DOCKET FILE

Docket No. 50-416 September 24, 1992

LICENSEE: Entergy Operations, Inc.

FACILITY: Grand Gulf Nuclear Station

SUBJECT: SUMMARY OF A MEETING ON SEPTEMBER 4, 1992, REGARDING THE GRAND GULF NUCLEAR STATION SHUTDOWN RISK ANALYSIS

On September 4, 1992, representatives of Entergy Operations, Inc., and its contractor, Erin Engineering and Research, Inc., briefed NRC management and staff on Grand Gulf Nuclear Station Shutdown Risk Activities and on the methodology and generic results of the Probabalistic Shutdown Safety Assessment sponsored by the Electric Power Research Institute (EPRI) and carried out by Erin Engineering. Meeting attendees are listed in Enclosure 1. Slides presented by Entergy and Erin Engineering are in Enclosure 2.

This meeting provided an opportunity for representatives of NRC management and staff involved in probabalistic risk assessment (PRA) and shutdown risk assessment to have a detailed discussion of the methodology and results achieved thus far in the Grand Gulf shutdown risk activities.

ORIGINAL SIGNED BY:

Paul W. O'Connor, Senior Project Manager
Project Directorate IV-1
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Office of Nuclear Reactor Regulation

Enclosures:
1. Meeting attendees
2. Slides

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Docket File	JWechselberger
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JLarkins	JDixon
GHolahan	ACRS (10)
PD4-1 Reading	MCaruso
HVandermolen	RRobinson
GThomas	MRubin
PD4-1 Reading	

200005

OFC	LA:PD4-1	PM:PD4-1 PWOC	PD:PD4-1 PWOC
NAME	PNoonan	PO'Connor:pk	JLarkins for JTL
DATE	9/24/92	9/24/92	9/24/92

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Grand Gulf Nuclear Station

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UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

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Vice President, Operations, Inc.
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Port Gibson, Mississippi 39150

Enclosure 1

September 4, 1992

Grand Gulf Nuclear Station Shutdown Risk Analysis Meeting

List of Attendees

Paul W. O'Connor	NRR/PD4-1
Jean-Pierre Sursock	EPRI
Jennifer Dixon	NRR/RSIB
George Alan Zinke	Entergy/Grand Gulf
Jim Hewitt	ERIN/Grand Gulf
John Gaertner	ERIN/Grand Gulf
Mark Caruso	NRR/SRXB
Harold Vandermolen	RES/DSIR/PRAB
Richard Robinson	RES/DSIR/PRAB
Geroge Thomas	NRR/DST/SRXB
Mark Rubin	NRR/SRXB
Gary Holahan	NRR/DST

Enclosure 2

Grand Gulf Nuclear Station
Presentation to NRC Staff
September 4, 1992

PRA
and
Shutdown Risk Management

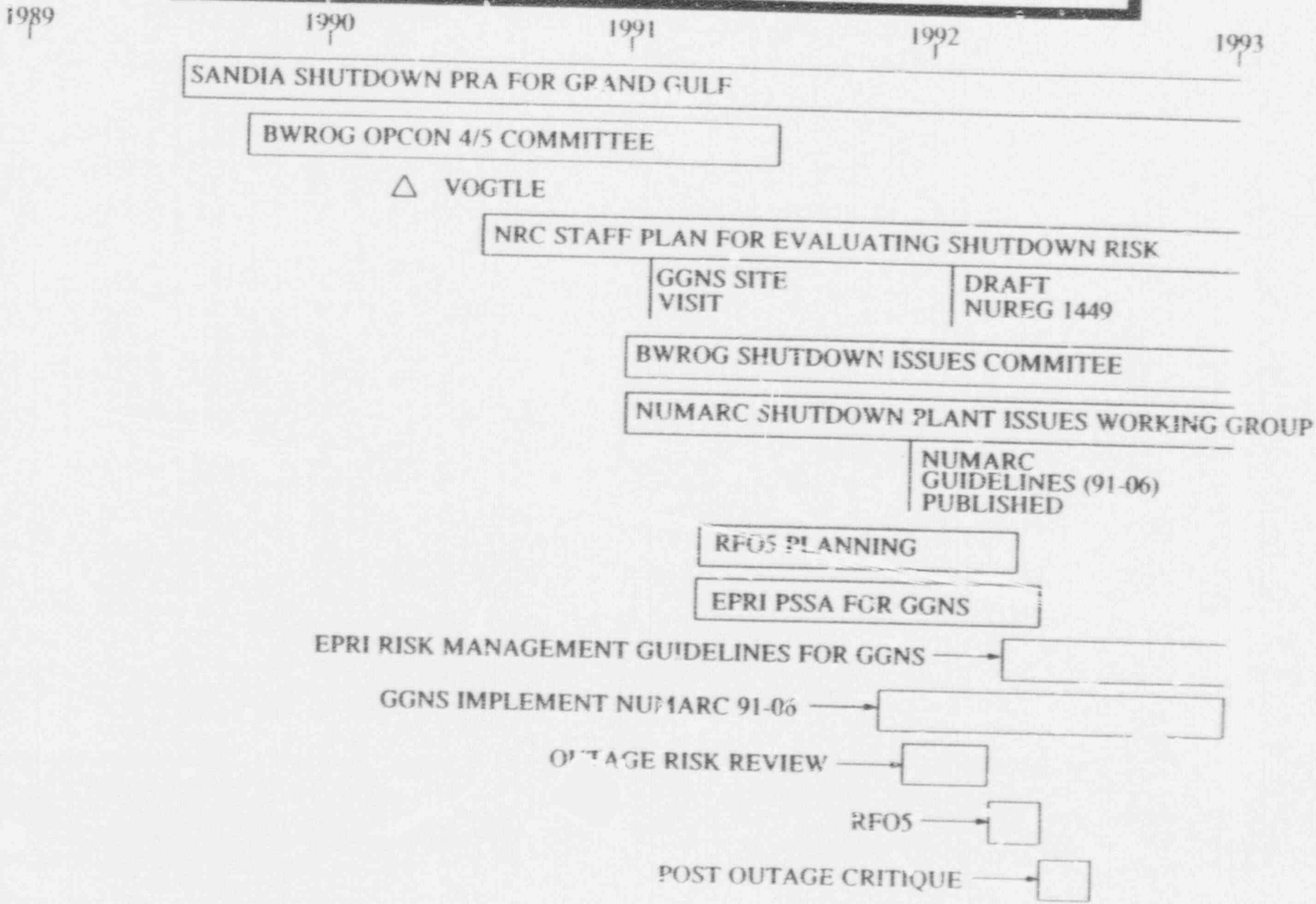
• Introduction - Grand Gulf shutdown risk activities	George Zinke
• Probabilistic Shutdown Safety Assessment	John Gaertner/ Jim Hewitt
- methodology	
- generic results	
• Insights from Grand Gulf RF05	George Zinke

Introduction

Grand Gulf Shutdown

Risk Activities

GGNS Shutdown Risk Activities



SELECTED OUTAGE INSIGHTS
SAFETY-SIGNIFICANT
EVENT TRENDS

	Length	# of IRs	IR/ day	# of LERs	LERs by day
RF01	88 days	60	.68	20	.23
RF02	61 days	48	.79	12	.20
RF03	44 days	30	.68	5	.11
RF04	57 days	32	.56	9	.16
RF05	52 days	25	.48	4	.08

- IRs/LERs capture all significant outage events
- Positive trend is real - i.e. not due to changing thresholds/definitions

Probabilistic Shutdown Safety Assessment

Insights From

Grand Gulf RF05

EVENT REVIEW RESULTS

LOSS OF COOLANT ACCIDENT

- At low water levels, insufficient water in Suppression Pool for recirculation path
- Primary Containment not established

ACTIONS:

- Schedule changed to minimize low water level periods
- External water sources available
- Floodable primary containment

Need To have procedure to reestablish containment integrity.

EVENT REVIEW RESULTS

STATION BLACKOUT

- Time to boil is key parameter
  - Decay heat load
  - Water volume
  - Time to recover power
- Highest risk period is early in outage (high decay heat) with vessel not flooded in upper pool (low water volume)

ACTIONS:

- Changed schedule to maintain Division III D/G operable during low water volume at beginning of outage
- Completed action based on NUREG 1410 to increase safety in switchyard activities
- Contingency plan to include actions to prevent loss of power

EVENT REVIEW RESULTS

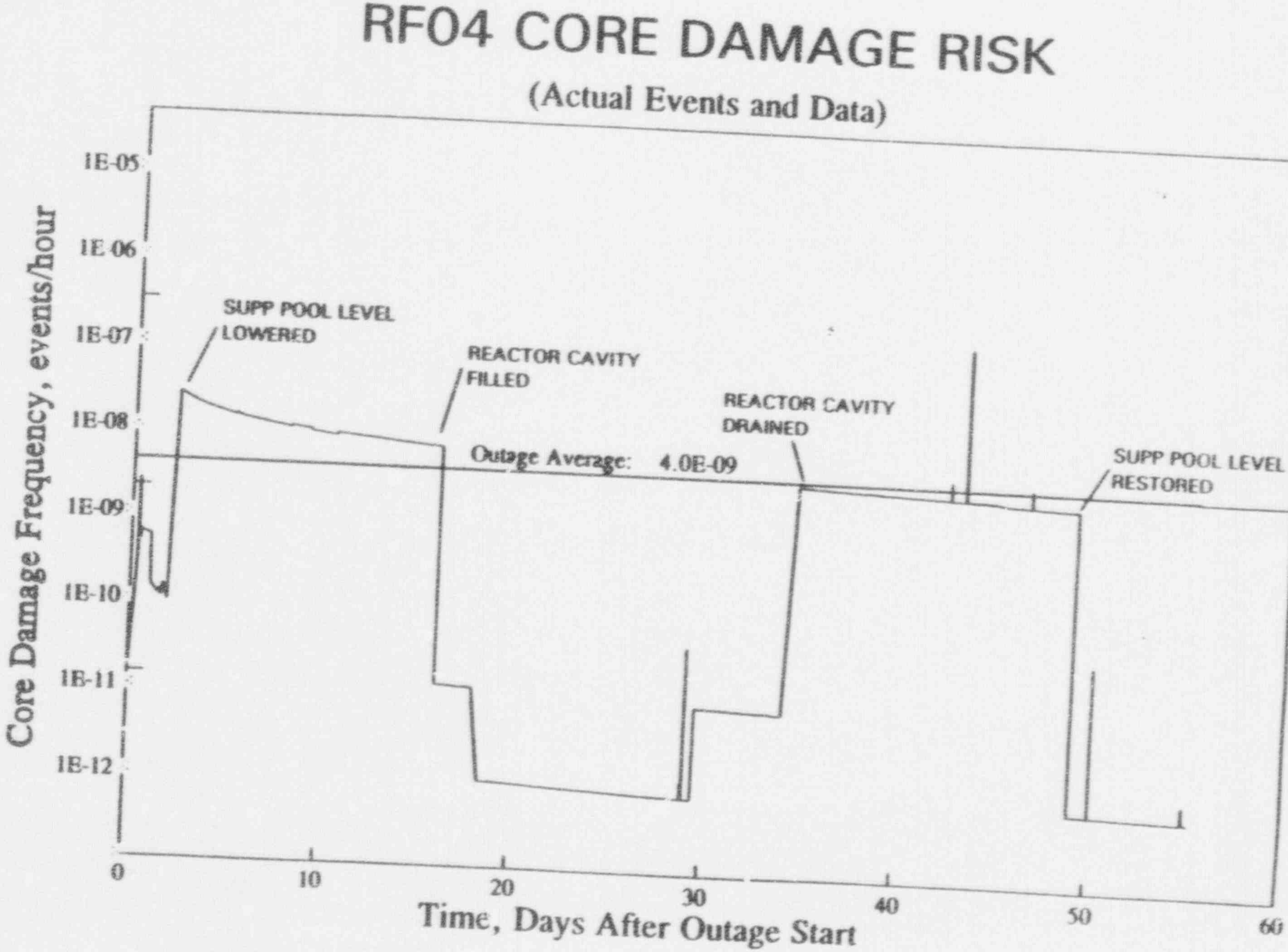
when protected division is out there needs to be additional measures

FIRE

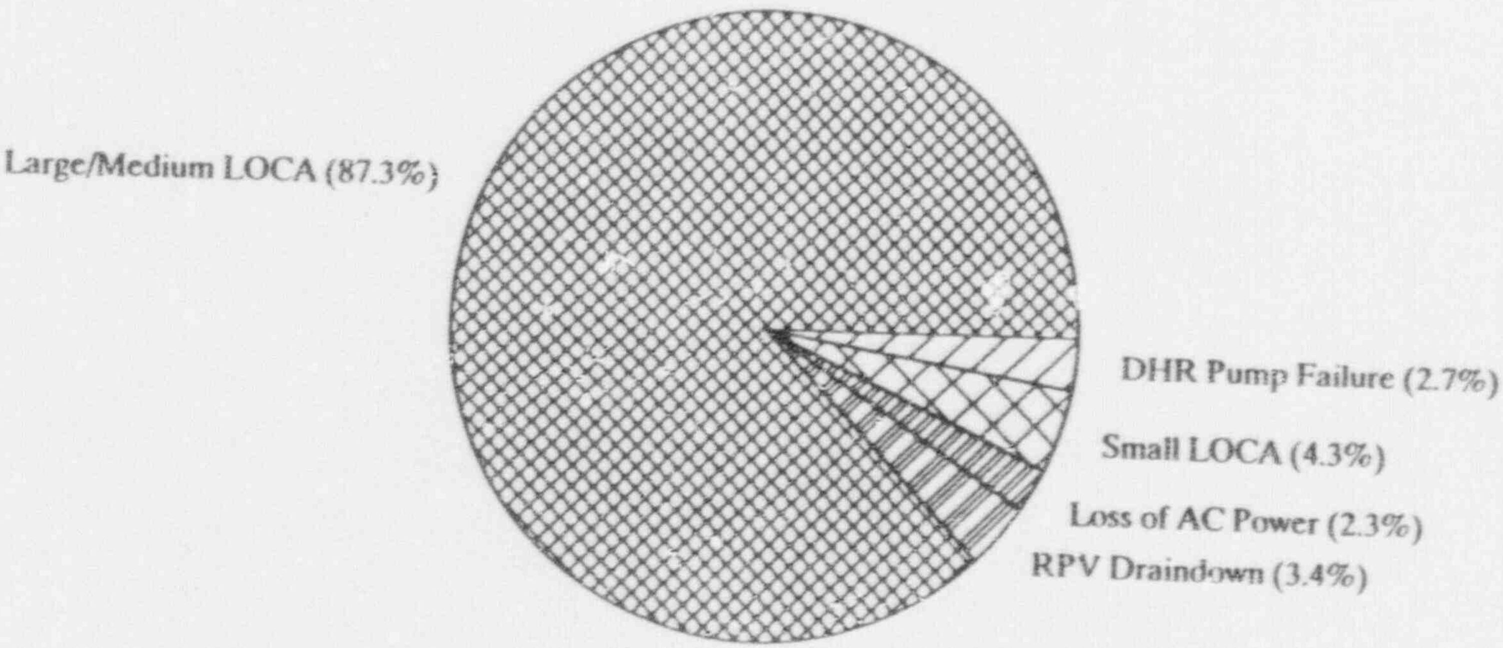
- GGNS protects Division I in accordance with Appendix R
- Division I outage relies on unprotected Division II

ACTIONS:

- Focus on prevention:
  - Knowledgeable personnel
  - Limiting ignition sources in non protected division
  - Additional vigilance for Division II

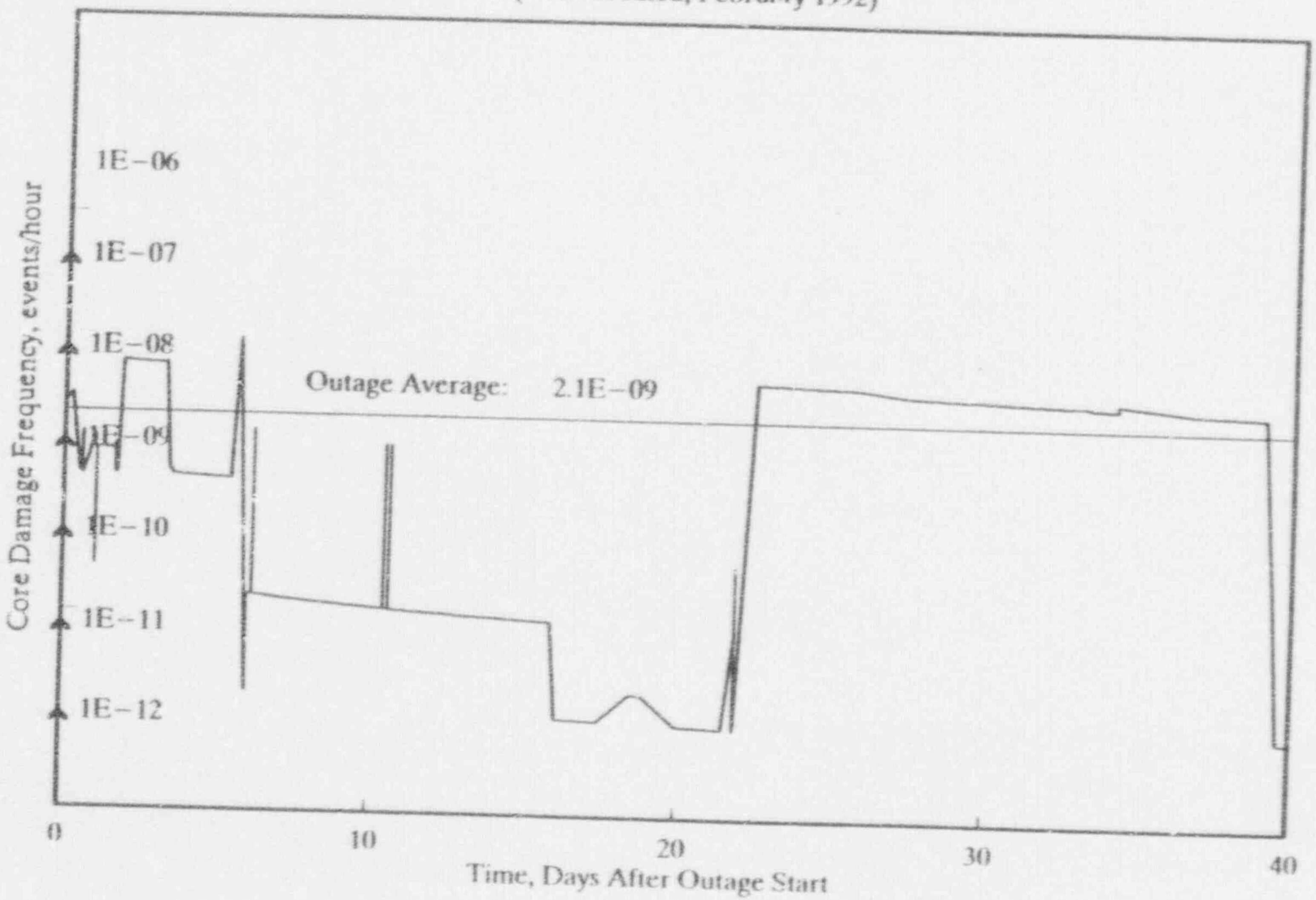

RF04 CORE DAMAGE RISK
(Actual Events and Data)
Core Damage Frequency, events/hour
1E-05
1E-06
1E-07
1E-08
1E-09
1E-10
1E-11
1E-12
SUPP POOL LEVEL LOWERED
REACTOR CAVITY FILLED
REACTOR CAVITY DRAINED
SUPP POOL LEVEL RESTORED
Outage Average: 4.0E-09
0
10
20
30
40
50
60
Time, Days After Outage Start

RF04 CORE DAMAGE RISK



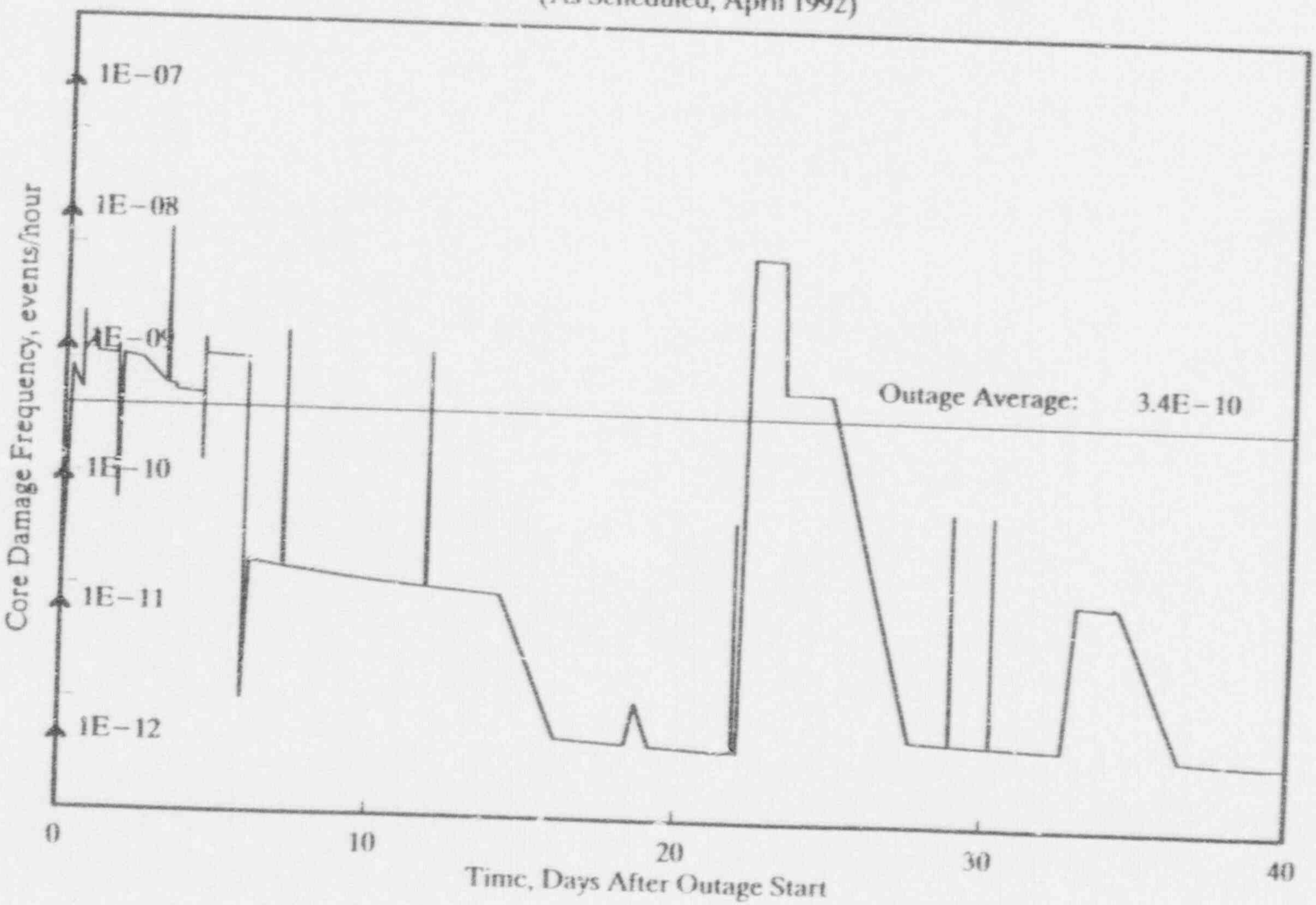
RF05 CORE DAMAGE RISK

(As Scheduled, February 1992)



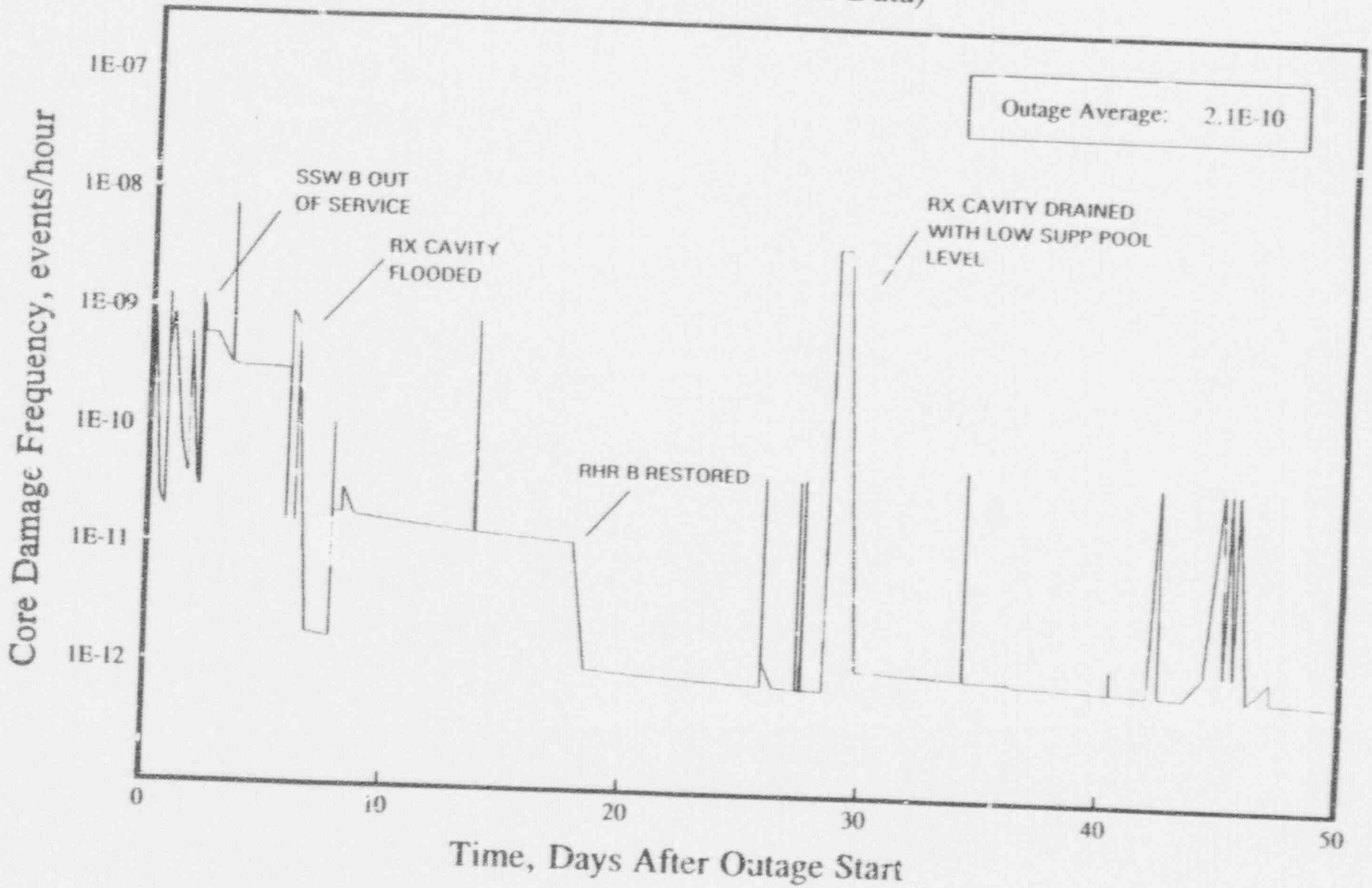
RF05 CORE DAMAGE RISK

(As Scheduled, April 1992)



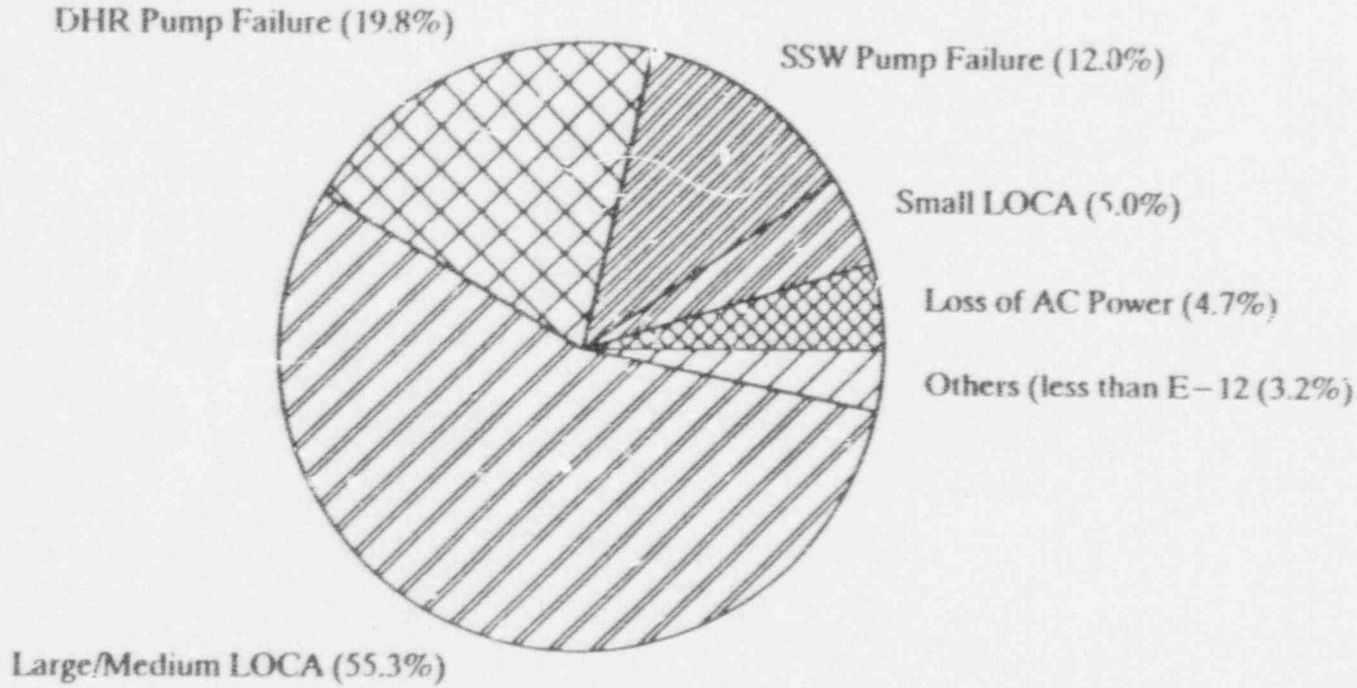
RF05 CORE DAMAGE RISK

(Actual Events and Data)



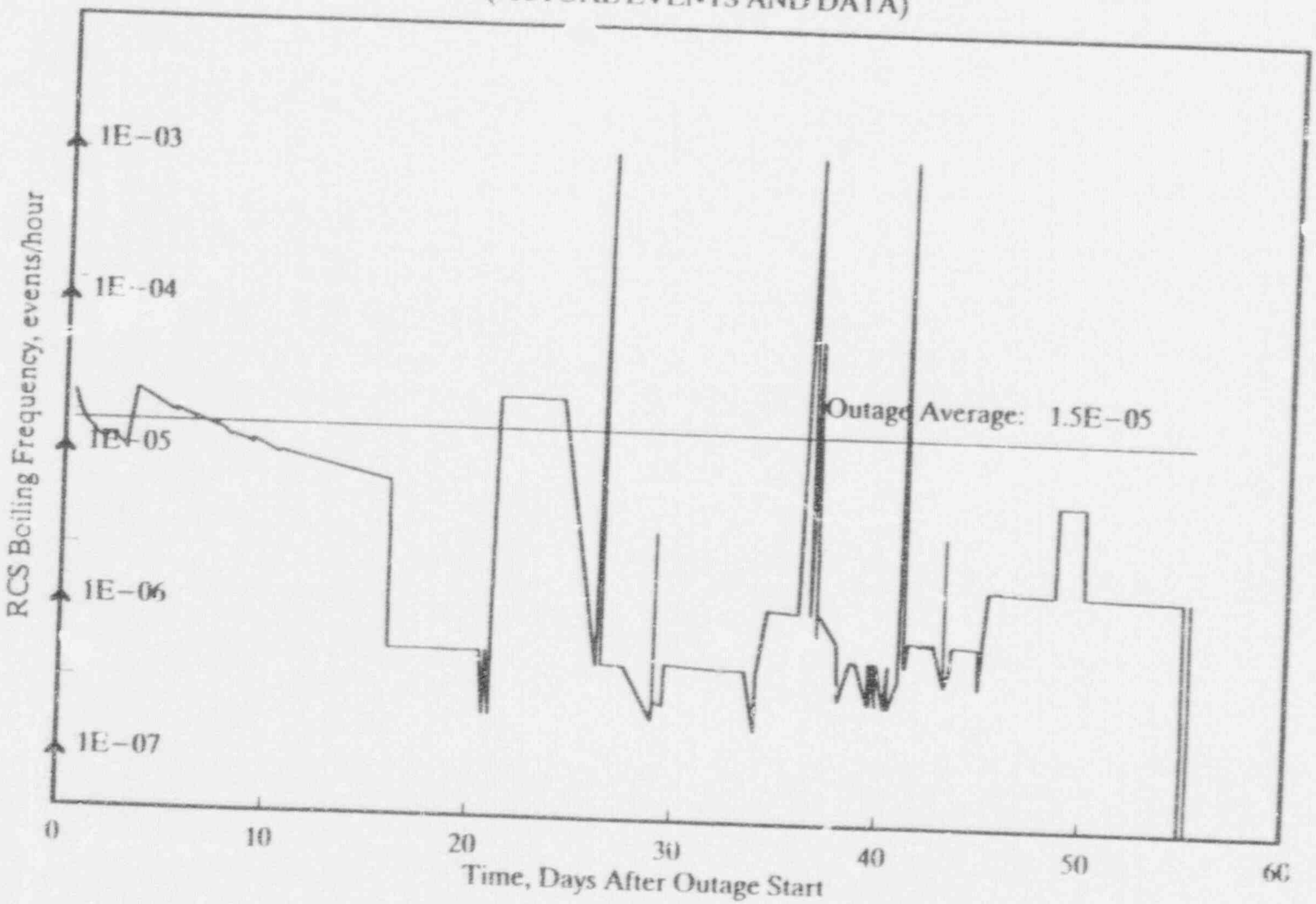
RF05 CORE DAMAGE RISK

(ACTUAL EVENTS AND DATA)



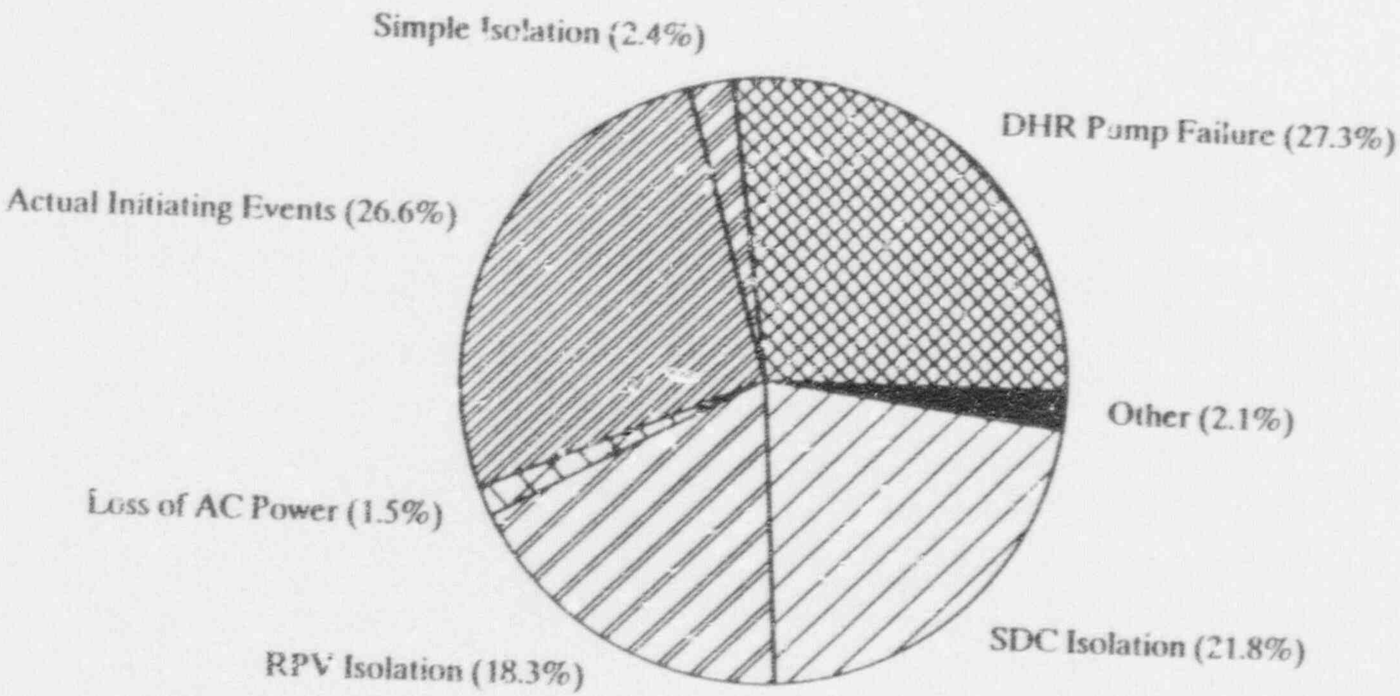
RF04 RCS BOILING RISK

(ACTUAL EVENTS AND DATA)



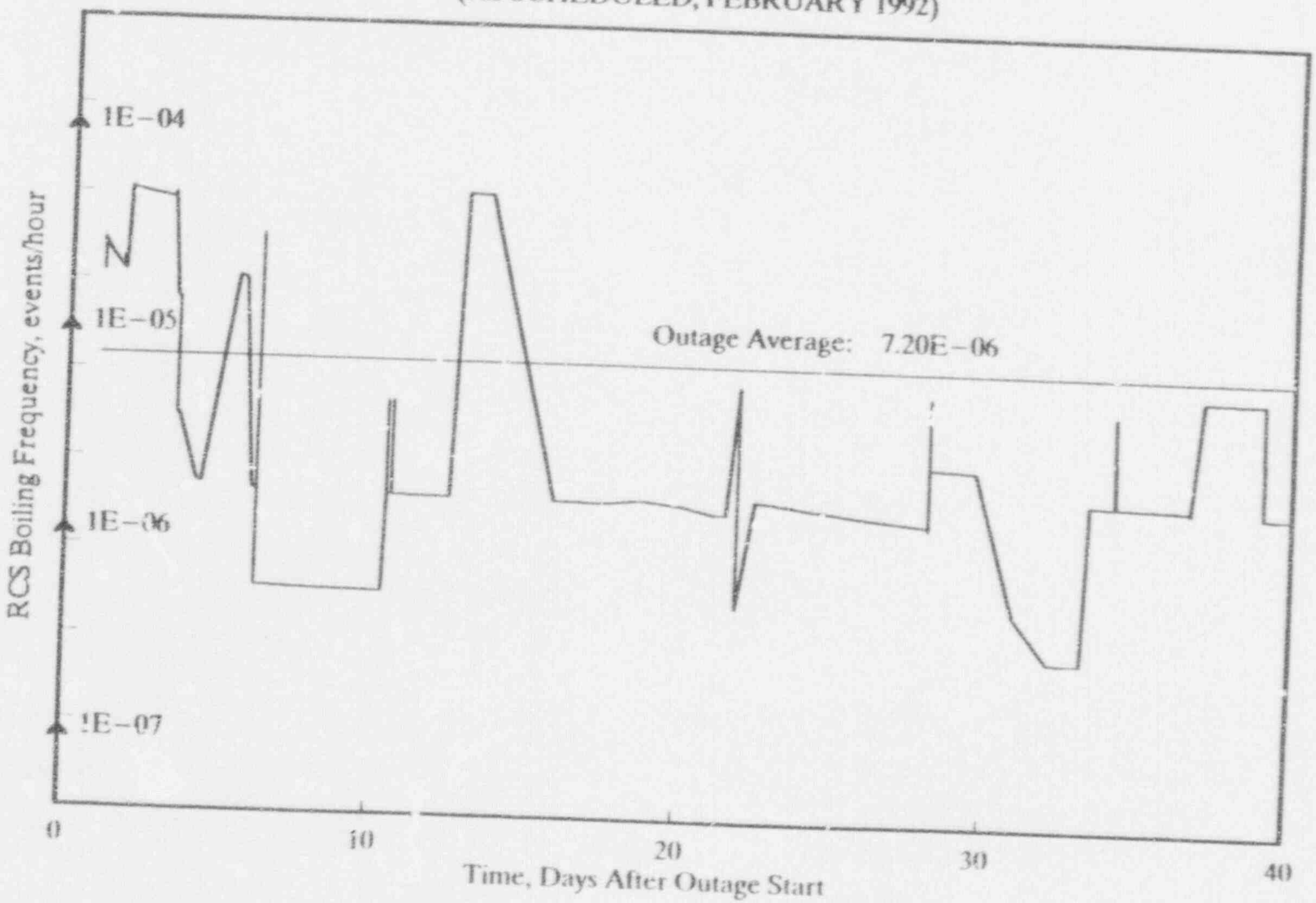
RF04 RCS BOILING RISK

(ACTUAL EVENTS AND DATA)



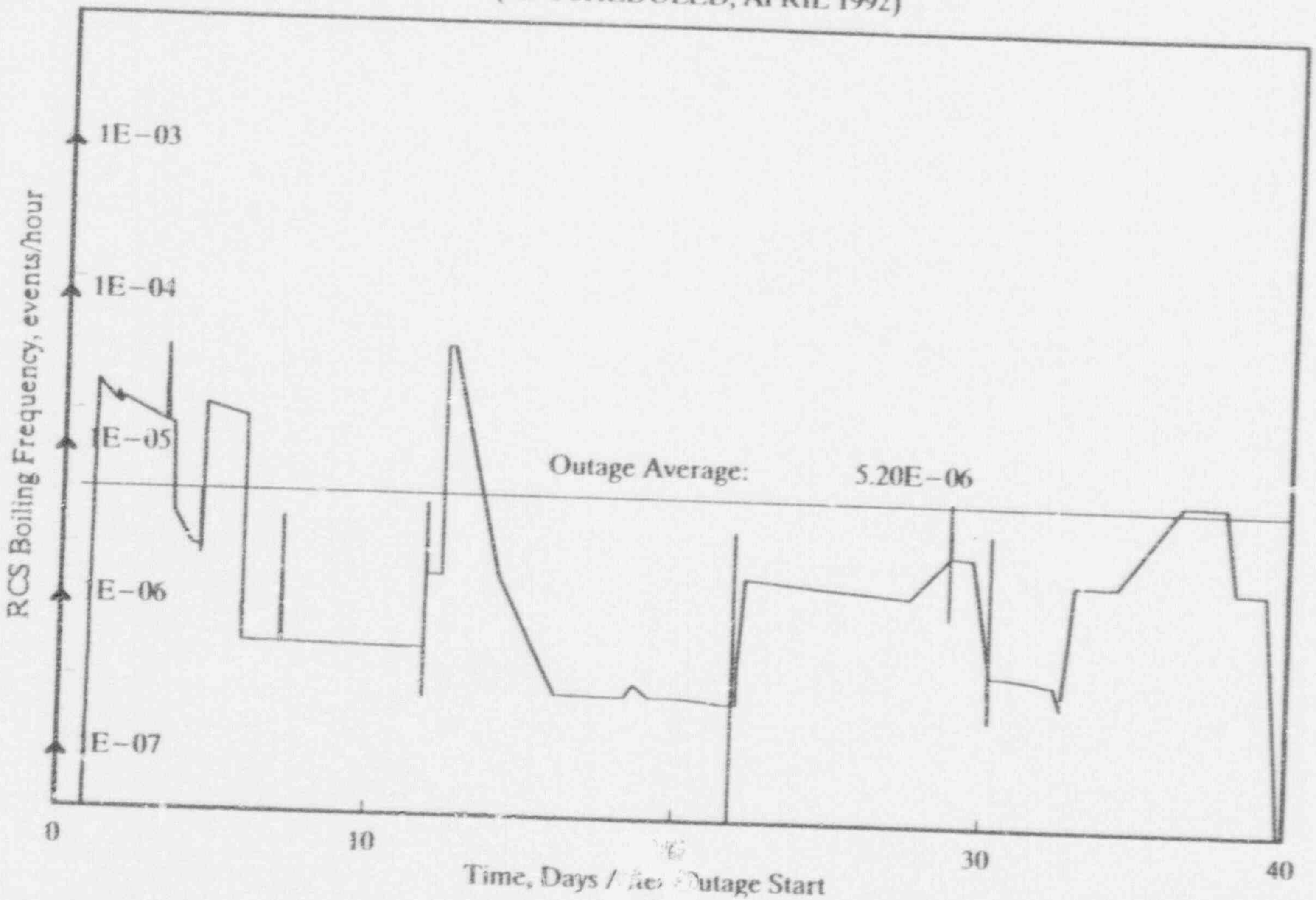
RF05 RCS BOILING RISK

(AS SCHEDULED, FEBRUARY 1992)



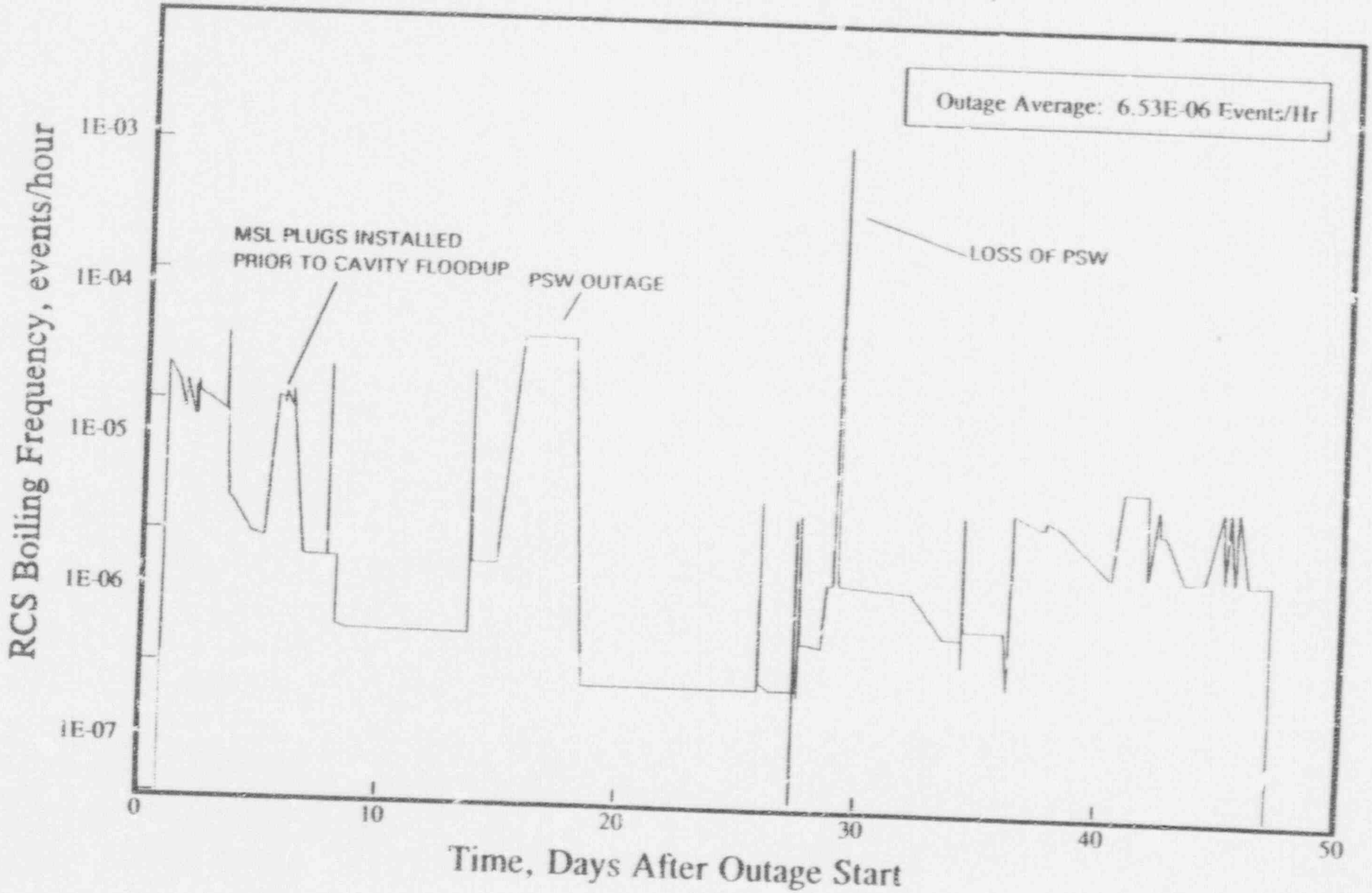
RCS BOILING RISK IN MODES 4 AND 5

(AS SCHEDULED, APRIL 1992)



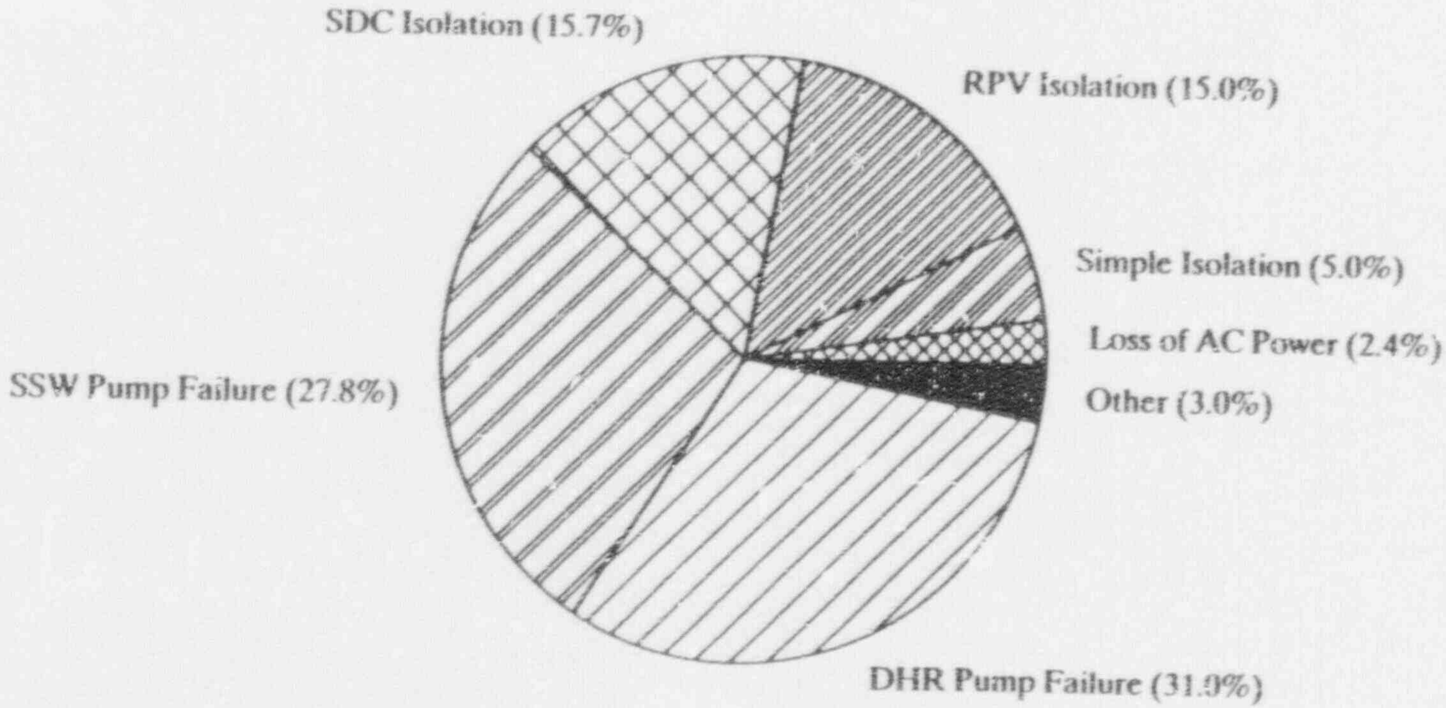
RCS BOILING RISK IN MODES 4 AND 5

(ACTUAL EVENTS AND DATA)



RISK OF RCS BOILING IN MODES 4 AND 5

(ACTUAL EVENTS AND DATA)



SELECTED INSIGHTS

- Coincidence of high decay heat and low water level should be minimized
- Sensitivity to suppression/fuel pool levels and LOCA
- Maintain RCS temperature well below Tech Spec limits to increase thermal margin
- AC power failures are a small risk contributor, unlike at-power operations
- Emergency procedures were designed with operating conditions in mind and do not reflect all unique plant configurations during shutdown
- Maintain shutdown cooling valve manipulations to a minimum
- Investigate the need for better contingency plans to restore primary containment

EPRI
OUTAGE RISK ASSESSMENT AND MANAGEMENT (ORAM)

PROGRAM OVERVIEW

Presented to:

U.S. Nuclear Regulatory Commission

By: ERIN® Engineering and Research, Inc.

For: Entergy Operations, Inc.

September 1992

OUTAGE SAFETY & MANAGEMENT PROGRAM STRUCTURE

Outage Safety & Management

- *Outage Risk Assessment & Management*
  - Outage Practices & Needs
  - PSSA Development
  - RMG Framework & Applications
  - Contingency Planning Guidance
  - ORAM-TIP Software
- *Human Reliability Enhancement*
  - Review of Industry Experience
  - HRA Risk Studies
  - Insights from Plant Personnel
  - Human Error Reduction
- *Risk-Based Regulation*
  - At-Power vs. Shutdown Maintenance/Tests
  - Maintenance Rule Requirements
  - Justification to Operate with Outage Issues
  - Instrumentation Needs
  - Tech Spec Optimization
  - Fire Risk Protection
- *Outage Optimization*
  - CAFTA Modeling for Configuration Analysis
  - PSSA Applications
  - Outage Equipment Reliability Database
  - Deterministic Models

Technology Transfer

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STEPS IN ORAM PROCESS

- Understanding Current Practices and Needs (Utility Survey, NSAC-173/174)
- Development of Probabilistic Shutdown Safety Assessment (PSSA, NSAC-175/176)
- Development of Risk Management Process (RMG, end of 1992)
- Applications of PSSA and RMG using ORAM-TIP (end of 1992)

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BENEFITS OF ORAM PARTICIPATION

- Plan and control for outage safety
- Respond to NUMARC, INPO, NRC attention to safety
- Make decisions from safety perspective

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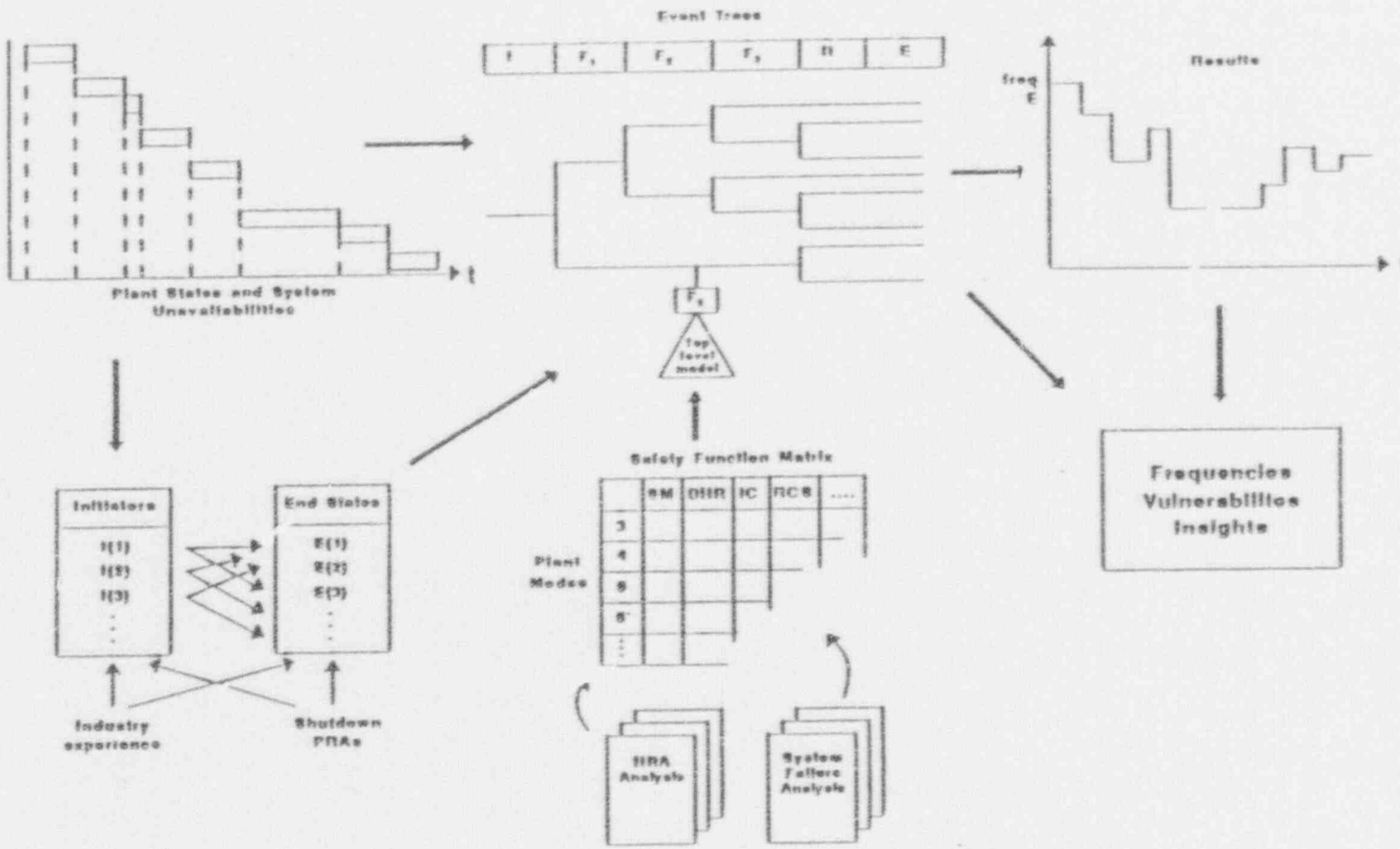
OVERVIEW OF PSSA METHODOLOGY



FEATURES OF PSSA METHODOLOGY

- Initiators determined from experience
- Multiple endstates
- Outage model is timeline of Plant States
- Accident sequences using event trees
- Top events modeled emphasizing
  - Human actions
  - Train unavailabilities
- Results displayed as
  - Frequencies vs. time
  - Insights for risk management

QUESTIONS ANSWERED BY PSSA

- What Initiators are of concern and when?
- What subsequent failures are important?
- What unavailabilities are important?
- What contingency plans are important?
- What human actions are critical?
- What issues are worthy of consideration?

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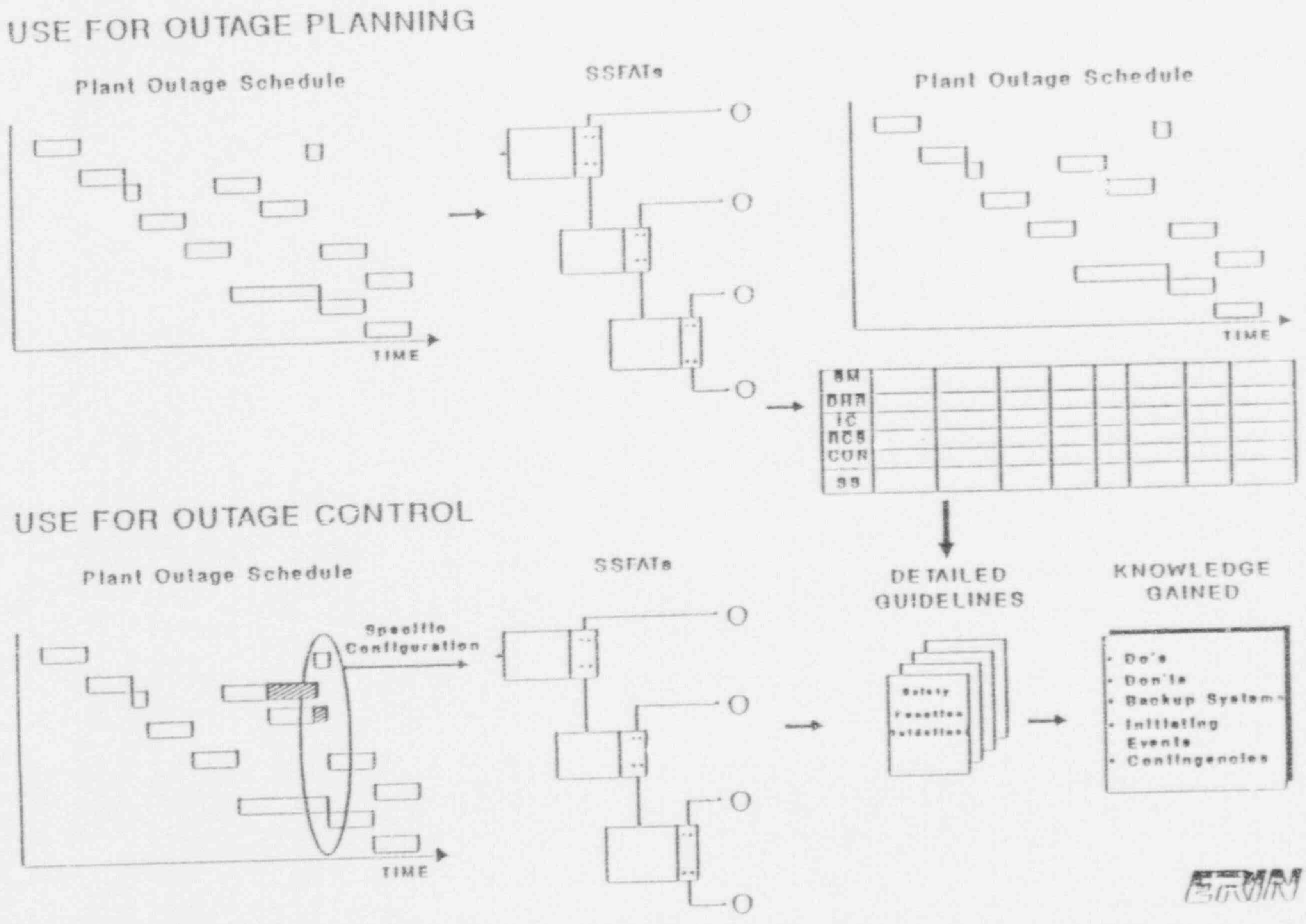
OVERVIEW OF RISK MANAGEMENT AND CONTINGENCY GUIDELINES



FEATURES OF RMG METHODOLOGY

- Outage represented as series of plant states
- Safety reviewed in terms of shutdown safety functions
- Each plant state/safety function combination reviewed with an SSFAT
- Level of safety function support represented by "color"
- Risk Management Guidance (RMG) specific to each plant state/safety function/color
- RMGs derived from PSSA, industry experience, and lessons learned

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FEATURES OF RMG METHODOLOGY
(continued)

- RMG process supportive of NUMARC initiative, INPO guidance, NUREG-1449
- To be used in outage planning, control, and post-outage
- Based on "Defense in Depth"
- Identifies need for Contingency Plans
- Provides graded approach depending on level of safety function support

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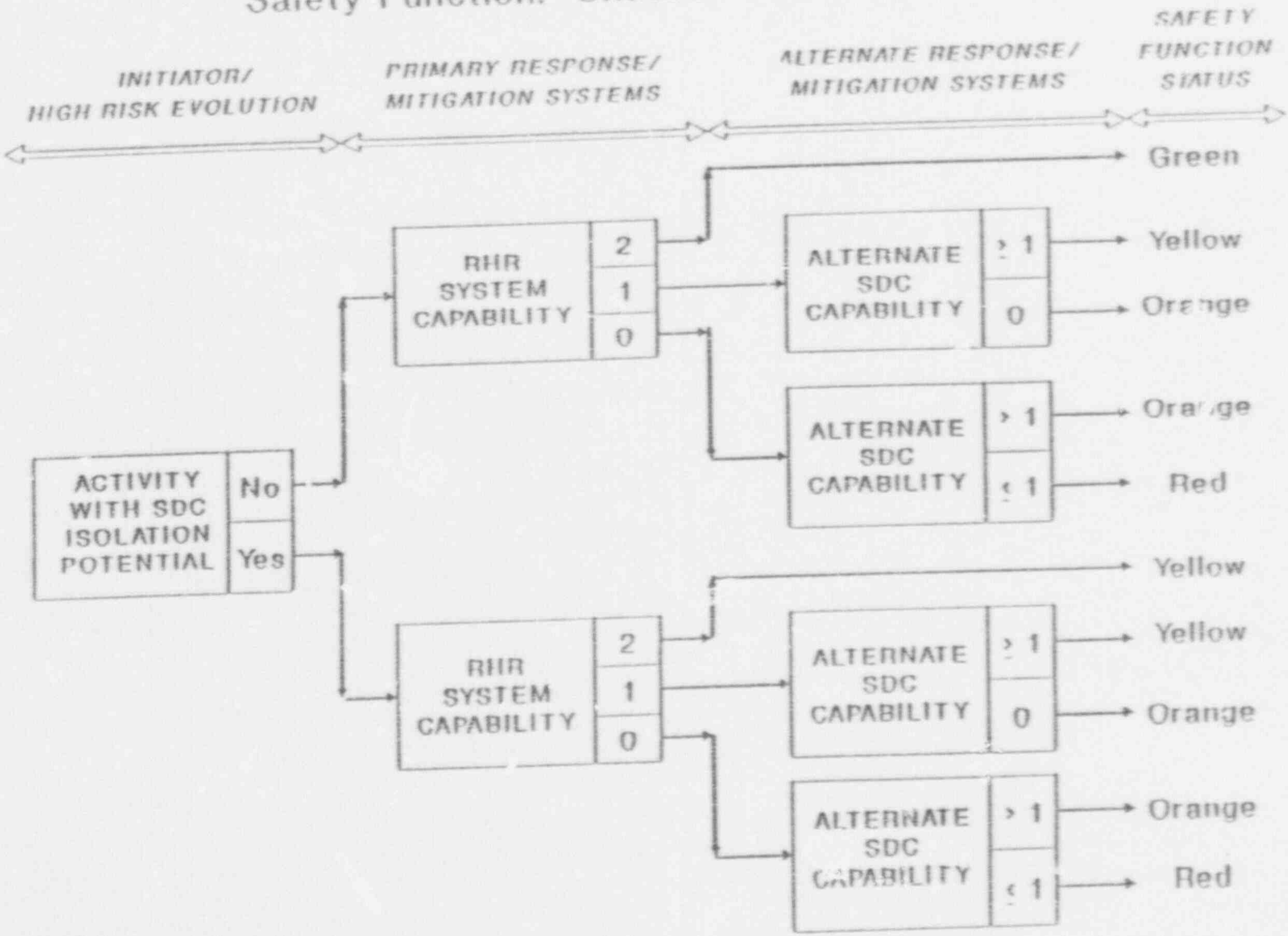
EXAMPLE SSFAT FORMAT

Safety Function: Shutdown Cooling



KEY SAFETY FUNCTIONS CONSIDERED IN RMG

- Reactivity Control
- Shutdown Cooling
- Fuel Pool Cooling
- Inventory Control
- Electric Power Control
- Vital Support System Control
- Primary and Secondary Containment Control

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RISK MANAGEMENT GUIDELINES

(INVENTORY)

Plant State(s)	Color Code	Guideline	Technical Basis
	0	Maintain enough water in the suppression pool, CST, and RWST to keep suppression pool water level above 14.5 ft after a LOCA. For the CST, credit only the volume above the level of 18 ft.	ECCS pump operation with SP level below 14.5 ft could be unstable and cause equipment damage (EP-2, Caution #5). Per Technical Specifications, when in Modes 4 and 5 with suppression pool level below 12 ft 8 in, the CST must have 170,000 gallons reserved for HPCS use. This corresponds to a CST level of 18 feet. Only the volume above that level is available if HPCS injection fails. This excess volume could be transferred to the RCS through either the CRD or condensate transfer system.

RISK MANAGEMENT GUIDELINES

(SHUTDOWN COOLING, SFP COOLING)

Plant State(s)	Color Code	Guideline	Technical Basis
Mode 3-4 Mode 5, UPPER POOL = "EMPTY"	Y	Avoid activities which increase the chance of disabling the decay heat removal system. In particular, surveillance testing of RPV water level instrument channels should be deferred whenever possible. These include: • Channel checks, functional tests, and calibration • Logic system functional tests • Isolation system response time demonstrations These activities have been among the dominant causes of inadvertent RPV, containment, and auxiliary building isolation events.	• NSAC-175 The chance of decay heat removal system isolation events dominates the chance of RCS boiling when not in Mode 5 with the refueling cavity flooded. The time to recover from an isolation event may be short, but, based on industry experience, it remains significant compared to the time for RCS boiling.

ORAM-TIP: WHAT IS IT?

- Outage Risk Assessment and Management - Technology Integration Package

- Outage safety PC workstation software

- Integrates products of EPRI ORAM project

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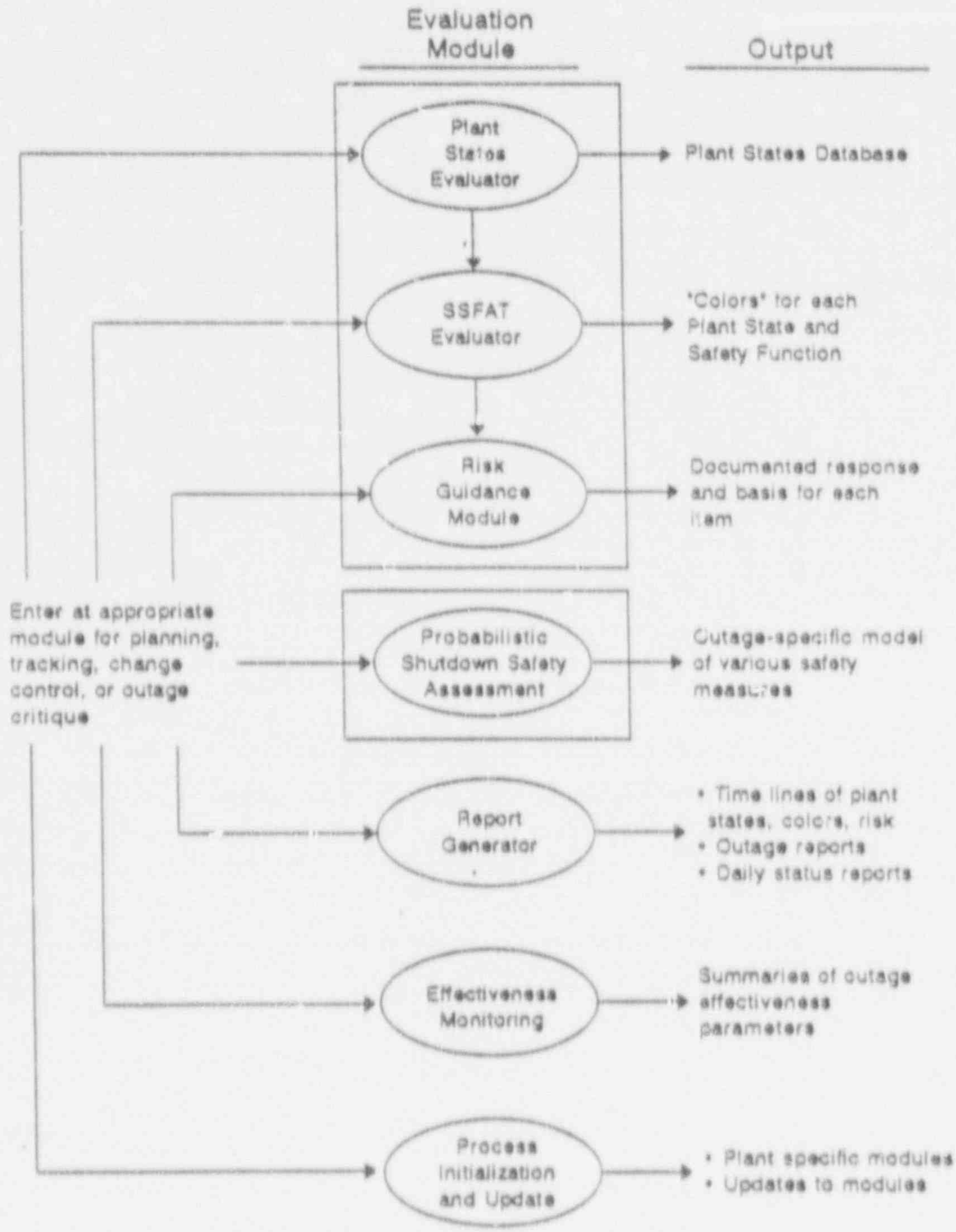
ORAM-TIP MODULES



RESOURCE REQUIREMENTS FOR PSSA

A. Creation of PSSA Plant Model

- 6-8 person-months
- Based on Peach Bottom experience

B. Evaluate a New Outage with Existing Model

- 1-2 person-months
- Based on Grand Gulf experience

C. Type of Expertise Required

- PRA experience helpful to build model
- Outage planning personnel to apply model

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EPRI

BWR SHUTDOWN SAFETY ASSESSMENT: RESULTS, INSIGHTS, AND METHOD

Presentation to:

US NUCLEAR REGULATORY COMMISSION

OFFICE OF NUCLEAR REACTOR REGULATION

By:

Jim Hewitt

John Gaertner

September 4, 1992

ERIN

FOUR QUESTIONS FOR A PSSA

I. How does plant safety vary over the course of an outage?

II. Which factors dominate risk?

III. How can plant safety best be improved?

IV. How do PSSA results compare with other plant safety measures?

SCOPE

Site: Grand Gulf Nuclear Station (GGNS), a BWR/6 with a modified Mark III containment.

Outage: GGNS' fourth refueling outage (RF04).

- Fuel shuffling
- Few switchyard activities
- Major Division I outage
- ~2 week delay in RPV disassembly
- (Non-safety) Plant service water outage
- 3 short-lived shutdown cooling isolation events
- Suppression pool draining (~2 feet)

Endstates Evaluated:

- RCS boiling in Cold Shutdown and Refueling
- Spent Fuel Pool boiling
- Core damage
- Prompt criticality
- Cold overpressurization
- Fuel bundle uncovery while in transit
- Radionuclide release

CONTRASTING RISK ASSESSMENT METHODS

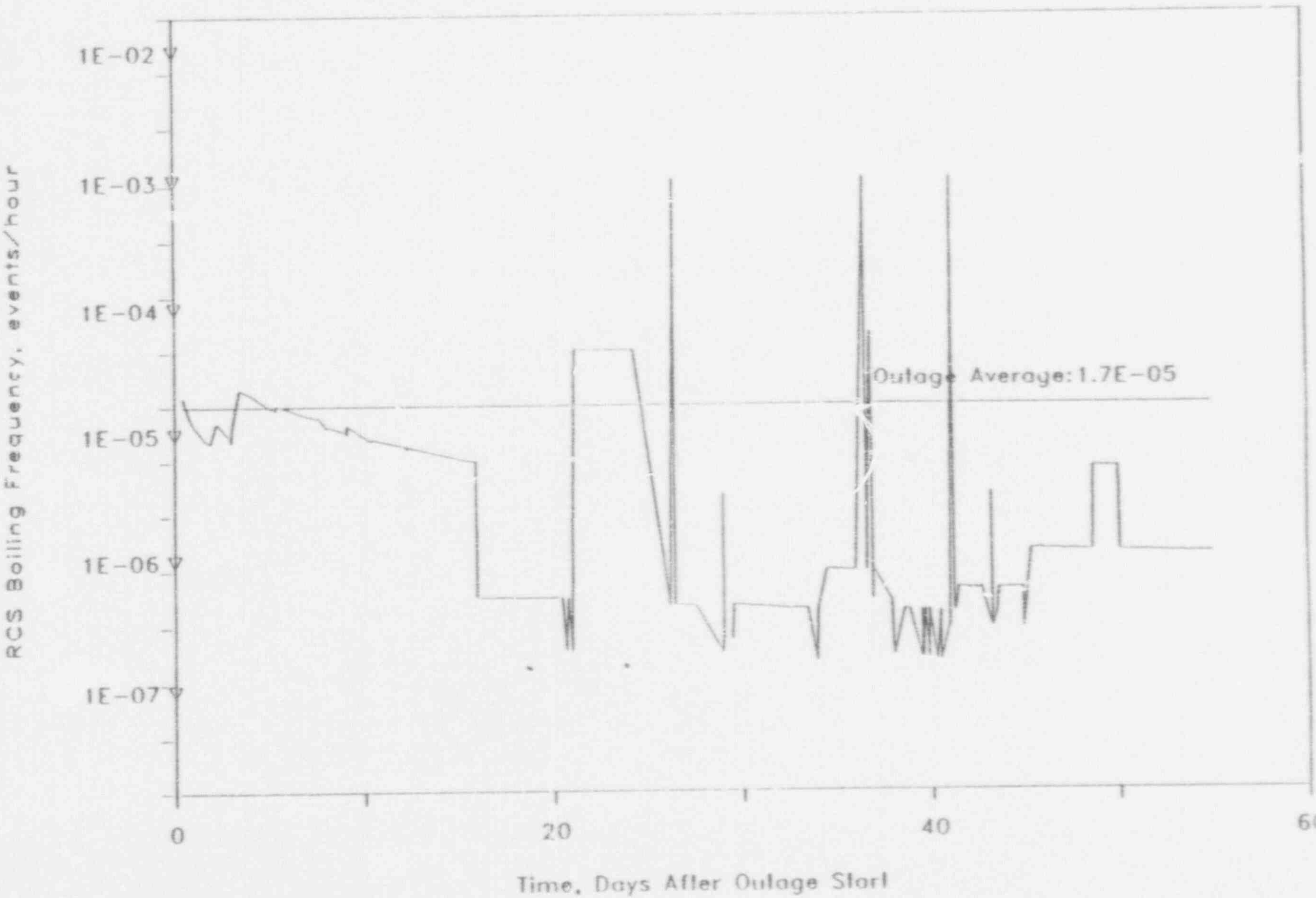
TOPIC	STANDARD PRA	CHRONOLOGICAL RISK MODEL
Plant States	1	∞
Maintenance Unavailability	"AVERAGE" Unavailability	0-1 Values
Fault Tree	Components	Trains
Event Tree	Multiple Safety Functions	Single Safety Function
Quantification Tool	REBECA	LOTUS-123
Validity	Plant Life	Specific Outage

QUESTION #1

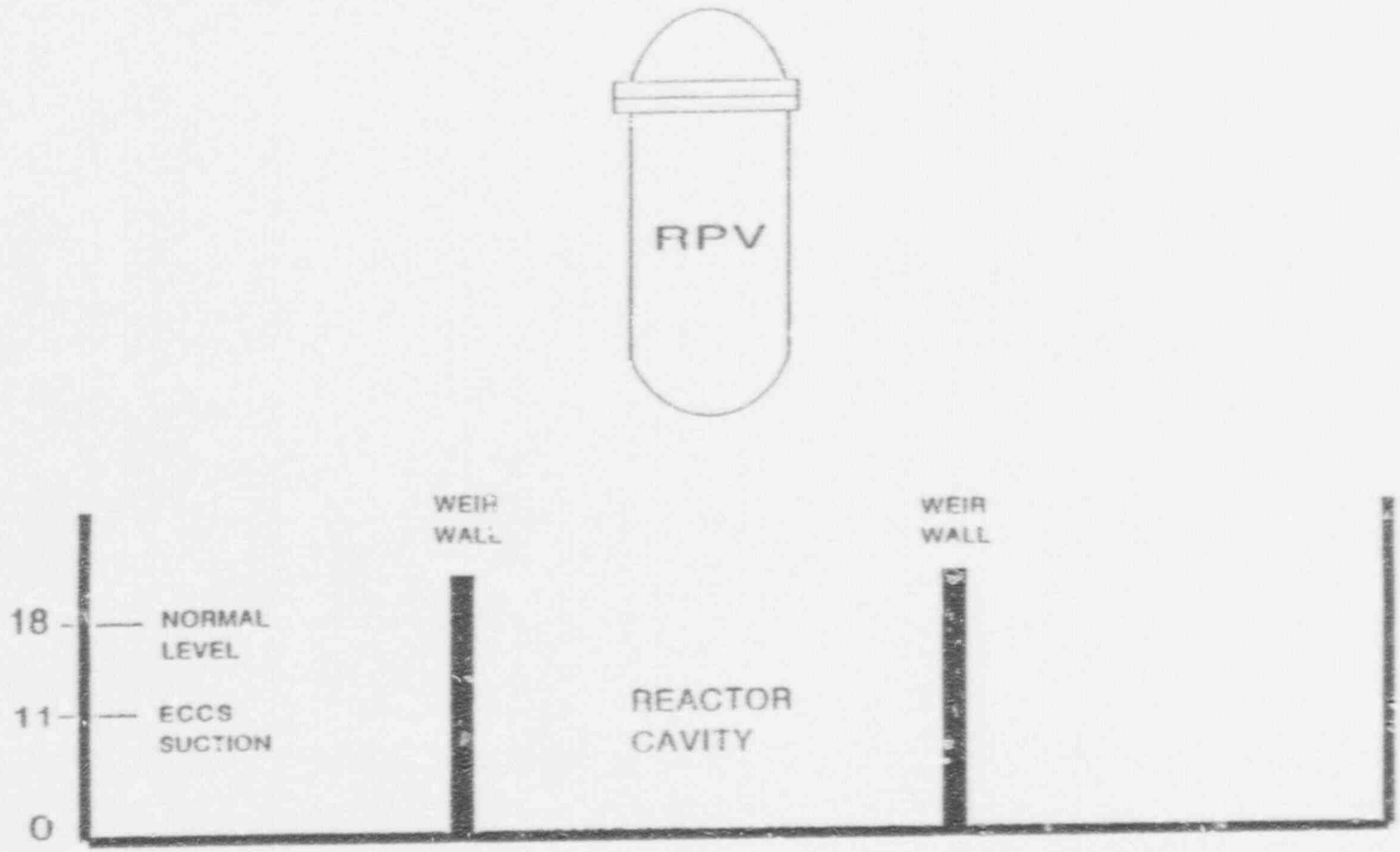
How does plant safety vary over the course of an outage?

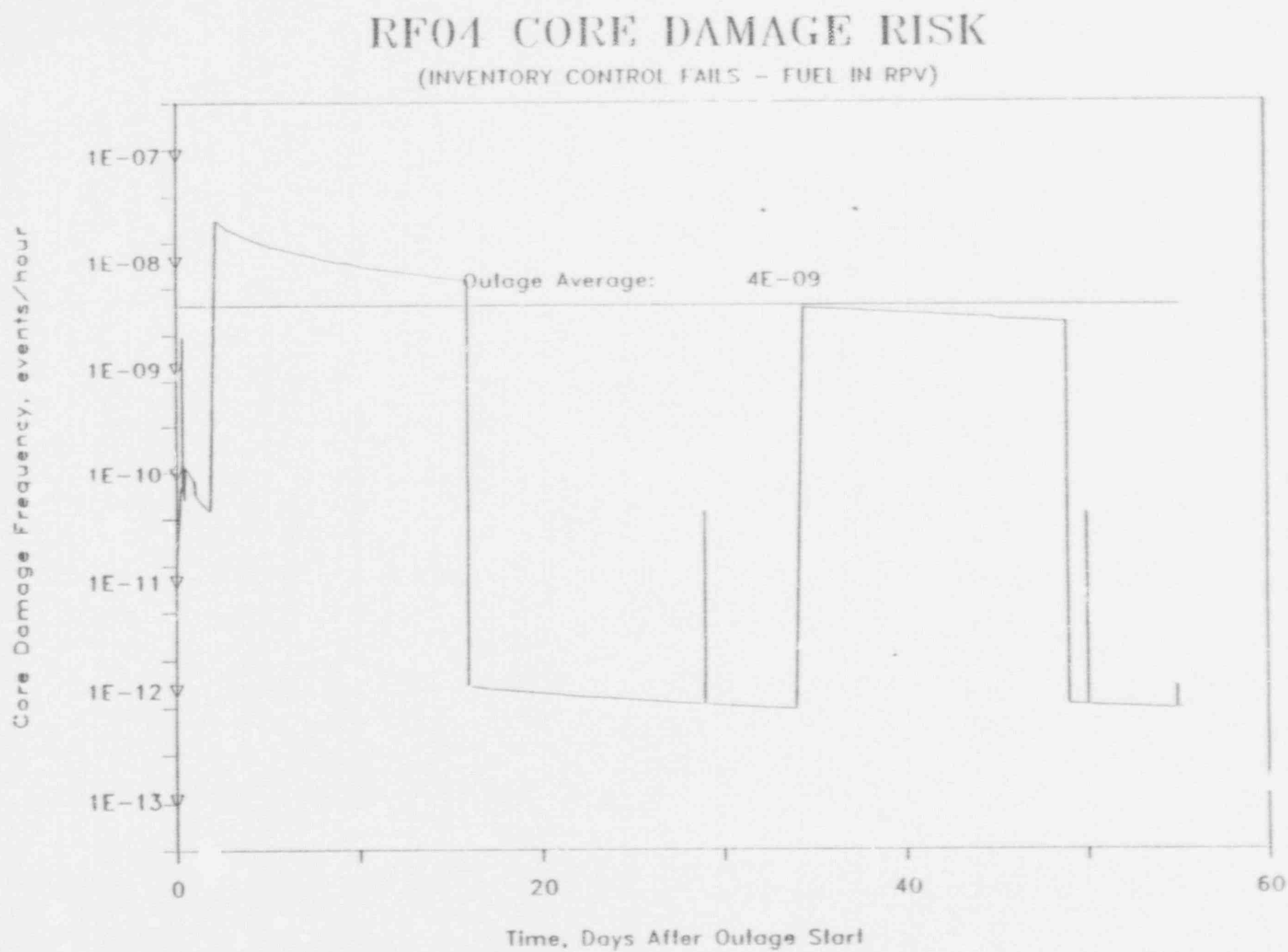
EPRI

RCS BOILING RISK IN MODES 4 AND 5

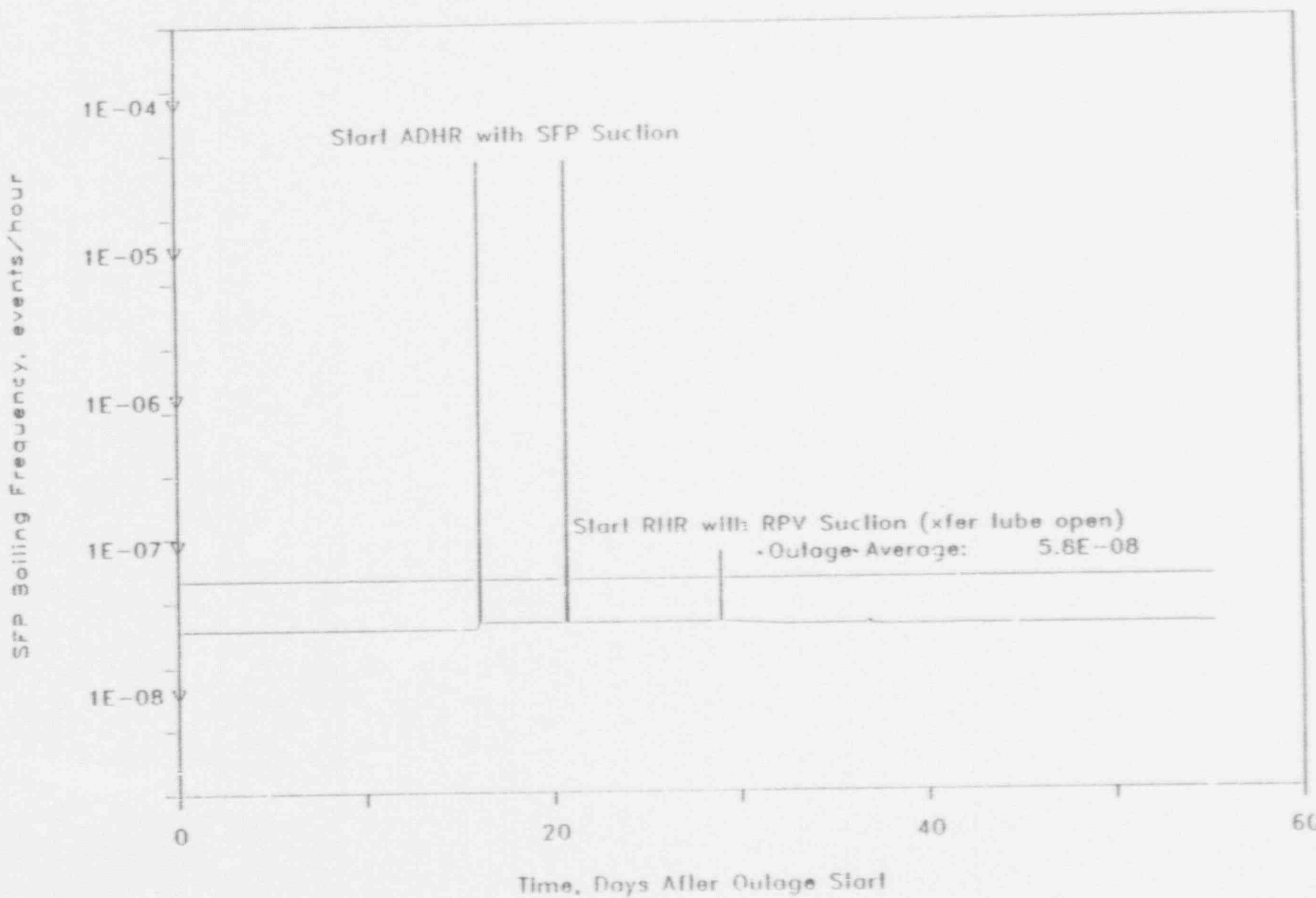


MARK III SUPPRESSION POOL




RF04 CORE DAMAGE RISK
(INVENTORY CONTROL FAILS - FUEL IN RPV)
Outage Average: 4E-09
1E-07
1E-08
1E-09
1E-10
1E-11
1E-12
1E-13
0
20
40
60
Core Damage Frequency, events/hour
Time, Days After Outage Start

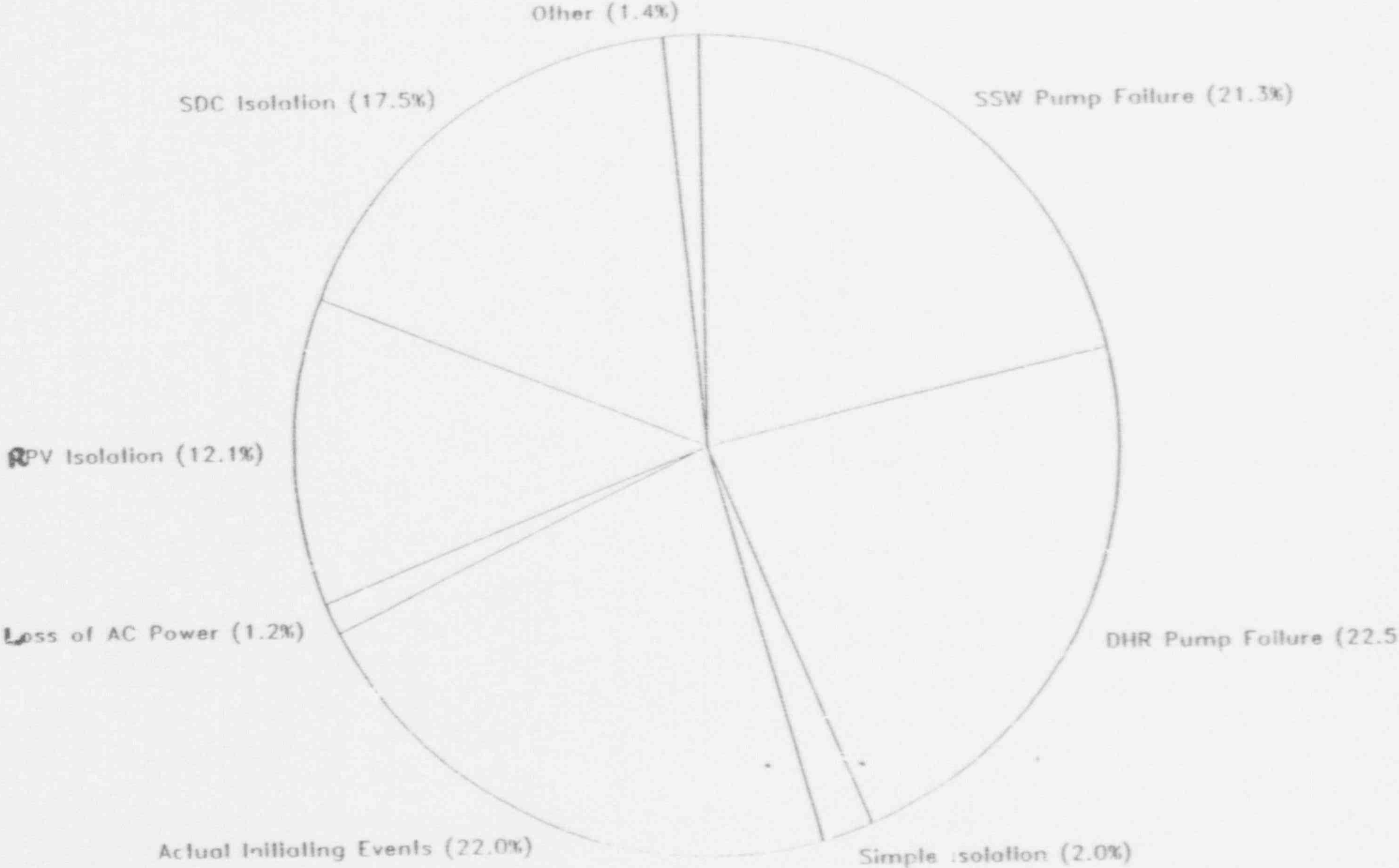
RF04 SFP BOILING RISK



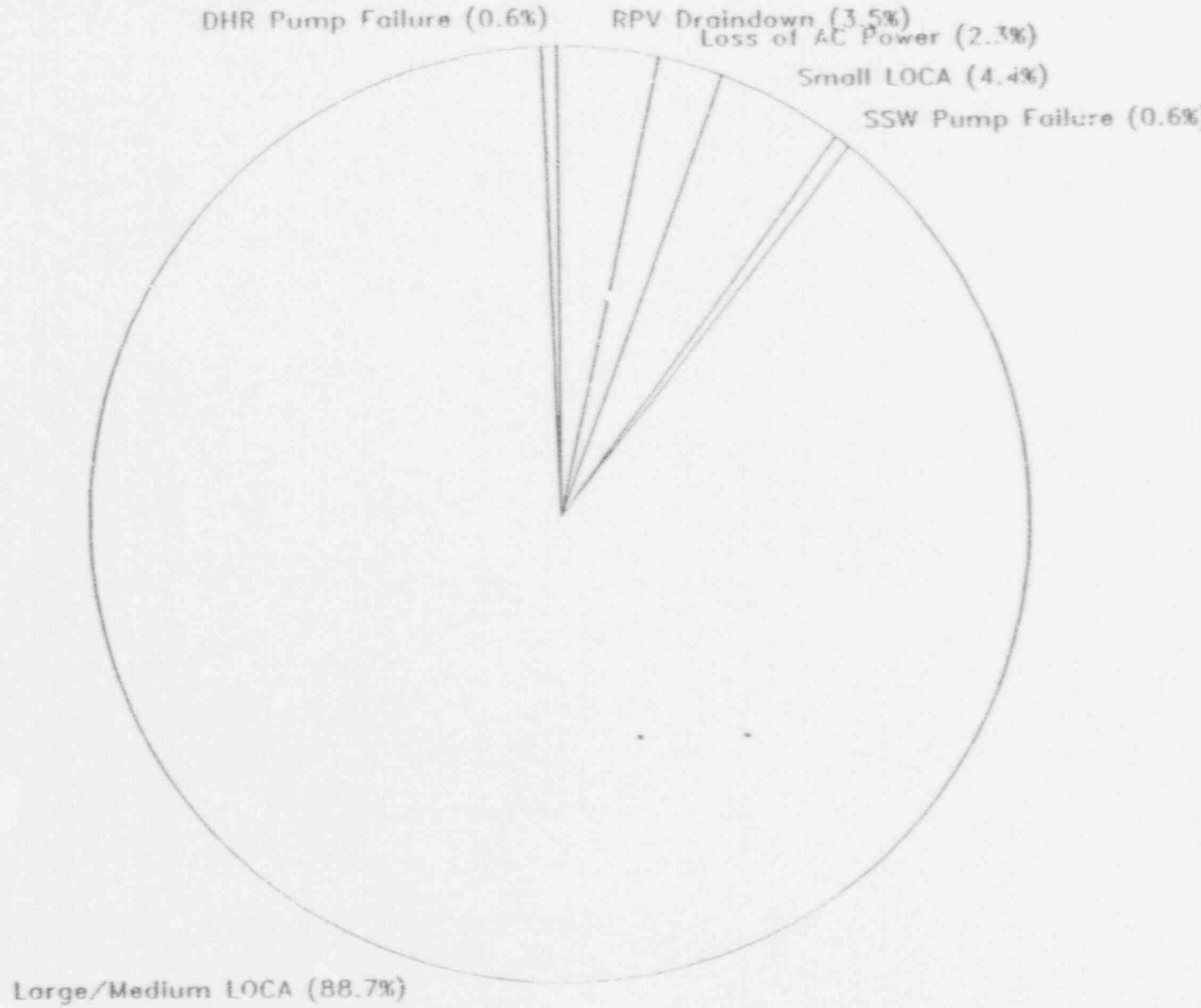
QUESTION #2

Which factors dominate shutdown risk?

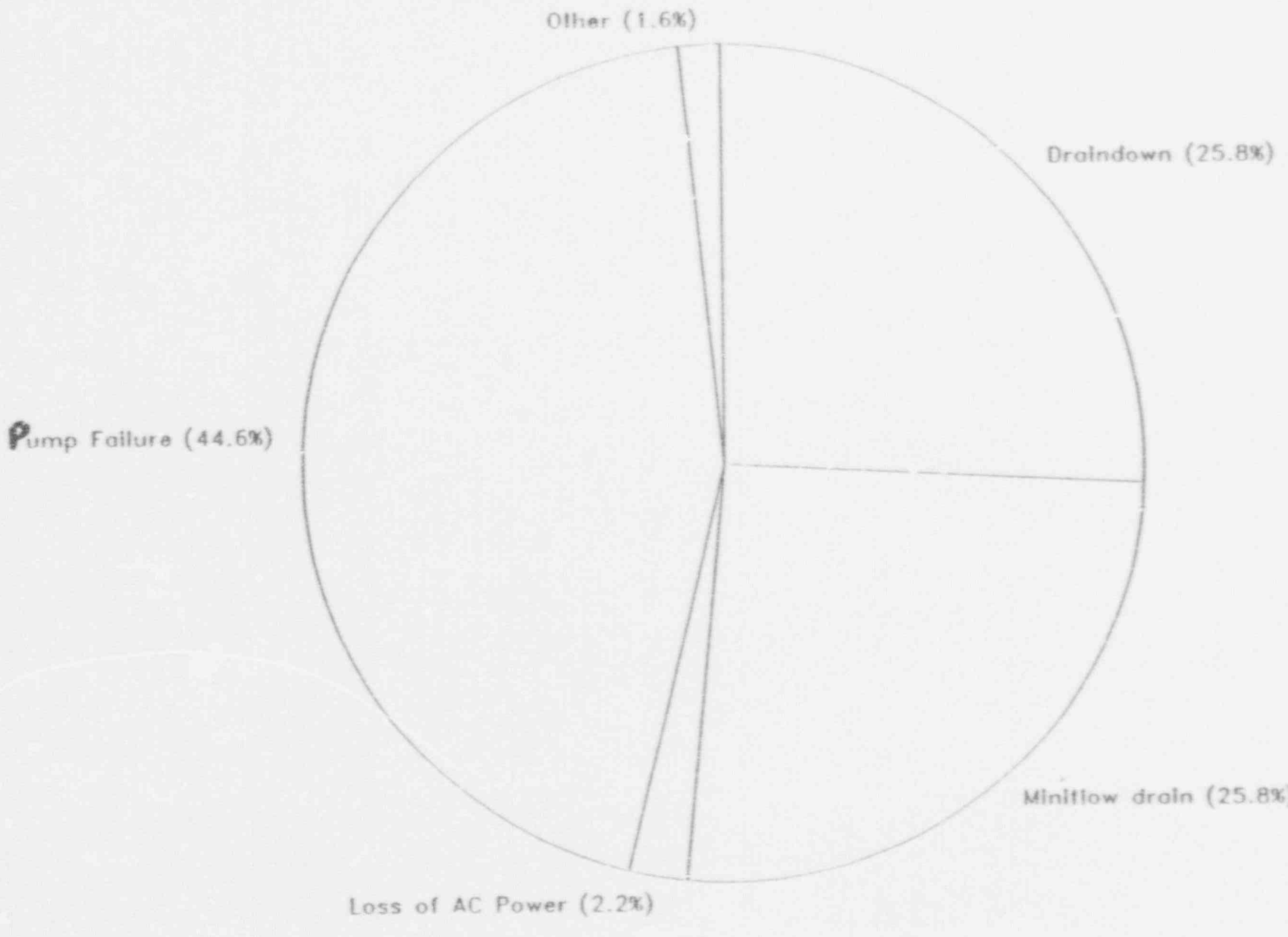
RISK OF RCS BOILING IN MODES 4 AND 5



RF04 CORE DAMAGE RISK



RF04 SFP BOILING RISK



III. How can plant safety best be improved?

SAFETY MEASURE	SAFETY MANAGEMENT INSIGHTS
RCS BOILING	• Carefully schedule key tasks (those associated with SDC or RPV isolation) • Increase RCS thermal margin • Keep suppression pool level near normal during Mode 4 • Plan for suppression pool use in Mode 5 • Strengthen procedures governing RHR system valves • Recognize the risk of operating with only one DHR train available, even in Mode 5 HWL • Reduce the number of DHR valve manipulations

ERIN

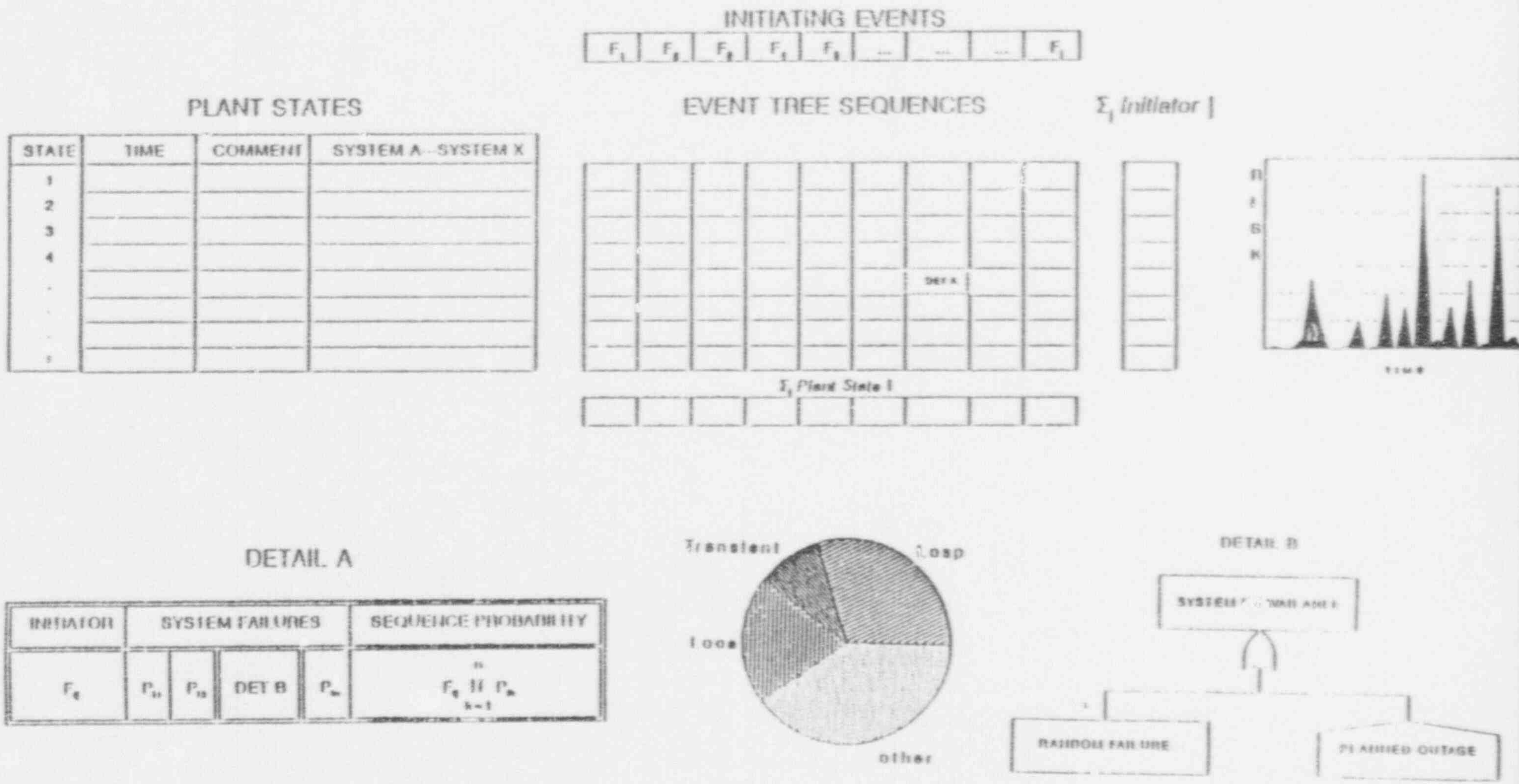
III. How can plant safety best be improved? (continued)

SAFETY MEASURE	SAFETY MANAGEMENT INSIGHTS
CORE DAMAGE	• Carefully schedule tasks requiring low suppression pool level • Develop inventory control plan when suppression pool level is low • Develop contingency plans for restoring containment during Mode 5
REACTIVITY EXCURSION (Prompt Critical Event)	• Strengthen controls to avoid misplaced fuel bundles
COLD OVERPRESSURIZATION	• Strengthen procedures governing CRD pump operation during Mode 4

IV.How do PSSA results compare with other plant safety measures?

SAFETY MEASURE	PSSA RESULT	COMPARABLE STATISTICS
RCS BOILING	1.5E-2/year	**US BWRs, 1977-1989** 1.6E-2/year
CORE DAMAGE	3.5E-6/year - 89% LOCA	**NUREG/CR-4550** 4.0E-6/year - 94% Station blackout - 6% ATWS
		RSSMAP - 72% Transient - 15% ATWS - 13% LOCA
		SEABROOK - MODES 4, 5, and 6 4.5E-5/year - 82% Loss of RHR - 18% LOCA

SHUTDOWN SAFETY ANALYSIS MODEL



GRAND GULF RF04 SHUTDOWN PLANT STATES DATABASE

Plant State	DATE	Hour	Min	Exposure Time	Days after SHUTDOWN	MODE	COMMENT	RPV Level	Press	Supp. Pool	Upper Pool	SFP XFER	Containment Primary	Containment Secnd
1	30-Sep-90	6	0	0.3	0.0	3	GREATER THAN 135 PSIG	36	>135	NORMAL	FULL	BEFORE	INTACT	INTACT
2	30-Sep-90	12	0	0.1	0.3	3	LESS THAN 135 PSIG	36	<135	NORMAL	FULL	BEFORE	INTACT	INTACT
3	30-Sep-90	14	3	0.0	0.3	3	RHR Valve Manipulation Begins	36	<135	NORMAL	FULL	BEFORE	INTACT	INTACT
4	30-Sep-90	14	3	0.0	0.3	3	START RHR A	36	<135	NORMAL	FULL	BEFORE	INTACT	INTACT
5	30-Sep-90	14	3	0.1	0.3	3	RHR Valve Manipulation Complete	36	<135	NORMAL	FULL	BEFORE	INTACT	INTACT
6	30-Sep-90	16	20	0.0	0.4	4	FLOOD VESSEL ABOVE FLANGE FOR COOLDOWN	230	0	NORMAL	FULL	BEFORE	INTACT	INTACT
7	30-Sep-90	17	30	0.1	0.5	4	Div I O/O, Div III O/O, HPCS Tagout	230	0	NORMAL	FULL	BEFORE	INTACT	INTACT
8	30-Sep-90	19	0	0.0	0.5	4	SECONDARY CONTAINMENT RELEASED	230	0	NORMAL	FULL	BEFORE	INTACT	INTACT
9	30-Sep-90	20	10	0.1	0.6	4	BROKE VACUUM	230	0	NORMAL	FULL	BEFORE	INTACT	OPEN
10	30-Sep-90	23	30	0.0	0.7	4	PRIMARY CONTAINMENT HATCHES OPENED	230	0	NORMAL	FULL	BEFORE	INTACT	OPEN
11	01-Oct-90	0	0	0.2	0.8	4	S/P CONDENSATE	230	0	NORMAL	FULL	BEFORE	OPEN	OPEN
12	01-Oct-90	5	30	0.0	1.0	4	REACTOR CAVITY GATE SET	230	0	NORMAL	FULL	BEFORE	OPEN	OPEN
13	01-Oct-90	5	40	0.0	1.0	4	Drywell Pumped Out	230	0	NORMAL	EMPTY	BEFORE	OPEN	OPEN
14	01-Oct-90	6	40	0.4	1.0	4	COMPLETED CAVITY DRAIN	230	0	NORMAL	EMPTY	BEFORE	OPEN	OPEN
15	01-Oct-90	15	30	0.0	1.4	4	RHR B STOPPED - TEMPORARY	230	0	NORMAL	EMPTY	BEFORE	OPEN	OPEN
16	01-Oct-90	16	10	0.2	1.4	4	RESTART RHR B	230	0	NORMAL	EMPTY	BEFORE	OPEN	OPEN
17	01-Oct-90	20	15	0.0	1.6	4	RHR B STOPPED - TEMPORARY	230	0	NORMAL	EMPTY	BEFORE	OPEN	OPEN
18	01-Oct-90	21	13	0.1	[illegible]	4	START ADHR	230	0	NORMAL	EMPTY	BEFORE	OPEN	OPEN
19	01-Oct-90	22	59	0.2	1.7	4	LINEUP P11 FOR CAVITY DRN TO SP	230	0	NORMAL	EMPTY	BEFORE	OPEN	OPEN
20	02-Oct-90	3	29	0.0	1.9	4	STOP ADHR	230	0	NORMAL	EMPTY	BEFORE	OPEN	OPEN
21	02-Oct-90	3	29	0.3	1.9	4	RESTART RHR B	230	0	NORMAL	EMPTY	BEFORE	OPEN	OPEN
22	02-Oct-90	11	3	0.0	2.2	4	DRAINED SUPP POOL; RHR A OUT	230	0	REDUCED	EMPTY	BEFORE	OPEN	OPEN
23	03-Oct-90	5	5	0.0	3.0	4	RHR B STOPPED - TEMPORARY	230	0	REDUCED	EMPTY	BEFORE	OPEN	OPEN
24	03-Oct-90	5	5	0.0	3.0	4	START ADHR	230	0	REDUCED	EMPTY	BEFORE	OPEN	OPEN
25	03-Oct-90	6	5	0.0	3.0	4	STOP ADHR	230	0	REDUCED	EMPTY	BEFORE	OPEN	OPEN
26	03-Oct-90	6	5	0.4	3.0	4	RESTART RHR B	230	0	REDUCED	EMPTY	BEFORE	OPEN	OPEN
27	03-Oct-90	16	33	0.3	3.4	5	ENTERED MODE 5	180	0	REDUCED	EMPTY	BEFORE	OPEN	OPEN
28	04-Oct-90	0	0	0.1	3.8	5	RE-ESTABLISHED SECONDARY CONTAINMENT	180	0	REDUCED	EMPTY	BEFORE	OPEN	INTACT
29	04-Oct-90	2	30	0.2	3.9	5	HEAD DETENSIONED	180	0	REDUCED	EMPTY	BEFORE	OPEN	INTACT
30	04-Oct-90	7	28	1.1	4.1	5	HEAD OFF	180	0	REDUCED	EMPTY	BEFORE	OPEN	INTACT
31	05-Oct-90	0	56	0.0	5.1	5	RHR B STOPPED - TEMPORARY	180	0	REDUCED	EMPTY	BEFORE	OPEN	INTACT
32	05-Oct-90	9	55	0.0	5.2	5	START ADHR	180	0	REDUCED	EMPTY	BEFORE	OPEN	INTACT
33	05-Oct-90	10	5	0.0	5.2	5	REDUCING LEVEL TO 172 TO SECURE RWCU	175	0	REDUCED	EMPTY	BEFORE	OPEN	INTACT
34	05-Oct-90	10	47	0.2	5.2	5	LEVEL 175" FOR RWCU	175	0	REDUCED	EMPTY	BEFORE	OPEN	INTACT
35	05-Oct-90	14	45	0.0	5.4	5	STOP ADHR	175	0	REDUCED	EMPTY	BEFORE	OPEN	INTACT
36	05-Oct-90	14	53	0.5	5.4	5	RESTART RHR B	175	0	REDUCED	EMPTY	BEFORE	OPEN	INTACT
37	06-Oct-90	2	50	0.0	5.9	5	SSW A TAGOUT, SSW BASIN A PUMPDOWN	185	0	REDUCED	EMPTY	BEFORE	OPEN	INTACT
38	06-Oct-90	3	21	0.9	5.9	5	WATER UP TO 195"	195	0	REDUCED	EMPTY	BEFORE	OPEN	INTACT
39	07-Oct-90	0	0	0.9	6.8	5	INSTALLED MAIN STEAM LINE PLUGS	90	0	REDUCED	EMPTY	BEFORE	OPEN	INTACT
40	07-Oct-90	21	41	0.4	7.7	5	CORE ALTS BEGIN	195	0	REDUCED	EMPTY	BEFORE	OPEN	INTACT
41	08-Oct-90	6	14	0.0	8.0	5	RHR B STOPPED - TEMPORARY	195	0	REDUCED	EMPTY	BEFORE	OPEN	INTACT
42	08-Oct-90	6	59	0.6	8.0	5	START ADHR	195	0	REDUCED	EMPTY	BEFORE	OPEN	INTACT
43	08-Oct-90	21	0	0.3	8.6	5	LOST SECONDARY CONT	195	0	REDUCED	EMPTY	BEFORE	OPEN	INTACT
44	09-Oct-90	3	10	0.1	8.9	5	SRV REMOVAL CONTINUE (WHEN STARTED?)	195	0	REDUCED	EMPTY	BEFORE	OPEN	OPEN
45	09-Oct-90	6	30	0.1	9.0	5	SC LOST AGAIN DUE TO DOOR AJAR/SC RESTRD	195	0	REDUCED	EMPTY	BEFORE	OPEN	OPEN
46	09-Oct-90	8	13	0.0	9.1	5	STOP ADHR	195	0	REDUCED	EMPTY	BEFORE	OPEN	INTACT
47	09-Oct-90	8	13	1.3	9.1	5	RESTART RHR B	195	0	REDUCED	EMPTY	BEFORE	OPEN	INTACT
48	10-Oct-90	15	18	0.0	10.4	5	RHR B STOPPEL - TEMPORARY	195	0	REDUCED	EMPTY	BEFORE	OPEN	INTACT

GRAND GULF RFO4 SHUTDOWN PLANT STATES DATABASE

Plant State	DIV1 SGTS	DIV2 SGTS	HPCS	RCIC	ADS	RHR A	RHR B	RHR C	LPCS	CNDS	RWCU	CRD	FIRE WTR	ADHR	FP CCW	CCW	DIV1 AC	DIV2 AC	DIV3 AC	DIV1 DC	DIV2 DC	DIV3 DC	EDG A	EDG B	EDG HPCS	INS AIR	STN AIR	PSW	SSW A	SSW B	SSW C
1	A	A	A	A	A	A	A	A	A	A	B	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
2	A	A	A	X	A	A	A	A	A	A	B	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
3	A	A	A	X	A	A	B	A	A	A	B	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
4	A	A	A	X	A	A	B	A	A	A	B	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
5	A	A	A	X	A	A	B	A	A	A	B	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
6	A	A	A	X	A	A	B	A	A	A	B	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
7	A	A	X	X	A	A	B	A	A	A	B	A	A	A	A	A	A	A	A	A	A	A	X	A	X	A	A	A	A	A	A
8	A	A	X	X	A	A	B	A	A	A	B	A	A	A	A	A	A	A	A	A	A	A	X	A	X	A	A	A	A	A	A
9	A	A	X	X	A	A	B	A	A	A	B	A	A	A	A	A	A	A	A	A	A	A	X	A	X	A	A	A	A	A	A
10	A	A	X	X	A	A	B	A	A	A	B	A	A	A	A	A	A	A	A	A	A	A	X	A	X	A	A	A	A	A	A
11	A	A	X	X	A	A	B	A	A	A	B	A	A	A	A	A	A	A	A	A	A	A	X	A	X	A	A	A	A	A	A
12	A	A	X	X	A	A	B	A	A	A	B	A	A	A	A	A	A	A	A	A	A	A	X	A	X	A	A	A	A	A	A
13	A	A	X	X	A	A	B	A	A	A	B	A	A	A	A	A	A	A	A	A	A	A	X	A	X	A	A	A	A	A	A
14	A	A	X	X	A	A	B	A	A	X	B	A	A	A	A	A	A	A	A	A	A	A	X	A	X	A	A	A	A	A	A
15	A	A	X	X	A	A	A	A	A	X	B	A	A	A	A	A	A	A	[illegible]	A	A	A	X	A	X	A	A	A	A	A	A
16	A	A	X	X	A	A	B	A	A	X	B	A	A	A	A	A	A	A	[illegible]	A	A	A	X	A	X	A	A	A	A	A	A
17	A	A	X	X	A	A	A	A	A	A	B	A	A	A	A	A	A	A	A	A	A	A	X	A	X	A	A	A	A	A	A
18	A	A	X	X	A	A	A	A	A	X	B	A	A	A	A	A	A	A	A	A	A	A	X	A	X	A	A	A	A	A	A
19	A	A	X	X	A	A	A	A	A	X	B	A	A	B	A	A	A	A	A	A	[illegible]	A	X	A	X	A	A	A	A	A	A
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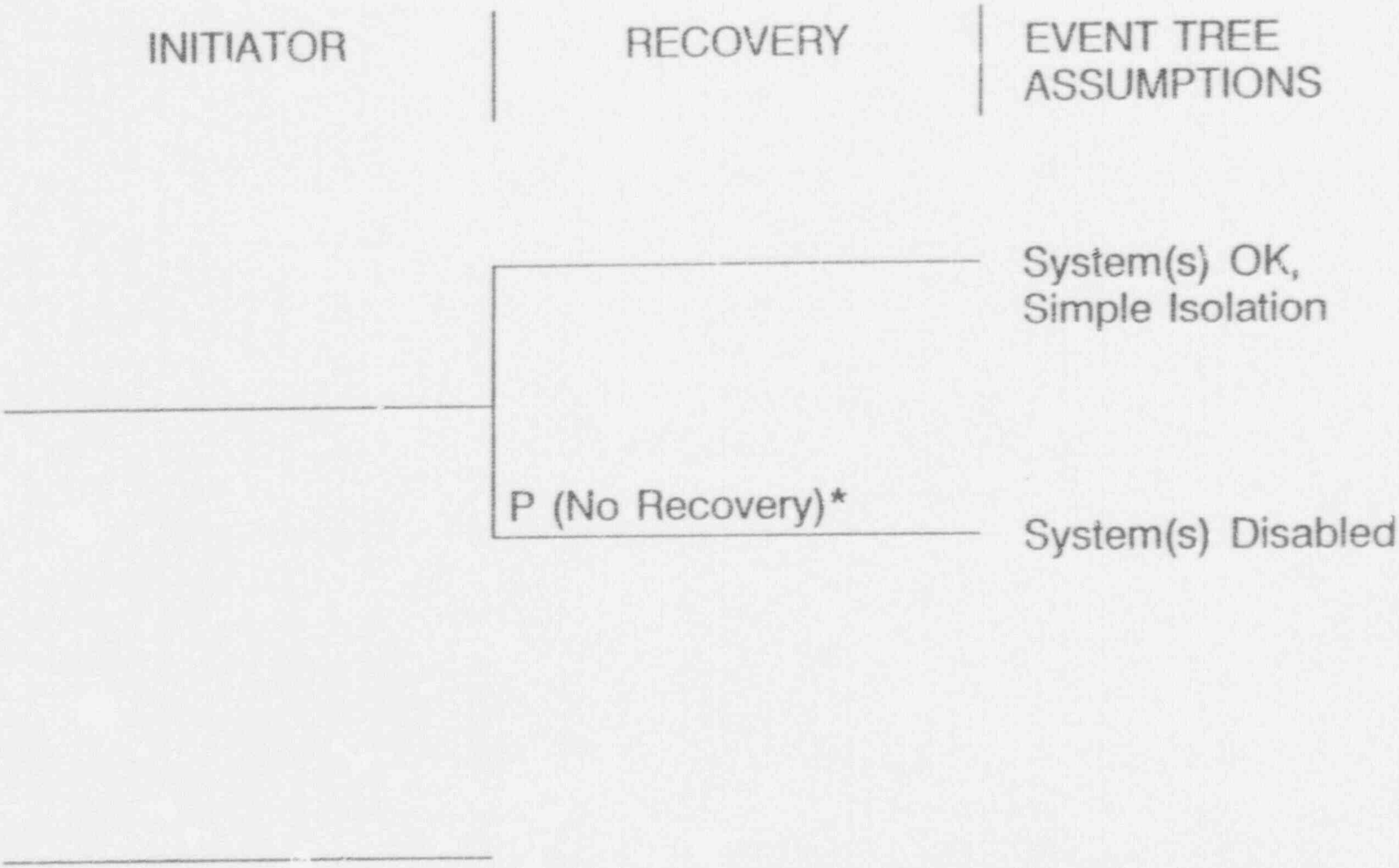
21	A	A	X	X	A	A	B	A	A	X	[illegible]	A	A	A	A	A	A	A	A	A	A	A	X	A	X	A	A	A	A	A	A
22	A	A	X	X	A	X	B	A	A	X	B	A	A	A	A	A	A	A	A	A	A	A	X	A	X	A	A	A	A	A	A
23	A	A	X	X	A	X	A	A	A	X	B	A	A	A	A	A	A	A	A	A	A	A	X	A	X	A	A	A	A	A	A
24	[illegible]	A	X	X	A	X	A	A	A	X	B	A	A	B	A	A	A	A	A	A	A	[illegible]	X	A	X	A	A	A	A	A	A
25	X	A	X	X	A	X	A	A	A	X	A	A	A	A	A	A	A	A	A	A	A	A	X	A	X	A	A	A	A	A	A
26	[illegible]	A	X	X	A	X	B	A	A	X	A	A	A	A	A	A	A	A	A	A	A	A	X	A	X	A	A	A	A	A	A
27	A	A	X	X	A	X	B	A	A	X	A	A	A	A	A	A	A	A	A	A	A	A	X	A	X	A	A	A	A	A	A
28	A	A	X	X	A	X	B	A	A	X	A	A	A	A	A	A	A	A	A	A	A	A	X	A	X	A	A	A	A	A	A
29	A	A	X	X	A	X	B	A	A	X	A	A	A	A	A	A	A	A	A	A	A	A	X	A	X	A	A	A	A	A	A
30	A	A	X	X	A	X	B	A	A	X	A	A	A	A	A	A	A	A	A	A	A	A	X	A	X	A	A	A	A	A	A
31	A	A	X	X	A	X	A	A	A	X	A	A	A	A	A	A	A	A	A	A	A	A	X	A	X	A	A	A	A	A	A
32	A	A	X	X	A	X	A	A	A	X	A	A	A	B	A	A	A	A	A	A	A	A	X	A	X	A	A	A	A	A	A
33	A	A	X	X	A	X	A	A	A	X	A	A	A	B	A	A	A	A	A	A	A	A	X	A	X	A	A	A	A	A	A
34	A	A	X	X	A	X	A	A	A	X	A	A	A	B	A	A	A	A	A	A	A	A	X	A	X	A	A	A	A	A	A
35	A	A	X	X	A	X	A	A	A	X	A	A	A	A	A	A	A	A	A	A	A	A	X	A	X	A	A	A	A	A	A
36	A	A	X	X	A	X	B	A	A	X	A	A	A	A	A	A	A	A	A	A	A	A	X	A	X	A	A	A	A	A	A
37	A	A	X	X	A	X	B	A	A	X	A	A	A	A	A	A	A	A	A	A	A	A	X	A	X	A	A	A	X	A	X
38	A	A	X	X	A	X	B	A	A	X	A	A	A	A	A	A	A	A	A	A	A	A	X	A	X	A	A	A	X	A	X
39	A	A	X	X	X	X	B	A	A	X	A	A	A	A	A	A	A	A	A	A	A	A	X	A	X	A	A	A	X	A	X
40	A	A	X	X	X	X	B	A	A	X	A	A	A	A	A	A	A	A	A	A	A	A	X	A	X	A	A	A	X	A	X
41	A	A	X	X	X	X	A	A	A	X	A	A	A	A	A	A	A	A	A	A	A	A	X	A	X	A	A	A	X	A	X
42	A	A	X	X	X	X	A	A	A	X	A	A	A	B	A	A	A	A	A	A	A	A	X	A	X	A	A	A	X	A	X
43	A	A	X	X	X	X	A	A	A	X	A	A	A	B	A	A	A	A	A	A	A	A	X	A	X	A	A	A	X	A	X
44	A	A	X	X	X	X	A	A	A	X	A	A	A	B	A	A	A	A	A	A	A	A	X	A	X	A	A	A	X	A	X
45	A	A	X	X	X	X	A	A	A	X	A	A	A	B	A	A	A	A	A	A	A	A	X	A	X	A	A	A	X	A	X
46	A	A	X	X	X	X	A	A	A	X	A	A	A	A	A	A	A	A	A	A	A	A	X	A	X	A	A	A	X	A	X
47	A	A	X	X	X	X	B	A	A	X	A	A	A	A	A	A	A	A	A	A	A	A	X	A	X	A	A	A	X	A	X
48	A	A	X	X	X	X	A	A	A	X	A	A	A	A	A	A	A	A	A	A	A	A	X	A	X	A	A	A	X	A	X

INITIATING EVENTS

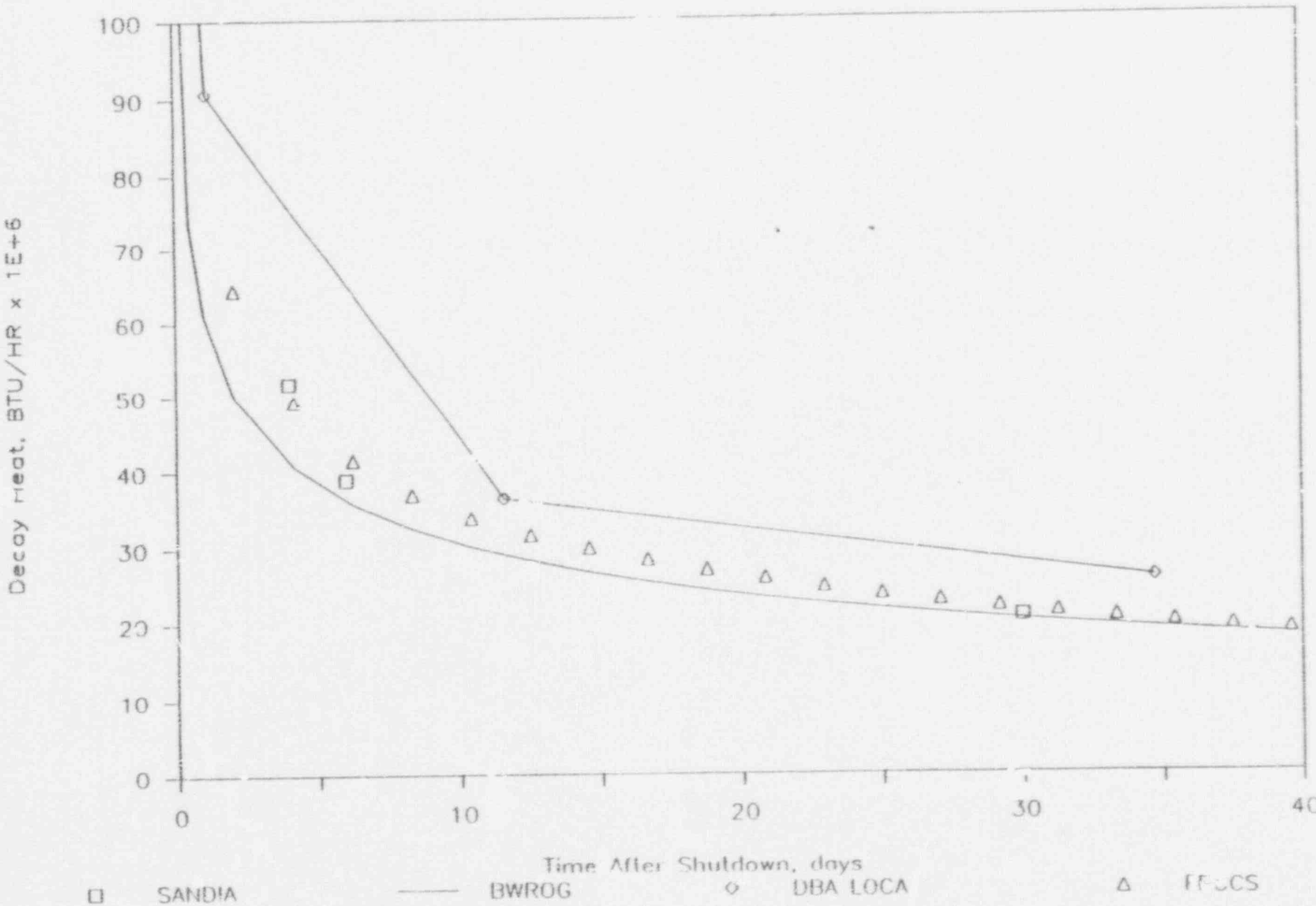
	FREQUENCY (events/hour)	SOURCE
DHR Pump Failure	1.0E-05	IEEE Std 500 1984
SSW Pump Failure	1.0E-05	IEEE Std 500 1984
Div I AC/DC Bus Failure	2.0E-07	IEEE Std 500 1984
Div II AC/DC Bus Failure	2.0E-07	IEEE Std 500 1984
SDC Isolation	8.3E-05	NSAC-88/157
RPV Isolation	5.4E-05	NSAC-88/157
Loss of AC Power	2.0E-05	NSAC-166, NUREG-1410
Loss of Instrument Air	9.6E-08	NUREG-4550
Large LOCA	1.1E-08	NUREG-4550

COUPLING INITIATING EVENTS AND RECOVERY ACTIONS



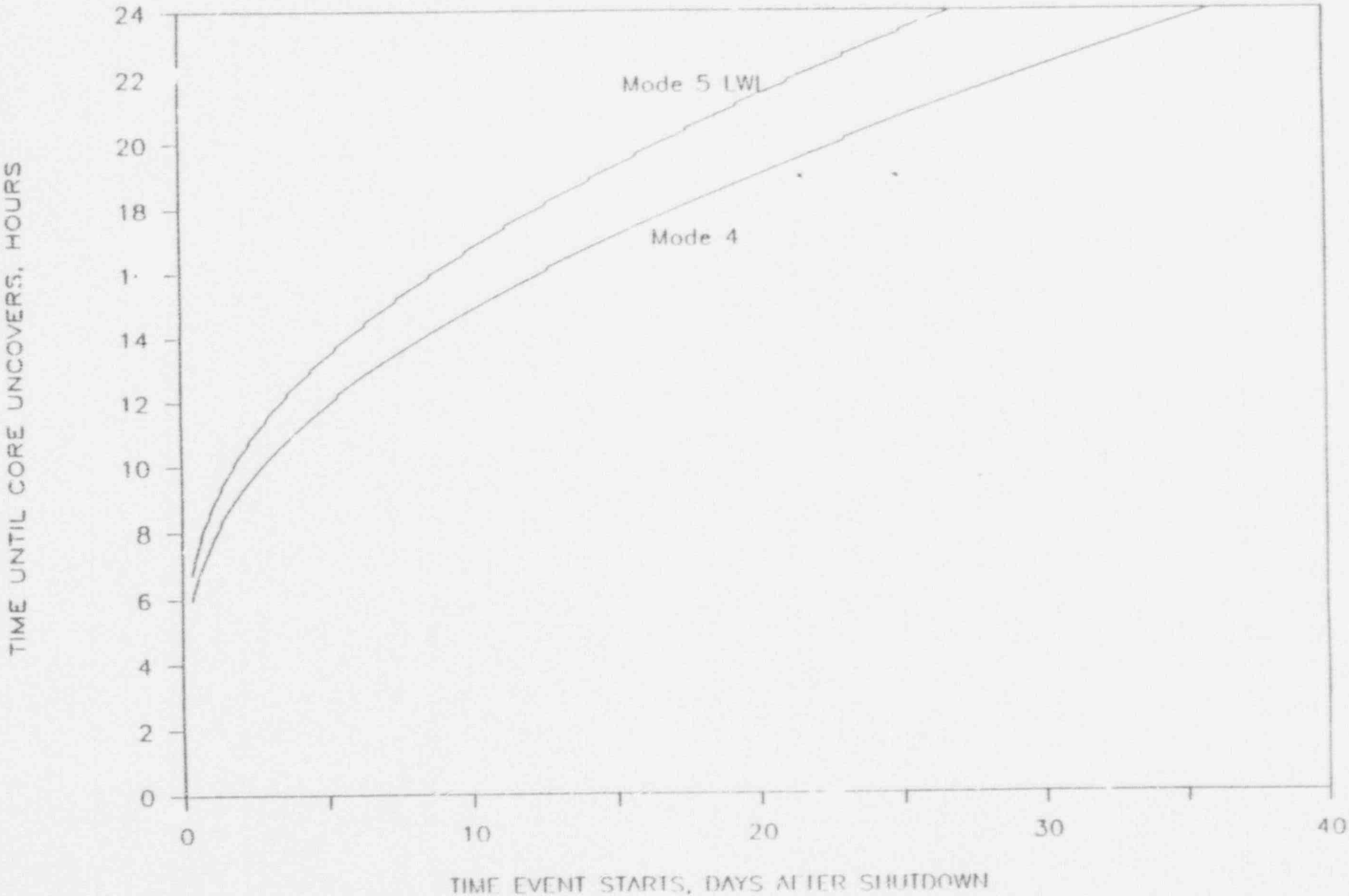
*Formula combines historical and thermal hydraulic data

Decay Heat Loads From Reactor Fuel



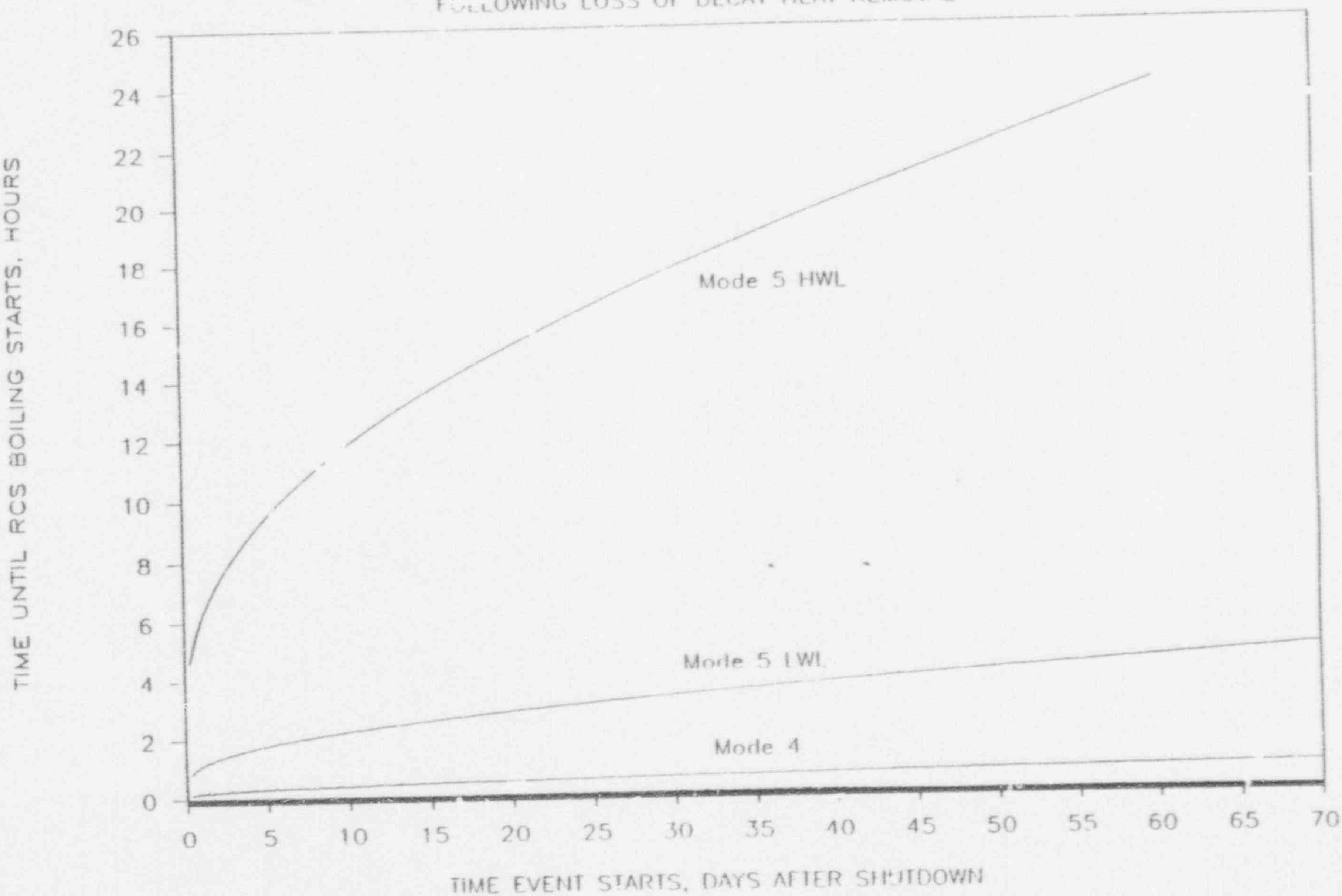
CORE UNCOVERY VS. TIME AFTER SHUTDOWN

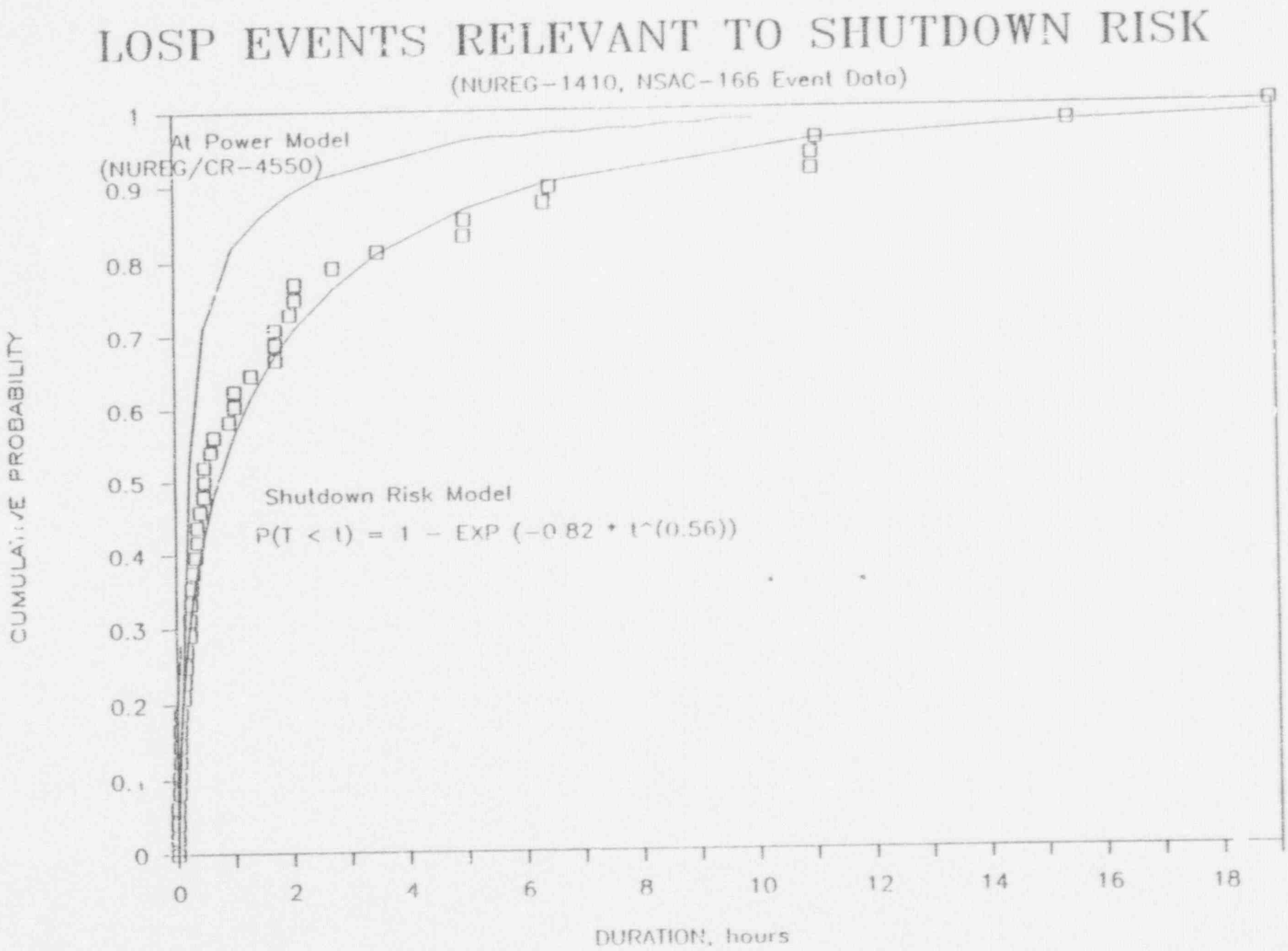
FOLLOWING LOSS OF DECAY HEAT REMOVAL



RCS HEATUP TIME VS. TIME AFTER SHUTDOWN

FOLLOWING LOSS OF DECAY HEAT REMOVAL

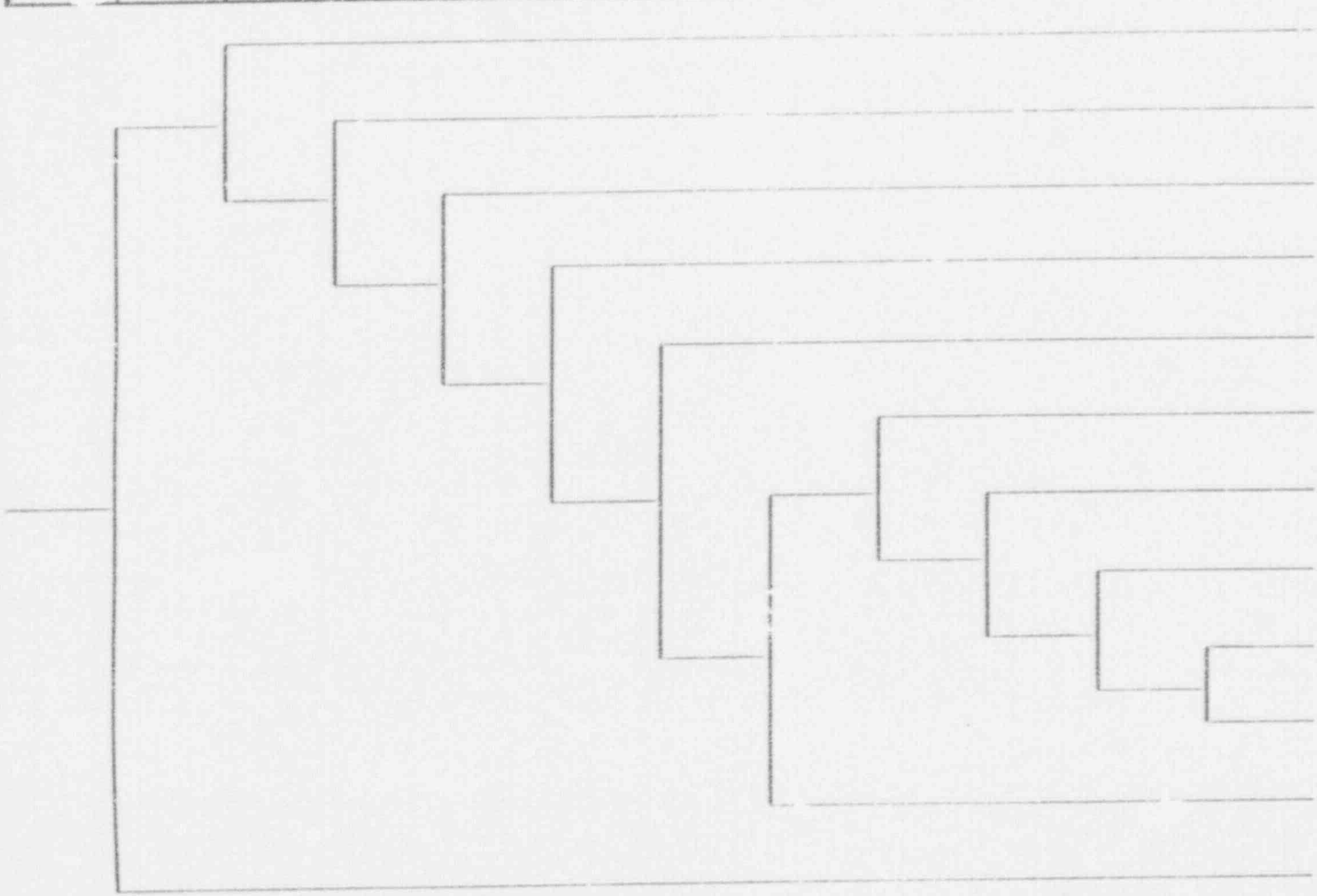




LOSP EVENTS RELEVANT TO SHUTDOWN RISK
(NUREG-1410, NSAC-166 Event Data)
At Power Model
(NUREG/CR-4550)
Shutdown Risk Model
P(T < t) = 1 - EXP (-0.82 * t^(0.56))
CUMULATIVE PROBABILITY
DURATION, hours
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
2
4
6
8
10
12
14
16
18

RCS BOILING RISK MODEL - GENERIC INITIATOR

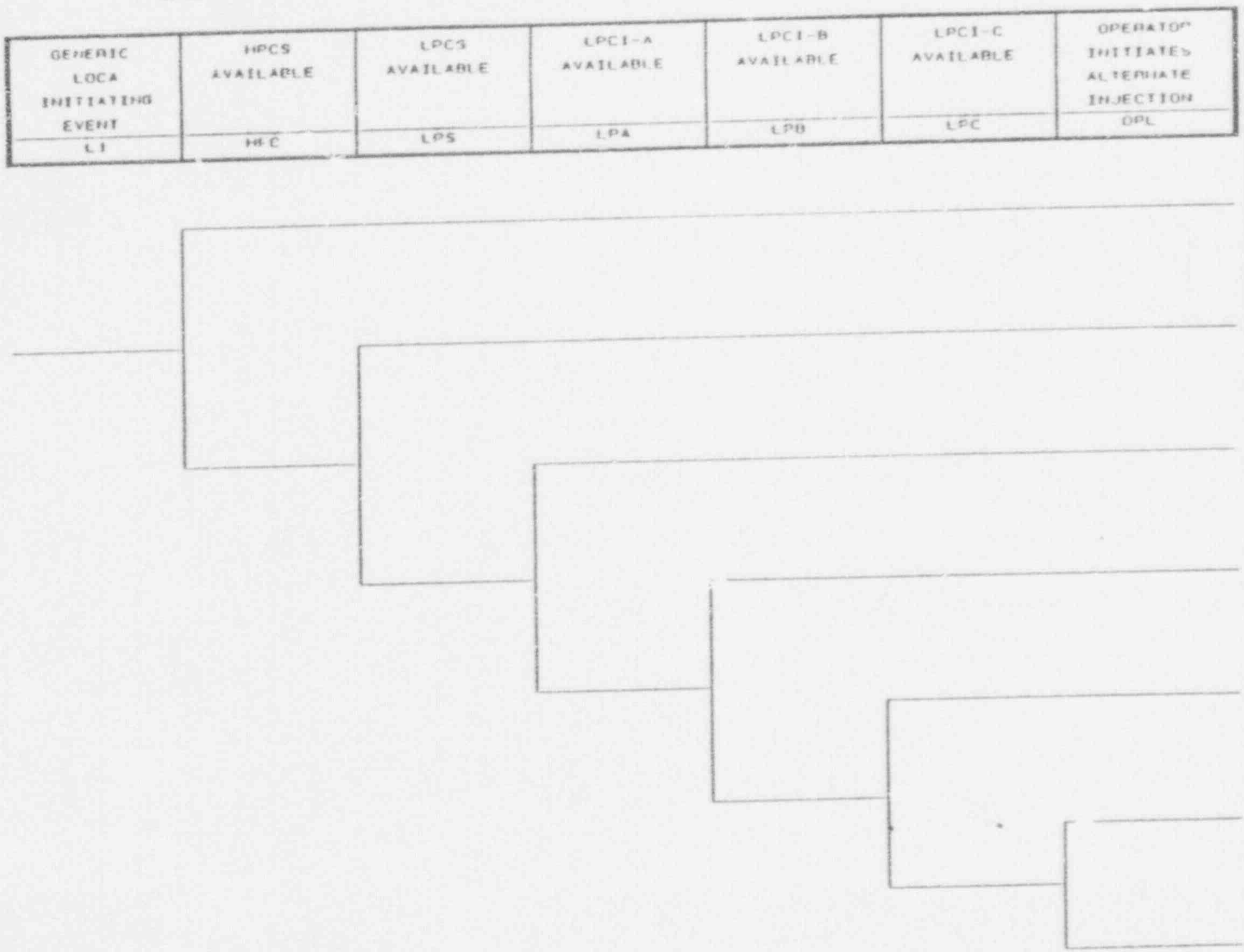
INITIATING EVENT	HEAT REMOVAL ------ OP INITIATES PROCEDURE	HEAT REMOVAL ------ TRAIN A RHR IN SDC MODE	HEAT REMOVAL ------ TRAIN B RHR IN SDC MODE	HEAT REMOVAL ------ ALTERNATE DECAY HT REM	HEAT REMOVAL ------ RWCU SYSTEM AVAILABLE	HEAT REMOVAL ------ FPCCU SYSTEM AVAILABLE	OPERATOR INITIATES RPV FLOODING W/LPCS LPCI	LPCS AVAILABLE FOR RPV FLOODING	LPCI A AVAILABLE FOR RPV FLOODING	LPCI B AVAILABLE FOR RPV FLOODING	LPCI C AVAILABLE FOR RPV FLOODING
II	OP	RHA	RHB	ADH	RWC	FPC	OP2	LPS	LPA	LPB	LPC



NUMBER	SEQUENCE DESIGNATION	ACCIDENT CLASS	SEQUENCE FREQUENCY
1	II	OK	
2	II RHA	OK	
3	II RHA RHB	OK	
4	II RHA RHB ADH	OK	
5	II RHA RHB ADH RWC	OK	
6	II RHA RHB ADH RWC FPC	OK	
7	II RHA RHB ADH RWC FPC LPS	OK	
8	II RHA RHB ADH RWC FPC LPS LPA	OK	
9	II RHA RHB ADH RWC FPC LPS LPA LPB	OK	
10	… RHB ADH RWC FPC LPS LPA LPB LPC	BOILING	
11	II RHA RHB ADH RWC FPC OP2	BOILING	
12	II OP	BOILING	

REBECA (C) ENIII Engineering and Research, Inc. Version 2.0B | EI Name: SDRC1 12-17-91 15:17:34 | Total Frequency: 0.00E+00

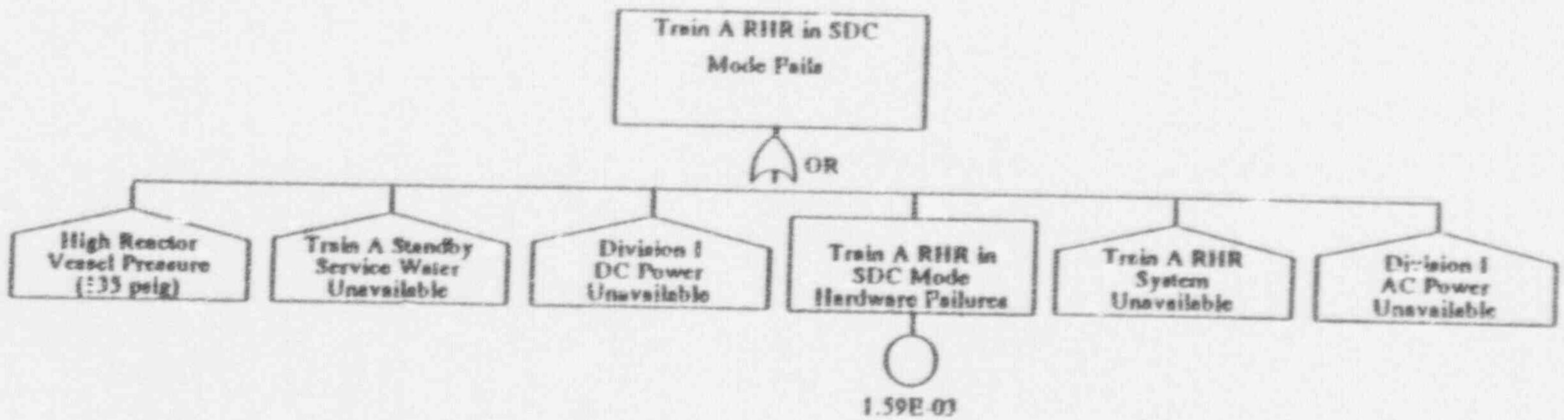
CORE DAMAGE RISK MODEL - INVENTORY CONTROL FAILURES



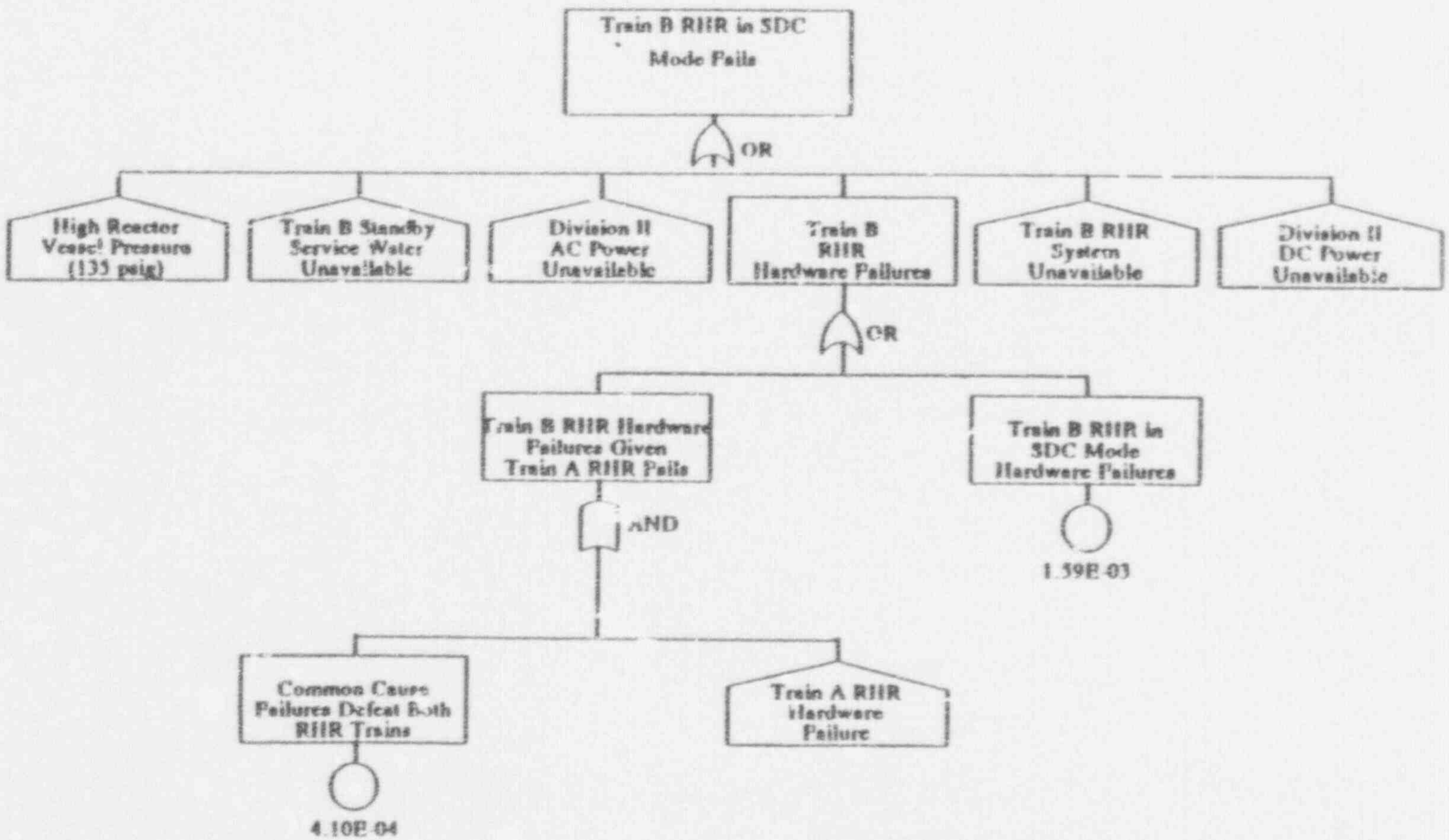
NUMBER	SEQUENCE DESIGNATION	ACCIDENT CLASS	SEQUENCE FREQUENCY
1	LI	OK	
2	LI-HPC	OK	
3	LI-HPC-LPS	OK	
4	LI-HPC-LPS-LPA	OK	
5	LI-HPC-LPS-LPA-LPB	OK	
6	LI-HPC-LPS-LPA-LPB-LPC	OK	
7	LI-HPC-LPS-LPA-LPB-LPC-OPL	CORE DAMG	

REBECA (C) ERIN Engineering and Research, Inc. Version 2.08 | EI Name: SDAL1 12-17-91 15:35:27 | Total Frequency: 0.00E+00

Fault Tree Example

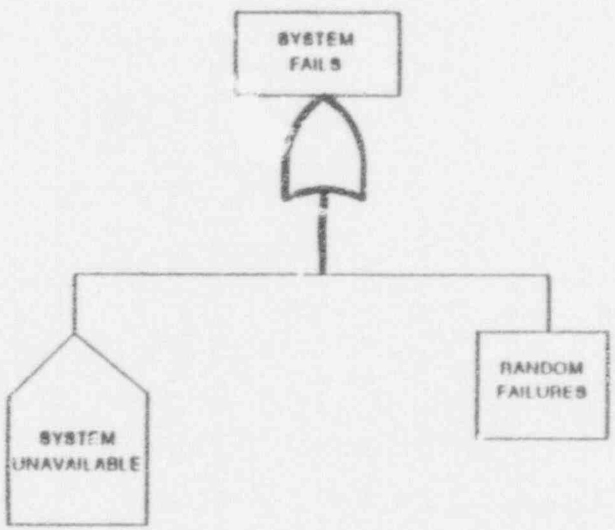


Fault Tree Example



EQUIVALENT METHODS FOR LOGIC MODELS

FAULT TREE



FORMULA

IF System_status = "UNAVAILABLE"

THEN P(Fail) = 1.0

ELSE P(Fail) = xxE-y