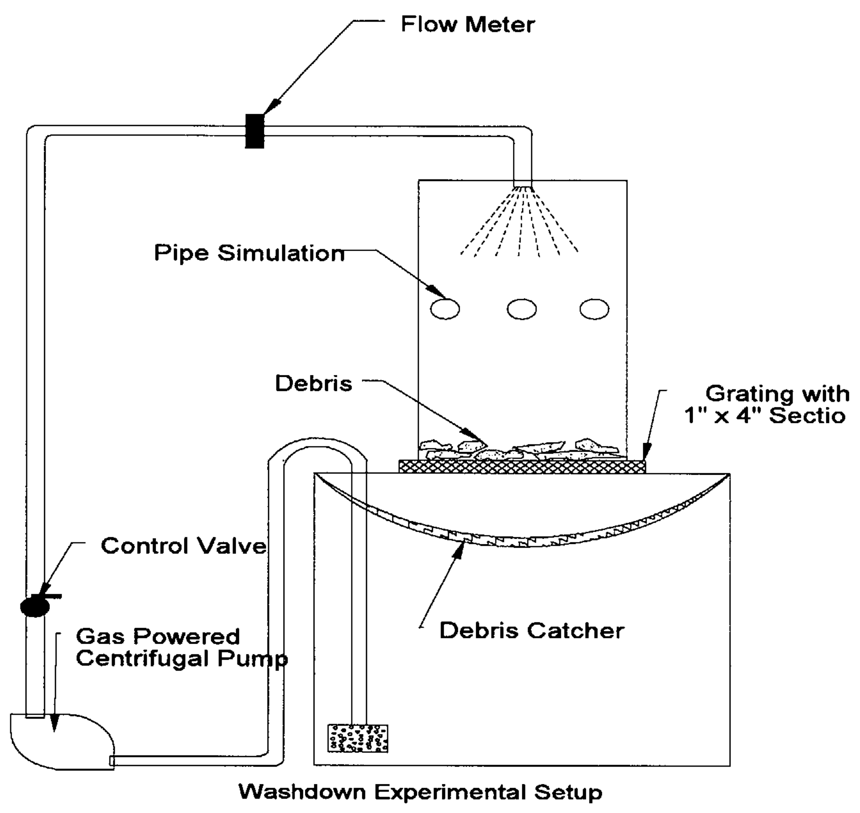
- Plant drawings for Mark I, II and III drywells for layout and vent design details.
- CFD runs to interpret previous existing data: PP&L Flume Transport data.
- BWROG Data.
- CFD runs simulating flow on drywell floor for Mark I, II and III containments corresponding to break overflow and spray.

Results:

- Mark II pools are turbulent during spray and break operation. Likely transport during both scenarios.
- Mark I and Mark III pools allow for debris settling in the case of spray operation. Break overflow induces enough turbulence to transport 100% of debris.

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

Table 2-3. Overview of Washdown Experimental Program



Objectives:

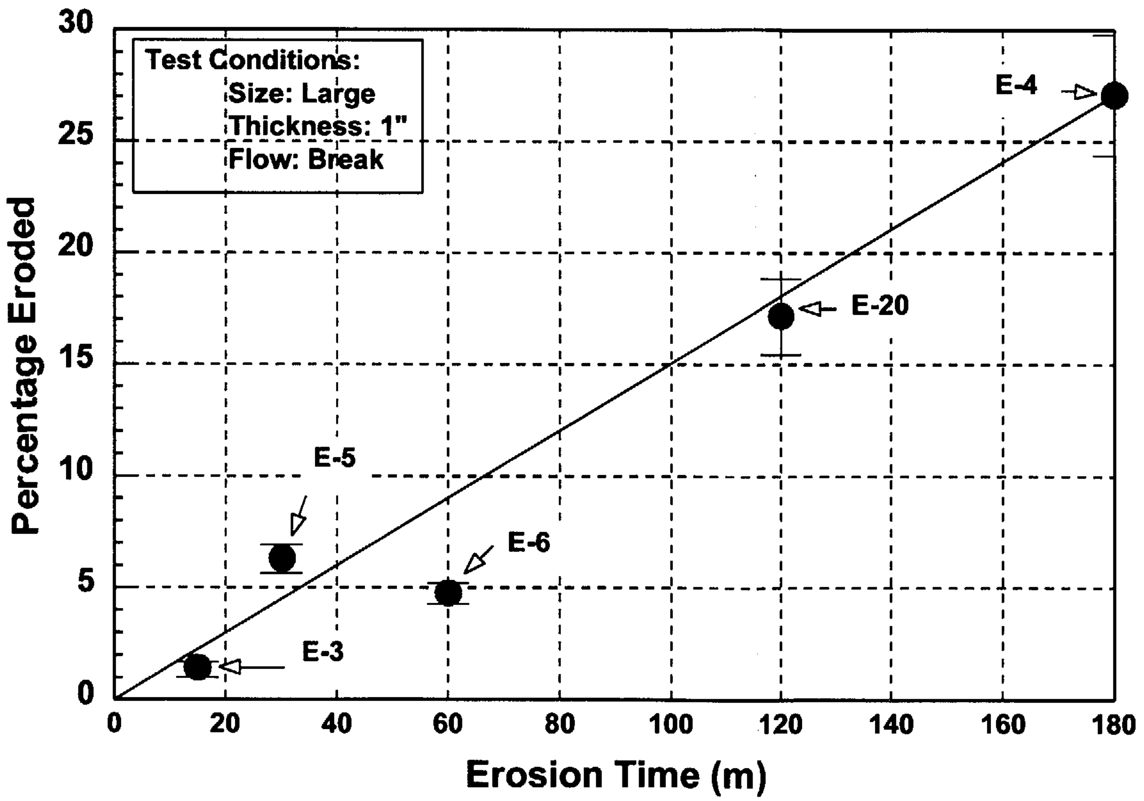
- •Obtain experimental data to estimate fraction of insulation initially captured on floor grating that would be eroded and transported by water flow typical of break overflow and containment sprays
- •Confirm trends of data reported by previous investigators.

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.

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[9], large, and large-canvassed, 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.

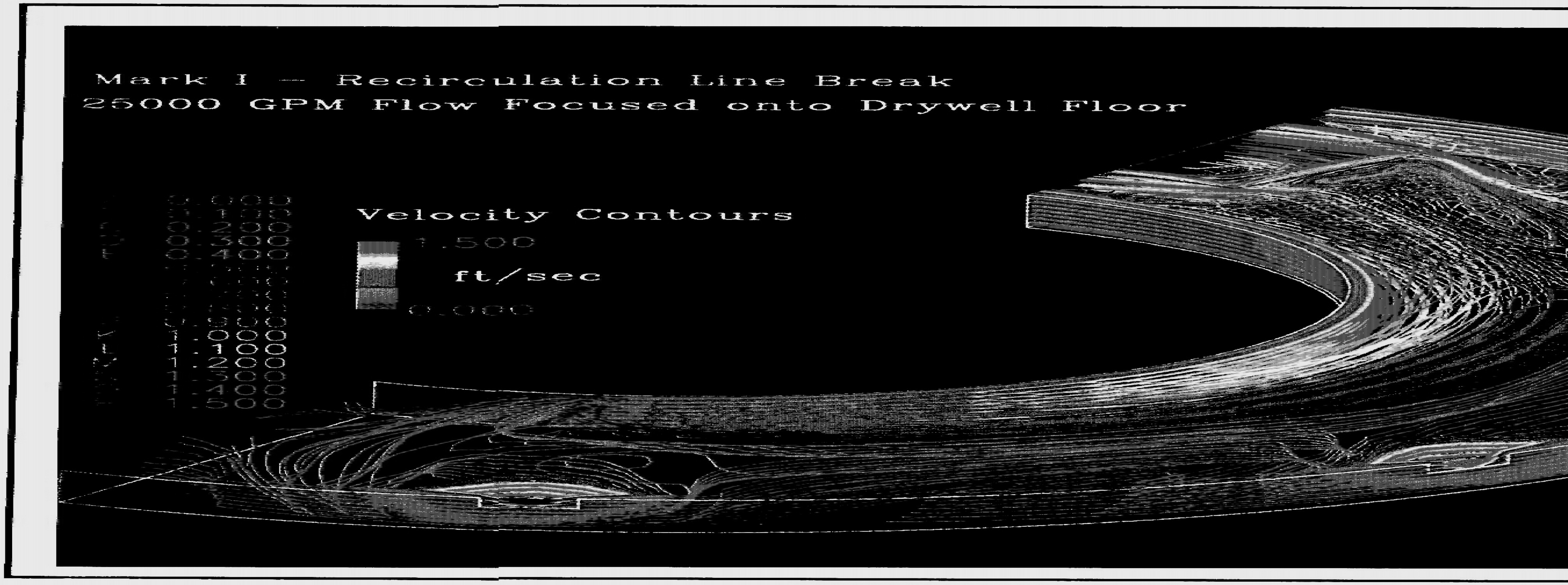
2.4 Debris Transport Factor Quantification

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[10]. 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-

[9] 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].

[10] Also, see NRC guidance listed in Section 1.

Table 2-4. Overview of CFD Simulation of Tr



CFD Simulation of Mark I Flow Patterns

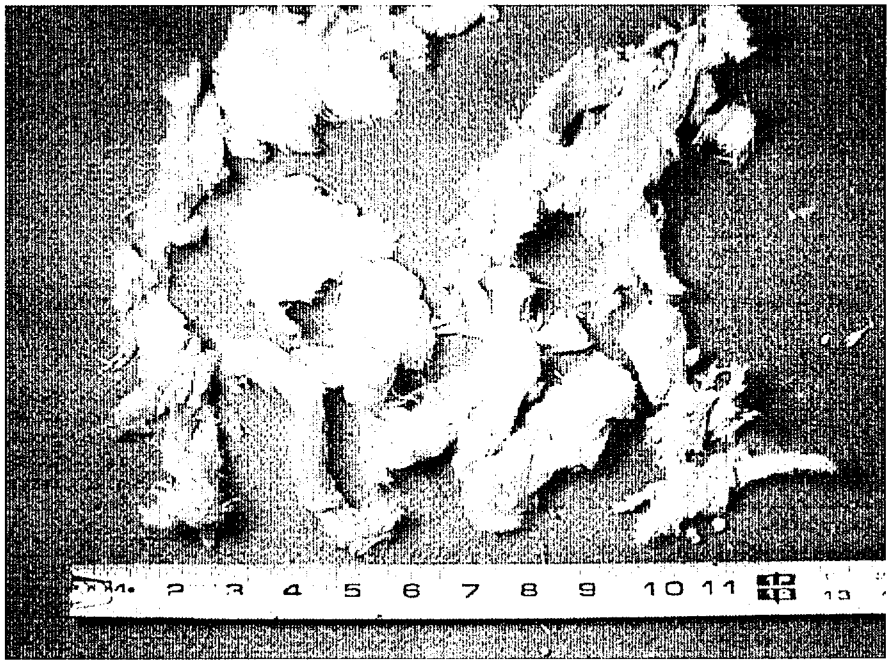


Figure 2-5. A photograph of small size insulation debris produced in air-jet tests.

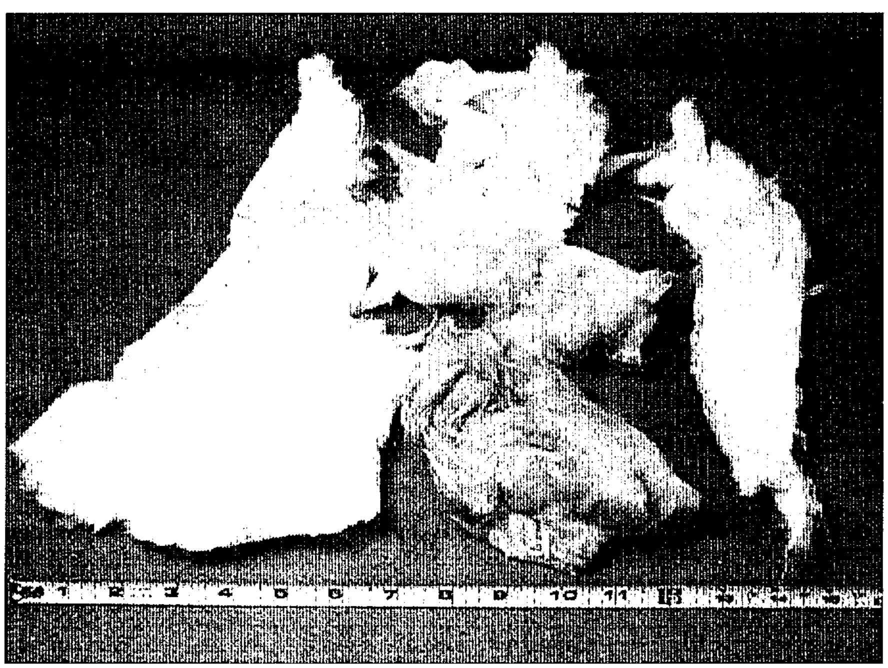


Figure 2-6. A Photograph of Large Size Insulation Debris Produced in Air-Jet Tests

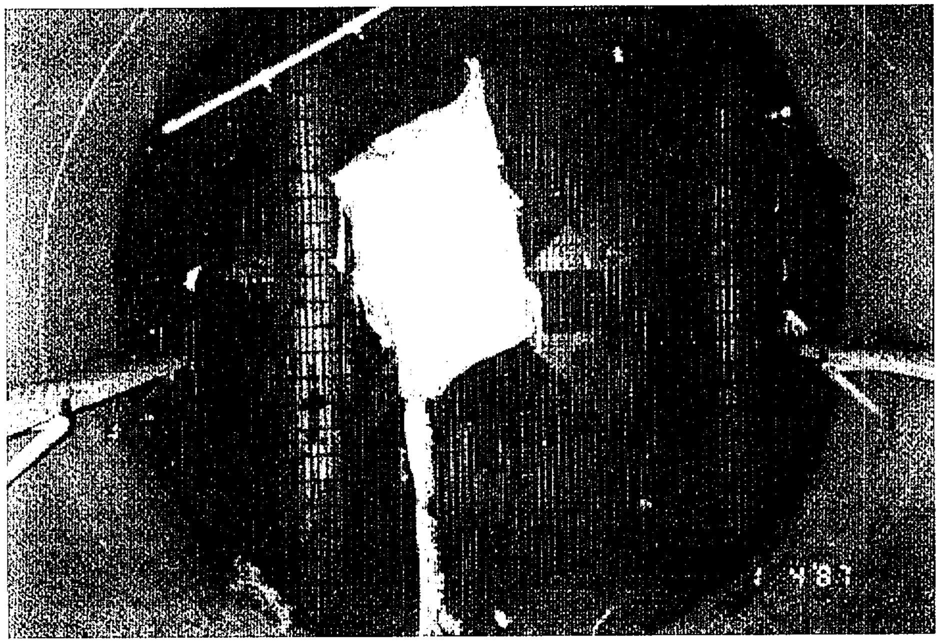


Figure 2-7. A Photograph of Large Canvassed Debris Produced in Air-Jet Tests

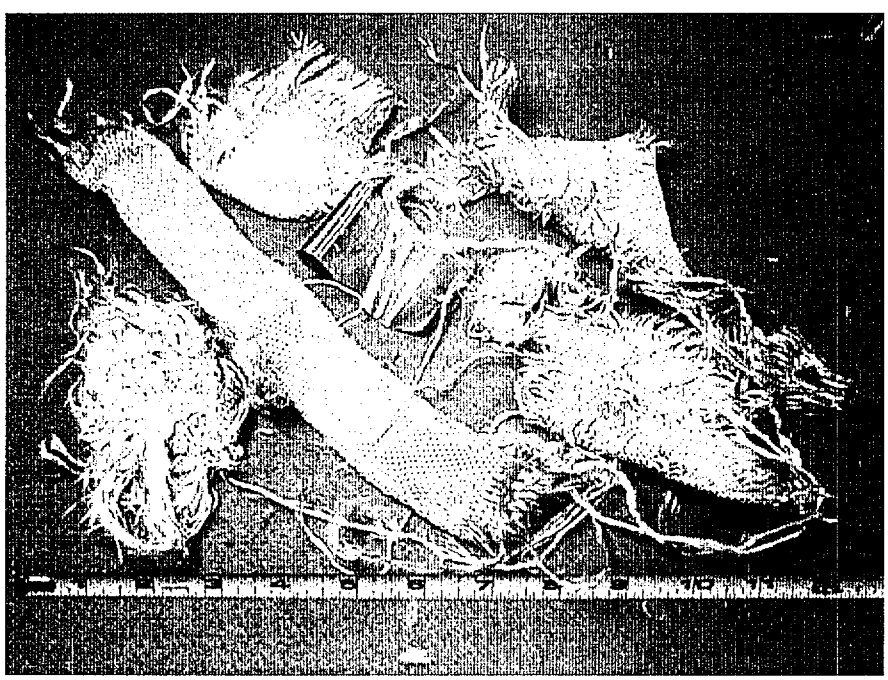
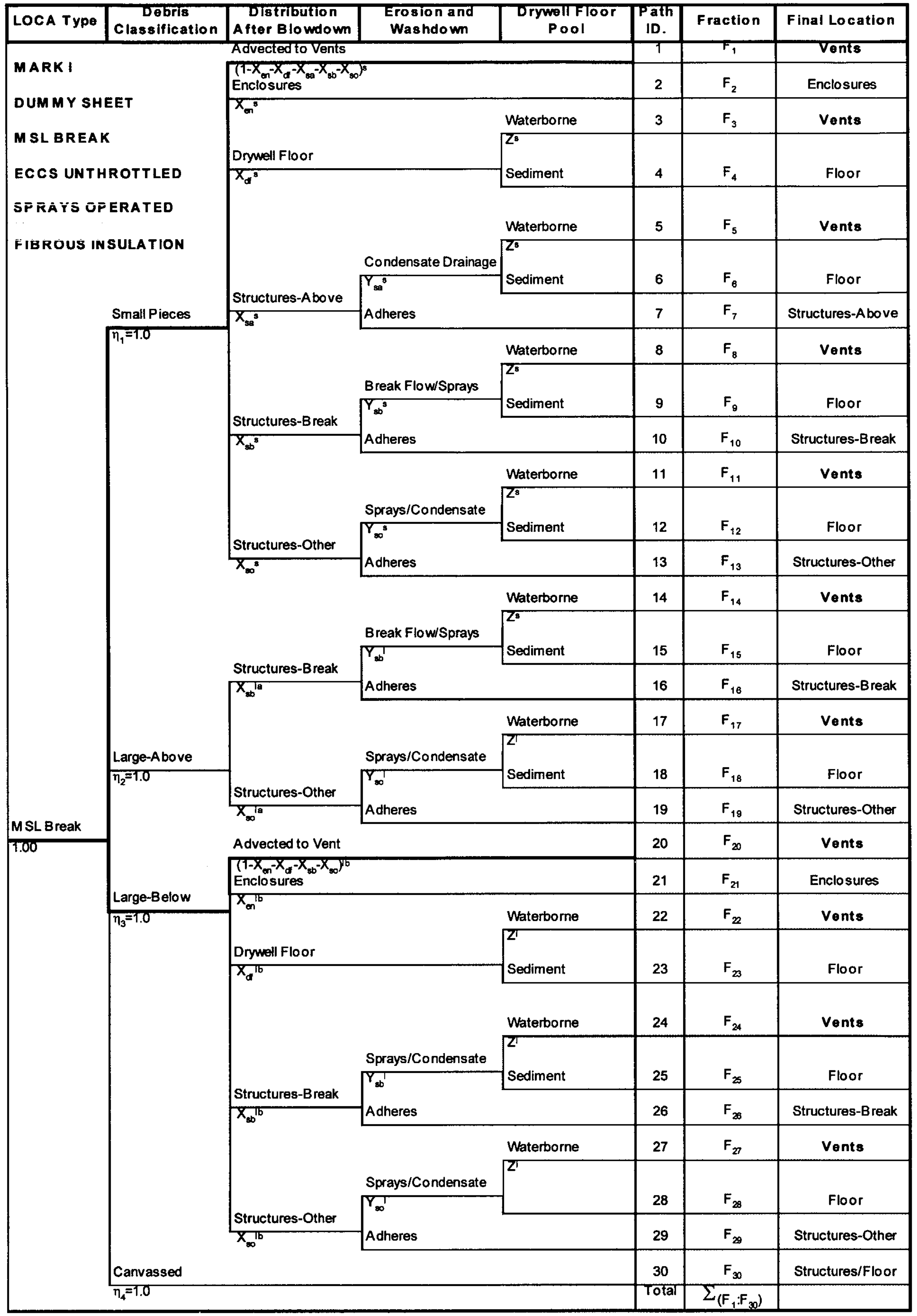


Figure 2-8. A Photograph of Shredded Canvassed Debris Produced in Air-Jet Tests

Table 2-5. Debris classification.

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

Figure 2-9. Generic Logic Chart Used for Quantification of Debris Transport.



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.

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.

Transport Factors Estimated

Factor	Formula	Explanation
F^s	$(F_1+F_3+F_5+F_8+F_{11})/\eta_1$	Fraction of Small Debris Transported
F^{la}	$(F_{14}+F_{17})/\eta_2$	Fraction of Large-Above Debris Transported
F^{lb}	$(F_{20}+F_{22}+F_{24}+F_{27})/\eta_3$	Fraction of Large-Below Debris Transported
F^{Large}	$(\eta_2F^{la}+\eta_3F^{lb})/(\eta_2+\eta_3)$	Fraction of All Large Debris Transported
F^{trans}	$(\eta_1F^s+\eta_2F^{la}+\eta_3F^{lb})/(\eta_1+\eta_2+\eta_3)$	Fraction of Transportable Debris Transported
F^{ZOI}	$(\eta F^s+\eta_2F^{la}+\eta_3F^{lb})$	Fraction of All Insulation in the ZOI Transported

Logic Chart Heading	Explanation	Rationale Used for Quantification
LOCA Scenario	A description of the scenario being quantified. (see Figure 2-10)	All assumptions related to systems response and time scales were based on a generic BWR Plant. Particular plant response may vary.
Debris Classification	See Size definitions above.	BWROG data is used as an example to derive η_1, η_2, η_3 and η_4.
Distribution after blowdown	Where is the debris located at the end of blowdown? What fraction onstructures-above, -break, etc.?	Removal efficiency from experiments was coupled with a simplified advection model was used.
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 break overflow were assumed to cause washdown. Experimental data was used to estimate washdown fractions for small debris and erosion rates for large debris.
Drywell Floor Pool	What fraction of the debris reaching the drywell pool will be transported?	CFD simulations of drywell floor pool was used to determine residual turbulence levels and flow patterns. This information was then coupled with experimental data to obtain the fraction of debris transported.

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^{1}_{ien}, X^{1}_{idf}, X^{1}_{isa}, X^{1}_{isb} and X^{1}_{iso}), washdown fractions (Y^{1}_{isa}, Y^{1}_{isb}, and Y^{1}_{iso}), and drywell pool transport fraction (Z^{i}) 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 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^{i} Fraction of small debris transported to the vents

F^{la} Fraction of large-above debris transported to the vents

F^{lb} Fraction of large-below debris transported to the vents

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

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 $(\eta 1 \bullet F^{s}+\eta 2 \bullet F^{la} + \eta 3 \bullet F^{lb})$

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:

1. Upper Bound Estimate. 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.

2. Central Estimate. 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).

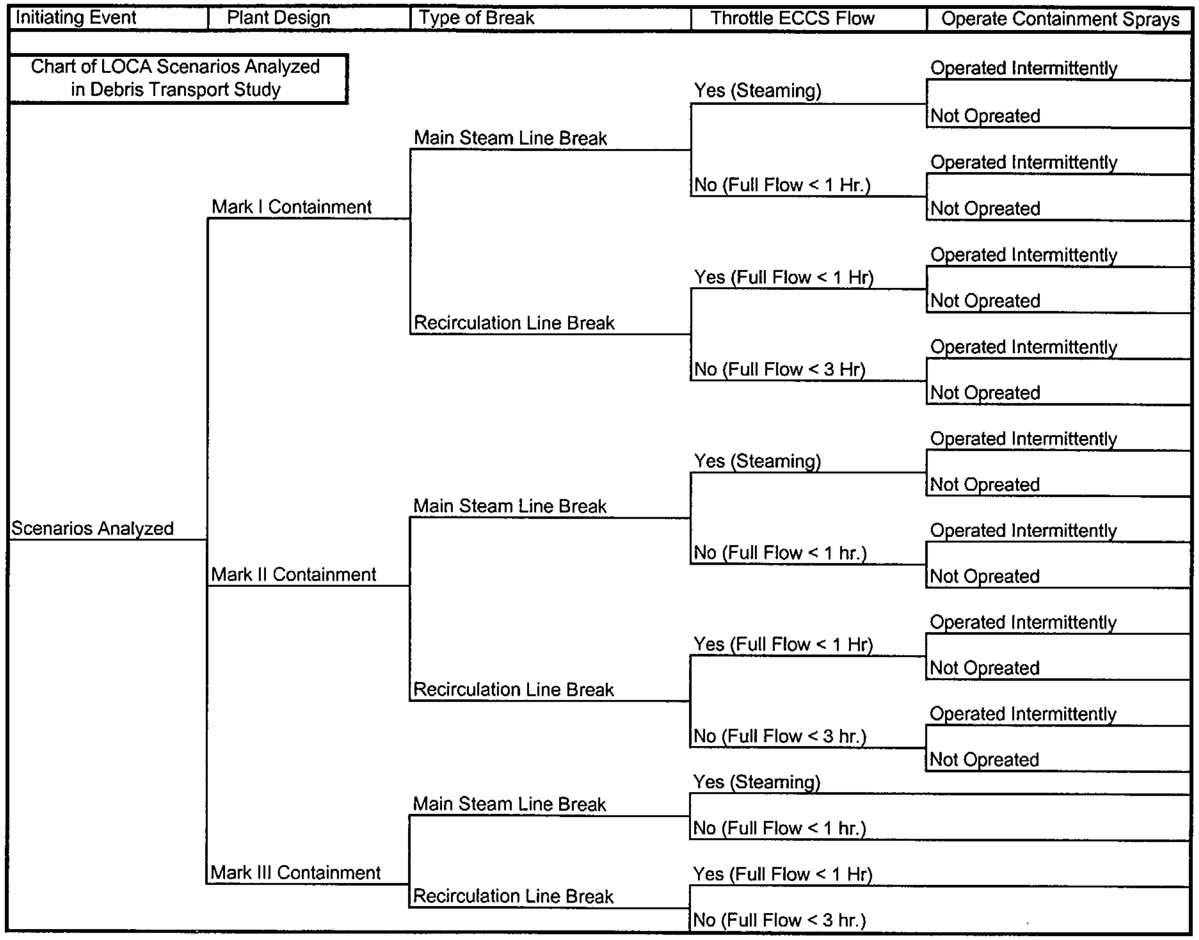


Figure 2-10. Accident scenarios analyzed in the study.

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[11] 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[12]. 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
2. 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[13].

[11] 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.
[12] 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.

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

[13] However, the logic charts were structured to accommodate breaks in other regions of the drywell by simply varying η_2 and η_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.

3. Controlling Phenomena and Plant Features

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:

1. Capture of small pieces is only possible if the grating surface is wet. Experiments demonstrated that capture efficiency of gratings for small debris are small (6%) if the grating surfaces are not wet[1].
2. If floor gratings do not cover the entire flow cross-section they may not be as effective at debris capture. 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. Combined effects of blowdown and washdown should be considered. 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.[2]. 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

[1] 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.

[2] 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.

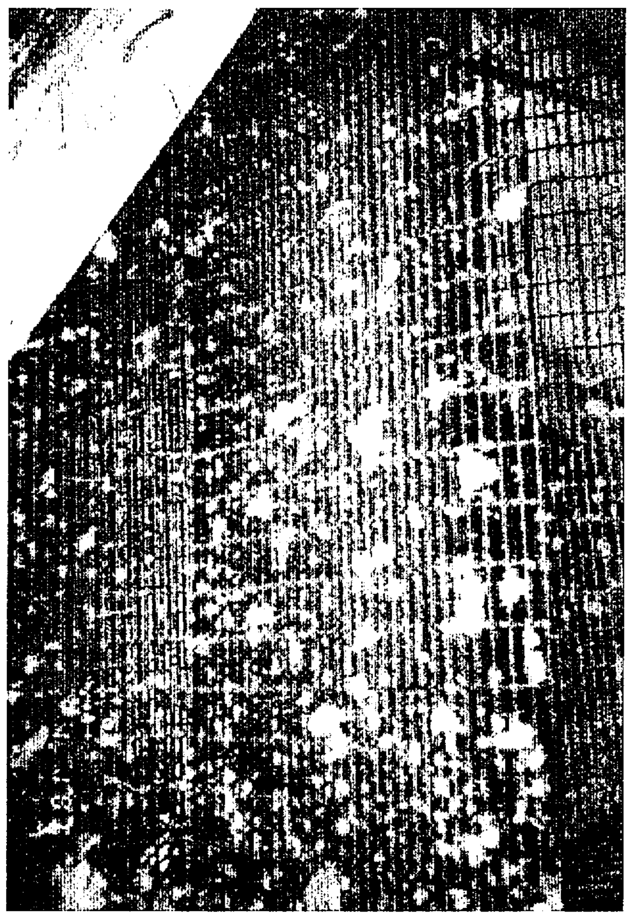


Figure 3-1. Typical small debris deposition on wet gratings observed in the experiments.

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

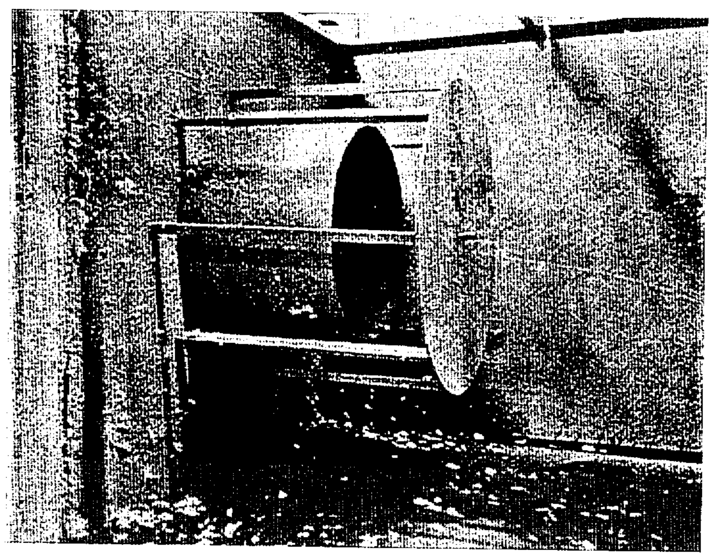


Figure 3-3. Capture of small debris around simulated Mark II vent.

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.

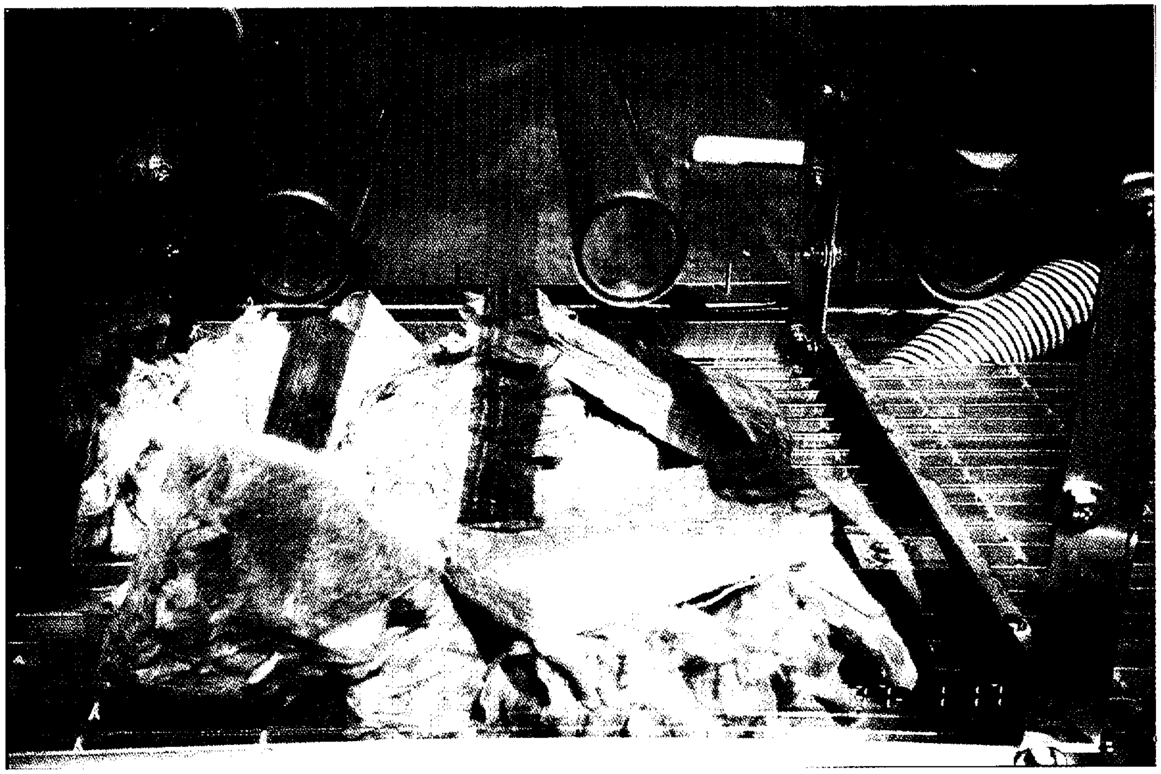
3.2.2 Large Debris

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 ($1/8^{th}$ or higher in thickness) exposed for several minutes to 150 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[4]. 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

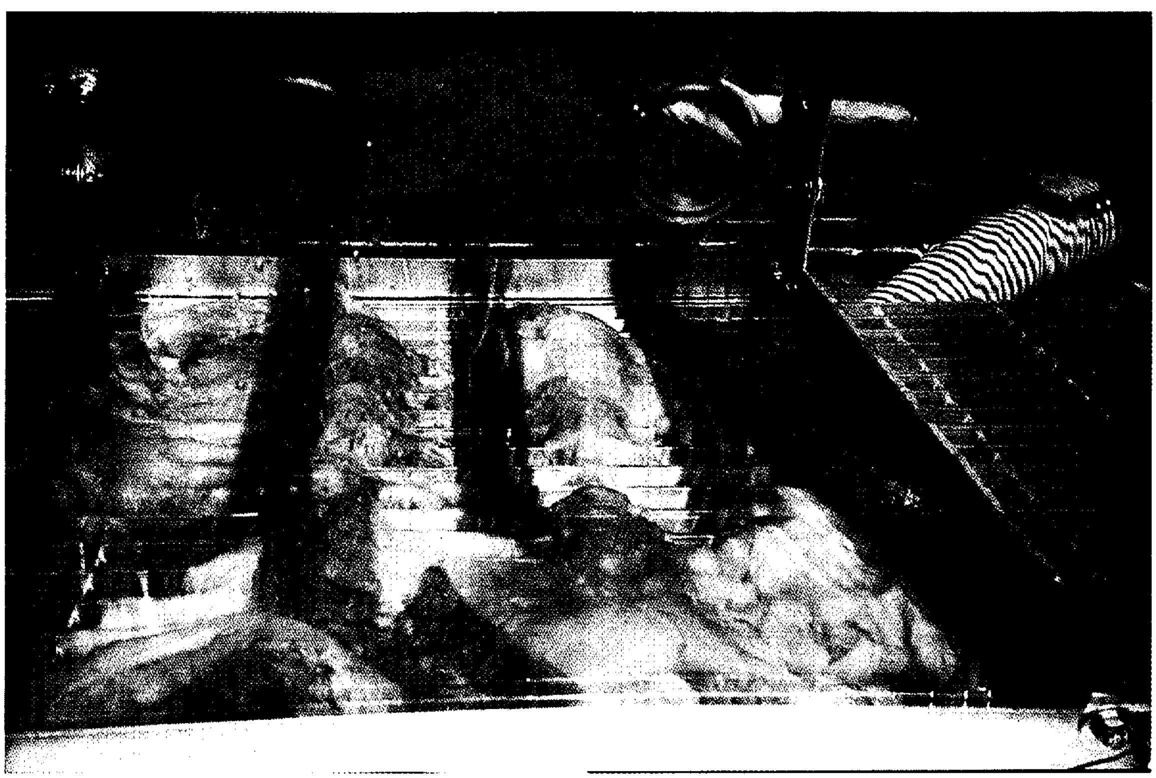
1. Advection of large debris generated below the lowest grating
2. Erosion of large debris by break flow and subsequent transport, and
3. Advection of large pieces through discontinuities in the floor gratings.

[3] Note that flow velocity of 150 ft/s corresponds to a situation in which blowdown flow from a main steam line break flows through $1/8^{th}$ of the drywell cross-section

[4] 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.

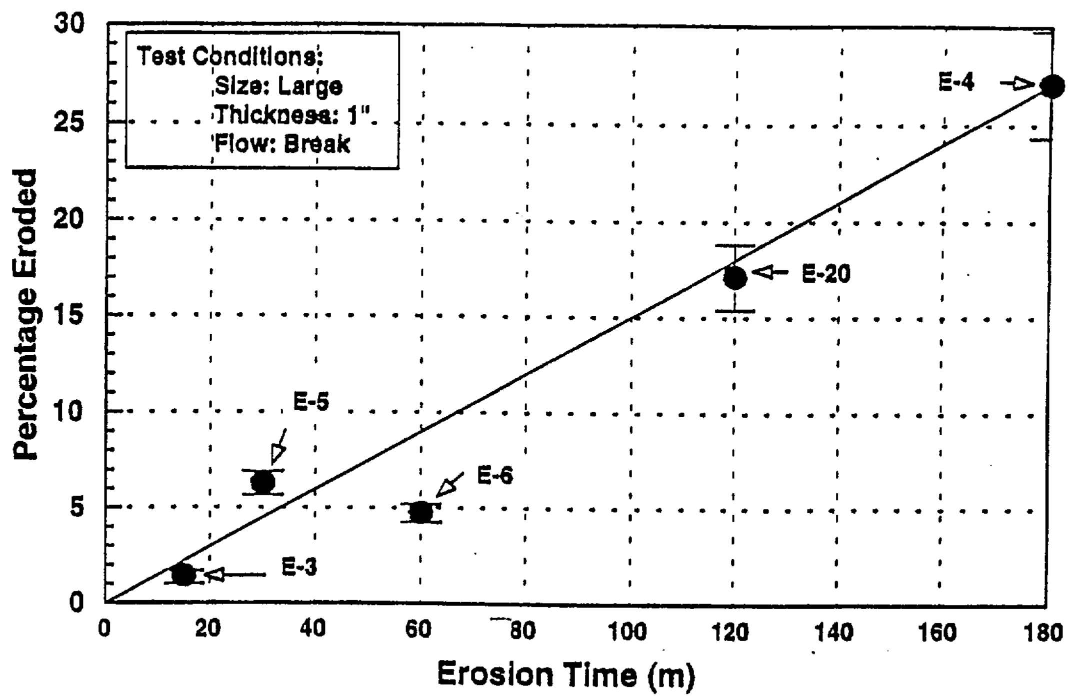


Figure 3-5. Erosion as a function of time for large pieces trapped on floor grating. (Flow is ≅ 50 GPM/ft^2)

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 scenario-specific 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[1] 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

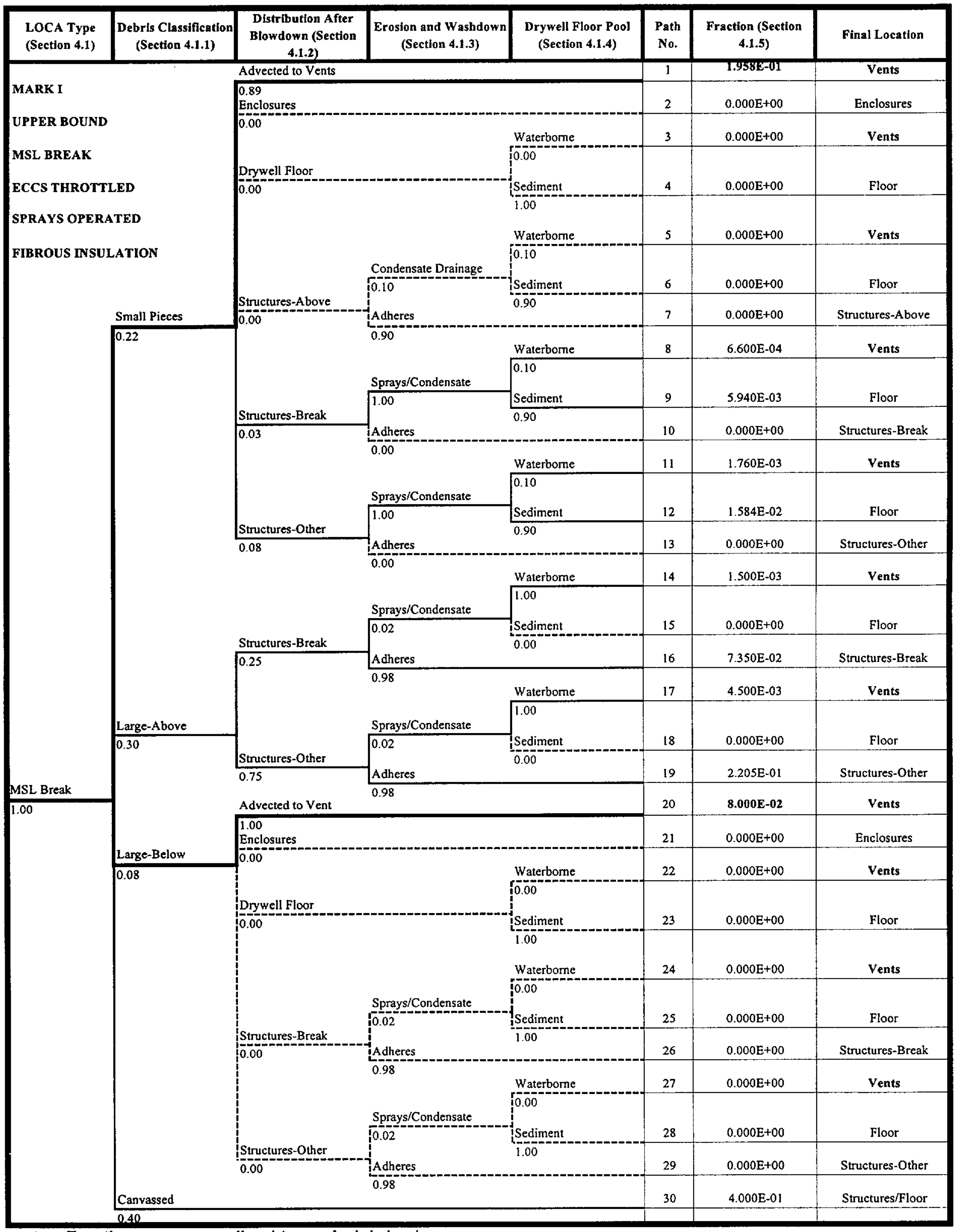
The accident scenario analyzed here is a postulated MSLB in a Mark I drywell. The break was assumed to be in the mid-region of the containment where it is likely to generate the maximum amount of debris. In this scenario, it was assumed that the operator would throttle the ECCS after recovering the pressure 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 cross-sectional area with no significant chances for debris to bypass the gratings. The drywell free-volume is 120,000 ft^3, 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

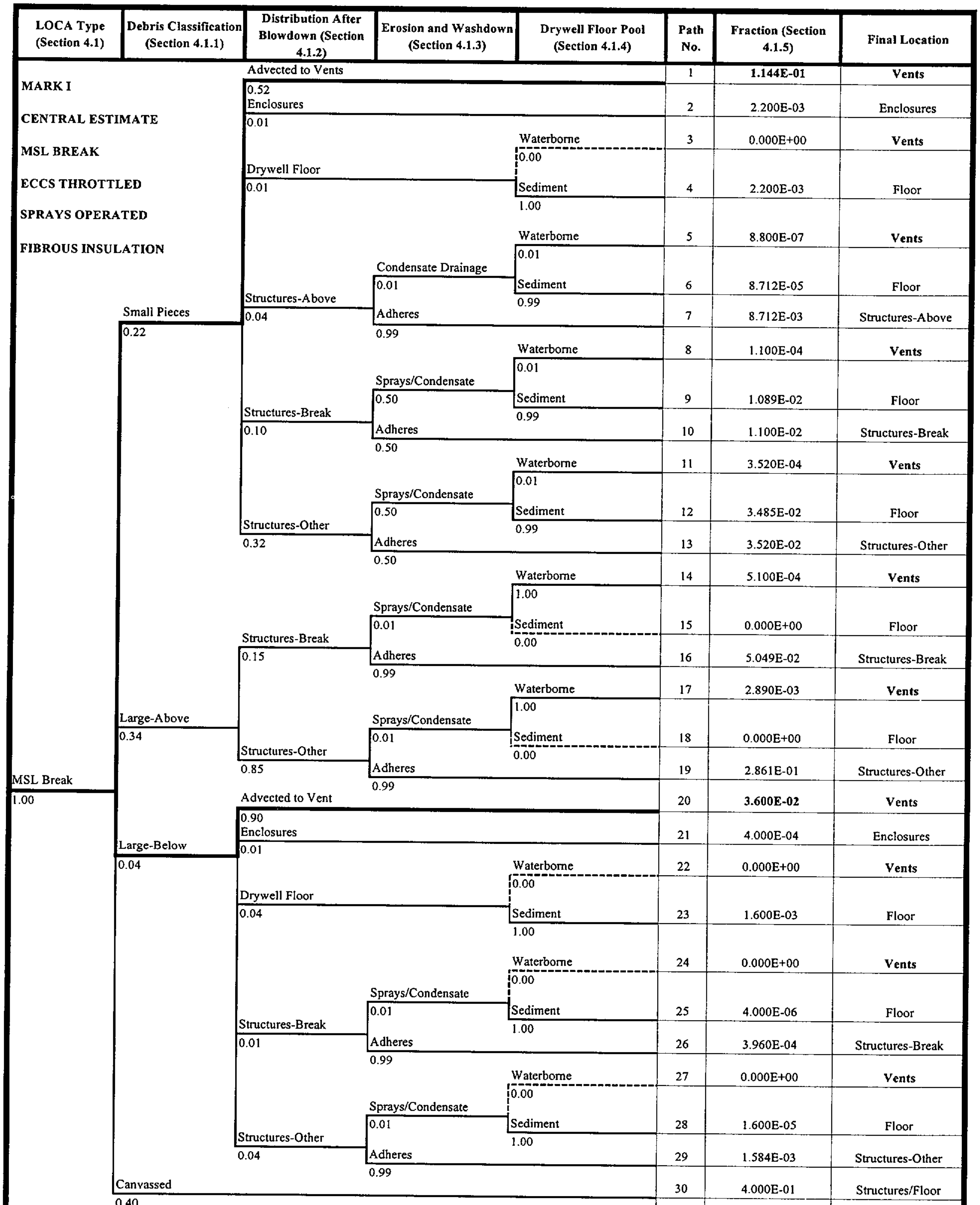
The debris generation data provide boundary conditions for all the subsequent processes. The scoping analyses [Ref. 4.1] have shown that debris transport is influenced most by the following parameters related to debris generation: a) duration of debris generation, b) location of debris generation, c)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

[1] 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.



note: Fractions are normalized to each debris class

Figure 4-1. Logic chart for upper bound estimate of transport factor for a MSLB scenario.



note: Fractions are normalized to each debris class

Figure 4-2. Logic chart for central estimate of transport factor for a MSLB scenario.

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:

1. *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 $\rho v^2/2g_c$, 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[2].

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[3]. Analytical efforts were undertaken to study jet expansion in the zone of influence, when subjected to structural congestion typical of the drywell mid-region. 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[4] 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

---

[2] 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.

[3] If such an approximation is invalid, then more complex modeling effort integrating debris generation and transport would be necessary.

[4] The zone of influence tends to be hemispherical for a postulated single-ended MSLB in a congested region.

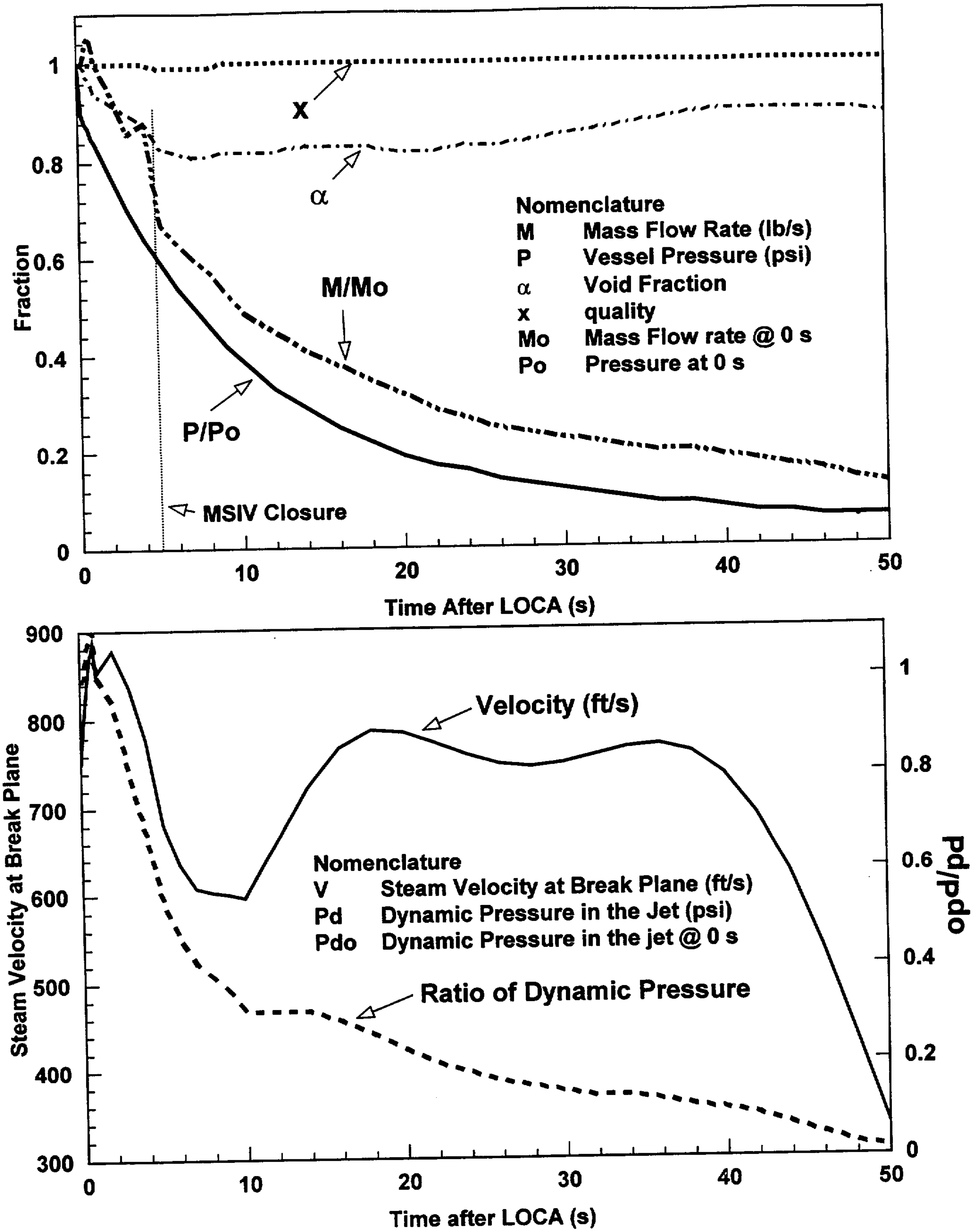


Figure 4-3. Blowdown data corresponding to a postulated main steam line break in a BWR/4 plant.

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 η_1, η_2, η_3, and η_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^{ZOI}).

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:

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

Where, F^i_{bd} is the blowdown transport factor for i^{th} 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:

1. *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[5]. 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[6] 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 ≈ 125,000 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^3) 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

[5] In Mark I and II drywells, down-comers would be occupied by water slug 4-6 ft in height.

[6] MELCOR was used because it already has a detailed vent model.

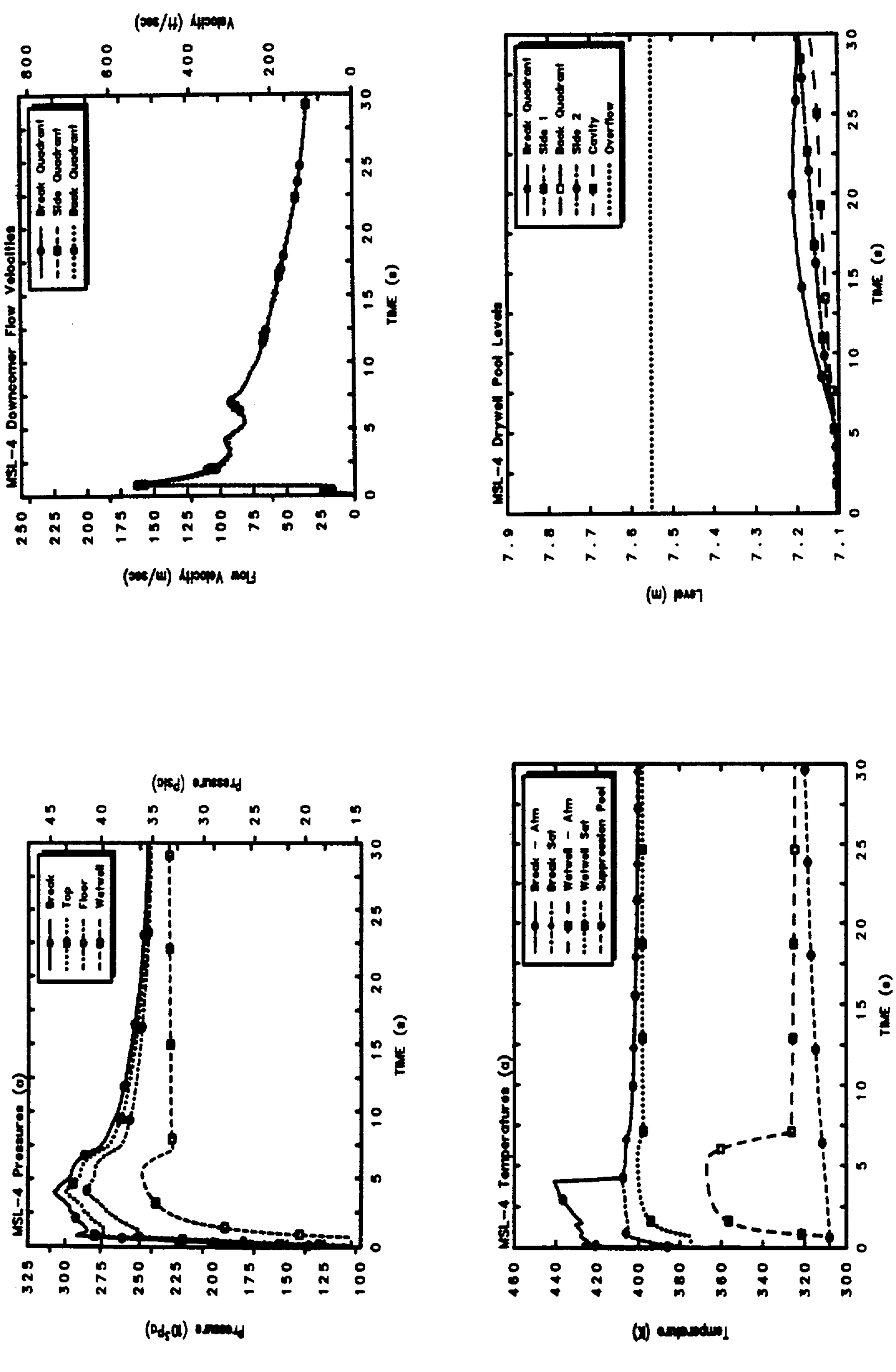


Figure 4-4. MELCOR predictions for drywell thermal hydraulics response following a MSLB.

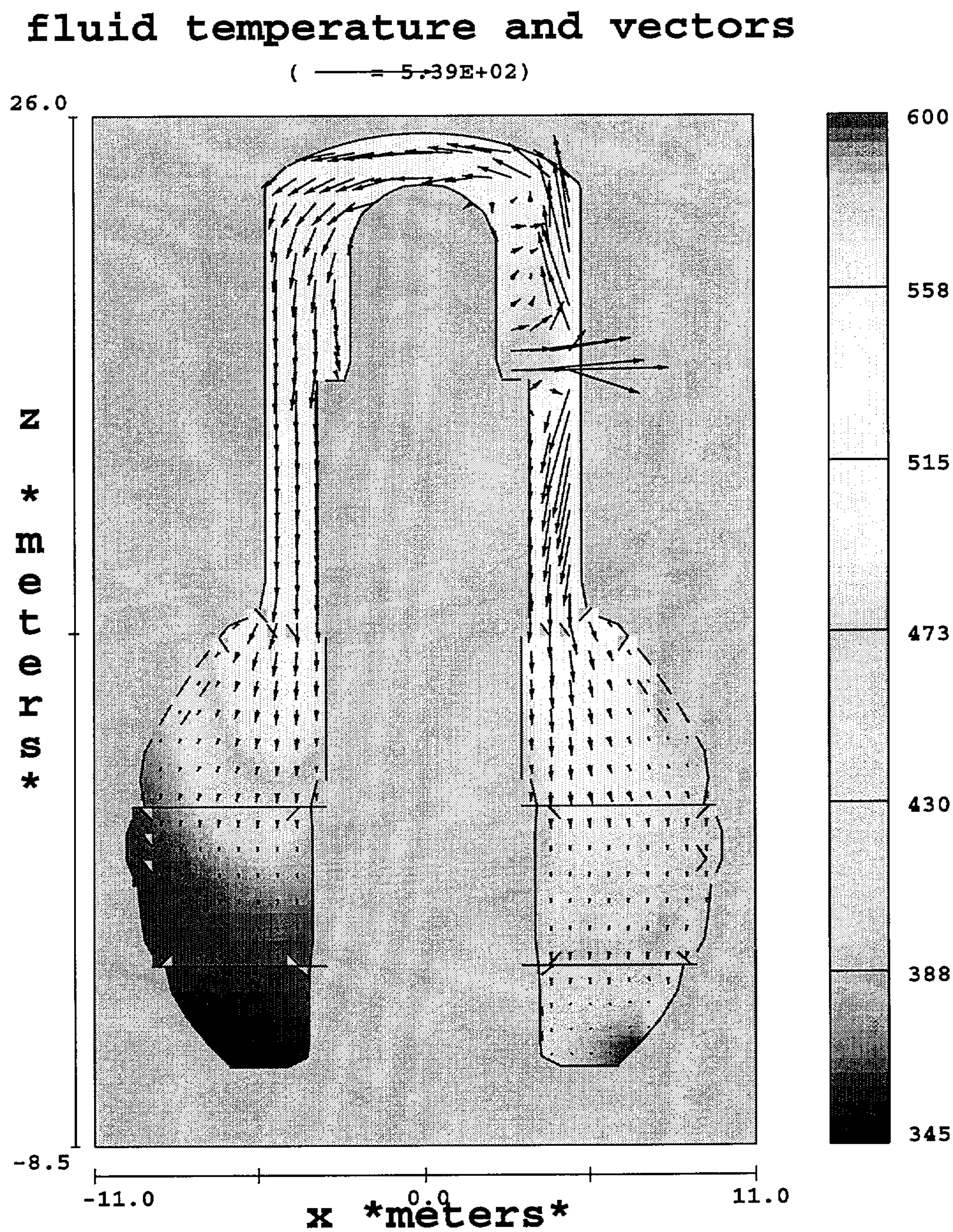


Figure 4-5. CFD code predictions for quasi-steady flow patterns that exist in the drywell following a MSLB.

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:

$$F(t) = \left(M_o - M(t)\right) \Big/ M_o \equiv 1 - e^{-(t - T_{vent})/\tau} \tag{4-1}$$

where,

F(t)	=	fraction of initial inventory transported in t seconds.
M_o	=	= debris mass inventory in the drywell at t=0,
M	=	debris mass inventory in the drywell at t,
T_{vent}	=	time required to clear vents/downcomers (0.5 –1.0 s for Mark I)
τ	=	turnover time[7] (3.4, 4.2 and 5.4 seconds, for Mark I, II and III)

For a Mark I drywell (T_{vent} = 0.75 s and τ = 3.4 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[8] 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

[7] 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)".

[8] 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[9] 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[10]. 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 (≈ 75-µm water film) and saturated (≈ 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 µm 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.
5. *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

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

Using T_{vent} = 0.5 s and τ = 3.4 s, F^{s}_{2sec} 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.
8. *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

[9] 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 µm in diameter.

[10] Saturation condition corresponds to a situation in which addition of water by condensation is off-set by film drainage by gravitational and entrainment mechanisms.

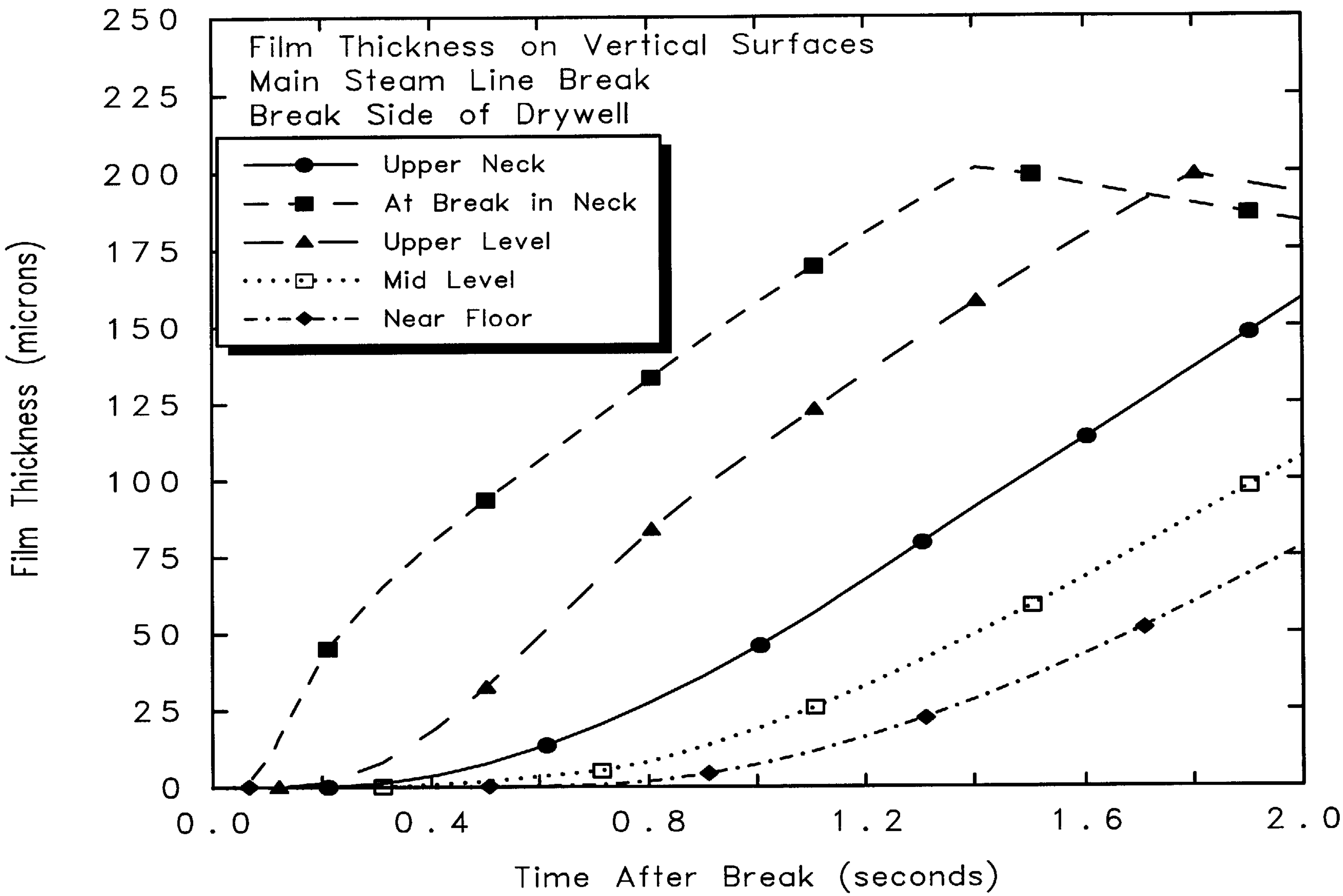


Figure 4-6. Liquid film build-up on drywell structures due to steam condensation.

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^s_{sb} and X^s_{so} in Figure 4-1. The remaining factors (X^s_{en}, X^s_{sa}, and X^s_{df}) 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^i_{en}, X^i_{sa}, X^i_{sb}, X^i_{so}, and X^i_{df} 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. Implicitly, it was assumed 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

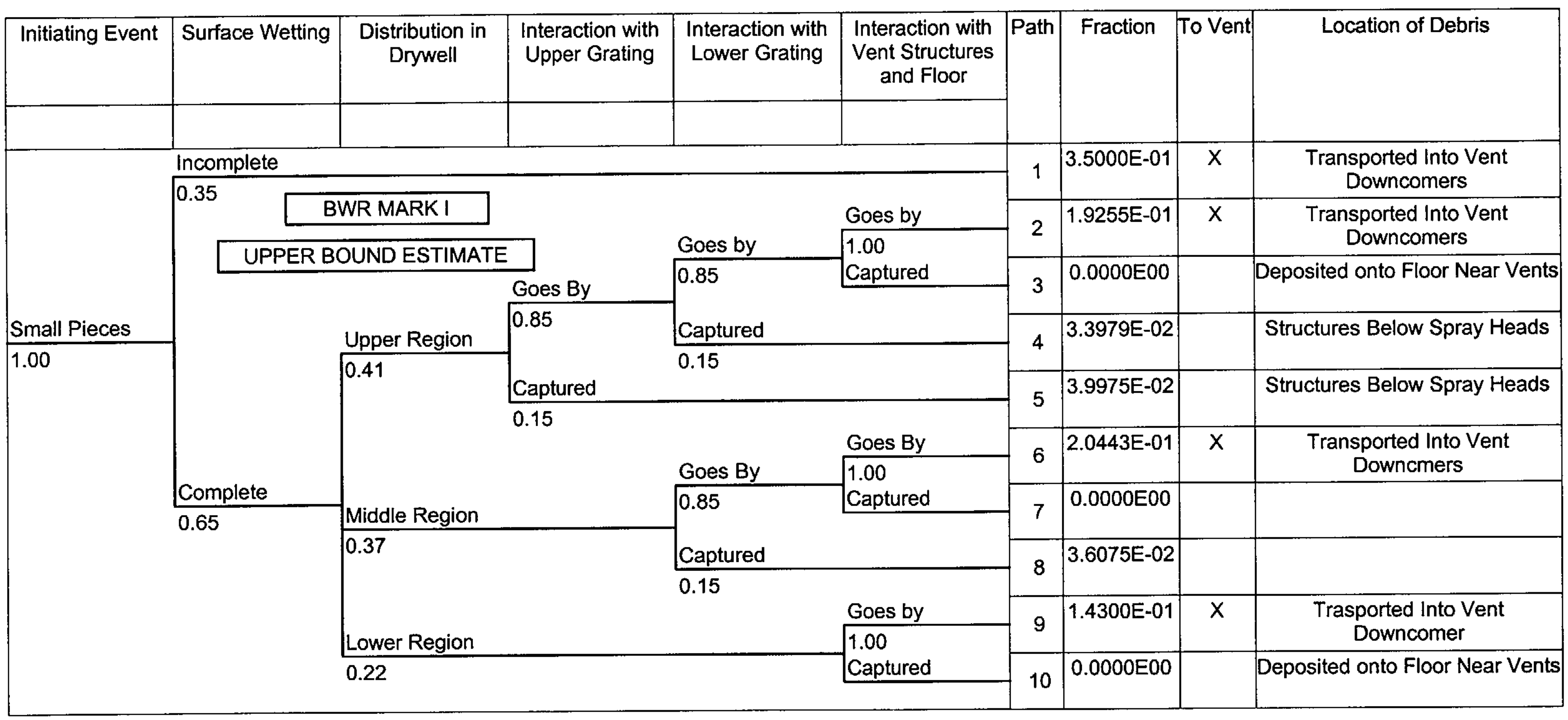


Figure 4-7. Secondary logic tree used to evaluate upper bound debris distribution after blowdown.

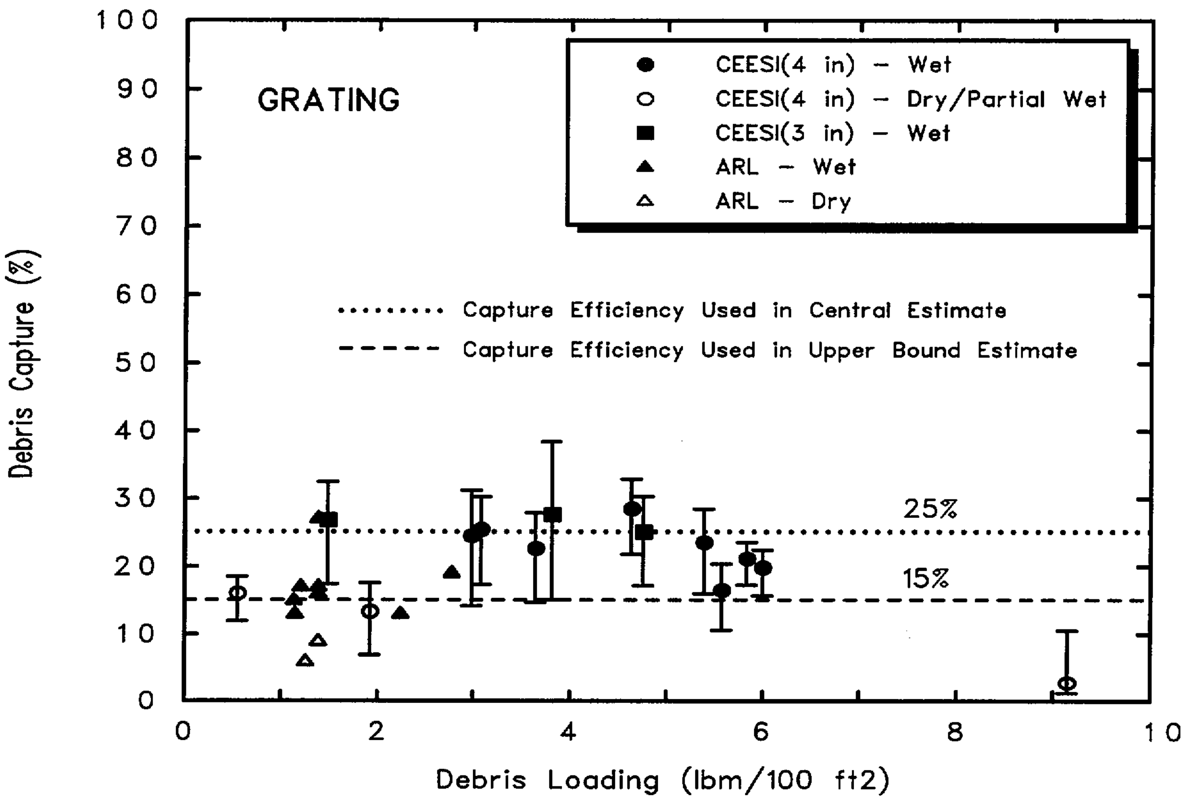
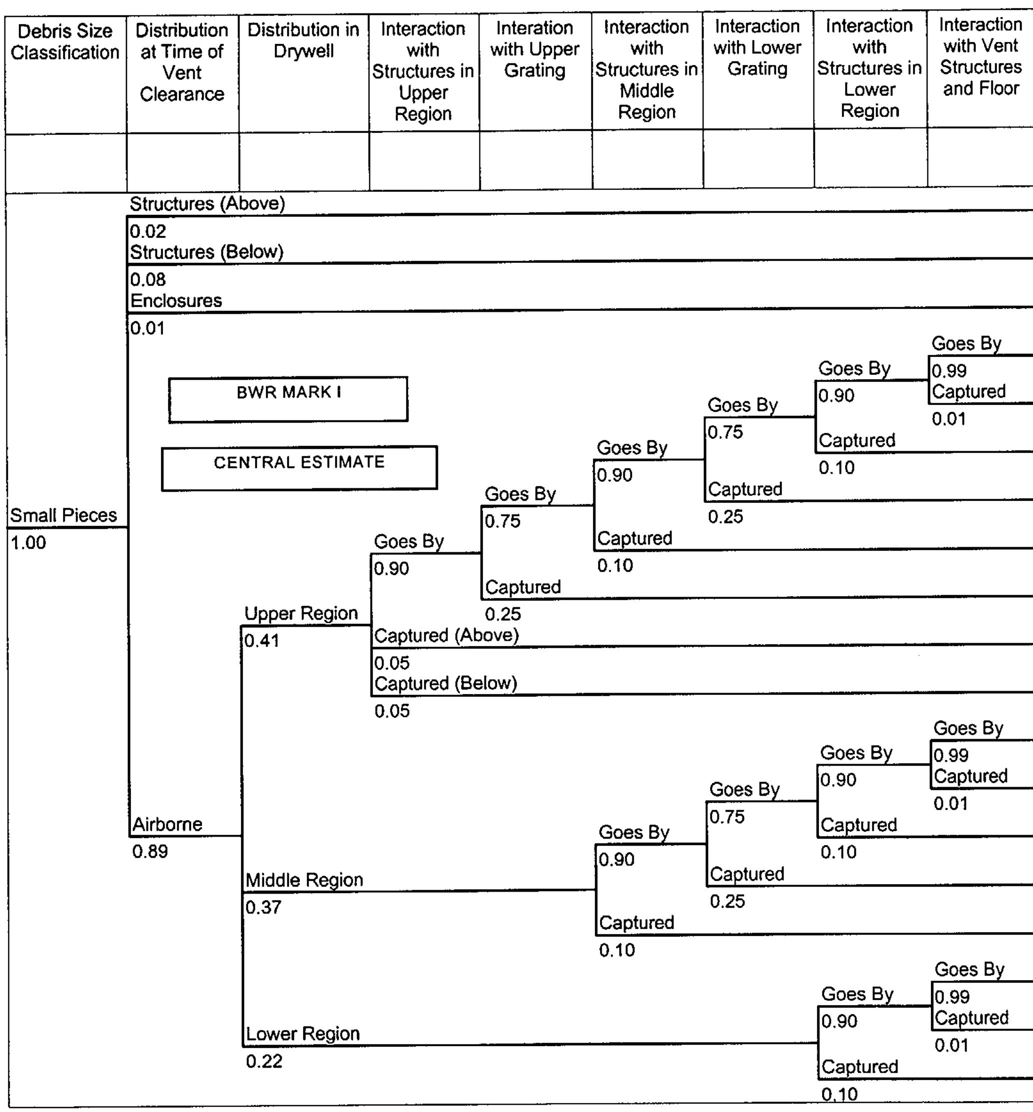


Figure 4-8. Efficiency for capture of small debris by floor grating.



Path	Fraction	To Vent	Location of Debris
1	2.0000E-02		Structures Above Spray Heads
2	8.0000E-02		Structures Below Spray Heads
3	1.0000E-02		Enclosures
4	1.4814E-01	X	Transported Into Vent Downcomers
5	1.4963E-03		Deposited onto Floor Near Vents
6	1.6626E-02		Structures Below Spray Heads
7	5.5419E-02		Structures Below Spray Heads
8	2.4631E-02		Structures Below Spray Heads
9	8.2103E-02		Structures Below Spray Heads
10	1.8245E-02		Structures Above Spray Heads
11	1.8245E-02		Structures Below Spray Heads
12	1.9805E-01	X	Transported Into Vent Downcomers
13	2.0005E-03		Deposited onto Floor Near Vents
14	2.2228E-02		Structures Below Spray Heads
15	7.4092E-02		Structures Below Spray Heads
16	3.2930E-02		Structures Below Spray Heads
17	1.7446E-01	X	Transported Into Vent Downcomers
18	1.7622E-03		Deposited onto Floor Near Vents
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.

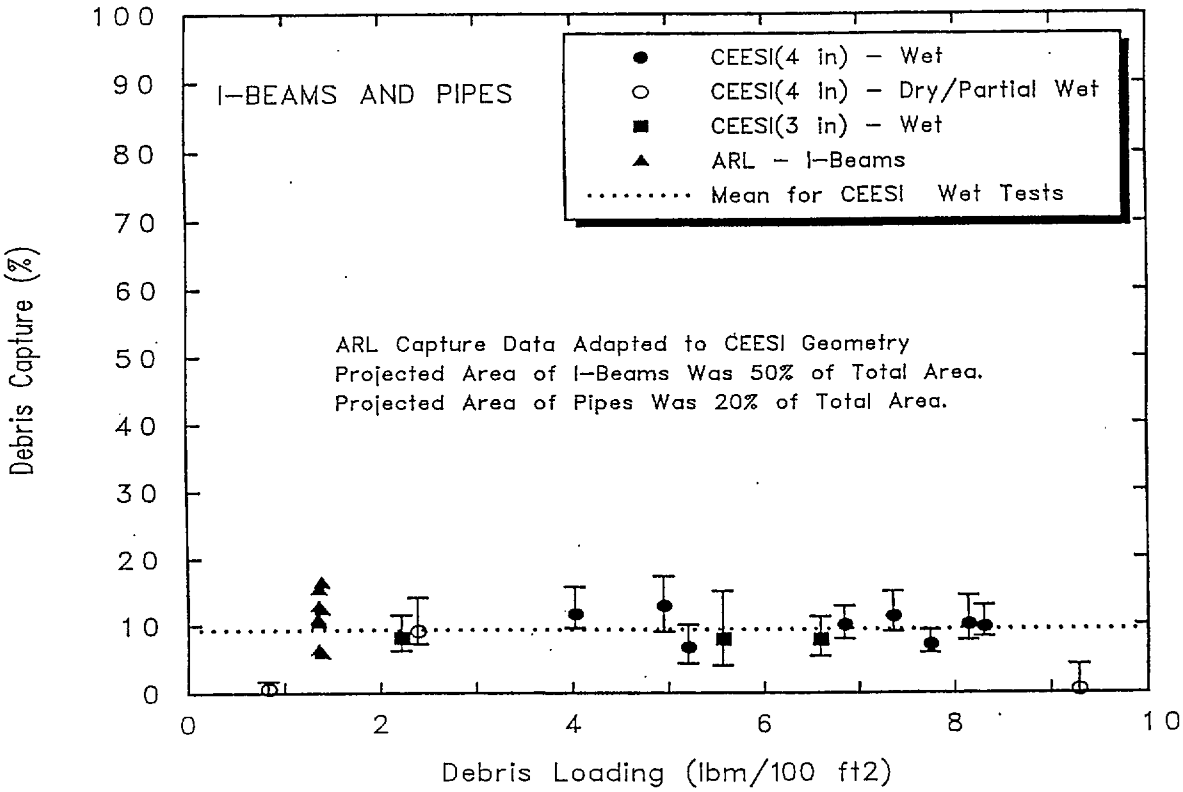


Figure 4-10. Structure capture fraction.

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^s_{en}), 1% on *drywell floor or vents* (X^s_{df}), 4% on *structures-above* (X^s_{sa}), 10% on *structures-break* (X^s_{sb}) and 32% on *structures-other* (X^s_{so}).

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.[11] 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,

[11] 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. Re-entrainment 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 *structures-other* 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*[12]. 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^s_{so} and Y^s_{sb}, and 0.1 for Y^s_{sa}. Also, a value of 0.02 was used for Y^1_{so} and Y^1_{sb}.

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

[12] In this particular case no debris were deposited on the *structure-above* 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^s_{so} and Y^s_{sb}, and 0.01 for Y^s_{sa}. In addition, a value of 0.01 was used for Y^1_{so} and Y^1_{sb}.

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

$$F^i_{Floor} = X^i_{sa} \bullet Y^i_{sa} + X^i_{sb} \bullet Y^i_{sb} + X^i_{so} \bullet Y^i_{so} + X^i_{df} \quad (2.5)$$

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[13] $< 10^{-4}$ ft^2/s^2) 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 re-suspend 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[14] 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^s) in Figure 4-1.

---

[13] Turbulence kinetic energy is an indicator of residual pool turbulence and is expressed as ½ U^2_{rms}; where U_{rms} is the root-mean-square velocity of the flow.

[14] 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.

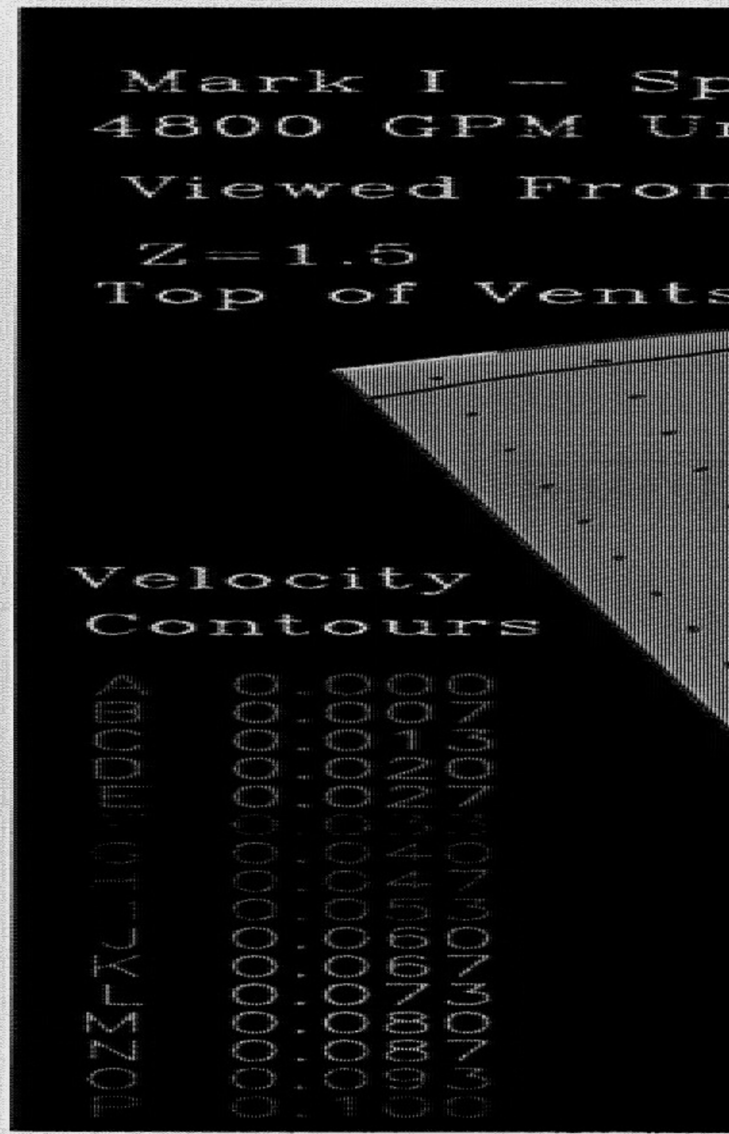


Figure 4-11. Flow velocit

Figure 4-12. Specifi

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

DEBRIS TRANSPORT RESULTS

Plant Design:	**MARK I**
Estimate:	**UPPER BOUND**
Break:	**MSL BREAK**
ECCS:	**ECCS THROTTLED**
Sprays:	**SPRAYS OPERATED**

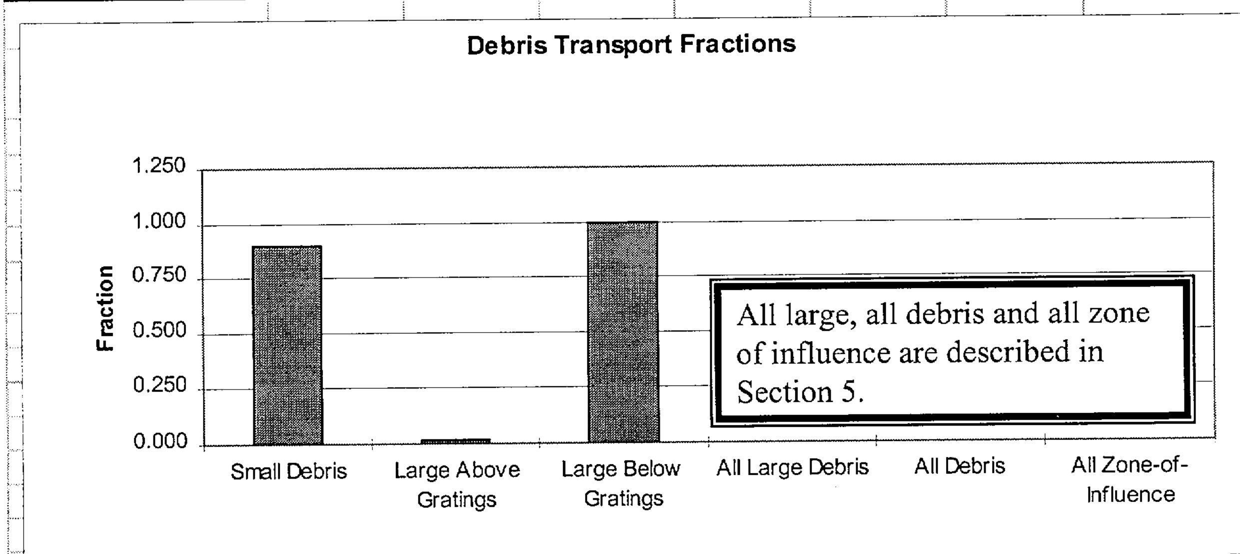
FIBROUS INSULATION

TREE QUANTIFICATION

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 DISTRIBUTIONS (Horizontal)

Debris Classification	Vents	Enclosures	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%



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 *large-below* 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.

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

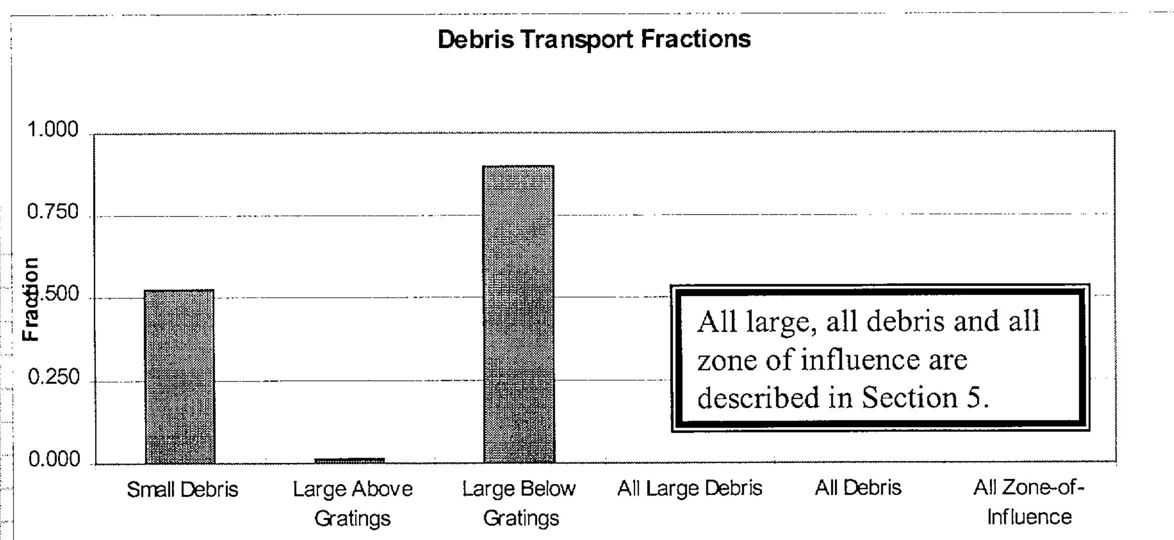
DEBRIS TRANSPORT RESULTS			
Plant Design:	MARK I		
Estimate:	CENTRAL ESTIMATE		FIBROUS INSULATION
Break:	MSL BREAK		
ECCS:	ECCS THROTTLED		
Sprays:	SPRAYS OPERATED		

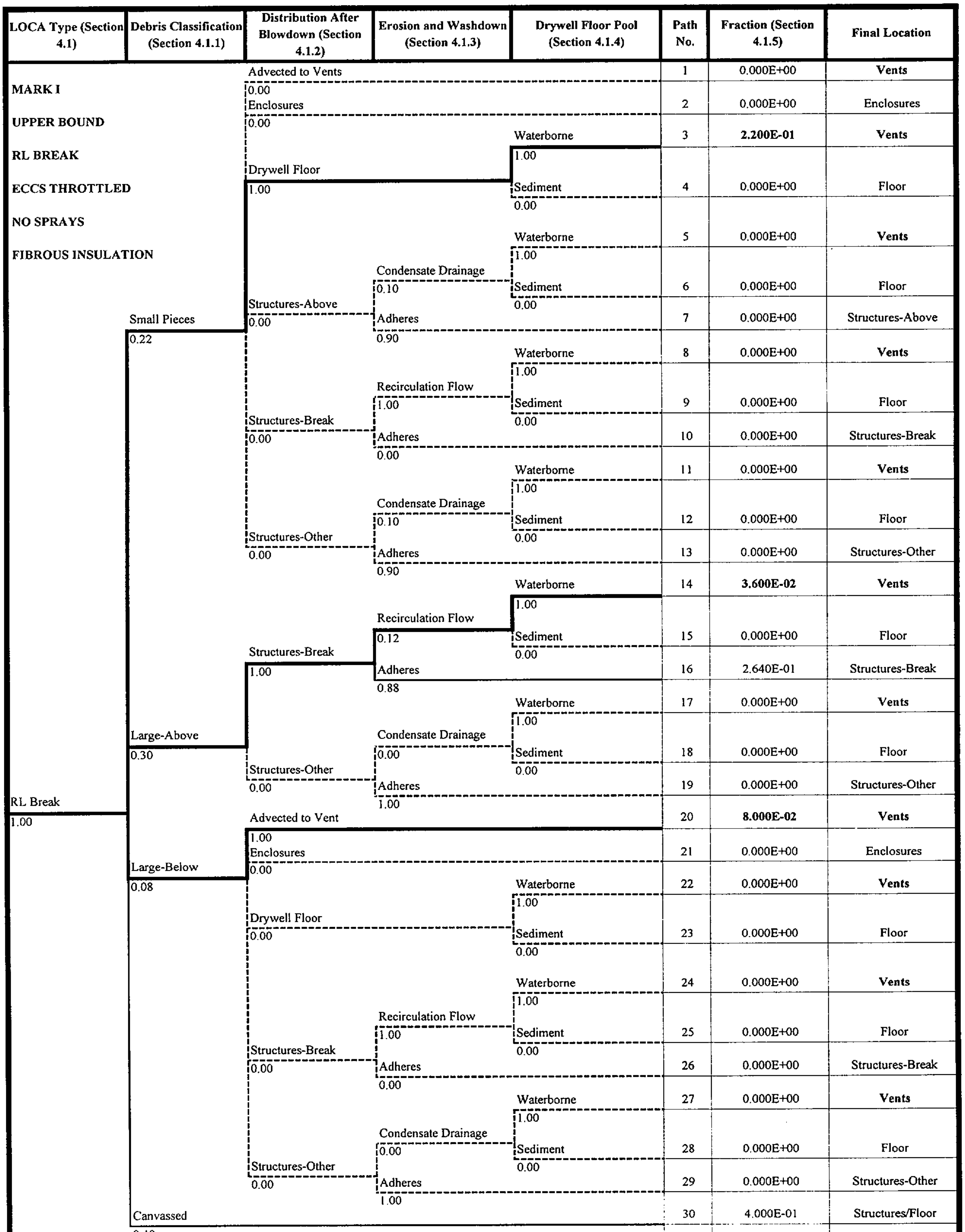
TREE QUANTIFICATION

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 DISTRIBUTIONS (Horizontal)

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%





note: Fractions are normalized to each debris class

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

MARK I
CENTRAL ESTIMATE
RL BREAK
ECCS THROTTLED
NO SPRAYS
FIBROUS INSULATION

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
RL Break 1.00	Small Pieces 0.22	Advected to Vents 0.46			1	**1.012E-01**	**Vents**
		Enclosures 0.01			2	2.200E-03	Enclosures
		Drywell Floor 0.20		Waterborne 1.00	3	**4.400E-02**	**Vents**
				Sediment 0.00	4	0.000E+00	Floor
		Structures-Above 0.02	Condensate Drainage 0.01	Waterborne 1.00	5	4.400E-05	**Vents**
				Sediment 0.00	6	0.000E+00	Floor
			Adheres 0.99		7	4.356E-03	Structures-Above
		Structures-Break 0.08	Recirculation Flow 1.00	Waterborne 1.00	8	**1.760E-02**	**Vents**
				Sediment 0.00	9	0.000E+00	Floor
			Adheres 0.00		10	0.000E+00	Structures-Break
		Structures-Other 0.23	Condensate Drainage 0.01	Waterborne 1.00	11	5.060E-04	**Vents**
				Sediment 0.00	12	0.000E+00	Floor
			Adheres 0.99		13	5.009E-02	Structures-Other
	Large-Above 0.34	Structures-Break 0.15	Recirculation Flow 0.08	Waterborne 1.00	14	4.080E-03	**Vents**
				Sediment 0.00	15	0.000E+00	Floor
			Adheres 0.92		16	4.692E-02	Structures-Break
		Structures-Other 0.85	Condensate Drainage 0.00	Waterborne 1.00	17	0.000E+00	**Vents**
				Sediment 0.00	18	0.000E+00	Floor
			Adheres 1.00		19	2.890E-01	Structures-Other
	Large-Below 0.04	Advected to Vent 0.90			20	**3.600E-02**	**Vents**
		Enclosures 0.01			21	4.000E-04	Enclosures
		Drywell Floor 0.04		Waterborne 0.90	22	1.440E-03	**Vents**
				Sediment 0.10	23	1.600E-04	Floor
		Structures-Break 0.01	Recirculation Flow 0.50	Waterborne 1.00	24	2.000E-04	**Vents**
				Sediment 0.00	25	0.000E+00	Floor
			Adheres 0.50		26	2.000E-04	Structures-Break
		Structures-Other 0.04	Condensate Drainage 0.00	Waterborne 1.00	27	0.000E+00	**Vents**
				Sediment 0.00	28	0.000E+00	Floor
			Adheres 1.00		29	1.600E-03	Structures-Other
	Canvassed 0.40				30	4.000E-01	Structures/Floor

note: Fractions are normalized to each debris class

Figure 4-14. Logic chart for central estimate of transport factor for a RLB scenario.

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 nozzle-diameters [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.

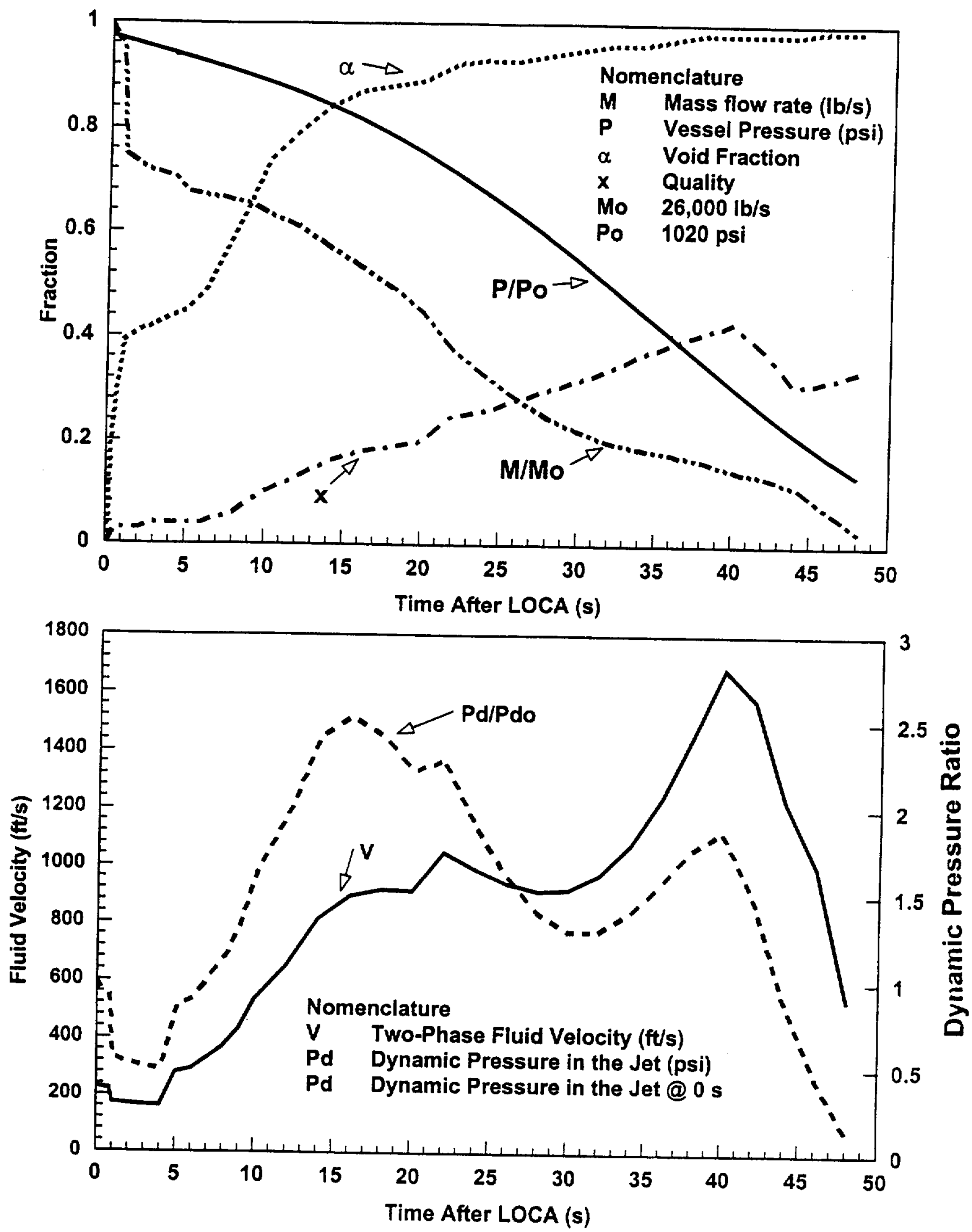


Figure 4-15. Blowdown data corresponding to a postulated recirculation line break in a BWR/4.

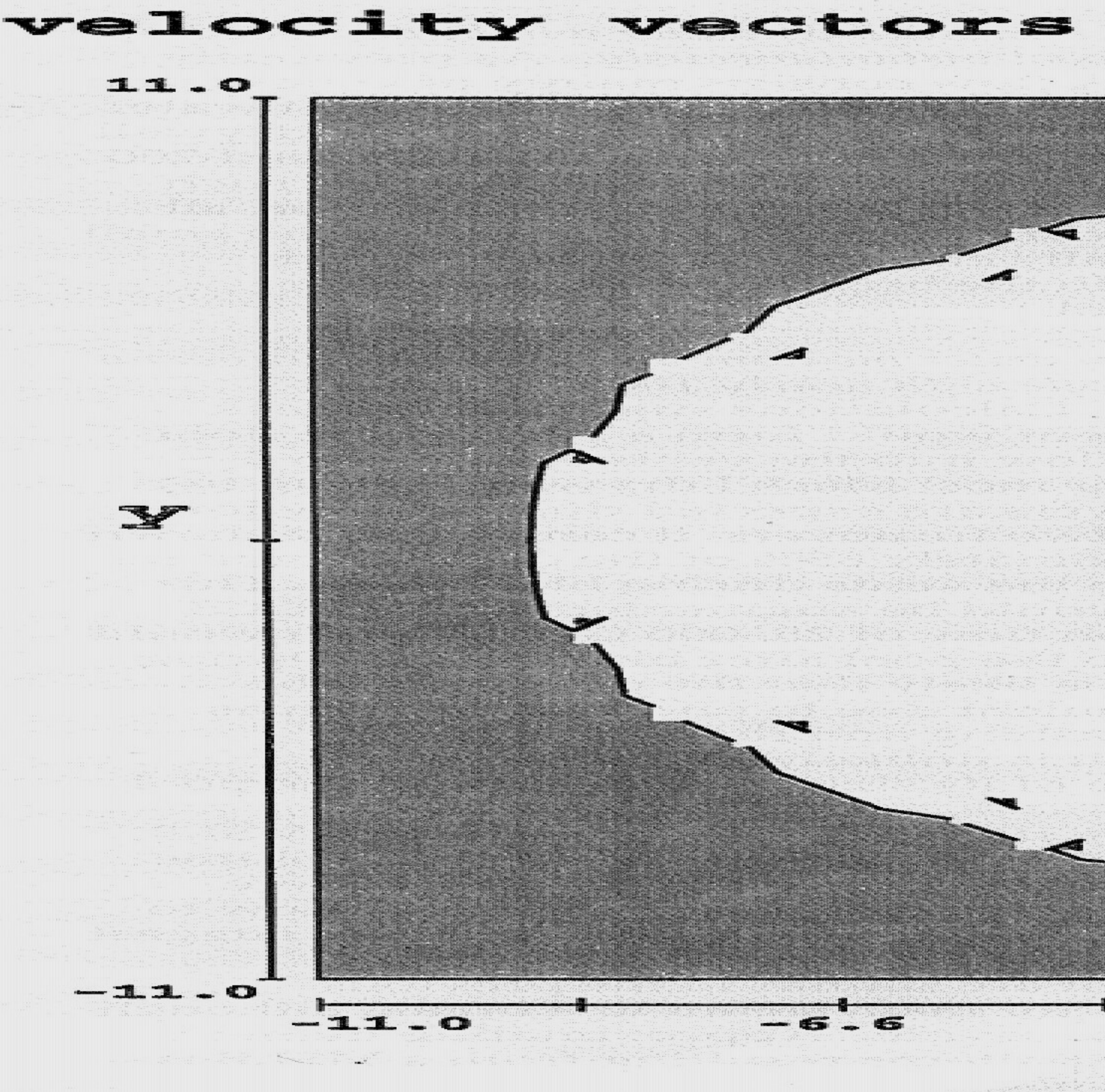


Figure 4-16. Expansion of

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 large-canvassed.

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 η_1, η_2, η_3, and η_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:

1. *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^2. 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.

2. *Advection by water medium would also occur over a 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[15]. 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.

[15] 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:

1. *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.

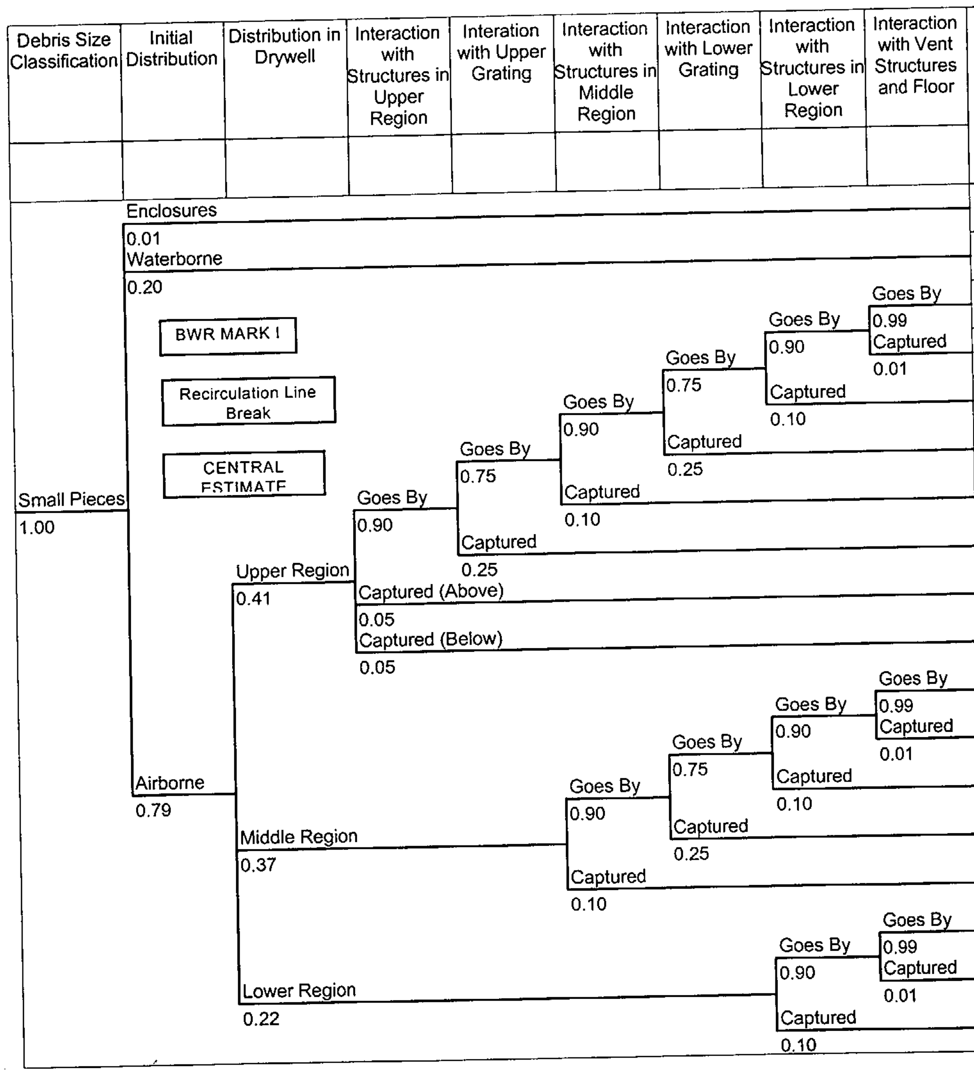
2. *Remaining 79% of the small debris would be transported similarly to a MSLB described in Section 4.1.2.2.* The important steps are as follows:
   a) The debris becomes inter-mixed with the drywell volume, with 41% of it above the upper grating, 37% between two gratings and 22% below the lowest grating.
   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^2 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.



Path	Fraction	To Vent	Location of Debris
1	1.0000E-02		Enclosures
2	2.0000E-01		Drywell Floor
3	1.3149E-01	X	Transported Into Vent Downcomers
4	1.3282E-03		Deposited onto Floor Near Vents
5	1.4758E-02		Structures Below Spray Heads
6	4.9192E-02		Structures Below Spray Heads
7	2.1863E-02		Structures Below Spray Heads
8	7.2878E-02		Structures Below Spray Heads
9	1.6195E-02		Structures Above Spray Heads
10	1.6195E-02		Structures Below Spray Heads
11	1.7580E-01	X	Transported Into Vent Downcomers
12	1.7757E-03		Deposited onto Floor Near Vents
13	1.9730E-02		Structures Below Spray Heads
14	6.5768E-02		Structures Below Spray Heads
15	2.9230E-02		Structures Below Spray Heads
16	1.5486E-01	X	Transported Into Vent Downcomers
17	1.5642E-03		Deposited onto Floor Near Vents
18	1.7380E-02		Structures Below Spray Heads

Figure 4-17. Logic used to estimate distribution as the end of blowdown.

4.2.3.1 Key Findings

1. *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^2. 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.

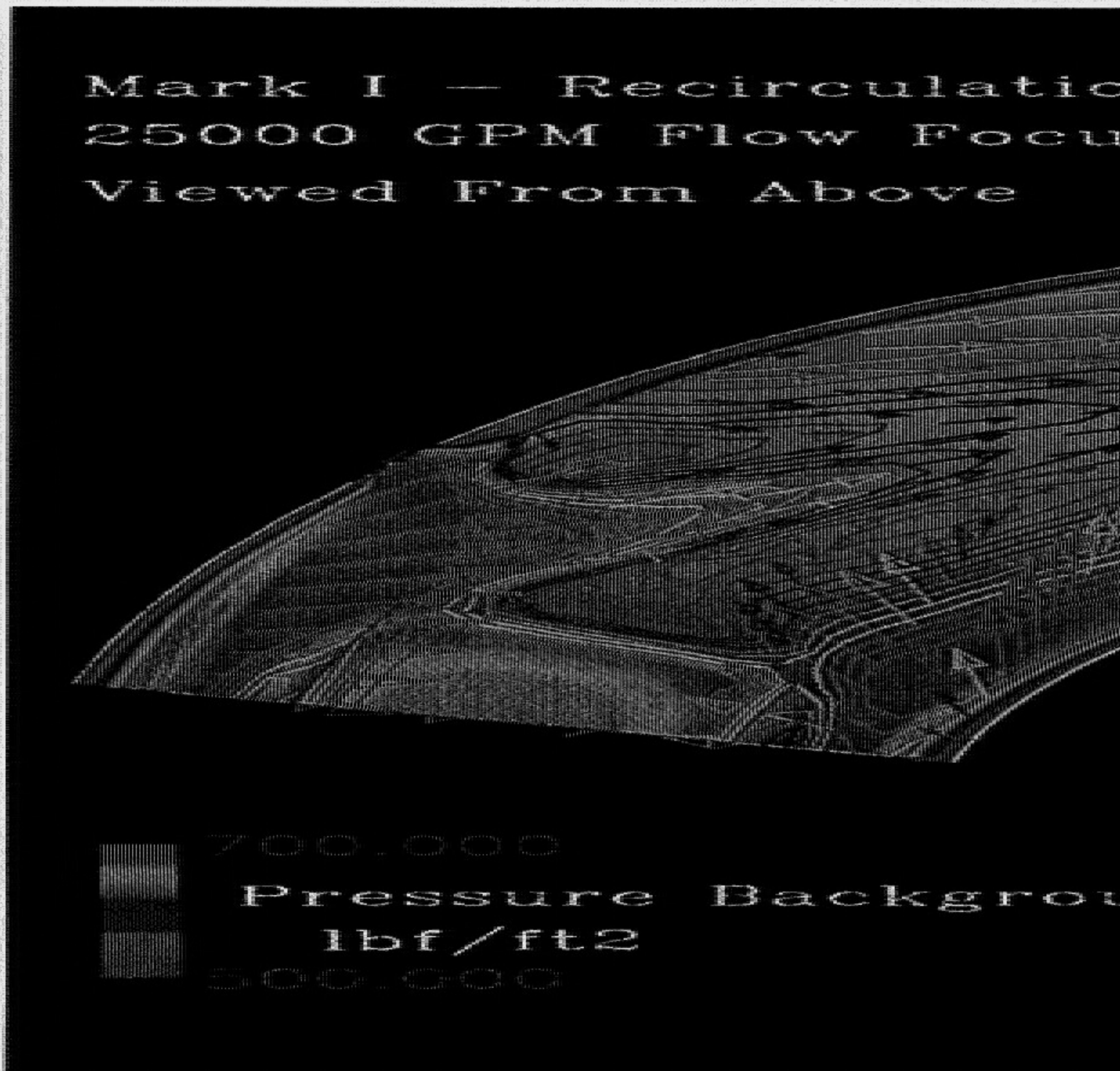


Figure 4-18. Flow veloc

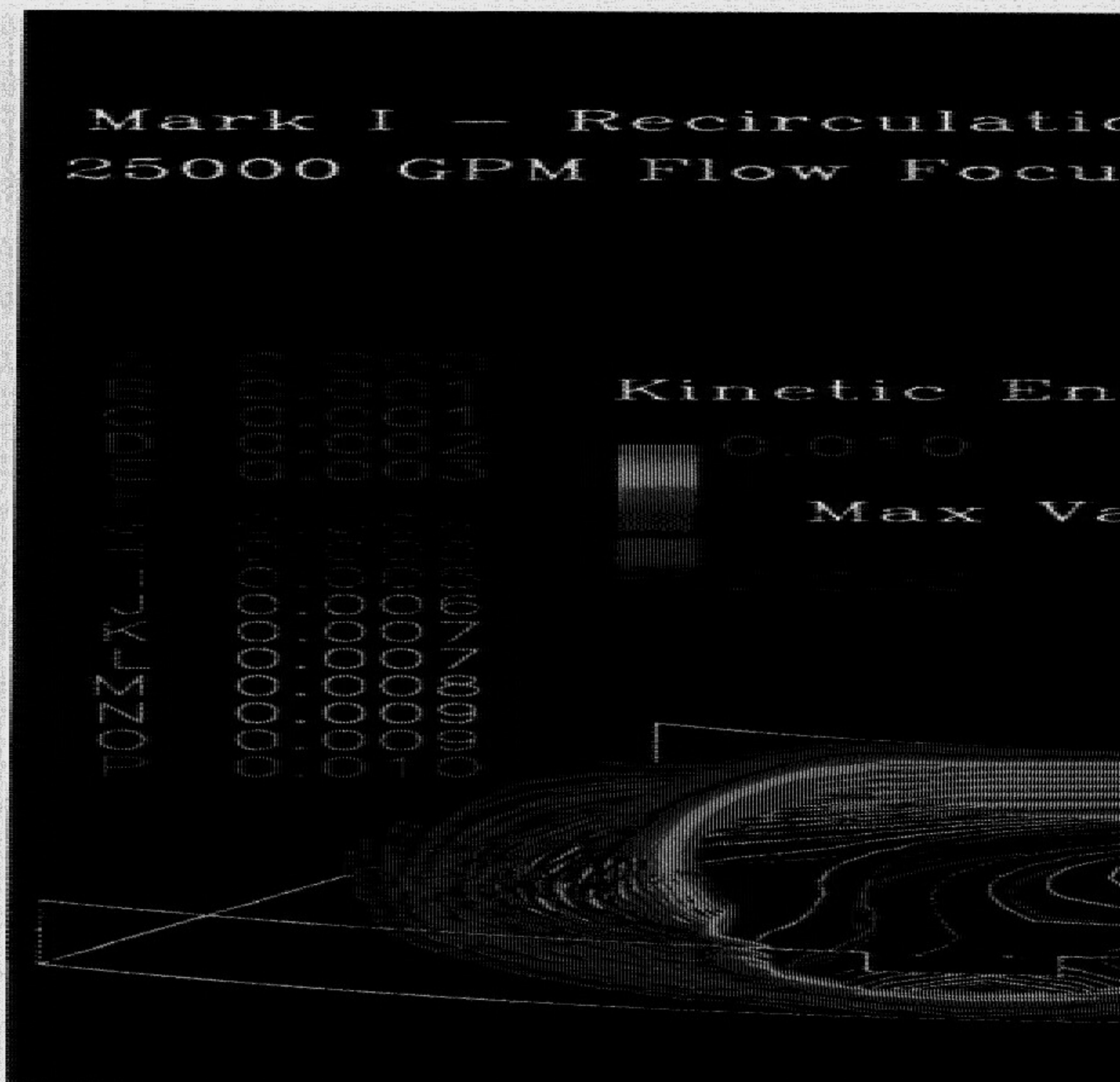


Figure 4-19. Specific kine

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

4.1 D. V. Rao, et al., "Drywell Debris Transport Study," Draft Phase 1 Letter Report, SEA 96-3105-010-A;2, September 27, 1996.

4.2 Boiling Water Reactor Owners' Group, "Utility Resolution Guidance for ECCS Suction Strainer Blockage," NEDO-32686, 1996

4.3 D. V. Rao, et al., "Drywell Debris Transport Study: Experimental Work, "NUREG/CR-6369, Supplement 1, Science and Engineering Associates, Inc., SEA 97-3105-A:15, September 1997.

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.

4.8 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.

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

DEBRIS TRANSPORT RESULTS							
Plant Design:	MARK I						
Estimate:	UPPER BOUND			FIBROUS INSULATION			
Break:	RL BREAK						
ECCS:	ECCS THROTTLED						
Sprays:	NO SPRAYS						
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 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%	

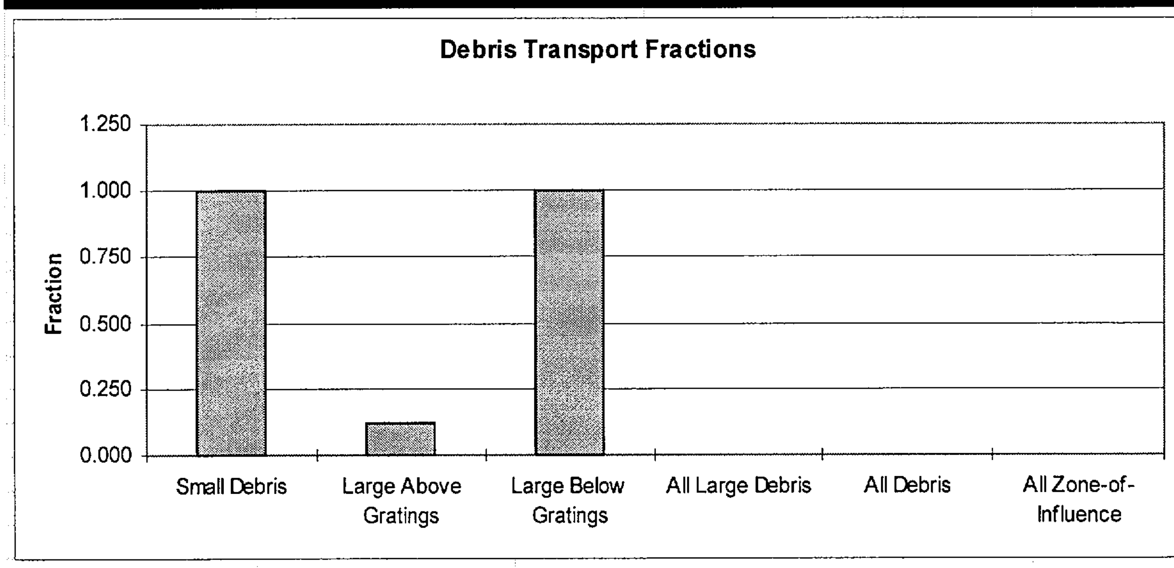
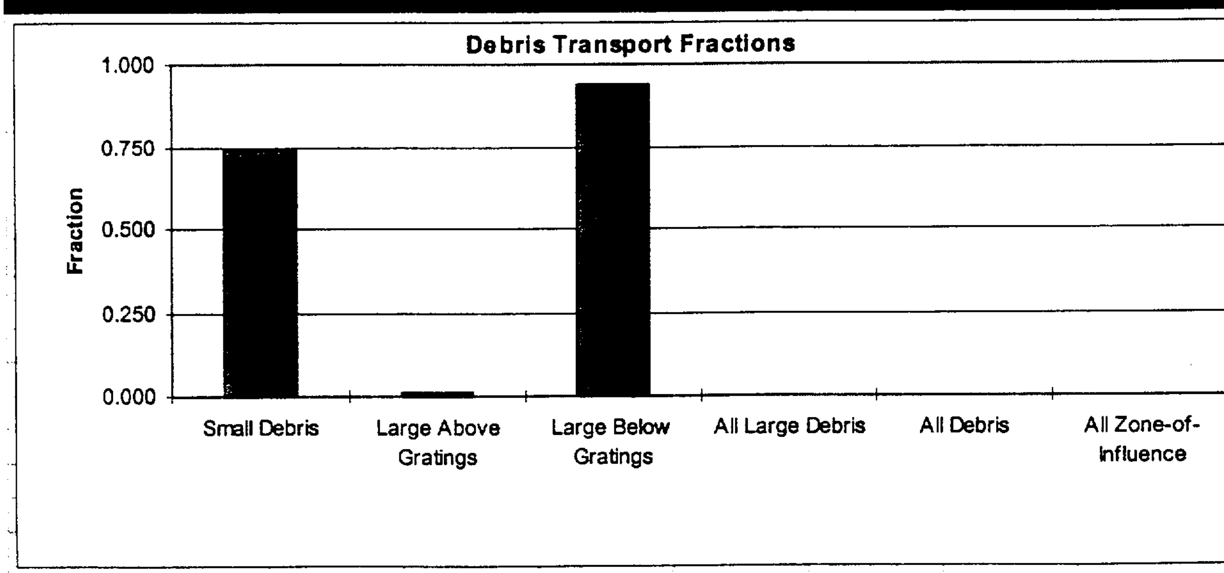


Table 4-4. Central estimate of debris transport fractions for a RLB scenario.

DEBRIS TRANSPORT RESULTS							
Plant Design:	MARK I						
Estimate:	CENTRAL ESTIMATE			FIBROUS INSULATION			
Break:	RL BREAK						
ECCS:	ECCS THROTTLED						
Sprays:	NO SPRAYS						
TREE QUANTIFICATION							
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 DISTRIBUTIONS (Horizontal)							
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%	



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:

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

where

Q_{pool}	is the quantity of debris reaching the suppression pool (ft^3)
Q_{ZOI}	is the quantity of insulation contained in the zone of influence (ft^3)
η_i	is the fraction of Q_{ZOI} destroyed into small pieces
η_2	is the fraction of Q_{ZOI} destroyed into large pieces, but generated above the lowest floor grating
η_3	is the fraction of Q_{ZOI} destroyed into large pieces, but generated below the lowest floor grating
η_4	is the fraction of Q_{ZOI} destroyed into large pieces covered in canvass
F^{ZOI}	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., η_1, η_2, η_3, and η_4) can be directly entered into them and the resulting values under the heading 'Fractions' can be summed to calculate F^{ZOI}.

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, η_1, η_2, η_3, and η_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, η_1, η_2, η_3, and η_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 η_1, η_2, η_3, and η_{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 for F^{ZOI} is 0.286, whereas the central 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.

BWROG Distribution of Generated Debris

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

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 (η_1)	0.22	0.22
Large Pieces (η_2)	0.30	0.34
Large Pieces – Below (η_3)	0.08	0.04
Canvassed (η_4)	0.40	0.40

postulated in this study. As shown in this table, the upper bound estimates for F^{ZOI} for a Mark I MSLB between 0.28 and 0.31 depending on the scenario considered. For a recirculation line break, F^{ZOI} 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.

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

DEBRIS TRANSPORT RESULTS							
Plant Design:	**MARK I**						
Estimate:	**UPPER BOUND**			**FIBROUS INSULATION**			
Break:	**MSL BREAK**						
ECCS:	**ECCS THROTTLED**						
Sprays:	**SPRAYS OPERATED**						
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)							
Debris Classification	**Vents**	**Enclosures**	**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%	
All Large Pieces	22.63%	0.00%	0.00%	0%	19.34%	58.03%	
All Debris	47.37%	0.00%	3.63%	0.00%	12.25%	36.75%	
RELATIVE CONTRIBUTIONS (Vertical)							
Debris Classification	**Vents**	**Enclosures**	**Floor**	**Structures Above**	**Structures Break**	**Structures 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%	

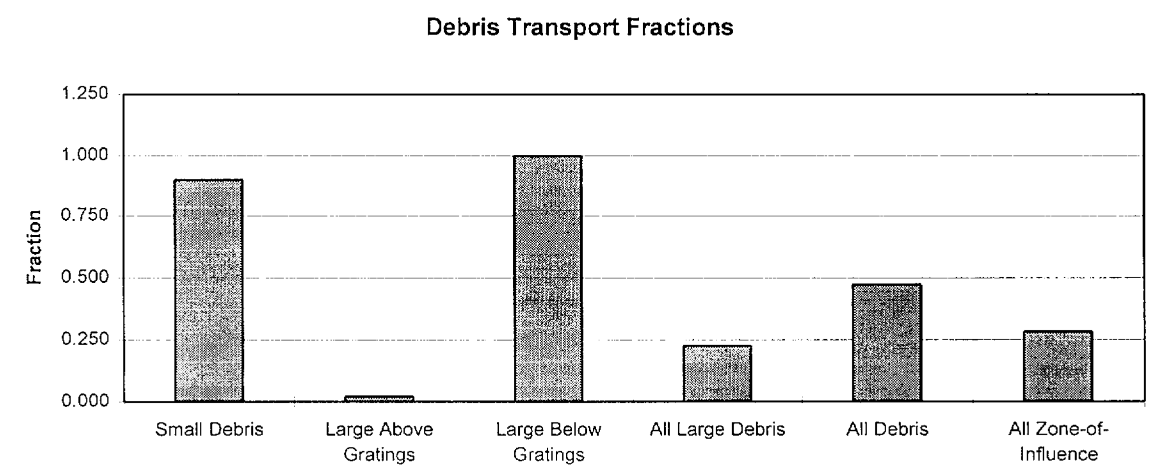


Table 5-3. Central estimate for debris transport based on BWROG size distribution data.

DEBRIS TRANSPORT RESULTS

Plant Design:	MARK I	
Estimate:	CENTRAL ESTIMATE	FIBROUS INSULATION
Break:	MSL BREAK	
ECCS:	ECCS THROTTLED	
Sprays:	SPRAYS OPERATED	

TREE QUANTIFICATION

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 DISTRIBUTIONS (Horizontal)

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%
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 CONTRIBUTIONS (Vertical)

Debris Classification	Vents	Enclosures	Floor	Structures Above	Structures Break	Structures 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%

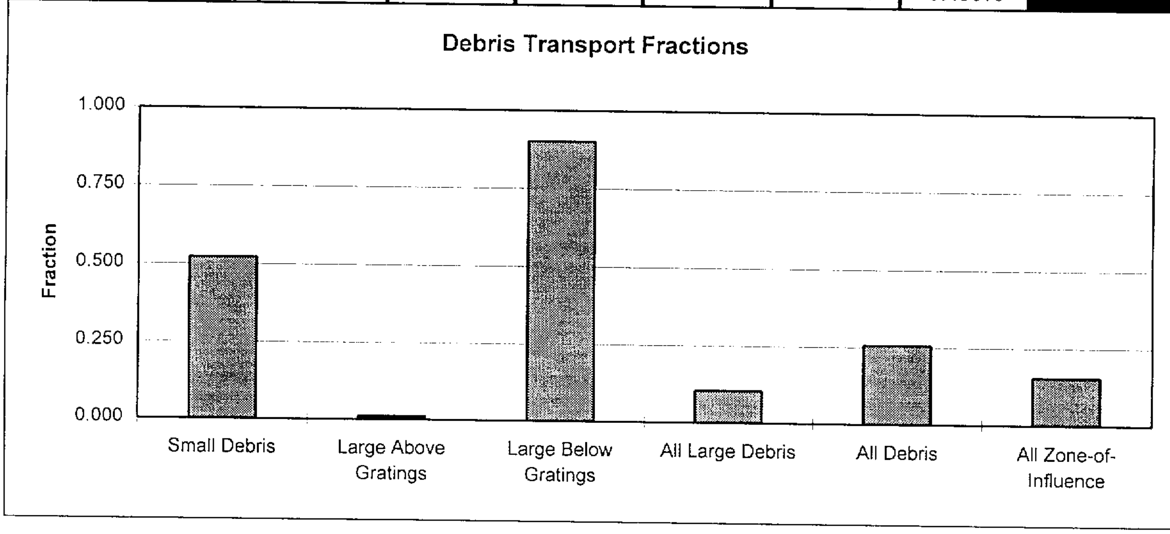


Table 5-4. Central and upper bound estimates for debris transport factors based on BWROG size distribution data.

DEBRIS TRANSPORT FRACTIONS															
Break	ECCS	Sprays	Small		Large Above		Large Below		All Large		All Debris		All ZOI	
			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															
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

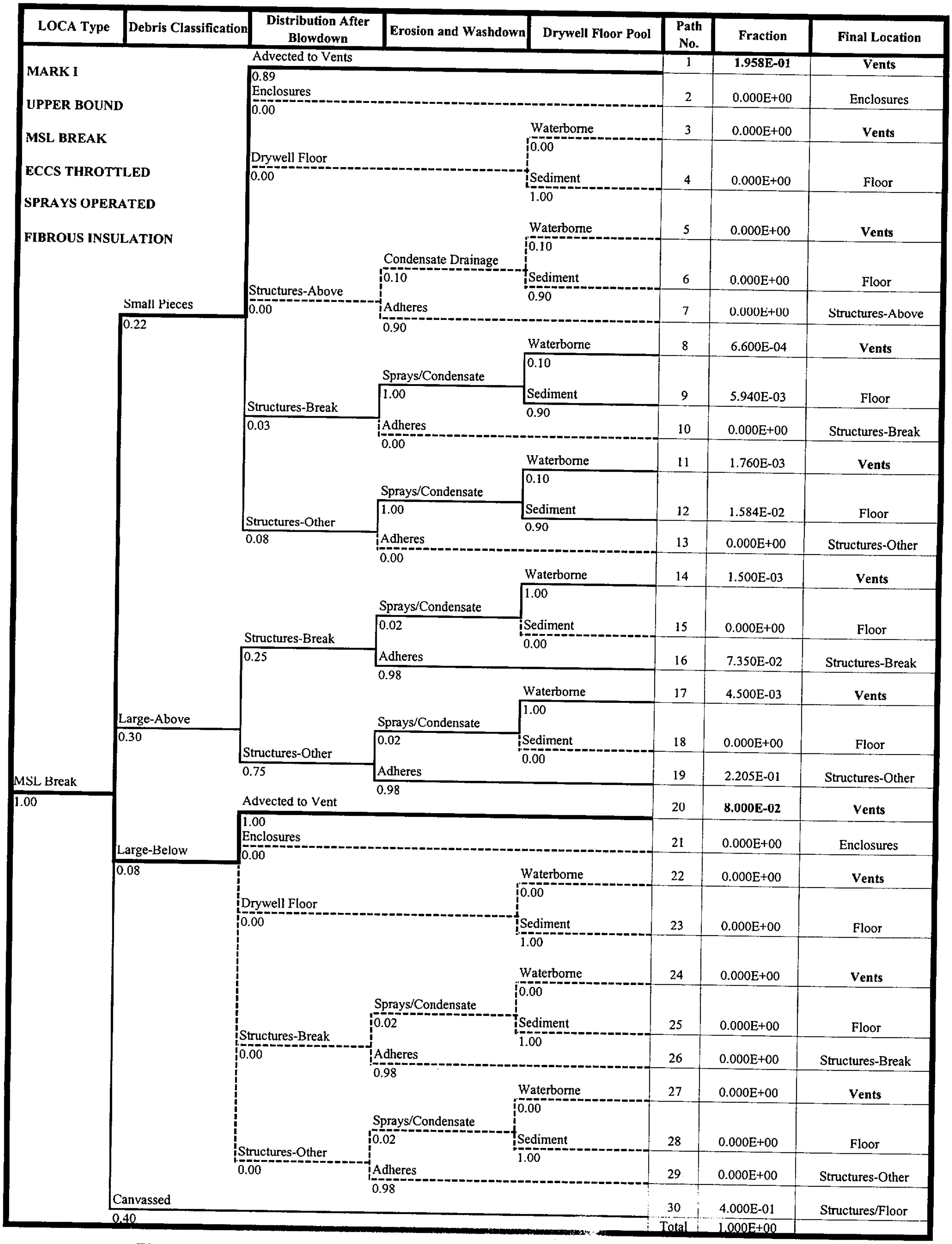


Figure 5-1. Upper bound logic chart with BWROG size distribution data.

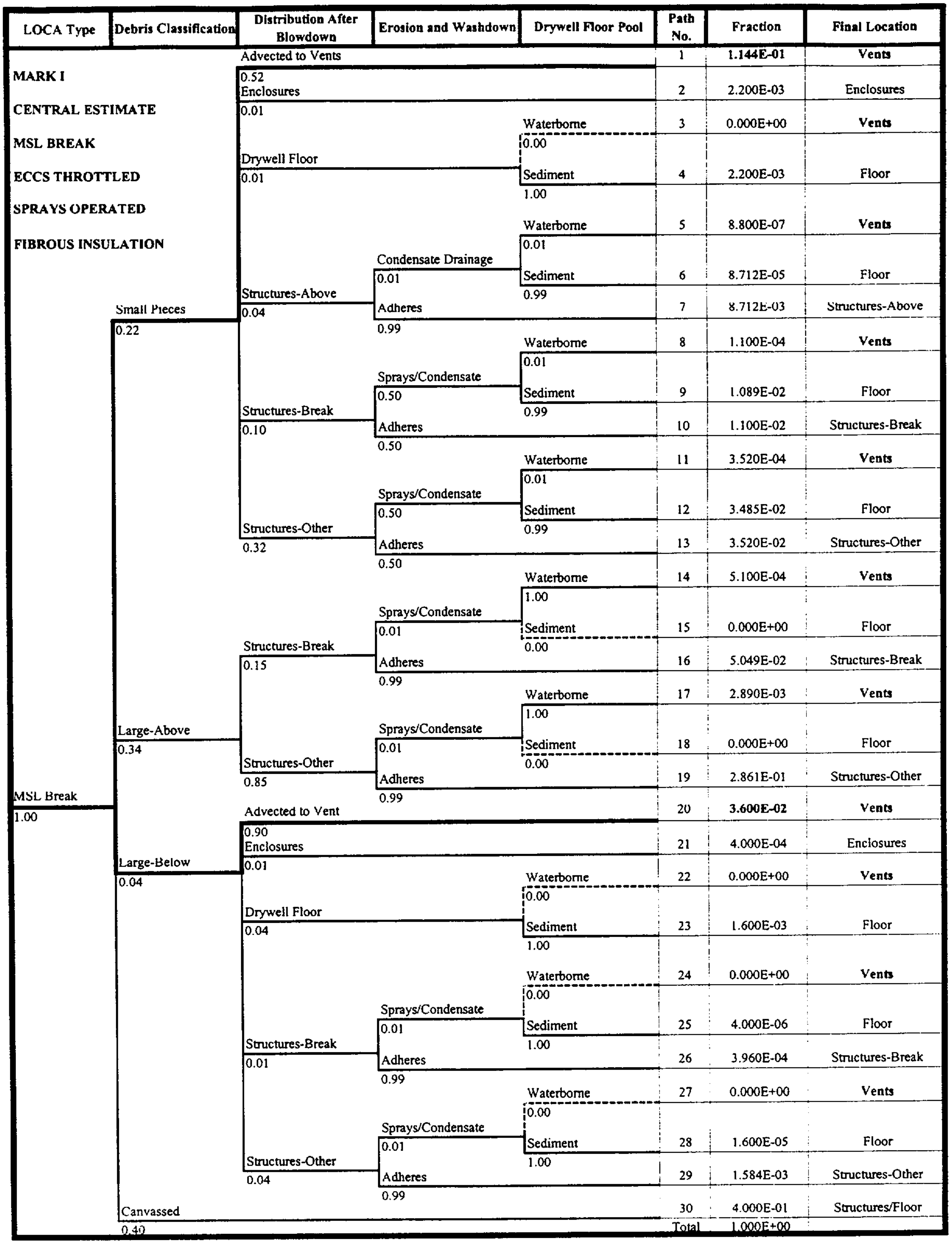


Figure 5-2. Central estimate logic chart with BWROG size distribution data.

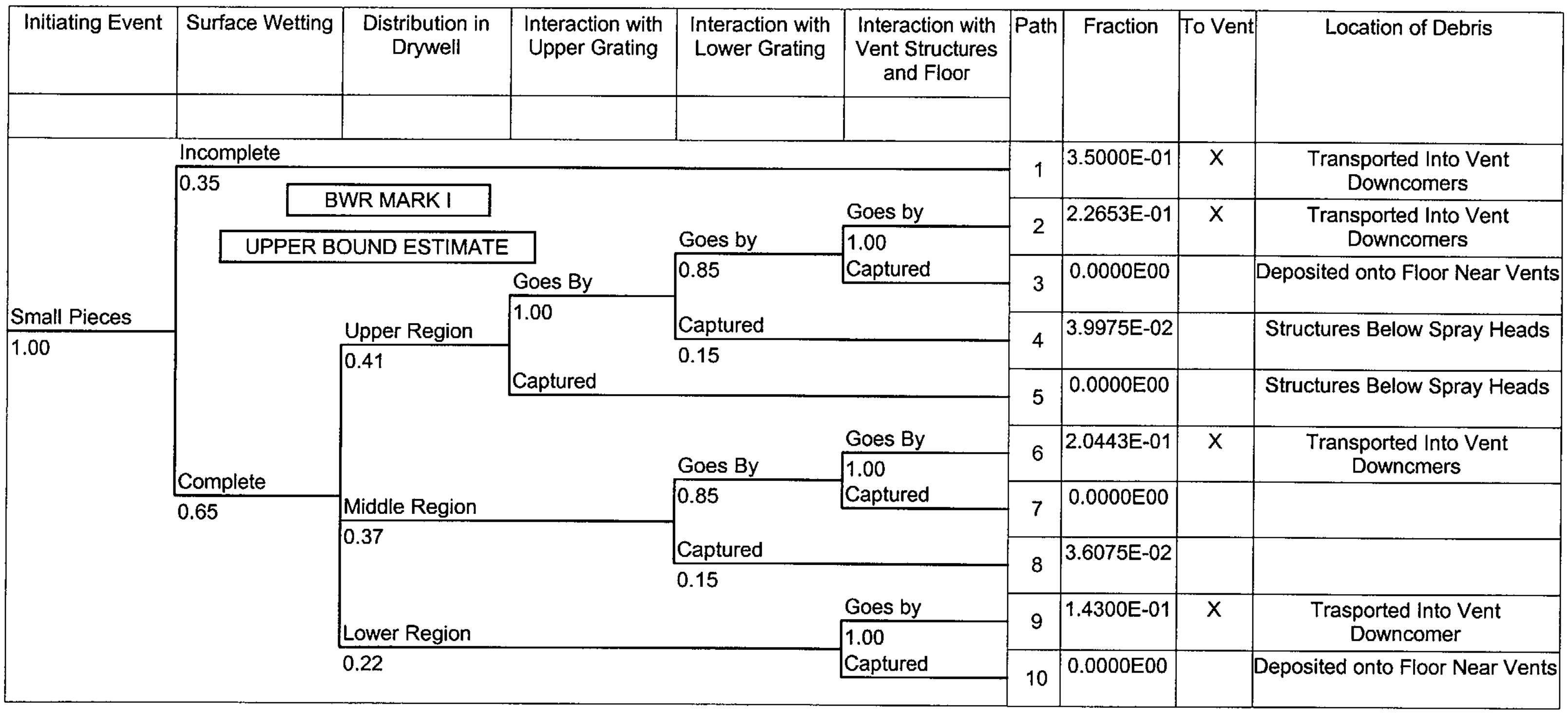


Figure 5-3. Effect of upper floor grating on upper bound estimate of debris distribution after blowdown.

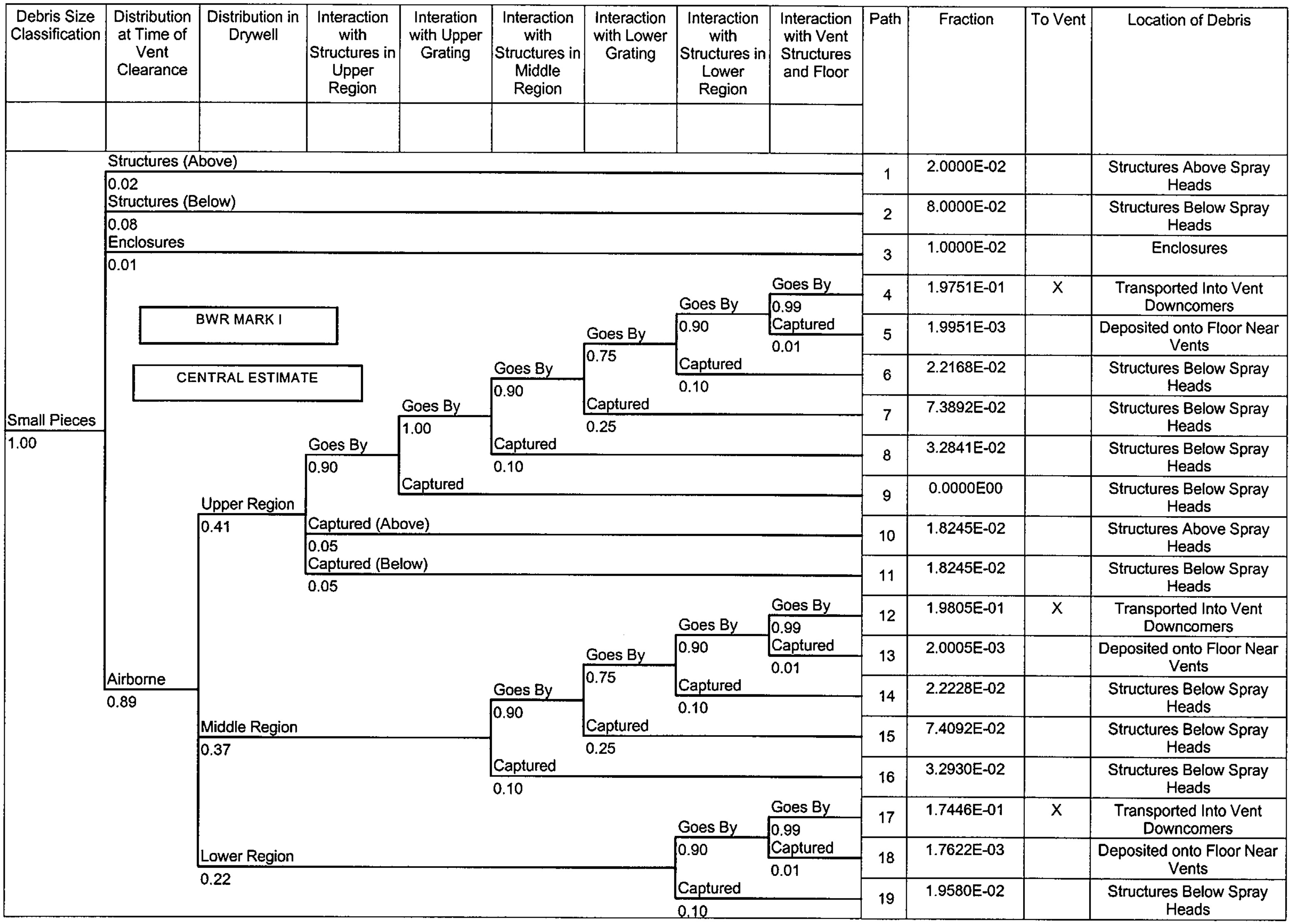


Figure 5-4. Effect of upper grating on central estimate of debris distribution after blowdown.

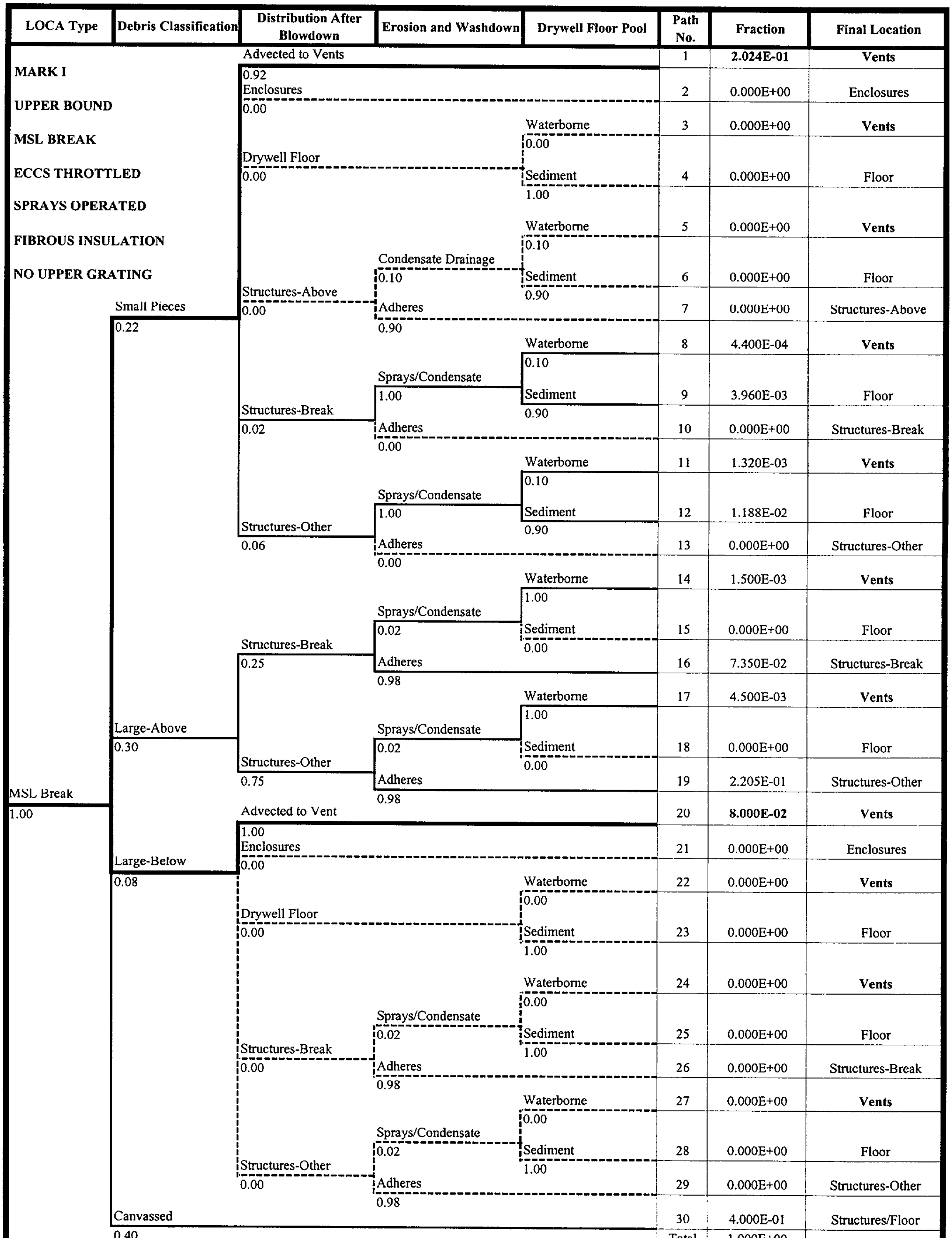


Figure 5-5. Upper bound logic tree for debris transport in a Mark I drywell with one floor grating.

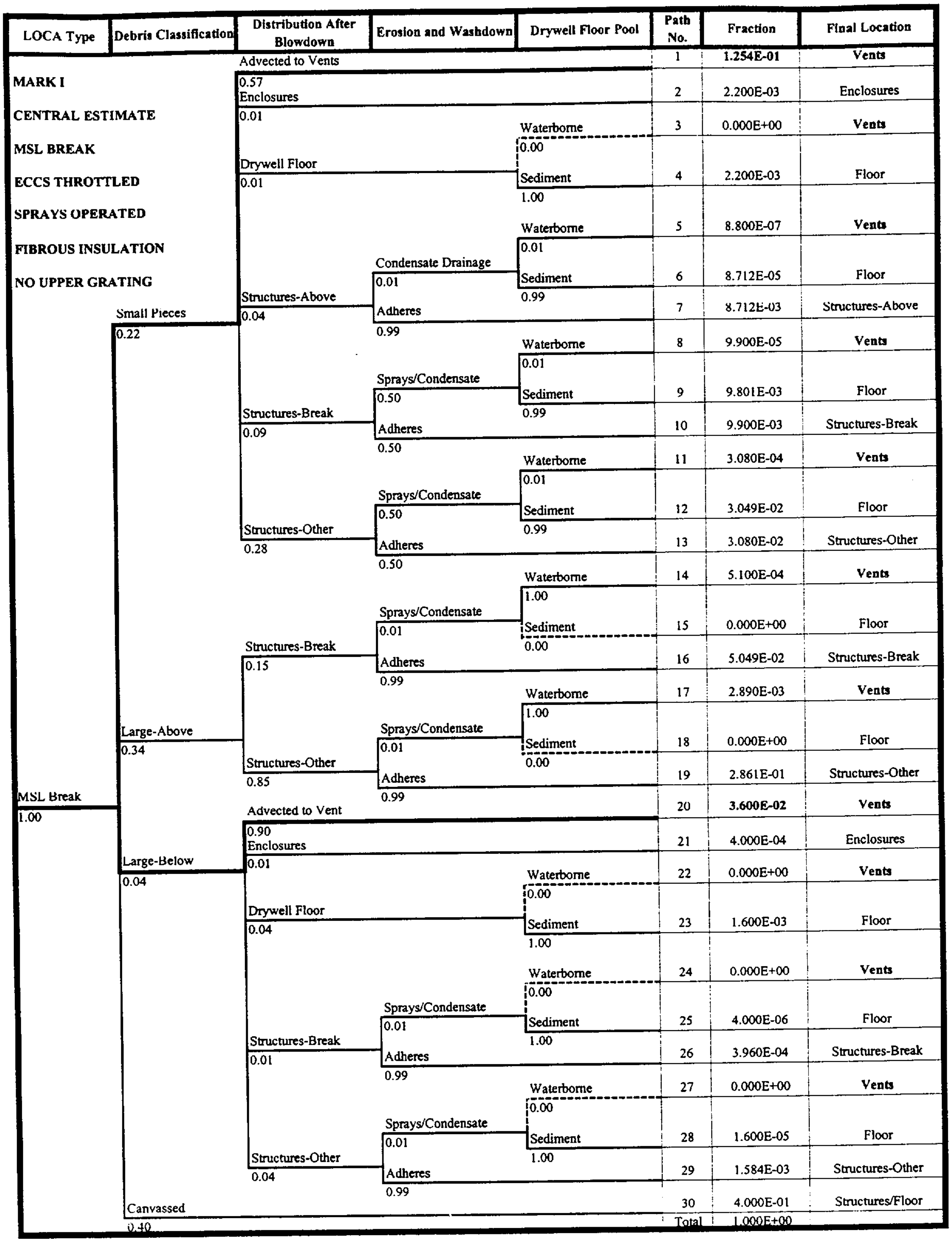


Figure 5-6. Central estimate logic tree for debris transport in a Mark I drywell with one floor grating.

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

DEBRIS TRANSPORT RESULTS							
Plant Design:	**MARK I**						
Estimate:	**UPPER BOUND**			**FIBROUS INSULATION**			
Break:	**MSL BREAK**						
ECCS:	**ECCS THROTTLED**						
Sprays:	**SPRAYS OPERATED**						
TREE QUANTIFICATION							
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 DISTRIBUTIONS (Horizontal)							
Debris Classification	**Vents**	**Enclosures**	**Floor**	**Structures Above**	**Structures Break**	**Structures 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 CONTRIBUTIONS (Vertical)							
Debris Classification	**Vents**	**Enclosures**	**Floor**	**Structures Above**	**Structures Break**	**Structures Other**	
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%	

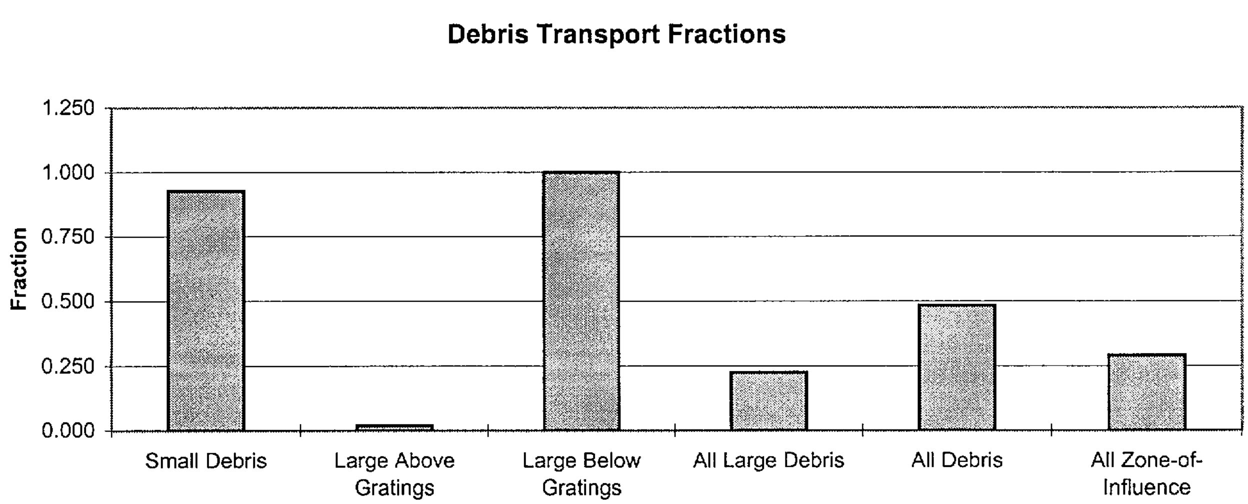


Table 5-6. Central estimate transport factors for debris transport in a Mark I drywell with one floor grating.

DEBRIS TRANSPORT RESULTS

Plant Design:	MARK I
Estimate:	CENTRAL ESTIMATE
Break:	MSL BREAK
ECCS:	ECCS THROTTLED
Sprays:	SPRAYS OPERATED

FIBROUS INSULATION

TREE QUANTIFICATION

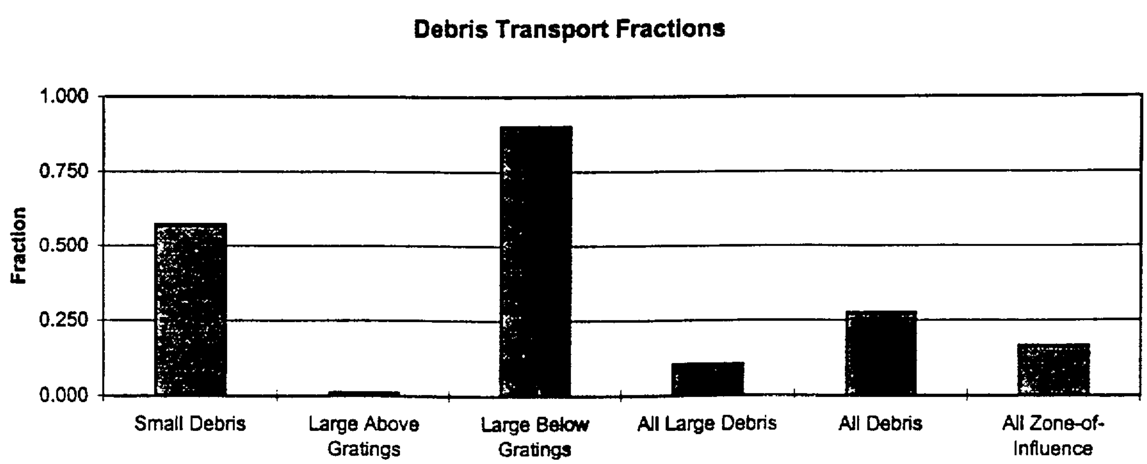
Debris Classification	Vents	Enclosures	Floor	Structures Above	Structures Break	Structures Other	Transport Fraction
Small Pieces	1.258E-01	2.200E-03	4.258E-02	8.712E-03	9.900E-03	3.080E-02	**0.5719**
Large Pieces-Above	3.400E-03	0	0.000E+00	0	5.049E-02	2.861E-01	**0.0100**
Large Pieces-Below	3.600E-02	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 DISTRIBUTIONS (Horizontal)

Debris Classification	Vents	Enclosures	Floor	Structures Above	Structures Break	Structures Other
Small Pieces	57.19%	1.00%	19.35%	3.96%	4.50%	14.00%
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	27.53%	0.43%	7.37%	1.45%	10.13%	53.08%

RELATIVE CONTRIBUTIONS (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%



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 and large debris still encased in the canvas cover. Further, large debris was subdivided into 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.

Table A-1: Basis for Quantification of Debris Transport by Debris Classification

Debris Classification	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.

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														
Break	ECCS	Sprays	Small		Large Above		Large Below		All Large		All Debris		All ZOI	
			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														
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 A-3: Relative Contributions to Transport into Vents

RELATIVE CONTRIBUTIONS TO TRANSPORT TO VENTS										
Break	ECCS	Sprays	Small		Large Above		Large Below		All Large	
			Central	UB	Central	UB	Central	UB	Central	UB
Mark I										
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	Full < 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	Full < 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										
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%

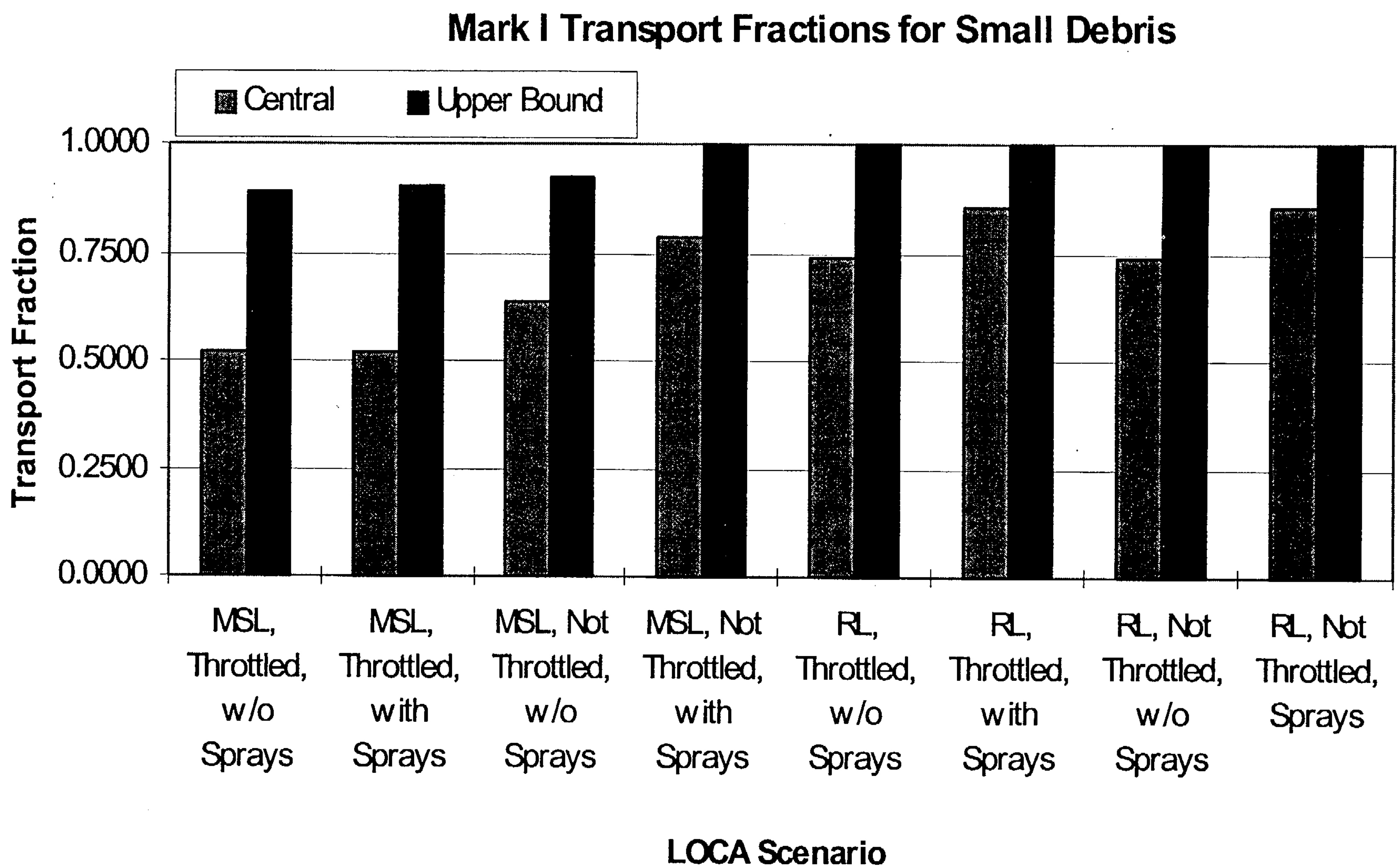


Figure A-1: Mark I Transport Fractions for Small Debris

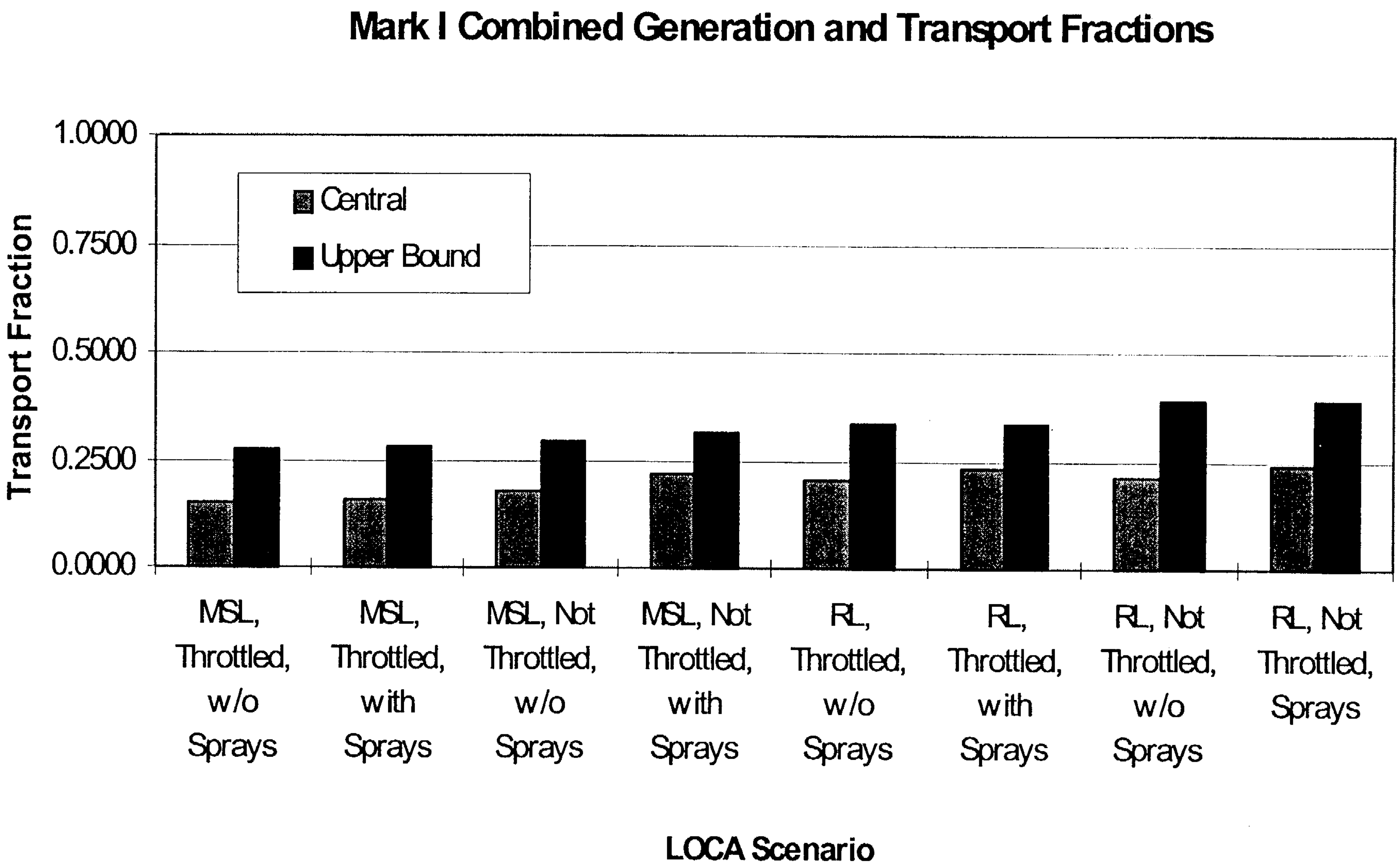


Figure A-2: Mark I Combined Generation and Transport Fractions

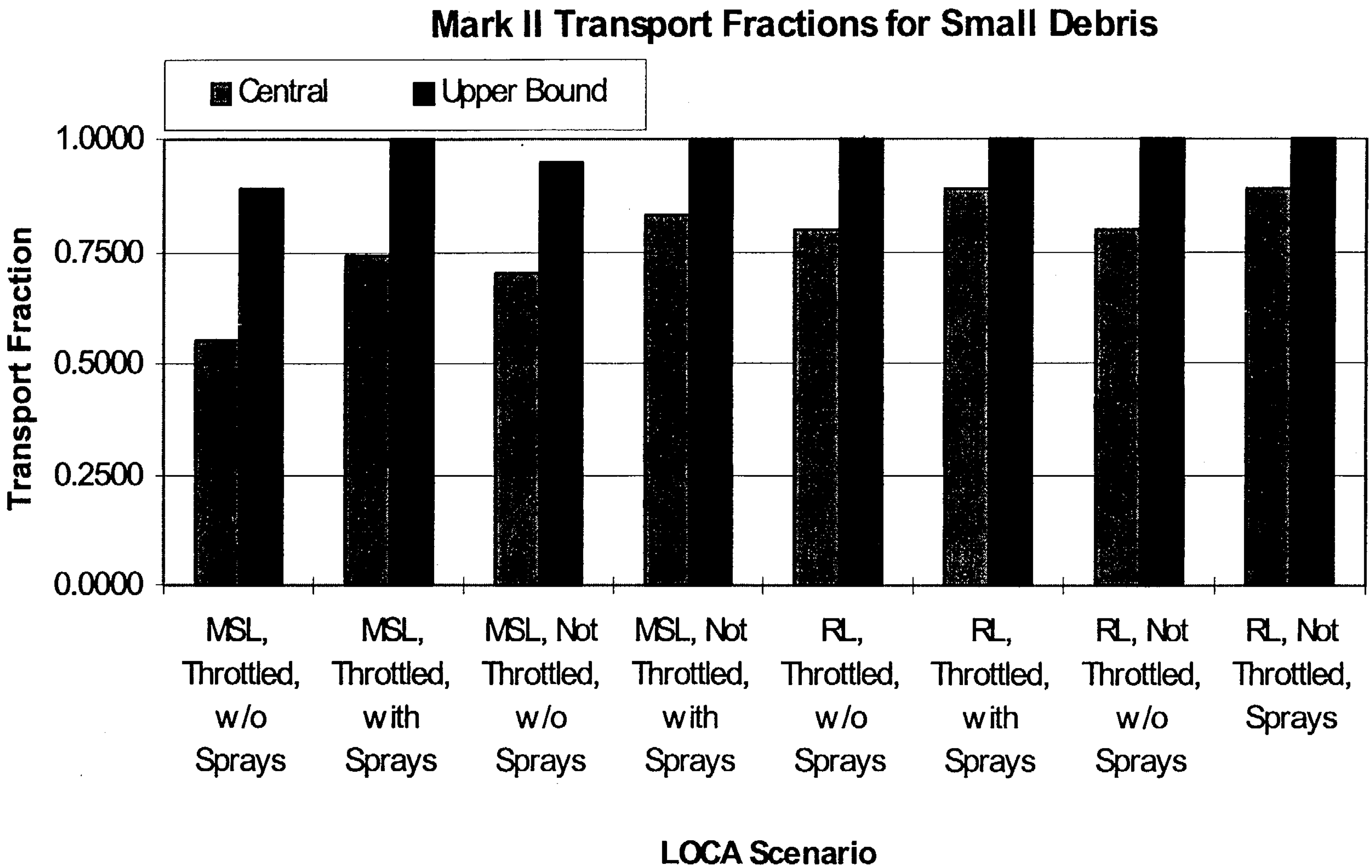


Figure A-3: Mark II Transport Fractions for Small Debris

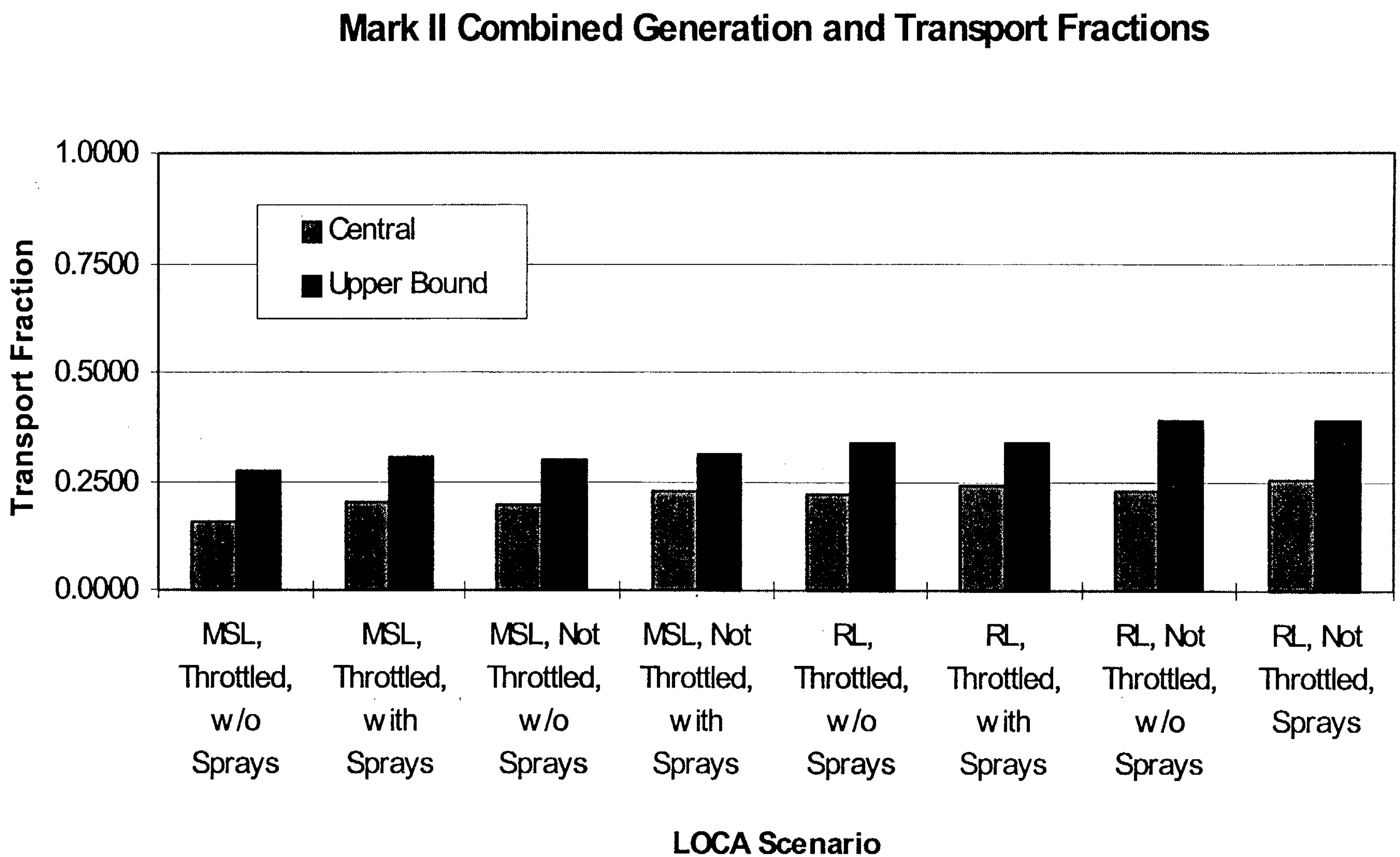


Figure A-4: Mark II Combined Generation and Transport Fractions

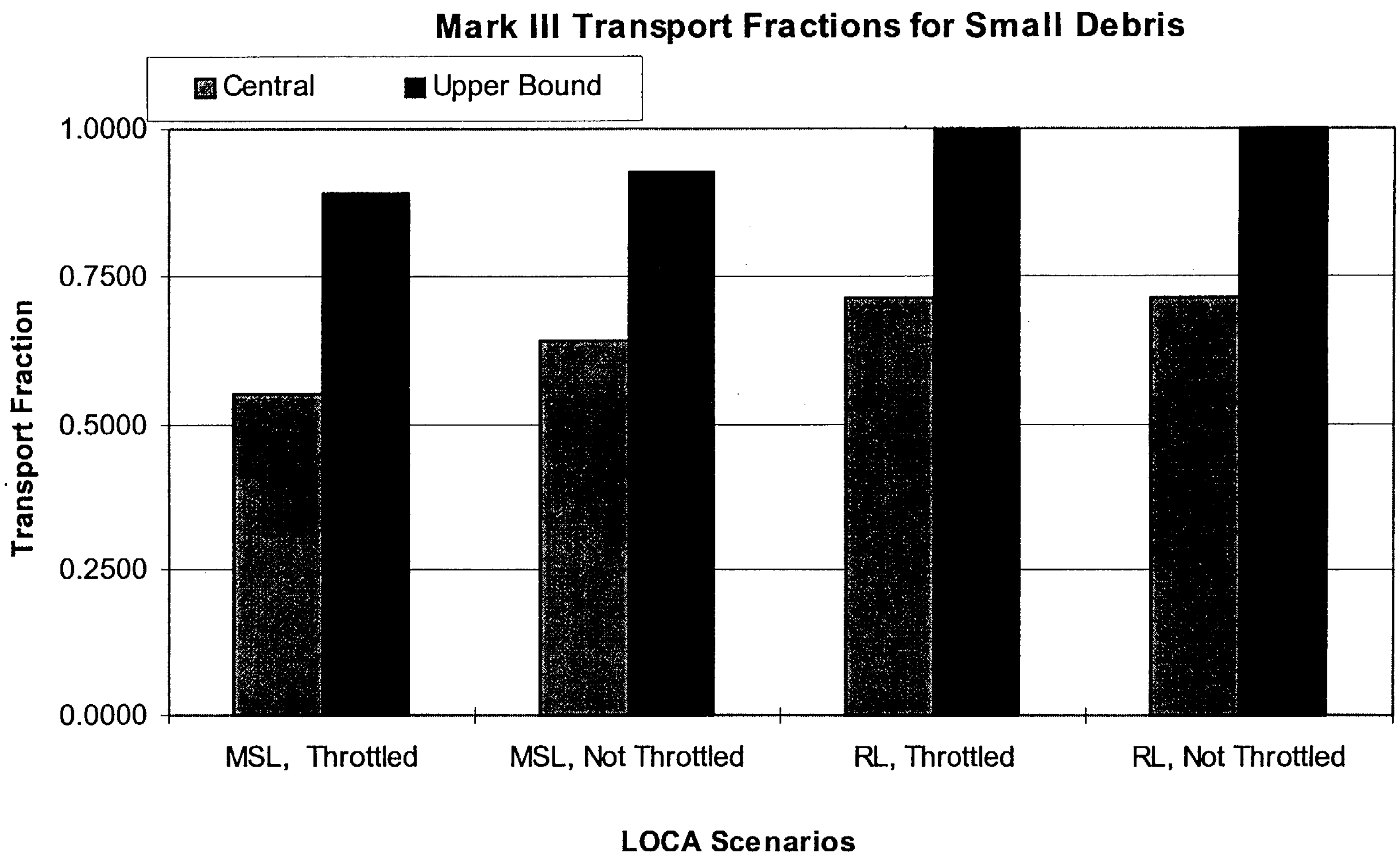


Figure A-5: Mark III Transport Fractions for Small Debris

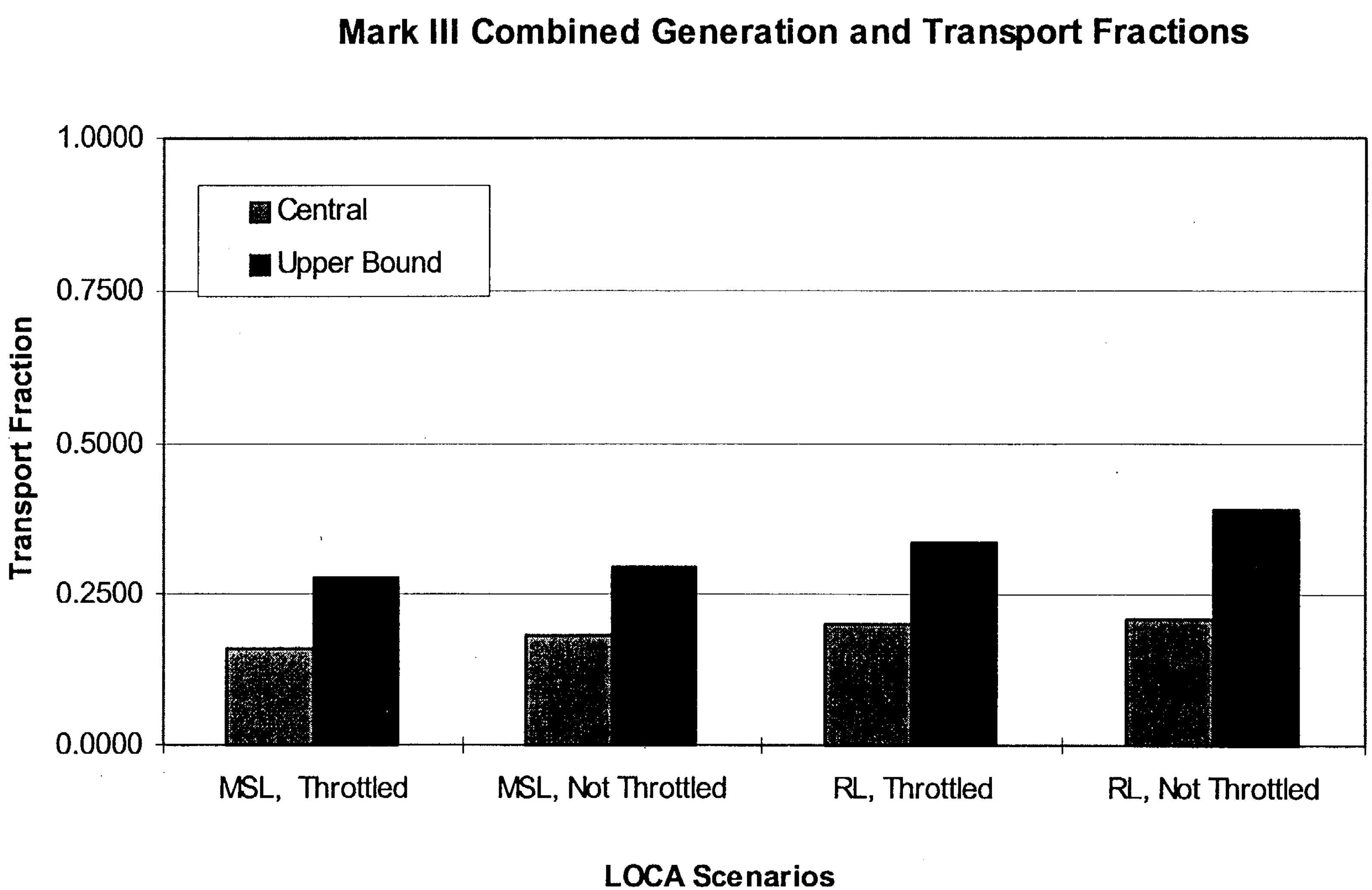


Figure A-6: Mark III Combined Generation and Transport Fraction

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

MARK I

CENTRAL ESTIMATE

MSL BREAK

ECCS THROTTLED

NO SPRAYS

FIBROUS INSULATION

LOCA Type	Debris Classification	Distribution After Blowdown	Erosion and Washdown	Drywell Floor Pool	Path No.	Fraction	Final Location
MSL Break 1.00	Small Pieces 0.22	Advected to Vents 0.52			1	**1.144E-01**	**Vents**
MSL Break 1.00	Small Pieces 0.22	Enclosures 0.01			2	2.200E-03	Enclosures
MSL Break 1.00	Small Pieces 0.22	Drywell Floor 0.01		Waterborne 0.00	3	0.000E+00	**Vents**
MSL Break 1.00	Small Pieces 0.22	Drywell Floor 0.01		Sediment 1.00	4	2.200E-03	Floor
MSL Break 1.00	Small Pieces 0.22	Structures-Above 0.04	Condensate Drainage 0.01	Waterborne 0.00	5	0.000E+00	**Vents**
MSL Break 1.00	Small Pieces 0.22	Structures-Above 0.04	Condensate Drainage 0.01	Sediment 1.00	6	8.800E-05	Floor
MSL Break 1.00	Small Pieces 0.22	Structures-Above 0.04	Adheres 0.99		7	8.712E-03	Structures-Above
MSL Break 1.00	Small Pieces 0.22	Structures-Break 0.10	Condensate Drainage 0.01	Waterborne 0.00	8	0.000E+00	**Vents**
MSL Break 1.00	Small Pieces 0.22	Structures-Break 0.10	Condensate Drainage 0.01	Sediment 1.00	9	2.200E-04	Floor
MSL Break 1.00	Small Pieces 0.22	Structures-Break 0.10	Adheres 0.99		10	2.178E-02	Structures-Break
MSL Break 1.00	Small Pieces 0.22	Structures-Other 0.32	Condensate Drainage 0.01	Waterborne 0.00	11	0.000E+00	**Vents**
MSL Break 1.00	Small Pieces 0.22	Structures-Other 0.32	Condensate Drainage 0.01	Sediment 1.00	12	7.040E-04	Floor
MSL Break 1.00	Small Pieces 0.22	Structures-Other 0.32	Adheres 0.99		13	6.970E-02	Structures-Other
MSL Break 1.00	Large-Above 0.34	Structures-Break 0.15	Condensate Drainage 0.00	Waterborne 0.00	14	0.000E+00	**Vents**
MSL Break 1.00	Large-Above 0.34	Structures-Break 0.15	Condensate Drainage 0.00	Sediment 1.00	15	0.000E+00	Floor
MSL Break 1.00	Large-Above 0.34	Structures-Break 0.15	Adheres 1.00		16	5.100E-02	Structures-Break
MSL Break 1.00	Large-Above 0.34	Structures-Other 0.85	Condensate Drainage 0.00	Waterborne 0.00	17	0.000E+00	**Vents**
MSL Break 1.00	Large-Above 0.34	Structures-Other 0.85	Condensate Drainage 0.00	Sediment 1.00	18	0.000E+00	Floor
MSL Break 1.00	Large-Above 0.34	Structures-Other 0.85	Adheres 1.00		19	2.890E-01	Structures-Other
MSL Break 1.00	Large-Below 0.04	Advected to Vent 0.90			20	**3.600E-02**	**Vents**
MSL Break 1.00	Large-Below 0.04	Enclosures 0.01			21	4.000E-04	Enclosures
MSL Break 1.00	Large-Below 0.04	Drywell Floor 0.04		Waterborne 0.00	22	0.000E+00	**Vents**
MSL Break 1.00	Large-Below 0.04	Drywell Floor 0.04		Sediment 1.00	23	1.600E-03	Floor
MSL Break 1.00	Large-Below 0.04	Structures-Break 0.01	Condensate Drainage 0.00	Waterborne 0.00	24	0.000E+00	**Vents**
MSL Break 1.00	Large-Below 0.04	Structures-Break 0.01	Condensate Drainage 0.00	Sediment 1.00	25	0.000E+00	Floor
MSL Break 1.00	Large-Below 0.04	Structures-Break 0.01	Adheres 1.00		26	4.000E-04	Structures-Break
MSL Break 1.00	Large-Below 0.04	Structures-Other 0.04	Condensate Drainage 0.00	Waterborne 0.00	27	0.000E+00	**Vents**
MSL Break 1.00	Large-Below 0.04	Structures-Other 0.04	Condensate Drainage 0.00	Sediment 1.00	28	0.000E+00	Floor
MSL Break 1.00	Large-Below 0.04	Structures-Other 0.04	Adheres 1.00		29	1.600E-03	Structures-Other
MSL Break 1.00	Canvassed 0.40				30	4.000E-01	Structures/Floor
					Total	1.000E+00	

DEBRIS TRANSPORT RESULTS							
Plant Design:	MARK I						
Estimate:	CENTRAL ESTIMATE		FIBROUS INSULATION				
Break:	MSL BREAK						
ECCS:	ECCS THROTTLED						
Sprays:	NO SPRAYS						

TREE QUANTIFICATION

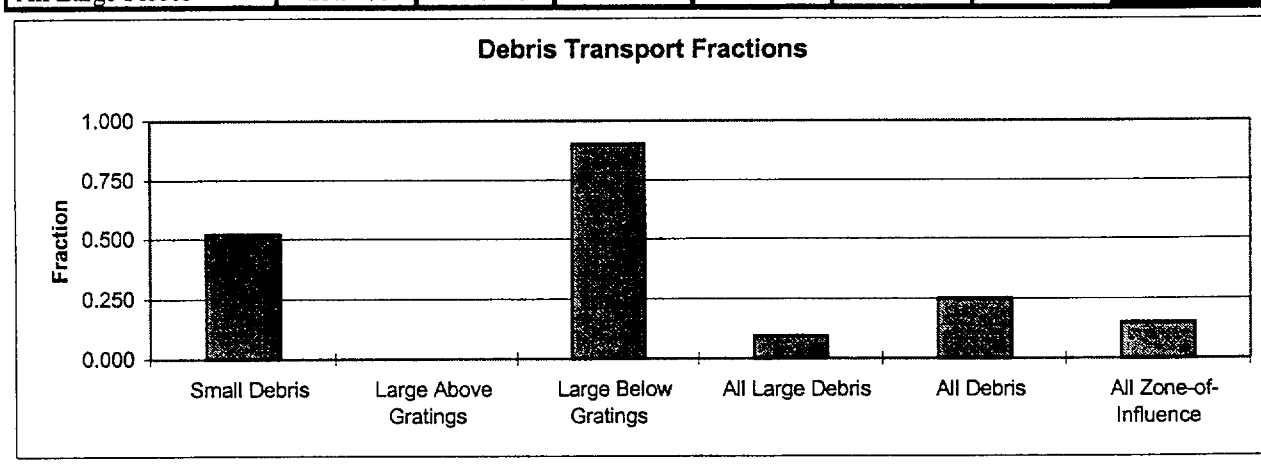
Debris Classification	Vents	Enclosures	Floor	Structures Above	Structures Break	Structures Other	Transport Fraction
Small Pieces	1.144E-01	2.200E-03	3.212E-03	8.712E-03	2.178E-02	6.970E-02	**0.5200**
Large Pieces-Above	0.000E+00	0	0.000E+00	0	5.100E-02	2.890E-01	**0.0000**
Large Pieces-Below	3.600E-02	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	1.504E-01	2.600E-03	4.812E-03	8.712E-03	7.318E-02	3.603E-01	**0.2507**
All Zone-of-Influence							**0.1504**

FINAL DISTRIBUTIONS (Horizontal)

Debris Classification	Vents	Enclosures	Floor	Structures Above	Structures Break	Structures Other
Small Pieces	52.00%	1.00%	1.46%	3.96%	9.90%	31.68%
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	25.07%	0.43%	0.80%	1.45%	12.20%	60.05%

RELATIVE CONTRIBUTIONS (Vertical)

Debris Classification	Vents	Enclosures	Floor	Structures Above	Structures Break	Structures Other
Small Pieces	76.06%	84.62%	66.75%	100.00%	29.76%	19.34%
Large Pieces-Above	0.00%	0%	0.00%	0%	69.69%	80.21%
Large Pieces-Below	23.94%	15.38%	33.25%	0%	0.55%	0.44%
All Large Pieces	23.94%	15.38%	33.25%	0%	70.24%	80.66%



MARK I
CENTRAL ESTIMATE
MSL BREAK
ECCS THROTTLED
SPRAYS OPERATED
FIBROUS INSULATION

LOCA Type	Debris Classification	Distribution After Blowdown	Erosion and Washdown	Drywell Floor Pool	Path No.	Fraction	Final Location
MSL Break 1.00	Small Pieces 0.22	Advected to Vents 0.52			1	**1.144E-01**	**Vents**
		Enclosures 0.01			2	2.200E-03	Enclosures
		Drywell Floor 0.01		Waterborne 0.00	3	0.000E+00	**Vents**
				Sediment 1.00	4	2.200E-03	Floor
		Structures-Above 0.04	Condensate Drainage 0.01	Waterborne 0.01	5	8.800E-07	**Vents**
				Sediment 0.99	6	8.712E-05	Floor
			Adheres 0.99		7	8.712E-03	Structures-Above
		Structures-Break 0.10	Sprays/Condensate 0.50	Waterborne 0.01	8	1.100E-04	**Vents**
				Sediment 0.99	9	1.089E-02	Floor
			Adheres 0.50		10	1.100E-02	Structures-Break
		Structures-Other 0.32	Sprays/Condensate 0.50	Waterborne 0.01	11	3.520E-04	**Vents**
				Sediment 0.99	12	3.485E-02	Floor
			Adheres 0.50		13	3.520E-02	Structures-Other
	Large-Above 0.34	Structures-Break 0.15	Sprays/Condensate 0.01	Waterborne 1.00	14	5.100E-04	**Vents**
				Sediment 0.00	15	0.000E+00	Floor
			Adheres 0.99		16	5.049E-02	Structures-Break
		Structures-Other 0.85	Sprays/Condensate 0.01	Waterborne 1.00	17	2.890E-03	**Vents**
				Sediment 0.00	18	0.000E+00	Floor
			Adheres 0.99		19	2.861E-01	Structures-Other
	Large-Below 0.04	Advected to Vent 0.90			20	**3.600E-02**	**Vents**
		Enclosures 0.01			21	4.000E-04	Enclosures
		Drywell Floor 0.04		Waterborne 0.00	22	0.000E+00	**Vents**
				Sediment 1.00	23	1.600E-03	Floor
		Structures-Break 0.01	Sprays/Condensate 0.01	Waterborne 0.00	24	0.000E+00	**Vents**
				Sediment 1.00	25	4.000E-06	Floor
			Adheres 0.99		26	3.960E-04	Structures-Break
		Structures-Other 0.04	Sprays/Condensate 0.01	Waterborne 0.00	27	0.000E+00	**Vents**
				Sediment 1.00	28	1.600E-05	Floor
			Adheres 0.99		29	1.584E-03	Structures-Other
	Canvassed 0.40				30	4.000E-01	Structures/Floor
					Total	1.000E+00	

DEBRIS TRANSPORT RESULTS

Plant Design:	MARK I
Estimate:	CENTRAL ESTIMATE
Break:	MSL BREAK
ECCS:	ECCS THROTTLED
Sprays:	SPRAYS OPERATED

FIBROUS INSULATION

TREE QUANTIFICATION

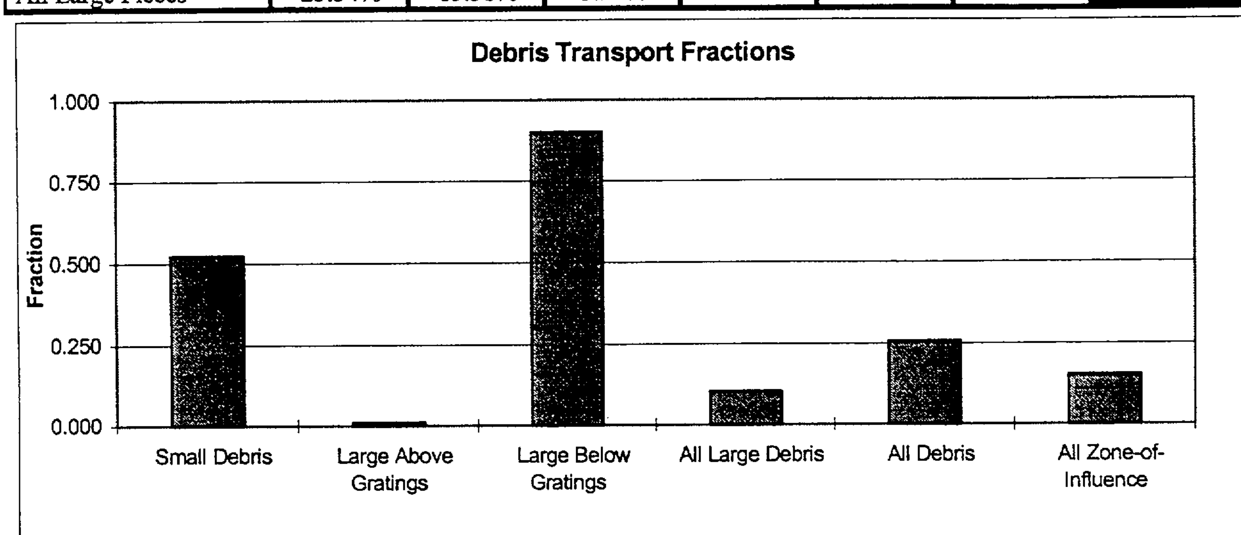
Debris Classification	Vents	Enclosures	Floor	Structures Above	Structures Break	Structures Other	Transport Fraction
Small Pieces	1.149E-01	2.200E-03	4.803E-02	8.712E-03	1.100E-02	3.520E-02	**0.5221**
Large Pieces-Above	3.400E-03	0	0.000E+00	0	5.049E-02	2.861E-01	**0.0100**
Large Pieces-Below	3.600E-02	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 DISTRIBUTIONS (Horizontal)

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%
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 CONTRIBUTIONS (Vertical)

Debris Classification	Vents	Enclosures	Floor	Structures Above	Structures Break	Structures 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%



MARK I
CENTRAL ESTIMATE
MSL BREAK
NOT THROTTLED
NO SPRAYS
FIBROUS INSULATION

LOCA Type	Debris Classification	Distribution After Blowdown	Erosion and Washdown	Drywell Floor Pool	Path No.	Fraction	Final Location
MSL Break 1.00	Small Pieces 0.22	Advected to Vents 0.52			1	**1.144E-01**	**Vents**
		Enclosures 0.01			2	2.200E-03	Enclosures
		Drywell Floor 0.01		Waterborne 1.00	3	2.200E-03	**Vents**
				Sediment 0.00	4	0.000E+00	Floor
		Structures-Above 0.04	Condensate Drainage 0.01	Waterborne 1.00	5	8.800E-05	**Vents**
				Sediment 0.00	6	0.000E+00	Floor
			Adheres 0.99		7	8.712E-03	Structures-Above
		Structures-Break 0.10	Recirculation Flow 1.00	Waterborne 1.00	8	**2.200E-02**	**Vents**
				Sediment 0.00	9	0.000E+00	Floor
			Adheres 0.00		10	0.000E+00	Structures-Break
		Structures-Other 0.32	Condensate Drainage 0.01	Waterborne 1.00	11	7.040E-04	**Vents**
				Sediment 0.00	12	0.000E+00	Floor
			Adheres 0.99		13	6.970E-02	Structures-Other
	Large-Above 0.34	Structures-Break 0.15	Recirculation Flow 0.08	Waterborne 1.00	14	4.080E-03	**Vents**
				Sediment 0.00	15	0.000E+00	Floor
			Adheres 0.92		16	4.692E-02	Structures-Break
		Structures-Other 0.85	Condensate Drainage 0.00	Waterborne 1.00	17	0.000E+00	**Vents**
				Sediment 0.00	18	0.000E+00	Floor
			Adheres 1.00		19	2.890E-01	Structures-Other
	Large-Below 0.04	Advected to Vent 0.90			20	**3.600E-02**	**Vents**
		Enclosures 0.01			21	4.000E-04	Enclosures
		Drywell Floor 0.04		Waterborne 0.90	22	1.440E-03	**Vents**
				Sediment 0.10	23	1.600E-04	Floor
		Structures-Break 0.01	Recirculation Flow 0.50	Waterborne 1.00	24	2.000E-04	**Vents**
				Sediment 0.00	25	0.000E+00	Floor
			Adheres 0.50		26	2.000E-04	Structures-Break
		Structures-Other 0.04	Condensate Drainage 0.00	Waterborne 1.00	27	0.000E+00	**Vents**
				Sediment 0.00	28	0.000E+00	Floor
			Adheres 1.00		29	1.600E-03	Structures-Other
	Canvassed 0.40				30	4.000E-01	Structures/Floor
					Total	1.000E+00	

DEBRIS TRANSPORT RESULTS	
Plant Design:	MARK I
Estimate:	CENTRAL ESTIMATE
Break:	MSL BREAK
ECCS:	NOT THROTTLED
Sprays:	NO SPRAYS

FIBROUS INSULATION

TREE QUANTIFICATION

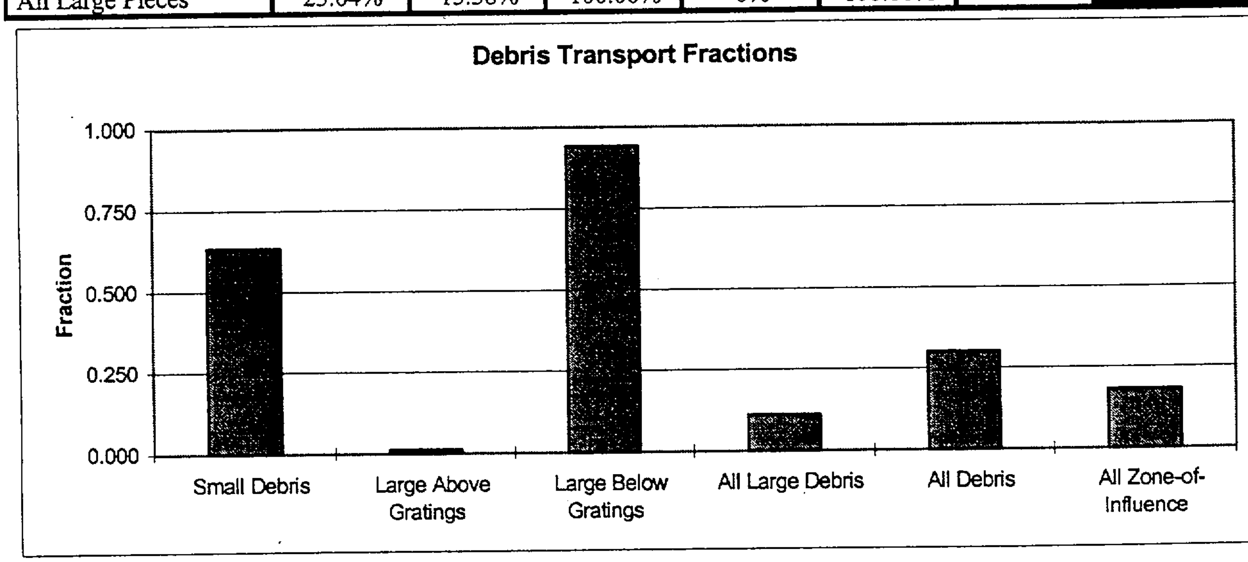
Debris Classification	Vents	Enclosures	Floor	Structures Above	Structures Break	Structures Other	Transport Fraction
Small Pieces	1.394E-01	2.200E-03	0.000E+00	8.712E-03	0.000E+00	6.970E-02	**0.6336**
Large Pieces-Above	4.080E-03	0	0.000E+00	0	4.692E-02	2.890E-01	**0.0120**
Large Pieces-Below	3.764E-02	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	1.811E-01	2.600E-03	1.600E-04	8.712E-03	4.712E-02	3.603E-01	**0.3019**
All Zone-of-Influence							**0.1811**

FINAL DISTRIBUTIONS (Horizontal)

Debris Classification	Vents	Enclosures	Floor	Structures Above	Structures Break	Structures Other
Small Pieces	63.36%	1.00%	0.00%	3.96%	0.00%	31.68%
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	30.19%	0.43%	0.03%	1.45%	7.85%	60.05%

RELATIVE CONTRIBUTIONS (Vertical)

Debris Classification	Vents	Enclosures	Floor	Structures Above	Structures Break	Structures 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%



MARK I

CENTRAL ESTIMATE

MSL BREAK

NOT THROTTLED

SPRAYS OPERATED

FIBROUS INSULATION

LOCA Type	Debris Classification	Distribution After Blowdown	Erosion and Washdown	Drywell Floor Pool	Path No.	Fraction	Final Location
MSL Break 1.00	Small Pieces 0.22	Advected to Vents 0.52			1	1.144E-01	Vents
		Enclosures 0.01			2	2.200E-03	Enclosures
		Drywell Floor 0.01		Waterborne 1.00	3	2.200E-03	Vents
				Sediment 0.00	4	0.000E+00	Floor
		Structures-Above 0.04	Condensate Drainage 0.01	Waterborne 1.00	5	8.800E-05	Vents
				Sediment 0.00	6	0.000E+00	Floor
			Adheres 0.99		7	8.712E-03	Structures-Above
		Structures-Break 0.10	Recirculation Flow 1.00	Waterborne 1.00	8	2.200E-02	Vents
				Sediment 0.00	9	0.000E+00	Floor
			Adheres 0.00		10	0.000E+00	Structures-Break
		Structures-Other 0.32	Sprays/Condensate 0.50	Waterborne 1.00	11	3.520E-02	Vents
				Sediment 0.00	12	0.000E+00	Floor
			Adheres 0.50		13	3.520E-02	Structures-Other
	Large-Above 0.34	Structures-Break 0.15	Recirculation Flow 0.08	Waterborne 1.00	14	4.080E-03	Vents
				Sediment 0.00	15	0.000E+00	Floor
			Adheres 0.92		16	4.692E-02	Structures-Break
		Structures-Other 0.85	Sprays/Condensate 0.01	Waterborne 1.00	17	2.890E-03	Vents
				Sediment 0.00	18	0.000E+00	Floor
			Adheres 0.99		19	2.861E-01	Structures-Other
	Large-Below 0.04	Advected to Vent 0.90			20	3.600E-02	Vents
		Enclosures 0.01			21	4.000E-04	Enclosures
		Drywell Floor 0.04		Waterborne 0.90	22	1.440E-03	Vents
				Sediment 0.10	23	1.600E-04	Floor
		Structures-Break 0.01	Recirculation Flow 0.50	Waterborne 1.00	24	2.000E-04	Vents
				Sediment 0.00	25	0.000E+00	Floor
			Adheres 0.50		26	2.000E-04	Structures-Break
		Structures-Other 0.04	Sprays/Condensate 0.01	Waterborne 1.00	27	1.600E-05	Vents
				Sediment 0.00	28	0.000E+00	Floor
			Adheres 0.99		29	1.584E-03	Structures-Other
	Canvassed 0.40				30	4.000E-01	Structures/Floor
					Total	1.000E+00	

DEBRIS TRANSPORT RESULTS

Plant Design:	**MARK I**
Estimate:	**CENTRAL ESTIMATE**
Break:	**MSL BREAK**
ECCS:	**NOT THROTTLED**
Sprays:	**SPRAYS OPERATED**

FIBROUS INSULATION

TREE QUANTIFICATION

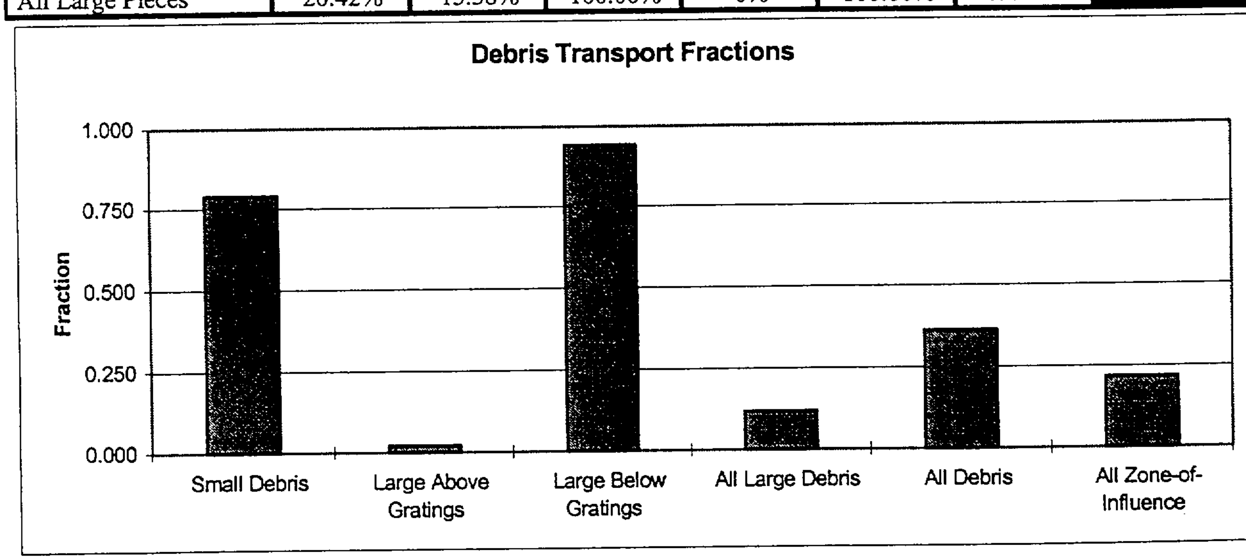
Debris Classification	Vents	Enclosures	Floor	Structures Above	Structures Break	Structures Other	Transport Fraction
Small Pieces	1.739E-01	2.200E-03	0.000E+00	8.712E-03	0.000E+00	3.520E-02	**0.7904**
Large Pieces-Above	6.970E-03	0	0.000E+00	0	4.692E-02	2.861E-01	**0.0205**
Large Pieces-Below	3.766E-02	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 DISTRIBUTIONS (Horizontal)

Debris Classification	Vents	Enclosures	Floor	Structures Above	Structures Break	Structures 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 CONTRIBUTIONS (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%



A.3.1.2 Recirculation Line Break

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

MARK I

CENTRAL ESTIMATE

RL BREAK

ECCS THROTTLED

NO SPRAYS

FIBROUS INSULATION

LOCA Type	Debris Classification	Distribution After Blowdown	Erosion and Washdown	Drywell Floor Pool	Path No.	Fraction	Final Location
RL Break 1.00	Small Pieces 0.22	Advected to Vents 0.46			1	**1.012E-01**	**Vents**
		Enclosures 0.01			2	2.200E-03	Enclosures
		Drywell Floor 0.20		Waterborne 1.00	3	**4.400E-02**	**Vents**
				Sediment 0.00	4	0.000E+00	Floor
		Structures-Above 0.02	Condensate Drainage 0.01	Waterborne 1.00	5	4.400E-05	**Vents**
				Sediment 0.00	6	0.000E+00	Floor
			Adheres 0.99		7	4.356E-03	Structures-Above
		Structures-Break 0.08	Recirculation Flow 1.00	Waterborne 1.00	8	**1.760E-02**	**Vents**
				Sediment 0.00	9	0.000E+00	Floor
			Adheres 0.00		10	0.000E+00	Structures-Break
		Structures-Other 0.23	Condensate Drainage 0.01	Waterborne 1.00	11	5.060E-04	**Vents**
				Sediment 0.00	12	0.000E+00	Floor
			Adheres 0.99		13	5.009E-02	Structures-Other
	Large-Above 0.34	Structures-Break 0.15	Recirculation Flow 0.08	Waterborne 1.00	14	4.080E-03	**Vents**
				Sediment 0.00	15	0.000E+00	Floor
			Adheres 0.92		16	4.692E-02	Structures-Break
		Structures-Other 0.85	Condensate Drainage 0.00	Waterborne 1.00	17	0.000E+00	**Vents**
				Sediment 0.00	18	0.000E+00	Floor
			Adheres 1.00		19	2.890E-01	Structures-Other
	Large-Below 0.04	Advected to Vent 0.90			20	**3.600E-02**	**Vents**
		Enclosures 0.01			21	4.000E-04	Enclosures
		Drywell Floor 0.04		Waterborne 0.90	22	1.440E-03	**Vents**
				Sediment 0.10	23	1.600E-04	Floor
		Structures-Break 0.01	Recirculation Flow 0.50	Waterborne 1.00	24	2.000E-04	**Vents**
				Sediment 0.00	25	0.000E+00	Floor
			Adheres 0.50		26	2.000E-04	Structures-Break
		Structures-Other 0.04	Condensate Drainage 0.00	Waterborne 1.00	27	0.000E+00	**Vents**
				Sediment 0.00	28	0.000E+00	Floor
			Adheres 1.00		29	1.600E-03	Structures-Other
	Canvassed 0.40				30	4.000E-01	Structures/Floor
					Total	1.000E+00	

DEBRIS TRANSPORT RESULTS							
Plant Design:	MARK I						
Estimate:	CENTRAL ESTIMATE			FIBROUS INSULATION			
Break:	RL BREAK						
ECCS:	ECCS THROTTLED						
Sprays:	NO SPRAYS						

TREE QUANTIFICATION

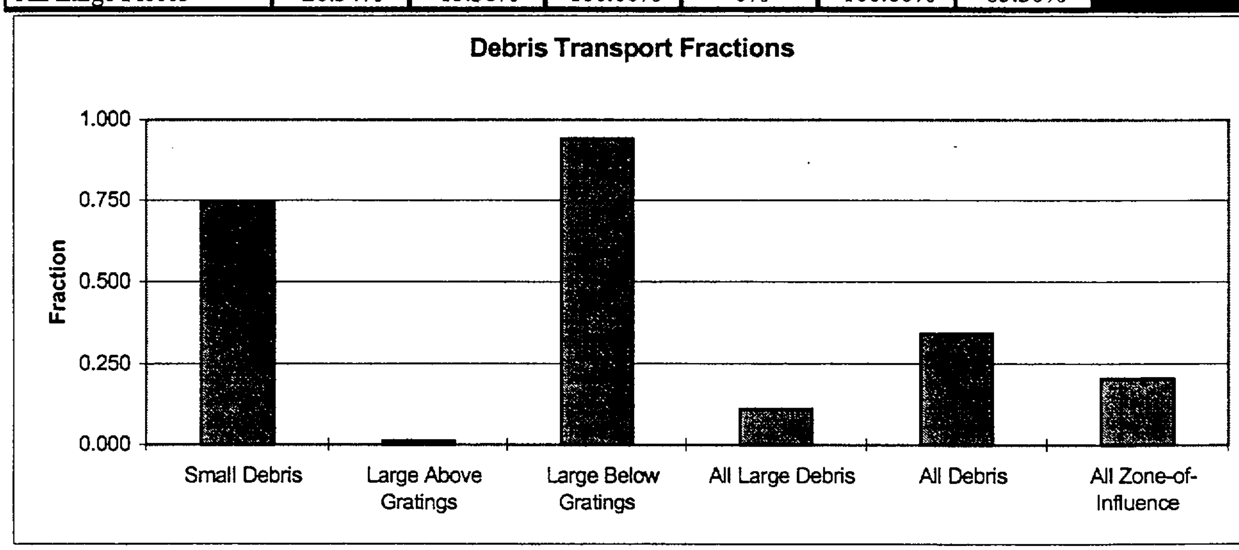
Debris Classification	Vents	Enclosures	Floor	Structures Above	Structures Break	Structures Other	Transport Fraction
Small Pieces	1.634E-01	2.200E-03	0.000E+00	4.356E-03	0.000E+00	5.009E-02	**0.7425**
Large Pieces-Above	4.080E-03	0	0.000E+00	0	4.692E-02	2.890E-01	**0.0120**
Large Pieces-Below	3.764E-02	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 DISTRIBUTIONS (Horizontal)

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 CONTRIBUTIONS (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%



MARK I

CENTRAL ESTIMATE

RL BREAK

ECCS THROTTLED

SPRAYS OPERATED

FIBROUS INSULATION

LOCA Type	Debris Classification	Distribution After Blowdown	Erosion and Washdown	Drywell Floor Pool	Path No.	Fraction	Final Location
RL Break 1.00	Small Pieces 0.22	Advected to Vents 0.46			1	**1.012E-01**	**Vents**
		Enclosures 0.01			2	2.200E-03	Enclosures
		Drywell Floor 0.20		Waterborne 1.00	3	**4.400E-02**	**Vents**
				Sediment 0.00	4	0.000E+00	Floor
		Structures-Above 0.02	Condensate Drainage 0.01	Waterborne 1.00	5	4.400E-05	**Vents**
				Sediment 0.00	6	0.000E+00	Floor
			Adheres 0.99		7	4.356E-03	Structures-Above
		Structures-Break 0.08	Recirculation Flow 1.00	Waterborne 1.00	8	**1.760E-02**	**Vents**
				Sediment 0.00	9	0.000E+00	Floor
			Adheres 0.00		10	0.000E+00	Structures-Break
		Structures-Other 0.23	Sprays/Condensate 0.50	Waterborne 1.00	11	**2.530E-02**	**Vents**
				Sediment 0.00	12	0.000E+00	Floor
			Adheres 0.50		13	2.530E-02	Structures-Other
	Large-Above 0.34	Structures-Break 0.15	Recirculation Flow 0.08	Waterborne 1.00	14	4.080E-03	**Vents**
				Sediment 0.00	15	0.000E+00	Floor
			Adheres 0.92		16	4.692E-02	Structures-Break
		Structures-Other 0.85	Sprays/Condensate 0.01	Waterborne 1.00	17	2.890E-03	**Vents**
				Sediment 0.00	18	0.000E+00	Floor
			Adheres 0.99		19	2.861E-01	Structures-Other
	Large-Below 0.04	Advected to Vent 0.90			20	**3.600E-02**	**Vents**
		Enclosures 0.01			21	4.000E-04	Enclosures
		Drywell Floor 0.04		Waterborne 0.90	22	1.440E-03	**Vents**
				Sediment 0.10	23	1.600E-04	Floor
		Structures-Break 0.01	Recirculation Flow 0.50	Waterborne 1.00	24	2.000E-04	**Vents**
				Sediment 0.00	25	0.000E+00	Floor
			Adheres 0.50		26	2.000E-04	Structures-Break
		Structures-Other 0.04	Sprays/Condensate 0.01	Waterborne 1.00	27	1.600E-05	**Vents**
				Sediment 0.00	28	0.000E+00	Floor
			Adheres 0.99		29	1.584E-03	Structures-Other
	Canvassed 0.40				30	4.000E-01	Structures/Floor
					Total	1.000E+00	

DEBRIS TRANSPORT RESULTS							
Plant Design:	**MARK I**						
Estimate:	**CENTRAL ESTIMATE**			**FIBROUS INSULATION**			
Break:	**RL BREAK**						
ECCS:	**ECCS THROTTLED**						
Sprays:	**SPRAYS OPERATED**						

TREE QUANTIFICATION

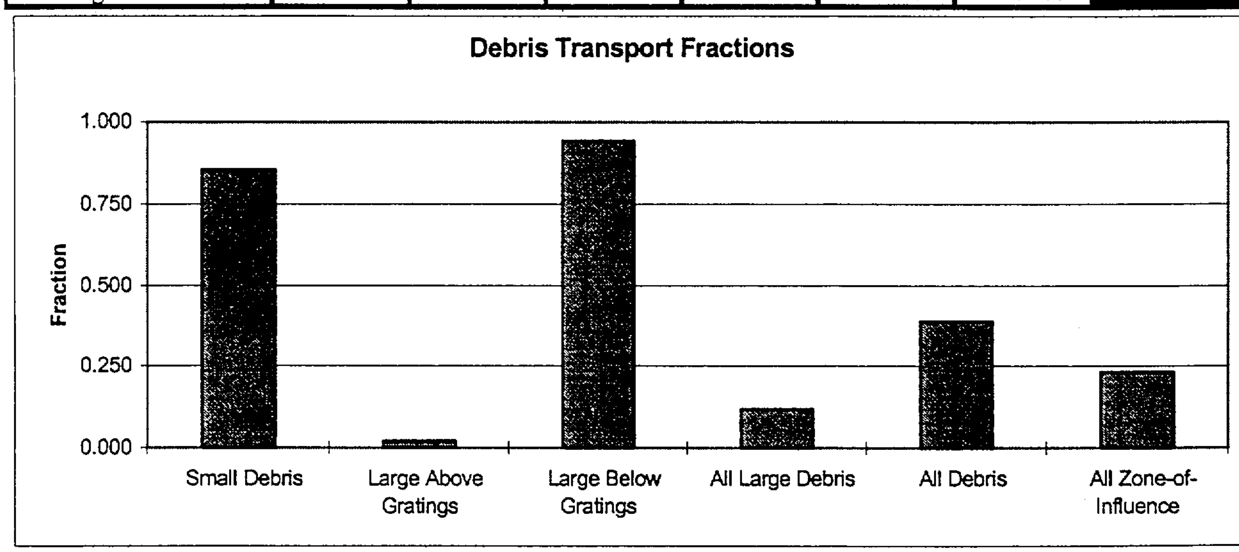
Debris Classification	Vents	Enclosures	Floor	Structures Above	Structures Break	Structures Other	Transport Fraction
Small Pieces	1.881E-01	2.200E-03	0.000E+00	4.356E-03	0.000E+00	2.530E-02	**0.8552**
Large Pieces-Above	6.970E-03	0	0.000E+00	0	4.692E-02	2.861E-01	**0.0205**
Large Pieces-Below	3.766E-02	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 DISTRIBUTIONS (Horizontal)

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 CONTRIBUTIONS (Vertical)

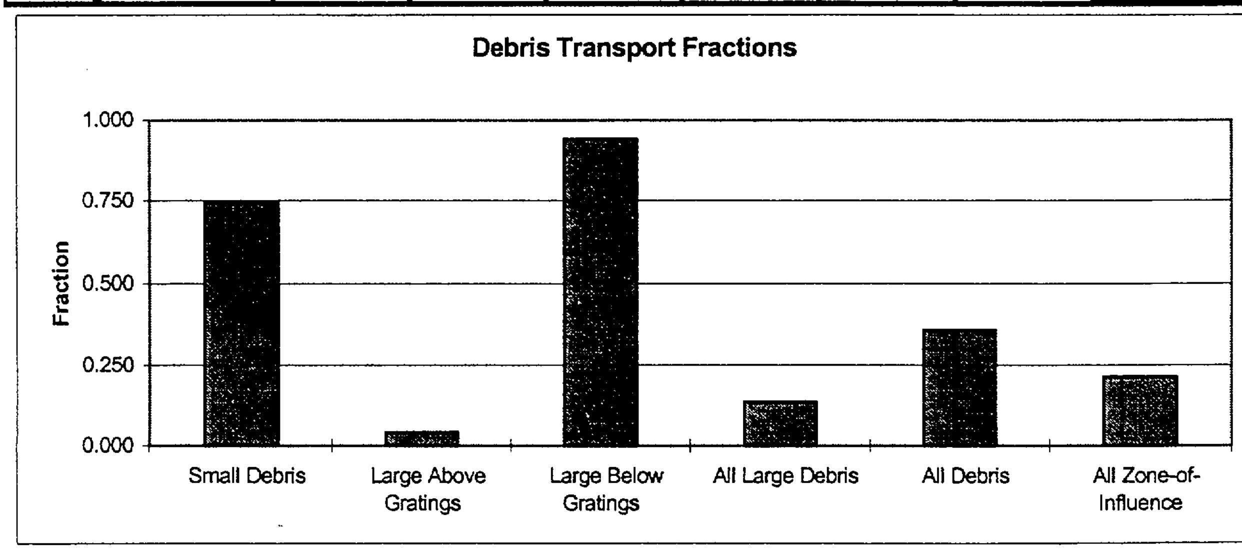
Debris Classification	Vents	Enclosures	Floor	Structures Above	Structures Break	Structures Other
Small Pieces	80.83%	84.62%	0.00%	100.00%	0.00%	8.08%
Large Pieces-Above	2.99%	0%	0.00%	0%	99.58%	91.41%
Large Pieces-Below	16.18%	15.38%	100.00%	0%	0.42%	0.51%
All Large Pieces	19.17%	15.38%	100.00%	0%	100.00%	91.92%



MARK I
CENTRAL ESTIMATE
RL BREAK
NOT THROTTLED
NO SPRAYS
FIBROUS INSULATION

LOCA Type	Debris Classification	Distribution After Blowdown	Erosion and Washdown	Drywell Floor Pool	Path No.	Fraction	Final Location
RL Break 1.00	Small Pieces 0.22	Advected to Vents 0.46			1	1.012E-01	Vents
		Enclosures 0.01			2	2.200E-03	Enclosures
		Drywell Floor 0.20		Waterborne 1.00	3	4.400E-02	Vents
				Sediment 0.00	4	0.000E+00	Floor
		Structures-Above 0.02	Condensate Drainage 0.01	Waterborne 1.00	5	4.400E-05	Vents
				Sediment 0.00	6	0.000E+00	Floor
			Adheres 0.99		7	4.356E-03	Structures-Above
		Structures-Break 0.08	Recirculation Flow 1.00	Waterborne 1.00	8	1.760E-02	Vents
				Sediment 0.00	9	0.000E+00	Floor
			Adheres 0.00		10	0.000E+00	Structures-Break
		Structures-Other 0.23	Condensate Drainage 0.01	Waterborne 1.00	11	5.060E-04	Vents
				Sediment 0.00	12	0.000E+00	Floor
			Adheres 0.99		13	5.009E-02	Structures-Other
	Large-Above 0.34	Structures-Break 0.15	Recirculation Flow 0.27	Waterborne 1.00	14	1.377E-02	Vents
				Sediment 0.00	15	0.000E+00	Floor
			Adheres 0.73		16	3.723E-02	Structures-Break
		Structures-Other 0.85	Condensate Drainage 0.00	Waterborne 1.00	17	0.000E+00	Vents
				Sediment 0.00	18	0.000E+00	Floor
			Adheres 1.00		19	2.890E-01	Structures-Other
	Large-Below 0.04	Advected to Vent 0.90			20	3.600E-02	Vents
		Enclosures 0.01			21	4.000E-04	Enclosures
		Drywell Floor 0.04		Waterborne 0.90	22	1.440E-03	Vents
				Sediment 0.10	23	1.600E-04	Floor
		Structures-Break 0.01	Recirculation Flow 0.50	Waterborne 1.00	24	2.000E-04	Vents
				Sediment 0.00	25	0.000E+00	Floor
			Adheres 0.50		26	2.000E-04	Structures-Break
		Structures-Other 0.04	Condensate Drainage 0.00	Waterborne 1.00	27	0.000E+00	Vents
				Sediment 0.00	28	0.000E+00	Floor
			Adheres 1.00		29	1.600E-03	Structures-Other
	Canvassed 0.40				30	4.000E-01	Structures/Floor
					Total	1.000E+00	

DEBRIS TRANSPORT RESULTS							
Plant Design:	MARK I						
Estimate:	CENTRAL ESTIMATE			FIBROUS INSULATION			
Break:	RL BREAK						
ECCS:	NOT THROTTLED						
Sprays:	NO SPRAYS						
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	3.743E-02	3.407E-01	**0.3579**
All Zone-of-Influence							**0.2148**
FINAL DISTRIBUTIONS (Horizontal)							
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 CONTRIBUTIONS (Vertical)							
Debris Classification	**Vents**	**Enclosures**	**Floor**	**Structures Above**	**Structures Break**	**Structures 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%	



MARK I

CENTRAL ESTIMATE

RL BREAK

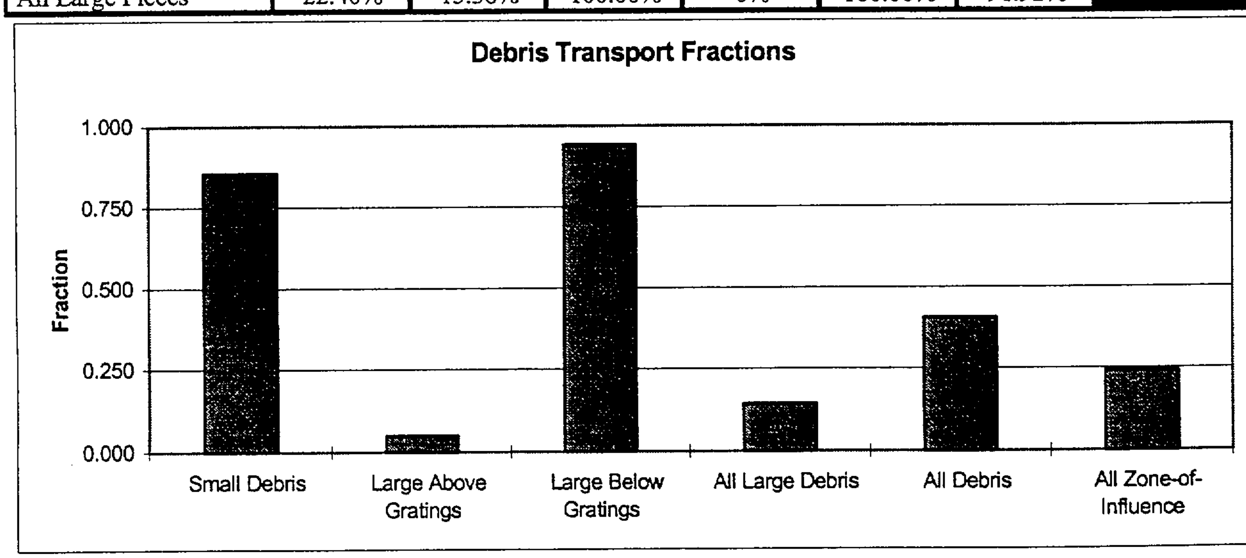
NOT THROTTLED

SPRAYS OPERATED

FIBROUS INSULATION

LOCA Type	Debris Classification	Distribution After Blowdown	Erosion and Washdown	Drywell Floor Pool	Path No.	Fraction	Final Location
RL Break 1.00	Small Pieces 0.22	Advected to Vents 0.46			1	1.012E-01	Vents
		Enclosures 0.01			2	2.200E-03	Enclosures
		Drywell Floor 0.20		Waterborne 1.00	3	4.400E-02	Vents
				Sediment 0.00	4	0.000E+00	Floor
		Structures-Above 0.02	Condensate Drainage 0.01	Waterborne 1.00	5	4.400E-05	Vents
				Sediment 0.00	6	0.000E+00	Floor
			Adheres 0.99		7	4.356E-03	Structures-Above
		Structures-Break 0.08	Recirculation Flow 1.00	Waterborne 1.00	8	1.760E-02	Vents
				Sediment 0.00	9	0.000E+00	Floor
			Adheres 0.00		10	0.000E+00	Structures-Break
		Structures-Other 0.23	Sprays/Condensate 0.50	Waterborne 1.00	11	2.530E-02	Vents
				Sediment 0.00	12	0.000E+00	Floor
			Adheres 0.50		13	2.530E-02	Structures-Other
	Large-Above 0.34	Structures-Break 0.15	Recirculation Flow 0.27	Waterborne 1.00	14	1.377E-02	Vents
				Sediment 0.00	15	0.000E+00	Floor
			Adheres 0.73		16	3.723E-02	Structures-Break
		Structures-Other 0.85	Sprays/Condensate 0.01	Waterborne 1.00	17	2.890E-03	Vents
				Sediment 0.00	18	0.000E+00	Floor
			Adheres 0.99		19	2.861E-01	Structures-Other
	Large-Below 0.04	Advected to Vent 0.90			20	3.600E-02	Vents
		Enclosures 0.01			21	4.000E-04	Enclosures
		Drywell Floor 0.04		Waterborne 0.90	22	1.440E-03	Vents
				Sediment 0.10	23	1.600E-04	Floor
		Structures-Break 0.01	Recirculation Flow 0.50	Waterborne 1.00	24	2.000E-04	Vents
				Sediment 0.00	25	0.000E+00	Floor
			Adheres 0.50		26	2.000E-04	Structures-Break
		Structures-Other 0.04	Sprays/Condensate 0.01	Waterborne 1.00	27	1.600E-05	Vents
				Sediment 0.00	28	0.000E+00	Floor
			Adheres 0.99		29	1.584E-03	Structures-Other
	Canvassed 0.40				30	4.000E-01	Structures/Floor
					Total	1.000E+00	

DEBRIS TRANSPORT RESULTS							
Plant Design:	**MARK I**						
Estimate:	**CENTRAL ESTIMATE**		**FIBROUS INSULATION**				
Break:	**RL BREAK**						
ECCS:	**NOT THROTTLED**						
Sprays:	**SPRAYS OPERATED**						
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 DISTRIBUTIONS (Horizontal)							
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 CONTRIBUTIONS (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%	

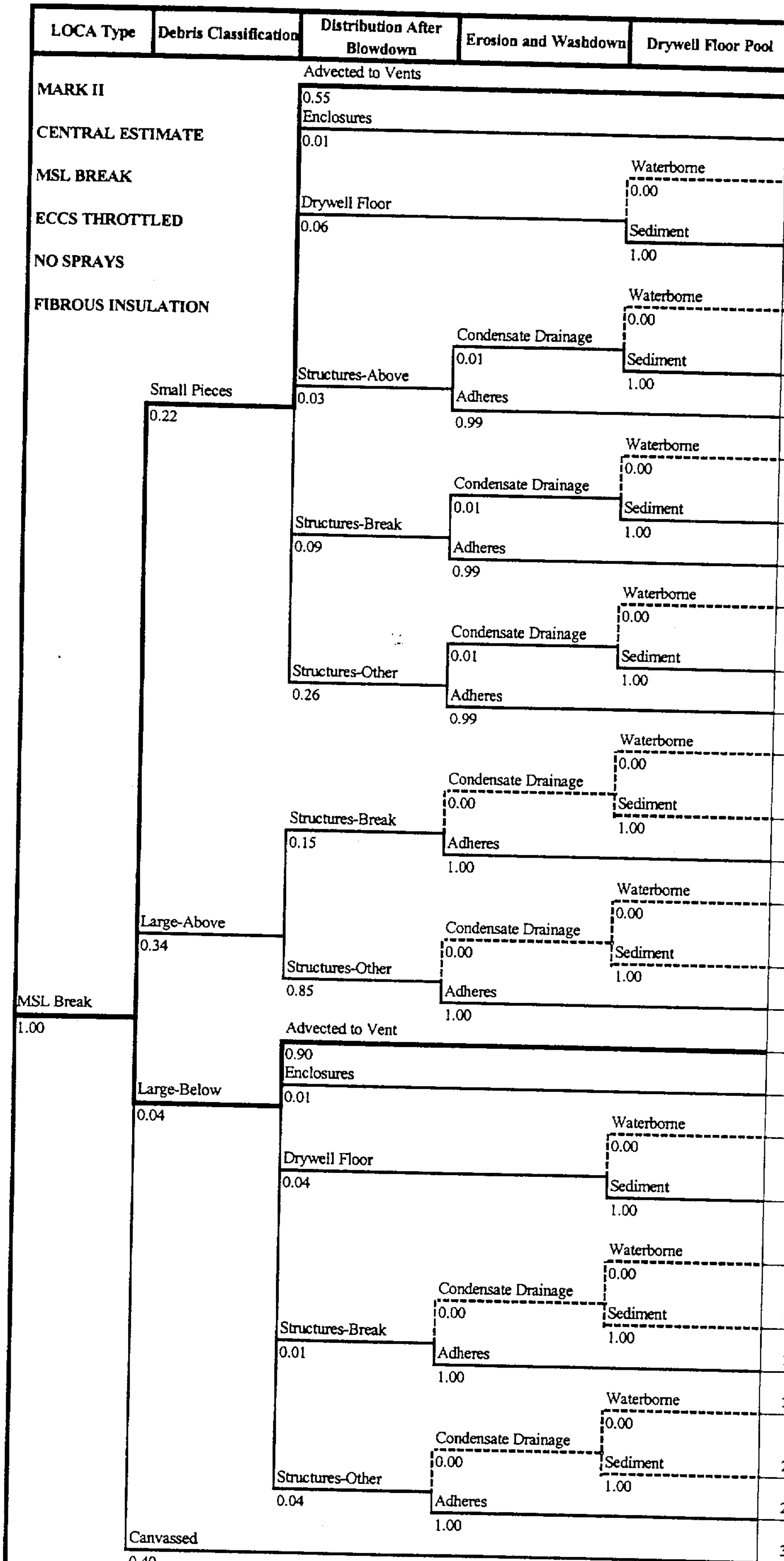


A.3.2 Mark II

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.



Path No.	Fraction	Final Location
1	1.210E-01	Vents
2	2.200E-03	Enclosures
3	0.000E+00	Vents
4	1.320E-02	Floor
5	0.000E+00	Vents
6	6.600E-05	Floor
7	6.534E-03	Structures-Above
8	0.000E+00	Vents
9	1.980E-04	Floor
10	1.960E-02	Structures-Break
11	0.000E+00	Vents
12	5.720E-04	Floor
13	5.663E-02	Structures-Other
14	0.000E+00	Vents
15	0.000E+00	Floor
16	5.100E-02	Structures-Break
17	0.000E+00	Vents
18	0.000E+00	Floor
19	2.890E-01	Structures-Other
20	3.600E-02	Vents
21	4.000E-04	Enclosures
22	0.000E+00	Vents
23	1.600E-03	Floor
24	0.000E+00	Vents
25	0.000E+00	Floor
26	4.000E-04	Structures-Break
27	0.000E+00	Vents
28	0.000E+00	Floor
29	1.600E-03	Structures-Other
30	4.000E-01	Structures/Floor
Total	1.000E+00	

DEBRIS TRANSPORT RESULTS

Plant Design:	MARK II	
Estimate:	CENTRAL ESTIMATE	FIBROUS INSULATION
Break:	MSL BREAK	
ECCS:	ECCS THROTTLED	
Sprays:	NO SPRAYS	

TREE QUANTIFICATION

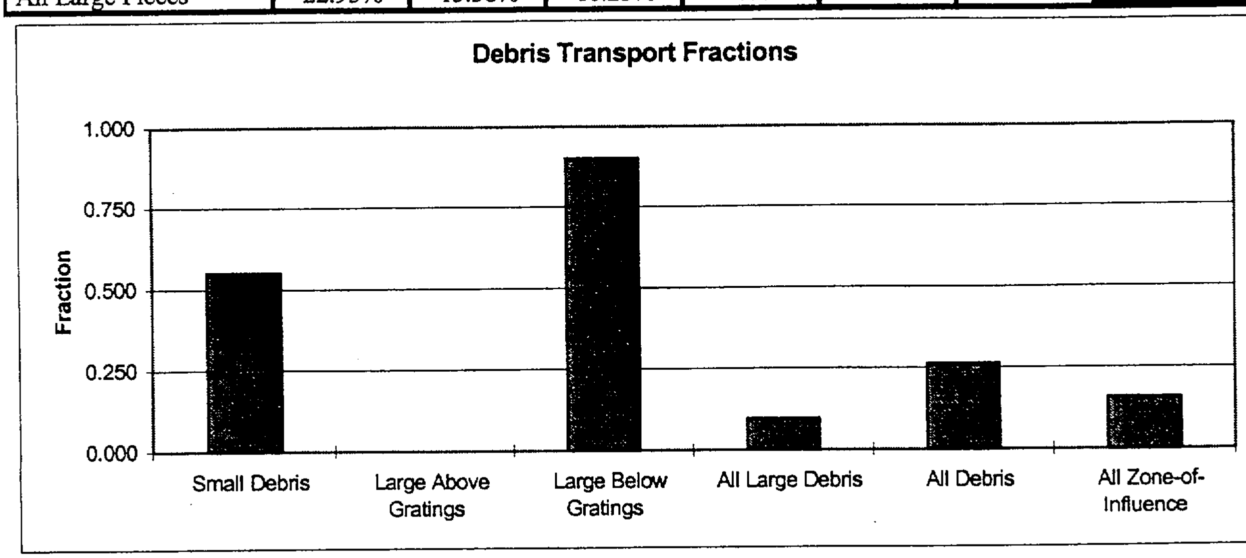
Debris Classification	Vents	Enclosures	Floor	Structures Above	Structures Break	Structures Other	Transport Fraction
Small Pieces	1.210E-01	2.200E-03	1.404E-02	6.534E-03	1.960E-02	5.663E-02	**0.5500**
Large Pieces-Above	0.000E+00	0	0.000E+00	0	5.100E-02	2.890E-01	**0.0000**
Large Pieces-Below	3.600E-02	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 DISTRIBUTIONS (Horizontal)

Debris Classification	Vents	Enclosures	Floor	Structures Above	Structures Break	Structures 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%

RELATIVE CONTRIBUTIONS (Vertical)

Debris Classification	Vents	Enclosures	Floor	Structures Above	Structures Break	Structures 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%



MARK II
CENTRAL ESTIMATE
MSL BREAK
ECCS THROTTLED
SPRAYS OPERATED
FIBROUS INSULATION

LOCA Type	Debris Classification	Distribution After Blowdown	Erosion and Washdown	Drywell Floor Pool	Path No.	Fraction	Final Location
MSL Break 1.00	Small Pieces 0.22	Advected to Vents 0.55			1	**1.210E-01**	**Vents**
		Enclosures 0.01			2	2.200E-03	Enclosures
		Drywell Floor 0.06		Waterborne 0.50	3	6.600E-03	**Vents**
				Sediment 0.50	4	6.600E-03	Floor
		Structures-Above 0.03	Condensate Drainage 0.01	Waterborne 0.90	5	5.940E-05	**Vents**
				Sediment 0.10	6	6.600E-06	Floor
			Adheres 0.99		7	6.534E-03	Structures-Above
		Structures-Break 0.09	Sprays/Condensate 0.50	Waterborne 0.90	8	8.910E-03	**Vents**
				Sediment 0.10	9	9.900E-04	Floor
			Adheres 0.50		10	9.900E-03	Structures-Break
		Structures-Other 0.26	Sprays/Condensate 0.50	Waterborne 0.90	11	**2.574E-02**	**Vents**
				Sediment 0.10	12	2.860E-03	Floor
			Adheres 0.50		13	2.860E-02	Structures-Other
	Large-Above 0.34	Structures-Break 0.15	Sprays/Condensate 0.01	Waterborne 1.00	14	5.100E-04	**Vents**
				Sediment 0.00	15	0.000E+00	Floor
			Adheres 0.99		16	5.049E-02	Structures-Break
		Structures-Other 0.85	Sprays/Condensate 0.01	Waterborne 1.00	17	2.890E-03	**Vents**
				Sediment 0.00	18	0.000E+00	Floor
			Adheres 0.99		19	2.861E-01	Structures-Other
	Large-Below 0.04	Advected to Vent 0.90			20	**3.600E-02**	**Vents**
		Enclosures 0.01			21	4.000E-04	Enclosures
		Drywell Floor 0.04		Waterborne 0.00	22	0.000E+00	**Vents**
				Sediment 1.00	23	1.600E-03	Floor
		Structures-Break 0.01	Sprays/Condensate 0.01	Waterborne 0.00	24	0.000E+00	**Vents**
				Sediment 1.00	25	4.000E-06	Floor
			Adheres 0.99		26	3.960E-04	Structures-Break
		Structures-Other 0.04	Sprays/Condensate 0.01	Waterborne 0.00	27	0.000E+00	**Vents**
				Sediment 1.00	28	1.600E-05	Floor
			Adheres 0.99		29	1.584E-03	Structures-Other
	Canvassed 0.40				30	4.000E-01	Structures/Floor
					Total	1.000E+00	

DEBRIS TRANSPORT RESULTS

Plant Design:	**MARK II**
Estimate:	**CENTRAL ESTIMATE**
Break:	**MSL BREAK**
ECCS:	**ECCS THROTTLED**
Sprays:	**SPRAYS OPERATED**

FIBROUS INSULATION

TREE QUANTIFICATION

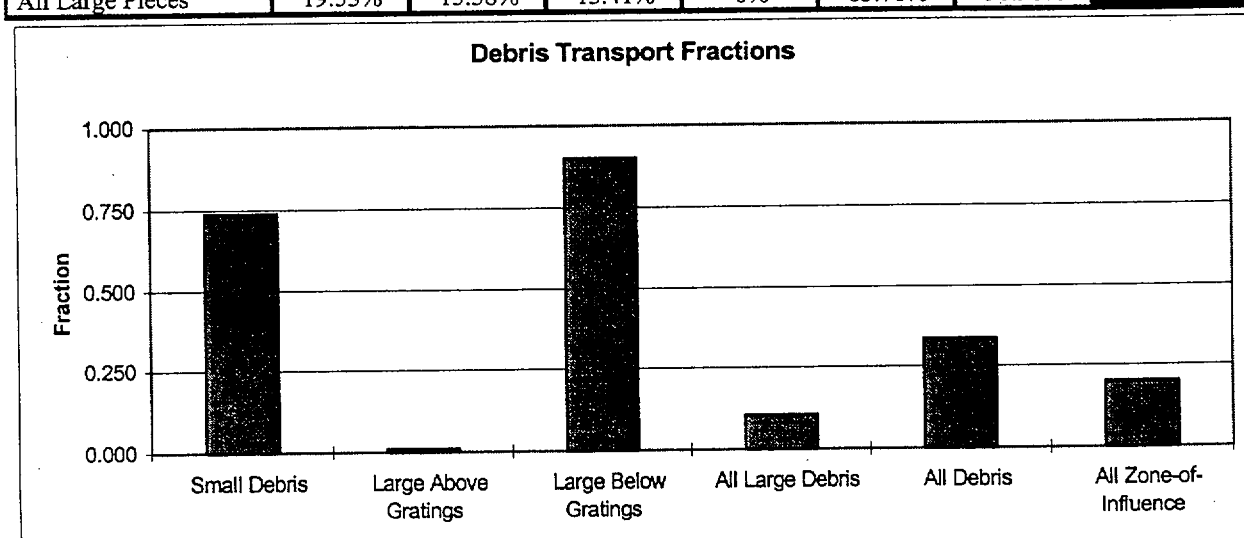
Debris Classification	Vents	Enclosures	Floor	Structures Above	Structures Break	Structures Other	Transport Fraction
Small Pieces	1.623E-01	2.200E-03	1.046E-02	6.534E-03	9.900E-03	2.860E-02	**0.7378**
Large Pieces-Above	3.400E-03	0	0.000E+00	0	5.049E-02	2.861E-01	**0.0100**
Large Pieces-Below	3.600E-02	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**

FINAL DISTRIBUTIONS (Horizontal)

Debris Classification	Vents	Enclosures	Floor	Structures Above	Structures Break	Structures 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%	13.39%	75.71%
All Debris	33.62%	0.43%	2.01%	1.09%	10.13%	52.72%

RELATIVE CONTRIBUTIONS (Vertical)

Debris Classification	Vents	Enclosures	Floor	Structures Above	Structures Break	Structures 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%



MARK II
CENTRAL ESTIMATE
MSL BREAK
NOT THROTTLED
NO SPRAYS
FIBROUS INSULATION

LOCA Type	Debris Classification	Distribution After Blowdown	Erosion and Washdown	Drywell Floor Pool	Path No.	Fraction	Final Location
MSL Break 1.00	Small Pieces 0.22	Advected to Vents 0.55			1	**1.210E-01**	**Vents**
		Enclosures 0.01			2	2.200E-03	Enclosures
		Drywell Floor 0.06		Waterborne 1.00	3	**1.320E-02**	**Vents**
				Sediment 0.00	4	0.000E+00	Floor
		Structures-Above 0.03	Condensate Drainage 0.01	Waterborne 1.00	5	6.600E-05	**Vents**
				Sediment 0.00	6	0.000E+00	Floor
			Adheres 0.99		7	6.534E-03	Structures-Above
		Structures-Break 0.09	Recirculation Flow 1.00	Waterborne 1.00	8	**1.980E-02**	**Vents**
				Sediment 0.00	9	0.000E+00	Floor
			Adheres 0.00		10	0.000E+00	Structures-Break
		Structures-Other 0.26	Condensate Drainage 0.01	Waterborne 1.00	11	5.720E-04	**Vents**
				Sediment 0.00	12	0.000E+00	Floor
			Adheres 0.99		13	5.663E-02	Structures-Other
	Large-Above 0.34	Structures-Break 0.15	Recirculation Flow 0.08	Waterborne 1.00	14	4.080E-03	**Vents**
				Sediment 0.00	15	0.000E+00	Floor
			Adheres 0.92		16	4.692E-02	Structures-Break
		Structures-Other 0.85	Condensate Drainage 0.00	Waterborne 1.00	17	0.000E+00	**Vents**
				Sediment 0.00	18	0.000E+00	Floor
			Adheres 1.00		19	2.890E-01	Structures-Other
	Large-Below 0.04	Advected to Vent 0.90			20	**3.600E-02**	**Vents**
		Enclosures 0.01			21	4.000E-04	Enclosures
		Drywell Floor 0.04		Waterborne 1.00	22	1.600E-03	**Vents**
				Sediment 0.00	23	0.000E+00	Floor
		Structures-Break 0.01	Recirculation Flow 0.50	Waterborne 1.00	24	2.000E-04	**Vents**
				Sediment 0.00	25	0.000E+00	Floor
			Adheres 0.50		26	2.000E-04	Structures-Break
		Structures-Other 0.04	Condensate Drainage 0.00	Waterborne 1.00	27	0.000E+00	**Vents**
				Sediment 0.00	28	0.000E+00	Floor
			Adheres 1.00		29	1.600E-03	Structures-Other
	Canvassed 0.40				30	4.000E-01	Structures/Floor
					Total	1.000E+00	

DEBRIS TRANSPORT RESULTS							
Plant Design:	**MARK II**						
Estimate:	**CENTRAL ESTIMATE**			**FIBROUS INSULATION**			
Break:	**MSL BREAK**						
ECCS:	**NOT THROTTLED**						
Sprays:	**NO SPRAYS**						

TREE QUANTIFICATION

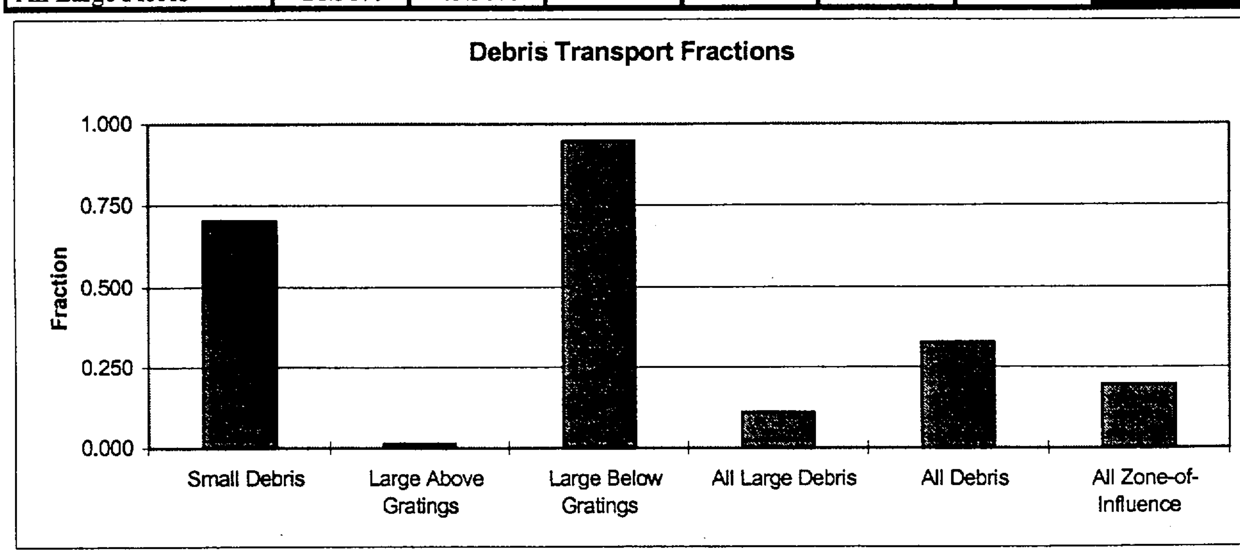
Debris Classification	Vents	Enclosures	Floor	Structures Above	Structures Break	Structures Other	Transport Fraction
Small Pieces	1.546E-01	2.200E-03	0.000E+00	6.534E-03	0.000E+00	5.663E-02	**0.7029**
Large Pieces-Above	4.080E-03	0	0.000E+00	0	4.692E-02	2.890E-01	**0.0120**
Large Pieces-Below	3.780E-02	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 DISTRIBUTIONS (Horizontal)

Debris Classification	Vents	Enclosures	Floor	Structures Above	Structures Break	Structures 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 CONTRIBUTIONS (Vertical)

Debris Classification	Vents	Enclosures	Floor	Structures Above	Structures Break	Structures 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%



MARK II

CENTRAL ESTIMATE

MSL BREAK

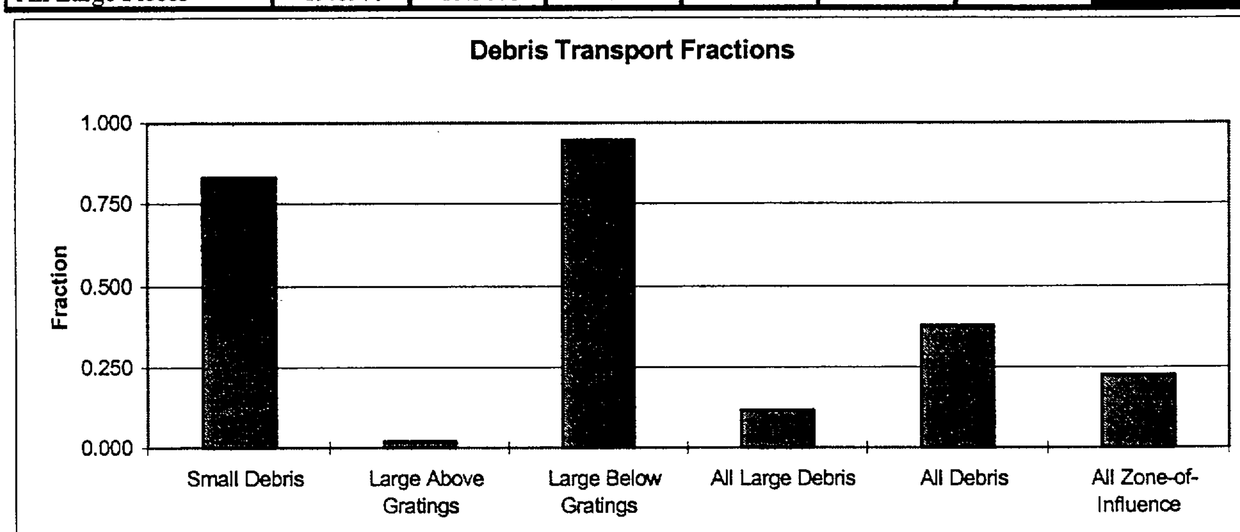
NOT THROTTLED

SPRAYS OPERATED

FIBROUS INSULATION

LOCA Type	Debris Classification	Distribution After Blowdown	Erosion and Washdown	Drywell Floor Pool	Path No.	Fraction	Final Location
MSL Break 1.00	Small Pieces 0.22	Advected to Vents 0.55			1	**1.210E-01**	**Vents**
		Enclosures 0.01			2	2.200E-03	Enclosures
		Drywell Floor 0.06		Waterborne 1.00	3	**1.320E-02**	**Vents**
				Sediment 0.00	4	0.000E+00	Floor
		Structures-Above 0.03	Condensate Drainage 0.01	Waterborne 1.00	5	6.600E-05	**Vents**
				Sediment 0.00	6	0.000E+00	Floor
			Adheres 0.99		7	6.534E-03	Structures-Above
		Structures-Break 0.09	Recirculation Flow 1.00	Waterborne 1.00	8	**1.980E-02**	**Vents**
				Sediment 0.00	9	0.000E+00	Floor
			Adheres 0.00		10	0.000E+00	Structures-Break
		Structures-Other 0.26	Sprays/Condensate 0.50	Waterborne 1.00	11	**2.860E-02**	**Vents**
				Sediment 0.00	12	0.000E+00	Floor
			Adheres 0.50		13	2.860E-02	Structures-Other
	Large-Above 0.34	Structures-Break 0.15	Recirculation Flow 0.08	Waterborne 1.00	14	4.080E-03	**Vents**
				Sediment 0.00	15	0.000E+00	Floor
			Adheres 0.92		16	4.692E-02	Structures-Break
		Structures-Other 0.85	Sprays/Condensate 0.01	Waterborne 1.00	17	2.890E-03	**Vents**
				Sediment 0.00	18	0.000E+00	Floor
			Adheres 0.99		19	2.861E-01	Structures-Other
	Large-Below 0.04	Advected to Vent 0.90			20	**3.600E-02**	**Vents**
		Enclosures 0.01			21	4.000E-04	Enclosures
		Drywell Floor 0.04		Waterborne 1.00	22	1.600E-03	**Vents**
				Sediment 0.00	23	0.000E+00	Floor
		Structures-Break 0.01	Recirculation Flow 0.50	Waterborne 1.00	24	2.000E-04	**Vents**
				Sediment 0.00	25	0.000E+00	Floor
			Adheres 0.50		26	2.000E-04	Structures-Break
		Structures-Other 0.04	Sprays/Condensate 0.01	Waterborne 1.00	27	1.600E-05	**Vents**
				Sediment 0.00	28	0.000E+00	Floor
			Adheres 0.99		29	1.584E-03	Structures-Other
	Canvassed 0.40				30	4.000E-01	Structures/Floor
					Total	1.000E+00	

DEBRIS TRANSPORT RESULTS							
Plant Design:	**MARK II**						
Estimate:	**CENTRAL ESTIMATE**			**FIBROUS INSULATION**			
Break:	**MSL BREAK**						
ECCS:	**NOT THROTTLED**						
Sprays:	**SPRAYS OPERATED**						
TREE QUANTIFICATION							
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 DISTRIBUTIONS (Horizontal)							
Debris Classification	**Vents**	**Enclosures**	**Floor**	**Structures Above**	**Structures Break**	**Structures 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%	7.85%	52.72%	
RELATIVE CONTRIBUTIONS (Vertical)							
Debris Classification	**Vents**	**Enclosures**	**Floor**	**Structures Above**	**Structures Break**	**Structures 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	16.63%	15.38%	N/A	0%	0.42%	0.50%	
All Large Pieces	19.69%	15.38%	N/A	0%	100.00%	90.96%	



A.3.2.2 Recirculation Line Break

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

MARK II
CENTRAL ESTIMATE
RL BREAK
ECCS THROTTLED
NO SPRAYS
FIBROUS INSULATION

LOCA Type	Debris Classification	Distribution After Blowdown	Erosion and Washdown	Drywell Floor Pool	Path No.	Fraction	Final Location
RL Break 1.00	Small Pieces 0.22	Advected to Vents 0.49			1	**1.078E-01**	**Vents**
		Enclosures 0.01			2	2.200E-03	Enclosures
		Drywell Floor 0.25		Waterborne 1.00	3	**5.500E-02**	**Vents**
				Sediment 0.00	4	0.000E+00	Floor
		Structures-Above 0.01	Condensate Drainage 0.01	Waterborne 1.00	5	2.200E-05	**Vents**
				Sediment 0.00	6	0.000E+00	Floor
			Adheres 0.99		7	2.178E-03	Structures-Above
		Structures-Break 0.06	Recirculation Flow 1.00	Waterborne 1.00	8	**1.320E-02**	**Vents**
				Sediment 0.00	9	0.000E+00	Floor
			Adheres 0.00		10	0.000E+00	Structures-Break
		Structures-Other 0.18	Condensate Drainage 0.01	Waterborne 1.00	11	3.960E-04	**Vents**
				Sediment 0.00	12	0.000E+00	Floor
			Adheres 0.99		13	3.920E-02	Structures-Other
	Large-Above 0.34	Structures-Break 0.15	Recirculation Flow 0.08	Waterborne 1.00	14	4.080E-03	**Vents**
				Sediment 0.00	15	0.000E+00	Floor
			Adheres 0.92		16	4.692E-02	Structures-Break
		Structures-Other 0.85	Condensate Drainage 0.00	Waterborne 1.00	17	0.000E+00	**Vents**
				Sediment 0.00	18	0.000E+00	Floor
			Adheres 1.00		19	2.890E-01	Structures-Other
	Large-Below 0.04	Advected to Vent 0.90			20	**3.600E-02**	**Vents**
		Enclosures 0.01			21	4.000E-04	Enclosures
		Drywell Floor 0.04		Waterborne 1.00	22	1.600E-03	**Vents**
				Sediment 0.00	23	0.000E+00	Floor
		Structures-Break 0.01	Recirculation Flow 0.50	Waterborne 1.00	24	2.000E-04	**Vents**
				Sediment 0.00	25	0.000E+00	Floor
			Adheres 0.50		26	2.000E-04	Structures-Break
		Structures-Other 0.04	Condensate Drainage 0.00	Waterborne 1.00	27	0.000E+00	**Vents**
				Sediment 0.00	28	0.000E+00	Floor
			Adheres 1.00		29	1.600E-03	Structures-Other
	Canvassed 0.40				30	4.000E-01	Structures/Floor
					Total	1.000E+00	

DEBRIS TRANSPORT RESULTS							
Plant Design:	MARK II						
Estimate:	CENTRAL ESTIMATE			FIBROUS INSULATION			
Break:	RL BREAK						
ECCS:	ECCS THROTTLED						
Sprays:	NO SPRAYS						

TREE QUANTIFICATION

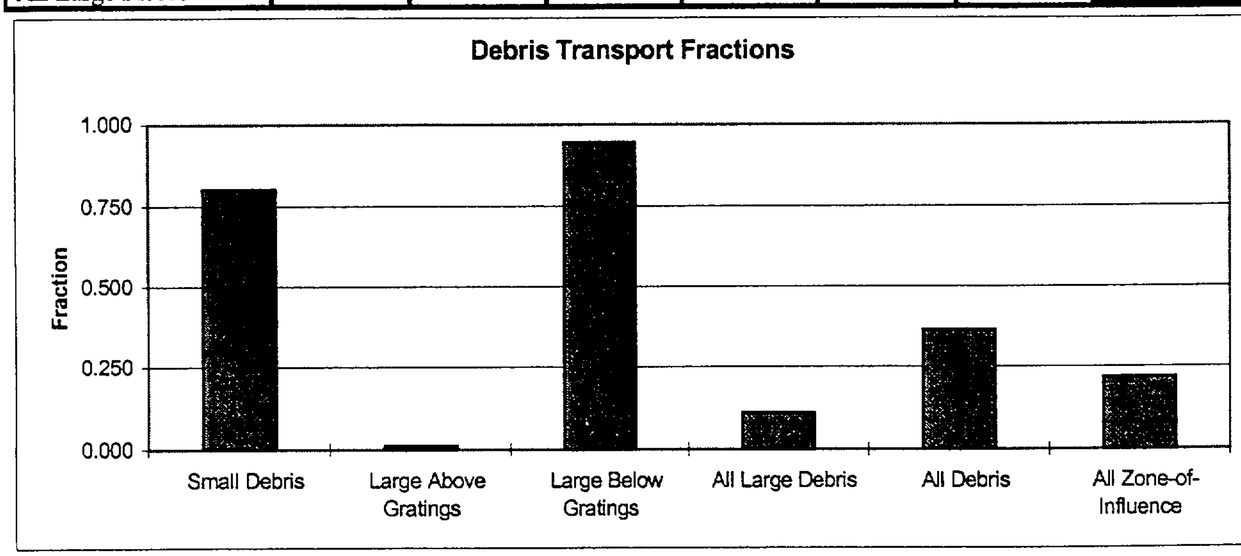
Debris Classification	Vents	Enclosures	Floor	Structures Above	Structures Break	Structures Other	Transport Fraction
Small Pieces	1.764E-01	2.200E-03	0.000E+00	2.178E-03	0.000E+00	3.920E-02	**0.8019**
Large Pieces-Above	4.080E-03	0	0.000E+00	0	4.692E-02	2.890E-01	**0.0120**
Large Pieces-Below	3.780E-02	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)

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	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)

Debris Classification	Vents	Enclosures	Floor	Structures Above	Structures Break	Structures 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%



MARK II

CENTRAL ESTIMATE

RL BREAK

ECCS THROTTLED

SPRAYS OPERATED

FIBROUS INSULATION

LOCA Type	Debris Classification	Distribution After Blowdown	Erosion and Washdown	Drywell Floor Pool	Path No.	Fraction	Final Location
RL Break 1.00	Small Pieces 0.22	Advected to Vents 0.49			1	**1.078E-01**	**Vents**
		Enclosures 0.01			2	2.200E-03	Enclosures
		Drywell Floor 0.25		Waterborne 1.00	3	**5.500E-02**	**Vents**
				Sediment 0.00	4	0.000E+00	Floor
		Structures-Above 0.01	Condensate Drainage 0.01	Waterborne 1.00	5	2.200E-05	**Vents**
				Sediment 0.00	6	0.000E+00	Floor
			Adheres 0.99		7	2.178E-03	Structures-Above
		Structures-Break 0.06	Recirculation Flow 1.00	Waterborne 1.00	8	**1.320E-02**	**Vents**
				Sediment 0.00	9	0.000E+00	Floor
			Adheres 0.00		10	0.000E+00	Structures-Break
		Structures-Other 0.18	Sprays/Condensate 0.50	Waterborne 1.00	11	**1.980E-02**	**Vents**
				Sediment 0.00	12	0.000E+00	Floor
			Adheres 0.50		13	1.980E-02	Structures-Other
	Large-Above 0.34	Structures-Break 0.15	Recirculation Flow 0.08	Waterborne 1.00	14	4.080E-03	**Vents**
				Sediment 0.00	15	0.000E+00	Floor
			Adheres 0.92		16	4.692E-02	Structures-Break
		Structures-Other 0.85	Sprays/Condensate 0.01	Waterborne 1.00	17	2.890E-03	**Vents**
				Sediment 0.00	18	0.000E+00	Floor
			Adheres 0.99		19	2.861E-01	Structures-Other
	Large-Below 0.04	Advected to Vent 0.90			20	**3.600E-02**	**Vents**
		Enclosures 0.01			21	4.000E-04	Enclosures
		Drywell Floor 0.04		Waterborne 1.00	22	1.600E-03	**Vents**
				Sediment 0.00	23	0.000E+00	Floor
		Structures-Break 0.01	Recirculation Flow 0.50	Waterborne 1.00	24	2.000E-04	**Vents**
				Sediment 0.00	25	0.000E+00	Floor
			Adheres 0.50		26	2.000E-04	Structures-Break
		Structures-Other 0.04	Sprays/Condensate 0.01	Waterborne 1.00	27	1.600E-05	**Vents**
				Sediment 0.00	28	0.000E+00	Floor
			Adheres 0.99		29	1.584E-03	Structures-Other
	Canvassed 0.40				30	4.000E-01	Structures/Floor
					Total	1.000E+00	

DEBRIS TRANSPORT RESULTS	
Plant Design:	MARK II
Estimate:	CENTRAL ESTIMATE
Break:	RL BREAK
ECCS:	ECCS THROTTLED
Sprays:	SPRAYS OPERATED

FIBROUS INSULATION

TREE QUANTIFICATION

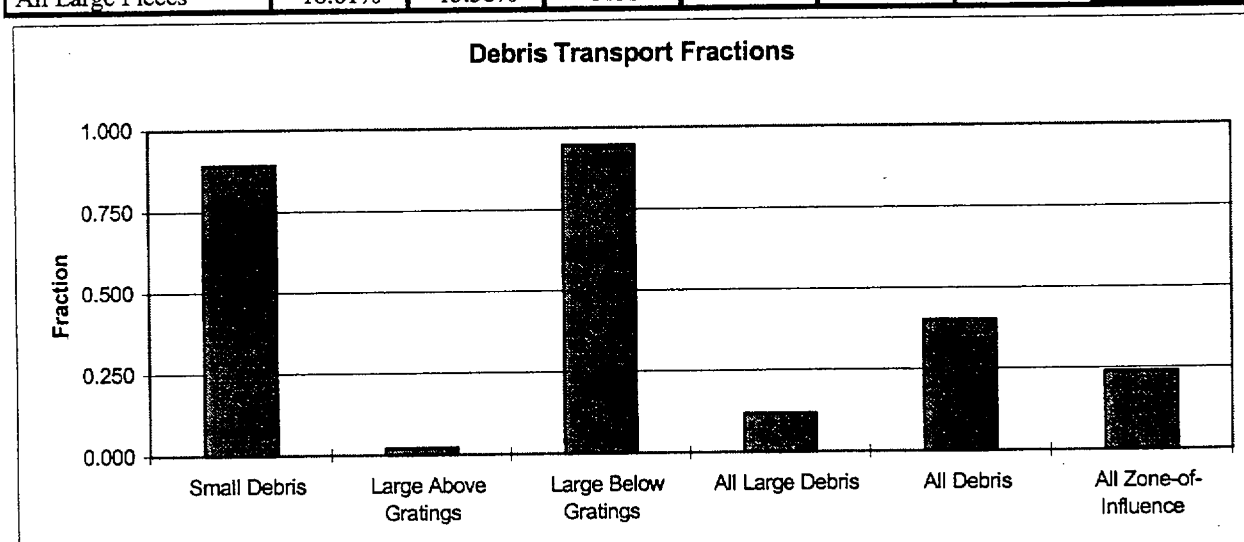
Debris Classification	Vents	Enclosures	Floor	Structures Above	Structures Break	Structures Other	Transport Fraction
Small Pieces	1.958E-01	2.200E-03	0.000E+00	2.178E-03	0.000E+00	1.980E-02	**0.8901**
Large Pieces-Above	6.970E-03	0	0.000E+00	0	4.692E-02	2.861E-01	**0.0205**
Large Pieces-Below	3.782E-02	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 DISTRIBUTIONS (Horizontal)

Debris Classification	Vents	Enclosures	Floor	Structures Above	Structures Break	Structures 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	Vents	Enclosures	Floor	Structures Above	Structures Break	Structures 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%	93.56%



MARK II
CENTRAL ESTIMATE
RL BREAK
NOT THROTTLED
NO SPRAYS
FIBROUS INSULATION

LOCA Type	Debris Classification	Distribution After Blowdown	Erosion and Washdown	Drywell Floor Pool	Path No.	Fraction	Final Location
RL Break 1.00	Small Pieces 0.22	Advected to Vents 0.49			1	1.078E-01	Vents
		Enclosures 0.01			2	2.200E-03	Enclosures
		Drywell Floor 0.25		Waterborne 1.00	3	5.500E-02	Vents
				Sediment 0.00	4	0.000E+00	Floor
		Structures-Above 0.01	Condensate Drainage 0.01	Waterborne 1.00	5	2.200E-05	Vents
				Sediment 0.00	6	0.000E+00	Floor
			Adheres 0.99		7	2.178E-03	Structures-Above
		Structures-Break 0.06	Recirculation Flow 1.00	Waterborne 1.00	8	1.320E-02	Vents
				Sediment 0.00	9	0.000E+00	Floor
			Adheres 0.00		10	0.000E+00	Structures-Break
		Structures-Other 0.18	Condensate Drainage 0.01	Waterborne 1.00	11	3.960E-04	Vents
				Sediment 0.00	12	0.000E+00	Floor
			Adheres 0.99		13	3.920E-02	Structures-Other
	Large-Above 0.34	Structures-Break 0.15	Recirculation Flow 0.27	Waterborne 1.00	14	1.377E-02	Vents
				Sediment 0.00	15	0.000E+00	Floor
			Adheres 0.73		16	3.723E-02	Structures-Break
		Structures-Other 0.85	Condensate Drainage 0.00	Waterborne 1.00	17	0.000E+00	Vents
				Sediment 0.00	18	0.000E+00	Floor
			Adheres 1.00		19	2.890E-01	Structures-Other
	Large-Below 0.04	Advected to Vent 0.90			20	3.600E-02	Vents
		Enclosures 0.01			21	4.000E-04	Enclosures
		Drywell Floor 0.04		Waterborne 1.00	22	1.600E-03	Vents
				Sediment 0.00	23	0.000E+00	Floor
		Structures-Break 0.01	Recirculation Flow 0.50	Waterborne 1.00	24	2.000E-04	Vents
				Sediment 0.00	25	0.000E+00	Floor
			Adheres 0.50		26	2.000E-04	Structures-Break
		Structures-Other 0.04	Condensate Drainage 0.00	Waterborne 1.00	27	0.000E+00	Vents
				Sediment 0.00	28	0.000E+00	Floor
			Adheres 1.00		29	1.600E-03	Structures-Other
	Canvassed 0.40				30	4.000E-01	Structures/Floor
					Total	1.000E+00	

DEBRIS TRANSPORT RESULTS

Plant Design:	MARK II
Estimate:	CENTRAL ESTIMATE
Break:	RL BREAK
ECCS:	NOT THROTTLED
Sprays:	NO SPRAYS

FIBROUS INSULATION

TREE QUANTIFICATION

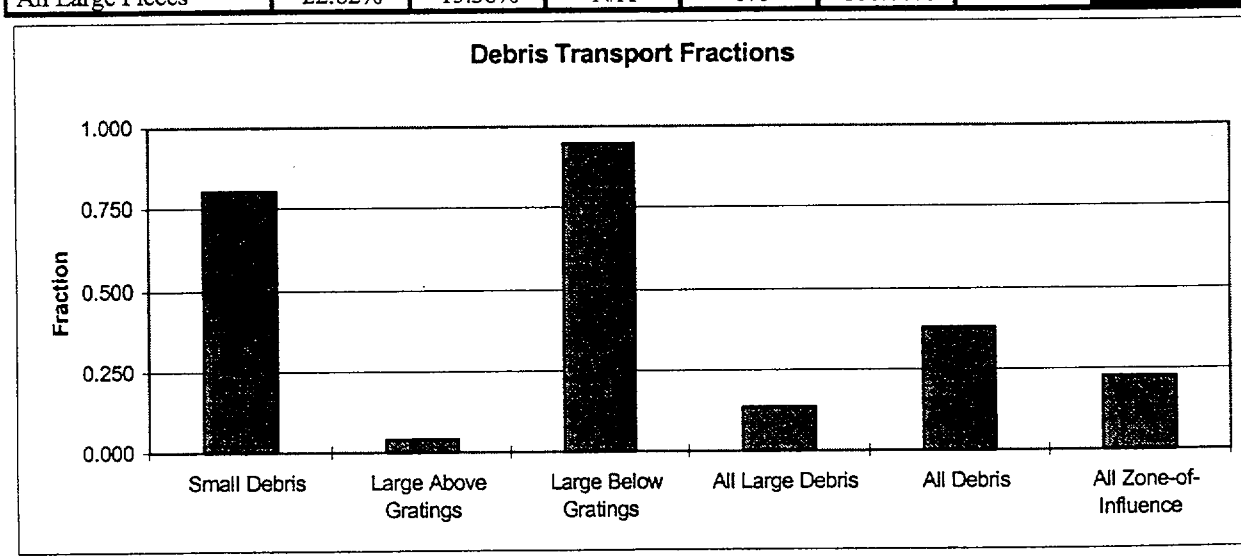
Debris Classification	Vents	Enclosures	Floor	Structures Above	Structures Break	Structures Other	Transport Fraction
Small Pieces	1.764E-01	2.200E-03	0.000E+00	2.178E-03	0.000E+00	3.920E-02	**0.8019**
Large Pieces-Above	1.377E-02	0	0.000E+00	0	3.723E-02	2.890E-01	**0.0405**
Large Pieces-Below	3.780E-02	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%



MARK II

CENTRAL ESTIMATE

RL BREAK

NOT THROTTLED

SPRAYS OPERATED

FIBROUS INSULATION

LOCA Type	Debris Classification	Distribution After Blowdown	Erosion and Washdown	Drywell Floor Pool	Path No.	Fraction	Final Location
RL Break 1.00	Small Pieces 0.22	Advected to Vents 0.49			1	**1.078E-01**	**Vents**
		Enclosures 0.01			2	2.200E-03	Enclosures
		Drywell Floor 0.25		Waterborne 1.00	3	**5.500E-02**	**Vents**
				Sediment 0.00	4	0.000E+00	Floor
		Structures-Above 0.01	Condensate Drainage 0.01	Waterborne 1.00	5	2.200E-05	**Vents**
				Sediment 0.00	6	0.000E+00	Floor
			Adheres 0.99		7	2.178E-03	Structures-Above
		Structures-Break 0.06	Recirculation Flow 1.00	Waterborne 1.00	8	**1.320E-02**	**Vents**
				Sediment 0.00	9	0.000E+00	Floor
			Adheres 0.00		10	0.000E+00	Structures-Break
		Structures-Other 0.18	Sprays/Condensate 0.50	Waterborne 1.00	11	**1.980E-02**	**Vents**
				Sediment 0.00	12	0.000E+00	Floor
			Adheres 0.50		13	1.980E-02	Structures-Other
	Large-Above 0.34	Structures-Break 0.15	Recirculation Flow 0.27	Waterborne 1.00	14	**1.377E-02**	**Vents**
				Sediment 0.00	15	0.000E+00	Floor
			Adheres 0.73		16	3.723E-02	Structures-Break
		Structures-Other 0.85	Sprays/Condensate 0.01	Waterborne 1.00	17	2.890E-03	**Vents**
				Sediment 0.00	18	0.000E+00	Floor
			Adheres 0.99		19	2.861E-01	Structures-Other
	Large-Below 0.04	Advected to Vent 0.90			20	**3.600E-02**	**Vents**
		Enclosures 0.01			21	4.000E-04	Enclosures
		Drywell Floor 0.04		Waterborne 1.00	22	1.600E-03	**Vents**
				Sediment 0.00	23	0.000E+00	Floor
		Structures-Break 0.01	Recirculation Flow 0.50	Waterborne 1.00	24	2.000E-04	**Vents**
				Sediment 0.00	25	0.000E+00	Floor
			Adheres 0.50		26	2.000E-04	Structures-Break
		Structures-Other 0.04	Sprays/Condensate 0.01	Waterborne 1.00	27	1.600E-05	**Vents**
				Sediment 0.00	28	0.000E+00	Floor
			Adheres 0.99		29	1.584E-03	Structures-Other
	Canvassed 0.40				30	4.000E-01	Structures/Floor
					Total	1.000E+00	

DEBRIS TRANSPORT RESULTS

Plant Design:	MARK II
Estimate:	CENTRAL ESTIMATE
Break:	RL BREAK
ECCS:	NOT THROTTLED
Sprays:	SPRAYS OPERATED

FIBROUS INSULATION

TREE QUANTIFICATION

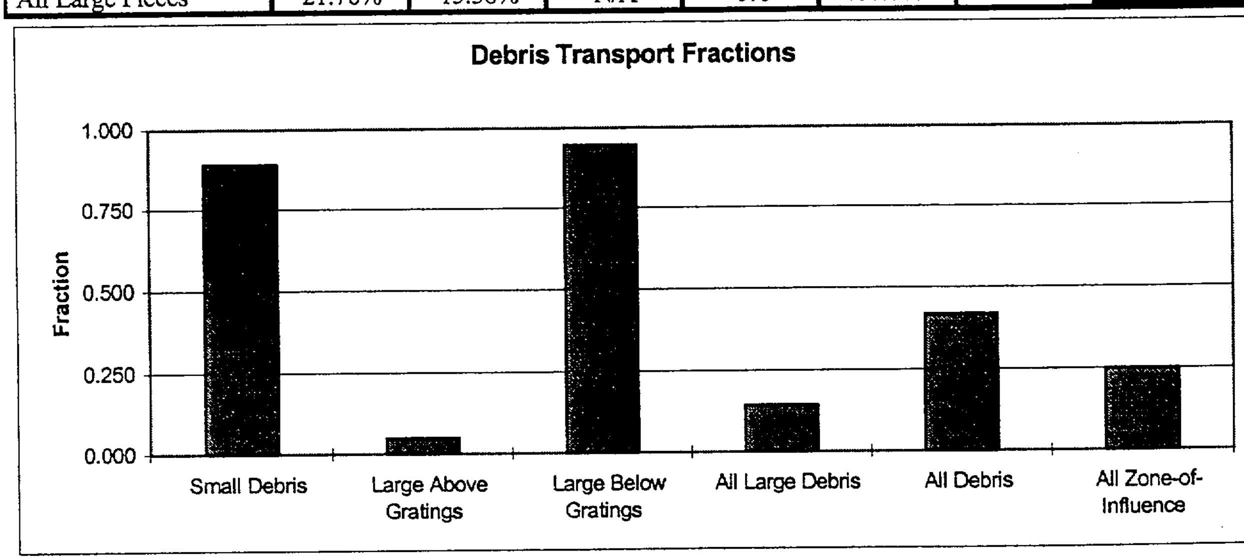
Debris Classification	Vents	Enclosures	Floor	Structures Above	Structures Break	Structures Other	Transport Fraction
Small Pieces	1.958E-01	2.200E-03	0.000E+00	2.178E-03	0.000E+00	1.980E-02	**0.8901**
Large Pieces-Above	1.666E-02	0	0.000E+00	0	3.723E-02	2.861E-01	**0.0490**
Large Pieces-Below	3.782E-02	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 DISTRIBUTIONS (Horizontal)

Debris Classification	Vents	Enclosures	Floor	Structures Above	Structures Break	Structures 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 CONTRIBUTIONS (Vertical)

Debris Classification	Vents	Enclosures	Floor	Structures Above	Structures Break	Structures 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%



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

MARK III

CENTRAL ESTIMATE

MSL BREAK

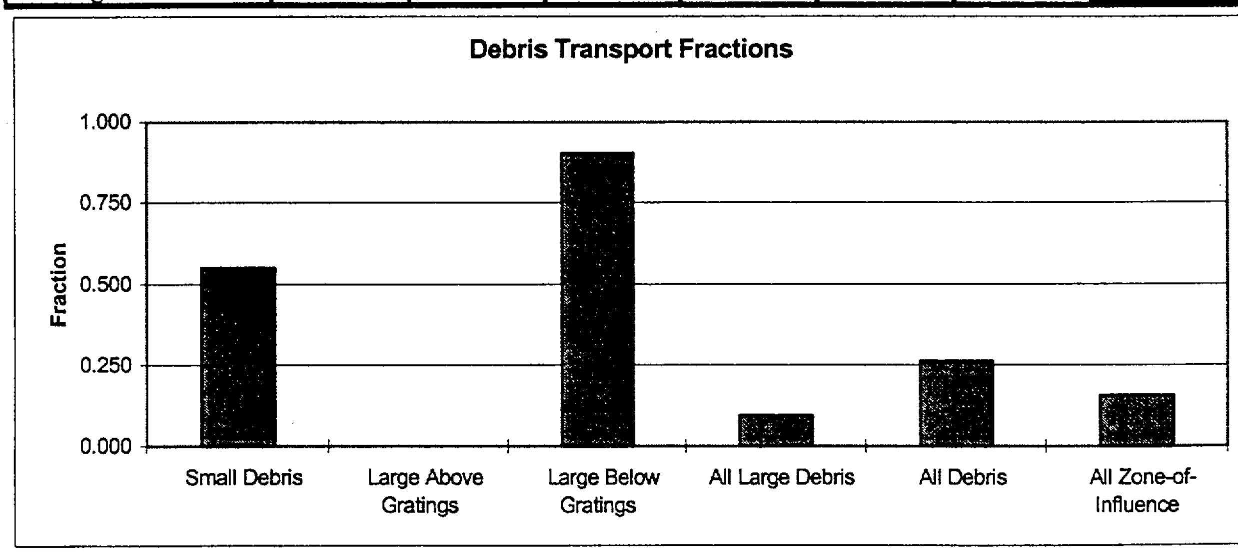
ECCS THROTTLED

NO SPRAYS

FIBROUS INSULATION

LOCA Type	Debris Classification	Distribution After Blowdown	Erosion and Washdown	Drywell Floor Pool	Path No.	Fraction	Final Location
MSL Break 1.00	Small Pieces 0.22	Advected to Vents 0.55			1	1.210E-01	Vents
		Enclosures 0.01			2	2.200E-03	Enclosures
		Drywell Floor 0.01		Waterborne 0.00	3	0.000E+00	Vents
				Sediment 1.00	4	2.200E-03	Floor
		Structures-Above 0.03	Condensate Drainage 0.01	Waterborne 0.00	5	0.000E+00	Vents
				Sediment 1.00	6	6.600E-05	Floor
			Adheres 0.99		7	6.534E-03	Structures-Above
		Structures-Break 0.10	Condensate Drainage 0.01	Waterborne 0.00	8	0.000E+00	Vents
				Sediment 1.00	9	2.200E-04	Floor
			Adheres 0.99		10	2.178E-02	Structures-Break
		Structures-Other 0.30	Condensate Drainage 0.01	Waterborne 0.00	11	0.000E+00	Vents
				Sediment 1.00	12	6.600E-04	Floor
			Adheres 0.99		13	6.534E-02	Structures-Other
	Large-Above 0.34	Structures-Break 0.15	Condensate Drainage 0.00	Waterborne 0.00	14	0.000E+00	Vents
				Sediment 1.00	15	0.000E+00	Floor
			Adheres 1.00		16	5.100E-02	Structures-Break
		Structures-Other 0.85	Condensate Drainage 0.00	Waterborne 0.00	17	0.000E+00	Vents
				Sediment 1.00	18	0.000E+00	Floor
			Adheres 1.00		19	2.890E-01	Structures-Other
	Large-Below 0.04	Advected to Vent 0.90			20	3.600E-02	Vents
		Enclosures 0.01			21	4.000E-04	Enclosures
		Drywell Floor 0.04		Waterborne 0.00	22	0.000E+00	Vents
				Sediment 1.00	23	1.600E-03	Floor
		Structures-Break 0.01	Condensate Drainage 0.00	Waterborne 0.00	24	0.000E+00	Vents
				Sediment 1.00	25	0.000E+00	Floor
			Adheres 1.00		26	4.000E-04	Structures-Break
		Structures-Other 0.04	Condensate Drainage 0.00	Waterborne 0.00	27	0.000E+00	Vents
				Sediment 1.00	28	0.000E+00	Floor
			Adheres 1.00		29	1.600E-03	Structures-Other
	Canvassed 0.40				30	4.000E-01	Structures/Floor
					Total	1.000E+00	

DEBRIS TRANSPORT RESULTS							
Plant Design:	MARK III						
Estimate:	CENTRAL ESTIMATE			FIBROUS INSULATION			
Break:	MSL BREAK						
ECCS:	ECCS THROTTLED						
Sprays:	NO SPRAYS						
TREE QUANTIFICATION							
Debris Classification	**Vents**	**Enclosures**	**Floor**	**Structures Above**	**Structures Break**	**Structures Other**	**Transport 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 DISTRIBUTIONS (Horizontal)							
Debris Classification	**Vents**	**Enclosures**	**Floor**	**Structures Above**	**Structures Break**	**Structures 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 CONTRIBUTIONS (Vertical)							
Debris Classification	**Vents**	**Enclosures**	**Floor**	**Structures Above**	**Structures Break**	**Structures 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%	



MARK III

CENTRAL ESTIMATE

MSL BREAK

NOT THROTTLED

NO SPRAYS

FIBROUS INSULATION

LOCA Type	Debris Classification	Distribution After Blowdown	Erosion and Washdown	Drywell Floor Pool	Path No.	Fraction	Final Location
MSL Break 1.00	Small Pieces 0.22	Advected to Vents 0.55			1	1.210E-01	Vents
		Enclosures 0.01			2	2.200E-03	Enclosures
		Drywell Floor 0.01		Waterborne 0.80	3	1.760E-03	Vents
				Sediment 0.20	4	4.400E-04	Floor
		Structures-Above 0.03	Condensate Drainage 0.01	Waterborne 0.80	5	5.280E-05	Vents
				Sediment 0.20	6	1.320E-05	Floor
			Adheres 0.99		7	6.534E-03	Structures-Above
		Structures-Break 0.10	Recirculation Flow 1.00	Waterborne 0.80	8	1.760E-02	Vents
				Sediment 0.20	9	4.400E-03	Floor
			Adheres 0.00		10	0.000E+00	Structures-Break
		Structures-Other 0.30	Condensate Drainage 0.01	Waterborne 0.80	11	5.280E-04	Vents
				Sediment 0.20	12	1.320E-04	Floor
			Adheres 0.99		13	6.534E-02	Structures-Other
	Large-Above 0.34	Structures-Break 0.15	Recirculation Flow 0.08	Waterborne 1.00	14	4.080E-03	Vents
				Sediment 0.00	15	0.000E+00	Floor
			Adheres 0.92		16	4.692E-02	Structures-Break
		Structures-Other 0.85	Condensate Drainage 0.00	Waterborne 1.00	17	0.000E+00	Vents
				Sediment 0.00	18	0.000E+00	Floor
			Adheres 1.00		19	2.890E-01	Structures-Other
	Large-Below 0.04	Advected to Vent 0.90			20	3.600E-02	Vents
		Enclosures 0.01			21	4.000E-04	Enclosures
		Drywell Floor 0.04		Waterborne 0.00	22	0.000E+00	Vents
				Sediment 1.00	23	1.600E-03	Floor
		Structures-Break 0.01	Recirculation Flow 0.50	Waterborne 0.00	24	0.000E+00	Vents
				Sediment 1.00	25	2.000E-04	Floor
			Adheres 0.50		26	2.000E-04	Structures-Break
		Structures-Other 0.04	Condensate Drainage 0.00	Waterborne 0.00	27	0.000E+00	Vents
				Sediment 1.00	28	0.000E+00	Floor
			Adheres 1.00		29	1.600E-03	Structures-Other
	Canvassed 0.40				30	4.000E-01	Structures/Floor
					Total	1.000E+00	

DEBRIS TRANSPORT RESULTS

Plant Design:	**MARK III**
Estimate:	**CENTRAL ESTIMATE**
Break:	**MSL BREAK**
ECCS:	**NOT THROTTLED**
Sprays:	**NO SPRAYS**

FIBROUS INSULATION

TREE QUANTIFICATION

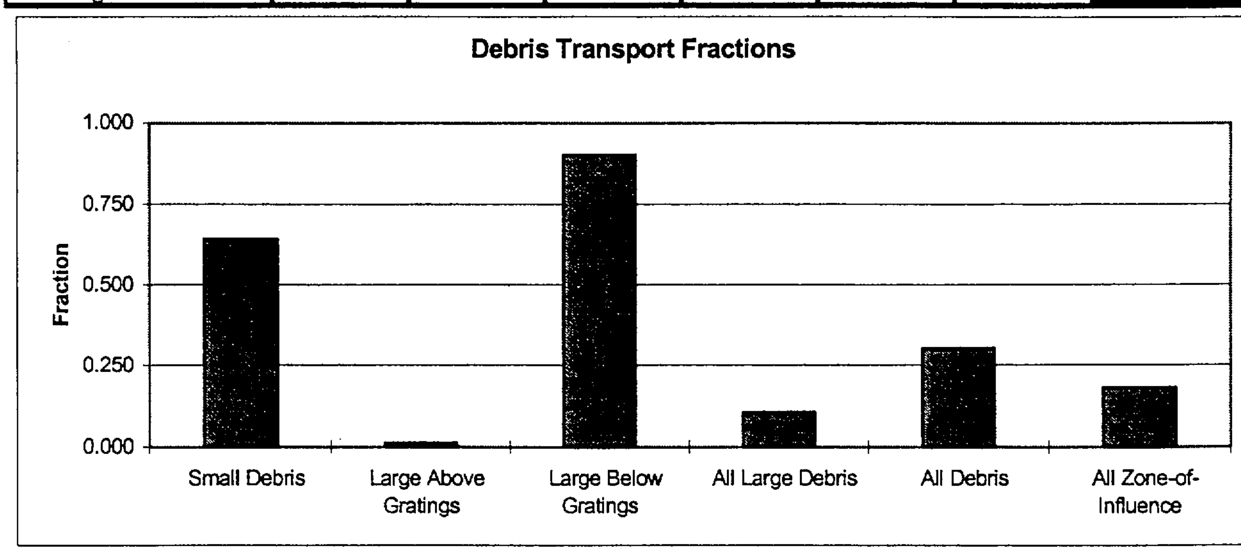
Debris Classification	Vents	Enclosures	Floor	Structures Above	Structures Break	Structures Other	Transport Fraction
Small Pieces	1.409E-01	2.200E-03	4.985E-03	6.534E-03	0.000E+00	6.534E-02	**0.6406**
Large Pieces-Above	4.080E-03	0	0.000E+00	0	4.692E-02	2.890E-01	**0.0120**
Large Pieces-Below	3.600E-02	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 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 CONTRIBUTIONS (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%



A.3.3.2 Recirculation Line Break

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

MARK III

CENTRAL ESTIMATE

RL BREAK

ECCS THROTTLED

NO SPRAYS

FIBROUS INSULATION

LOCA Type	Debris Classification	Distribution After Blowdown	Erosion and Washdown	Drywell Floor Pool	Path No.	Fraction	Final Location
RL Break 1.00	Small Pieces 0.22	Advected to Vents 0.49			1	**1.078E-01**	**Vents**
		Enclosures 0.01			2	2.200E-03	Enclosures
		Drywell Floor 0.21		Waterborne 0.80	3	**3.696E-02**	**Vents**
				Sediment 0.20	4	9.240E-03	Floor
		Structures-Above 0.01	Condensate Drainage 0.01	Waterborne 0.80	5	1.760E-05	**Vents**
				Sediment 0.20	6	4.400E-06	Floor
			Adheres 0.99		7	2.178E-03	Structures-Above
		Structures-Break 0.07	Recirculation Flow 1.00	Waterborne 0.80	8	**1.232E-02**	**Vents**
				Sediment 0.20	9	3.080E-03	Floor
			Adheres 0.00		10	0.000E+00	Structures-Break
		Structures-Other 0.21	Condensate Drainage 0.01	Waterborne 0.80	11	3.696E-04	**Vents**
				Sediment 0.20	12	9.240E-05	Floor
			Adheres 0.99		13	4.574E-02	Structures-Other
	Large-Above 0.34	Structures-Break 0.15	Recirculation Flow 0.08	Waterborne 1.00	14	4.080E-03	**Vents**
				Sediment 0.00	15	0.000E+00	Floor
			Adheres 0.92		16	4.692E-02	Structures-Break
		Structures-Other 0.85	Condensate Drainage 0.00	Waterborne 1.00	17	0.000E+00	**Vents**
				Sediment 0.00	18	0.000E+00	Floor
			Adheres 1.00		19	2.890E-01	Structures-Other
	Large-Below 0.04	Advected to Vent 0.90			20	**3.600E-02**	**Vents**
		Enclosures 0.01			21	4.000E-04	Enclosures
		Drywell Floor 0.04		Waterborne 0.00	22	0.000E+00	**Vents**
				Sediment 1.00	23	1.600E-03	Floor
		Structures-Break 0.01	Recirculation Flow 0.50	Waterborne 0.00	24	0.000E+00	**Vents**
				Sediment 1.00	25	2.000E-04	Floor
			Adheres 0.50		26	2.000E-04	Structures-Break
		Structures-Other 0.04	Condensate Drainage 0.00	Waterborne 0.00	27	0.000E+00	**Vents**
				Sediment 1.00	28	0.000E+00	Floor
			Adheres 1.00		29	1.600E-03	Structures-Other
	Canvassed 0.40				30	4.000E-01	Structures/Floor
					Total	1.000E+00	

DEBRIS TRANSPORT RESULTS

Plant Design:	MARK III
Estimate:	CENTRAL ESTIMATE
Break:	RL BREAK
ECCS:	ECCS THROTTLED
Sprays:	NO SPRAYS

FIBROUS INSULATION

TREE QUANTIFICATION

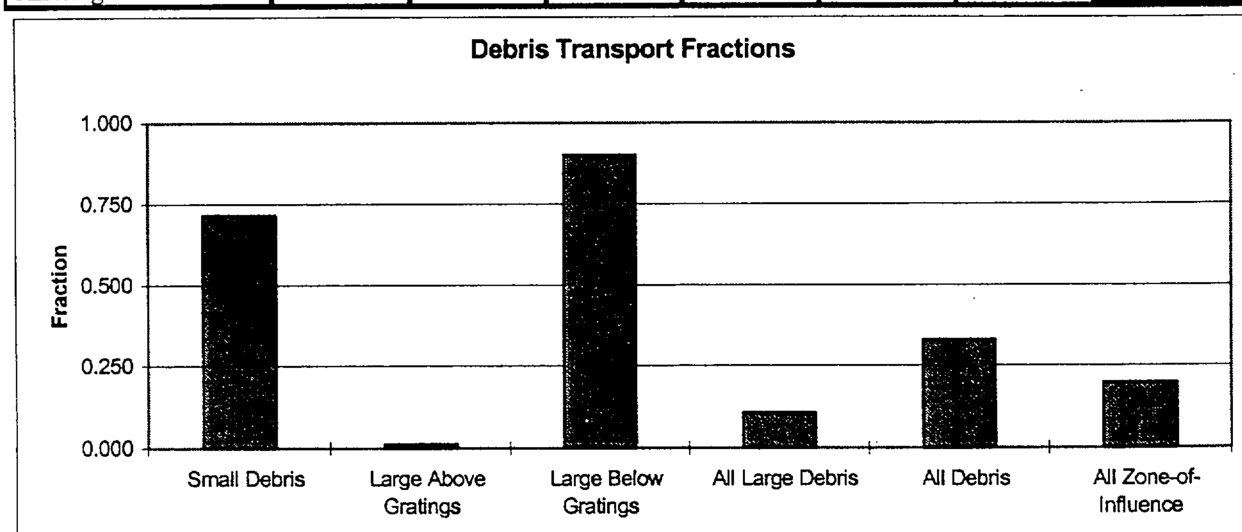
Debris Classification	Vents	Enclosures	Floor	Structures Above	Structures Break	Structures Other	Transport Fraction
Small Pieces	1.575E-01	2.200E-03	1.242E-02	2.178E-03	0.000E+00	4.574E-02	**0.7158**
Large Pieces-Above	4.080E-03	0	0.000E+00	0	4.692E-02	2.890E-01	**0.0120**
Large Pieces-Below	3.600E-02	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 DISTRIBUTIONS (Horizontal)

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 CONTRIBUTIONS (Vertical)

Debris Classification	Vents	Enclosures	Floor	Structures Above	Structures Break	Structures 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%



MARK III

CENTRAL ESTIMATE

RL BREAK

NOT THROTTLED

NO SPRAYS

FIBROUS INSULATION

LOCA Type	Debris Classification	Distribution After Blowdown	Erosion and Washdown	Drywell Floor Pool	Path No.	Fraction	Final Location
RL Break 1.00	Small Pieces 0.22	Advected to Vents 0.49			1	1.078E-01	Vents
		Enclosures 0.01			2	2.200E-03	Enclosures
		Drywell Floor 0.21		Waterborne 0.80	3	3.696E-02	Vents
				Sediment 0.20	4	9.240E-03	Floor
		Structures-Above 0.01	Condensate Drainage 0.01	Waterborne 0.80	5	1.760E-05	Vents
				Sediment 0.20	6	4.400E-06	Floor
			Adheres 0.99		7	2.178E-03	Structures-Above
		Structures-Break 0.07	Recirculation Flow 1.00	Waterborne 0.80	8	1.232E-02	Vents
				Sediment 0.20	9	3.080E-03	Floor
			Adheres 0.00		10	0.000E+00	Structures-Break
		Structures-Other 0.21	Condensate Drainage 0.01	Waterborne 0.80	11	3.696E-04	Vents
				Sediment 0.20	12	9.240E-05	Floor
			Adheres 0.99		13	4.574E-02	Structures-Other
	Large-Above 0.34	Structures-Break 0.15	Recirculation Flow 0.27	Waterborne 1.00	14	1.377E-02	Vents
				Sediment 0.00	15	0.000E+00	Floor
			Adheres 0.73		16	3.723E-02	Structures-Break
		Structures-Other 0.85	Condensate Drainage 0.00	Waterborne 1.00	17	0.000E+00	Vents
				Sediment 0.00	18	0.000E+00	Floor
			Adheres 1.00		19	2.890E-01	Structures-Other
	Large-Below 0.04	Advected to Vent 0.90			20	3.600E-02	Vents
		Enclosures 0.01			21	4.000E-04	Enclosures
		Drywell Floor 0.04		Waterborne 0.00	22	0.000E+00	Vents
				Sediment 1.00	23	1.600E-03	Floor
		Structures-Break 0.01	Recirculation Flow 0.50	Waterborne 0.00	24	0.000E+00	Vents
				Sediment 1.00	25	2.000E-04	Floor
			Adheres 0.50		26	2.000E-04	Structures-Break
		Structures-Other 0.04	Condensate Drainage 0.00	Waterborne 0.00	27	0.000E+00	Vents
				Sediment 1.00	28	0.000E+00	Floor
			Adheres 1.00		29	1.600E-03	Structures-Other
	Canvassed 0.40				30	4.000E-01	Structures/Floor
					Total	1.000E+00	

DEBRIS TRANSPORT RESULTS							
Plant Design:	**MARK III**						
Estimate:	**CENTRAL ESTIMATE**		**FIBROUS INSULATION**				
Break:	**RL BREAK**						
ECCS:	**NOT THROTTLED**						
Sprays:	**NO SPRAYS**						

TREE QUANTIFICATION

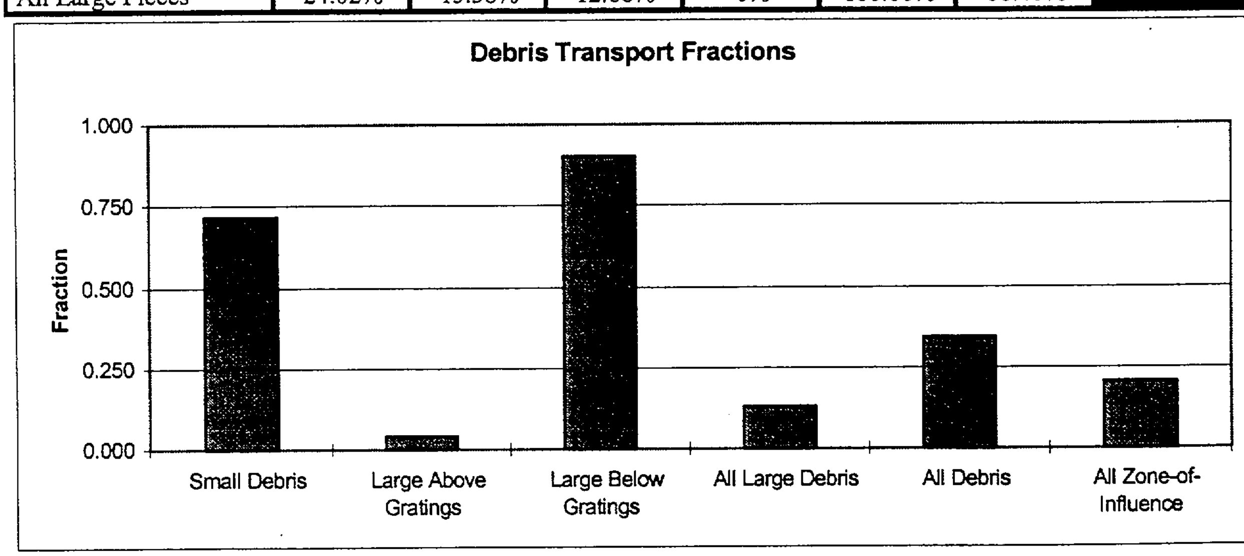
Debris Classification	Vents	Enclosures	Floor	Structures Above	Structures Break	Structures Other	Transport Fraction
Small Pieces	1.575E-01	2.200E-03	1.242E-02	2.178E-03	0.000E+00	4.574E-02	**0.7158**
Large Pieces-Above	1.377E-02	0	0.000E+00	0	3.723E-02	2.890E-01	**0.0405**
Large Pieces-Below	3.600E-02	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 DISTRIBUTIONS (Horizontal)

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	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 CONTRIBUTIONS (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%



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.

MARK I
UPPER BOUND
MSL BREAK
ECCS THROTTLED
NO SPRAYS
FIBROUS INSULATION

LOCA Type	Debris Classification	Distribution After Blowdown	Erosion and Washdown	Drywell Floor Pool	Path No.	Fraction	Final Location
MSL Break 1.00	Small Pieces 0.22	Advected to Vents 0.89			1	**1.958E-01**	**Vents**
		Enclosures 0.00			2	0.000E+00	Enclosures
		Drywell Floor 0.00		Waterborne 0.00	3	0.000E+00	**Vents**
				Sediment 1.00	4	0.000E+00	Floor
		Structures-Above 0.00	Condensate Drainage 0.10	Waterborne 0.00	5	0.000E+00	**Vents**
				Sediment 1.00	6	0.000E+00	Floor
			Adheres 0.90		7	0.000E+00	Structures-Above
		Structures-Break 0.03	Condensate Drainage 0.10	Waterborne 0.00	8	0.000E+00	**Vents**
				Sediment 1.00	9	6.600E-04	Floor
			Adheres 0.90		10	5.940E-03	Structures-Break
		Structures-Other 0.08	Condensate Drainage 0.10	Waterborne 0.00	11	0.000E+00	**Vents**
				Sediment 1.00	12	1.760E-03	Floor
			Adheres 0.90		13	1.584E-02	Structures-Other
	Large-Above 0.30	Structures-Break 0.25	Condensate Drainage 0.00	Waterborne 0.00	14	0.000E+00	**Vents**
				Sediment 1.00	15	0.000E+00	Floor
			Adheres 1.00		16	7.500E-02	Structures-Break
		Structures-Other 0.75	Condensate Drainage 0.00	Waterborne 0.00	17	0.000E+00	**Vents**
				Sediment 1.00	18	0.000E+00	Floor
			Adheres 1.00		19	2.250E-01	Structures-Other
	Large-Below 0.08	Advected to Vent 1.00			20	**8.000E-02**	**Vents**
		Enclosures 0.00			21	0.000E+00	Enclosures
		Drywell Floor 0.00		Waterborne 0.00	22	0.000E+00	**Vents**
				Sediment 1.00	23	0.000E+00	Floor
		Structures-Break 0.00	Condensate Drainage 0.00	Waterborne 0.00	24	0.000E+00	**Vents**
				Sediment 1.00	25	0.000E+00	Floor
			Adheres 1.00		26	0.000E+00	Structures-Break
		Structures-Other 0.00	Condensate Drainage 0.00	Waterborne 0.00	27	0.000E+00	**Vents**
				Sediment 1.00	28	0.000E+00	Floor
			Adheres 1.00		29	0.000E+00	Structures-Other
	Canvassed 0.40				30	4.000E-01	Structures/Floor
					Total	1.000E+00	

DEBRIS TRANSPORT RESULTS

Plant Design:	**MARK I**
Estimate:	**UPPER BOUND**
Break:	**MSL BREAK**
ECCS:	**ECCS THROTTLED**
Sprays:	**NO SPRAYS**

FIBROUS INSULATION

TREE QUANTIFICATION

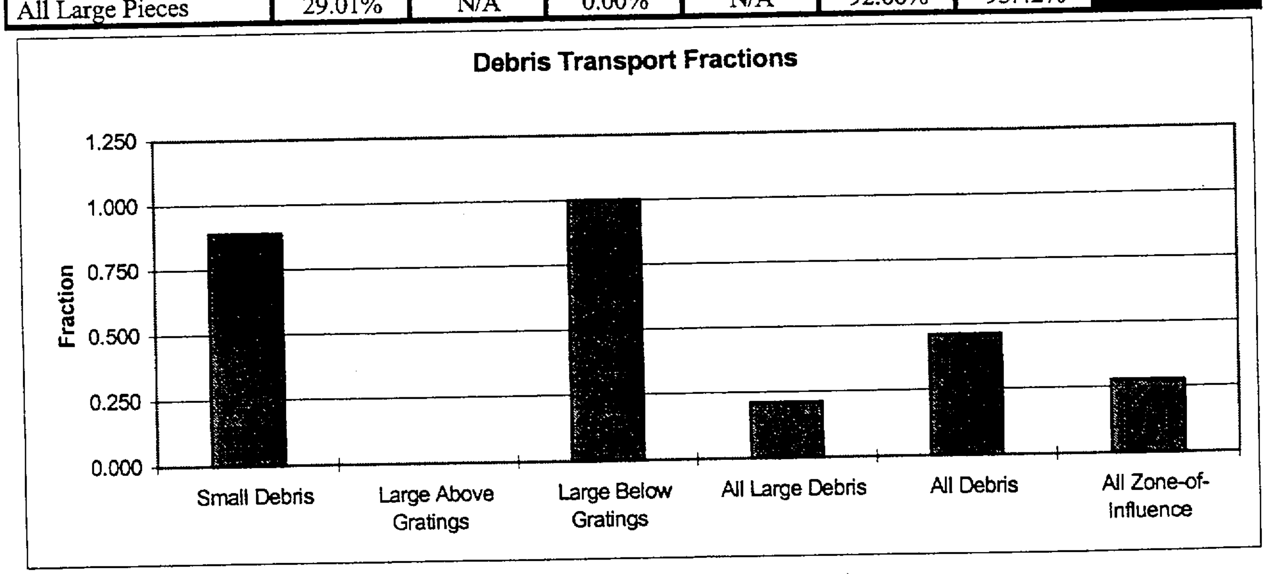
Debris Classification	Vents	Enclosures	Floor	Structures Above	Structures Break	Structures Other	Transport Fraction
Small Pieces	1.958E-01	0.000E+00	2.420E-03	0.000E+00	5.940E-03	1.584E-02	**0.8900**
Large Pieces-Above	0.000E+00	0	0.000E+00	0	7.500E-02	2.250E-01	**0.0000**
Large Pieces-Below	8.000E-02	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)

Debris Classification	Vents	Enclosures	Floor	Structures Above	Structures Break	Structures 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 CONTRIBUTIONS (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%



MARK I
UPPER BOUND
MSL BREAK
ECCS THROTTLED
SPRAYS OPERATED
FIBROUS INSULATION

LOCA Type	Debris Classification	Distribution After Blowdown	Erosion and Washdown	Drywell Floor Pool	Path No.	Fraction	Final Location
MSL Break 1.00	Small Pieces 0.22	Advected to Vents 0.89			1	**1.958E-01**	**Vents**
		Enclosures 0.00			2	0.000E+00	Enclosures
		Drywell Floor 0.00		Waterborne 0.00	3	0.000E+00	**Vents**
				Sediment 1.00	4	0.000E+00	Floor
		Structures-Above 0.00	Condensate Drainage 0.10	Waterborne 0.10	5	0.000E+00	**Vents**
				Sediment 0.90	6	0.000E+00	Floor
			Adheres 0.90		7	0.000E+00	Structures-Above
		Structures-Break 0.03	Sprays/Condensate 1.00	Waterborne 0.10	8	6.600E-04	**Vents**
				Sediment 0.90	9	5.940E-03	Floor
			Adheres 0.00		10	0.000E+00	Structures-Break
		Structures-Other 0.08	Sprays/Condensate 1.00	Waterborne 0.10	11	1.760E-03	**Vents**
				Sediment 0.90	12	1.584E-02	Floor
			Adheres 0.00		13	0.000E+00	Structures-Other
	Large-Above 0.30	Structures-Break 0.25	Sprays/Condensate 0.02	Waterborne 1.00	14	1.500E-03	**Vents**
				Sediment 0.00	15	0.000E+00	Floor
			Adheres 0.98		16	7.350E-02	Structures-Break
		Structures-Other 0.75	Sprays/Condensate 0.02	Waterborne 1.00	17	4.500E-03	**Vents**
				Sediment 0.00	18	0.000E+00	Floor
			Adheres 0.98		19	2.205E-01	Structures-Other
	Large-Below 0.08	Advected to Vent 1.00			20	**8.000E-02**	**Vents**
		Enclosures 0.00			21	0.000E+00	Enclosures
		Drywell Floor 0.00		Waterborne 0.00	22	0.000E+00	**Vents**
				Sediment 1.00	23	0.000E+00	Floor
		Structures-Break 0.00	Sprays/Condensate 0.02	Waterborne 0.00	24	0.000E+00	**Vents**
				Sediment 1.00	25	0.000E+00	Floor
			Adheres 0.98		26	0.000E+00	Structures-Break
		Structures-Other 0.00	Sprays/Condensate 0.02	Waterborne 0.00	27	0.000E+00	**Vents**
				Sediment 1.00	28	0.000E+00	Floor
			Adheres 0.98		29	0.000E+00	Structures-Other
	Canvassed 0.40				30	4.000E-01	Structures/Floor
					Total	1.000E+00	

DEBRIS TRANSPORT RESULTS

Plant Design:	**MARK I**
Estimate:	**UPPER BOUND**
Break:	**MSL BREAK**
ECCS:	**ECCS THROTTLED**
Sprays:	**SPRAYS OPERATED**

FIBROUS INSULATION

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**

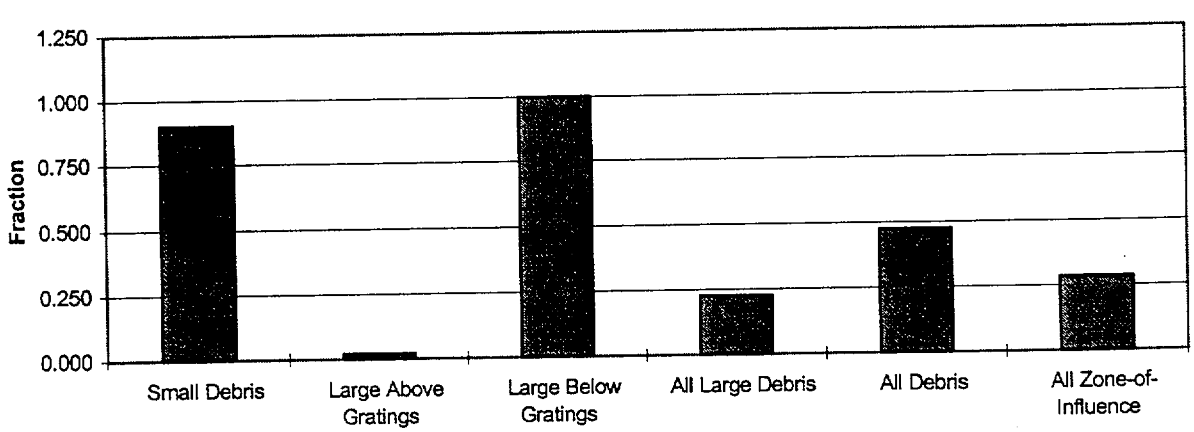
FINAL DISTRIBUTIONS (Horizontal)

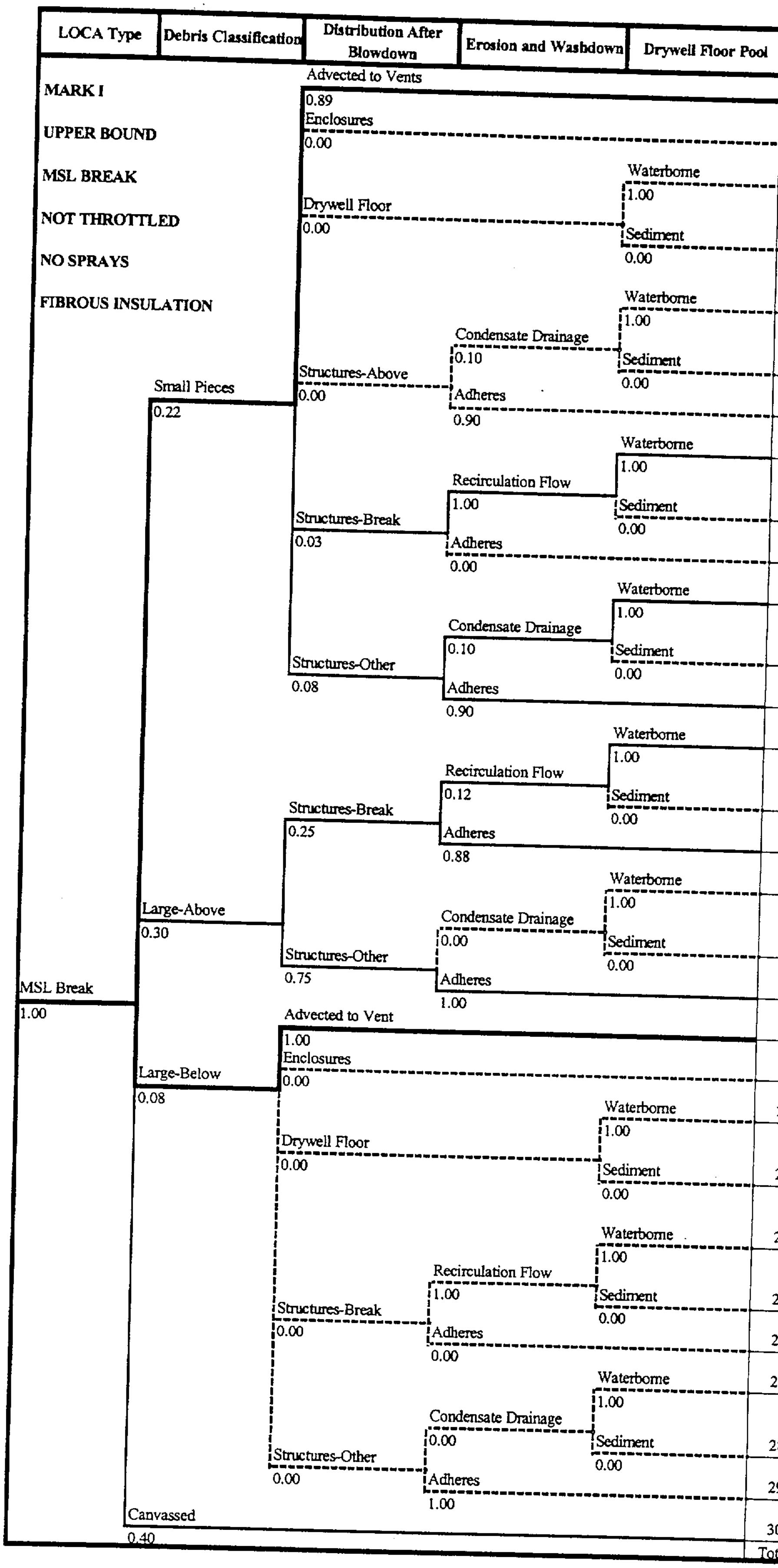
Debris Classification	Vents	Enclosures	Floor	Structures Above	Structures Break	Structures Other
Small Pieces	90.10%	0.00%	9.90%	0.00%	0.00%	0.00%
Large Pieces-Above	2.00%	0%	0.00%	0%	24.50%	73.50%
Large Pieces-Below	100.00%	0.00%	0.00%	0%	0.00%	0.00%
All Large Pieces	22.63%	0.00%	0.00%	0%	19.34%	58.03%
All Debris	47.37%	0.00%	3.63%	0.00%	12.25%	36.75%

RELATIVE CONTRIBUTIONS (Vertical)

Debris Classification	Vents	Enclosures	Floor	Structures Above	Structures Break	Structures 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%

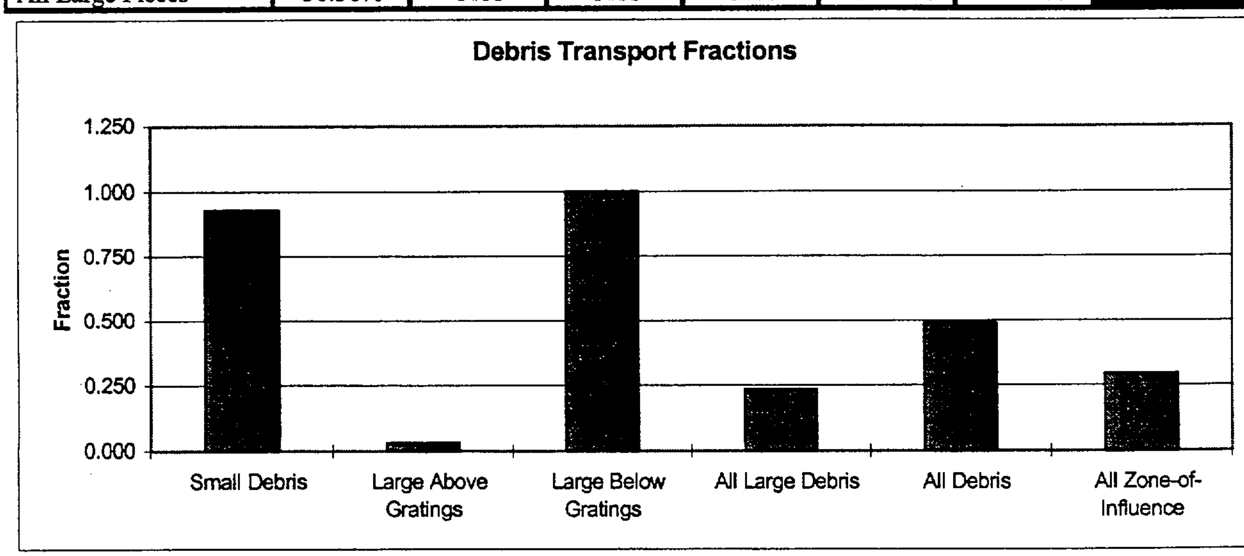
Debris Transport Fractions





Path No.	Fraction	Final Location
1	**1.958E-01**	**Vents**
2	0.000E+00	Enclosures
3	0.000E+00	**Vents**
4	0.000E+00	Floor
5	0.000E+00	**Vents**
6	0.000E+00	Floor
7	0.000E+00	Structures-Above
8	6.600E-03	**Vents**
9	0.000E+00	Floor
10	0.000E+00	Structures-Break
11	1.760E-03	**Vents**
12	0.000E+00	Floor
13	1.584E-02	Structures-Other
14	9.000E-03	**Vents**
15	0.000E+00	Floor
16	6.600E-02	Structures-Break
17	0.000E+00	**Vents**
18	0.000E+00	Floor
19	2.250E-01	Structures-Other
20	**8.000E-02**	**Vents**
21	0.000E+00	Enclosures
22	0.000E+00	**Vents**
23	0.000E+00	Floor
24	0.000E+00	**Vents**
25	0.000E+00	Floor
26	0.000E+00	Structures-Break
27	0.000E+00	**Vents**
28	0.000E+00	Floor
29	0.000E+00	Structures-Other
30	4.000E-01	Structures/Floor
Total	1.000E+00	

DEBRIS TRANSPORT RESULTS							
Plant Design:	MARK I						
Estimate:	UPPER BOUND			FIBROUS INSULATION			
Break:	MSL BREAK						
ECCS:	NOT THROTTLED						
Sprays:	NO SPRAYS						
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 DISTRIBUTIONS (Horizontal)							
Debris Classification	Vents	Enclosures	Floor	Structures Above	Structures Break	Structures 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%	
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%	



MARK I

UPPER BOUND

MSL BREAK

NOT THROTTLED

SPRAYS OPERATED

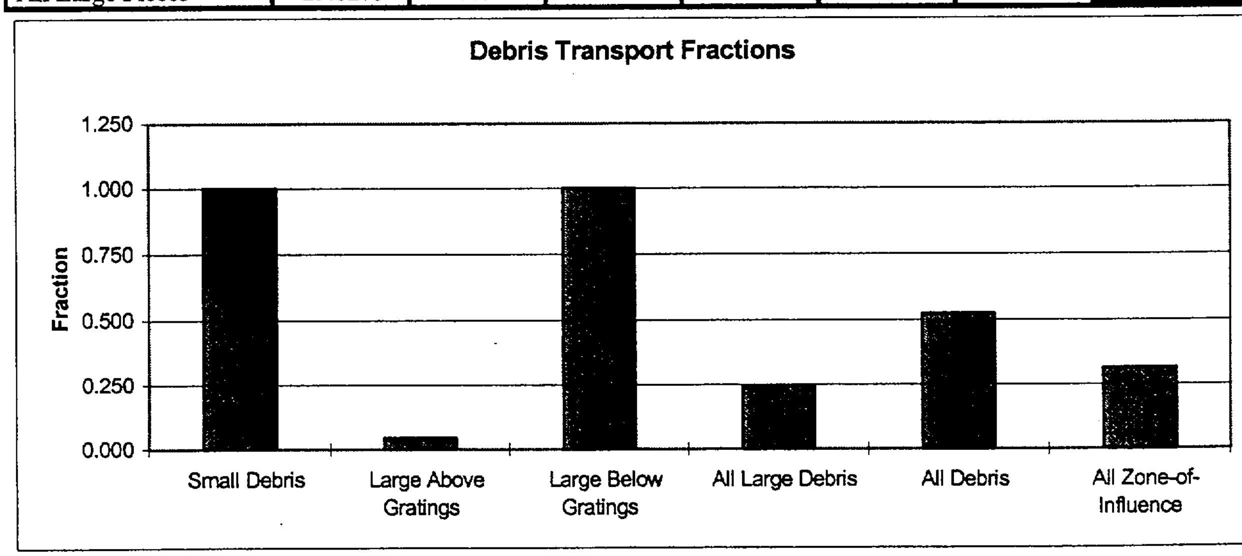
FIBROUS INSULATION

LOCA Type	Debris Classification	Distribution After Blowdown	Erosion and Washdown	Drywell Floor Pool	Path No.	Fraction	Final Location
MSL Break 1.00		Advected to Vents 0.89			1	1.958E-01	Vents
		Enclosures 0.00			2	0.000E+00	Enclosures
		Drywell Floor 0.00		Waterborne 1.00	3	0.000E+00	Vents
				Sediment 0.00	4	0.000E+00	Floor
	Small Pieces 0.22	Structures-Above 0.00	Condensate Drainage 0.10	Waterborne 1.00	5	0.000E+00	Vents
				Sediment 0.00	6	0.000E+00	Floor
			Adheres 0.90		7	0.000E+00	Structures-Above
		Structures-Break 0.03	Recirculation Flow 1.00	Waterborne 1.00	8	6.600E-03	Vents
				Sediment 0.00	9	0.000E+00	Floor
			Adheres 0.00		10	0.000E+00	Structures-Break
		Structures-Other 0.08	Sprays/Condensate 1.00	Waterborne 1.00	11	1.760E-02	Vents
				Sediment 0.00	12	0.000E+00	Floor
			Adheres 0.00		13	0.000E+00	Structures-Other
	Large-Above 0.30	Structures-Break 0.25	Recirculation Flow 0.12	Waterborne 1.00	14	9.000E-03	Vents
				Sediment 0.00	15	0.000E+00	Floor
			Adheres 0.88		16	6.600E-02	Structures-Break
		Structures-Other 0.75	Sprays/Condensate 0.02	Waterborne 1.00	17	4.500E-03	Vents
				Sediment 0.00	18	0.000E+00	Floor
			Adheres 0.98		19	2.205E-01	Structures-Other
	Large-Below 0.08	Advected to Vent 1.00			20	8.000E-02	Vents
		Enclosures 0.00			21	0.000E+00	Enclosures
		Drywell Floor 0.00		Waterborne 1.00	22	0.000E+00	Vents
				Sediment 0.00	23	0.000E+00	Floor
		Structures-Break 0.00	Recirculation Flow 1.00	Waterborne 1.00	24	0.000E+00	Vents
				Sediment 0.00	25	0.000E+00	Floor
			Adheres 0.00		26	0.000E+00	Structures-Break
		Structures-Other 0.00	Sprays/Condensate 0.02	Waterborne 1.00	27	0.000E+00	Vents
				Sediment 0.00	28	0.000E+00	Floor
			Adheres 0.98		29	0.000E+00	Structures-Other
	Canvassed 0.40				30	4.000E-01	Structures/Floor
					Total	1.000E+00	

DEBRIS TRANSPORT RESULTS							
Plant Design:	MARK I						
Estimate:	UPPER BOUND		FIBROUS INSULATION				
Break:	MSL BREAK						
ECCS:	NOT THROTTLED						
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	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 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	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 CONTRIBUTIONS (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
MARK I		Advected to Vents 0.00			1	0.000E+00	Vents
UPPER BOUND		Enclosures 0.00			2	0.000E+00	Enclosures
RL BREAK		Drywell Floor 1.00		Waterborne 1.00	3	2.200E-01	Vents
ECCS THROTTLED				Sediment 0.00	4	0.000E+00	Floor
NO SPRAYS		Structures-Above 0.00	Condensate Drainage 0.10	Waterborne 1.00	5	0.000E+00	Vents
FIBROUS INSULATION				Sediment 0.00	6	0.000E+00	Floor
	Small Pieces 0.22		Adheres 0.90		7	0.000E+00	Structures-Above
		Structures-Break 0.00	Recirculation Flow 1.00	Waterborne 1.00	8	0.000E+00	Vents
				Sediment 0.00	9	0.000E+00	Floor
			Adheres 0.00		10	0.000E+00	Structures-Break
		Structures-Other 0.00	Condensate Drainage 0.10	Waterborne 1.00	11	0.000E+00	Vents
				Sediment 0.00	12	0.000E+00	Floor
			Adheres 0.90		13	0.000E+00	Structures-Other
	Large-Above 0.30	Structures-Break 1.00	Recirculation Flow 0.12	Waterborne 1.00	14	3.600E-02	Vents
				Sediment 0.00	15	0.000E+00	Floor
			Adheres 0.88		16	2.640E-01	Structures-Break
		Structures-Other 0.00	Condensate Drainage 0.00	Waterborne 1.00	17	0.000E+00	Vents
				Sediment 0.00	18	0.000E+00	Floor
			Adheres 1.00		19	0.000E+00	Structures-Other
RL Break 1.00	Large-Below 0.08	Advected to Vent 1.00			20	8.000E-02	Vents
		Enclosures 0.00			21	0.000E+00	Enclosures
		Drywell Floor 0.00		Waterborne 1.00	22	0.000E+00	Vents
				Sediment 0.00	23	0.000E+00	Floor
		Structures-Break 0.00	Recirculation Flow 1.00	Waterborne 1.00	24	0.000E+00	Vents
				Sediment 0.00	25	0.000E+00	Floor
			Adheres 0.00		26	0.000E+00	Structures-Break
		Structures-Other 0.00	Condensate Drainage 0.00	Waterborne 1.00	27	0.000E+00	Vents
				Sediment 0.00	28	0.000E+00	Floor
			Adheres 1.00		29	0.000E+00	Structures-Other
	Canvassed 0.40				30	4.000E-01	Structures/Floor
					Total	1.000E+00	

DEBRIS TRANSPORT RESULTS							
Plant Design:	**MARK I**						
Estimate:	**UPPER BOUND**			**FIBROUS INSULATION**			
Break:	**RL BREAK**						
ECCS:	**ECCS THROTTLED**						
Sprays:	**NO SPRAYS**						

TREE QUANTIFICATION

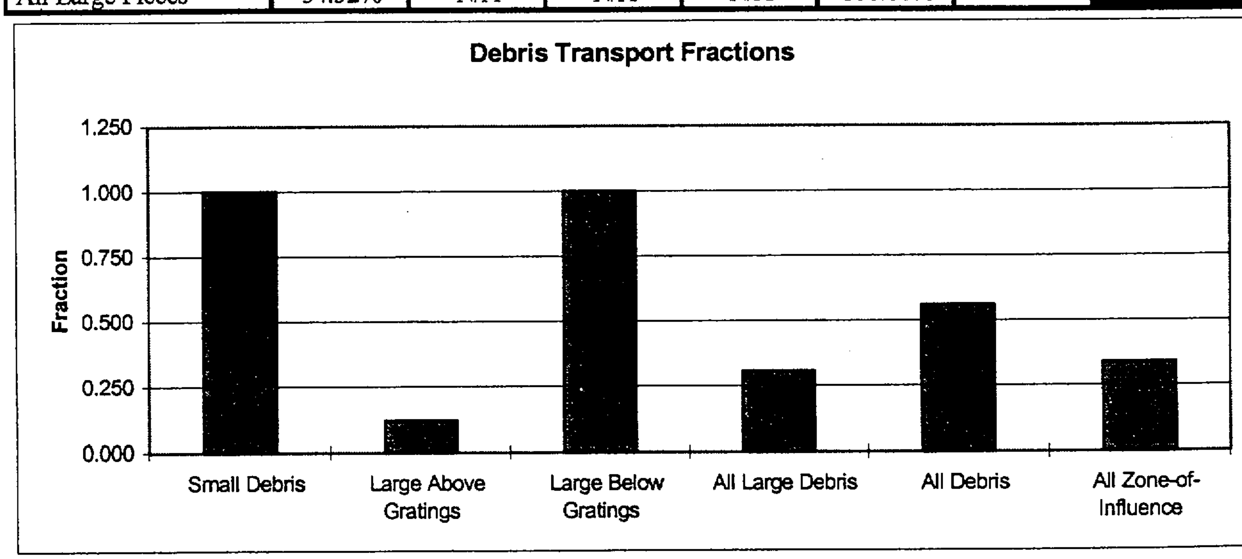
Debris Classification	Vents	Enclosures	Floor	Structures Above	Structures Break	Structures Other	Transport Fraction
Small Pieces	2.200E-01	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	**1.0000**
Large Pieces-Above	3.600E-02	0	0.000E+00	0	2.640E-01	0.000E+00	**0.1200**
Large Pieces-Below	8.000E-02	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**

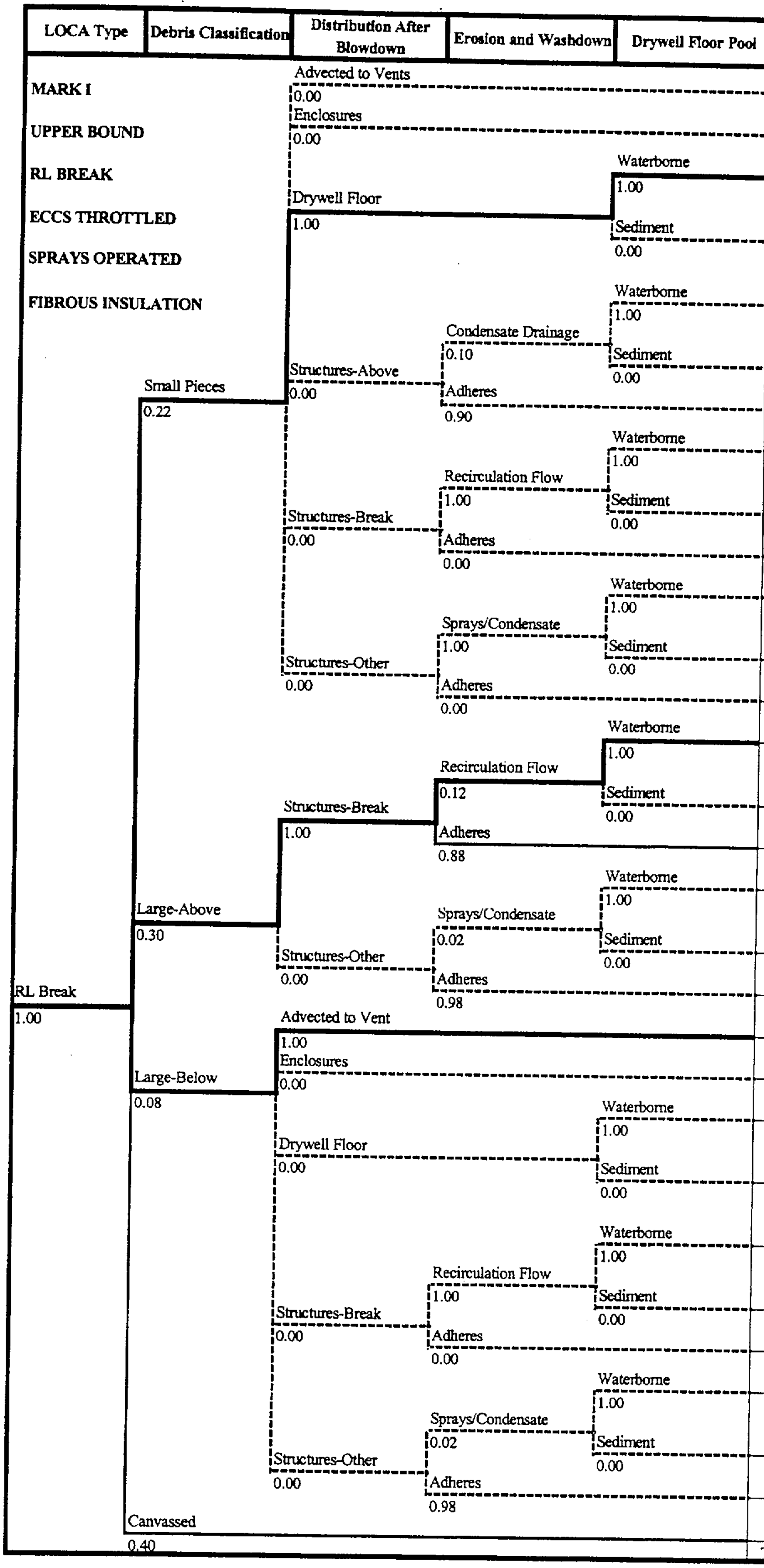
FINAL DISTRIBUTIONS (Horizontal)

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 CONTRIBUTIONS (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





Path No.	Fraction	Final Location
1	0.000E+00	**Vents**
2	0.000E+00	Enclosures
3	**2.200E-01**	**Vents**
4	0.000E+00	Floor
5	0.000E+00	**Vents**
6	0.000E+00	Floor
7	0.000E+00	Structures-Above
8	0.000E+00	**Vents**
9	0.000E+00	Floor
10	0.000E+00	Structures-Break
11	0.000E+00	**Vents**
12	0.000E+00	Floor
13	0.000E+00	Structures-Other
14	**3.600E-02**	**Vents**
15	0.000E+00	Floor
16	2.640E-01	Structures-Break
17	0.000E+00	**Vents**
18	0.000E+00	Floor
19	0.000E+00	Structures-Other
20	**8.000E-02**	**Vents**
21	0.000E+00	Enclosures
22	0.000E+00	**Vents**
23	0.000E+00	Floor
24	0.000E+00	**Vents**
25	0.000E+00	Floor
26	0.000E+00	Structures-Break
27	0.000E+00	**Vents**
28	0.000E+00	Floor
29	0.000E+00	Structures-Other
30	4.000E-01	Structures/Floor
Total	1.000E+00	

DEBRIS TRANSPORT RESULTS							
Plant Design:	MARK I						
Estimate:	UPPER BOUND		FIBROUS INSULATION				
Break:	RL BREAK						
ECCS:	ECCS THROTTLED						
Sprays:	SPRAYS OPERATED						

TREE QUANTIFICATION

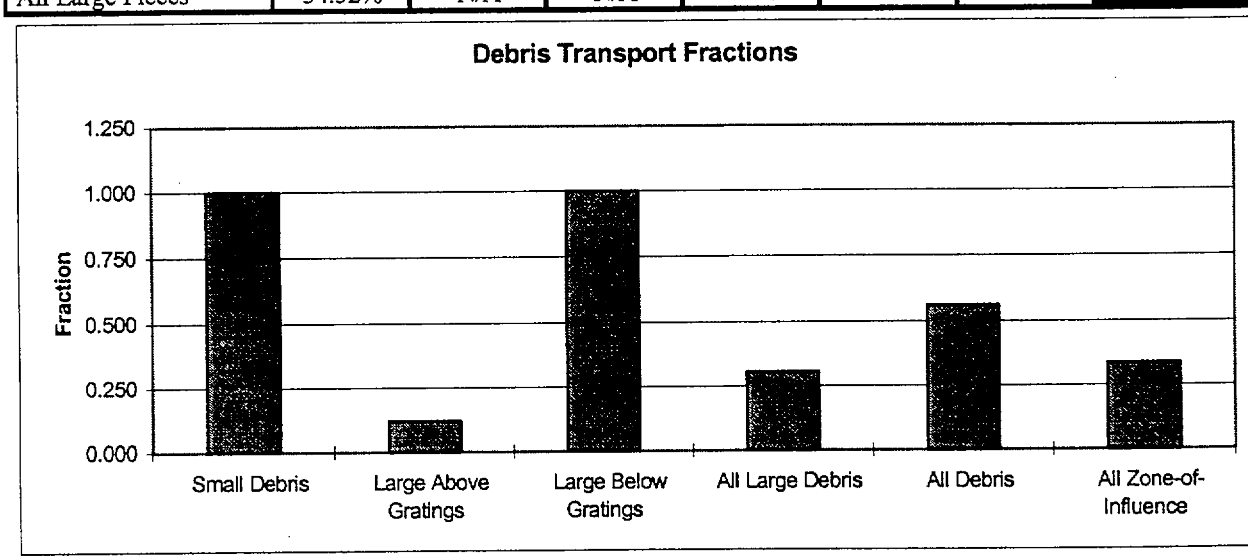
Debris Classification	Vents	Enclosures	Floor	Structures Above	Structures Break	Structures Other	Transport Fraction
Small Pieces	2.200E-01	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	**1.0000**
Large Pieces-Above	3.600E-02	0	0.000E+00	0	2.640E-01	0.000E+00	**0.1200**
Large Pieces-Below	8.000E-02	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 CONTRIBUTIONS (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 Washdown	Drywell Floor Pool

MARK I

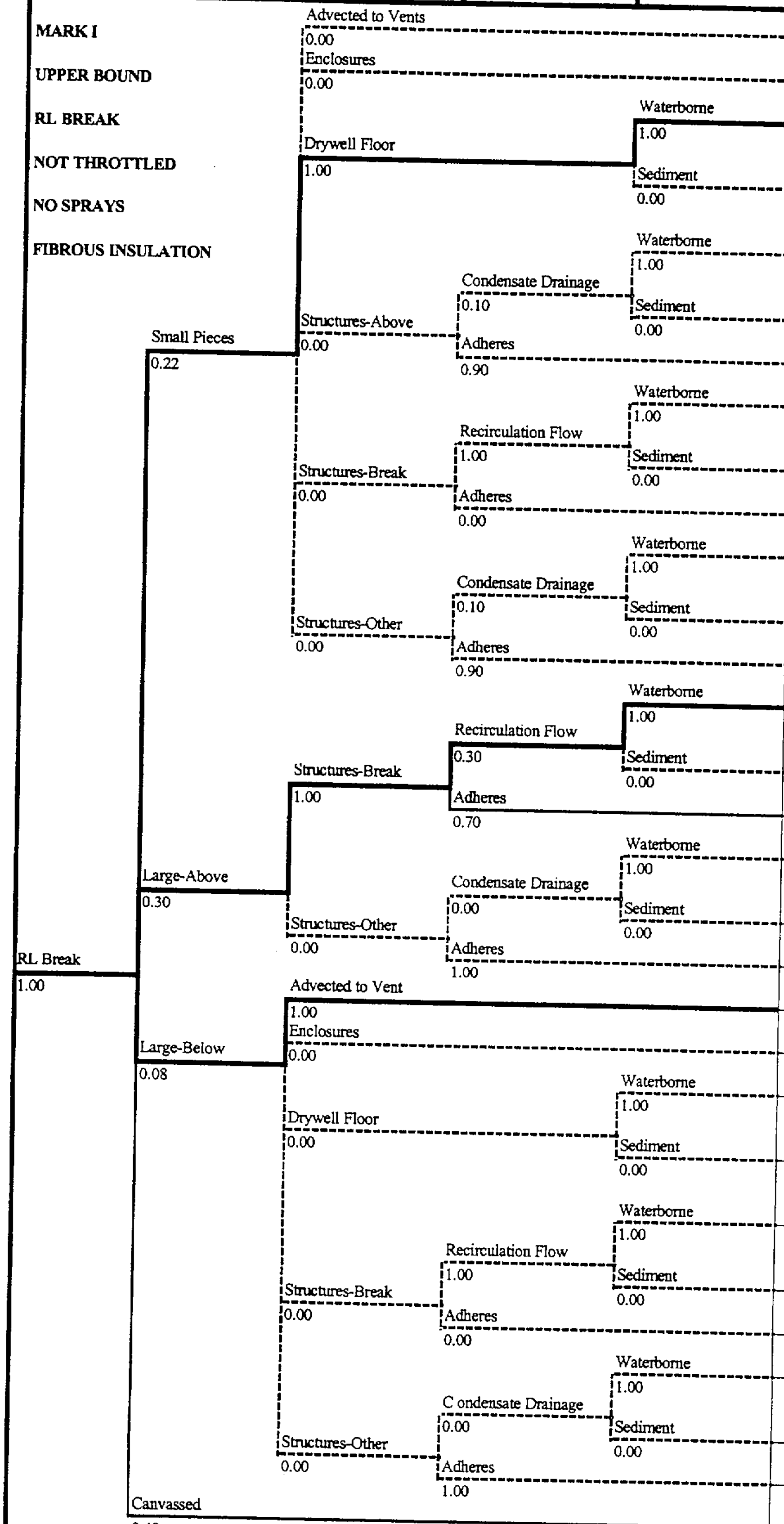
UPPER BOUND

RL BREAK

NOT THROTTLED

NO SPRAYS

FIBROUS INSULATION



Path No.	Fraction	Final Location
1	0.000E+00	**Vents**
2	0.000E+00	Enclosures
3	**2.200E-01**	**Vents**
4	0.000E+00	Floor
5	0.000E+00	**Vents**
6	0.000E+00	Floor
7	0.000E+00	Structures-Above
8	0.000E+00	**Vents**
9	0.000E+00	Floor
10	0.000E+00	Structures-Break
11	0.000E+00	**Vents**
12	0.000E+00	Floor
13	0.000E+00	Structures-Other
14	**9.000E-02**	**Vents**
15	0.000E+00	Floor
16	2.100E-01	Structures-Break
17	0.000E+00	**Vents**
18	0.000E+00	Floor
19	0.000E+00	Structures-Other
20	**8.000E-02**	**Vents**
21	0.000E+00	Enclosures
22	0.000E+00	**Vents**
23	0.000E+00	Floor
24	0.000E+00	**Vents**
25	0.000E+00	Floor
26	0.000E+00	Structures-Break
27	0.000E+00	**Vents**
28	0.000E+00	Floor
29	0.000E+00	Structures-Other
30	4.000E-01	Structures/Floor
Total	1.000E+00	

DEBRIS TRANSPORT RESULTS	
Plant Design:	MARK I
Estimate:	UPPER BOUND
Break:	RL BREAK
ECCS:	NOT THROTTLED
Sprays:	NO SPRAYS

FIBROUS INSULATION

TREE QUANTIFICATION

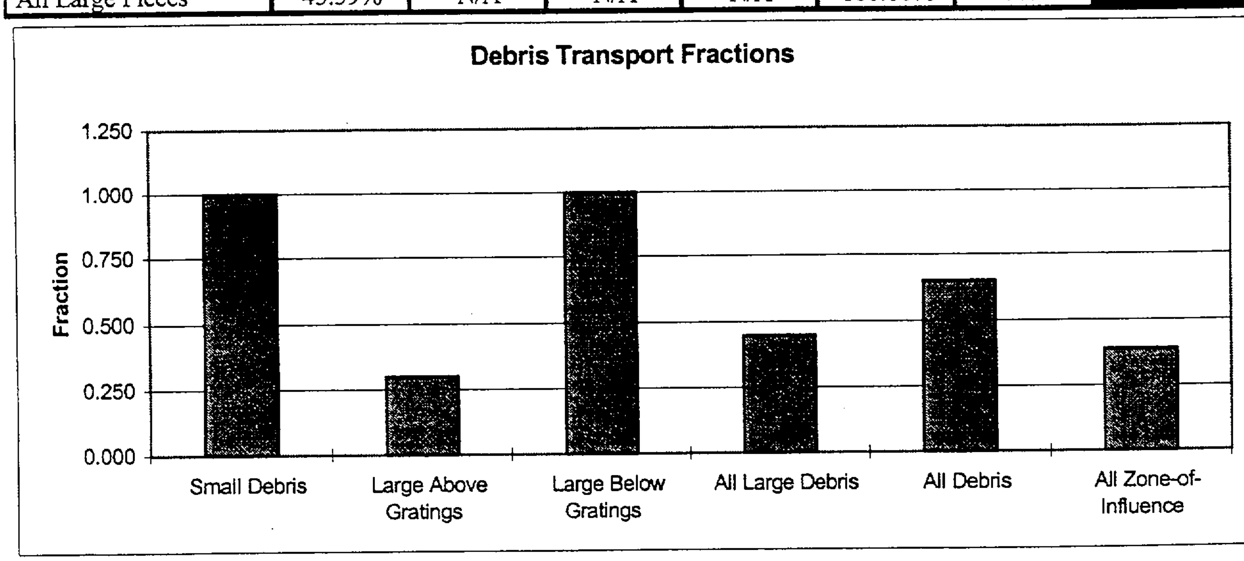
Debris Classification	Vents	Enclosures	Floor	Structures Above	Structures Break	Structures Other	Transport Fraction
Small Pieces	2.200E-01	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	**1.0000**
Large Pieces-Above	9.000E-02	0	0.000E+00	0	2.100E-01	0.000E+00	**0.3000**
Large Pieces-Below	8.000E-02	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)

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 CONTRIBUTIONS (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



MARK I
UPPER BOUND
RL BREAK
NOT THROTTLED
SPRAYS OPERATED
FIBROUS INSULATION

LOCA Type	Debris Classification	Distribution After Blowdown	Erosion and Washdown	Drywell Floor Pool	Path No.	Fraction	Final Location
RL Break 1.00	Small Pieces 0.22	Advected to Vents 0.00			1	0.000E+00	Vents
		Enclosures 0.00			2	0.000E+00	Enclosures
		Drywell Floor 1.00		Waterborne 1.00	3	2.200E-01	Vents
				Sediment 0.00	4	0.000E+00	Floor
		Structures-Above 0.00	Condensate Drainage 0.10	Waterborne 1.00	5	0.000E+00	Vents
				Sediment 0.00	6	0.000E+00	Floor
			Adheres 0.90		7	0.000E+00	Structures-Above
		Structures-Break 0.00	Recirculation Flow 1.00	Waterborne 1.00	8	0.000E+00	Vents
				Sediment 0.00	9	0.000E+00	Floor
			Adheres 0.00		10	0.000E+00	Structures-Break
		Structures-Other 0.00	Sprays/Condensate 1.00	Waterborne 1.00	11	0.000E+00	Vents
				Sediment 0.00	12	0.000E+00	Floor
			Adheres 0.00		13	0.000E+00	Structures-Other
	Large-Above 0.30	Structures-Break 1.00	Recirculation Flow 0.30	Waterborne 1.00	14	9.000E-02	Vents
				Sediment 0.00	15	0.000E+00	Floor
			Adheres 0.70		16	2.100E-01	Structures-Break
		Structures-Other 0.00	Sprays/Condensate 0.02	Waterborne 1.00	17	0.000E+00	Vents
				Sediment 0.00	18	0.000E+00	Floor
			Adheres 0.98		19	0.000E+00	Structures-Other
	Large-Below 0.08	Advected to Vent 1.00			20	8.000E-02	Vents
		Enclosures 0.00			21	0.000E+00	Enclosures
		Drywell Floor 0.00		Waterborne 1.00	22	0.000E+00	Vents
				Sediment 0.00	23	0.000E+00	Floor
		Structures-Break 0.00	Recirculation Flow 1.00	Waterborne 1.00	24	0.000E+00	Vents
				Sediment 0.00	25	0.000E+00	Floor
			Adheres 0.00		26	0.000E+00	Structures-Break
		Structures-Other 0.00	Sprays/Condensate 0.02	Waterborne 1.00	27	0.000E+00	Vents
				Sediment 0.00	28	0.000E+00	Floor
			Adheres 0.98		29	0.000E+00	Structures-Other
	Canvassed 0.40				30	4.000E-01	Structures/Floor
					Total	1.000E+00	

DEBRIS TRANSPORT RESULTS

Plant Design:	MARK I
Estimate:	UPPER BOUND
Break:	RL BREAK
ECCS:	NOT THROTTLED
Sprays:	SPRAYS OPERATED

FIBROUS INSULATION

TREE QUANTIFICATION

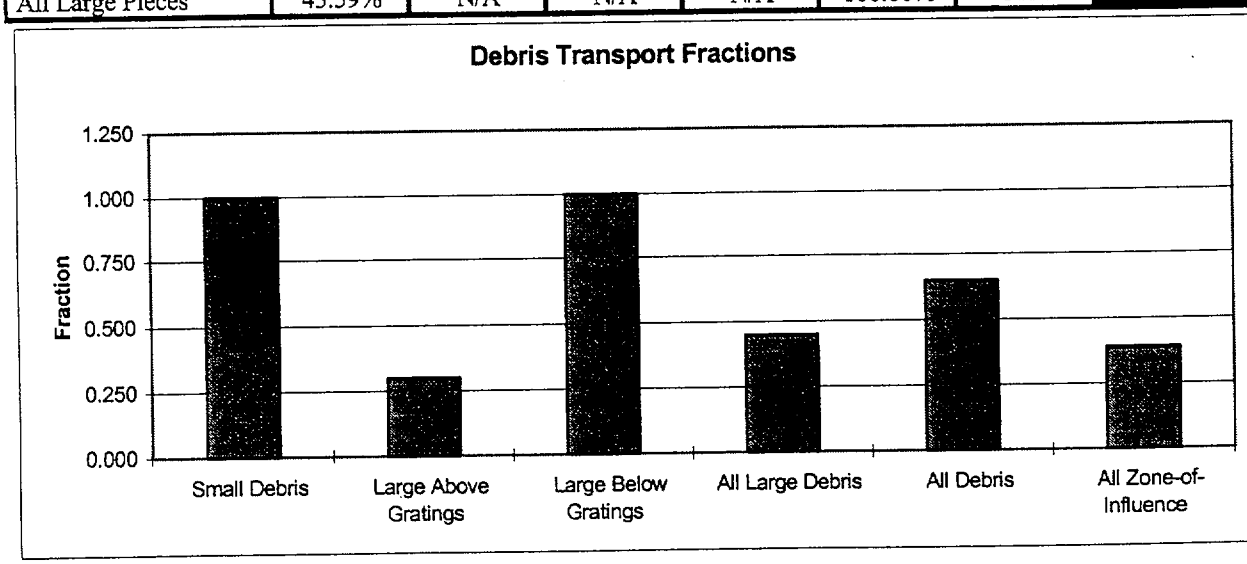
Debris Classification	Vents	Enclosures	Floor	Structures Above	Structures Break	Structures Other	Transport Fraction
Small Pieces	2.200E-01	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	1.0000
Large Pieces-Above	9.000E-02	0	0.000E+00	0	2.100E-01	0.000E+00	0.3000
Large Pieces-Below	8.000E-02	0.000E+00	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)

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 CONTRIBUTIONS (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



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

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.

MARK II
UPPER BOUND
MSL BREAK
ECCS THROTTLED
NO SPRAYS
FIBROUS INSULATION

LOCA Type	Debris Classification	Distribution After Blowdown	Erosion and Washdown	Drywell Floor Pool	Path No.	Fraction	Final Location
MSL Break 1.00	Small Pieces 0.22	Advected to Vents 0.89			1	1.958E-01	Vents
		Enclosures 0.00			2	0.000E+00	Enclosures
		Drywell Floor 0.03		Waterborne 0.00	3	0.000E+00	Vents
				Sediment 1.00	4	6.600E-03	Floor
		Structures-Above 0.00	Condensate Drainage 0.10	Waterborne 0.00	5	0.000E+00	Vents
				Sediment 1.00	6	0.000E+00	Floor
			Adheres 0.90		7	0.000E+00	Structures-Above
		Structures-Break 0.02	Condensate Drainage 0.10	Waterborne 0.00	8	0.000E+00	Vents
				Sediment 1.00	9	4.400E-04	Floor
			Adheres 0.90		10	3.960E-03	Structures-Break
		Structures-Other 0.06	Condensate Drainage 0.10	Waterborne 0.00	11	0.000E+00	Vents
				Sediment 1.00	12	1.320E-03	Floor
			Adheres 0.90		13	1.188E-02	Structures-Other
	Large-Above 0.30	Structures-Break 0.25	Condensate Drainage 0.00	Waterborne 0.00	14	0.000E+00	Vents
				Sediment 1.00	15	0.000E+00	Floor
			Adheres 1.00		16	7.500E-02	Structures-Break
		Structures-Other 0.75	Condensate Drainage 0.00	Waterborne 0.00	17	0.000E+00	Vents
				Sediment 1.00	18	0.000E+00	Floor
			Adheres 1.00		19	2.250E-01	Structures-Other
	Large-Below 0.08	Advected to Vent 1.00			20	8.000E-02	Vents
		Enclosures 0.00			21	0.000E+00	Enclosures
		Drywell Floor 0.00		Waterborne 0.00	22	0.000E+00	Vents
				Sediment 1.00	23	0.000E+00	Floor
		Structures-Break 0.00	Condensate Drainage 0.00	Waterborne 0.00	24	0.000E+00	Vents
				Sediment 1.00	25	0.000E+00	Floor
			Adheres 1.00		26	0.000E+00	Structures-Break
		Structures-Other 0.00	Condensate Drainage 0.00	Waterborne 0.00	27	0.000E+00	Vents
				Sediment 1.00	28	0.000E+00	Floor
			Adheres 1.00		29	0.000E+00	Structures-Other
	Canvassed 0.40				30	4.000E-01	Structures/Floor
					Total	1.000E+00	

DEBRIS TRANSPORT RESULTS		
Plant Design:	MARK II	
Estimate:	UPPER BOUND	FIBROUS INSULATION
Break:	MSL BREAK	
ECCS:	ECCS THROTTLED	
Sprays:	NO SPRAYS	

TREE QUANTIFICATION

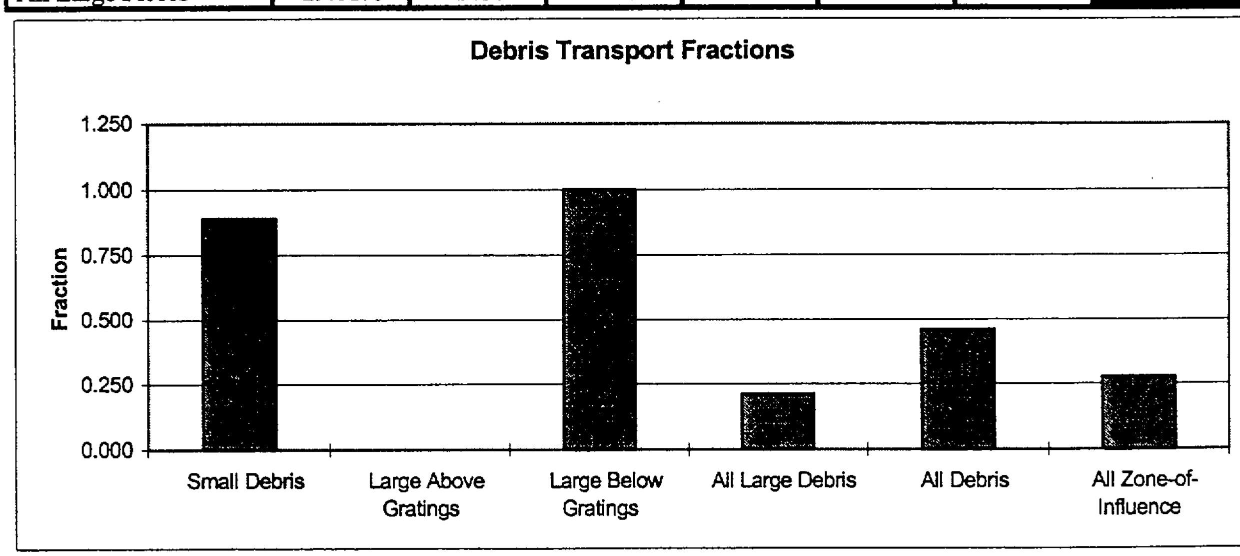
Debris Classification	Vents	Enclosures	Floor	Structures Above	Structures Break	Structures Other	Transport Fraction
Small Pieces	1.958E-01	0.000E+00	8.360E-03	0.000E+00	3.960E-03	1.188E-02	**0.8900**
Large Pieces-Above	0.000E+00	0	0.000E+00	0	7.500E-02	2.250E-01	**0.0000**
Large Pieces-Below	8.000E-02	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**

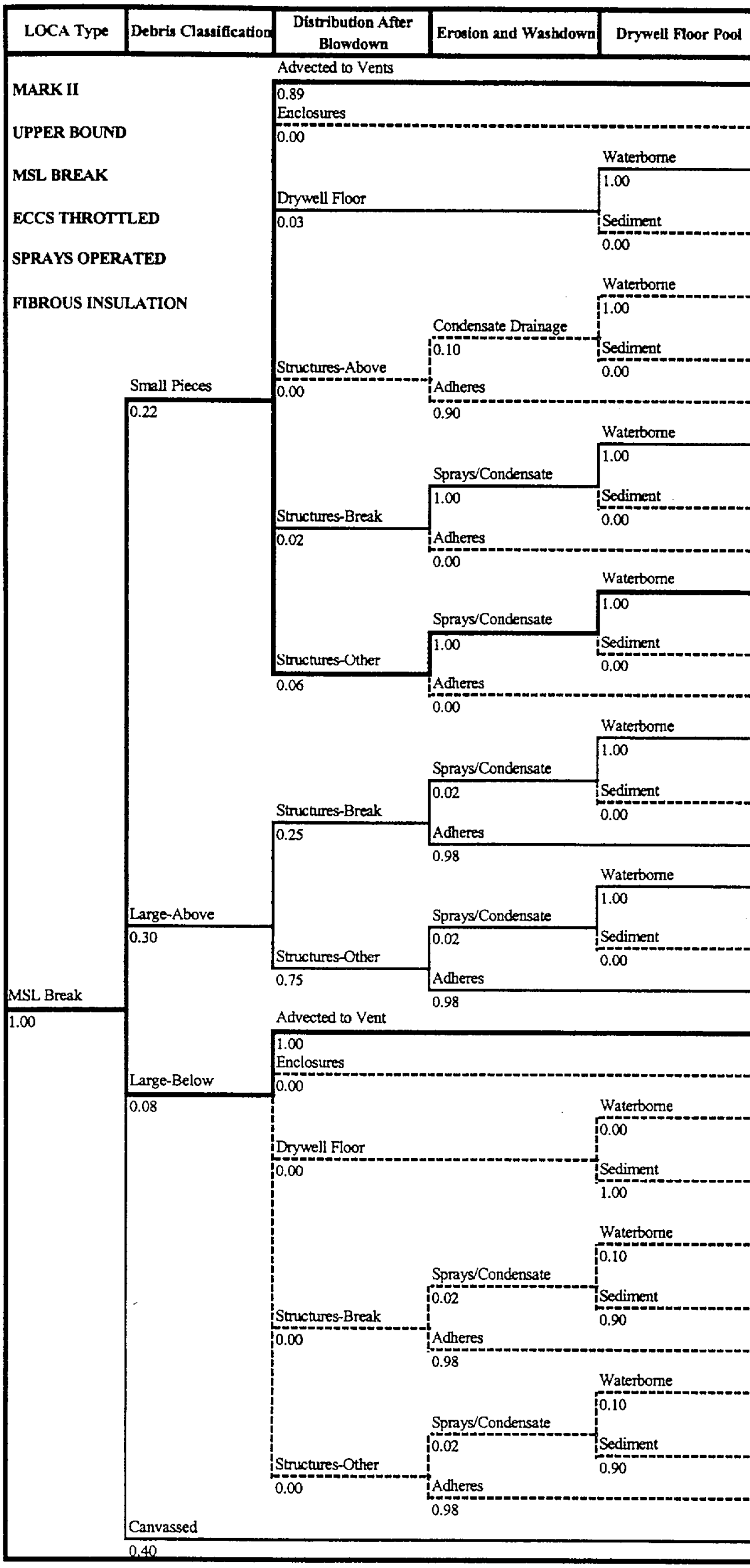
FINAL DISTRIBUTIONS (Horizontal)

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 CONTRIBUTIONS (Vertical)

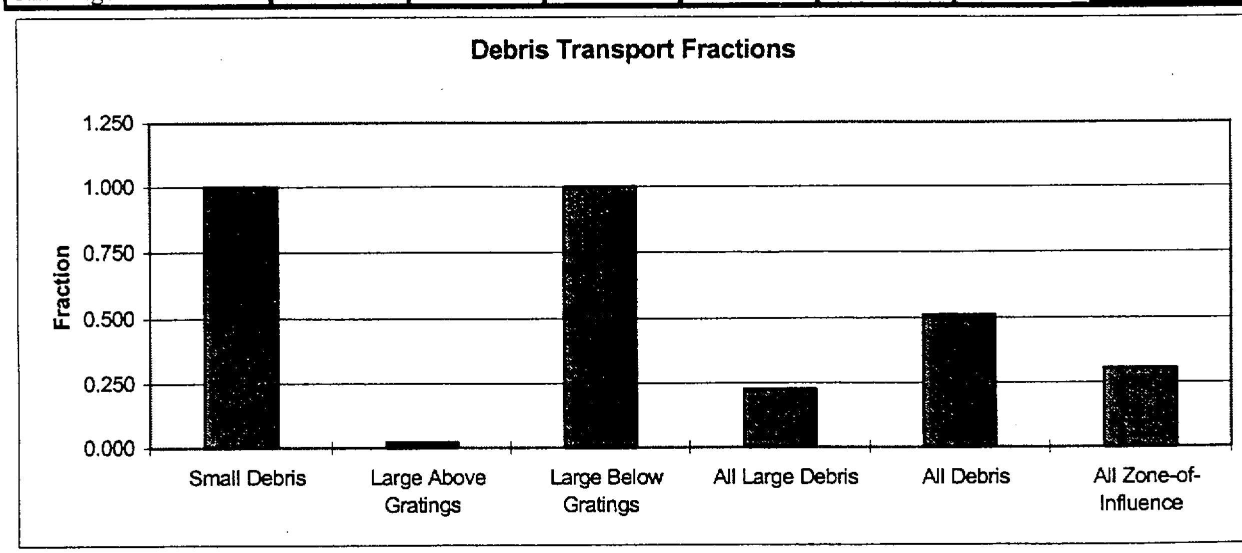
Debris Classification	Vents	Enclosures	Floor	Structures Above	Structures Break	Structures Other
Small Pieces	70.99%	N/A	100.00%	N/A	5.02%	5.02%
Large Pieces-Above	0.00%	N/A	0.00%	N/A	94.98%	94.98%
Large Pieces-Below	29.01%	N/A	0.00%	N/A	0.00%	0.00%
All Large Pieces	29.01%	N/A	0.00%	N/A	94.98%	94.98%

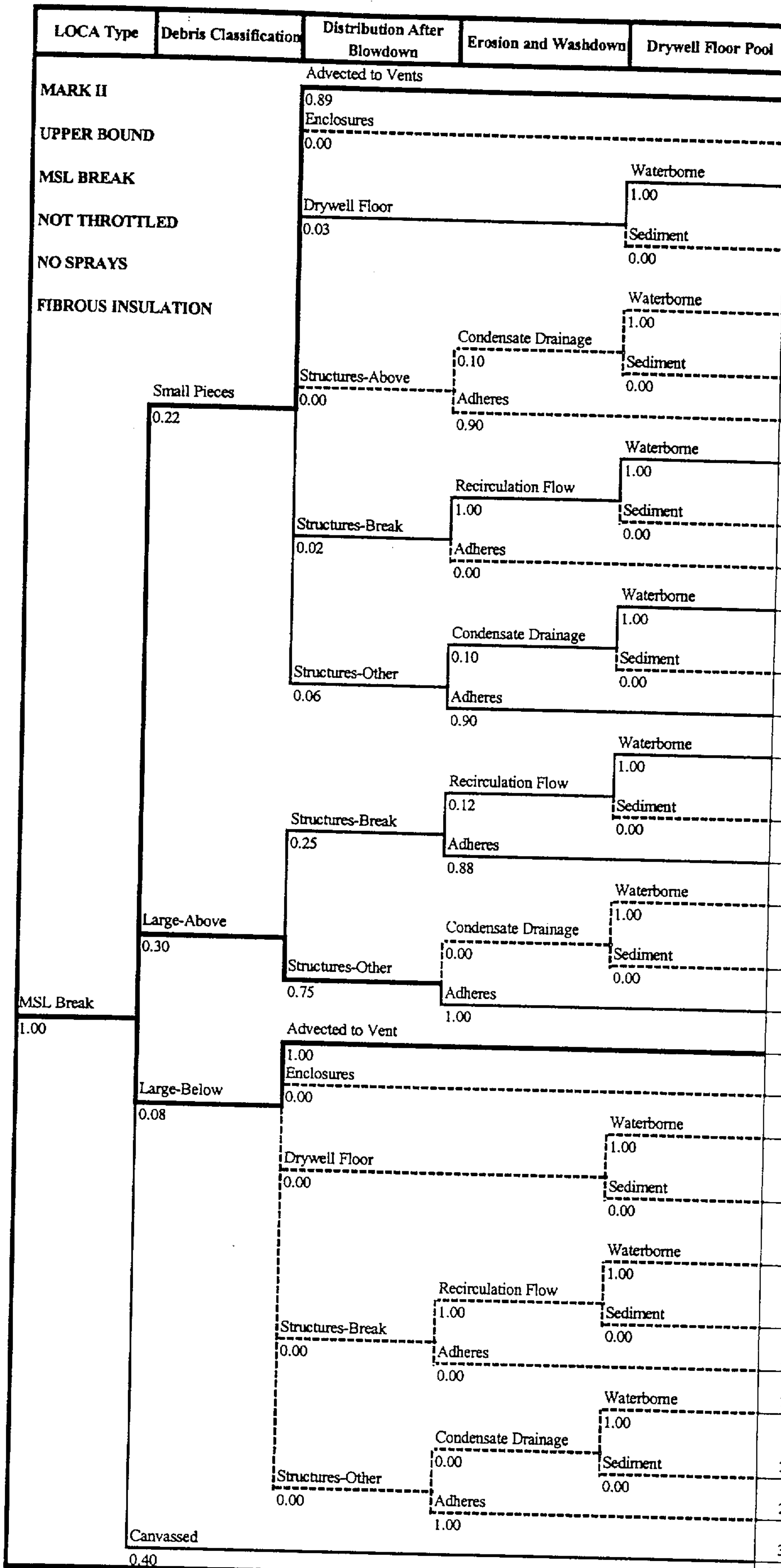




Path No.	Fraction	Final Location
1	**1.958E-01**	**Vents**
2	0.000E+00	Enclosures
3	6.600E-03	**Vents**
4	0.000E+00	Floor
5	0.000E+00	**Vents**
6	0.000E+00	Floor
7	0.000E+00	Structures-Above
8	4.400E-03	**Vents**
9	0.000E+00	Floor
10	0.000E+00	Structures-Break
11	**1.320E-02**	**Vents**
12	0.000E+00	Floor
13	0.000E+00	Structures-Other
14	1.500E-03	**Vents**
15	0.000E+00	Floor
16	7.350E-02	Structures-Break
17	4.500E-03	**Vents**
18	0.000E+00	Floor
19	2.205E-01	Structures-Other
20	**8.000E-02**	**Vents**
21	0.000E+00	Enclosures
22	0.000E+00	**Vents**
23	0.000E+00	Floor
24	0.000E+00	**Vents**
25	0.000E+00	Floor
26	0.000E+00	Structures-Break
27	0.000E+00	**Vents**
28	0.000E+00	Floor
29	0.000E+00	Structures-Other
30	4.000E-01	Structures/Floor
Total	1.000E+00	

DEBRIS TRANSPORT RESULTS							
Plant Design:	**MARK II**						
Estimate:	**UPPER BOUND**			**FIBROUS INSULATION**			
Break:	**MSL BREAK**						
ECCS:	**ECCS THROTTLED**						
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	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 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	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 CONTRIBUTIONS (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%	
All Large Pieces	28.10%	N/A	N/A	N/A	100.00%	100.00%	





Path No.	Fraction	Final Location
1	**1.958E-01**	**Vents**
2	0.000E+00	Enclosures
3	6.600E-03	**Vents**
4	0.000E+00	Floor
5	0.000E+00	**Vents**
6	0.000E+00	Floor
7	0.000E+00	Structures-Above
8	4.400E-03	**Vents**
9	0.000E+00	Floor
10	0.000E+00	Structures-Break
11	1.320E-03	**Vents**
12	0.000E+00	Floor
13	1.188E-02	Structures-Other
14	9.000E-03	**Vents**
15	0.000E+00	Floor
16	6.600E-02	Structures-Break
17	0.000E+00	**Vents**
18	0.000E+00	Floor
19	2.250E-01	Structures-Other
20	**8.000E-02**	**Vents**
21	0.000E+00	Enclosures
22	0.000E+00	**Vents**
23	0.000E+00	Floor
24	0.000E+00	**Vents**
25	0.000E+00	Floor
26	0.000E+00	Structures-Break
27	0.000E+00	**Vents**
28	0.000E+00	Floor
29	0.000E+00	Structures-Other
30	4.000E-01	Structures/Floor
Total	1.000E+00	

DEBRIS TRANSPORT RESULTS							
Plant Design:	MARK II						
Estimate:	UPPER BOUND			FIBROUS INSULATION			
Break:	MSL BREAK						
ECCS:	NOT THROTTLED						
Sprays:	NO SPRAYS						

TREE QUANTIFICATION

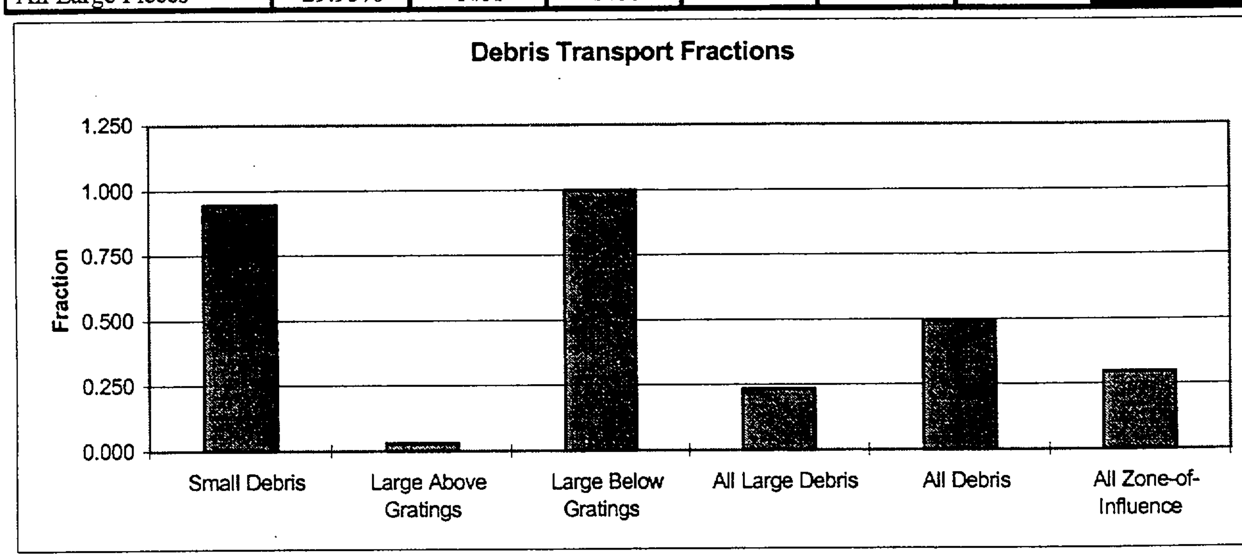
Debris Classification	Vents	Enclosures	Floor	Structures Above	Structures Break	Structures Other	Transport Fraction
Small Pieces	2.081E-01	0.000E+00	0.000E+00	0.000E+00	0.000E+00	1.188E-02	**0.9460**
Large Pieces-Above	9.000E-03	0	0.000E+00	0	6.600E-02	2.250E-01	**0.0300**
Large Pieces-Below	8.000E-02	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 DISTRIBUTIONS (Horizontal)

Debris Classification	Vents	Enclosures	Floor	Structures Above	Structures Break	Structures 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 CONTRIBUTIONS (Vertical)

Debris Classification	Vents	Enclosures	Floor	Structures Above	Structures Break	Structures Other
Small Pieces	70.05%	N/A	N/A	N/A	0.00%	5.02%
Large Pieces-Above	3.03%	N/A	N/A	N/A	100.00%	94.98%
Large Pieces-Below	26.93%	N/A	N/A	N/A	0.00%	0.00%
All Large Pieces	29.95%	N/A	N/A	N/A	100.00%	94.98%



MARK II

UPPER BOUND

MSL BREAK

NOT THROTTLED

SPRAYS OPERATED

FIBROUS INSULATION

LOCA Type	Debris Classification	Distribution After Blowdown	Erosion and Washdown	Drywell Floor Pool	Path No.	Fraction	Final Location
MSL Break 1.00	Small Pieces 0.22	Advected to Vents 0.89			1	**1.958E-01**	**Vents**
		Enclosures 0.00			2	0.000E+00	Enclosures
		Drywell Floor 0.03		Waterborne 1.00	3	6.600E-03	**Vents**
				Sediment 0.00	4	0.000E+00	Floor
		Structures-Above 0.00	Condensate Drainage 0.10	Waterborne 1.00	5	0.000E+00	**Vents**
				Sediment 0.00	6	0.000E+00	Floor
			Adheres 0.90		7	0.000E+00	Structures-Above
		Structures-Break 0.02	Recirculation Flow 1.00	Waterborne 1.00	8	4.400E-03	**Vents**
				Sediment 0.00	9	0.000E+00	Floor
			Adheres 0.00		10	0.000E+00	Structures-Break
		Structures-Other 0.06	Sprays/Condensate 1.00	Waterborne 1.00	11	**1.320E-02**	**Vents**
				Sediment 0.00	12	0.000E+00	Floor
			Adheres 0.00		13	0.000E+00	Structures-Other
	Large-Above 0.30	Structures-Break 0.25	Recirculation Flow 0.12	Waterborne 1.00	14	9.000E-03	**Vents**
				Sediment 0.00	15	0.000E+00	Floor
			Adheres 0.88		16	6.600E-02	Structures-Break
		Structures-Other 0.75	Sprays/Condensate 0.02	Waterborne 1.00	17	4.500E-03	**Vents**
				Sediment 0.00	18	0.000E+00	Floor
			Adheres 0.98		19	2.205E-01	Structures-Other
	Large-Below 0.08	Advected to Vent 1.00			20	**8.000E-02**	**Vents**
		Enclosures 0.00			21	0.000E+00	Enclosures
		Drywell Floor 0.00		Waterborne 1.00	22	0.000E+00	**Vents**
				Sediment 0.00	23	0.000E+00	Floor
		Structures-Break 0.00	Recirculation Flow 1.00	Waterborne 1.00	24	0.000E+00	**Vents**
				Sediment 0.00	25	0.000E+00	Floor
			Adheres 0.00		26	0.000E+00	Structures-Break
		Structures-Other 0.00	Sprays/Condensate 0.02	Waterborne 1.00	27	0.000E+00	**Vents**
				Sediment 0.00	28	0.000E+00	Floor
			Adheres 0.98		29	0.000E+00	Structures-Other
	Canvassed 0.40				30	4.000E-01	Structures/Floor
					Total	1.000E+00	

DEBRIS TRANSPORT RESULTS	
Plant Design:	MARK II
Estimate:	UPPER BOUND
Break:	MSL BREAK
ECCS:	NOT THROTTLED
Sprays:	SPRAYS OPERATED

FIBROUS INSULATION

TREE QUANTIFICATION

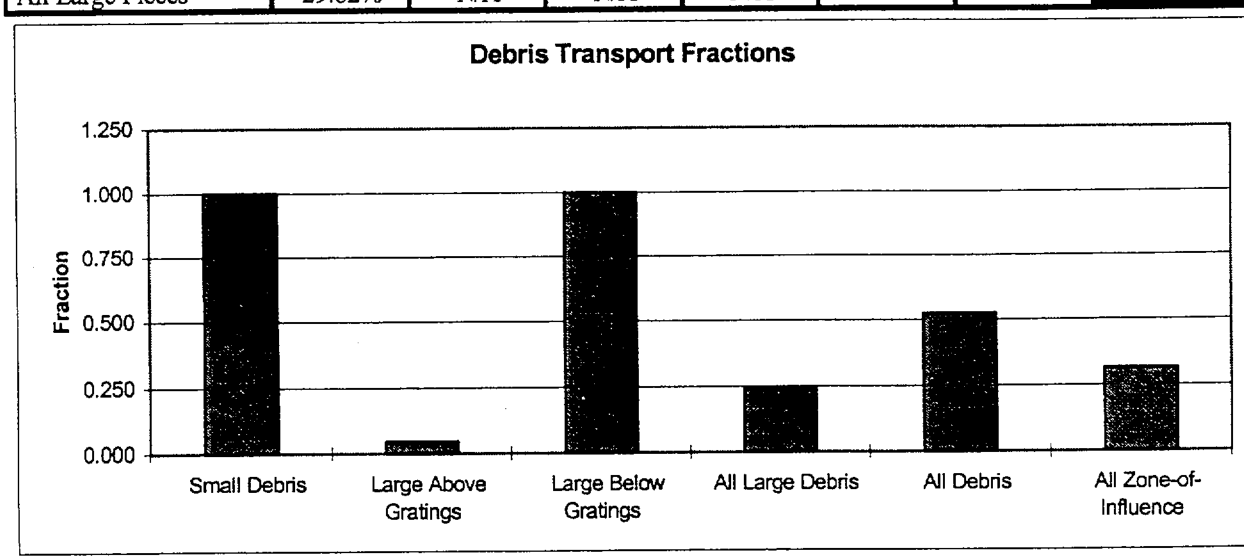
Debris Classification	Vents	Enclosures	Floor	Structures Above	Structures Break	Structures Other	Transport Fraction
Small Pieces	2.200E-01	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	**1.0000**
Large Pieces-Above	1.350E-02	0	0.000E+00	0	6.600E-02	2.205E-01	**0.0450**
Large Pieces-Below	8.000E-02	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 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	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 CONTRIBUTIONS (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.4.2.2 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
MARK II **UPPER BOUND** **RL BREAK** **ECCS THROTTLED** **NO SPRAYS** **FIBROUS INSULATION**							
RL Break 1.00	Small Pieces 0.22	Advected to Vents 0.00			1	0.000E+00	**Vents**
		Enclosures 0.00			2	0.000E+00	Enclosures
		Drywell Floor 1.00		Waterborne 1.00	3	**2.200E-01**	**Vents**
				Sediment 0.00	4	0.000E+00	Floor
		Structures-Above 0.00	Condensate Drainage 0.10	Waterborne 1.00	5	0.000E+00	**Vents**
				Sediment 0.00	6	0.000E+00	Floor
			Adheres 0.90		7	0.000E+00	Structures-Above
		Structures-Break 0.00	Recirculation Flow 1.00	Waterborne 1.00	8	0.000E+00	**Vents**
				Sediment 0.00	9	0.000E+00	Floor
			Adheres 0.00		10	0.000E+00	Structures-Break
		Structures-Other 0.00	Condensate Drainage 0.10	Waterborne 1.00	11	0.000E+00	**Vents**
				Sediment 0.00	12	0.000E+00	Floor
			Adheres 0.90		13	0.000E+00	Structures-Other
	Large-Above 0.30	Structures-Break 1.00	Recirculation Flow 0.12	Waterborne 1.00	14	**3.600E-02**	**Vents**
				Sediment 0.00	15	0.000E+00	Floor
			Adheres 0.88		16	2.640E-01	Structures-Break
		Structures-Other 0.00	Condensate Drainage 0.00	Waterborne 1.00	17	0.000E+00	**Vents**
				Sediment 0.00	18	0.000E+00	Floor
			Adheres 1.00		19	0.000E+00	Structures-Other
	Large-Below 0.08	Advected to Vent 1.00			20	**8.000E-02**	**Vents**
		Enclosures 0.00			21	0.000E+00	Enclosures
		Drywell Floor 0.00		Waterborne 1.00	22	0.000E+00	**Vents**
				Sediment 0.00	23	0.000E+00	Floor
		Structures-Break 0.00	Recirculation Flow 1.00	Waterborne 1.00	24	0.000E+00	**Vents**
				Sediment 0.00	25	0.000E+00	Floor
			Adheres 0.00		26	0.000E+00	Structures-Break
		Structures-Other 0.00	Condensate Drainage 0.00	Waterborne 1.00	27	0.000E+00	**Vents**
				Sediment 0.00	28	0.000E+00	Floor
			Adheres 1.00		29	0.000E+00	Structures-Other
	Canvassed 0.40				30	4.000E-01	Structures/Floor
					Total	1.000E+00	

DEBRIS TRANSPORT RESULTS

Plant Design:	MARK II
Estimate:	UPPER BOUND
Break:	RL BREAK
ECCS:	ECCS THROTTLED
Sprays:	NO SPRAYS

FIBROUS INSULATION

TREE QUANTIFICATION

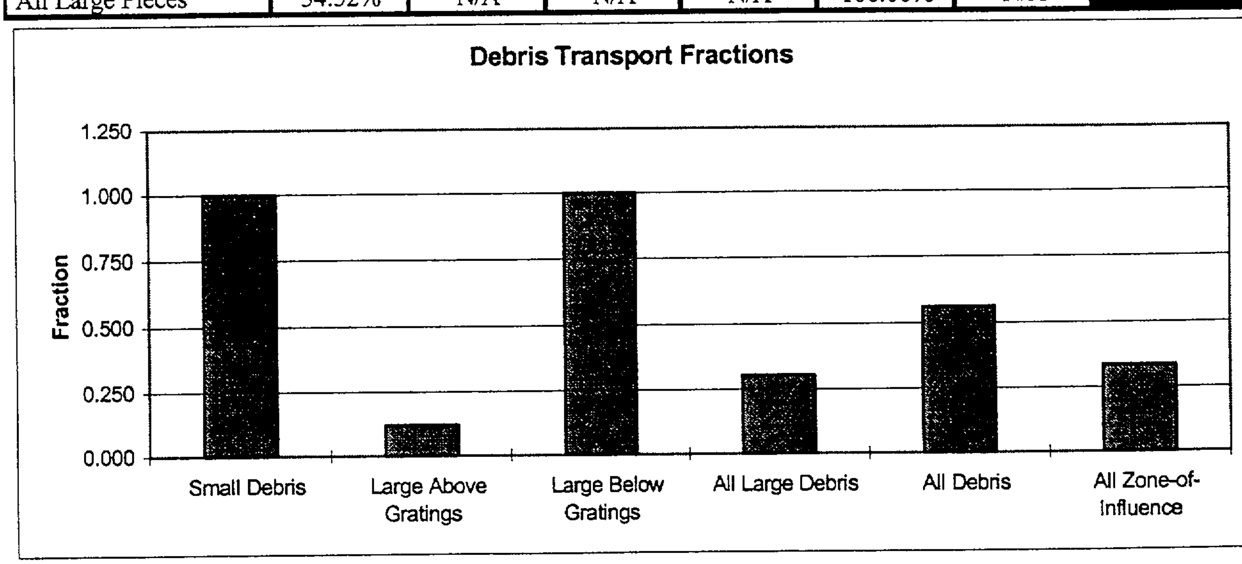
Debris Classification	Vents	Enclosures	Floor	Structures Above	Structures Break	Structures Other	Transport Fraction
Small Pieces	2.200E-01	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	**1.0000**
Large Pieces-Above	3.600E-02	0	0.000E+00	0	2.640E-01	0.000E+00	**0.1200**
Large Pieces-Below	8.000E-02	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 CONTRIBUTIONS (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 Washdown	Drywell Floor Pool	Path No.	Fraction	Final Location
MARK II UPPER BOUND RL BREAK ECCS THROTTLED SPRAYS OPERATED FIBROUS INSULATION							
RL Break 1.00	Small Pieces 0.22	Advected to Vents 0.00			1	0.000E+00	Vents
		Enclosures 0.00			2	0.000E+00	Enclosures
		Drywell Floor 1.00		Waterborne 1.00	3	**2.200E-01**	Vents
				Sediment 0.00	4	0.000E+00	Floor
		Structures-Above 0.00	Condensate Drainage 0.10	Waterborne 1.00	5	0.000E+00	Vents
				Sediment 0.00	6	0.000E+00	Floor
			Adheres 0.90		7	0.000E+00	Structures-Above
		Structures-Break 0.00	Recirculation Flow 1.00	Waterborne 1.00	8	0.000E+00	Vents
				Sediment 0.00	9	0.000E+00	Floor
			Adheres 0.00		10	0.000E+00	Structures-Break
		Structures-Other 0.00	Sprays/Condensate 1.00	Waterborne 1.00	11	0.000E+00	Vents
				Sediment 0.00	12	0.000E+00	Floor
			Adheres 0.00		13	0.000E+00	Structures-Other
	Large-Above 0.30	Structures-Break 1.00	Recirculation Flow 0.12	Waterborne 1.00	14	**3.600E-02**	Vents
				Sediment 0.00	15	0.000E+00	Floor
			Adheres 0.88		16	2.640E-01	Structures-Break
		Structures-Other 0.00	Sprays/Condensate 0.02	Waterborne 1.00	17	0.000E+00	Vents
				Sediment 0.00	18	0.000E+00	Floor
			Adheres 0.98		19	0.000E+00	Structures-Other
	Large-Below 0.08	Advected to Vent 1.00			20	**8.000E-02**	Vents
		Enclosures 0.00			21	0.000E+00	Enclosures
		Drywell Floor 0.00		Waterborne 1.00	22	0.000E+00	Vents
				Sediment 0.00	23	0.000E+00	Floor
		Structures-Break 0.00	Recirculation Flow 1.00	Waterborne 1.00	24	0.000E+00	Vents
				Sediment 0.00	25	0.000E+00	Floor
			Adheres 0.00		26	0.000E+00	Structures-Break
		Structures-Other 0.00	Sprays/Condensate 0.02	Waterborne 1.00	27	0.000E+00	Vents
				Sediment 0.00	28	0.000E+00	Floor
			Adheres 0.98		29	0.000E+00	Structures-Other
	Canvassed 0.40				30	4.000E-01	Structures/Floor
					Total	1.000E+00	

DEBRIS TRANSPORT RESULTS	
Plant Design:	MARK II
Estimate:	UPPER BOUND
Break:	RL BREAK
ECCS:	ECCS THROTTLED
Sprays:	SPRAYS OPERATED

FIBROUS INSULATION

TREE QUANTIFICATION

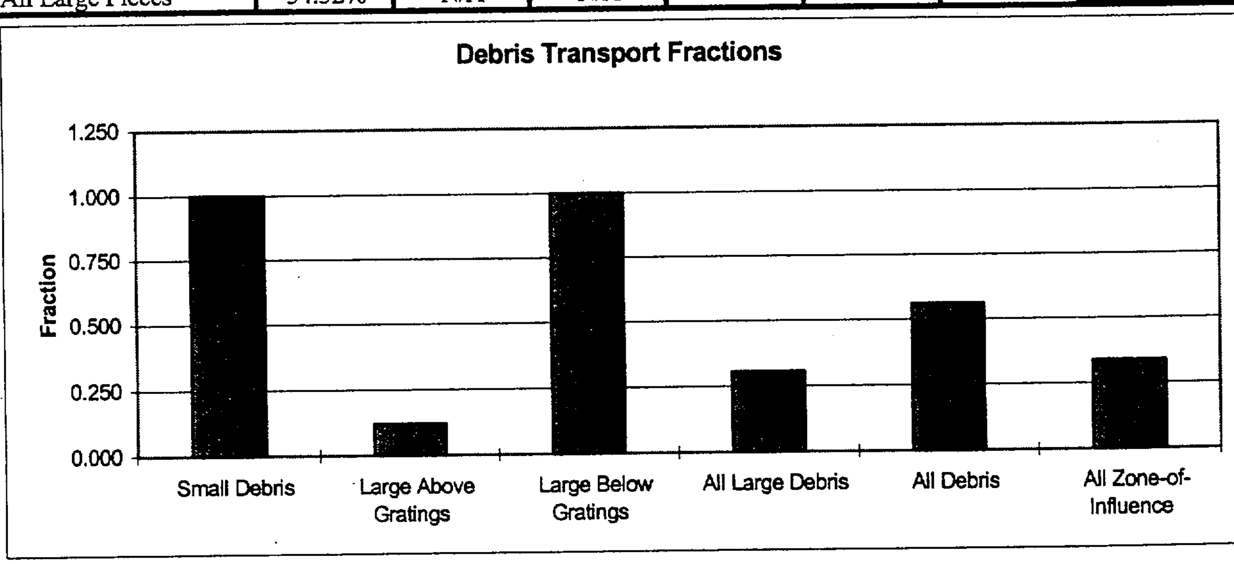
Debris Classification	Vents	Enclosures	Floor	Structures Above	Structures Break	Structures Other	Transport Fraction
Small Pieces	2.200E-01	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	1.0000
Large Pieces-Above	3.600E-02	0	0.000E+00	0	2.640E-01	0.000E+00	0.1200
Large Pieces-Below	8.000E-02	0.000E+00	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 CONTRIBUTIONS (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



MARK II
UPPER BOUND
RL BREAK
NOT THROTTLED
NO SPRAYS
FIBROUS INSULATION

LOCA Type	Debris Classification	Distribution After Blowdown	Erosion and Washdown	Drywell Floor Pool	Path No.	Fraction	Final Location
RL Break 1.00	Small Pieces 0.22	Advected to Vents 0.00			1	0.000E+00	Vents
		Enclosures 0.00			2	0.000E+00	Enclosures
		Drywell Floor 1.00		Waterborne 1.00	3	2.200E-01	Vents
				Sediment 0.00	4	0.000E+00	Floor
		Structures-Above 0.00	Condensate Drainage 0.10	Waterborne 1.00	5	0.000E+00	Vents
				Sediment 0.00	6	0.000E+00	Floor
			Adheres 0.90		7	0.000E+00	Structures-Above
		Structures-Break 0.00	Recirculation Flow 1.00	Waterborne 1.00	8	0.000E+00	Vents
				Sediment 0.00	9	0.000E+00	Floor
			Adheres 0.00		10	0.000E+00	Structures-Break
		Structures-Other 0.00	Condensate Drainage 0.10	Waterborne 1.00	11	0.000E+00	Vents
				Sediment 0.00	12	0.000E+00	Floor
			Adheres 0.90		13	0.000E+00	Structures-Other
	Large-Above 0.30	Structures-Break 1.00	Recirculation Flow 0.30	Waterborne 1.00	14	9.000E-02	Vents
				Sediment 0.00	15	0.000E+00	Floor
			Adheres 0.70		16	2.100E-01	Structures-Break
		Structures-Other 0.00	Condensate Drainage 0.00	Waterborne 1.00	17	0.000E+00	Vents
				Sediment 0.00	18	0.000E+00	Floor
			Adheres 1.00		19	0.000E+00	Structures-Other
	Large-Below 0.08	Advected to Vent 1.00			20	8.000E-02	Vents
		Enclosures 0.00			21	0.000E+00	Enclosures
		Drywell Floor 0.00		Waterborne 1.00	22	0.000E+00	Vents
				Sediment 0.00	23	0.000E+00	Floor
		Structures-Break 0.00	Recirculation Flow 1.00	Waterborne 1.00	24	0.000E+00	Vents
				Sediment 0.00	25	0.000E+00	Floor
			Adheres 0.00		26	0.000E+00	Structures-Break
		Structures-Other 0.00	C ondensate Drainage 0.00	Waterborne 1.00	27	0.000E+00	Vents
				Sediment 0.00	28	0.000E+00	Floor
			Adheres 1.00		29	0.000E+00	Structures-Other
	Canvassed 0.40				30	4.000E-01	Structures/Floor
					Total	1.000E+00	

DEBRIS TRANSPORT RESULTS

Plant Design:	MARK II
Estimate:	UPPER BOUND
Break:	RL BREAK
ECCS:	NOT THROTTLED
Sprays:	NO SPRAYS

FIBROUS INSULATION

TREE QUANTIFICATION

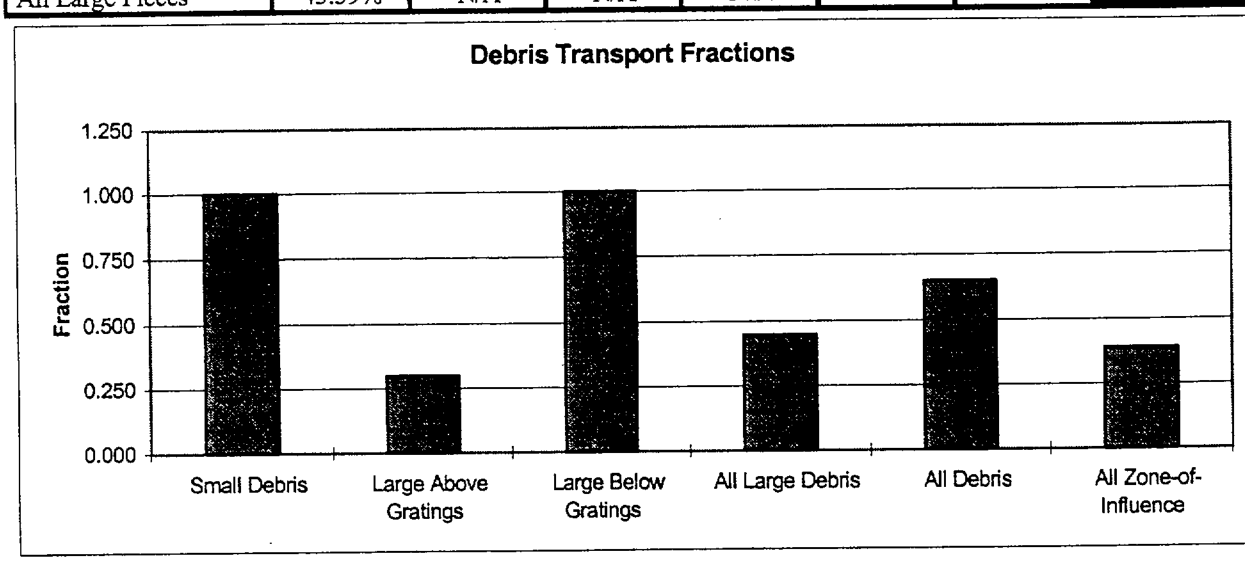
Debris Classification	Vents	Enclosures	Floor	Structures Above	Structures Break	Structures Other	Transport Fraction
Small Pieces	2.200E-01	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	1.0000
Large Pieces-Above	9.000E-02	0	0.000E+00	0	2.100E-01	0.000E+00	0.3000
Large Pieces-Below	8.000E-02	0.000E+00	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

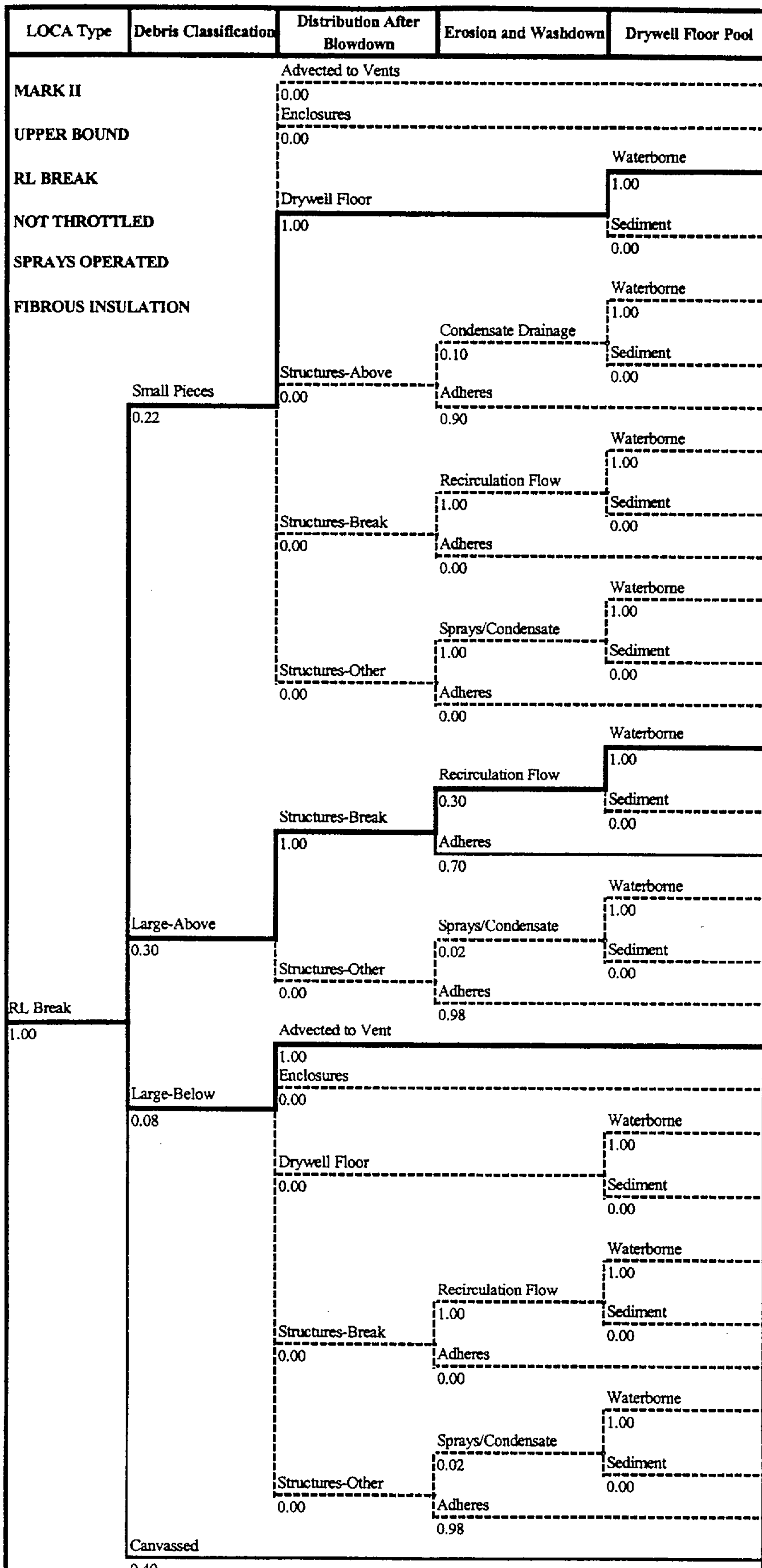
FINAL DISTRIBUTIONS (Horizontal)

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 CONTRIBUTIONS (Vertical)

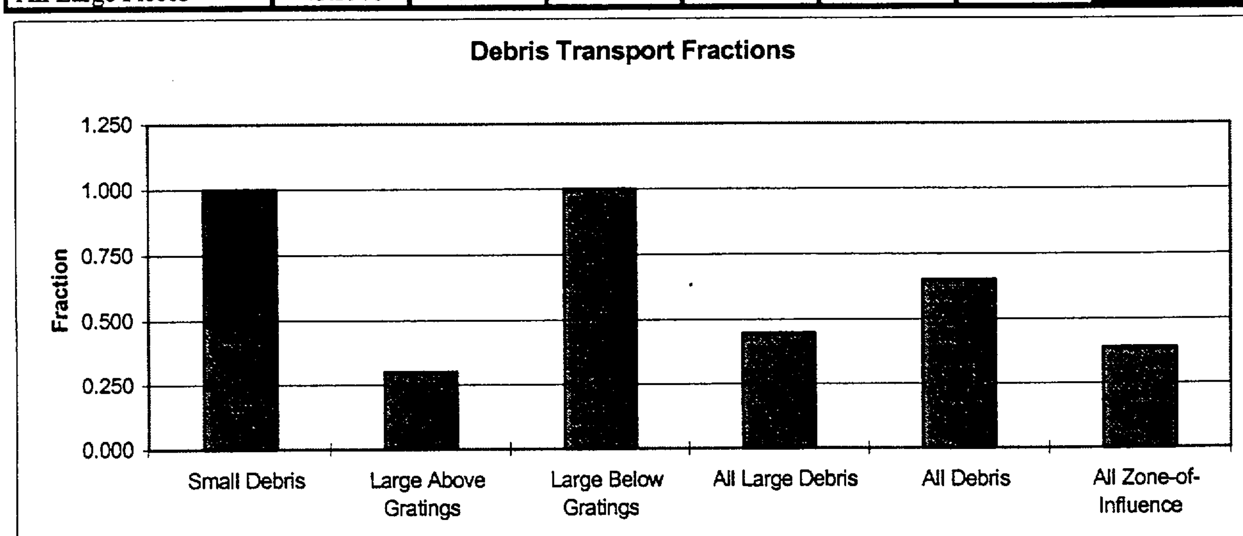
Debris Classification	Vents	Enclosures	Floor	Structures Above	Structures Break	Structures Other
Small Pieces	56.41%	N/A	N/A	N/A	0.00%	N/A
Large Pieces-Above	23.08%	N/A	N/A	N/A	100.00%	N/A
Large Pieces-Below	20.51%	N/A	N/A	N/A	0.00%	N/A
All Large Pieces	43.59%	N/A	N/A	N/A	100.00%	N/A





Path No.	Fraction	Final Location
1	0.000E+00	Vents
2	0.000E+00	Enclosures
3	2.200E-01	Vents
4	0.000E+00	Floor
5	0.000E+00	Vents
6	0.000E+00	Floor
7	0.000E+00	Structures-Above
8	0.000E+00	Vents
9	0.000E+00	Floor
10	0.000E+00	Structures-Break
11	0.000E+00	Vents
12	0.000E+00	Floor
13	0.000E+00	Structures-Other
14	9.000E-02	Vents
15	0.000E+00	Floor
16	2.100E-01	Structures-Break
17	0.000E+00	Vents
18	0.000E+00	Floor
19	0.000E+00	Structures-Other
20	8.000E-02	Vents
21	0.000E+00	Enclosures
22	0.000E+00	Vents
23	0.000E+00	Floor
24	0.000E+00	Vents
25	0.000E+00	Floor
26	0.000E+00	Structures-Break
27	0.000E+00	Vents
28	0.000E+00	Floor
29	0.000E+00	Structures-Other
30	4.000E-01	Structures/Floor
Total	1.000E+00	

DEBRIS TRANSPORT RESULTS							
Plant Design:	MARK II						
Estimate:	UPPER BOUND			FIBROUS INSULATION			
Break:	RL BREAK						
ECCS:	NOT THROTTLED						
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 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	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 CONTRIBUTIONS (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	



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.

MARK III
UPPER BOUND
MSL BREAK
ECCS THROTTLED
NO SPRAYS
FIBROUS INSULATION

LOCA Type	Debris Classification	Distribution After Blowdown	Erosion and Washdown	Drywell Floor Pool	Path No.	Fraction	Final Location
MSL Break 1.00	Small Pieces 0.22	Advected to Vents 0.89			1	**1.958E-01**	**Vents**
		Enclosures 0.00			2	0.000E+00	Enclosures
		Drywell Floor 0.00		Waterborne 0.00	3	0.000E+00	**Vents**
				Sediment 1.00	4	0.000E+00	Floor
		Structures-Above 0.00	Condensate Drainage 0.10	Waterborne 0.00	5	0.000E+00	**Vents**
				Sediment 1.00	6	0.000E+00	Floor
			Adheres 0.90		7	0.000E+00	Structures-Above
		Structures-Break 0.03	Condensate Drainage 0.10	Waterborne 0.00	8	0.000E+00	**Vents**
				Sediment 1.00	9	6.600E-04	Floor
			Adheres 0.90		10	5.940E-03	Structures-Break
		Structures-Other 0.08	Condensate Drainage 0.10	Waterborne 0.00	11	0.000E+00	**Vents**
				Sediment 1.00	12	1.760E-03	Floor
			Adheres 0.90		13	1.584E-02	Structures-Other
	Large-Above 0.30	Structures-Break 0.25	Condensate Drainage 0.00	Waterborne 0.00	14	0.000E+00	**Vents**
				Sediment 1.00	15	0.000E+00	Floor
			Adheres 1.00		16	7.500E-02	Structures-Break
		Structures-Other 0.75	Condensate Drainage 0.00	Waterborne 0.00	17	0.000E+00	**Vents**
				Sediment 1.00	18	0.000E+00	Floor
			Adheres 1.00		19	2.250E-01	Structures-Other
	Large-Below 0.08	Advected to Vent 1.00			20	**8.000E-02**	**Vents**
		Enclosures 0.00			21	0.000E+00	Enclosures
		Drywell Floor 0.00		Waterborne 0.00	22	0.000E+00	**Vents**
				Sediment 1.00	23	0.000E+00	Floor
		Structures-Break 0.00	Condensate Drainage 0.00	Waterborne 0.00	24	0.000E+00	**Vents**
				Sediment 1.00	25	0.000E+00	Floor
			Adheres 1.00		26	0.000E+00	Structures-Break
		Structures-Other 0.00	Condensate Drainage 0.00	Waterborne 0.00	27	0.000E+00	**Vents**
				Sediment 1.00	28	0.000E+00	Floor
			Adheres 1.00		29	0.000E+00	Structures-Other
	Canvassed 0.40				30	4.000E-01	Structures/Floor
					Total	1.000E+00	

DEBRIS TRANSPORT RESULTS							
Plant Design:	**MARK III**						
Estimate:	**UPPER BOUND**			**FIBROUS INSULATION**			
Break:	**MSL BREAK**						
ECCS:	**ECCS THROTTLED**						
Sprays:	**NO SPRAYS**						

TREE QUANTIFICATION

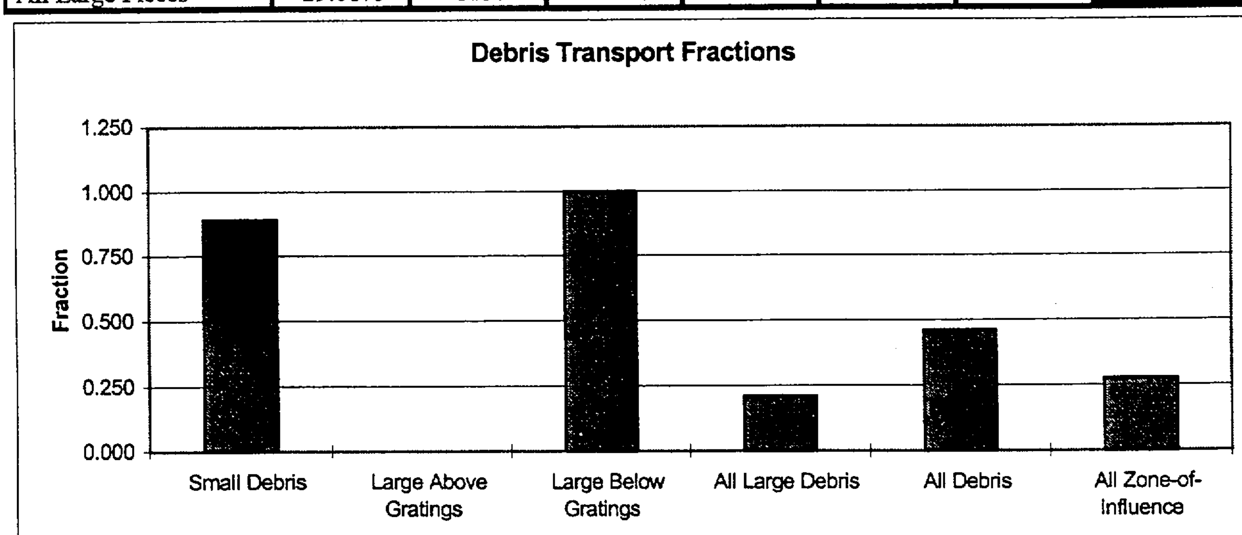
Debris Classification	Vents	Enclosures	Floor	Structures Above	Structures Break	Structures Other	Transport Fraction
Small Pieces	1.958E-01	0.000E+00	2.420E-03	0.000E+00	5.940E-03	1.584E-02	**0.8900**
Large Pieces-Above	0.000E+00	0	0.000E+00	0	7.500E-02	2.250E-01	**0.0000**
Large Pieces-Below	8.000E-02	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)

Debris Classification	Vents	Enclosures	Floor	Structures Above	Structures Break	Structures 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 CONTRIBUTIONS (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%



MARK III
UPPER BOUND
MSL BREAK
NOT THROTTLED
NO SPRAYS
FIBROUS INSULATION

LOCA Type	Debris Classification	Distribution After Blowdown	Erosion and Washdown	Drywell Floor Pool	Path No.	Fraction	Final Location
MSL Break 1.00	Small Pieces 0.22	Advected to Vents 0.89			1	1.958E-01	Vents
		Enclosures 0.00			2	0.000E+00	Enclosures
		Drywell Floor 0.00		Waterborne 1.00	3	0.000E+00	Vents
				Sediment 0.00	4	0.000E+00	Floor
		Structures-Above 0.00	Condensate Drainage 0.10	Waterborne 1.00	5	0.000E+00	Vents
				Sediment 0.00	6	0.000E+00	Floor
			Adheres 0.90		7	0.000E+00	Structures-Above
		Structures-Break 0.03	Recirculation Flow 1.00	Waterborne 1.00	8	6.600E-03	Vents
				Sediment 0.00	9	0.000E+00	Floor
			Adheres 0.00		10	0.000E+00	Structures-Break
		Structures-Other 0.08	Condensate Drainage 0.10	Waterborne 1.00	11	1.760E-03	Vents
				Sediment 0.00	12	0.000E+00	Floor
			Adheres 0.90		13	1.584E-02	Structures-Other
	Large-Above 0.30	Structures-Break 0.25	Recirculation Flow 0.12	Waterborne 1.00	14	9.000E-03	Vents
				Sediment 0.00	15	0.000E+00	Floor
			Adheres 0.88		16	6.600E-02	Structures-Break
		Structures-Other 0.75	Condensate Drainage 0.00	Waterborne 1.00	17	0.000E+00	Vents
				Sediment 0.00	18	0.000E+00	Floor
			Adheres 1.00		19	2.250E-01	Structures-Other
	Large-Below 0.08	Advected to Vent 1.00			20	8.000E-02	Vents
		Enclosures 0.00			21	0.000E+00	Enclosures
		Drywell Floor 0.00		Waterborne 0.10	22	0.000E+00	Vents
				Sediment 0.90	23	0.000E+00	Floor
		Structures-Break 0.00	Recirculation Flow 1.00	Waterborne 0.10	24	0.000E+00	Vents
				Sediment 0.90	25	0.000E+00	Floor
			Adheres 0.00		26	0.000E+00	Structures-Break
		Structures-Other 0.00	Condensate Drainage 0.00	Waterborne 0.10	27	0.000E+00	Vents
				Sediment 0.90	28	0.000E+00	Floor
			Adheres 1.00		29	0.000E+00	Structures-Other
	Canvassed 0.40				30	4.000E-01	Structures/Floor
					Total	1.000E+00	

DEBRIS TRANSPORT RESULTS	
Plant Design:	MARK III
Estimate:	UPPER BOUND
Break:	MSL BREAK
ECCS:	NOT THROTTLED
Sprays:	NO SPRAYS

FIBROUS INSULATION

TREE QUANTIFICATION

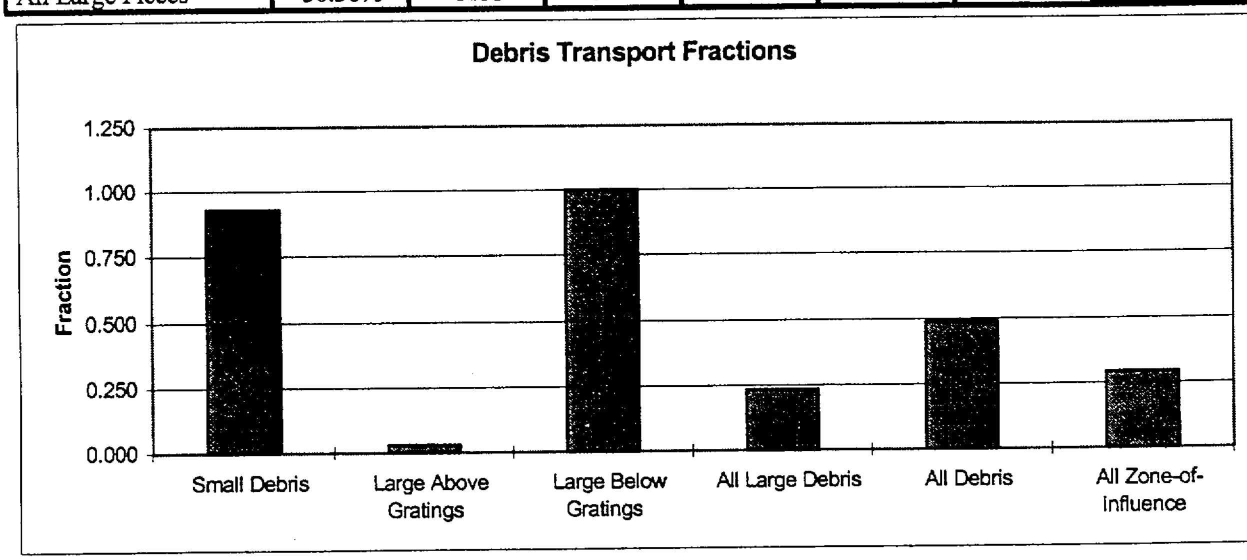
Debris Classification	Vents	Enclosures	Floor	Structures Above	Structures Break	Structures Other	Transport Fraction
Small Pieces	2.042E-01	0.000E+00	0.000E+00	0.000E+00	0.000E+00	1.584E-02	**0.9280**
Large Pieces-Above	9.000E-03	0	0.000E+00	0	6.600E-02	2.250E-01	**0.0300**
Large Pieces-Below	8.000E-02	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 DISTRIBUTIONS (Horizontal)

Debris Classification	Vents	Enclosures	Floor	Structures Above	Structures Break	Structures 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%
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%



A.4.3.2 Recirculation Line Break

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

LOCA Type	Debris Classification	Distribution After Blowdown	Erosion and Washdown	Drywell Floor Pool	Path No.	Fraction	Final Location
MARK III UPPER BOUND RL BREAK ECCS THROTTLED NO SPRAYS FIBROUS INSULATION							
RL Break 1.00	Small Pieces 0.22	Advected to Vents 0.00			1	0.000E+00	Vents
		Enclosures 0.00			2	0.000E+00	Enclosures
		Drywell Floor 1.00		Waterborne 1.00	3	**2.200E-01**	Vents
				Sediment 0.00	4	0.000E+00	Floor
		Structures-Above 0.00	Condensate Drainage 0.10	Waterborne 1.00	5	0.000E+00	Vents
				Sediment 0.00	6	0.000E+00	Floor
			Adheres 0.90		7	0.000E+00	Structures-Above
		Structures-Break 0.00	Recirculation Flow 1.00	Waterborne 1.00	8	0.000E+00	Vents
				Sediment 0.00	9	0.000E+00	Floor
			Adheres 0.00		10	0.000E+00	Structures-Break
		Structures-Other 0.00	Condensate Drainage 0.10	Waterborne 1.00	11	0.000E+00	Vents
				Sediment 0.00	12	0.000E+00	Floor
			Adheres 0.90		13	0.000E+00	Structures-Other
	Large-Above 0.30	Structures-Break 1.00	Recirculation Flow 0.12	Waterborne 1.00	14	**3.600E-02**	Vents
				Sediment 0.00	15	0.000E+00	Floor
			Adheres 0.88		16	2.640E-01	Structures-Break
		Structures-Other 0.00	Condensate Drainage 0.00	Waterborne 1.00	17	0.000E+00	Vents
				Sediment 0.00	18	0.000E+00	Floor
			Adheres 1.00		19	0.000E+00	Structures-Other
	Large-Below 0.08	Advected to Vent 1.00			20	**8.000E-02**	Vents
		Enclosures 0.00			21	0.000E+00	Enclosures
		Drywell Floor 0.00		Waterborne 0.10	22	0.000E+00	Vents
				Sediment 0.90	23	0.000E+00	Floor
		Structures-Break 0.00	Recirculation Flow 1.00	Waterborne 0.10	24	0.000E+00	Vents
				Sediment 0.90	25	0.000E+00	Floor
			Adheres 0.00		26	0.000E+00	Structures-Break
		Structures-Other 0.00	Condensate Drainage 0.00	Waterborne 0.10	27	0.000E+00	Vents
				Sediment 0.90	28	0.000E+00	Floor
			Adheres 1.00		29	0.000E+00	Structures-Other
	Canvassed 0.40				30	4.000E-01	Structures/Floor
					Total	1.000E+00	

DEBRIS TRANSPORT RESULTS							
Plant Design:	MARK III						
Estimate:	UPPER BOUND			FIBROUS INSULATION			
Break:	RL BREAK						
ECCS:	ECCS THROTTLED						
Sprays:	NO SPRAYS						

TREE QUANTIFICATION

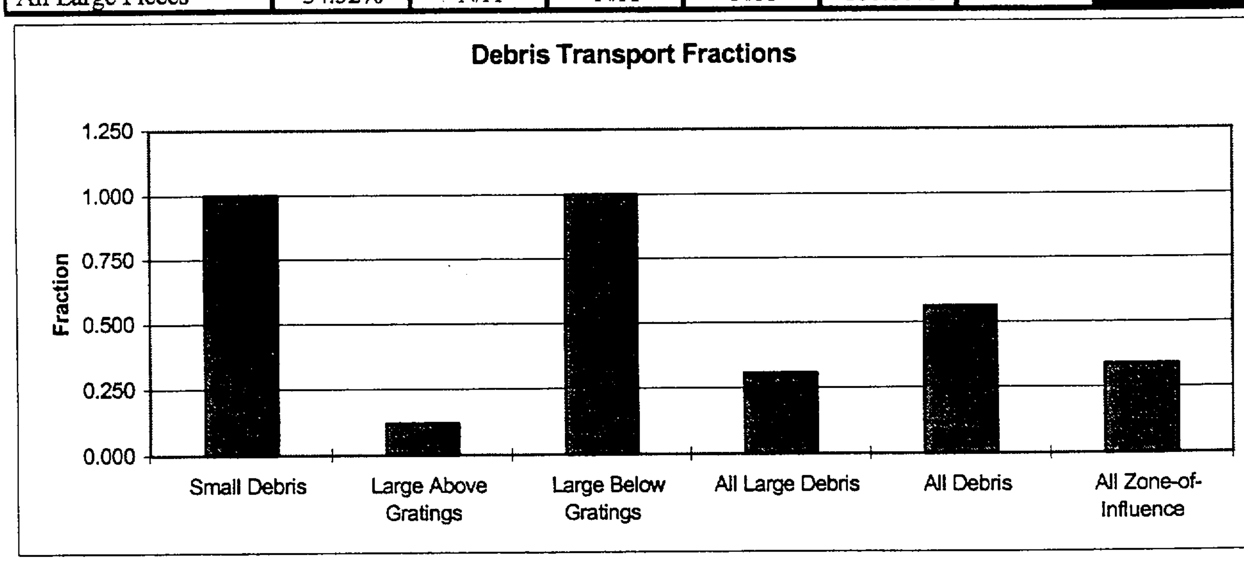
Debris Classification	Vents	Enclosures	Floor	Structures Above	Structures Break	Structures Other	Transport Fraction
Small Pieces	2.200E-01	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	**1.0000**
Large Pieces-Above	3.600E-02	0	0.000E+00	0	2.640E-01	0.000E+00	**0.1200**
Large Pieces-Below	8.000E-02	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 CONTRIBUTIONS (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



MARK III

UPPER BOUND

RL BREAK

NOT THROTTLED

NO SPRAYS

FIBROUS INSULATION

LOCA Type	Debris Classification	Distribution After Blowdown	Erosion and Washdown	Drywell Floor Pool	Path No.	Fraction	Final Location
RL Break 1.00	Small Pieces 0.22	Advected to Vents 0.00			1	0.000E+00	Vents
		Enclosures 0.00			2	0.000E+00	Enclosures
		Drywell Floor 1.00		Waterborne 1.00	3	**2.200E-01**	Vents
				Sediment 0.00	4	0.000E+00	Floor
		Structures-Above 0.00	Condensate Drainage 0.10	Waterborne 1.00	5	0.000E+00	Vents
				Sediment 0.00	6	0.000E+00	Floor
			Adheres 0.90		7	0.000E+00	Structures-Above
		Structures-Break 0.00	Recirculation Flow 1.00	Waterborne 1.00	8	0.000E+00	Vents
				Sediment 0.00	9	0.000E+00	Floor
			Adheres 0.00		10	0.000E+00	Structures-Break
		Structures-Other 0.00	Condensate Drainage 0.10	Waterborne 1.00	11	0.000E+00	Vents
				Sediment 0.00	12	0.000E+00	Floor
			Adheres 0.90		13	0.000E+00	Structures-Other
	Large-Above 0.30	Structures-Break 1.00	Recirculation Flow 0.30	Waterborne 1.00	14	**9.000E-02**	Vents
				Sediment 0.00	15	0.000E+00	Floor
			Adheres 0.70		16	2.100E-01	Structures-Break
		Structures-Other 0.00	Condensate Drainage 0.00	Waterborne 1.00	17	0.000E+00	Vents
				Sediment 0.00	18	0.000E+00	Floor
			Adheres 1.00		19	0.000E+00	Structures-Other
	Large-Below 0.08	Advected to Vent 1.00			20	**8.000E-02**	Vents
		Enclosures 0.00			21	0.000E+00	Enclosures
		Drywell Floor 0.00		Waterborne 0.10	22	0.000E+00	Vents
				Sediment 0.90	23	0.000E+00	Floor
		Structures-Break 0.00	Recirculation Flow 1.00	Waterborne 0.10	24	0.000E+00	Vents
				Sediment 0.90	25	0.000E+00	Floor
			Adheres 0.00		26	0.000E+00	Structures-Break
		Structures-Other 0.00	Condensate Drainage 0.00	Waterborne 0.10	27	0.000E+00	Vents
				Sediment 0.90	28	0.000E+00	Floor
			Adheres 1.00		29	0.000E+00	Structures-Other
	Canvassed 0.40				30	4.000E-01	Structures/Floor
					Total	1.000E+00	

DEBRIS TRANSPORT RESULTS	
Plant Design:	MARK III
Estimate:	UPPER BOUND
Break:	RL BREAK
ECCS:	NOT THROTTLED
Sprays:	NO SPRAYS

FIBROUS INSULATION

TREE QUANTIFICATION

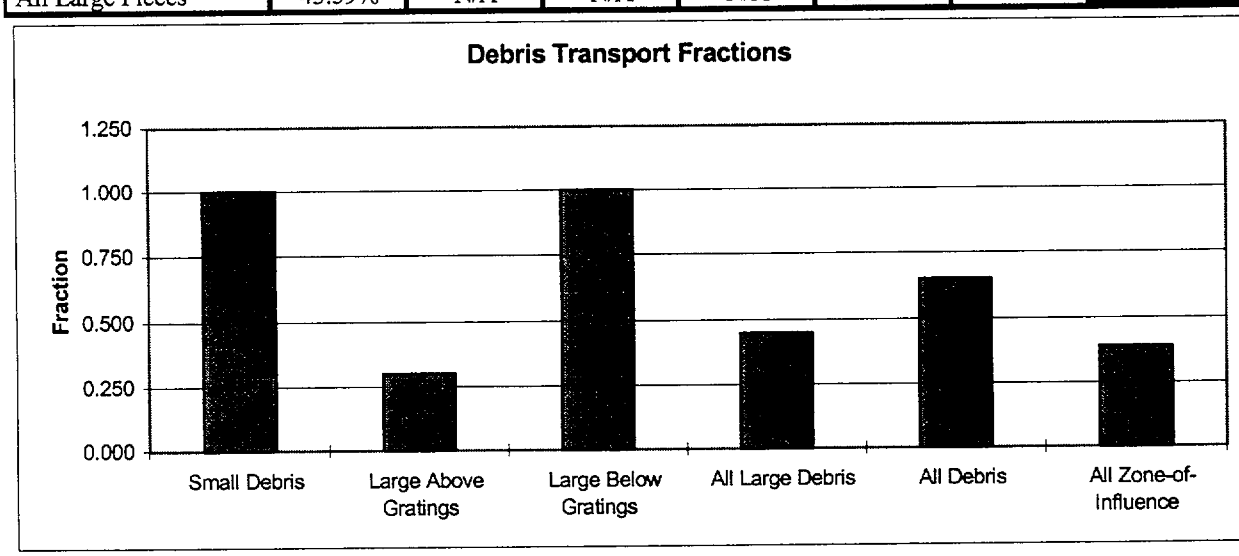
Debris Classification	Vents	Enclosures	Floor	Structures Above	Structures Break	Structures Other	Transport Fraction
Small Pieces	2.200E-01	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	**1.0000**
Large Pieces-Above	9.000E-02	0	0.000E+00	0	2.100E-01	0.000E+00	**0.3000**
Large Pieces-Below	8.000E-02	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)

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 CONTRIBUTIONS (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



NRC FORM 335
(2-89)
NRCM 1102,
3201, 3202

U.S. NUCLEAR REGULATORY COMMISSION

BIBLIOGRAPHIC DATA SHEET

(See instructions on the reverse)

1. REPORT NUMBER
(Assigned by NRC, Add Vol., Supp., Rev., and Addendum Numbers, if any.)

NUREG/CR-6369, Vol. 1
SEA 97-3105-A:14

2. TITLE AND SUBTITLE

Drywell Debris Transport Study

3. DATE REPORT PUBLISHED

MONTH	YEAR
September	1999

4. FIN OR GRANT NUMBER

W6325

5. AUTHOR(S)

D.V. Rao, C. Shaffer, E. Haskin

6. TYPE OF REPORT

Final

7. PERIOD COVERED *(Inclusive Dates)*

8. PERFORMING ORGANIZATION - NAME AND ADDRESS *(If NRC, provide Division, Office or Region, U.S. Nuclear Regulatory Commission, and mailing address; if contractor, provide name and mailing address.)*

Science and Engineering Associates, Inc.
6100 Uptown Blvd. NE
Albuquerque, NM 87110

9. SPONSORING ORGANIZATION - NAME AND ADDRESS *(If NRC, type "Same as above"; if contractor, provide NRC Division, Office or Region, U.S. Nuclear Regulatory Commission, and mailing address.)*

Division of Engineering Technology
Officeof Nuclear Regulatory Research
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001

10. SUPPLEMENTARY NOTES

M. Marshall, NRC Project Manager

11. ABSTRACT *(200 words or less)*

This report describes results of the drywell debris transport study. The objec tive of the study is to develop a methodology for estimating fraction of LOCA generated fibrous insulation debris that would be t ransported 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 ex periments, analytical modeling and engineering calculations. Experiments and analytical studies were undertaken t o compile the necessary knowledge base on debris transport during blowdown, washdown of debris by ECCS water flow and deb ris sedimentation on the drywell floor. Logic charts were used to link both experimental and analytical results. The r esults of the study were used to delineate plant features and transport phenomena that dominate debris transport in the BWR dryw ell. A separate logic chart was developed for each postulated accident scenario and generic plant type analyzed. The log ic charts can be modified to take into account effects of the plant specific features. The overall method is comprehensible t o engineers who are not experts in the subject of debris transport. Also, it is sufficiently flexible that new evidence and assu mptions, related to debris size and distribution, can be easily accommodated.

12. KEY WORDS/DESCRIPTORS *(List words or phrases that will assist researchers in locating the report.)*

BWR Suction Strainers
Drywell Debris Transport
Transport Experiment
Computational Fluid Dynamics
Transport Fractions

13. AVAILABILITY STATEMENT

unlimited

14. SECURITY CLASSIFICATION

(This Page)
unclassified

(This Report)
unclassified

15. NUMBER OF PAGES

16. PRICE

ISBN 0-16-050193-8

9 780160 501937 90000

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, DC 20555-0001

OFFICIAL BUSINESS
PENALTY FOR PRIVATE USE, $300

SPECIAL STANDARD MAIL
POSTAGE AND FEES PAID
USNRC
PERMIT NO. G-67