Evaluation of Potential Severe Accidents During Low Power and Shutdown Operations at Grand Gulf, Unit 1

Analysis of Core Damage Frequency from Internal Events for Plant Operational State 5 During a Refueling Outage

Internal Events Appendices A to H

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Abstract

This report provides supporting documentation for various tasks associated with the performance of the probabilistic risk assessment for Plant Operational State 5 (approximately Cold Shutdown as defined by Grand Gulf Technical Specifications) during a refueling outage at Grand Gulf, Unit 1 as documented in Volume 2, Part 1 of NUREG/CR-6143. The report contains the following appendices:

- A - Definition and Characterization of Plant Operational States (POSs) and POS Change Initiators
- B - Summary of the Detailed Review of Selected Grand Gulf Procedures
- C - Overview of Grand Gulf Power Plant
- D - Initiating Event Analysis from Screening Report
- E - Updated Success Criteria
- F - Supporting Calculations
- G - Calculation of the Frequency and Recovery of LOSP Plus Recovery of LOSP/DG Failures
- H - Event Trees

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Acronyms

ADHR	Auxiliary Decay Heat Removal
ADS	Automatic Depressurization System
ATWS	Anticipated Transient Without Scram
BNL	Brookhaven National Laboratory
BWR	Boiling Water Reactor
CCW	Component Cooling Water
CDS	Condensate
CI	Containment Isolation
CRD	Control Rod Drive
CRWST	Condensate and Refueling Water Storage Transfer System
CS	Containment Spray
CST	Condensate Storage Tank
CV	Check Valves
CVS	Containment Venting System
DBA	Design Basis Accident
DG	Diesel Generator
ECCS	Emergency Core Cooling Systems
EHC	Electro-Hydraulic Controller
EHV	Emergency Ventilation System
ENSDC	Enhanced Shutdown Cooling
EPS	Emergency Power System
FCV	Flow Control Valve
FDW	Feed Water System
FW	Fire Water
HCU	Hydraulic Control Unit
HPCS	High Pressure Core Spray
IAS	Instrument Air System
IRRAS	Integrated Reliability and Risk Analysis System
LCO	Limiting Condition of Operation
LOCA	Loss of Coolant Accident
LPCI	Low Pressure Coolant Injection
LPCS	Low Pressure Core Spray
MSIV	Main Steam Isolation Valve
MSL	Mean Sea Level
MSR	Moisture Separator Reheater
NPSHA	Net Positive Suction Head Available
NPSHR	Net Positive Suction Head Required
NRC	Nuclear Regulatory Commission
OC	Operating Condition
POS	Plant Operating State
PRA	Probabilistic Risk Assessment
PSW	Plant Service Water
PWR	Pressurized Water Reactor
RCIC	Reactor Core Isolation Cooling
RES	Research (Office of NRC)
RFPT	Reactor Feedwater Pump Turbine
RHR	Residual Heat removal
RPV	Reactor Pressure Vessel
RRS	Reactor Recirculation System
RWCU	Reactor Water Cleanup System
SDC	Shutdown Cooling System(s)
SGTS	Standby Gas Treatment System

Acronyms (Continued)

SL	Safety Limit
SLC	Standby Liquid Control
SP	Suppression Pool
SPC	Suppression Pool Cooling
SPMU	Suppression Pool Makeup
SPMU	Suppression Pool Makeup
SR	Surveillance Requirement
SRV	Safety Relief Valve
SSWXT	Standby Service Water Crosstie
TBCW	Turbine Building Cooling Water
TBV	Turbine Bypass Valve(s)
UFSAR	Updated Final Safety Analysis Report

Foreword

(NUREG/CR-6143 and 6144) Low Power and Shutdown Probabilistic Risk Assessment Program

Traditionally, probabilistic risk assessments (PRA) of severe accidents in nuclear power plants have considered initiating events potentially occurring only during full power operation. Some previous screening analyses that were performed for other modes of operation suggested that risks during those modes were small relative to full power operation. However, more recent studies and operational experience have implied that accidents during low power and shutdown could be significant contributors to risk.

During 1989, the Nuclear Regulatory Commission (NRC) initiated an extensive program to carefully examine the potential risks during low power and shutdown operations. The program includes two parallel projects performed by Brookhaven National Laboratory (BNL) and Sandia National Laboratories (SNL), with the seismic analysis performed by Future Resources Associates. Two plants, Surry (pressurized water reactor) and Grand Gulf (boiling water reactor), were selected as the plants to be studied.

The objectives of the program are to assess the risks of severe accidents due to internal events, internal fires, internal floods, and seismic events initiated during plant operational states other than full power operation and to compare the estimated core damage frequencies, important accident sequences and other qualitative and quantitative results with those accidents initiated during full power operation as assessed in NUREG-1150. The scope of the program includes that of a level-3 PRA.

The results of the program are documented in two reports, NUREG/CR-6143 and 6144. The reports are organized as follows:

For Grand Gulf:

NUREG/CR-6143 - Evaluation of Potential Severe Accidents During Low Power and Shutdown Operations at Grand Gulf, Unit 1

- Volume 1: Summary of Results
- Volume 2: Analysis of Core Damage Frequency from Internal Events for Plant Operational State 5 During a Refueling Outage
 - Part 1: Main Report
 - Part 1A: Sections 1 - 9
 - Part 1B: Section 10
 - Part 1C: Sections 11 - 14
 - Part 2: Internal Events Appendices A to H
 - Part 3: Internal Events Appendices I and J
 - Part 4: Internal Events Appendices K to M
- Volume 3: Analysis of Core Damage Frequency from Internal Fire Events for Plant Operational State 5 During a Refueling Outage
- Volume 4: Analysis of Core Damage Frequency from Internal Flooding Events for Plant Operational State 5 During a Refueling Outage
- Volume 5: Analysis of Core Damage Frequency from Seismic Events for Plant Operational State 5 During a Refueling Outage
- Volume 6: Evaluation of Severe Accident Risks for Plant Operational State 5 During a Refueling Outage
 - Part 1: Main Report
 - Part 2: Supporting MELCOR Calculations

Foreword (Continued)

For Surry:

NUREG/CR-6144 - Evaluation of Potential Severe Accidents During Low Power and Shutdown Operations at Surry Unit-1

- Volume 1: Summary of Results
- Volume 2: Analysis of Core Damage Frequency from Internal Events During Mid-loop Operations
 - Part 1: Main Report
 - Part 1A: Chapters 1 - 6
 - Part 1B: Chapters 7 - 12
 - Part 2: Internal Events Appendices A to D
 - Part 3: Internal Events Appendix E
 - Part 3A: Sections E.1 - E.8
 - Part 3B: Sections E.9 - E.16
 - Part 4: Internal Events Appendices F to H
 - Part 5: Internal Events Appendix I
- Volume 3: Analysis of Core Damage Frequency from Internal Fires During Mid-loop Operations
 - Part 1: Main Report
 - Part 2: Appendices
- Volume 4: Analysis of Core Damage Frequency from Internal Floods During Mid-loop Operations
- Volume 5: Analysis of Core Damage Frequency from Seismic Events During Mid-loop Operations
- Volume 6: Evaluation of Severe Accident Risks During Mid-loop Operations
 - Part 1: Main Report
 - Part 2: Appendices

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Appendix A. Definition and Characterization of Plant Operational States (POSS) and POS Change Initiators

A.1 Introduction

This section of the report is taken from the earlier coarse screening study report [Whitehead et al, 1991]. It is included in this report so that the definition of Plant Operating State (POS) is clearly explained, and so that the concept of a known, pre-existing unavailability prior to an accident initiating event is clearly explained.

In order to analyze accidents initiated from conditions other than full power, a clear understanding of how the plant changes its operational status was needed. In addition, it was necessary to gain an understanding of why the plant changes its mode of operation. To evaluate how the plant transitions from full power to other conditions, a detailed review of several of the operational procedures for Grand Gulf was performed. To evaluate reasons for transitioning to conditions other than full power, the Technical Specifications were reviewed [USNRC, 1984], the Safety Analysis Report was reviewed [SERI, 1992], and discussions were held with Grand Gulf staff. Also, the experience of the authors of this report was brought to bear on evaluating the reasons for transitioning the plant.

This appendix uses information from various procedures at Grand Gulf. These procedures are discussed more completely in Appendix B. Appendix C is a summary of general information about BWRs with an emphasis on Grand Gulf, that is pertinent to understanding plant characteristics.

A.2 Definition and Characterization of POSS

As originally envisioned, the study would have identified and quantified potential accidents for the five modes of operation as defined by the Technical Specifications [USNRC 1984]. However, as the review of the plant's operating characteristics progressed, it became apparent that another means of classifying the status of the plant would be necessary. This new classification scheme needed to account for the various changes in system configurations, decay heat, pressure and temperature, and water level that occur during transitions from power operation to refueling and back to power operation, or some subset of these transitions. This need resulted in the development of Plant Operational States (POSS).

The technical specifications define Modes or Operating

Conditions (OCs) as follows [USNRC 1984]:

- (1) OC 1, Power Operation: Mode Switch in Run, Any Temperature
- (2) OC 2, Startup: Mode Switch in Startup/Hot Standby, Any Temperature
- (3) OC 3, Hot Shutdown: Mode Switch in Shutdown, Temperature Greater than 200 F
- (4) OC 4, Cold Shutdown: Mode Switch in Shutdown, Temperature 200 F or Lower
- (5) OC 5, Refueling: Fuel in Vessel with Head Detensioned or Removed, Mode Switch in Shutdown or Refuel, temperature 140 F or Lower.

The normal configuration of the plant in each of the five OCs is summarized in Table A.2-1 "Plant Configuration in Various OCs based on Procedures". (The entries in this table correspond to normal conditions as the plant is cooled down from full power. The situation for startup is subsequently discussed.) This table delineates when certain systems are placed into service, removed from service, or operated in a different mode as the plant transitions among OCs. (Note, this table was developed in the initial screening study, and does not consider the Hydro condition during cold shutdown. In the detailed analysis of POS 5, the Hydro condition during cold shutdown was considered, as discussed in Section 3 of this report.) The systems aspects of Table A.2-1 are influenced by the design characteristics of the systems. For example, the Reactor Core Isolation Cooling (RCIC) system is auto isolated at 60 psig since it requires adequate steam for the turbine driven pump. Also, the steam condensing mode of the RCIC system can only be used below 500 psig since this is the design rating of the RHR heat exchangers. (The steam condensing mode of RCIC is not currently used at Grand Gulf.) Design limitations are summarized in Table A.2-2 "System Limitations". To facilitate event tree development and review, Table A.2-3, "Summary of Major Systems Available for each OC", was prepared. This table summarizes the availability of systems to provide the

Characterization of POSS

Table A.2-1 Plant Configuration in Various OC's Based on Procedures

OC	P _i	P _e	P (psig)T °F (Sat. Unless Noted)	Heat Removal	Level Control	Rods	Recirculation
1	100%	100%	~ 1000 psig ~ 550°F	TG	FDW	Out	High Speed FCVs open Gradually close FCVs
	50%	50%			At ~ 50 % power secure one RFPT	Above 45 % core flow, insert rods and continue to insert to reduce power	
							Above 30 % core flow, switch to low speed, open FCVs fully
	20%	20%	~ 950 psig ~ 540°F	TG, TBVs open below 20% at 950 psig setpoint	FDW on startup		
	~ 12%	150 MWe					
	~ 12%	0		Manually trip turbine, generator trips on reverse power, TBVs open			
	~ 12%	0	~ 950 psig ~ 540°F	TBVs	FDW	Partly in, insert as required to reduce power	low speed, FCVs full open
2 (mode switch in STARTUP)	~ 8%	0	TBVs close as pressure goes below 950 psig, no heat removal	FDW			
3 (mode switch in SHUTDOWN)	0	0		Take TBVs in Manual to continue cooldown	FDW	<u>All Rods in</u>	
			~ 500 psig		Secure running RFPT, control level with condensate and booster		
			~ 135 psig	Place RHR in SDC, TBVs still open (Manual)			

Table A.2-1 Plant Configuration in Various OC's Based on Procedures

OC	P _i	P _s	P (psig) T °F (Sat. Unless Noted)	Heat Removal	Level Control	Rods	Recirculation
			~ 100 psig	Shut TBVs, set pressure demand 100 psig > reactor pressure. RHR on SDC	RWCU blowdown, break condenser vacuum if desired		
				Close MSIVs if desired to go to OC 5. Cool down to below 200°F with RHR on SDC			
4 (when T < 200°F)			190°F, vent to atmosphere 0 psig, subcooled	Cooldown to ~ 120 to 130°F and maintain with RHR on SDC	RWCU blowdown, maintain condensate <u>if</u> desired to go to OC 5	All in	Low speed, FCVs full open
4	0	0	0 psig ~ 120°F subcooled	RHR on SDC	Raise level with condensate to above head flange		
				to go to refuel OC, cooldown to 80 to 100°F with RHR on SDC			
			~ 80°F subcooled		Open fuel transfer tube closure hatch, close gate connecting upper pool and reactor cavity, drain upper Rx cavity to RWST		
					Remove drywell head, lower vessel level to 1 ft. or more below head flange, remove RPV lead connections		
5 (as soon as detension head)					Detension RPV head, remove RPV head, remove steam dryer		Throttle FCVs to reduce water ripple

Characterization of POSS

Table A.2-1 Plant Configuration in Various OC's Based on Procedures

OC	P _t	P _s	P (psig)/T °F (Sat. Unless Noted)	Heat Removal	Level Control	Rods	Recirculation
					Drain level to below steam lines (RWCU blowdown), install steam line plugs		
					Reflood upper reactor cavity from RWST, lift steam separator as cavity fills		
					Open gate connecting upper pool and reactor cavity		
5	0	0	0 psig ~80°F subcooled	RHR on SDC	RWCU blowdown, condensate available as needed		
5, commence required in-vessel activities							

Table A.2-2 System Limitations

RHR on SDC

- RPV pressure < 135 psig (pressure interlock FSAR 5.4.7.1.3.1)
- Requires manual alignment

RCIC

- HPCS can perform same function
- Auto isolates at 60 psig
- Once through mode can operate at rated pressure
- RHR steam condensing mode only if < 500 psig (HX pressure rating)*
- Once through mode auto initiated on Level 2, low low water level (-42")
- Steam condensing mode requires manual actuation*

HPCS

- Injects over all pressure, rated to 0 psig, evidently no concern about runout (NPSH or power)
- Auto on at high drywell pressure (1.4 psig) or low low vessel water level (Level 2, -42")

ADS

- 8 SRVs open auto if either:
 - Low water (level 3, +11") and Low low low water (level 1, -150") and high drywell pressure (1.4 psig) and one low pressure pump running and 105 sec timer times out
 - Low water (level 3, +11") and Low low low water (level 1, -150") and one low pressure pump running and 10 min. timer times out

LPCS

- Low pressure permissive 500 psig and decreasing
- Given low pressure permissive, auto on if low low low level (Level 1, -150") or high drywell pressure (1.4 psig)

LPCI Train A RHR

- Low pressure permissive 500 psig and decreasing
- Given low pressure permissive, auto on if low low low level (Level 1, -150") or high drywell pressure (1.4 psig)

LPCI Train B RHR, or Train C

- Low pressure permissive 500 psig and decreasing
- Given low pressure permissive, auto on if low low low level or high drywell pressure

ADHRS

- Section piping rated at 80 psig
- Only allowed in operation in OC 4 or OC 5

*Not used at Grand Gulf

Table A.2.3 Summary of Major Systems Available for Each OC

p psig	OC	Level Control				Reactivity Control		Availability of Heat Removal Systems										
		Injection		Letdown														
		CRD	FDW/ CDS	Steam	RWCU	Rods	SLC ¹	Recirc	TBVs	SDC	ADHRS	RCIC	SRVs	HPCS	LPCS	LPCI	Pool Cooling	Other
~1000	1, 2, and 3	Y	Y	Y	N ¹⁷	Y		Not needed if reactor tripped ^{2,13}	Y ³	N ⁴	N ⁵	Y ⁶	Y	Y	Y ⁹	Y ⁹	N	To be developed ⁷
~500	3	Y	Y ⁸	Y	N ¹⁷	IN		Not needed ^{2,13}	Y ³	N ⁴	N ⁵	Y ⁶	Y	Y	Y ⁹	Y ⁹	N	See above
~100	3	Y	N ¹⁰	N	Y	IN		Not needed ^{2,13}	N ¹¹	Y ¹²	N ⁵	Y ⁶	Y	Y	Y ⁹	Y ^{9,12}	N	See above
~60 to ~0	3 and 4	Y	N ¹⁰	N	Y	IN		Not needed ^{2,13}	N ¹¹	Y ¹²	Y - OC 4 only ¹⁴	N ⁶	Y ¹⁸	Y	Y ⁹	Y ^{9,12}	N	See above
0	5 head removed upper cavity filled pools connected	Y	Y ¹⁰	N	Y	IN		Not needed ¹³	N ¹¹	Y ¹²	Y ¹⁴	N ⁶	N ¹⁹	N ^{15,16}	N ^{15,16}	N ^{9,15,16}	Y	See above
0	5 head removed upper cavity not filled but level raised	Y	Y ¹⁰	N	Y	IN		Not needed ¹³	N ¹¹	Y ¹²	Y ¹⁴	N ⁶	N ¹⁹	N ^{15,16}	N ^{15,16}	N ^{9,15,16}	N	See above

Y is Yes
N is No

Table A.2-3 Summary of Major Systems Available for Each OC (Concluded)

Notes

1. SLC needed only if rods unavailable.
2. Natural circulation with raised level OK with reactor tripped.
3. TBVs auto control to 950 psig. Below 950 psig use of TBVs requires manual operation.
4. RHR SDC auto isolated above 135 psig
5. ADHRS can only be used in OC 4; suction piping rated at 80 psig.
6. RCIC auto mode (once through) available from full pressure down to 60 psig (auto isolate). RCIC manual mode (steam condensing) available below 500 psig (auto isolate) down to 60 psig (auto isolate). RHR HX limits steam condensing mode to below 500 psig.
7. Consider CRD, fire water, RWCU, condensate, etc. Some of these will only work at low decay heat levels (e.g., RWCU letdown, CRD/condensate makeup).
8. FDW secured but injection with condensate and booster pumps.
9. LPCI/LPCS requires $p < 500$ psig permissive for injection.
10. Condensate kept available to raise level if going to OC 5, refueling.
11. Below 135 psig, initiate RHR SDC, close TBVs. Assume condenser not available when TBVs are closed (stop circ. water, break vacuum, etc.).
12. When RHR on SDC, manual re-alignment of RHR A and B required for use as LPCI A and B.
13. Without recirc. on low, speed natural circulation can be established with level raised.
14. ADHRS can only be operated in OC 4 or 5 ($< 200^{\circ}\text{F}$); suction piping rated at 80 psig.
15. In OC 5 with upper cavity filled and pools connected, TS 3.5.2 allows ECCS to be inoperable. In OC 4, or 5 without cavity filled and pools connected, 2 of 5 ECCS must be operable according to TS 3.5.2. In OC 1, 2, and 3 all ECCS must be operable according to TS 3.5.1
16. Inadequate Decay Heat Removal procedure does not discuss use of ECCS when head is off.
17. RWCU is not the primary means of letdown level control since steaming to the condenser is used.
18. 2 SRVs required per procedure.
19. Steam Line Plugs in place, vessel head removed.

Characterization of POSs

following functions: level control, reactivity control, and heat removal. All of these functions must be provided to cool fuel in the vessel.

During startup, the plant configuration in certain OCs is different than during shutdown. As indicated in the summary of the startup procedure (see Appendix B, Procedure # 03-1-01-1), Grand Gulf uses nuclear heat, as opposed to pump heat, to heatup (decay heat is typically too low to be used for startup). For example, if the plant is in OC 4, and startup is requested, the following steps are taken:

- (1) RHR/SDC is taken out of service and RHR is lined up for LPCI.
- (2) Mode switch placed in Startup (this places unit in OC 2).
- (3) Rods are pulled to critical.
- (4) Turbine bypass is made operable.
- (5) Rods are pulled and primary heats to temperature (pressure) where moderator feedback re-establishes criticality.
- (6) Step 5 continues with heatup rate limited to ≤ 80 degrees F per hour.
- (7) At rated pressure (temperature), Turbine Bypass Valves (TBVs) control pressure. Rods pulled to position for 4% power, and power goes to 4% (fuel Doppler re-establishes criticality at 4% power).
- (8) Mode switch placed in Run, and power increased. Recirc flow controlled, turbine rolled, and generator loaded per procedure. Full Power established.

In contrast to the situation during shutdown, during normal startup the unit goes from OC 4 directly to OC 2 without passing through OC 3. This is because the mode switch is placed in Startup to allow rods to be pulled to heat up the unit. When the unit initially enters OC 2 during startup, it is at low pressure and temperature. However, the system lineups are basically the same as when the unit is in OC 2 during shutdown (i.e., RHR/SDC is isolated, ECCS is operable, and turbine bypass is operable). During the startup process, should it be required to initiate RHR/SDC, the rods will be fully inserted prior to establishing RHR/SDC, per the

RHR/SDC procedure (# 04-1-01-E12-1, rev 44, step 3.6.1).

Since OCs are not one-to-one with system availabilities, the initial conditions of the plant prior to the occurrence of an accident initiating event cannot be easily specified based purely on OCs. For this reason, we developed a set of Plant Operational States (POSs), to segregate the various off power situations into a set of states for which the normal configuration of systems (prior to an accident initiating event) can be specified. Thus, a POS is defined as: a plant condition for which the status of plant systems (operating, standby, unavailable) can be specified with sufficient accuracy to model subsequent accident events. A POS is not identical to an OC, but POSs are defined based on OCs. In general, an OC cannot in itself meet the requirement for a POS. For example, in OC 3, above 135 psig RHR on SDC cannot be used and the Turbine Bypass Valves (TBV) or RCIC are used; while in OC 3, below 60 psig RCIC cannot be used.

There are some OCs that are essentially the same in terms of system availabilities and primary thermal hydraulic conditions, and these were treated as one POS. For example, OC 1 and OC 2 differ only in the power level, rods positions, and recirculation pumps speed -- all of which are minor in terms of accident sequence progression, since reactor shutdown/trip with the rods is essentially the same regardless of power level, and recirc is not required post trip. The pressure/temperature of the primary is almost identical in OC 1 and 2 (during shutdown): about 1000 psig and about 550 degrees F. In OC 3 from 1000 psig down to 500 psig, the systems configurations important to the accident analysis are identical to the configurations in OC 1. The main differences are: in this upper pressure range of OC 3 the rods are all in, and the turbine/generator is tripped. Also, the pressure/temperature conditions that affect accident sequence progression are not drastically different at 500 psig from those at 1000 psig.

Using the OCs as a starting point, the following seven POSs were defined:

- (1) POS 1 consisting of: OC 1 and OC 2 with pressure at rated conditions (about 1000 psig) and thermal power no greater than 15%.
- (2) POS 2 consisting of: OC 3 from rated pressure to 500 psig.
- (3) POS 3 consisting of: OC 3 from 500 psig to where RHR/SDC is initiated (about 100 psig).

- (4) POS 4 consisting of: OC 3 with the unit on RHR/SDC.
- (5) POS 5 consisting of: OC 4 ($T \leq 200$ degrees F) and OC 5 until the vessel head is off and level is raised to the steam lines.
- (6) POS 6 consisting of: OC 5 with the head off and level raised to the steam lines.
- (7) POS 7 consisting of: OC 5 with the head off, the upper pool filled, and the refueling transfer tube open.

Control rods are fully inserted in POSs 2, 3, 4, 5, 6, and 7.

The reasons for this segregation of the five OC into these seven POSs are indicated in Table A.2-3, and the most salient ones are as follows:

- (1) OC 1, OC 2, and OC 3, down to 500 psig: steam dump to the condenser is used, feedwater is available, and other similar characteristics exist.
- (2) OC 3, between 500 and 100 psig: have the potential to use RCIC in the steam condensing mode (not used currently at Grand Gulf), the pressure is below the LPCI/LPCS permissive setpoint, and feedwater is secured but condensate/booster makeup is still available.
- (3) OC 3, between 100 and 0 psig: RHR on SDC, level control with RWC, RCIC unavailable (conservative assumption since it is available above 60 psig), LPCI trains A and B require manual re-alignment of RHR from SDC.
- (4) OC 4: vent can be opened, ADHRS can be used, RCIC cannot be used, RHR on SDC and LPCI trains A or B requires manual re-alignment, LPCI/LPCS flooding through two open SRV's to the SP can be used.
- (5) OC 5 with head off, level raised but upper cavity not flooded: spent fuel pool cooling cannot be used for fuel in vessel, ECCS required operable per Tech Spec 3.5.2 (see Appendix B for discussion of procedure for Inadequate Decay Heat Removal).
- (6) OC 5 with head off, upper cavity flooded, and

upper and spent fuel pools connected: spent fuel pool cooling can be used to cool fuel in vessel, ECCS allowed inoperable per Tech Spec 3.5.2.

This selection of POSs was based on the factors indicated in Table A.2-3. Because the information in this table is based on system configurations during shutdown, it must be shown that these POSs handle system configurations during startup as well. For POSs 6 and 7, there is no distinction between system configurations for shutdown and startup. As discussed previously, during normal startup the unit passes from POS 5 directly to POS 1. However, should the heatup process be stopped (for example, to institute RHR/SDC), the rods are inserted and the mode switch placed in Shutdown. Therefore, should the unit enter POS 4, 3, or 2 during startup, it will do so with the same system configurations as during shutdown, and POS 4, 3, and 2 apply equally well to both situations. POS 1 is characterized as being at rated pressure, the situation during shutdown. During startup, the unit enters POS 1 at low pressure, but with the same lineups as for rated pressure since the idea is to heat up to rated pressure in this configuration. A rise to rated pressure is therefore of no concern in POS 1 during startup, and POS 1, as defined for shutdown, applies equally well for startup.

It is interesting to note that for Grand Gulf, ECCS injection is not required to be manually blocked during cooldown as the unit depressurizes, because ECCS actuates on level, not purely on pressure, and water is maintained at normal level during cooldown. This is in contrast to PWR's where ECCS actuates on pressure and must be blocked during cooldown and reset during heatup.

A.3 Definition and Characterization of POS Change Initiators

After an understanding of how the plant operates and/or transitions among the identified POSs was obtained, it became necessary to identify the reasons why the plant would be required to change its POS and the implications of such a change (i.e., known pre-existing system and/or component unavailabilities). Since the major concern of this study was with accidents occurring in non full power POSs, its focus was on controlled shutdown initiating events. Also included are reactor trip events which allow orderly transition among POSs, hereafter called 'nuisance trips'. These 'nuisance' trips are included because they affect the amount of time that the plant is in POSs associated with conditions other than full power.

Characterization of POSs

Note, that by definition such nuisance trips do not prevent the plant from transitioning among POSs in an orderly manner.

For accident sequences initiated from full power as modeled in full power PRA's, this study addresses only those sequences defined in the top success path of the full power accident sequence event trees, for which the plant can transition among POSs in an orderly manner.

The coarse screening study did not address the long term issues following a non-nuisance reactor trip from full power. Consideration of such events is an extension of traditional full power PRA analyses of accident sequences. Full power PRAs model the response of the plant out to the time at which conditions are stabilized (e.g., hot shutdown for transient initiated accident sequences). However, the long term response of the plant is not considered.

The methodology employed in this study is not directly suitable for analyzing such concerns, since the methodology assumes that the plant is initially in a stable condition in a POS, and not initially transitioning into a POS from an accident at full power. The concept of POS is not always meaningful for accidents initiated at full power anyway, since the plant responds to the accident rather than transitioning among POS. For example, following a large LOCA the plant systems attempt to mitigate the LOCA rather than transition in a controlled manner to cold shutdown.

The fact that the screening study did address these nuisance trips and not the more stressful, but less likely, trips which progress along an event tree path (other than the top success path) should not be taken to imply that a transition to a POS following a nuisance trip is believed to be of higher risk than long term considerations following the more stressful trips. Rather it is a reflection of two facts: (1) nuisance trips occur relatively frequently (on the order of one to ten times a year depending on the particular plant), and (2) the methodology developed for quantifying accidents occurring following transitions among POSs can easily handle the nuisance trips as defined above. Also, the full power PRAs do analyze the accident sequences associated with non-nuisance trips, although long term accident management issues are not addressed.

A distinction must be made between what is meant by accident initiating events and initiating events which require a transition among POS. For example, initiating events requiring controlled shutdown but not a reactor

trip are not accident initiating events, since they do not prevent controlled transitions among POS. However, they can impose known, pre-existing unavailabilities if a subsequent accident initiating event occurs. Reactor trip initiating events are, in general, accident initiating events since they require mitigative actions to handle the event without regard to orderly transitions among POSs. For example, following a LOCA at full power, the plant does not undergo an orderly transition to cold shutdown -- ECCS systems respond as necessary to mitigate the break. Only certain types of events requiring reactor trip allow subsequent transitions among POSs. These include those that do not affect the ability to transition, or those that can be easily fixed to allow transition (e.g., the nuisance trips described above). Events requiring controlled shutdown, such as refueling or inoperable equipment, lead to orderly transitions "down" among POS. Transitions "up" among POS occur following outages or equipment repair.

In this study a POS Initiator has the following definition: An event which initiates controlled shutdown of the plant from full power, a nuisance trip from full power, or an event which requires the plant to transition up or down among POS in response to outage requirements or equipment conditions.

For the purposes of describing how the POS change initiators were identified and the implications of such initiators, the initial state of the plant is assumed to be full power; and before the first initiating event occurs it is assumed that no significant known system unavailabilities exist. The analysis starts when an event occurs that requires transitioning the plant through a set of POSs.

In general a given POS can be entered in one of four ways:

- (1) coming down from full power for a scheduled refueling outage,
- (2) coming down from full power not for a scheduled refueling outage,
- (3) going up to full power following a refueling outage, or
- (4) going up to full power not following a refueling outage.

The following seven categories or classes of POS Initiators were identified:

Class	Description
1.	Refueling. The plant is scheduled for its next refueling outage.
2.	Controlled shutdown required by Technical Specifications (Tech Specs) due to violation of a Safety Limit (SL) or Limiting Condition of Operation (LCO).
3.	Controlled shutdown required by Tech Specs due to missed Surveillance Requirement (SR).
4.	Controlled shutdown due to failures in non-Tech Spec equipment.
5.	Preventive maintenance.
6.	Change necessitated by a reactor trip from full power (nuisance trip only).
7.	First time startup or final shutdown.

After these seven classes were developed, they were examined to determine if a change in the plant's POS necessitated by one of these events would impose known, pre-existing unavailabilities. For Class 1, the following assumption was made: the plant would not enter refueling (i.e., POSs 6 and 7) knowing that a system required during the refueling outage was unavailable. Class 2 events can impose pre-existing unavailabilities. If an inoperable system is required during shutdown, then entry into an action statement will impose known, pre-existing unavailabilities. If the system is not required, then no known, pre-existing unavailability exists. Events in Class 3 do not impose known, pre-existing unavailabilities. Class 4 events may impose pre-existing unavailabilities. If the equipment is taken credit for in a PRA (i.e., used to mitigate an accident initiating event), then its failure does impose a pre-existing unavailability. If not, then no pre-existing unavailability exists. Class 5 events do not impose pre-existing unavailabilities, because if the equipment were non-functional, then it would be in Class 2 or 4. Class 6 events do not impose pre-existing unavailabilities, since only reactor trips associated with nuisance trips are analyzed. No exact determination of Class 7 events was made, as these events were outside the scope of this project.

Based on our understanding of the plant characteristics and operating practices, we developed seven rules of analysis for evaluating each POS.

Rule (1): When an accident initiating event occurs in a given POS, the event tree for that accident initiator in that POS totally describes the subsequent behavior of the plant. Once an accident occurs, the plant systems focus on mitigating that particular accident rather than on transitioning among the POS.

Rule (2): The structure of the accident event trees and constituent fault trees in a given POS for a given accident initiating event, are independent of how the plant transitioned to that POS; (except that consideration of additional methods of core cooling are considered at low decay heat levels that exist going up following a refueling outage). This rule follows from rule (1), in that any accident within a POS renders transitioning to a subsequent POS invalid. Thus, entry into a given POS is without an accident having previously occurred. Of course, the availability of systems and components is affected by known, pre-existing unavailabilities.

Rule (3): For any POS 6, 5, 4, 3, 2, or 1 that is entered following a refueling outage, there are no known, pre-existing unavailabilities. This rule is based on the assumption that the plant will not be restarted following a refueling outage if known, major equipment unavailabilities are present.

Rule (4): For POS 6, no known, pre-existing unavailabilities exist. This rule is based on the assumption that a refueling outage is a scheduled event and does not occur simultaneously with any other POS initiator. Conversely, if a POS initiator occurs which renders equipment inoperable, it is assumed that the problem will be fixed in POS 4 or 5. POS 6 or 7, which involve vessel head removal, are not entered.

Rule (5): For any POS entered in returning to power following a non-refueling outage, there are no known, pre-existing unavailabilities from any time prior to entry into the first POS. This rule is based on the assumption that the reason for coming down in power is fixed prior to going back up in power.

Rule (6): Failures occurring in a POS following the POS initiator which required entry into the POS, are accident initiating events, and by rule (1), do not affect subsequent POS. Failures in one POS can affect the availability of equipment in a subsequent POSs. Rules (3), (4), and (5) limit those earlier POS to which

Characterization of POSs

consideration should be given. We have made the additional assumption that any failure subsequent to the POS initiator initiates an accident. The rationale for this assumption is that in most cases in the POS, even if redundant trains exist, only one train is in operation (Shutdown Cooling with RHR, for example), and a failure in the running train and starting the backup train is modeled in the accident sequence event trees.

Rule (7): For any POS entered except as part of a planned refueling outage, the fault exposure time for standby components is $T_i/2$, where T_i is the average time between testing of component i . For any POS entered as part of a scheduled refueling outage, the fault exposure time is $T_{ir} + T_{pos}/2$, where T_{ir} is the time interval from the last test of component i , and entry in to the POS, and T_{pos} is the duration of the POS. This rule is based on the fact that refueling is a scheduled (non-random) event.

These seven rules taken together, enable the accident sequences for a given POS to be evaluated without rigorously considering all the details of how the plant transitioned to that POS.

However, this methodology cannot in general handle time dependent changes in system configurations. For example, the methodology cannot easily model all the possible changes in system availabilities during a refueling outage as extensive maintenance is performed on different systems. For cold shutdown at Grand Gulf, (the subject of this report), this is not a serious limitation since train A is frequently taken out for maintenance in cold shutdown. This was the conservative assumption used in our model. To assess risk during actual refueling operations involving extensive testing and maintenance, the methodology may have to be improved to consider 'rolling' unavailabilities of equipment.

Similarly, the methodology cannot easily consider accidents that occur as the plant transitions among modes during shutdown. For example, in hot shutdown the plant operators switch from cooling with turbine bypass to cooling with shutdown cooling at about 100 psig. Plant conditions are changing during this transition, and are different than those present while either on turbine bypass cooling or on shutdown cooling. We have assumed that accidents occurring during such transition operations are adequately considered by our models for the initial and final states of the transition, for the following reasons:

- a) The time spent in transition is less than the time spent in the states transitioned from and

transitioned to; thus, accidents due to random failures are less likely.

- b) For Grand Gulf, and many other plants, this assumption is further supported by the practice to not disable one functional system (such as core cooling with turbine bypass) until the replacement system (such as shutdown cooling) is shown to be operable.
- c) Finally, the historical record of events occurring at shutdown shows that they do not occur during transition states.

We believe that the most probable situations for which unique initiating events can occur during a transition state, are those associated with rod withdrawal during startup. Errors in rod movements during such situations can challenge the reactor trip system. Such situations do not occur in cold situation.

References for Appendix A

[Whitehead et al, 1991]	D. W. Whitehead, J. L. Darby, B. D. Staple, B. Walsh, T. M. Hake, and T. D. Brown, "BWR Power and Shutdown Accident Frequencies Project, Phase 1 - Coarse Screening Analysis", Vol. 1, Draft Letter Report, Sandia National Laboratories and Science and Engineering Associates, Inc., November 23, 1991 update. (Available in USNRC Public Document Room)	[USNRC 1984]	USNRC, "Technical Specifications, Grand Gulf Nuclear Station Unit No. 1", Docket No. 50-416, Appendix "A" to License No. NPF-29, NUREG-0934, October, 1984.
		[SERI, 1992]	System Energy Resources, Inc., "Grand Gulf Updated Final Safety Analysis Report," Revision 7, 1992

Appendix B Summary of the Detailed Review of Selected Grand Gulf Procedures

This appendix summarizes the information obtained during detailed reviews of selected Grand Gulf Procedures. The reviewed procedures include:

- (1) Power Operations - #03-1-01-2,
- (2) Plant Shutdown - #03-1-01-3,
- (3) Refueling - #03-1-01-5,
- (4) Cold Shutdown to Generator Carrying Minimum Load - #03-1-01-1, and
- (5) Inadequate Decay Heat Removal - #05-1-02-III-1.

For each procedure the most important steps (tasks) are identified and summarized both in text and tabular format. In addition, the important precautions, limitations, actions, and prerequisites are presented.

B.1 Power Operations - #03-1-01-2

This procedure covers three situations: (A) low to full power increase, (B) full to low power decrease, and (C) rapid power reduction.

The prerequisites (initial conditions) for this procedure are as follows: For situation (A) recirculation is on low speed, the flow control valves are fully open, one reactor feed pump is maintaining vessel level, and the main generator is synchronized to the grid carrying about 15 % (196 MWe) load. Heat removal is through the loaded turbine with Turbine Bypass Valves (TBVs) open. For situations (B) and (C), the prerequisite conditions are those established in this procedure for a defined power level. See Table B.1.1 for a list of the most important precautions, limitations, and actions.

B.1.1 Low Power to Full Power Increase

Situation (A), low to full power increase, is accomplished as follows: The loading instructions are obtained from the system dispatcher. The load demand is increased in increments until the TBVs are fully closed. (As more steam flows to the turbine, the turbine header pressure drops, and once it is below the TBVs setpoint they close.) The TBVs are verified to be fully closed before raising power above 20 % to satisfy Tech Spec 4.1.4.1; and the reactor feedwater pump turbine (RFPT) is verified to be on the master level controller

(off startup). Power is increased by withdrawing rods. Power is held at 20 % for about 1.5 hours to allow heat rate data to be gathered. As soon as the low power setpoint (20 %) is exceeded, the operability of the Rod Withdrawal Limiter (RWL) is verified per Tech Spec 4.1.4.2.b.1. Power is held at 40 % for about 1.5 hours to allow heat rate data to be obtained. When the reactor is stable above 34 % power and below the 80 % rod line, the flow control valves are closed to minimum position, and the recirculation pumps are switched from low to high speed. At about 40 % power, feedwater is placed in three element control where pump speed is a function of steam flow, vessel water level, and feedwater flow. At about 45 % power, the second RFPT is placed in service on master level control, and the second circulating water pump is placed in service. Rods are positioned at the desired flow control line, and power is increased by opening the recirculation flow control valves and thereby increasing recirculation, with the rods fixed. Power is held at 60 % for about 1.5 hours to allow for gathering of heat rate data. As soon as the high power setpoint is reached (70 %), RWL operability is demonstrated. At about 80 % power and 90 % core flow, all ECCS line break alarms should be cleared, but any applicable LCOs are entered for alarms not cleared. (Evidently the "ECCS line break alarms" are readouts from the "injection permissive" low pressure sensors of Tech Spec table 3.3.3-1 which, upon low pressure, permit LPCI and LPCS injection given either low vessel level or high drywell pressure.) Power is held steady at both 80 % and 100 % for about 1.5 hours to allow heat rate data to be gathered.

The above information is a summarization of the information presented in Table B.1.2.

B.1.2 Full Power to Low Power Decrease

Full power to low power decrease, situation (B), is accomplished essentially by reversing the steps just described for (A). If it is desired to trip the turbine, this is accomplished by manual action once power is 100 to 150 MWe. The generator then automatically trips on reverse power since with no driving torque it acts like a motor and draws power from the grid. The TBVs are verified to be maintaining vessel pressure. See Table B.1.3 for the appropriate steps for this portion of the procedure.

B.1.3 Rapid Power Reduction

Rapid power reduction, situation (C), is achieved by

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using the fast mode of recirculation flow reduction. If further reduction in power is required, the rods are inserted. The appropriate steps in (A) of this procedure are then followed. If reactor scram occurs, the Reactor Scram procedure #05-1-02-1 is followed.

Table B.1.4 lists the steps necessary for performance of this section of the procedure.

B.2 Plant Shutdown - #03-1-01-3

This procedure takes the plant from Operating Condition (OC) 1 at about 12% power down to zero power in either OC 3 or 4. The prerequisites (initial conditions) are as follows. Reactor power is about 12%, and the turbine is offline. Recirculation pump(s) on low speed with flow control valves (FCVs) full open in loop manual control. Heat removal is via TBVs to the main condenser.

The procedure has two parts. One deals with cooldown keeping the main steam isolation valves MSIVs open, and the other deals with cooldown when the MSIVs are closed during the cooldown. See Table B.2.1 for a list of the most important precautions, limitations, and actions.

B.2.1 Cooldown with the MSIVs Open

Cooldown with the MSIVs open is accomplished as follows. If rapid and complete shutdown is desired, the reactor is manually tripped and the Reactor Scram procedure #ONEP 05-1-02-I-1 is followed. Otherwise, the following steps are taken. Rods are inserted to reduce power to about 8%. The IRMs are inserted. All surveillance requirements (SRs), per the Tech Specs, are completed before entry into OC 2. The mode switch is placed in STARTUP, and hence the unit enters OC 2. Rods are inserted, the SRMs are inserted, and the TBVs are verified to close at the 950 psig turbine header pressure control setpoint. All conditions for entry into OC 3 are met, and the unit enters OC 3 as the mode switch is placed in SHUTDOWN position when all rods are fully inserted. Reactor power is zero (except for decay heat). Cooldown is continued at less than 80 degrees F per hour by manually opening/closing the TBVs. (Operation of the TBVs reduces reactor pressure. Temperature also decreases along the saturation line due to controlled flashing as pressure decreases.) Level control is maintained with feedwater. The steam jet air ejectors (SJAEs) are secured and hoggers are placed in operation to maintain condenser vacuum. At about 500

psig, the running RFPT is secured, and it is verified that only one booster/condensate pump combination is running. Cooldown with the TBVs is continued as long as possible. When necessary, SDC with RHR is placed into operation. At 200 psig, one RWCU pump is secured if both pumps are running. At 100 psig, the running RWCU pump is transferred to the pre-pump mode. The TBVs are closed (manual operation is stopped), and the pressure setpoint is set at 100 psig above reactor pressure. Heat removal is via RHR on SDC. If desired, the condenser vacuum is broken, and circ water is shutdown. When vessel temperature is below 190 degrees F (unit enters OC 4 at 200 degrees F), the primary is vented to the atmosphere by opening F001 and F002 and closing F005. This establishes 0 psig and renders the primary subcooled. To prevent thermal stratification, recirculation on low speed is continued. If either recirculation or SDC is lost, procedure #ONEP 05-1-02-III-1 "Inadequate Decay heat removal" is followed. Cooldown is continued to 120 to 130 degrees F. Level is controlled via RWCU blowdown to either the condenser or radwaste. To maintain cold shutdown conditions as desired, RHR is operated in the SDC mode per procedure #SOI 04-1-01-E12-1.

The above information is a summarization of the information presented in Table B.2.2.

B.2.2 Cooldown with the MSIVs Closed

Cooldown with the MSIVs closed during the cooldown process is similar to the case with the MSIVs open. The main difference is that just before the MSIVs are closed, RCIC is placed in operation in the open cycle mode (injection from the CST or SP) per procedure #SOI 04-1-01-E51-1. Unless decay heat is so low that the steam discharged to the RCIC turbine provides adequate heat removal, the SRVs will cycle and relieve to the SP. SP cooling is instituted if necessary. RHR on SDC is placed in operation below 135 psig, and RCIC is isolated above 75 psig (RCIC auto isolates at 60 psig). It is important to note that if RCIC is inoperable, then HPCS with SRVs (relief mode) can be used. See Table B.2.3 for the steps necessary for performing this portion of the procedure.

B.3 Refueling - #03-1-01-5

This procedure takes the plant from OC 3 down to OC 5, and from OC 5 up to OC 4. The prerequisites going down are that the plant is in OC 3 per procedure #03-1-01-3 "Plant Shutdown." The prerequisites going up are

that the plant is in OC 5 as specified in this procedure. See Table A.3.1 for a list of the most important precautions and limitations.

B.3.1 Plant Cooldown and Entry into OC 5

The steps for going from OC 3 down to OC 5 are as follows. Per procedure #03-1-01-3 the unit is being cooled down with the TBVs. Once pressure is below 135 psig, SDC via RHR is instituted, and the TBVs are removed from service. The MSIVs are closed. RWCU is placed in the blowdown mode, but the condensate system is retained for vessel flooding. With condensate and using the startup level controller, the level is raised above the RPV head flange. Cooldown with SDC is continued (OC 4 is entered at 200 degrees F) to about 80 degrees F. (It is verified that RCIC auto isolated at 60 psig.) The fuel transfer tube closure hatch is opened, thus enabling fuel to be moved from the upper containment pool to the spent fuel storage transfer pool in the auxiliary building, once isolation valves in the transfer tube are opened. The gate and seal between the upper containment pool and the reactor upper cavity is installed, thus isolating the upper reactor cavity. The upper reactor cavity is drained to the Refueling Water Storage Tank (RWST). The drywell head is removed. Vessel level is lowered (with RWCU blowdown) to one foot or more below the flange. All external connections to the vessel head are removed. The head studs are detensioned. This places the unit in OC 5, Refueling. The vessel head is removed. Recirculation is throttled with the FCVs to reduce water ripple. The steam dryer is removed. The vessel is drained to below the main steam lines, and steam line plugs are installed. The upper reactor cavity is reflooded from the RWST and the steam separator is removed as the upper cavity fills. Once the upper cavity is filled, the gate/seal between the upper reactor cavity and the upper containment pool is removed. (Later, in preparation for fuel transfer, the transfer tube isolation valves will be opened. At this time, the vessel water, the water in the upper reactor cavity, the water in the upper containment pool, and the water in the spent fuel storage pool are interconnected since the vessel head is off, the upper reactor cavity is flooded, the gate between the upper cavity and the upper containment pool is open, and the refueling tube connecting the upper containment pool to the spent fuel storage pool is open.) Most of the required in-vessel work is performed with the unit in these conditions. (In service inspection of the vessel is performed with a lower water level.)

The above information is a summarization of the

information presented in Table B.3.2.

B.3.2 Reactor Pressure Vessel Reassembly and Entry into OC 4

The steps for bringing the unit from OC 5 with the upper reactor cavity flooded, to OC 4 are essentially the reverse of the appropriate preceding steps. See Table B.3.3 for a list of the appropriate steps.

B.4 Cold Shutdown to Generator Carrying Minimum Load - #03-1-01-1

This procedure controls the activities necessary for reactor startup, unit heatup, and turbine startup and generator synchronization. The prerequisites (initial conditions) for this procedure are as follows: The reactor vessel head must be in place with the studs tensioned. The mode switch must be in the SHUTDOWN or REFUEL position. Recirculation is in operation on low speed, with the flow control valves full open and in loop manual control. The control rod hydraulic system is in operation, and the RWCU system is blowing down to the condenser or radwaste system to maintain level at normal level. RHR is in LPCI standby, or another mode as required, and ADHRS is in the isolate mode per procedure #SOI-04-1-01-E12-1. (It should be noted that Section 3.1 of the procedure defines "standby" as able to respond upon automatic or manual initiation.) RCIC is ready for operation or on standby. The integrity of primary containment, secondary containment, and the drywell is verified per Tech Spec sections 3.6.1, 3.6.2, and 3.6.6. The turbine is on turning gear. Circulating water is in operation. Usually, the MSIVs are closed, atmospheric vents F001 and F002 are open, and temperature is below 190 degrees F. The primary coolant is subcooled, and the unit is in OC 4. See Table B.4.1 for a list of the most important precautions, limitations, and actions associated with this procedure.

B.4.1 Reactor Startup

Reactor startup is completed as follows. RHR is aligned so that LPCI can be initiated with no manual realignment; thus, shutdown cooling is not provided since alignment of RHR for shutdown cooling is not allowed. The only active core cooling present is that due to injection from the control rod hydraulic system and blowdown with the RWCU system, and that is

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insufficient to prevent heatup. It is acceptable to have no active core cooling during heatup because:

- (1) It is desired to heatup the unit anyway,
- (2) The time to heat to saturation in this condition is long since the unit has been shutdown for an appreciable time and decay heat is low (procedure #05-1-02-3-1 provides curves giving time to boil), and
- (3) LPCI is available if needed.

The mode switch is placed in STARTUP and this places the unit in OC 2 (not that OC 3 is skipped during abnormal startup). The rods are withdrawn per the specified pattern until the unit is critical. This plant uses nuclear heat to heat up as opposed to pump heat as utilized in many PWRs. (The BWR can maintain shutdown margin with rods alone at near ambient temperatures while the PWR cannot. Thus, criticality on rods in the BWR at low temperatures is acceptable.)

The above information is a summarization of the information presented in Table B.4.2.

B.4.2 Unit Heatup

Unit heatup is accomplished as follows: The vent to atmosphere is isolated by closing F001 and F002. F005 is opened to provide controlled venting of noncondensibles to the main condenser. As the unit is heated up, the water will follow the saturation curve and temperature will be the saturated value at the existing pressure. The vacuum in the main condenser is established with hoggers (mechanical vacuum pumps). Heatup is initiated by withdrawing rods, and the rate is kept below 80 degrees F per hour. The rods must be withdrawn to maintain criticality as the primary heats up to counter the negative temperature coefficient of the moderator. The turbine bypass stop valves are opened. The chemical conditions of the primary are verified to be acceptable. It is verified that one condensate pump is in operation. Feedwater level control is instituted using the startup level controller. At about 60 psig, RCIC is placed in standby. Letdown with RWCU is stopped when automatic control on level with feedwater is established. At about 100 psig, one RWCU pump/filter is placed in cleanup mode. At about 200 psig, the second RWCU pump/filter is placed in cleanup mode. At about 400 psig, the TBVs are verified to be about 10% open and one feed pump turbine is rolled into service; evidently, the second feed pump is placed in

service per procedure #SOI-04-1-01-N21-1. At about 500 to 800 psig, the steam jet air ejectors are placed in service to provide condenser vacuum. At about 950 psig, the TBVs operate at their setpoint, and open as thermal power increases. The mode switch is transferred to RUN and the unit is in OC 1, with thermal power at about 4%, electrical power zero, pressure about 950 psig saturated, and steam being dumped to the condenser via the TBVs. As power increases, the rods are withdrawn to overcome the Doppler effect in the fuel and maintain criticality. See Table B.4.3 for the important steps associated with this portion of the procedure.

B.4.3 Turbine Startup and Generator Synchronization

Turbine startup and generator synchronization are accomplished as follows. The turbine stop valves are opened. The second stage moisture separator reheater is placed in service. The EHC is set for 400 rpm and the turbine is rolled to 400 rpm as the turbine control valves open in response to the EHC signal. The turbine speed is increased to 1800 rpm. The turbine bypass valves are verified to be at least 20% open to accommodate generator synchronization and loading. The generator is to be operated with constant output voltage using the voltage regulator in auto control (the emf of the generator is varied with load to maintain constant terminal voltage). The load dispatcher is notified that the generator is ready to come on the grid. The EHC is set to 1805 rpm, and at the 12 o'clock position on the synchroscope, the generator is connected to the grid. The 12 o'clock position corresponds to the generator voltage being equal and opposite to the grid voltage and hence the generator is not loaded (no current to the grid). The grid provides synchronizing power to lock the speed in at 1800 rpm. (A speed setting of slightly greater than 1800 rpm does not change the turbine speed once the generator is on the grid. It moves the TCVs to a position corresponding to the speed setting and thereby establishes the generator output power. Speed control can only be used up to about 175 MWe, thereafter load control is used.) Power output is increased with speed control to between 75 and 150 MWe. The first stage moisture separator reheater is placed in service. Power output is raised to about 175 MWe by setting speed demand at about 1812 rpm. Control is transferred from speed to load demand. Electrical power is not to exceed 24% during use of this procedure. The second condensate and booster pumps are started. The high pressure feedwater heaters are placed in service. (The low pressure feedwater heaters were placed in service

when steam was admitted to the low pressure turbines, since no valves need to be opened to extract steam to the low pressure heaters, as indicated on Figure 10.3-4 in the FSAR.) See Table B.4.4 for a list of the steps described above.

B.5 Inadequate Decay Heat Removal - #05-1-02-III-1

The Inadequate Decay Heat Removal Procedure addresses two situations with respect to loss of decay heat removal. These are inadequate decay heat removal when fuel is in the vessel and the unit is in OC 4 and when fuel is in the vessel and the vessel head is off. Table B.5.1 lists the symptoms which indicate a loss of heat removal capability, and Table B.5.2 provides a list of the immediate operator actions which should be performed given entry into the procedure.

B.5.1 Fuel in the Vessel and the Unit in OC 4

If inadequate decay heat removal is encountered while the unit is in OC 4, the following steps are taken. Note that if decay heat removal is not restored prior to entering OC 3, the ADHRS must be isolated (its suction design pressure is only 80 psig). If the in-service loop of RHR on SDC is lost, the other RHR loop or the ADHRS is placed in operation for SDC. If forced recirculation (low speed) is lost, level is raised to about 82 inches to promote natural circulation and attempts are made to restore recirculation. If RHR SDC is also lost, the head spray is operated, if available. If SDC with RHR and cooling with ADHRS are completely lost, RWCU letdown and makeup (CRD hydraulic and condensate) are increased to the maximum to maximize their effect on cooling. (This alone will only work for low decay heat levels, but it does increase the time available to institute other measures. The maximum letdown rate with RWCU is about 360 gpm, which can match decay heat only if the unit has been shutdown for about 17 days or longer.) Also, Attachment #1 of the procedure is used to estimate the time to boil. If SDC or ADHRS cannot be restored within this time, the following steps are taken: SP cooling is initiated, all vents are closed (F001, F002, and F005), the MSIVs are closed, the RCIC steam line isolation valves are closed, SRVs are manually operated so that two of them are open, the vessel level is increased with any available means to 101 inches to 129 inches to allow water discharge to the SP, LPCS and/or LPCI are actuated to supply coolant to the vessel from the suppression pool,

and the unit is taken to cold shutdown per procedure #03-1-01-3. See Table B.5.3 for the important steps corresponding to this portion of the procedure.

B.5.2 Fuel in the Vessel and the RPV Head is Off

If inadequate decay heat removal is encountered with the vessel head removed, the mitigative actions depend on whether or not the upper reactor cavity pool is filled with water. If the upper cavity is filled with water, then fuel pool cooling is maximized if necessary until SDC with RHR or ADHRS can be re-established. (As discussed in Section B.3, the vessel water, the upper reactor cavity pool, the upper containment pool, and the spent fuel storage pool are interconnected when the head is off and the gates and valves isolating the pools are open. In this situation, the pool cooling system can cool vessel water as well as pool water.)

If inadequate heat removal is encountered with the vessel head off and the upper reactor cavity pool not filled, then the following steps are taken. Recovery of SDC with RHR or ADHRS is attempted as soon as possible, and vessel level is raised. If SDC with RHR and ADHRS are totally lost, letdown and makeup are increased to the maximum (RWCU and CRD/condensate). If increased letdown is not adequate, the fire water system is aligned to flood the vessel, and appropriate vessel drain lines are opened.

Tables B.5.4 and B.5.5 list the important steps associated with this section of the procedure.

With the vessel head off, if ECCS injection is used, the water injected into the vessel will exit the open top and fill the upper containment if the SRV's are unavailable due to installation of steam line plugs. In this situation, the operator will throttle ECCS injection to avoid overfilling upper containment.

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Table B.1.1
Precautions, Limitations, and Actions Associated with Procedure 03-1-01-2

<u>Step</u>	<u>Description</u>
2.2	Adhere to power distribution limits specified in Tech Spec 3/4.2.
2.4	Generator loading must be within limits of the curves given in Figures 1 and 2.
2.5	Maintain thermal power less than or equal to that allowed as a function of core flow as specified by "Power to Flow Operating Map".
2.7	Balance recirculation loop flows per Tech Spec 3.4.1.3.
2.10	Decrease load as specified when feedwater heaters/reheaters are out of service.
2.16	Do not pull rods if thermal power > 20% unless TBVs are closed (Tech Spec 3.4.1).
2.21	At turbine loads < 50% condensor vacuum should be maintained ≥ 3.63 psia as steam cooling on last stage blades is minimal.

Table B.1.2 Summarization of Procedure Steps Necessary for Low Power to Full Power Increase

Step	OC Reactor Power, P Electric Power, P P (psig) T (°F)	Reactivity	Heat Removal	Comments
5.0 Low power to full power increase	OC 1 $P_t \sim 15\%$ $P_o \sim 15\%$ P_{rated} $T_{sat}(p)$	Critical on rods with recirculation low speed, FCVs full open	Loaded turbine and turbine bypass	
5.1 Obtain loading instructions from system dispatcher				
5.2 Increase load demand in increments until TBVs are closed		Reactor power fixed; send more steam to turbine and less via TBVs		As flow to turbine increases, turbine header pressure drops below TBVs set point and bypass valves close.
5.3 Before increasing thermal power > 20%, verify TBVs closed per Tech Spec 4.1.4.1		Change reactor power with rods only until switch recirculation to high speed and establish rod pattern (5.11 and 5.16)	Loaded turbine	Load demand increase opens TCVs, generator voltage automatically shifts in phase to provide more electrical power. Don't pull rods if < 20% power <u>unless</u> TBVs closed.
5.4 Check that RFPT is on FW master level controller before exceeding 20% power				Off startup, on master level controller
5.5 Hold for 1.5 hrs. at ~20% power				Allow for gathering of heat rate data
5.7 As soon as low power setpoint (LPSP) exceeded, verify RWL operability per Tech Spec 4.1.4.2.6.1				LPSP = 20% P RWL is Rod Withdrawal Limiter (for power peaking)

Table B.1.2 Summarization of Procedure Steps Necessary for Low Power to Full Power Increase

Step	OC Reactor Power, P Electric Power, P P (psig) T (°F)	Reactivity	Heat Removal	Comments
5.10 At ~40% power hold for 1.5 hrs.				Allow for gathering of heat rate data
While changing reactor power, stay out of Region IV, Tech Spec figure 3.4.1.1-1. If in Region IV, reduce power to be in Regions II or III within 2 hours				
5.11 When reactor power stable > 34% and below 80% rod line, shift-recirculation pumps to high speed		Critical on rods, don't increase recirculation until Step 5.16		Switch to hi speed when clear low FW flow limit (~30%), set FCVs on min. open <u>before</u> speed change (30% FW is control valve cavitation interlock)
5.13 At ~40 to 45% reactor power, verify level, steam, and feed flow are stable. Place FW control in 3-element mode				3 element mode is where RFP speed is a function of vessel water level, steam flow, and FW flow
5.14 At ~45 to 55% reactor power, place 2nd RFPT in service on master level control, place 2nd circ. water pump in service				
5.16 When desired flow control line reached, increase power by increasing recirculation flow with loop controllers in manual		Increase power with recirculation after desired rod pattern reached		Rod pattern fixed, increase power by opening FCVs
5.17 At ~60% power, hold ~1.5 hrs.				Allow for gathering of heat rate data

Table B.1.2 Summarization of Procedure Steps Necessary for Low Power to Full Power Increase

Step	OC Reactor Power, P Electric Power, P P (psig) T (°F)	Reactivity	Heat Removal	Comments
5.20 As soon as high power set point (HPSP) reached (~70%) demonstrate RWL operability. At ~80% power 90% core flow all ECCS line break alarms should be cleared; enter applicable LCOs for any like break alarms not cleared of these conditions				Assumed: "ECCS line break alarm;" is associated with the "low pressure" sensors in the ECCS actuating I&C, per TS 3/4.3.3. Table 3.3.3-1. These sensors provide "injection permissive" signals to allow LPCI and LPCS to actuate on either low vessel level or on high drywell pressure if pressure is also low.
5.21 At ~80% power maintain steady state for 1.5 hrs.				Allow for gathering of heat rate data
5.24 At ~100% power hold for ~1.5 hrs.				Allow for gathering of heat rate data

Table B.1.3 Summarization of Procedure Steps Necessary for Full Power to Low Power Decrease

Step	OC Reactor Power, P_t Electric Power, P_e P (psig) T (°F)	Reactivity	Heat Removal	Comments
6.0 Full power to low power decrease	OC 1 $P_t \sim 100\%$ $P_e \sim 100\%$ P_{rated} $T_{sat}(p)$	Rods positions and recirculation flow	Loaded turbine	
6.1 Notify system dispatcher before decreasing generator load				
6.3 Decrease power by closing FCVs		Decrease with recirculation flow		
6.4 Below $\sim 14 \times 10^6$ lbm/hr FW flow secure 1 condensate booster, then 1 condensate pump				
6.7 Before reducing core flow < 45% begin inserting rods		Decrease with recirc. flow; and rods when $\sim 45\%$		Insert rods per SOI 04-1-01-C11-2
6.10 At $\sim 45\%$ to 55% reactor power, secure one RFPT				
6.12 Before FW decreases to 30% and after below 80% rod line, switch recirculation to low speed and open FCVs to maximum.		Decrease with rods once switch to low speed		
6.17 At ~ 20 to 25% rated FW flow, verify stable level, transfer to single element control				

Table B.1.3 Summarization of Procedure Steps Necessary for Full Power to Low Power Decrease

6.19 At 15 to 20% power, remove steam side of HP FW heaters from service				
6.20 At ~15 to 20% power transfer FW to startup level controller				
6.21 At ~15 to 20% generator load (196-261 MWe) shutdown MSRs				
6.22 At generator load ~157 MWe verify off load demand				Load demand control only > 157 MWe; speed demand control below 175 MWe
6.23 Insert IRMs				
6.24 Notify system dispatcher generator is ready to be disconnected from grid				
6.25 Insert rods until 100 to 150 MWe				
6.26 Manually trip turbine				
6.28 Generator auto trips on reverse power (bypass valves maintain reactor pressure)			Turbine bypass to condenser	With no driving power, generator acts like a motor (reverse power)

Table B.1.4 Summarization of Procedure Steps Necessary for Rapid Power Reduction

Step	OC Reactor Power, P_t Electric Power, P_e P (psig) T (°F)	Reactivity	Heat Removal	Comments
7.0 Rapid power reduction	OC 1 $P_t \sim 100\%$ $P_e \sim 100\%$ P_{rated} $T_{sat}(p)$			
7.1 Reduce recirculation flow using fast detent, then insert rods if further power reduction necessary or if scram occurred then follow 6.0; enter ONEP-05-1-02-I-1 "Reactor Scram"				Take appropriate action if in unallowed power/flow regions

Table B.2.1 Precautions, Limitations, and Actions Associated with Procedure 03-1-01-3

<u>Step</u>	<u>Description</u>
2.1	With mode switch in STARTUP, an APRM block occurs at 12 % power, scram at 15 % power.
2.2	With mode switch in RUN, APRM rod block if power < 5 % (Procedure #03-1-01-1 Step 2.1.10 says 4 %).
2.4	Maintain vessel level normal + 32 to 40 inches.
2.5	Cooldown rate $\leq$ 80°F/hr.
2.6	Follow Tech Spec Figure 3.4.6-1-1 for vessel materials integrity.
2.8	If desired to remain in hot shutdown, reduce Rx pressure to approximately 400 psig to minimize feedwater (feedwater temperature approximately 100 °F with no feedwater heaters; T_{sat} (400 psig) is approximately 450°F).
2.10	If cold shutdown is required, refer to SOI #04-1-01-E12-1 and have shutdown cooling flushed & ready for service as soon as pressure permits.
2.12	Do not run two RWCU pumps in post pump mode at < 200 psig RPV pressure as loss of NPSH may occur.

Table B.2.2 Summarization of Procedure Steps Necessary for Cool down with the MSIVs Open

Step	OC Reactor Power, P_t Electric Power, P_e p (psig) T (°F)	Reactivity	Heat Removal	Comments
5.0 Shutdown and Cooldown MSIVs open	OC 1 $P_t \sim 12\%$ $P_e = 0$ P_{rated} $T_{sat}(p)$	Rods and recirculation on low speed	Turbine bypass to condenser	
5.5 If rapid and complete shutdown desired manually scram and refer to ONEP 05-1-02-I-1, Reactor Scram				
5.8 Insert rods in specified order to reduce power to 8%, insert IRMs	$P_t \sim 8\%$			
5.10 Ensure SRs met to change mode				
5.12 Place mode switch in STARTUP	OC 2			
5.15 Continue to insert rods	OC 2 $P_t \sim 0$			
5.15 Insert SRMs, verify turbine bypass valves close at 950 psig (pressure setpoint), continue to insert rods until all rods in			None (until 5.20)	With 0 power, turbine header pressure decreases
5.16 Verify all signoffs for entry into Mode 3, verify SRs met				

Table B.2.2 Summarization of Procedure Steps Necessary for Cool down with the MSIVs Open

Step	OC Reactor Power, P_r Electric Power, P_e p (psig) T (°F)	Reactivity	Heat Removal	Comments
5.17 Place mode switch in SHUTDOWN when all control rods fully inserted	OC 3 $P_r = 0$ $P_e = 0$ $p < p_{rated}$ $T_{sat}(p)$	All rods in	None (until 5.20)	Decay heat only
5.20 Initiate and maintain cooldown < 80 °F/hr by manually opening/ closing TBVs			TBVs on manual to condenser	Cooldown by lowering pressure $T_{sat}(p)$ decreases via controlled flashing
5.21 Control level with FW				
5.24 Secure SJAEs and use mechanical pump for condenser vacuum				
5.24.1 At a 500 psig secure the running RFPT				FW pumps off line
5.24.2 Check that only 1 condensate booster and 1 condensate pump running				Level control still with FW injection
Note: If no recirculation per TS 3.4.9.1, one loop of SDC must be in service within 2 hrs. of $p < 135$ psig				RHR SDC only if $p < 135$ psig
Caution: Do not secure one mode of heat removal before establishing another				
5.25 Maintain TBVs in operation for cooldown as long as possible; when necessary place RHR SDC in operation			From TBVs to RHR SDC	RHR SDC per procedure SOI-04-1-01-E12-1

Table B.2.2 Summarization of Procedure Steps Necessary for Cool down with the MSIVs Open

Step	OC Reactor Power, P_t Electric Power, P_e p (psig) T (°F)	Reactivity	Heat Removal	Comments
5.26 At 200 psig secure 1 RWCU pump if both are running				
5.27 At 100 psig transfer RWCU to pre-pump mode				RWCU blowdown to condenser or radwaste, can take over level control from FW
5.29 Shut the TBVs, set steam demand setpoint 100 psig > reactor pressure	OC 3 $P_t = 0$ $P_e = 0$ $p < 135$ psig T_{sat} (p)		RHR SDC	
5.30 Break condenser vacuum if desired - Shut down mech vacuum pump - Open condenser vacuum breakers - Shut down gland seal steam - Shut down circ. water, if desired				
5.31 When $T < 190^\circ\text{F}$, open F001, open F002, and close F006	OC 4 $P_t = 0$ $P_e = 0$ $p = 0$ psig $T < 190^\circ\text{F}$ subcooled			Vent primary to atmosphere
To prevent thermal stratification, maintain recirculation on low speed				

Table B.2.2 Summarization of Procedure Steps Necessary for Cool down with the MSIVs Open

Step	OC Reactor Power, P_t Electric Power, P_e p (psig) T (°F)	Reactivity	Heat Removal	Comments
If recirculation or shutdown cooling lost, go to procedure ONEP 05-1-02-III-1				Inadequate decay heat removal procedure (ONEP 05-1-02-III-1) (off normal event procedure)
5.32 Cool down to and maintain 120-130°F	OC 4 $P_t = 0$ $P_e = 0$ $P = 0$ psig			
5.33 Secure condensate/FW system				Level control with RWCU
5.34 Reject water with RWCU to maintain normal level				Reject to counter CRD hydraulic injection
5.35 While maintaining COLD SHUTDOWN and as necessary to maintain desired reactor coolant temperature operate RHR in SDC per SOI 04-1-01-E12-1				

Table B.2.3 Summarization of Procedure Steps Necessary for Cool down with the MSIVs Closed

Step	OC Reactor Power, P_t Electric Power, P_e p (psig) T (°F)	Reactivity	Heat Removal	Comments
6.0 Shutdown and Cooldown with MSIVs closed	OC 1 $P_t \sim 12\%$ $P_e = 0$ $p = p_{rated}$ $T_{sat}(p)$	Rods and recirculation on low speed	Turbine bypass to condenser (if MSIVs open)	This section assumes MSIVs initially open. If MSIVs are closed perform only applicable steps
6.5 Check for availability of operation (with MSIVs closed) of: - RCIC - RWCU (level control) - SRVs - SP - SSW				
6.6 If rapid and complete shutdown desired, scram reactor and follow ONEP 05-1-02-I-1 "Reactor Scram"				
6.9 Insert rods and reduce power to $\sim 8\%$, insert IRMs, mode switch to STARTUP	OC 2 $P_t \sim 8\%$			
6.15.9 Insert all rods, verify signoffs for entry to OC 3	OC 2 $P_t \sim 0\%$			
6.17 Place mode switch in SHUTDOWN when all rods inserted	OC 3 $P_t \sim 0\%$			

Table B.2.3 Summarization of Procedure Steps Necessary for Cool down with the MSIVs Closed

Step	OC Reactor Power, P _r Electric Power, P _e p (psig) T (°F)	Reactivity	Heat Removal	Comments
In following it is assumed RCIC operable; if not, use HPCS for makeup and cycle reliefs (SRVs)				MSIVs still open (close in 6.25/26)
6.23 Start up RCIC per SOI 04-1-01-E51-1			Turbine bypass if p > 950 psig and RCIC	
6.24 When level and pressure stable and being maintained with RCIC, shut down running RFPT and secure FW and condensate.				
6.25 Close Inboard MSIVs			RCIC only	Close in board MSIVs
6.26 When pressure downstream of Inboard MSIVs ~ 0, close outboard MSIVs			RCIC	All MSIVs closed
6.29 As necessary use RWCU to assist in level control				
6.32 When p < 135 psig place RHR in SDC mode per SOI 04-1-01-E12-1	OC 3 p < 135 psig T _{sat} (p)		RCIC and RHR	
6.34 Before 75 psig shutdown RCIC			RHR	
6.35 At 60 psig check RCIC auto isolation				

Table B.2.3 Summarization of Procedure Steps Necessary for Cool down with the MSIVs Closed

Step	OC Reactor Power, P_t Electric Power, P_e p (psig) T (°F)	Reactivity	Heat Removal	Comments
6.36 When $T < 190^\circ$ vent by opening F001 and F002 and closing F005	OC 4 $P_t = 0$ $P_e = 0$ $p = 0$ psig $T < 190^\circ\text{F}$ subcooled		RHR	Vent the primary
Maintain recirculation low speed. If forced circulation or SDC lost, Go to ONEP 05-1-02-III-1	-			Inadequate decay heat removal procedure
6.37 Cooldown to and maintain $120\text{-}130^\circ\text{F}$	OC 4 $P_t = 0$ $P_e = 0$ $p = 0$ psig $T \sim 120^\circ\text{F}$ subcooled		RHR	
6.39 Maintain level with RWCU				

Table B.3.1
Precautions and Limitations Associated with Procedure 03-1-01-5

<u>Step</u>	<u>Description</u>
2.19	Recirculation on low speed. Go to ONEP 05-1-02-III-1 ("Inadequate Decay Heat Removal") if recirculation or SDC lost.
2.20	Limit cooldown $\leq 100^{\circ} \Delta F/hr$.
2.21	Adhere to pressure and temperature limits per Tech Spec Figure 3.4.6.1-1.
2.22	Vessel temperature $> 70^{\circ}F$ when studs tensioned.

Table B.3.2 Summarization of Procedure Steps Necessary for Plant Cool down and Entry into OC 5

Step	OC Reactor Power, P_r Electric Power, P_e p (psig) T (°F)	Reactivity	Heat Removal	Comments
5.0 Cooldown & entry to mode 5	OC 3 $P_r = 0$ $P_e = 0$ $T > 200^\circ\text{F}$ $p_{sat}(T)$			
5.1 Cooldown with TBVs until pressure interlock for SDC clears			TBVs to condenser	≤ 135 psig for SDC
5.2 Place SDC A or B in operation (refer to TS 3.5.1 and 3.6.3.2)				
5.3 Remove TBVs from service			RHR in SDC mode	
5.4 Fast close inboard MSIVs				Fast closure required to support local leak rate test (LLRT)
5.5 Let pressure downstream of inboard MSIVs drop to 0, then fast close outboard MSIVs, initiate head spray <u>if</u> desired but don't exceed 100°F/hr cooldown				Head spray to cooldown head for detensioning
5.7 At 200 psig transfer RWCU to blowdown mode				
5.8 With condensate and startup level controller raise level $>$ flange				$\sim 230''$ on shutdown range
5.9 Continue cooldown to 80 to 100°F			RHR on SDC	
5.10 At 60 psig verify RCIC auto isolates	OC 4			
5.12 Open HFTS transfer tube closure hatch				Connect spent fuel pool in aux building to upper pool in containment

Table B.3.2 Summarization of Procedure Steps Necessary for Plant Cool down and Entry into OC 5

Step	OC Reactor Power, P_r Electric Power, P_e p (psig) T (°F)	Reactivity	Heat Removal	Comments
5.14 Open containment air locks				
5.17 Containment and drywell equipment hatches removed				
5.20 Install upper pool to reactor upper cavity gate and inflate gate seal				Isolate upper cavity from upper pool to allow draining upper cavity
5.21 Drain upper cavity to RWST				Refueling water storage tank (RWST)
5.23 Drain RWST to Hotwell for cleanup in preparation for reflooding upper pool if required				
5.24 Remove drywell head				
5.25 Lower vessel level to 1 ft or move below flange and verify head spray not in service				
5.26 Remove connections to RPV head				
5.29 Detension RPV head	OC 5			
5.30 Remove RPV head				
5.31 Throttle recirculation to reduce water ripple				
5.32 Establish containment cleanup mode ventilation. May remove airlock doors and equipment hatches				
5.33 Remove RPV steam dryer				
5.34 Drain level to below steam lines				~ 90" on shutdown range

Table B.3.2 Summarization of Procedure Steps Necessary for Plant Cool down and Entry into OC 5

Step	OC Reactor Power, P _r Electric Power, P _e p (psig) T (°F)	Reactivity	Heat Removal	Comments
5.35 Install steam line plugs				Can't use SRVs with plugs installed
5.37 Reflood reactor cavity from RWST. Lift steam separator as reactor cavity fills				5.23 Drained RWST?
5.39 Deflate gate seals and remove upper pool to reactor upper cavity gate				
5.42 Commence required in-vessel work (e.g., fuel movement)			SDC with RHR	

Table B.3.3 Summarization of Procedure Steps Necessary for Reactor Pressure Vessel Reassembly and Entry into OC 4

Step	OC Reactor Power, P _r Electric Power, P _e p (psig) T (°F)	Reactivity	Heat Removal	Comments
6.0 Pressure vessel reassembly	OC 5		RHR or SDC	
6.5 Upper pool to reactor cavity gate installed and seal inflated				
6.7 Drain upper reactor cavity to RWST. Lower level to 1 ft. below flange				
6.8 Install steam separator				
6.9 Lower vessel level below main steam lines				
6.10 Deflate and remove main steam line plugs				
6.12 Install steam dryer				
6.13 Install RPV head				
6.15 Tension RPV head studs				
6.17 Place mode switch in SHUTDOWN	OC 4			
6.21 Commence RPV heatup in preparation for 03-1-01-6			SDC	Throttle SDC to heat up
6.24 Install drywell head				
6.26 Reflood upper reactor cavity				
6.27 Deflate gate seals and remove upper pool to reactor upper cavity gate				

Review Procedures

Table B.4.1
Precautions, Limitations, and Actions Associated with Procedure 03-1-01-1

<u>Step</u>	<u>Description</u>
2.1.4	Period $\geq$ 50 Sec
2.1.9	In STARTUP an APRM Rod Block occurs at 12% Power and an APRM Scram at 15% Power.
2.1.10	In RUN RPRM Rod Block it $<$ 4% Power.
2.1.11	No Rod Withdrawal unless TBVs fully closed and power $>$ low setpoint of RCII's (rod control and information system).
2.2.3	Maintain heatup to $\leq$ 80° F to prevent exceeding Tech Spec 3.4.6.1 limits
2.10.1&2	No gland seal steam to turbine if shaft not turning. Turbine on turning gear for 24 hour if performing a cold startup and 1.5 hrs for a hot startup if turbine not off turning gear during shutdown.
2.10.11	At turbine loads $<$ 50%, condenser vacuum $\geq$ 3.63 psia since little steam cooling occurs on the last stage of the turbine under $<$ 50% load.

Table B.4.2 Summarization of the Procedure Steps Necessary for Reactor Startup

Step	OC Reactor Power, P_r Electric Power, P_e P (psig) T (°F)	Reactivity	Heat Removal	Comments
5.0 Reactor Startup	OC4 or 3 P_r = decay heat P_e = 0 p and T per 5.4			Only in OC3 if $T > 2000$ per Step 5.4
5.1 Verify recirculation in operation on low speed		Rods positions per mode Switch in Shutdown on REFUEL	Per prerequisite 3.3.3, RHR can be out of shutdown cooling mode, thus <u>no</u> heat removal (except for CRD injection RWCU letdown)	If unit has been shutdown ≥ 20 days, decay heat in low, and in preparation for startup RHR SDC may be stopped & RHR lined up for LPCI. This is OK since 1. heatup is slow (curves in 05-1-02-III-1). 2. Rx will be heated up anyway. 3. RHR lined up for LPCI <u>See Step 5.15.</u>
5.2 Verify CRD hydraulic system in operation 54-66 gpm				
5.3 Verify level 32 -> 40" being maintained by RWCU letdown to main cond or radwaste (letdown to match CRD injection)				
5.4 If inboard MSIVs open or $T \geq 190^\circ\text{F}$ verify: close F001 & F002 open F005 If inboard MSIVs closed and $T \leq 190^\circ\text{F}$ verify: open F001 & F002 closed F005	$T \geq 190^\circ\text{F}$ $P = P_{set}(T)$ $T \leq 190^\circ$ $p = 0$			If $T < 200^\circ\text{F}$, in OC3 in OC 4
5.6 Verify SFMs IRMs full in IRMs full in IRMs range 1				
5.8 Verify all OPERABLE rods in				

Table B.4.2 Summarization of the Procedure Steps Necessary for Reactor Startup

Step	OC Reactor Power, P_t Electric Power, P_e P (psig) T (°F)	Reactivity	Heat Removal	Comments
5.15 Verify RHR A,B,C in Standby (or in mode not requiring manual re-alignment for LPCI)				No shutdown cooling; see comment associated with Step 5.1.
5.20 Verify chemistry				
5.23 Place mode switch in STARTUP	OC2 P_t = decay heat P_e = 0 p and T per 5.4			TS Table 1.2 allows 'any temp' for OC2. Normal cold startup passes from OC4 to OC2 <u>without</u> any time in OC3 Heatup on nuclear heat; not pump heat as for PWR
5.29 Pull 1 rod or 1 barg				
5.23 Withdraw rods until Rx critical				
5.38 Fully withdraw SRMs when IRMs on $\geq$ range 3				

Table B.4.3 Summarization of the Procedure Steps Necessary for Unit Heatup

Step	OC Reactor Power, P_r Electric Power, P_e P (psig) T (°F)	Reactivity	Heat Removal	Comments
6.0 Unit Heatup				
6.1 Establish Main Cond Vacuum - If MSIVs closed, at ~190°F: open F005, close F001 & F002 - verify main turbine & RFPTs on turning gear - lineup seal steam condensate to main turbine & REPTs - draw vacuum in main cond using mech vacuum pumps to maintain 20 to 26" Hg - place cond demin's in service	$P = P^{sat}(T)$ once F001 & F002 closed			

Table B.4.3 Summarization of the Procedure Steps Necessary for Unit Heatup

Step	OC Reactor Power, P _r Electric Power, P _e P (psig) T (°F)	Reactivity	Heat Removal	Comments
<p>6.2 Rx Heatup and Pressurization</p> <ul style="list-style-type: none"> - If bypass <u>stop</u> valves closed, open them - verify chemistry - verify 1 cond pump in oper; if pump in oper & if p > 400 psi one RFPT should also be in oper. - ensure at least 2 CCW & TBCW HYs in service - establish FW level control with startup level controller <ul style="list-style-type: none"> • manually adjust then place in auto at 36" • increase to 40" before opening MSIVs to compensate for level decrease - if MSIVs closed: <ul style="list-style-type: none"> • equalize steam p across MSIVs • open MSIVs at desired RX pressure - at ~60 psig <ul style="list-style-type: none"> • place RCIC in standby • stop letdown when no longer needed for level control 				

Table B.4.3 Summarization of the Procedure Steps Necessary for Unit Heatup

Step	OC Reactor Power, P_r Electric Power, P_e P (psig) T (°F)	Reactivity	Heat Removal	Comments
<p>6.2 Rx Heatup and Pressurization (Continued)</p> <ul style="list-style-type: none"> - At ~100 psig transfer RWCU to post pump made with 1 pump & filter in service - At ~200 psig place 2nd RWCU pump & filter in service - At ~400 psig pull rods as necessary to obtain at least 10% bypass valve opening (for FW pump start) - Place 1 RFP in service and insure 2nd RFP is ready for service - At ~500 to 800 psig <ul style="list-style-type: none"> ◦ place SJAE in service • depress HPCS hi level reset button when level 8 (+55") HI annunciator cleared - At ~950 psig when turb stm press demand has been raised to 950 psig, stop - Raise P setpoint and allow bypass valves to open as P_r increase - Transfer to RUN as follows: <ul style="list-style-type: none"> • verify all mode change conds met - Withdraw rods until APRM down-indicator lights off (~4% power) - Verify main stm pressure > 850 psig - Transfer mode switch to RUN - withdraw IRMs & place on range 3 - continue rods withdrawal for p to give 5-10% total steam flow 	<p>OC2 $P_r \sim 4\%$ $P_e = 0$ $P > 950$ $T = T_{sat}(P)$</p> <p>OC1 $P_e = 0$ $p > 950$ $T = T_{sat}(P)$</p>	<p>Rods positions to hold critical at desired P (overcome doppler)</p>	<p>Turbine bypass to main cond.</p> <p>Turbine bypass to main cond.</p>	<p>Rx pressure higher (~950 psig)</p> <p>Ts Table 1.2 says OC1 can have 'any temperature'</p>

Table B.4.4 Summarization of the Procedure Steps Necessary for Turbine Startup and Generator Synchronization

Step	OC Reactor Power, P_r Electric Power, P_e P (psig) T ($^{\circ}$ F)	Reactivity	Heat Removal	Comments
7.0 Turbine Startup + Generator Synchronization	OCI $P_5 > 10\%$ $P = 0$ $P \sim 950$ $T = T_{sat}(P)$	Critical at desired power with rods	Turbine bypass to main cond.	on FW level control
7.1 Turbine startup - Reset turbine trip solenoids & begin TSV warming, open HP and LP TSVs - Place 2nd stage heating steam for MSR into service - Roll turbine to 400 rpm as follows: • verify on turbine gear sufficiently long • verify sufficient Rx steam to roll to 180 rpm • set ETTC sp demand to 400 rpm (opens TCVs) • verify vibration OK at 400 rpm - increase turbine to 180 rpm as follows: • set ETTC sp demand to 1800 (TCVs open) + • verify 1800 rpm - verify TBVs at least 20% open			Turbine bypass + unloaded turbine	TCVs still closed Limitation 2.10.2 Roll the turbine Turbine totaled speed Ensure adequate steam for generator sync & min loading

Table B.4.4 Summarization of the Procedure Steps Necessary for Turbine Startup and Generator Synchronization

Step	OC Reactor Power, P_i Electric Power, P_e P (psig) T (°F)	Reactivity	Heat Removal	Comments
<p>7.2 Generator Synchronization</p> <ul style="list-style-type: none"> - ensure motor disconnect J5230 ready to be closed - For breakers J5228 + J5231: <ul style="list-style-type: none"> • verify switchyard lineup is such that 228 + 232 can be opened without losing loads; open 228 + 232 - close disconnect J5230 - place isophase bus cooling in oper. - notify load dispatcher ready to sync to grid - verify generator > 1710 rpm + close generator field breaker - adjust generator output to 22Kv - close breaker J5228 or J5232 - depress ETTC sp demand to 1805 rpm - watch synchroscope + decrease speed slowly until synchroscope is slowly rotating in clockwise (fast) direction - At 12 o'clock on synchroscope, close J5232 (or J5228) [depending on which closed earlier] - Increase gen load immediately (by increasing speed demand of EHC) to > 75 Mw but $\leq$ 150 Mw - Establish 1st stage MSR heating steam - Raise gen output to 175 Mw with EHC demand (~1812 rpm demand) - Transfer from speed demand control to load demand control - Do not exceed 34% power in the procedure - Start 2nd cond & Booster pump - Maintain 1812 rpm 175 Mwe - Place HP FW Ltrs in service 	<p>1 $P \sim 10\%$ $P \sim 75$ to 150 Mw $P > 950$ T = $T_{sat}(P)$</p> <p>$P_e \leq 24\%$ rated</p>	<p>Turbine bypass & unloaded turbine</p>		<p>Voltage regulator in AUTO whenever generator II turgid, except if regulator fails (regulates terminal voltage by varying exciter hence emf) J5230 ties gen to switchyard (FSAR Fig. 8.1-1) J5228 + 232 tie gen to switchyard (FSAR Fig 8.1-1)</p> <p>Generator freq slightly above grid; ready to sync</p> <p>Generator sync'd to grid; at any fixed synchroscope position, gen. & grid frequency are equal; at 12 o'clock position, in addition to frequencies being equal, in each of 3 phases induced emf is equal and opposite (180° out of phase) with line voltages and hence generator is <u>not</u> loaded.</p> <p>Ensure ~ 175 Mwe at least regardless of load demand</p> <p>HP FW Htr steam extraction lines have isolation valves that are opened to place HPFW Htrs in service</p> <p>LP FW Htr steam extraction lines <u>probably</u> have only check valves</p>

Review Procedures

Table B.5.1
Symptoms Which Require Use of Procedure 05-1-02-III-1

<u>Step</u>	<u>Description</u>
2.2	Malfunction of RHR or SSW component associated with SDC mode of RHR.
2.3	Less than adequate RHR SDC flow.
2.4	Uncontrollable increase in reactor coolant temperature.
2.5	Steaming from head vents even though reactor coolant temperature indicates < 212 °F.
2.6	RPV pressurization in OC4, Cold shutdown.
2.7	Loss of ADHRS flow or loss of PSW to ADHRS.

Table B.5.2
Immediate Operator Actions

<u>Step</u>	<u>Description</u>
4.1	Check reactor pressure and temperature.
4.2	Check spent fuel pool temperature.
4.3	Ensure redundant loop available.
4.4	Increase frequency of monitoring temperature and reactor pressure.

Table B.5.3 Summarization of Steps Necessary to Restore Decay Heat Removal When Fuel is in the Vessel and the Unit is in OC 4

Step	OC Reactor Power, P Electric Power, P _e p (psig) T (°F)	Reactivity	Heat Removal	Comments
5.0 Subsequent Operator Actions				
If unable to restore decay heat removal prior to reaching OC 3, isolate ADHRS (close F066A, F410, and F424)				ADHRS suction design pressure is 80 psig
5.1 Fuel in vessel	OC 4			
5.1.1 If in-service RHR loop in SDC lost, place redundant loop in operation per SOI 04-1-01-E12-1 or place ADHRS in operation per same procedure	OC 4		RHR in SDC (backup loop) or ADHRS, recirculation on low speed	"Time to boiloff" curves attached to this procedure; also minimum core flows provided in attachment
5.1.2 If forced recirculation lost, raise level to 82" to promote natural circulation, attempt to regain recirculation. If RHR SDC also lost, operate head spray			RHR in SDC, natural circulation	Core water hotter than downcomer water due to loss of circulation.
5.1.3 If RHR SDC and ADHRS completely lost <ul style="list-style-type: none"> - Increase RWCU reject to max and use CRD and condensate for makeup - Use Attachment 1 to estimate time to boil - If adequate cooling cannot be maintained or restarted in acceptable amount of time: <ul style="list-style-type: none"> •Initiate SP cooling •Close F001, F002, and F005 			None	<p>ΔH RWCU provides some heat removal; only enough if unit has been shutdown for a long time, RWCU max ~360 gpm. With vent to atmosphere, boil at 212°F</p> <p>SOI 04-1-01-E12-1</p> <p>Isolate all vent paths</p>

Table B.5.3 Summarization of Steps Necessary to Restore Decay Heat Removal When Fuel is in the Vessel and the Unit is in OC 4

Step	OC Reactor Power, P_r Electric Power, P_e p (psig) T ($^{\circ}$ F)	Reactivity	Heat Removal	Comments
5.1.3 (Continued) <ul style="list-style-type: none"> •Close MSIVs •Close RCIC steam line isolation valves •Open/shut SRVs so that 2 SRVs are open •Increase RPV water level (using any available injection system) to 101 to 129" to flow through open SRVs to SP •Start the LPCS or LPCI with suction from SP •Increase LPCS/LPCI to maximum. If RPV pressure does not stabilize > 55 psig, then start additional LPCS/LPCI pumps until $p > 55$ psig. If RPV > 202 psig open another SRV. Maintain cool down < 100 $^{\circ}$F/hr by throttling flow of LPCS/LPCI if necessary. 			LPCI/LPCS injection, water out SRVs (MSIVs closed)	Use relief/manual mode to open 2 SRVs Steam lines rated for full water load up to MSIVs SOI 04-1-01-E12-1
<ul style="list-style-type: none"> •Control SP temp to maintain RPV temp > 70 $^{\circ}$F •Go to cold shutdown per procedure IOI 03-1-01-3 "Plant Shutdown" 				Don't go below 70 $^{\circ}$ F with head bolts tensioned

Table B.5.4 Summarization of Steps Necessary to Restore Decay Heat Removal When Fuel is in the Vessel and the RPV Head is Off

Step	OC Reactor Power, P_r Electric Power, P_e p (psig) T (°F)	Reactivity	Heat Removal	Comments
5.2 Fuel in vessel, RPV head removed				
5.2.1 With upper pools <u>filled</u> - Notify refueling crew - Maximize fuel pool cooling if necessary - Re-establish SDC or ADHRS ASAP				If upper reactor cavity filled and gate to upper containment pool and fuel transfer tube open to spent fuel pool, then fuel pool cooling cools pools and vessel
5.2.2 With upper pools <u>not</u> filled - Contact personnel if any on refueling floor - Raise level - Re-establish SDC or ADHRS ASAP				Cannot use fuel pool cooling to cool vessel
5.2.3 If SDC & ADHRS totally lost, increase RWCU blowdown to maximum and increase makeup with CRD hydraulic and condensate; if inadequate to go 5.3				RWCU maximum ~ 360 gpm

Table B.5.5 Summarization of Steps Necessary to Restore Decay Heat Removal When Fuel is in the Containment or Spent Fuel Pools

Step	OC Reactor Power, P_r Electric Power, P_e p (psig) T (°F)	Reactivity	Heat Removal	Comments
5.3 Decay heat removal for fuel in containment or spent fuel pools				See comment for 5.2.1.
5.3.1 If in-service loop of fuel pool cooling lost, place redundant equipment in operation				
5.3.2 If fuel pool cooling completely lost align pool cooling to RHR				
5.3.3 If fuel pool cooling <u>and</u> RHR lost, inject with fire water				

Appendix C. Overview of Grand Gulf Power Plant

This section is a brief summary of the technical aspects of the Grand Gulf power plant noted in our initial review of the referenced literature which are of special interest for the off-power risk study.

The following literature was reviewed:

- (1) The NUREG 1150 PRA dealing with Grand Gulf at full power [USNRC, 1989]
- (2) The Grand Gulf Updated Final Safety Analysis Report (FSAR) [SERI, 1992]
- (3) The Grand Gulf Technical Specifications [USNRC 1984]
- (4) Numerous Grand Gulf Procedures, as presented in Appendix B
- (5) Class notebooks from the BWR/6 Fundamentals Course in Tulsa [General Electric, 1981]
- (6) The textbook Nuclear Energy Conversion [El-Wakil, 1971]
- (7) The NRC's BWR Fundamentals Manual [USNRC, 1983]
- (8) The GE General Description of the BWR/6 [General Electric, 1980]
- (9) Various sources of information on nuclear power plant components.

The Operational Conditions (OCs) for Grand Gulf are defined in Table 1.2 of the Technical Specifications. At some plants, these are called operational modes. The OCs as defined in the technical specifications are as follows:

<u>Condition</u>	<u>Mode Switch Position and Average Reactor Coolant Temp.</u>
1. Power	Run Any Temperature
2. Startup	Startup/Hot Standby Any temperature

3. Hot Shutdown Shutdown
 > 200 Degrees F

4. Cold Shutdown Shutdown
 ≤ 200 Degrees F

5. Refueling Shutdown or Refuel
 ≤ 140 degrees F

Five conditions are specified: Power Operation, Startup, Hot Shutdown, Cold Shutdown, and Refueling. No condition on K_{eff} is specified for these conditions in contrast to the case for typical PWR tech specs. This is because BWRs use rodged cores with no chemical shim, and the 1% shutdown margin can be maintained by rods alone with the highest single worth rod withdrawn [Section 4.3.2.4.1 of Grand Gulf, UFSAR]. Below Hot Zero Power, PWRs must borate to maintain shutdown margin and their tech specs limit K_{eff} in each mode (operational condition). The table does specify the mode switch position which places limitations on rod positions in each condition as the mode switch activates various rod blocks in its various positions. Section 7 of the UFSAR discusses the limitations imposed by the Mode Switch Position. In the Refueling position, only one control rod can be withdrawn (without special bypass). In the Shutdown position, all rods are in. The control rod circuitry is in a scram state for ten seconds. In the Startup position, a rod block is set at 12% power, and a scram is set at 15% power. In the run position, power can be up to 100%, but the full power protective scrams, and rod position/pattern limits, are present. The tech specs specify reactor coolant temperature limits in each OC, but do not specify pressure. The system is saturated (until it is vented at very low temperatures—typically 190 degrees F) and thus there is a unique pressure at each temperature. Other portions of the tech specs limit pressure to the ASME code allowable (design + 10%) and specify temperature/pressure limits for thermal stress and NDTT considerations in the vessel. The refueling OC does not cover refueling operations. The refueling condition applies for fuel in the vessel with the head studs less than fully tensioned. Refueling operations involving fuel transfer to and from the vessel are subject to tech spec section 3/4.9 "Refueling Operations".

Grand Gulf, like all latter-day BWR designs, is a recirculation controlled plant with turbine following (turbine leading is unstable). At steady state the turbine/generator rotor rotates at 1800 rpm. Load changes within the response capability of the plant are

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accommodated as follows. If it is desired to increase (decrease) the electrical load on the generator, the torque on the turbine shaft must be increased (decreased) to increase the instantaneous speed of the rotor and move it to a new position with respect to the stator windings where the torque from the magnetic field equals the driving torque. In a synchronous electromagnetic machine (alternator) such as an AC generator, with a change in driving torque the rotor changes its instantaneous speed and establishes a new position with respect to the stator so as to produce an equal opposing torque. Once this equality is established, the rotor regains its initial rotational speed. The stability of the speed control is enhanced by the grid 'flywheel' effect which provides synchronizing power to hold the generator output frequency at the grid value. Thus, a change in electrical load does not change shaft speed, so long as the control range of the generator (90 electrical degree shift between rotor position and stator field) is not exceeded. The turbine drives the rotor so as to change the phase angle between grid voltage and generator terminal voltage which changes the power delivered to the grid from the generator. The turbine demand is in response to the load desired on the grid, not in response to speed changes. Speed controllers on the turbine are used in startup (no load), for protection against overspeed if the control range of the generator is exceeded (e.g., loss of load), and for contributing to grid frequency stability by being set at 1800 rpm for 60 cycle. [This discussion on speed stability is specific to a synchronous machine. For a DC generator or an induction motor, speed changes with load.] The change in driving torque is provided by a change in recirculation flow with the turbine following. The load demand signal is sensed by the turbine Electro-Hydraulic Controller (EHC) which interacts with recirculation flow control system to increase (decrease) recirculation flow. (Currently, at Grand Gulf, this automatic load following is not used and recirculation is manually controlled.) This increase (decrease) in recirc flow decreases (increases) the void fraction of the water exiting the core and via negative void fraction feedback the reactor thermal power increases (decreases). The steam header pressure increases (decreases) in response to the increased (decreased) steaming from the core and the turbine pressure controller opens (closes) the turbine control valves to restore header pressure as much as possible (the turbine follows the boiler). The increased (decreased) steam flow to the turbine increases (decreases) the driving torque on the rotor thereby 'instantaneously' (response time determined by rotational inertia of the shaft) shifting the rotor to provide the desired power output. Turbine header pressure is at its

setpoint. The previous increase (decrease) in recirc results in lowering (raising) the vessel downcomer water level. The level is restored to its normal range by increasing (decreasing) feedwater flow, at the new steady state the feedwater flow equals the steam flow.

The following discussion focuses on those systems normally involved in changing operational conditions, such as: turbine and bypass, recirc, and shutdown cooling. These are the systems which the operations personnel will be manipulating during changes in operational condition, and they are those which will first drive the course of any accident scenario. The additional systems - such as LPCI, HPCS, SP Cooling - are already well understood as a result of the NUREG 4550 study. The primary effects on these systems are out-of-service conditions resulting from operational constraints (e.g., switching RHR trains A or B from LPCI to Shutdown Cooling) or resulting from down-for-maintenance as allowed by tech specs.

Since the BWR is operated at saturated conditions, special attention is paid to providing enough Net Positive Suction Head Available (NPSHA) to meet the Net Positive Suction Head Required (NPSHR) for the recirc and RHR pumps to prevent cavitation. When the recirc pumps are at rated speed (1800 rpm) adequate NPSHA is provided by the amount of subcooling due to subcooled feedwater (420 degrees F) mixing with saturated recirculating water from the core exit (549 degrees F) with a recirc ratio - core exit recirc flow to feedwater (or steam) flow - of 7:1. The recirc suction water is 20 Btu/lbm subcooled (about 16 degrees F subcooled) at rated conditions. The recirc pumps are tripped to low speed if the subcooling margin ($T_{\text{steam}} - T_{\text{suction}}$) is less than 8 degrees F. On low speed, the recirc pumps are at 25% speed and adequate NPSHA is provided by the static head of water in the downcomer. This information on recirc NPSHA was taken from Section 5 of the UFSAR. Figure 5.4-4 of the FSAR indicates the NPSHR for the recirc pumps on high speed is about 100 ft. Since head is proportional to pump speed squared, the NPSHR on low speed should be about 1/16 of 100, or about 6 ft (rough estimate neglecting actual system resistance and pump suction details). Since the vessel contains 570 in. of water in normal operation [Figure 5.3-2 of Grand Gulf, UFSAR], it is seen that the static head alone prevents cavitation.

The RHR pumps have a NPSHR of 2 feet, and they are located at an elevation of 96 ft Mean Sea Level (MSL). With saturated water in the suppression pool at its minimum level of 107.5 ft, the NPSHA to the RHR

pumps is 5.8 ft under worst case flow loss conditions. This information is from Section 5 of the UFSAR. Since the vessel is at an elevation above the suppression pool, there is ample NPSHA to the RHR pumps in the shutdown cooling mode due to static head alone.

Certain options for energy removal which cool liquid in the downcomer region (such as RHR/SDC) require that the measured level, measured in the downcomer, be sufficiently high for adequate recirculation between the core and downcomer regions. This required measured level is significantly higher than the top of the core. The recirculation system is normally kept in operation in the off power conditions to reduce thermal stratification (from the Plant Shutdown Procedure. See Appendix B of this report). However, it is not required to be in operation at shutdown, as long as level in the core region is adequate, natural recirculation due to the difference in density between downcomer and core fluid is sufficient. The actual level of concern is the level in the core region which must be above the steam separator turnaround point to allow core water to flow back into the downcomer.

The actual core level is different from the measured level in the downcomer due to the following reasons: The core fluid is a two phase mixture (at power). If the recirculation pumps are on, they raise the core level with respect to the downcomer level. The level measurements are based on a standard delta p sensor which measures the pressure difference between the head of water in the vessel and the head of water in a reference leg filled with condensate. In the safety grade level instrumentation (narrow and wide range), this pressure differential is converted to an equivalent level without compensating for changes in water density with temperature, which causes the measured level to be higher than the actual downcomer level at low temperature conditions.

A design basis accident at power is loss of both recirc pumps [Section 15 of Grand Gulf, UFSAR]. Tech Specs require operator action to scram the reactor via placing the mode switch in the Shutdown position [TS 3/4.4.1 of Grand Gulf, Tech Specs]. This is to reduce the time (prior to trip) during which the thermal margin (critical heat flux ratio) is below normal. The reactor will trip on high water level if the operator fails to manually trip. Note that a decrease in recirculation increases measured water level. The level is measured in the downcomer, and following a decrease in recirculation flow with feedwater flow constant, the level in the downcomer will increase. Without forced recirculation, cooldown is governed by the Inadequate Decay Heat Removal

procedure which instructs operators to ensure natural recirculation by controlling the water level.

The following information is from the UFSAR and the BWR/6 Fundamentals Manual. The recirc system in BWR/5 and 6 designs is flow valve controlled rather than variable pump speed controlled as in earlier designs. The induction motors for the recirc pumps have two speeds: 1800 rpm via a 60 hz line source and 450 rpm via a 15 hz low frequency motor-generator source. The low speed is used during off-power conditions. The pumps are not canned, they use a dual mechanical shaft seal design with controlled leakage, and cooling with the Component Cooling Water (CCW) system. The CCW also cools the lube oil and the air to the motor stator windings. The pump/motors have sufficient inertia to provide slow coastdown to preserve thermal margin until the reactor can be tripped. A seized recirc pump accident is a design basis accident [Section 15 of Grand Gulf, UFSAR]. The high speed power circuit breakers incorporate an Anticipated Transient Without Scram (ATWS) trip coil to reduce power given an ATWS. The recirc flow control valves (FCV) are ball valves, hydraulically operated, with a linear flow control response (C_v versus position). The recirc pumps are always started on high speed with the FCVs at minimum position in order to lift the journals off the bearing faces. Evidently the bearing oil pump is gear driven off the recirc pump shaft and requires high speed to develop enough head to inject oil into the bearing and 'lift' the shaft. Once the pump has started and attained 95 % high speed, the 60 hz source is auto-tripped and the recirc pump coasts down to 25 % speed where the 15 hz power source is engaged. The major recirc pump trips are as follows:

- (1) At any power, trip to low speed if inadequate subcooling for NPSH ($T_{\text{steam}} - T_{\text{recirc}} \text{ suction} < 8$ degrees F)
- (2) At feedwater flow $< 23.3\%$ and FCV $< 24\%$ open, trip to low speed to prevent FCV cavitation
- (3) With either discharge or suction isolation valves $< 90\%$ open, pumps are tripped and cannot be started.

During startup, the plant follows the power flow operating map [Figure 4.4-5 of Grand Gulf, UFSAR]. The recirc pumps are started with the FCVs at minimum open position. Once the pumps trip to low speed, the FCVs are opened to maximum open position. When

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power is $> 30\%$ the low feedwater interlock is cleared, and the recirc pumps are switched to high speed after the FCVs are closed to minimum (to avoid reactivity insertion). The rod pattern is established and the FCVs are throttled open to achieve the desired operating power.

The RHR system has seven modes of operation, five of which are emphasized: LPCI, Containment Spray, SP Cooling, RCIC steam condensing (not used at Grand Gulf), and shutdown cooling [Section 5 of Grand Gulf, UFSAR] [USNRC, 1983]. The other two modes (containment flooding and spent fuel pool cooling) are less likely to be used. At power, RHR is lined up for LPCI and is subject to auto initiation in either that mode or the containment spray mode. Two of the RHR trains, A and B, contain RHR heat exchangers and can be manually realigned for shutdown cooling when in OC 3 if the vessel pressure is below the cut-in permissive [TS 3/4.4.9 of Grand Gulf, Tech Specs]. The cut-in permissive is 135 psig vessel pressure [Section 5 of Grand Gulf UFSAR].

The Reactor Core Isolation Cooling System (RCIC) serves the BWR as does the auxiliary feedwater system at a PWR. RCIC is used to remove decay heat if the main condenser/feedwater heat sink/makeup capability is unavailable [Section 15 of Grand Gulf, UFSAR] [USNRC, 1983]. RCIC has two modes of operation. The auto mode is one in which steam is relieved by the Safety Relief Valves to the SP, and makeup is from either the condensate storage tank or the SP via the steam-driven RCIC pump. This lineup can operate at rated pressure and temperature. The manual mode uses the RHR heat exchangers in a steam condensing mode with their condensate returned to the vessel by the RCIC pump. This mode is only allowed at less than 500 psig reactor pressure due to the limiting design pressure of the RHR heat exchangers. This steam condensing mode can match decay heat 1.5 hr after shutdown. (Grand Gulf does not utilize the RCIC steam condensing lineup.) Since the HPCS is a fully diverse backup for RCIC, tech specs allow RCIC to be unavailable for up to 14 days if HPCS is operable [TS 3/4/7/3 of Grand Gulf, Tech Specs]. The RCIC pump turbine is driven off main steam line A.

The main steam system consists of four main steam lines: A, B, C, and D, details of which are provided in Sections 5 and 10 of the FSAR. Each line contains two Main Steam Isolation Valves (MSIV), one inboard and one outboard of containment, which fail closed and isolate the vessel given such accidents as a main steam

line break. Downstream of the MSIVs, the steam lines provide steam to the high pressure turbine through the turbine stop and control valves. Between the outboard MSIV and the stop/control valves in each steam line, a branch feed is provided to the Reactor Feedwater Pump Turbine (RFPT) supply header. All four main steam lines feed this header. This header also is piped to the three parallel turbine bypass lines each of which contains a turbine bypass valve and discharges to one of the three parallel condensers.

Between the inboard MSIV and the vessel, each main steam line contains Safety Relief Valves (SRVs) which discharge to the SP. As in most BWRs, these valves serve both a safety function and a relief function and are different from the case at most PWRs which use separate safety and relief valves. The safety function is to prevent the primary system from exceeding the ACME code allowable pressure of 1375 psig (design + 10%).

The system cannot be depressurized with the SRVs purely performing their safety function. The SRVs pop open at their safety pressure setting and require no power to do so. The SRVs automatically open at their lower relief setting, require air to do so, and fail closed on loss of air. Accumulators are provided. To operate an SRV in its relief mode, DC powered solenoid control valves in the air supply line must be energized. To depressurize the system, the SRVs can be manually opened, and of the 20 total SRVs eight can be actuated by the Automatic Depressurization System (ADS).

Main steam line A provides steam to the RCIC drive turbine. This steam is provided off the main line upstream of the inboard MSIV. Also, a continuous vent to vent noncondensibles is provided off main steam line A upstream of its inboard MSIV. This vent path is provided with an isolation valve (F005) and two pressure reducing orifices, and it discharges to the main condenser where deaeration occurs. At power F005 is open. This line also connects to the reactor head vent line which vents the vessel to atmospheric pressure when two isolation valves (F001 and F002) are opened. At power F001 and F002 are closed. The Plant Shutdown procedure specifies that when reactor temperature is less than 190 degrees F, F005 is closed and both F001 and F002 are opened. This establishes atmospheric pressure in the vessel and renders the fluid slightly subcooled.

The turbine system is described in Section 10 of the FSAR. The following discussion is based on that information supplemented with information on the design and operational characteristics of power plant

components. The turbine pressure control setpoint is 950 psig. The turbine bypass capacity is 35 % of rated steam. With bypass, the turbine generator system can accommodate a 100 % to 40 % load rejection at up to 1 % per second, and it can accommodate a step load reduction of 35 %. A turbine trip with power greater than 35 % causes a reactor trip. The high pressure turbine exhausts to two parallel Moisture Separator Reheaters (MSR) which reheat the exhaust to remove moisture before feeding the three parallel low pressure turbines. Gland seal steam is supplied by a seal steam generator. Gland seal steam is required to provide controlled bleeding of steam across the turbine seals to prevent air in leakage into the main condenser when it is at vacuum. The seal steam generator is heated by either main steam or turbine extraction, and it supplies nonradioactive steam. The turbine shaft is provided with a hydraulic-driven turning gear to rotate the drum whenever the turbine is heating up or cooling off to minimize thermal stresses which could kink the shaft. The turbine must be on turning gear rotation before any steam is admitted. The Cold Shutdown to Generator Carrying Minimum Load procedure requires that seal steam never be applied to the main turbine shaft seals if the turbine is not on turning gear. When gland seal steam is admitted, it rises to the top of the turbine casing and heats the top of the rotor, while the bottom of the rotor is kept cool due to condenser circulating water. Thus, if the rotor is not turning, it is stressed due to a thermal gradient and can bow and become unbalanced. To prevent thermal stresses, the turbine is kept on turning gear whenever it is heated up or cooled down. The major turbine trips are low condenser vacuum and overspeed. The turbine uses the EHC system for control. The condenser vacuum is maintained by steam jet air ejectors when steam is available and by mechanical vacuum pumps when it is not available.

The feedwater and condensate systems provide feedwater to the vessel. Three 50 % capacity motor driven condensate pumps pull from the intermediate pressure condenser hotwell and supply three 50 % capacity motor driven condensate booster pumps. The flow from the booster pumps is heated by a series of low pressure feedwater heaters, then the water is supplied to two variable speed turbine driven feedwater pumps. The output of the feedwater pumps passes through a series of high pressure feedwater heaters then enters the vessel downcomer at 420 degrees F. Regenerative feedwater heating is used to increase the thermal efficiency of the rankine cycle. During startup, flow to the vessel is supplied by the condensate and booster pumps up to about 550 psig, with the first feedwater pump turbine

rolled off turning gear at about 400 psig. Check valves isolate the vessel following a feedwater line break.

The Reactor Water Cleanup (RWCU) system is used to purify the reactor water. Also, during startup and shutdown when level is not controlled with feedwater, the RWCU system is used to blowdown to either the main condenser or the liquid radwaste system to control level which tends to increase due to fill from the control rod drive cooling system, and due to swell during heatup. This system is indirectly in the tech specs through chemistry control [TS 3/4.4.4, of Grand Gulf, Tech Specs].

References for Appendix C

[USNRC, 1989]	USNRC, "Severe Accident Risks: An Assessment for Five U.S. Nuclear Power Plants," NUREG-1150, June, 1989.	[General Electric, 1981]	General Electric Co., BWR/6 Fundamentals, Operator Training Services, Tulsa, Oklahoma, 1981.
[SERI, 1992]	System Energy Resources, Inc., "Grand Gulf Updated Final Safety Analysis Report", 1992.	[El-Wakil, 1971]	<u>Nuclear Energy Conversion</u> , Intext Educational Publishers, 1971.
[USNRC 1984]	USNRC, "Technical Specifications, Grand Gulf Nuclear Station Unit No. 1," Docket No. 50-416, Appendix "A" to License No. NPF-29, NUREG-0934, October, 1984.	[USNRC, 1983]	USNRC, Course Material for R-104B, "Technology Manual for BWR/4 Design".
		[General Electric, 1980]	General Electric Co. "BWR/6 General Description of a Boiling Water Reactor", Revised September 1980.

Appendix D. Initiating Event Analysis from Screening Report

This Appendix describes the initiating events that were identified and used for each POS during the coarse screening analysis [Whitehead et al., 1991]. This Appendix is from that earlier analysis. It correlates each initiating event to the appropriate plant operational state (POS). In addition, the information sources used to quantify the initiating event frequencies and the screening values assigned to each initiating event are presented.

D.1 Approach and Summary

The initiating event analysis task for this project was performed in much the same manner as for any full power PRA. First, a definition of what is meant by an initiating event was developed, and then a search for events which fit the definition was made. Finally, information was analyzed to produce estimates of the frequency for each initiating event.

For this study there are two definitions used for an initiating event depending upon the initial POS of the plant. For power operation, an initiating event is defined as an event which requires a rapid shutdown or trip of the plant, so as to challenge the safety systems to remove the decay heat still being generated in the reactor core. For non-power operations, an initiating event is defined as an event which would require an automatic or manual response to prevent core damage in the vessel.

Five major groups of initiating events were identified in this project: Transients, Loss of Coolant Accidents (LOCAs), Decay Heat Removal Challenges, Special Events, and Hazards Events. The Internal Fire and Flood Hazards Events will be considered in a subsequent stage of this project. The effects of seismic events will be analyzed by another organization, and all other externally initiated events are beyond the scope of this project. Table D.1-1 summarizes the initiators included in this study along with the screening values assigned to each initiator for each POS. The event nomenclature defines the shorthand notation used for each initiator in the subsequent tasks of this project.

The remainder of the section is divided into four subsections:

1. Transient Initiating Events,
2. LOCA Initiating Events,
3. Decay Heat Removal Challenge Initiators, and

4. Special Events.

In each of these subsections, the scope of events considered, as well as the methods employed to obtain the frequencies and distributions for each of the events, are described. A table summarizing the frequencies and distributions for the events is included in each subsection, along with comments that provide detailed descriptions of the methods for obtaining the frequencies.

D.2 Transient Initiating Events

D.2.1 Background

In order to obtain the transient categories considered in NUREG/CR-4550 volume 6 [Drouin et al., 1989], EPRI transient events were grouped according to similar plant response. The reader is referred to Table 4.3-3 of Reference 1, which describes in detail the individual EPRI events and their grouping into the categories presented in Table 4.3-1 of Reference 1. From Table 4.3-1, the following transient categories are considered:

<u>Transient Category</u>	<u>Description</u>
T1	Loss of Offsite Power
T2	Transients with Loss of the Power Conversion System (PCS)
T3A	Transients with the PCS initially available
T3B	Transients involving Loss of Feedwater but with the steamside of PCS initially available
T3C	Transient caused by Inadvertent Open Relief Valve

D.2.2 Introduction

The individual EPRI events comprising the transient categories discussed in section D.2.1 were reviewed for their applicability to the various POSs. Each of these transient categories is listed in Table D.2-1, and the comments included with the table describe in detail the applicability of the various events in each POS. Loss of Offsite Power (T1) is applicable to all POSs. See

Table D.1.1 Grand Gulf Low Power and Shutdown Initiating Events and Frequencies

Initiating Event Nomenclature	Description	Mean Frequency (per year) for Each POS						
		1	2	3	4	5	6	7
T1	Loss of Offsite Power (LOSP) transient	0.07	0.13	0.13	0.13	0.13	0.13	0.13
T2	Transient with loss of the Power Conversion System (PCS)	1.62	1.62	1.62	-	-	-	-
T3A	Transient with PCS initially available	4.54	4.54	4.54	-	-	-	-
T3B	Transients involving loss of Feedwater	0.88	0.88	0.88	-	-	-	-
T3C	Transient caused by Inadvertent Open Relief Valve	0.14	0.14	0.14	-	-	-	-
A	Large LOCA	1E-4	1E-4	1E-4	1E-4	1E-5	1E-5	1E-5
S1	Intermediate LOCA	3E-4	3E-4	3E-4	3E-4	3E-5	3E-5	3E-5
S2	Small LOCA	3E-3	3E-3	3E-3	3E-3	3E-4	3E-4	3E-4
S3	Small-Small LOCA	3E-2	3E-2	3E-2	3E-2	3E-3	3E-3	3E-3
V	Interfacing System LOCA	-	-	-	-	-	-	-
R	Vessel Rupture	-	-	-	-	-	-	-
H1	Diversion to Suppression Pool via RHR	-	-	-	8E-2	8E-2	8E-2	8E-2
H2	Diversion to Condenser via RWCU	-	-	-	-	-	-	-
J1	LOCA in Connected System (RCIC)	8E-4	8E-4	8E-4	-	-	-	-
J2	LOCA in Connected System (RHR)	-	-	-	5E-2	5E-2	5E-2	5E-2
K	Test/Maintenance-Induced LOCA	-	-	-	-	-	-	-
E1B	Isolation of SDC Loop B only	-	-	-	0.1	0.1	0.1	0.1
E1C	Isolation of RWCU as DHR	-	-	-	-	-	-	0.1
E1D	Isolation of ADHRS only	-	-	-	-	0.1	0.1	0.1
E1T	Isolation of SDC Common Suction Line	-	-	-	0.1	0.1	0.1	0.1

Table D.1.1 Grand Gulf Low Power and Shutdown Initiating Events and Frequencies

Initiating Event Nomenclature	Description	Mean Frequency (per year) for Each POS						
E1V	Isolation of Common Suction Line for ADHRS	-	-	-	-	0.1	0.1	0.1
E2B	Loss of SDC Loop B only	-	-	-	0.37	0.37	0.37	0.37
E2C	Loss of RWCU as DHR	-	-	-	-	-	-	0.1
E2D	Loss of ADHRS only	-	-	-	-	0.37	0.37	0.37
E2T	Loss of SDC Common Suction Line	-	-	-	0.37	0.37	0.37	0.37
E2V	Loss of Common Suction Line for ADHRS	-	-	-	-	0.37	0.37	0.37
T4A	Rod Withdrawal Error	-	-	-	-	-	-	-
T4B	Refueling Accident (Rod or Fuel Misposition)	-	-	-	-	-	-	-
T4C	Instability Event	-	-	-	-	-	-	-
T5A	Loss of all SSW	-	-	-	1.8E-2	1.8E-2	1.8E-2	1.8E-2
T5B	Loss of all TBCW	1.8E-2	1.8E-2	1.8E-2	1.8E-2	1.8E-2	1.8E-2	-
T5C	Loss of all PSW (includes Radial Well)	1.8E-2	1.8E-2	1.8E-2	1.8E-2	1.8E-2	1.8E-2	-
T5D	Loss of all CCW	-	-	-	1.8E-2	1.8E-2	1.8E-2	-
TAB	Loss of 1E 4160 V AC Bus B	-	-	-	9E-4	9E-4	9E-4	9E-4
TDB	Loss of 1E 125 V DC Bus B	-	-	-	6E-3	6E-3	6E-3	6E-3
TIA	Loss of Instrument Air	0.5	0.5	0.5	0.5	0.5	0.5	-
TORV	Inadvertent Open Relief Valve at Shutdown	-	-	-	0.1	-	-	-
TIOP	Inadvertent Overpressurization (makeup greater than letdown)	-	-	-	0.16	0.16	-	-
TIHP	Inadvertent Overpressurization via Spurious HPCS Actuation	-	-	-	1E-2	1E-2	-	-
TIOF	Inadvertent Overfill via LPCS or LPCI	-	-	-	4E-2	4E-2	-	-
TLM	Loss of Makeup	-	-	-	0.49	0.49	0.49	-

Table D.2.1 Transients

Description	Plant State: Mean Frequency [per Calendar Year]	Distribution	Comments
T1 LOSS OF OFFSITE POWER	FULL POWER: 0.078	-	1
	1: 0.07	-	1
	2: 0.13	-	1
	3: 0.13	-	1
	4: 0.13	-	1
	5: 0.13	-	1
	6: 0.13	-	1
	7: 0.13	-	1
T2 TRANSIENTS WITH LOSS OF THE POWER CONVERSION SYSTEM (PCS)	FULL POWER: 1.62	LOGNORMAL; EF=3	2
	1: 1.62	"	2
	2: 1.62	"	2
	3: 1.62	"	2
	4: N/A	N/A	3
	5: N/A	"	3
	6: N/A	"	3
	7: N/A	"	3
T3A TRANSIENTS WITH PCS INITIALLY AVAILABLE	FULL POWER: 4.51	LOGNORMAL; EF=3	4
	1: 4.54 (4.50 to 4.54)	"	4 and 5
	2: 4.54 (4.50 to 4.54)	"	4 and 5
	3: 4.54 (4.50 to 4.54)	"	4 and 5
	4: N/A	N/A	6
	5: N/A	"	6
	6: N/A	"	6
	7: N/A	"	6
T3B TRANSIENTS INVOLVING LOSS OF FEEDWATER (LOFW)	FULL POWER: 0.76	LOGNORMAL; EF=3	7
	1: 0.88 (0.76 to 0.88)	"	8
	2: 0.88 (0.76 to 0.88)	"	8
	3: 0.88 (0.76 to 0.88)	"	8
	4: N/A	N/A	9
	5: N/A	"	9
	6: N/A	"	9
	7: N/A	"	9
T3C INADVERTENT OPEN RELIEF VALVE (IORV)	FULL POWER: 0.14	LOGNORMAL; EF=3	10
	1: 0.14	"	10
	2: 0.14	"	11
	3: 0.14	"	11
	4: N/A	N/A	12
	5: N/A	"	12
	6: N/A	"	12
	7: N/A	"	12

Table D.2.1 Comments

- {1} The calculation of LOSP frequency and distribution is described in Appendix G.
- {2} The frequency and distribution for T2 were taken from Table 4.9-26 of [Drouin et al., 1989]. Table 4.3-1 of [Drouin et al., 1989] describes the individual EPRI transient events comprising event T2. The values in Table 4.9-26 were calculated from the EPRI transient category frequency data in Table 33 of [Mackowiak et al., 1985]. The frequency used for full power is taken to apply to POS 1, based on a review of the individual EPRI events included in T2. For POSs 2 and 3 where the turbine/generator is tripped, but the turbine bypass and condensate are still used, the frequency is conservatively taken to be that which was used for the full power analysis. This is conservative since not all events that make up T2 are valid during these POSs; however, it is expected that this conservatism will not be important because of the small amount of time spent in these two POSs.
- {3} The events which make up T2 are not valid during these POSs.
- {4} The frequency reported in Table 4.9-26 of [Drouin et al., 1989] includes the EPRI transient events listed in Table 4.3-1 of [Drouin et al., 1989] for the event T3A. For POS 1, all of these events are included in the T3A frequency. It should be noted that several of the events included in T3A may not be applicable for POS 1 when the mode switch is in RUN. EPRI events 14, 18, and 21 are all postulated to cause reactor SCRAM on high neutron flux. It is unclear whether, during POS 1 operations with the mode switch in the RUN position, the reactivity insertion from these events would be sufficient to cause SCRAM on high neutron flux. In this case, these events would have to be removed from T3A for POS 1. For this analysis we conservatively assume that these events will cause a SCRAM and therefore are included in the initiating event frequency. For POS 1 with the mode switch in STARTUP, the EPRI event 26, "High Feedwater Flow During Startup or Shutdown", has been added to T3A. The frequency for this event in Table 33 of [Mackowiak et al., 1985] is 0.04/year.
- {5} Note that the events 14, 18, and 21 as described above in {4} are postulated to cause a reactor SCRAM on high neutron flux. With the mode switch in STARTUP a reactor trip will occur at a flux-indicated power level of 15%, according to Grand Gulf Technical Specifications. It is assumed that these reactivity insertions are sufficient to cause an increase in power level which exceeds the 15% setpoint.
- {6} None of the EPRI transient events under T3A apply in POSs 4 through 7, based on a review of the individual EPRI transient events comprising T3A. Although several might be postulated to cause an interruption in decay heat removal operations via the RHR, these are assumed to be included in the frequency determined for the DHR challenge initiators involving the RHR (see Table 4.2.3-1).
- {7} The frequency and distribution for T3B are taken from Table 4.9-26 of [Drouin et al., 1989]; Table 4.3-1 of [Drouin et al., 1989] describes the individual EPRI transient events comprising event T3B. The values in Table 4.9-26 were calculated from the EPRI transient category frequency data in Table 33 of [Mackowiak et al., 1985].
- {8} The frequency used for full power is taken to apply to POS 1 when the mode switch is in RUN, based on a review of the individual EPRI events included in T3B. The frequency of T3B in POS 1 when the mode switch is in STARTUP is calculated by adding the frequency for EPRI event 25, Low Feedwater Flow During Startup or Shutdown, to the full power frequency described in {7}. Table 33 of [NRC, NUREG 3862] reports the event 25 frequency as 0.12/year. The error factor is assumed to be the same as for full power. To be conservative the frequency for POS 1 is taken to be 0.88 with a lognormal distribution having an error factor of 3. This same frequency was conservatively assumed to apply to POSs 2 and 3.
- {9} Loss of feedwater events are not applicable in these POSs.
- {10} The event T3C, Inadvertent Open Relief Valve, is considered in terms of its potential to cause a SCRAM (due to high suppression pool temperature) for POS 1, as it was for Full Power [1]. The same frequency reported in Table 4.9-26 of [Drouin et al., 1989] for this event was assigned to POS 1, as it is not expected to be any higher.
- {11} Although not a concern in terms of causing a SCRAM, the potentially high pressure and temperature conditions existing in these plant states require that this event be considered for its loss of vessel inventory potential.
- {12} For POSs 5, 6, and 7 this event is not of concern since the reactor is at atmospheric pressure (vented in POS 5; head off in POS 6 and 7). For POS 4 a special initiator was developed. See discussion in Section 4.2.4.3.

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Appendix G of this report for a listing of the data used to determine the frequency of T1.

It should be noted that the frequencies listed for the various transient initiators are given in terms of plant calendar years. A reference used for many of the frequency calculations [Mackowiak et al., 1985] states that "reactor years" (which usually denotes a time corrected by a plant's capacity factor) were used to determine event frequencies. However, the definition of "reactor year" in this report appears to be equivalent to a plant calendar year.

Because the frequencies are given on a per-calendar-year basis, it is intended that the transient frequencies reported in Table D.2-1 will be corrected by factors representing the fraction of the plant calendar year spent in a particular POS. In addition, events which depend on operation of a particular system, such as the condenser, should be multiplied by the fraction of time the given system operates in a particular POS. For the screening analysis this fraction was assumed to be 1.0.

D.3 LOCA Initiating Events

D.3.1 Background

The accident initiator termed Loss of Coolant Accident (LOCA) has traditionally referred to piping ruptures of various sizes causing a failure of the coolant pressure boundary. In NUREG-4550, Vol. 6 [Drouin et al., 1989], the possible LOCAs were categorized according to size of the break, based on similar safety system requirements within a category. The various LOCA categories used in the NUREG 4550 analysis are described below:

<u>LOCA</u>	<u>SIZE</u>
A	Steam > 0.4 sq.ft. Liquid > 0.4 sq.ft.
S1	Steam 0.13 - 0.4 sq.ft. Liquid 0.007 - 0.4 sq.ft.
S2	Steam < 0.13 sq.ft. Liquid < 0.007 sq.ft.
S3	Recirculation pump seal break; categorized as S2 if operator does not isolate.

Another type of LOCA considered in the NUREG 4550 analysis is the Interfacing System LOCA, or V, which typically involves the failure of a high-to-low pressure interface such that reactor pressure causes failure within a low pressure system. Such failures were found to most likely involve failure of a testable check valve on ECCS injection lines. The V scenario was eliminated as an initiating event for Grand Gulf based on plant-specific arguments regarding testing practices and plant configuration [Drouin et al., 1989].

A final type of LOCA considered in NUREG 4550 is the Reactor Vessel Rupture event, R. The argument for excluding this initiating event in the Grand Gulf analysis draws upon previous studies involving PWRs, and concludes a lower vessel rupture frequency for BWRs. The argument also states that because Grand Gulf's vessel is newer, the rupture event is even less likely (presumably due to material considerations with regard to the pressurized thermal shock concern) [Drouin et al., 1989].

D.3.2 Introduction

The following sections describe the LOCA initiating events considered for this study. Applicability of events considered in NUREG 4550 are discussed first, followed by descriptions of LOCA events unique to this study. The scope of events considered is presented, as well as the justification for exclusion of certain events. Table D.3-1 summarizes the mean frequencies and distributions assigned to the various LOCA events, along with comments specifically describing the method for obtaining the frequencies.

It should be noted that the frequencies listed for the various LOCA initiators are given in terms of plant calendar years. It is intended that these frequencies will be corrected by factors representing the fraction of the plant calendar year spent in the POS being examined. In addition, events which involve operating systems are to be multiplied by the fraction of time the given system operates in a POS. This fraction was conservatively assumed to be 1.0 for this screening study.

D.3.3 LOCA Events from NUREG 4550

In determining the applicability of events considered in NUREG 4550 to POSs other than full power, consideration of the differing plant configurations and conditions for the various POSs is necessary. In most

Table D.3.1 Loss of Coolant Accidents

Description	Plant State: Mean Frequency [per CALENDAR YEAR]	Distribution	Comments
A LARGE LOCA	FULL POWER: 1E-4	LOGNORMAL; EF=3	1
	1: 1E-4	"	1
	2: 1E-4	"	1
	3: 1E-4	"	1
	4: 1E-4	"	1
	5: 1E-5	"	2
	6: 1E-5	"	2
	7: 1E-5	"	2
S1 INTERMEDIATE LOCA	FULL POWER: 3E-4	LOGNORMAL; EF=3	1
	1: 3E-4	"	1
	2: 3E-4	"	1
	3: 3E-4	"	1
	4: 3E-4	"	1
	5: 3E-5	"	2
	6: 3E-5	"	2
	7: 3E-5	"	2
S2 SMALL LOCA	FULL POWER: 3E-3	LOGNORMAL; EF=3	1
	1: 3E-3	"	1
	2: 3E-3	"	1
	3: 3E-3	"	1
	4: 3E-3	"	1
	5: 3E-4	"	2
	6: 3E-4	"	2
	7: 3E-4	"	2
S3 SMALL-SMALL LOCA	FULL POWER: 3E-2	LOGNORMAL; EF=3	1
	1: 3E-2	"	1
	2: 3E-2	"	1
	3: 3E-2	"	1
	4: 3E-2	"	1
	5: 3E-3	"	2
	6: 3E-3	"	2
	7: 3E-3	"	2
V INTERFACING SYSTEM LOCA (failure of high to low pressure interface)	FULL POWER: N/A	N/A	3
	1: N/A	"	3
	2: N/A	"	4
	3: N/A	"	4
	4: N/A	"	4
	5: N/A	"	4
	6: N/A	"	4
	7: N/A	"	4

Table D.3.1 Loss of Coolant Accidents

Description	Plant State: Mean Frequency [per CALENDAR YEAR]	Distribution	Comments
R VESSEL RUPTURE	FULL POWER: N/A	N/A	5
	1: N/A	"	5
	2: N/A	"	5
	3: N/A	"	5
	4: N/A	"	5
	5: N/A	"	5
	6: N/A	"	5
	7: N/A	"	5
H1 DIVERSION OF VESSEL INVENTORY TO THE SUPPRESSION POOL via RHR	FULL POWER: N/A	N/A	6
	1: N/A	"	6
	2: N/A	"	7
	3: N/A	"	7
	4: 8E-2	LOGNORMAL; EF 5	8, 9
	5: 8E-2	"	8, 9
	6: 8E-2	"	8, 9
	7: 8E-2	"	8, 9
H2 DIVERSION OF VESSEL INVENTORY via RWCU	FULL POWER: N/A	N/A	10
	1: N/A	"	10
	2: "	"	10
	3: "	"	10
	4: "	"	10
	5: "	"	10
	6: "	"	10
	7: "	"	10
J1 LOCA IN OPERATING CONNECTED SYSTEM (RCIC)	FULL POWER: N/A	N/A	11
	1: 8E-4	LOGNORMAL; EF=10	12
	2: 8E-4	"	12
	3: 8E-4	"	12
	4: N/A	N/A	13
	5: "	"	13
	6: "	"	13
	7: "	"	13
J2 LOCA IN OPERATING CONNECTED SYSTEM (RHR)	FULL POWER: N/A	N/A	11
	1: N/A	"	14
	2: "	"	14
	3: "	"	14
	4: 5E-2	LOGNORMAL; EF=10	15
	5: 5E-2	"	15
	6: 5E-2	"	15
	7: 5E-2	"	15

Table D.3.1 Loss of Coolant Accidents

Description	Plant State: Mean Frequency [per CALENDAR YEAR]	Distribution	Comments
K1 MAINTENANCE INDUCED LOCA IN RHRS			16, 17
K2 MAINTENANCE INDUCED LOCA IN RWCU SYSTEM			16, 17
K3 MAINTENANCE INDUCED LOCA IN RCIC SYSTEM			16, 17
K4 MAINTENANCE INDUCED LOCA IN HPCS SYSTEM			16, 17
K5 MAINTENANCE INDUCED LOCA IN LPCS SYSTEM			16, 17
K6 MAINTENANCE INDUCED LOCA IN RECIRC SYSTEM			16, 17

Table D.3.1 Comments

- {1} Frequency values for primary system LOCAs at Full Power are from Table 4.9-26 of [Drouin et al., 1989] and the distribution value from [Mackowiak et al., 1985]. Values for POSs 1 through 4 were taken to be the same as for Full Power (see {2}).
- {2} The frequencies for POSs 5 through 7 are scaled down by 0.1 from the values listed in Table 4.9-26 of [Drouin et al., 1989], based on the information in Table A-5 of [Wright et al., 1987]. This table presents the expected effect on overall LOCA frequency for various factors such as pipe size or mode of operation. The multipliers in the table are meant to be applied to overall mean frequency. The factor 0.1 reported for "Shutdown" in this table seems to apply only to Cold Shutdown and Refueling. "Starting Up" and "Shutting Down" as defined in [Wright et al., 1987] encompass Hot Shutdown and Startup, whereas "Normal Operation" covers Low and Full Power. Although the results presented in Appendix A of the report have a large associated uncertainty (because expert elicitation was used to obtain the results), this multiplier is considered to be a valid qualitative adjustment for LOCA frequency during shutdown, versus the overall frequency used in the full power analysis. Factors greater than one are reported in the table for modes other than "Shutdown", but are not considered applicable to the Full Power values, because the overall mean frequency reported in the table is four orders of magnitude lower than

Table D.3.1 Comments (Continued)

the smallest Full Power frequency. The distributions from [Mackowiak et al., 1985] have been applied to all plant states, as they are considered realistic for this analysis.

- {3} Section 4.4.15 of [Drouin et al., 1989] justifies the exclusion of Interfacing LOCAs from consideration in the Grand Gulf Full Power study. These arguments are taken to apply to POS 1 since the plant configuration and conditions are nearly the same as for Full Power.
- {4} For POSs 2 through 7, the plant conditions are such that a high-to-low pressure interface is not likely to exist. For these modes, new event identifiers have been created to describe LOCAs involving interfacing systems: H for recoverable diversion of vessel inventory through a system connected to the primary, J for LOCAs in a connected system through which primary water is flowing, and K for maintenance-induced LOCAs in connected systems.
- {5} Section 4.4.16 of [Drouin et al., 1989] describes the reason for exclusion of the Vessel Rupture event from the Full Power study. This same reasoning should apply to POS 1.

In POSs 2 through 7, the existing pressure or potential for overpressure in the vessel is considered to be significantly less than at Full Power. The arguments employed in [Drouin et al., 1989] regarding the probability of vessel rupture while at power are considered to bound the probability during POSs 2 through 7.

- {6} Diversion of Vessel Inventory Through the RHRS is not considered applicable for Full Power for the reasons explained in the Interfacing LOCA section of [Drouin et al., 1989], and does not apply to POS 1 according to the same arguments.
- {7} The "Diversion of Vessel Inventory Through RHRS" event is not applicable in POSs 2 and 3 since the RHR system is not normally used in these POSs.
- {8} The "Diversion of Vessel Inventory Through RHRS" event frequency for POSs 4 through 7 has been calculated using the data collected in [Vine et al., 1989]. Thirteen events involving loss of vessel inventory through the RHR system were identified over the seven-year (1977-1983) time period covered by the study. Of the thirteen events, five events occurred during pre-commercial operation, and two events involved heat exchanger leakage, which is considered under event J2. One event, counted as a single event in [Vine et al., 1989], has been considered as two separate events in this frequency calculation. Six of the remaining seven commercial events involved loss of coolant inventory to the suppression pool. The seventh event involved significant coolant shrinkage upon cooldown initiation. Diversion of Vessel Inventory is defined to include events involving diversion to a sizable fluid sink, e.g. the suppression pool. The seven events mentioned above are the basis for the RHR Diversion of Vessel Inventory frequency. In each of these events the coolant was "recoverable", i.e. not lost to the system. This type of event appears to be the only credible diversion of inventory event involving the RHR (piping ruptures, component failures, or maintenance/test-induced LOCAs are considered in events J2 and K). The events encompass two possible paths out of the vessel: through the RHR Recirculation Loop connection, and via the RHR/LPCI inlet line. The first path terminates at 2/3 core height while the latter path naturally terminates at over 50 inches above the top of the active fuel, but is still included as part of the RHR inventory diversion frequency. It should be noted that the inventory diversion event is potentially significant during shutdown because of possible disabling of isolation signals on vessel level, as has been the case in one precommercial event. The seven years covered by the study represent approximately 152 BWR plant operating years.

A mean frequency for RHR Loss of Vessel Inventory is calculated using seven events over 152 years, by first calculating a median value using a binomial distribution computer [Binomial Computer] (5E-2). The error factor is estimated by finding the 5% and 95% confidence values on the binomial computer (1E-2 and 2.5E-1), and roughly doubling that value. The mean, assuming a lognormal distribution about the median value found above, is then 8E-2/yr.

Table D.3.1 Comments (Continued)

- {9} Diversion of vessel inventory via the HPCS and LPCS systems is credible, based on the possible paths to the suppression pool involving failure on the testable check valve combined with two open isolation valves. However, according to [Vine et al., 1986], all previous diversion events have involved only RHR. In addition, the HPCS and LPCS events, would terminate with a water level above the top of the active fuel. The dominant contributors to this event are expected to be maintenance/test errors and as such will be included in the K events.
- {10} System normally in operation. Not considered as a diversion path.
- {11} This initiator applies to systems through which primary water is flowing. The RCIC and RHR (SDC) systems are not normally operating in Full Power.
- {12} The frequency was estimated by assuming a steam line break down stream of MOV 45. The pipe segment contains two valves with a failure rate of $4.5\text{E-}9/\text{hr}$. Multiplying by the number of hours in a year yields a value of $7.8894\text{E-}5$. This value was increased by a factor of 10, producing a final result of $8\text{E-}4/\text{yr}$. An EF of 10 was assumed for a lognormal distribution. This should be conservative since the value should be reduced by the fraction of time RCIC is operating in POS 1, 2, or 3.
- {13} RCIC not operated in these POSs.
- {14} RHR (SDC) does not normally operate during POS 1. It was operated one time in the Startup phase ("Training Startups"), but the utility decided not to operate SDC in this state again. Thus this initiator for POS1 was assumed to be not applicable. RHR (SDC) does not normally operate in POSs 2 and 3 and is assumed to be not applicable for these POSs.
- {15} For POSs 4 through 7, the RHR LOCA frequency due to pipe or component ruptures is derived from the argument of Expert "B" on Component Cooling Water Pipe Rupture in [Wheeler et al., 1989], p. C-172. This expert used data from Appendix A, Figure A-2 of [Wright et al., 1987] which has a very high associated uncertainty. This expert's mean value estimate for CCW pipe rupture was one order of magnitude lower than the aggregate mean for the three experts involved. Because no better source of information was located, Figure A-3 of [Wright et al., 1987] was consulted to obtain a RHR pipe rupture frequency. The pipe rupture frequency for RHR at power was found to be about the same as that for the CCW system ($2\text{E-}7/\text{system year}$). Assuming the same distribution as expert "B" applied to the CCW frequency, the mean for RHR should be about the same as CCW: $1\text{E-}5/\text{yr}$. Increasing this value by one order of magnitude in order to more closely match the aggregate CCW frequency for the three experts yields $1\text{E-}4/\text{system year}$.

Although the operating conditions of the RHR system may be more harsh than for CCW, the CCW system contains over 2.5 times the length of piping as in RHR, so this frequency seems reasonable.

In considering piping system component failures, Expert "C" of [Wheeler et al., 1989] indicated that valves would probably not fail at low pressure. However, pump or heat exchanger failures must also be taken into account. [Vine et al., 1986] reports two RHR Heat Exchanger leak events causing about a 4000 gallon loss of vessel inventory to the RBCCW system. Assuming two events over 43.9 shutdown years, the frequency estimate is $0.05/\text{year}$. This value is much larger than the pipe rupture frequency estimated above, and is thus the value used for POSs 4 through 7.

- {16} Maintenance/Test-Induced LOCAs were not analyzed in the Full Power Study.
- {17} Maintenance/Test-Induced LOCAs are of concern for POSs 2 through 7, where maintenance or test activities inadvertently open a path whereby coolant inventory is lost (e.g. removal of components for maintenance and improper valve alignments). All systems connected to the primary are considered for their K event potential. The analysis for these events will take place during the detailed phase of the project.

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cases, the less stressful temperature and pressure conditions during shutdown should reduce the frequency of the various LOCA events considered at full power, or allow elimination of some events. Table D.3-1 lists the various LOCA events considered, their assigned screening frequencies and distributions, and comments describing in detail the method for obtaining the frequencies.

D.3.3.1 LOCA Categories

The various LOCA categories (A, S1, S2, and S3) assigned for full power are considered applicable for all POSs. Reclassification of the LOCA sizes for the various plant states is not considered necessary. The frequencies presented in NUREG 4550 are considered applicable to POSs 1, 2, 3, and 4. The error factors from NUREG/CR-4550 Vol. 1 are applied because they are considered more realistic. Although the transient conditions existing in the Startup Phase of POS 1 could be construed as more stressful to the plant than at full power, this is not considered to have a significant effect on the frequencies assigned for POS 1. The frequencies for POSs 5, 6, and 7 have been scaled down from the full power values, as described in comment {2} of Table D.3-1.

D.3.3.2 Interfacing System LOCA

As described in the Background section above, Interfacing System LOCAs (V) were screened out of the Reference 1 analysis by the use of arguments that apply to POS 1 as well. The high-to-low pressure interface conditions necessary for the V scenario do not exist during Plant States 5, 6, and 7 except possibly as a result of an accident initiating event. This type of V sequence is included in the appropriate event trees. Such conditions may exist during Plant States 2, 3, and 4, where maintenance/test conditions may increase the likelihood of a V event, but new LOCA categories have been created to take into account these situations (see Section D.3.4.3).

D.3.3.3 Vessel Rupture

As described in the previous section, Vessel Rupture (R) was excluded for Full Power. The less harsh conditions experienced in the POSs of this study allow exclusion of the R event for these POSs as well. Although POS 1 (i.e., the Startup Phase) may involve increased stresses to the vessel due to the transient vessel conditions, the R event is also excluded for POS 1 (see comment {3} of Table D.3-1). A special event, Inadvertent

Overpressurization (see Table 4.5-1), may have a bearing on vessel rupture, as discussed in note {15} of Table D.5-1.

D.3.4 LOCA Events Unique to Low Power/Shutdown Operations

Additional loss of coolant events have been postulated for the POSs defined in this study, due to the unusual plant configurations and maintenance practices occurring in these POSs. Three types of events, all involving systems connected to the primary, are identified for these POSs: 1) H, involving recoverable diversion of vessel inventory through a connected system; 2) J, loss of coolant in an operating connected system involving piping or component failures; and 3) K, maintenance/test-induced LOCAs on connected systems with potential for draining vessel inventory. These events, combined with the full-power events described in the previous section, are thought to encompass the credible loss of coolant events possible in all POSs.

In several of the events described in this section, the frequency has been estimated using a known number of events over a certain number of plant calendar years. A binomial distribution computer (see note {8} of Table D.3-1) has been used to provide an estimate for the median frequency (using the 50% confidence value), and to give an indication of the error factor (using the 5% and 95% confidence values). The error factor indicated by the binomial computer was approximately doubled, and a mean frequency was calculated from the binomial median assuming a lognormal distribution. This method has been applied for H and J events.

D.3.4.1 Recoverable Diversion of Vessel Inventory (H)

The Recoverable Diversion of Vessel Inventory event involves the establishment of a path through a connected system whereby vessel inventory is reduced, but the inventory is recoverable. All of these events involve diversion to the suppression pool. These events are kept separate from the J and K events because the possibility of inventory recovery creates a potentially different response to this type of initiator.

In identifying the possible systems for the H event, connections from the vessel to a possible sink, such as the suppression pool are identified. The paths are brought about in most cases by misalignment or failure of valves. Only two connected systems have the

potential to directly drain the vessel below the Top of the Active Fuel (TAF): 1) the Residual Heat Removal (RHR); and 2) Reactor Water Cleanup (RWCU) systems through the RHR connection on the B recirculation loop. Other connections, such as the LPCI/RHR injection line, have the potential for draining coolant from the vessel but will naturally terminate above the top of the active fuel. These connections are also considered in this event because of the possibility of non-detection during shutdown and the need for makeup or cooling.

The following subsections describe the connections considered and justification for exclusion. It should be noted that instrumentation and leak-detection lines were not considered significant diversion paths and thus were not considered. The Alternate Decay Heat Removal System (ADHRS) is considered as part of the RHRS.

D.3.4.1.1 Residual Heat Removal System

The RHRS is an important system with regard to vessel diversion potential in the shutdown POSs. Several events have occurred in the past involving vessel inventory diversion to the suppression pool. These events formed the basis for the RHR inventory diversion (H1) frequency, as described in comment {8} of Table D.3-1. Diversion is possible through either the recirculation loop Shutdown Cooling (SDC) suction connection, or through the LPCI/RHR injection line to the vessel. This event has been excluded for POSs 1, 2, and 3 since the plant configuration is so similar to Full Power.

D.3.4.1.2 Reactor Water Cleanup System

Section 4.4.15 (Interfacing LOCA) of NUREG 4550 considered the RWCU system. The contribution to core damage frequency from a RWCU pipe break was assessed to be less than for large LOCA, and was thus ruled out. The arguments for ruling out the RWCU included isolation potential, the high pressure design of the entire system, and the fact that the location of the RWCU precludes any adverse affect of a RWCU pipe break on coolant injection systems. These arguments apply to POS 1.

Diversion of vessel inventory through the RWCU is not considered as an initiating event because no credible drain path with a sizable fluid sink other than the Condenser or Rad-Waste was identified. Since RWCU is normally rejecting to either Rad-Waste or the Condenser (or both), this diversion event was excluded as a potential initiating event. Furthermore, NSAC 88

notes that all known diversions have been through RHR. (For POSs 1, 2, and 3, RWCU is in normal alignment (i.e., cleanup mode). Beginning in POS 4, RWCU rejects water to the condenser or Rad-waste as a means of level control.)

D.3.4.1.3 Reactor Core Isolation Cooling (RCIC)

An interfacing LOCA at full power involving the RCIC was ruled out in NUREG 4550, and the same arguments apply to POSs 1 through 7 as well. Vessel inventory diversion through the RCIC system connection (to the feedwater line via the RHRS) is not considered credible because two check valves (one feedwater and one RCIC) must fail in addition to the testable check valve on the feedwater line. The event is thus ruled out for all plant states.

D.3.4.1.4 High Pressure Core Spray (HPCS)

As with other connected systems, NUREG 4550 screened out interfacing LOCAs involving the HPCS system. Again, this applies to POSs 1 through 7 as well. For all POSs, however, maintenance or testing activities involving the testable check valve or other valves make this event a concern and will be considered in the Maintenance/Test-Induced (M/T-I) LOCA initiating event. (This type of initiating event requires development by the detailed HRA methodology program and will be used if available. NOTE: Development not available.) where it can be used. A path to the suppression pool exists through one testable check valve and two isolation valves. Thus, from a hardware perspective, the M/T-I LOCA IEs are unlikely to occur. The event has been ruled out for all plant states.

D.3.4.1.5 Low Pressure Core Spray (LPCS)

The comments for HPCS above apply directly to LPCS.

D.3.4.2 LOCA in Operating Connected System

The LOCA in an Operating Connected System (J) event refers to pipe ruptures and component failures (e.g., heat exchangers) in operating systems connected to the primary. Three systems fit this definition: RHRS, RCIC, and RWCU. (Note that ADHRS is considered part of RHRS.) A J event involving the RWCU system has been ruled out of all POSs because it should be included in the full power LOCA initiators since RWCU operates at full power. The J event for the RCIC system (J1) and the RHR system (J2) are possible and the methods used to estimate their frequencies are described

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in Table D.3-1. These events apply to POSs 1, 2, and 3 for J1 and POSs 4, 5, 6, and 7 for J2. Note that the frequencies should be reduced by the fraction of time these systems are actually operating. For the screening analysis this factor was assumed to be 1.0.

D.3.4.3 Maintenance/Test-Induced LOCAs

Maintenance/test-induced LOCAs (K) involve systems connected to the primary wherein maintenance or test activities result in a primary coolant loss through the connected system. Actions such as removal of system components for maintenance/test combined with inadvertent valve misalignment are considered in the K event. Maintenance/test-induced LOCAs are of concern for POSs 2 through 7, during which such maintenance or test activities are postulated to occur.

All systems connected to the primary will be considered for their K event potential. Other possible K events, such as maintenance/test involving the control rod drive system, have been identified. The analysis for these events did not occur because the detailed human reliability analysis methodology program was completed.

D.4 Decay Heat Removal Challenge Initiators

D.4.1 Introduction

A group of initiators that are unique to this project are the Decay Heat Removal (DHR) challenge initiators. These events involve an interruption or failure to establish decay heat removal during POSs 4 through 7. They are broadly categorized into two types of events: isolation from an operating DHR system (E1); and failure of an operating DHR system (E2). All systems normally used for decay heat removal at various times in each POS are considered for these initiators (based on a review of Grand Gulf operating procedures). This includes the use of the condenser for decay heat removal after a shutdown evolution. However, this event has been included under the T2 event for POSs 2 and 3.

D.4.2 Identification and Estimation

The majority of the events involve the RHR system, with much of the data for RHR failure taken from NSAC [Vine et al., 1986]. For several of the events described in this section, the frequency has been estimated using a known number of events found in NSAC 88 over a certain number of plant calendar years. A binomial

distribution computer has been used to provide an estimate for the median frequency (using the 50% confidence value), and to give an indication of the error factor (using the 5% and 95% confidence values) [Binomial Computer]. The error factor indicated by the binomial computer was approximately doubled, and a mean frequency was calculated from the binomial median assuming a lognormal distribution.

Table D.4-1 describes in detail the various events considered as well as the method for obtaining the event frequencies and distributions. It should be noted that the frequencies listed for the various DHR initiators are given in terms of plant calendar years. It is intended that these frequencies will be corrected by factors representing the fraction of the plant calendar year spent in the POS being analyzed. These events, which depend on operation of a particular system, should be multiplied by the fraction of time the given system operates in a particular POS. For this screening analysis, this factor was assumed to be 1.0.

D.5 Special Events

D.5.1 Introduction

Events which did not fit into the previous three categories but which present a challenge to plant safety are included under the Special Initiating Events category. Events identified for inclusion in this category include some of the special events considered in full power, as well as events unique to POSs being examined by this study. Various sources were consulted to identify the events possible in the different plant states, including the NUREG/CR-4550 volumes, Nuclear Safety Analysis Center Reports, several years of BWR operating experience described in Nuclear Power Experience, and the information contained in the Precursor Reports.

The following sections describe the various events considered in this category. Table D.5-1 describes in detail the events considered as well as the method for obtaining the event frequencies and distributions. It should be noted that the frequencies listed for the various special initiators are given in terms of plant calendar years. It is intended that these frequencies will be corrected by factors representing the fraction of the plant calendar year spent in the POS. The events which depend on operation of a particular system, such as a service water system, should be multiplied by the fraction of time the given system operates in a particular POS. For this screening analysis the factor was assumed to be 1.0.

Table D.4.1 Decay Heat Removal (DHR) Challenge Initiators

Description	Plant State: Mean Frequency [per Calendar Year]	Distribution	Comments
E1B ISOLATION FROM OPERATING	FULL POWER: N/A	N/A	1
RHR-SHUTDOWN COOLING LOOP B	1: N/A	"	2
	2: "	"	2
	3: "	"	2
	4: 0.1	LOGNORMAL; EF=5	3
	5: 0.1	"	3
	6: 0.1	"	3
	7: 0.1	"	3
E1C ISOLATION FROM OPERATING	FULL POWER: N/A	N/A	1
RWCU SYSTEM (DHR)	1: N/A	"	4
	2: "	"	4
	3: "	"	4
	4: "	"	4
	5: "	"	4
	6: "	"	4
	7: 0.1	LOGNORMAL; EF=5	4
E1D ISOLATION FROM OPERATING	FULL POWER: N/A	N/A	1
ADHRS	1: N/A	"	5
	2: N/A	"	5
	3: N/A	"	5
	4: N/A	"	5
	5: 0.1	LOGNORMAL; EF=5	5
	6: 0.1	"	5
	7: 0.1	"	5
E1T ISOLATION OF SDC COMMON SUCTION LINE	FULL POWER: N/A	N/A	1
	1: N/A	"	6
	2: N/A	"	6
	3: N/A	"	6
	4: 0.1	LOGNORMAL; EF=5	7
	5: 0.1	"	7
	6: 0.1	"	7
	7: 0.1	"	7
E1V ISOLATION OF COMMON SUCTION LINE FOR ADHRS	FULL POWER: N/A	N/A	1
	1: N/A	"	6
	2: "	"	6
	3: "	"	6
	4: "	"	6
	5: 0.1	LOGNORMAL; EF=5	8
	6: 0.1	"	8
	7: 0.1	"	8

Table D.4.1 Decay Heat Removal (DHR) Challenge Initiators

Description	Plant State: Mean Frequency [per Calendar Year]	Distribution	Comments
E2B LOSS OF OPERATING RHR SHUTDOWN SYSTEM	FULL POWER: N/A	N/A	9
	1: N/A	"	9
	2: "	"	9
	3: "	"	9
	4: 0.37	LOGNORMAL; EF=5	10
	5: 0.37	"	10
	6: 0.37	"	10
	7: 0.37	"	10
E2C LOSS OF OPERATING RWCU SYSTEM (DHR)	FULL POWER: N/A	N/A	11
	1: N/A	"	4
	2: "	"	4
	3: "	"	4
	4: "	"	4
	5: "	"	4
	6: "	"	4
	7: 0.1	"	4
E2D LOSS OF OPERATING ADHRS	FULL POWER: N/A	N/A	12
	1: N/A	"	12
	2: N/A	"	12
	3: N/A	"	12
	4: N/A	"	12
	5: 0.37	LOGNORMAL; EF=5	13
	6: 0.37	"	13
	7: 0.37	"	13
E2T LOSS OF SDC COMMON SUCTION LINE	FULL POWER: N/A	N/A	1
	1: N/A	"	6
	2: "	"	6
	3: "	"	6
	4: 0.37	LOGNORMAL; EF=5	7
	5: 0.37	"	7
	6: 0.37	"	7
	7: 0.37	"	7
E2V LOSS OF COMMON SUCTION LINE FOR ADHRS	FULL POWER: N/A	N/A	1
	1: N/A	"	6
	2: "	"	6
	3: "	"	6
	4: "	"	6
	5: 0.37	LOGNORMAL; EF=5	8
	6: 0.37	"	8
	7: 0.37	"	8

Table D.4.1 Comments

- {1} A decay heat removal (DHR) system is not normally operating in Full Power, so that events E1B (RHRS), E1C (RWCU as DHR system), and E1D (ADHRS) do not apply.
- {2} RHR Shutdown Cooling (SDC) is not normally operated in POSs 2 and 3. This event is assumed to be not applicable for these POSs.
- {3} The frequency for E1B is found using nine events identified in [Vine et al., 1986]. NSAC-88 identifies 25 events involving isolation of the RHRS, but 16 of these were pre-commercial. The study covered approximately 152 years of BWR plant operating years (1977-83).

A mean frequency for E1B was calculated using nine events over 152 years, by first calculating a median value using a binomial distribution computer [Binomial Computer] (0.065). The error factor was estimated by finding the 5% and 95% confidence values on the binomial computer (0.036 and 0.099), and roughly doubling that value. The mean, assuming a lognormal distribution about the median value found above, is then 0.1/yr.
- {4} RWCU used only in POS 7. The same numerical value for E1B is used for E1C and E2C.
- {5} ADHRS is only allowed to operate in POSs 5, 6, and 7 per Grand Gulf Technical Specifications [USNRC 1984]. The frequency calculated for event E1B, {3}, was applied to E1D, since the ADHRS operates through the RHRS, and isolation of RHR would also isolate ADHRS.
- {6} Not normally operated in these POSs.
- {7} Assume same numerical value for E1T (E2T) as for E1B (E2B).
- {8} Assume same numerical value for E1V (E2V) as for E1B (E2B).
- {9} SDC is not normally operated at Full Power or in these POSs.
- {10} The calculational method for the E2B frequency is as described in [Wright et al., 1987], using 13 events for loss of RHR due to valve problems, four events for loss or degradation of RHR due to loss of a running RHR pump, five events involving RHR heat exchanger problems, three events for loss of RHR due to overfill or overpressurization of the RPV, (These events are considered here only for their potential to cause an interruption in decay heat removal operations. Overpressurization is considered as a special event, see Table 4.5-1.), and seven of the nine events for loss of RHR due to planned maintenance. The remaining two events were pre-commercial. All events are from [Vine et al., 1986].
- {11} RWCU used in a decay heat removal capacity does not apply to Full Power.
- {12} Grand Gulf Technical Specifications mandate that ADHRS only be used in Modes 4 and 5 (i.e., POSs 5, 6, and 7).
- {13} A screening frequency for loss of ADHRS has been estimated using the E2B events, since ADHRS operates through the RHRS and has similar components.

D.5.2 Criticality Events

Three criticality events were identified for consideration. They are:

- T4A: Rod Withdrawal Error
- T4B: Refueling Accident (rod or fuel misposition)
- T4C: Instability Event.

All three of these were screened from the analysis, based on the following reasons.

T4A, the rod withdrawal accident at power (rod drop in a BWR), is a design basis accident. Thus, for significant fuel damage to occur, other failures (such as control rod pattern errors) must exist. (Rod drop during startup is precluded by design.) BNL concluded that the likelihood of significant fuel damage from a rod drop event at full power is $< 1E-8/RY$ [Diamond et al., 1990]. The value for off-power conditions should not be higher. It is concluded that this event can be screened from the analysis.

T4B, the refueling accident, can be of two types. The first type involves incorrect placement of a fuel bundle in the core during refueling. This is a design basis accident and does not lead to unacceptable consequences. The second type is associated with local loading of fuel when more than one control blade is removed. This accident is discussed in reference [Drouin et al., 1989] which concludes that it can damage fuel and that its frequency may not be below $1E-7/RY$ (depending on the specific characteristics of a particular plant). BNL points out that improvements in technical specifications, such as suspending fuel loading when control blades are out, can reduce the frequency of this accident [Diamond et al., 1990]. The pertinent technical specification for Grand Gulf that allows for removal of more than one control blade during refueling is # 3.9.10.2, and it requires that all fuel loading operations be suspended unless all control blades are inserted in the core [USNRC 1984]. Based on this control provided by the technical specifications, it is concluded that this event can be screened from the analysis.

T4C, the flow instability event refers to operation of the core with a local high power-to-mass-flow ratio. The concern is that with the instability, should a design basis event take place, the high power regions of the core can be damaged due to the occurrence of phenomena such as

critical heat flux or excessive fuel enthalpy. BNL addressed early fuel damage from reactivity insertion events occurring given operation with instabilities, and concluded that early fuel damage due to excessive fuel enthalpy is not of concern [Diamond et al., 1990]. No detailed study of all design basis accidents occurring while core instabilities are present has been performed for the off power study. However, during off power conditions, instabilities are less likely than at full power, and therefore these events have been screened from the analysis.

BNL also concluded that a particular type of reactivity insertion can occur during an ATWS sequence, and it may not be sufficiently low to be screened from consideration [Diamond et al., 1990]. The reactivity insertion results from failure of the operator to inhibit (automatic) ADS following injection of borated water from the SLC. If the reactor depressurized, auto injection of non-borated water from LPCI or LPCS can displace borated water and result in a reactivity excursion which can damage fuel. This issue was not specifically addressed in the Grand Gulf full power PRA [Drouin et al., 1989]. This regulation does not address inhibiting ADS for those sequences involving successful shutdown with SLC. ADS can actuate if vessel level is low, and this can occur following an ATWS. (Table A-1 of NUREG 4550 indicates that the level will drop to the top of the active fuel following an ATWS even with injection from SLC, CRD, and HPCS.) Since ATWS sequences were contributors to core damage for accidents from full power at Grand Gulf, this issue should be addressed for full power. ATWS events are of concern for the off power study only in POS 1, and in this POS, power is limited to 15% which reduces the severity of the ATWS. The success criteria for the ATWS in POS 1 are the same as those used in NUREG 4550 for full power, hence this particular reactivity excursion is not considered.

D.5.3 Support System Events

Several support system initiators were identified based on a review of the equipment required to function during the POSs. These include:

1. Loss of SSW (T5A),
2. Loss of TBCW (T5B),
3. Loss of PSW (T5C),
4. Loss of CCW (T5D),

Table D.5.1 Special Initiating Events

Description	Plant State: Mean Frequency [per Calendar Year]	Distribution	Comments
NOTE: THE FOLLOWING "T4" EVENTS ARE "CRITICALITY EVENTS"			
T4A ROD WITHDRAWAL ERROR	FULL POWER: N/A 1: N/A	N/A "	1 2
T4B REFUELING ACCIDENT	2: "	"	2
T4C INSTABILITY EVENT	3: "	"	2
	4: "	"	2
	5: "	"	2
	6: "	"	2
	7: "	"	2
T5A LOSS OF SSW	FULL POWER: N/A 1: N/A 2: N/A 3: N/A 4: 1.8E-2 5: " 6: " 7: "	N/A " " " LOGNORMAL; EF=5 " " "	3 3 3 3 4 4 4 4
T5B LOSS OF TBCW	FULL POWER: N/A 1: 1.8E-2 2: " 3: " 4: " 5: " 6: " 7: "	N/A LOGNORMAL; EF=5 " " " " " "	3 5 5 5 5 5 5 5
T5C LOSS OF PSW	FULL POWER: N/A 1: 1.8E-2 2: " 3: " 4: " 5: " 6: " 7: "	N/A LOGNORMAL; EF=5 " " " " " "	3 5 5 5 5 5 5 5
T5D LOSS OF CCW	FULL POWER: N/A 1: N/A 2: " 3: " 4: 1.8E-2 5: " 6: " 7: "	N/A " " " LOGNORMAL; EF=5 " " "	3 3 3 3 5 5 5 5

Table D.5.1 Special Initiating Events

Description	Plant State: Mean Frequency [per Calendar Year]	Distribution	Comments
TAB OR TDB	FULL POWER: N/A	N/A	3
	1: N/A	"	3
	2: N/A	"	3
	3: N/A	"	3
	4: 9E-4 OR 6E-3	LOGNORMAL; EF=5	6
	5: "	"	6
	6: "	"	6
	7: "	"	6
TIA LOSS OF INSTRUMENT AIR SYSTEM	FULL POWER: N/A	SEE "T2"	7
	1: 0.5	TBD	8
	2: 0.5	"	8
	3: 0.5	"	8
	4: 0.5	"	8
	5: 0.5	"	8
	6: 0.5	"	8
	7: 0.5	"	8
TORV INADVERTENT OPEN RELIEF VALVE (SHUTDOWN)	FULL POWER: N/A	SEE "T3C"	9
	1: N/A	"	9
	2: "	"	9
	3: "	"	9
	4: 0.1	TBD	10
	5: N/A	N/A	11
	6: N/A	"	11
	7: N/A	"	11
TIOP INADVERTENT OVERPRESSURIZATION EVENT	FULL POWER: N/A	N/A	12
	1: N/A	"	12
	2: N/A	"	12
	3: N/A	"	12
	4: 0.16	TBD	13
	5: 0.16	"	13
	6: N/A	N/A	14
	7: N/A	"	14
TIHP INADVERTENT OVERPRESSURIZATION VIA SPURIOUS HPCS ACTUATION	FULL POWER: See T3A	N/A	15
	1: See T3A	"	15
	2: "	"	15
	3: "	"	15
	4: 1E-2	TBD	16
	5: 1E-2	TBD	16
	6: N/A	N/A	14
	7: N/A	"	14

Table D.5.1 Special Initiating Events

Description	Plant State: Mean Frequency [per Calendar Year]	Distribution	Comments
TIOF INADVERTENT OVERFILL VIA LPCS OR LPCI	FULL POWER: N/A	N/A	17
	1: N/A	"	17
	2: "	"	17
	3: "	"	17
	4: 4E-2	TBD	18
	5: 4E-2	TBD	18
	6: N/A	N/A	14
TLM LOSS OF MAKEUP	7: "	"	14
	FULL POWER: See T3B	N/A	19
	1: N/A	"	19
	2: "	"	19
	3: "	"	19
	4: 0.49	TBD	20
	5: 0.49	"	20
	6: 0.49	"	20
	7: N/A	N/A	21

Table D.5.1 Comments

- {1} The Rod Withdrawal Error event for Full Power was included in the "T3A" frequency in Table 3.1-1. This is EPRI event number 27, Rod Withdraw at Power.
- {2} See Section D.5.2 for justification for excluding these events.
- {3} System not normally used during these POSs or was excluded from the Full Power analysis.
- {4} NUREG-1275 Vol. 3 [Lam et al., 1988] gives a value of $1.8E-2$ for the frequency of loss of service water. This value was assumed to be appropriate for this screening study.
- {5} See note {4}.
- {6} TAB estimated using hourly failure rate for an AC Bus. TDB used TDC value given in [Drouin et al., 1989].
- {7} For Full Power [Drouin et al., 1989], Loss of Instrument Air (TIA) was considered to result in the same plant response as transient category T2, Loss of PCS, and was thus considered part of this transient category.
- {8} Loss of Instrument Air applies to all POSs. The frequency is based on two events at Grand Gulf over a four year period.
- {9} The Inadvertent Open Relief Valve (IORV) event, as it applies to causing a reactor SCRAM, is considered in event T3C (see Table D.2-1).
- {10} Conservatively assumed same value as for transient from Inadvertent Open Relief Valve from [Drouin et al., 1989] Vol. 1, Rev. 1, page 8-20.
- {11} Not applicable. Vessel is depressurized.
- {12} Not applicable. System pressure can be as high as normal (approx. 1000 psi).
- {13} Frequency estimated using value for EPRI category 20.
- {14} Vessel head is off, cannot pressurize.
- {15} Included in T3A.
- {16} Frequency estimated using value for EPRI category 33.
- {17} Low pressure systems cannot overpressurize the primary.
- {18} Frequency estimated by multiplying the EPRI category 33 value by four.
- {19} Included in T3B.
- {20} Frequency estimated using value for EPRI category 24.
- {21} Makeup can be off in POS 7.

5. Loss of 1E AC Bus B (TAB),
6. Loss of 1E DC Bus B (TDB), and
7. Loss of IA (TIA).

The methods for quantifying these events are described in Table D.5-1

D.5.4 Other Events

In addition to the events identified above, several other events were identified that could lead to problems if unmitigated. These include:

1. Inadvertent Open Relief Valve at Shutdown (TORV),
2. Inadvertent Overpressurization (makeup greater than letdown) (TIOP),
3. Inadvertent Overpressurization via Spurious HPCS Actuation (TIHP),
4. Inadvertent Overfill via LPCI or LPCS (TIOF), and
5. Loss of Makeup (TLM).

The methods for quantifying these events are described in Table D.5-1.

References for Appendix D

[Drouin et al., 1989]	M.T. Drouin et al., "Analysis of Core Damage Frequency: Grand Gulf, Unit 1; Internal Events," NUREG/CR-4550, SAND86-2084, Vol. 6, Rev. 1, Part 1, September 1989.	[Vine et al., 1986]	G. Vine et al., "Residual Heat Removal Experience Review and Safety Analysis: Boiling Water Reactors," NSAC-88, March 1986.
[Diamond et al., 1990]	D.J. Diamond et al., "Reactivity Accidents: A Reassessment of the Design-Basis Events," NUREG/CR-5368, BNL-NUREG-52198, September 1989.	[Wheeler et al., 1989]	T. A. Wheeler et al., "Analysis of Core Damage Frequency From Internal Events: Expert Judgment Elicitation," NUREG/CR-4550, SAND86-2084, Vol. 2, April 1989.
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Appendix E. Updated Success Criteria

This Appendix is the Success Criteria used in the screening study [Whitehead et al., 1991], updated for the detailed study of POS 5. The update was performed for POS 5, but if the update affected other POSs, then the success criteria for these POSs were also updated.

This appendix provides the success criteria for POS 4, 5, 6, and 7. (The success criteria for POS 1, 2, and 3 are the NUREG 4550 success criteria for full power and are not reproduced here.)

E.1 Summary Description of the Success Criteria for the Systems vs POSs: Low Pressure Conditions

There are two basic methods of cooling the core:

- (1) Injecting subcooled or saturated water so that the fluid exiting the vessel after being heated by decay heat is subcooled or is a two phase mixture of low quality.
- (2) Injecting subcooled or saturated water in small quantities and steaming out the vessel.

Method (1) is the normal way of cooling the core. Method (2) must be verified to work in the limiting case of natural convection of boiling saturated water at 15 psia. It must be verified that dryout due to flooding does not occur with 1% decay heat at 15 psia. NUREG 4550 assumed that method (2) works after trip from full power. However, in this case, the dryout heat flux will be higher (even though the decay heat is also higher) due to a higher density for saturated vapor at the higher pressure (dryout heat flux is proportional to the square root of the vapor density according to the Wallis flooding criteria). Using Lahey and Moody, it is conservatively estimated that the dryout heat flux for flooding is $8.5E+3$ Btu/hr/ft² at 15 psia [Lahey and Moody, 1984]. The UFSAR, table 4.4-1, specifies a maximum full power heat flux of $3.62E+5$ Btu/hr/ft² and 1% of this value is less than the estimated dryout heat flux [SERI, 1992]. Thus, method (2) should prevent core damage. The success criteria used in this study assume that steaming the core at low pressure does not lead to flooding induced dryout.

The functional event tree for POS 4, 5, 6 and 7 is shown in Figure E.1.1.

In terms of functions, the tree is very simple. Three functions must be successfully provided to prevent core damage: (1) reactivity control to ensure that the core is not producing heat in excess of decay heat, (2) level control to ensure that the core is maintained "covered" with water, and (3) energy removal to remove energy from the water covering the core. (The situation following a large LOCA in a recirculation line, for which only two thirds of the core is covered with water, is a special case.) The specific combinations of systems which can fulfill these three functions depend on the POS and the specific accident initiating event. A discussion of each function follows, addressing success criteria which maintain system pressure low enough so that isolation of RHR/SDC is not required. Options for cooling the core considering isolation of RHR/SDC and pressurization of the system are subsequently discussed.

Function 1: Reactivity Control

Shutdown margin at Grand Gulf can be maintained with the rods alone all the way down to refueling conditions without the need for boron injection. The SLC is a backup for the rods. Since in POS 4, 5, 6, and 7 the rods are fully inserted, it is considered extremely improbable that loss of reactivity control can occur.

Function 2: Level Control

The core can be cooled as long as the top of the core is "covered" with water, assuming that natural convection of boiling saturated water does not lead to dryout (as discussed earlier). "Covered" means that the collapsed level of the water is above the top of the core. A design basis large LOCA in a recirculation suction line leads to uncover of about one third of the core. Licensing analyses verify that for LOCAs from full power, the top third can be cooled by steam. The situation for off power is different, as discussed in the following description of function 3, Energy Removal.

Certain options for energy removal which cool liquid in the downcomer region (such as RHR/DHR) require that the measured level, measured in the downcomer, be sufficiently high for adequate recirculation between the core and downcomer regions. This required measured level is significantly higher than the top of the core. The actual level of concern is the level in the core region which must be above the minimum steam separator turnaround point to allow core water to flow back into

IE	RC	LC	ER	SEQ #	OUTCOME
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FUNCTIONAL EVENT TREE

IE: PREEXISTING KNOWN UNAVAILABILITIES AND ACCIDENT INITIATOR

RC: REACTIVITY CONTROL

LC: LEVEL CONTROL

ER: ENERGY REMOVAL

- 1 OK
- 2 CD
- 3 CD
- 4 NA-FOR-4

Figure E.1-1. Functional Event Tree for Plant Operational States 4, 5, 6, and 7

the downcomer. The actual core level is different from the measured level in the downcomer due to the following reasons:

- The core fluid is a two phase mixture (at power);
- If the recirculation pumps are on, they raise the core level with respect to the downcomer level; and
- The safety-related level measurements are based on converting a differential pressure measurement made using a reference leg into an equivalent level without compensating for changes in water density with temperature which causes the measured level to be different than the actual downcomer level at low temperature conditions. (If actual level is above instrument zero, then actual level is less than measured level at cold conditions. If actual level is below instrument zero, then actual level is greater than measured level at cold conditions.)

At shutdown, operation of the recirculation pumps is not required if level is sufficient, since natural circulation due to the difference in density between downcomer and core fluid can remove decay heat. If the recirculation pumps are not available and the measured level is too low for natural recirculation, it is possible to establish core cooling by operating both loops of RHR/SDC at high flow rates [Vine et al., 1986]. This 'Enhanced Shutdown Cooling' method can provide mixing of downcomer and core water with the measured level as low as a few feet below normal. The required (measured downcomer) levels at shutdown used for our success criteria are:

- +11.4 inches with forced recirculation;
- +82 inches for natural recirculation; and
- +36 inches minus 2 feet for enhanced shutdown cooling.

(Normal measured downcomer level, when forced recirculation is on, is between +36 and +40 inches. RHR/SDC isolates on measured low level 3, +11.4 inches. Forced recirculation with at least one recirc pump provides enough head to maintain core-to-downcomer recirculation down to this level.)

For Non-LOCA situations, level control is accomplished by matching letdown, with RWCU, to makeup, with CDS or CRD. During refueling, after the cavity is

flooded, letdown and makeup can be isolated.

For LOCA situations, level control is accomplished with ECCS, SSW cross-tie, or FW (given sufficient makeup until alignment of FW can be achieved). The ECCS sources ultimately recirculate from the SP. The SSW cross-tie and FW systems provide once through cooling. When level control is provided with ECCS using the SP, fluid exiting the vessel must not bypass containment, or even with SPMU, eventual loss of SP inventory with subsequent loss of ECCS cannot be prevented.

Function 3: Energy Removal

Energy Removal from the core is accomplished by maintaining level control. Adequate level control depends on the method of energy removal.

Energy Removal from fluid in the vessel must match decay heat. The methods which can be used to remove energy depend on the accident situation and the availability of systems in that accident as well as the decay heat level. Five options are available to remove the energy, but not every option can be used in every situation. The five options are:

- (1) Closed loop cooling of subcooled vessel water using the RHR on SDC, the ADHRS (not available in POS 4), or the fuel pool cooling system (only available in POS 7). Downcomer level must be sufficient for recirculation from the core to the downcomer region when RHR/SDC or ADHRS is used; with forced recirculation the minimum allowed measured level is +11.4 inches, and with natural circulation the minimum allowed measured level is +82 inches. (Enhanced shutdown cooling can be used if the measured level is no lower than two feet below the average normal measured level of +36 inches.)
- (2) Recirculation of water from the SP using the ECCS (HPCS, LPCS, or LPCI) with water flow out a break and/or the SRVs, or the vessel when the head is removed. For sufficiently small breaks, normal makeup with CDS or CRD can match the break flow if let down is isolated, and method (1) can be used. The acceptable upper limit on this break size depends on the driving pressure. To prevent loss of SP inventory, fluid exiting the vessel must not bypass containment. Thus, the MSIVs must be closed except when

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steam line plugs are in place.

- (3) Injection of water from the SSW cross-tie or the FW system with water flow out a break and/or the SRVs, or the vessel when the head is removed. (If SPMU or SRVs are available, then lower containment can be flooded up to the maximum level specified in the EP. If SPMU and the SRVs are not available, then vessel level is controlled. Upper containment is not flooded and, if necessary, the core can be steamed.)
- (4) Steaming out a break and/or the SRVs, or the vessel when the head is removed, with makeup from low capacity systems such as the CRD. If necessary, other sources of makeup can be used (such as SSW cross-tie) and the core steamed.
- (5) At sufficiently low decay heat levels (e.g., after refueling), letdown of hot water through the RWCU with makeup from the CDS and/or the CRD.

Options (1) and (5) require a high enough water level for adequate forced or natural recirculation between the core and downcomer regions, or for enhanced shutdown cooling. Options (2) and (3) fill the vessel to a level determined by the size and location of the exit path (break and/or SRVs). Option (4) requires the core to be covered with water.

Of these five options, three are once through: (3), (4), and (5). Option (5) requires no heat removal from containment. Option (3) requires heat removal from containment in the short term only if the core is steamed. If lower containment is flooded, containment heat removal is required only after the entire inventory of water is heated to saturation.

Options (2), (4), and sometimes (3) require containment cooling to prevent containment overpressurization. Containment cooling can be provided by either the SPC or CS. If containment cooling is not provided, the containment can be vented and the heat sink for these two options is boiling to the atmosphere at 15 psia. If containment cooling is lost and the containment is not vented, for these options in which energy is being added to containment, the containment pressure will rise to maintain saturation conditions as the SP temperature increases. NUREG 4550 concluded that containment would overpressurize and fail before equipment temperature limits are reached (pumps, relays, and so on), and that structural failure of the containment would

not render the SP unavailable [Drouin et al., 1989]. This important conclusion means that option (2) can be used to cool the core with the containment failed. That is, containment overpressurization is an effective way to vent containment. The success criteria use this conclusion.

The SPMU system has two functions: (1) maintain SP inventory by compensating for all water entrapment volumes (e.g., drywell volume below the top of the weir wall) [Section 6.2.7.1 of SERI, 1992], and (2) lower the long term containment pressure since the heat removal capacity of one RHR train is less than the decay heat at 30 minutes, the time when containment cooling is assumed to be actuated in a DBA [Section 6.2.7.3.4 of SERI, 1992]. The second function of the SPMU is not required for POS 4, 5, 6, and 7, since the maximum decay heat is 38 Mw and the heat removal capacity of one RHR train is 54 Mw [185 E+6 Btu/hr from Table 6.2-2 of SERI, 1992].

The first function ensures that the SP level is not decreased below the minimum level required for pumps NPSH while the SP is supplying water to the core and water out the break is filling up the drywell. This function of SPMU is required for LOCAs in POS 4, 5, 6, and 7, since, as is the case at full power, the fluid is discharged to the drywell and not to the SP. (For a small LOCA at full power, SPMU is not required until 30 minutes due to the relatively low amount of water drawn from the SP by HPCS/RCIC to feed the pressurized vessel [Section 6.2.7.3.1 of SERI, 1992].)

SPMU is not required to maintain SP inventory for transients in POS 4 and 5, since any use of the SP in these cases is associated with the use of the SRVs which discharge directly to the SP. (To prevent bypass flow outside of containment, one of two MSIVs in each steam line must be closed.) In POS 6 and 7, the head is off the vessel and steam line plugs are installed. Thus, the SRVs are not available, and if the SP is used for core cooling in plant states 6 or 7, the SPMU system must be made available to refill the SP with water pumped from the SP out the vessel head into the upper cavity/upper containment pool.

Long term makeup to the suppression pool is required if the containment is vented, to prevent boiloff of water to where adequate inventory for ECCS is lost.

The three functions of the functional event tree have been discussed. From this discussion success criteria can be developed. The success criteria need to be specified for

the following situations:

- POS 4 at 38 Mw
- POS 4 at 6 Mw
- POS 5 at 34 Mw
- POS 5 at 6 Mw
- POS 6 at 15 Mw
- POS 6 at 6 Mw
- POS 7 at 12 Mw.

Both LOCAs and Transients need to be considered for these situations.

A basic distinction between POS 4 and the other three POSs should be discussed. In POS 4 the primary pressure is 100 psig (about one tenth the full power value) and the temperature is 328 degrees F (full power is 550 degrees F). For a LOCA in POS 4, the primary will flash as in the full power case, but the blowdown rate will be less due to the lower pressure. The internal energy of the primary water in POS 4 is about half that at full power since it is determined mainly by the temperature (32 degree F reference for zero internal energy). Thus about half of the full power energy is deposited into containment following a large LOCA in POS 4. LOCAs in POS 4 are similar to LOCAs from full power. Instead of calculating detailed thermal hydraulic behavior for POS 4 LOCAs (a lengthy process), we chose to use the full power LOCA success criteria with three modifications: (1) there is no need for SPMU for long term containment pressure control as discussed previously for event #3 of the functional event tree; (2) ADS is not required to allow low pressure ECCS systems to be used since the initial pressure is already low; (3) the SRVs are required to be manually operated in a relief mode for small LOCAs, and for small size medium LOCAs, to prevent pressure from rising to where the integrity of RHR/SDC components are threatened during the time from when adequate level for core cooling is lost and the time at which level has dropped to the minimum ECCS auto-actuation setpoint. (If one SRV is opened allowing discharge of steam following a small or medium LOCA, pressure will not threaten RHR/SDC components during the time required for auto-actuation of ECCS. Following refill with ECCS

and a water solid vessel, SRVs are required to be open to control pressure below the shutoff heads of the ECCS pumps, and to allow for discharge of enthalpy. If RHR/SDC fails to auto-isolate on high pressure or low level, one SRV is sufficient to prevent overpressurizing RHR/SDC piping, rated at 220 psig. However, two SRVs must be open to prevent possible overpressurizing of ADHR piping, rated at 80 psig.)

LOCAs in POS 5, 6, and 7, with the primary subcooled at 15 psia, are very different from LOCAs at higher pressure during the initial time period following the LOCA. No primary inventory is lost due to flashing, thus LOCAs in steam lines are not of concern unless they interrupt level control or energy removal. The only vessel penetrations which are located below the top of the core are the recirculation connections, and the control rod and instrumentation penetrations. A recirculation line break will not completely drain the core since the jet pump riser separates the downcomer (the source for recirculation) from the lower plenum. Instead about one third of the core would be uncovered. Similarly, a break in an RHR line during SDC, or diversion of inventory to the SP, cannot completely drain the core since the RHR connects to a recirculation suction line. Licensing analyses demonstrate that for LOCAs from full power, the top one third of the core can be adequately cooled by steam. However, in POS 4, 5, 6, and 7 the core fluid can be initially subcooled leading to no steam cooling of the top one third of the core immediately following a LOCA. (Vine et al., 1986 also points out the need to verify the coolability of the top 1/3 of the core with ECCS in off-power modes.) HPCS or LPCS should adequately cool the top 1/3, since they spray down over the top of the fuel. LPCI fills the volume outside of each fuel channel and flows over the top and down into the fuel assemblies. Based on MELCOR analyses, 2 of 3 LPCI trains are needed to cool the top 1/3 of the core at low temperature conditions. Since SSWXT and FW inject into LPCI lines, for a large LOCA, the flow from either of these two systems should be at least equal to that from 2 LPCI pumps. SSWXT can provide sufficient flow, but FW cannot.

Vessel rupture, and failures in the control rod and instrumentation penetrations in the bottom of the vessel can drain the core. Vessel rupture can be screened out on low frequency. Failures of bottom penetrations were screened from analysis in NUREG 4550. We discussed the potential for failure of lower vessel penetrations with Grand Gulf, and asked if any maintenance is performed during refueling which could contribute to an increased potential for such failure. Based on the results of this

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discussion, we deferred examination of this event until the detailed human action phase of the study, which is beyond the scope of this report. It is not possible to syphon or pump out water below the top of the core through any of the penetrations above the top of the core since the steam separators ensure that the pressure at the top of the downcomer is that at the top of the core region (i.e., the steam separators act as a syphon break). We verified with Grand Gulf that during refueling, no temporary lineups are used which could completely drain the core (e.g., hoses dropped to the lower plenum of the vessel).

The same LOCA sizes as used in NUREG 4450 can be used for POSs 4 through 7. A large LOCA is greater than or equal to 0.4 sq ft. An intermediate LOCA is 0.007 sq ft to 0.4 sq ft. A small LOCA is less than 0.007 sq ft. As previously discussed, for small and medium LOCAs SRVs must be opened to: (1) prevent potential overpressurization of SDC piping (2) prevent system pressurization to pump shutoff heads, and (3) to allow for discharge of enthalpy sufficient to match decay heat. At full power, this requirement is provided by the safety function of the SRVs. In POS 4, 5, 6, and 7, the pressure is low (below 135 psig, except for the special Hydro condition which is discussed later) and the safety function of the SRVs (high pressure control) cannot be used. The SRVs must be manually opened (relief mode). In POS 6 and 7, the SRVs are unavailable due to the installation of steam line plugs, but the head is off the vessel, thus providing a relief path.

Option (2) considers the possibility that small breaks can be within the capability of the normal makeup systems. First, consider a large or medium size LOCA in the worst location, a recirc suction line. In the steady state, following blowdown and refill, the top 1/3 of the core is not covered with water since the break is so large. (This is a conservative assumption for medium LOCAs.) Core cooling is accomplished with injection of ECCS water from above the core. In steady state it is possible that injection from only the CRD, to match steaming, can cool the core. The CRD can supply about 240 gpm. 240 gpm can match decay heat if steaming is allowed. The situation with CRD makeup differs from the case of ECCS addition in two important respects:

- (a) CRD injection into the vessel is via the control rod drive cooling water header through the rod drive seals (i.e., the water enters from the bottom of the vessel). ECCS water is injected from above the core and provides for some cooling of the top 1/3 of the core as it is

injected.

- (b) The CRD flow rate is substantially less than the ECCS flow rate. This may not be too significant because the ECCS water that is not boiled merely flows out the break. However, mixing considerations may be important. Without examining in detail the case for 1/3 core uncover, with steaming, and with bottom makeup sufficient only for inventory replacement, we do not know if this option will work. Also, the option of using CRD is only possible if the transient aspects of the LOCA are not of concern. By transient aspects, we mean the flashing, blowdown, and rewetting aspects immediately following a LOCA in a pressurized primary. The CRD has insufficient capacity to prevent cladding damage under these conditions. Therefore, we cannot take credit for this option in POS 4 (100 psig) even if the steady state situation is acceptable. We could take credit for this option in POSs 5, 6, and 7 (0 psig) if the steady state situation is acceptable since no flashing/blowdown occurs. We decided to take no credit for this option in POSs 5, 6, and 7 until detailed thermal hydraulic analyses justify doing so. The only situation under which this option is needed is if all the ECCS injection options fail, and even if CRD makeup is available throughout the accident it cannot prevent level falling to the actuation setpoint of ECCS due to the size of the break, and thus CRD makeup is not an option for preventing the use of ECCS.

[Note that using condensate makeup (as a backup for CRD makeup) for steaming in the steady state following a large or medium LOCA, should not even be considered, since condensate is supplied to the downcomer, not the core, and thus the injected water would run out the break and never reach the core.]

The situation for small break LOCAs is different from the case just discussed for the larger breaks. We defined small break LOCAs as less than or equal to 0.007 sq ft in area, to be consistent with the NUREG 4550 full-power PRA. In general, a loss of inventory is not considered to be a LOCA if it is within the capability of the normal makeup systems. In POS 4 (100 psig), a 0.007 sq ft hole discharges about 160 gpm (water flashing, Moody model). In POS 5, 6, and 7 (0 psig), a 0.007 sq ft hole with a 100 foot head discharges about 200 gpm (water draining through the hole). As

discussed previously, the CRD can supply about 240 gpm (CDS can supply even more), and normal letdown via the RWCU can be isolated. Therefore, the small break LOCA is not really a LOCA for the POS of concern. We continue to call it a small break LOCA since it is treated so at full power, and we use success criteria for a small break LOCA tree which accounts for the possibility of isolation of letdown/increased makeup.

Steaming through one open SRV is adequate to prevent overpressurization of RHR/SDC and ADHR piping and components.

An interfacing systems LOCA, V sequence due to overpressurization of low pressure piping, can only occur in POSs 4 and 5 (non hydro condition) if a prior failure pressurizes the primary, because the typical pressure in POS 4 is 100 psig (unless a pressurization transient occurs) which is below the 135 psig permissive pressure for RHR SDC initiation. Overpressurization of low pressure piping is not an initiating event in POSs 4 and 5 (excluding the Hydro condition). Overpressurization of low pressure piping cannot occur in POS 6 and 7 since the vessel head is off which prevents pressurization of the primary.

The likelihood of a pipe break LOCA in POSs 4, 5, 6 and 7 is lower than at full power due to the lower driving pressure (135 psig at most -- excluding the Hydro condition -- as compared to 1000 psig at full power). For a LOCA to occur, a critical crack must exist which can propagate under the driving pressure. The lower the pressure, the greater the required size of the critical crack.

E.2 Pressurization Concerns and Success Criteria at Rated Pressure

Pressure control could be lost in POS 4 and 5. For example, if cooling is lost and SRVs cannot be opened to relieve pressure, the system pressurizes along the saturation line. Pressurization is not of concern in POS 6 and 7, since the vessel head is off.

If pressure rises too high, and the shutdown cooling system is not isolated, the piping/components in the RHR/SDC or ADHR systems could rupture, leading to a LOCA outside containment. The pressure rating of the RHR/SDC is 220 psig, and the pressure rating of the ADHR is 80 psig. Failure is not expected unless system pressure is about a factor of two greater than rated

pressure. However, if the system pressurizes all the way to the SRV safety setpoints, about 1000 psig, the shutdown cooling systems will fail if they are not isolated.

In POS 4, the high pressure auto-isolation for RHR/SDC (135 psig) is active, and the low level 3 auto-isolation for RHR/SDC is active. In POS 5, the high pressure auto-isolation for RHR/SDC (135 psig) is active, and the low level 3 auto-isolation for RHR/SDC is active. (In the screening study [Whitehead et al., 1991], it was assumed that in POS 5 auto-isolation of RHR/SDC on high pressure was inactive, based on information received during the plant visit in January 1991. During a subsequent visit to the site in June, 1992, we were informed that auto-isolation of RHR/SDC is active in cold shutdown, POS 5.)

If the primary pressurizes and shutdown cooling is not isolated on high pressure (either automatically or manually), we assume that an interfacing systems LOCA outside containment occurs. This LOCA can be isolated by the auto-isolation of shutdown cooling on low level 3, in which case the isolated LOCA becomes a transient. If the interfacing LOCA is not isolated, ECCS is lost since SP inventory cannot be maintained even with SPMU. In this case, we assume core melt since the LOCA drains the top third of the core and, without ECCS, a partially drained core cannot be cooled. (It is possible to flood with SSWXT, but this leads to flooding of equipment in the auxiliary building. We have conservatively assumed that flooding with SSWXT cannot mitigate the RHR/SDC LOCA outside containment.)

If shutdown cooling is isolated either on high pressure or low level, the system can pressurize up to the SRV safety setpoints and the core can be cooled by steaming on the SRVs. (For operation in the safety mode, the SRVs do not require any support systems and do not require operator action. As discussed previously, for operation of the SRVs in the relief mode at low pressure, operator action, dc power, and control air are required.) Steaming can be accomplished with one SRV cycling at its safety setpoint, and with makeup water from HPCS or CRD. (LPCS, LPCI, and CDS -- without feedpumps -- cannot inject at 1000 psig.)

During hydro testing in POS 5 coming up from a refueling outage, the 200 degrees F subcooled water is pressurized to about 1000 psig. The low pressure SDC system is isolated, and pressure protection is provided by the SRVs in the safety mode.

E.3 Success Criteria

Table E.1-1 through E.5-4 presents the detailed success criteria for POS 4, 5, 6 and 7. These success criteria are based on the previous discussions. Three considerations affect the application of these success criteria: (1) Systems unavailabilities as allowed by tech specs. (2) Whether or not procedures are in place for every proposed option. (3) The time available for instituting systems operations which can be substantial considering the low decay heat levels present.

An example of consideration (1) is as follows. Given a large LOCA in POS 5, portions of ECCS are required to be operable per tech spec 3.5.2, but the SPMU can be inoperable per tech spec 3.6.3.4. The success criteria require SPMU when ECCS pulls from the SP to prevent depleting the SP inventory (see earlier discussion on SPMU). Thus, if SPMU is unavailable, ECCS injection from the SP following a large LOCA cannot be maintained and this option for core cooling is not valid. Similarly, tech spec 3.4.2.1 allows the SRVs to be inoperable in POS 5, and without opening the SRVs, transients cannot be mitigated by injection of water from any source since no relief path exists. In applying the success criteria, we modeled the availability of systems allowed unavailable by the Tech Specs based on discussions with Grand Gulf staff. For example, SPMU is taken out of service in POS 5, but two SRVs remain operable in POS 5.

An example of consideration (2) is as follows. The success criteria allow for enhanced shutdown cooling if forced recirculation is not available and the level is below that required for natural circulation. This option is not specified in the Grand Gulf procedures.

An example of consideration (3) is as follows. Given a transient in POS 5 to be mitigated by pumping water from the SP to the vessel and returning the heated water to the SP via opening SRVs, SP cooling with the SPC or CS systems is not needed until the SP water increases in temperature by at least 80 degrees F (100 to 180 degrees F). At low decay heat levels, this requires a long time. The FSAR Table 1.3-4 specifies the SP inventory as 136,000 cubic feet. At an initial decay heat level of 38 Mw it would take about 6 hours to heat the SP by 80 degrees F. At an initial decay heat level of 6 Mw, it would take about 32 hours to heat the SP by 80 degrees F. Such long times available for operator action are considered in the detailed analysis.

Table E.1.1 Success Criteria for Plant Operational State (POS) 4^a

Plant State	Event	Level Control	Energy Removal
<p>4 (338 F, Saturated at 100 psig)</p> <p>Maximum decay heat is 1.0% (38MW), 5 hours after shutdown.</p> <p>After refueling decay heat is 0.16% (6MW), 30 days after shutdown.</p>	<p>Large LOCA ($\geq 0.4 \text{ ft}^2$)^a</p>	<p>[HPCS or 2/3 LPCI^b or LPCS]^q and 1/2 SPMU^{c,p} and 4, 1/2 MSIVs^v and 1/2 CVs^v and 1 SRV^v</p> <p><u>or</u></p> <p>SSW Crosstie^{o,q,z} and 1 SRV^w</p>	<p>{[1/2 SPC or 1/2 CS]^d or [Vent Containment and 1/2 SPMU^e]}^p</p> <p>(Once through)</p>
	<p>Medium LOCA (0.007 to 0.4 ft²)^a</p>	<p>[HPCS or 1/3 LPCI^b or LPCS]^q and 1/2 SPMU^{c,p} and 1 SRV^{f,j} and 4, 1/2 MSIVs^w and 1/2 CVs^v</p> <p><u>or</u></p> <p>SSW crosstie^{o,q,z} and 1 SRV^{f,j,w}</p>	<p>{[1/2 SPC or 1/2 CS]^d or [Vent Containment and 1/2 SPMU^e]}^p</p> <p>(Once through)</p>
	<p>Small LOCA ($< 0.007 \text{ ft}^2$)</p>	<p>Isolate letdown and [increase condensate/booster^r or {increase CRD and forced recirc^s}^x]</p> <p><u>or</u></p> <p>[HPCS or 1/3 LPCI^b or LPCS]^q and 1/2 SPMU^{c,p} and 1 SRV^{f,j} and 4, 1/2 MSIVs^w and 1/2 CVs^v</p> <p><u>or</u></p> <p>SSW crosstie^{o,q} and 1 SRV^{f,j}</p> <p><u>or</u></p> <p>FW given temporary makeup^{s,o} and 1 SRV^{f,j}</p>	<p>Transfer to transient success criteria</p> <p>{[1/2 SPC or 1/2 CS]^d or [Vent Containment and 1/2 SPMU^e]}^p</p> <p>(Once through)</p> <p>(Once through)</p>

Table E.1.1 Success Criteria for Plant Operational State (POS) 4^a

Plant State	Event	Level Control	Energy Removal
	Transients ^b	<p>[Letdown (RWCU) and Makeup (CRD^k or Condensate/Booster^l)] or alternate source of makeup^u</p> <p style="text-align: center;"><u>or</u></p> <p>enhanced SDC^t</p> <p style="text-align: center;"><u>or</u></p> <p>1 SRV^j and 4, 1/2 MSIVs^w and [HPCS or 1/3 LPCI^b or LPCS]^q</p> <p style="text-align: center;"><u>or</u></p> <p>1 SRV^j and [SSW^{o,q} crosstie or FW given temporary makeup^{s,o}]</p> <p style="text-align: center;"><u>or</u></p> <p>[CRD^k and/or Condensate/Booster^l] and 1 SRV (steaming)^{l,j}</p> <p style="text-align: center;"><u>or</u></p> <p>{[CRD^k and/or Condensate/Booster^l] and RWCU (360 gpm)^m}ⁿ</p> <p style="text-align: center;"><u>or</u></p> <p>Isolation of RHR/SDC and 1 SRV/Safety and {[HPCS and 4, 1/2 MSIVs^w] or CRD}^y</p>	<p>1/2 RHR on SDC^b with SSW heat sink^q</p> <p>2/2 RHR on SDC^b with SSW heat sink^q</p> <p>{[1/2 SPC or 1/2 CS]^d <u>or</u> [Vent containment and 1/2 SPMU^o]}^p</p> <p>(Once through)</p> <p>{[1/2 SPC or 1/2 CS]^d <u>or</u> [Vent containment and 1/2 SPMU^o]}^p</p> <p>(Once through)</p> <p>{[1/2 SPC or 1/2 CS]^d <u>or</u> [Vent containment and 1/2 SPMU^o]}^p if HPCS used</p>

Table E.1.1 Notes

- ^a Reactivity control by fully inserted rods
- ^b LPCI Trains A and B require manual re-alignment from SDC. RHR SDC operability per Tech Spec 3.4.9.2. 2/3 LPCI per MELCOR calc.
- ^c SPMU required to prevent loss of SP inventory
- ^d SPMU not required since maximum decay heat less than one RHR train heat removal capability
- ^e SPMU required to makeup for boiloff from SP when containment vented
- ^f 1 SRV required to augment flow out break and prevent pressurization for break $\leq 0.3 \text{ ft}^2$
- ^g Use NUREG/CR-4550 model for FW; thus, assume for small LOCAs and Transients FW can be aligned in time. Need to quantify makeup required until FW available
- ^h PCS not available, and Feedwater not available. SPMU to compensate for loss of inventory not required since SRVs discharge to SP.
- ⁱ Condensate/Booster injection may either be on standby or be unavailable.
- ^j 1 SRV provides for flow of hot water or steam out of vessel to SP and prevents pressurization of primary
- ^k CRD flow rate at low vessel pressure is 240 gpm max. If forced recirc lost, CRD cannot raise level for natural recirc before auto isolation of RHR/SDC occurs on high pressure in POS 4 at 38 MW.
- ^l 240 gpm injection required.
- ^m Maximum RWCU letdown of 360 gpm per Inadequate Decay Heat Removal Procedure Step 5.1.3.
- ⁿ This method can match decay heat only after refueling when decay heat is low.
- ^o NUREG/CR-4550 modeled SSW crosstie and FW.
- ^p SPC, CS, SPMU required to be operable in POS 4 per Tech Specs 3.6.3.3, 3.6.3.2, and 3.6.3.4, respectively. SRVs required to be operable in PS 4 per Tech Spec 3.4.2.1
- ^q ECCS and SP operability per Tech Spec 3.5.2 and 3.5.3. SSW operability per Tech Spec 3.7.1.1
- ^r Small LOCA is within makeup capability, but CRD cannot both match break flow and raise level.
- ^s Adequate cooling with 1/3 core uncovered evaluated with MELCOR
- ^t With normal level and with no recirc, increased SDC provides mixing between downcomer and core. Not enough time to establish enhanced SDC in POS 4 at 38 MW before auto isolation of RHR/SDC occurs on high pressure
- ^u To provide adequate natural circulation, raise level with alternate sources including ECCS
- ^v If LOCA is Main Steam Line Break outside containment, one of two MSIVs in line with break must close to prevent eventual loss of SP inventory and subsequent loss of ECCS from SP. Following closure of MSIV to isolate break, one SRV must open to provide relief path for ECCS fluid injection, and at least one MSIV in each steam line without the break must close to prevent bypass flow outside containment which would result in loss of SP inventory. For Feedwater Line Break outside containment, one of two check valves in the broken line must close to prevent injection from the SP from draining the SP.
- ^w If the LOCA is a feedwater line break that is isolated, 1 SRV is required for egress of injected water.
- ^x Whenever SRVs are used in conjunction with ECCS from SP, one of two MSIVs in all four steam lines must close to prevent bypass flow outside containment, and subsequent loss of SP inventory and loss of ECCS.
- ^y Only with forced recirculation, can level be sufficient following small break LOCA for core-to-downcomer recirculation if CRD is the only source of makeup.
- ^z Cooling option for pressurization to rated pressure and temperature (1000 psig, 545 F). In POS 4, RHR/SDC is auto-isolated on high pressure or low level. One SRV steaming at its safety setpoint can remove energy, makeup is from either the HPCS or CRD pumps which can supply sufficient water at rated pressure.
- ^z FW not sufficient for large LOCA since flow not equal to 2 LPCI; SSWXT provides sufficient flow.

Table E.1.2 Success Criteria for Plant Operational State (POS) 5^a

Plant State	Event	Level Control	Energy Removal
<p>5 (200 F, 0 psig, except for HYDRO; 200 F, 1000 psig during HYDRO)</p> <p>Maximum decay heat is 0.9% (34MW), 7 hours after shutdown.</p> <p>After refueling decay heat is 0.16% (6MW), 30 days after shutdown</p>	<p>Large LOCA ($\geq 0.4\text{ft}^2$)^{b,v} which affects level control and/or heat removal^c</p>	<p>[HPCS or 2/3 LPCI^d or LPCS]^a and 1/2 SPMU^{e,r} and 4, 1/2 MSIVs^y and 1 SRV^y and 1/2 CVs^y</p> <p><u>or</u></p> <p>CRD and/or condensate booster steaming^y (for unisolated feedwater line break only)</p> <p><u>or</u></p> <p>Transient Success Criteria^y (for isolated feedwater line breaks only)</p> <p><u>or</u></p> <p>SSW Crosstie^{p,s,i} and 1 SRV^y</p> <p><u>or</u></p> <p>CRD makeup (steam out break)ⁱ</p>	<p>{[1/2 SPC or 1/2 CS]^f or [Vent Containment and 1/2 SPMU^g]}^r</p> <p>(Once through)</p> <p>Transient Success Criteria</p> <p>(Once through)</p> <p>{[1/2 SPC or 1/2 CS]^f or [Vent Containment and 1/2 SPMU^g]}^r</p>

Table E.1.2 Success Criteria for Plant Operational State (POS) 5^a

Plant State	Event	Level Control	Energy Removal
	Medium LOCA (0.007 to 0.4 ft ²) ^{b,v} which affects level control and/or heat removal ^c	<p>[HPCS or 1/3 LPCI^d or LPCS]^a and 1/2 SPMU^{e,r} and 1 SRV^{h,r} and 4, 1/2 MSIVs^z and 1/2 CVs^y</p> <p><u>or</u></p> <p>CRD and/or condensate booster steaming^y (for unisolated feedwater line break only)</p> <p><u>or</u></p> <p>Transient Success Criteria^y (for isolated feedwater line breaks only)</p> <p><u>or</u></p> <p>SSW crosstie^{p,s,i} and 1 SRV^{h,r}</p> <p><u>or</u></p> <p>CRD makeup and 1 SRV (steam out break and SRV)^t</p>	<p>{[1/2 SPC or 1/2 CS]^f or [Vent Containment and 1/2 SPMU^g]}^r</p> <p>(Once through)</p> <p>Transient Success Criteria</p> <p>(Once through)</p> <p>{[1/2 SPC or 1/2 CS]^f or [Vent Containment and 1/2 SPMU^g]}^r</p>

Table E.1.2 Success Criteria for Plant Operational State (POS) 5^a

Plant State	Event	Level Control	Energy Removal
	Small LOCA (<0.007 ft ²) ^b which affects level control and/or heat removal ^c	Isolate letdown and [increase condensate booster ^u , or {increase CRD and forced recirc} ^{aa}] or CRD and/or condensate booster steaming ^y (for unisolated feedwater line break only) or Transient Success Criteria ^y (for isolated feedwater line breaks only) or [HPCS or 1/3 LPCI ^d or LPCS] ^e and 1/2 SPMU ^{e,r} and 1 SRV ^{h,r} and 4, 1/2 MSIVs ^z and 1/2 CVs ^y or SSW crosstie ^{p,s} and 1 SRV ^{h,r} or FW given temporary makeup ^{i,p} and 1 SRV ^{h,r} or CRD makeup and 1 SRVs (steam out break and SRV) ^t	Transfer to transient success criteria Transient Success Criteria (Once through) {[1/2 SPC or 1/2 CS] ^f or [Vent Containment and 1/2 SPMU ^g]} ^r (Once through) (Once through) {[1/2 SPC or 1/2 CS] ^f or [Vent Containment and 1/2 SPMU ^g]} ^r

Table E.1.2 Success Criteria for Plant Operational State (POS) 5^a

Plant State	Event	Level Control	Energy Removal
	Transients ^j	<p>[Letdown (RWCU) and Makeup (CRD or Condensate/Booster^h)] or alternate source of makeup^x</p> <p><u>or</u></p> <p>enhanced SDC^w</p> <p><u>or</u></p> <p>[Letdown (RWCU) and Makeup (CRD or Condensate/Booster^h)] or alternate source of makeup^x</p> <p><u>or</u></p> <p>1 SRV^{i,r} and 4, 1/2 MSIVs^z and [HPCS or 1/3 LPCI^d or LPCS]^a</p> <p><u>or</u></p> <p>1 SRV^{i,r} and [SSW^{p,s} cross tie or FW given temporary makeup^{i,p}]</p> <p><u>or</u></p> <p>[CRD^m and/or Condensate/Booster^h] and 1 SRV (steaming)^{n,r}</p> <p><u>or</u></p> <p>{[CRD^m and/or Condensate/Booster^h] and RWCU (360 gpm)^{o,q}}</p> <p><u>or</u></p> <p>Isolation of SDC and 1 SRV/Safety and [{HPCS and 4, 1/2 MSIVs^z} or CRD]^{bb}</p> <p><u>or</u></p> <p>Isolation of RHR/SDC and 1 SRV/Safety and [{HPCS and and [HPC [HPCS</p>	<p>1/2 RHR on SDC^d with SSW heat sink^a</p> <p>2/2 RHR on SDC^d with SSW heat sink^a</p> <p>1/1 ADHRS^d with PSW heat sink</p> <p>{[1/2 SPC or 1/2 CS]^f <u>or</u> [Vent containment and 1/2 SPMU^u]}^r</p> <p>(Once through)</p> <p>{[1/2 SPC or 1/2 CS]^f <u>or</u> [Vent containment and 1/2 SPMU^u]}^r</p> <p>(Once through)</p> <p>{[1/2 SPC or 1/2 CS]^f <u>or</u> [Vent containment and 1/2 SPMU^u]}^r if HPCS used</p>

Table E.1.2 Notes

- ^a Reactivity Control by Fully Inserted Rods
- ^b Verify that in POS 5 lineups do not allow LOCA to drain the vessel (this cannot be mitigated); concern is loss of level control and/or loss of heat removal due to LOCA
- ^c LOCA in "steam" lines not of concern since 0 psig primary will not flash
- ^d LPCI Trains A and B require manual re-alignment from SDC. If ADHRS is operable, only one train of RHR on SDC required to be operable per Tech Spec 3.4.9.2. 2/3 LPCI per MELCOR calc. ADHR cannot handle decay heat load until 24 hrs after shutdown.
- ^e SPMU required to prevent loss of SP inventory
- ^f SPMU not required since maximum decay heat less than one RHR train heat removal capability
- ^g SPMU required to makeup for boiloff from SP when containment vented
- ^h 1 SRV required to augment flow out break and prevent pressurization for break $\leq 0.3 \text{ ft}^2$
- ⁱ FW not sufficient for large LOCA since flow not equal to 2 LPCI; SSWXT provides sufficient flow.
- ^j PCS not available, and Feedwater not available. SPMU to compensate for loss of inventory not required since SRVs discharge to SP.
- ^k Condensate/Booster injection may either be on standby or be unavailable
- ^l 1 SRV provide for flow of hot water out of vessel to SP and prevents pressurization
- ^m CRD flow rate at low vessel pressure is 240 gpm max.
- ⁿ 146 gpm injection required
- ^o Maximum RWCU letdown of 360 gpm per Inadequate Decay Heat Removal Procedure step 5.1.3
- ^p NUREG/CR-4550 modeled SSW crosstie and FW.
- ^q This method can match decay heat only after refueling when decay heat is low. Either of two modes can be used. The RWCU can be used in a closed loop transferring heat to its heat exchangers, or RWCU letdown can be increased to a level such that the change in enthalpy between letdown and makeup matches decay heat.
- ^r SPC, CS, SPMU not required to be operable in POS 5 per Tech Specs 3.6.3.3, 3.6.3.2, and 3.6.3.4, respectively. SRVs not required to be operable in POS 5 per Tech Spec 3.4.2.1
- ^s ECCS and SP operability per Tech Specs 3.5.2 and 3.5.3. SSW operability per Tech Spec 3.7.1.1.
- ^t Not modeled in the ET's; requires detailed thermal-hydraulic evaluation
- ^u Small LOCA is within makeup capability, but CRD cannot both match break flow and raise level.
- ^v Adequate cooling with 1/3 core uncovered evaluated with MELCOR.
- ^w With normal level and with no recirc, increased SDC provides mixing between downcomer and core
- ^x To provide adequate natural circulation, raise level with alternate sources including ECCS
- ^y Main Steam Line Break not a LOCA in POS 5 (even in Hydro, it just drains full vessel down to steam lines, no flashing), but Feedwater Line Break outside containment requires one of two check valves in the broken line to close, and an MSIV on each main steam line to close to prevent loss of SP inventory with ECCS injection. Given closure of check valve and MSIVs, one SRV must open to provide for egress of injected water (see footnote v for POS 4 success criteria). In POS 5, following feedwater line break, 200 degrees F fluid does not flash, and level drops no lower than elevation of feedwater injection nozzle; no syphon concern since in a BWR the core region is 'open' to the downcomer region. Thus, in POS 5, if feedwater line break is not isolated, which renders ECCS from SP unavailable after SP level drops below ECCS suction, core is still covered and can be steamed.
- ^z Whenever SRVs are used in conjunction with ECCS from SP, one of two MSIVs in all four steam lines must close to prevent bypass flow outside containment, and subsequent loss of SP inventory and loss of ECCS.
- ^{aa} Only with forced recirculation, can level be sufficient following small break LOCA for core-to-downcomer recirculation if CRD is only source of makeup.
- ^{bb} Cooling option if heat and pressurize to rated conditions (545 F, 1000psig). RHR/SDC must be isolated; auto-isolation either on high pressure or low level. SRV steams at safety setpoint. HPCS or CRD can provide makeup for steaming at high pressure.

Table E.1.3 Success Criteria for Plant Operational State (POS) 6^a

Plant State	Event	Level Control	Energy Removal
<p>6</p> <p>(140 F, 0 psig, Head off, steam line plugs in place, upper cavity not filled)</p> <p>Maximum decay heat is 0.4 % (15MW), 4 days after shutdown</p> <p>After refueling decay heat is 0.16 % (6MW), 30 days after shutdown</p>	<p>Large LOCA ($\geq 0.4\text{ft}^3$)^{b,v} which affects level control and/or heat removal^c</p>	<p>[HPCS or 2/3 LPCI^d or LPCS]^f and 1/2 SPMU^{e,g} and 1/2 CVs^x</p> <p><u>or</u></p> <p>CRD and/or condensate booster steaming^x (for unisolated feedwater line break only)</p> <p><u>or</u></p> <p>Transient Success Criteria^x (for isolated feedwater line breaks only)</p> <p><u>or</u></p> <p>SSW Crosstie^{p,r,h}</p> <p><u>or</u></p> <p>CRD makeup (steam out break/open head)ⁱ</p>	<p>{[1/2 SPC or 1/2 CS]^f or [Vent Containment and 1/2 SPMU^e]}^g</p> <p>(Once through)</p> <p>Transient Success Criteria</p> <p>(Once through)</p> <p>{[1/2 SPC or 1/2 CS]^f or [Vent Containment and 1/2 SPMU^e]}^g</p>

Table E.1.3 Success Criteria for Plant Operational State (POS) 6^a

Plant State	Event	Level Control	Energy Removal
	Medium LOCA (0.007 to 0.4 ft ²) ^{b,v} which affects level control and/or heat removal ^c	<p>[HPCS or 1/3 LPCI^d or LPCS]^e and 1/2 SPMU^{e,i,q} and 1/2 CVs^x</p> <p><u>or</u></p> <p>CRD and/or condensate booster steaming [*] (for unisolated feedwater line break only)</p> <p><u>or</u></p> <p>Transient Success Criteria [*] (for isolated feedwater line breaks only)</p> <p><u>or</u></p> <p>SSW crosstie^{b,r,h} and [1/2 SPMU^{i,q,s} or control level^g]</p> <p><u>or</u></p> <p>CRD makeup (steam out break/open head)ⁱ</p>	<p>{[1/2 SPC or 1/2 CS]^f or [Vent Containment and 1/2 SPMU^g]}^q</p> <p>(Once through)</p> <p>Transient Success Criteria</p> <p>(Once Through)</p> <p>{[1/2 SPC or 1/2 CS]^f or [Vent Containment and 1/2 SPMU^g]}^q</p>

Table E.1.3 Success Criteria for Plant Operational State (POS) 6^a

Plant State	Event	Level Control	Energy Removal
	Small LOCA (<0.007 ft^2) ^b which affects level control and/or heat removal ^c	<p>Isolate letdown and [increase CRD and/or condensate/booster]^u</p> <p><u>or</u></p> <p>[HPCS or 1/3 LPCI^d or LPCS]^f and 1/2 SPMU^{g,i,q} and 1/2 CVs^x</p> <p><u>or</u></p> <p>CRD and/or condensate booster steaming [*] (for unisolated feedwater line break only)</p> <p><u>or</u></p> <p>Transient Success Criteria [*] (for isolated feedwater line breaks only)</p> <p><u>or</u></p> <p>SSW crosstie^{p,r} and [1/2 SPMU^{i,q,s} or control level^q]</p> <p><u>or</u></p> <p>FW given temporary makeup^{h,p} and [1/2 SPMU^{i,q,s} or control level^q]</p> <p><u>or</u></p> <p>CRD makeup (steam out break/open head)ⁱ</p>	<p>Transfer to transient success criteria</p> <p>{[1/2 SPC or 1/2 CS]^f or [Vent Containment and 1/2 SPMU^g]}^q</p> <p>(Once through)</p> <p>Transient Success Criteria</p> <p>(Once through)</p> <p>(Once Through)</p> <p>{[1/2 SPC or 1/2 CS]^f or [Vent Containment and 1/2 SPMU^g]}^q</p>

Table E.1.3 Success Criteria for Plant Operational State (POS) 6^a

Plant State	Event	Level Control	Energy Removal
	Transients ^j	<p>[Letdown (RWCU) and Makeup (CRD and/or Condensate/Booster^k)] or long term makeup^w</p> <p><u>or</u></p> <p>enhanced SDC^t</p> <p><u>or</u></p> <p>1/2 SPMU^{i,q,o} and [HPCS or 1/3 LPCI^d or LPCS]^f</p> <p><u>or</u></p> <p>[1/2 SPMU^{i,q,s} or control level^s] and [SSW crosstie^{p,r} or FW given temporary makeup^{h,p}]</p> <p><u>or</u></p> <p>[CRD^l and/or Condensate/Booster^k] and steaming out the open head^m and 1/2 SPMU^{i,q,s}</p> <p><u>or</u></p> <p>{[CRD^l and/or Condensate/Booster^k] and RWCU (360 gpm)ⁿ}^o</p>	<p>1/2 RHR on SDC^d with SSW heat sink^r</p> <p><u>or</u></p> <p>1/1 ADHRS^d with PSW heat sink</p> <p>2/2 RHR on SDC^d with SSW heat sink^r</p> <p>{[1/2 SPC or 1/2 CS]^f <u>or</u> [Vent containment and 1/2 SPMU^s]}^q</p> <p>(Once through)</p> <p>{[1/2 SPC or 1/2 CS]^f <u>or</u> [Vent containment and 1/2 SPMU^s]}^q</p> <p>(Once through)</p>

Table E.1.3 Notes

- Reactivity Control by Fully Inserted Rods
- ^b Verify that in POS 6 lineups do not allow LOCA to drain the vessel (this cannot be mitigated); concern is loss of level control and/or loss of heat removal due to LOCA
- ° LOCA in "steam" lines not of concern since 0 psig primary will not flash. Assume steam line plugs are installed
- ^d LPCI Trains A and B require manual re-alignment from SDC. If ADHRS is operable, only one train of RHR on SDC required to be operable per Tech Spec 3.9.11.2. 2/3 LPCI per MELCOR calc. ADHR can handle decay heat load in POS 6, since entry into POS 6 is longer than 24 hours after shutdown.
- ° SPMU required to prevent loss of SP inventory
- ^f SPMU not required since maximum decay heat less than one RHR train heat removal capability
- ^g SPMU required to makeup for boiloff from SP when containment vented
- ^h FW not sufficient for large LOCA since flow not equal to 2 LPCI; SSWXT provides sufficient flow.
- ⁱ SRVs unavailable for water discharge due to presence of steam line plugs; water or condensed steam out top of open vessel returned to SP by SPMU.
- ^j PCS not available, and Feedwater not available. SPMU required when SP used for injection since SRVs unavailable due to presence of steam line plugs and injected water flows out open vessel top to upper pool
- ^k Condensate/Booster injection may either be on standby or be unavailable
- ^l CRD flow rate at low vessel pressure is 240 gpm max.
- ^m 146 gpm injection required. SRVs unavailable due to presence of steam line plugs.
- ⁿ Maximum RWCU letdown of 360 gpm per Inadequate Decay Heat Removal Procedure step 5.1.3
- ° This method can match decay heat only after refueling when decay heat is low
- ^p NUREG/CR-4550 modeled SSW crosstie and FW.
- ^q SPC, CS, SPMU not required to be operable in POS 6 per Tech Specs 3.6.3.3, 3.6.3.2, and 3.6.3.4, respectively. SRVs not required to be operable in POS 6 per Tech Spec 3.4.2.1
- ^r ECCS and SP operability per Tech Specs 3.5.2 and 3.5.3. SSW operability per Tech Spec 3.7.1.1.
- ^s Assume overfill of upper containment is a problem; SPMU drains upper pool to SP.
- ^t Not modeled in the ET's; requires detailed thermal-hydraulic evaluation
- ^u Small LOCA is within makeup capability, but CRD cannot both match break flow and raise level. In POS 6, level high enough for natural recirc if letdown isolated early, and CRD can maintain level.
- ^v Adequate cooling with 1/3 core uncovered evaluated with MELCOR
- ^w Level sufficient for natural circulation, long term makeup to compensate for leakage.
- ^x Main Steam Line Break not a LOCA in POS 6, since main steam line plugs in place. Feedwater Line Break LOCA outside containment requires check valve(s) to close for ECCS injection to not drain SP (as discussed for POS 5); MSIVs closure not required since steam line plugs in place; SRV not required since head is off. For Feedwater line break, core is not uncovered and can be steamed (as discussed for POS 5).
- ^y MSIV closure required whenever ECCS from SP used to not drain SP.
- ^z With normal level and with no recirc, increased SDC provides mixing between downcomer and core

Table E.1.4 Success Criteria for Plant Operational State (POS) 7^a

Plant State	Event	Level Control	Energy Removal
<p>7</p> <p>(100 F, 0 psig Head off, steam line plugs in place, upper cavity filled)</p> <p>Decay heat is 0.3 % (12MW) initially- 6 days after shutdown- decreasing to 0.16 % (6MW) at end of refueling, 30 days after refueling^d</p>	<p>Large LOCA ($\geq 0.4\text{ft}^2$)^{b,x} which affects level control and/or heat removal^c</p>	<p>[HPCS or 2/3 LPCI^e or LPCS]^z and 1/2 SPMU^{f,j} and 1/2 CVs^z</p> <p><u>or</u></p> <p>CRD and/or condensate booster steaming^z (for unisolated feedwater line break only)</p> <p><u>or</u></p> <p>Transient Success Criteria^z (for isolated feedwater line breaks only)</p> <p><u>or</u></p> <p>SSW Crosstie^{g,k,l}</p> <p><u>or</u></p> <p>CRD makeup (steam out break/open head)^v</p>	<p>{[1/2 SPC or 1/2 CS]^h or [Vent Containment and 1/2 SPMU^h]}^j</p> <p>(Once Through)</p> <p>Transient Success Criteria</p> <p>(Once through)</p> <p>{[1/2 SPC or 1/2 CS]^h or [Vent Containment and 1/2 SPMU^h]}^j</p>

Table E.1.4 Success Criteria for Plant Operational State (POS) 7^a

Plant State	Event	Level Control	Energy Removal
	Medium LOCA (0.007 to 0.4 ft ²) ^{b,x} which affects level control and/or heat removal ^c	<p>[HPCS or 1/3 LPCI^e or LPCS]^g and 1/2 SPMU^{f,j,m} and 1/2 CVs^z</p> <p><u>or</u></p> <p>CRD and/or condensate booster steaming ^z (for unisolated feedwater line break only)</p> <p><u>or</u></p> <p>Transient Success Criteria ^z (for isolated feedwater line breaks only)</p> <p><u>or</u></p> <p>SSW crosstie^{s,k,l,u}</p> <p><u>or</u></p> <p>CRD makeup (steam out break /open head)^v</p>	<p>{[1/2 SPC or 1/2 CS]^h or [Vent Containment and 1/2 SPMU^h]}^j</p> <p>(Once Through)</p> <p>Transient Success Criteria</p> <p>(Once through)</p> <p>{[1/2 SPC or 1/2 CS]^h or [Vent Containment and 1/2 SPMU^h]}^j</p>

Table E.1.4 Success Criteria for Plant Operational State (POS) 7^a

Plant State	Event	Level Control	Energy Removal
	Small LOCA (<0.007 ft ²) ^b which affects level control and/or heat removal ^c	Isolate letdown and [increase CRD and/or condensate/booster] ^w <u>or</u> [HPCS or 1/3 LPCI ^e or LPCS] ^z and 1/2 SPMU ^{f,j,m} and 1/2 CVs ^z <u>or</u> CRD and/or condensate booster steaming ^z (for unisolated feedwater line break only) <u>or</u> Transient Success Criteria ^z (for isolated feedwater line breaks only) <u>or</u> SSW crosstie ^{g,k,u} <u>or</u> FW given temporary makeup ^{k,l,u} <u>or</u> CRD makeup (steam out break/open head) ^v	Transfer to transient success criteria {[1/2 SPC or 1/2 CS] ^h or [Vent Containment and 1/2 SPMU ^h]} ^j (Once through) Transient Success Criteria (Once through) (Once through) {[1/2 SPC or 1/2 CS] ^h or [Vent Containment and 1/2 SPMU ^h]} ^j

Table E.1.4 Success Criteria for Plant Operational State (POS) 7^a

Plant State	Event	Level Control	Energy Removal
	Transients ⁿ	<p>[{Letdown (RWCU) and Makeup (CRD and/or Condensate/Booster^o)^p] or long term makeup^y</p> <p><u>or</u></p> <p>enhanced SDC^{aa}</p> <p><u>or</u></p> <p>1/2 SPMU^{j,m,f} and [HPCS or 1/3 LPCI^e or LPCS]^z</p> <p><u>or</u></p> <p>[SSW crosstie^{z,k} or FW given temporary makeup^{k,l,u}</p> <p><u>or</u></p> <p>{[CRD^a and/or Condensate/Booster^o] and steaming out the open head^v}</p> <p><u>or</u></p> <p>{[CRD^a and/or Condensate/Booster^o] and RWCU (360 gpm)^u}</p>	<p>1/2 RHR on SDC^e with SSW heat sink^z</p> <p><u>or</u></p> <p>1/1 ADHRS^e with PSW heat sink</p> <p><u>or</u></p> <p>Fuel Pool Cooling</p> <p>2/2 RHR on SDC^e with SSW heat sink^z</p> <p>{[1/2 SPC or 1/2 CS]^b <u>or</u> [Vent containment and 1/2 SPMUⁱ]^j}</p> <p>(Once through)</p> <p>{[1/2 SPC or 1/2 CS]^b <u>or</u> [Vent containment and 1/2 SPMUⁱ]^j}</p> <p>(Once through)</p>

Table E.1.4 Notes

- Reactivity Control by Fully Inserted Rods
- ^b Verify in POS 7 lineups do not allow LOCA to drain the vessel (this cannot be mitigated); concern is loss of level control and/or loss of heat removal due to LOCA
- ^c LOCA in "steam" lines not of concern since 0 psig primary will not flash. Steam line plugs are installed in PS 7
- ^d Conservatively take decay heat as 0.3 % throughout POS 7
- ^e LPCI Trains A and B require manual re-alignment from SDC. If ADHRS is operable, neither train of RHR on SDC is required to be operable per Tech Spec 3.9.11.1. 2/3 LPCI per MELCOR calc. ADHR can remove decay heat in POS 7 since entry into POS 7 not within 24 hours from shutdown.
- ^f SPMU required to prevent loss of SP inventory
- ^g ECCS not required to be operable, per Tech Spec 3.5.2, in POS 7. SSW required to be operable, per Tech Spec 3.7.1.1, in POS 7 (required operable only when RHR on SDC required operable).
- ^h SPMU not required since maximum decay heat less than one RHR train heat removal capability
- ⁱ SPMU required to makeup for boiloff from SP when containment vented
- ^j SPC, CS, SPMU not required to be operable in POS 7 per Tech Specs 3.6.3.3, 3.6.3.2, and 3.6.3.1 respectively. SRVs not required to be operable in POS 7 per Tech Spec 3.4.2.1.
- ^k NUREG/CR-4550 modeled SSW crosstie and FW.
- ^l FW not sufficient for large LOCA since flow not equal to 2 LPCI; SSWXT provides sufficient flow.
- ^m SRVs unavailable for water discharge due to presence of steam line plugs; water out top of open vessel returned to SP by SPMU.
- ⁿ PCS not available and Feedwater not available. SPMU required when SP used for injection since SRVs unavailable due to presence of steam line plugs and injected water flows out open vessel top to upper pool
- ^o Condensate/Booster injection may be either on standby or unavailable
- ^p Letdown/makeup is normally isolated in POS 7
- ^q CRD flow rate at low vessel pressure is 240 gpm max.
- ^r SRVs unavailable for steaming due to presence of steam line plugs. 146 gpm injection required (see footnote d)
- ^s Maximum RWCU letdown of 360 gpm per Inadequate Decay Heat Removal Procedure Step 5.1.3
- ^t This method can match decay heat only toward the end of refueling. Based on the assumption in footnote d, it is not to be considered
- ^u Assume overfill of upper containment is a problem, but water flows out transfer canal to spent fuel pool
- ^v Not modeled in the ET's; requires detailed thermal-hydraulic evaluation
- ^w Small LOCA is within makeup capability, but CRD cannot both match break flow and raise level. In POS 7, level high enough for natural recirc if letdown isolated early, and CRD can maintain level.
- ^x Adequate cooling with 1/3 core uncovered evaluated with MELCOR.
- ^y Level sufficient for natural circulation, long term makeup to compensate for leakage
- ^z Main Steam Line Break not a LOCA in POS 7, since main steam line plugs in place. Feedwater Line Break LOCA outside containment requires check valve(s) to close for ECCS injection to not drain SP (as discussed for POS 5); MSIVs closure not required since steam line plugs in place; SRV not required since head is off. For Feedwater line break, core is not uncovered and can be steamed (as discussed for POS 5).
- ^{aa} With normal level and with no recirc, increased SDC provides mixing between downcomer and core

References for Appendix E

- [Whitehead et al., 1991] D. W. Whitehead, J. L. Darby, B. D. Staple, B. Walsh, T. M. Hake, and T. D. Brown, "BWR Low Power and Shutdown Accident Frequencies Project, Phase 1 - Coarse Screening Analysis," Vol. 1, Draft Letter Report, Sandia National Laboratories and Science and Engineering Associates, Inc., November 23, 1991 update, (Available at the USNRC Public Document Room).
- [Lahey and Moody, 1984] R. T. Lahey, Jr, and F. J. Moody, "The Thermal-Hydraulics of a Boiling Water Nuclear Reactor." American Nuclear Society, 1984.
- [SERI, 1992] System Energy Resources, Inc., "Grand Gulf Updated Final Safety Analysis Report," 1992
- [Vine et al., 1986] G. Vine, et al., "Residual Heat Removal Experience Review and Safety Analysis: Boiling Water Reactors," Nuclear Safety Analysis Center, NSAC-88, March, 1986.
- [Drouin et al., 1989] M. T. Drouin et al., "Analysis of Core Damage Frequency: Grand Gulf, Unit 1 Internal Events." NUREG/CR-4550, SAND86-2084, Vol. 6, Rev. 1, Part 1, September 1989.

Appendix F. Supporting Calculations

This Appendix summarizes calculations performed to support the success criteria and event tree development for the detailed analysis of POS 5.

Some of the calculations summarized were performed to support the earlier screening study [Whitehead et al., 1991], and they are also described in this Appendix.

The actual calculations which are described in this Appendix are maintained in project files. To facilitate cross referencing of the information in this Appendix to the actual calculations, the information in this Appendix is referenced by calculation number.

F.1 Calculation Files

Table F.1-1 summarizes the calculations performed. A brief summary of each calculation that is active is provided in the following discussions.

F.2 Scoping Calculations

To understand the basic characteristics of POSs 4, 5, 6, and 7, various scoping calculations were performed. Based on the results of these scoping calculations, and the development of the event trees, more detailed calculations were subsequently performed, as necessary.

F.2.1 Calculation #2

Calculation 90-492-01-A:2, "Thermodynamics Calcs for Grand Gulf", documents scoping calculations performed for POS 4, 5, 6, and 7. The following topics were addressed:

- (1) Decay Heat
- (2) Injection to Remove Decay Heat without Steaming
- (3) Injection to Remove Decay Heat with Steaming
- (4) Heat Vessel Water to Saturation
- (5) Boil Off Vessel Water to Top of Fuel
- (6) Overheat Suppression Pool
- (7) Drain Vessel to Top of Core
- (8) Pressurize to 200 psig after Loss of

Recirculation

(9) Heat Removal Capability of ADHR at 200 F

(10) Heat Removal Capability of FPCCU at 200 F.

The results of these calculations are given in Table F.2-1. The decay heat was determined by a curve fit to that given in the NRC Standard Review Plan [USNRC, 1987]. For times of interest for POSs 4, 5, 6, and 7 [5 to 720 hours] the fit is:

$$\ln(DH_x) = -0.368 \ln(t_{hr}) + 0.593$$

where DH_x is decay heat in per cent of full power and t_{hr} is time after shutdown in hours.

Based on information received during a visit to Grand Gulf [Plant Visit, 1991], appropriate conservative times, after reactor shutdown, for entry into the POSs are as follows:

POS 4, 5 hours

POS 5, 7 hours

POS 6, 4 days

POS 7, 6 days

Heatup After Refueling Outage, 30 days.

F.2.2 Calculation #3

Calculation 90-492-01-A:3, "Miscellaneous Thermodynamics Calcs for Grand Gulf", documents additional scoping analyses. the topics addressed were:

- (1) Capacity of 1 SRV in Safety Mode at Rated Pressure
- (2) Capacity of 1 SRV in Relief Mode at 100 psig (Steam)
- (3) Capacity of 1 SRV in Relief Mode at 200 psig (Steam)
- (4) Capacity of 1 SRV Passing Water at 100 psig and 200 psig
- (5) Loss through Small LOCA in POS 4

Table F.1.1 Calculations Performed

Calculation Name and Number	Purpose of Calculation	Status of Calculation
"Grand Gulf Shutdown 24 Hour Success Criteria", 90-492-01-A:1	Perform Scoping Thermalhydraulic Calculations for POSs 4, 5, 6, and 7	Superseded by Calculation 90-492-01-A:2 based on more accurate information received during 1/91 Site Visit (Plant Visit, 1/91)
"Thermodynamics Calcs for Grand Gulf", 90-492-01-A:2	Perform Scoping Thermalhydraulic Calculations for POSs 4, 5, 6, and 7	Active
"Miscellaneous Thermodynamics Calculations for Grand Gulf", 90-492-01-A:3	Expand Calc 90-492-01-A:2	Active
"Multiple Initiators for GG Shutdown", 90-492-01-A:4	Perform Screening Search for Multiple Initiating Events of Potential Importance for POSs 4, 5, 6, and 7	Active, but Updated for POS 5 by Calc 90-492-01-A:14
"Relief Capabilities at Grand Gulf", 90-492-01-A:4.1	Calculate Relief Capabilities for SRV and Vent Line, Calculate Pressures for ECCS Water Solid Cases (ECCS pumps and 1 or 2 SRVs)	Active
"Levels for Grand Gulf", 90-492-01-A:5	Determine Actual vs. Measured Level, Levels required for Shutdown Cooling	Active
"SRVs for Small/Medium LOCAs", 90-492-01-A:6	Determine Need for SRV for Small LOCA in POS 4	Active, Levels Recalculated with Calc 90-492-01-A:19
"Loss of ECCS due to Loss of SP", 90-492-01-A:7	Calculate Conditions under which SP Inventory is Insufficient for ECCS	Active
"Containment Flooded or Vented", 90-492-01-A:8	Estimate Time to Boil Off SP Inventory to lose ECCS if no Heat Removal, Estimate Time for Containment Overpressure if Flooded with no Heat Removal	Active
"Restore Makeup for Recirculation", 90-492-01-A:9	Estimate Time Available to Restore Makeup given No Makeup, Letdown Isolated, Nominal Leakage	Active
"1 CRD Pump for POS 5", 90-492-01-A:10	Calculate Effectiveness of 1 CRD Pump for Restoring Level, and for Matching Steaming in POS 5	Active, Levels Recalculated with Calc 90-492-01-A:19
SDC Relief Valves for POS 4 and 5", 90-492-01-A:11	Calculate Ability of Relief Valves in RHR/SDC to Prevent Overpressurizing RHR and ADHR Components	Active, Levels Recalculated with Calc 90-492-01-A:19

Table F.1.1 Calculations Performed

Calculation Name and Number	Purpose of Calculation	Status of Calculation
"Time for Operator Actions POS 5H Transients," 90-492-01-A:12	Conservatively Estimate Times Available for Operator Actions for Operator Events on Event Trees	Superseded by Calculation 90-492-01-A:16
"Overpressurization of ADHR in POS 5H", 90-492-01-A:13	Calculate Time to Overpressurize ADHR in POS 5	Active, Levels Recalculated with Calc 90-492-01-A:19
"Multiple Initiators for POS 5H", 90-492-01-A:14	Perform Screening Search for Multiple Initiators in POS 5	Superseded by Calculation 90-492-01-A:19
"Time for Operator Actions POS 5, Completion", 90-492-01-A:15	Complete Conservative Estimates for Operator Action Times Begun in Calculation 90-492-01-A:12	Superseded by Calculation 90-492-01-A:16
"Update: Time for Operator Actions POS 5", 90-492-01-A:16	Conservatively Estimate Times Available for Operator Actions for Operator Events on Event Trees	Active
"SRVs for Small/Medium LOCAs in POS 5", 90-492-01-A:17	Determine Need for SRV for Small LOCA in POS 5	Active, Levels Recalculated with Calc 90-492-01-A:19
"Multiple Initiators for POS 5 (Revised)", 90-492-01-A:18	Update Calculation 90-492-01-A:14 to Reflect Final POS 5 Initiating Event Frequencies	Active
"Energy Balances Update", 90-492-01-A:19	Check on All Previous Energy Balances, Include Calculation of Levels Accounting for Swell	Active
"SGTS Filter Overheating Scoping Study", 90-492-01-A:DRAFT	Estimate Temperatures of SGTS Filters following Core Meltdown	Draft
"Flooding Induced Dryout", 90-492-01-A:22	Document Conclusion that Flooding Does Not Occur at 0 psig	Active

Table F.2.1.
Results of Initial Thermal Hydraulic Calculations for Screening Study

Plant State	Decay Heat	Remove Decay Heat without Steaming	Remove Decay Heat with Steaming	Heat Vessel Water to Saturation	Boil off to Top of Core ^d	Overheat Suppression Pool	Drain to Top of Core	Pressurize to 200 psig ^{4,j}	Ability of ADHRS to Remove Decay Heat	Ability of FPCCU to Remove Decay Heat
4 ^a	38 MW	1333 gpm	278 gpm ^c	0 min ^d	2.0 hr	15.5 hr	1.7 hr	12 min	f	f
5 ^a	34 MW	2087 gpm	249 gpm ^c	5.4 min	2.6 hr	16.8 hr	1.7 hr	0.8 hr ⁱ	h	f
6 ^a	15 MW	921 gpm	110 gpm	1.8 hr	12.0 hr	35.9 hr	3.1 hr	e	2 HX	f
7 ^a	12 MW	737 gpm	88 gpm	19.4 hr	100.1 hr	41.2 hr	20.7 hr	e	2 HX ⁴	2 HX
6 ^b	6 MW	368 gpm	44 gpm	3.8 hr	24.8 hr	72.2 hr	3.1 hr	e	1 HX	f
5 ^b	6 MW	368 gpm	44 gpm	30 min	13.8 hr	72.2 hr	1.7 hr	4.5 hr ⁱ	1 HX	f
4 ^b	6 MW	368 gpm	44 gpm	0 min ^d	11.7 hr	72.2 hr	1.7 hr	1.1 hr	f	f

NOTES:

^aComing down from full power^bGoing up after 30 days^c240 gpm makeup adequate to prevent core uncover^dSaturated initially^eHead off, cannot pressurize^fNot available in this POS⁴Results indicates 1ADHRS HX can just match decay heat; 2HX to be sure^hADHRS cannot remove 34 Mw; ADHRS can match decay heat at 24 hours after shutdownⁱNeglecting relief through vent line^jAssume water in downcomer has no effect (Conservative)

- (6) Loss through Small LOCA at 0 psig (POSs 5, 6, and 7)
- (7) Drop in Level when SRV Opens in POS 4 at 100 psig.

The conclusions of this calculation are as follows:

- (1) 1 SRV steaming at its safety setpoint can match 4% decay heat without makeup, and 8% decay heat with makeup at 100 degrees F to maintain constant level,
- (2) At 100 psig, 1 SRV steaming in relief can match 0.5% decay heat without makeup, and 0.6% decay heat with makeup at 100 degrees F to maintain constant level,
- (3) At 230 psig, 1 SRV steaming in relief can match 1 % decay heat without makeup. At 200 psig, 1 SRV steaming in relief can match 1.2% decay heat with makeup at 100 degrees F to maintain constant level,
- (4) When injecting with one ECCS pump at 8000 gpm:
 - (a) at 100 psig, 2 SRVs can provide relief (2 SRVs pass water at 9600 gpm),
 - (b) at 200 psig, 1 SRV cannot provide relief (1 SRV passes water at 6700 gpm),
- (5) Makeup with 2 CRD pumps at 240 gpm can equal mass loss from small LOCA (0.007 sq ft) in POSs 4, 5, 6, and 7. Loss is about 160 gpm in POS 4 200 psig (flashing water), loss is about 200 gpm in POSs 5, 6, and 7 (subcooled water, 100 ft gravity head), and
- (6) If 1 SRV spuriously opens in POS 4 at 100 psig, with no operator action, and assuming instant flashing to 0 psig, level drops below low level 3, SDC isolation setpoint, but not below level 2 setpoint for ECCS actuation (a later calculation, # 6, performed a time dependent analysis including heat addition).

F.2.3 Calculation #7

Calculation 90-492-01-A:7, "Loss of ECCS due to Loss of SP", evaluated under what conditions the SP inventory is inadequate for ECCS. According to the Tech Specs,

in POS 4 the SP is required to be at Low Water Level, 18 feet 4 1/12 inches. However, in POSs 5, 6, and 7, the SP can be at 12 feet 8 inches, or empty if 170,000 gal are available to HPCS from the CST. This calculation concluded that:

- (1) In POS 4 or 5 with SP at Low Water Level:
 - (a) For a LOCA inside containment, SPMU is required,
 - (b) For water solid operation with SRVs returning water to the SP, no SPMU is required except if long term boiloff occurs, and
 - (c) For a LOCA outside containment that is not isolated, adequate SP inventory can be lost between 6 and 25 minutes, depending on the number of ECCS pumps operating.
- (2) In POS 5 with SP at 12 feet 8 inches:
 - (a) For a LOCA inside containment, adequate SP inventory is lost even with SPMU, and
 - (b) For water solid operation with SRVs returning water to the SP, no SPMU is required except if long term boiloff occurs.
- (3) In POS 5 with SP Empty and 170,000 for HPCS:
 - (a) For a LOCA inside containment, adequate SP inventory is lost even with SPMU, and
 - (b) For water solid operation with SRVs returning water to the SP, adequate SP inventory cannot be maintained even with SPMU.

F.2.4 Calculation #8

Calculation 90-492-01-A:8, "Containment Flooded or Vented", addressed two issues:

- (1) Time for heating flooded containment to failure pressure (taken as 70 psia) with no heat removal, and
- (2) Time to boil off SP inventory to where ECCS is lost.

Supporting Calculations

The calculation concluded:

- (1) Time to heat flooded containment to 70 psia is 54 to 80 hours, depending on volume flooded.
- (2) Time to boil off SP inventory at 15 psia to where ECCS is lost, assuming initially saturated water, is as follows:

- (a) SP at Low Water Level:

12 hours for LOCA,
18 hours for Transients

- (b) SP at 12 Feet 8 Inches:

LOCA cannot be mitigated (see calc #7)
3 hours for Transients.

F.2.5 Calculation #9

Calculation 90-492-01-A:9, "Restore Makeup for Recirculation", estimates the time available to restore makeup if makeup is lost and letdown is isolated, before recirculation from the core to the downcomer is lost. Two cases are of interest, forced recirculation and enhanced shutdown cooling. In either case, the time available is that for leakage to lower level from the initial level (+36 inches measured or +27.5 inches actual) to the low level 3 SDC isolation setpoint (+11.4 inches measured or +8.7 inches actual).

The Tech Specs allow a total leakage of 30 gpm at rated pressure. We assumed a nominal full power leakage of 10 gpm. At full power the leaking water flashes, and converting 10 gpm flashing at full pressure to subcooled water draining from a 100 foot head of water, the estimated leak rate at shutdown is about 6 gpm. This allows 10 hours before level drains to low level 3.

F.2.6 Calculation #DRAFT

Calculation 90-492-01-A:DRAFT, "SGTS Filter Overheating Scoping Study", was performed to assist Sandia personnel examining the source term for core melt in POS 6. This calculation showed that for the radionuclides released into the auxiliary building, it is possible that the SGTS can maintain aux building integrity and its filters possibly not overheat. The calculation was a scoping study using a filter heatup model developed for the Savannah River K Reactor Confinement [Darby et al., 1991]. The results indicate

that ignition of the charcoal filters may or may not occur depending on the fraction of iodine released in vapor form, the number of SGTS trains running (1 or 2), and the filter peaking factors. HEPA filter ignition is unlikely.

F.2.7 Calculation #22

Calculation 90-492-01-A:22, "Flooding Induced Dryout", documents a conservative calculation showing that at zero psig the core can be steamed. The Wallis flooding criterion (in combination with an energy balance and a mass balance) is used to calculate the maximum heat flux allowed: $8.5E+3 \text{ Btu/ht/ft}^2$.

F.3 Calculations for Multiple Initiators

Three calculations addressing multiple initiating events were performed. Calculation 90-492-01-A:4, "Multiple Initiators for GG Shutdown", addressed multiple initiators for the earlier screening study. Two calculations, 90-492-01-A:14 "Multiple Initiators for POS 5H" and 90-492-01-A:18 "Multiple Initiators for POS 5: Revised", addressed multiple initiators for the detailed study of POS 5. The latter of these two calculations updated the analysis of the former, by using revised initiating event frequencies.

This section provides results of the search for multiple initiating events of potential importance at Grand Gulf in POS 5.

If every possible event subsequent to the first event is in the PRA model, then the concept of a multiple initiating event is merely one of semantics. No "multiple" initiator is possible, since every event subsequent to the first one is included in the mitigation model. In practice, PRAs do not include every possible event subsequent to the first event in the mitigation model. For example, randomly occurring LOCAs following a transient initiating event are not considered. Thus, the concept of a multiple initiating event is one for which the events subsequent to the initial event are not in the model. Many such multiple initiating events are of low frequency and can be screened out. The set of initiating events can be analyzed to quantitatively identify those combinations of events that are numerically significant, and that are not present in the original model. Once these multiple initiating events are identified, they can be analyzed for importance.

The frequency of a multiple initiating event containing "n" events is the product of:

- (a) the frequency of the first initiating event
- (b) the probability the second initiating event occurring within the fault exposure time following the first initiating event
- (n) the probability the n^{th} initiating event occurs within the fault exposure time following the first initiating event.

Let T denote the fault exposure time. Let f_i denote the frequency of initiating event i . Let P_{ji} denote the probability that event j occurs, given i , within time T . If event j is independent of event i , then P_{ji} equals P_j , where P_j is: $1 - \exp(-f_j T)$.

In shorthand notation, a double event multiple initiator can be expressed as "ij", a triple event multiple initiator can be expressed as "ijk", and so on, where the first index refers to the frequency of the first event, and the succeeding indices refer to the probability of the indicated initiating event over time T . Note that numerically, assuming no dependence among events:

- (1) $ij \neq ji$
- (2) $ijk \neq jik \neq kij$
- (3) $ijk = ikj$.

When dependent effects are considered, it may be that:

- (4) $ijk \neq ikj$.

A code was written to identify and quantify all double and triple multiple initiating events. The code is MULINIT.PAS, written in TurboPascal 6.0; source code is provided in Table F.3-1. This code eliminates user-defined illogical dependencies, and it eliminates user-defined combinations of multiple initiating events for which events subsequent to the first event are already considered in the fault trees. An example of an illogical dependency is loss of offsite power followed by loss of main feedwater, because the event trees for loss of offsite power already account for the fact that main feedwater is unavailable given loss of offsite power. An example of a dependency already "hard-wired" into the fault trees is any initial initiating event followed by loss of shutdown cooling, if loss of shutdown cooling is

included as a failure during the fault exposure time everywhere in the fault trees.

A listing of all multiple initiating events with a frequency of greater than 10^{-8} per year is provided in Table F.3.2. There are about 450 double initiating event sequences, and no triple initiating event sequences. Those multiple initiating events with a frequency greater than or equal to 10^{-6} per year which are not already addressed by the existing models are as follows (NOTE: Not all sequences of table F.3-2 greater than 10^{-6} per year are listed. Upon detailed examination of the model, many of these sequences were determined to already be considered):

$E1T*H1$, $1.8E-6$ per year,

$E1V*H1$, $1.8E-6$ per year,

$T1*TORV$, $1.5E-6$ per year,

$E1T*TORV$, $4.2E-6$ per year,

$E1V*TORV$, $4.2E-6$ per year, and

$T1A*TORV$, $2.1E-6$ per year.

The calculated frequencies consider the fraction of time that the plant is in POS 5, 0.031, but do not factor in the fractions of time that POS 5 is in HYDRO, on SDC/RHR, or on ADHR. These fractions are 0.11, 0.81, and 0.08, respectively. When these six sequences are corrected for these effects, only the first one is above 10^{-6} , and its frequency is $1.5E-6$ per year. Furthermore, $E1T$ is isolation of the SDC common suction line when using RHR, and $H1$ (diversion of water through the SDC system(s) to the suppression pool) cannot occur if the common suction line is isolated. Therefore, $E1T*H1$ is a valid sequence only if the operators restore the common suction line, which requires success of event RESCS, and then the remainder of the sequence is essentially the same as the $H1$ sequence. Therefore, the impact of the multiple initiating event, $E1T*H1$, is to increase the frequency of the $H1$ initiating event by a factor:

$$(1 + E1T*RESCS)$$

where $RESCS$ is success of RESCS. Numerically, this factor is equal to $1 + (0.356)*(0.9) = 1.32$.

Table F.3.1 MULINIT.PAS Source Code

```

program mulinit; {search for multiple initiators for GG shutdown}
    {search for double and triple initiators}
    {include GG specific procedure to remove unallowed}
    {combinations per calc 492-001-A:4}
    {revised to include 3/18/92 initiators and}
    {dependencies as noted}

    {Turbo Pascal 6.0. J. Darby, SEA, Inc., Oct 15, 1991 Version}

type
    basdat=record
        name:string[10];
        freq:real
    end;
    strtype=string[10];
var
    outfil:text;
    pos,i,j,n,k,aryctr:integer;
    init:array [1..50] of basdat;
    trunc,ovrlap,posfrac,mulfreq:real;
    flag2,flag3,depflag:boolean;
    depstr:array[1..50] of string[20];

procedure dep2(event1,event2:strtype); {remove doubles per GG logic}
var
    events:string[20];
    ctr:integer;
begin
    depflag:=false;
    events:=event1+event2;
    ctr:=0;
    while (depflag=false) and (ctr<=50) do begin
        ctr:=ctr+1;
        if events=depstr[ctr] then depflag:=true; {dependence is true}
        if event2='T1' then depflag:=true {## 3/18/92 revision, since T1
            is an}
            {event in every detailed POSSH event tree #####}
        end {while}
    end; {procedure}

procedure dep3(event1,event2,event3:strtype);
    {remove doubles per GG logic}
var
    eventsa,eventsb,eventsc:string[20];
    ctr:integer;
begin
    depflag:=false;
    eventsa:=event1+event2;
    eventsb:=event1+event3;
    eventsc:=event2+event3;

```

Table F.3.1 MULINIT.PAS Source Code (Continued)

```

ctr:=0;
while (depflag=false) and (ctr<=50) do begin
  ctr:=ctr+1;
  if eventsa=depstr[ctr] then depflag:=true;
  if eventsb=depstr[ctr] then depflag:=true;
  if eventsc=depstr[ctr] then depflag:=true;
  {dependence is true}
  if (event2='T1') or (event3='T1') then depflag:=true
    {### 3/18/92 change since T1 is in every POSSH detailed
    event tree ###}
end {while}
end; {procedure}

begin {main program}
  assign(outfil,'mulinit.dat');
  rewrite (outfil);
  depstr[1]:='T1T2';depstr[2]:='T1T3A';depstr[3]:='T1T3B'; {Grand Gulf}
    {specific dependencies as defined in calc 90-492-001-A:4}
  depstr[4]:='T1E1C';depstr[5]:='T1E1D';depstr[6]:='T1E2C';
  depstr[7]:='T1E2D';depstr[8]:='T1T5B';depstr[9]:='T1T5C';
  depstr[10]:='T2T3A';depstr[11]:='T2T3B';depstr[12]:='T3BT3A';
  depstr[13]:='T5BT5C';depstr[14]:='T5BTIA';depstr[15]:='T5CT5B';
  depstr[16]:='T5CTIA';depstr[17]:='TIAT5B';depstr[18]:='TIAT5C';
  depstr[19]:='T5AE1B';depstr[20]:='T5AE2B';depstr[21]:='T5BT2';
  depstr[22]:='T5BT3A';depstr[23]:='T5BT3B';depstr[24]:='T5CT5D';
  depstr[25]:='T5CE1D';depstr[26]:='T5CE2D';depstr[27]:='E2VE1V';
  depstr[28]:='E2TE1T';depstr[29]:='E2DE1D';depstr[30]:='E2CE1C';
  depstr[31]:='E2BE1B';depstr[32]:='T5DE1C';depstr[33]:='T5DE2C';
  depstr[34]:='TABE1B';depstr[35]:='TABE2B';depstr[36]:='TDBE1B';
  depstr[37]:='TDBE2B';depstr[38]:='TDBTAB';depstr[39]:='TIAT2';
  depstr[40]:='TIAT3A';depstr[41]:='TIAT3B';depstr[42]:='TIATLM';
  depstr[43]:='TIAE1C';depstr[44]:='TIAE2C';
  {### 3/18/92 dependencies for TRFT follow ###}
  depstr[45]:='T1TRFT';depstr[46]:='T5BTRFT';depstr[47]:='T5CTRFT';
  depstr[48]:='T5DTRFT';depstr[49]:='TIATRFT';
  for aryctr:=50 to 50 do depstr[aryctr]:='xxxxxxxxxxxxxx';

  flag2:=true;flag3:=true;
  writeln('enter truncation value in 1/yr, e.g. 1e-8');readln(trunc);
  writeln('enter POS of interest');readln(pos);
  writeln('enter overlap time in hours');readln(ovrlap);
  writeln('enter fraction of time in POS');readln(posfrac);
  writeln('enter number of initiating events <=50');
  readln(n);
  writeln(outfil);writeln(outfil,'SEARCH FOR MULTIPLE INITIATORS');
  writeln(outfil);writeln(outfil);
  writeln(outfil,'  INPUT');writeln(outfil);
  write(outfil,'truncation value for multiple initiator search in 1/yr is ');
  writeln(outfil,trunc:12);
  writeln(outfil,'POS is # ',pos:2);
  writeln(outfil,'Overlap time in hours is ',ovrlap:12);

```


Table F.3.1 MULINIT.PAS Source Code (Continued)

```

writeln(outfil,'Fraction of time spent in POS is ',posfrac:12);
writeln(outfil,'Number of initiating events examined is ',n:3);
writeln(outfil);

for i:=1 to n do begin {input}
  with init[i] do begin
    writeln('for initiator no. ',i:2,' enter name up to 10 characters');
    readln(name);
    writeln(' enter its freq in 1/yr');readln(freq);writeln;
    writeln(outfil,name,' has freq 1/yr of ',freq:12);
    end; {with}
  end; {i loop} {end input}
  writeln(outfil);writeln(outfil);
  writeln(outfil,'  OUTPUT');writeln(outfil);
  write(outfil,'List of double and triple multiple initiators ');
  writeln(outfil,'with freq >= ',trunc:12,' per yr,');
  writeln(outfil,' using ',ovrlap:12,' hours as overlap time ,and weighted
    by');
  writeln(outfil,posfrac:12,' ,the fraction of time in the selected POS. ');
  writeln(outfil);
  writeln(outfil,'DOUBLE INITIATORS');writeln(outfil);
  for i:=1 to n do begin
    for j:=1 to n do begin
      if i < > j then begin
        dep2(init[i].name,init[j].name); {search for GG          specific
dependencies}
        mulfreq:=init[i].freq*(1-exp(-init[j].freq*ovrlap/(24*365.25)));
          {1/(24*365.25) yr/hr}
        mulfreq:=mulfreq*posfrac; {weight by fraction of time in POS}
        if (mulfreq>=trunc) and (depflag=false) then begin
          flag2:=false;
          writeln(outfil,'freq in 1/yr of ',init[i].name,' and ',init[j].name,'
            is');
          writeln(outfil,mulfreq:12);writeln(outfil);
          end {if mulfreq}
          end {if i < > j}
        end {j}
      end; {i}
    if flag2=true then
      writeln(outfil,'NO DOUBLE INITIATORS ABOVE TRUNCATION VALUE');
      writeln(outfil,'TRIPLE INITIATORS');writeln(outfil);
      for i:=1 to n do begin
        for j:=1 to n do begin
          for k:=1 to n do begin
            if (i < > j) and (i < > k) and (j < > k) then begin
              dep3(init[i].name,init[j].name,init[k].name); {search for GG sepc. dep's}
              mulfreq:=init[i].freq*
                (1-exp(-init[j].freq*ovrlap/(24*365.25)))*
                (1-exp(-init[k].freq*ovrlap/(24*365.25)));
                {1/(24*365.25) yr/hr}
              mulfreq:=mulfreq*posfrac; {weight by fraction of time in POS}

```

Table F.3.1 MULINIT.PAS Source Code (Continued)

```
if (mulfreq >= trunc) and (depflag=false) then begin
    flag3:=false;
    write(outfil,'freq in 1/yr of ',init[i].name,' and ',init[j].name);
    writeln(outfil,' and ',init[k].name,' is');
    writeln(outfil,mulfreq:12);writeln(outfil);
    end {if mulfreq}
    end {if i < > j}
end {k}
end {j}
end; {i}
if flag3=true then
    writeln(outfil,'NO TRIPLE INITIATORS ABOVE TRUNCATION
    VALUE');

close(outfil);
end.
```

Table F.3.2 Multiple Initiating Events for POS 5

SEARCH FOR MULTIPLE INITIATORS**INPUT**

truncation value for multiple initiator search in 1/yr is
1.00000E-08

POS is # 5

Overlap time in hours is 2.40000E+01

Fraction of time spent in POS is 3.10000E-02

Number of initiating events examined is 34

T1 has freq 1/yr of 1.30000E-01
A has freq 1/yr of 3.62000E-05
ASHY has freq 1/yr of 1.25000E-04
S1 has freq 1/yr of 3.62000E-05
S1H has freq 1/yr of 1.25000E-04
S2 has freq 1/yr of 3.62000E-05
S2H has freq 1/yr of 1.25000E-04
S3 has freq 1/yr of 3.62000E-05
S3H has freq 1/yr of 1.25000E-04
H1 has freq 1/yr of 6.10000E-02
J2 has freq 1/yr of 1.56000E-02
E1B has freq 1/yr of 5.70000E-02
E1C has freq 1/yr of 1.57000E-03
E1D has freq 1/yr of 5.70000E-02
E1T has freq 1/yr of 3.56000E-01
E1V has freq 1/yr of 3.56000E-01
E2B has freq 1/yr of 6.50000E-02
E2C has freq 1/yr of 1.57000E-03
E2D has freq 1/yr of 6.50000E-02
E2T has freq 1/yr of 3.80000E-02
E2V has freq 1/yr of 3.80000E-02
T5A has freq 1/yr of 2.40000E-02
T5B has freq 1/yr of 2.40000E-02
T5C has freq 1/yr of 2.40000E-02
T5D has freq 1/yr of 2.40000E-02
TAB has freq 1/yr of 1.66000E-03
TDB has freq 1/yr of 6.00000E-03
TIA has freq 1/yr of 1.80000E-01
TORV has freq 1/yr of 1.40000E-01
TIOP has freq 1/yr of 1.57000E-03
TIHP has freq 1/yr of 1.40000E-02
TIOF has freq 1/yr of 2.20000E-02
TRPT has freq 1/yr of 7.20000E-02
TLM has freq 1/yr of 8.00000E-03

OUTPUT

List of double and triple multiple initiators with freq
≤ 1.00000E-08 per yr, using 2.40000E+01 hours as
overlap time, and weighted by 3.10000E-02, the
fraction of time in the selected POS.

DOUBLE INITIATORS

freq in 1/yr of T1 and H1 is 6.72990E-07

freq in 1/yr of T1 and J2 is 1.72120E-07

freq in 1/yr of T1 and E1B is 6.28863E-07

freq in 1/yr of T1 and E1T is 3.92603E-06

freq in 1/yr of T1 and E1V is 3.92603E-06

freq in 1/yr of T1 and E2B is 7.17116E-07

freq in 1/yr of T1 and E2T is 4.19253E-07

freq in 1/yr of T1 and E2V is 4.19253E-07

freq in 1/yr of T1 and T5A is 2.64796E-07

freq in 1/yr of T1 and T5D is 2.64796E-07

freq in 1/yr of T1 and TAB is 1.83156E-08

freq in 1/yr of T1 and TDB is 6.62007E-08

freq in 1/yr of T1 and TIA is 1.98555E-06

freq in 1/yr of T1 and TORV is 1.54440E-06

freq in 1/yr of T1 and TIOP is 1.73226E-08

freq in 1/yr of T1 and TIHP is 1.54467E-07

freq in 1/yr of T1 and TIOF is 2.42731E-07

freq in 1/yr of T1 and TRPT is 7.94336E-07

freq in 1/yr of T1 and TLM is 8.82673E-08

freq in 1/yr of H1 and J2 is 8.07638E-08

freq in 1/yr of H1 and E1B is 2.95082E-07

Table F.3.2 Multiple Initiating Events for POS 5 (Continued)

freq in 1/yr of H1 and E1D is 2.95082E-07	freq in 1/yr of J2 and T5A is 3.17755E-08
freq in 1/yr of H1 and E1T is 1.84221E-06	freq in 1/yr of J2 and T5B is 3.17755E-08
freq in 1/yr of H1 and E1V is 1.84221E-06	freq in 1/yr of J2 and T5C is 3.17755E-08
freq in 1/yr of H1 and E2B is 3.36493E-07	freq in 1/yr of J2 and T5D is 3.17755E-08
freq in 1/yr of H1 and E2D is 3.36493E-07	freq in 1/yr of J2 and TIA is 2.38266E-07
freq in 1/yr of H1 and E2T is 1.96726E-07	freq in 1/yr of J2 and TORV is 1.85328E-07
freq in 1/yr of H1 and E2V is 1.96726E-07	freq in 1/yr of J2 and TIHP is 1.85360E-08
freq in 1/yr of H1 and T5A is 1.24251E-07	freq in 1/yr of J2 and TIOF is 2.91277E-08
freq in 1/yr of H1 and T5B is 1.24251E-07	freq in 1/yr of J2 and TRPT is 9.53204E-08
freq in 1/yr of H1 and T5C is 1.24251E-07	freq in 1/yr of J2 and TLM is 1.05921E-08
freq in 1/yr of H1 and T5D is 1.24251E-07	freq in 1/yr of E1B and H1 is 2.95080E-07
freq in 1/yr of H1 and TDB is 3.10634E-08	freq in 1/yr of E1B and J2 is 7.54678E-08
freq in 1/yr of H1 and TIA is 9.31680E-07	freq in 1/yr of E1B and E1D is 2.75732E-07
freq in 1/yr of H1 and TORV is 7.24680E-07	freq in 1/yr of E1B and E1T is 1.72141E-06
freq in 1/yr of H1 and TIHP is 7.24805E-08	freq in 1/yr of E1B and E1V is 1.72141E-06
freq in 1/yr of H1 and TIOF is 1.13897E-07	freq in 1/yr of E1B and E2B is 3.14428E-07
freq in 1/yr of H1 and TRPT is 3.72727E-07	freq in 1/yr of E1B and E2D is 3.14428E-07
freq in 1/yr of H1 and TLM is 4.14178E-08	freq in 1/yr of E1B and E2T is 1.83826E-07
freq in 1/yr of J2 and H1 is 8.07588E-08	freq in 1/yr of E1B and E2V is 1.83826E-07
freq in 1/yr of J2 and E1B is 7.54635E-08	freq in 1/yr of E1B and T5A is 1.16103E-07
freq in 1/yr of J2 and E1D is 7.54635E-08	freq in 1/yr of E1B and T5B is 1.16103E-07
freq in 1/yr of J2 and E1T is 4.71123E-07	freq in 1/yr of E1B and T5C is 1.16103E-07
freq in 1/yr of J2 and E1V is 4.71123E-07	freq in 1/yr of E1B and T5D is 1.16103E-07
freq in 1/yr of J2 and E2B is 8.60539E-08	freq in 1/yr of E1B and TDB is 2.90265E-08
freq in 1/yr of J2 and E2D is 8.60539E-08	freq in 1/yr of E1B and TIA is 8.70586E-07
freq in 1/yr of J2 and E2T is 5.03103E-08	freq in 1/yr of E1B and TORV is 6.77160E-07
freq in 1/yr of J2 and E2V is 5.03103E-08	freq in 1/yr of E1B and TIHP is 6.77277E-08

Supporting Calculations

Table F.3.2 Multiple Initiating Events for POS 5 (Continued)

freq in 1/yr of E1B and TIOF is 1.06428E-07	freq in 1/yr of E1T and H1 is 1.84296E-06
freq in 1/yr of E1B and TRPT is 3.48286E-07	freq in 1/yr of E1T and J2 is 4.71343E-07
freq in 1/yr of E1B and TLM is 3.87018E-08	freq in 1/yr of E1T and E1B is 1.72212E-06
freq in 1/yr of E1C and E1T is 4.74143E-08	freq in 1/yr of E1T and E1C is 4.74373E-08
freq in 1/yr of E1C and E1V is 4.74143E-08	freq in 1/yr of E1T and E1D is 1.72212E-06
freq in 1/yr of E1C and TIA is 2.39793E-08	freq in 1/yr of E1T and E1V is 1.07513E-05
freq in 1/yr of E1C and TORV is 1.86516E-08	freq in 1/yr of E1T and E2B is 1.96380E-06
freq in 1/yr of E1D and H1 is 2.95080E-07	freq in 1/yr of E1T and E2C is 4.74373E-08
freq in 1/yr of E1D and J2 is 7.54678E-08	freq in 1/yr of E1T and E2D is 1.96380E-06
freq in 1/yr of E1D and E1B is 2.75732E-07	freq in 1/yr of E1T and E2T is 1.14811E-06
freq in 1/yr of E1D and E1T is 1.72141E-06	freq in 1/yr of E1T and E2V is 1.14811E-06
freq in 1/yr of E1D and E1V is 1.72141E-06	freq in 1/yr of E1T and T5A is 7.25134E-07
freq in 1/yr of E1D and E2B is 3.14428E-07	freq in 1/yr of E1T and T5B is 7.25134E-07
freq in 1/yr of E1D and E2D is 3.14428E-07	freq in 1/yr of E1T and T5C is 7.25134E-07
freq in 1/yr of E1D and E2T is 1.83826E-07	freq in 1/yr of E1T and T5D is 7.25134E-07
freq in 1/yr of E1D and E2V is 1.83826E-07	freq in 1/yr of E1T and TAB is 5.01567E-08
freq in 1/yr of E1D and T5A is 1.16103E-07	freq in 1/yr of E1T and TDB is 1.81288E-07
freq in 1/yr of E1D and T5B is 1.16103E-07	freq in 1/yr of E1T and TIA is 5.43735E-06
freq in 1/yr of E1D and T5C is 1.16103E-07	freq in 1/yr of E1T and TORV is 4.22928E-06
freq in 1/yr of E1D and T5D is 1.16103E-07	freq in 1/yr of E1T and TIOP is 4.74373E-08
freq in 1/yr of E1D and TDB is 2.90265E-08	freq in 1/yr of E1T and TIHP is 4.23001E-07
freq in 1/yr of E1D and TIA is 8.70586E-07	freq in 1/yr of E1T and TIOF is 6.64708E-07
freq in 1/yr of E1D and TORV is 6.77160E-07	freq in 1/yr of E1T and TRPT is 2.17526E-06
freq in 1/yr of E1D and TIHP is 6.77277E-08	freq in 1/yr of E1T and TLM is 2.41717E-07
freq in 1/yr of E1D and TIOF is 1.06428E-07	freq in 1/yr of E1V and H1 is 1.84296E-06
freq in 1/yr of E1D and TRPT is 3.48286E-07	freq in 1/yr of E1V and J2 is 4.71343E-07
freq in 1/yr of E1D and TLM is 3.87018E-08	freq in 1/yr of E1V and E1B is 1.72212E-06

Table F.3.2 Multiple Initiating Events for POS 5 (Continued)

freq in 1/yr of E1V and E1C is 4.74373E-08	freq in 1/yr of E2B and E2T is 2.09626E-07
freq in 1/yr of E1V and E1D is 1.72212E-06	freq in 1/yr of E2B and E2V is 2.09626E-07
freq in 1/yr of E1V and E1T is 1.07513E-05	freq in 1/yr of E2B and T5A is 1.32398E-07
freq in 1/yr of E1V and E2B is 1.96380E-06	freq in 1/yr of E2B and T5B is 1.32398E-07
freq in 1/yr of E1V and E2C is 4.74373E-08	freq in 1/yr of E2B and T5C is 1.32398E-07
freq in 1/yr of E1V and E2D is 1.96380E-06	freq in 1/yr of E2B and T5D is 1.32398E-07
freq in 1/yr of E1V and E2T is 1.14811E-06	freq in 1/yr of E2B and TDB is 3.31003E-08
freq in 1/yr of E1V and E2V is 1.14811E-06	freq in 1/yr of E2B and TIA is 9.92774E-07
freq in 1/yr of E1V and T5A is 7.25134E-07	freq in 1/yr of E2B and TORV is 7.72200E-07
freq in 1/yr of E1V and T5B is 7.25134E-07	freq in 1/yr of E2B and TIHP is 7.72333E-08
freq in 1/yr of E1V and T5C is 7.25134E-07	freq in 1/yr of E2B and TIOF is 1.21365E-07
freq in 1/yr of E1V and T5D is 7.25134E-07	freq in 1/yr of E2B and TRPT is 3.97168E-07
freq in 1/yr of E1V and TAB is 5.01567E-08	freq in 1/yr of E2B and TLM is 4.41337E-08
freq in 1/yr of E1V and TDB is 1.81288E-07	freq in 1/yr of E2C and E1T is 4.74143E-08
freq in 1/yr of E1V and TIA is 5.43735E-06	freq in 1/yr of E2C and E1V is 4.74143E-08
freq in 1/yr of E1V and TORV is 4.22928E-06	freq in 1/yr of E2C and TIA is 2.39793E-08
freq in 1/yr of E1V and TIOP is 4.74373E-08	freq in 1/yr of E2C and TORV is 1.86516E-08
freq in 1/yr of E1V and TIHP is 4.23001E-07	freq in 1/yr of E2D and H1 is 3.36495E-07
freq in 1/yr of E1V and TIOF is 6.64708E-07	freq in 1/yr of E2D and J2 is 8.60598E-08
freq in 1/yr of E1V and TRPT is 2.17526E-06	freq in 1/yr of E2D and E1B is 3.14431E-07
freq in 1/yr of E1V and TLM is 2.41717E-07	freq in 1/yr of E2D and E1T is 1.96301E-06
freq in 1/yr of E2B and H1 is 3.36495E-07	freq in 1/yr of E2D and E1V is 1.96301E-06
freq in 1/yr of E2B and J2 is 8.60598E-08	freq in 1/yr of E2D and E2B is 3.58558E-07
freq in 1/yr of E2B and E1D is 3.14431E-07	freq in 1/yr of E2D and E2T is 2.09626E-07
freq in 1/yr of E2B and E1T is 1.96301E-06	freq in 1/yr of E2D and E2V is 2.09626E-07
freq in 1/yr of E2B and E1V is 1.96301E-06	freq in 1/yr of E2D and T5A is 1.32398E-07
freq in 1/yr of E2B and E2D is 3.58558E-07	freq in 1/yr of E2D and T5B is 1.32398E-07

Supporting Calculations

Table F.3.2 Multiple Initiating Events for POS 5 (Continued)

freq in 1/yr of E2D and T5C is 1.32398E-07	freq in 1/yr of E2T and TLM is 2.58012E-08
freq in 1/yr of E2D and T5D is 1.32398E-07	freq in 1/yr of E2V and H1 is 1.96720E-07
freq in 1/yr of E2D and TDB is 3.31003E-08	freq in 1/yr of E2V and J2 is 5.03119E-08
freq in 1/yr of E2D and TIA is 9.92774E-07	freq in 1/yr of E2V and E1B is 1.83821E-07
freq in 1/yr of E2D and TORV is 7.72200E-07	freq in 1/yr of E2V and E1D is 1.83821E-07
freq in 1/yr of E2D and TIHP is 7.72333E-08	freq in 1/yr of E2V and E1T is 1.14761E-06
freq in 1/yr of E2D and TIOF is 1.21365E-07	freq in 1/yr of E2V and E2B is 2.09619E-07
freq in 1/yr of E2D and TRPT is 3.97168E-07	freq in 1/yr of E2V and E2D is 2.09619E-07
freq in 1/yr of E2D and TLM is 4.41337E-08	freq in 1/yr of E2V and E2T is 1.22551E-07
freq in 1/yr of E2T and H1 is 1.96720E-07	freq in 1/yr of E2V and T5A is 7.74020E-08
freq in 1/yr of E2T and J2 is 5.03119E-08	freq in 1/yr of E2V and T5B is 7.74020E-08
freq in 1/yr of E2T and E1B is 1.83821E-07	freq in 1/yr of E2V and T5C is 7.74020E-08
freq in 1/yr of E2T and E1D is 1.83821E-07	freq in 1/yr of E2V and T5D is 7.74020E-08
freq in 1/yr of E2T and E1V is 1.14761E-06	freq in 1/yr of E2V and TDB is 1.93510E-08
freq in 1/yr of E2T and E2B is 2.09619E-07	freq in 1/yr of E2V and TIA is 5.80391E-07
freq in 1/yr of E2T and E2D is 2.09619E-07	freq in 1/yr of E2V and TORV is 4.51440E-07
freq in 1/yr of E2T and E2V is 1.22551E-07	freq in 1/yr of E2V and TIHP is 4.51518E-08
freq in 1/yr of E2T and T5A is 7.74020E-08	freq in 1/yr of E2V and TIOF is 7.09520E-08
freq in 1/yr of E2T and T5B is 7.74020E-08	freq in 1/yr of E2V and TRPT is 2.32191E-07
freq in 1/yr of E2T and T5C is 7.74020E-08	freq in 1/yr of E2V and TLM is 2.58012E-08
freq in 1/yr of E2T and T5D is 7.74020E-08	freq in 1/yr of T5A and H1 is 1.24244E-07
freq in 1/yr of E2T and TDB is 1.93510E-08	freq in 1/yr of T5A and J2 is 3.17759E-08
freq in 1/yr of E2T and TIA is 5.80391E-07	freq in 1/yr of T5A and E1D is 1.16098E-07
freq in 1/yr of E2T and TORV is 4.51440E-07	freq in 1/yr of T5A and E1T is 7.24805E-07
freq in 1/yr of E2T and TIHP is 4.51518E-08	freq in 1/yr of T5A and E1V is 7.24805E-07
freq in 1/yr of E2T and TIOF is 7.09520E-08	freq in 1/yr of T5A and E2D is 1.32391E-07
freq in 1/yr of E2T and TRPT is 2.32191E-07	freq in 1/yr of T5A and E2T is 7.74005E-08

Table F.3.2 Multiple Initiating Events for POS 5 (Continued)

freq in 1/yr of T5A and E2V is 7.74005E-08	freq in 1/yr of T5B and TRPT is 1.46647E-07
freq in 1/yr of T5A and T5B is 4.88855E-08	freq in 1/yr of T5B and TLM is 1.62955E-08
freq in 1/yr of T5A and T5C is 4.88855E-08	freq in 1/yr of T5C and H1 is 1.24244E-07
freq in 1/yr of T5A and T5D is 4.88855E-08	freq in 1/yr of T5C and J2 is 3.17759E-08
freq in 1/yr of T5A and TDB is 1.22217E-08	freq in 1/yr of T5C and E1B is 1.16098E-07
freq in 1/yr of T5A and TIA is 3.66563E-07	freq in 1/yr of T5C and E1T is 7.24805E-07
freq in 1/yr of T5A and TORV is 2.85120E-07	freq in 1/yr of T5C and E1V is 7.24805E-07
freq in 1/yr of T5A and TIHP is 2.85169E-08	freq in 1/yr of T5C and E2B is 1.32391E-07
freq in 1/yr of T5A and TIOF is 4.48118E-08	freq in 1/yr of T5C and E2T is 7.74005E-08
freq in 1/yr of T5A and TRPT is 1.46647E-07	freq in 1/yr of T5C and E2V is 7.74005E-08
freq in 1/yr of T5A and TLM is 1.62955E-08	freq in 1/yr of T5C and T5A is 4.88855E-08
freq in 1/yr of T5B and H1 is 1.24244E-07	freq in 1/yr of T5C and TDB is 1.22217E-08
freq in 1/yr of T5B and J2 is 3.17759E-08	freq in 1/yr of T5C and TORV is 2.85120E-07
freq in 1/yr of T5B and E1B is 1.16098E-07	freq in 1/yr of T5C and TIHP is 2.85169E-08
freq in 1/yr of T5B and E1D is 1.16098E-07	freq in 1/yr of T5C and TIOF is 4.48118E-08
freq in 1/yr of T5B and E1T is 7.24805E-07	freq in 1/yr of T5C and TRPT is 1.46647E-07
freq in 1/yr of T5B and E1V is 7.24805E-07	freq in 1/yr of T5C and TLM is 1.62955E-08
freq in 1/yr of T5B and E2B is 1.32391E-07	freq in 1/yr of T5D and H1 is 1.24244E-07
freq in 1/yr of T5B and E2D is 1.32391E-07	freq in 1/yr of T5D and J2 is 3.17759E-08
freq in 1/yr of T5B and E2T is 7.74005E-08	freq in 1/yr of T5D and E1B is 1.16098E-07
freq in 1/yr of T5B and E2V is 7.74005E-08	freq in 1/yr of T5D and E1D is 1.16098E-07
freq in 1/yr of T5B and T5A is 4.88855E-08	freq in 1/yr of T5D and E1T is 7.24805E-07
freq in 1/yr of T5B and T5D is 4.88855E-08	freq in 1/yr of T5D and E1V is 7.24805E-07
freq in 1/yr of T5B and TDB is 1.22217E-08	freq in 1/yr of T5D and E2B is 1.32391E-07
freq in 1/yr of T5B and TORV is 2.85120E-07	freq in 1/yr of T5D and E2D is 1.32391E-07
freq in 1/yr of T5B and TIHP is 2.85169E-08	freq in 1/yr of T5D and E2T is 7.74005E-08
freq in 1/yr of T5B and TIOF is 4.48118E-08	freq in 1/yr of T5D and E2V is 7.74005E-08

Supporting Calculations

Table F.3.2 Multiple Initiating Events for POS 5 (Continued)

freq in 1/yr of T5D and T5A is 4.88855E-08	freq in 1/yr of TDB and TORV is 7.12800E-08
freq in 1/yr of T5D and T5B is 4.88855E-08	freq in 1/yr of TDB and TIOF is 1.12029E-08
freq in 1/yr of T5D and T5C is 4.88855E-08	freq in 1/yr of TDB and TRPT is 3.66617E-08
freq in 1/yr of T5D and TDB is 1.22217E-08	freq in 1/yr of TIA and H1 is 9.31832E-07
freq in 1/yr of T5D and TIA is 3.66563E-07	freq in 1/yr of TIA and J2 is 2.38319E-07
freq in 1/yr of T5D and TORV is 2.85120E-07	freq in 1/yr of TIA and E1B is 8.70733E-07
freq in 1/yr of T5D and TIHP is 2.85169E-08	freq in 1/yr of TIA and E1D is 8.70733E-07
freq in 1/yr of T5D and TIOF is 4.48118E-08	freq in 1/yr of TIA and E1T is 5.43604E-06
freq in 1/yr of T5D and TRPT is 1.46647E-07	freq in 1/yr of TIA and E1V is 5.43604E-06
freq in 1/yr of T5D and TLM is 1.62955E-08	freq in 1/yr of TIA and E2B is 9.92930E-07
freq in 1/yr of TAB and E1T is 5.01323E-08	freq in 1/yr of TIA and E2D is 9.92930E-07
freq in 1/yr of TAB and E1V is 5.01323E-08	freq in 1/yr of TIA and E2T is 5.80504E-07
freq in 1/yr of TAB and TIA is 2.53539E-08	freq in 1/yr of TIA and E2V is 5.80504E-07
freq in 1/yr of TAB and TORV is 1.97208E-08	freq in 1/yr of TIA and T5A is 3.66641E-07
freq in 1/yr of TAB and TRPT is 1.01431E-08	freq in 1/yr of TIA and T5D is 3.66641E-07
freq in 1/yr of TDB and H1 is 3.10611E-08	freq in 1/yr of TIA and TAB is 2.53601E-08
freq in 1/yr of TDB and E1D is 2.90244E-08	freq in 1/yr of TIA and TDB is 9.16625E-08
freq in 1/yr of TDB and E1T is 1.81201E-07	freq in 1/yr of TIA and TORV is 2.13840E-06
freq in 1/yr of TDB and E1V is 1.81201E-07	freq in 1/yr of TIA and TIOP is 2.39852E-08
freq in 1/yr of TDB and E2D is 3.30977E-08	freq in 1/yr of TIA and TIHP is 2.13877E-07
freq in 1/yr of TDB and E2T is 1.93501E-08	freq in 1/yr of TIA and TIOF is 3.36088E-07
freq in 1/yr of TDB and E2V is 1.93501E-08	freq in 1/yr of TIA and TRPT is 1.09985E-06
freq in 1/yr of TDB and T5A is 1.22214E-08	freq in 1/yr of TORV and H1 is 7.24758E-07
freq in 1/yr of TDB and T5B is 1.22214E-08	freq in 1/yr of TORV and J2 is 1.85359E-07
freq in 1/yr of TDB and T5C is 1.22214E-08	freq in 1/yr of TORV and E1B is 6.77237E-07
freq in 1/yr of TDB and T5D is 1.22214E-08	freq in 1/yr of TORV and E1C is 1.86551E-08
freq in 1/yr of TDB and TIA is 9.16407E-08	freq in 1/yr of TORV and E1D is 6.77237E-07

Table F.3.2 Multiple Initiating Events for POS 5 (Continued)

freq in 1/yr of TORV and E1T is 4.22803E-06	freq in 1/yr of TIHP and E1T is 4.22803E-07
freq in 1/yr of TORV and E1V is 4.22803E-06	freq in 1/yr of TIHP and E1V is 4.22803E-07
freq in 1/yr of TORV and E2B is 7.72279E-07	freq in 1/yr of TIHP and E2B is 7.72279E-08
freq in 1/yr of TORV and E2C is 1.86551E-08	freq in 1/yr of TIHP and E2D is 7.72279E-08
freq in 1/yr of TORV and E2D is 7.72279E-07	freq in 1/yr of TIHP and E2T is 4.51503E-08
freq in 1/yr of TORV and E2T is 4.51503E-07	freq in 1/yr of TIHP and E2V is 4.51503E-08
freq in 1/yr of TORV and E2V is 4.51503E-07	freq in 1/yr of TIHP and T5A is 2.85165E-08
freq in 1/yr of TORV and T5A is 2.85165E-07	freq in 1/yr of TIHP and T5B is 2.85165E-08
freq in 1/yr of TORV and T5B is 2.85165E-07	freq in 1/yr of TIHP and T5C is 2.85165E-08
freq in 1/yr of TORV and T5C is 2.85165E-07	freq in 1/yr of TIHP and T5D is 2.85165E-08
freq in 1/yr of TORV and T5D is 2.85165E-07	freq in 1/yr of TIHP and TIA is 2.13828E-07
freq in 1/yr of TORV and TAB is 1.97245E-08	freq in 1/yr of TIHP and TORV is 1.66320E-07
freq in 1/yr of TORV and TDB is 7.12931E-08	freq in 1/yr of TIHP and TIOF is 2.61402E-08
freq in 1/yr of TORV and TIA is 2.13828E-06	freq in 1/yr of TIHP and TRPT is 8.55439E-08
freq in 1/yr of TORV and TIOP is 1.86551E-08	freq in 1/yr of TIOF and H1 is 1.13891E-07
freq in 1/yr of TORV and TIHP is 1.66349E-07	freq in 1/yr of TIOF and J2 is 2.91279E-08
freq in 1/yr of TORV and TIOF is 2.61402E-07	freq in 1/yr of TIOF and E1B is 1.06423E-07
freq in 1/yr of TORV and TRPT is 8.55439E-07	freq in 1/yr of TIOF and E1D is 1.06423E-07
freq in 1/yr of TORV and TLM is 9.50571E-08	freq in 1/yr of TIOF and E1T is 6.64404E-07
freq in 1/yr of TIOP and E1T is 4.74143E-08	freq in 1/yr of TIOF and E1V is 6.64404E-07
freq in 1/yr of TIOP and E1V is 4.74143E-08	freq in 1/yr of TIOF and E2B is 1.21358E-07
freq in 1/yr of TIOP and TIA is 2.39793E-08	freq in 1/yr of TIOF and E2D is 1.21358E-07
freq in 1/yr of TIOP and TORV is 1.86516E-08	freq in 1/yr of TIOF and E2T is 7.09505E-08
freq in 1/yr of TIHP and H1 is 7.24758E-08	freq in 1/yr of TIOF and E2V is 7.09505E-08
freq in 1/yr of TIHP and J2 is 1.85359E-08	freq in 1/yr of TIOF and T5A is 4.48117E-08
freq in 1/yr of TIHP and E1B is 6.77237E-08	freq in 1/yr of TIOF and T5B is 4.48117E-08
freq in 1/yr of TIHP and E1D is 6.77237E-08	freq in 1/yr of TIOF and T5C is 4.48117E-08

Supporting Calculations

Table F.3.2 Multiple Initiating Events for POS 5 (Continued)

freq in 1/yr of TIOF and T5D is 4.48117E-08	freq in 1/yr of TRPT and TLM is 4.88865E-08
freq in 1/yr of TIOF and TDB is 1.12032E-08	freq in 1/yr of TLM and H1 is 4.14147E-08
freq in 1/yr of TIOF and TIA is 3.36016E-07	freq in 1/yr of TLM and J2 is 1.05920E-08
freq in 1/yr of TIOF and TORV is 2.61360E-07	freq in 1/yr of TLM and E1B is 3.86992E-08
freq in 1/yr of TIOF and TIHP is 2.61405E-08	freq in 1/yr of TLM and E1D is 3.86992E-08
freq in 1/yr of TIOF and TRPT is 1.34426E-07	freq in 1/yr of TLM and E1T is 2.41602E-07
freq in 1/yr of TIOF and TLM is 1.49376E-08	freq in 1/yr of TLM and E1V is 2.41602E-07
freq in 1/yr of TRPT and H1 is 3.72733E-07	freq in 1/yr of TLM and E2B is 4.41302E-08
freq in 1/yr of TRPT and J2 is 9.53277E-08	freq in 1/yr of TLM and E2D is 4.41302E-08
freq in 1/yr of TRPT and E1B is 3.48293E-07	freq in 1/yr of TLM and E2T is 2.58002E-08
freq in 1/yr of TRPT and E1D is 3.48293E-07	freq in 1/yr of TLM and E2V is 2.58002E-08
freq in 1/yr of TRPT and E1T is 2.17441E-06	freq in 1/yr of TLM and T5A is 1.62952E-08
freq in 1/yr of TRPT and E1V is 2.17441E-06	freq in 1/yr of TLM and T5B is 1.62952E-08
freq in 1/yr of TRPT and E2B is 3.97172E-07	freq in 1/yr of TLM and T5C is 1.62952E-08
freq in 1/yr of TRPT and E2D is 3.97172E-07	freq in 1/yr of TLM and T5D is 1.62952E-08
freq in 1/yr of TRPT and E2T is 2.32201E-07	freq in 1/yr of TLM and TIA is 1.22188E-07
freq in 1/yr of TRPT and E2V is 2.32201E-07	freq in 1/yr of TLM and TORV is 9.50400E-08
freq in 1/yr of TRPT and T5A is 1.46656E-07	freq in 1/yr of TLM and TIOF is 1.49373E-08
freq in 1/yr of TRPT and T5B is 1.46656E-07	freq in 1/yr of TLM and TRPT is 4.88822E-08
freq in 1/yr of TRPT and T5C is 1.46656E-07	
freq in 1/yr of TRPT and T5D is 1.46656E-07	TRIPLE INITIATORS
freq in 1/yr of TRPT and TAB is 1.01440E-08	NO TRIPLE INITIATORS ABOVE TRUNCATION
freq in 1/yr of TRPT and TDB is 3.66650E-08	VALUE
freq in 1/yr of TRPT and TIA is 1.09969E-06	
freq in 1/yr of TRPT and TORV is 8.55360E-07	
freq in 1/yr of TRPT and TIHP is 8.55507E-08	
freq in 1/yr of TRPT and TIOF is 1.34435E-07	

F.4 Detailed Calculations

Based on results of the scoping calculations as described in Section F.2 of this report, more detailed calculations were performed.

At shutdown, the normal methods for core cooling use the shutdown cooling system, either with RHR or with ADHR. The minimum design pressure for these systems is 220 psig for RHR and 80 psig for ADHR. In POSs 4 and 5 the vessel head is on and pressurization transients can overpressurize these systems. We have taken the failure pressure of these systems as twice the design rating -- namely, 440 psig for RHR and 160 psig for ADHR. Overpressurization of these systems leads to an interfacing systems LOCA outside containment. In POSs 4 and 5 these systems are auto-isolated at 135 psig, and they are auto-isolated at low level 3. If the systems are isolated, shutdown cooling is lost, but the overpressurization is prevented.

To perform these calculations, a computer code was written. This code, GGENER.PAS, performs an energy balance on a system of saturated steam/water accounting for time dependent decay heat, addition of water, and blowdown of steam or flashing water. The code uses the following special case of the first law of thermodynamics for the energy balance:

$$\int P(t) dt = \Delta U + \Delta H$$

where $P(t)$ is the power (decay heat), ΔU is the change in internal energy of the water/steam in the vessel, and ΔH is the net enthalpy lost from the vessel.

$$P(t) = \exp(-0.368 * \ln(t_{hr}) + 0.593)$$

$$\Delta U = U_{fin} - U_{ini}$$

$$\Delta H = H_{outof} - H_{into}$$

where $P(t)$ is the power in % of full power as a function of time in hours since shutdown (t_{hr}), U_{fin} is final internal energy, U_{ini} is initial internal energy, H_{outof} is enthalpy out of the vessel, and H_{into} is enthalpy into the vessel.

$$U_{fin} = (1 - x_{fin}) * M_{fin} * u_{watfin} + x_{fin} * M_{fin} * u_{stmfin}$$

$$U_{ini} = (1 - x_{ini}) * M_{ini} * u_{watini} + x_{ini} * M_{ini} * u_{stmmini}$$

$$H_{outof} = \int massout(t) * h_{outof} dt$$

$$H_{into} = \int massin(t) * h_{into} dt$$

M denotes total fluid mass, x denotes quality, u denotes specific internal energy, subscript fin denotes final state, subscript ini denotes initial state, subscript wat denotes water, and subscript stm denotes vapor (steam). Massout and massin are time dependent mass flow rates out of and into the vessel, respectively. "h" denotes specific enthalpy, subscript outof denotes mass out, and subscript into denotes mass in.

The source code is given as Table F.4-1. The code was modified and improved throughout the project. For example, the capability to handle time dependent decay heat was added, and the numerical fit to Moody's blowdown model was improved. Also, in the latest version, the code calculates actual and measured water levels, relative to instrument zero, accounting for changes in actual density of water at the calculated thermodynamic state. Calculation 90-492-01-A:19 contains the latest version of the code (that listed in Table F.4-1). Also, this calculation contains detailed results for the re-analysis of all earlier energy balances. The re-analysis results agreed with the original analysis results. However, levels were more accurately calculated in the re-analyzed results. The re-analysis was performed for the following calculations in the 90-492-01 series: A:6, A:10, A:11, A:13, and A:17.

F.4.1 Calculation #11

Calculation 90-492-01-A:11, SDC Relief Valves POS 4 and 5", addressed whether or not relief valves in the RHR/SDC system could prevent overpressurization given heatup of the system due to loss of heat removal. The calculation concludes the following (including the effects of the re-analysis of calculation 19):

- (1) For POS 4, 440 psig is reached at 49 min even

Table F.4.1 GGENER.PAS Source Code

{J. Darby, SEA 7/22/92 Version}

```

program ggblfil; {modification of blowfil.pas code to include}
{$N+}           {Grand Gulf time dependent decay heat}
{initial saturated state, blowdown sat water or sat steam via Moody}
{from tank out to 15 psia sink; MAKEUP AT CONSTANT RATE and no work}
{case of two phase IN tank NOT modeled here}
{calculates final sat state, fixed volume, both initial and final}
{states must be sat > 212 F, 15 psia}
{stops if tank has no water}
{limit polynomial fit of Moody's data to 5 points in dataset to }
{better fit high pressure data}
{change Moody steam mass flux from 500 to 600 for steam at 300 psia}
{7/15/92 add option for static head into driving pressure for}
{FLASHING water out the hole; no effect if steam out hole}
{7/22/92 use simple linear fit to Moody, add level indication}

```

var

```

nameofrun:string[50];
filevar,outfil:text;
stopit:boolean;
i,no:longint;
p,numdatapts:integer;
massperarea:real;
holesize:real;id:string[1];
v,x,m,uw,us,u,tend,dt,time:real;
actlevel,measlevel,lbmtollevel:real;
temp,press,diff,diff1:real;
height,heightin,inspvol,staticpress,staticpressin:real;
vw,vs,enthw,enth,mo,xo,uwo,uso,a,temp,pressp,xp,hop:real;
mir,hi:real; {mass rate IN lbm/sec, and specific enthalpy in}
ti,pinit:real;
qr,qri,timpos,mor,ho,entnet,engnet:real; {qri is initial decay heat}
      {timpos is time since shutdown in HOURS at which initial decay heat}
      {qri is specified}

```

```

procedure linfit(xu,hxu:real;var pxu:real); {for use in blowdown.pas}
      {piecewise Linear Fit of Moody Blowdown data}
      {xu is given pressure, pxu is calculated blowdown lbm/ft**2/sec}
      {hxu is hole enthalpy}

```

begin

```

if id='w' then begin
  if xu > 100 then pxu:=21.5*hxu-3.75e3; {function of enthalpy}
  if (xu <= 100) and (xu > 15) then pxu:=19.33*xu+767; {function of pressure}
    {use pressure to more accurately include static head of water}
  if xu <= 15 then pxu:=0
end; {end if 'w'}
if id='s' then begin
  if xu > 2000 then pxu:=-28.23*hxu+3.71e4;

```

Table F.4.1 GGENER.PAS Source Code (Continued)

```

if (xu <= 2000) and (xu > 600) then pxu:=-48.28*hxu+6.02e4;
if (xu <= 600) and (xu > 25) then pxu:=2.087*xu-2.174;{function of pressure}
  {in this range pressure fit better}
if xu <= 25 then pxu:=5*hxu-5.75e3
end {end if 's'}
end; {procedure linfit}

function massout(tankpress,holeenthalpy:real):real;
begin
  linfit(tankpress,holeenthalpy,massperarea);
    {Moody sat steam lbm/ft**2/sec}
  massout:=massperarea
end; {function massout}

procedure thereql; {calculate new saturated state in tank}
    {at end of timestep}
begin
  reset(filevar);
  readln(filevar);readln(filevar);readln(filevar);readln(filevar);
  temp:=ti;press:=pinit;x:=xo;
  repeat
  begin
    temp:=temp;press:=press;xp:=x;{p's, eg xp, are previous iteration values}
    hop:=ho;{enthalpy out hole for previous iteration}
    {read string leader}
    readln(filevar,temp,press,vw,vs,enthw,enths);
    uw:=enthw-press*vw*144/778;
    us:=enths-press*vs*144/778;
    {for assumed sat at temp, calc x from 1st law}
    x:=engnet+xo*mo*uso+(1-xo)*mo*uwo;
    x:=x-engnet;
    x:=(x-m*uw)/(m*us-m*uw);
    {check volume balance}
    diff1:=diff;
    a:=vw*(1-x)*m+vs*x*m;
    diff:=abs(a-v);
    if id='s' then ho:=enths;if id='w' then ho:=enthw;
  end;
  until (diff >= diff1) or (eof(filevar));
  if eof(filevar)=true then begin
    writeln(outfil,'OUT OF CODE P/T LIMITS');stopit:=true;exit end;
  if xp<0.0 then xp:=0.0;{avoid - x due to interpolation}

  {actual and measured levels}
  actlevel:=(1-xp)*m*lbmtollevel*vw/inspvol;{water mass * inches/lbm *}
    {density ratio for new water density rel to initial}
  actlevel:=actlevel-533; {actual level wrt instr 0}
  measlevel:=actlevel*0.02177/vw;{meas level wrt instr 0 uncompensated}

  if i mod p=0 then begin  {##### print out values each 0.1*p sec #####}
    writeln('time is ',time:12,' sec');
  end;
end;

```

Table F.4.1 GGENER.PAS Source Code (Continued)

```

writeln(outfil);           {Note: time step set at 0.1 sec}
writeln(outfil,'at time sec',time:12,' quality is ',xp:12);
writeln(outfil,'      ', 'steam mass lbm is ',xp*m:12);
writeln(outfil,'      ', 'water mass lbm is ',(1-xp)*m:12);
writeln(outfil,'      ', 'temp F is ',tempp:12);
writeln(outfil,'      ', 'vapor press psia is ',pressp:12);
writeln(outfil,'      ', 'pressure psi at hole from static head');
writeln(outfil,'      ', '      of water is ',staticpress:12);
writeln(outfil,'      ', 'actual level wrt instr 0 inches ',actlevel:12);
writeln(outfil,'      ', 'meas"d level wrt instr 0 inches ',measlevel:12);

if id='s' then
  writeln(outfil,'      ', 'static head has no effect since steaming out hole');
  writeln(outfil,'      ', 'heat Btu/sec is ',qr:12);
  writeln(outfil,'      ', 'lbm/sec out hole is ',mor:12);
  writeln(outfil,'      ', 'spec enthalpy Btu/lbm out hole is ',hop:12)
end; {mod if to output}
{specify mass out for next time step}
{calculate pressure from static head of water}
height:=heightin*(1-xp)/(1-xo)*m/mo*inspvol/vw; {static head in ft}
staticpress:=1/vw*height/144; {static presure in psi}
if id='s' then staticpress:=0.0; {static head does not affect steaming case}
mor:=holesize*massout(pressp+staticpress,hop)
end; {procedure thereql}

begin {main program}
stopit:=false;
engnet:=0;entnet:=0;qr:=0;qri:=0;
{input data}
{access steam table data for sat conditions}
assign(filevar,'blowdown.dat');
assign(outfil,'tank.dat');
rewrite(outfil);
writeln('enter name of case to be run');readln(nameofrun);
writeln('enter initial temp,f');readln(ti);
writeln('enter initial pressure,psia');readln(pinit);
writeln('enter fixed volume v,ft3');
readln(v);
writeln('enter initial specific volume of sat liquid in ft**3/lbm');
readln(inspvol);
writeln('enter initial height in feet from hole to liquid/vapor surface');
writeln('  enter 0.0 if static head not of interest');
writeln('  static head only affects water, flashing case, not steam case');
readln(heightin);
{calculate initial static pressure from height of liquid above hole}
staticpressin:=1/inspvol*heightin/144;
writeln('enter initial actual level in inches above instr. zero (e.g. 60)');
readln(actlevel);
measlevel:=actlevel*0.02177/inspvol; {measured level above instr 0}
  {uncompensated}
writeln('enter initial quality,fraction');
readln(xo);

```

Table F.4.1 GGENER.PAS Source Code (Continued)

```

writeln('enter initial total mass water&steam,lbm');
readln(mo);
lbmtolevel:=(533+actlevel)/((1-xo)*mo); {actual inches/lbm, 533 is instr 0}
writeln('enter initial spec internal energy water,btu/lbm');
readln(uwo);
writeln('enter initial spec internal energy steam,btu/lbm');
readln(uso);
{start time is 0}
writeln('enter end time,sec');
readln(tend);
writeln('enter number of data sets to be saved');
readln(numdatapts);
p:=round(tend/numdatapts);
dt:=1; {1 second time step}

{FOR TIME STEP OF 1 SEC CHANGE ABOVE 2 STATEMENTS TO:}
  {p:=round(tend/numdatapts)}
  {dt:=1; 1 second time step}
{FOR TIME STEP OF 0.1 SEC CHANGE ABOVE 2 STATEMENTS TO:}
  {p:=round(10*tend/numdatapts)}
  {dt:=0.1; 0.1 second time step}

m:=mo;
writeln(outfil,'      NAME OF THIS RUN ');
writeln(outfil,'      ',nameofrun:30);
writeln(outfil);
writeln(outfil,'      INITIAL CONDITIONS ');
writeln(outfil,'Initial temp F ',ti:12);
writeln(outfil,'Initial pressure psia ',pinit:12);
writeln(outfil,'Fixed Tank Volume cubic ft ',v:12);
writeln(outfil,'Initial quality ',xo:12);
writeln(outfil,'Initial total mass water & steam lbm',mo:12);
writeln(outfil,'Initial height water above hole in ft is ',heightin:12);
writeln(outfil,'Initial specific volume water ft3/lbm is ',inspvol:12);
writeln(outfil,'Initial pressure from static head of water psi is ');
writeln(outfil,'      ',staticpressin:12,' only affects water, flashing case');
writeln(outfil,'      not steaming case');
writeln(outfil,'Initial Actual Level inches wrt instr. 0 ',actlevel:12);
writeln(outfil,'Initial Measured Level inches wrt instr. 0 ',measlevel:12);
writeln(outfil,'Initial spec int ener Btu/lbm water ',uwo:12);
writeln(outfil,'Initial spec int ener steam Btu/lbm ',uso:12);
writeln(outfil,'Time step sec ',dt:12);
writeln(outfil,'End time sec ',tend:12);writeln(outfil);

{calculate number of intervals}
no:=round(tend/dt);

{input data}
writeln('enter initial heat input in btu/sec');readln(qri);
  {initial decay heat}
writeln('enter time in HOURS corresponding to initial heat input');
readln(timpos); {time initially, used for time dependent decay heat calc}

```


Table F.4.1 GGENER.PAS Source Code (Continued)

```

writeln('enter hole size in ft**2');readln(holesize);
writeln('Water or Steam from break (enter w or s ?)');readln(id);
writeln(outfil,'Initial heat input at ',qri:12,' Btu/sec');
writeln(outfil,'Initial heating at ',timpos:12,' HOURS after shutdown');
writeln(outfil,'Hole size in square ft is ',holesize:12);
if id='s' then writeln(outfil,'Steam out hole');
if id='w' then writeln(outfil,'Water out hole (flashes)');
writeln('enter constant mass rate in, lbm/sec');readln(mir);
writeln(outfil,'Mass coming in at constant rate lbm/sec of ',mir:12);
writeln('enter enthalpy of mass in, in Btu/lbm');readln(hi);
writeln(outfil,'Specific enthalpy of mass coming in Btu/lbm is ',hi:12);
writeln(outfil);
if id='s' then begin
  writeln('enter spec enthalpy Btu/lbm of steam at ',pinit:12,' psia');
  readln(ho);
  writeln;writeln('End time is ',tend:12,' sec');writeln;
  {pressure at hole from static head of water for steaming is 0}
  staticpressin:=0.0;
  mor:=holesize*massout(pinit+staticpressin,ho)
end;
if id='w' then begin
  writeln('enter spec enthalpy Btu/lbm of water at ',pinit:12,' psia');
  readln(ho);
  writeln;writeln('End time is ',tend:12,' sec');writeln;
  {calculate pressure at hole from static head of water}
  staticpressin:=1/inspvol*heightin/144;
  mor:=holesize*massout(pinit+staticpressin,ho)
end;

{iterate to get equil state via procedure}
for i:=1 to no do
begin
  time:=i*dt;
  qr:=exp(-0.368*ln(time/3600+timpos)+0.593); {decay heat per cent}
  {via calc 492-01:2, page 4, note time is in HOURS in this equation}
  qr:=qr*0.01*3833e6*3.413/3600; {per cent to fraction to watts}
  {to Btu/hr to Btu/sec}
  if qri=0 then qr:=0; {0 Heat Case}
  diff:=1e8;
  entnet:=entnet+(mor*ho-mir*hi)*dt; {net enthalpy out from time 0}
  engnet:=engnet+qr*dt; {net heat in from time 0}
  m:=m+(mir-mor)*dt;
  if m<=0.0 then begin writeln(outfil,'OUT OF FLUID');
    close(filevar);close(outfil);exit end;
  if stopit=true then begin close(outfil);close(filevar);exit end;
  thereql
end;
close(filevar);
close(outfil);
end.

```

with relief from both RHR trains available,

- (2) For POS 5, 440 psig is reached at 120 min even with relief from both RHR trains available,
- (3) For ADHR with decay heat at 24 hours, 160 psig is reached at 113 min even with relief from both RHR trains available.

The relief capability is inadequate to prevent overpressurizing the components.

F.4.2 Calculation #4.1

Calculation 90-492-01-A:4.1, "Relief Capabilities at Grand Gulf", was a more detailed evaluation of the ability of the SRVs to relieve pressure than performed in the earlier scoping calculation # 3. This calculation addressed the following topics:

- (1) Friction Factors for SRV Relief and the 2 Inch vent line
- (2) Relief of Saturated Steam and 200 degree F Water from One SRV between 100 and 1400 psig
- (3) Relief of Saturated Steam and 200 degree F Water from the Vent Line between 100 and 1400 psig
- (4) Grand Gulf Steaming Rate:
 - (a) No Makeup
 - (b) Makeup with 100 degree F Water to Maintain Level
- (5) Vessel Pressure for Water through SRVs from: HPCS, LPCS, LPCI, and Combinations
- (6) Steam Relief through 1 SRV to match 1% Decay Heat for the two cases of Item (4)
- (7) Ability of the Vent Line to Match Decay Heat.

The calculated relief capacities for one SRV and for the vent line, for steam and water, are provided in Figures F.4-1 through F.4-4.

The steaming rate for Grand Gulf, with and without makeup, is given in Figure F.4-5 and F.4-6. The decay heat curve used to calculate these steaming rates is given in Figure F.4-7.

The vessel pressure for various combinations of ECCS injection and either 1 or 2 SRVs open is provided in Figure F.4-8 and F.4-9.

Steaming through 1 SRV will match 1% decay heat, without makeup, at 220 psig. With makeup, steaming can match 1% decay heat at 180 psig.

Steaming through the vent line is inadequate to prevent pressurization to SRV safety setpoints in POSs 4 and 5 with decay heat at 1% and 0.9%, respectively. After a 30 day refueling outage, with decay heat at 0.16%, steaming through the vent line can match decay heat only if pressure is 600 psig (without makeup), or 400 psig (with makeup).

F.4.3 Calculation #6

Calculation 90-492-01-A:6, "SRVs for Small/Medium LOCAs in POS 4" evaluated the ability of breaks and SRVs to control pressure in POS 4. The re-analyses of calculation 19 agreed with the results of the original calculation, except that level was calculated to be higher due to swell.

The updated results are as follows. The calculation evaluated the need for opening an SRV in relief on POS 4 following a small LOCA (0.007 sq ft) to prevent pressurization before ECCS is auto-actuated. Assuming a steam line break of 0.007 sq ft, complete phase separation in the vessel, and complete mixing of core and downcomer water, the system pressure /measured water level history is as follows:

- (a) 135 psig and +88 inches at 420 seconds
- (b) 440 psig and +128 inches at 3220 seconds.

The high measured levels at these pressures are due to swell of the actual level with temperature. ECCS does not actuate until level 2, -41.6 inches measured, or level 1, -150.3 inches measured. Thus, a small (or small, medium LOCA) will pressurize the system before ECCS injection is auto-initiated. A 0.007 sq ft water break was also analyzed, and the conclusions are the same as for the steam break as expected, since water breaks do not depressurize as effectively as steam breaks. This same calculation showed that if one SRV is opened for steam relief, even with a zero size LOCA, pressure never exceeds 135 psia before the level 1 ECCS actuation setpoint is reached. Thus, opening an SRV prevents significant pressurization of the system. [The difference

Figure F.4-1 1 SRV, Water

Figure F.4.2 1 SRV, Steam

Figure F.4.3 Vent Line, Water

Figure F.4.4 Vent Line, Steam

Figure F.4.5 Steaming with Makeup

Figure F.4.6 Steaming with No Makeup

Figure F.4.7 Decay Heat

- X HPCS** HPCS intersects 1SRV curve at 260 psig, 7000 gpm
- Δ LPCS** LPCS intersects 1SRV curve at 170 psig, 5700 gpm
- O LPCI** LPCI intersects 1SRV curve at 120 psig, 4700 gpm (1 pump)

Figure F.4-8 Pressure: Water Solid With 1 ECCS Pump

X LPCI and LPCS
 Δ HPCS and LPCS
 O 2 LPCI Pumps (Separate lines)

Figure F.4-9 Pressure: Water Solid With 2 ECCS Pump

between the 135 psia calculated here and the 220 psig calculated in # 4.1, is that a more conservative friction factor was used in 4.1, while this calculation used Moody data.] This calculation also showed that for a 0.04 sq ft water LOCA, level 1 is reached before the system pressurizes above about 118 psia. Therefore, for a large LOCA (or large, medium LOCA) opening of an SRV is not required to prevent pressurization before ECCS auto-actuation is reached.

F.4.4 Calculation #17

Calculation 90-492-01:17, "SRVs for Small/Medium LOCAs in POS 5", performed the same analyses for POS 5 that calculation #6 performed for POS 4. The re-analyses of calculation 19 agreed with the results of the original calculation, except that level was calculated to be higher due to swell. Assuming a water line break of 0.007 sq ft (a steam line break is of no concern in POS 5), and complete phase separation in the vessel, and complete mixing of core and downcomer water, the system pressure /measured water level history is as follows:

- (a) 135 psig and +78 inches at 4000 seconds, and
- (b) 440 psig and +39 inches at 7200 seconds.

The high measured levels at these pressures are due to swell of the actual level with temperature. ECCS does not actuate until level 2, -41.6 inches measured, or level 1, -150.3 inches measured; thus, a small (or small, medium LOCA) will pressurize the system before ECCS injection is completely auto-initiated. This same calculation showed that if one SRV is opened for steam relief, even with a zero size LOCA, pressure never exceeds 118 psia before the level 1 ECCS actuation setpoint is reached; thus, opening an SRV prevents significant pressurization of the system. This calculation also showed that for a 0.4 sq ft water LOCA, level 1 is reached before the system pressurizes above 50 psia; thus, for a large LOCA (or large, medium LOCA) opening of an SRV is not required to prevent pressurization before ECCS auto-actuation is reached.

F.4.5 Calculation #5

Calculation 90-492-01-A:5, "Levels for Grand Gulf", derived factors for converting from actual to measured levels.

For 200 °F water, measured level is 1.31 times actual

level, in agreement with NSAC-88 (NSAC 88). Because levels can be negative with respect to instrument zero, actual level is less than measured level for actual level above instrument zero, and actual level is greater than measured level for actual level below instrument zero. For example, if actual level is +10 inches, measured level is +13 inches. If actual level is -10 inches, measured level is -13 inches. This calculation also concludes that with one recirculation pump in operation, the height of water in the core region is above the minimum steam separator turnaround point so long as measured (downcomer) level is above level 3 (+11.4 inches measured). At low level 3, shutdown cooling is isolated.

Calculation 90-492-01-A:19, "Energy Balances Checked", included calculations of actual and measured levels at each thermodynamic state during an energy balance calculation. Based on the derivations on Calculation #5,

$$MeasLv = v_{w_{rated}} / v_w * (h_{water} - 533)$$

where MeasLv is the measured level in inches, with respect to instrument zero. $v_{w_{rated}}$ is the uncompensated water specific volume, 0.02177 cu ft per lbm, v_w is the actual specific volume, h_{water} is the actual height of water relative to vessel bottom, and 533 inches is the distance from vessel bottom to instrument zero. h_{water} is calculated from water mass as follows:

$$h_{water} = Term1 * Term2$$

$$Term1 = MassWtr / InMassWtr * (533 + InActLv)$$

$$Term2 = v_w / v_{win}$$

where Term1 is the actual water level relative to vessel bottom, not corrected for density changes. MassWtr is water mass, InMassWtr is initial water mass, and InActLv is initial actual level with respect to instrument zero. Term2 corrects for density changes (due to swell) where v_w is water specific volume, and v_{win} is initial water specific volume. Actual level with respect to instrument zero is:

Supporting Calculations

$$ActLv = h_{water} - 533$$

and measured level with respect to instrument zero is:

$$MeasLv = 0.02177/v_w * Actlv$$

Note that $0.02177/v_w$ is equal to 1.31 only for 200 degree F water.

F.4.6 Calculation #10

Calculation 90-492-01-A:10, "1 CRD pump for POS 5H", evaluated the ability of 1 CRD pump to restore level or match steaming in POS 5H. The re-analyses of calculation 19 agreed with the results of the original calculation, except that level was calculated to be higher due to swell. This calculation was performed, because, as discussed in Section 3 of the main report, the detailed model for POS 5 assumes train A is out for maintenance. Thus, only one CRD pump is available. The calculation concluded that if forced recirculation is lost, one CRD pump can raise level to allow natural circulation in 33 minutes, and pressure is only 103 psia, below the auto-isolation setpoint of 135 psig for auto-isolation of shutdown cooling. The calculation also concluded that if the core is steamed and only one CRD pump is available for makeup, the makeup rate is insufficient to prevent core uncover. The core uncovers by about four feet.

F.4.7 Calculation #13

Calculation 90-492-01-A:13, "Over Pressurization of ADHR in POS 5", evaluated overpressurization concerns for ADHR. In comparison with RHR, ADHR has a lower failure pressure, but the maximum decay heat when on ADHR is less than when on RHR, since ADHR cannot be used until at least 24 hours after shutdown. The re-analyses of calculation 19 agreed with the results of the original calculation, except that level was calculated to be higher due to swell. The calculation concluded that the time to overpressurize ADHR piping is similar to times calculated for overpressurizing RHR piping. The calculation concluded that the effect of having 1 CRD pump when on ADHR is similar to that when on RHR -- namely, 1 CRD pump can restore level for natural circulation shutdown cooling before auto-isolation or overpressurization occur. The calculation

pointed out that when on water solid ECCS operation, if auto-isolation of shutdown cooling at 135 psig does not occur, and if only 1 SRV is available for relief, ADHR can overpressurize (assuming a failure pressure of 160 psig, twice design rated pressure). Figure F.1-8 of this Appendix illustrates this concern. The calculation also showed that if one SRV is opened in response to a small LOCA (or no LOCA), pressure does not exceed 78 psia, and ADHR will not overpressurize.

F.5 Operator Actions

Calculation 90-492-01-A:16, "Update: Time for Operator Actions POS 5", provided estimates of times available for operator actions in the event trees.

Table F.5-1 summarizes the times available for operator actions from this calculation.

Table F.5.1 Times Available for Operator Actions: POS 5

Operator Action in Event Trees	Times Available for Action
RM-LT	10 hr, All Trees
LCMK	2.5 hr, All Trees
OPDHR	10 min, All Trees
OPLC	Action Simultaneous with OPDHR
OPSDC	37 min, All Trees
OPECS, OPFLD, OPSTM	23 min each, All Trees
OPIS	Action Simultaneous with OPSTM, All Trees
OPISA	Action Simultaneous with OPECS, All Trees
RESCS, RESAD, RESB	Action Simultaneous with OPSDC, All Trees
RESRW	No Time, All Trees
OPSTH	4.0 hr, All Trees
OPMSV	4.4 min for Trees: E, EA, ES, EP, EX, EAP, EAX, ESP, ESX 35 min for Trees: S15OU, S1HOU, S, SP, SX, FS, FSP, FSX Action Simultaneous with OPOSF for Trees: F, FP, FX, FNP, HWSPR
OPOMS	Operators will not do this event (open MSIVs)
LCHPC, LC-LP	7.7 min each, All Trees
OP1SV	Action Simultaneous with OPECS, All Trees
OPHIS	Action Simultaneous with OPECS, All Trees
OPICT	6.4 hr but Simultaneous with OPSTM (11 hr time) for Trees: ECAOH, ECACH, ECOHP, ECOHX, ECCHP, ECCHX, EC, ECP, ECX, ECNP, ECNPL, ECACN, ECAON, CAUXN, CAUXP, CAUXX, CAUX 6.4 hr for Trees: ECAC, ECAOP, ECACP, ECACX, ECAOX, ECAO For Trees FC, FCACP, FCACX, FCAO, FCAOP, FCAOX, FCP, FCX, FCAON, FCACN, FCN: 20 min if event 'CTGOP' is 'No'; 6.4 hr if event 'CTGOP' is 'Yes'

Table F.5.1 Times Available for Operator Actions: POS 5

Operator Action in Event Trees	Times Available for Action
OPCMT	54 hr, All Trees
OPSPM, SPMUN	13 min for Trees: A5IN, A5INH, S15IN, S1HIN 11 hr for All Other Trees
OPVNT	Action Simultaneous with SPMKP (11 hr) for Trees: ECAC, ECACH, ECACP, ECACX, ECCHP, ECCHX, EC, ECP, ECX, ECACN Action Simultaneous with OPCMT for Trees: FCAC, FC, FCACP, FCACX, FCP, FCX, FCACN, FCN
SPMKP	Action Simultaneous with OPSPM (11 hr) for Trees: ECAOH, ECACH, ECOHP, ECOHX, ECCHP, ECCHX, EC, ECP, ECX 11 hr for Trees: ECAC, ECAO, ECAOP, ECAOX, ECACP, ECACX
OPSOF	20 min, All Trees
CS, CSA	Action Simultaneous with SPMKP, All Trees
HPCAO	7.7 min, All Trees
ISSSL	15 min, All Trees
OPDSV	No Time, All Trees
OPDEP	8.7 hr, All Trees
OPFLL	0.64 hr, All Trees
OPHPC	7.7 min, All Trees
OPNCF	8.7 hr, All Trees
OPLDM	15 min for Trees: S2-5 and S2H-5 Action Simultaneous with ISSSL for Trees: S3-5 and S3H-5
OPLMS	6.4 hr, All Trees
OPLST	1.7 hr, All Trees
OPL1L	23 sec, All Trees
OPL1S	3.8 min, All Trees
OPL2L	3.5 min, All Trees

Table F.5.1 Times Available for Operator Actions: POS 5

Operator Action in Event Trees	Times Available for Action
OPSLP	7.7 min, All Trees
OPSRV	1.9 hr, All Trees
OPSTL	33 hr, All Trees
SDCUI	8.7 hr if event 'OPDEP' not in sequence Action Simultaneous with OPDEP if event 'OPDEP' in sequence
SPC, SPCA	Action Simultaneous with SPMKP, All Trees
ISO89	Action Simultaneous with OPECS for Tree HPSWA Action Not Required for Tree HPSWR
SPMKN	Action Simultaneous with OPSPM (11 hr) for Trees: ECNP, ECNPL, ECACN, ECAON 35 min for Tree SNP
FWMAN	Action Simultaneous with OPFLD for Tree FNP Action Simultaneous with OPFLL for Tree FAMN Action Simultaneous with OPSTM for TREE SNP

References for Appendix F

[Whitehead et al., 1991]	D. W. Whitehead, J. L. Darby, B. D. Staple, B. Walsh, T. M. Hake, and T. D. Brown, "BWR Low Power and Shutdown Accident Frequencies Project, Phase 1 - Coarse Screening Analysis," Vol. 1, Draft Letter Report, Sandia National Laboratories and Science and Engineering Associates, Inc., November 23, 1991 update, (Available in the NRC Public Document Room).	[USNRC, 1987]	USNRC, "Standard Review Plan for the Review of Nuclear Power Plants," NUREG 0800, June, 1987.
		[Darby et al., 1991]	J. L. Darby, et al., "Savannah River Site K Reactor Filter Heatup Model," SEA 90-500-007-A:1, July 31, 1991.

Appendix G. Calculation of the Frequency and Recovery of LOSP Plus Recovery of LOSP/DG Failures

The process used to estimate the frequency of loss of off-site power (LOSP) for the Low Power and Shutdown Program (LP&S) is similar to the one used in NUREG-1150 [1]. The only significant difference is that for the LP&S Program the events occurring during shutdown conditions (i.e., the Category IV events) were used in determining the frequency of LOSP for those plant operational states (POSS) wherein the plant was shutdown (i.e., POSS 2 through 7). In addition, the data base used in Reference 1 was updated to the end of 1988 using the information in NSAC-144 [2].

G.1 Calculation of the Frequency of LOSP

G.1.1 Process

G.1.1.1 Overview

The information contained in Reference 2 was examined to determine which events should be used in estimating the frequency of LOSP for either power operation or for shutdown conditions. Table G.1.1 lists the events used in determining the initiating event frequency for LOSP for low power and startup conditions, and Table G.1.2 provides additional events which must be considered when calculating the LOSP frequency for shutdown conditions.

After the shutdown events were identified, a data base of all LOSP events was created. The data base includes information on how long each plant has been in operation, how much time the plant has been in shutdown conditions, and the number of LOSP events that have occurred at the plant. Table G.1.3 presents the information contained in this data base.

In order to calculate the LOSP initiating event frequency for each plant operational state (POS), certain information in Table G.1.3 was extracted and combined into two data bases. First, information for each multi-unit site was combined to produce an aggregate data set for each plant. This process involved combining the plant centered and grid/weather LOSP events into a single number, combining the Category IV events into a single number, estimating the total amount of time multi-unit sites are operated in the low power and shutdown conditions of interest, determining the total site calendar years of commercial operation, and replacing the plant name (site name) with a number identifier. Next, for

each single unit site, the plant centered and grid/weather LOSP events were combined, the amount of time the unit is operated in low power and shutdown conditions was determined, the total calendar years of commercial operation were calculated, and the plant name was replaced by a unique number identifier. Using this interim information, the two data bases needed to start the LOSP frequency calculation were constructed by parsing the above interim data base into one containing plant information for non-Category IV events and another containing Category IV events. The information in these two data bases is presented in Tables G.1.4 and G.1.5 respectively.

These two data bases were then processed using the same procedures used in the NUREG-1150 analysis of LOSP for Grand Gulf [1].

G.1.1.2 Procedure

The processing of the data which led to the LOSP frequency was done on a VAX computer. While the description given here describes the operations for a VAX, the detail should be sufficient to allow the reader to translate it to a PC or any other appropriate machine. The process is described in steps with additional detail given in sub-steps as appropriate. The determination of LOSP frequency was done in two phases. The first phase, which had nine steps, resulted in 32 point frequency/probability distributions for initiating events for PCGW (Plant Centered, Grid and Weather) and Category IV scenarios. The second phase, which had six steps, used these distributions to determine the point estimate LOSP frequency.

G.1.1.2.1 Phase 1

The processing started with a file titled IE.BCK. This file contained the following information for 67 plants: plant name, plant name abbreviation, number of PC (plant centered) LOSP events at the plant, number of years the plant had been on line, number of G/W (grid or weather caused) LOSP events at the plant, and the number of years that the plant had been operational.

Step 1. The IE.BCK file was edited to:

- a. Add a line number for each plant entry.
- b. Update the number of LOSP events for each plant since the data were originally entered.

LOSP Frequency

- c. Add Category IV events and shutdown times.

This file was saved under a different version number of IE.BCK in order to preserve the original data. It is given in Attachment G-1.

Step 2. The new IE.BCK was further edited to:

- a. Delete plant names and abbreviations (the line numbers served as plant identifiers in subsequent steps).
- b. Combine PC and G/W events (the occurrences were added).
- c. Delete the on-line time.

This file was saved under still another IE.BCK version number. It is given in Attachment G-2.

Step 3. The latest IE.BCK file was then edited to:

- a. Delete Category IV events.
- b. Delete shutdown times.

This file contains the data for the non-Category IV LOSP events. It was saved as LOSP_IE_PCGW.DAT and is given in Attachment G-3.

Step 4. The latest IE.BCK file was again edited to:

- a. Delete the operating time.
- b. Delete the PC and G/W events.

This file was saved as LOSP_IE_IV.DAT. It contained the Category IV initiating events. It is given in Attachment G-4.

Step 5. The program IEFREQ1.EXE was run for PC/GW data. This is an interactive program that calculates the cumulative probability for LOSP for a user specified failure frequency at a user specified plant. The plant is identified by the line number in the input file.

- a. The code requires a data base from which to draw basic plant data for the initiating event. For the PC/GW events the LOSP_IE_PCGW.DAT file was copied to IE.DAT (Attachment G-5) and IE.DAT was used as input. The file title IE.DAT is the input file title hard-wired into the code.

b. At the command to run the code it is only necessary to respond to a few simple prompts on the screen.

- (1) At the plant ID input (GGNS=23) the code summarizes the input file data for the plant and the total number of plant years for the whole file.
- (2) At the prompt "If you know the value of the constant..." input 2 to let the code determine it.
- (3) At the prompt "Input the failure frequency..." input the best estimate (a guess based on engineering judgement) for LOSP. The code will return the cumulative probability for LOSP for the input failure frequency.
- (4) Iterate on the failure frequency of step (3) until a cumulative probability of .99900 is obtained.
- (5) When .99900 is obtained
 - (a) Record the input failure frequency.
 - (b) Enter "Y" at the prompt "Is this satisfactory?"
 - (c) The .99900 value for PC/GW for GGNS was found to be .416.

A copy of the screen and prompts is included in Attachment G-5.

Step 6. In preparation for running the IEBAT1 code, and input file for the code, LOSP_IE_PCGW.INP, was prepared. This input file consisted of a single line which contained:

- a. The file containing the PC/GW data for the listed plants enclosed in single ticks.
- b. Plant ID number.
- c. The failure frequency for the .999 LOSP probability obtained in Step 5.b.(4) above.
- d. The number of points to output.

The single line was:

'LOSP_IE_PCGW.DAT' 23 .416 30

The IEBAT1 code produces an initiating event probability distribution for a range of failure frequencies from near zero to the frequency .999 frequency determined in Step 5.b.(4) above. The number of output points is specified by the last entry of the single line input file. The input file is given in Attachment G-6.

Step 7. The IEBAT.COM file (Attachments G-7, G-7A & G-7B) was created to run IEBAT1. This file:

- a. Renames LOSP_IE_PCGW.INP to IEFREQ.INP, the name of the input file hard-wired into IEBAT1.
- b. Runs IEBAT1.
- c. Renames IEFREQ.INP back to LOSP_IE_PCGW.INP.
- d. Renames the plot file of frequency and IE probability produced by IEBAT1, PLOT.DAT, to IE_PCGW.DAT (Attachment G-8).

Once the COM file for IEBAT1 was completed, the file was executed producing the above mentioned .DAT file.

Step 8. IE_PCGW.DAT was updated to include probabilities of 0.0 and 1.0. This was done by plotting the 30 output points of IEBAT1 and, using engineering judgement, extrapolating the resulting curve to 0.0 and 1.0. See Attachment G-9.

Step 9. Steps 6-9 were repeated for Category IV data. File titles had IV instead of PCGW in them. Otherwise, the process was exactly the same. The input and output files for the Category IV analysis are given in Attachments G-10 through G-17.

G.1.1.2.2 Phase 2

The second phase of the process produced 1000 point distributions for the PCGW and Category IV scenarios from the 30 point distributions determined in Phase 1. The files IE_PCGW.DAT and IE_IV.DAT produced in the first phase were used as input to the LHS code to produce 1000 point distributions.

Step 1. Preparation for the LHS run.

- a. Prepared LHS.COM (Attachment G-18):

```
ASSIGN LHS.DAT      FOR001
ASSIGN LHS.INP      FOR005
ASSIGN LHS.OUT      FOR006
RUN LHS
DELETE FOR*.DAT;*
```

- (1) LHS.DAT is the 1000 point output from LHS.
- (2) LHS.OUT is a histogram output file that
 - (a) Lists IE_XXX.DAT data.

- (b) Puts the 1000 output points from LHS into a 20 bin histogram.

This file is used as a diagnostic tool to assure the analyst that the 1000 points fit a distribution that makes sense.

- b. Prepare LHS.INP (Attachment G-19), the input file to LHS:

```
TITLE - (Specify Title of Analysis)
RANDOM SEED (Specify a 10 digit integer)
NOBS 1000 (no. of observations desired)
RANDOM SAMPLE (LHS Option)
USER DISTRIBUTION
IE_PCGW.DAT (1 line w/above)
USER DISTRIBUTION IE_IV_.DAT
OUTPUT HIST
```

- c. Edited SUBROUTINE USRDST (Attachment G-20):

Four lines were edited to specify input files and titles in FORMAT statements.

- (1) Nested IF:
IF(IFLAG.EQ.1)OPEN(UNIT=60,FILE
='IE_PCGW.DAT',...)
- (2) 12 FORMAT ('1',/,/,6X,
'INPUT DATA FOR IE_PCGW',/...)
- (3) ELSEIF(J.EQ.2)THEN
IF(IFLAG.EQ.2)OPEN(UNIT=61,FILE
='IE_IV',/...)
- (4) 16 FORMAT('1',/,/,6X,'INPUT DATA
FOR IE_IV',/...)

Step 2. Run LHS with the above files:

- a. Compile USRDST
- b. Link USRDST to LHS
- c. Run LHS.COM (i.e. @ LHS)

Step 3. LHS Outputs

- a. LHS.OUT-Described above
- b. LHS.DAT - 4 columns, 1000 lines
 - (1) Line Number
 - (2) No. of data points in the line
 - (3) PCGW value
 - (4) Category IV value.

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LHS.OUT and LHS.DAT are given in Attachments G-21 and G-22.

Step 4. The analysis requires the combined values of the PC/GW and Category IV data. Thus, the two data sets were added.

a. LHS.DAT was edited to remove the first and second columns. This required the use of the program REMOVECOL2.FOR (Attachments G-23).

(1) The program input is LHS.DAT. This file name is hard wired into the program.

(2) The output file is LHSLOSP.INP (Attachment G-24). This is also hard wired into the program. The output is two columns of data, PC/GW and CAT IV.

b. Using LHSLOSP.INP as input, the program LHSADDITION (Attachment G-25) was run to add the PGCW and Cat IV columns. The output was contained in LHSLOSP.DAT (Attachment G-26). The two file names are hard wired into LHSADDITION.

Step 5. Prepare TEMAC input file. The Cat IV data was removed from LHSLOSP.INP by a second REMOVECOL program (Attachment G-27). This left just the PC/GW data. This file was stored as PCGWLOSP.DAT (Attachment G-28).

Step 6. The STAT.SAS program (Attachment G-29) was run on LHSLOSP.DAT and PCGWLOSP.DAT. PROC UNIVARIATE was specified for the two files to determine the statistical characteristics of the data in each. Among the outputs was the mean value of the data which was used as the point estimate for the LOSP frequency in the ensuing PRA analyses. The outputs are given in STAT.LIS, Attachment G-30.

Step 6 completed the LOSP frequency point estimate calculation.

G.1.2 Results

Using the above process, the mean frequency for LOSP in POS 1 was calculated to be 0.0649. For POSs 2-7 it was 0.1235.

Table G.1.1 Loss of Offsite Power Events Used to Estimate Frequency During POS 1

#	PLANT	SY	CAT	DATE	DURATION	FREQ?	RECOV?
1	ANO	2	PC	09/16/78	1.480	F	R
2	Beaver Valley	2	PC	07/28/78	0.280	F	R
3	Big Rock Point	3	G	01/25/75	0.333	F	R
4	Brunswick	2	PC	03/26/75	0.070	F	R
5	Calvert Cliffs	3	PC	07/23/87	1.970	F	R
6	Davis Besse	1	PC	11/29/77	0.002	F	R
7	Davis Besse	1	PC	10/15/79	0.430	F	R
8	Diablo Canyon	1	PC	07/17/88	0.633	F	R
9	Dresden	2	W	11/12/65	4.000	F	R
10	Dresden	2	PC	08/16/85	0.083	F	R
11	Farley	3	PC	09/16/77	0.900	F	R
12	Farley	3	PC	10/08/83	2.750	F	R
13	Fort Calhoun	3	PC	02/21/76	0.900	F	R
14	Fort Calhoun	3	PC	08/22/77	0.015	F	R
15	Fort St. Vrain	3	W	05/17/83	1.750	F	R
16	Ginna	2	PC	03/04/71	0.500	F	R
17	Ginna	2	PC	10/21/73	0.670	F	R
18	Haddam Neck	1	PC	04/27/68	0.480	F	R
19	Haddam Neck	1	PC	07/15/69	0.150	F	R
20	Haddam Neck	1	PC	07/19/72	0.017	F	R
21	Haddam Neck	1	PC	01/19/74	0.330	F	R
22	Haddam Neck	1	PC	06/26/76	0.270	F	R
23	Haddam Neck	1	PC	08/01/84	0.167	F	R
24	Indian Point	3	G	11/09/65	-	F	
25	Indian Point	3	G	07/20/72	0.920	F	R
26	Indian Point	3	G	07/13/77	6.470	F	R

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Table G.1.1 Loss of Offsite Power Events Used to Estimate Frequency During POS 1 (Continued)

#	PLANT	SY	CAT	DATE	DURATION	FREQ?	RECOV?
27	Indian Point	3	PC	06/03/80	1.750	F	R
28	Indian Point	3	PC	06/03/80	0.500	F	R
29	McGuire	2	PC	08/21/84	0.334	F	R
30	Millstone	1	PC	07/21/76	0.080	F	R
31	Millstone	1	W	08/10/76	5.000	F	R
32	Millstone	1	W	09/27/85	5.500	F	R
33	Monticello	1	PC	04/27/81	0.250	F	R
34	Nine Mile Point	1	PC	11/17/73	0.003	F	R
35	Nine Mile Point	1	PC	12/26/88	0.150	F	R
36	Oconee	1	PC	01/04/74	0.013	F	R
37	Oyster Creek	2	PC	09/08/73	0.003	F	R
38	Palisades	3	PC	09/02/71	0.930	F	R
39	Palisades	3	PC	09/24/77	0.500	F	R
40	Palisades	3	PC	07/14/87	7.430	F	R
41	Palo Verde	3	PC	10/03/85	0.400	F	R
42	Palo Verde	3	PC	10/07/85	0.200	F	R
43	Pilgrim	1	W	05/10/77	2.670	F	R
44	Pilgrim	1	W	02/06/78	8.900	F	R
45	Pilgrim	1	W	11/19/86	4.317	F	R
46	Pilgrim	1	W	11/12/87	11.000	F	R
47	Point Beach	2	PC	02/05/71	0.130	F	R
48	Point Beach	2	PC	04/27/74	0.020	F	R
49	Prairie Island	2	PC	07/15/80	1.030	F	R
50	Quad Cities	3	PC	11/06/77	1.150	F	R
51	Quad Cities	3	PC	06/22/82	0.570	F	R
52	River Bend	3	PC	01/01/86	0.767	F	R

Table G.1.1 Loss of Offsite Power Events Used to Estimate Frequency During POS 1 (Continued)

#	PLANT	SY	CAT	DATE	DURATION	FREQ?	RECOV?
53	Robinson	3	PC	01/28/86	1.667	F	R
54	San Onofre	3	PC	11/22/80	0.004	F	R
55	San Onofre	3	PC	11/21/85	0.067	F	R
56	St. Lucie	2	G	05/16/77	0.330	F	R
57	St. Lucie	2	G	05/16/77	1.500		R
58	St. Lucie	2	G	05/14/78	0.130	F	R
59	Susquehanna	1	PC	07/26/84	0.183	F	R
60	Turkey Point	2	G	04/03/73	0.300	F	R
61	Turkey Point	2	G	04/04/73	0.250	F	R
62	Turkey Point	2	G	04/25/74	0.330	F	R
63	Turkey Point	2	G	06/28/74	0.180	F	R
64	Turkey Point	2	G	05/16/77	1.030	F	R
65	Turkey Point	2	G	05/16/77	2.000	F	R
66	Turkey Point	2	PC	02/12/84	0.250	F*	R*
67	Turkey Point	2	PC	02/16/84	0.250	F	R
68	Turkey Point	2	G	05/17/85	2.083	F	R
69	Yankee Rowe	3	G	11/09/65	0.550	F	R

*This event is used in the LOSP calculation for power operation and startup only, not for the shutdown states.

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Table G.1.2 Additional Loss of Off-Site Power Events Used to Estimate Frequency During POS 2 - 7

#	PLANT	SY	CAT	DATE	DURATION	FREQ?	RECOV ?
1	Brunswick	2	PC	04/26/83	0.283	F	R
2	Fitzpatrick	1	PC	04/10/78	0.004	F	R
3	Fitzpatrick	1	PC	03/27/79	0.050	F	R
4	Fitzpatrick	1	PC	10/31/88	1.000	F	R
5	Ft. Calhoun	3	PC	03/13/75	11.083	F	R
6	Indian Point	3	PC	11/16/84	0.233	F	R
7	Haddam Neck	1	PC	08/24/84	0.367	F	R
8	McGuire	2	PC	09/16/87	0.417	F	R
9	Monticello	1	PC	06/04/84	0.033	F	R
10	Oyster Creek	2	PC	11/14/83	4.000	F	R
11	Palisades	3	PC	01/08/84	2.683	F	R
12	Point Beach	2	PC	10/13/73	-	F	
13	Point Beach	2	PC	10/22/84	0.050	F	R
14	Quad Cities	3	PC	05/07/85	0.717	F	R
15	Salem	2	PC	06/05/84	2.000	F	R
16	San Onofre	3	PC	06/07/73	4.983	F	R
17	San Onofre	3	PC	04/22/80		F	
18	Turkey Point	2	PC	04/29/85		F	
19	Yankee Rowe	3	PC	05/03/84	0.117	F	R

Table G.1.3 Informational Worksheet for LOSP Calculation

plant	Start Date	% Cap.	% Avail.	End Date	Optime	Online	Modonline	Comment	#pc LOSP	#g&w LOSP	Cat. IV	FP Time	ModFP Time	SD Time	ModSD Time
arkansas1	Dec-74	0.59	0.69	Dec-88	14.09	8.31	10.78		1	0	0	9.65	11.64	4.44	6.18
arkansas2	Mar-80	0.68	0.71	Dec-88	na	6.01	na					6.29	na	2.55	na
beavervally1	Oct-76	0.54	0.61	Dec-88	12.26	6.62	7.07		1	0	0	7.48	7.88	4.78	4.83
beavervally2	Nov-87	0.88	0.93	Dec-88	na	0.99	na					1.04	na	0.08	na
bigrockpoint	Mar-63	0.6	0.71	Dec-88	25.85	15.51	15.51		0	1	0	18.25	18.25	7.6	7.6
braidwood1	na	na	na	Dec-88	na	na	na	notupyet				na	na	na	na
brownsferry1	Aug-74	0.4	0.46	Dec-88	14.43	5.77	10.6		0	0	0	6.64	11.51	7.79	12.69
brownsferry2	Mar-75	0.38	0.45	Dec-88	na	5.26	na					6.23	na	7.62	na
brownsferry3	Mar-77	0.38	0.43	Dec-88	na	4.5	na					5.09	na	6.75	na
brunswick1	Mar-77	0.53	0.62	Dec-88	na	6.28	na					7.34	na	4.5	na
brunswick2	Nov-75	0.48	0.6	Dec-88	13.18	6.32	9.59		1	0	1	7.91	10.84	5.27	7.97
byron1	Sep-85	0.63	0.74	Dec-88	3.33	2.1	2.42		0	0	0	2.47	2.78	0.87	0.98
byron2	Aug-87	0.63	0.89	Dec-88	na	0.86	na					1.21	na	0.15	na
callaway1	Dec-84	0.78	0.84	Dec-88	4.08	3.19	3.19		0	0	0	3.43	3.43	0.65	0.65
calvertcliffs1	May-75	0.73	0.76	Dec-88	13.68	9.96	12.52		1	0	0	10.42	12.72	3.26	4.87
calvertcliffs2	Apr-77	0.8	0.82	Dec-88	na	9.41	na					9.64	na	2.12	na
catawba1	Jun-85	0.65	0.7	Dec-88	3.59	2.33	3.07		0	0	0	2.51	3.24	1.08	1.77
catawba2	Aug-85	0.62	0.71	Dec-88	na	2.12	na					2.43	na	0.99	na
clinton1	Nov-87	0.73	0.84	Dec-88	1.1	0.81	0.81		0	0	0	0.93	0.93	0.18	0.18
cook1	Aug-75	0.66	0.73	Dec-88	13.43	8.86	11.01		0	0	0	9.8	11.67	3.63	6.23
cook2	Jul-78	0.6	0.66	Dec-88	na	6.31	na					6.94	na	3.57	na
cooper	Jul-74	0.6	0.74	Dec-88	14.51	8.71	8.71		0	0	0	10.74	10.74	3.77	3.77
crystalriver3	Mar-77	0.56	0.63	Dec-88	11.84	6.63	6.63		0	0	0	7.46	7.46	4.38	4.38

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Table G.1.3 Informational Worksheet for LOSP Calculation (Continued)

plant	Start Date	% Cap.	% Avail.	End Date	Optime	Online	Modonline	Comment	#pc LOSP	#g&w LOSP	Cal. IV	FP Time	ModFP Time	SD Time	ModSD Time
davisbase1	Jul-78	0.4	0.52	Dec-88	10.51	4.2	4.2		2	0	0	5.46	5.46	5.04	5.04
diablocanyon1	May-85	0.7	0.79	Dec-88	3.67	2.57	3.16		1	0	0	2.9	3.35	0.77	1.31
diablocanyon2	Mar-86	0.69	0.76	Dec-88	na	1.96	na					2.16	na	0.68	na
dresden1	Aug-80	na	na	Dec-88	na	na	na	shutdown				na	na	na	na
dresden2	Jun-70	0.58	0.72	Dec-88	18.6	10.79	14.83		1	1	0	13.37	16.68	5.23	9.1
dresden3	Nov-71	0.56	0.69	Dec-88	na	9.62	na					11.78	na	5.39	na
dunnenmold	Feb-75	0.55	0.69	Dec-88	13.92	7.66	7.66		0	0	0	9.62	9.62	4.3	4.3
farley1	Dec-77	0.7	0.73	Dec-88	11.09	7.76	9.63		2	0	0	8.1	9.84	2.99	3.76
farley2	Jul-81	0.83	0.86	Dec-88	na	6.23	na					6.46	na	1.05	na
fermi2	na	na	na	Dec-88	na	na	na	notupyet				na	na	na	na
fitzpatrick	Jul-75	0.65	0.71	Dec-88	13.51	8.78	8.78		0	0	3	9.59	9.59	3.92	3.92
fortcalhoun	Jun-74	0.68	0.77	Dec-88	14.59	9.92	9.92		2	0	1	11.19	11.19	3.4	3.4
fortstclair	Jul-79	0.14	0.3	Dec-88	9.51	1.33	1.33		0	1	0	2.85	2.85	6.66	6.66
ginna	Jul-70	0.74	0.77	Dec-88	18.52	13.7	13.7		2	0	0	14.2	14.2	4.31	4.31
grandgulf1	Jul-85	0.69	0.67	Dec-88	3.5	2.42	2.42		0	0	0	2.35	2.35	1.16	1.16
haddenneck	Aug-67	0.78	0.8	Dec-88	21.43	16.72	16.72		6	0	1	17.19	17.19	4.24	4.24
hatch1	Dec-75	0.59	0.67	Dec-88	13.09	7.72	10.06		0	0	0	8.81	10.93	4.28	6.21
hatch2	Sep-79	0.61	0.69	Dec-88	na	5.7	na					6.47	na	2.87	na
hopecreek	Dec-86	0.79	0.82	Dec-88	2.03	1.61	1.61	?	0	0	0	1.67	1.67	0.37	0.37
humboldt	Aug-63	na	na	Dec-88	na	na	na	shutdown				na	na	na	na
indianpoint2	Aug-74	0.61	0.67	Dec-88	14.43	8.8	11.77		2	3	1	9.67	12.18	4.76	8.16
indianpoint3	May-76	0.6	0.6	Dec-88	na	7.61	na					7.61	na	5.07	na
kewaunee	Jun-74	0.81	0.84	Dec-88	14.59	11.82	11.82		0	0	0	12.27	12.27	2.32	2.32

Table G.1.3 Informational Worksheet for LOSP Calculation (Continued)

plant	Start Date	% Cap.	% Avail.	End Date	Optime	Online	Modonline	Comment	#pc LOSP	#g&w LOSP	Cat. IV	FP Time	ModFP Time	SD Time	ModSD Time
lacrosse	Nov-69	na	na	Dec-88	na	na	na	shutdown				na	na	na	na
lasalle1	Jan-84	0.47	0.58	Dec-88	5	2.35	3.57		0	0	0	2.9	3.95	2.1	3.12
lasalle2	Oct-84	0.54	0.59	Dec-88	na	2.3	na					2.5	na	1.76	na
limerick1	Feb-86	0.7	0.82	Dec-88	2.92	2.04	2.04		0	0	0	2.39	2.39	0.52	0.52
maineyan	Dec-72	0.7	0.77	Dec-88	16.09	11.27	11.27		0	0	0	12.44	12.44	3.65	3.65
mcguire1	Dec-81	0.6	0.68	Dec-88	7.09	4.25	5.63		1	0	1	4.83	5.96	2.25	3.14
mcguire2	Mar-84	0.71	0.73	Dec-88	na	3.44	na					3.53	na	1.31	na
millstone1	Mar-71	0.7	0.77	Dec-88	17.85	12.49	15.3		1	2	0	13.74	16.03	4.11	7.35
millstone2	Dec-75	0.66	0.71	Dec-88	na	8.64	na					9.3	na	3.8	na
millstone3	Apr-86	0.75	0.79	Dec-88	na	2.07	na					2.18	na	0.58	na
monticello	Jun-71	0.72	0.77	Dec-88	17.6	12.67	12.67		1	0	1	13.55	13.55	4.05	4.05
ninemilept1	Dec-69	0.59	0.67	Dec-88	19.1	11.27	11.27		2	0	0	12.79	12.79	6.3	6.3
ninemilept2	na	na	na	Dec-88	na	na	na	notupyet				na	na	na	na
northanna1	Jun-78	0.62	0.69	Dec-88	10.59	6.57	8.81		0	0	0	7.31	9.31	3.28	4.4
northanna2	Dec-80	0.73	0.8	Dec-88	na	5.9	na					6.47	na	1.62	na
oconee1	Jul-73	0.67	0.73	Dec-88	15.51	10.39	14.61		1	0	0	11.32	14.91	4.19	9
oconee2	Sep-74	0.67	0.75	Dec-88	na	9.61	na					10.73	na	3.61	na
oconee3	Dec-74	0.68	0.72	Dec-88	na	9.58	na					10.1	na	3.99	na
oystercreek	Dec-69	0.54	0.63	Dec-88	19.1	10.29	10.29		1	0	1	12.03	12.03	7.07	7.07
palisades	Dec-71	0.43	0.5	Dec-88	17.1	7.35	7.35		3	0	1	8.55	8.55	8.55	8.55
paloverde1	Feb-86	0.58	0.6	Dec-88	2.92	1.69	2.4		2	0	0	1.75	2.44	1.17	1.53
paloverde2	Sep-86	0.72	0.74	Dec-88	na	1.68	na					1.73	na	0.61	na
paloverde3	na	na	na	Dec-88	na	na	na	notupyet				na	na	na	na

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Table G.1.3 Information Worksheet for LOSP Calculation (Continued)

plant	Start Date	% Cap.	% Avail.	End Date	Optime	Online	Modonline	Comment	#pc LOSP	#g&w LOSP	Cal. IV	FP Time	ModFP Time	SD Time	ModSD Time
pencbot2	Jul-74	0.5	0.57	Dec-88	14.51	7.26	10.99	.	0	0	0	8.27	11.91	6.24	9.45
pencbot3	-Dec-74	0.53	0.6	Dec-88	na	7.47	na					8.46	na	5.64	na
perry1	Nov-87	0.68	0.76	Dec-88	1.12	0.76	0.76		0	0	0	0.85	0.85	0.27	0.27
pilgrim1	Dec-72	0.46	0.55	Dec-88	16.09	7.4	7.4		0	4	0	8.85	8.85	7.24	7.24
pointbeach1	Dec-70	0.73	0.81	Dec-88	18.1	13.21	16.77		2	0	2	14.66	17.33	3.44	5.23
pointbeach2	Oct-72	0.81	0.86	Dec-88	na	13.17	na					14.05	na	2.21	na
prairie1a1	Dec-73	0.79	0.83	Dec-88	15.09	11.92	14.41		1	0	0	12.53	14.61	2.57	4.11
prairie1a2	Dec-74	0.84	0.87	Dec-88	na	11.84	na					12.23	na	1.86	na
quadtite1	Feb-73	0.66	0.78	Dec-88	15.92	10.51	13.88		2	0	1	12.36	15.02	3.57	6.63
quadtite2	Mar-73	0.63	0.75	Dec-88	na	9.9	na					11.9	na	3.95	na
ranchosoco	Apr-75	0.4	0.47	Dec-88	13.76	5.5	5.5		0	0	0	6.47	6.47	7.29	7.29
riverbend1	Jun-86	0.6	0.69	Dec-88	2.59	1.55	1.55		1	0	0	1.78	1.78	0.8	0.8
robinson2	Mar-71	0.64	0.7	Dec-88	17.85	11.42	11.42		1	0	0	12.48	12.48	5.37	5.37
salem1	Jun-77	0.55	0.62	Dec-88	11.59	6.38	8.04		0	0	1	7.19	8.81	4.4	6.25
salem2	Oct-81	0.51	0.59	Dec-88	na	3.7	na					4.28	na	2.97	na
sanonofre1	Jan-68	0.52	0.56	Dec-88	21.01	10.93	13.19		2	0	2	11.77	13.9	9.25	10.74
sanonofre2	Aug-83	0.69	0.71	Dec-88	na	3.74	na					3.85	na	1.57	na
sanonofre3	Jan-84	0.63	0.69	Dec-88	na	3.15	na					3.45	na	1.55	na
sequoyah1	Jul-81	0.33	0.57	Dec-88	7.51	2.48	4.24		0	0	0	4.28	5.58	3.23	5.26
sequoyah2	Jun-82	0.4	0.46	Dec-88	na	2.64	na					3.03	na	3.56	na
shearoharris1	May-87	0.69	0.74	Dec-88	1.67	1.15	1.15		0	0	0	1.23	1.23	0.44	0.44
shoreham	na	na	na	Dec-88	na	na	na	notupyet				na	na	na	na
sluciel	Dec-76	0.71	0.74	Dec-88	12.09	8.62	9.98		0	2	0	8.89	10.16	3.2	3.78

Table G.1.3 Informational Worksheet for LOSP Calculation (Continued)

plant	Start Date	% Cap.	% Avail.	End Date	Optime	Online	Modonline	Comment	#pc LOSP	#g&w LOSP	Cat. IV	FP Time	ModFP Time	SD Time	ModSD Time
stlucie2	Jun-83	0.85	0.86	Dec-88	na	4.75	na					4.81	na	0.78	na
summer1	Jan-84	0.69	0.73	Dec-88	5	3.45	3.45		0	0	0	3.65	3.65	1.35	1.35
surry1	Dec-72	0.56	0.64	Dec-88	16.09	9.01	13.07		0	0	0	10.3	13.91	5.79	9.41
surry2	May-73	0.59	0.64	Dec-88	na	9.22	na					10.03	na	5.64	na
susquehanna1	Jun-83	0.7	0.74	Dec-88	5.59	3.91	4.8		1	0	0	4.14	4.95	1.45	2.03
susquehanna2	Feb-85	0.76	0.8	Dec-88	na	2.98	na			-		3.13	na	0.78	na
threemileisland1	Sep-74	0.41	0.42	Dec-88	14.34	5.88	5.88		0	0	0	6.02	6.02	8.32	8.32
threemileisland2	Dec-78	na	na	Dec-88	na	na	na	shutdown				na	na	na	na
trojan	May-76	0.56	0.65	Dec-88	12.68	7.1	7.1		0	0	0	8.24	8.24	4.44	4.44
turkeypoint3	Dec-72	0.63	0.66	Dec-88	16.09	10.14	13.72		2	7	1	10.59	14.02	5.5	9.01
turkeypoint4	Sep-73	0.63	0.65	Dec-88	na	9.67	na					10.02	na	5.32	na
vermontyankee	Nov-72	0.72	0.78	Dec-88	16.18	11.65	11.65		0	0	0	12.62	12.62	3.56	3.56
vogle1	Jun-87	0.72	0.75	Dec-88	1.59	1.14	1.14		0	0	0	1.19	1.19	0.4	0.4
washingtonnp2	Dec-84	0.59	0.72	Dec-88	4.08	2.41	2.41		0	0	0	2.94	2.94	1.14	1.14
waterford3	Sep-85	0.75	0.78	Dec-88	3.33	2.5	2.5		0	0	0	2.6	2.6	0.73	0.73
wolfcreek1	Sep-85	0.7	0.73	Dec-88	3.33	2.33	2.33		0	0	0	2.43	2.43	0.9	0.9
yankeerowe	Nov-60	0.74	0.79	Dec-88	28.18	20.86	20.86		0	1	1	22.27	22.27	5.92	5.92
zion1	Dec-73	0.58	0.69	Dec-88	15.09	8.75	12.49		0	0	0	10.41	13.56	4.68	7.58
zion2	Sep-74	0.62	0.71	Dec-88	na	8.89	na					10.14	na	4.2	na

Table G.1.3 Informational Worksheet for LOSP Calculation (Continued)

- + StartDate = Beginning Date of Commercial Operation [Nuclear Safety, Vol. 28, No. 4]
- + % Cap = Cumulative Plant Capacity Factor [Nuclear Safety, Vol. 30, No. 2]
- + End Date = End Date of Analysis, December 31, 1988
- + Optime = Site Calendar Years of Commercial Operation (End Date - StartDate)
- Online = Optime times the Capacity Factor
- ModOnline = Effective Online Time for Multiple Unit Sites
- + PC LOSP = Number of Plant-Centered LOSP Occurring at Site During Optime
- + G&W LOSP = Number of Grid and Weather Events Occurring at Site During Optime
- + Cat IV = Number of Category IV Events (Unique to Shutdown) Occurring at Site During Optime
- FP time = Optime times the Availability Factor
- modFPtime = Effective FP time for Multiple Unit Sites
- + SDtime = Optime times (1 - Avail Factor)
- + modSDtime = Effective SD time for Multiple Unit Sites
- + Parameter Used in Shutdown Study LOSP Calculation

Table G.1.4 Non-Category IV Event Data

Plant	No. Events	Site Years	Plant	No. Events	Site Years
1	1	14.09	51	2	21.01
2	1	12.25	52	0	7.50
3	1	25.85	53	2	12.09
4	0	14.42	54	0	1.69
5	1	13.17	55	0	5.00
6	0	3.33	56	0	16.09
7	0	4.08	57	1	5.59
8	1	13.68	58	0	14.34
9	0	3.58	59	0	12.67
10	0	1.10	60	9	16.09
11	0	13.42	61	0	16.17
12	0	14.51	62	0	1.58
13	0	11.84	63	0	4.08
14	0	10.51	64	0	3.33
15	1	3.67	65	0	3.33
16	2	18.59	66	1	28.18
17	0	13.92	67	0	15.09
18	0	11.09			
19	0	13.51			
20	2	14.59			
21	1	9.51			
22	2	18.51			
23	0	3.50			
24	6	21.43			
25	0	13.09			
26	0	2.03			
27	5	14.42			
28	0	14.59			
29	0	5.00			
30	0	2.92			
31	0	16.09			
32	1	7.08			
33	3	17.85			
34	1	17.59			
35	2	19.09			
36	0	10.59			
37	1	15.51			
38	1	19.09			
39	3	17.09			
40	2	2.91			
41	0	14.51			
42	0	1.12			
43	4	16.09			
44	2	18.09			
45	1	15.09			
46	2	15.92			
47	0	13.76			
48	1	2.58			
49	1	17.85			
50	0	11.59			

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Table G.1.5 Category IV Event Data

Plant	No. Events	Site Years	Plant	No. Events	Site Years
1	0	6.18	51	2	10.74
2	0	4.83	52	0	5.26
3	0	7.60	53	0	3.78
4	0	12.69	54	0	0.44
5	1	7.97	55	0	1.35
6	0	0.98	56	0	9.41
7	0	0.65	57	0	2.03
8	0	4.87	58	0	8.32
9	0	1.77	59	0	4.44
10	0	0.18	60	1	9.01
11	0	6.23	61	0	3.56
12	0	3.77	62	0	0.40
13	0	4.38	63	0	1.14
14	0	5.04	64	0	0.73
15	0	1.31	65	0	0.90
16	0	9.10	66	1	5.92
17	0	4.30	67	0	7.58
18	0	3.76			
19	3	3.92			
20	1	3.40			
21	0	6.66			
22	0	4.31			
23	0	1.16			
24	1	4.24			
25	0	6.21			
26	0	0.37			
27	1	8.16			
28	0	2.32			
29	0	3.12			
30	0	0.52			
31	0	3.65			
32	1	3.14			
33	0	7.35			
34	1	4.05			
35	0	6.30			
36	0	4.40			
37	0	9.00			
38	1	7.07			
39	1	8.55			
40	0	1.53			
41	0	9.45			
42	0	0.27			
43	0	7.24			
44	1	5.23			
45	0	4.11			
46	1	6.63			
47	0	7.29			
48	0	0.80			
49	0	5.37			
50	1	6.25			

G.2 Determination of the Mean Probability of Recovery from LOSP at Different Times

G.2.1 Process

G.2.1.1 Overview

This section contains a summary of the methodology used to determine the times to recover from a LOSP event at the Grand Gulf Nuclear Station (GGNS) and the mean probabilities of recovery at the different times. The report covers all LOSP events up to 1988 and includes Category IV (Shutdown) events summarized in Reference 2. The steps used to determine these recovery times and probabilities are given below.

G.2.1.2 Procedure

Step 1. The LOSP events listed in Reference 2 were categorized by type: Plant Centered (PC), Grid (G), and Weather caused (W). Plant centered events are those in which the design and operational characteristics of the plant played a role in the LOSP and its duration [3]. Grid caused events are those in which the design and operational characteristics of the power grid from which the plant draws its off-site power are a factor.

Six data files (Attachments G-31 - G-36) were constructed for the LOSP recovery times. One contained the recovery times for grid events (GGGRID.DAT) and another contained the recovery times for weather events (GGWEAT.DAT). The plant centered events were subdivided into three subsets based on switchyard configuration classifications defined in NUREG-1032 [4]. The three data files for these three subsets were GGPC1.DAT, GGPC2.DAT, and GGPC3.DAT. A fourth PC file containing all of the recovery times of the first three was also established. This file was GGPC4.DAT. The recovery times are also summarized in Table G.2.1.

Step 2. The program MODEL was run to calculate the probabilities of recovery from LOSP at different times from each of the three categories. MODEL is an interactive program that implements the mixture model for the distribution of the recovery from LOSP as developed in Reference 3. The program has a number of values hardwired into it. These values were updated to reflect the most recent data on the occurrence of and recovery from LOSP events (including Category IV events) in the United States as of 1988. The values

updated were P(1), a weighting function for each PC LOSP category; S(1), a sample mean term for each PC LOSP category; and N(1), the number of events in each PC LOSP category. The values are different for each of the three PC LOSP types and, in the MODEL code, reside in different branches of an IF-THEN-ELSE statement (Statement 13). The variable NPC (just below Statement 12) was changed to 62, the updated number of PC LOSP events. A copy of the MODEL.FOR code is given in the Attachment G-37.

The P(N) and S(N) terms are statistical characteristics of the PC LOSP recovery time populations. They were determined using the program GAMMA. GAMMA is an interactive program that prompts the user for an input file which contains data for which the user requires the Maximum Likelihood Estimates of the Geometric and Sample Means. The input files for the LOSP recovery analyses were the GGXXX.DAT files containing the recovery times for the six types of LOSP events. The output of the code is written to the file MLE.OUT. In the case of the PC LOSP events, the output "Geometric Mean" is the P(1) value for the corresponding GGPCN.DAT data. The output "Sample Mean" is the S(1) value, and N(1) is the Sample Size. Copies of GAMMA.FOR and MLE.OUT are given in Attachments G-38 and G-39.

After the changes were incorporated into MODEL.FOR, it was compiled and linked to two libraries, AMOSLIB (see Attachment G-40) and IMSLIBS/LIB [5] and run. The MODEL output was written to the file GG.DAT (Attachment G-41). This file contained the probabilities of recovery from LOSP at different times for the three categories of LOSP events.

Step 3. The results of the MODEL calculations were plotted using the program MAPPER, a graphics routine. The GG.DAT file was copied to a file for MAPPER input called MAP.DAT. The plot contained curves for the fifth, 50th and 95th percentiles of the recovery times. The plot is shown in Figure G.2-1.

Step 4. The program COMMEAN was run using the MAP.DAT file as input. The program uses a lognormal distribution routine to calculate the error factor (EF) and the mean probability for recovery from LOSP at the different time steps in the MODEL output. The results of the calculation are stored in LOGNORMAL.DAT. COMMEAN also creates a file called MEAN.DAT which is essentially LOGNORMAL.DAT without the column headings. Listings of COMMEAN.FOR and LOGNORMAL.DAT are included in the Attachments G-

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42 and G-43.

Step 5. Finally, the probability of recovery was plotted against the mean time to recover. This plot is given in Figure G.2.2.

G.2.2 Results

Using the process outlined above, the mean probability of recovery of LOSP versus time was determined and recorded in Table G.2.2 and plotted as shown in Figure G.2.2.

Table G.2.1 Time to Recover from LOSP through 1988

Plant Centered Switchyard Group 1 Recovery Times(hrs)	Plant Centered Switchyard Group 2 Recovery Times(hrs)	Plant Centered Switchyard Group 3 Recovery Times(hrs)	Grid Recovery Times(hrs)	Severe Weather Recovery Times(hrs)
.002	.070	1.970	.130	1.750
.003	1.480	.900	.180	2.670
.004	.280	2.740	.250	4.000
.033	.083	.900	.300	4.317
.050	.500	.015	.330	5.000
.330	.670	1.750	.330	5.500
.367	.334	.500	.333*	8.900
1.000	.003	.930	.550	11.000*
.430	.130	.500	.920	
.663	.020	7.430	1.030	
.270	1.030	.400	1.500	
.167	.250	.200	2.000	
.080	.250	1.150	2.083	
.250	.283	.570	6.470	
.150	.417	.767		
.013	4.000	1.667		
.183	.050	.004		
.480	2.000	.067		
.150		11.083		
.017		.233		
		2.683		
		4.983		
		.117		
		.717		

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Figure G.2-1 Probability of Recovery from LOSP vs Time for the Fifth, the Fiftyth and the Ninety-fifth Percentiles

Table G.2.2 Mean Probability of Recovery from LOSP at Different Times

Time	EF	Mean	Time	EF	Mean
0.00	1.0	1.000E+00	2.50	1.8	8.706E-02
0.05	1.2	7.501E-01	2.75	1.9	8.010E-02
0.10	1.2	6.370E-01	3.00	1.9	7.453E-02
0.15	1.2	5.564E-01	3.17	1.9	7.066E-02
0.20	1.3	4.958E-01	3.50	2.0	6.528E-02
0.25	1.3	4.472E-01	3.75	2.1	6.247E-02
0.30	1.4	4.069E-01	4.00	2.1	5.898E-02
0.35	1.4	3.697E-01	4.25	2.2	5.575E-02
0.40	1.4	3.404E-01	4.50	2.2	5.284E-02
0.45	1.4	3.146E-01	4.75	2.3	5.054E-02
0.50	1.4	2.921E-01	5.00	2.3	4.828E-02
0.55	1.4	2.720E-01	5.25	2.4	4.652E-02
0.60	1.5	2.548E-01	5.50	2.5	4.526E-02
0.65	1.5	2.396E-01	5.75	2.5	4.336E-02
0.70	1.5	2.266E-01	6.00	2.6	4.141E-02
0.75	1.5	2.160E-01	6.25	2.6	3.970E-02
0.80	1.5	2.053E-01	6.50	2.7	3.840E-02
0.85	1.5	1.962E-01	6.75	2.8	3.725E-02
0.90	1.5	1.885E-01	7.00	2.8	3.603E-02
0.95	1.5	1.801E-01	7.25	2.9	3.474E-02
1.00	1.5	1.730E-01	7.50	3.0	3.346E-02
1.05	1.5	1.671E-01	7.75	3.1	3.242E-02
1.10	1.5	1.614E-01	8.00	3.2	3.151E-02
1.13	1.5	1.575E-01	8.25	3.2	3.022E-02
1.20	1.6	1.523E-01	8.50	3.3	2.910E-02
1.25	1.6	1.483E-01	8.75	3.4	2.798E-02
1.28	1.6	1.451E-01	9.00	3.5	2.708E-02
1.33	1.6	1.416E-01	9.25	3.6	2.640E-02
1.40	1.6	1.365E-01	9.50	3.7	2.559E-02
1.45	1.6	1.329E-01	9.75	3.8	2.503E-02
1.50	1.6	1.290E-01	10.00	3.9	2.430E-02
1.55	1.6	1.257E-01	13-30	6.2	1.970E-02
1.60	1.7	1.230E-01	15.00	7.7	1.780E-02
1.65	1.7	1.203E-01	16.00	8.8	1.682E-02
1.70	1.7	1.173E-01	18.00	11.5	1.597E-02
1.75	1.7	1.147E-01	23.00	22.1	1.476E-02
1.80	1.7	1.124E-01	27.00	32.8	1.328E-02
1.85	1.7	1.098E-01			
1.90	1.7	1.077E-01			
1.95	1.7	1.051E-01			
2.00	1.7	1.032E-01			
2.05	1.7	1.011E-01			
2.10	1.8	9.923E-02			
2.15	1.8	9.724E-02			
2.20	1.8	9.540E-02			
2.25	1.8	9.410E-02			
2.30	1.8	9.273E-02			
2.35	1.8	9.120E-02			
2.40	1.8	8.973E-02			
2.45	1.8	8.832E-02			

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Figure G.2-2 Mean Probability of Recovery from LOSP vs Time at Grand Gulf

G.3 Determination of Recovery Values for LOSP/DG-Failure Restorations: DG Fails to Start

G.3.1 Process

G.3.1.1 Overview

The following process describes the steps carried out in the calculation of the non-recovery probabilities for LOSP accompanied by the failure of the diesel generators to start. The process assumes that the DGs were called for at the onset of LOSP.

The calculations consider failure to start due to hardware failures and due to common mode failures. The results of the calculations are tables of non-recovery probabilities vs. time after the DG(s) fail to start.

The correction factor (or recovery factor) for the recovery from LOSP and failure of diesel generators to start at time T (CF_{DGS}) is given by

$$CF_{DGS}(T) = P_{nr}(T) * P_{NDG}(T)$$

where:

$P_{nr}(T)$ = probability of non-recovery of off-site power at time T after LOSP.

$P_{NDG}(T)$ = probability of non-recovery of DG at time T after LOSP.

G.3.1.2 Procedure

Step 1. Data for the probability of non-recovery of off-site power versus time were plotted.

The plot was in the form

$$\ln(P_{nr}) \text{ vs. } T$$

where:

P_{nr} = probability of non-recovery of off-site power.

T = time required for recovery after which core damage is to be expected.

A second treatment of the data involved the

determination of an interpolating polynomial using Newton's Interpolatory Algorithm [7]. This polynomial was of the form:

$$y(x) = \sum_{i=1}^3 Q_{ii} \prod_{j=0}^{i-1} (x-x_j)$$

where:

$$y = \ln(P_{nr})$$

$$x = \ln(1+t)$$

t = time at which LOSP occurs.

The expression for x has a 1 in the $\ln$ argument because t may be set to zero.

Step 2. Data for the probability of non-recovery of diesel generators after their failure to start were plotted [8]. Two cases were considered: a) failure to start due to a hardware failure; and b) failure to start due to a common mode failure. In both cases a linear fit was made of $\ln(P_{NDGS})$, the log of the probability of non-recovery of the DG after failure to start vs. time from the failure to start. Thus:

$$P_{NDGS}(T) = \exp(m \cdot T)$$

where: m = slope of the $\ln[P_{NDGS}(T)]$ graph
 T = time since failure to start.

Step 3. A table of values for CF_{DGS} was formed from the product:

$$CF_{DGS} = \exp\{\ln[P_{nr}(T)]\} * \{\ln[P_{NDG}(T)]\}$$

for values of T from 0 to 24 hours in half-hour time steps.

Analyses requiring a value between the half-hour increments was either interpolated from the table or calculated directly from the equations (curve fits) for P_{nr} and P_{NDG} .

G.3.2 Results

The table of results is given in Table G.3.1.

Table G.3.1 Correction/Recovery Factors for DG Fails to Start (LOSP as Initiating Event)

Time (hr.)	Hardware	Common Mode
0	1	1
.5	2.988E-1	2.945E-1
1.0	1.5298E-1	1.4861E-1
1.5	9.9556E-2	9.5127E-2
2.0	7.3188E-2	6.9064E-2
2.5	5.8076E-2	5.4015E-2
3.0	4.8821E-2	4.4294E-2
3.5	4.1504E-2	3.7498E-2
4.0	3.6452E-2	3.2460E-2
4.5	3.2535E-2	2.8555E-2
5.0	2.9389E-2	2.5422E-2
5.5	2.6788E-2	2.2839E-2
6.0	2.4589E-2	2.0662E-2
6.5	2.2695E-2	1.8796E-2
7.0	2.1038E-2	1.7173E-2
7.5	1.9570E-2	1.5745E-2
8.0	1.8257E-2	1.4477E-2
8.5	1.7072E-2	1.3342E-2
9.0	1.5994E-2	1.2320E-2
9.5	1.5008E-2	1.1394E-2
10.0	1.4102E-2	1.0552E-2
10.5	1.3265E-2	9.7828E-3
11.0	1.2490E-2	9.0786E-3
11.5	1.1770E-2	8.4319E-3
12.0	1.1099E-2	7.8867E-3
12.5	1.0472E-2	7.2879E-3

Table G.3.1 Correction/Recovery Factors for DG Fails to Start (LOSP as Initiating Event) (Continued)

Time (hr.)	Hardware	Common Mode
13.0	9.8859E-3	6.7809E-3
13.5	9.3367E-3	6.3120E-3
14.0	8.8215E-3	5.8778E-3
14.5	8.3374E-3	5.4754E-3
15.0	7.8823E-3	5.1019E-3
15.5	7.4539E-3	4.7552E-3
16.0	7.0504E-3	4.4330E-3
16.5	6.6701E-7	4.1335E-3
17.0	6.3114E-3	3.8550E-3
17.5	5.9730E-3	3.5957E-3
18.0	5.6535E-3	3.3544E-3
18.5	5.3517E-3	3.1297E-3
19.0	5.0667E-3	2.9203E-3
19.5	4.7973E-3	2.7253E-3
20.0	4.5427E-3	2.5435E-3
20.5	4.3020E-3	2.3740E-3
21.0	4.0743E-3	2.2160E-3
21.5	3.8590E-3	2.0687E-3
22.0	3.6552E-3	1.9312E-3
22.5	3.4625E-3	1.8031E-3
23.0	3.2801E-3	1.6835E-3
23.5	3.1075E-3	1.5719E-3
24.0	2.9441E-3	1.4678E-3

G.4 Determination of Recovery Values for LOSP/DG-Failure Restorations: DG Fails To Run

G.4.1 Process

G.4.1.1 Overview

This section describes the steps carried out in the calculation of the non-recovery probabilities for LOSP accompanied by the failure of diesel generators to run at some time after LOSP.

The correction factor (or recovery factor) for the recovery from LOSP given that the DGs fail to run is given by

$$CF_{op}(T) = \frac{P_{DGRt}(T)}{P_{DGR}}$$

where

- $P_{DGRt}(T)$ = probability that the DG fails to run during the mission time (t) before offsite power is recovered.
- P_{DGR} = probability that DG will fail to run in any given 24 hour period (the mission time).

The result of the calculations was a table of probabilities of non-recovery of off-site power for times up to 24 hours after the DG failed to run.

G.4.1.2 Procedure

Step 1. Determine P_{DGR} . The probability that the DG will fail to run in any given 24 hour period is given by

$$P_{DGR} = \int_0^{24hr} \lambda \exp(-\lambda t) dt \quad (1)$$

$$= 1 - \exp(-\lambda t_{mission})$$

where

λ = the failure rate for DG to run.

$$t_{mission} = 24 \text{ hrs.}$$

For GGNS, $P_{DGR} = .047$ and $\lambda = 2E-3/\text{hr.}$

Step 2. Determine P_{DGRt} . The probability that the DG fails to run during the mission time before offsite power is recovered is

$$P_{DGRt} = \int_0^{24} \lambda \exp(-\lambda t) P_{nr}(t+T) dt \quad (2)$$

where P_{nr} = non-recovery of offsite power in time t + T after LOSP:
 t = time DG ran before failure;
 T = time available to restore off-site power before core damage occurs.

The integration of Equation (2) was performed using the MathCAD integration function[9]. In order to perform the integration it was necessary to express $P_{nr}(t+T)$ in a form compatible with the integration scheme. This form was the polynomial described in the DG Fails to Start case. (Section G.3.2)

The integration provided a table of values of $P_{DGRt}(T)$ for values of T from 0 to 12 hours.

Step 3. Form the quotient

$$CF_{op}(T) = \frac{P_{DGRt}(T)}{P_{DGR}}$$

G.4.2 Results

The resulting values are given in Table G.4.1.

Table G.4.1 Correction/Recovery Factors for DG Fails to Run (LOSP as Initiating Event)

Time (hr.)	CF _∞ (T)
0	4.8211E-2
0.5	3.5676E-2
1.0	3.117E-2
1.5	2.8631E-2
2.0	2.6899E-2
2.5	2.5585E-2
3.0	2.4521E-2
3.5	2.3621E-2
4.0	2.2835E-2
4.5	2.2133E-2
5.0	2.1495E-2
5.5	2.0907E-2
6.0	2.0360E-2
6.5	1.9846E-2
7.0	1.9360E-2
7.5	1.8899E-2
8.0	1.8458E-2
8.5	1.8036E-2
9.0	1.7630E-2
9.5	1.7239E-2
10.0	1.6862E-2
10.5	1.6497E-2
11.0	1.6143E-2
11.5	1.5799E-2
12.0	1.5465E-2
12.5	1.5141E-2

Table G.4.1 Correction/Recovery Factors for DG Fails to Run (LOSP as Initiating Event) (Continued)

Time (hr.)	CF _{sp} (T)
13.0	1.4825E-2
13.5	1.4517E-2
14.0	1.4218E-2
14.5	1.3925E-2
15.0	1.3640E-2
15.5	1.3362E-2
16.0	1.3090E-2
16.5	1.2925E-2
17.0	1.2566E-2
17.5	1.2312E-2
18.0	1.2065E-2
18.5	1.1823E-2
19.0	1.1586E-2
19.5	1.1355E-2
20.0	1.1128E-2
20.5	1.0907E-2
21.0	1.0690E-2
21.5	1.0479E-2
22.0	1.0271E-2
22.5	1.0068E-2
23.0	9.8698E-3
23.5	9.6755E-3
24.0	9.4953E-3

G.5 Determination of Recovery Values for LOSP/DG Failure Restoration (LOSP Not an IE) : DG Fails to Run

G.5.1 Overview

This section describes the calculation of the non-recovery probabilities for LOSP (LOSP not an IE) accompanied by failure of the diesel generators to run sometime after LOSP.

The correction factor for recovery from LOSP, with the failure of the DG to run at some time after LOSP, is given by:

$$CF(T) = \frac{\int_0^t \int_0^t \lambda_{OP} e^{-\lambda_{OP} t_1} \lambda_{DGR} e^{-\lambda_{DGR}(t-t_1)} P_{nrOP}(t-t_1+T) dt_1 dt}{\int_0^t \lambda_{OP} e^{-\lambda_{OP} t_1} dt_1 \int_0^t \lambda_{DGR} e^{-\lambda_{DGR} t} dt}$$

where:

- λ_{OP} = frequency of the loss of off-site power
- λ_{DGR} = frequency of DG failure to run
- t = mission time (24 hrs.)
- P_{nrOP}^m = probability of non-recovery of off-site power in time $t - t_1 + T$.
- t = time at which DG fails to run
- t_1 = time at which LOSP occurs

The double integral in the numerator of $CF(T)$ is the probability that (during the mission time t) offsite power will be lost, the diesel generator will fail to run and offsite power cannot be recovered in time to prevent core damage at time $t - t_1 - T$. The denominator is the probability that offsite power will be lost and the diesel generator will fail to run during the mission time.

G.5.2 Procedure

Step 1. P_{nrOP} was put into integrable form. Data for P_{nrOP} versus time was formed into a polynomial using Newton's interpolating algorithm. The form of the polynomial is given in the earlier discussion of DG fails to start with LOSP as an initiating event.

Step 2. The double integral of the numerator was performed using MathCAD [9]. The polynomial fit of P_{nrOP} was placed in the integrand in the form $\exp \{ \ln[P_{nrOP}(t_1)] \}$ to account for the logarithm fit of the

polynomial fit. This double integral resulted in a set of numerator values from $T = 0$ to $T = 24$ hours in half-hour increments.

Step 3. The product of the integrals in the denominator gives a point value. With $\lambda_{OP} = 1.484E-5$, $\lambda_{DGR} = 2.0E-3$ and $T = 24$ hours, the denominator was found to be $1.6689E-5$.

Step 4. $CF(T)$ was determined by dividing each value of the numerator by the value determined in Step 3. In the MathCAD calculation, these values were given the symbol $CF_{ofpwr}(T)$.

G.5.3 Results

The values for $CF(T)$ determined in Step 4 above are given in Table G.5.1 which follows.

LOSP Frequency

Table G.5.1 Correction/Recovery Factors for LOSP (not an IE) with DG Fails to Run

Time (hr.)	CF(T)
0	3.5746E-2
0.5	2.4606E-2
1.0	2.0556E-2
1.5	1.8354E-2
2.0	1.6912E-2
2.5	1.5862E-2
3.0	1.5043E-2
3.5	1.4373E-2
4.0	1.3805E-2
4.5	1.3311E-2
5.0	1.2872E-2
5.5	1.2476E-2
6.0	1.2113E-2
6.5	1.1778E-2
7.0	1.1465E-2
7.5	1.1171E-2
8.0	1.0893E-2
8.5	1.0630E-2
9.0	1.0378E-2
9.5	1.0137E-2
10.0	9.9060E-3
10.5	9.6833E-3
11.0	9.4685E-3
11.5	9.2608E-3
12.0	9.0598E-3
12.5	8.8649E-3

Table G.5.1 Correction/Recovery Factors for LOSP (not an IE) with DG Fails to Run (Continued)

Time (hr.)	CF(T)
13.0	8.6757E-3
13.5	8.4918E-3
14.0	8.3130E-3
14.5	8.1390E-3
15.0	7.9694E-3
15.5	7.8042E-3
16.0	7.6431E-3
16.5	7.4859E-3
17.0	7.3325E-3
17.5	7.1828E-3
18.0	7.0365E-3
18.5	6.8937E-3
19.0	6.7541E-3
19.5	6.6177E-3
20.0	6.4843E-3
20.5	6.3539E-3
21.0	6.2264E-3
21.5	6.1017E-3
22.0	5.9798E-3
22.5	5.8605E-3
23.0	5.7438E-3
23.5	5.6296E-3
24.0	5.5179E-3

G.6 Determination of Recovery Values for LOSP/DG Failure Restoration (LOSP not an IE): DG Fails to Start

The diesel generator would be called for at the time off-site power is lost. This is the case whether the LOSP is random after an initiating event or it is itself an initiating event. Thus, the time available for recovery is the same as for DG fails to start for LOSP as an initiating event and the results are the same. The probabilities of non-recovery from DG failure to start for either as a hardware or common mode failure are given in Table G.3.1.

G.7 Recovery/Correction Factors for Uncertainty Analysis

This section describes the calculation of the offsite power recovery correction factors. The equations which form the basis for the calculation are given in Reference 10.

For uncertainty analysis, the calculations must consider the uncertainty in the inputs to these equations. To do this, distributions characterizing the uncertainty in the equations were developed. Once the distributions for the input parameters were obtained, these distributions were incorporated into the appropriate correction factor (CF) expressions. The output from this operation was a distribution of correction factors which reflected the uncertainties in the inputs.

Distributions of correction factors for recovery from four LOSP events were calculated:

- LOSP as an initiating event (CF_1)
- LOSP as an initiating event, diesel generator (DG) fails to run (CF_2)
- LOSP as an initiating event, DG fails to start (Hardware failure) (CF_3)
- LOSP as an initiating event, DG fails to start (Common Mode failure) (CF_4)

The process for the CF distribution calculations is given in Figure G.7-1.

The output of the process was a distribution of 500 values for $CF_n(T)$ at 7 values of T (2, 3, 3.5, 5, 6, 11 and 14 hours). Each distribution reflects the uncertainty in $CF_n(T)$ at its particular value of T.

G.7.1 LOSP as Initiating Event (CF_1)

The expression for this correction factor is

$$CF_1(T) = P_{nrOP}T$$

where P_{nrOP} = probability of not recovering off-site power in time T.

The calculation of this CF distribution used only the left branch of Figure G.7-1. A data base of plant data for $P_{nrOP}(T)$ versus T was used as input to MODEL.FOR. The MODEL code applies the mixture model of Reference 3 to the plant input data. The result is a set of 500 $P_{nrOP}(T)$ vs. T curves which reflect the uncertainty in the probability of recovery of off-site power. Each curve is identified by a number (called a pointer). For the Grand Gulf analysis, T varied from .05 to 100 hours and each curve was constructed of 85 points. The time range and number of points are user specified inputs to MODEL. The curves are written to a curve file.

The 500 point distribution for $P_{nrOP}(T)$ at each of the seven time steps consists of the set of values from each of the 500 curves for the specified T.

G.7.2 LOSP as Initiating Event: DG Fails to Run

The correction factor for this case is given by

$$CF_2(T) = \frac{\int_0^{t_m} \lambda_{DGR} e^{-\lambda_{DGR}t} P_{nrOP}(T+t) dt}{1 - e^{-\lambda_{DGR}t_m}}$$

where:

- λ_{DGR} = DG run failure frequency of the DG
- t_m = mission time (24 hours)
- P_{nrOP} = value from non-recovery curve for off-site power
- T = time after which core damage occurs
- t = time at which DG fails to run

Figure G.7-1 CF Distribution Calculation

LOSP Frequency

The determination of CF_2 required both branches of Figure G.7-1. The curves for P_{nrOP} were taken from the CF_1 case. Using an input distribution of DG failure to run frequencies based on plant data, the LHS code developed a 500 point distribution for λ_{DGR} . This distribution is lognormal with a mean of $2.0E-3$ and an error factor of 10. The LHS step also writes a uniform distribution of the 500 points for the P_{nrOP} curves. The input for LHS used to determine these and subsequent distributions is given as Attachment G-44 to this Appendix.

The denominator of the $CF_2(T)$ expression is a point value evaluated at the mean value for λ_{DGR} . This term cancels out the existing event in the cut set which was quantified using the same λ_{DGR} value. The numerator of CF_2 is calculated by the RLOSP code which samples λ_{DGR} and P_{nrOP} and performs the integral. First, RLOSP selects (at random) a value for λ_{DGR} from the 500 calculated by LHS and a pointer corresponding to one of the 500 P_{nrOP} curves. RLOSP then integrates the numerator over the mission time using a Runge-Kutta solution technique. The sampling and integration are repeated a total of 500 times until the 500 values of P_{nrOP} and 500 λ_{DGR} curves have been used, yielding 500 numerators. Each numerator is divided by the point value denominator yielding a distribution of 500 values of $CF_2(T)$.

A listing of the RLOSP code is given in Attachment G-45 to this Appendix.

G.7.3 LOSP as Initiating Event: DG Fails to Start

The correction factor for this event is given by

$$CF_3(T) = P_{nrOP}(T)P_{nrDG}(T)$$

where P_{nrDG} is the non-recovery probability for the diesel generator at time T. Both offsite power and the DG are taken to fail at time 0. Both P_{nrOP} and P_{nrDG} are sampled. Values for P_{nrOP} are obtained from the 500 curves calculated for $CF_1(T)$. A maximum entropy distribution was used to characterize P_{nrDG} . Each $P_{nrDG}(T)$ 500 point distribution was calculated by LHS. This required an input of the lower value, mean, and upper value for the desired distribution. These inputs for each of the seven recovery times are given in Table G.7.1.

For each specified T, the mean value was selected from the mean non-recovery curve of Reference 10. The upper value was set to 1.0 and the lower value was set an order of magnitude below the mean.

Having the 500 P_{nrOP} curves and pointers and the 500 point maximum entropy distribution for P_{nrDG} for a given time T, the RLOSP code samples both and forms their product as $CF_3(T)$. The sampling and multiplication are performed 500 times to form a 500 point distribution for $CF_3(T)$ at each desired T.

G.7.4 LOSP as Initiating Event: DG Fails to Start, Common Mode

The correction factor for this event is given by

$$CF_4 = P_{nrOP}(T) P_{nrDGCM}(T)$$

where $P_{nrDGCM}(T)$ is the probability of non-recovery at time T of a DG that failed to start due to a common mode failure. P_{nrOP} has the usual definition. A maximum entropy distribution for P_{nrDGCM} at each desired T was determined in the same manner as for P_{nrDG} . The distribution inputs are given in Table G.7-2. Sampling and the calculation of $CF_4(T)$ was performed in the same manner as for $CF_3(T)$.

Table G.7.1 DG Fail to Start non-Recovery Distributions

Distribution Parameters	Time Available for Recovery						
	2.0	3.0	3.5	5.0	6.0	11.0	14.0
Distribution Type	Max. Entropy	Max. Entropy	Max. Entropy	Max. Entropy	Max. Entropy	Max. Entropy	Max. Entropy
Upper Value	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Mean	0.87	0.8	0.775	0.7	0.65	0.48	0.41
Lower Value	0.087	0.08	0.0775	0.07	0.065	0.048	0.041

Table G.7.2 DG Fail to Start Common Mode non-Recovery Distributions

Distribution Parameters	Time Available for Recovery						
	0.8	3.0	3.5	5.0	6.0	11.0	14.0
Distribution Type	Max. Entropy	Max. Entropy	Max. Entropy	Max. Entropy	Max. Entropy	Max. Entropy	Max. Entropy
Upper Value	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Mean	0.77	0.7	0.675	0.6	0.55	0.29	0.24
Lower Value	0.077	0.07	0.0675	0.06	0.055	0.029	0.024

G.8 IRRAS Histogram Development

The uncertainty analysis was performed using the IRRAS code. The histograms are limited to 20 points. Thus, the 500 point CF_n distributions whose development was described in Section G.7 had to be reduced to 20 bin histograms for entry into IRRAS. This binning was performed with the QUATTRO PRO spread sheet software [11]. It was done using the following steps for each CF_n .

Step 1. The seven columns corresponding to each recovery time (T) were read into a QUATTRO PRO spread sheet and parsed into seven spread sheet columns. Time headings for each T were assigned to row 1 of each column. This first page in the spread sheet served as the repository for the CF_n s as calculated by RLOSP in section G.7. The binning for each time T was done on a separate page in the spread sheet.

Step 2. On a separate spread sheet page, headings Step, CF_n , Bin Bound, Frequency, Bin Mdpt, Prob. Density and Running Total were assigned to row 1 of columns A, B, D, E, G, H, and I respectively.

Step 3. Rows 2 through 502 of column A were filled with quantile values from 0.0 to 1.0 in .002 increments.

Step 4. The column of CF_n s to be binned for the time T of interest was copied from the first spread sheet page into rows 3 through 502 of column B. The value 0.0E0 was assigned to row 2 of column B. Exponential format was used.

Step 5. Using the spread sheet sorting utility, the CF_n s in column B were sorted in ascending order. The sorted values remained in column B.

Step 6. The values in column B and quantiles in column A were plotted in a Cumulative Distribution Function (CDF). See Figure Attachment G-47-1 for an example.

Step 7. Bin bounds were estimated and filled into rows 2 through 22 of column D. The bounds were estimated so as to:

- Preserve the high frequencies in the tail of the CDF at a high bin midpoint value.
- Match the frequency population of each bin as closely as possible to the CDF.

Step 8. Several equations were copied into columns to track and fine-tune the calculation.

- Column G, the bin midpoint column, had 0.0 assigned to row 2. In row 3, the expression

$$(D2 + D3) / 2$$

was inserted and copied into rows 4 through 22. As the expression is copied down the column, the indices on D are changed to reflect the new row position so that the appropriate bin midpoint is calculated.

- Row 3 of column H was assigned the expression

$$E3 / 500 * 100$$

to calculate the bin probability density in percent. This expression was copied down to row 22. Row 24 was assigned the sum of rows 3 through 22. After each calculation, row 24 was checked for the value 100 to be sure all points were counted.

- A running total of the cumulative probability density was kept in column I. The expression

$$I2 + H3 / 100$$

was assigned to row 3 of column I and copied into rows 4 through 22.

Step 9. Using the frequency function from the Data menu in QUATTRO PRO, the CF_n s in column B were sorted according to the bin bounds of column D. The frequency of CF_n s in each bin was entered into column E by the software. The software also filled in columns G, H, and I using the mathematical expressions defined in Step 8.

Step 10. Results of the calculation were compared to the CDF for the 500 points in Column B in the following manner.

- The frequency (COLUMN E) of the highest value bin was checked to ensure the high frequencies in the tail of the CDF were represented at a sufficiently high bin midpoint value.
- Using the spread sheet plotting package, the running total (column I) was plotted twice against the bin midpoint column on the same

graph. One plot was of spread sheet elements I2 to I20 vs. G3 to G21. The second was of I3 to I21 vs. G3 to G21. This results in a "stair-step" representation of the Cumulative Distribution Function plotted in Step 6. Figure Attachment G-47-2 is an example of this type of plot. This is discussed in greater detail in Step 12 and Step 13.

Step 11. The plot of 10b was overlaid on the CDF plot of Step 6. The degree to which the CDF plot passed through the middle of the vertical part of each step of the Step 10 graph was assessed by engineering judgement. The closer the CDF is to the middle of the vertical step, the better the 20 bin approximation is to the CDF.

Step 12. Depending on the CDF-step fit of Step 11, the bin bounds were adjusted and the process was repeated beginning at Step 9 until a satisfactory fit was obtained. An example of the spread sheet and graphs are given in Attachments G-46 and G-47.

Step 13. The results were entered into the appropriate IRRAS data base as a percentage histogram: Bin Midpoint (COLUMN G) and Probability Density in percent (COLUMN H).

Statistically speaking, the step representation of the CDF in Step 11 results from the histogram representation of the CF frequency distribution. The histogram (which is our approximation of the CF probability density function) is a series of delta functions at discrete points (the bin midpoints).

One obtains the CDF for a continuous distribution by integrating over the population density. The result is the smooth CDF of Step 6. When integrating over a density function represented by delta functions, the probability density (integrated) is equal to zero where the delta functions do not exist. The resulting CDF is then a series of steps (one step for each data function) located at the bin midpoints.

In order to assess the adequacy of the 20 bin histogram, the bottom as well as the top of each step must be defined. That is the purpose of the two plots of Step 10b. One plot represents the top of each step, while the other represents the bottom. Since the top of one step is the bottom of the next, the step bottoms in the histogram CDF are given by the I2 to I20 curve. The step tops are given by the I3 to I21 curve.

References for Appendix G

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Attachment G-1

IE.BCK

LOSP Frequency

1 ARKANSAS NUCLEAR ONE	ANO	1	9.81	0	14.09	0	6.18
2 BEAVER VALLEY	BV	1	5.80	0	12.25	0	4.83
3 BIG ROCK POINT	BRP	0	14.64	0	25.85	0	7.60
4 BROWNS FERRY	BF	0	10.52	0	14.42	0	12.69
5 BRUNSWICH	BRU	1	8.5	0	13.17	1	7.97
6 BYRON	BYR	0	1.31	0	3.33	0	0.98
7 CALLAWAY	CAL	0	2.37	0	4.08	0	0.65
8 CALVERT CLIFFS	CC	1	11.50	0	13.68	0	4.87
9 CATAWABA	CAT	0	2.17	0	3.58	0	1.77
10 CLINTON	CLN	0	0.08	0	1.10	0	0.18
11 COOK	COK	0	10.23	0	13.42	0	6.23
12 COOPER	COP	0	7.92	0	14.51	0	3.77
13 CRYSTAL RIVER	CR	0	6.21	0	11.48	0	4.38
14 DAVIS-BESSE	DB	2	3.85	0	10.51	0	5.04
15 DIABLO CANYON	DC	0	2.27	0	3.67	0	1.31
16 DRESDEN	DR	1	13.89	1	18.59	0	9.10
17 DUANE ARNOLD	DA	0	6.83	0	13.92	0	4.30
18 FARLEY	FAR	2	8.60	0	11.09	0	3.76
19 FITZPATRICK	FIT	0	8.01	0	13.51	3	3.92
20 FORT CLAHOUN	FC	2	9.01	0	14.59	1	3.40
21 FORT ST. VRAIN	FSV	0	1.11	1	9.51	0	6.66
22 GINNA	GIN	2	12.61	0	18.51	0	4.31
23 GRAND GULF	GG	0	1.45	0	3.50	0	1.16
24 HADDAM NECK	HN	6	16.49	0	21.43	1	4.24
25 HATCH	HAT	0	9.10	0	13.09	0	6.21
26 HOPE CREEK	HC	0	0.81	0	2.03	0	0.37
27 INDIAN POINT	IP	2	10.40	3	14.42	1	8.16
28 KEWAUNEE	KEW	0	10.89	0	14.59	0	2.32
29 LASALLE	LAS	0	2.27	0	5.00	0	3.12
30 LIMERICK	LIM	0	1.43	0	2.01	0	0.52
31 MAIN YANKEE	MY	0	10.56	0	16.09	0	3.65
32 MCGUIRE	MCG	1	4.47	0	7.08	1	3.14
33 MILLSTONE	MIL	1	14.17	2	17.85	0	7.35
34 MONTICELLO	MON	1	11.70	0	17.59	1	4.05
35 NINE MILE POINT	NMP	1	11.11	0	19.09	0	6.30
36 NORTH ANNA	NA	0	7.91	0	10.59	0	4.40
37 OCONEE	OCO	1	13.56	0	15.51	0	9.00
38 OYSTER CREEK	OYC	1	9.75	0	19.09	1	7.07
39 PALISADES	PAL	3	7.69	0	17.09	1	8.55
40 PALO VERDE	PV	2	1.54	0	2.91	0	1.53
41 PEACH BOTTOM	PB	0	11.00	0	14.51	0	9.45
42 PERRY	PER	0	0.08	0	1.12	0	0.27
43 PILGRIM	PIL	0	7.71	4	16.09	0	7.24
44 POINT BEACH	PB	2	15.73	0	18.09	1	5.23
45 PRAIRIE ISLAND	PI	1	13.38	0	15.09	0	4.11
46 QUAD CITIES	QC	2	12.95	0	15.92	1	6.63
47 RANCHO SECO	RS	0	5.230	1	3.76	0	7.29
48 RIVER BEND	RB	1	1.04	0	2.58	0	0.80
49 ROBINSON	ROB	1	10.78	0	17.85	0	5.37
50 SALEM	SAL	0	7.15	0	11.59	1	6.25
51 SAN ONOFRE	SO	2	12.13	0	21.01	2	10.74
52 SEQUOYAH	SEQ	0	4.30	0	7.50	0	5.26
53 ST LUCIE	STL	0	9.03	2	12.09	0	3.78

LOSP Frequency

54 SHEARON HARRISON	SH	0	0.49	0	1.69	0	0.44
55 SUMMER	SUM	0	2.69	0	5.00	0	1.35
56 SURRY	SUR	0	12.28	0	16.09	0	9.41
57 SUSQUEHANNA	SUS	1	3.81	0	5.59	0	2.03
58 THREE MILE ISLAND	TMI	0	4.70	1	4.34	0	8.32
59 TROJAN	TRO	0	6.63	0	12.67	0	4.44
60 TURKEY POINT	TP	2	13.05	7	16.09	1	9.01
61 VERMONT YANKEE	VY	0	10.68	0	16.17	0	3.56
62 VOGTLE	VOG	0	0.15	0	1.58	0	0.40
63 WASHINGTON NUCLEAR	WN	0	1.57	0	4.08	0	1.14
64 WATERFORD	WAT	0	1.75	0	2.33	0	0.73
65 WOLF CREEK	WC	0	1.84	0	3.33	0	0.90
66 YANKEE ROWE	YR	0	20.11	1	28.18	1	5.92
67 ZION	ZIO	0	11.59	0	15.09	0	7.58

LOSP Frequency

Attachment G-2

IE.BCK

LOSP Frequency

1	1	14.09	0	6.18
2	1	12.25	0	4.83
3	1	25.85	0	7.60
4	0	14.42	0	12.69
5	1	13.17	1	7.97
6	0	3.33	0	0.98
7	0	4.08	0	0.65
8	1	13.68	0	4.87
9	0	3.58	0	1.77
10	0	1.10	0	0.18
11	0	13.42	0	6.23
12	0	14.51	0	3.77
13	0	11.84	0	4.38
14	0	10.51	0	5.04
15	1	3.67	0	1.31
16	2	18.59	0	9.10
17	0	13.92	0	4.30
18	0	11.09	0	3.76
19	0	13.51	3	3.92
20	2	14.59	1	3.40
21	1	9.51	0	6.66
22	2	18.51	0	4.31
23	0	3.50	0	1.16
24	6	21.43	1	4.24
25	0	13.09	0	6.21
26	0	2.03	0	0.37
27	5	14.42	1	8.16
28	0	14.59	0	2.32
29	0	5.00	0	3.12
30	0	2.92	0	0.52
31	0	16.09	0	3.65
32	1	7.08	1	3.14
33	3	17.85	0	7.35
34	1	17.59	1	4.05

LOSP Frequency

35	2	19.09	0	6.30
36	0	10.59	0	4.40
37	1	15.51	0	9.00
38	1	19.09	1	7.07
39	3	17.09	1	8.55
40	2	2.91	0	1.53
41	0	14.51	0	9.45
42	0	1.12	0	0.27
43	4	16.09	0	7.24
44	2	18.09	2	5.23
45	1	15.09	0	4.11
46	2	15.92	1	6.63
47	0	13.76	0	7.29
48	1	2.58	0	0.80
49	1	17.85	0	5.37
50	0	11.59	1	6.25
51	2	21.01	2	10.74
52	0	7.50	0	5.26
53	2	12.09	0	3.78
54	0	1.69	0	0.44
55	0	5.00	0	1.35
56	0	16.09	0	9.41
57	1	5.59	0	2.03
58	0	14.34	0	8.32
59	0	12.67	0	4.44
60	9	16.09	1	9.01
61	0	16.17	0	3.56
62	0	1.58	0	0.40
63	0	4.08	0	1.14
64	0	3.33	0	0.73
65	0	3.33	0	0.90
66	1	28.18	1	5.92
67	0	15.09	0	7.58

Attachment G-3

LOSP_IE_PCGW.DAT

LOSP Frequency

1	1	14.09
2	1	12.25
3	1	25.85
4	0	14.42
5	1	13.17
6	0	3.33
7	0	4.08
8	1	13.68
9	0	3.58
10	0	1.10
11	0	13.42
12	0	14.51
13	0	11.84
14	0	10.51
15	1	3.67
16	2	18.59
17	0	13.92
18	0	11.09
19	0	13.51
20	2	14.59
21	1	9.51
22	2	18.51
23	0	3.50
24	6	21.43
25	0	13.09
26	0	2.03
27	5	14.42
28	0	14.59
29	0	5.00
30	0	2.92
31	0	16.09
32	1	7.08
33	3	17.85
34	1	17.59

LOSP Frequency

35	2	19.09
36	0	10.59
37	1	15.51
38	1	19.09
39	3	17.09
40	2	2.91
41	0	14.51
42	0	1.12
43	4	16.09
44	2	18.09
45	1	15.09
46	2	15.92
47	0	13.76
48	1	2.58
49	1	17.85
50	0	11.59
51	2	21.01
52	0	7.50
53	2	12.09
54	0	1.69
55	0	5.00
56	0	16.09
57	1	5.59
58	0	14.34
59	0	12.67
60	9	16.09
61	0	16.17
62	0	1.58
63	0	4.08
64	0	3.33
65	0	3.33
66	1	28.18
67	0	15.09

LOSP Frequency

Attachment G-4

LOSP_IE_IV.DAT

LOSP Frequency

1	0	6.18
2	0	4.83
3	0	7.60
4	0	12.69
5	1	7.97
6	0	0.98
7	0	0.65
8	0	4.87
9	0	1.77
10	0	0.18
11	0	6.23
12	0	3.77
13	0	4.38
14	0	5.04
15	0	1.31
16	0	9.10
17	0	4.30
18	0	3.76
19	3	3.92
20	1	3.40
21	0	6.66
22	0	4.31
23	0	1.16
24	1	4.24
25	0	6.21
26	0	0.37
27	1	8.16
28	0	2.32
29	0	3.12
30	0	0.52
31	0	3.65
32	1	3.14
33	0	7.35
34	1	4.05

LOSP Frequency

35	0	6.30
36	0	4.40
37	0	9.00
38	1	7.07
39	1	8.55
40	0	1.53
41	0	9.45
42	0	0.27
43	0	7.24
44	1	5.23
45	0	4.11
46	1	6.63
47	0	7.29
48	0	0.80
49	0	5.37
50	1	6.25
51	2	10.74
52	0	5.26
53	0	3.78
54	0	0.44
55	0	1.35
56	0	9.41
57	0	2.03
58	0	8.32
59	0	4.44
60	1	9.01
61	0	3.56
62	0	0.40
63	0	1.14
64	0	0.73
65	0	0.90
66	1	5.92
67	0	7.58

Attachment G-5

IE.DAT

LOSP Frequency

1	1	14.09
2	1	12.25
3	1	25.85
4	0	14.42
5	1	13.17
6	0	3.33
7	0	4.08
8	1	13.68
9	0	3.58
10	0	1.10
11	0	13.42
12	0	14.51
13	0	11.84
14	0	10.51
15	1	3.67
16	2	18.59
17	0	13.92
18	0	11.09
19	0	13.51
20	2	14.59
21	1	9.51
22	2	18.51
23	0	3.50
24	6	21.43
25	0	13.09
26	0	2.03
27	5	14.42
28	0	14.59
29	0	5.00
30	0	2.92
31	0	16.09
32	1	7.08
33	3	17.85
34	1	17.59

LOSP Frequency

35	2	19.09
36	0	10.59
37	1	15.51
38	1	19.09
39	3	17.09
40	2	2.91
41	0	14.51
42	0	1.12
43	4	16.09
44	2	18.09
45	1	15.09
46	2	15.92
47	0	13.76
48	1	2.58
49	1	17.85
50	0	11.59
51	2	21.01
52	0	7.50
53	2	12.09
54	0	1.69
55	0	5.00
56	0	16.09
57	1	5.59
58	0	14.34
59	0	12.67
60	9	16.09
61	0	16.17
62	0	1.58
63	0	4.08
64	0	3.33
65	0	3.33
66	1	28.18
67	0	15.09

LOSP Frequency

\$ RUN IEFREQ1

INPUT THE NAME OF THE DATA FILE(ENCLOSED IN TICK MARKS)

'IE.DAT'

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

16 17 18 19 20 21 22 23 24 25 26 27 28 29 30

31 32 33 34 35 36 37 38 39 40 41 42 43 44 45

46 47 48 49 50 51 52 53 54 55 56 57 58 59 60

61 62 63 64 65 66 67

INPUT THE ID FOR THE PLANT OF INTEREST

23

PLANT ID = 23, NUMBER OF FAILURES = 0., NUMBER OF YEARS = 3.5

SUM OPER. YRS = 789.520000000000

IF YOU KNOW THE VALUE OF CONSTANT, TYPE 1;O.W.TYPE 2

2

INPUT THE FAILURE FREQUENCY FOR PLANT LOSP

FOR 23

15

PLEASE WAIT WHILE THE INTEGRATION IS PERFORMED

CONSTK= 1.580239660651922E-095

THE CUMULATIVE PROBABILITY FOR PLANT LOSP FOR

A FAILURE FREQUENCY OF 0.415000

AT 23

IS 0.998994

IS THIS VALUE SATISFACTORY? Y OR N

N

INPUT THE FAILURE FREQUENCY FOR PLANT LOSP

FOR 23

.45

PLEASE WAIT WHILE THE INTEGRATION IS PERFORMED

CONSTK= 1.580239660651922E-095

E CUMULATIVE PROBABILITY FOR PLANT LOSP FOR

A FAILURE FREQUENCY OF 0.450000

AT 23

IS 0.999392

IS THIS VALUE SATISFACTORY? Y OR N

N

INPUT THE FAILURE FREQUENCY FOR PLANT LOSP

FOR 23

.44

PLEASE WAIT WHILE THE INTEGRATION IS PERFORMED

CONSTK= 1.580239660651922E-095

THE CUMULATIVE PROBABILITY FOR PLANT LOSP FOR

A FAILURE FREQUENCY OF 0.440000

23

IS 0.999304

IS THIS VALUE SATISFACTORY? Y OR N

N

INPUT THE FAILURE FREQUENCY FOR PLANT LOSP
FOR 23

.43

PLEASE WAIT WHILE THE INTEGRATION IS PERFORMED

CONSTK= 1.580239660651922E-095

THE CUMULATIVE PROBABILITY FOR PLANT LOSP FOR
A FAILURE FREQUENCY OF 0.430000

AT 23

O .999191

THIS VALUE SATISFACTORY? Y OR N

N

INPUT THE FAILURE FREQUENCY FOR PLANT LOSP
FOR 23

.42

PLEASE WAIT WHILE THE INTEGRATION IS PERFORMED

CONSTK= 1.580239660651922E-095

THE CUMULATIVE PROBABILITY FOR PLANT LOSP FOR
FAILURE FREQUENCY OF 0.420000

AT 23

IS 0.999062

IS THIS VALUE SATISFACTORY? Y OR N

N

INPUT THE FAILURE FREQUENCY FOR PLANT LOSP
FOR 23

.418

PLEASE WAIT WHILE THE INTEGRATION IS PERFORMED

CONSTK= 1.580239660651922E-095

THE CUMULATIVE PROBABILITY FOR PLANT LOSP FOR
A FAILURE FREQUENCY OF 0.418000

AT 23

IS 0.999030

IS THIS VALUE SATISFACTORY? Y OR N

N

INPUT THE FAILURE FREQUENCY FOR PLANT LOSP
FOR 23

.417

PLEASE WAIT WHILE THE INTEGRATION IS PERFORMED

CONSTK= 1.580239660651922E-095

THE CUMULATIVE PROBABILITY FOR PLANT LOSP FOR
A FAILURE FREQUENCY OF 0.417000

AT 23

IS 0.999019

IS THIS VALUE SATISFACTORY? Y OR N

LOSP Frequency

INPUT THE FAILURE FREQUENCY FOR PLANT LOSP
FOR 23

.416

PLEASE WAIT WHILE THE INTEGRATION IS PERFORMED

CONSTK= 1.580239660651922E-095

THE CUMULATIVE PROBABILITY FOR PLANT LOSP FOR
A FAILURE FREQUENCY OF 0.416000

AT 23

IS 0.999006

IS THIS VALUE SATISFACTORY? Y OR N

Y

FORTRAN STOP

Attachment G-6

LOSP_IE_PCGW.INP

LOSP Frequency

'LOSP IE PCGW.DAT'23.416 30

Attachment G-7

IEBAT.COM

LOSP Frequency

```
$ SET VERIFY  
$ SET DEFAULT UD4:[BDSTAPL]  
$ RENAME LOSP_IE_PCGW.INP IEFREQ.INP  
$ RUN IEBAT1  
$ RENAME IEFREQ.INP LOSP_IE_PCGW.INP  
$ RENAME PLOT.DAT IE_PCGW.DAT
```

Attachment G-7a

IEBAT.COM
(Slow Batch Mode)

LOSP Frequency

\$ SUBMIT/Q=SLOW\$BATCH/LOG_FILE=IEBAT/NOPRINT/CPU=1:30:00 IEBAT.COM
\$ EXIT ~--

Attachment G-7b

IEBAT.COM LOG FILE

LOSP Frequency

```
$Set NoControl=Y
$Set NoVerify
$ SET DEFAULT UD4:[BDSTAPL]
$ RENAME LOSP_IE PCGW.INP IEFREQ.INP
$ RUN IEBAT1
FORTRAN STOP
$ RENAME IEFREQ.INP LOSP_IE_PCGW.INP
$ RENAME PLOT.DAT IE_PCGW.DAT
BDSTAPL    job terminated at 3-JUN-1991 18:43:33.13
```

Accounting information:

Buffered I/O count:	129	Peak working set size:	1239
Direct I/O count:	100	Peak page file size:	4311
Page faults:	4276	Mounted volumes:	0
Charged CPU time:	0 00:05:32.22	Elapsed time:	0 01:15:18 51

Attachment G-8

IE_PCGW.DAT

(BEFORE UPDATE)

LOSP Frequency

0.154074E-04	0.000978
0.123259E-03	0.003558
0.416000E-03	0.008215
0.986074E-03	0.015590
0.192593E-02	0.026452
0.332800E-02	0.041697
0.528474E-02	0.062328
0.788859E-02	0.089409
0.112320E-01	0.124002
0.154074E-01	0.167035
0.205073E-01	0.219149
0.266240E-01	0.280514
0.338501E-01	0.350585
0.422779E-01	0.427906
0.520000E-01	0.510082
0.631087E-01	0.593832
0.756966E-01	0.675337
0.898560E-01	0.750074
0.105679E+00	0.814062
0.123259E+00	0.865966
0.142688E+00	0.906261
0.164058E+00	0.936288
0.187462E+00	0.957847
0.212992E+00	0.972826
0.240741E+00	0.982946
0.270801E+00	0.989592
0.303264E+00	0.993861
0.338223E+00	0.996512
0.375771E+00	0.998145
0.416000E+00	0.999006

Attachment G-9

IE_PCGW.DAT

(After Update)

LOSP Frequency

0.100000E-07	0.000000
0.154074E-04	0.000978
0.123259E-03	0.003558
0.416000E-03	0.008215
0.986074E-03	0.015590
0.192593E-02	0.026452
0.332800E-02	0.041697
0.528474E-02	0.062328
0.788859E-02	0.089409
0.112320E-01	0.124002
0.154074E-01	0.167035
0.205073E-01	0.219149
0.266240E-01	0.280514
0.338501E-01	0.350585
0.422779E-01	0.427906
0.520000E-01	0.510082
0.631087E-01	0.593832
0.756966E-01	0.675337
0.898560E-01	0.750074
0.105679E+00	0.814062
0.123259E+00	0.865966
0.142688E+00	0.906261
0.164058E+00	0.936288
0.187462E+00	0.957847
0.212992E+00	0.972826
0.240741E+00	0.982946
0.270801E+00	0.989592
0.303264E+00	0.993861
0.338223E+00	0.996512
0.375771E+00	0.998145
0.416000E+00	0.999006
0.900000E+00	1.000000

Attachment G-10

IE.DAT for CATEGORY IV

LOSP Frequency

1	0	6.18
2	0	4.83
3	0	7.60
4	0	12.69
5	1	7.97
6	0	0.98
7	0	0.65
8	0	4.87
9	0	1.77
10	0	0.18
11	0	6.23
12	0	3.77
13	0	4.38
14	0	5.04
15	0	1.31
16	0	9.10
17	0	4.30
18	0	3.76
19	3	3.92
20	1	3.40
21	0	6.66
22	0	4.31
23	0	1.16
24	1	4.24
25	0	6.21
26	0	0.37
27	1	8.16
28	0	2.32
29	0	3.12
30	0	0.52
31	0	3.65
32	1	3.14
33	0	7.35
34	1	4.05

LOSP Frequency

35	0	6.30
36	0	4.40
37	0	9.00
38	1	7.07
39	1	8.55
40	0	1.53
41	0	9.45
42	0	0.27
43	0	7.24
44	1	5.23
45	0	4.11
46	1	6.63
47	0	7.29
48	0	0.80
49	0	5.37
50	1	6.25
51	2	10.74
52	0	5.26
53	0	3.78
54	0	0.44
55	0	1.35
56	0	9.41
57	0	2.03
58	0	8.32
59	0	4.44
60	1	9.01
61	0	3.56
62	0	0.40
63	0	1.14
64	0	0.73
65	0	0.90
66	1	5.92
67	0	7.58

LOSP Frequency

\$ RUN IEFREQ1

INPUT THE NAME OF THE DATA FILE (ENCLOSED IN TICK MARKS)

'IE.DAT'

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
31 32 33 34 35 36 37 38 39 40 41 42 43 44 45
46 47 48 49 50 51 52 53 54 55 56 57 58 59 60
61 62 63 64 65 66 67

INPUT THE ID FOR THE PLANT OF INTEREST

23

PLANT ID = 23, NUMBER OF FAILURES = 0., NUMBER OF YEARS = 1.2

SUM OPER. YRS = 312.690000000000

IF YOU KNOW THE VALUE OF CONSTANT, TYPE 1;O.W.TYPE 2

2

INPUT THE FAILURE FREQUENCY FOR PLANT LOSP

FOR 23

'91

PLEASE WAIT WHILE THE INTEGRATION IS PERFORMED

CONSTK= 5.158047635733690E-030

THE CUMULATIVE PROBABILITY FOR PLANT LOSP FOR

A FAILURE FREQUENCY OF 0.291000

AT 23

IS 0.999005

IS THIS VALUE SATISFACTORY? Y OR N

y

FORTRAN STOP

Attachment G-11

IEBAT.COM for CATEGORY IV

LOSP Frequency

```
$ SET VERIFY
$ SET DEFAULT UD4:[BDSTAPL]
$ RENAME LOSP_JE_IV.INP IEFREQ.INP
$ RUN IEBATI
$ RENAME IEFREQ.INP LOSP_IE IV.INP
$ RENAME PLOT.DAT IE IV.DAT
```

Attachment G-12

LOSP_IE_IV.INP

LOSP Frequency

'LOSP IE IV.DAT' 23 .291 30

Attachment G-13

IE_IV.DAT

LOSP Frequency

0.107778E-04	0.000552
0.862222E-04	0.001262
0.291000E-03	0.002208
0.689778E-03	0.003445
0.134722E-02	0.005048
0.232800E-02	0.007116
0.369678E-02	0.009782
0.551822E-02	0.013229
0.785700E-02	0.017711
0.107778E-01	0.023589
0.143452E-01	0.031407
0.186240E-01	0.042058
0.236788E-01	0.057274
0.295742E-01	0.085147
0.363750E-01	0.136164
0.441458E-01	0.238943
0.529512E-01	0.443061
0.628560E-01	0.695064
0.739248E-01	0.840654
0.862222E-01	0.925578
0.998130E-01	0.960696
0.114762E+00	0.977024
0.131133E+00	0.985120
0.148992E+00	0.990093
0.168403E+00	0.993320
0.189430E+00	0.995462
0.212139E+00	0.996903
0.236594E+00	0.997882
0.262859E+00	0.998550
0.291000E+00	0.999005

Attachment G-14

IE_IV.DAT

LOSP Frequency

0.100000E-07	0.000000
0.107778E-04	0.000552
0.862222E-04	0.001262
0.291000E-03	0.002208
0.689778E-03	0.003445
0.134722E-02	0.005048
0.232800E-02	0.007116
0.369678E-02	0.009782
0.551822E-02	0.013229
0.785700E-02	0.017711
0.107778E-01	0.023589
0.143452E-01	0.031407
0.186240E-01	0.042058
0.236788E-01	0.057274
0.295742E-01	0.085147
0.363750E-01	0.136164
0.441458E-01	0.238943
0.529512E-01	0.443061
0.628560E-01	0.695064
0.739248E-01	0.840654
0.862222E-01	0.925578
0.998130E-01	0.960696
0.114762E+00	0.977024
0.131133E+00	0.985120
0.148992E+00	0.990093
0.168403E+00	0.993320
0.189430E+00	0.995462
0.212139E+00	0.996903
0.236594E+00	0.997882
0.262859E+00	0.998550
0.291000E+00	0.999005
0.850000E+00	1.000000

Attachment G-15

IEBAT.LOG for CATEGORY IV

LOSP Frequency

```
$Set NoControl=Y
$Set NoVerify
$ SET DEFAULT UD4:[BDSTAPL]
$ RENAME LOSP_IE_IV.INP IEFREQ.INP
$ RUN IEBAT1
FORTRAN STOP
$ RENAME IEFREQ.INP LOSP_IE_IV.INP
$ RENAME PLOT.DAT IE_IV.DAT
BDSTAPL    job terminated at 31-MAY-1991 13:57:27.78
```

Accounting information:

Buffered I/O count:132	Peak working set size:1199
Direct I/O count:102	Peak page file size:4274
Page faults:4115	Mounted volumes:0
Charged CPU time:0 00:33:21.77	Elapsed time:0 00:36:17.30

Attachment G-16

IE_IV.DAT

LOSP Frequency

0.107778E-04	0.000552
0.862222E-04	0.001262
0.291000E-03	0.002208
0.689778E-03	0.003445
0.134722E-02	0.005048
0.232800E-02	0.007116
0.369678E-02	0.009782
0.551822E-02	0.013229
0.785700E-02	0.017711
0.107778E-01	0.023589
0.143452E-01	0.031407
0.186240E-01	0.042058
0.236788E-01	0.057274
0.295742E-01	0.085147
0.363750E-01	0.136164
0.441458E-01	0.238943
0.529512E-01	0.443061
0.628560E-01	0.695064
0.739248E-01	0.840654
0.862222E-01	0.925578
0.998130E-01	0.960696
0.114762E+00	0.977024
0.131133E+00	0.985120
0.148992E+00	0.990093
0.168403E+00	0.993320
0.189430E+00	0.995462
0.212139E+00	0.996903
0.236594E+00	0.997882
0.262859E+00	0.998550
0.291000E+00	0.999005

Attachment G-17

IE_IV.DAT

(Updated)

LOSP Frequency

0.100000E-07	0.000000
0.107778E-04	0.000552
0.862222E-04	0.001262
0.291000E-03	0.002208
0.689778E-03	0.003445
0.134722E-02	0.005048
0.232800E-02	0.007116
0.369678E-02	0.009782
0.551822E-02	0.013229
0.785700E-02	0.017711
0.107778E-01	0.023589
0.143452E-01	0.031407
0.186240E-01	0.042058
0.236788E-01	0.057274
0.295742E-01	0.085147
0.363750E-01	0.136164
0.441458E-01	0.238943
0.529512E-01	0.443061
0.628560E-01	0.695064
0.739248E-01	0.840654
0.862222E-01	0.925578
0.998130E-01	0.960696
0.114762E+00	0.977024
0.131133E+00	0.985120
0.148992E+00	0.990093
0.168403E+00	0.993320
0.189430E+00	0.995462
0.212139E+00	0.996903
0.236594E+00	0.997882
0.262859E+00	0.998550
0.291000E+00	0.999005
0.850000E+00	1.000000

Attachment G-18

LHS.COM

LOSP Frequency

\$ ASSIGN LHS.DAT FOR001
\$ ASSIGN LHS.INP FOR005
\$ ASSIGN LHS.OUT FOR006
\$ RUN LHS
\$ DELETE FOR*.DAT;*

Attachment G-19

LHS.INP

LOSP Frequency

TITLE - LHS SAMPLE FOR LOSP INITIATING EVENT

RANDOM SEED 1787673089

NOBS 1000

RANDOM SAMPLE

USER DISTRIBUTION IE_PCGW.DAT

USER DISTRIBUTION IE_IV.DAT

OUTPUT HIST

Attachment G-20

Subroutine USRDST.FOR

LOSP Frequency

```
C*****
SUBROUTINE USRDST(J)
C
C MODIFIED BY G. WILKINSON (11/8/88) FOR ARTHUR PAYNE SAMPLE -
C MODIFIED FOR LASALLE BY T. T. SYPE (6/15/89)
C MODIFIED FOR GRAND GULF LOSP BY BEVAN STAPLE (5/31/91)
C SUBROUTINE USRDST WILL GENERATE VALUES FROM A
C 1) DISCRETE DISTRIBUTION (WITH AND WITHOUT INTERPOLATION);
C
C THE FOLLOWING SIX LINES OF CODE ARE REQUIRED BY USRDST:
C
C NMAX IS THE MAXIMUM NUMBER OF OBSERVATIONS.
C NVAR IS THE MAXIMUM NUMBER OF VARIABLES.
C LENT IS THE LENGTH OF THE TITLE.
C
    PARAMETER (NMAX=1000)
    PARAMETER (NVAR=200)
    PARAMETER (LENT=125)
    COMMON/PARAM/TITLE(LENT),ISEED,N,NV,IRS,ICM,NREP,IDATA,IHIST,
1  ICORR,IDIST(NVAR),IRP
    COMMON/SAMP/X(NMAX*NVAR)
C
C THE FOLLOWING PARAMETERS ARE REQUIRED FOR THE DISCRETE PROBABILITY FUNCTION
C
    PARAMETER (NCP=100)
    DIMENSION XVAL(NCP), CP(NCP)
C
C THE FOLLOWING PARAMETERS ARE REQUIRED FOR THE LOSP VARIABLES
C
C NP IS THE NUMBER OF PAIRS OF IVAL AND FREQ
C IVAL(K) IS THE KTH UNIQUE VALUE OF THE RANDOM VARIABLE
C FREQ(K) IS THE PROBABILITY ASSOCIATED WITH THE KTH VALUE
C
    PARAMETER(MAXNP=500)
    DIMENSION IVAL(MAXNP),FREQ(MAXNP),CDF(MAXNP+1)
C
C THE FOLLOWING FUNCTION DEFINITION IS REQUIRED BY USRDST.
C
    LOC(I,J) = (J-1) * N + I
C
C READ FROM LHS INPUT FILES
C
    IFLAG = IFLAG + 1
    IF(J.EQ.1) THEN
        IF (IFLAG.EQ.1) OPEN(UNIT=60,FILE='IE_PCGW.DAT',STATUS='OLD')
        NP=32
        IF(IFLAG.EQ.1) WRITE(6,12)
12 FORMAT('1',/,/,6X,'INPUT DATA FOR IE_PCGW',/,11X,'XVAL',14X,'CP')
        DO 5 K=1,NP
            READ(60,*) XVAL(K), CP(K)
            IF(IFLAG.EQ.1) WRITE(6,14) XVAL(K), CP(K)
14 FORMAT (6X,E13.7,3X,E13.7)
        5    CONTINUE
        REWIND 60
```

```

C
  ELSEIF (J.EQ.2) THEN
    IF(IFLAG.EQ.2)OPEN(UNIT=61,FILE='IE_IV.DAT',STATUS='OLD')
    NP=32
    IF (IFLAG.EQ.2)WRITE(6,16)
    16   FORMAT('I',/,/,6X,'INPUT DATA FOR IE_IV',/,IIX,'XVAL',14X,'CP')
    DO 1 K=1,NP
      READ(61,*) XVAL(K), CP(K)
      IF(IFLAG.EQ.2) WRITE(6,18) XVAL(K), CP(K)
      18   FORMAT(6X,E13.7,3X,E13.7)
      1 CONTINUE
      REWIND 61
C
  ENDIF
C
C SET THE STARTING POINT (STRPT) EQUAL TO ZERO AND THE PROBABILITY
C INCREMENT (PROBINC) EQUAL TO 1/N FOR A LHS WHERE N IS THE SAMPLE SIZE
C
  STRPT=0.0
  PROBINC=1.0/FLOAT(N)
  IF(IRS.EQ.1)PROBINC=1.0
C
C THIS LOOP WILL OBTAIN THE N SAMPLES
C
  ITEMP=1
  DO 4 I=1,N
    R=STRPT + PROBINC*RAN(ISEED)
C
    DO 3 K=ITEMP,NP-1
      IF(R.GE.CP(K).AND.R.LT.CP(K+1)) THEN
        IF(XVAL(K).EQ.XVAL(K+1)) THEN
C
C DISCRETE PROBABILITY
C
          X(LOC(I,J))=XVAL(K)
          ELSE
C
C INTERPOLATION
C
          X(LOC(I,J)) = ((R-CP(K))/(CP(K+1)-CP(K)))*
            1 (XVAL(K+1)-XVAL(K))+XVAL(K)
          ENDIF
          IF(IRS.NE.1) ITEMP=K
          GO TO 25
        ENDIF
      3 CONTINUE
      25 CONTINUE
      IF(IRS.NE.1)STRPT=STRPT + PROBINC
      4 CONTINUE
      GO TO 99
C
    99 RETURN
    END

```

LOSP Frequency

Attachment G-21

LHS.OUT

TITLE - LHS SAMPLE FOR LOSP INITIATING EVENT ***RANDOM SAMPLE***
 RANDOM SEED = 1787673089
 NUMBER OF VARIABLES = 2
 NUMBER OF OBSERVATIONS = 1000

HISTOGRAMS OF THE ACTUAL SAMPLE WILL BE PLOTTED FOR EACH INPUT VARIABLE

TITLE - LHS SAMPLE FOR LOSP INITIATING EVENT

VARIABLE	DISTRIBUTION	RANGE	LABEL
1	USER SUPPLIED DISTRIBUTION		IE_PCGW.DAT
2	USER SUPPLIED DISTRIBUTION		IE IV.DAT

INPUT DATA FOR IE_PCGW

XVAL	CP
0.1000000E-07	0.0000000E+00
0.1540740E-04	0.9780000E-03
0.1232590E-03	0.3558000E-02
0.4160000E-03	0.8215000E-02
0.9860740E-03	0.1559000E-01
0.1925930E 02	0.2645200E-01
0.3328000E-02	0.4169700E-01
0.5284740E-02	0.6232800E-01
0.7888590E-02	0.8940900E 01
0.1123200E-01	0.1240020E+00
0.1540740E-01	0.1670350E+00
0.2050730E 01	0.2191490E+00
0.2662400E-01	0.2805140E+00
0.3385010E-01	0.3505850E+00
0.4227790E-01	0.4279060E+00
0.5200000E-01	0.5100820E+00
0.6310870E-01	0.5938320E+00
0.7569660E 01	0.6753370E+00
0.8985600E-01	0.7500740E+00
0.1056790E+00	0.8140620E+00
0.1232590E+00	0.8659660E+00
0.1426880E+00	0.9062610E+00
0.1640580E+00	0.9362880E+00
0.1874620E+00	0.9578470E+00
0.2129920E+00	0.9728260E+00
0.2407410E+00	0.9829460E+00
0.2708010E+00	0.9895920E+00
0.3032640E+00	0.9938610E+00
0.3382230E+00	0.9965120E+00
0.3757710E+00	0.9981450E+00
0.4160000E+00	0.9990060E+00
0.9000000E+00	0.1000000E+01

LOSP Frequency

INPUT DATA FOR IE_IV

XVAL	CP
0.1000000E-07	0.0000000E+00
0.1077780E-04	0.5520000E-03
0.8622220E-04	0.1262000E-02
0.2910000E-03	0.2208000E-02
0.6897780E-03	0.3445000E-02
0.1347220E-02	0.5048000E-02
0.2328000E-02	0.7116000E-02
0.3696780E-02	0.9782000E-02
0.5518220E-02	0.1322900E-01
0.7857000E-02	0.1771100E-01
0.1077780E-01	0.2358900E-01
0.1434520E-01	0.3140700E-01
0.1862400E-01	0.4205800E-01
0.2367880E-01	0.5727400E-01
0.2957420E-01	0.8514700E-01
0.3637500E-01	0.1361640E+00
0.4414580E-01	0.2389430E+00
0.5295120E-01	0.4430610E+00
0.6285600E-01	0.6950640E+00
0.7392480E-01	0.8406540E+00
0.8622220E-01	0.9255780E+00
0.9981300E-01	0.9606960E+00
0.1147620E+00	0.9770240E+00
0.1311330E+00	0.9851200E+00
0.1489920E+00	0.9900930E+00
0.1684030E+00	0.9933200E+00
0.1894300E+00	0.9954620E+00
0.2121390E+00	0.9969030E+00
0.2365940E+00	0.9978820E+00
0.2628590E+00	0.9985500E+00
0.2910000E+00	0.9990050E+00
0.8500000E+00	0.1000000E+01

TITLE - LHS SAMPLE FOR LOSP INITIATING EVENT ***RANDOM SAMPLE***

HISTOGRAM FOR VARIABLE NO. 1 USER SUPPLIED DISTRIBUTION

MIDPOINT	FREQ.
0.1050000E-01	237
0.3150000E-01	199
0.5250001E-01	154
0.7350001E-01	116
0.9450002E-01	98
0.1155000	67
0.1365000	38
0.1575000	34
0.1785000	19

0.1995000	14
0.2205000	10
0.2415000	5
0.2625000	1
0.2835000	2
0.3045000	3
0.3255000	1
0.3465000	0
0.3675000	0
0.3885000	1
0.4095000	1

1000

MIN	MAX	RANGE	MEAN	MEDIAN	VARIANCE
0.1252443E-05	0.4126163	0.4126150	0.6490128E-01	0.5088609E-01	0.3193550E-02

Vol. 2, Part 2

RANDOM SAMPLE

LOSP Frequency

0.2100000E 01 229

XX

0.6299999E 01 676

[illegible]

```
0.1050000      70      XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
```

0.1470000	18	XXXXXXXXXXXXXXXXXXXX
-----------	----	----------------------

0.1890000	3	XXX
-----------	---	-----

0.2310000	0
-----------	---

0.2729999	2	XX
-----------	---	----

0.3149999 0

0.3569999	0
-----------	---

0.3989999 0

0.4409999 0

0.4829999 0

0.5249999 0

0.5669999 0

0.6089999 0

0.6509999 0

0.6929999 0

0.7349999 0

0.7769999 1 X

0.8189999 0

0.8609999	1	X
-----------	---	---

1000

MIN	MAX	RANGE	MEAN	MEDIAN	VARIANCE
887E-03	0.8440393	0.8438997	0.5864298E-01	0.5470004E-01	0.1796476E-02

Attachment G-22

LHS.DAT

LOSP Frequency

1	2	9.5802836E-02	5.7157081E-02	54	2	6.3890698E-03	6.1642252E-02
2	2	5.0940670E-02	6.0416732E-02	55	2	1.1955368E-02	5.3150438E-02
3	2	3.7110481E-02	5.8251712E-02	56	2	2.0493850E-02	0.1857526
4	2	0.3011881	5.3329077E-02	57	2	3.9378010E-02	3.7598554E-02
5	2	6.8660229E-02	5.5287939E-02	58	2	3.5381936E-02	4.7152728E-02
6	2	4.1418765E-02	5.6494150E-02	59	2	6.2365174E-02	7.5856574E-02
7	2	3.8164826E-03	6.1932772E-02	60	2	6.9060028E-02	8.9874759E-02
8	2	7.3756211E-02	9.4944753E-02	61	2	4.4734307E-02	5.6779027E-02
9	2	0.1116926	5.5104259E-02	62	2	4.3982375E-02	6.2561035E-02
10	2	8.3901752E-03	5.9206437E-02	63	2	6.0694963E-02	3.8645752E-02
11	2	2.1001803E-04	0.1903778	64	2	9.1746241E-02	0.1081921
12	2	0.19843083.84	71486E-02	65	2	1.2195393E-02	0.1378729
13	2	6.1446220E-02	5.7531755E-02	66	2	9.7427778E-03	4.6029627E-02
14	2	1.3037866E-02	7.0953816E-02	67	2	1.9653393E-02	4.2656578E-02
15	2	8.6331956E-02	6.8710037E-02	68	2	3.1145809E-02	4.1980006E-02
16	2	3.7155967E-02	3.2672279E-02	69	2	7.1229465E-02	6.0362123E-02
17	2	3.2555930E-02	4.4575006E-02	70	2	5.5966739E-02	0.1215986
18	2	4.5071386E-02	3.1056585E-02	71	2	2.9009812E-02	6.5682463E-02
19	2	6.3797474E-02	4.6071306E-02	72	2	7.5244442E-02	5.8911454E-02
20	2	4.3774538E-02	3.0516183E-02	73	2	7.8743502E-02	5.4237224E-02
21	2	0.1065058	7.9281092E-02	74	2	5.0527163E-02	6.1270196E-02
22	2	5.5102311E-02	3.2996830E-02	75	2	3.1681322E-02	8.5060455E-02
23	2	3.5599325E-02	4.8942689E-02	76	2	5.1817849E-02	5.0090570E-02
24	2	2.0490789E-03	4.5054294E-02	77	2	5.0831504E-02	2.4951266E-02
25	2	2.5542006E-02	2.5336470E-02	78	2	0.1170508	6.8073846E-02
26	2	4.6561282E-02	7.3678486E-02	79	2	3.0360568E-02	4.9490560E-02
27	2	9.7525999E-02	7.1654484E-02	80	2	3.7065927E-02	5.0325025E-02
28	2	3.6980748E-02	6.9754799E-03	81	2	8.4724374E-02	3.4361262E-02
29	2	3.8461756E-02	2.1312614E-03	82	2	0.2172877	7.2943039E-02
30	2	0.1308402	4.2214524E-02	83	2	0.1707056	6.1654635E-02
31	2	1.5121906E-02	6.1416168E-02	84	2	4.1157823E-02	6.0433898E-02
32	2	0.1576969	4.6902116E-02	85	2	4.6242714E-02	5.8522064E-02
33	2	1.1520608E-02	6.0953710E-02	86	2	7.8710178E-03	6.0102671E-02
34	2	0.1065259	9.9590011E-02	87	2	8.4139876E-02	7.9868220E-02
35	2	0.1838354	9.7384945E-02	88	2	9.9810176E-02	6.6642977E-02
36	2	2.3105722E-02	5.1488169E-02	89	2	5.6254819E-02	7.4072085E-02
37	2	7.8000881E-02	8.7991364E-02	90	2	4.5131359E-02	3.6564417E-02
38	2	8.4191918E-02	4.7253303E-02	91	2	0.1175776	6.0518596E-02
39	2	3.0882679E-02	3.7661687E-02	92	2	2.3901181E-02	5.5216696E-02
40	2	0.1168672	9.2032492E-02	93	2	6.8641901E-02	4.5617305E-02
41	2	6.9784876E-03	2.3598088E-02	94	2	8.4755734E-02	3.5917133E-02
42	2	2.8681975E-02	3.9681610E-02	95	2	4.7624674E-02	5.0922580E-02
43	2	2.7508037E-02	8.6506894E-03	96	2	7.6687358E-02	4.7751363E-02
44	2	5.7893977E-02	3.1828873E-02	97	2	6.1508259E-03	6.2739216E-02
45	2	8.7122709E-02	3.0945832E-02	98	2	6.9542497E-02	6.6954583E-02
46	2	4.0420175E-02	0.1134561	99	2	5.0025929E-02	7.1312711E-02
47	2	6.7433029E-02	4.9484331E-02	100	2	7.6181762E-02	0.1293133
48	2	3.1565614E-02	5.5348329E-02	101	2	4.7242548E-02	2.8041681E-02
49	2	6.2981918E-02	4.5933411E-02	102	2	5.1474594E-02	4.7649670E-02
50	2	3.6439944E-02	6.5376133E-02	103	2	1.6576273E-02	8.9545082E-03
51	2	2.3256298E-03	6.1091572E-02	104	2	3.3260591E-02	4.7793541E-02
52	2	3.7388284E-02	6.3234374E-02	105	2	5.7211630E-02	4.9049694E-02
53	2	4.9667925E-02	8.1571952E-02	106	2	9.6157566E-02	5.0513197E-02

107	2	0.1619431	3.6086690E-02	160	2	0.1213369	6.8935312E-02
108	2	6.5522656E-02	5.0114769E-02	161	2	4.5888089E-03	8.6619906E-02
109	2	9.9551871E-02	5.3492881E-02	162	2	7.6253237E-03	7.2223626E-02
110	2	3.2978956E-02	8.2634754E-02	163	2	0.1213599	5.0378244E-02
111	2	5.2812852E-02	6.2103730E-02	164	2	5.0322939E-02	5.5347841E-02
112	2	4.1240700E-02	5.0557747E-02	165	2	5.3692952E-02	1.6964931E-02
113	2	7.0628084E-02	3.3015352E-02	166	2	6.8447582E-02	5.8529630E-02
114	2	3.2155325E-03	5.7052251E-02	167	2	0.3917790	4.3206576E-02
115	2	0.2955990	0.1668376	168	2	5.7127774E-02	1.4987160E-02
116	2	0.1707724	1.8475348E-02	169	2	8.3935164E-02	8.4336311E-02
117	2	5.5750683E-02	5.8639225E-02	170	2	5.8236878E-02	5.1324982E-02
118	2	3.3989530E-02	5.5715863E-02	171	2	2.7824761E-02	5.8796186E-02
119	2	9.6589506E-02	6.0960405E-02	172	2	1.0342170E-02	6.6040970E-02
120	2	4.4756867E-02	2.0783002E-02	173	2	0.1130472	4.6403021E-02
121	2	7.3829912E-02	3.9646626E-02	174	2	1.9324374E-03	2.1041799E-02
122	2	0.12158771.57	97980E-02	175	2	2.1123756E-02	5.4619823E-02
123	2	8.4925257E-02	2.0765597E-02	176	2	7.3582875E-03	3.7066460E-02
124	2	5.1617451E-02	5.5218507E-02	177	2	8.1938533E-03	5.8557700E-02
125	2	1.6678156E-02	5.4130182E-02	178	2	3.8392141E-03	5.4025233E-02
126	2	1.7280921E-02	4.7160003E-02	179	2	0.1114586	4.5126867E-02
127	2	6.1498184E-02	5.8692340E-02	180	2	3.7242990E-02	6.1717805E-02
128	2	0.1538038	2.3057584E-02	181	2	1.9190241E-02	4.8077114E-02
129	2	7.0079938E-02	5.9342016E-02	182	2	2.3559626E-02	4.2224646E-02
130	2	4.6549104E-02	1.9712312E-02	183	2	6.7579068E-02	5.4060549E-02
131	2	8.5495159E-02	1.8631760E-02	184	2	0.1495474	0.1292609
132	2	2.9121149E-02	6.0043842E-02	185	2	8.7243997E-02	5.6941222E-02
133	2	5.2379847E-02	6.7772292E-02	186	2	3.9188843E-03	4.8121687E-02
134	2	2.2424161E-02	5.7133570E-02	187	2	2.0487398E-02	6.9975689E-02
135	2	1.4448942E-02	7.5433329E-02	188	2	0.1687348	5.1983319E-02
136	2	0.12594440	4.9683046E-02	189	2	1.9494988E-02	3.7827380E-02
137	2	2.1840738E-02	3.7463218E-02	190	2	3.1080063E-02	2.2208920E-02
138	2	4.6944050E-03	6.5001808E-02	191	2	3.3260230E-02	3.4254942E-02
139	2	6.5334700E-02	3.5716325E-02	192	2	0.1394177	6.1570350E-02
140	2	0.1371943	1.9875966E-02	193	2	4.6089880E-02	8.3428882E-02
141	2	1.6964525E-02	8.1631653E-02	194	2	0.1716556	5.5070791E-02
142	2	0.1015151	2.9490849E-02	195	2	5.3486563E-02	7.9588860E-02
143	2	1.8315334E-02	4.2935792E-02	196	2	4.7258500E-02	0.1550756
144	2	3.3113606E-02	3.9712951E-02	197	2	3.3940416E-02	8.4298290E-02
145	2	0.1321511	6.5156333E-02	198	2	2.1830970E-02	5.5529773E-02
146	2	4.2373762E-02	6.5489277E-02	199	2	4.0602647E-03	5.6944489E-02
147	2	7.2913952E-03	5.9004165E-02	200	2	1.0020436E-02	5.4907784E-02
148	2	6.3795552E-02	4.7587328E-02	201	2	3.7182402E-02	4.9482226E-02
149	2	0.2103213	8.3966292E-02	202	2	4.2706481E-03	0.1606795
150	2	0.1109417	4.0622294E-02	203	2	3.1993993E-02	5.3374309E-02
151	2	0.1395433	5.4257885E-02	204	2	7.7867016E-02	2.8862229E-02
152	2	4.7899157E-02	0.1202568	205	2	4.5282654E-02	4.6392612E-02
153	2	6.8555456E-02	6.0329355E-02	206	2	2.3415735E-02	6.4310737E-02
154	2	4.7816616E-03	3.7393130E-02	207	2	0.2160491	5.5371974E-02
155	2	1.3575777E-02	2.2464391E-02	208	2	6.4673787E-03	0.7566715
156	2	3.7566062E-02	1.2979862E-02	209	2	1.7433336E-02	5.5316355E-02
157	2	9.9475965E-02	3.7282106E-02	210	2	2.2904482E-05	4.6597488E-02
158	2	0.1179500	4.4079732E-02	211	2	0.1147942	5.9636269E-02
159	2	0.1407464	8.6003169E-02	212	2	7.6124631E-02	7.3863171E-02

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213	2	5.3303089E-02	6.8604030E-02	266	2	0.1101487	5.3302426E-02
214	2	5.0968453E-02	3.0148089E-02	267	2	1.0786332E-02	6.1759170E-02
215	2	0.1519960	5.0956085E-02	268	2	0.1050531	6.6191122E-02
216	2	9.9529408E-02	5.1027179E-02	269	2	8.6179286E-02	3.9748408E-02
217	2	1.2661025E-02	3.2987788E-02	270	2	7.1867579E-03	4.2479008E-02
218	2	1.1452804E-02	1.9742427E-02	271	2	9.5057264E-02	5.1139485E-02
219	2	5.9550323E-02	8.1923068E-02	272	2	0.1684978	2.7940258E-02
220	2	8.4897578E-02	3.2943714E-02	273	2	1.2539796E-02	7.8760505E-02
221	2	0.1265632	4.4650719E-02	274	2	6.4291013E-03	4.0083379E-02
222	2	0.1636941	6.5610617E-02	275	2	7.7832922E-02	5.9734005E-02
223	2	7.2806217E-02	7.1486212E-02	276	2	0.1206533	4.1501082E-02
224	2	9.7682148E-02	0.1179187	277	2	5.6917291E-02	4.7410175E-02
225	2	4.3897450E-02	5.7352368E-02	278	2	3.6365487E-02	5.2262317E-02
226	2	5.3755235E-02	0.1008180	279	2	7.0993602E-02	4.4433460E-02
227	2	7.2366193E-02	0.1015658	280	2	4.3315183E-02	6.5824345E-02
228	2	0.2446719	3.0301256E-02	281	2	7.4349679E-02	0.1840891
229	2	8.7504514E-02	7.1135163E-02	282	2	9.5265292E-02	8.2059130E-02
230	2	6.1651595E-02	7.9552941E-02	283	2	0.1238719	3.2222025E-02
231	2	0.1204444	5.2140828E-02	284	2	9.5689654E-02	8.1871301E-02
232	2	1.0141240E-02	4.9205273E-02	285	2	0.2603333	0.1265700
233	2	2.9848058E-02	5.8265250E-02	286	2	0.1145876	5.6587834E-02
234	2	9.4402153E-03	5.9602566E-02	287	2	6.2036499E-02	5.0692923E-02
235	2	4.3066703E-03	7.0935003E-02	288	2	0.1287113	5.4666784E-02
236	2	8.8652149E-03	8.9759074E-02	289	2	7.6434948E-02	0.2836348
237	2	8.2147315E-02	3.4737453E-02	290	2	3.7384395E-02	5.1759280E-02
238	2	8.9766808E-02	2.2139974E-02	291	2	5.5710252E-02	7.9793416E-02
239	2	5.7522781E-02	8.4488504E-02	292	2	3.0785400E-02	6.5113649E-02
240	2	1.9196231E-02	7.9581648E-02	293	2	0.1471515	6.0857952E-02
241	2	3.2749761E-02	6.2474120E-02	294	2	1.6241783E-02	5.7650033E-02
242	2	7.4022703E-02	4.1953418E-02	295	2	5.5924322E-02	3.0042961E-02
243	2	2.8199911E-02	5.1889852E-02	296	2	3.6231801E-02	4.6817876E-02
244	2	0.1044558	6.7030467E-02	297	2	5.1834852E-02	7.3877349E-02
245	2	3.6798760E-02	8.6043261E-02	298	2	1.36161041E-02	4.0530287E-02
246	2	2.8888844E-02	3.2008789E-02	299	2	0.1356705	3.7863705E-02
247	2	0.1416059	4.2976875E-02	300	2	6.1036717E-02	5.6248203E-02
248	2	1.1433396E-02	4.2970411E-02	301	2	3.2080885E-02	8.4085375E-02
249	2	8.4602527E-02	4.8343554E-02	302	2	6.3935861E-02	5.3747039E-02
250	2	0.1223382	4.7623150E-02	303	2	8.4782112E-03	5.2066682E-02
251	2	5.3186379E-02	7.3586397E-02	304	2	0.1483902	3.3199754E-02
252	2	9.5278546E-03	7.3705859E-02	305	2	1.6334236E-02	4.4072583E-02
253	2	3.6003832E-02	6.3980505E-02	306	2	2.6464649E-02	6.5281264E-02
254	2	0.2368298	6.8291128E-02	307	2	3.3093113E-02	6.1957162E-02
255	2	9.8380804E-02	5.4853976E-02	308	2	0.1980580	6.3871555E-02
256	2	0.1627849	6.9135174E-02	309	2	3.2279663E-02	3.2386724E-02
257	2	4.3205872E-02	5.5737238E-02	310	2	7.2981618E-02	2.3961281E-02
258	2	7.7809721E-02	5.7787050E-02	311	2	1.0505857E-02	6.9583394E-02
259	2	9.2956319E-02	6.5993495E-02	312	2	2.7589556E-02	4.9572527E-02
260	2	0.1799912	5.1761754E-02	313	2	9.8100808E-03	4.5669530E-02
261	2	5.3744238E-02	0.1043923	314	2	0.1137452	6.7695037E-02
262	2	2.3056671E-02	5.9782274E-02	315	2	7.2744422E-02	8.2279146E-02
263	2	6.4727686E-02	7.6576352E-02	316	2	9.1899738E-02	5.7338905E-02
264	2	0.1216711	5.7241727E-02	317	2	3.0302284E-02	7.9181217E-02
265	2	0.3209038	7.3334612E-02	318	2	4.4912171E-02	5.0130807E-02

319	2	1.7556440E-02	4.8635080E-02	372	2	5.7035097E-04	5.1698089E-02
320	2	7.8613654E-02	7.7345565E-02	373	2	4.2432569E-02	7.5730167E-02
321	2	7.6832488E-02	6.1814152E-02	374	2	1.4777359E-02	4.6410918E-02
322	2	5.3756524E-02	3.1926371E-02	375	2	3.2787994E-02	6.7062199E-02
323	2	0.1039997	5.9751723E-02	376	2	5.1232055E-02	5.1038437E-02
324	2	5.1588386E-02	6.9555439E-02	377	2	5.4714889E-03	4.4249024E-02
325	2	4.1753639E-02	4.2831965E-02	378	2	2.0741522E-02	8.2121037E-02
326	2	9.4200537E-02	5.0937343E-02	379	2	8.3291810E-04	4.7168367E-02
327	2	0.2072446	5.0402451E-02	380	2	9.0837017E-02	3.1095194E-02
328	2	1.9067375E-02	0.1326806	381	2	2.3047213E-02	7.5219192E-02
329	2	5.2268062E-02	4.6196971E-02	382	2	4.1621886E-02	7.2013229E-02
330	2	9.3951240E-02	5.7576288E-02	383	2	3.9833665E-02	5.4039750E-02
331	2	2.5747674E-02	4.7689557E-02	384	2	9.0728611E-02	5.1099844E-02
332	2	9.1002814E-02	5.8826875E-02	385	2	0.1397989	8.3080105E-02
333	2	5.2193556E-02	7.2790295E-02	386	2	4.4620942E-02	4.7020800E-02
334	2	1.3168592E-02	6.9407247E-02	387	2	0.1943297	4.5590665E-02
335	2	7.8425752E-03	5.0967094E-02	388	2	3.5363667E-02	3.1711053E-02
336	2	2.4083138E-02	0.1204861	389	2	6.8349316E-04	4.6826027E-02
337	2	2.9606896E-02	6.9861956E-02	390	2	0.1459142	1.5171967E-02
338	2	3.2791542E-03	8.4400952E-02	391	2	8.0266237E-02	6.2088851E-02
339	2	5.5754423E-02	7.2532296E-02	392	2	1.9203138E-02	5.7292338E-02
340	2	1.9297315E-02	0.1260565	393	2	7.1140945E-02	4.8464339E-02
341	2	0.1221153	0.1444877	394	2	5.2328020E-02	6.8254374E-02
342	2	0.1836627	7.1748078E-02	395	2	7.3376082E-02	5.7114784E-02
343	2	2.6211066E-02	1.8517802E-02	396	2	6.3577600E-02	4.6294525E-02
344	2	0.1165744	4.8370954E-02	397	2	1.2584946E-03	4.2093381E-02
345	2	7.7690028E-02	5.5468269E-02	398	2	1.5184088E-02	4.1216429E-02
346	2	8.6576715E-03	4.8304219E-02	399	2	2.0581085E-02	4.8308022E-02
347	2	3.0842939E-02	5.0762452E-02	400	2	2.4160979E-02	6.1195992E-02
348	2	3.4306709E-02	7.1425423E-02	401	2	0.1186002	6.8436407E-02
349	2	8.0743775E-02	3.7325677E-02	402	2	6.6469684E-02	3.3913091E-02
350	2	1.8435411E-02	5.4139994E-02	403	2	3.7167817E-02	4.7778640E-02
351	2	3.2321534E-03	6.7153610E-02	404	2	0.1164128	4.5537926E-02
352	2	4.0109031E-02	0.2683479	405	2	5.5276338E-02	8.6885706E-02
353	2	7.1211591E-02	9.8831236E-02	406	2	0.1067105	6.1804399E-02
354	2	4.9363904E-02	4.6027701E-02	407	2	6.9141306E-02	5.4143526E-02
355	2	3.8666770E-02	6.8053164E-02	408	2	8.5148111E-02	5.0867260E-02
356	2	5.1464181E-02	5.0975636E-02	409	2	1.0854620E-02	3.4957122E-02
357	2	2.9909359E-02	8.1957847E-02	410	2	7.3132701E-03	4.1457672E-02
358	2	8.5642956E-02	6.1596613E-02	411	2	3.9495885E-02	6.5525882E-02
359	2	0.1428766	3.1131679E-02	412	2	0.1621865	4.4940747E-03
360	2	6.8073608E-02	4.3255195E-02	413	2	2.7274314E-02	9.0562209E-02
361	2	3.6340430E-03	2.4262222E-02	414	2	9.4924212E-02	6.5175451E-02
362	2	9.6433230E-02	6.5032646E-02	415	2	7.8715859E-03	7.2900273E-02
363	2	0.1015370	5.0547209E-02	416	2	7.6369330E-02	0.1102054
364	2	4.2306870E-02	3.0492617E-02	417	2	1.1159037E-02	4.9953319E-02
365	2	8.6678125E-02	2.2774333E-02	418	2	1.6781913E-02	5.9157480E-02
366	2	8.0561943E-02	4.8459731E-02	419	2	9.4187953E-02	3.6562186E-02
367	2	3.5065666E-02	0.1246275	420	2	1.5712211E-02	7.7645145E-02
368	2	5.6423653E-02	5.6726296E-02	421	2	0.1357202	4.8308227E-02
369	2	9.1383748E-02	0.1002052	422	2	9.6314792E-03	5.2776337E-02
370	2	9.0465531E-02	6.9393113E-02	423	2	3.5887018E-02	4.6999138E-02
371	2	8.2488284E-02	6.2411986E-02	424	2	6.3044518E-02	2.9852998E-02

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425	2	6.0450430E-03	5.4368593E-02	478	2	5.8667913E-02	1.1793434E-02
426	2	1.9245146E-02	0.8440393	479	2	8.5019536E-02	5.3816400E-02
427	2	7.1171016E-02	7.2131597E-02	480	2	3.2430448E-02	4.2968925E-02
428	2	6.7888290E-02	7.7404454E-02	481	2	2.9151317E-02	7.0211180E-02
429	2	5.5506688E-02	7.5137384E-02	482	2	2.0972826E-02	3.0125555E-02
430	2	0.2476660	1.9120978E-02	483	2	9.0942435E-02	6.9475524E-02
431	2	2.9247994E-02	6.0947556E-02	484	2	0.1594650	8.8435039E-02
432	2	6.4376746E-03	5.6334939E-02	485	2	0.1471007	3.7287861E-02
433	2	1.3259222E-02	3.8407531E-02	486	2	6.9947779E-02	6.6194192E-02
434	2	9.5137425E-02	5.0707649E-02	487	2	2.9659139E-03	3.6363807E-02
435	2	1.6477322E-02	2.4710726E-02	488	2	0.1435275	6.4530842E-02
436	2	4.0688049E-02	4.2610008E-02	489	2	0.1113859	7.8945436E-02
437	2	2.2278026E-02	5.1053967E-02	490	2	3.9282557E-02	4.3159917E-02
438	2	2.4768834E-03	6.1949339E-02	491	2	6.1981261E-02	3.8630560E-02
439	2	1.9059179E-02	7.1737774E-02	492	2	1.9839078E-02	7.6724023E-02
440	2	4.2819299E-02	5.2731704E-02	493	2	5.7827588E-02	5.1710501E-02
441	2	9.5047787E-02	8.5911974E-02	494	2	2.5132930E-02	3.8794026E-02
442	2	2.2842348E-02	6.0070943E-02	495	2	4.0411420E-02	5.6560256E-02
443	2	8.9984555E-03	0.1145708	496	2	0.1284811	8.2200252E-02
444	2	4.0717803E-02	4.3459535E-02	497	2	8.3482713E-03	6.4073250E-02
445	2	1.8620146E-02	7.6692447E-02	498	2	0.1010389	7.6155193E-02
446	2	5.5759195E-03	1.6390927E-02	499	2	1.0805682E-02	6.2696621E-02
447	2	5.9370346E-02	4.4554576E-02	500	2	6.1287235E-02	5.4863572E-02
448	2	1.4559478E-02	4.8129562E-02	501	2	4.9389787E-03	6.3365564E-02
449	2	2.1993279E-02	4.8157401E-02	502	2	5.8028206E-02	6.8783589E-02
450	2	3.4803309E-02	0.1230489	503	2	1.0797053E-02	4.3770362E-02
451	2	0.1713544	5.8508251E-02	504	2	6.0769171E-02	5.1254261E-02
452	2	4.7787406E-02	5.6298438E-02	505	2	2.5214817E-02	4.5434184E-02
453	2	0.1166827	9.4757400E-02	506	2	1.1230638E-02	6.0345143E-02
454	2	0.1062214	4.4456623E-02	507	2	2.5707522E-02	4.3819964E-02
455	2	1.4152073E-02	3.3927958E-02	508	2	2.2795934E-02	4.3428607E-02
456	2	7.3292643E-02	2.9449234E-02	509	2	6.2227350E-02	5.0626360E-02
457	2	3.0571070E-02	6.2851891E-02	510	2	0.1672506	1.6204851E-02
458	2	0.1430519	1.2923073E-02	511	2	1.8789757E-02	5.9325770E-02
459	2	5.7888649E-02	4.0874809E-02	512	2	2.6002435E-02	4.6509504E-02
460	2	0.1176199	5.1488835E-02	513	2	8.3665326E-02	5.5244900E-02
461	2	8.8838212E-02	3.5273183E-02	514	2	3.0448386E-02	7.2145104E-02
462	2	8.3055459E-02	5.2958019E-02	515	2	0.2885319	6.7223296E-02
463	2	7.8486003E-02	4.2060331E-02	516	2	7.5610541E-02	5.3584695E-02
464	2	3.7651348E-03	4.5594558E-02	517	2	0.1016252	5.0296757E-02
465	2	8.9207999E-02	4.9712803E-02	518	2	4.5112247E-04	3.4339830E-02
466	2	0.1019203	5.3399816E-02	519	2	3.3670895E-02	5.3941634E-02
467	2	3.8159367E-02	6.1574344E-02	520	2	5.0228938E-02	2.8962769E-02
468	2	7.2341422E-03	3.9367147E-02	521	2	6.2303629E-02	5.5208676E-02
469	2	2.1741793E-02	4.9255345E-02	522	2	1.5903739E-03	6.3049272E-02
470	2	1.7596968E-02	6.9260821E-02	523	2	2.3061221E-02	3.7146755E-02
471	2	4.9762029E-02	5.0212156E-02	524	2	1.7828470E-02	2.2134250E-02
472	2	6.2078778E-02	4.3626074E-02	525	2	0.1489135	4.6703458E-02
473	2	0.1199143	6.5188862E-02	526	2	2.9991554E-02	5.4632392E-02
474	2	7.7847488E-02	4.6927504E-02	527	2	3.8592044E-02	6.0892493E-02
475	2	1.0528071E-02	3.3243977E-02	528	2	2.6665970E-03	4.0781397E-02
476	2	8.3635688E-02	6.8293311E-02	529	2	0.1594036	5.7811223E-02
477	2	0.2009909	5.2799009E-02	530	2	4.8654587E-03	6.7245990E-02

LOSP Frequency

531	2	4.1176889E-02	2.3709267E-02	584	2	9.8734237E-02	5.2587286E-02
532	2	0.1111817	5.4197088E-02	585	2	1.3600629E-02	5.6890666E-02
533	2	3.2693163E-02	6.3513294E-02	586	2	5.8635902E-02	5.5508066E-02
534	2	2.7328093E-02	4.5014217E-02	587	2	0.1916036	6.0558066E-02
535	2	5.4314032E-02	6.1339408E-02	588	2	4.9487189E-03	3.9720256E-02
536	2	0.1534035	1.9215468E-02	589	2	1.2524434E-06	6.1670996E-02
537	2	0.1076253	2.8773729E-02	590	2	3.2651860E-02	6.2497389E-02
538	2	1.1158386E-02	5.3947240E-02	591	2	0.1841026	2.5924018E-02
539	2	7.5296283E-02	5.1808033E-02	592	2	0.1599361	7.9104915E-02
540	2	9.0385396E-03	4.2649522E-02	593	2	5.8705285E-02	3.7483837E-02
541	2	1.8177083E-02	2.3263156E-02	594	2	6.6332571E-02	6.2288031E-02
542	2	3.4835618E-02	3.4496263E-02	595	2	2.1626830E-02	5.4086905E-02
543	2	0.2126295	7.1400881E-02	596	2	2.8318062E-02	5.9075210E-02
544	2	0.1055460	3.7581399E-02	597	2	1.5888639E-02	5.6085356E-02
545	2	1.6926570E-02	8.2580023E-02	598	2	3.4715347E-02	5.3803716E-02
546	2	9.7805411E-02	6.6657782E-02	599	2	4.7073562E-02	8.2605429E-02
547	2	2.4215424E-02	5.5337630E-02	600	2	5.9949227E-02	4.7632530E-02
548	2	4.6272218E-02	7.3172510E-02	601	2	4.5089148E-02	8.4848598E-02
549	2	0.1436211	2.3976738E-02	602	2	7.4199475E-02	6.5386884E-02
550	2	9.6115790E-02	5.8919404E-02	603	2	4.3561067E-02	5.8682919E-02
551	2	1.8233091E-02	5.0471243E-02	604	2	7.8390967E-03	4.0172376E-02
552	2	7.0725784E-02	4.9269639E-02	605	2	8.5252132E-03	5.8117419E-02
553	2	8.6573020E-02	3.0284656E-02	606	2	9.4841480E-02	5.9852250E-02
554	2	5.2638784E-02	7.0753917E-02	607	2	9.8654538E-02	3.0269235E-02
555	2	1.2816365E-02	5.8832102E-02	608	2	8.2921065E-02	6.1462905E-02
556	2	9.5106354E-03	9.2986114E-02	609	2	0.1212057	4.6906881E-02
557	2	2.0517757E-02	9.1534806E-03	610	2	4.1389301E-02	7.1643874E-02
558	2	8.8717468E-02	5.4625418E-02	611	2	3.9176088E-02	5.8735572E-02
559	2	0.1110684	6.2296972E-02	612	2	3.6713161E-02	5.9419930E-02
560	2	0.1252603	3.7447959E-02	613	2	2.6123142E-02	4.9866855E-02
561	2	1.4984865E-02	4.1524138E-02	614	2	7.1415707E-02	9.7280517E-02
562	2	4.1367975E-03	7.9745278E-02	615	2	0.1111227	4.7417659E-02
563	2	0.1044355	4.4853296E-02	616	2	3.3226274E-02	0.1087197
564	2	0.1163967	4.7956627E-02	617	2	4.3823916E-02	5.3581931E-02
565	2	6.4864228E-03	5.0529066E-02	618	2	2.3118341E-02	2.6443675E-02
566	2	8.6171895E-02	5.2243385E-02	619	2	1.5971426E-02	5.5992521E-02
567	2	9.6399421E-03	3.5095360E-02	620	2	1.8822059E-02	6.8028539E-02
568	2	0.1216575	5.9582046E-03	621	2	5.8292266E-02	7.5867422E-02
569	2	7.5110182E-02	8.3018109E-02	622	2	5.7775807E-02	6.8557747E-02
570	2	9.4210796E-02	3.5506029E-02	623	2	3.5423137E-02	5.8446933E-02
571	2	0.1249922	2.4129305E-02	624	2	2.9857086E-02	3.0045392E-02
572	2	0.1011262	8.6357377E-02	625	2	0.1548729	7.3036246E-02
573	2	2.4293195E-02	1.3958868E-04	626	2	4.3557987E-02	5.5324331E-02
574	2	6.6678897E-03	6.0641464E-02	627	2	1.5834160E-02	3.4643687E-02
575	2	0.1111950	3.6001086E-02	628	2	3.0191801E-02	0.1435142
576	2	1.9772781E-02	3.8195383E-02	629	2	4.0227517E-02	4.2338185E-02
577	2	0.1155881	3.9210908E-02	630	2	6.4106800E-02	5.5072434E-02
578	2	0.1582730	6.9811329E-02	631	2	0.1264381	6.1384298E-02
579	2	0.1393309	4.6100881E-02	632	2	5.0514825E-03	8.6178847E-02
580	2	1.4094720E-02	3.6581177E-02	633	2	7.4786786E-03	4.3397933E-02
581	2	0.1499535	0.1384112	634	2	5.6379151E-02	3.2816466E-02
582	2	7.1544766E-02	3.3210576E-02	635	2	6.5043934E-02	2.6079575E-02
583	2	3.0904636E-02	5.6052897E-02	636	2	2.3314461E-02	3.8492594E-02

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637	2	7.4765138E-02	3.5316885E-02	690	2	1.2667705E-02	3.7954487E-02
638	2	1.7438317E-02	6.0133357E-02	691	2	9.5690675E-03	4.6867296E-02
639	2	1.9293664E-02	4.6111993E-02	692	2	8.5062332E-02	6.7823358E-02
640	2	1.2643554E-02	2.4007510E-02	693	2	8.1150882E-02	5.9913274E-02
641	2	6.2489253E-04	7.0830792E-02	694	2	1.4643470E-02	5.0341334E-02
642	2	7.2150782E-02	4.0100031E-02	695	2	8.3918739E-03	8.7849453E-02
643	2	8.0911592E-02	0.1194109	696	2	5.2297127E-02	3.3744439E-02
644	2	4.5478538E-02	7.1966670E-02	697	2	0.1712909	6.2485963E-02
645	2	0.1769705	6.1874941E-02	698	2	3.9250352E-03	6.0935359E-02
646	2	1.2616337E-02	2.7611544E-03	699	2	0.1462693	3.8154949E-02
647	2	7.2607398E-03	1.8355193E-02	700	2	6.3159265E-02	6.9870718E-02
648	2	4.3000471E-02	7.4872628E-02	701	2	6.3968100E-02	5.8013394E-02
649	2	0.2969601	1.4178558E-02	702	2	6.1579641E-02	4.4959161E-02
650	2	0.1011943	6.3337684E-02	703	2	3.1537369E-02	5.3400274E-02
651	2	4.0632688E-02	6.2715657E-02	704	2	0.1300344	3.3928584E-02
652	2	1.1991364E-02	5.5741306E-02	705	2	4.2458829E-02	5.9283480E-02
653	2	0.1659063	2.9904557E-02	706	2	6.8499178E-02	6.9322161E-02
654	2	6.7917205E-02	4.2753242E-02	707	2	5.0882958E-03	5.6380130E-02
655	2	2.9479271E-02	5.0045524E-02	708	2	0.1220675	7.6671772E-02
656	2	2.7579788E-02	4.5462053E-02	709	2	6.1601184E-02	5.8840957E-02
657	2	1.8036981E-04	8.4291220E-02	710	2	6.6456713E-02	5.7752959E-02
658	2	3.4363531E-02	5.3680379E-02	711	2	0.1217265	8.9464970E-02
659	2	7.1762465E-02	4.8111111E-02	712	2	4.7997069E-03	9.1979116E-02
660	2	0.1614968	8.2661159E-02	713	2	2.9600626E-02	4.9833305E-02
661	2	2.5125390E-02	5.7087846E-02	714	2	0.1141646	3.4966715E-02
662	2	3.1458316E-05	5.2861001E-02	715	2	7.1259312E-02	5.4746557E-02
663	2	0.1076581	6.9154672E-02	716	2	8.6525485E-02	5.2404400E-02
664	2	2.6002066E-02	8.3394058E-02	717	2	7.5258906E-03	0.1074915
665	2	0.1655387	5.6196619E-02	718	2	7.5813979E-02	7.3007323E-02
666	2	2.6791573E-02	6.6164300E-02	719	2	1.0426432E-04	3.1289287E-02
667	2	0.1573987	0.1171114	720	2	9.9009417E-02	8.5363977E-02
668	2	3.7749022E-02	5.5093467E-02	721	2	8.5491806E-02	6.5238811E-02
669	2	3.2987423E-02	8.3813868E-02	722	2	6.9037460E-02	5.1741201E-02
670	2	7.6349050E-02	4.0644743E-02	723	2	4.4828497E-02	5.3312019E-02
671	2	0.1368688	6.2713839E-02	724	2	7.9834806E-03	4.3321740E-02
672	2	1.0591272E-02	3.0946087E-02	725	2	4.4560567E-02	5.8733013E-02
673	2	5.0359242E-02	1.6257817E-02	726	2	6.5790229E-02	0.1134825
674	2	8.6674066E-03	6.6296309E-02	727	2	2.3019051E-02	5.6591086E-02
675	2	2.7813993E-02	8.4544651E-02	728	2	4.8554119E-02	5.5661380E-02
676	2	9.2147784E-06	4.8570462E-02	729	2	2.3537399E-02	4.0238518E-02
677	2	9.7445004E-02	6.9969364E-02	730	2	3.9333194E-02	5.5914365E-02
678	2	0.1148768	5.1222965E-02	731	2	6.6698194E-02	0.1130819
679	2	1.2202328E-02	9.6307933E-02	732	2	1.9953102E-02	8.5162811E-02
680	2	1.8492657E-03	6.1574437E-02	733	2	6.7289076E-03	4.5264572E-02
681	2	4.1577820E-02	5.2975034E-03	734	2	0.2049074	9.3866616E-02
682	2	0.1904121	6.1209939E-02	735	2	2.6612628E-02	6.4750165E-02
683	2	1.9257167E-02	5.7236783E-02	736	2	6.2301848E-02	6.2756054E-02
684	2	6.0050576E-03	4.2949833E-02	737	2	4.7661878E-02	8.2719140E-02
685	2	1.5237578E-02	6.6271603E-02	738	2	0.1032232	3.4457006E-02
686	2	0.1926419	6.1559569E-02	739	2	2.2303181E-02	4.6219658E-02
687	2	0.2087683	3.2510523E-02	740	2	2.3918238E-02	5.8558207E-02
688	2	0.1375539	7.4545696E-02	741	2	8.8102572E-02	4.6565115E-02
689	2	0.1049394	7.7320695E-02	742	2	1.0482088E-02	3.9032046E-02

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743	2	0.1262614	5.7312895E-02	796	2	7.3502332E-02	3.0958410E-02
744	2	5.1675425E-03	8.5691601E-02	797	2	1.9874904E-02	6.5839842E-02
745	2	0.2224558	6.0074564E-02	798	2	4.0966433E-02	6.1447807E-02
746	2	4.9047388E-02	8.3372809E-02	799	2	0.1398786	1.0918747E-02
747	2	4.1865766E-02	5.8311015E-02	800	2	0.1679944	6.4998902E-02
748	2	3.0313108E-02	5.0959568E-02	801	2	3.6314774E-02	6.1941538E-02
749	2	6.0838363E-03	5.0049245E-02	802	2	3.9298572E-02	2.6657805E-02
750	2	0.1005661	5.2472834E-02	803	2	0.1538339	5.7514656E-02
751	2	4.4937138E-02	5.8725663E-02	804	2	7.3337995E-02	4.7599960E-02
752	2	0.1633220	2.5648102E-02	805	2	3.2945636E-03	4.7168393E-02
753	2	4.3697253E-02	3.0470233E-02	806	2	7.4707083E-02	2.7054267E-02
754	2	3.1902997E-03	6.9020033E-02	807	2	3.7277136E-02	0.1055952
755	2	0.2287423	3.2850880E-02	808	2	2.3415873E-03	6.3766249E-02
756	2	3.0959342E-02	4.8091192E-02	809	2	0.1363300	5.8460943E-02
757	2	9.4964199E-02	5.4733302E-02	810	2	2.7190035E-02	4.6317127E-02
758	2	0.4126163	6.5297917E-02	811	2	6.1469404E-03	5.7112314E-02
759	2	6.2819786E-02	3.2475919E-02	812	2	4.8396634E-03	1.8904120E-02
760	2	4.5202851E-02	4.1657679E-02	813	2	6.1320782E-02	1.3836190E-02
761	2	1.2994861E-02	6.9093086E-02	814	2	5.1850434E-02	4.4858344E-02
762	2	5.1764749E-02	3.1948324E-02	815	2	2.9650316E-02	4.5002442E-02
763	2	0.1174101	3.8581774E-02	816	2	5.2909732E-02	5.2177414E-02
764	2	0.1159837	7.1235195E-02	817	2	7.2582185E-02	7.4897297E-02
765	2	0.1918874	3.1310797E-02	818	2	2.7631711E-02	6.0897086E-02
766	2	9.2250086E-02	2.7791988E-02	819	2	0.1479920	3.7642244E-02
767	2	0.1249470	6.7267433E-02	820	2	6.8155609E-02	0.1125266
768	2	9.5545508E-02	5.5780765E-02	821	2	4.8517105E-03	3.7218831E-02
769	2	1.9758463E-02	6.1134670E-02	822	2	1.0592137E-02	5.7463851E-02
770	2	6.9996879E-02	5.1670320E-02	823	2	8.4417984E-02	4.8830070E-02
771	2	8.2011253E-02	3.5231430E-02	824	2	1.3834529E-02	5.6467827E-02
772	2	9.7375177E-02	0.1671166	825	2	3.1368252E-02	5.5263419E-02
773	2	9.4023019E-02	3.9594948E-02	826	2	0.1733319	2.1836525E-02
774	2	0.1476692	5.1349733E-02	827	2	0.1083883	7.8432508E-02
775	2	4.5043502E-02	5.9255589E-02	828	2	3.4713827E-02	5.4580510E-02
776	2	7.7810525E-03	3.5913724E-02	829	2	6.9029287E-02	4.9784124E-02
777	2	4.3228015E-02	5.2891221E-02	830	2	8.6368740E-02	0.1490737
778	2	4.5226362E-02	6.0764175E-02	831	2	1.0906375E-02	4.3313839E-02
779	2	1.1131806E-02	4.4246893E-02	832	2	2.3066474E-02	6.1758589E-02
780	2	7.1365029E-02	4.6598349E-02	833	2	0.1874645	0.1090954
781	2	0.1534233	3.6120445E-02	834	2	2.9084072E-02	5.4830268E-02
782	2	4.5220446E-02	8.1419945E-02	835	2	3.2290604E-02	0.1488167
783	2	4.0321246E-02	4.4738114E-02	836	2	0.1759330	4.1155804E-02
784	2	9.2383265E-02	6.0023449E-02	837	2	1.4150621E-02	6.6617176E-02
785	2	0.1957802	3.8790107E-02	838	2	0.1159350	3.4868266E-02
786	2	6.2168173E-02	4.6073996E-02	839	2	4.2492867E-02	5.3134032E-02
787	2	0.1421046	4.9145039E-02	840	2	0.2267004	6.1173547E-02
788	2	4.6885949E-02	2.6521334E-02	841	2	0.1055374	4.8246101E-02
789	2	2.9114503E-02	5.4491013E-02	842	2	0.1955333	6.4037368E-02
790	2	9.4231784E-02	2.7507348E-02	843	2	2.6470978E-02	4.3714132E-02
791	2	3.5982575E-02	1.0827117E-02	844	2	6.8814188E-02	3.6620829E-02
792	2	0.2368337	6.6368714E-02	845	2	5.3744357E-02	5.1303342E-02
793	2	8.9359716E-02	4.3520104E-02	846	2	0.2325092	6.4085588E-02
794	2	1.8088779E-03	4.3661300E-02	847	2	6.0120583E-02	8.2462795E-02
795	2	0.1065253	6.1910994E-02	848	2	0.1314537	6.8409018E-02

LOSP Frequency

849	2	0.1753536	7.1260124E-02	902	2	9.5153023E-03	0.1135739
850	2	7.0344500E-02	3.3605255E-02	903	2	1.3199417E-02	7.3137805E-02
851	2	1.9798214E-02	5.2160297E-02	904	2	0.1678364	1.6668446E-02
852	2	4.2904954E-02	8.3821729E-02	905	2	3.6986031E-02	6.3447930E-02
853	2	8.9058951E-02	4.7565345E-02	906	2	0.1057777	4.8246510E-02
854	2	0.1282351	5.6744356E-02	907	2	4.0126458E-04	5.1750962E-02
855	2	6.3481316E-02	9.3530454E-03	908	2	0.1166051	8.0631763E-02
856	2	5.8032546E-02	5.0135382E-02	909	2	9.2176422E-03	5.7477903E-02
857	2	4.0085889E-02	3.6050949E-02	910	2	0.1591447	4.3792546E-02
858	2	6.8856232E-02	5.4024547E-02	911	2	7.9803653E-02	4.5938723E-02
859	2	0.1148059	5.0873883E-02	912	2	6.8583310E-02	4.3378543E-02
860	2	3.3868130E-02	6.0785957E-02	913	2	3.3945039E-02	3.2092944E-02
861	2	1.5916673E-02	6.5029919E-02	914	2	1.5667401E-02	7.0161469E-02
862	2	2.4237448E-02	5.5624705E-02	915	2	1.2216034E-02	3.7499879E-02
863	2	3.8375910E-02	5.2462641E-02	916	2	2.6205523E-02	0.1016790
864	2	7.1393445E-02	1.5578598E-02	917	2	0.1345783	5.8055867E-02
865	2	6.6492967E-02	1.9284455E-02	918	2	2.7402056E-02	2.1080213E-02
866	2	1.2682325E-02	5.7558499E-02	919	2	5.2395917E-02	0.1310989
867	2	2.5767982E-02	4.4060186E-02	920	2	9.7891323E-02	5.1882077E-02
868	2	1.9472765E-02	6.1348185E-02	921	2	8.9353189E-02	8.4825300E-02
869	2	1.3780744E-02	5.5703067E-04	922	2	2.7940512E-02	7.4167669E-02
870	2	7.0846647E-02	2.5572006E-02	923	2	5.0494056E-02	7.5886257E-02
871	2	3.2919362E-02	1.4207551E-02	924	2	9.0468293E-03	3.9250501E-02
872	2	0.1041866	7.3884562E-02	925	2	0.2264951	0.1131693
873	2	6.4161711E-04	3.8655475E-02	926	2	5.8889549E-02	6.8122149E-02
874	2	2.7210578E-02	5.3686421E-02	927	2	1.8761925E-03	5.3185504E-02
875	2	5.0297618E-02	3.0133445E-02	928	2	8.0460243E-02	6.2511340E-02
876	2	3.9070893E-02	3.9580315E-02	929	2	5.6212086E-02	4.4533499E-02
877	2	0.2120718	7.1436375E-02	930	2	0.1232555	4.9721505E-02
878	2	0.1207141	8.4866486E-02	931	2	1.7296594E-02	4.0684052E-02
879	2	7.0493244E-02	0.1654756	932	2	2.5122650E-02	5.3252496E-02
880	2	0.2736189	5.8602590E-02	933	2	2.4814460E-02	5.1550169E-02
881	2	0.1644907	3.9456370E-03	934	2	0.1282181	6.1518714E-02
882	2	0.1962140	5.2651335E-02	935	2	2.2284815E-02	7.6629288E-02
883	2	1.2658233E-03	5.1541779E-02	936	2	5.1063392E-02	9.5875099E-02
884	2	9.3008801E-03	5.8484331E-02	937	2	2.3033345E-02	7.2320491E-02
885	2	9.6362727E-03	1.4103325E-03	938	2	0.1255693	5.7018407E-02
886	2	0.1297920	5.3637575E-02	939	2	4.9152099E-02	4.2099785E-02
887	2	7.4851378E-03	5.6227304E-02	940	2	0.1012888	9.5059328E-02
888	2	7.1975842E-02	6.0246613E-02	941	2	3.2810923E-02	6.8614222E-02
889	2	3.9767893E-04	7.8546464E-02	942	2	5.5024467E-02	5.5538766E-02
890	2	0.1267434	4.3185066E-02	943	2	0.1023091	0.1114717
891	2	1.7169040E-02	3.8028657E-02	944	2	4.7409418E-03	6.2105045E-02
892	2	1.1717744E-02	6.0267188E-02	945	2	3.1449161E-02	7.2473414E-02
893	2	2.5022475E-03	7.1386263E-02	946	2	3.5321389E-03	0.1433671
894	2	2.8072709E-02	3.6606077E-02	947	2	2.1979650E-02	3.7572309E-02
895	2	8.4042564E-02	2.4940511E-02	948	2	3.2869723E-02	6.4480387E-02
896	2	3.6001012E-02	1.9995760E-02	949	2	1.6251069E-02	3.8868442E-02
897	2	4.6982206E-03	4.1722868E-02	950	2	9.9207006E-02	5.0651442E-02
898	2	1.1233456E-02	7.1409829E-02	951	2	0.1344099	4.9624890E-02
899	2	4.3577466E-02	3.5525009E-02	952	2	1.4781847E-02	5.6478623E-02
900	2	7.6863907E-02	6.3962050E-02	953	2	7.0901610E-02	1.3658642E-02
901	2	4.2035021E-02	6.0748342E-02	954	2	1.0775675E-03	4.9721941E-02

955	2	2.9384814E-02	7.2166272E-02
956	2	9.1045044E-02	5.0976101E-02
957	2	2.7149079E-02	6.9073819E-02
958	2	0.1487750	4.9753133E-02
959	2	0.1281379	3.3494946E-02
960	2	0.2261254	4.8859332E-02
961	2	7.0052288E-02	4.7748096E-02
962	2	5.5682145E-02	5.8132105E-02
963	2	0.1027336	4.9926355E-02
964	2	1.4832543E-02	5.5490620E-02
965	2	5.5337563E-02	8.2520597E-02
966	2	6.2655270E-02	3.8574792E-02
967	2	4.0548373E-02	6.3032411E-02
968	2	6.2372845E-02	7.3105752E-02
969	2	6.0694687E-02	6.0532637E-02
970	2	0.1315373	5.8275152E-02
971	2	5.6101017E-02	5.1635120E-02
972	2	0.1784956	4.4583969E-02
973	2	1.0766561E-02	6.2380012E-02
974	2	4.4256584E-03	3.2339543E-02
975	2	0.1317025	0.1138625
976	2	0.1184175	7.8903660E-02
977	2	8.3891869E-02	7.8740507E-02
978	2	1.3691519E-02	3.7798133E-02
979	2	0.1829110	4.5573011E-02
980	2	1.2218891E-02	3.7880022E-02
981	2	3.5861585E-02	5.3079080E-02
982	2	3.0800391E-03	5.3664945E-02
983	2	3.8509235E-02	4.5091420E-02
984	2	8.6480059E-02	3.8442094E-02
985	2	3.8517248E-02	6.3969307E-02
986	2	2.0938128E-02	6.4974770E-02
987	2	6.3549548E-02	8.5598998E-02
988	2	7.8335539E-02	3.6386952E-02
989	2	6.9398761E-02	5.0369952E-02
990	2	3.5620485E-02	5.3879078E-02
991	2	5.7140426E-03	7.6112233E-02
992	2	4.2732999E-02	4.7157414E-02
993	2	1.0141055E-02	5.9863053E-02
994	2	5.2287020E-02	5.2066594E-02
995	2	0.1110769	6.1749782E-02
996	2	2.7594246E-02	5.7561927E-02
997	2	0.1713138	4.4933297E-02
998	2	2.2145273E-02	7.4739300E-02
999	2	0.1135392	3.7415762E-02
1000	2	4.1683346E-02	5.8121778E-02

LOSP Frequency

Attachment G-23

REMOVECOL2.FOR

```

Character*25 remo
Character*60 infile,outfile
character*55 irse

infile = 'ud4:[bdstapl]lhs.dat'
outfile = 'ud4:[bdstapl]lhslosp.inp'

open(unit=10,name=infile,status='old')
open(unit=15,name=outfile,status='new')

25 read(10,20,end=50)remo,inse
20 format(a,a)
      write(15,30)irse
30 format(a)
goto 25

50 close(10)
close(15)
end

```


LOSP Frequency

Attachment G-24

LHSLOSP.1NP

9.5802836E-02	5.7157081E-02	6.3890698E-03	6.1642252E-02	0.1619431	3.6086690E-02
5.0940670E-02	6.0416732E-02	1.1955368E-02	5.3150438E-02	6.5522656E-02	5.0114769E-02
3.7110481E-02	5.8251712E-02	2.0493850E-02	0.1857526	9.9551871E-02	5.3492881E-02
0.3011881	5.3329077E-02	3.9378010E-02	3.7598554E-02	3.2978956E-02	8.2634754E-02
6.8660229E-02	5.5287939E-02	3.5381936E-02	4.7152728E-02	5.2812852E-02	6.2103730E-02
4.1418765E-02	5.6494150E-02	6.2365174E-02	7.5856574E-02	4.1240700E-02	5.0557747E-02
3.8164826E-03	6.1932772E-02	6.9060028E-02	8.9874759E-02	7.0628084E-02	3.3015352E-02
7.3756211E-02	9.4944753E-02	4.4734307E-02	5.6779027E-02	3.2155325E-03	5.7052251E-02
0.1116926	5.5104259E-02	4.3982375E-02	6.2561035E-02	0.2955990	0.1668376
8.3901752E-03	5.9206437E-02	6.0694963E-02	3.8645752E-02	0.1707724	1.8475348E-02
2.1001803E-04	0.1903778	9.1746241E-02	0.1081921	5.5750683E-02	5.8639225E-02
0.1984308	3.8471486E-02	1.2195393E-02	0.1378729	3.3989530E-02	5.5715863E-02
6.1446220E-02	5.7531755E-02	9.7427778E-03	4.6029627E-02	9.6589506E-02	6.0960405E-02
1.3037866E-02	7.0953816E-02	1.9653393E-02	4.2656578E-02	4.4756867E-02	2.0783002E-02
8.6331956E-02	6.8710037E-02	3.1145809E-02	4.1980006E-02	7.3829912E-02	3.9646626E-02
3.7155967E-02	3.2672279E-02	7.1229465E-02	6.0362123E-02	0.1215877	1.5797980E-02
3.2555930E-02	4.4575006E-02	5.5966739E-02	0.1215986	8.4925257E-02	2.0765597E-02
4.5071386E-02	3.1056585E-02	2.9009812E-02	6.5682463E-02	5.1617451E-02	5.5218507E-02
6.3797474E-02	4.6071306E-02	7.5244442E-02	5.8911454E-02	1.6678156E-02	5.4130182E-02
4.3774538E-02	3.0516183E-02	7.8743502E-02	5.4237224E-02	1.7280921E-02	4.7160003E-02
0.1065058	7.9281092E-02	5.0527163E-02	6.1270196E-02	6.1498184E-02	5.8692340E-02
5.5102311E-02	3.2996830E-02	3.1681322E-02	8.5060455E-02	0.1538038	2.3057584E-02
3.5599325E-02	4.8942689E-02	5.1817849E-02	5.0090570E-02	7.0079938E-02	5.9342016E-02
2.0490789E-03	4.5054294E-02	5.0831504E-02	2.4951266E-02	4.6549104E-02	1.9712312E-02
2.5542006E-02	2.5336470E-02	0.1170508	6.8073846E-02	8.5495159E-02	1.8631760E-02
4.6561282E-02	7.3678486E-02	3.0360568E-02	4.9490560E-02	2.9121149E-02	6.0043842E-02
9.7525999E-02	7.1654484E-02	3.7065927E-02	5.0325025E-02	5.2379847E-02	6.7772292E-02
3.6980748E-02	6.9754799E-03	8.4724374E-02	3.4361262E-02	2.2424161E-02	5.7133570E-02
3.8461756E-02	2.1312614E-03	0.2172877	7.2943039E-02	1.4448942E-02	7.5433329E-02
0.1308402	4.2214524E-02	0.1707056	6.1654635E-02	0.1259440	4.9683046E-02
1.5121906E-02	6.1416168E-02	4.1157823E-02	6.0433898E-02	2.1840738E-02	3.7463218E-02
0.1576969	4.6902116E-02	4.6242714E-02	5.8522064E-02	4.6944050E-03	6.5001808E-02
1.1520608E-02	6.0953710E-02	7.8710178E-03	6.0102671E-02	6.5334700E-02	3.5716325E-02
0.1065259	9.9590011E-02	8.4139876E-02	7.9868220E-02	0.1371943	1.9875966E-02
0.1838354	9.7384945E-02	9.9810176E-02	6.6642977E-02	1.6964525E-02	8.1631653E-02
2.3105722E-02	5.1488169E-02	5.6254819E-02	7.4072085E-02	0.1015151	2.9490849E-02
7.8000881E-02	8.7991364E-02	4.5131359E-02	3.6564417E-02	1.8315334E-02	4.2935792E-02
8.4191918E-02	4.7253303E-02	0.1175776	6.0518596E-02	3.3113606E-02	3.9712951E-02
3.0882679E-02	3.7661687E-02	2.3901181E-02	5.5216696E-02	0.1321511	6.5156333E-02
0.1168672	9.2032492E-02	6.8641901E-02	4.5617305E-02	4.2373762E-02	6.5489277E-02
6.9784876E-03	2.3598088E-02	8.4755734E-02	3.5917133E-02	7.2913952E-03	5.9004165E-02
2.8681975E-02	3.9681610E-02	4.7624674E-02	5.0922580E-02	6.3795552E-02	4.7587328E-02
2.7508037E-02	8.6506894E-03	7.6687358E-02	4.7751363E-02	0.2103213	8.3966292E-02
5.7893977E-02	3.1828873E-02	6.1508259E-03	6.2739216E-02	0.1109417	4.0622294E-02
8.7122709E-02	3.0945832E-02	6.9542497E-02	6.6954583E-02	0.1395433	5.4257885E-02
4.0420175E-02	0.1134561	5.0025929E-02	7.1312711E-02	4.7899157E-02	0.1202568
6.7433029E-02	4.9484331E-02	7.6181762E-02	0.1293133	6.8555456E-03	6.0329355E-02
3.1565614E-02	5.5348329E-02	4.7242548E-02	2.8041681E-02	4.7816616E-03	3.7393130E-02
6.2981918E-02	4.5933411E-02	5.1474594E-02	4.7649670E-02	1.3575777E-02	2.2464391E-02
3.6439944E-02	6.5376133E-02	1.6576273E-02	8.9545082E-03	3.7566062E-02	1.2979862E-02
2.3256298E-03	6.1091572E-02	3.3260591E-02	4.7793541E-02	9.9475965E-02	3.7282106E-02
3.7388284E-02	6.3234374E-02	5.7211630E-02	4.9049694E-02	0.1179500	4.4079732E-02
4.9667925E-02	8.1571952E-02	9.6157566E-02	5.0513197E-02	0.1407464	8.6003169E-02

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0.1213369	6.8935312E-02	5.3303089E-02	6.8604030E-02	0.1101487	5.3302426E-02
4.5888089E-03	8.6619906E-02	5.0968453E-02	3.0148089E-02	1.0786332E-02	6.1759170E-02
7.6253237E-03	7.2223626E-02	0.1519960	5.0956085E-02	0.1050531	6.6191122E-02
0.1213599	5.0378244E-02	9.9529408E-02	5.1027179E-02	8.6179286E-02	3.9748408E-02
5.0322939E-02	5.5347841E-02	1.2661025E-02	3.2987788E-02	7.1867579E-03	4.2479008E-02
5.3692952E-02	1.6964931E-02	1.1452804E-02	1.9742427E-02	9.5057264E-02	5.1139485E-02
6.8447582E-02	5.8529630E-02	5.9550323E-02	8.1923068E-02	0.1684978	2.7940258E-02
0.3917790	4.3206576E-02	8.4897578E-02	3.2943714E-02	1.2539796E-02	7.8760505E-02
5.7127774E-02	1.4987160E-02	0.1265632	4.4650719E-02	6.4291013E-03	4.0083379E-02
8.3935164E-02	8.4336311E-02	0.1636941	6.5610617E-02	7.7832922E-02	5.9374005E-02
5.8236878E-02	5.1324982E-02	7.2806217E-02	7.1486212E-02	0.1206533	4.1501082E-02
2.7824761E-02	5.8796186E-02	9.7682148E-02	0.1179187	5.6917291E-02	4.7410175E-02
1.0342170E-02	6.6040970E-02	4.3897450E-02	5.7352368E-02	3.6365487E-02	5.2262317E-02
0.1130472	4.6403021E-02	5.3755235E-02	0.1008180	7.0993602E-03	4.4433460E-02
1.9324374E-03	2.1041799E-02	7.2366193E-02	0.1015658	4.3315183E-02	6.5824345E-02
2.1123756E-02	5.4619823E-02	0.2446719	3.0301256E-02	7.4349679E-02	0.1840891
7.3582875E-03	3.7066460E-02	8.7504514E-02	7.1135163E-02	9.5265292E-02	8.2059130E-02
8.1938533E-03	5.8557700E-02	6.1651595E-02	7.9552941E-02	0.1238719	3.2222025E-02
3.8392141E-03	5.4025233E-02	0.1204444	5.2140828E-02	9.5689654E-02	8.1871301E-02
0.1114586	4.5126867E-02	1.0141240E-02	4.9205273E-02	0.2603333	0.1265700
3.7242990E-02	6.1717805E-02	2.9848058E-02	5.8265250E-02	0.1145876	5.6587834E-02
1.9190241E-02	4.8077114E-02	9.4402153E-03	5.9602566E-02	6.2036499E-02	5.0692923E-02
2.3559626E-02	4.2224646E-02	4.3066703E-03	7.0935003E-02	0.1287113	5.4666784E-02
6.7579068E-02	5.4060549E-02	8.8652149E-03	8.9759074E-02	7.6434948E-02	0.2836348
0.1495474	0.1292609	8.2147315E-02	3.4737453E-02	3.7384395E-02	5.1759280E-02
8.7243997E-02	5.6941222E-02	8.9766808E-02	2.2139974E-02	5.5710252E-02	7.9793416E-02
3.9188843E-03	4.8121687E-02	5.7522781E-02	8.4488504E-02	3.0785400E-02	6.5113649E-02
2.0487398E-02	6.9975689E-02	1.9196231E-02	7.9581648E-02	0.1471515	6.0857952E-02
0.1687348	5.1983319E-02	3.2749761E-02	6.2474120E-02	1.6241783E-02	5.7650033E-02
1.9494988E-02	3.7827380E-02	7.4022703E-02	4.1953418E-02	5.5924322E-02	3.0042961E-02
3.1080063E-02	2.2208920E-02	2.8199911E-02	5.1889852E-02	3.6231801E-02	4.6817876E-02
3.3260230E-02	3.4254942E-02	0.1044558	6.7030467E-02	5.1834852E-02	7.3877349E-02
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4.6089880E-02	8.3428882E-02	2.8888844E-02	3.2008789E-02	0.1356705	3.7863705E-02
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4.7258500E-02	0.1550756	8.4602527E-02	4.8343554E-02	6.3935861E-02	5.3747039E-02
3.3940416E-02	8.4298290E-02	0.1223382	4.7623150E-02	8.4782112E-03	5.1066682E-02
2.1830970E-02	5.5529773E-02	5.3186379E-02	7.3586397E-02	0.1483902	3.3199754E-02
4.0602647E-03	5.6944489E-02	9.5278546E-03	7.3705859E-02	1.6334236E-02	4.4072583E-02
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3.7182402E-02	4.9482226E-02	0.2368298	6.8291128E-02	3.3093113E-02	6.1957162E-02
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7.7867016E-02	2.8862229E-02	4.3205872E-02	5.5737238E-02	7.2981618E-02	2.3961281E-02
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7.6124631E-02	7.3863171E-02	0.3209038	7.3334612E-02	4.4912171E-02	5.0130807E-02

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9.3951240E-02	5.7576288E-02	3.9833665E-02	5.4039750E-02	4.0688049E-02	4.2610008E-02
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9.1002814E-02	5.8826875E-02	0.1397989	8.3080105E-02	2.4768834E-03	6.1949339E-02
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1.3168592E-02	6.9407247E-02	0.1943297	4.5590665E-02	4.2819299E-02	5.2731704E-02
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2.9606896E-02	6.9861956E-02	9.1459142	1.5171967E-02	8.9984555E-03	0.1145708
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3.8666770E-02	6.8053164E-02	8.5148111E-02	5.0867260E-02	8.8838212E-02	3.5273183E-02
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8.5642956E-02	6.1596613E-02	3.9495885E-02	6.5525882E-02	3.7651348E-03	4.5594558E-02
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8.2488284E-02	6.2411986E-02	6.3044518E-02	2.9852998E-02	0.2009909	5.2799009E-02

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8.5019536E-02	5.3816400E-02	0.1111817	5.4197088E-02	1.3600629E-02	5.6890666E-02
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6.1981261E-02	3.8630560E-02	0.1055460	3.7581399E-02	1.5888639E-02	5.6085356E-02
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1.7438317E-02	6.0133357E-02	9.5690675E-03	4.6867296E-02	5.1675425E-03	8.5691601E-02
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6.2489253E-04	7.0830792E-02	1.4643470E-02	5.0341334E-02	4.1865766E-02	5.8311015E-02
7.2150782E-02	4.0100031E-02	8.3918739E-03	8.7849453E-02	3.0313108E-02	5.0959568E-02
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2.9479271E-02	5.0045524E-02	0.1220675	7.6671772E-02	1.2994861E-02	6.9093086E-02
2.7579788E-02	4.5462053E-02	6.1601184E-02	5.8840957E-02	5.1764749E-02	3.1948324E-02
1.8036981E-04	8.4291220E-02	6.6456713E-02	5.7752959E-02	0.1174101	3.8581774E-02
3.4363531E-02	5.3680379E-02	0.1217265	8.9464970E-02	0.1159837	7.1235195E-02
7.1762465E-02	4.8111111E-02	4.7997069E-03	9.1979116E-02	0.1918874	3.1310797E-02
0.1614968	8.2661159E-02	2.9600626E-02	4.9833305E-02	9.2250086E-02	2.7791988E-02
2.5125390E-02	5.7087846E-02	0.1141646	3.4966715E-02	0.1249470	6.7267433E-02
3.1458316E-05	5.2861001E-02	7.1259312E-02	5.4746557E-02	9.5545508E-02	5.5780765E-02
0.1076581	6.9154672E-02	8.6525485E-02	5.2404400E-02	1.9758463E-02	6.1134670E-02
2.6002066E-02	8.3394058E-02	7.5258906E-03	0.1074915	6.9996879E-02	5.1670320E-02
0.1655387	5.6196619E-02	7.5813979E-02	7.3007323E-02	8.2011253E-02	3.5231430E-02
2.6791573E-02	6.6164300E-02	1.0426432E-04	3.1289287E-02	9.7375177E-02	0.1671166
? .1573987	0.1171114	9.9009417E-02	8.5363977E-02	9.4023019E-02	3.9594948E-02
3.7749022E-02	5.5093467E-02	8.5491806E-02	6.5238811E-02	0.1476692	5.1349733E-02
3.2987423E-02	8.3813868E-02	6.9037460E-02	5.1741201E-02	4.5043502E-02	5.9255589E-02
7.6349050E-02	4.0644743E-02	4.4828497E-02	5.3312019E-02	7.7810525E-03	3.5913724E-02
0.1368688	6.2713839E-02	7.9834806E-03	4.3321740E-02	4.3228015E-02	5.2891221E-02
1.0591272E-02	3.0946087E-02	4.4560567E-02	5.8733013E-02	4.5226362E-02	6.0764175E-02
5.0359242E-02	1.6257817E-02	6.5790229E-02	0.1134825	1.1131806E-02	4.4246893E-02
8.6674066E-03	6.6296309E-02	2.3019051E-02	5.6591086E-02	7.1365029E-02	4.6598349E-02
2.7813993E-02	8.4544651E-02	4.8554119E-02	5.5661380E-02	0.1534233	3.6120445E-02
9.2147784E-06	4.8570462E-02	2.3537399E-02	4.0238518E-02	4.5220446E-02	8.1419945E-02
9.7445004E-02	6.9969364E-02	3.9333194E-02	5.5914365E-02	4.0321246E-02	4.4738114E-02
0.1148768	5.1222965E-02	6.6698194E-02	0.1130819	9.2383265E-02	6.0023449E-02
1.2202328E-02	9.6307933E-02	1.9953102E-02	8.5162811E-02	0.1957802	3.8790107E-02
1.8492657E-03	6.1574437E-02	? .7289076E-03	4.5264572E-02	8.2168173E-02	4.6073996E-02
4.1577820E-02	5.2975034E-03	0.2049074	9.3866616E-02	0.1421046	4.9145039E-02
0.1904121	6.1209939E-02	2.6612628E-02	6.4750165E-02	4.6885949E-02	2.6521334E-02
1.9257167E-02	5.7236783E-02	6.2301848E-02	6.2756054E-02	2.9114503E-02	5.4491013E-02
6.0050576E-03	4.2949833E-02	4.7661878E-02	8.2719140E-02	9.4231784E-02	2.7507348E-02
1.5237578E-02	6.6271603E-02	0.1032232	3.4457006E-02	3.5982575E-02	1.0827117E-02
0.1926419	6.1559569E-02	2.2303181E-02	4.6219658E-02	0.2368337	6.6368714E-02
0.2087683	3.2510523E-02	2.3918238E-02	5.8558207E-02	8.9359716E-02	4.3520104E-02
0.1375539	7.4545696E-02	8.8102572E-02	4.6565115E-02	1.8088779E-03	4.3661300E-02
0.1049394	7.7320695E-02	1.0482088E-02	3.9032046E-02	0.1065253	6.1910994E-02

LOSP Frequency

7.3502332E-02	3.0958410E-02	0.1753536	7.1260124E-02	9.5153023E-03	0.1135739
1.9874904E-02	6.5839842E-02	7.0344500E-02	3.3605255E-02	1.3199417E-02	7.3137805E-02
4.0966433E-02	6.1447807E-02	1.9798214E-02	5.2160297E-02	0.1678364	1.6668446E-02
? .1398786	1.0918747E-02	4.2904954E-02	8.3821729E-02	3.6986031E-02	6.3447930E-02
0.1679944	6.4998902E-02	8.9058951E-02	4.7565345E-02	0.1057777	4.8246510E-02
3.6314774E-02	6.1941538E-02	0.1282351	5.6744356E-02	4.0126458E-04	5.1750962E-02
3.9298572E-02	2.6657805E-02	6.3481316E-02	9.3530454E-03	0.1166051	8.0631763E-02
0.1538339	5.7514656E-02	5.8032546E-02	5.0135382E-02	9.2176422E-03	5.7477903E-02
7.3337995E-02	4.7599960E-02	4.0085889E-02	3.6050949E-02	0.1591447	4.3792546E-02
3.2945636E-03	4.7168393E-02	6.8856232E-02	5.4024547E-02	7.9803653E-02	4.5938723E-02
7.4707083E-02	2.7054267E-02	0.1148059	5.0873883E-02	6.8583310E-02	4.3378543E-02
3.7277136E-02	0.1055952	3.3868130E-02	6.0785957E-02	3.3945039E-02	3.2092944E-02
2.3415873E-03	6.3766249E-02	1.5916673E-02	6.5029919E-02	1.5667401E-02	7.0161469E-02
0.1363300	5.8460943E-02	2.4237448E-02	5.5624705E-02	1.2216034E-02	3.7499879E-02
2.7190035E-02	4.6317127E-02	3.8375910E-02	5.2462641E-02	2.6205523E-02	0.1016790
? .1469404E-03	5.7112314E-02	? .1393445E-02	1.5578598E-02	0.1345783	5.8055867E-02
4.8396634E-03	1.8904120E-02	? .6492967E-02	1.9284455E-02	2.7402056E-02	2.1080213E-02
6.1320782E-02	1.3836190E-02	1.2682325E-02	5.7558499E-02	5.2395917E-02	0.1310989
5.1850434E-02	4.4858344E-02	2.5767982E-02	4.4060186E-02	9.7891323E-02	5.1882077E-02
2.9650316E-02	4.5002442E-02	1.9472765E-02	6.1348185E-02	8.9353189E-02	8.4825300E-02
5.2909732E-02	5.2177414E-02	1.3780744E-02	5.5703067E-04	2.7940512E-02	7.4167669E-02
7.2582185E-02	7.4897297E-02	7.0846647E-02	2.5572006E-02	5.0494056E-02	7.5886257E-02
2.7631711E-02	6.0897086E-02	3.2919362E-02	1.4207551E-02	9.0468293E-03	3.9250501E-02
0.1479920	3.7642244E-02	0.1041866	7.3884562E-02	0.2264951	0.1131693
6.8155609E-02	0.1125266	6.4161711E-04	3.8655475E-02	5.8889549E-02	6.8122149E-02
4.8517105E-03	3.7218831E-02	2.7210578E-02	5.3686421E-02	1.8761925E-03	5.3185504E-02
1.0592137E-02	5.7463851E-02	5.0297618E-02	3.0133445E-02	8.0460243E-02	6.2511340E-02
8.4417984E-02	4.8830070E-02	3.9070893E-02	3.9580315E-02	5.6212086E-02	4.4533499E-02
1.3834529E-02	5.6467827E-02	? .2120718	7.1436375E-02	0.1232555	4.9721505E-02
3.1368252E-02	5.5263419E-02	0.1207141	8.4866486E-02	L.7296594E-02	4.0684052E-02
0.1733319	2.1836525E-02	7.0493244E-02	0.1654756	2.5122650E-02	5.3252496E-02
0.1083883	7.8432508E-02	0.2736189	5.8602590E-02	2.4814460E-02	5.1550169E-02
3.4713827E-02	5.4580510E-02	0.1644907	3.9456370E-03	0.1282181	6.1518714E-02
6.9029287E-02	4.9784124E-02	0.1962140	5.2651335E-02	2.2284815E-02	7.6629288E-02
8.6368740E-02	0.1490737	1.2658233E-03	5.1541779E-02	5.1063392E-02	9.5875099E-02
1.0906375E-02	4.3313839E-02	9.3008801E-03	5.8484331E-02	2.3033345E-02	7.2320491E-02
2.3066474E-02	6.1758589E-02	9.6362727E-03	1.4103325E-03	0.1255693	5.7018407E-02
0.1874645	0.1090954	0.1297920	5.3637575E-02	4.9152099E-02	4.2099785E-02
2.9084072E-02	5.4830268E-02	7.4851378E-03	5.6227304E-02	0.1012888	9.5059328E-02
3.2290604E-02	0.1488167	7.1975842E-02	6.0246613E-02	3.2810923E-02	6.8614222E-02
0.1759330	4.1155804E-02	3.9767893E-04	7.8546464E-02	5.5024467E-02	5.5538766E-02
1.4150621E-02	6.6617176E-02	0.1267434	4.3185066E-02	0.1023091	0.1114717
0.1159350	3.4868266E-02	1.7169040E-02	3.8028657E-02	4.7409418E-03	6.2105045E-02
4.2492867E-02	5.3134032E-02	1.1717744E-02	6.0267188E-02	3.1449161E-02	7.2473414E-02
0.2267004	6.1173547E-02	2.5022475E-03	7.1386263E-02	3.5321389E-03	0.1433671
0.1055374	4.8246101E-02	2.8072709E-02	3.6606077E-02	2.1979650E-02	3.7572309E-02
0.1955333	6.4037368E-02	8.4042564E-02	2.4940511E-02	3.2869723E-02	6.4480387E-02
2.6470978E-02	4.3714132E-02	3.6001012E-02	1.9995760E-02	1.6251069E-02	3.8868442E-02
6.8814188E-02	3.6620829E-02	4.6982206E-03	4.1722868E-02	9.9207006E-02	5.0651442E-02
5.3744357E-02	5.1303342E-02	1.1233456E-02	7.1409829E-02	0.1344099	4.9624890E-02
0.2325092	6.4085588E-02	4.3577466E-02	3.5525009E-02	1.4781847E-02	5.6478623E-02
6.0120583E-02	8.2462795E-02	7.6863907E-02	6.3962050E-02	7.0901610E-02	1.3658642E-02
0.1314537	6.8409018E-02	4.2035021E-02	6.0748342E-02	1.0775675E-03	4.9721941E-02

2.9384814E-02	7.2166272E-02
9.1045044E-02	5.0976101E-02
2.7149079E-02	6.9073819E-02
0.1487750	4.9753133E-02
0.1281379	3.3494946E-02
0.2261254	4.8859332E-02
7.0052288E-02	4.7748096E-02
5.5682145E-02	5.8132105E-02
0.1027336	4.9926355E-02
1.4832543E-02	5.5490620E-02
5.5337563E-02	8.2520597E-02
6.2655270E-02	3.8574792E-02
4.0548373E-02	6.3032411E-02
6.2372845E-02	7.3105752E-02
6.0694687E-02	6.0532637E-02
0.1315373	5.8275152E-02
5.6101017E-02	5.1635120E-02
0.1784956	4.4583969E-02
1.0766561E-02	6.2380012E-02
4.4256584E-03	3.2339543E-02
0.1317025	0.1138625
0.1184175	7.8903660E-02
8.3891869E-02	7.8740507E-02
1.3691519E-02	3.7798133E-02
0.1829110	4.5573011E-02
1.2218891E-02	3.7880022E-02
3.5861585E-02	5.3079080E-02
3.0800391E-03	5.3664945E-02
3.8509235E-02	4.5091420E-02
8.6480059E-02	3.8442094E-02
3.8517248E-02	6.3969307E-02
2.0938128E-02	6.4974770E-02
6.3549548E-02	8.5598998E-02
7.8335539E-02	3.6386952E-02
6.9398761E-02	5.0369952E-02
3.5620485E-02	5.3879078E-02
5.7140426E-03	7.6112233E-02
4.2732999E-02	4.7157414E-02
1.0141055E-02	5.9863053E-02
5.2287020E-02	5.2066594E-02
0.1110769	6.1749782E-02
2.7594246E-02	5.7561927E-02
0.1713138	4.4933297E-02
2.2145273E-02	7.4739300E-02
0.1135392	3.7415762E-02
4.1683346E-02	5.8121778E-02

LOSP Frequency

Attachment G-25

LHSADDITION.FOR

C
C THIS PROGRAM READS IN TWO VALUES FROM LHSLOSP.INP, ADDS
C THEM AND OUTPUTS TO LHSLOSP.DAT.
C

```
PROGRAM ADDITION
DIMENSION X1(1000),X2(1000),Y(1000)
OPEN(UNIT=62,FILE='LHSLOSP.INP',STATUS='OLD')
OPEN(UNIT=63,FILE='LHSLOSP.DAT',STATUS='NEW')
NP=1000
DO 5 K=1,NP
READ(62,*)X1(K), X2(K)
Y(K)=X1(K) + X2(K)
5 CONTINUE
DO 15 K=1,NP
WRITE(63,10)Y(K)
10 FORMAT(4X,F13.7)
15 CONTINUE
END
```

LOSP Frequency

Attachment G-26

LHSLOSP.DATC

LOSP Frequency

0.1529599	0.0680313	0.1980298	0.1902722	0.1219071
0.1113574	0.0651058	0.1156374	0.0912087	0.0811165
0.0953622	0.2062465	0.1530448	0.0798490	0.2029521
0.3545172	0.0769766	0.1156137	0.1717381	0.1505566
0.1239482	0.0825347	0.1149166	0.1056708	0.0456488
0.0979129	0.1382218	0.0917984	0.0706579	0.0311952
0.0657493	0.1589348	0.1036434	0.1269772	0.1414734
0.1687010	0.1015133	0.0602678	0.4349856	0.1178413
0.1667969	0.1065434	0.4624366	0.0721149	0.1712139
0.0675966	0.0993407	0.1892478	0.1682715	0.2293047
0.1905878	0.1999383	0.1143899	0.1095619	0.1442924
0.2369023	0.1500683	0.0897054	0.0866209	0.2156008
0.1189780	0.0557724	0.1575499	0.0763831	0.1012498
0.0839917	0.0623100	0.0655399	0.1594502	0.1545732
0.1550420	0.0731258	0.1134765	0.0229742	0.1739320
0.0698282	0.1315916	0.1373857	0.0757436	0.2749732
0.0771309	0.1775653	0.1056909	0.0444247	0.1586397
0.0761280	0.0946923	0.1068360	0.0667516	0.1412045
0.1098688	0.1341559	0.0708083	0.0578644	0.1725852
0.0742907	0.1329807	0.0644409	0.1565855	0.0593465
0.1857869	0.1117974	0.1201905	0.0989608	0.0881133
0.0880991	0.1167418	0.1768614	0.0672674	0.0690428
0.0845420	0.1019084	0.1294219	0.0657843	0.0752417
0.0471034	0.0757828	0.0662614	0.1216396	0.0986243
0.0508785	0.1851247	0.1041269	0.2788083	0.1168848
0.1202398	0.0798511	0.0891650	0.1441852	0.1119068
0.1691805	0.0873910	0.1201521	0.0520406	0.1420113
0.0439562	0.1190856	0.0795577	0.0904631	0.0987779
0.0405930	0.2902308	0.0898823	0.2207181	0.0952239
0.1730547	0.2323602	0.1756271	0.0573224	0.1159761
0.0765381	0.1015917	0.0593040	0.0532890	0.0800898
0.2045990	0.1047648	0.0696962	0.0675152	0.1714863
0.0724743	0.0679737	0.1010510	0.2009880	0.1228420
0.2061159	0.1640081	0.1570703	0.1295188	0.0608976
0.2812203	0.1664532	0.0985962	0.2267264	0.1845828
0.0745939	0.1303269	0.1310059	0.1330754	0.0544038
0.1659922	0.0816958	0.0612511	0.2023341	0.1329461
0.1314452	0.1780962	0.0728266	0.1182387	0.1699613
0.0685444	0.0791179	0.1973074	0.0773607	0.1267728
0.2088997	0.1142592	0.1078630	0.0610048	0.0832337
0.0305766	0.1206729	0.0662956	0.0649282	0.0999843
0.0683636	0.0985473	0.1113829	0.0866646	0.3051209
0.0361587	0.1244387	0.2942876	0.1649501	0.1532348
0.0897228	0.0688900	0.1515640	0.0853683	0.2319201
0.1180685	0.1364971	0.1938012	0.1067292	0.0989431
0.1538763	0.1213386	0.1681560	0.0916753	0.1355968
0.1169174	0.2054951	0.0671849	0.0877265	0.1589498
0.0869139	0.0752842	0.0421748	0.2714211	0.2317530
0.1089153	0.0991243	0.0360402	0.7631389	0.1581365
0.1018161	0.0255308	0.0505459	0.0727497	0.0828389
0.0634172	0.0810541	0.1367581	0.0466204	0.1413040
0.1006227	0.1062613	0.1620297	0.1744305	0.1789128
0.1312399	0.1466708	0.2267496	0.1499878	0.3942384

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0.1634511	0.0661915	0.0522684	0.0604136	0.0704613
0.0725455	0.1559592	0.1181627	0.8632845	0.1388359
0.1712442	0.1386466	0.0611883	0.1433026	0.0753994
0.1259277	0.0856829	0.0998502	0.1452927	0.0993625
0.0496658	0.1637514	0.1022705	0.1306441	0.0510984
0.1461968	0.1211438	0.0497205	0.2667870	0.1604180
0.1964381	0.0845856	0.1028626	0.0901956	0.2479000
0.0913003	0.1451379	0.0480013	0.0627726	0.1843886
0.0465125	0.2576471	0.1219322	0.0516668	0.1361420
0.1372069	0.1517480	0.0982664	0.1458451	0.0393297
0.1621544	0.0984650	0.1136351	0.0411881	0.2080583
0.1043275	0.1515275	0.0938734	0.0832981	0.1903313
0.0886278	0.0734372	0.1418285	0.0733320	0.0824425
0.0515328	0.1498297	0.2228790	0.0644262	0.1006118
0.1091395	0.1249839	0.0916417	0.0907970	0.0965631
0.2584388	0.0825758	0.2399204	0.0955510	0.1095381
0.1773244	0.0588097	0.0670747	0.1809598	0.0639270
0.1560939	0.1445692	0.0475095	0.0829133	0.0969717
0.1775610	0.0994688	0.1610862	0.1235693	0.2106814
0.3869033	0.0876801	0.1423551	0.0841773	0.0724215
0.1711754	0.1282867	0.0764955	0.0953126	0.1771941
0.1127294	0.1453538	0.1196053	0.0219668	0.0735023
0.1833781	0.2666030	0.1205824	0.1039249	0.1161508
0.3600698	0.2554108	0.1304909	0.0626890	0.0683045
0.0891437	0.0447289	0.1098721	0.0701507	0.1268118
0.1355037	0.1649453	0.0433519	0.1578522	0.0545674
0.0958991	0.1331583	0.0564005	0.2298626	0.1120234
0.2080095	0.0569619	0.0688891	0.1040858	0.0706490
0.0738918	0.0816054	0.0853570	0.2114401	0.0715758
0.0859673	0.1057321	0.1870366	0.1506780	0.0695275
0.0830497	0.1180695	0.1003828	0.0480800	0.0662245
0.1257122	0.0725754	0.0849465	0.1027419	0.1128537
0.0541463	0.0703858	0.1620107	0.0934230	0.1834555
0.1735342	0.3084569	0.1421620	0.1559750	0.0781155
0.1172849	0.1700428	0.1685149	0.0987635	0.0725119
0.1161663	0.0953916	0.1232848	0.1691087	0.1389102
0.1176829	0.1067199	0.1360154	0.1241114	0.1025935
0.0595449	0.1024398	0.0458117	0.1360135	0.3557552
0.1815900	0.1118672	0.0487709	0.1205463	0.1291952
0.0604068	0.1472396	0.1050218	0.0493597	0.1519220
0.0817459	0.1740083	0.1666806	0.1389208	0.0347910
0.0950503	0.1113288	0.1178365	0.1553201	0.0876125
0.2619295	0.0278963	0.1600997	0.0997337	0.0791917
0.0646664	0.1614659	0.0807719	0.0466013	0.1175123
0.0969429	0.1520842	0.1865747	0.0709971	0.0646396
0.0800892	0.0727995	0.0611124	0.0868578	0.0602080
0.0771621	0.1094525	0.0759394	0.0999742	0.0399627
0.0554796	0.1290217	0.1307501	0.1057049	0.1956170
0.1814402	0.1596932	0.0933574	0.1851032	0.0846239
0.1550236	0.1131499	0.1840284	0.1247750	0.0994845
0.1492386	0.1915890	0.0624078	0.0437720	0.0434480
0.1094835	0.1598586	0.0828862	0.1519290	0.2172148
0.0950430	0.1449003	0.0928975	0.2537899	0.0721115

0.0648862	0.1513215	0.1100820	0.0506222	0.1835743
0.1653788	0.0704913	0.0775717	0.0564364	0.0908591
0.0962065	0.1141440	0.0654057	0.1528857	0.2825304
0.0723423	0.2521617	0.0366511	0.1410642	0.1324202
0.1156534	0.0446690	0.0714557	0.0649848	0.1001768
0.1726190	0.0616722	0.1122508	0.0962413	0.0812727
0.1363990	0.0951492	0.2003225	0.0860416	0.0561331
0.0651056	0.2100266	0.1174452	0.2337769	0.1530389
0.1271043	0.2390410	0.2388454	0.0648604	0.1036628
0.0516881	0.0961891	0.0153775	0.1844243	0.1889701
0.0414402	0.1286206	0.0256159	0.1330300	0.0741675
0.0693319	0.0757137	0.1178731	0.1219815	0.0722103
0.2840304	0.0873933	0.3111386	0.1065388	0.2615932
0.1431274	0.0719740	0.1645320	0.0849376	0.0790505
0.0995066	0.0885191	0.1033483	0.1639630	0.1496975
0.1644632	0.1296790	0.0677327	0.1017423	0.4779142
0.0795531	0.1075818	0.1958109	0.1378213	0.0952957
0.1194447	0.1299378	0.1106704	0.0614684	0.0868605
0.1675978	0.1395864	0.0795248	0.1987393	0.0820879
0.1550352	0.1022440	0.0730418	0.1204421	0.0837131
0.0687043	0.0480115	0.0844716	0.1242097	0.1559919
0.1199954	0.0666426	0.0880439	0.2111915	0.1872189
0.1168577	0.1546937	0.1198736	0.0967788	0.2231982
0.1233927	0.1289238	0.2441580	0.0794339	0.1200421
0.0716485	0.1443840	0.0822132	0.1491313	0.1922144
0.1024968	0.1681126	0.0528925	0.1260059	0.1513263
0.0296712	0.1130332	0.1768128	0.1389299	0.0808931
0.1433429	0.0979117	0.1093961	0.1150174	0.1216672
0.1733654	0.0961331	0.2217353	0.1488213	0.1172427
0.1627083	0.0759900	0.0929559	0.0313936	0.2644918
0.0565090	0.1686962	0.2745101	0.1843734	0.1336180
0.0838821	0.1585404	0.0928425	0.1507306	0.1990189
0.1492888	0.1419460	0.1168013	0.1207787	0.1042991
0.1643533	0.0974059	0.1169938	0.0981405	0.0436948
0.0570155	0.0495620	0.1995827	0.0513052	0.0961192
0.1384153	0.0719640	0.0415374	0.1032936	0.1059905
0.0447353	0.0868506	0.0666171	0.1792727	0.0553787
0.1276157	0.1341597	0.0749637	0.0796101	0.1179634
0.1581283	0.1263335	0.1123586	0.1042155	0.1895437
0.1297168	0.0938701	0.0485797	0.0637759	0.1266404
0.1491215	0.0599025	0.1674144	0.0952476	0.0850594
0.1874836	0.2279091	0.1660998	0.1797801	0.1524067
0.0244328	0.0988823	0.1085103	0.1051159	0.2345703
0.0673094	0.0504778	0.0634237	0.0519935	0.1082422
0.1471961	0.1737060	0.0468753	0.2987740	0.1912496
0.0579682	0.0825657	0.2516221	0.0913628	0.0734073
0.1547990	0.1191792	0.0764939	0.1250579	0.0836055
0.2280843	0.1878224	0.0489549	0.1303810	0.1217391
0.1854318	0.0912303	0.0815092	0.1376802	0.0468097
0.0506759	0.0508766	0.2542015	0.0685228	0.3032024
0.2883647	0.0891956	0.2412788	0.0824764	0.1328798
0.1047553	0.0911235	0.2120996	0.1346677	0.0454702
0.0869575	0.0618071	0.1822601	0.0495141	0.1684363

LOSP Frequency

0.1044607	0.2466137	0.1230892	0.1015511
0.0857147	0.1039498	0.0863372	0.1420211
0.1024142	0.0719585	0.1845049	0.0962229
0.1507974	0.1267267	0.1004340	0.1985281
0.2329933	0.1366243	0.1540242	0.1616329
0.0982563	0.1849795	0.0521522	0.2749847
0.0659564	0.0728344	0.1972369	0.1178004
0.2113485	0.1081679	0.0666955	0.1138142
0.1209380	0.0761368	0.2029372	0.1526600
0.0504630	0.1228808	0.1257424	0.0703232
0.1017613	0.1656798	0.1119619	0.1378582
0.1428723	0.0946541	0.0660380	0.1012301
0.0661078	0.0809466	0.0858289	0.1035808
0.1947909	0.0798622	0.0497159	0.1354786
0.0735072	0.0908386	0.1278845	0.1212273
0.0632593	0.0869720	0.1926342	0.1898125
0.0237438	0.0857774	0.0484823	0.1077361
0.0751570	0.0702408	0.1834948	0.2230796
0.0967088	0.0698282	0.1497734	0.0731466
0.0746528	0.0808209	0.1741785	0.0367652
0.1050871	0.0143378	0.1021082	0.2455650
0.1474795	0.0964187	0.1263803	0.1973212
0.0885288	0.0471269	0.0482973	0.1626324
0.1856342	0.1780712	0.3396644	0.0514897
0.1806822	0.0392971	0.1270117	0.2284840
0.0420705	0.0808970	0.0550617	0.0500989
0.0680560	0.0804311	0.1429716	0.0889407
0.1332481	0.0786512	0.1007456	0.0567450
0.0703024	0.2835082	0.1729770	0.0836007
0.0866317	0.2055806	0.0579806	0.1249222
0.1951684	0.2359689	0.0783751	0.1024866
0.1868208	0.3322215	0.0763646	0.0859129
0.0892943	0.1684363	0.1897368	0.1491486
0.1188134	0.2488653	0.0989141	0.1147225
0.2354424	0.0528076	0.1469385	0.1197687
0.0542202	0.0677852	0.0953538	0.0894996
0.0848251	0.0110466	0.1825877	0.0818263
0.2965599	0.1834296	0.0912519	0.0898904
0.0839143	0.0637124	0.1963481	0.0700041
0.1811073	0.1322225	0.1014251	0.1043536
0.2170888	0.0789441	0.1105632	0.1728267
0.0807678	0.1699285	0.2137808	0.0851562
0.1508033	0.0551977	0.0668460	0.2162471
0.0956269	0.0719849	0.1039226	0.0968846
0.2878740	0.0738885	0.1468992	0.1509550
0.1537835	0.0646788	0.0595520	0.0998051
0.2595707	0.1089831	0.0973501	
0.0701851	0.0559968	0.0551195	
0.1054350	0.0464211	0.1498584	
0.1050477	0.0826433	0.1840348	
0.2965948	0.0791025	0.0712605	
0.1425834	0.1408260	0.0845603	
0.1998627	0.1027834	0.0507995	

Attachment G27

REMOVE COL. FOR

LOSP Frequency

Character*64 remo

Character*60 infile,outfile

character*16 inse

infile = 'ud4:[bdstapl]lhslosp.inp'

outfile = 'ud4:[bdstapl]pcgwlosp.dat'

open(unit=10,name=infile,status='old')

open(unit=15,name=outfile,status='new')

25 read(10,20,end=50)inse,remo

20 format(a,a)

write(15,30)inse

30 format(a)

goto 25

50 close(10

close(15

end

Attachment G-28

PCGWLOSP.DAT

LOSP Frequency

9.5802836E-02	6.3890698E-03	0.1619431	0.1213369	5.3303089E-02
5.0940670E-02	1.1955368E-02	6.5522656E-02	4.5888089E-03	5.0968453E-02
3.7110481E-02	2.0493850E-02	9.9551871E-02	7.6253237E-03	0.1519960
0.3011881	3.9378010E-02	3.2978956E-02	0.1213599	9.9529408E-02
6.8660229E-02	3.5381936E-02	5.2812852E-02	5.0322939E-02	1.2661025E-02
4.1418765E-02	6.2365174E-02	4.1240700E-02	5.3692952E-02	1.1452804E-02
3.8164826E-03	6.9060028E-02	7.0628084E-02	6.8447582E-02	5.9550323E-02
7.3756211E-02	4.4734307E-02	3.2155325E-03	0.3917790	8.4897578E-02
0.1116926	4.3982375E-02	0.2955990	5.7127774E-02	0.1265632
8.3901752E-03	6.0694963E-02	0.1707724	8.3935164E-02	0.1636941
2.1001803E-04	9.1746241E-02	5.5750683E-02	5.8236878E-02	7.2806217E-02
0.1984308	1.2195393E-02	3.3989530E-02	2.7824761E-02	9.7682148E-02
6.1446220E-02	9.7427778E-03	9.6589506E-02	1.0342170E-02	4.3897450E-02
1.3037866E-02	1.9653393E-02	4.4756867E-02	0.1130472	5.3755235E-02
8.6331956E-02	3.1145809E-02	7.3829912E-02	1.9324374E-03	7.2366193E-02
3.7155967E-02	7.1229465E-02	0.1215877	2.1123756E-02	0.2446719
3.2555930E-02	5.5966739E-02	8.4925257E-02	7.3582875E-03	8.7504514E-02
4.5071386E-02	2.9009812E-02	5.1617451E-02	8.1938533E-03	6.1651595E-02
6.3797474E-02	7.5244442E-02	1.6678156E-02	3.8392141E-03	0.1204444
4.3774538E-02	7.8743502E-02	1.7280921E-02	0.1114586	1.0141240E-02
0.1065058	5.0527163E-02	6.1498184E-02	3.7242990E-02	2.9848058E-02
5.5102311E-02	3.1681322E-02	0.1538038	1.9190241E-02	9.4402153E-03
3.5599325E-02	5.1817849E-02	7.0079938E-02	2.3559626E-02	4.3066703E-03
2.0490789E-03	5.0831504E-02	4.6549104E-02	6.7579068E-02	8.8652149E-03
2.5542006E-02	0.1170508	8.5495159E-02	0.1495474	8.2147315E-02
4.6561282E-02	3.0360568E-02	2.9121149E-02	8.7243997E-02	8.9766808E-02
9.7525999E-02	3.7065927E-02	5.2379847E-02	3.9188843E-03	5.7522781E-02
3.6980748E-02	8.4724374E-02	2.2424161E-02	2.0487398E-02	1.9196231E-02
3.8461756E-02	0.2172877	1.4448942E-02	0.1687348	3.2749761E-02
0.1308402	0.1707056	0.1259440	1.9494988E-02	7.4022703E-02
1.5121906E-02	4.1157823E-02	2.1840738E-02	3.1080063E-02	2.8199911E-02
0.1576969	4.6242714E-02	4.6944050E-03	3.3260230E-02	0.1044558
1.1520608E-02	7.8710178E-03	6.5334700E-02	0.1394177	3.6798760E-02
0.1065259	8.4139876E-02	0.1371943	4.6089880E-02	2.8888844E-02
0.1838354	9.9810176E-02	1.6964525E-02	0.1716556	0.1416059
2.3105722E-02	5.6254819E-02	0.1015151	5.3486563E-02	1.1433396E-02
7.8000881E-02	4.5131359E-02	1.8315334E-02	4.7258500E-02	8.4602527E-02
8.4191918E-02	0.1175776	3.3113606E-02	3.3940416E-02	0.1223382
3.0882679E-02	2.3901181E-02	0.1321511	2.1830970E-02	5.3186379E-02
0.1168672	6.8641901E-02	4.2373762E-02	4.0602647E-03	9.5278546E-03
6.9784876E-03	8.4755734E-02	7.2913952E-03	1.0020436E-02	3.6003832E-02
2.8681975E-02	4.7624674E-02	6.3795552E-02	3.7182402E-02	0.2368298
2.7508037E-02	7.6687358E-02	0.2103213	4.2706481E-03	9.8380804E-02
5.7893977E-02	6.1508259E-03	0.1109417	3.1993993E-02	0.1627849
8.7122709E-02	6.9542497E-02	0.1395433	7.7867016E-02	4.3205872E-02
4.0420175E-02	5.0025929E-02	4.7899157E-02	4.5282654E-02	7.7809721E-02
6.7433029E-02	7.6181762E-02	6.8555456E-03	2.3415735E-02	9.2956319E-02
3.1565614E-02	4.7242548E-02	4.7816616E-03	0.2160491	0.1799912
6.2981918E-02	5.1474594E-02	1.3575777E-02	6.4673787E-03	5.3744238E-02
3.6439944E-02	1.6576273E-02	3.7566062E-02	1.7433336E-02	2.3056671E-02
2.3256298E-03	3.3260591E-02	9.9475965E-02	2.2904482E-05	6.4727686E-02
3.7388284E-02	5.7211630E-02	0.1179500	0.1147942	0.1216711
4.9667925E-02	9.6157566E-02	0.1407464	7.6124631E-02	0.3209038

0.1101487	1.7556440E-02	5.7035097E-04	6.0450430E-03	5.8667913E-02
1.0786332E-02	7.8613654E-02	4.2432569E-02	1.9245146E-02	8.5019536E-02
0.1050531	7.6832488E-02	1.4777359E-02	7.1171016E-02	3.2430448E-02
8.6179286E-02	5.3756524E-02	3.2787994E-02	6.7888290E-02	2.9151317E-02
7.1867579E-03	0.1039997	5.1232055E-02	5.5506688E-02	2.0972826E-02
9.5057264E-02	5.1588386E-02	5.4714889E-03	0.2476660	9.0942435E-02
0.1684978	4.1753639E-02	2.0741522E-02	2.9247994E-02	0.1594650
1.2539796E-02	9.4200537E-02	8.3291810E-04	6.4376746E-03	0.1471007
6.4291013E-03	0.2072446	9.0837017E-02	1.3259222E-02	6.9947779E-02
7.7832922E-02	1.9067375E-02	2.3047213E-02	9.5137425E-02	2.9659139E-03
0.1206533	5.2268062E-02	4.1621886E-02	1.6477322E-02	0.1435275
5.6917291E-02	9.3951240E-02	3.9833665E-02	4.0688049E-02	0.1113859
3.6365487E-02	2.5747674E-02	9.0728611E-02	2.2278026E-02	3.9282557E-02
7.0993602E-03	9.1002814E-02	0.1397989	2.4768834E-03	6.1981261E-02
4.3315183E-02	5.2193556E-02	4.4620942E-02	1.9059179E-02	1.9839078E-02
7.4349679E-02	1.3168592E-02	0.1943297	4.2819299E-02	5.7827588E-02
9.5265292E-02	7.8425752E-03	3.5363667E-02	9.5047787E-02	2.5132930E-02
0.1238719	2.4083138E-02	6.8349316E-04	2.2842348E-02	4.0411420E-02
9.5689654E-02	2.9606896E-02	0.1459142	8.9984555E-03	0.1284811
0.2603333	3.2791542E-03	8.0266237E-02	4.0717803E-02	8.3482713E-03
0.1145876	5.5754423E-02	1.9203138E-02	1.8620146E-02	0.1010389
6.2036499E-02	1.9297315E-02	7.1140945E-02	5.5759195E-03	1.0805682E-02
0.1287113	0.1221153	5.2328020E-02	5.9370346E-02	6.1287235E-02
7.6434948E-02	0.1836627	7.3376082E-02	1.4559478E-02	4.9389787E-03
3.7384395E-02	2.6211066E-02	6.3577600E-02	2.1993279E-02	5.8028206E-02
5.5710252E-02	0.1165744	1.2584946E-03	3.4803309E-02	1.0797053E-02
3.0785400E-02	7.7690028E-02	1.5184088E-02	0.1713544	6.0769171E-02
0.1471515	8.6576715E-03	2.0581085E-02	4.7787406E-02	2.5214817E-02
1.6241783E-02	3.0842939E-02	2.4160979E-02	0.1166827	1.1230638E-02
5.5924322E-02	3.4306709E-02	0.1186002	0.1062214	2.5707522E-02
3.6231801E-02	8.0743775E-02	6.6469684E-02	1.4152073E-02	2.2795934E-02
5.1834852E-02	1.8435411E-02	3.7167817E-02	7.3292643E-02	6.2227350E-02
1.3616041E-02	3.2321534E-03	0.1164728	3.05 1070E-02	0.1672506
0.1356705	4.0109031E-02	5.5276338E-02	0.1430519	1.8789757E-02
6.1036717E-02	7.1211591E-02	0.1067105	5.7888649E-02	2.6002435E-02
3.2080885E-02	4.9363904E-02	6.9141306E-02	0.1176199	8.3665326E-02
6.3935861E-02	3.8666770E-02	8.5148111E-02	8.8838212E-02	3.0448386E-02
8.4782112E-03	5.1464181E-02	1.0854620E-02	8.3055459E-02	0.2885319
0.1483902	2.9909359E-02	7.3132701E-03	7.8486003E-02	7.5610541E-02
1.6334236E-02	8.5642956E-02	3.9495885E-02	3.7651348E-03	0.1016252
1.6464649E-02	0.1428766	0.1621865	8.9207999E-02	4.5112247E-04
3.3093113E-02	6.8073608E-02	2.7274314E-02	0.1019203	3.3670895E-02
0.1980580	3.6340430E-03	9.4924212E-02	3.8159367E-02	5.0228938E-02
3.2279663E-02	9.6433230E-02	7.8715859E-03	7.2341422E-03	6.2303629E-02
7.2981618E-02	0.1015370	7.6369330E-02	2.1741793E-02	1.5903739E-03
1.0505857E-02	4.2306870E-02	1.1159037E-02	1.7596968E-02	2.3061221E-02
2.7589556E-02	8.6678125E-02	1.6781913E-02	4.9762029E-02	1.7828470E-02
9.8100808E-03	8.0561943E-02	9.4187953E-02	6.2078778E-02	0.1489135
0.1137452	3.5065666E-02	1.5712211E-02	0.1199143	2.9991554E-02
7.2744422E-02	5.6423653E-02	0.1357202	7.7847488E-02	3.8592044E-02
9.1899738E-02	9.1383748E-02	9.6314792E-03	1.0528071E-02	2.6665970E-03
3.0302284E-02	9.0465531E-02	3.5887018E-02	8.3635688E-02	0.1594036
4.4912171E-02	8.2488284E-02	6.3044518E-02	0.2009909	4.8654587E-03

LOSP Frequency

4.1176889E-02	9.8734237E-02	7.4765138E-02	1.2667705E-02	0.1262614
0.1111817	1.3600629E-02	1.7438317E-02	9.5690675E-03	5.1675425E-03
3.2693163E-02	5.8635902E-02	1.9293664E-02	8.5062332E-02	0.2224558
2.7328093E-02	0.1916036	1.2643554E-02	8.1150882E-02	4.9047388E-02
5.4314032E-02	4.9487189E-03	6.2489253E-04	1.4643470E-02	4.1865766E-02
0.1534035	1.2524434E-06	7.2150782E-02	8.3918739E-03	3.0313108E-02
0.1076253	3.2651860E-02	8.0911592E-02	5.2297127E-02	6.0838363E-03
1.1158386E-02	0.1841026	4.5478538E-02	0.1712909	0.1005661
7.5296283E-02	0.1599361	0.1769705	3.9250352E-03	4.4937138E-02
9.0385396E-03	5.8705285E-02	1.2616337E-02	0.1462693	0.1633220
1.8177083E-02	6.6332571E-02	7.2607398E-03	6.3159265E-02	4.3697253E-02
3.4835618E-02	2.1626830E-02	4.3000471E-02	6.3968100E-02	3.1902997E-03
0.2126295	2.8318062E-02	0.2969601	6.1579641E-02	0.2287423
0.1055460	1.5888639E-02	0.1011943	3.1537369E-02	3.0959342E-02
1.6926570E-02	3.4715347E-02	4.0632688E-02	0.1300344	9.4964199E-02
9.7805411E-02	4.7073562E-02	1.1991364E-02	4.2458829E-02	0.4126163
2.4215424E-02	5.9949227E-02	0.1659063	6.8499178E-02	6.2819786E-02
4.6272218E-02	4.5089148E-02	6.7917205E-02	5.0882958E-03	4.5202851E-02
0.1436211	7.4199475E-02	2.9479271E-02	0.1220675	1.2994861E-02
9.6115790E-02	4.3561067E-02	2.7579788E-02	6.1601184E-02	5.1764749E-02
1.8233091E-02	7.8390967E-03	1.8036981E-04	6.6456713E-02	0.1174101
7.0725784E-02	8.5252132E-03	3.4363531E-02	0.1217265	0.1159837
8.6573020E-02	9.4841480E-02	7.1762465E-02	4.7997069E-03	0.1918874
5.2638784E-02	9.8654538E-02	0.1614968	2.9600626E-02	9.2250086E-02
1.2816365E-02	8.2921065E-02	2.5125390E-02	0.1141646	0.1249470
9.5106354E-03	0.1212057	3.1458316E-05	7.1259312E-02	9.5545508E-02
2.0517757E-02	4.1389301E-02	0.1076581	8.6525485E-02	1.9758463E-02
8.8717468E-02	3.9176088E-02	2.6002066E-02	7.5258906E-03	6.9996879E-02
0.1110684	3.6713161E-02	0.1655387	7.5813979E-02	8.2011253E-02
0.1252603	2.6123142E-02	2.6791573E-02	1.0426432E-04	9.7375177E-02
1.4984865E-02	7.1415707E-02	0.1573987	9.9009417E-02	9.4023019E-02
4.1367975E-03	0.1111227	3.7749022E-02	8.5491806E-02	0.1476692
0.1044355	3.3226274E-02	3.2987423E-02	6.9037460E-02	4.5043502E-02
0.1163967	4.3823916E-02	7.6349050E-02	4.4828497E-02	7.7810525E-03
6.4864228E-03	2.3118341E-02	0.1368688	7.9834806E-03	4.3228015E-02
8.6171895E-02	1.5971426E-02	1.0591272E-02	4.4560567E-02	4.5226362E-02
9.6399421E-03	1.8822059E-02	5.0359242E-02	6.5790229E-02	1.1131806E-02
0.1216575	5.8292266E-02	8.6674066E-03	2.3019051E-02	7.1365029E-02
7.5110182E-02	5.7775807E-02	2.7813993E-02	4.8554119E-02	0.1534233
9.4210796E-02	3.5423137E-02	9.2147784E-06	2.3537399E-02	4.5220446E-02
0.1249922	2.9857086E-02	9.7445004E-02	3.9333194E-02	4.0321246E-02
0.1011262	0.1548729	0.1148768	6.6698194E-02	9.2383265E-02
2.4293195E-02	4.3557987E-02	1.2202328E-02	1.9953102E-02	0.1957802
6.6678897E-03	1.5834160E-02	1.8492657E-03	6.7289076E-03	6.2168173E-02
0.1111950	3.0191801E-02	4.1577820E-02	0.2049074	0.1421046
1.9772781E-02	4.0227517E-02	0.1904121	2.6612628E-02	4.6885949E-02
0.1155881	6.4106800E-02	1.9257167E-02	6.2301848E-02	2.9114503E-02
0.1582730	0.1264381	6.0050576E-03	4.7661878E-02	9.4231784E-02
0.1393309	5.0514825E-03	1.5237578E-02	0.1032232	3.5982575E-02
1.4094720E-02	7.4786786E-03	0.1926419	2.2303181E-02	0.2368337
0.1499535	5.6379151E-02	0.2087683	2.3918238E-02	8.9359716E-02
7.1544766E-02	6.5043934E-02	0.1375539	8.8102572E-02	1.8088779E-03
3.0904636E-02	2.3314461E-02	0.1049394	1.0482088E-02	0.1065253

7.3502332E-02	0.1753536	9.5153023E-03	2.9384814E-02
1.9874904E-02	7.0344500E-02	1.3199417E-02	9.1045044E-02
4.0966433E-02	1.9798214E-02	0.1678364	2.7149079E-02
0.1398786	4.2904954E-02	3.6986031E-02	0.1487750
0.1679944	8.9058951E-02	0.1057777	0.1281379
3.6314774E-02	0.1282351	4.0126458E-04	0.2261254
3.9298572E-02	6.3481316E-02	0.1166051	7.0052288E-02
0.1538339	5.8032546E-02	9.2176422E-03	5.5682145E-02
7.3337995E-02	4.0085889E-02	0.1591447	0.1027336
3.2945636E-03	6.8856232E-02	7.9803653E-02	1.4832543E-02
7.4707083E-02	0.1148059	6.8583310E-02	5.5337563E-02
3.7277136E-02	3.3868130E-02	3.3945039E-02	6.2655270E-02
2.3415873E-03	1.5916673E-02	1.5667401E-02	4.0548373E-02
0.1363300	2.4237448E-02	1.2216034E-02	6.2372845E-02
2.7190035E-02	3.8375910E-02	2.6205523E-02	6.0694687E-02
6.1469404E-03	7.1393445E-02	0.1345783	0.1315373
4.8396634E-03	6.6492967E-02	2.7402056E-02	5.6101017E-02
6.1320782E-02	1.2682325E-02	5.2395917E-02	0.1784956
5.1850434E-02	2.5767982E-02	9.7891323E-02	1.0766561E-02
2.9650316E-02	1.9472765E-02	8.9353189E-02	4.4256584E-03
5.2909732E-02	1.3780744E-02	2.7940512E-02	0.1317025
7.2582185E-02	7.0846647E-02	5.0494056E-02	0.1184175
2.7631711E-02	3.2919362E-02	9.0468293E-03	8.3891869E-02
0.1479920	0.1041866	0.2264951	1.3691519E-02
6.8155609E-02	6.4161711E-04	5.8889549E-02	0.1829110
4.8517105E-03	2.7210578E-02	1.8761925E-03	1.2218891E-02
1.0592137E-02	5.0297618E-02	8.0460243E-02	3.5861585E-02
8.4417984E-02	3.9070893E-02	5.6212086E-02	3.0800391E-03
1.3834529E-02	0.2120718	0.1232555	3.8509235E-02
3.1368252E-02	0.1207141	1.7296594E-02	8.6480059E-02
0.1733319	7.0493244E-02	2.5122650E-02	3.8517248E-02
0.1083883	0.2736189	2.4814460E-02	2.0938128E-02
3.4713827E-02	0.1644907	0.1282181	6.3549548E-02
6.9029287E-02	0.1962140	2.2284815E-02	7.8335539E-02
8.6368740E-02	1.2658233E-03	5.1063392E-02	6.9398761E-02
1.0906375E-02	9.3008801E-03	2.3033345E-02	3.5620485E-02
2.3066474E-02	9.6362727E-03	0.1255693	5.7140426E-03
0.1874645	0.1297920	4.9152099E-02	4.2732999E-02
2.9084072E-02	7.4851378E-03	0.1012888	1.0141055E-02
3.2290604E-02	7.1975842E-02	3.2810923E-02	5.2287020E-02
0.1759330	3.9767893E-04	5.5024467E-02	0.1110769
1.4150621E-02	0.1267434	0.1023091	2.7594246E-02
0.1159350	1.7169040E-02	4.7409418E-03	0.1713138
4.2492867E-02	1.1717744E-02	3.1449161E-02	2.2145273E-02
0.2267004	2.5022475E-03	3.5321389E-03	0.1135392
0.1055374	2.8072709E-02	2.1979650E-02	4.1683346E-02
0.1955333	8.4042564E-02	3.2869723E-02	
2.6470978E-02	3.6001012E-02	1.6251069E-02	
6.8814188E-02	4.6982206E-03	9.9207006E-02	
5.3744357E-02	1.1233456E-02	0.1344099	
0.2325092	4.3577466E-02	1.4781847E-02	
6.0120583E-02	7.6863907E-02	7.0901610E-02	
0.1314537	4.2035021E-02	1.0775675E-03	

LOSP Frequency

Attachment G-29

STAT-SAS

```

OPTIONS LINESIZE=79;
DATA DATA1;
    INFILE PCGWLOSP
    INPUT X;
PROC UNIVARIATE;
    TITLE 'PC/GW DATA';
    VAR X;
DATA DATA2;
    INFILE LHSLOSP;
    INPUT X;
PROC UNIVARIATE;
    TITLE 'CAT IV DATA';
    VAR X;

```


LOSP Frequency

Attachment G-30

STAT.LIS

PC/GW DATA14:17 TUESDAY, JUNE 4, 1991

UNIVARIATE

VARIABLE=X

MOMENTS

N	1000	SUM WGTS	1000
MEAN	0.0649013	SUM	64.9013
STD DEV	0.0565115	VARIANCE	0.00319355
SKEWNESS	1.59296	KURTOSIS	3.86073
USS	7.40253	CSS	3.19036
CV	87.073	STD MEAN	0.00178705
T:MEAN=0	36.3175	PROB> T	0.0001
SGN RANK	250250	PROB> S	0.0001
NUM = 0	1000		

QUANTILES(DEF=4)

EXTREMES

100% MAX	0.412616	99%	0.247636	LOWEST	HIGHEST
75% Q3	0.09235	95%	0.171641	1.252E-06	0.29696
50% MED	0.0508861	90%	0.14066	9.215E-06	0.301188
25% Q1	0.0228075	10%	0.00840051	.000022904	0.320904
0% MIN	1.252E-06	5%	0.0046946	.000031458	0.391779
		1%	.000452315	.000104264	0.412616
RANGE	0.412615				
Q3-Q1	0.0695424				
MODE	1.252E-06				

LOSP Frequency

CAT IV DATA 14:17 TUESDAY, JUNE 4, 19912

UNIVARIATE

VARIABLE=X

MOMENTS

N	1000	SUM WGTS	1000
MEAN	0.123544	SUM	123.544
STD DEV	0.0698132	VARIANCE	0.00487388
SKEWNESS	2.93389	KURTOSIS	20.8052
USS	20.1322	CSS	4.86901
CV	56.5087	STD MEAN	0.00220769
T:MEAN=0	55.9609	PROB> T	0.0001
SGN RANK	250250	PROB> S	0 0001
NUM ^= 0	1000		

QUANTILES(DEF=4) EXTREMES

100% MAX	0.863285	99%	0.354369	LOWEST	HIGHEST
75% Q3	0.154967	95%	0.244014	0.0110466	0.434986
50% MED	0.1078	90%	0.199931	0.0143378	0.462437
25% Q1	0.0765061	10%	0.0565326	0.0153775	0.477914
0% MIN	0.0110466	5%	0.0480018	0.0219668	0 763139
		1%	0.02919	0.0229742	0.863285
RANGE	0.852238				
Q3-Q1	0.0784613				
MODE	0.0698282				

Attachment G-31

GGGRID.DAT

LOSP Frequency

**.13
.18
.25
.3
.33
.33
.333
.55
.92
1.03
1.5
2.0
2.083
6.470**

Attachment G-32

GGWEAT.DAT

LOSP Frequency

1.75
2.67
4.0
4.317
5.0
5.5
8.9
11.

Attachment G-33

GGPC1.DAT

LOSP Frequency

.002
.003
.004
.033
.05
.33
.367
1.
.43
.633
.27
.167
.08
.25
.15
.013
.183
.48
.15
.017

Attachment G-34

GGPC2.DAT

LOSP Frequency

.07
1.48
.28
.083
.5
.67
.334
.003
.13
.02
1.03
.25
.25
.283
.417
4.0
.050
2.

Attachment G-35

GGPC3.DAT

LOSP Frequency

1.97
.9
2.75
.9
.015
1.75
.5
.93
.5
7.43
.4
.2
1.15
.57
.767
1.667
.004
.067
11.083
.233
2.683
4.983
.117
.717

Attachment G-36

GGPC4.DAT

LOSP Frequency

.002
.003
.004
.033
.05
.33
.367
1.
.43
.633
.27
.167
.08
.25
.15
.013
.183
.48
.15
.017
.07
1.48
.28
.083
.5
.67
.334
.003
.13
.02
1.03
.25
.25
.283
.417
4.0
.050
2.
1.97
.9
2.75
.9
.015
1.75
.5
.93
.5
7.43
.4
.2
1.15
.57
.767
1.667
.004
.067
11.083
.233
2.683
4.983
.117
.717

Attachment G-37

MODEL.FOR

LOSP Frequency

C AN INTERACTIVE PROGRAM TO IMPLEMENT THE MIXTURE MODEL FOR THE DISTRIBUTION
C OF TIME TO RECOVERY OF LOSP AS DEVELOPED IN NUREG/CR-5032, SAND87-2428,
C JANUARY 1988:

C
C "MODELING TIME TO RECOVERY AND INITIATING EVENT FREQUENCY FOR LOSS OF
C OFF-SITE POWER INCIDENTS AT NUCLEAR POWER PLANTS"

C BY RONALD L. IMAN AND STEPHEN C. HORA

C THE MIXTURE MODEL MODEL AS GIVEN IN EQUATION (23) OF THAT REPORT IS
C OF THE FORM:

C
C $G(x) = P1*G1(x) + P2*G2(x) + P3*G3(x)$

C WHERE THE $G(x)$'s REPRESENT THE FITTED GAMMA DISTRIBUTIONS

C AND THE P's ARE WEIGHTS THAT ARE TREATED WITH A DIRICHLET DISTRIBUTION

C
C ADDITIONAL INFORMATION CAN BE FOUND IN THE FOLLOWING REFERENCE:

C
C RONALD L. IMAN AND STEPHEN C. HORA (1989). "BAYESIAN METHODS FOR
C MODELING RECOVERY TIMES WITH AN APPLICATION TO THE LOSS OF OFF-SITE
C POWER AT NUCLEAR POWER PLANTS," RISK ANALYSIS, VOL. 9, NO. 1, 25-36.
C NOTE THAT ERRATA FOR THIS ARTICLE APPEARS IN VOL. 9, NO. 3.

C
C TO RUN USE LINK RECOVERY, AMOSLIB, IMSLIBS/LIB

C
C NREP = NUMBER OF REPLICATIONS TO BE USED IN THE MONTE CARLO
C NPLANT = NUMBER OF PLANTS IN THE DATA BASE CONTAINED IN FILE "REC.DAT"

C
C "NX" TIME STEPS ARE USED TO GENERATE A GRAPH OF THE RECOVERY CURVE.
C THE "NX" TIME STEPS CORRESPOND TO TIMES IN HOURS OF .05, .10, .15,
C 1.30, 1.33, 1.40, 1.45, ... , 2.50, 2.75, 3.00, 3.167, 3.25, 3.50,
C 10.00, 13.3, 15, 16, 18, 23, 27

C
C THE VECTOR IDT IS USED TO SPECIFY "NTIME" TIMES AT WHICH THE UNCERTAINTY
C DISTRIBUTION WILL BE SAVED IN AN OUTPUT FILE NAMED "XX.DAT," WHERE XX IS
C ABBREVIATION OF THE PLANT NAME THAT APPEARS IN FILE REC.DAT. THE EXACT
C TIMES SPECIFIED WILL VARY FROM ONE PLANT ANALYSIS TO THE NEXT. THE
C DIMENSIONS OF THE MATRIX "XX.DAT" ARE "NREP" x "NTIME."

C
C FOR EXAMPLE, IF THE DISTRIBUTION OF TIME TO RECOVERY OF LOSP FOR A
C PARTICULAR PLANT IS DESIRED FOR THE FOLLOWING "NTIME=20" TIMES (IN HOURS):
C .5, .8, 1, 1.133, 1.283, 1.33, 2.5, 3, 3.167, 5, 7, 8, 9, 10, 13.3,
C 15, 16, 18, 23, 27

C
C THEN THE VECTOR IDT MUST SPECIFY TO SAVE "NTIME" RESULTS. IN PARTICULAR,
C SAVE THE RESULTS OF THE 10th, 16th, 20th, OUT OF THE "NX" TIMES FOR
C WHICH THE DISTRIBUTION OF RECOVERY TIMES IS GENERATED AS SPECIFIED ABOVE.
C FOR THIS EXAMPLE THE VALUES STORED IN THE VECTOR IDX ARE : 10, 16, 20, 23,
C 26, 27, 50, 52, 53, 60, 68, 72, 76, 80, 81, 82, 83, 84, 85, 86.

PROGRAM MODEL

PARAMETER(NREP=500,NPLANT=70,K=3,NX=86,NTIME=20)

DIMENSION RESULTS(NREP,NX),X(NX),OUTPUT(K,NX),FMAX(K),IDT(NTIME)

1,ISWITCH(NPLANT),P(K),S(K),CUMPROB(K),PD(K),B(K),ICOMP(K)

CHARACTER*1 CANS

```

CHARACTER*3 IP
CHARACTER*21 IPLANT(NPLANT)
CHARACTER*3 NAME(NPLANT)
CHARACTER*80 CFILE
EXTERNAL GAMIC,GAMMAMA,QUANT,SIFT
COMMON A(3),N(3),NN
COMMON ISEED,AA
DATA IDT/10,16,20,23,26,27,50,52,53,60,68,72,76,80,81,82,83,84,
1    85,86/
CALL ERXSET(100,1)
C    READ IN THE PLANT DATA FILE
    OPEN(UNIT=10,FILE='REC',STATUS='OLD')
    I=1
9    READ(10,100,END=5)IPLANT(I),NAME(I),ISWITCH(I)
100  FORMAT(2A,I4)
    I = I + 1
    GO TO 9
5    NP = I - 1
    CLOSE(10)
C    SELECT THE PLANT WHOSE INITIATING EVENT FREQUENCY IS DESIRED
C
    DO 10 I = 1,21
    WRITE(*,101)NAME(I),IPLANT(I),NAME(I+22),IPLANT(I+22),
INAME(I+43),IPLANT(I+43)
10    CONTINUE
    WRITE(*,101)NAME(22),IPLANT(22)
101  FORMAT(IX,A,'- ',A19,2X,A,'- ',A19,2X,A,'- ',A19)
    PRINT *, 'INPUT THE ABBREVIATION FOR THE PLANT OF INTEREST'
    READ '(A)',IP
    DO 11 I = 1,NP
        IF(IP.EQ.NAME(I))THEN
            ID=ISWITCH(I)
            LAST = I
            GO TO 12
        ENDIF
11    CONTINUE
12    CONTINUE
    NPC = 62
C    IDENTIFY THE COMPONENTS TO BE USED IN THE COMPOSITE MODEL
C
C        1 - PLANT CENTERED COMPONENT
C        2 - GRID COMPONENT
C        3 - WEATHER COMPONENT
C
1    PRINT *, 'IS THE PLANT CENTERED COMPONENT TO BE USED IN THE'
    PRINT 105,IPLANT(LAST)
105  FORMAT(IX, 'COMPOSITE MODEL FOR 'A, '?')
    PRINT *, 'Y OR N'
    READ '(A)',CANS
    ICOMP(1)=1
    IF(CANS.EQ.'N')ICOMP(1)=0
    PRINT *, 'IS THE GRID COMPONENT TO BE USED IN THE'
    PRINT 105,IPLANT(LAST)

```

LOSP Frequency

```
PRINT *, 'Y OR N'
READ '(A)', CANS
ICOMP(2)=1
IF(CANS.EQ. 'N')ICOMP(2)=0
PRINT *, 'IS THE WEATHER COMPONENT TO BE USED IN THE'
PRINT 105, IPLANT(LAST)
PRINT *, 'Y OR N'
READ '(A)', CANS
ICOMP(3)=1
IF(CANS.EQ. 'N')ICOMP(3)=0
ISUM = ICOMP(1) + ICOMP(2) + ICOMP(3)
IF(ISUM.EQ.0)THEN
    PRINT *, 'NO COMPONENTS WERE SELECTED'
    GO TO 1
ENDIF

C
C INPUT SECTION FOR THE GAMMA DISTRIBUTIONS, G(x)'s
C CALCULATE THE PRODUCT, P, OF THE Xs FROM THE GEOMETRIC MEAN
C CALCULATE THE SUM, S, OF THE Xs FROM THE ARITHMETIC MEAN
    IF(ICOMP(1).EQ.0)GO TO 2

C
C INPUT THE FLAG FOR SWITCHYARD CONFIGURATION AS DEFINED IN NUREG-1032
C  1 = I1
C  2 = I2
C  3 = I3
C  4 = ALL PLANT CENTERED DATA USED
C
    PRINT *, 'THE SWITCHYARD CONFIGURATION PER NUREG-1032 FOR'
    PRINT 106, IPLANT(LAST), ID
106 FORMAT(IX, A, 'IS ', I1)
    PRINT *, 'DO YOU WISH TO CHANGE THIS VALUE? Y OR N'
    READ '(A)', CANS
    IF(CANS.EQ. 'N')GO TO 13
    PRINT *, 'INPUT NUMBER FOR SWITCHYARD CONFIGURATION PER NUREG-1032'
    PRINT *, 'ENTER 1 FOR I1 SWITCHYARD'
    PRINT *, 'ENTER 2 FOR I2 SWITCHYARD'
    PRINT *, 'ENTER 3 FOR I3 SWITCHYARD'
    PRINT *, 'ENTER 4 IF CONFIGURATION IS UNKNOWN'
    READ *, ID
13 IF(ID.EQ.1)THEN
    P(1)=.08621**20
    S(1)=.2306*20
    N(1)=20
ELSE IF(ID.EQ.2)THEN
    P(1)=.23882**18
    S(1)=.6583*18
    N(1)=18
ELSE IF(ID.EQ.3)THEN
    P(1)=.61987**24
    S(1)=1.76192*24
    N(1)=24
ELSE
    P(1)=.2487**62
```

```

        S(1)=.94755*62
        N(1)=62
    ENDIF
2 CONTINUE
    IF(ICOMP(2).EQ.0)GO TO 3
C
C SET THE PARAMETERS FOR GRID
C
    P(2)=.62347**14 '
    S(2)=1.17186*14
    N(2)=14
3 CONTINUE
    IF(ICOMP(3).EQ.0)GO TO 4
C
C SET THE PARAMETERS FOR WEATHER
C
    P(3)=4.6464**8 S(3)=5.392*8
    N(3)=8
4 CONTINUE
C
C INPUT SECTION FOR THE DIRICHLET DISTRIBUTIONS, P's
C
C INPUT THE WEATHER HAZARD RATIO FOR THE SPECIFIC PLANT
C
    RATIO = 1.
    IF(ICOMP(3).EQ.1.AND.ISUM.GT.1)THEN
        PRINT *, 'THE GENERIC WEATHER RATIO FOR'
        PRINT 107,IPLANT(LAST)
107 FORMAT(IX,A,'IS 1')
        PRINT *, 'DO YOU WISH TO CHANGE THIS VALUE? Y OR N'
        READ '(A)',CANS
        IF(CANS.EQ.'N')GO TO 14
        PRINT *, 'INPUT THE PLANT SPECIFIC WEATHER HAZARD RATIO'
        READ *,RATIO
14 CONTINUE
    ENDIF
    R1=ICOMP(1)*NPC
    R2=ICOMP(2)*N(2)
    R3=ICOMP(3)*N(3)
C
C GENERATE THE TIME IN STEPS OF .05 FROM .05 TO 2.5 FOR THE RECOVERY CURVE
C WITH EXCEPTIONS FOR 1.133, 1.283 AND 1.33
C
    DO 15 I=1,50
    X(I)=.05*I
C
C PATCH TO GENERATE A TIME OF 1.133 , 1.283 AND 1.33 HOURS
    IF (I .EQ. 23) X(I) = 1.133
    IF (I .EQ. 26) X(I) = 1.283
    IF (I .EQ. 27) X(I) = 1.333
15 CONTINUE
C GENERATE THE TIME IN STEPS OF .25 FROM 2.75 TO 10 FOR THE RECOVERY CURVE
C WITH ONE EXCEPTION AT 3.167

```

LOSP Frequency

```
C
      DO 16 I=51,80
      X(I) = 0.25 * I - 10.0
      IF (I.EQ. 53) X(I) = 3.167
16 CONTINUE
C      SET THE LAST SIX TIME STEPS
      X(81) = 13.3
      X(82) = 15.
      X(83) = 16.
      X(84) = 18.
      X(85) = 23.
      X(86) = 27.
      ISEED=327251
C
C SETUP
C
      DO 50 I=1,K
      IF(ICOMP(I).EQ.0)GO TO 50
C
C      FIND THE MAXIMUM VALUE OF THE VARIABLE THAT MAXIMIZES THE MARGINAL
C      DENSITY OF ALPHA (EQUATION 18 OF THE LOSP REPORT)
      CALL RMAX(XMAX,S(I),P(I),N(I))
C      FIND THE MAXIMUM VALUE OF THE MARGINAL DENSITY OF ALPHA
      FMAX(I)=F(XMAX,N(I),P(I),S(I))
50 CONTINUE
      DO 6 I = 1,K 6 PD(I) = 1.
      PRINT *, '
      PRINT *, 'PLEASE WAIT WHILE THE MONTE CARLO IS BEING PERFORMED'
      PRINT *
      IPC = 0
      DO 500 J=1, NREP
300 DO 70 I=1,K
      IF(ICOMP(I).EQ.0)GO TO 70
      NN=N(I)
C
C      OBTAIN A VALUE OF BETA FROM THE CONDITIONAL DENSITY GIVEN BY
C      EQUATION 17 OF THE LOSP REPORT
C
      CALL GAMPARAM(A(I),B(I),S(I),P(I),FMAX(I))
70 CONTINUE
C
C
      ARG4=.001
      IARGI=1
      IF(ISUM.EQ.1)GO TO 7
      IF(ISUM.EQ.3)THEN
          CALL DIRICHLET(R1,R2,R3,PD(1),PD(2))
          PD(3)=1.-PD(1)-PD(2)
      ELSE IF(ICOMP(1)+ICOMP(2).EQ.2)THEN
          CALL DIRICHLET2(R1,R2,PD(1))
          PD(2)=1.-PD(1)
      ELSE IF(ICOMP(1)+ICOMP(3).EQ.2)THEN
          CALL DIRICHLET2(R1,R3,PD(1))
```

```

        PD(3)=1.-PD(1)
    ELSE IF(ICOMP(2)+ICOMP(3).EQ.2)THEN
        CALL DIRICHLET2(R2,R3,PD(2))
        PD(3)=1.-PD(2)
    ENDIF
7 CONTINUE
    TOT = 0.
    PD(3) = PD(3)*RATIO
    DO 8 I = 1,K
        TOT = TOT + PD(I) * ICOMP(I)
8 CONTINUE
C   WRITE(99,*) ' J,TOT ',J,TOT
    DO 410 I=1,NX
        DO 450 IC=1,K
            IF(ICOMP(IC).EQ.0)GO TO 450
            Y=x(I)*B(Ic)
            IF(Y.GT.200.) GO TO 300
            CALL GAMIC(Y,A(IC),ARG4,IARG1,CUMPROB(IC),NZ)
450 CONTINUE
C   WRITE(99,*) ' I,X(I),CUM ',I,X(I),(CUMPROB(IC),IC=1,3)
        RESULTS(J,I) = 1. - ICOMP(1)*PD(1)/TOT*CUMPROB(1)
        1 - ICOMP(2)*PD(2)/TOT*CUMPROB(2) - ICOMP(3)*PD(3)/TOT*CUMPROB(3)
410 CONTINUE
        IF(MOD(J,NREP/100).EQ.0)THEN
            IPC=IPC+1
            PRINT 109,IPC
109 FORMAT(' +THE CALCULATION IS ',I3,'% COMPLETE')
        ENDIF
500 CONTINUE
C
C   WRITE OUT THE FILE CONTAINING THE UNCERTAINTY DISTRIBUTION AT
C   EACH OF THE NTIME SPECIFIED TIME POINTS
C
C   THIS FILE WILL BE AN NREP x NTIME MATRIX WITH EACH COLUMN CONTAINING
C   THE UNCERTAINTY DISTRIBUTION AT A GIVEN TIME POINT. THESE DISTRIBUTIONS
C   ARE USED BY THE LHS PROGRAM IN THE UNCERTAINTY ANALYSIS. THE VALUES IN
C   EACH COLUMN HAVE BEEN SORTED FROM SMALLEST TO LARGEST.
C
    OPEN (UNIT = 11, FILE = IP//'.DAT', STATUS = 'NEW')
    DO 800 I=1,NX
        CALL SIFT(NREP,RESULTS(I,I))
800 CONTINUE
    DO 9000 I = 1,NREP
        WRITE (11,*) (RESULTS(I,IDT(J)),J=1,NTIME)
9000 CONTINUE
    CLOSE (UNIT = 11)
C   WRITE OUT FILE FOR MAPPER WITH 90% UNCERTAINTY BOUNDS
C   AND FILE WITH THE COMPLETE UNCERTAINTY DISTRIBUTION
C   FOR THOSE TIME POINTS IDENTIFIED IN IDT
C
    PRINT *, 'DO YOU WANT TO CREATE A MAPPER FILE FOR PLOTTING? Y OR N'
    READ '(A)',CANS
    IF(CANS.EQ.'N')GO TO 802

```

LOSP Frequency

```
DO 801 I=1,NX  
CALL QUANT(.05,NREP,RESULTS(1,I),OUTPUT(1,I))  
CALL QUANT(.50,NREP,RESULTS(1,I),OUTPUT(2,I))  
CALL QUANT(.95,NREP,RESULTS(1,I),OUTPUT(3,I))
```

```
801 CONTINUE
```

```
CALL MAPPER(OUTPUT,X,IPLANT(LAST),IP)
```

```
802 CONTINUE
```

```
STOP
```

```
END
```

C

C

```
SUBROUTINE TO SELECT A RANDOM VARIABLE FROM A GAMMA DISTRIBUTION  
USING THE ACCEPTANCE-REJECTION METHOD
```

C

```
SUBROUTINE GAMPARAM(AA,B,S,P,FMAX)  
COMMON A(3),N(3),NN  
COMMON ISEED,AAA  
EXTERNAL GAMIC,GAMMAMA,QUANT,SIFT
```

```
300 T=RAN(ISEED)
```

```
PB=RAN(ISEED)
```

```
AA=T/(1.-T)
```

```
AAA=AA
```

C

C

```
IF ALPHA IS TOO LARGE OR TOO SMALL, TRY ANOTHER VALUE.  
THIS AVOIDS NUMERICAL PROBLEMS.
```

C

C

```
IF (AA.LT.(5.0E-3)) GOTO 300
```

```
IF(AA.GT..999999) GOTO 300
```

```
F1=F(T,NN,P,S)
```

C

C

```
ACCEPT OR REJECT THE VALUE OF ALPHA
```

C

```
IF (F1/FMAX.LT.RAN(ISEED)) GOTO 300
```

```
ARG1=2.*PB*AA*NN
```

```
ARG2=0.1*NN*AA
```

```
ARG3=.0001*NN*AA
```

```
ARG4=1.
```

```
IF(AA.GT.20.) GOTO 300
```

C

C

```
FIND A VALUE OF BETA CORRESPONDING TO A CUMULATIVE PROBABILITY P
```

C

```
CALL FINVER(GAMMAMA,PB,ARG1,ARG2,ARG3,ARG3,ARG4)
```

```
B=ARG1/S
```

```
330 CONTINUE
```

```
RETURN
```

```
END
```

C

C

C

```
REAL FUNCTION F(T,N,P,S)
```

```
DIMENSION P(1),S(1),N(1)
```

```
A=T/(1.-T)
```

```
NN=N(1)
```

```
SS=S (1)
```

```

      PP=P (1)
      FL=(A-1.)*LOG(PP)+GAMLN(NN*A)-NN*GAMLN(A)
X -NN*A*LOG(SS)-2*LOG(1.-T)-LOG(A)
      F=EXP(FL)
      FTEST=F
      RETURN
      END

```

C
C
C

```

      REAL FUNCTION FNEG(T,P,S,N,N2,N3)
      DIMENSION P(1),S(1),N(1)
      FNEG=-F(T,N,P,S)
      FTEST=FNEG
      RETURN
      END

```

C
C
C

FINDS THE VALUE OF THE VARIABLE THAT MAXIMIZES THE DENSITY F

```

      SUBROUTINE RMAX(XMIN,S,P,N)
      DIMENSION P(1),S(1),N(1)
      EXTERNAL FNEG
      E=.01
      A=E
      B=1.-E
      TOL=.001
      CALL ZXGSP(FNEG,P,S,N,IP4,IP5,A,B,TOL,XMIN,IER)
      FTEST=XMIN
      RETURN
      END

```

C
C
C

```

      SUBROUTINE GAMMAMA(X,FOFX)
      COMMON A(3),N(3),NN
      COMMON ISEED,AA
      IF (X.LT.0.0) THEN
        FOFX=0.
        RETURN
      ENDIF
      TOL=1.E-5
      NUNIT=1
      XX=X AAA=AA*NN
      IF (X.GT.5.*AAA) THEN
        FOFX=1.0
        RETURN
      ENDIF
      CALL GAMIC(X,AAA,TOL,NUNIT,FOFX,NZ)
      FOFXX=FOFX
      RETURN
      END

```

C
C

LOSP Frequency

```

SUBROUTINE DIRICHLET(R1,R2,R3,P1,P2)
COMMON A(3),N(3),NN
COMMON ISEED,AA
CONL=GAMLN(R1+R2+R3)-GAMLN(R1)-GAMLN(R2)-GAMLN(R3)
RN=R1+R2+R3
PIMAX=(R1-1.)/(RN-1.)
P2MAX=(R2-1.)/(RN-1.)
FMAX=CONL+(R1-1.)*LOG(PIMAX)+(R2-1.)*LOG(P2MAX)+(R3-1.)*
X LOG(1.-PIMAX-P2MAX)
100 CONTINUE
P1=RAN(ISEED)
P2=RAN(ISEED)
P3=RAN(ISEED)
IF(P1+P2.GT.1.) GOTO 100
F=CONL+(R1-1.)*LOG(P1)+(R2-1.)*LOG(P2)+(R3-1.)*LOG(1-P1-P2)
IF (P3.LT.EXP(F-FMAX)) RETURN
GOTO 100
END

```

C
C

```

SUBROUTINE DIRICHLET2(R1,R2,P1)
COMMON A(3),N(3),NN
COMMON ISEED,AA
CONL=GAMLN(R1+R2)-GAMLN(R1)-GAMLN(R2)
RN=R1+R2
PIMAX=(R1-1.)/(RN-1.)
FMAX=CONL+(R1-1.)*LOG(PIMAX)+(R2-1.)*LOG(1.-PIMAX)
100 CONTINUE
P1=RAN(ISEED)
P2=RAN(ISEED)
F=CONL+(R1-1.)*LOG(P1)+(R2-1.)*LOG(1-P1)
IF (P2.LT.EXP(F-FMAX)) RETURN
GO TO 100
END

```

C
C
C

```

SUBROUTINE QUANT(QNT,N,X,XQNT)
DIMENSION X(N)
IF (MOD(FLOAT(N)*QNT,1.0) .EQ. 0.0) THEN
  IQNT = N * QNT
  JQNT = IQNT + 1
ELSE
  IQNT = N * QNT + 1
  JQNT = IQNT
ENDIF
XQNT = 0.5 * (X(IQNT) + X(JQNT))
RETURN
END
SUBROUTINE SIFT (N,XV)
DIMENSION XV(N)
M=N
10 M=M/2

```

```

      IF (M) 30,20,30
20 RETURN
30 K=N-M
      J=1
40 I=J
50 L=I+M
      IF (XV(I)-XV(L)) 70,70,60
60 A=XV(I)
      XV(I)=XV(L)
      XV(L)=A
      I=I-M
      IF (I) 70,70,50
70 J=J+1
      IF (J-K) 40,40,10
      END
C
C   SUBROUTINE TO WRITE OUT MAPPER FILE FOR PLOTTING
C
      SUBROUTINE MAPPER(XQ,X,IPLANT,IP)
      PARAMETER (K=3,N=86)
      DIMENSION XQ(K,N),X(N)
      CHARACTER*(*) IPLANT,IP
      OPEN (UNIT=2, FILE= IP//'.MAP', STATUS='NEW')
C
C   WRITE OUT THE TITLE IN THE PLOT FILE FOR MAPPER
C
      WRITE (2,104)
      WRITE (2,105)IPLANT
C
C   WRITE OUT LOWER 5% POINTS
      ONE=1.0
      ZERO=0.0
      WRITE (2,106)
      WRITE (2,101) ZERO,ONE
      DO 40 I = 1,N-1
      WRITE (2,102) X(I), XQ(1,I)
40 CONTINUE
      WRITE (2,103) X(N), XQ(1,N)
C
C   WRITE OUT 50% POINTS
C
      WRITE (2,107)
      WRITE (2,101) ZERO,ONE
      DO 50 I = 1,N-1
      WRITE (2,102) X(I), XQ(2,I)
50 CONTINUE
      WRITE (2,103) X(N), XQ(2,N)
C
C   WRITE OUT UPPER 5% POINTS
C
      WRITE (2,108)
      WRITE (2,101) ZERO,ONE
      DO 60 I = 1,N-1

```

LOSP Frequency

```
      WRITE (2,102) X(I), XQ(3,I)
60 CONTINUE
      WRITE (2,103) X(N), XQ(3,N)
      CLOSE (2)
101 FORMAT ('SLINE(',E14.7,',',E14.7,',1')
102 FORMAT (E14.7,',',E14.7)
103 FORMAT (E14.7, ',',E14.7,',2',/, 'RETURN')
104 FORMAT ('*TITLE*',/'LABEL(1,,8.5,9.5,11,2,0')
105 FORMAT ('&I.35> RECOVERY CURVE FOR ',A,/, 'RETURN')
106 FORMAT ('*LOWER*')
107 FORMAT ('*MEDIAN*')
108 FORMAT ('*UPPER*')
      RETURN
```

Attachment G-38

GAMMA.FOR

LOSP Frequency

```
C      PROGRAM TO CALCULATE THE MLE'S FOR THE GAMMA DISTRIBUTION
C      PER LAWLESS
      CHARACTER*80 CFILE
      REAL LAMBDA
      PRINT *, 'INPUT FILE NAME ENCLOSED IN SINGLE QUOTES'
      READ *, CFILE OPEN(UNIT=1, FILE=CFILE, STATUS='OLD')
      OPEN(UNIT=6, FILE='MLE.OUT', STATUS='NEW')
      SUM = 0.
      SUMLOG = 0.
      N = 0
10 READ(1, *, END=1)X
      N = N + 1
      SUM = SUM + X
      SUMLOG = SUMLOG + LOG(X)
      GO TO 10
1 CONTINUE AMEAN = SUM/FLOAT(N)
      GMEAN = EXP(SUMLOG/FLOAT(N))
      S = LOG(AMEAN/GMEAN)
      IF(S.GT.5772)ALPHAT = (8.898919 + 9.059950*S + .9775373*S*S)/
1 (S*(17.79728 + 11.968477*S + S*S))
      IF(S.LE.5772)ALPHAT=(.5000876 + .1648852*S - .0544274*S*S)/S
      BETAHAT = ALPHAT/AMEAN
      WRITE(6,102)CFILE
102 FORMAT(' MLEs FOR INPUT FILE: ',A)
      WRITE(6,100)AMEAN,GMEAN,S,ALPHAT,BETAHAT,N
100 FORMAT('0SAMPLE MEAN = ',E12.7/
1      ' GEOMETRIC MEAN = ',E12.7/
2      ' S = ',F12.7/
3      ' ALPHA HAT = ',F12.7/
4      ' BETA HAT = ',F12.7/
5      ' SAMPLE SIZE = ',I5)
      CALL EXIT
      END
```

Attachment G-39

MLE.OUT

LOSP Frequency

MLEs FOR INPUT FILE: ggpc4.dat

SAMPLE MEAN	=	.9475484E+00
GEOMETRIC MEAN	=	.2486961E+00
S	=	1.3376462
ALPHA HAT	=	0.4659370
BETA HA	=	0.4917290
SAMPLE SIZE	=	62

Attachment G-40

AMOSLIB.FOR

LOSP Frequency

SUBROUTINE ERRCHK (NCHARS,NARRAY)

SANDIA MATHEMATICAL PROGRAM LIBRARY
APPLIED MATHEMATICS DIVISION 2642
SANDIA LABORATORIES
ALBUQUERQUE, NEW MEXICO 87115

SIMPLIFIED VERSION FOR STAND-ALONE USE. APRIL 1977

ABSTRACT

THE ROUTINES ERRCHK, ERXSET, AND ERRGET TOGETHER PROVIDE A UNIFORM METHOD WITH SEVERAL OPTIONS FOR THE PROCESSING OF DIAGNOSTICS AND WARNING MESSAGES WHICH ORIGINATE IN THE MATHEMATICAL PROGRAM LIBRARY ROUTINES. ERRCHK IS THE CENTRAL ROUTINE, WHICH ACTUALLY PROCESSES MESSAGES.

DESCRIPTION OF ARGUMENTS

NCHARS - NUMBER OF CHARACTERS IN HOLLERITH MESSAGE.
IF NCHARS IS NEGATED, ERRCHK WILL UNCONDITIONALLY PRINT THE MESSAGE AND STOP EXECUTION. OTHERWISE, THE BEHAVIOR OF ERRCHK MAY BE CONTROLLED BY AN APPROPRIATE CALL TO ERXSET.
NARRAY - NAME OF ARRAY OR VARIABLE CONTAINING THE MESSAGE, OR ELSE A LITERAL HOLLERITH CONSTANT CONTAINING THE MESSAGE. BY CONVENTION, ALL MESSAGES SHOULD BEGIN WITH *IN SUBNAM, ... *, WHERE SUBNAM IS THE NAME OF THE ROUTINE CALLING ERRCHK.

EXAMPLES

1. TO ALLOW CONTROL BY CALLING ERXSET, USE
CALL ERRCHK(30,30HIN QUAD, INVALID VALUE OF ERR.)
2. TO UNCONDITIONALLY PRINT A MESSAGE AND STOP EXECUTION, USE
CALL ERRCHK(-30,30HIN QUAD, INVALID VALUE OF ERR.)

ERRCHK USES SUBROUTINES ERRGET, ERRPRT, ERXSET, ERSTGT
COMPILE DECKS ERRCHK
DIMENSION NARRAY(14)

CALL ERRGET(NF,NT)

IF ERRCHK WAS CALLED WITH NEGATIVE CHARACTER COUNT, SET FATAL FLAG

IF (NCHARS.LT.0) NF = -1

IF MESSAGES ARE TO BE SUPPRESSED, RETURN

IF (NF.EQ.0) RETURN

IF CHARACTER COUNT IS INVALID, STOP

IF (NCHARS.EQ.0) PRINT 5

5 FORMAT(/31H ERRCHK WAS CALLED INCORRECTLY.)

IF (NCHARS.EQ.0) STOP

PRINT MESSAGE

CALL ERRPRT(IABS(NCHARS),NARRAY)

IF LAST MESSAGE, SAY SO

```

      IF (NF.EQ.1) PRINT 10
10  FORMAT (30H ERRCHK MESSAGE LIMIT REACHED.)
C    PRINT TRACE-BACK IF ASKED TO
C    IF ((NT.GT.0).OR.(NF.LT.0)) CALL SYSTEM ROUTINE FOR TRACEBACK
C    DECREMENT MESSAGE COUNT
      IF (NF.GT.0) NF = NF-1
      CALL ERXSET(NF,NT)
C    IF ALL IS WELL, RETURN
      IF (NF.GE.0) RETURN
C    IF THIS MESSAGE IS SUPPRESSABLE BY AN ERXSET CALL,
C    THEN EXPLAIN ERXSET USAGE.
      IF (NCHARS.GT.0) PRINT 15
15  FORMAT (/13H *** NOTE ***
      1/53H TO MAKE THE ERROR MESSAGE PRINTED ABOVE BE NONFATAL,
      2/39H OR TO SUPPRESS THE MESSAGE COMPLETELY,
      3/37H INSERT AN APPROPRIATE CALL TO ERXSET
      4 30H AT THE START OF YOUR PROGRAM.
      5/62H FOR EXAMPLE, TO PRINT UP TO 10 NONFATAL WARNING MESSAGES, USE
      6/27H      CALL ERXSET(10,0)
      PRINT 20
20  FORMAT (/28H PROGRAM ABORT DUE TO ERROR.)
      STOP
      END
      SUBROUTINE ONECHK(NCHARS,NARRAY)
C
C    ABSTRACT
C
C      ONECHK IS A COMPANION ROUTINE OF ERRCHK. IT IS CALLED
C      JUST LIKE ERRCHK, AND MESSAGES FROM IT MAY BE SUPPRESSED
C      BY AN APPROPRIATE CALL TO ERXSET. IT DIFFERS FROM ERRCHK
C      IN THAT EACH CALL TO ONECHK WILL PRODUCE NO MORE THAN ONE
C      PRINTED MESSAGE, REGARDLESS OF HOW MANY TIMES THAT CALL IS
C      EXECUTED, AND ONECHK NEVER TERMINATES EXECUTION.
C      ITS PURPOSE IS TO PROVIDE ONE-TIME-ONLY INFORMATIVE
C      DIAGNOSTICS.
C
C    DESCRIPTION OF ARGUMENTS
C      NCHARS -      NUMBER OF CHARACTERS IN THE MESSAGE.
C                   IF NEGATED, THE MESSAGE WILL BE PRINTED (ONCE) EVEN
C                   IF NFATAL HAS BEEN SET TO 0 (SEE ERXSET).
C      NARRAY -      SAME AS IN ERRCHK
C
C    ONECHK USES SUBROUTINES ERRGET, ERRPRT, ERXSET, ERSTGT C COMPILE   DECKS
ERRCHK
C
      DIMENSION NARRAY(14)
      DATA NFLAG/4H.$,*/
      IF (NARRAY(1).EQ.NFLAG) RETURN
      CALL ERRGET(NF,NT)
      IF ((NF.EQ.0).AND.(NCHARS.GT.0)) RETURN
      CALL ERRPRT (59,59H THE FOLLOWING INFORMATIVE DIAGNOSTIC WILL APPEA
IR ONLY ONCE.)
      CALL ERRPRT(IABS(NCHARS),NARRAY)

```

LOSP Frequency

```
IF (NF.GT.0) NF = NF-1
CALL ERXSET(NF,NT)
NARRAY(1) = NFLAG
END
SUBROUTINE ERRPRT(NCHARS,NARRAY)
```

```
C
C UTILITY ROUTINE TO SIMPLY PRINT THE HOLLERITH MESSAGE IN NARRAY,
C WHOSE LENGTH IS NCHARS CHARACTERS.
```

```
C
C DIMENSION NARRAY(14)
```

```
C
C NOTE - NCH MUST BE THE NUMBER OF HOLLERITH CHARACTERS STORED
C PER WORD. IF NCH IS CHANGED, FORMAT 1 MUST ALSO BE
C CHANGED CORRESPONDINGLY.
```

```
C
C NCH = 10
```

```
C FOR LINE PRINTERS, USE
```

```
1 FORMAT (IX,13A10)
```

```
C FOR DATA TERMINALS, USE
```

```
C 1 FORMAT (IX,7A10)
```

```
NWORDS = (NCHARS+NCH-1)/NCH
```

```
PRINT 1,(NARRAY(I),I=1,NWORDS)
```

```
RETURN
```

```
END
```

```
SUBROUTINE ERXSET(NFATAL,NTRACE)
```

```
C
C ABSTRACT
```

```
ERXSET IS A COMPANION ROUTINE TO SUBROUTINE ERRCHK.
```

```
ERXSET ASSIGNS THE VALUES OF NFATAL AND NTRACE RESPECTIVELY
TO NF AND NT IN COMMON BLOCK MBLK0 THEREBY SPECIFYING THE
STATE OF THE OPTIONS WHICH CONTROL THE EXECUTION OF ERRCHK.
```

```
C
C DESCRIPTION OF ARGUMENTS
```

```
BOTH ARGUMENTS ARE INPUT ARGUMENTS OF DATA TYPE INTEGER.
```

```
NFATAL - IS A FATAL-ERROR / MESSAGE-LIMIT FLAG. A NEGATIVE
VALUE DENOTES THAT DETECTED DIFFICULTIES ARE TO BE
TREATED AS FATAL ERRORS. NONNEGATIVE MEANS NONFATAL.
A NONNEGATIVE VALUE IS THE MAXIMUM NUMBER OF NONFATAL
WARNING MESSAGES WHICH WILL BE PRINTED BY ERRCHK,
AFTER WHICH NONFATAL MESSAGES WILL NOT BE PRINTED.
(DEFAULT VALUE IS -1.)
```

```
NTRACE - .GE.1 WILL CAUSE A TRACE-BACK TO BE GIVEN,
IF THIS FEATURE IS IMPLEMENTED ON THIS SYSTEM.
.LE.0 WILL SUPPRESS ANY TRACE-BACK, EXCEPT FOR
CASES WHEN EXECUTION IS TERMINATED.
(DEFAULT VALUE IS 0.)
```

```
C
C *NOTE* -- SOME CALLS TO ERRCHK WILL CAUSE UNCONDITIONAL
C TERMINATION OF EXECUTION. ERXSET HAS NO EFFECT ON SUCH CALLS.
```

```
C
C EXAMPLES
```

- ```
C 1. TO PRINT UP TO 100 MESSAGES AS NONFATAL WARNINGS USE
C CALL ERXSET(100,0)
```

2. TO SUPPRESS ALL MATHLIB WARNING MESSAGES USE  
CALL ERXSET(0,0)

ERXSET USES SUBROUTINES ERSTGT C COMPILE DECKS ERRCHK

CALL ERSTGT(0,NFATAL,NTRACE)  
RETURN  
END  
SUBROUTINE ERRGET(NFATAL,NTRACE)

#### ABSTRACT

ERRGET IS A COMPANION ROUTINE TO SUBROUTINE ERRCHK.  
ERRGET ASSIGNS TO NFATAL AND NTRACE RESPECTIVELY THE VALUES  
OF NF AND NT IN COMMON BLOCK MBLK0 THEREBY ASCERTAINING THE  
STATE OF THE OPTIONS WHICH CONTROL THE EXECUTION OF ERRCHK.

#### DESCRIPTION OF ARGUMENTS

BOTH ARGUMENTS ARE OUTPUT ARGUMENTS OF DATA TYPE INTEGER.  
NFATAL - CURRENT VALUE OF NF (SEE DESCRIPTION OF ERXSET.)  
NTRACE - CURRENT VALUE OF NT (SEE DESCRIPTION OF ERXSET.)

CALL ERSTGT(1,NFATAL,NTRACE)  
RETURN  
END  
SUBROUTINE ERSTGT(K,NFATAL,NTRACE)

THIS ROUTINE IS A SLAVE TO ERRGET AND ERRSET WHICH KEEPS  
THE FLAGS AS LOCAL VARIABLES.

\*\*\* IF LOCAL VARIABLES ARE NOT NORMALLY RETAINED BETWEEN  
CALLS ON THIS SYSTEM, THE VARIABLES LNF AND LNT CAN BE  
PLACED IN A COMMON BLOCK AND PRESET TO THE FOLLOWING  
VALUES IN THE MAIN PROGRAM.

DATA LNF/-1/~LNT/0/  
IF (K.LE.0) LNF = NFATAL  
IF (K.LE.0) LNT = NTRACE  
IF (K.GT.0) NFATAL = LNF  
IF (K.GT.0) NTRACE = LNT  
RETURN  
END  
SUBROUTINE FINVER(FUN,Y,X,DELX,ABSERR,RELERR,FMON)

WRITTEN BY D.E.AMOS AND S.L.DANIEL, SEPTEMBER, 1969.

#### REFERENCES

SC-DR-72-0917

ELEMENTS OF NUMERICAL ANALYSIS BY P. HENRICI, WILEY, 1964,  
PP. 211-213

ABSTRACT

FINVER INVERTS  $F(X)=Y$  OR FINDS A ROOT OF  $F(X)-Y=0$ .  
 AN INITIAL ESTIMATE FOR X MUST BE SUPPLIED AS WELL AS AN  
 INCREMENT FOR SEARCHING OUT A CHANGE IN SIGN OF  $F(X)-Y$ .  
 MONOTONICITY OF F IN THE AREA OF SEARCH MUST ALSO BE  
 SPECIFIED. ONCE BOUNDS ARE ESTABLISHED ON A ROOT ~  
 THE ESTIMATE IS REFINED BY LINEAR INTERPOLATION ~  
 WHICH GIVES A THIRD POINT. SUCCESSIVE UPPER AND LOWER  
 BOUNDS ARE REFINED REPEATEDLY BY QUADRATIC INTERPOLATION.

DESCRIPTION OF ARGUMENTS

INPUT

FUN - AN EXTERNAL SUBROUTINE FOR  $F(X)$  TO BE SUPPLIED  
 BY THE USER WITH THE CALL LIST

SUBROUTINE FUN(X,FOFX)

AN EXTERNAL STATEMENT

EXTERNAL FUN

MUST APPEAR IN THE CALLING PROGRAM.

Y - GIVEN FUNCTION VALUE

X - INITIAL ESTIMATE FOR THE SOLUTION OF  $F(X)-Y=0$

DELX - SEARCH INCREMENT FOR BOUNDING THE ROOT,  $DELX.GT.0.0$

ABSERR - ABSOLUTE ERROR TOLERANCE IN MIXED ERROR TEST

$ABS(F(X)-Y).LE.RELERR*ABS(Y)+ABSERR.$

$RELERR=0.0$  FOR A PURE ABSOLUTE ERROR.

$0.LE.ABSERR.LE.1.$

RELERR - RELATIVE ERROR TOLERANCE IN MIXED ERROR TEST

$ABS(F(X)-Y).LE.RELERR*ABS(Y)+ABSERR.$

$ABSERR=0.0$  FOR A PURE RELATIVE ERROR.

$0.LE.RELERR.LE.1.$

FMON - A MONOTONICITY INDICATOR FOR  $F(X)$

$FMON=-1.$  MEANS F IS MONOTONE DECREASING,

$FMON=+1.$  MEANS F IS MONOTONE INCREASING

IN THE VICINITY OF X.

OUTPUT

X - RESULT FOR THE SOLUTION OF  $F(X)=Y$

ERROR CONDITIONS

IMPROPER VALUES FOR DELX OR FMON ARE FATAL ERRORS.

FINVER USES SUBROUTINES ERRCHK ~ ERRGET ~ ERRPRT, ERXSET, ERSTGT  
 COMPILE DECKS FINVER, ERRCHK

EXTERNAL FUN

IF(FMON.NE.-1.0.AND. FMON.NE.1.0) GO TO 901

```

IF(DELX.EQ.0.0) GO TO 902
IF(ABSERR.LT.0.0 .OR. ABSERR.GT.1.) GO TO 903
IF(RELERR.LT.0.0 .OR. RELERR.GT.1.) GO TO 904
SIGN=FMON/ ABS(FMON)
FLAG=0.
ALFA=SIGN*Y
D=DELX
IFLAG=0
PTOL=RELERR*ABS(ALFA)+ABSERR

C
C
C : COMPUTATION OF FOFX
100 CONTINUE
CALL FUN(X,FOFX)
FOFX=SIGN*FOFX
F2=FOFX-ALFA
FAB= ABS(F2)
IF(FAB-PTOL) 200,200,86
86 CONTINUE
IF(IFLAG.EQ.1) GO TO 36
C BOUNDING THE ZERO OF F(X)-Y
IF(FLAG) 20,21,20
21 IF(F2) 25,200,85
20 IF(F2) 30,200,70
30 IF(F1) 40,75,80
25 FLAG=1.
40 XP=X
X=X+D
F1=F2
GO TO 100
70 IF(F1) 80,75,90
85 FLAG=1.
90 XP=X
X=X-D
F1=F2
GO TO 100
75 F2=F1
X=XP
GO TO 100
C
C END PROGRAM FOR BOUNDING THE ZERO
C
C MULLERS METHOD FOR INVERSE INTERPOLATION
C HENRICI, ELEMENTS OF NUMERICAL ANALYSIS, P.212
80 CONTINUE
F0=F1
F1=F2
XO O=XP
X10=X
XPI = X
X11=(F1*X00-F0*X10)/(F1-F0)
X20=X11
IF(X20.GE.XP.AND.X20.LE.XPI) GO TO 88
IF(X20.GE.XPI.AND.X20.LE.XP) GO TO 88

```

## LOSP Frequency

```
 X=.5*(XP+X)
 GO TO 100
88 X=X20
 IFLAG = 1
 GO TO 100
36 IFLAG=0
 DEN1=F2-F1
 IF(DEN1.EQ.0.0) GO TO 205
 DEN2 = F2-F0
 IF(DEN2.EQ.0.0) GO TO 205
 X21 = (F2*X10-F1*X20)/DEN1
 X22 =(F2*X11-F0*X21)/DEN2
 IF(X22.GE.XP.AND.X22.LE.XP1) GO TO 99
 IF(X22.GE.XP1.AND.X22.LE.XP) GO TO 99
 X=.5*(X00+X10)
 D=.5*D
 GO TO 100
99 F0=F1
 F1=F2
 X00=X10
 X10=X20
 X11=X21
 X20=X22
 GO TO 88
200 CONTINUE
C FAB=ABS(FOFX-Y)
C
 RETURN
205 IFLAG = 0
 FLAG = 0.
 D=D*.5
 GO TO 100
901 CALL ERRCHK(54,54HIN FINVER, MONOTONIC INDICATOR, FMON, IS NOT 1.
 IOR -1.)
 RETURN
902 CALL ERRCHK(23,23HIN FINVER, DELX IS ZERO)
 RETURN
903 CALL ERRCHK(37,37HIN FINVER, IMPROPER INPUT FOR ABSERR.)
 RETURN
904 CALL ERRCHK(37,37HIN FINVER, IMPROPER INPUT FOR RELERR.)
 RETURN
 END
 SUBROUTINE GAMIC(X,ALPHA,REL,N,Y,NZ)
C
C WRITTEN BY D.E. AMOS AND S.L. DANIEL, NOVEMBER, 1974.
C
C REFERENCE SC-DR-72 0303
C
C ABSTRACT
C GAMIC COMPUTES AN N MEMBER SEQUENCE OF INCOMPLETE GAMMA
C FUNCTIONS NORMALIZED SO THAT AT X=INFINITY, THE INCOMPLETE
C GAMMA FUNCTION HAS THE VALUE 1. THE SEQUENCE IS DENOTED BY
```

$Y(K) = \text{INCGAMMA}(\text{ALPHA} + K - 1, X) / \text{GAMMA}(\text{ALPHA} + K - 1), K = 1, 2, \dots, N$

AND IS COMPUTED TO A RELATIVE ERROR REL OR BETTER WHERE ALPHA .GT.0. IF ALPHA + N - 1 .GE. X, THE LAST MEMBER IS COMPUTED BY THE CONFLUENT HYPERGEOMETRIC SERIES WITH THE OTHER MEMBERS COMPUTED BY BACKWARD RECURSION ON A TWO-TERM FORMULA,

$$Y(K-1) = Y(K) + \exp((\text{ALPHA} + K - 1) * \text{ALOG}(X) - X - \text{GAMLN}(\text{ALPHA} + K)).$$

IF ALPHA + N - 1 .LT. X, AN INTEGER M IS ADDED SO THAT ALPHA + N - 1 + M .GE. X AND THE FIRST PROCEDURE IS APPLIED. SPECIAL PROCEDURES APPLY FOR ALPHA .EQ. 1 OR AN UNDERFLOW OCCURS OR X EXCEEDS A CRITICAL VALUE, APTST, WHERE ALL MEMBERS ARE 1. TO THE WORD LENGTH OF THE CDC 6600. GAMIC USES GAMLN.

#### DESCRIPTION OF ARGUMENTS

##### INPUT

X - ARGUMENT, X .GE. 0.0  
 ALPHA - PARAMETER, ALPHA .GT. 0.0  
 REL - RELATIVE ERROR TOLERANCE, REL = 1.E-S FOR S SIGNIFICANT DIGITS  
 N - NUMBER OF GAMMA FUNCTIONS IN THE SEQUENCE BEGINNING AT PARAMETER ALPHA, N .GE. 1

##### OUTPUT

Y - A VECTOR CONTAINING AN N MEMBER SEQUENCE  
 $Y(K) = \text{INCGAMMA}(\text{ALPHA} + K - 1, X) / \text{GAMMA}(\text{ALPHA} + K - 1), K = 1, \dots, N$  TO A RELATIVE ERROR REL.  
 NZ - UNDERFLOW FLAG  
 NZ .EQ. 0, A NORMAL RETURN  
 NZ .NE. 0, UNDERFLOW,  $Y(K) = 0.0, K = N - NZ + 1, N$  RETURNED

#### ERROR CONDITIONS

IMPROPER INPUT PARAMETERS - A FATAL ERROR  
 UNDERFLOW - A NON-FATAL ERROR.

GAMIC USES SUBROUTINES GAMLN, ERRCHK, ERRGET, ERRPRT, ERXSET, ERSTGT

COMPILE DECKS GAMIC, GAMLN, ERRCHK

DIMENSION Y(1)

DIMENSION AA(6) BB(6), CC(5)

DATA AA / 1.18399941922176E+00, 3.30888136276861E+02,  
 1 1.04930832947926E+04, 3.78420325596908E+04, 1.57586618187374E+02,  
 2 1.30569632410551E+03/  
 DATA BB / 1.02652821626751E+00, 9.29753107520368E+03,  
 1 6.53848923630220E+06, 2.89543295992889E+08, 8.16836456953161E+03,  
 2 4.12237656364399E+06/  
 DATA CC / 4.30952856710482E+05, 8.27988256743362E+09,  
 1 2.41944468684445E+12, 4.21722873236008E+05, 7.56593802747116E+09/



# LOSP Frequency

```

DATA SLOG /-6.67749676968273E+2/
DATA CON14 / 3.32361913019165E+1/
DATA SCALE /1.E-35/
DATA ASCL /1.E-18/

```

C

```

IF(REL.LE.0.) GO TO 91
IF(N.LT.1) GO TO 92
IF(ALPHA.LE.0.0) GO TO 93
NZ=0
IF(X) 94,10,20
10 DO 11 I=1,N
11 Y(I)=0.
RETURN

```

C

```

C IF X.GE.XLIM(ALPHA+N-1), THEN Y(K)=1., K=1,2,,N
20 NN=N
RX=1./X
NBAR=0
APN=ALPHA+FLOAT(N)-1.
APTEST=APN
AM1=ALPHA-1.
IF(APN.LE.1.) GO TO 22
21 IF(X.LE.APTEST) GO TO 40
IF(APTEST.GT.200.) GO TO 25
S1=((AA(1)*APTEST+AA(2))*APTEST+AA(3))*APTEST+AA(4)
S2=(APTEST+AA(5))*APTEST+AA(6)
GO TO 226
25 IF(APTEST.GT.10000.) GO TO 36
S1=((BB(1)*APTEST+BB(2))*APTEST+BB(3))*APTEST+BB(4)
S2=(APTEST+BB(5))*APTEST+BB(6)
226 XLIM=S1/S2

```

C

```

IF(X.GE.XLIM) GO TO 26
GO TO 35
36 S1=((APTEST+CC(1))*APTEST+CC(2))*APTEST+CC(3)
S2=(APTEST+CC(4))*APTEST+CC(5)
GO TO 226
26 DO 27 I=1,N
27 Y(I)=1.
RETURN

```

C

```

22 IF(ALPHA.NE.1.) GO TO 32
IF(X.GT.CON14) GO TO 26
IF(X.LT.0.1) GO TO 40
Y(NN)=1.-EXP(-X)
RETURN
32 NBAR=1
APTEST=APN+1.
GO TO 21
35 NBAR=X-APTEST+5.+FLOAT(NBAR)
40 ABAR=APN+FLOAT(NBAR)
XLOG=ALOG(X)
AI=1.

```

```

SUM=1.
ABK=ABAR+1.
80 AI = AI*X/ABK
SUM = SUM + AI
IF(AI.LT.REL) GO TO 100
ABK=ABK+1.
GO TO 80
100 YY=SUM*SCALE
D=ABAR
IF(NBAR.EQ.0) GO TO 110
105 CONTINUE
DO 106 K=1,NBAR
XOD=X/D
IF(XOD.LT.ASCL) GO TO 106
YY=XOD*YY+SCALE
106 D=D-1.
C
IF(NZ.NE.0) GO TO 114
110 E= -X+D*XLOG-GAMLN(D+1.)
114 IF(E.GE.SLOG) GO TO 120
Y(NN)=0
NZ=NZ+1
NN=NN-1
IF(NN.EQ.0) RETURN
NBAR=1
APN=APN-1.
E=E+ALOG(D*RX)
GO TO 105
120 EXE = EXP(E)
Y(NN)=(EXE/SCALE)*YY
NM1=NN-1
IF(NM1.EQ.0) RETURN
F=EXE*APN*RX
KK = NN
AK=FLOAT(NN)+AM1
DO 125 K=1,NM1
Y(KK-1)=Y(KK)+F
KK=KK-1
AK=AK-1.
F=F*AK*RX
125 CONTINUE
RETURN
C
91 CALL ERRCHK(33,33HIN GAMIC, IMPROPER INPUT FOR REL.)
RETURN
92 CALL ERRCHK(31,31HIN GAMIC, IMPROPER INPUT FOR N.)
RETURN
93 CALL ERRCHK(35,35HIN GAMIC, IMPROPER INPUT FOR ALPHA.)
RETURN
94 CALL ERRCHK(31,31HIN GAMIC, IMPROPER INPUT FOR X.)
RETURN
END
FUNCTION GAMLN(X)

```

LOSP Frequency

WRITTEN BY D. E. AMOS, SEPTEMBER, 1977.

REFERENCES

SAND-77-1518

COMPUTER APPROXIMATIONS BY J.F.HART, ET.AL., SIAM SERIES IN  
APPLIED MATHEMATICS, WILEY, 1968, P.135-136.

NBS HANDBOOK OF MATHEMATICAL FUNCTIONS, AMS 55, BY  
M. ABRAMOWITZ AND I.A. STEGUN, DECEMBER. 1955, P.257.

ABSTRACT

GAMLN COMPUTES THE NATURAL LOG OF THE GAMMA FUNCTION FOR  
X.GT.0. A RATIONAL CHEBYSHEV APPROXIMATION IS USED ON  
8.LT.X.LT.1000., THE ASYMPTOTIC EXPANSION FOR X.GE.1000. AND  
A RATIONAL CHEBYSHEV APPROXIMATION ON 2.LT.X.LT.3. FOR  
0.LT.X.LT.8. AND X NON-INTEGRAL, FORWARD OR BACKWARD  
RECURSION FILLS IN THE INTERVALS 0.LT.X.LT.2 AND  
3.LT.X.LT.8. FOR X=1.,2.,... ,100., GAMLN IS SET TO  
NATURAL LOGS OF FACTORIALS.

DESCRIPTION OF ARGUMENTS

INPUT

X - X.GT.0

OUTPUT

GAMLN - NATURAL LOG OF THE GAMMA FUNCTION AT X

ERROR CONDITIONS

IMPROPER INPUT ARGUMENT - A FATAL ERROR

GAMLN USES SUBROUTINES ERRCHK, ERRGET, ERRPRT, ERXSET, ERSTGT  
COMPILE DECKS GAMLN, ERRCHK  
DIMENSION GLN(100),P(5),Q(2),PCOE(9),QCOE(4)

DATA XLIM1,XLIM2,RTWPIL/ 8.,1000., 9.18938533204673E-01/  
DATA P / 7.66345188000000E-04,-5.94095610520000E-04,  
1 7.93643110484500E-04,-2.7777775657725E-03, 8.333333333333169E-02/

DATA Q /-2.77777777777778E-03, 8.33333333333333E-02/

DATA PCOE / 2.97378664481017E-03, 9.23819455902760E-03,  
1 1.09311595671044E-01, 3.98067131020357E-01, 2.15994312846059E+00,  
2 6.33806799938727E+00, 2.07824725317921E+01, 3.60367725300248E+01,  
3 6.20038380071273E+01/

DATA QCOE / 1.00000000000000E+00,-8.90601665949746E+00,  
1 9.82252110471399E+00, 6.20038380071270E+01/

```

DATA(GLN(I),I=1,60) / 2*0.0 , 6.93147180559945E-01,
1 1.79175946922806E+00, 3.17805383034795E+00, 4.78749174278205E+00,
2 6.57925121201010E+00, 8.52516136106541E+00, 1.06046029027453E+01,
3 1.28018274800815E+01, 1.51044125730755E+01, 1.75023078458739E+01,
4 1.99872144956619E+01, 2.25521638531234E+01, 2.51912211827387E+01,
5 2.78992713838409E+01, 3.06718601060807E+01, 3.35050734501369E+01,
6 3.63954452080331E+01, 3.93398841871995E+01, 4.23356164607535E+01,
7 4.53801388984769E+01, 4.84711813518352E+01, 5.16066755677644E+01,
8 5.47847293981123E+01, 5.80036052229805E+01, 6.12617017610020E+01,
9 6.45575386270063E+01, 6.78897431371815E+01, 7.12570389671680E+01,
A 7.46582363488302E+01, 7.80922235533153E+01, 8.15579594561150E+01,
B 8.50544670175815E+01, 8.85808275421977E+01, 9.21361756036871E+01,
C 9.57196945421432E+01, 9.93306124547874E+01, 1.02968198614514E+02,
D 1.06631760260643E+02, 1.10320639714757E+02, 1.14034211781462E+02,
E 1.17771881399745E+02, 1.21533081515439E+02, 1.25317271149357E+02,
F 1.29123933639127E+02, 1.32952575035616E+02, 1.36802722637326E+02,
G 1.40673923648234E+02, 1.44565743946345E+02, 1.48477766951773E+02,
H 1.52409592584497E+02, 1.56360836303079E+02, 1.60331128216631E+02,
I 1.64320112263195E+02, 1.68327445448428E+02, 1.72352797139163E+02,
J 1.76395848406997E+02, 1.80456291417544E+02, 1.84533828861449E+02/
DATA(GLN(I),I=61,100)/ 1.88628173423672E+02, 1.92739047287845E+02,
1 1.96866181672890E+02, 2.01009316399282E+02, 2.05168199482641E+02,
2 2.09342586752537E+02, 2.13532241494563E+02, 2.17736934113954E+02,
3 2.21956441819130E+02, 2.26190548323728E+02, 2.30439043565777E+02,
4 2.34701723442818E+02, 2.38978389561834E+02, 2.43268849002983E+02,
5 2.47572914096187E+02, 2.51890402209723E+02, 2.56221135550010E+02,
6 2.60564940971863E+02, 2.64921649798553E+02, 2.69291097651020E+02,
7 2.73673124285694E+02, 2.78067573440366E+02, 2.82474292687630E+02,
8 2.86893133295427E+02, 2.91323950094270E+02, 2.95766601350761E+02,
9 3.00220948647014E+02, 3.04686856765669E+02, 3.09164193580147E+02,
A 3.13652829949879E+02, 3.18152639620209E+02, 3.22663499126726E+02,
B 3.27185287703775E+02, 3.31717887196928E+02, 3.36261181979198E+02,
C 3.40815058870799E+02, 3.45379407062267E+02, 3.49954118040770E+02,
D 3.54539085519441E+02, 3.59134205369575E+02/

```

C

```

IF(X) 90,90,5
5 NDX=X
T=X-FLOAT(NDX)
IF(T.EQ.0.0) GO TO 51
DX=XLIMI-X
IF(DX.LT.0.0) GO TO 40

```

C

C

C

RATIONAL CHEBYSHEV APPROXIMATION ON 2.LT.X.LT.3 FOR GAMMA(X)

```

NXM=NDX-2
PX=PCOE(I)
DO 10 I=2,9
10 PX=T*PX+PCOE(I)
QX=QCOE(I)
DO 15 I=2,4
15 QX=T*QX+QCOE(I)
DGAM=PX/QX
IF(NXM.GT.0) GO TO 22

```

# LOSP Frequency

```
 IF(NXM.EQ.0) GO TO 25
C
C BACKWARD RECURSION FOR 0.LT.X.LT.2
C
 DGAM=DGAM/(1.+T)
 IF(NXM.EQ.-1) GO TO 25
 DGAM=DGAM/T
 GAMLN=ALOG(DGAM)
 RETURN
C
C FORWARD RECURSION FOR 3.LT.X.LT.8
C
 22 XX=2.+T
 DO 24 I=1,NXM
 DGAM=DGAM*XX
 24 XX=XX+1.
 25 GAMLN=ALOG(DGAM)
 RETURN
C
C X.GT.XLIM1
C
 40 RX=1./X
 RXX=RX*RX
 IF((X-XLIM2).LT.0.) GO TO 41
 PX=Q(1)*RXX+Q(2)
 GAMLN=PX*RX+(X-.5)*ALOG(X)-X+RTWPIL
 RETURN
C
C X.LT.XLIM2
C
 41 PX=P(1)
 SUM=(X-.5)*ALOG(X)-X
 DO 42 I=2,5
 PX=PX*RXX+P(I)
 42 CONTINUE
 GAMLN=PX*RX+SUM+RTWPIL
 RETURN
C
C TABLE LOOK UP FOR INTEGER ARGUMENTS LESS THAN OR EQUAL 100.
C
 51 IF(NDX.GT.100) GO TO 40
 GAMLN=GLN(NDX)
 RETURN
 90 CALL ERRCHK(49,49HIN GAMLN, ARGUMENT IS LESS THAN OR EQUAL TO ZERO
 1.)
 RETURN
 END
 SUBROUTINE GAMTL(X,B,REL,N,Y,NZ)
C
C WRITTEN BY D.E. AMOS AND S.L. DANIEL, OCTOBER,1974
C
C REFERENCE SC-DR-72 0303
C
```

## C ABSTRACT

C GAMTL COMPUTES AN N MEMBER SEQUENCE OF COMPLEMENTARY  
C GAMMA FUNCTIONS

C  $Y(K)=1.-\text{INCGAMMA}(B+K-1,X)/\text{GAMMA}(B+K-1)$ ,  $K=1,\dots,N$ ,

C TO A RELATIVE ERROR REL FOR  $X.\text{GE}.0$  AND  $B.\text{GT}.0$ . THE CONTINUED  
C FRACTION IS EVALUATED FOR  $BO.\text{GT}.0$ ,  $BO=B$ -INTEGER PART OF  
C B, FOLLOWED BY FORWARD RECURSION ON ITS TWO TERM RELATION TO  
C RAISE BO TO  $B+N-1$ . THE CONVERGENCE IS BEST FOR LARGE  
C  $X.\text{GE}.$   $\text{MAX}(1,BO)$ . WHERE SPEED IS A CONSIDERATION, EVALUATE  
C  $Y(K)$  BY SUBTRACTING THE INCOMPLETE GAMMA FUNCTION FROM 1.  
C USING SUBROUTINE GAMIC FOR  $X.\text{LT}.$   $\text{MAX}(1,B+K-1)$  AND GAMTL FOR  
C  $X.\text{GE}.$   $\text{MAX}(1,B+K-1)$ .

## C DESCRIPTION OF ARGUMENTS

## C INPUT

C X - ARGUMENT,  $X.\text{GE}.0.0$

C B - PARAMETER,  $B.\text{GT}.0.0$

C REL - RELATIVE ERROR REQUIREMENT,  
C  $\text{REL}=1.E-S$  FOR S SIGNIFICANT DIGITS,  $0.\text{LE}.S.\text{LE}.12$

C N - NUMBER OF COMPLEMENTARY FUNCTIONS IN THE SEQUENCE  
C BEGINNING AT PARAMETER B,  $N.\text{GE}.1$

## C OUTPUT

C Y - A VECTOR CONTAINING AN N MEMBER SEQUENCE  
C  $Y(K)=1.-\text{INCGAMMA}(B+K-1,X)/\text{GAMMA}(B+K-1)$ ,  $K=1,\dots,N$   
C TO A RELATIVE ERROR REL.

C NZ - UNDERFLOW FLAG  
C  $\text{NZ.EQ}.0$ , A NORMAL RETURN  
C  $\text{NZ.NE}.0$ , UNDERFLOW,  $Y(K)=0.0$ ,  $K=1,\text{NZ}$  RETURNED.

## C ERROR CONDITIONS

C IMPROPER INPUT - A FATAL ERROR

C CONTINUED FRACTION DOES NOT CONVERGE - A FATAL ERROR.

C UNDERFLOW - A NON-FATAL ERROR.

C GAMTL USES SUBROUTINES GAMLN, ERRCHK, ERRGET, ERRPRT, ERXSET,  
C ERSTGT

C COMPILE DECKS GAMTL, GAMLN, ERRCHK

C DIMENSION Y( 1)

C DIMENSION AA(6),BB(6),CC(6),DD(5)

C DATA AA / 1.68859588328389E+00, 1.46584889514920E+03,

1 1.73155244984160E+05, 2.30183328529532E+06, 2.27877181874608E+02,

2 3.47933198737331E+03/

C DATA BB / 1.25558472503917E+00, 4.44539043255409E+03,

1 2.40212910342450E+06, 2.22905539488737E+08, 1.84918400518640E+03,

2 3.17776548571970E+05/

C DATA CC / 1.09010860762347E+00, 2.03790209154944E+04,

1 4.60641404764333E+07, 1.36803284952888E+10, 1.39702132796605E+04,

2 1.59209661717833E+07/

# LOSP Frequency

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DATA DD / 4.68251145610753E+05, 1.11348212926478E+10,
1 1.38713354995651E+13, 4.29493174834810E+05, 7.88439389479852E+09/
DATA MAXR,W,SP250,SM250,A250/1280,632.5,1.E+35,1.E-35,
$5.75646273248511E+2/
DATA ELIM , RLIM/ 667. , 1.E-12/
IF(N.LE.0) GO TO 91
IF(B.LE.0.0) GO TO 92
NZ=0
IF (X) 93,6,8
6 DO 7 J=1,N
7 Y(J) = 1.
RETURN
8 CONTINUE
IF(REL.LT.RLIM) GO TO 94
C IF X.GE.XLIM(B+N-1), Y(K)=0., K=1,2,,N DUE TO UNDERFLOW
C
BPN=B+FLOAT(N)-1.
BPTEST=BPB
BML=B-1.
IF(BPN.LE.1.) GO TO 11
IF(X.LE.BPTEST) GO TO 9
IF(BPTEST.GT.200.) GO TO 12
S1=((AA(1)*BPTEST+AA(2))*BPTEST+AA(3))*BPTEST+AA(4)
S2=(BPTEST+AA(5))*BPTEST+AA(6)
GO TO 15
12 IF(BPTEST.GT.1000.) GO TO 14
S1=((BB(1)*BPTEST+BB(2))*BPTEST+BB(3))*BPTEST+BB(4)
S2=(BPTEST+BB(5))*BPTEST+BB(6)
GO TO 15
14 IF(BPTEST.GT.10000.) GO TO 16
S1=((CC(1)*BPTEST+CC(2))*BPTEST+CC(3))*BPTEST+CC(4)
S2=(BPTEST+CC(5))*BPTEST+CC(6)
GO TO 15
16 S1=((BPTEST+DD(1))*BPTEST+DD(2))*BPTEST+DD(3)
S2=(BPTEST+DD(4))*BPTEST+DD(5)
15 XLIM=S1/S2
IF(X.GE.XLIM) GO TO 17
GO TO 9
17 DO 18 I=1,N
18 Y(I)=0-
NZ=N
RETURN
11 IF(X.LT.ELIM) GO TO 9
GO TO 17
9 CONTINUE
NB=B
BO=B-FLOAT(NB)
IF(BO) 10,10,20
10 BO=1.
NB=NB-1
GBOPLX=0.
SCALE = 0.
RI = X

```

```

 GBX=1.
 GO TO 100
C
C COMPUTE BIGGAM (BO,X) BY CONTINUED FRACTION
C
20 KFLAG=0
 NBAR=10. + 1./(X+.01)
30 IF(NBAR.GT.MAXR) GO TO 95
 RNPI=0.
 SN=NBAR+1
 DO 21 J=1,NBAR
 SN=SN-1.
 RN=X+(SN-BO)*RNPI/(SN+RNPI)
 RNPI=RN
21 CONTINUE
C
 IF(KFLAG.NE.0) GO TO 23
 KFLAG=1
 NBAR=NBAR+NBAR
 RSAVE=RN
 GO TO 30
C
23 RTEST=ABS((RSAVE-RN)/RN)
 IF(RTEST.LE.REL) GO TO 40
 RSAVE=RN
 NBAR=NBAR+NBAR
 GO TO 30
C
40 CONTINUE
 GBOPLX=BO*ALOG(X)-GAMLN(BO)
 SCALE=0.
 RI=1./BO
 GBX=1./RN
100 AJ = BO
 ETERM=-X+GBOPLX
 IF(NB.LE.0) GO TO 110
C
C RAISE PARAMETER FROM BO TO B BY RECURSION
C IF TERM.GT.SP250 OR .LT.SM250, SCALE AND CONTINUE
C
102 DO 105 K=1,NB
 GBX = GBX + RI
 AJ=AJ+1.
 RI=RI*X/AJ
 IF(RI.LE.SP250) GO TO 104
 RI=RI*SM250
 GBX=GBX*SM250
 SCALE = SCALE + A250
 GO TO 105
104 IF(RI.GE.SM250) GO TO 105
 RI=RI*SP250
 GBX=GBX*SP250
 SCALE=SCALE-A250

```



## LOSP Frequency

```
105 CONTINUE
110 CONTINUE
 GARG=ETERM+ALOG(GBX)+SCALE
 IF(GARG.GT.-ELIM) GO TO 114
C
C UNDERFLOW VALUES SET TO ZERO
C
 NZ=NZ+1
 Y(NZ)=0.0
 IF(NZ.EQ.N) RETURN
 NB=1
 GO TO 102
C
C COMPUTATION OF Y(K) BY RECURSION
C
114 IK=NZ+1
 Y(IK)=EXP(GARG)
 IF(N.EQ.IK) RETURN
 IF(R1.LE.0.0) GO TO 116
 R1=EXP(ETERM+ALOG(R1)+SCALE)
117 KEND=N-1
 DO 115 K=IK,KEND
 Y(K+1)=Y(K)+R1
 AJ = AJ + 1.
 R1 = R1*X/AJ
115 CONTINUE
 RETURN
116 R1 = 0.
 GO TO 117
C
91 CALL ERRCHK(31,31HIN GAMTL, IMPROPER INPUT FOR N.)
 RETURN
92 CALL ERRCHK(31,31HIN GAMTL, IMPROPER INPUT FOR B.)
 RETURN
93 CALL ERRCHK(31,31HIN GAMTL, IMPROPER INPUT FOR X.)
 RETURN
94 CALL ERRCHK(33,33HIN GAMTL, IMPROPER INPUT FOR REL.)
 RETURN
95 CALL ERRCHK(67,67HIN GAMTL, CONTINUED FRACTION DOES NOT CONVERGE,
 IUSE 1.-INCGAMMA(X).)
 RETURN
 END
 FUNCTION FNORM(X,KODE,NZ)
C
C WRITTEN BY D.E. AMOS AND S.L. DANIEL, OCTOBER, 1974
C
C REFERENCE SC-DR-72-0918
C
C ABSTRACT
C FNORM COMPUTES THE CUMULATIVE NORMAL DISTRIBUTION F(X) OR
C ITS COMPLEMENT 1.-F(X). CHEBYSHEV EXPANSIONS FOR ERF(Z) ON
C 0.LE.Z.LT.2 AND ERFC(Z) ON 2.LE.Z.LE.4 AND Z.GT.4 ARE
C USED FOR EVALUATION. THE RELATIONS
```

$F(X) = .5 * \text{ERFC}(Z)$  ,  $Z = -X/\text{SQRT}(2)$  ,  $X.LT.-2.*\text{SQRT}(2)$   
 $F(X) = .5 - .5 * \text{ERF}(Z)$  ,  $Z = -X/\text{SQRT}(2)$  ,  $-2.*\text{SQRT}(2).LE.X.LT.0$   
 $F(X) = .5 + .5 * \text{ERF}(Z)$  ,  $Z = X/\text{SQRT}(2)$  ,  $0.LE.X.LT.2.*\text{SQRT}(2)$   
 $F(X) = 1 - .5 * \text{ERFC}(Z)$  ,  $Z = X/\text{SQRT}(2)$  ,  $2.LE.Z.LT.6$   
 $F(X) = 1$  ,  $X.GE.6.*\text{SQRT}(2)$   
 $F(-X) = 1 - F(X)$  ,

ARE USED TO COMPLETE THE DEFINITION ON THE REAL LINE SO THAT  
SIGNIFICANT DIGITS ARE RETAINED OVER THE FULL EXPONENT RANGE.

# DESCRIPTION OF ARGUMENTS

## INPUT

X - ARGUMENT OF THE DISTRIBUTION

KODE - A SELECTION PARAMETER

KODE=1 RETURNS FNORM=F(X)

KODE=2 RETURNS FNORM=1.-F(X)

## OUTPUT

FNORM - ANSWER FOR F(X) OR 1.-F(X) DEPENDING ON KODE.

NZ - UNDERFLOW FLAG

NZ=0, A NORMAL RETURN

NZ=1, UNDERFLOW, FNORM=0.0 RETURNED

## ERROR CONDITIONS

IMPROPER INPUT FOR KODE- A FATAL ERROR

UNDERFLOW - A NON-FATAL ERROR, XLIM=-36.5444845898331 IS THE  
CRITICAL VALUE.

FNORM USES SUBROUTINES ERRCHK, ERRGET, ERRPRT, ERXSET, ERSTGT

COMPILE DECKS FNORM, ERRCHK

DIMENSION A1(21),A2(23),A3(17)

DATA A1 / 2.94268192595158E-01,-1.20794002859252E-01,  
1-5.38155411612267E-03, 9.61245872309754E-03,-1.56928442055175E-03,  
2-3.13379686339925E-04, 1.34539944432857E-04,-2.01886311941572E-06,  
3-6.02924420904726E-06, 7.33514212717164E-07, 1.68200375041707E-07,  
4-4.21496636122487E-08,-2.34089537886964E-09, 1.54397950861409E-09,  
5-3.83910453258562E-11,-4.18791755643448E-11, 3.66254323806330E-12,  
6 8.67662501706706E-13,-1.38490737068408E-13,-1.30609215123467E-14,  
7 3.76420840390550E-15/

DATA A2 / 3.93098827656776E-01, 0.

1-5.72072868438617E-03, 0.0 , 1.18630151591342E-04,  
2 0.0 , -3.91103704629101E-06, 0.0  
3 1.72795234431416E-07, 0.0 , -9.42361518118889E-09,  
4 0.0 , 6.04595735693237E-10, 0.0  
5-4.42225118426537E-11, 0.0 , 3.60747153118711E-12,  
6 0.0 , -3.22932023145379E-13, 0.0  
7 3.13323522258447E-14, 0.0 , -3.26302072101379E-15/

DATA A3 / 2.66657721330163E-01, 8.94380310492471E-03,

1-1.90087646908402E-03, 3.48555717528185E-04,-5.81844230476253E-05,  
2 9.06838380458210E-06,-1.33859970500872E-06, 1.88850668170541E-07,

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3-2.56245596590501E-08, 3.35935312400552E-09,-4.27010392442662E-10,  
4 5.27726756655456E-11,-6.35545872359585E-12, 7.47249710210314E-13,  
5-8.59121451944801E-14, 9.67175305486972E-15,-1.06741339515971E-15/

C

DATA RTWO,TRTWO,FRTWO,SRTWO,XLIM/

1 1.41421356237310E+00, 2.82842712474619E+00, 5.65685424949238E+00,  
2 8.48528137423857E+00,-3.65444845898331E+01/

C

DATA N1,N2,N3,M1,M2,M3/21,23,17,19,21,15/

C

IF(KODE.LT.1.OR.KODE.GT.2) GO TO 900

NZ=0

GO TO (100,200),KODE

100 CONTINUE

XX=X

150 IF(XX.GE.XLIM) GO TO 102

FNORM=0.0

NZ=1

RETURN

102 IF(XX.LT.SRTWO) GO TO 104

FNORM=1.0

RETURN

104 IF(XX.LE.FRTWO) GO TO 106

ASSIGN 110 TO ISET

107 CONTINUE

Z=FRTWO/XX

TZ=Z+Z

J=N2 BI=A2(J)

B2=0.

DO 25 I=1,M2

J=J-1

TEMP=BI

BI=TZ\*BI-B2+A2(J)

B2=TEMP

25 CONTINUE

ANS=Z\*BI-B2+A2(1)

FNORM=(EXP(-XX\*XX\*.5)/XX)\*ANS

GO TO ISET,(110,115)

110 FNORM=1.-FNORM

115 RETURN

106 IF(XX.GT.TRTWO) GO TO 112

IF(XX.LT.-TRTWO) GO TO 108

Z=ABS(XX)/RTWO-1.

TZ=Z+Z

J=N1

BI=A1(J)

B2=0.

DO 45 I=1,M1

J=J-1

TEMP=BI

BI=TZ\*BI-B2+A1(J)

B2=TEMP

45 CONTINUE

```
 FNORM=XX*(Z*B1-B2+A1(1))+0.5
 RETURN
108 IF(XX.GT.-FRTWO) GO TO 109
 ASSIGN 115 TO ISET
 XX=-XX GO TO 107
109 CONTINUE XS=-XX/RTWO
113 Z=XS-3.
 TZ=Z+Z
 J=N3
 B1=A3(J)
 B2=0.
 DO 36 I=1,M3
 J=J-1
 TEMP=B1
 B1=TZ*B1-B2+A3(J)
 B2 = TEMP
36 CONTINUE
 ANS=Z*B1-B2+A3(1)
 FNORM=EXP(-XS*XS)*ANS/XS
 IF(XX.GT.0.0) FNORM=1.-FNORM
 RETURN
200 XX=-X
 GO TO 150
112 XS=XX/RTWO
 GO TO 113
900 CALL ERRCHK(34,34HIN FNORM, IMPROPER INPUT FOR KODE.)
 RETURN
 END
```

LOSP Frequency

Attachnent G-41

GG.DAT

TITLE*
TABEL(1,,8.5,9.5,11,2,0
I.35> RECOVERY CURVE FOR GRAND GULF
RETURN
LOWER*
LINE(0.000000E+00, 0.100000E+01,1
0.500000E-01, 0.6332765E+00
0.100000E+00, 0.5221666E+00
0.150000E+00, 0.4418805E+00
0.200000E+00, 0.3805399E+00
0.250000E+00, 0.3321897E+00
0.300000E+00, 0.2959414E+00
0.350000E+00, 0.2639019E+00
0.400000E+00, 0.2377258E+00
0.450000E+00, 0.2159356E+00
0.500000E+00, 0.1979217E+00
0.550000E+00, 0.1835196E+00
0.600000E+00, 0.1708331E+00
0.650000E+00, 0.1598593E+00
0.700000E+00, 0.1493906E+00
0.750000E+00, 0.1405793E+00
0.800000E+00, 0.1333128E+00
0.850000E+00, 0.1262909E+00
0.900000E+00, 0.1205451E+00
0.950000E+00, 0.1149577E+00
0.100000E+01, 0.1102719E+00
0.105000E+01, 0.1056353E+00
0.110000E+01, 0.1014440E+00
0.113300E+01, 0.9869112E-01
0.120000E+01, 0.9392024E-01
0.125000E+01, 0.8945530E-01
0.128300E+01, 0.8722764E-01
0.133300E+01, 0.8405942E-01
0.140000E+01, 0.8031324E-01
0.145000E+01, 0.7762612E-01
0.150000E+01, 0.7501823E-01
0.155000E+01, 0.7281739E-01
0.160000E+01, 0.7047690E-01
0.165000E+01, 0.6827596E-01
0.170000E+01, 0.6635383E-01
0.175000E+01, 0.6447174E-01
0.180000E+01, 0.6267905E-01
0.185000E+01, 0.6098870E-01
0.190000E+01, 0.5930665E-01
0.195000E+01, 0.5773523E-01
0.200000E+01, 0.5629625E-01
0.205000E+01, 0.5508481E-01
0.210000E+01, 0.5343305E-01
0.215000E+01, 0.5228697E-01
0.220000E+01, 0.5091853E-01
0.225000E+01, 0.4930571E-01
0.230000E+01, 0.4812152E-01
0.235000E+01, 0.4712099E-01
0.240000E+01, 0.4609329E-01
0.245000E+01, 0.4509338E-01

LOSP Frequency

0.2500000E+01, 0.4413055E-01
0.2750000E+01, 0.3985612E-01
0.3000000E+01, 0.3599319E-01
0.3167000E+01, 0.3364090E-01
0.3500000E+01, 0.2977570E-01
0.3750000E+01, 0.2700900E-01
0.4000000E+01, 0.2464051E-01
0.4250000E+01, 0.2305845E-01
0.4500000E+01, 0.2131568E-01
0.4750000E+01, 0.1970513E-01
0.5000000E+01, 0.1842000E-01
0.5250000E+01, 0.1704338E-01
0.5500000E+01, 0.1558531E-01
0.5750000E+01, 0.1451475E-01
0.6000000E+01, 0.1370299E-01
0.6250000E+01, 0.1289671E-01
0.6500000E+01, 0.1204479E-01
0.6750000E+01, 0.1111974E-01
0.7000000E+01, 0.1035678E-01
0.7250000E+01, 0.9655474E-02
0.7500000E+01, 0.8968785E-02
0.7750000E+01, 0.8355397E-02
0.8000000E+01, 0.7840881E-02
0.8250000E+01, 0.7255260E-02
0.8500000E+01, 0.6714201E-02
0.8750000E+01, 0.6235197E-02
0.9000000E+01, 0.5782876E-02
0.9250000E+01, 0.5418809E-02
0.9500000E+01, 0.5086483E-02
0.9750000E+01, 0.4756637E-02
0.1000000E+02, 0.4432298E-02
0.1330000E+02, 0.1716932E-02
0.1500000E+02, 0.1068773E-02
0.1600000E+02, 0.7913224E-03
0.1800000E+02, 0.4602075E-03
0.2300000E+02, 0.1144893E-03
0.2700000E+02, 0.4291907E-04,2
RETURN
MEDIAN*
LINE(0.0000000E+00, 0.1000000E+01,1
0.5000000E-01, 0.7463541E+00
0.1000000E+00, 0.6327068E+00
0.1500000E+00, 0.5513938E+00
0.2000000E+00, 0.4899929E+00
0.2500000E+00, 0.4406971E+00
0.3000000E+00, 0.4001229E+00
0.3500000E+00, 0.3628054E+00
0.4000000E+00, 0.3333218E+00
0.4500000E+00, 0.3073997E+00
0.5000000E+00, 0.2850477E+00
0.5500000E+00, 0.2652728E+00
0.6000000E+00, 0.2483225E+00
0.6500000E+00, 0.2333687E+00
0.7000000E+00, 0.2203711E+00
0.7500000E+00, 0.2097112E+00

0.8000000E+00, 0.1992576E+00
0.8500000E+00, 0.1902534E+00
0.9000000E+00, 0.1825861E+00
0.9500000E+00, 0.1743934E+00
0.1000000E+01, 0.1675142E+00
0.1050000E+01, 0.1616396E+00
0.1100000E+01, 0.1559624E+00
0.1133000E+01, 0.1521893E+00
0.1200000E+01, 0.1468149E+00
0.1250000E+01, 0.1425016E+00
0.1283000E+01, 0.1393100E+00
0.1333000E+01, 0.1357623E+00
0.1400000E+01, 0.1306901E+00
0.1450000E+01, 0.1270454E+00
0.1500000E+01, 0.1232989E+00
0.1550000E+01, 0.1200562E+00
0.1600000E+01, 0.1172448E+00
0.1650000E+01, 0.1145043E+00
0.1700000E+01, 0.1116334E+00
0.1750000E+01, 0.1090089E+00
0.1800000E+01, 0.1066669E+00
0.1850000E+01, 0.1041265E+00
0.1900000E+01, 0.1020300E+00
0.1950000E+01, 0.9953812E-01
0.2000000E+01, 0.9761813E-01
0.2050000E+01, 0.9561905E-01
0.2100000E+01, 0.9363572E-01
0.2150000E+01, 0.9173092E-01
0.2200000E+01, 0.8988579E-01
0.2250000E+01, 0.8837061E-01
0.2300000E+01, 0.8693677E-01
0.2350000E+01, 0.8543687E-01
0.2400000E+01, 0.8396951E-01
0.2450000E+01, 0.8256046E-01
0.2500000E+01, 0.8126954E-01
0.2750000E+01, 0.7452092E-01
0.3000000E+01, 0.6894428E-01
0.3167000E+01, 0.6517889E-01
0.3500000E+01, 0.5970375E-01
0.3750000E+01, 0.5649908E-01
0.4000000E+01, 0.5294258E-01
0.4250000E+01, 0.4993482E-01
0.4500000E+01, 0.4706598E-01
0.4750000E+01, 0.4466926E-01
0.5000000E+01, 0.4245387E-01
0.5250000E+01, 0.4051010E-01
0.5500000E+01, 0.3881580E-01
0.5750000E+01, 0.3692094E-01
0.6000000E+01, 0.3515644E-01
0.6250000E+01, 0.3354414E-01
0.6500000E+01, 0.3214720E-01
0.6750000E+01, 0.3076831E-01
0.7000000E+01, 0.2945143E-01
0.7250000E+01, 0.2812898E-01
0.7500000E+01, 0.2681594E-01

LOSP Frequency

0.7750000E+01, 0.2568585E-01
0.8000000E+01, 0.2471176E-01
0.8250000E+01, 0.2344669E-01
0.8500000E+01, 0.2230225E-01
0.8750000E+01, 0.2121469E-01
0.9000000E+01, 0.2026050E-01
0.9250000E+01, 0.1950373E-01
0.9500000E+01, 0.1871312E-01
0.9750000E+01, 0.1803369E-01
0.1000000E+02, 0.1727138E-01
0.1330000E+02, 0.1065451E-01
0.1500000E+02, 0.8241972E-02
0.1600000E+02, 0.7000074E-02
0.1800000E+02, 0.5302712E-02
0.2300000E+02, 0.2524897E-02
0.2700000E+02, 0.1405742E-02,2
ETURN
UPPER*
LINE(0.0000000E+00, 0.1000000E+01,1
0.5000000E-01, 0.8269160E+00
0.1000000E+00, 0.7265984E+00
0.1500000E+00, 0.6552023E+00
0.2000000E+00, 0.6002278E+00
0.2500000E+00, 0.5536128E+00
0.3000000E+00, 0.5119509E+00
0.3500000E+00, 0.4762957E+00
0.4000000E+00, 0.4432515E+00
0.4500000E+00, 0.4168997E+00
0.5000000E+00, 0.3915053E+00
0.5500000E+00, 0.3703218E+00
0.6000000E+00, 0.3497718E+00
0.6500000E+00, 0.3339318E+00
0.7000000E+00, 0.3173733E+00
0.7500000E+00, 0.3034671E+00
0.8000000E+00, 0.2909432E+00
0.8500000E+00, 0.2791729E+00
0.9000000E+00, 0.2671401E+00
0.9500000E+00, 0.2573200E+00
0.1000000E+01, 0.2478499E+00
0.1050000E+01, 0.2388053E+00
0.1100000E+01, 0.2307131E+00
0.1133000E+01, 0.2259223E+00
0.1200000E+01, 0.2174941E+00
0.1250000E+01, 0.2112151E+00
0.1283000E+01, 0.2075935E+00
0.1333000E+01, 0.2024275E+00
0.1400000E+01, 0.1960352E+00
0.1450000E+01, 0.1915764E+00
0.1500000E+01, 0.1879017E+00
0.1550000E+01, 0.1843548E+00
0.1600000E+01, 0.1809978E+00
0.1650000E+01, 0.1770544E+00
0.1700000E+01, 0.1745154E+00
0.1750000E+01, 0.1718642E+00
0.1800000E+01, 0.1693036E+00

0.1850000E+01, 0.1652479E+00
0.1900000E+01, 0.1621052E+00
0.1950000E+01, 0.1594075E+00
0.2000000E+01, 0.1562051E+00
0.2050000E+01, 0.1529781E+00
0.2100000E+01, 0.1505008E+00
0.2150000E+01, 0.1481019E+00
0.2200000E+01, 0.1457740E+00
0.2250000E+01, 0.1435089E+00
0.2300000E+01, 0.1412663E+00
0.2350000E+01, 0.1389527E+00
0.2400000E+01, 0.1368531E+00
0.2450000E+01, 0.1348111E+00
0.2500000E+01, 0.1328239E+00
0.2750000E+01, 0.1253677E+00
0.3000000E+01, 0.1184479E+00
0.3167000E+01, 0.1137395E+00
0.3500000E+01, 0.1056090E+00
0.3750000E+01, 0.9968156E-01
0.4000000E+01, 0.9447845E-01
0.4250000E+01, 0.9048945E-01
0.4500000E+01, 0.8682710E-01
0.4750000E+01, 0.8340991E-01
0.5000000E+01, 0.8040784E-01
0.5250000E+01, 0.7825368E-01
0.5500000E+01, 0.7641406E-01
0.5750000E+01, 0.7468758E-01
0.6000000E+01, 0.7307281E-01
0.6250000E+01, 0.7154985E-01
0.6500000E+01, 0.7011337E-01
0.6750000E+01, 0.6821700E-01
0.7000000E+01, 0.6626640E-01
0.7250000E+01, 0.6491457E-01
0.7500000E+01, 0.6326144E-01
0.7750000E+01, 0.6150336E-01
0.8000000E+01, 0.5973991E-01
0.8250000E+01, 0.5795457E-01
0.8500000E+01, 0.5645822E-01
0.8750000E+01, 0.5527582E-01
0.9000000E+01, 0.5412262E-01
0.9250000E+01, 0.5270466E-01
0.9500000E+01, 0.5174899E-01
0.9750000E+01, 0.5086838E-01
0.1000000E+02, 0.4984432E-01
0.1330000E+02, 0.3822363E-01
0.1500000E+02, 0.3366899E-01
0.1600000E+02, 0.3180100E-01
0.1800000E+02, 0.2834608E-01
0.2300000E+02, 0.2041070E-01
0.2700000E+02, 0.1534511E-01,2
RETURN

LOSP Frequency

Attachment G-42

COMMEAN.FOR

PROGRAM COMMEAN

```

C COMPUTE MEAN FOR EACH TIME STEP PRODUCED BY 'MODEL'.
C 'MODEL' NAMES THE PLOT FILE 'plant name'.DAT. THAT NAME IS
C CHANGED TO MAP.DAT SO THAT RMAPPER CAN BE USED WITHOUT CHANGE.
C THIS PROGRAM PRODUCES A PLOT FILE, 'MEAN.DAT', THAT IS USED
C IN THE CONTROL STREAM IN 'UPPER.DAT'.
C TO GET A,PLOT:
C . MAPPER device name
C The response to ENTER OPTIONS is
C I=UPPER.DAT
 PARAMETER(NOT=88)
 DIMENSION XVAL(NOT,3),XMEAN(NOT),TIM(NOT),EF(NOT)
 CHARACTER LINE*80
 OPEN (10,FILE='MAP.DAT',READONLY,STATUS='OLD')
 OPEN (12,FILE='LOGNORMAL.DAT',STATUS='NEW')
 OPEN (13,FILE='MEAN.DAT',STATUS='NEW')
 DO 1 I=1,NOT
 XMEAN(I)=0.
 DO 2 M=1,5
 READ(10,'(A)')LINE
 WRITE(13,'(A)')LINE
 2 CONTINUE
 DO 50 J=1,3
 READ(10,11)TIM(I),XVAL(I,J)
 11 FORMAT(6X,E14.3,1X,E14.3)
 DO 10 I=2,NOT
 READ(10,*)TIM(I),XVAL(I,J)
 TYPE*,TIM(I),XVAL(I,J)
 10 CONTINUE
 READ(10,'(A)')LINE
 READ(10,'(A)',END=99)
 50 CONTINUE
C COMPUTE ERROR FACTOR
 60 DO 100 I=1,NOT
 IF(XVAL(I,1).EQ.0)THEN
 TYPE *,I
 ENDIF
 EF(I)= XVAL(I,2)/XVAL(I,1)
 XMEAN(I)=XVAL(I,2)*EXP(~LOG(EF(I))**2/5.42)
 100 CONTINUE
 WRITE (12,110)
 110 FORMAT(' TIME ', ' EF ', ' MEAN ')
 DO 120 I=1,NOT
 WRITE(12,111)TIM(I),EF(I),XMEAN(I)
 111 FORMAT(F8.2,4X,4X,F4.1,4X,1PE12.3)
 112 FORMAT('SLINE(',E14.3,',',E14.3,',1')
 113 FORMAT(E14.7,',',E14.7)
 114 FORMAT(E14.3,',',E14.3,',2')
 IF(I.EQ.1)WRITE(13,112)TIM(I),XMEAN(I)
 IF(I.EQ.NOT)THEN
 WRITE(13,114)TIM(I),XMEAN(I)
 GO TO 120
 ENDIF
 WRITE(13,113)TIM(I),XMFAN(I)
 120 CONTINUE
 WRITE(13,115)
 115 FORMAT('RETURN')
 STOP
 99 GO TO 60
 END

```

LOSP Frequency

Attachment G-43

LOGNORMAL.DAT

TIME	EF	MEAN
0.00	1.0	1.000E+00
0.05	1.2	7.501E-01
0.10	1.2	6.370E-01
0.15	1.2	5.564E-01
0.20	1.3	4.958E-01
0.25	1.3	4.472E-01
0.30	1.4	4.069E-01
0.35	1.4	3.697E-01
0.40	1.4	3.404E-01
0.45	1.4	3.146E-01
0.50	1.4	2.921E-01
0.55	1.4	2.720E-01
0.60	1.5	2.548E-01
0.65	1.5	2.396E-01
0.70	1.5	2.266E-01
0.75	1.5	2.160E-01
0.80	1.5	2.053E-01
0.85	1.5	1.962E-01
0.90	1.5	1.885E-01
0.95	1.5	1.801E-01
1.00	1.5	1.730E-01
1.05	1.5	1.671E-01
1.10	1.5	1.614E-01
1.13	1.5	1.575E-01
1.20	1.6	1.523E-01
1.25	1.6	1.483E-01
1.28	1.6	1.451E-01
1.33	1.6	1.416E-01
1.40	1.6	1.365E-01
1.45	1.6	1.329E-01
1.50	1.6	1.290E-01
1.55	1.6	1.257E-01
1.60	1.7	1.230E-01
1.65	1.7	1.203E-01
1.70	1.7	1.173E-01
1.75	1.7	1.147E-01
1.80	1.7	1.124E-01
1.85	1.7	1.098E-01
1.90	1.7	1.077E-01
1.95	1.7	1.051E-01
2.00	1.7	1.032E-01
2.05	1.7	1.011E-01
2.10	1.8	9.923E-02
2.15	1.8	9.724E-02
2.20	1.8	9.540E-02
2.25	1.8	9.410E-02
2.30	1.8	9.273E-02
2.35	1.8	9.120E-02
2.40	1.8	8.973E-02
2.45	1.8	8.832E-02
2.50	1.8	8.706E-02
2.75	1.9	8.010E-02

TIME	EF	MEAN
3.00	1.9	7.453E-02
3.17	1.9	7.066E-02
3.50	2.0	6.528E-02
3.75	2.1	6.247E-02
4.00	2.1	5.898E-02
4.25	2.2	5.575E-02
4.50	2.2	5.284E-02
4.75	2.3	5.054E-02
5.00	2.3	4.828E-02
5.25	2.4	4.652E-02
5.50	2.5	4.526E-02
5.75	2.5	4.336E-02
6.00	2.6	4.141E-02
6.25	2.6	3.970E-02
6.50	2.7	3.840E-02
6.75	2.8	3.725E-02
7.00	2.8	3.603E-02
7.25	2.9	3.474E-02
7.50	3.0	3.346E-02
7.75	3.1	3.242E-02
8.00	3.2	3.151E-02
8.25	3.2	3.022E-02
8.50	3.3	2.910E-02
8.75	3.4	2.798E-02
9.00	3.5	2.708E-02
9.25	3.6	2.640E-02
9.50	3.7	2.559E-02
9.75	3.8	2.503E-02
10.00	3.9	2.430E-02
13.30	6.2	1.970E-02
15.00	7.7	1.780E-02
16.00	8.8	1.682E-02
18.00	11.5	1.597E-02
23.00	22.1	1.476E-02
27.00	32.8	1.328E-02

LOSP Frequency

Attachment G-44

LHS Input File: LOSP.EKI

\$ Developed 9/8/93
 \$ LHS and LHSPPOST Keywords for LOSP CF
 \$
 LHSTITL RLOSP SAMPLE FOR LEVEL I
 LHJOBS 500
 LHSPEED 1
 LHSPVAL 1
 LHSMMSG C:\LPS\POS5\LOSP.LMO
 LHSOUT C:\LPS\POS5\LOSP.LSP
 LHSPPOST C:\LPS\POS5\LOSP.MSP
 \$
 DATASET:
 RNLOSP 250 UNIFORM 1.0 500.9999
 PNTLOSP 250 = INT(RNLOSP)
 LAMDG 2.OE-3 LOGNORMAL 2.OE-3 10
 LAM-DG 2.OE-3 = LAMDG
 PNRDGDG2 0.87 MAXIMUM ENTROPY 0.087 0.87 1.0
 PNR-DG2 0.87 = PNRDG2
 PNRDG3 0.80 MAXIMUM ENTROPY 0.08 0.80 1.0
 PNR-DG3 0.80 = PNRDG3
 PNRDG35 0.9 MAXIMUM ENTROPY 0.0775 0.775 1.0
 PNR-DG35 0.775 = PNRDG35
 PNRDG5 0.7 MAXIMUM ENTROPY 0.07 0.7 1.0
 PNR-DG5 0.7 = PNRDG5
 PNRDG6 0.65 MAXIMUM ENTROPY 0.065 0.65 1.0
 PNR-DG6 0.65 = PNRDG6
 PNRDGII 0.48 MAXIMUM ENTROPY 0.048 0.48 1.0
 PNR-DGII 0.48 = PNRDGII
 PNRDG14 0.41 MAXIMUM ENTROPY 0.041 0.41 1.0
 PNR-DG14 0.41 = PNRDG14
 \$
 PNRCMDG2 0.77 MAXIMUM ENTROPY 0.077 0.77 1.0
 PNRCM-DG2 0.77 = PNRCMDG2
 PNRCMDG3 0.70 MAXIMUM ENTROPY 0.07 0.70 1.0
 PNRCM-DG3 0.70 = PNRCMDG3
 PNRCMDG35 0.675 MAXIMUM ENTROPY 0.0675 0.675 1.0
 PNRCM-DG35 0.675 = PNRCMDG35
 PNRCMDG5 0.6 MAXIMUM ENTROPY 0.06 0.6 1.0
 PNRCM-DG5 0.6 = PNRCMDG5
 PNRCMDG6 0.55 MAXIMUM ENTROPY 0.055 0.55 1.0
 PNRCM-DG6 0.55 = PNRCMDG6
 PNRCMDGII 0.29 MAXIMUM ENTROPY 0.029 0.29 1.0
 PNRCM-DGII 0.29 = PNRCMDGII
 PNRCMDG14 0.24 MAXIMUM ENTROPY 0.024 0.24 1.0
 PNRCM-DG14 0.24 = PNRCMDG14

LOSP Frequency

Attachment G-45

FORTTRAN Program: RLOSP

PROGRAM RLOSP

C

```

PARAMETER (NPT=86, NOBS=500, NLHS=500, NTIME=7, NVAR1=7, NVAR2=7)
CHARACTER*10 NAME
INTEGER IN, OUT,OUT1,OUT2,OUT3,OUT4
EXTERNAL EQ2
DOUBLE PRECISION TSTR1,TM,TCD,LAMDG,TCDVEC(NTIME),TEND
DOUBLE PRECISION H,HMIN,HMAX,EMIN,EMAX,TPRCV(NPT), XINTRP
DOUBLE PRECISION VPDG1(NVARI), VPDG2(NVAR2), LDGPTE
DOUBLE PRECISION CF1(NTIME),CF2(NTIME),CF3(NTIME),CF4(NTIME)
DOUBLE PRECISION PNRMN(NPT),PNRDAT(NOBS,NPT), PRCV(NPT,2)
DOUBLE PRECISION X, XCTCD(NTIME), XMNTCD(NTIME)
DOUBLE PRECISION T, TCTCD(NTIME), TMNTCD(NTIME)
COMMON /VSETI/ TCD, LAMDG
COMMON /PRDATA/ PRCV, NTIMPT
COMMON /INOUT/ IN, OUT
DATA IN2,IN3/8,9/
DATA OUT1,OUT2,OUT3,OUT4/11,12,13,14/
DATA TCDVEC/2.0, 3.0, 3.5, 5.0, 6.0, 11.0, 14.0/
NTIMPT = NPT
IN = 7
OUT = 10

```

C

C INPUT FILES

C

```

OPEN(UNIT=IN2, STATUS='OLD', FILE='C:\F77L3\LPSFOR\LOSP.MSP')
OPEN(UNIT=IN3, STATUS='OLD', FILE='C:\F77L3\LPSFOR\RLOSPCUR.LPS')

```

C

C OUTPUT FILES

C

```

OPEN(UNIT=OUT, FILE='C:\F77L3\LPSFOR\RLOSP.OUT')
OPEN(UNIT=OUT1,FILE='C:\F77L3\LPSFOR\CF1.OUT')
OPEN(UNIT=OUT2,FILE='C:\F77L3\LPSFOR\CF2.OUT')
OPEN(UNIT=OUT3,FILE='C:\F77L3\LPSFOR\CF3.OUT')
OPEN(UNIT=OUT4,FILE='C:\F77L3\LPSFOR\CF4.OUT')

```

C INITIALIZE VARIABLES

```

TSTR1 = 0.0
TEND = 24.0
LAMDG = 2.0D-03
LDGPTE = LAMDG

```

C TOLERANCES FOR INTEGRATION

```

HMIN = 3D-7
HMAX = 20.0
EMIN = 0.0
EMAX = 1D-4
ITMAX = 1000000

```

C=====

LOSP Frequency

C READ INPUT FILE

```
READ(IN3,*)NCURVE,IMAX
```

C CHECK TO MAKE SURE DIMENSIONS ARE CORRECT

```
IF(NPT.NE.IMAX + 1)THEN
```

```
WRITE(OUT,920)
```

```
920. FORMAT(IX,'ERROR: NUMBER OF POINTS (IMAX) EXCEEDS DIMENSION')
```

```
STOP
```

```
ELSEIF(NOBS.NE.NCURVE)THEN
```

```
WRITE(OUT,921)
```

```
921. FORMAT(IX,'ERROR: NUMBER OF POWER CURVES EXCEEDS DIMENSION')
```

```
STOP
```

```
ENDIF
```

```
READ(IN3,*)(TPRCV(J+1),J=1,IMAX)
```

```
TPRCV(1) = 0.0
```

```
READ(IN3,*)(PNRMN(J+1),J=1,IMAX)
```

```
PNRMN(1) = 1.0
```

```
DO 65 I = 1, NCURVE
```

```
READ(IN3,*)(PNRDAT(I,J+1),J=1,IMAX)
```

```
PNRDAT(I,1) = 1.0
```

```
CONTINUE
```

C READ LHS FILE

```
C
```

```
ICLK = 1
```

```
1 IF(ICLK.EQ.1)THEN
```

```
READ(IN2,801,END=999)NAME
```

```
801 FORMAT(IX,A10)
```

```
IF(NAME.EQ.'SAMPLEDATA')ICLK = 0
```

```
GOTO 1
```

```
ENDIF
```

```
C
```

C SELECT MEAN POWER NON-RECOVERY CURVE

```
C
```

```
DO 70 I=1,NPT
```

```
PRCV(I,1) = TPRCV(I)
```

```
PRCV(I,2) = PNRMN(I)
```

```
70 CONTINUE
```

```
DO 85 L2 = 1,NTIME
```

```
TM = TEND
```

```
TCD = TCDVEC(L2)
```

```
C
```

C CALL INTEGRATION SUBROUTINE

```
C
```

```
C IFLAG = 0; SUCCESSFUL PROCEDURE
```

```
C IFLAG = 1; H OUT OF RANGE
```

```
C IFLAG = 2; H OUT OF RANGE AT ENDPOINT
```

```
C IFLAG = 3; MAXIMUM NUMBER OF ITERATIONS REACHED
```

```
C
```

C INITIAL CONDITIONS FOR INTEGRATION

```

X = 0.0
T = TSTRI
H = 0.1

CALL RK45AD(EQ2,T,X,H,TM,ITMAX,EMIN,EMAX,HMIN,HMAX,IFLAG) XMNTCD(L2) = X
TMNTCD(L2)= T 85 CONTINUE
WRITE(OUT,940)
940 FORMAT(IX,'CF2 WITHOUT DENOMINATOR FOR MEAN CURVE')
WRITE(OUT,950)(TCDVEC(I),I=1,NTIME)
950 FORMAT(IX,7(1X,'TIME-',F4.1,1X),/IX)
WRITE(OUT,951)(XMNTCD(I),I=1,NTIME)
951 FORMAT(IX,7(1X,IPE10.3))
C
C WRITE OUTPUT FILE HEADER c WRITE(OUT1,942)
942 FORMAT(IX,'CF1: POWER NON-RECOVERY CURVES') WRITE(OUT1,950)(TCDVEC(I),I=1,NTIME)
WRITE(OUT2,944)
944 FORMAT(IX,'CF2: LOSP AS I.E: D ~ FAILS TO RUN') WRITE(OUT2,950)(TCDVEC(I),I=1,NTIME)
WRITE(OUT3,946)
946 FORMAT(IX,'CF3: LOSP AS I.E: DG FAILS TO START') WRITE(OUT3,950)(TCDVEC(I),I=1,NTIME)
WRITE(OUT4,948)
948 FORMAT(IX,'CF4: LOSP AS I.E: DG FAILS TO START COMMON MODE')
WRITE(OUT4,950)(TCDVEC(I),I=1,NTIME)
C LHS LOOP
C
DO 30 L1 = 1,NLHS
READ(IN2,*)DUM1,DUM2,LHSPNT,LAMDG,(VPDGI(I),I=1,NVAR1),
+ (VPDG2(I),I=1,NVAR2)
C
C SELECT APPROPRIATE POWER NON-RECOVERY CURVE
C
DO 75 I=1,NPT
PRCV(I,1) = TPRCV(I)
PRCV(I,2) = PNRDAT(LHSPNT,I)
75 CONTINUE
C PERFORM CALCULATIONS FOR EACH CORE DAMAGE TIME
C
DO 80 L2 = 1,NTIME
TM = TEND
TCD = TCDVEC(L2)
C CASE 1: CF = NON-RECOVERY CURVES
CFI(L2) = XINTRP(TCD,PRCV,NPT)
C
C CASE 2: CF = LOSS OF OFFSITE POWER AS I.E.: DG FAILS TO RUN
C
C CALL INTEGRATION SUBROUTINE
C INITIAL CONDITIONS FOR INTEGRATION
C
X = 0.0
T = TSTRI
H = 0.1

CALL RK45AD(EQ2,T,X,H,TM,ITMAX,EMIN,EMAX,HMIN,HMAX,IFLAG)
XCTCD(L2) = X

```

LOSP Frequency

```
TCTCD(L2) = T
CF2(L2) = X/(1.0-DEXP(-LDGPTE*TM))
C
C CASE 3: CF = LOSS OF OFFSITE POWER AS I.E.: DG FAILS TO START
CF3(L2) = CF1(L2)*VPDG1(L2)
C
C CASE 4: CF = LOSS OF OFFSITE POWER AS I.E.: DG FAILS TO START COMMON MODE
CF4(L2) = CF1(L2)*VPDG2(L2)
C
80 CONTINUE
C
C .WRITE OUTPUT TO FILE
C
WRITE(OUT1,951)(CF1(I),I=1,NTIME)
WRITE(OUT2,951)(CF2(I),I=1,NTIME)
WRITE(OUT3,951)(CF3(I),I=1,NTIME)
WRITE(OUT4,951)(CF4(I),I=1,NTIME)
C
C WRITE(OUT,952)TCDVEC(I),TCTCD(I),XCTCD(I),IFLAG
C 952 FORMAT(IX,2X,F6.2,2X,F6.2,5X,IPE10.3,6X,II)
30 CONTINUE
STOP
999 .WRITE(9,910)
10 FORMAT(IX,'ERROR - END OF FILE REACHED')
STOP
END
```

C FUNCTION EQ2

```
C =====
C FUNCTION USED TO EVALUATE CASE 2: LOSP I.E & DG FAILS TO RUN
```

```
DOUBLE PRECISION FUNCTION EQ2(T,X)
DOUBLE PRECISION T, X, XINTRP
DOUBLE PRECISION TCD, LAMDG
DOUBLE PRECISION TRCV, PRCV, PNR
COMMON /VSETI/ TCD, LAMDG
COMMON /PRDATA/ PRCV(86,2),NTIMPT
```

```
TRCV = T + TCD
PNR = XINTRP(TRCV,PRCV,NTIMPT)
EQ2 = LAMDG*DEXP(-LAMDG*T)*PNR
RETURN
END
```

C ADAPTATIVE STEPPING ROUTINE FOR RUNGE-KUTTA

```
C=====
SUBROUTINE RK45AD(F,T,X,H,TB,ITMAX,EMIN,EMAX,HMIN,HMAX,IFLAG)
EXTERNAL F
DOUBLE PRECISION F,T,X,H,TB,EMIN,EMAX,HMIN,HMAX
DOUBLE PRECISION EPSI,DT,XSAVE,TSAVE,EST
INTEGER IN, OUT

COMMON /INOUT/ IN, OUT
```

```

DATA EPSI/0.5D-10/
IFLAG = 3
NSTEP = 0

2 DT = DABS(TB - T)
 IF(DT .GT. DABS(H)) GOTO 3
 IFLAG = 0
 IF(DT .LE. EPSI*DMAXI(DABS(TB),DABS(T))) RETURN
 H = DSIGN(DT,H)
 IF(HMIN .LE. DABS(H) .AND. DABS(H) .LE. HMAX) GOTO 3
 IFLAG = 2
 RETURN
3 XSAVE = X
 TSAVE = T
 CALL RK45(F,T,X,H,EST)
 NSTEP = NSTEP + 1
 IF(NSTEP .GT. ITMAX .OR. IFLAG .EQ. 0) RETURN
 IF(EST .LT. EMIN) GOTO 4
 IF(EST .LE. EMAX) GOTO 2
 H = 0.5*H
 GOTO 5
4 H = 2.0*H
5 X = XSAVE
 T = TSAVE
 IF(HMIN .LE. DABS(H) .AND. DABS(H) .LE. HMAX) GOTO 2
 IFLAG = 1
 RETURN
END

```

```

C=====
C RUNGE-KUTTA INTEGRATION ROUTINE

```

```

C=====
SUBROUTINE RK45(F,T,X,H,EST)

```

```

C
 EXTERNAL F
 DOUBLE PRECISION F,T,X,H,EST
 DOUBLE PRECISION C21,C31,C32,C41,C42,C43,C51,C52,C53,C54
 DOUBLE PRECISION C61,C62,C63,C64,C65,A1,A3,A4,A5
 DOUBLE PRECISION B1,B3,B4,B5,B6,C40,F1,F2,F3,F4,F5,F6,X5

```

```

 DATA C21,C31,C32,C41,C42,C43,C51,C52,C53,C54,
+ C61,C62,C63,C64,C65,A1,A3,A4,A5,B1,B3,B4,B5,B6, C40
+ /0.25, 0.09375, 0.28125,
+ 0.87938097405553, -3.27719617660446,3.32089212562585,
+ 2.0324074074074,-8.0, 7.17348927875244,-0.20589668615984,
+ -0.2962962962963,2.0,-1.38167641325536,0.45297270955166,-0.275,
+ 0.11574074074074,0.54892787524366,0.5353313840156,-0.2,
+ 0.11851851851852,0.51898635477583,0.50613149034201,-0.18,
+ 0.0363636363636364,0.92307692307692/

```

```

 F1= H*F(T,X) F2= H*F(T+0.25*H, X + C21*F1)
 F3= H*F(T+0.375*H, X + C31*F1 + C32*F2)
 F4= H*F(T + C40*H, X + C41*F1 + C42*F2 + C43*F3)

```

LOSP Frequency

$F5 = H * F(T + H, X + C51 * F1 + C52 * F2 + C53 * F3 + C54 * F4)$
 $F6 = H * F(T + 0.5 * H, X + C61 * F1 + C62 * F2 + C63 * F3 + C64 * F4 + C65 * F5)$

$X5 = X + B1 * F1 + B3 * F3 + B4 * F4 + B5 * F5 + B6 * F6$
 $X = X + A1 * F1 + A3 * F3 + A4 * F4 + A5 * F5$ $T = T + H$
 $EST = DABS(X - X5)$ RETURN END

C LINEAR INTERPOLATION ROUTINE

C=====

C THIS FUNCTION PERFORMS A LINEAR INTERPOLATION

C T(IMAX,2) = 2 DIMENSIONAL ARRAY

C T(I,1) = X DATA

C T(I,2) = Y DATA

C IMAX = TOTAL NUMBER OF X VALUES (AND ALSO Y VALUES)

C X = X VALUE FOR WHICH A Y VALUE WILL BE CALCULATED

DOUBLE PRECISION FUNCTION XINTRP(X,T,IMAX)
DOUBLE PRECISION T(IMAX,2), X, XLO, XHI, YLO, YHI

C IF THE VALUE OF X IS GREATER THAN THE LAST VALUE IN T, SET Y TO THE
C LAST VALUE IN T

```
 IF(X .GT. T(IMAX,1))THEN
 XINTRP = T(IMAX,2)
 ELSEIF(X .LT. T(1,1))THEN
 XINTRP = T(1,2)
 ELSE
 I = 1
10 IF(X .GT. T(I,1))THEN
 I = I + 1
 GOTO 10
 ELSE IF(I .EQ. 1)
 I = 2
 XLO = T(I-1,1)
 YLO = T(I-1,2)
 XHI = T(I, 1)
 YHI = T(I, 2)
 XINTRP = (X - XLO)/(XHI - XLO)*(YHI - YLO) + YLO
 ENDIF
 ENDIF
 RETURN
 END
```

Attachment G-46

IRRAS Histogram Development Spread Sheet Input

LOSP Frequency

Point	LOSP-2H	LOSP-3H	LOSP-3.5H	LOSP-5H	LOSP-6H	LOSP-11H	LOSP-14H
1	0.09264	0.0658	0.05742	0.03928	0.03137	0.01291	0.007832
2	0.08686	0.06034	0.05324	0.03491	0.0286	0.01133	0.006642
3	0.06559	0.04222	0.03629	0.02212	0.01718	0.00505	0.002583
4	0.08587	0.05961	0.05215	0.03465	0.02782	0.01087	0.00651
5	0.1197	0.08889	0.07911	0.05563	0.04664	0.02354	0.01611
6	0.08475	0.05921	0.05158	0.03443	0.02743	0.01057	0.006332
7	0.08327	0.05792	0.05068	0.03383	0.02648	0.01008	0.005758
8	0.1082	0.07709	0.06884	0.04924	0.04043	0.01874	0.01217
9	0.07628	0.05248	0.04552	0.02988	0.02296	0.00756	0.004266
10	0.1174	0.08649	0.07679	0.05394	0.04525	0.02254	0.01555
11	0.09791	0.06905	0.06116	0.04258	0.03531	0.01511	0.009755
12	0.1506	0.1116	0.1013	0.07769	0.06876	0.04103	0.03315
13	0.06128	0.03966	0.03366	0.02091	0.0152	0.00395	0.001831
14	0.0705	0.047	0.04061	0.02574	0.01992	0.00612	0.003154
15	0.1119	0.08114	0.07204	0.05108	0.04205	0.01987	0.0132
16	0.1018	0.07257	0.06418	0.04537	0.0373	0.01669	0.01076
17	0.07839	0.05388	0.04693	0.03049	0.02373	0.00768	0.004419
18	0.1328	0.1004	0.09019	0.06652	0.05691	0.02973	0.02186
19	0.09006	0.06254	0.05492	0.03659	0.02968	0.01207	0.007246
20	0.1506	0.1115	0.1012	0.07764	0.06817	0.04096	0.03284
21	0.1623	0.1249	0.114	0.0912	0.07934	0.04995	0.04132
22	0.1417	0.1062	0.09609	0.07146	0.06149	0.03465	0.02548
23	0.05871	0.03852	0.03255	0.01916	0.01442	0.00365	0.001635
24	0.1445	0.107	0.09706	0.07427	0.06396	0.03722	0.02707
25	0.09323	0.06588	0.05752	0.03939	0.03149	0.01301	0.007935
26	0.07097	0.04759	0.04116	0.02583	0.02021	0.00613	0.003204
27	0.07595	0.05207	0.04526	0.02962	0.02292	0.00755	0.004259
28	0.1348	0.101	0.09085	0.06738	0.05731	0.03018	0.02256
29	0.07988	0.05518	0.04816	0.03195	0.02474	0.00869	0.004903
30	0.04782	0.02948	0.02451	0.01327	0.00882	0.00193	0.0007853
31	0.04742	0.02849	0.02361	0.0126	0.00871	0.00164	0.0005726
32	0.1563	0.1187	0.1073	0.08054	0.07374	0.0455	0.03725
33	0.1107	0.07858	0.06993	0.05001	0.04141	0.01933	0.01276

Point	LOSP-2H	LOSP-3H	LOSP-3.5H	LOSP-5H	LOSP-6H	LOSP-11H	LOSP-14H
34	0.06524	0.04204	0.03607	0.02193	0.01683	0.00504	0.002508
35	0.09456	0.06662	0.0583	0.03996	0.03239	0.01333	0.008309
36	0.0555	0.03453	0.0294	0.01735	0.01321	0.00317	0.001309
37	0.08316	0.05787	0.05053	0.03373	0.02629	0.01005	0.00574
38	0.06521	0.0419	0.03586	0.02184	0.01682	0.00503	0.00248
39	0.1234	0.09091	0.08109	0.05838	0.04871	0.02464	0.017
40	0.1201	0.08925	0.07932	0.0558	0.04704	0.0237	0.01621
41	0.1383	0.1025	0.09352	0.06942	0.0589	0.03261	0.02401
42	0.1221	0.09009	0.08018	0.05627	0.04782	0.02416	0.01629
43	0.0808	0.05594	0.04889	0.03227	0.0251	0.00904	0.005035
44	0.07962	0.05502	0.04795	0.03155	0.0247	0.00851	0.004757
45	0.2028	0.183	0.1792	0.1691	0.1636	0.1454	0.1391
46	0.08213	0.0568	0.04972	0.03319	0.02597	0.00969	0.005408
47	0.09475	0.06665	0.05838	0.04003	0.03246	0.01335	0.00833
48	0.108	0.07688	0.06866	0.0489	0.04028	0.0187	0.01205
49	0.05899	0.03862	0.03271	0.01959	0.01459	0.00369	0.001714
50	0.1409	0.1043	0.09455	0.07018	0.06026	0.03358	0.02442
51	0.1468	0.1082	0.09804	0.07465	0.06452	0.03803	0.0293
52	0.1317	0.09866	0.08864	0.0653	0.05562	0.02852	0.0205
53	0.1206	0.08941	0.07961	0.05586	0.04714	0.02394	0.01624
54	0.1413	0.1048	0.09509	0.07092	0.06062	0.03433	0.0249
55	0.04487	0.02696	0.02183	0.01226	0.00847	0.00118	0.0004245
56	0.09804	0.0694	0.06138	0.04276	0.03539	0.01535	0.009771
57	0.1149	0.0832	0.07376	0.05236	0.04328	0.02046	0.01403
58	0.1249	0.09146	0.08172	0.05988	0.05007	0.02507	0.0173
59	0.06699	0.04462	0.03829	0.02376	0.01809	0.00556	0.002774
60	0.0942	0.06649	0.058	0.0397	0.03222	0.01331	0.008271
61	0.1002	0.07147	0.06301	0.04388	0.03674	0.01603	0.01025
62	0.09155	0.06487	0.05645	0.03837	0.03102	0.01243	0.007448
63	0.1266	0.09322	0.0835	0.06082	0.05137	0.02566	0.01787
64	0.07582	0.05196	0.04516	0.02951	0.02287	0.00752	0.004182
65	0.09516	0.06703	0.05864	0.04036	0.03314	0.01368	0.0085
66	0.08381	0.05854	0.0511	0.03399	0.02701	0.01027	0.006071

LOSP Frequency

Point	LOSP-2H	LOSP-3H	LOSP-3.5H	LOSP-5H	LOSP-6H	LOSP-11H	LOSP-14H
67	0.1033	0.07291	0.06456	0.04556	0.03748	0.01681	0.01123
68	0.07098	0.04776	0.04126	0.02608	0.02026	0.00619	0.003241
69	0.1647	0.1324	0.1213	0.09333	0.08578	0.05293	0.04275
70	0.07543	0.05173	0.04486	0.02927	0.02272	0.00737	0.004142
71	0.06044	0.03911	0.03322	0.02061	0.0149	0.00385	0.001783
72	0.08194	0.05655	0.0494	0.03297	0.02564	0.00952	0.005281
73	0.07448	0.0505	0.04394	0.02866	0.02218	0.00714	0.003934
74	0.09409	0.06631	0.05789	0.03967	0.03211	0.01326	0.00819
75	0.1132	0.08196	0.07274	0.05169	0.04234	0.02002	0.01362
76	0.09131	0.06459	0.05631	0.03816	0.03083	0.01239	0.007341
77	0.07757	0.05384	0.04659	0.03029	0.02343	0.00767	0.004413
78	0.06569	0.04262	0.03668	0.0225	0.01734	0.0052	0.002644
79	0.1198	0.08894	0.07915	0.05575	0.04687	0.02355	0.0162
80	0.1075	0.07646	0.06827	0.04858	0.03995	0.01838	0.01182
81	0.05214	0.03142	0.02622	0.01512	0.01151	0.00249	0.001023
82	0.1951	0.1586	0.145	0.1158	0.1071	0.07912	0.06775
83	0.162	0.1195	0.1109	0.09118	0.07721	0.04979	0.03954
84	0.08853	0.06185	0.0543	0.03576	0.02942	0.01182	0.007001
85	0.1923	0.1576	0.1441	0.1119	0.1006	0.06848	0.05719
86	0.07056	0.04709	0.04087	0.0258	0.02021	0.00612	0.003163
87	0.06002	0.03908	0.03319	0.01989	0.01464	0.00377	0.001771
88	0.0959	0.06752	0.05933	0.04109	0.03405	0.01402	0.008765
89	0.07457	0.05125	0.04444	0.02893	0.02246	0.00719	0.004009
90	0.09767	0.06895	0.06096	0.04249	0.03517	0.01503	0.009647
91	0.1252	0.09161	0.08216	0.06008	0.05048	0.02534	0.0174
92	0.1523	0.1149	0.1031	0.07866	0.06919	0.04315	0.03324
93	0.1084	0.0771	0.06892	0.04942	0.04054	0.01876	0.01227
94	0.08642	0.05981	0.05248	0.0348	0.02834	0.011	0.006555
95	0.06565	0.04228	0.0365	0.02243	0.01731	0.00519	0.002634
96	0.07904	0.05482	0.04775	0.03146	0.02463	0.00841	0.004707
97	0.1153	0.08342	0.07388	0.05238	0.04334	0.02061	0.01413
98	0.1641	0.1321	0.1208	0.09311	0.08362	0.05272	0.04241
99	0.06473	0.04119	0.03519	0.02141	0.01646	0.0049	0.002326

Point	LOSP-2H	LOSP-3H	LOSP-3.5H	LOSP-5H	LOSP-6H	LOSP-11H	LOSP-14H
100	0.1279	0.09488	0.08524	0.0629	0.05283	0.02646	0.01925
101	0.1411	0.1045	0.09475	0.07045	0.0603	0.03392	0.02443
102	0.1473	0.1084	0.09818	0.07479	0.06473	0.03914	0.02958
103	0.06645	0.04361	0.03744	0.02337	0.01775	0.00542	0.002772
104	0.166	0.1366	0.1264	0.1016	0.0909	0.05555	0.0466
105	0.07884	0.05464	0.04756	0.03092	0.02436	0.00802	0.004586
106	0.1479	0.1098	0.09921	0.07652	0.06544	0.0396	0.0313
107	0.1363	0.1021	0.09201	0.06823	0.05851	0.03062	0.02345
108	0.06346	0.04056	0.0347	0.02126	0.01632	0.00462	0.002157
109	0.1036	0.07297	0.06467	0.04577	0.03756	0.01689	0.01125
110	0.1067	0.07564	0.06742	0.04738	0.03912	0.01785	0.01164
111	0.1474	0.1088	0.09846	0.07586	0.0649	0.03917	0.03
112	0.09945	0.06997	0.06203	0.04341	0.03595	0.01553	0.009865
113	0.0869	0.06058	0.05343	0.03511	0.02871	0.01138	0.006707
114	0.05525	0.03409	0.02891	0.01705	0.01284	0.0029	0.001263
115	0.09757	0.06894	0.06092	0.04242	0.03514	0.01479	0.009557
116	0.1055	0.07505	0.06692	0.04695	0.03865	0.01775	0.01152
117	0.07979	0.05512	0.04809	0.03182	0.02471	0.00856	0.004782
118	0.08269	0.05727	0.05013	0.03339	0.02612	0.00982	0.005529
119	0.05791	0.03713	0.03147	0.01886	0.01419	0.00342	0.001471
120	0.1243	0.09144	0.08169	0.05968	0.04949	0.025	0.0173
121	0.1168	0.08547	0.07585	0.05331	0.04483	0.02199	0.01518
122	0.04112	0.02174	0.0187	0.00978	0.00641	0.0011	0.0004035
123	0.09454	0.06649	0.05802	0.0399	0.03226	0.01331	0.008306
124	0.09635	0.06758	0.05954	0.04127	0.03416	0.01415	0.008828
125	0.1319	0.09877	0.08874	0.06532	0.05569	0.02854	0.02056
126	0.06861	0.04618	0.03939	0.02419	0.01848	0.00581	0.002876
127	0.1094	0.07843	0.06977	0.04975	0.04081	0.01923	0.01261
128	0.1413	0.1049	0.09535	0.07094	0.06106	0.03441	0.02498
129	0.08282	0.05745	0.0503	0.03345	0.02616	0.00998	0.00565
130	0.155	0.1174	0.1052	0.08019	0.07193	0.04521	0.03468
131	0.08816	0.06177	0.05424	0.03571	0.02942	0.01177	0.006993
132	0.08662	0.06013	0.05286	0.03485	0.02849	0.01118	0.006562
133	0.1431	0.1066	0.09673	0.07232	0.06238	0.03542	0.02571

LOSP Frequency

Point	LOSP-2H	LOSP-3H	LOSP-3.5H	LOSP-5H	LOSP-6H	LOSP-11H	LOSP-14H
134	0.07479	0.05169	0.04477	0.02912	0.02267	0.00733	0.004141
135	0.07557	0.05194	0.04513	0.02943	0.02275	0.00748	0.004181
136	0.1393	0.1034	0.09403	0.06951	0.05891	0.03299	0.0241
137	0.08674	0.06016	0.05291	0.03491	0.02858	0.01119	0.006582
138	0.05782	0.03706	0.03125	0.01868	0.01406	0.00338	0.001466
139	0.09981	0.07092	0.06266	0.04367	0.03637	0.01598	0.01008
140	0.1003	0.07157	0.06307	0.04389	0.0368	0.01613	0.01029
141	0.06852	0.04578	0.03902	0.02405	0.01843	0.00565	0.002853
142	0.1364	0.1022	0.09226	0.06826	0.05865	0.03065	0.02363
143	0.1011	0.07191	0.0635	0.04468	0.03694	0.01631	0.01045
144	0.07851	0.05405	0.04708	0.03052	0.0238	0.00777	0.004448
145	0.06816	0.04515	0.03865	0.02403	0.01837	0.00563	0.002834
146	0.07637	0.05301	0.04602	0.03015	0.02318	0.00761	0.004278
147	0.1294	0.09661	0.0867	0.06396	0.05396	0.02727	0.01988
148	0.1088	0.07742	0.06912	0.04943	0.04064	0.01881	0.01228
149	0.08544	0.05958	0.05205	0.03463	0.02773	0.01076	0.006397
150	0.07435	0.05024	0.0438	0.02854	0.02217	0.0071	0.00383
151	0.09529	0.06704	0.05869	0.04047	0.03327	0.01369	0.008582
152	0.09555	0.06723	0.05884	0.04088	0.03353	0.01374	0.008626
153	0.08278	0.05737	0.05021	0.03341	0.02614	0.00988	0.005539
154	0.06676	0.04377	0.03771	0.02339	0.01785	0.00543	0.002772
155	0.06444	0.04108	0.035	0.0214	0.01641	0.00489	0.002289
156	0.07631	0.05249	0.04566	0.02992	0.02312	0.00757	0.004271
157	0.1282	0.09514	0.08568	0.06329	0.05367	0.02668	0.01952
158	0.08343	0.05811	0.05083	0.03389	0.02683	0.01021	0.005879
159	0.1114	0.08023	0.07144	0.0506	0.04199	0.01975	0.013
160	0.07396	0.0496	0.04331	0.02794	0.0216	0.00694	0.003734
161	0.1167	0.08511	0.07565	0.0533	0.04481	0.02183	0.01513
162	0.08732	0.06136	0.05394	0.03531	0.02897	0.01144	0.006834
163	0.08854	0.06186	0.05432	0.03585	0.02944	0.0119	0.007016
164	0.1015	0.07229	0.06384	0.04484	0.03715	0.01648	0.01063
165	0.09374	0.0661	0.0577	0.03954	0.03164	0.01308	0.008125
166	0.1518	0.1126	0.1019	0.07842	0.06886	0.04107	0.0332
167	0.06504	0.04135	0.03547	0.02162	0.01673	0.00497	0.002469

Point	LOSP-2H	LOSP-3H	LOSP-3.5H	LOSP-5H	LOSP-6H	LOSP-11H	LOSP-14H
168	0.104	0.07395	0.06554	0.04601	0.03804	0.01704	0.01138
169	0.05901	0.03905	0.033	0.01961	0.01461	0.00373	0.001737
170	0.1133	0.082	0.07279	0.05175	0.04254	0.02011	0.01368
171	0.1316	0.09856	0.08853	0.06506	0.0554	0.02824	0.02047
172	0.09183	0.06521	0.05678	0.03868	0.03119	0.0128	0.007574
173	0.1399	0.1039	0.09426	0.0698	0.05962	0.033	0.02414
174	0.07851	0.05425	0.04719	0.03056	0.02389	0.00778	0.004486
175	0.09709	0.06789	0.0602	0.04213	0.03493	0.01458	0.009229
176	0.1174	0.0866	0.07687	0.05399	0.04527	0.02265	0.01563
177	0.09113	0.06395	0.05585	0.03752	0.03077	0.0123	0.007315
178	0.1138	0.08234	0.07304	0.05195	0.04258	0.02027	0.01382
179	0.09802	0.06913	0.06122	0.04262	0.03538	0.01529	0.009766
180	0.1274	0.09382	0.08403	0.06239	0.05235	0.02633	0.01876
181	0.06617	0.04341	0.03725	0.02311	0.01758	0.00536	0.002711
182	0.08893	0.06196	0.05447	0.03611	0.0295	0.01194	0.007116
183	0.08323	0.0579	0.05064	0.03377	0.02646	0.01008	0.005758
184	0.07426	0.05024	0.0437	0.02834	0.02206	0.00698	0.003828
185	0.08199	0.05666	0.0496	0.03315	0.02565	0.00968	0.005398
186	0.1561	0.1181	0.1056	0.08027	0.0724	0.04543	0.03476
187	0.1055	0.07502	0.06684	0.04667	0.03835	0.01766	0.0115
188	0.1157	0.08435	0.07506	0.05276	0.04381	0.0211	0.01464
189	0.08339	0.05808	0.05077	0.03386	0.02673	0.0102	0.005809
190	0.1322	0.0992	0.0891	0.06589	0.056	0.02874	0.02107
191	0.1407	0.1042	0.09447	0.07008	0.06004	0.03348	0.02424
192	0.09654	0.06776	0.06003	0.04139	0.03445	0.01432	0.008983
193	0.05488	0.03407	0.0286	0.01689	0.01233	0.00289	0.001217
194	0.07653	0.05334	0.0462	0.03017	0.02323	0.00764	0.00429
195	0.09682	0.06779	0.06011	0.042	0.03486	0.01446	0.009215
196	0.07456	0.05067	0.04413	0.02885	0.0222	0.00718	0.003935
197	0.1221	0.09035	0.08032	0.05677	0.04794	0.02428	0.01629
198	0.1411	0.1046	0.09489	0.07083	0.06061	0.03406	0.02459
199	0.09716	0.06883	0.06084	0.04239	0.03504	0.01471	0.009463
200	0.1069	0.07585	0.06764	0.04773	0.03922	0.01796	0.01167
201	0.1154	0.08371	0.07451	0.05254	0.04342	0.02075	0.01425

LOSP Frequency

Point	LOSP-2H	LOSP-3H	LOSP-3.5H	LOSP-5H	LOSP-6H	LOSP-11H	LOSP-14H
202	0.1345	0.1008	0.0906	0.0671	0.05718	0.03011	0.0225
203	0.09009	0.06258	0.05497	0.0366	0.0301	0.01215	0.00725
204	0.05274	0.03245	0.02713	0.01556	0.01178	0.00275	0.001087
205	0.09174	0.0652	0.05677	0.03864	0.03113	0.01261	0.007528
206	0.1116	0.0804	0.07161	0.05067	0.042	0.01979	0.01305
207	0.1433	0.1066	0.09681	0.07297	0.06333	0.03619	0.02594
208	0.09677	0.06778	0.0601	0.04189	0.03474	0.01444	0.009135
209	0.08151	0.05643	0.04933	0.03296	0.0256	0.00945	0.005219
210	0.1673	0.1397	0.1292	0.1029	0.0911	0.05991	0.04855
211	0.1311	0.09848	0.0885	0.06498	0.05493	0.02785	0.02043
212	0.09909	0.06968	0.06168	0.04305	0.03562	0.01543	0.009817
213	0.06898	0.04658	0.03996	0.02505	0.01901	0.00603	0.003001
214	0.0803	0.05593	0.04878	0.03226	0.02509	0.00892	0.005018
215	0.08597	0.05965	0.0522	0.03467	0.02788	0.01096	0.006514
216	0.02701	0.01349	0.01095	0.00582	0.00422	0.00085	0.0003165
217	0.07168	0.04823	0.0415	0.02672	0.02043	0.00625	0.003256
218	0.1618	0.1193	0.1094	0.08589	0.07561	0.04842	0.03919
219	0.0739	0.04934	0.04314	0.02783	0.02159	0.00693	0.003698
220	0.1154	0.08412	0.07488	0.05272	0.04361	0.02105	0.01433
221	0.05413	0.03346	0.02793	0.01625	0.01231	0.00288	0.001196
222	0.08361	0.05833	0.05097	0.03392	0.02691	0.01021	0.005942
223	0.1126	0.0816	0.07248	0.0514	0.0423	0.01995	0.01333
224	0.07174	0.04829	0.04157	0.02673	0.02056	0.00627	0.003294
225	0.138	0.1024	0.09332	0.0691	0.05889	0.03211	0.02392
226	0.1416	0.1051	0.09554	0.07122	0.06108	0.03453	0.02548
227	0.1349	0.1013	0.09134	0.06741	0.05776	0.03038	0.0227
228	0.1278	0.09466	0.08504	0.06261	0.05271	0.02644	0.01921
229	0.06344	0.04013	0.03431	0.02124	0.01625	0.00458	0.002118
230	0.1164	0.0847	0.07533	0.05296	0.04426	0.02167	0.01499
231	0.1492	0.1111	0.101	0.07737	0.06626	0.04034	0.03238
232	0.0849	0.05925	0.0516	0.0345	0.02753	0.01063	0.006358
233	0.09984	0.07137	0.06291	0.04378	0.03639	0.01601	0.01017
234	0.1324	0.1001	0.08975	0.06642	0.05662	0.02969	0.02142
235	0.07402	0.04993	0.04354	0.02829	0.02201	0.00698	0.003745

Point	LOSP-2H	LOSP-3H	LOSP-3.5H	LOSP-5H	LOSP-6H	LOSP-11H	LOSP-14H
236	0.1038	0.0736	0.06514	0.04594	0.03801	0.01692	0.01132
237	0.1117	0.0808	0.07185	0.0507	0.04201	0.01981	0.01307
238	0.1042	0.07403	0.0656	0.04605	0.03807	0.01737	0.0114
239	0.09232	0.06551	0.05727	0.03917	0.03125	0.01283	0.007795
240	0.06549	0.0422	0.03626	0.02206	0.01709	0.00504	0.002558
241	0.08542	0.05936	0.05185	0.03463	0.02768	0.01069	0.006368
242	0.1149	0.08269	0.0735	0.05221	0.04328	0.0204	0.01399
243	0.1203	0.08934	0.07956	0.05581	0.0471	0.02389	0.01623
244	0.1286	0.09526	0.08578	0.06358	0.05374	0.02674	0.01978
245	0.06191	0.03984	0.03397	0.021	0.01564	0.00418	0.001917
246	0.09214	0.06549	0.05716	0.03911	0.03124	0.01282	0.007782
247	0.1267	0.09329	0.08367	0.06189	0.05154	0.0257	0.01801
248	0.1005	0.07173	0.06324	0.04454	0.03693	0.01624	0.01042
249	0.1171	0.08605	0.07641	0.05375	0.04523	0.02221	0.01542
250	0.08298	0.05782	0.0505	0.03365	0.02618	0.00999	0.005721
251	0.1188	0.08806	0.07784	0.05467	0.04566	0.02314	0.01583
252	0.0953	0.06712	0.05876	0.04048	0.03336	0.01373	0.008583
253	0.1604	0.1193	0.1085	0.08286	0.07524	0.04796	0.03799
254	0.09112	0.06382	0.05578	0.03733	0.03071	0.01226	0.007307
255	0.07295	0.04878	0.04245	0.02742	0.02109	0.0067	0.003553
256	0.1091	0.07834	0.06969	0.04963	0.0408	0.01911	0.01249
257	0.06947	0.04668	0.04033	0.02532	0.0194	0.00605	0.003084
258	0.06887	0.04627	0.03965	0.02453	0.01873	0.00588	0.002882
259	0.111	0.07966	0.07064	0.05015	0.04156	0.01938	0.01284
260	0.1536	0.1166	0.1048	0.07917	0.06994	0.04353	0.03412
261	0.07229	0.04862	0.04229	0.02702	0.02079	0.0065	0.003355
262	0.1369	0.1023	0.09252	0.06853	0.05878	0.03128	0.02369
263	0.09626	0.06756	0.05944	0.04112	0.03408	0.01404	0.008826
264	0.1072	0.0762	0.06797	0.04839	0.03936	0.01828	0.01168
265	0.1282	0.09504	0.08544	0.0631	0.05361	0.02652	0.01939
266	0.06443	0.04088	0.03489	0.02133	0.01635	0.0048	0.00225
267	0.05835	0.03794	0.03212	0.01911	0.01428	0.00362	0.001611
268	0.05158	0.02971	0.02489	0.01366	0.00943	0.00207	0.0008738
269	0.09127	0.06414	0.05605	0.0376	0.03077	0.01238	0.007338

LOSP Frequency

Point	LOSP-2H	LOSP-3H	LOSP-3.5H	LOSP-5H	LOSP-6H	LOSP-11H	LOSP-14H
270	0.05656	0.03616	0.03043	0.01846	0.01372	0.00331	0.001417
271	0.1529	0.1155	0.1041	0.07911	0.06946	0.04332	0.03393
272	0.1465	0.1078	0.09776	0.07455	0.06437	0.03755	0.02864
273	0.07349	0.04897	0.04257	0.02751	0.02118	0.00678	0.003593
274	0.1797	0.142	0.1336	0.1109	0.09598	0.06402	0.05498
275	0.1448	0.1077	0.09757	0.07435	0.06419	0.03742	0.02828
276	0.08431	0.05862	0.05117	0.03402	0.0271	0.01035	0.006095
277	0.06973	0.04693	0.04056	0.02563	0.01974	0.0061	0.003134
278	0.1112	0.08009	0.07127	0.05053	0.04187	0.01962	0.013
279	0.09374	0.06607	0.05763	0.03941	0.03157	0.01304	0.008047
280	0.04613	0.02728	0.02257	0.01229	0.00858	0.00118	0.0004862
281	0.1207	0.0896	0.0798	0.05587	0.0472	0.02403	0.01626
282	0.08601	0.05968	0.05239	0.03478	0.02799	0.01097	0.006549
283	0.09481	0.06666	0.05839	0.04008	0.03261	0.01349	0.008363
284	0.09583	0.06735	0.05909	0.04108	0.03399	0.01396	0.008757
285	0.119	0.08819	0.07807	0.05478	0.04596	0.02317	0.01583
286	0.06559	0.04226	0.03633	0.02218	0.01726	0.00516	0.002604
287	0.07366	0.04903	0.04291	0.02755	0.02137	0.00682	0.003661
288	0.09652	0.0677	0.05997	0.04132	0.03438	0.01426	0.008921
289	0.1826	0.1448	0.1359	0.1115	0.1005	0.06492	0.05624
290	0.1263	0.09307	0.08338	0.06069	0.05132	0.02565	0.0177
291	0.1144	0.08257	0.0734	0.05206	0.04314	0.02038	0.01397
292	0.1154	0.08351	0.07404	0.05252	0.04335	0.02074	0.01419
293	0.08948	0.06238	0.05475	0.03638	0.02962	0.01206	0.00715
294	0.09877	0.0696	0.0616	0.04289	0.03548	0.01541	0.009816
295	0.1054	0.07441	0.06593	0.0465	0.03811	0.01758	0.01146
296	0.09264	0.06583	0.05745	0.0393	0.03145	0.01291	0.007913
297	0.07731	0.05373	0.04649	0.03023	0.02336	0.00766	0.004375
298	0.04772	0.0292	0.02404	0.01312	0.00878	0.00189	0.0007708
299	0.08689	0.06051	0.05333	0.035	0.02864	0.01134	0.006696
300	0.08859	0.06192	0.05443	0.03607	0.02948	0.01193	0.007099
301	0.05179	0.03062	0.02555	0.01408	0.01039	0.00212	0.0008958
302	0.1647	0.1331	0.1235	0.1002	0.08815	0.05499	0.0435
303	0.1079	0.07657	0.06845	0.04875	0.04023	0.01855	0.01192

LOSP Frequency

Point	LOSP-2H	LOSP-3H	LOSP-3.5H	LOSP-5H	LOSP-6H	LOSP-11H	LOSP-14H
304	0.1487	0.1107	0.1008	0.07712	0.06599	0.04016	0.03228
305	0.1309	0.09743	0.08778	0.06468	0.05426	0.02751	0.02022
306	0.09167	0.06498	0.05665	0.03862	0.03112	0.01255	0.00752
307	0.06617	0.04351	0.03735	0.02318	0.01766	0.00538	0.002726
308	0.1294	0.09681	0.08693	0.06418	0.054	0.02731	0.01998
309	0.1639	0.1291	0.1184	0.09277	0.08286	0.0527	0.04215
310	0.1295	0.09686	0.08732	0.0643	0.05411	0.02732	0.02
311	0.1225	0.09035	0.08036	0.05685	0.04833	0.02428	0.01661
312	0.0802	0.05535	0.04841	0.03198	0.02494	0.0087	0.004947
313	0.1478	0.1096	0.09909	0.07639	0.06541	0.03919	0.03017
314	0.1075	0.07648	0.06834	0.04862	0.04001	0.01846	0.01191
315	0.1089	0.07829	0.06963	0.04961	0.04078	0.0189	0.01233
316	0.07374	0.04931	0.04308	0.02762	0.02157	0.00692	0.003689
317	0.08753	0.06142	0.05402	0.03539	0.02899	0.01146	0.006853
318	0.07861	0.05436	0.04729	0.03071	0.02397	0.0079	0.004493
319	0.0668	0.04416	0.03796	0.02366	0.01793	0.00554	0.002773
320	0.09909	0.06974	0.06173	0.04313	0.03567	0.01544	0.009835
321	0.1258	0.09268	0.08292	0.06039	0.05094	0.02546	0.01753
322	0.1089	0.07752	0.06922	0.0495	0.04076	0.01888	0.01232
323	0.08141	0.05635	0.04927	0.03294	0.02557	0.00931	0.005196
324	0.09514	0.06688	0.05855	0.04027	0.03285	0.01364	0.008498
325	0.09786	0.06901	0.0611	0.04251	0.0353	0.01507	0.009733
326	0.1033	0.07286	0.06441	0.04555	0.03747	0.01674	0.01108
327	0.06927	0.04665	0.04015	0.02516	0.01928	0.00604	0.003068
328	0.09714	0.06879	0.06081	0.04236	0.03502	0.01467	0.009388
329	0.08755	0.06149	0.05406	0.03542	0.02913	0.01159	0.006893
330	0.08647	0.05991	0.05253	0.03484	0.02838	0.01112	0.006557
331	0.09936	0.06984	0.06193	0.04318	0.03569	0.01545	0.009837
332	0.08024	0.05563	0.04857	0.03205	0.02495	0.00874	0.004958
333	0.07435	0.05024	0.0438	0.02854	0.02217	0.0071	0.00383
334	0.06574	0.04296	0.03685	0.02287	0.01734	0.0053	0.002658
335	0.1251	0.09158	0.08195	0.05995	0.05029	0.0253	0.01736
336	0.1074	0.07629	0.06812	0.0485	0.03973	0.01828	0.01169
337	0.118	0.08718	0.07726	0.0543	0.04538	0.02282	0.01573

LOSP Frequency

Point	LOSP-2H	LOSP-3H	LOSP-3.5H	LOSP-5H	LOSP-6H	LOSP-11H	LOSP-14H
338	0.1129	0.08172	0.07255	0.05164	0.0423	0.01998	0.01351
339	0.1052	0.07431	0.06574	0.0463	0.03811	0.01745	0.01144
340	0.09105	0.06374	0.05569	0.03728	0.03046	0.01226	0.0073
341	0.08541	0.0593	0.05165	0.03453	0.02759	0.01067	0.006359
342	0.07883	0.05464	0.0475	0.03083	0.02418	0.00799	0.004503
343	0.05592	0.03542	0.0299	0.0174	0.01349	0.00318	0.001396
344	0.1232	0.09073	0.08095	0.05782	0.04853	0.02456	0.01692
345	0.0299	0.02082	0.01676	0.00802	0.00528	0.00106	0.0003858
346	0.1277	0.0941	0.08435	0.06246	0.05244	0.02636	0.01884
347	0.1158	0.08436	0.07509	0.0528	0.04389	0.02129	0.01474
348	0.07188	0.04835	0.04181	0.02682	0.0206	0.00628	0.003294
349	0.1164	0.08453	0.0752	0.05287	0.04402	0.02167	0.01484
350	0.1194	0.08854	0.07894	0.05511	0.04661	0.02348	0.01605
351	0.1016	0.07241	0.06396	0.04485	0.03715	0.01652	0.01063
352	0.1169	0.08573	0.07618	0.05362	0.04521	0.02218	0.0154
353	0.106	0.07512	0.06699	0.04698	0.03869	0.01779	0.01156
354	0.1293	0.09603	0.08633	0.06396	0.05382	0.02684	0.01986
355	0.06278	0.04013	0.03426	0.02118	0.01588	0.00456	0.002064
356	0.07842	0.05394	0.047	0.0305	0.0238	0.00773	0.004441
357	0.1487	0.1101	0.1	0.07655	0.06594	0.03995	0.03174
358	0.06973	0.0468	0.04046	0.02545	0.01945	0.0061	0.003102
359	0.07301	0.04886	0.04251	0.02749	0.02114	0.00673	0.003571
360	0.0938	0.06621	0.05782	0.03967	0.03197	0.01311	0.008137
361	0.09968	0.07053	0.06245	0.04364	0.03619	0.01596	0.009976
362	0.1423	0.1063	0.09629	0.07215	0.06228	0.03481	0.02563
363	0.1096	0.07856	0.06985	0.04987	0.04099	0.0193	0.01261
364	0.09712	0.06872	0.06068	0.0422	0.03498	0.01463	0.009236
365	0.1191	0.0882	0.07813	0.05491	0.0461	0.02319	0.01588
366	0.1307	0.09723	0.08763	0.06465	0.05416	0.02738	0.02019
367	0.1038	0.07347	0.06497	0.0458	0.03778	0.01689	0.01128
368	0.08245	0.05686	0.04985	0.03328	0.02601	0.00975	0.005501
369	0.09955	0.07018	0.06227	0.04345	0.03606	0.01564	0.009965
370	0.0949	0.06679	0.05848	0.04019	0.03267	0.01351	0.008381
371	0.08094	0.05604	0.04895	0.03232	0.02519	0.00914	0.005038

LOSP Frequency

Point	LOSP-2H	LOSP-3H	LOSP-3.5H	LOSP-5H	LOSP-6H	LOSP-11H	LOSP-14H
372	0.1017	0.07245	0.06405	0.04529	0.03715	0.01654	0.01071
373	0.1375	0.1023	0.09279	0.06858	0.05887	0.03198	0.02389
374	0.07212	0.04846	0.04187	0.027	0.02061	0.00643	0.003296
375	0.079	0.05475	0.04768	0.03145	0.02441	0.00836	0.004606
376	0.1066	0.07523	0.06706	0.04701	0.03884	0.0178	0.01162
377	0.1126	0.08142	0.07237	0.05136	0.04222	0.01995	0.01326
378	0.1322	0.1	0.08958	0.06614	0.05612	0.02929	0.02131
379	0.08025	0.0559	0.04875	0.03216	0.02505	0.00889	0.005017
380	0.07546	0.0519	0.04507	0.02928	0.02272	0.00743	0.004147
381	0.1191	0.08832	0.07856	0.05508	0.04626	0.02328	0.01592
382	0.0794	0.05486	0.04785	0.03149	0.02465	0.00848	0.00472
383	0.08973	0.06249	0.05484	0.03652	0.02965	0.01207	0.007163
384	0.1706	0.1419	0.1333	0.109	0.09349	0.0618	0.0507
385	0.1401	0.104	0.09434	0.07008	0.05977	0.03325	0.02416
386	0.1137	0.08214	0.07291	0.05186	0.04257	0.02019	0.01375
387	0.1235	0.09093	0.08122	0.05853	0.04873	0.02468	0.01701
388	0.08433	0.05905	0.05141	0.03436	0.02726	0.01041	0.006207
389	0.1066	0.07554	0.06735	0.04714	0.03889	0.01781	0.01164
390	0.08443	0.0591	0.05144	0.03441	0.0273	0.01043	0.006287
391	0.06578	0.04312	0.03697	0.02296	0.01758	0.00532	0.002693
392	0.09258	0.06562	0.05732	0.03926	0.03135	0.01285	0.007815
393	0.1023	0.07261	0.06421	0.04543	0.03734	0.0167	0.01081
394	0.1295	0.09718	0.0876	0.06464	0.05412	0.02737	0.02014
395	0.1421	0.1062	0.09622	0.07187	0.06151	0.03476	0.02551
396	0.1184	0.08768	0.07758	0.0546	0.04554	0.02305	0.01575
397	0.1627	0.125	0.1152	0.09261	0.08215	0.05149	0.04136
398	0.07852	0.05434	0.04726	0.03068	0.02394	0.00789	0.004487
399	0.1071	0.07598	0.06781	0.04773	0.03935	0.01798	0.01168
400	0.124	0.09137	0.08165	0.05941	0.04943	0.02479	0.01704
401	0.1005	0.07172	0.06316	0.04443	0.03684	0.01614	0.01032
402	0.1096	0.07857	0.06988	0.04988	0.04136	0.01932	0.01263
403	0.1668	0.1368	0.1272	0.102	0.09099	0.05834	0.0468
404	0.07235	0.04867	0.04239	0.02704	0.02085	0.00663	0.003361
405	0.1006	0.07182	0.06343	0.04462	0.03693	0.01626	0.01043

LOSP Frequency

Point	LOSP-2H	LOSP-3H	LOSP-3.5H	LOSP-5H	LOSP-6H	LOSP-11H	LOSP-14H
406	0.08107	0.05624	0.04909	0.03257	0.02523	0.00915	0.005063
407	0.131	0.09837	0.08832	0.06494	0.05441	0.02783	0.02035
408	0.05247	0.03233	0.02703	0.0153	0.01169	0.00275	0.001074
409	0.134	0.1007	0.09049	0.06693	0.05717	0.03004	0.02245
410	0.1187	0.08793	0.07771	0.05465	0.04563	0.02312	0.01582
411	0.06911	0.04663	0.04004	0.02516	0.01927	0.00603	0.003052
412	0.1154	0.08343	0.07399	0.05247	0.04334	0.02062	0.01417
413	0.09156	0.06496	0.05652	0.03856	0.03108	0.01244	0.007488
414	0.1214	0.09003	0.08008	0.05603	0.04758	0.02405	0.01627
415	0.1109	0.07876	0.07018	0.05009	0.04152	0.01936	0.01283
416	0.06478	0.04131	0.03526	0.02158	0.01658	0.00496	0.002466
417	0.1692	0.1399	0.1299	0.1051	0.09146	0.0618	0.0486
418	0.1264	0.09317	0.08347	0.06079	0.05132	0.02565	0.01771
419	0.06815	0.04466	0.03837	0.02386	0.01812	0.00562	0.002816
420	0.09961	0.07037	0.06237	0.04362	0.03619	0.01585	0.009972
421	0.07988	0.05513	0.0481	0.03193	0.02473	0.00862	0.004802
422	0.07764	0.05384	0.04679	0.0304	0.02372	0.00768	0.004416
423	0.08253	0.05714	0.05001	0.03338	0.02603	0.00976	0.005505
424	0.1128	0.08161	0.07249	0.05164	0.0423	0.01997	0.01349
425	0.07373	0.04929	0.04306	0.02756	0.02153	0.00682	0.003669
426	0.1144	0.08257	0.0734	0.05206	0.04314	0.02038	0.01397
427	0.08139	0.05634	0.04923	0.03283	0.02555	0.00921	0.005171
428	0.1267	0.09322	0.08355	0.06122	0.05138	0.02567	0.01792
429	0.1575	0.1191	0.1079	0.08187	0.07472	0.04654	0.03759
430	0.1293	0.09564	0.08599	0.06363	0.05379	0.02681	0.01978
431	0.1118	0.08104	0.07198	0.05093	0.04202	0.01985	0.01315
432	0.1631	0.1263	0.116	0.09261	0.08272	0.05204	0.04182
433	0.09572	0.0673	0.05904	0.04098	0.03391	0.01394	0.008709
434	0.1255	0.09239	0.08273	0.0602	0.0508	0.02535	0.01744
435	0.1329	0.1004	0.09026	0.06655	0.05698	0.02999	0.02197
436	0.1154	0.08396	0.07466	0.05256	0.04345	0.02075	0.01431
437	0.06196	0.04008	0.03421	0.02117	0.01572	0.00433	0.001971
438	0.1166	0.08504	0.07556	0.05306	0.04454	0.02178	0.01512
439	0.2393	0.2101	0.203	0.1873	0.1817	0.171	0.169

LOSP Frequency

Point	LOSP-2H	LOSP-3H	LOSP-3.5H	LOSP-5H	LOSP-6H	LOSP-11H	LOSP-14H
440	0.08694	0.06106	0.05367	0.03525	0.02872	0.01139	0.00673
441	0.1015	0.07196	0.06363	0.04474	0.0371	0.01638	0.01062
442	0.1054	0.07497	0.06658	0.04664	0.03811	0.0176	0.01147
443	0.09684	0.0678	0.06011	0.04209	0.03486	0.01456	0.009222
444	0.1267	0.09328	0.08363	0.06185	0.05149	0.02568	0.01798
445	0.09668	0.06777	0.06008	0.04164	0.03473	0.0144	0.009131
446	0.09558	0.06729	0.05895	0.04089	0.03369	0.01384	0.008627
447	0.08791	0.06168	0.05418	0.03543	0.02936	0.01174	0.006938
448	0.1226	0.09072	0.08065	0.05753	0.04841	0.02431	0.01681
449	0.1272	0.09355	0.08389	0.0623	0.05163	0.02607	0.01834
450	0.09079	0.06339	0.05548	0.03727	0.0304	0.01223	0.00729
451	0.05801	0.03747	0.03186	0.01904	0.01421	0.00362	0.001475
452	0.1362	0.102	0.09182	0.06799	0.0584	0.03061	0.02288
453	0.1111	0.07971	0.07083	0.05019	0.04176	0.01947	0.01291
454	0.1326	0.1003	0.09004	0.0665	0.05677	0.02971	0.02183
455	0.07474	0.05135	0.04453	0.02896	0.0225	0.00728	0.004088
456	0.1168	0.0857	0.07615	0.0534	0.04503	0.02214	0.01538
457	0.08919	0.06229	0.05469	0.03629	0.02954	0.01201	0.00714
458	0.08024	0.05573	0.04863	0.03213	0.02496	0.00888	0.004962
459	0.08721	0.06111	0.05371	0.03528	0.02885	0.01139	0.006734
460	0.135	0.1017	0.09151	0.0675	0.05781	0.03048	0.02273
461	0.1026	0.07281	0.06439	0.04555	0.03741	0.01673	0.0109
462	0.05544	0.03442	0.02919	0.01723	0.01298	0.00315	0.001276
463	0.05181	0.03068	0.02561	0.01504	0.01131	0.00243	0.001017
464	0.07478	0.05155	0.04464	0.02904	0.02251	0.00731	0.004099
465	0.1319	0.09902	0.089	0.06551	0.05576	0.02856	0.02087
466	0.1261	0.09285	0.08305	0.06068	0.05126	0.02555	0.01768
467	0.05603	0.03583	0.03021	0.01838	0.01368	0.00328	0.001406
468	0.1438	0.107	0.09701	0.07366	0.0639	0.03708	0.02622
469	0.1192	0.0885	0.07865	0.0551	0.04645	0.02334	0.01602
470	0.08432	0.05884	0.0513	0.03423	0.02716	0.01038	0.006187
471	0.07874	0.05441	0.04736	0.03071	0.02416	0.00798	0.004494
472	0.09196	0.06523	0.05689	0.03881	0.03119	0.01282	0.007616
473	0.05722	0.03618	0.03076	0.01854	0.01402	0.00338	0.001426

LOSP Frequency

Point	LOSP-2H	LOSP-3H	LOSP-3.5H	LOSP-5H	LOSP-6H	LOSP-11H	LOSP-14H
474	0.1081	0.07704	0.0688	0.04919	0.04037	0.01873	0.01206
475	0.1111	0.08007	0.07117	0.05021	0.04177	0.01954	0.01297
476	0.1356	0.1017	0.09165	0.06756	0.05834	0.03061	0.02283
477	0.05234	0.03201	0.02656	0.01514	0.01155	0.0026	0.001023
478	0.08443	0.0591	0.05144	0.03441	0.0273	0.01043	0.006287
479	0.1236	0.09136	0.08144	0.05873	0.04927	0.02476	0.01704
480	0.05319	0.03263	0.0273	0.01604	0.01178	0.0028	0.001158
481	0.07672	0.05349	0.04632	0.03022	0.02324	0.00766	0.004302
482	0.04476	0.02668	0.02154	0.01076	0.00724	0.00113	0.0004241
483	0.08367	0.05846	0.05104	0.03393	0.02691	0.01026	0.006028
484	0.1141	0.08245	0.07322	0.05204	0.0431	0.02027	0.01392
485	0.04638	0.02785	0.02302	0.01246	0.00859	0.00154	0.0005338
486	0.1277	0.09438	0.08455	0.0625	0.05256	0.02636	0.01894
487	0.09043	0.0631	0.05525	0.03675	0.03026	0.01218	0.007259
488	0.1164	0.08487	0.07543	0.05297	0.04436	0.02168	0.01503
489	0.06889	0.04652	0.03982	0.02488	0.01884	0.00593	0.002986
490	0.06114	0.03945	0.03345	0.02083	0.01491	0.00392	0.001823
491	0.07285	0.04877	0.04245	0.02738	0.02093	0.00666	0.003438
492	0.09639	0.0676	0.05979	0.04129	0.03435	0.01421	0.008897
493	0.06172	0.03971	0.03369	0.02097	0.01534	0.00411	0.001914
494	0.1156	0.08432	0.07502	0.05274	0.04374	0.02106	0.0146
495	0.1332	0.1005	0.09042	0.06692	0.05712	0.03	0.02212
496	0.1175	0.08676	0.077	0.05421	0.04534	0.02275	0.0157
497	0.1168	0.08549	0.07601	0.05331	0.04484	0.02201	0.01531
498	0.1654	0.1361	0.125	0.1007	0.08931	0.05512	0.04512
499	0.06889	0.04654	0.03994	0.02503	0.01895	0.00598	0.002998
500	0.1323	0.1001	0.08963	0.06641	0.05647	0.02936	0.02142

Attachment G-47

IRRAS Histogram Development Spread Sheet

LOSP Frequency

Step	LOSP-2H	Bin Bound	Frequency	Bin Mdpt	Prob Density (%)	Running Tot
0.00	0.00	0.0252	0.00	0.00		0.00
0.002	2.7010e-02	0.0504	10	0.04	2.00	0.02
0.004	2.9900e-02	0.0599	24	0.06	4.80	0.07
0.006	4.1120e-02	0.0693	40	0.06	8.00	0.15
0.008	4.4760e-02	0.0756	35	0.07	7.00	0.22
0.01	4.4870e-02	0.0819	37	0.08	7.40	0.29
0.012	4.6130e-02	0.0845	22	0.08	4.40	0.34
0.014	4.6380e-02	0.0882	22	0.09	4.40	0.38
0.016	4.7420e-02	0.0945	33	0.09	6.60	0.45
0.018	4.7720e-02	0.1008	48	0.10	9.60	0.54
0.02	4.7820e-02	0.1071	26	0.10	5.20	0.59
0.022	5.1580e-02	0.1134	33	0.11	6.60	0.66
0.024	5.1790e-02	0.1197	39	0.12	7.80	0.74
0.026	5.1810e-02	0.126	21	0.12	4.20	0.78
0.028	5.2140e-02	0.1323	33	0.13	6.60	0.85
0.03	5.2340e-02	0.1386	18	0.14	3.60	0.88
0.032	5.2470e-02	0.1512	29	0.14	5.80	0.94
0.034	5.2740e-02	0.1638	14	0.16	2.80	0.97
0.036	5.3190e-02	0.1764	10	0.17	2.00	0.99
0.038	5.4130e-02	0.2016	4	0.19	0.80	1.00
0.04	5.4880e-02	0.2394	2	0.22	0.40	1.00
0.042	5.5250e-02		0.00			
0.044	5.5440e-02		500		100	

Step	LOSP-2H
0.046	5.5500e-02
0.048	5.5920e-02
0.05	5.6030e-02
0.052	5.6560e-02
0.054	5.7220e-02
0.056	5.7820e-02
0.058	5.7910e-02
0.06	5.8010e-02

Step	LOSP-2H
0.062	5.8350e-02
0.064	5.8710e-02
0.066	5.8990e-02
0.068	5.9010e-02
0.07	6.0020e-02
0.072	6.0440e-02
0.074	6.1140e-02
0.076	6.1280e-02
0.078	6.1720e-02
0.08	6.1910e-02
0.082	6.1960e-02
0.084	6.2780e-02
0.086	6.3440e-02
0.088	6.3460e-02
0.09	6.4430e-02
0.092	6.4440e-02
0.094	6.4730e-02
0.096	6.4780e-02
0.098	6.5040e-02
0.1	6.5210e-02
0.102	6.5240e-02
0.104	6.5490e-02
0.106	6.5590e-02
0.108	6.5590e-02
0.11	6.5650e-02
0.112	6.5690e-02
0.114	6.5740e-02
0.116	6.5780e-02
0.118	6.6170e-02
0.12	6.6170e-02
0.122	6.6450e-02
0.124	6.6760e-02
0.126	6.6800e-02
0.128	6.6990e-02

LOSP Frequency

Step	LOSP-2H
0.13	6.8150e-02
0.132	6.8160e-02
0.134	6.8520e-02
0.136	6.8610e-02
0.138	6.8870e-02
0.14	6.8890e-02
0.142	6.8890e-02
0.144	6.8980e-02
0.146	6.9110e-02
0.148	6.9270e-02
0.15	6.9470e-02
0.152	6.9730e-02
0.154	6.9730e-02
0.156	7.0500e-02
0.158	7.0560e-02
0.16	7.0970e-02
0.162	7.0980e-02
0.164	7.1680e-02
0.166	7.1740e-02
0.168	7.1880e-02
0.17	7.2120e-02
0.172	7.2290e-02
0.174	7.2350e-02
0.176	7.2850e-02
0.178	7.2950e-02
0.18	7.3010e-02
0.182	7.3490e-02
0.184	7.3660e-02
0.186	7.3730e-02
0.188	7.3740e-02
0.19	7.3900e-02
0.192	7.3960e-02
0.194	7.4020e-02
0.196	7.4260e-02

Step	LOSP-2H
0.198	7.4350e-02
0.2	7.4350e-02
0.202	7.4480e-02
0.204	7.4560e-02
0.206	7.4570e-02
0.208	7.4740e-02
0.21	7.4780e-02
0.212	7.4790e-02
0.214	7.5430e-02
0.216	7.5460e-02
0.218	7.5570e-02
0.22	7.5820e-02
0.222	7.5950e-02
0.224	7.6280e-02
0.226	7.6310e-02
0.228	7.6370e-02
0.23	7.6530e-02
0.232	7.6720e-02
0.234	7.7310e-02
0.236	7.7570e-02
0.238	7.7640e-02
0.24	7.8390e-02
0.242	7.8420e-02
0.244	7.8510e-02
0.246	7.8510e-02
0.248	7.8520e-02
0.25	7.8610e-02
0.252	7.8740e-02
0.254	7.8830e-02
0.256	7.8840e-02
0.258	7.9000e-02
0.26	7.9040e-02
0.262	7.9400e-02
0.264	7.9620e-02

LOSP Frequency

Step	LOSP-2H
0.266	7.9790e-02
0.268	7.9880e-02
0.27	7.9880e-02
0.272	8.0200e-02
0.274	8.0240e-02
0.276	8.0240e-02
0.278	8.0250e-02
0.28	8.0300e-02
0.282	8.0800e-02
0.284	8.0940e-02
0.286	8.1070e-02
0.288	8.1390e-02
0.29	8.1410e-02
0.292	8.1510e-02
0.294	8.1940e-02
0.296	8.1990e-02
0.298	8.2130e-02
0.3	8.2450e-02
0.302	8.2530e-02
0.304	8.2690e-02
0.306	8.2780e-02
0.308	8.2820e-02
0.31	8.2980e-02
0.312	8.3160e-02
0.314	8.3230e-02
0.316	8.3270e-02
0.318	8.3390e-02
0.32	8.3430e-02
0.322	8.3610e-02
0.324	8.3670e-02
0.326	8.3810e-02
0.328	8.4310e-02
0.33	8.4320e-02
0.332	8.4330e-02

Step	LOSP-2H
0.334	8.4430e-02
0.336	8.4430e-02
0.338	8.4750e-02
0.34	8.4900e-02
0.342	8.5410e-02
0.344	8.5420e-02
0.346	8.5440e-02
0.348	8.5870e-02
0.35	8.5970e-02
0.352	8.6010e-02
0.354	8.6420e-02
0.356	8.6470e-02
0.358	8.6620e-02
0.36	8.6740e-02
0.362	8.6860e-02
0.364	8.6890e-02
0.366	8.6900e-02
0.368	8.6940e-02
0.37	8.7210e-02
0.372	8.7320e-02
0.374	8.7530e-02
0.376	8.7550e-02
0.378	8.7910e-02
0.38	8.8160e-02
0.382	8.8530e-02
0.384	8.8540e-02
0.386	8.8590e-02
0.388	8.8930e-02
0.39	8.9190e-02
0.392	8.9480e-02
0.394	8.9730e-02
0.396	9.0060e-02
0.398	9.0090e-02
0.4	9.0430e-02

LOSP Frequency

Step	LOSP-2H
0.402	9.0790e-02
0.404	9.1050e-02
0.406	9.1120e-02
0.408	9.1130e-02
0.41	9.1270e-02
0.412	9.1310e-02
0.414	9.1550e-02
0.416	9.1560e-02
0.418	9.1670e-02
0.42	9.1740e-02
0.422	9.1830e-02
0.424	9.1960e-02
0.426	9.2140e-02
0.428	9.2320e-02
0.43	9.2580e-02
0.432	9.2640e-02
0.434	9.2640e-02
0.436	9.3230e-02
0.438	9.3740e-02
0.44	9.3740e-02
0.442	9.3800e-02
0.444	9.4090e-02
0.446	9.4200e-02
0.448	9.4540e-02
0.45	9.4560e-02
0.452	9.4750e-02
0.454	9.4810e-02
0.456	9.4900e-02
0.458	9.5140e-02
0.46	9.5160e-02
0.462	9.5290e-02
0.464	9.5300e-02
0.466	9.5550e-02
0.468	9.5580e-02

Step	LOSP-2H
0.47	9.5720e-02
0.472	9.5830e-02
0.474	9.5900e-02
0.476	9.6260e-02
0.478	9.6350e-02
0.48	9.6390e-02
0.482	9.6520e-02
0.484	9.6540e-02
0.486	9.6680e-02
0.488	9.6770e-02
0.49	9.6820e-02
0.492	9.6840e-02
0.494	9.7090e-02
0.496	9.7120e-02
0.498	9.7140e-02
0.5	9.7160e-02
0.502	9.7570e-02
0.504	9.7670e-02
0.506	9.7860e-02
0.508	9.7910e-02
0.51	9.8020e-02
0.512	9.8040e-02
0.514	9.8770e-02
0.516	9.9090e-02
0.518	9.9090e-02
0.52	9.9360e-02
0.522	9.9450e-02
0.524	9.9550e-02
0.526	9.9610e-02
0.528	9.9680e-02
0.53	9.9810e-02
0.532	9.9840e-02
0.534	1.0020e-01
0.536	1.0030e-01

LOSP Frequency

Step	LOSP-2H
0.538	1.0050e-01
0.54	1.0050e-01
0.542	1.0060e-01
0.544	1.0110e-01
0.546	1.0150e-01
0.548	1.0150e-01
0.55	1.0160e-01
0.552	1.0170e-01
0.554	1.0180e-01
0.556	1.0230e-01
0.558	1.0260e-01
0.56	1.0330e-01
0.562	1.0330e-01
0.564	1.0360e-01
0.566	1.0380e-01
0.568	1.0380e-01
0.57	1.0400e-01
0.572	1.0420e-01
0.574	1.0520e-01
0.576	1.0540e-01
0.578	1.0540e-01
0.58	1.0550e-01
0.582	1.0550e-01
0.584	1.0600e-01
0.586	1.0660e-01
0.588	1.0660e-01
0.59	1.0670e-01
0.592	1.0690e-01
0.594	1.0710e-01
0.596	1.0720e-01
0.598	1.0740e-01
0.6	1.0750e-01
0.602	1.0750e-01
0.604	1.0790e-01

Step	LOSP-2H
0.606	1.0800e-01
0.608	1.0810e-01
0.61	1.0820e-01
0.612	1.0840e-01
0.614	1.0880e-01
0.616	1.0890e-01
0.618	1.0890e-01
0.62	1.0910e-01
0.622	1.0940e-01
0.624	1.0960e-01
0.626	1.0960e-01
0.628	1.1070e-01
0.63	1.1090e-01
0.632	1.1100e-01
0.634	1.1110e-01
0.636	1.1110e-01
0.638	1.1120e-01
0.64	1.1140e-01
0.642	1.1160e-01
0.644	1.1170e-01
0.646	1.1180e-01
0.648	1.1190e-01
0.65	1.1260e-01
0.652	1.1260e-01
0.654	1.1280e-01
0.656	1.1290e-01
0.658	1.1320e-01
0.66	1.1330e-01
0.662	1.1370e-01
0.664	1.1380e-01
0.666	1.1410e-01
0.668	1.1440e-01
0.67	1.1440e-01
0.672	1.1490e-01

LOSP Frequency

Step	LOSP-2H
0.674	1.1490e-01
0.676	1.1530e-01
0.678	1.1540e-01
0.68	1.1540e-01
0.682	1.1540e-01
0.684	1.1540e-01
0.686	1.1540e-01
0.688	1.1560e-01
0.69	1.1570e-01
0.692	1.1580e-01
0.694	1.1640e-01
0.696	1.1640e-01
0.698	1.1640e-01
0.7	1.1660e-01
0.702	1.1670e-01
0.704	1.1680e-01
0.706	1.1680e-01
0.708	1.1680e-01
0.71	1.1690e-01
0.712	1.1710e-01
0.714	1.1740e-01
0.716	1.1740e-01
0.718	1.1750e-01
0.72	1.1800e-01
0.722	1.1840e-01
0.724	1.1870e-01
0.726	1.1880e-01
0.728	1.1900e-01
0.73	1.1910e-01
0.732	1.1910e-01
0.734	1.1920e-01
0.736	1.1940e-01
0.738	1.1970e-01
0.74	1.1980e-01

Step	LOSP-2H
0.742	1.2010e-01
0.744	1.2030e-01
0.746	1.2060e-01
0.748	1.2070e-01
0.75	1.2140e-01
0.752	1.2210e-01
0.754	1.2210e-01
0.756	1.2250e-01
0.758	1.2260e-01
0.76	1.2320e-01
0.762	1.2340e-01
0.764	1.2350e-01
0.766	1.2360e-01
0.768	1.2400e-01
0.77	1.2430e-01
0.772	1.2490e-01
0.774	1.2510e-01
0.776	1.2520e-01
0.778	1.2550e-01
0.78	1.2580e-01
0.782	1.2610e-01
0.784	1.2630e-01
0.786	1.2640e-01
0.788	1.2660e-01
0.79	1.2670e-01
0.792	1.2670e-01
0.794	1.2670e-01
0.796	1.2720e-01
0.798	1.2740e-01
0.8	1.2770e-01
0.802	1.2770e-01
0.804	1.2780e-01
0.806	1.2790e-01
0.808	1.2820e-01

LOSP Frequency

Step	LOSP-2H
0.81	1.2820e-01
0.812	1.2860e-01
0.814	1.2930e-01
0.816	1.2930e-01
0.818	1.2940e-01
0.82	1.2940e-01
0.822	1.2950e-01
0.824	1.2950e-01
0.826	1.3070e-01
0.828	1.3090e-01
0.83	1.3100e-01
0.832	1.3110e-01
0.834	1.3160e-01
0.836	1.3170e-01
0.838	1.3190e-01
0.84	1.3190e-01
0.842	1.3220e-01
0.844	1.3220e-01
0.846	1.3230e-01
0.848	1.3240e-01
0.85	1.3260e-01
0.852	1.3280e-01
0.854	1.3290e-01
0.856	1.3320e-01
0.858	1.3400e-01
0.86	1.3450e-01
0.862	1.3480e-01
0.864	1.3490e-01
0.866	1.3500e-01
0.868	1.3560e-01
0.87	1.3620e-01
0.872	1.3630e-01
0.874	1.3640e-01
0.876	1.3690e-01

Step	LOSP-2H
0.878	1.3750e-01
0.88	1.3800e-01
0.882	1.3830e-01
0.884	1.3930e-01
0.886	1.3990e-01
0.888	1.4010e-01
0.89	1.4070e-01
0.892	1.4090e-01
0.894	1.4110e-01
0.896	1.4110e-01
0.898	1.4130e-01
0.9	1.4130e-01
0.902	1.4160e-01
0.904	1.4170e-01
0.906	1.4210e-01
0.908	1.4230e-01
0.91	1.4310e-01
0.912	1.4330e-01
0.914	1.4380e-01
0.916	1.4450e-01
0.918	1.4480e-01
0.92	1.4650e-01
0.922	1.4680e-01
0.924	1.4730e-01
0.926	1.4740e-01
0.928	1.4780e-01
0.93	1.4790e-01
0.932	1.4870e-01
0.934	1.4870e-01
0.936	1.4920e-01
0.938	1.5060e-01
0.94	1.5060e-01
0.942	1.5180e-01
0.944	1.5230e-01

LOSP Frequency

Step	LOSP-2H
0.946	1.5290e-01
0.948	1.5360e-01
0.95	1.5500e-01
0.952	1.5610e-01
0.954	1.5630e-01
0.956	1.5750e-01
0.958	1.6040e-01
0.96	1.6180e-01
0.962	1.6200e-01
0.964	1.6230e-01
0.966	1.6270e-01
0.968	1.6310e-01
0.97	1.6390e-01
0.972	1.6410e-01
0.974	1.6470e-01
0.976	1.6470e-01
0.978	1.6540e-01
0.98	1.6600e-01
0.982	1.6680e-01
0.984	1.6730e-01
0.986	1.6920e-01
0.988	1.7060e-01
0.99	1.7970e-01
0.992	1.8260e-01
0.994	1.9230e-01
0.996	1.9510e-01
0.998	2.0280e-01
1	2.3930e-01

RA-LOSP-2H

Figure Attachment G-47-1 Example Plot of Cumulative Distribution Function

RA-LOSP-2H-Binned

Figure Attachment G-47-2 Example "Stair-Step" Plot of Cumulative Distribution Function

Appendix H. Event Trees

This Appendix contains various event trees that are not in Section 6 of this report.

H.1 Generic System-Level Event Trees

The generic, system-level event trees for transients are included in Figure H.1-1 through H.1-93. The purpose of each tree is described in Section 6.1, and the acronyms used in the trees are defined in Section 6.4.

H.2 Transfer Event Trees

Sections 6.2 and 6.3 provide the top level event trees for each initiating event. Section 6.2 provides them for specific transient initiating events, and Section 6.3 provides them for each LOCA initiating event. These top level trees transfer to numerous other event trees. Some of the event trees transferred to are the generic, system-level event trees of Section H.1; other special event trees transferred to are included in Figure H.2-1 through H.2-84. The acronyms used in the trees are defined in Section 6.4.

A5ISO	ISSDC	RLOSP	DV1-2	HPCSA	XTIEB	SEQ #	OUTCOME
<pre>graph LR Start(( )) --- RHR[RHR Loop B] Start --- ADHR[ADHR] RHR --- E1[ ] E1 --- E2[ ] E2 --- E3[ ] E3 --- E4[ ] E4 --- E5[ ] ADHR --- E6[ ] E6 --- E7[ ] E7 --- E8[ ] E8 --- E9[ ] E9 --- E10[ ]</pre>						1 T 2 T 3 4 T 5 T 6 T 7 T 8 9 T 10 T	E ° EP 1 @NOT-DEVELOPED EX @CCN EA EAP 1 @NOT-DEVELOPED EAX @CCN
1 : Sequence logic not developed. Sequence frequency below truncation a: In POS 5, a feedwater line break LOCA that is isolated is like a loss of shutdown cooling transient. See A5 event tree notes.							

Figure H.1-1 A5ISO Tree

Figure H.1-2 ADEP Tree

Event Trees

	ADEPP	STSRV	RWCUC	SDCUI	STISO	SDCBS	SDCA	ADHR1	SEQ #	OUTCOME
									1	@NOT-VALID
									2	LP
									3	LP
									4	EP
									5	@NOT-VALID
									6	EP

Figure H.1-3 ADEPP Tree

	ADEPX	STSRV	RWCUC	SDCUI	STISO	SDCBS	SDCA	ADHR1	SEQ #	OUTCOME
</										

Figure H.1-4 ADEPX Tree

	ADH	RLOSP	DV1-2	HPCSA	XTIEB	ADHRR	OPSDC	SDCBS	SDCA	SEQ #	OUTCOME
a a: Like SDC but initially on ADHR 1: LA and EA are similar to L and E except since ADHR piping is rated at 80 psig, LPCS/LPCI can overpressurize ADHR										1	LA 1
										2	LA
										3	LA
										4	EA 1
										5	EA
										6	LAP
										7	LAP
										8	EAP
										9	EAP
										10	HPSWA
										11	LAX
										12	LAX
										13	EAX
										14	EAX
										15	@CCN

Figure H.1-5 ADH Tree

AIAD	RHRIP	SDCIL	ISOAD	SEQ #	OUTCOME
a: Set 'ADHIS' to TRUE in all event trees transferred to (SDC has already isolated which also isolates ADHR from overpressure) 1: ADHR isolated, no overpressurization 2: Overpressurize ADHR				1 2 T 3 T 4 T	@NOT-VALID EA 1 IL 2 IL

Figure H.1-6 AIAD Tree

Event Trees

AIADP	RHRIP	SDCIL	ISOAD	SEQ #	OUTCOME
a: Set 'ADHIS' to TRUE in all event trees transferred to (SDC has already isolated which also isolates ADHR from overpressure) 1: ADHR isolated, no overpressurization 2: Overpressurize ADHR 3: ADHR isolated, no overpressurization 4: ADHR isolated, no overpressurization				1 2 3 4	NOT-VALID EAP1 LP 2 LP

Figure H.1-7 AIADP Tree

AIADX	RHRIP	SDCIL	ISOAD	SEQ #	OUTCOME
			a: Set 'ADHS' to TRUE, in all event trees transferred to (SDC has already isolated which also isolates ADHR from overpressure) 1: ADHR isolated, no overpressurization 2: Overpressurize ADHR	1 2 3 4	NOT-VALID EAX¹ LX² LX

Figure H.1-8 AIADX Tree

Event Trees

Figure H.1-9 AISD Tree

	AISDP	RHRIP	SDCIL	SEQ #	OUTCOME
				1 2 3	EP 1 ILP 2 LP

1: SDC isolated, no overpressurization
2: Overpressurize RHR Loop B piping

Figure H.1-10 AISDP Tree

Event Trees

	AI SDX	RHRIP	SDCIL	SEQ #	OUTCOME
				1 T 2 T 3 T	EX ¹ LX ² LX
	1: SDC isolated, no overpressurization 2: Overpressurize RHR Loop B piping				

Figure H.1-11 AISDX Tree

Figure H.1-12 CAUX Tree

Figure H.1-13 CAUXN Tree

Figure H.1-14 CAUXP Tree

CAUXX	ISTCT	CTGOP	OPICT	CTISO	SPC	CS	EQSTM	SEQ #	OUTCOME		
a: Susceptibility of core cooling equipment to steam out open containment into auxiliary building 1: If containment closed, steam can overpressurize containment if no suppression pool cooling, but failure of containment is into shield building and this has no effect on core cooling equipment per NUREG 4550 2: No steam since SP is cooled 3: Equip. not damaged by steam 4: Equip. rendered inoperable due to effects of steam								1	@OK	1	
								2	@OK	1	
								3	@OK	2	
								4	@OK	2	
								5	@OK	3	
								6	T	CCX	4
								7	@OK		
								8	@OK		
								9	@OK		
								10	T	CCX	
								11	@OK		
								12	@OK		
								13	@OK		
								14	@OK		
								15	T	CCX	
								16	@OK		
								17	@OK		
								18	@OK		
								19	T	CCX	

Figure H.1-15 CAUXX Tree

Figure H.1-16 CB Tree

Event Trees

Figure H.1-17 CB1 Tree

Figure H.1-18 CBIP Tree

Event Trees

Figure H.1-19 CB1X Tree

	CB2	SGTS	H2	VENT	SEQ #	OUTCOME
					1 2 3 4	CD CD CD CD

Figure H.1-20 CB2 Tree

Event Trees

	CB2P	SGTS	H2	VENT	SEQ #	OUTCOME
					1	CD
					2	CD
					3	CD
					4	CD

Figure H.1-21 CB2P Tree

Figure H.1-22 CB2X Tree

Event Trees

Figure H.1-23 CBN Tree

Figure H.1-24 CBP Tree

Figure H.1-25 CC Tree

Figure H.1-26 CC1 Tree

Event Trees

Figure H.1-27 CC1P Tree

Figure H.1-28 CC1X Tree

Figure H.1-29 CBX Tree

	CSTMN	EQSTM	SEQ #	OUTCOME
	α	1 2	OK CBN	α: CSTMN is CSTM tree without offsite power and without DV1-2

Figure H.1-30 CSTMN Tree

Event Trees

	CSTMP	EQSTM	SEQ #	OUTCOME
			1 2 T	OK CBP

Figure H.1-31 CSTMP Tree

	CSTMX	EQSTM	SEQ #	OUTCOME
			1 2 T	OK CBX

Figure H.1-32 CSTMX Tree

Event Trees

Figure H.1-33 CC2 Tree

Figure H.1-34 CC2P Tree

Event Trees

Figure H.1-35 CC2X Tree

Figure H.1-36 CCP Tree

Figure H.1-37 CCX Tree

Figure H.1-38 CCN Tree

Event Trees

	CSTM	EQSTM	SEQ #	OUTCOME
			1 2 T	OK 1 CB 2
α: Susceptibility of core cooling equipment to steam out open MSIV's or out feedwater line LOCA outside containment 1: Equipment not damaged by steam 2: Equipment inoperable due to effect of steam				

Figure H.1-39 CSTM Tree

DEP	STSRV	OPDEP	SDCUI	STISO	SDCBS	SDCA	ADHR1	SEQ #	OUTCOME
	a	b	c	d					
								1	@NOT-VALID
								2	L ₁
								3	L
								4	L
								5	E ₂
								6	@NOT-VALID
								7	E
								8	OVPR
a: All SRV's initially available during HYDRO. In all trees transferred to, do the following: Replace event 2SRV with 2SALL, Replace event 1SRV with 1SALL, Replace event 1SRVS with SAFE. c: Since SDC with RHR and ADHR is isolated, set event OPIS to 'Yes' in all trees transferred to, and set event SDCIL to 'Yes' in all event trees transferred to. b: Assume hardware to depressurize works given success of OPDEP, since RWCJ works (transfer from HYDRO) and CRD1 can be stopped to reduce pressure d: Only one ADHRS pump/heat exchanger required for low decay heat level (calc 492-02) 1: Transfer to L is conservative since actual decay heat is lower and water level can be higher (depending on where operator lowers level to) 2: Transfer to E is conservative for same reasons as in note 1									

Figure H.1-40 DEP Tree

Figure H.1-41 E Tree

Figure H.1-42 EA Tree

Event Trees

Figure H.1-43 EAP Tree

Figure H.1-44 EAX Tree

Event Trees

Figure H.1-45 EC Tree

Event Trees

Event Trees

Figure H1-47 ECP Tree

Figure H.1-48 ECX Tree

Event Trees

Figure H.1-49 EP Tree

Figure H.1-50 EX Tree

Event Trees

Figure H.1-51 F Tree

Figure H.1-52 FC Tree

Figure H.1-53 FCP Tree

Figure H.1-54 FCX Tree

Event Trees

Figure H.1-55 FNP Tree

Figure H.1-56 FP Tree

Figure H.1-57 FX Tree

Figure H.1-58 HPSWA Tree

Figure H.1-59 HPSWR Tree

HYDRO	STAHD	RLOSP	DV1-2	HPCSA	XTIEB	RWCU	CRD1	RWCUC	SEQ #	OUTCOME
a									1	⊙NOT-VALID
									2	⊙OK
									3	DEP 1
									4	ADEP 2
									5	OVPR 3
									6	OVPRP 4
									7	HYHPA
									8	OVPRX 4
									9	⊙CCN
a: STAHD specifies status of MSIV's and RECIRC when in hydro mode. Set ISMSV and ISTRC both to 'Yes' in all event trees transferred to. Since decay heat is low during HYDRO, one CRD pump can steam core; change event CRD to CRD1 in all event trees transferred to. 1: Cooling lost, vessel full and at 1000 psig. Decay heat will pressurize 2: With CRD1 lost and RWCU providing letdown, system depressurizes 3: If RWCU is lost there is no letdown and CRD1 will quickly raise pressure to safety valves setpoints 4: RWCU is lost with loss of offsite power. See note 3										

Figure H.1-60 HYDRO Tree

	HYHPA	SAFE	SAFEC	OPDSV	1SYHA	SEQ #	OUTCOME
1: HYDRO case with loss of offsite power and loss of DV1-2, HPCS available. With such a power loss, CRD and RWCU lost; conservatively assume RWCU lags CRD loss so that pressurize to SRV safety setpoints. 1: Seal cooling lost; cannot cool if pressurize along saturation line 2: Assume vessel fails						1 T	HPSWR
						2 T	CCN 1
						3 T	CCN 1
						4 T	HPSWR
						5 T	CCN 2

Figure H.1-61 HYPHA Tree

Figure H.1-62 IL Tree

IL	RHRIL	SDCIL	SEQ #	OUTCOME
1: Break in SDC outside containment isolated due to auto closure of MV 8 or MV 9 on low level 3. Transfer to portion of large LOCA tree for LOCA outside cont. that is isolated. 2: LOCA in SDC line outside cont. not isolated. Top 1/3 core uncovered. ECCS ineffective since SP inventory will be lost for LOCA outside cont. CD with containment bypassed. Flood ineffective assuming LOCA in SDC line diverts any SSWXT or FW out the break			1 T 2 T 3 T	A5ISO 1 CB 2 CB 2

Event Trees

	ILP	RHRIL	SDCIL	SEQ #	OUTCOME
	1: A5ISO has 'P' and 'X' logic in it.				A5ISO 1 CBP CBP

Figure H.1-63 ILP Tree

	ILX	RHRIL	SDCIL	SEQ #	OUTCOME
				1 T 2 T 3 T	A5ISO 1 CBX CBX

Figure H.1-64 ILX Tree

Figure H.1-65 L Tree

Figure H.1-66 LA Tree

Event Trees

Figure H.1-67 LAP Tree

Figure H.1-68 LAX Tree

Event Trees

Figure H.1-69 LP Tree

Figure H.1-70 LX Tree

	OF	OPSOF	SEQ #	OUTCOME
	a		1 T 2 T	S ² CB ¹
	a: overfill with CDS, HPCS, LPCS, LPCI, SSWXT, or FW; with MSIV's open. 1: operator fails to stop overfill of steam lines. flooding CD cont bypassed 2: operator stops injection before flooding occurs. Go to STEAM. HPCS, LPCS, LPCI not available since MSIV's are open.			

Figure H.1-71 OF Tree

	OFP	OPSOF	SEQ #	OUTCOME
			1 T 2 T	SP CBP

Figure H.1-72 OFP Tree

Event Trees

	OFX	OPSOF	SEQ #	OUTCOME
			1 T	SX
			2 T	CBX

Figure H.1-73 OFX Tree

Figure H.1-74 OVPR Tree

	OVPRP	SAFE	SAFEC	OPDSV	1SRVH	SEQ #	OUTCOME	
						1 2 3 4 5	T T T T T	ADEPP 2 PISLP 1 PISLP 1 ADEPP 2 CCP 3
1: System stays at pressure 2: System automatically depressurizes 3: Vessel fails if no safety valve opens								

Figure H.1-75 OVPRP Tree

	OVPRX	SAFE	SAFEC	OPDSV	1SRVH	SEQ #	OUTCOME
-	1: System stays at pressure 2: System automatically depressurizes 3: Vessel fails if no safety valve opens					1 2 3 4 5	ADEPX 2 PISLX 1 PISLX 1 ADEPX 2 CCX 3

Figure H.1-76 OVPRX Tree

Figure H.1-77 P Tree

	PISLP	OPSTL	CRD1	SEAL	SEQ #	OUTCOME
	a b				1 T 2 T 3 T 4 T	CAUXP CCP CCP CCP
	a: SRV's already available through success of SAFE b: only 1 CRD pump required for steaming with low decay heat					

Figure H.1-78 PISLP Tree

Event Trees

	PISLX	OPSTL	CRD1	SEAL	SEQ #	OUTCOME
	a	—	b		1 2 3 4	CAUXX CCX CCX CCX
	c: SRV's already available through success of SAFE b: only 1 CRD pump required for steaming with low decay heat					

Figure H.1-79 PISLX Tree

	PISOL	OPSTL	CRD1	SEAL	SEQ #	OUTCOME
	a b 1 T 2 T 3 T 4 T c: SRV's already available through success of SAFE b: only 1 CRD pump required for steaming with low decay heat					CAUX CC CC CC

Figure H.1-80 PISOL Tree

Figure H.1-81 PP Tree

PX	RHRIP	OPIS	RHRIL	SDCIL	1SRVS	OPSTH	CRD	SEQ #	OUTCOME
								1 T CCX	
								2 T CCX	
								3 T CCX	
								4 T CBX	
								5 T CCX	
								6 T CCX	
								7 T CCX	
								8 T CBX	
								9 T CCX	
								10 T CCX	
								11 T CCX	
								12 T CBX	
								13 T CBX	

Figure H.1-82 PX Tree

Figure H.1-83 R Tree

Figure H.1-84 RA Tree

Event Trees

Figure H.1-85 RAP Tree

Figure H.1-86 RAX Tree

Figure H.1-87 RP Tree

Figure H.1-88 RX Tree

Figure H.1-89 S Tree

Figure H.1-90 SDC Tree

Figure H.1-91 SNP Tree

Figure H.1-92 SP Tree

Figure H.1-93 SX Tree

Event Trees

Figure H.2.3 A5INM Tree

	A5ISH	STAHD	RLOSP	DV1-2	HPCSA	XTIEB	STISO	- SEQ #	OUTCOME
The diagram is an event tree starting from an initial event 'b' (SDC isolated in HYDRO). It branches through several components: STAHD, RLOSP, DV1-2, HPCSA, XTIEB, and STISO. The final outcomes are listed in the 'OUTCOME' column, corresponding to sequence numbers 1 through 9. Some outcomes are marked as 'NOT-VALID', 'NOT-DEVELOPED', or 'NOT-VALID'.									
a: In POS 5, a feedwater line break LOCA that is isolated is like a loss of shutdown cooling transient. See A5 event tree notes. 1 : Sequence logic not developed. Sequence frequency below truncation b: SDC isolated in HYDRO.									
								1	@NOT-VALID
								2	@NOT-VALID
								3 T	E ^a
								4	@NOT-VALID
								5 T	EP
								6	@NOT-DEVELOPED ¹
								7	@NOT-VALID
								8 T	EX
								9 T	@CCN

Figure H.2-5 A5ISJ Tree

A5ISJ	ISSDC	RLOSP	DV1-2	HPCSA	XTIEB	SEQ #	OUTCOME -
						1 T 2 T 3 T 4 T 5 T 6 T 7 T 8 T 9 T 10 T	E ^a EP HPSWR ¹ EX ² @CCN ² E ² EP ² HPSWR ¹ EX ² @CCN
a: In POS 5, a feedwater line break LOCA that is isolated is like a loss of shutdown cooling transient. See A5 event tree notes.							
1 : HPSWR not HPSWA since SDC is isolated.							
2 : E not EA since SDC was isolated.							

A50UH	RLOSP	DV1--2	HPCSA	XTIEB	OPLST	CRD1	CDS	FWLVL	SEQ #	OUTCOME
<										

Figure H.2-8 ADEPS Tree

Figure H.2-9 ADESP Tree

Figure H.2-10 ADESX Tree

Figure H.2-11 ADRH Tree

Event Trees

Figure H.2-12 ADRHP Tree

Figure H.2-13 ADRHX Tree

	AINMN	ISSP	SEQ #	OUTCOME
a b			1 T	EAMN
			2 T	FAMN
a: AINMN is A5INM tree modified for no offsite power, no DV1-2, HPCS available. b: If SP empty and HPCS lined up to 170,000 gal in CST, dump of 170,000 gal + 8,000 ft³ from vessel (due to drop to 2/3 core height) adds only 4.2 feet to SP (using 7353 ft³/ft in SP from calc 7), and this is insufficient for ECCS recirc. Addition of 36163 ft³ from SPMU adds another 4.9 feet for a total of 9.1 feet, which is below the ABSOLUTE minimum of 9.95 feet per calc 7. If SP is at either LWL or 12'8", sufficient water for ECCS recirc				

Figure H.2-14 AINMN Tree

Event Trees

DEPS	STSRV	STRWC	OPDEP	SDCUI	STISO	SDCBS	SDCA	ADHR1	SEQ #	OUTCOME
									1 2 3 T 4 T 5 T 6 T 7 8 T 9 T	@NOT-VALID @NOT-VALID L 1 L L E 2 @NOT-VALID E OVPRS --
e: In all event trees transferred to, do the following: Replace event RWCU with RWLS, Replace event RWCUC with event RWCUS.										
a: All SRV's initially available during HYDRO. In all trees transferred to, do the following: Replace event 2SRV with 2SALL, Replace event 1SRV with 1SALL, Replace event 1SRVS with SAFE.										
c: Since SDC with RHR and ADHR is isolated, set event OPIS to 'Yes' in all trees transferred to, and set event SDCIL to 'Yes' in all event trees transferred to.										
b: Assume hardware to depressurize works given success of OPDEP, since RWCU works (transfer from HYDRO) and CRD1 can be stopped to reduce pressure d: Only one ADHRS pump/heat exchanger required for low decay heat level (calc 492-02)										
1: Transfer to L is conservative since actual decay heat is lower and water level can be higher (depending on where operator lowers level to) 2: Transfer to E is conservative for same reasons as in note 1										

Figure H.2-16 EAM Tree

Figure H.2-17 EAMH Tree

Figure H.2-18 EAMHP Tree

EAMHX	HPCS	LPCS	2LPCI	ISMSV	ACMSV	OPLMS	MSV	SEQ #	OUTCOME	
								1	T	ECCHX
								2	T	ECCHX
								3	T	ECCHX
								4	T	ECCHX
								5	T	ECCHX
								6	T	ECCHX
								7	T	ECCHX
								8	T	ECCHX
								9	T	ECCHX
								10	T	ECCHX
								11	T	ECCHX
								12	T	ECCHX
								13	T	FAMX

Figure H.2-19 EAMHX Tree

Figure H.2-20 EAMN Tree

Figure H.2-21 EAMP Tree

Figure H.2-22 EAMX Tree

Figure H.2-23 ECAC Tree

Event Trees

Figure H.2-24 ECACH Tree

Figure H.2-25 ECACN Tree

Figure H.2-26 ECACP Tree

Figure H.2-27 ECACX Tree

Figure H.2-28 ECAO Tree

Figure H.2-29 ECAOH Tree

Figure H.2-30 ECAON Tree

Figure H.2-31 ECAOP Tree

Figure H.2-32 ECAOX Tree

Figure H.2-33 ECCHP Tree

Event Trees

Figure H.2-34 ECCHX Tree

Figure H.2-35 ECNPL Tree

Figure H.2-36 ECOHP Tree

Figure H.2-37 ECOHX Tree

Figure H.2-38 ES Tree

Figure H.2-39 ESP Tree

Event Trees

Figure H.2-40 ESX Tree

Figure H.2-41 FAM Tree

Figure H.2-42 FAMN Tree

Figure H.2-43 FAMP

Figure H.2-44 FAMX Tree

Figure H.2-45 FCAC Tree

Event Trees

Figure H.2-46 FCACN Tree

Figure H.2-47 FCACP Tree

Figure H.2-48 FCACX Tree

FCAO	ISTCT	CTGOP	OPICT	CTISO	SPC	CS	SEQ #	OUTCOME
a closed open open high open low open high open low closed open high closed open low							1 T 2 T 3 T 4 T 5 T 6 T 7 T 8 T 9 T 10 T 11 T 12 T 13 T 14 T 15 T 16 T 17 T	CSTM CSTM CSTM CSTM CSTM CSTM CSTM CSTM CSTM CSTM CSTM CSTM CSTM CSTM CSTM CB¹ CB¹

a: MSIV's open, no need for VENT or OPCMT.

1: containment open below grade, flood out equipment.

Figure H.2-49 FCAO Tree

Event Trees

OUTCOME	SEQ #	CS	SPC	CTISN	OPICT	CTGOP	ISTCT	FCAON
CSTMN	1 T							
CSTMN	2 T							
CSTMN	3 T							
CSTMN	4 T							
CSTMN	5 T							
CBN	6 T							
CBN	7 T							

Figure H.2-50 FCAON Tree

FCAOP	ISTCT	CTGOP	OPICT	CTISO	SPC	CS	SEQ #	OUTCOME	
							1	T	CSTMP
							2	T	CSTMP
							3	T	CSTMP
							4	T	CSTMP
							5	T	CSTMP
							6	T	CSTMP
							7	T	CSTMP
							8	T	CSTMP
							9	T	CSTMP
							10	T	CSTMP
							11	T	CSTMP
							12	T	CSTMP
							13	T	CSTMP
							14	T	CSTMP
							15	T	CSTMP
							16	T	CBP
							17	T	CBP

Figure H.2-51 FCAOP Tree

FCAOX	ISTCT	CTGOP	OPICT	CTISO	SPC	CS	SEQ #	OUTCOME
							1 T	CSTMX
							2 T	CSTMX
							3 T	CSTMX
							4 T	CSTMX
							5 T	CSTMX
							6 T	CSTMX
							7 T	CSTMX
							8 T	CSTMX
							9 T	CSTMX
							10 T	CSTMX
							11 T	CSTMX
							12 T	CSTMX
							13 T	CSTMX
							14 T	CSTMX
							15 T	CSTMX
							16 T	CBX
							17 T	CBX

Figure H.2-52 FCAOX Tree

Figure H.2-53 FCN Tree

Figure H.2-54 FS Tree

Figure H.2-55 FSP Tree

Figure H.2-56 FSX Tree

	HPCSW	ISSDC	SEQ #	OUTCOME
	a			
		ADHR RHR Loop B	1 T 2 T	HPSWR HPSWA
a: Offsite power lost, DV1-2 lost, HPCS pump available				

Figure H.2-57 HPCSW Tree

Figure H.2-58 LH Tree

Event Trees

Event Trees

Figure H.2-60 LHAP Tree

Figure H.2-61 LHAX Tree

Event Trees

Figure H.2-62 LHP Tree

Figure H.2-63 LHX Tree

Event Trees

Figure H.2-64 OFS Tree

	OFSP	OPSOF	SEQ #	OUTCOME
			1 T 2 T	FSP CBP

Figure H.2-65 OFSP Tree

Event Trees

	OFSX	OPSOF	SEQ #	OUTCOME
			1 T 2 T	FSX CBX

Figure H.2-66 OFSX Tree

	OVPRS	SAFE	SAFEC	OPDSV	1SRVH	SEQ #	OUTCOME
	1: System stays at pressure 2: System automatically depressurizes 3: Vessel fails if no safety valve opens					1 2 3 4 5	ADEPS 2 PISOL 1 PISOL 1 ADEPS 2 CC 3

Figure H.2-67 OVPRS Tree

	OVPSP	SAFE	SAFEC	OPDSV	1SRVH	SEQ #	OUTCOME
1: System stays at pressure 2: System automatically depressurizes 3: Vessel fails if no safety valve opens							1 T ADESP 2 2 T PISOL 1 3 T PISOL 1 4 T ADESP 2 5 T CCP 3

Figure H.2-68 OVPSP Tree

Figure H.2-69 OVPSX Tree

Event Trees

Figure H.2-70 RAH1 Tree

Figure H.2-71 RAH2 Tree

Figure H.2-72 RH1 Tree

Figure H.2-73 RH2 Tree

S15IN	NOFW	RLOSP	DV1-2	HPCSA	XTIEB	OPSPM	SPMU1	ISSP	SPWLV	SEQ #	OUTCOME
A										1	●NOT-VALID
										2	T
										3	T
										4	T
										5	T
										6	T
										7	T
										8	T
										9	T
										10	T
										11	T
										12	●NOT-DEVELOPED 1
										13	T
										14	T
										15	T
										16	T
										17	T
										18	T
1 : Sequence logic not developed. Sequence frequency below truncation. A: Set FW to Failed in every tree transferred to. FW not equal to 2LPCI for big break.											

Figure H.2-74 SISIN Tree

Figure H.2-75 S15NF Tree

Figure H.2-76 S15OU Tree

Figure H.2-77 S1HIN Tree

S1HNF	SDISO	STAHD	STSRV	RLOSP	DV1-2	HPCSA	XTIEB	OPSPM	SPMU1	ISSP	SPWLV	SEQ #	OUTCOME
												a	
												1 2 3 4 T 5 FS 6 T 7 T 8 T 9 T 10 T 11 T 12 T 13 T 14 15 T 16 T 17 T 18 T 19 T 20 T	●NOT-VALID ●NOT-VALID ●NOT-VALID FS FS FS FS FS FSP FSP FSP FSP FSP ●NOT-DEVELOPED FSX FSX FSX FSX FSX ●CCN
1 : Sequence logic not developed. Sequence frequency below truncation.													
a : SDISO is a flag which sets RHRL, RHRIP, ADHIS, and SDCL to true in every tree transfered to.													

Figure H.2-79 S1HOU Tree

S1XFH	WHERE	NOLPB	CHECK	SEQ #	OUTCOME
a: S1XFH is identical to S1H except that POS5 has been removed. It is transfer tree for S2H LOCA that is not compensated for by CDS. t: S1HNF is S1HIN tree with FW considered.				1 T 2 T 3 T 4 T	S1HNF ¹ @NOT-VALID A5ISH S1HOU

Figure H.2-80 S1XFH Tree

S1XFR	WHERE	NOLPB	CHECK	SEQ #	OUTCOME
a: S1XFR is identical to S1-5 except that POS5 has been removed. It is transfer tree for S2-5 LOCA that is not compensated for by CDS. 1: S15NF is S15IN tree with FW considered.				1 T 2 3 T 4 T	S15NF ¹ @NOT-VALID A5ISO S150U

Figure H.2-81 S1XFR Tree

Event Trees

Figure H.2-82 SDCH Tree

	SDCHP	SDCB	OPSDC	SDCA	SEQ #	OUTCOME
					1 2 3 4	LHP LHP EP EP

Figure H.2-83 SDCHP Tree

Event Trees

Figure H.2-84 SDCHX Tree

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