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Revision 2

DIESEL GENERATOR TECHNICAL SPECIFICATION STUDY FOR INDIAN POINT 3

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1. OBJECTIVES AND OVERVIEW

The objective of this study is to quantify the impact of changes in the allowed outage time for the diesel generators (7 days versus 72 hours) on the reliability performance of the Class 1E AC onsite AC power system at Indian Point 3 by:

- Updating the applicable system reliability models that were originally developed in the Indian Point Probabilistic Safety Study (IPPSS) to account for recent advances in the treatment of common cause failures as documented in NUREG/CR-4780; i.e., the approach suggested for individual plant examinations (IPE).
- Accounting for any significant design and procedural changes that have been made since the IPPSS was completed in 1982.
- Developing qualitative conclusions regarding the potential impact of the above changes on core damage frequency as was originally determined in the IPPSS and estimating the approximate numerical effects of these impacts.

The general approach taken to accomplish this began with a review of the IPPSS electric power system models. The key aspects of the original system model are documented in Appendix A, as modified to accommodate the design and procedural changes that occurred since the original IPPSS study was completed. This qualitative modeling information was used to prepare the input needed to develop quantitative models using the RISKMAN® PC-based software program. The system models that are defined in the next section were then quantified to assess the impact of varying the allowed outage time (AOT) for diesel generator maintenance. These system-level results were then evaluated in terms of the impact on core melt frequency. This approximate evaluation takes advantage of the knowledge gained in the original IPPSS study and of the additional analysis performed in support of the NRC's review of the study. It was not found necessary to perform a complete requantification of the IPPSS event trees to support the conclusions derived from this examination.

2. SYSTEM MODELING

A key first step in this project was to define the scope of the plant evaluation model that would be updated for the current design and used to evaluate each of the assumed allowed outage times. Based on the knowledge that sequences involving failures of one or more diesel generators affect plant safety only if such sequences also involve a loss of offsite power, the electrical system analysis was restricted to the condition in which offsite power is assumed to be unavailable. This simplifies the system models to be evaluated.

2.1 TOP EVENT DEFINITIONS

The system analysis effort was geared to evaluating the unavailability of power to the four engineered safeguard 480V buses (i.e., 2A, 3A, 5A, and 6A), given a loss of offsite power to the 6.9-kV buses 1, 2, 3, 4, 5, and 6. An event tree (see Figure 2-1) was developed to characterize the different states of electric power that result from postulating various combinations of success and failure of the 480V buses. Five different top events were defined for this event tree:

1. **Top Event T1**. Availability of power to at least one of 480V buses 2A, 5A, and 6A.
2. **Top Event T2**. Availability of power to at least two of 480V buses 2A, 5A, and 6A.
3. **Top Event T3**. Availability of power to all three of 480V buses 2A, 5A, and 6A, excluding failures of the diesel generator fuel oil transfer system.
4. **Top Event TX**. Availability power to 480V bus 3A given power is available at 480V bus 2A from diesel generator 31.
5. **Top Event FO**. Availability the fuel oil transfer system to deliver fuel oil to the day tank of each operable diesel generator.

The DC power supplies that must operate to start and load the corresponding diesel generators for buses 2A, 5A, and 6A in Top Events T1, T2, and T3 are included in the associated fault trees for those top events. However, the fuel oil transfer system is modeled separately.

Since the fuel oil transfer system is dependent on the status of power from the three diesel generators (i.e., diesel generators 31, 32, and 33) to the fuel oil transfer pumps, Top Event FO is evaluated under three loss of offsite power conditions:

- **FOA**. All three diesel generators operable.
- **FO1**. Power to one fuel oil transfer pump not available due to failure of one diesel generator.
- **FO2**. Power to exactly two of the three fuel oil transfer pumps not available, (i.e., power to one is available) due to failure of exactly two diesel generators.

As in the original IPPSS for Indian Point 3, the above top events assumed no recovery of electric power. A mission time of 6 hours was assumed for the electrical equipment (i.e.,

diesels and the fuel oil transfer system) that needs to operate only until offsite power is restored. A mission time of 24 hours was assumed for the electrical equipment that must still operate once offsite power is restored; e.g., switchgear. Credit for electric power recovery is assumed to be as calculated in the original IPPSS. That analysis considered both the alignment of the backup gas turbines as well as restoration of power from the offsite grid. These recovery factors are considered in the determination of the impact of the change in AOT on core melt frequency. The backup Appendix R diesel generator is not considered explicitly in the system models or in the determination of plant impacts. However, the consideration of manual alignment of this additional power source would only serve to minimize the impact that the proposed change in AOT would have on the associated reliability and risk factors.

2.2 TREATMENT OF COMMON CAUSE FAILURES

A key enhancement to the system models, over those originally developed in the IPPSS, was the treatment of common cause events. For this study, common cause failures were modeled for a number of component groups. Common cause failures were modeled for the diesels failing to start, the diesels failing to run, the fuel oil transfer pumps failing to start, the pumps failing to run, the diesel generator output breakers failing to close, and the 480V bus supply breakers failing to open. Each of these equipment groups involves three redundant trains. Consequently, the multiple Greek letter (MGL) model was used for quantification purposes; i.e., the common cause models permit the possibility that common cause events can impact two or all three components. This approach is consistent with the methodology described in NUREG/CR-4780. The data used to quantify these common cause models have been tailored from the events found in EPRI-NP-3967 specifically for the system design at Indian Point 3 according to the procedures for event screening and mapping published in NUREG/CR-4780. A review of the data analysis performed is provided in Section 3.

2.3 FAULT TREES

The system fault trees for each evaluated top event are provided in Appendix B. These models are very similar to the fault trees provided in the original IPPSS, although they have been modified to reflect the revised conditions imposed by the top events defined for this study. However, in the IPPSS study, these fault trees were used only for describing the electrical system models. In this analysis, the fault trees were used directly as input to the RISKMAN computer program. All of the component failure modes quantified in the IPPSS study are also evaluated here. This includes not only diesel generator maintenance effects, but also errors in realigning equipment after tests, and, in the case of the diesels, also includes the potential for a fire in a diesel room disabling the associated diesel.

2.4 SYSTEM EQUATIONS

The fault trees presented in Appendix B were solved for the minimal cutsets after the basic events associated with common cause failure were added to the tree. These cutsets were then revised to reflect the different system initial alignments of interest; e.g., normal versus maintenance alignments. The system cutsets are solved once for each initial alignment that the system may be in at the start of the accident. These cutsets are used to calculate the

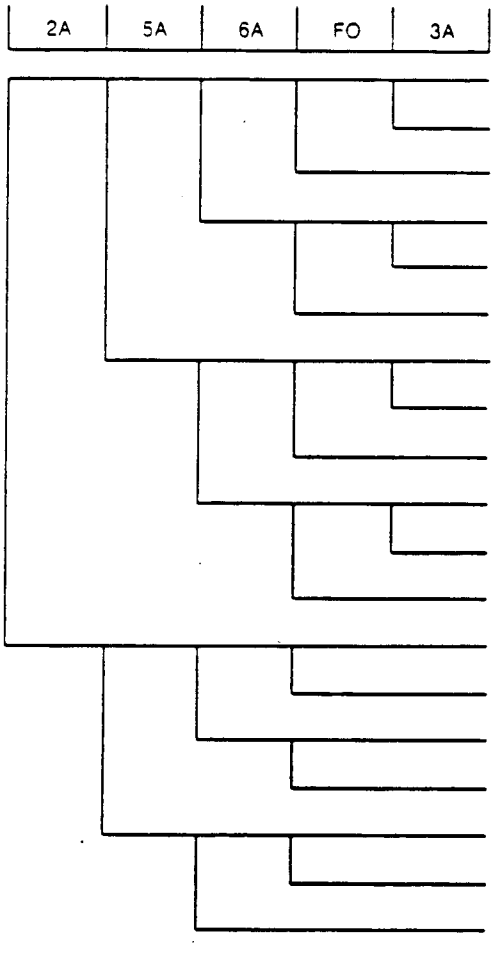
system unavailability, given that the system is in each of the initial alignments. The fraction of time that the system is in each initial alignment is also computed, usually by multiplying the frequency of entering each alignment by the average duration spent in the alignment. Of course, the fraction of time spent in the normal alignment is obtained by subtracting the time spent in the off-normal alignments from 1. The AOT (i.e., 3-day or 7-day) enters into the calculation via the average diesel generator maintenance duration. The maximum AOT is not used directly for the maintenance duration, but it does define the operating environment that affects the average maintenance duration time. This is explained more fully in Section 3.2.

By this approach to the problem, the contribution from each initial alignment to the total system unavailability can be determined. For this analysis, consistent with the original IPPSS study, the initial alignments modeled include the normal alignment and separate alignments for maintenance on each diesel. Additional alignments, such as testing, can be easily added as the need arises.

The basic events in the fault trees were then related to the variables in the database and the assumed mission times. The resulting equations are presented in Appendix C. The cutsets have been sorted by the software according to their contribution to the system unavailability. The numerical results listed alongside the equations in Appendix C are for the case in which the AOT is assumed to be 3 days, and a realistic mean outage duration time is used rather than the full 3 days. Since both scheduled and unscheduled maintenance actions are included in the determination of the diesel generator maintenance frequency, and only a few of the unscheduled maintenance events would require that the affected diesel be out of service for the entire AOT, it should not be surprising that the average maintenance duration is actually much less than the full AOT. This is described further in Section 4.

2.5 UNAVAILABILITY OF POWER AT THE 480V BUSES

The top events defined in Section 2.1 are combined to determine the unavailability of power at each of the four key 480V buses; i.e., buses 2A, 3A, 5A, and 6A. The event tree displayed in Figure 2-1 indicates the different possibilities. The split fractions at each node of the event tree are derived from the results of the fault tree analysis presented earlier. If the fuel oil system fails, all of the buses are assumed to lose power within the 6-hour mission time. Similarly, if power is not available to 480V bus 2A under loss of offsite power conditions, bus 3A cannot be energized by the diesels. This event tree does not consider power from the three gas turbines or the Appendix R diesel. These alternative sources are considered qualitatively in the assessment of the impact of the different AOTs on the core damage frequency. See Section 5 for the qualitative assessment of the plant impact.



#	480V BUS FAILURES 2A	3A	5A	6A
1				
2		F		
3	F	F	F	F
4				F
5		F		F
6	F	F	F	F
7			F	
8		F	F	
9	F	F	F	F
10			F	F
11		F	F	F
12	F	F	F	F
13	F	F		
14	F	F	F	F
15	F	F		F
16	F	F	F	F
17	F	F	F	
18	F	F	F	F
19	F	F	F	F

Figure 2-1. Electric Power State Event Tree

3. DATA ANALYSIS

Most of the failure data used to quantify the system equations presented in Appendix C come from PLG's proprietary database. This generic data represents the accumulation of data from several different plants collected over the years. The generic data uncertainty distributions reflect the impact of plant-to-plant variability on the failure distributions. To limit the scope of this investigation, it was decided not to update the plant-specific data that were originally collected in the IPPSS. Those data covered plant experience through 1979. Because PLG's generic data are more current and yield a wider distribution of uncertainty, these were judged to be more appropriate for this investigation than the older, plant-specific data developed for the IPPSS. From what we know, this approach tends to exaggerate the possible effect of increasing the AOT. Data from the IPPSS study were used for a few items where appropriate generic data were unavailable. In particular, the human error rates and discovery times for restoring the diesel control switch to AUTO following a test are assumed the same as in the IPPSS. Also, the frequency of fires of sufficient severity to disable a diesel is assumed to be the same as in the IPPSS. All of the other data used in this study come from the PLG generic database or were developed specifically for this analysis by updating the generic data with evidence judged to be directly applicable to Indian Point 3.

3.1 PLANT-SPECIFIC COMMON CAUSE DATA

Key failure model parameters developed specifically for Indian Point 3 include the common cause failure parameters for the diesels, and the maintenance frequencies and durations for the diesels subject to different AOTs. For the common cause failure parameters, the 22 common cause events involving diesel generators that have been observed in the industry and listed in EPRI-NP-3967 were screened for applicability to Indian Point 3. Those events that were judged to be applicable to Indian Point 3 during power operation were used to derive the common cause failure parameter distributions. Of the 22 common cause events involving diesels listed in EPRI-NP-3967, 14 have been found to be applicable to nuclear power plants during normal power operation. These were interpreted explicitly to account for differences between Indian Point 3 and the system in which the data originated, the differences due to system design, component type, operating conditions, environment, etc., and in the system size (degree of redundancy). The assessment of the events for Indian Point 3 resulted in five failure-to-start events and six failure-to-run events that were weighted probabilistically using the methods in NUREG/CR-4780 to determine the probable common cause failures of diesels at Indian Point 3. Using these data and PLG's generic database of independent events for a three-train diesel system such as the one at Indian Point 3 (583 independent start failures and 253 independent run failures), the beta and gamma factors for the diesel generator common cause models were calculated based on mapping rules in NUREG/CR-4780. The resulting beta and gamma factor distributions for Indian Point 3 are listed in Table 3-1 along with the rest of the data distributions used.

3.2 PLANT-SPECIFIC DIESEL GENERATOR MAINTENANCE DATA

Special attention was paid to the diesel generator maintenance frequencies and durations. Use was made of the observation that maintenance durations of equipment covered by technical specifications are highly correlated to the AOTs; i.e., if the out of service time exceeds the AOT, the plant will be shut down prior to the time of technical specification violation. Diesel generator maintenance data were used from several plants, some of which were operated with 3-day AOTs, and some of which had 7-day AOTs. A summary of these data is presented in Table 3-2. Data from all of the plants were used to derive a single diesel generator maintenance frequency including a point estimate and an overall distribution. This frequency was then used for all four sensitivity cases, as discussed in the next section.

For the 7-day AOT maintenance duration, generic data on these durations from plants with 7-day AOT are used and updated to account for the Indian Point 3 data. These Indian Point 3 data were collected for 6 years (1973 through 1979) when the IPPSS study was performed, and the plant was subject to a 7-day AOT. For the 3-day AOT maintenance duration, two approaches were considered for making this distribution plant-specific. Data from the period in which Indian Point 3 had been operated subject to the current 3-day AOT are not readily available. One approach considered was to use generic data from 3-day AOT plants as is. A second approach was to perform Bayesian update of the 3-day generic maintenance durations with the old data from Indian Point 3, but adjusted to ensure that none of the individual maintenance events had a duration longer than 72 hours. The second approach was found to yield an appreciably longer average maintenance duration (i.e., 17 hours) than the generic data alone; i.e., 11 hours. It was decided to use the generic data alone rather than updating with the adjusted and old Indian Point 3 plant-specific data collected under a different AOT. The lower average maintenance duration of the 3-day generic distribution probably overestimates the relative difference between plant operation under a 3-day versus a 7-day AOT. This approach is therefore conservative for the purpose of determining the acceptability of this AOT change.

The resulting distributions for maintenance are also presented in Table 3-1. The data variable names for diesel generator maintenance are as defined below:

- **ZMDGSF**. The frequency per hour of maintenance events on a diesel generator.
- **ZMOMSD**. The average maintenance duration for diesels subject to a 3-day AOT, not updated with any plant-specific data from Indian Point 3.
- **ZMOMSN**. The average maintenance duration for diesels subject to a 3-day AOT, updated with the plant-specific data collected from Indian Point 3 when it was operating under a 7-day AOT, but adjusted to ensure that none of the maintenance durations exceeded 3 days.
- **ZMOLSD**. The average maintenance duration for diesels subject to a 7-day AOT, updated with the older Indian Point 3 data collected from plant operation when the plant was subject to a 7-day AOT.
- **ZMOLSN**. The average maintenance duration for diesels subject to a 7-day AOT, computed assuming that the older Indian Point 3 data would not be representative of plant operation today, but included as just another plant's data, equally weighted to the data from other plants in the generic database.

Variables ZMDGSF, ZMOMSD, and ZMOLSD are used to represent the most applicable data for the realistic estimates of maintenance frequencies and durations.

Table 3-1. Data Distribution Report

	NAME OF DISTRIBUTION	MEAN	5TH %ILE	MEDIAN	95TH %ILE
ZIBSIR	BUS - FAILURE DURING OPERATION	4.98E-07	8.74E-08	3.40E-07	1.13E-06
ZICB10	CIRCUIT BREAKER (480 VAC AND ABOVE) - FAILURE TO OPEN ON	6.49E-04	6.48E-05	3.65E-04	1.40E-03
ZICB1C	CIRCUIT BREAKER (480 VAC AND ABOVE) - FAIL TO CLOSE ON DE	1.61E-03	2.68E-04	1.07E-03	3.49E-03
ZICB1T	CIRCUIT BREAKER (480VAC AND ABOVE)-TRANSFER OPEN DURING O	8.28E-07	5.48E-08	3.79E-07	2.79E-06
ZIDGSS	DIESEL GENERATOR - FAILURE TO START ON DEMAND	2.14E-02	2.50E-02	1.35E-02	6.44E-02
ZIDGS1	DIESEL GENERATOR - FAILURE DURING FIRST HR OF OPERATION	1.70E-02	1.07E-03	8.24E-03	5.36E-02
ZIDGS2	DIESEL GENERATOR - FAILURE TO RUN AFTER FIRST HOUR	2.51E-03	2.97E-04	1.49E-03	7.44E-03
ZIFUIR	FUSE - FAIL OPEN DURING OPERATION	9.20E-07	2.67E-08	2.91E-07	2.54E-06
ZIBATD	125V DC BATTERY - FAILURE OF OUTPUT ON DEMAND	4.84E-04	[illegible]0E-05	3.30E-04	1.10E-03
ZIBATR	125V DC BATTERY - FAILURE OF OUTPUT DURING OPERATION	7.53E-07	6.36E-08	3.79E-07	1.64E-06
ZIFMSS	FUEL OIL TRANSFER PUMP--FAILURE TO START ON DEMAND	3.29E-03	2.01E-04	1.63E-03	1.12E-02
ZIFMSR	FUEL OIL TRANSFER PUMP - FAILURE DURING OPERATION	3.42E-05	2.60E-06	1.77E-05	9.32E-05
HE1DG	UNAVAIL. OF 1 DG DUE TO CONTROL SWITCH BEING NOT LEFT IN	2.51E-05	4.54E-07	6.67E-06	9.38E-05
HE2DG	UNAVAIL. OF 2 DG DUE TO CONTROL SWITCH BEING NOT LEFT IN	2.03E-06	7.61E-08	7.62E-07	7.34E-06
HE3DG	UNAVAIL. OF 3 DG DUE TO CONTROL SWITCH BEING NOT LEFT IN	7.63E-07	2.60E-07	6.49E-07	1.59E-06
FIREDG	RATE OF FIRES DISABLING DIESEL GENERATOR ROOM PER HOUR	1.08E-06	6.18E-07	1.02E-06	1.68E-06
ZBCB1C	BETA FACTOR CIRCUIT BREAKERS FAIL TO CLOSE	7.00E-02	5.86E-04	5.46E-02	1.57E-01
ZGCB1C	GAMMA FACTOR CIRCUIT BREAKERS FAIL TO CLOSE	1.40E-01	3.40E-02	1.27E-01	2.45E-01
ZBCB10	BETA FACTOR CIRCUIT BREAKERS FAIL TO OPEN	7.00E-02	5.86E-04	5.46E-02	1.57E-01
ZGCB10	GAMMA FACTOR CIRCUIT BREAKERS FAIL TO OPEN	1.40E-01	3.40E-02	1.27E-01	2.45E-01
ZBFMSS	BETA FACTOR - FUEL OIL XFR PUMPS FAIL TO START	7.00E-02	5.86E-04	5.46E-02	1.57E-01
ZGFMSS	GAMMA FACTOR - FUEL OIL XFR PUMPS FAIL TO START	1.40E-01	3.40E-02	1.27E-01	2.45E-01
ZBFMSR	BETA FACTOR - FUEL OIL XFR PUMPS FAIL TO RUN	1.00E-02	8.83E-04	7.60E-03	2.30E-02
ZGFMSR	GAMMA FACTOR - FUEL OIL PUMPS FAIL TO RUN	1.40E-01	3.40E-02	1.27E-01	2.45E-01
ZGDGSS	GAMMA FACTOR - DIESEL GENERATORS FAIL TO START	1.40E-01	3.40E-02	1.27E-01	2.45E-01
ZGDGSR	GAMMA FACTOR - DIESEL GENERATORS FAIL TO RUN	2.52E-01	7.76E-02	2.36E-01	4.11E-01
ZHDGSI	DIESEL GENERATOR MAINTENANCE FREQUENCY	3.36E-04	2.16E-04	3.21E-04	4.44E-04
ZHUMSD	DIESEL GENERATOR - 48 & 72 HR. AOT,MAINTENANCE DURATION	1.08E+01	7.75E-01	5.37E+00	3.13E+01
ZHUMSN	DG- 48 & 72 HR. AOT,(UPDATED WITH <72 HOUR IPS DATA)	1.73E+01	8.71E+00	1.45E+01	2.31E+01
ZHULSD	DG- 168 HOURS AOT, UPDATED WITH IPS DATA, MAINT. DUR.	2.40E+01	1.03E+01	2.14E+01	3.40E+01
ZHULSN	DG-168 HOURS AOT,IPS INCLUDED IN THE PRIOR,MAINT.DUR.	3.85E+01	5.34E+00	2.45E+01	9.42E+01
ZBDGS	BETA FACTOR DIESEL GEN(3-TRAIN) FAIL TO START	1.42E-02	5.92E-03	1.34E-02	2.18E-02
ZBDR1	BETA FACTOR DIESEL-GEN(3-TRAIN) FAIL TO RUN T< 1 HR	1.79E-02	5.19E-03	1.63E-02	3.04E-02
ZBDR1T	BETA FACTOR DIESEL-GEN(3-TRAIN) FAIL TO RUN T>1 HR	1.08E-02	4.74E-06	3.39E-03	3.81E-02

NUMBER OF VARIABLES: 34

Table 3-2. Industry Data Collected for Diesel Generator Maintenance		
Maintenance Frequency		
Plant	**Events**	**Data Period (hours)**
A	132	2×10^5
B	53	5.35×10^4
C (Indian Point 3)	19	5.98×10^4
D	102	6.36×10^4
E	137	1.62×10^5
F	17	1.03×10^5
G	117	1.18×10^5
H	24	3.07×10^4
I	22	1.1×10^5
Maintenance Duration — 3-Day AOT or Less		
Plant	**Events**	**Mean Duration (hours)**
A	66	5.05
H	24	10.18
Maintenance Duration — 7-Day AOT		
Plant	**Events**	**Mean Duration (hours)**
E	137	35.6
B	53	28.9
C (Indian Point 3)	19	23.8
D	102	17.6
F	17	9.9
G	114	57.1

4. SYSTEM QUANTIFICATION

The system equations for the top events defined in Section 2.1 are presented in Appendix C. These equations were then quantified using the data distributions in Table 3-1. Point estimate quantification is used to compute the top event unavailabilities for several cases. These cases are described below:

- **Case 1**. The current 3-day AOT with a realistic estimate of the maintenance durations based on industry data from plants with the same AOT; i.e., a mean of about 11 hours outage per maintenance event.
- **Case 2**. The current 3-day AOT with a conservative, bounding, estimate of the maintenance durations that would be permitted, but not expected; i.e., 72 hours outage per maintenance event.
- **Case 3**. The requested 7-day AOT with a realistic estimate of the maintenance durations based on data collected from Indian Point 3 operation; i.e., about 25 hours outage per maintenance event.
- **Case 4**. The requested 7-day AOT with a conservative estimate of the maintenance durations that would be permitted, but not expected; i.e., 168 hours outage per maintenance event.

4.1 CURRENT MODEL AND DATA PARAMETERS

The results for each of these four cases are provided in Table 4-1. Note that only the diesel generator top event boundary conditions are affected by the diesel generator maintenance durations assumed; i.e., T11, T21, and T31. The results in Table 4-1 are obtained via point estimate quantification; i.e., by using the mean values from the data distributions only in the system unavailability equations. For comparison, Monte Carlo uncertainty propagation was performed for two of the top event boundary conditions. These results are provided in Table 4-2. Note that, in each case, the Monte Carlo distribution mean is greater than the point estimate result. This difference is greatest for the selected top event boundary conditions; i.e., for systems involving three redundant trains. In such systems, the true mean differs from the point estimate because of the correlation between the failure mode distributions common to each train, which leads to the well-known result that the mean of the cube of a random variable is greater than the cube of the mean of the random variable. (This phenomenon was identified in WASH-1400 as "failure rate coupling.") Of interest for this analysis is that, while the true mean is greater than the point estimate, the difference between the 3-day AOT and the 7-day AOT true means is much less than the difference between the point estimates because cutsets involving maintenance on a diesel generator do not involve such coupled failure rate data dependencies. For simplicity, point estimates are used hereafter in this analysis because of the above result that the AOT-related differences are insignificant in relation to the underlying uncertainties. Based on the results in Table 4-2, this approach may overestimate the difference in system unavailabilities between the 3-day and 7-day AOTs.

These top event unavailabilities are related to the failure frequencies of different 480V bus electric power states via the event tree provided in Figure 2-1. The electric power state conditional frequencies given a loss of offsite power event, are provided in Table 4-3 for the four cases defined earlier. The top event unavailabilities provided in Table 4-1 are used to compute the frequencies of each sequence through the event tree. Use is made of symmetry between the diesel generator trains. The calculation of the frequency for each sequence and for collection into electric power support state frequencies is performed using the RISKMAN program.

Table 4-3 lists two results for the electric power condition in which all four 480V AC buses lose power; i.e., with and without the inclusion of the contribution from service water system failures. The electric power system analysis did not include the contribution from service water system failures in the original study. Amendment 2 to the IPPSS study did include this contribution. The nuclear header of the service water system supplies diesel generators 31, 32, and 33. Therefore, combinations of degraded electric power states together with service water system pump failures can also lead to the end state, loss of all AC power. Table 1.6.2.3.8-1 (i.e., Service Water System Analysis - Summary of Results) provides the service water unavailabilities for the nuclear header as a function of electric power state. Per Amendment 1 of Section 1.6.2.3.8.6 in the IPPSS study, these results apply, assuming that just one service water pump supplying flow to the nuclear header is sufficient to cool the diesel generators, as verified by testing at the plant. When considering the effects on overall plant risk, it is the loss of all AC state, including the effects of service water system failures, that is of interest.

Table 4-3 shows that there is about a 9% increase in the conditional unavailability of power to all 480V buses when changing from a 3-day AOT to a 7-day AOT, given that a loss of offsite power has occurred; i.e., the last row of Table 4-3 for the realistic cases. This increase is insignificant in relation to the underlying uncertainties.

The core melt frequency was also calculated for the other analyzed diesel generator maintenance outage durations. Figure 4-1 is a plot of the core melt frequency versus diesel generator mean maintenance duration. As can be seen from the data in Table 3-1, even for a 7-day AOT, the anticipated mean maintenance duration is less than 40 hours. The plot in Figure 4-1 extends to 7 days, only as a sensitivity evaluation. Assuming that the mean maintenance duration is equal to the AOT would be unrealistically conservative.

4.2 COMPARISON OF CURRENT RESULTS TO IPPSS RESULTS

Table 4-4 is a comparison between the current model results and those in Table 1.6.2.2.1-2C from the original IPPSS. The results from the original IPPSS study are noticeably lower than the corresponding results for Case 3; i.e., the original IPPSS study assumed a realistic 7-day AOT, consistent with the plant technical specifications in effect at that time. In particular, the result for the failure of power at all AC buses is noticeably lower. When the contribution from degraded electric power states and service water pump failures is added, the failure frequency for loss of all AC is somewhat closer, though still differing appreciably.

These differences are attributable to the differences in the assumed basic failure rates input to the model and the common cause failure treatment, as shown below. Much more generic industry data have been collected since the completion of the IPPSS base study. Moreover, the plant-specific data collected for Indian Point 3 during the original study are now several

years old, and may no longer apply to the plant as operated today. It was decided to use current generic data for most of the failure rates of interest. This approach was taken, in part, to ensure consistency with the common cause failure modes that have been added in the current model.

For comparison, a requantification of the current system models was performed, using the same data as those developed in the original IPPSS study. Table 4-4 also compares the original IPPSS results for each electric power state with those computed using the current model, but assuming the old IPPSS data. In general, there is good agreement. The differences are explained by the manner of quantification. In the original IPPSS study, the system models were quantified using discrete probabilistic arithmetic, accounting for uncertainties. For this study, only point estimates for the frequencies of each state were computed. The minor differences between the second and third columns, as can be seen in Table 4-4, are explained by recognizing that one is a true mean whereas one is just a point estimate.

The current results are substantially greater for some states because of the revised failure data and the more modern treatment of common cause. The extended treatment of common cause failures accounts for the largest change. Of the other data parameters, the diesel generator failure-to-start-on-demand (i.e., 2.1×10^{-2} versus old value of 1.4×10^{-2}) and failure-to-run (i.e., 1.7×10^{-2} for first hour versus old value of 9.4×10^{-4}) failure rates increased the most, as compared with the original data developed for IPPSS.

Table 4-1. Comparison of Top Event Point Estimate Unavailabilities, Given Loss of Offsite Power, No Recovery, and 6-Hour Mission Time				
Top Event Boundary Condition	Realistic Maintenance Durations		Conservative Maintenance Durations	
	3-Day AOT	7-Day AOT	3-Day AOT	7-Day AOT
T11	.169	.181	.175	.193
T21	1.07-2	1.21-2	1.14-2	1.34-2
T31	4.16-4	4.59-4	4.35-4	4.99-4
TX1	2.27-3	2.27-3	2.27-3	2.27-3
FOA	3.36-5	3.36-5	3.36-5	3.36-5
F01	1.44-4	1.44-4	1.44-4	1.44-4
F02	3.50-3	3.50-3	3.50-3	3.50-3

Note: Exponential notation is indicated in abbreviated form; e.g., 1.07-2 = 1.07×10^{-2}.

Table 4-2. Comparison of Point Estimate System Unavailabilities to Full Uncertainty Analyses

System Analysis Split Fraction	Point Estimate	True Mean	5th Percentile	50th Percentile	95th Percentile
T31 (3-Day AOT Realistic Maintenance Duration)	4.16-4	6.84-4	6.55-5	2.58-4	1.99-3
T31 (7-Day AOT Realistic Maintenance Duration)	4.59-4	6.86-4	6.63-5	2.90-4	1.98-3
FOA (3-Day AOT Realistic Maintenance Duration)	3.36-5	3.64-5	5.03-7	1.02-5	1.14-4

Note: Exponential notation is indicated in abbreviated form; e.g., 4.16-4 = 4.16×10^{-4}.

Table 4-3. Comparison of Support State Frequencies, Given Loss of Offsite Power, No Recovery, and 6-Hour Mission Time

Failure of Power at Bus(es)	Realistic Maintenance Durations		Conservative Maintenance Durations	
	3-Day AOT	7-Day AOT	3-Day AOT	7-Day AOT
None	.829	.817	.824	.806
3A	1.89-3	1.86-3	1.87-3	1.83-3
5A	5.27-2	5.63-2	5.43-2	5.96-2
6A	5.27-2	5.63-2	5.43-2	5.96-2
2A, 3A	5.28-2	5.64-2	5.44-2	5.97-2
3A, 5A	1.20-4	1.28-4	1.24-4	1.36-4
3A, 6A	1.20-4	1.28-4	1.24-4	1.36-4
5A, 6A	3.42-3	3.871-3	3.62-3	4.29-3
2A, 3A, 5A	3.43-3	3.88-3	3.63-3	4.30-3
2A, 3A, 6A	3.43-3	3.88-3	3.63-3	4.30-3
3A, 5A, 6A	7.78-6	8.81-6	8.24-6	9.77-6
All Buses without Service Water	5.02-4	5.52-4	5.25-4	5.98-4
All Buses with Service Water	6.29-4	6.84-4	6.53-4	7.34-4

Note: Exponential notation is indicated in abbreviated form; e.g., 1.89-3 = 1.89×10^{-3}.

Table 4-4. Comparison of Table 1.6.2.2.1-2C IPPSS Results to Current Model			
Failure of Power at Bus(es)	IPPSS Mean	Current Model Point Estimate for 7-Day Realistic Case	Current Model, Old Data for 7-Day Realistic Case (point estimate)
None	.899	.817	.898
3A	2.60-3	1.86-3	2.51-3
5A	3.16-2	5.63-2	3.18-2
6A	3.16-2	5.63-2	3.18-2
2A, 3A	3.17-2	5.64-2	3.19-2
3A, 5A	9.65-5	1.28-4	8.87-5
3A, 6A	9.65-5	1.28-4	8.87-5
5A, 6A	1.11-3	3.87-3	1.11-3
2A, 3A, 5A	1.11-3	3.88-3	1.12-3
2A, 3A, 6A	1.11-3	3.88-3	1.12-3
3A, 5A, 6A	3.50-6	8.81-6	3.10-6
All Buses	5.81-5	5.52-4	5.49-5
All Buses*	1.57-4	6.84-4	1.54-4

*With service water.

Note: Exponential notation is indicated in abbreviated form; e.g., 2.60-3 = 2.60×10^{-3}.

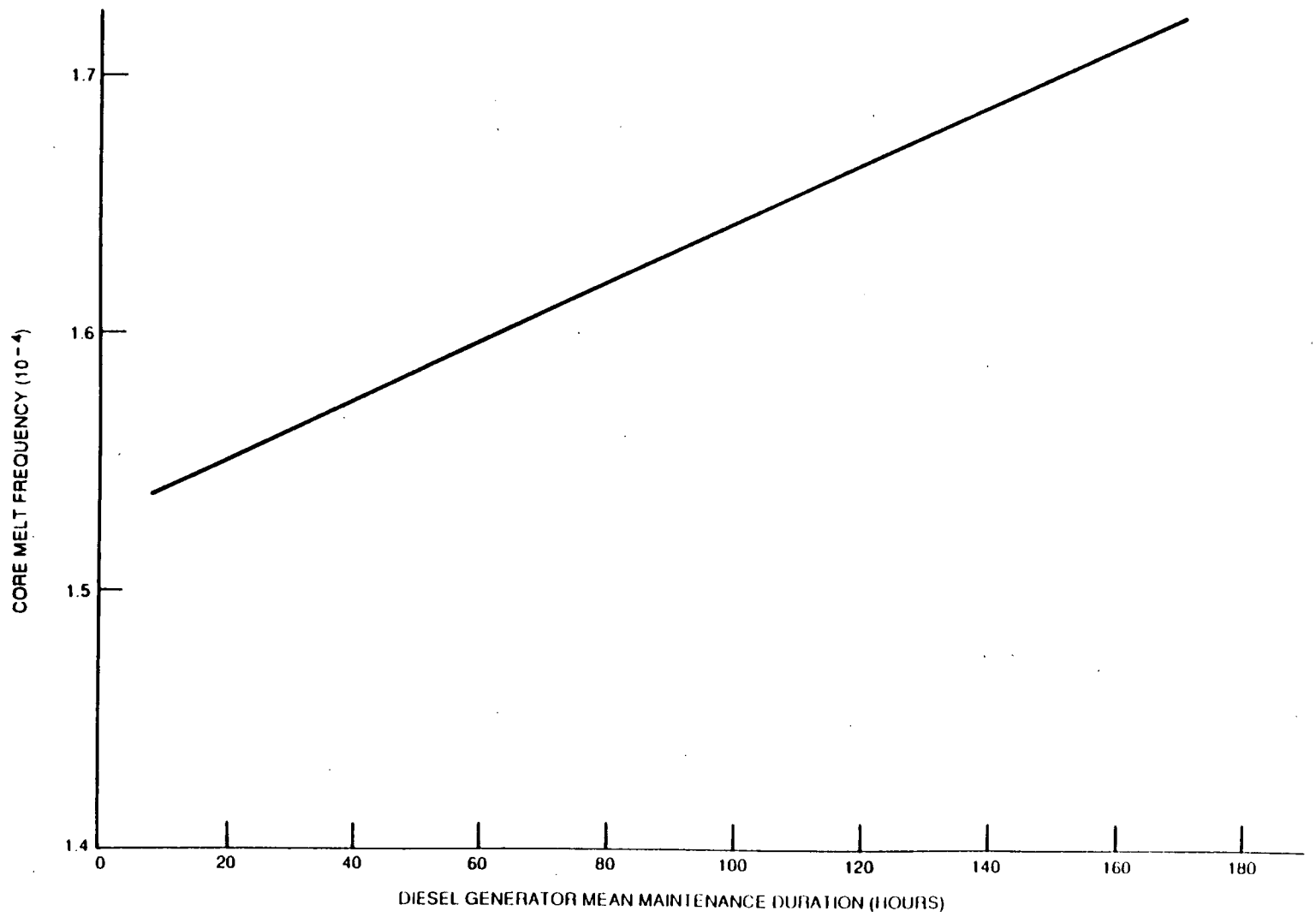


Figure 4-1. Core Melt Frequency versus Diesel Generator Maintenance Duration

5. IMPACT ON CORE DAMAGE FREQUENCY

Table 8.3-3A-1 from Amendment 2 to the IPPSS provides the core damage frequency results from the earlier assessment. A total core melt frequency of 1.4×10^{-4} per year was indicated, with loss of offsite power events contributing 4.7×10^{-6} per year of the total. The electric power state, loss of all AC power, contributes the majority of the loss of offsite power contribution to the core damage frequency. The change in core melt frequency can then be computed by combining the contribution of loss of offsite power events with the relative increase in the loss of all AC frequency. The impacts are presented below:

- 1.54×10^{-4} for 3-day AOT
- 1.56×10^{-4} for 7-day AOT

Thus, the change in core melt frequency due to changing the diesel generator AOT is about 1.3%. In light of the uncertainties in this number, the increase is insignificant. The difference in results between the current model and the previous model is attributed to the revised component failure rate and maintenance unavailability data and the enhanced treatment of common cause failures.

6. SUMMARY

In summary, the impact of the revised electric power systems analysis and the change in AOT for the diesels are provided in Table 6-1. The change in AOT has an insignificant impact on the core damage frequency. In addition, the quantitative results that are presented, while accounting for recovery of AC power from offsite and from diesels 31, 32, and 33, do not account for recovery using the Appendix R diesel. This equipment was added since the completion of the IPPSS. It essentially provides a backup supply of power to key pumps and valves that would be very useful for the station blackout events of interest in this analysis; i.e., it would permit continued RCP seal injection that would prevent the occurrences of seal LOCAs. Although the Appendix R diesel generator cannot be considered completely independent of the power sources that are explicitly modeled in this assessment, it is certainly true that accounting for the Appendix R diesel would have a positive influence on the results in reducing the core damage frequency and thereby the difference between the two AOTs of interest.

Table 6-1. Summary of Core Damage Frequency Impacts				
Consequence Measure (per year)	IPPSS Results	Current Model		Percentage Change from 3-Day to 7-Day
		3-Day AOT Realistic Maintenance Duration	7-Day AOT Realistic Maintenance Duration	
Core Melt Frequency	1.4-4	1.54-4	1.56-4	1.3
Note: Exponential notation is indicated in abbreviated form; i.e., 1.4-4 = 1.4×10^{-4}.				

APPENDIX A. KEY ASPECTS OF THE ORIGINAL SYSTEM MODEL

A.1 SYSTEM FUNCTION

The electric power system provides a source of motive, control, and instrumentation power to those components of the plant safeguards systems whose operation is needed to mitigate any abnormal event affecting the reactor core, its heat removal systems, or systems that could mitigate the release of radioactivity into the environment.

A.2 SUCCESS CRITERIA

- **FSAR**. Any two of the three diesels have adequate capacity to supply the engineered safety features to the hypothetical accident concurrent with loss of offsite power.
- **PRA**. The system model is evaluated for different combinations of bus failures involving 480V buses 2A, 3A, 5A, and 6A. Calculations are performed to evaluate the failure frequency of one, two, three, and all four 480V buses given a loss of offsite power, and of the fuel oil transfer system given the status of power at each of the three 480V buses that supply power to the fuel oil transfer pumps.

A.3 SUPPORT SYSTEMS FOR THE DIESEL GENERATORS

- Diesel engine starting air system.
- Diesel fuel oil transfer system.
- Station service water system (for diesel generator engine cooling).
- 125V DC control power for the starting air system, for field flushing, and for closing the diesel generators output breakers.
- Safeguards actuation, reactor protection, main turbine generator protection, and offsite tieline fault protection systems provide initiation of automatic bus transfer operation, bus load shedding, diesel generator starting, and automatic bus load sequencing.

A.4 SYSTEMS SUPPORTED

- Components rated between 100 and 400 horsepower are supplied from the 480V switchgear buses.
- Components rated less than 100 horsepower are supplied from the 480V motor control centers, which are fed from the 480V switchgear buses.
- The specific loads from each 480V switchgear bus are summarized in Table 1.6.2.2.1-3 of the IPPSS.
- The specific loads from each DC power panel are listed in Table 1.6.2.2.1-5 of the IPPSS.

- 118V AC instrument power buses.

A.5 OPERATING FEATURES

A.5.1 System Actuation

1. **Automatic**

   a. On a bus undervoltage signal, the diesel generator starts, the normal feeder breaker to the bus opens, the diesel generator output breaker closes, and the auxiliary feedwater, service water, and component cooling pumps are reenergized sequentially through a series of time delay, bus loading relays.

   b. The diesel generator output breakers automatically close onto the associated 480V buses if

      1) There is no fault on the bus.

      2) There is normal diesel generator output voltage.

      3) Synchronizing scope is on as there is an undervoltage condition on the bus.

      4) The normal feed breaker is open.

      5) The associated 480V bus tie breaker is open (except for 2AT3A between buses 2A and 3A, which may be closed; both of these buses are powered by diesel generator 31).

   c. Crosstie breaker 2AT3A automatically closes if there is an undervoltage on 3A, tie breaker 3AT6A is open, normal feed to bus 3A is open, diesel generator 31 output breaker is closed, and there are no faults on buses 2A or 3A.

   d. The diesel generator feed breaker to the 480V buses trip automatically if the bus lock-out relay actuates, the associated diesel generator trips, or there is overcurrent.

   e. Except for MCC 36A, B, and C, which supply the fuel oil transfer pumps, all load breakers from the 480V buses trip on undervoltage. Nonessential MCCs remain stripped.

   f. Given a safety injection (SI), the diesel generators start, nonessential loads (i.e., all except MCC 34, 39, 36A, B, C) are stripped and locked out, and, if normal voltage is present on the bus, the safeguards equipment starts and the diesel generators run unloaded. If an undervoltage condition also occurs in the bus, all loads except MCCs 36A, B, and C are shed, the diesel generator is loaded, and the safeguards components are then sequentially energized. Also, on a safeguard signal, three normal protective function trip signals are overridden:

      1) Local Emergency Stop Pushbutton
      2) Generator Overcurrent
      3) Generator Reverse Power

g. Diesel generator 31 starts on undervoltage at bus 2A only. It is not started by undervoltage at bus 3A alone.

h. The fuel oil transfer pump starts automatically on a low level in the associated dry tank. Even if the associated fuel oil pump fails, the diesel generator may still be supplied fuel oil, provided that one of the other two diesel generators starts and its associated fuel oil transfer pump is successful; i.e., any one of the fuel oil transfer pumps, once started, can supply all three diesel generators, if necessary.

2. **Manual**

a. Given a fault on a 480V bus, lockout relays trip to prevent closure of all breakers associated with the bus. The lockout relays must be manually reset to allow the tripped breakers to be enclosed. These relays must also be reset if the diesel generator trips.

b. Under non-SI conditions, the crosstie breakers between 2A and 5A, and between 3A and 6A, may be manually closed.

c. After the diesel generator repowers a bus, which experienced an undervoltage condition, the nonessential MCCs and other components must be manually loaded.

A.5.2 Test/Maintenance (Occurrence Frequency, System Reconfiguration, and Potential Misalignments)

- During the diesel generator functional tests or monthly operability tests, the diesels are attended and running. As they are available for emergency service, the normal system alignment is used to represent the time that the diesels are undergoing these tests; i.e., no degradation is assumed.
- The diesel generator engine starting mode control switch may be left in OFF following the monthly operability test, which would prevent it from starting automatically. This condition is alarmed in the control room. Not leaving the switch in the AUTO position is considered to be a failure mode of the corresponding diesel.
- Routine preventative maintenance on the electric power system is scheduled, to the greatest extent possible, for cold shutdown periods.
- During breaker maintenance, a spare breaker is installed, and the associated bus work remains energized; thus, separate initial alignments are not modeled for such maintenance.
- Schedule preventative maintenance performed on the diesel generators with the reactor at power includes repair of minor cooling water and oil leaks, replacement of oil filters, air compressor overhauls, and calibration of electrical and mechanical control systems (annual, semiannual, and quarterly inspections). Preventative and corrective maintenance actions for the diesels are included in the data for maintenance frequencies and durations.

A.6 TECHNICAL SPECIFICATIONS (LCOs)

- The three fuel oil storage tanks must contain 5,676 gallons of diesel generator fuel oil. Additionally, 26,700 gallons must be available onsite (3.7.A.5).
- The 480V switchgear buses must be energized with crosstie breakers 2AT5A and 3AT6A open (3.7.A.4).
- All three batteries, DC power panels, and battery chargers must be operable (3.7.A.6).
- One diesel generator may be out for 72 hours, if the other two are verified operable daily and both offsite sources of power are available (3.7.B.1).
- One battery may be out for 2 hours provided that all of the other batteries and the four battery chargers are operable. The DC power panel supplied by the inoperable battery must be energized from a battery charger (3.7.B.4).

If any of the above conditions are not met, the unit must be in hot shutdown within 6 hours, and in cold shutdown within the following 30 hours.

A.7 SURVEILLANCE TESTS (PERFORMED DURING OPERATION OR SHUTDOWN)

- Any periodic testing that requires that electrical equipment be removed from normal service must be performed during cold shutdown or refueling.
- A visual inspection of each diesel generator is performed weekly to verify and record satisfactory lube oil level; to check for jacket water, fuel oil, and lube oil system leaks to verify operation of the starting air compressor; and to record the volume of fuel in the underground storage tanks and reserve fuel oil tanks onsite (3PT-W1, Revision 8) (4.6.A.4).
- Each diesel generator is started manually and loaded at a maximum rate of 500 kW per minute onto its associated 480V bus in parallel with the normal bus power supply once each month (4.6.A.1). The diesel generator is operated for a minimum of 1 hour.
- A safety injection with blackout signal is simulated during each refueling to verify the automatic starting of each diesel generator and the operation of the 480V bus load shedding and associated load sequencing control circuits (3PT-R3D).
- Each diesel generator is started manually and loaded onto its associated 480V bus in parallel with the normal bus power supply within 60 seconds once each refueling. The diesel generator is operated for a period of time sufficient to reach operating temperatures (4.6.A.2 and 4.6.A.3).
- If one of the diesel generators is unavailable for service during unit operation, the remaining two diesel generators are started daily to verify their continued operability. The diesel generators are not loaded onto their buses during these nonroutine operability checks.

- The terminal voltage, individual cell voltage, and pilot cell electrolyte specific gravity are measured and recorded once per month for each station battery (3PT-M21, Revision 10).
- Each station battery is inspected and placed on a equalizing charge for 24 hours once each quarter (3PT-Q1, Revision 9) (4.6.8.2).
- The station battery electrolyte levels and "float" charge voltage are inspected weekly (3PT-W13, Revision 2).
- Each battery is disconnected from its power panel and discharged into a load resistance bank for a period of 8 hours to verify its ampere hour capacity once each refueling (3PT-R29A, Revision 8) (4.6.8.4).

A.8 REFERENCES

1. Pickard, Lowe and Garrick, Inc., Westinghouse Electric Corporation, and Fauske & Associates, Inc., "Indian Point Probabilistic Safety Study," prepared for the Power Authority of the State of New York and Consolidated Edison Company of New York, Inc., March 1982.
2. Indian Point Station Unit No. 3 System Description No. 27.1, Electrical Systems, Revision 0, October 1988.
3. Test and Surveillance Procedures

   a. Diesel Generators

   (1) 3-PM-A-ES-3, Revision 4

   (2) 3-PM-SA-ES-11, Revision 4

   (3) 3PT-V16, Revision 6

   (4) 3PT-W1, Revision 8

   b. Batteries

   (1) 3PT-R29A, Revision 8

   (2) 3PT-Q1, Revision 9

   (3) 3PT-M21, Revision 10

   (4) 3PT-W13, Revision 2

4. Plant Technical Specifications, Sections 3.7 and 4.6.
5. Drawings

   a. 9321-F-33853-4, Electrical Distribution
   b. 9321-F-30083-28, DC System Single Line Diagram
   c. 9321-F-30043, Revision 14, 480V MCC Single Line Diagram, Sheets 1, 2, and 3

d. 617F644, 480V One Line Diagram
e. 617F645, Main One Line Diagram
f. 617F643, 6900V One Line Diagram

A.9 MODELING ASSUMPTIONS

A.9.1 Equipment Boundaries

- The system is modeled down to the level of individual motor control centers and power distribution panels. System failure quantification determines the power unavailability at the four 480V switchgear buses.
- The three gas turbine generating units available to the site (i.e., one onsite and two at Buchanan Station, which is nearsite) are not included explicitly in the quantitative system analysis.
- These additional power sources are considered explicitly in the electric power recovery assessment as part of the original IPPSS, which is used in the assessment of the core damage frequency of different allowed outage times for the diesel generators.
- No credit for electric power recovery actions is considered in this system analysis; e.g., no credit for manual crossties.
- The starting air receiver volumes are sufficient to provide three or four normal diesel engine starts. Therefore, the starting air compressors are not modeled explicitly.
- The diesel generator fuel oil transfer system is included in the analysis.
- The additional Appendix R diesel, which must be manually loaded, is not modeled explicitly in this quantitative system analysis.
- The station service water system required for diesel generator engine cooling is assumed to be available for purposes of evaluating the diesel's unavailability. Failure of the station service water system is considered at the plant level, when evaluating the impact of the different diesel allowed outage times on the total core melt frequency.
- The safeguards actuation signals to start and load the diesel generators are not modeled explicitly. The bus undervoltage signals are relied upon to automatically start and load the diesels. These undervoltage signals are implicitly modeled in the failure rates for the diesel generators.
- The 118V instrument buses are not modeled in this system analysis.

A.9.2 Initial Conditioning

- The 345-kV transmission system and the 138-kV supply lines from Buchanan Station (termed offsite power) are assumed unavailable, after plant trip.
- All four 480V buses (2A, 3A, 5A, and 6A) are initially energized by the 6.9-kV buses from the station service transformers, prior to plant trip.

- Tie breaker 2AT3A between buses 2A and 3A is normally open, as are tie breakers 2AT5A and 3AT6A between buses 5A and 2A, and between 3A and 6A, respectively.
- The diesel generators engine starting mode control switches are in AUTO, except where explicitly modeled otherwise.
- The tie breaker between DC power panels 32 and 31 is normally open.
- The DC power panels are normally supplied from their associated battery chargers.

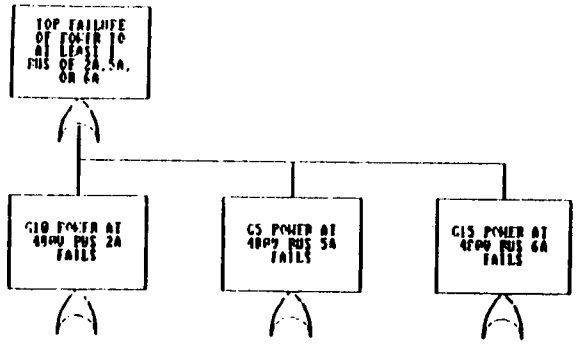
A.9.3 Failure Mode Impacts

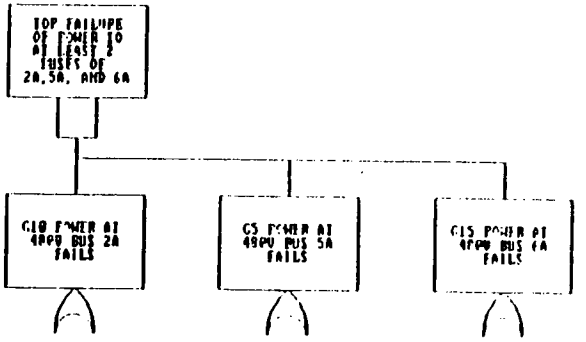
- A mission time of 6 hours is assumed, consistent with the basis for the electric power recovery analysis performed in the IPPSS, and on which the impact in core melt frequency is determined.
- No credit is given for any manual actions to recover from failed equipment; e.g., bus crossties, manual start of fuel oil transfer pumps.
- DC control power is assumed unnecessary after the diesel generator is started and loaded; i.e., the battery chargers are not modeled.
- The residual inventory in a diesel generator day tank is assumed to be sufficient, and the loads are evenly distributed so that if the associated fuel oil transfer pump fails, a second fuel oil transfer pump would start on low level in a second tank, before the first day tank runs dry.

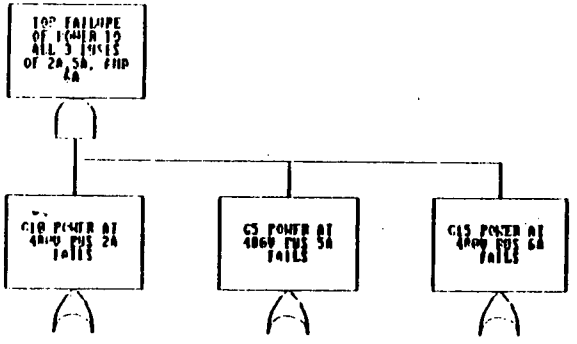
A.9.4 Common Cause

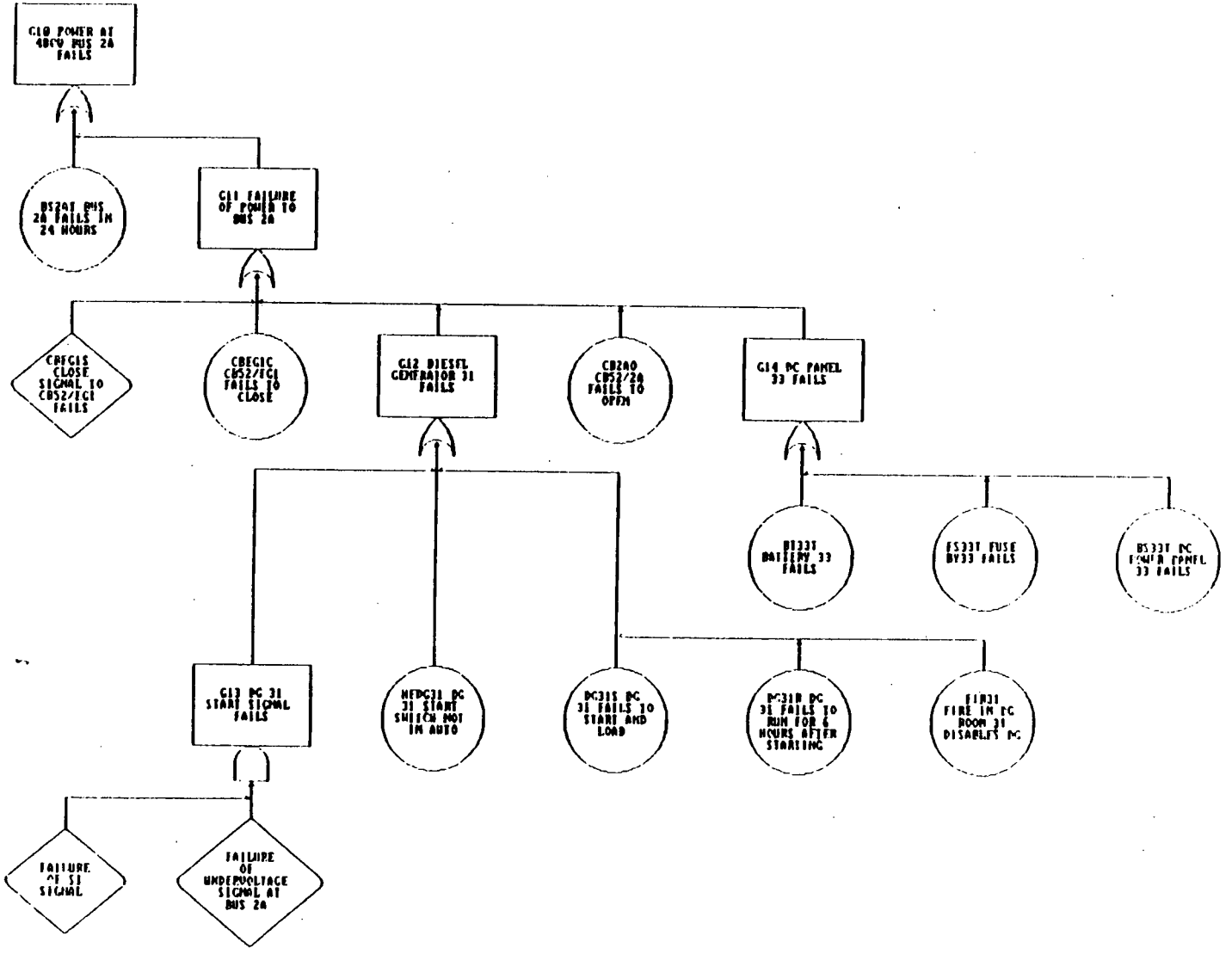
- Common cause dependencies are considered between equipment which must activate. The common cause groups modeled are for the following failure modes:
  - Diesel generators fail to start.
  - Diesel generators fail to run.
  - Fuel oil transfer pumps fail to start.
  - Fuel oil transfer pumps fail to run.
  - 480V supply circuit breakers fail to open.
  - Diesel generator output circuit breakers fail to close.
  - Multiple human errors to restore the diesel starting mode switch to AUTO, following tests.

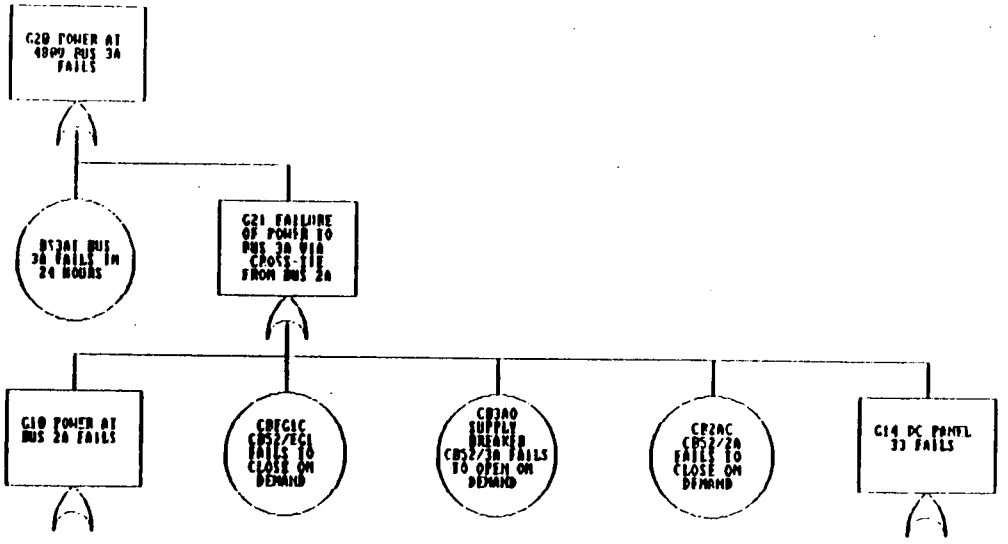
APPENDIX B. FAULT TREES

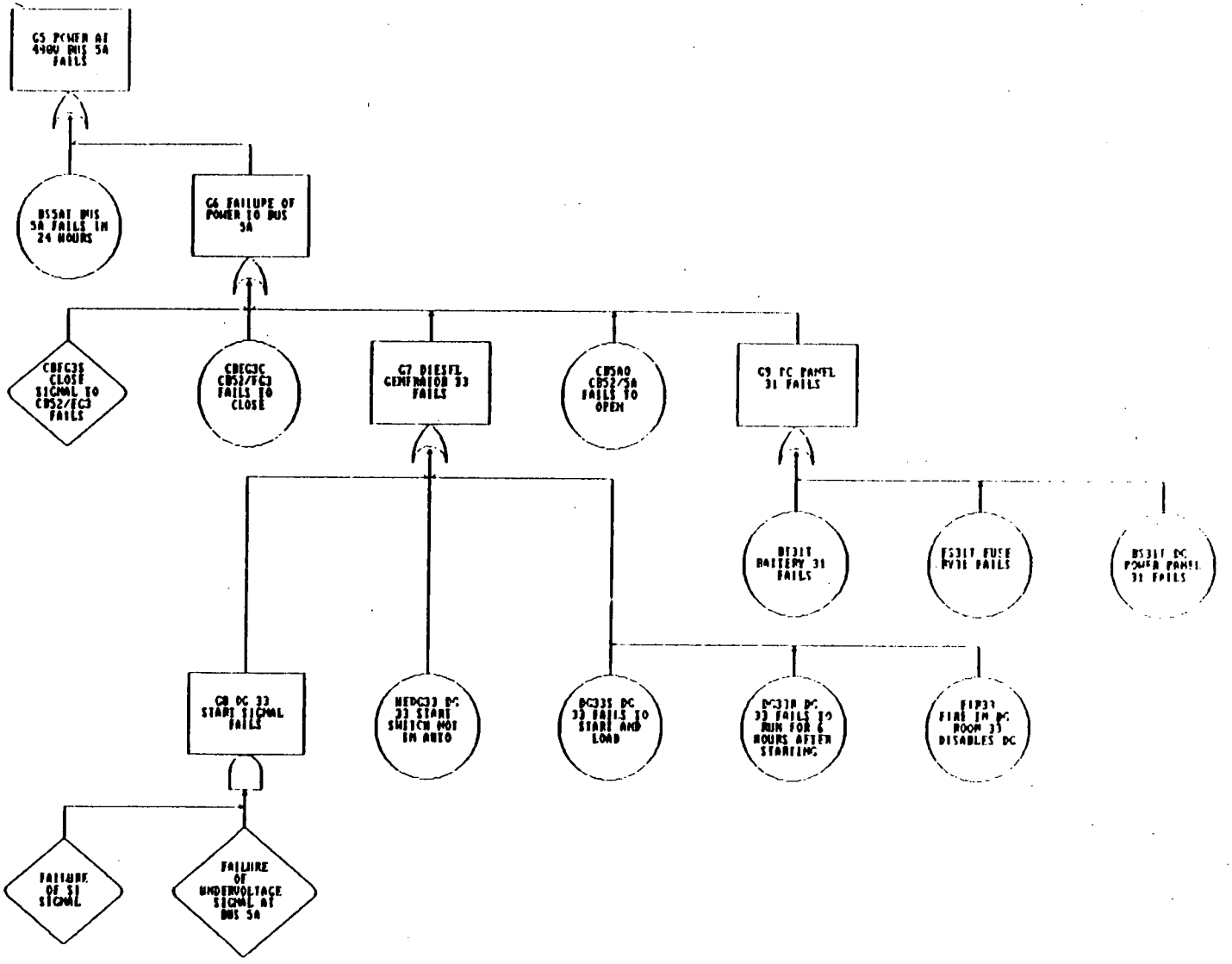

TOP FAILURE OF POWER TO AT LEAST 1 FUS OF 2A,5A, OR 6A
G10 POWER AT 480V BUS 2A FAILS
G5 POWER AT 480V BUS 5A FAILS
G15 POWER AT 480V BUS 6A FAILS

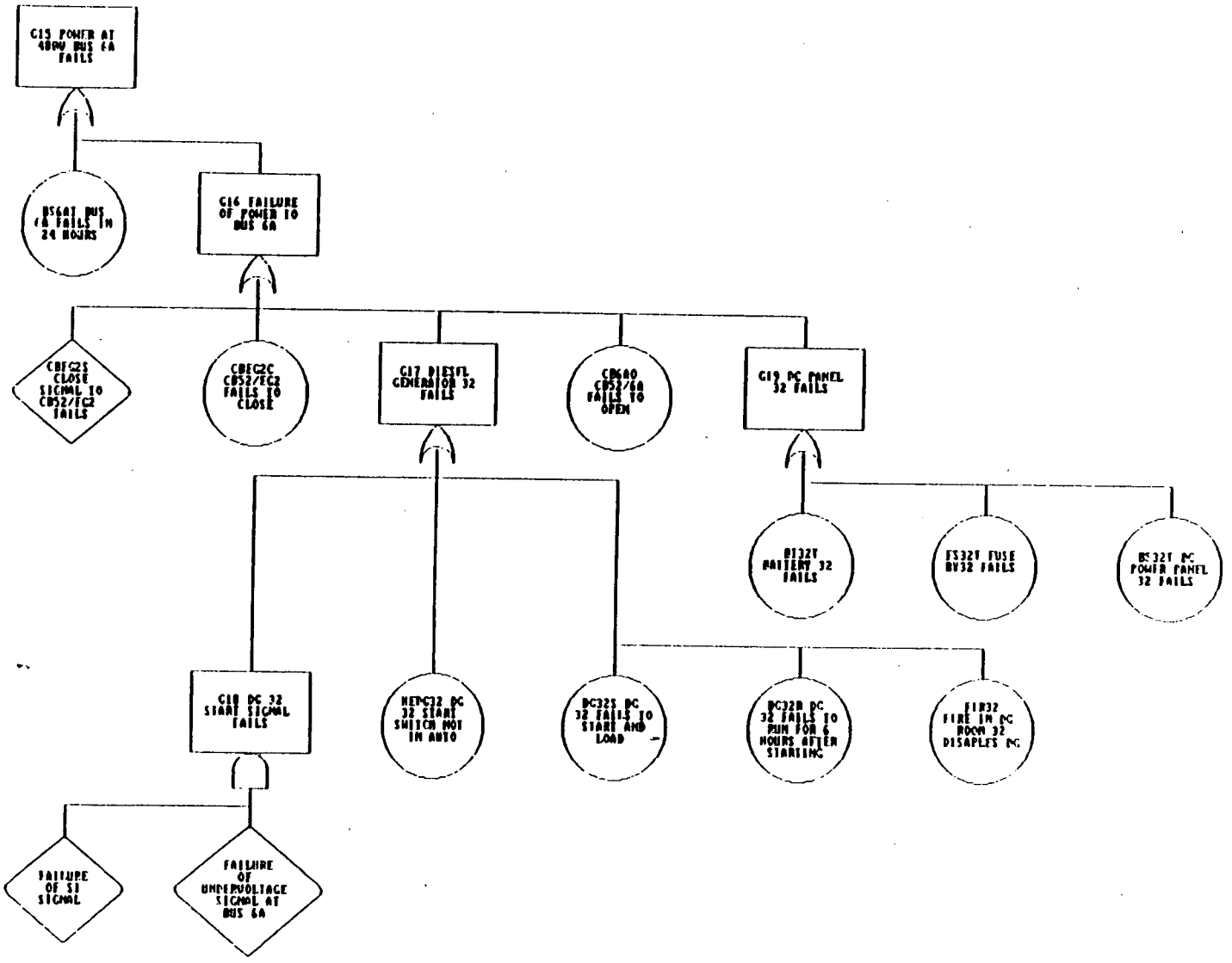

TOP FAILURE OF POWER TO AT LEAST 2 FUSES OF 2A,5A, AND 6A
G10 POWER AT 480V BUS 2A FAILS
G5 POWER AT 480V BUS 5A FAILS
G15 POWER AT 480V BUS 6A FAILS

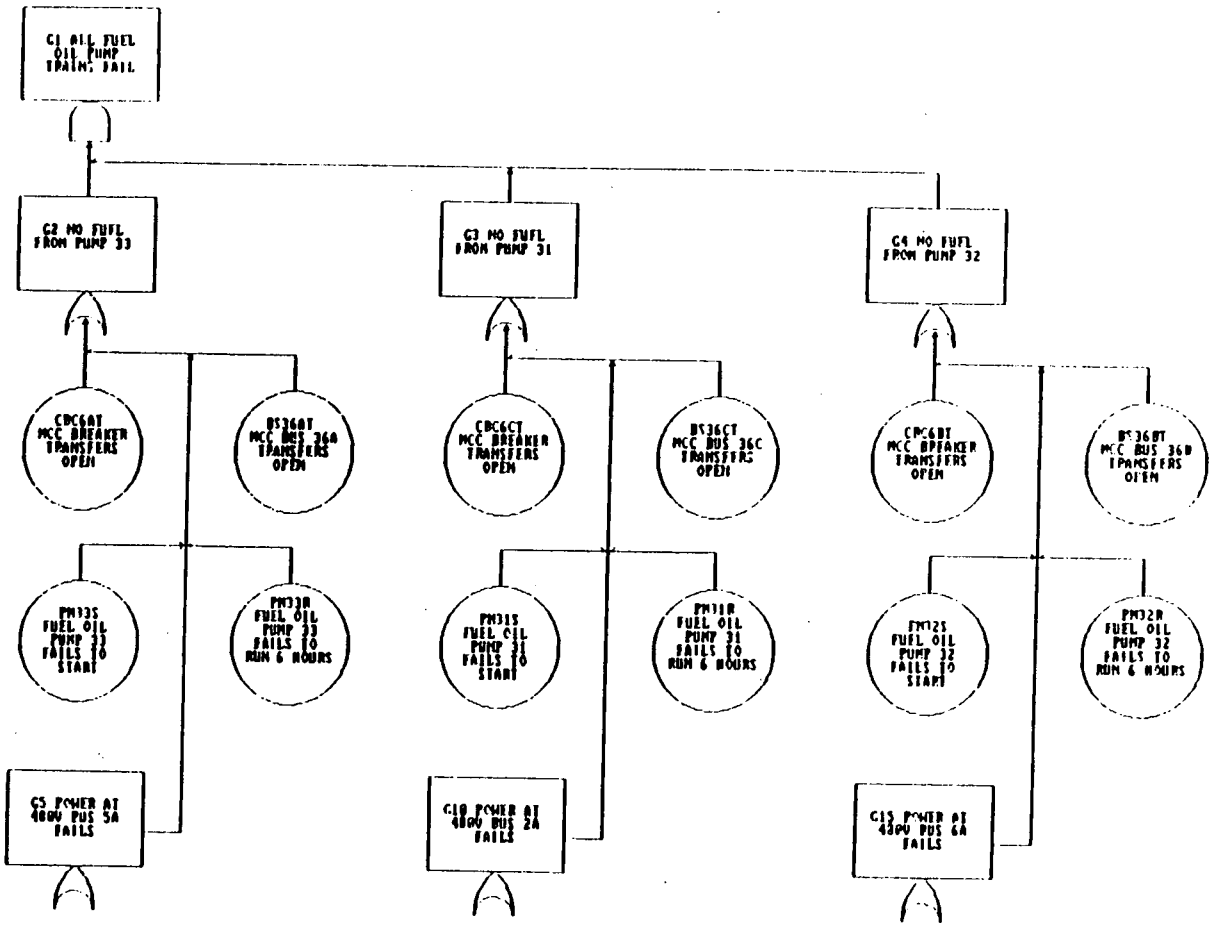

TOP FAILURE OF POWER TO ALL 3 FUSES OF 2A,5A, AND 6A
G10 POWER AT 480V BUS 2A FAILS
G5 POWER AT 480V BUS 5A FAILS
G15 POWER AT 480V BUS 6A FAILS


G10 POWER AT 480V BUS 2A FAILS
BS24T BUS 2A FAILS IN 24 HOURS
G11 FAILURE OF POWER TO BUS 2A
CBFG1S CLOSE SIGNAL TO CB52/EG1 FAILS
CBEG1C CB52/EG1 FAILS TO CLOSE
G12 DIESEL GENERATOR 31 FAILS
CB2A0 CB52/2A FAILS TO OPEN
G14 DC PANEL 33 FAILS
BB33T BATTERY 33 FAILS
FS33T FUSE BY33 FAILS
BS33T DC POWER PANEL 33 FAILS
G13 DG 31 START SIGNAL FAILS
HFDG31 DG 31 START SWITCH NOT IN AUTO
DG31S DG 31 FAILS TO START AND LOAD
DG31R DG 31 FAILS TO RUN FOR 6 HOURS AFTER STARTING
FIR31 FIRE IN DG ROOM 31 DISABLES DG
FAILURE OF SI SIGNAL
FAILURE OF UNDERVOLTAGE SIGNAL AT BUS 2A


G20 POWER AT 4809 BUS 3A FAILS
BS3A1 BUS 3A FAILS IN 24 HOURS
G21 FAILURE OF POWER TO BUS 3A VIA CROSS-TIE FROM BUS 2A
G10 POWER AT BUS 2A FAILS
CB2C1C CB52/2C1 FAILS TO CLOSE ON DEMAND
CB3A0 SUPPLY BREAKER CB52/3A FAILS TO OPEN ON DEMAND
CB2AC CB52/2A FAILS TO CLOSE ON DEMAND
G14 DC PANEL 33 FAILS


G5 POWER AT 480V BUS 5A FAILS
BS5AT BUS 5A FAILS IN 24 HOURS
G6 FAILURE OF POWER TO BUS 5A
CBEC3S CLOSE SIGNAL TO CB52/EC3 FAILS
CBEC3C CB52/EC3 FAILS TO CLOSE
G7 DIESEL GENERATOR 33 FAILS
CB5A0 CB52/5A FAILS TO OPEN
G9 EC PANEL 31 FAILS
BT31T BATTERY 31 FAILS
FS31T FUSE BY31 FAILS
BS31T DC POWER PANEL 31 FAILS
G8 DC 33 START SIGNAL FAILS
HEDC33 DC 33 START SWITCH NOT IN AUTO
DC33S DC 33 FAILS TO START AND LOAD
DC33R DC 33 FAILS TO RUN FOR 6 HOURS AFTER STARTING
FIP33 FIRE IN DC ROOM 33 DISABLES DC
FAILURE OF SI SIGNAL
FAILURE OF UNDERVOLTAGE SIGNAL AT BUS 5A


G15 POWER AT 480V BUS 6A FAILS
BS6AT BUS 6A FAILS IN 24 HOURS
G16 FAILURE OF POWER TO BUS 6A
CBEC2S CLOSE SIGNAL TO CB52/EC2 FAILS
CBEC2C CB52/EC2 FAILS TO CLOSE
G17 DIESEL GENERATOR 32 FAILS
CB6A0 CB52/6A FAILS TO OPEN
G18 DC PANEL 32 FAILS
BT32T BATTERY 32 FAILS
FS32T FUSE BV32 FAILS
BS32T DC POWER PANEL 32 FAILS
G18 DG 32 START SIGNAL FAILS
HEPC32 DC 32 START SWITCH NOT IN AUTO
DC32S DC 32 FAILS TO START AND LOAD
DC32R DC 32 FAILS TO RUN FOR 6 HOURS AFTER STARTING
FIR32 FIRE IN DG ROOM 32 DISABLES DG
FAILURE OF SI SIGNAL
FAILURE OF UNDERVOLTAGE SIGNAL AT BUS 6A


C1 ALL FUEL OIL PUMP TRAINS FAIL
G2 NO FUEL FROM PUMP 33
G3 NO FUEL FROM PUMP 31
G4 NO FUEL FROM PUMP 32
CBC6AT MCC BREAKER TRANSFERS OPEN
BS36AT MCC BUS 36A TRANSFERS OPEN
CBC6CT MCC BREAKER TRANSFERS OPEN
BS36CT MCC BUS 36C TRANSFERS OPEN
CBC6BT MCC BREAKER TRANSFERS OPEN
BS36BT MCC BUS 36B TRANSFERS OPEN
FM33S FUEL OIL PUMP 33 FAILS TO START
FM33R FUEL OIL PUMP 33 FAILS TO RUN 6 HOURS
FM31S FUEL OIL PUMP 31 FAILS TO START
FM31R FUEL OIL PUMP 31 FAILS TO RUN 6 HOURS
FM32S FUEL OIL PUMP 32 FAILS TO START
FM32R FUEL OIL PUMP 32 FAILS TO RUN 6 HOURS
G5 POWER AT 4800 BUS 5A FAILS
G10 POWER AT 4800 BUS 2A FAILS
G15 POWER AT 4800 BUS 6A FAILS

APPENDIX C. SYSTEM EQUATIONS AND CUTSETS IN RANKED ORDER

C.1 TOP EVENT AND SPLIT FRACTION DEFINITIONS

TOP EVENT AND SPLIT FRACTION DEFINITIONS

TOP EVENT T1 - FAILURE OF POWER TO AT LEAST ONE OF 480V BUSES 2A,5A, AND 6A

T11 OFFSITE POWER FAILED,SERVICE WATER&ACTUATION SUCCESSFUL

TOP EVENT T2 - FAILURE OF POWER TO AT LEAST 2 OF 480V BUSES 2A,5A, AND 6A

T21 OFFSITE POWER FAILED,SERVICE WATER&ACTUATION SUCCESSFUL

TOP EVENT T3 - FAILURE OF POWER TO ALL THREE 480V BUSES 2A,5A,AND 6A

T31 OFFSITE POWER FAILED,SERVICE WATER&ACTUATION SUCCESSFUL

TOP EVENT TX - FAILURE OF POWER TO 480V BUS 3A GIVEN POWER AVAILABLE AT BUS 2A

TX1 OFFSITE POWER FAILED,SERVICE WATER&ACTUATION SUCCESSFUL

TOP EVNT FO - FAILURE OF FUEL OIL TRANSFER SYSTEM

FOA OFFSITE POWER FAILED,SERVICE WATER&ACTUATION SUCCESSFUL
FO1 POWER TO PUMP 33 FROM BUS 5A NOT AVAILABLE,SERVICE WATER&ACTUATION SUCCESSFUL
FO2 POWER TO PUMPS 33&31 FROM BUSES 5A &2A NOT AVAILABLE,SERVICE WATER&ACTUATION SUCCESSFUL

T1	SF	T11	ALL SUPPORT AVAILABLE S
T2	SF	T21	ALL SUPPORT AVAILABLE S
T3	SF	T31	ALL SUPPORT AVAILABLE S
TX	SF	TX1	ALL SUPPORT AVAILABLE S
TX	SF	TXF	SUPPORT FOR POWER TO BUS 3A UNAVAILABLES
FO	SF	FOA	ALL SUPPORT AVAILABLE S
FO	SF	FO1	POWER TO PUMP 33 FROM BUS 5A NOT AVAILABLES
FO	SF	FO2	POWER TO PUMPS 33&31 FROM BUSES 5A &2A NOT AVAILABLES
FO	SF	FO3	NO POWER TO THE FUEL OIL PUMPSS

```
CIS FILE FOR 3 DAY AOT WITH REALISTIC MAINTENANCE DURATION AND TRUNCATION
 OF INDIVIDUAL CUTSETS AT 1E-5
F02      1  3.503E-03 TOTAL  POWER TO PUMPS 33&31 FROM BUSES 5A &2A NOT $
F02      2  3.503E-03 NORMAL SYSTEM NOT UNDERGOING TEST OR MAINTENANCE$ $T
F02      3  1.000E+00 Fraction of time in: NORMAL                      $F
F02      4  3.503E-03 Conditional system failure frequency given: NORMAL$C
F02      5  3.060E-03     1 *  PMIS                                   $**
F02      6  2.031E-04     1 *  PMIR                                   $**
F02      7  1.979E-04     2 *  PMDS                                   $**
F02      8  3.228E-05     1 *  PMTS                                   $**
F02      9  4.968E-06     1 *  CBC6BT                                 $**
F02     10  2.988E-06     1 *  BS36BT                                 $**
F02     11  1.764E-06     2 *  PMDR                                   $**
F02     12  2.878E-07     1 *  PMTR                                   $**
T11      1  1.694E-01 TOTAL  OFFSITE POWER FAILED,SERVICE WATER&ACTUATIO$
T11      2  1.585E-01 NORMAL SYSTEM NOT IN TEST OR MAINTENANCE         $T
T11      3  9.891E-01 Fraction of time in: NORMAL                      $F
T11      4  1.603E-01 Conditional system failure frequency given: NORMAL$C
T11      5  8.733E-02     3 *  DGIR                                   $**
T11      6  6.320E-02     3 *  DGIS                                   $**
T11      7  4.492E-03     3 *  CBDGIC                                 $**
T11      8  1.811E-03     3 *  CBSPIO                                 $**
T11      9  4.943E-04     3 *  DGDR                                   $**
T11     10  4.855E-04     1 *  BT33T                                  $**
T11     11  4.855E-04     1 *  BT31T                                  $**
T11     12  4.855E-04     1 *  BT32T                                  $**
T11     13  3.924E-04     3 *  DGDS                                   $**
T11     14  1.453E-04     3 *  CBDGDC                                 $**
T11     15  1.110E-04     1 *  DGTR                                   $**
T11     16  1.814E-04     1 *  FIR31                                  $**
T11     17  1.814E-04     1 *  FIR32                                  $**
T11     18  1.814E-04     1 *  FIR33                                  $**
T11     19  7.530E-05     3 *  HEDGI                                  $**
T11     20  5.857E-05     3 *  CBSPDO                                 $**
T11     21  4.266E-05     1 *  DGTS                                   $**
T11     22  1.580E-05     1 *  CBDGTC                                 $**
T11     23  1.195E-05     1 *  BS6AT                                  $**
T11     24  1.195E-05     1 *  BS32T                                  $**
T11     25  1.195E-05     1 *  BS5AT                                  $**
T11     26  1.195E-05     1 *  BS2AT                                  $**
T11     27  1.195E-05     1 *  BS31T                                  $**
T11     28  1.195E-05     1 *  BS33T                                  $**
T11     29  6.368E-06     1 *  CBSPIO                                 $**
T11     30  6.090E-06     3 *  HEDGD                                  $**
T11     31  1.840E-06     1 *  FS32T                                  $**
T11     32  1.840E-06     1 *  FS33T                                  $**
T11     33  1.840E-06     1 *  FS31T                                  $**
T11     35  3.644E-03 MAIN31 UNSHEDULED MAINTENANCE ON DIESEL 31      $T
T11     36  3.644E-03 Fraction of time in: MAIN31                     $F
T11     37  1.000E+00 Conditional system failure frequency given: MAIN31$C
T11     38  3.644E-03 MAIN32 UNSHEDULED MAINTENANCE ON DIESEL 32      $T
T11     39  3.644E-03 Fraction of time in: MAIN32                     $F
T11     40  1.000E+00 Conditional system failure frequency given: MAIN32$C
T11     41  3.644E-03 MAIN33 UNSHEDULED MAINTENANCE ON DIESEL 33      $T
T11     42  3.644E-03 Fraction of time in: MAIN33                     $F
T11     43  1.000E+00 Conditional system failure frequency given: MAIN33$C
T21      1  1.076E-02 TOTAL  OFFSITE POWER FAILED,SERVICE WATER&ACTUATIO$
T21      2  9.590E-03 NORMAL SYSTEM NOT IN TEST OR MAINTENANCE         $T
T21      3  9.891E-01 Fraction of time in: NORMAL                      $F
T21      4  9.696E-03 Conditional system failure frequency given: NORMAL$C
T21      5  3.679E-03     6 *  DGIS *  DGIR                           $**
T21      6  2.542E-03     3 *  DGIR *  DGIR                           $**
T21      7  1.331E-03     3 *  DGIS *  DGIS                           $**
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T21    8  4.943E-04    3 *  DGDR                                  $**
T21    9  3.924E-04    3 *  DGDS                                  $**
T21   10  2.615E-04    6 *  DGIR *  CBDGIC                        $**
T21   11  1.893E-04    6 *  DGIS *  CBDGIC                        $**
T21   12  1.453E-04    3 *  CBDGDC                                $**
T21   13  1.119E-04    1 *  DGIR                                  $**
T21   14  1.054E-04    6 *  DGIR *  CBSPIO                        $**
T21   15  7.629E-05    6 *  DGIS *  CBSPIO                        $**
T21   16  5.857E-05    3 *  CBSPDO                                $**
T21   17  4.266E-05    1 *  DGIS                                  $**
T21   18  2.827E-05    2 *  BT32T *  DGIR                         $**
T21   19  2.827E-05    2 *  BT33T *  DGIR                         $**
T21   20  2.827E-05    2 *  BT31T *  DGIR                         $**
T21   21  2.046E-05    2 *  DGIS *  BT32T                        $**
T21   22  2.046E-05    2 *  DGIS *  BT33T                        $**
T21   23  2.046E-05    2 *  DGIS *  BT31T                        $**
T21   24  1.580E-05    1 *  CBDGIC                                $**
T21   25  6.726E-06    3 *  CBDGIC *  CBDGIC                      $**
T21   28  6.368E-06    1 *  CBSPIO                                $**
T21   29  6.090E-06    3 *  HEDGD                                 $**
T21   30  5.423E-06    6 *  CBDGIC *  CBSPIO                      $**
T21   31  1.056E-05    2 *  DGIR *  FIR32                        $**
T21   32  1.056E-05    2 *  DGIR *  FIR33                        $**
T21   33  1.056E-05    2 *  DGIR *  FIR31                        $**
T21   41  4.384E-06    6 *  DGIR *  HEDGI                        $**
T21   54  7.644E-06    2 *  DGIS *  FIR32                        $**
T21   66  7.644E-06    2 *  DGIS *  FIR31                        $**
T21   78  7.644E-06    2 *  DGIS *  FIR33                        $**
T21   89  3.173E-06    6 *  DGIS *  HEDGI                        $**
T21   99  1.454E-06    2 *  BT33T *  CBDGIC                      $**
T21  107  1.454E-06    2 *  BT32T *  CBDGIC                      $**
T21  108  1.454E-06    2 *  BT31T *  CBDGIC                      $**
T21  109  1.093E-06    3 *  CBSPIO *  CBSPIO                     $**
T21  110  7.630E-07    1 *  HEDGT                                 $**
T21  115  6.958E-07    2 *  BS31T *  DGIR                        $**
T21  117  6.958E-07    2 *  BS2AT *  DGIR                        $**
T21  118  6.958E-07    2 *  BS32T *  DGIR                        $**
T21  119  6.958E-07    2 *  BS5AT *  DGIR                        $**
T21  124  6.958E-07    2 *  BS6AT *  DGIR                        $**
T21  126  6.958E-07    2 *  BS33T *  DGIR                        $**
T21  127  5.861E-07    2 *  BT32T *  CBSPIO                      $**
T21  132  5.861E-07    2 *  BT31T *  CBSPIO                      $**
T21  134  5.861E-07    2 *  BT33T *  CBSPIO                      $**
T21  135  5.036E-07    2 *  DGIS *  BS31T                        $**
T21  136  5.036E-07    2 *  DGIS *  BS33T                        $**
T21  137  5.036E-07    2 *  DGIS *  BS2AT                        $**
T21  138  5.036E-07    2 *  DGIS *  BS6AT                        $**
T21  139  5.036E-07    2 *  DGIS *  BS5AT                        $**
T21  140  5.036E-07    2 *  DGIS *  BS32T                        $**
T21  141  2.357E-07    1 *  BT32T *  BT33T                       $**
T21  142  2.357E-07    1 *  BT31T *  BT33T                       $**
T21  143  2.357E-07    1 *  BT31T *  BT32T                       $**
T21  144  5.434E-07    2 *  CBDGIC *  FIR33                      $**
T21  145  5.434E-07    2 *  CBDGIC *  FIR31                      $**
T21  146  5.434E-07    2 *  CBDGIC *  FIR32                      $**
T21  149  2.255E-07    6 *  CBDGIC *  HEDGI                      $**
T21  150  1.071E-07    2 *  DGIR *  FS31T                       $**
T21  151  1.071E-07    2 *  DGIR *  FS32T                       $**
T21  177  1.071E-07    2 *  DGIR *  FS33T                       $**
T21  180  3.907E-04 MAIN31 UNSHEDULED MAINTENANCE ON DIESEL 31   $I
T21  181  3.644E-03 Fraction of time in: MAIN31                  $F
T21  182  1.073E-01 Conditional system failure frequency given: MAIN31$C
T21  183  5.822E-02    2 *  DGIR                                $**
T21  184  4.213E-02    2 *  DGIS                                $**
T21  185  2.975E-03    2 *  CBDGIC                              $**
T21  186  1.207E-03    2 *  CBSPIO                              $**
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T21   187  4.943E-04   3 *  DGDR                                          $**
T21   188  4.855E-04   1 *  BT32T                                         $**
T21   189  4.855E-04   1 *  BT31T                                         $**
T21   190  3.924E-04   3 *  DGDS                                          $**
T21   191  1.453E-04   3 *  CBDGDC                                        $**
T21   193  1.110E-04   1 *  DGTR                                          $**
T21   194  1.814E-04   1 *  FIR33                                         $**
T21   195  1.814E-04   1 *  FIR32                                         $**
T21   196  5.857E-05   3 *  CBSPDO                                        $**
T21   197  5.020E-05   2 *  HEDGI                                         $**
T21   198  4.266E-05   1 *  DGIS                                          $**
T21   199  1.580E-05   1 *  CBDGIC                                        $**
T21   200  1.195E-05   1 *  BS6AT                                         $**
T21   201  1.195E-05   1 *  BS32T                                         $**
T21   202  1.195E-05   1 *  BS5AT                                         $**
T21   203  1.195E-05   1 *  BS31T                                         $**
T21   204  6.368E-06   1 *  CBSPIO                                        $**
T21   205  6.090E-06   3 *  HEDGD                                         $**
T21   206  1.840E-06   1 *  FS32T                                         $**
T21   207  1.840E-06   1 *  FS31T                                         $**
T21   208  3.909E-04 MAIN32 UNSHEDULED MAINTENANCE ON DIESEL 32           $T
T21   209  3.644E-03 Fraction of time in: MAIN32                          $F
T21   210  1.073E-01 Conditional system failure frequency given: MAIN32$C
T21   211  5.822E-02   2 *  DGIR                                          $**
T21   212  4.213E-02   2 *  DGIS                                          $**
T21   213  2.995E-03   2 *  CBDGIC                                        $**
T21   214  1.207E-03   2 *  CBSPIO                                        $**
T21   215  4.943E-04   3 *  DGDR                                          $**
T21   216  4.855E-04   1 *  BT33T                                         $**
T21   217  4.855E-04   1 *  BT31T                                         $**
T21   218  3.924E-04   3 *  DGDS                                          $**
T21   219  1.453E-04   3 *  CBDGDC                                        $**
T21   221  1.110E-04   1 *  DGTR                                          $**
T21   222  1.814E-04   1 *  FIR33                                         $**
T21   223  1.814E-04   1 *  FIR31                                         $**
T21   224  5.857E-05   3 *  CBSPDO                                        $**
T21   225  5.020E-05   2 *  HEDGI                                         $**
T21   226  4.266E-05   1 *  DGIS                                          $**
T21   227  1.580E-05   1 *  CBDGIC                                        $**
T21   228  1.195E-05   1 *  BS5AT                                         $**
T21   229  1.195E-05   1 *  BS31T                                         $**
T21   230  1.195E-05   1 *  BS33T                                         $**
T21   231  1.195E-05   1 *  BS2AT                                         $**
T21   232  6.368E-06   1 *  CBSPIO                                        $**
T21   233  6.090E-06   3 *  HEDGD                                         $**
T21   234  1.840E-06   1 *  FS33T                                         $**
T21   235  1.840E-06   1 *  FS31T                                         $**
T21   236  3.909E-04 MAIN33 UNSHEDULED MAINTENANCE ON DIESEL 33           $T
T21   237  3.644E-03 Fraction of time in: MAIN33                          $F
T21   238  1.073E-01 Conditional system failure frequency given: MAIN33$C
T21   239  5.822E-02   2 *  DGIR                                          $**
T21   240  4.213E-02   2 *  DGIS                                          $**
T21   241  2.995E-03   2 *  CBDGIC                                        $**
T21   242  1.207E-03   2 *  CBSPIO                                        $**
T21   243  4.943E-04   3 *  DGDR                                          $**
T21   244  4.855E-04   1 *  BT33T                                         $**
T21   245  4.855E-04   1 *  BT32T                                         $**
T21   246  3.924E-04   3 *  DGDS                                          $**
T21   247  1.453E-04   3 *  CBDGDC                                        $**
T21   249  1.110E-04   1 *  DGTR                                          $**
T21   250  1.814E-04   1 *  FIR32                                         $**
T21   251  1.814E-04   1 *  FIR31                                         $**
T21   252  5.857E-05   3 *  CBSPDO                                        $**
T21   253  5.020E-05   2 *  HEDGI                                         $**
T21   254  4.266E-05   1 *  DGIS                                          $**
T21   255  1.580E-05   1 *  CBDGIC                                        $**
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T21   256  1.195E-05   1 *  BS6AI                                  $**
T21   257  1.195E-05   1 *  BS32I                                  $**
T21   258  1.195E-05   1 *  BS33I                                  $**
T21   259  1.195E-05   1 *  BS2AI                                  $**
T21   260  6.368E-06   1 *  CBSP10                                 $**
T21   261  6.090E-06   3 *  HEDGD                                  $**
T21   262  1.840E-06   1 *  FS33I                                  $**
T21   263  1.840E-06   1 *  FS32I                                  $**
T31     1  4.167E-04 TOTAL  OFFSITE POWER FAILED,SERVICE WATER&ACTUATIO$
T31     2  3.797E-04 NORMAL SYSTEM NOT IN TEST OR MAINTENANCE        $T
T31     3  9.891E-01 Fraction of time in: NORMAL                     $F
T31     4  3.839E-04 Conditional system failure frequency given: NORMAL$C
T31     5  1.110E-04   1 *  DGIR                                    $**
T31     6  5.355E-05   3 *  DGIS *  DGIR *  DGIR                    $**
T31     7  4.266E-05   1 *  DGIS                                    $**
T31     8  3.875E-05   3 *  DGIS *  DGIS *  DGIR                    $**
T31     9  2.467E-05   1 *  DGIR *  DGIR *  DGIR                    $**
T31    10  2.216E-05   1 *  BRKST                                   $**
T31    11  1.439E-05   3 *  DGIR *  DGDR                            $**
T31    12  1.142E-05   3 *  DGDS *  DGIR                            $**
T31    13  1.041E-05   3 *  DGIS *  DGDR                            $**
T31    15  9.348E-06   1 *  DGIS *  DGIS *  DGIS                    $**
T31    16  8.265E-06   3 *  DGIS *  DGDS                            $**
T31    17  7.730E-06   6 *  DGIS *  DGIR *  BRKSI                   $**
T31    18  5.934E-06   3 *  DGIR *  BRKSD                           $**
T31    19  5.341E-06   3 *  DGIR *  DGIR *  BRKSI                   $**
T31    21  4.294E-06   3 *  DGIS *  BRKSD                           $**
T31    22  2.797E-06   3 *  DGIS *  DGIS *  BRKSI                   $**
T31    24  1.038E-06   3 *  DGDR *  BRKSI                           $**
T31    25  8.243E-07   3 *  DGDS *  BRKSI                           $**
T31    27  7.630E-07   1 *  HEDGT                                   $**
T31    28  6.124E-07   2 *  DGIS *  DGIR *  DC31                    $**
T31    38  6.124E-07   2 *  DGIS *  DGIR *  DC33                    $**
T31    39  6.124E-07   2 *  DGIS *  DGIR *  DC32                    $**
T31    40  4.283E-07   3 *  BRKSI *  BRKSD                          $**
T31    41  4.231E-07   1 *  DGIR *  DGIR *  DC32                    $**
T31    42  4.231E-07   1 *  DGIR *  DGIR *  DC31                    $**
T31    43  4.231E-07   1 *  DGIR *  DGIR *  DC33                    $**
T31    44  3.855E-07   3 *  DGIR *  BRKSI *  BRKSI                  $**
T31    46  2.789E-07   3 *  DGIS *  BRKSI *  BRKSI                  $**
T31    47  2.216E-07   1 *  DGIS *  DGIS *  DC31                    $**
T31    48  2.216E-07   1 *  DGIS *  DGIS *  DC32                    $**
T31    49  2.216E-07   1 *  DGIS *  DGIS *  DC33                    $**
T31    50  1.773E-07   3 *  DGIR *  HEDGD                           $**
T31    51  1.293E-07   6 *  DGDS *  DGDR                            $**
T31    53  1.283E-07   3 *  DGIS *  HEDGD                           $**
T31    55  2.225E-07   2 *  DGIS *  DGIR *  FIR33                   $**
T31    57  2.225E-07   2 *  DGIS *  DGIR *  FIR32                   $**
T31    59  2.225E-07   2 *  DGIS *  DGIR *  FIR31                   $**
T31    61  9.235E-08   6 *  DGIS *  DGIR *  HEDGI                   $**
T31    63  8.226E-08   1 *  DGDR *  DC31                            $**
T31    65  8.226E-08   1 *  DGDR *  DC33                            $**
T31    67  8.226E-08   1 *  DGDR *  DC32                            $**
T31    69  8.144E-08   3 *  DGDR *  DGDR                            $**
T31    70  6.717E-08   6 *  DGDR *  BRKSD                           $**
T31    71  1.537E-07   1 *  DGIR *  DGIR *  FIR33                   $**
T31    72  1.537E-07   1 *  DGIR *  DGIR *  FIR32                   $**
T31    73  1.537E-07   1 *  DGIR *  DGIR *  FIR31                   $**
T31    74  6.530E-08   1 *  DGDS *  DC31                            $**
T31    75  6.530E-08   1 *  DGDS *  DC33                            $**
T31    76  6.530E-08   1 *  DGDS *  DC32                            $**
T31    77  6.381E-08   3 *  DGIR *  DGIR *  HEDGI                   $**
T31    78  6.107E-08   2 *  DGIR *  DC32 *  BRKSI                   $**
T31    79  6.107E-08   2 *  DGIR *  DC33 *  BRKSI                   $**
T31    80  6.107E-08   2 *  DGIR *  DC31 *  BRKSI                   $**
T31    82  5.332E-08   6 *  DGDS *  BRKSD                           $**
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T31   87   5.15PE-00   3 *  DGDS *  DGDS                          $**
T31   92   4.420E 00   2 *  DGIS *  DC32 *  BRKSI                 $**
T31   93   4.420E 00   2 *  DGIS *  DC33 *  BRKSI                 $**
T31   94   4.420E-08   2 *  DGIS *  DC31 *  BRKSI                 $**
T31   95   8.052E-08   1 *  DGIS *  DGIS *  FIR33                 $**
T31   96   8.052E-08   1 *  DGIS *  DGIS *  FIR31                 $**
T31   97   8.052E-08   1 *  DGIS *  DGIS *  FIR32                 $**
T31   98   3.393E-08   1 *  DC33 *  BRKSD                         $**
T31   99   3.393E-08   1 *  DC31 *  BRKSD                         $**
T31  102   3.393E-08   1 *  DC32 *  BRKSD                         $**
T31  105   3.342E-08   3 *  DGIS *  DGIS *  HEDGI                 $**
T31  108   1.466E-08   2 *  DGIS *  BS5AT *  DGIR                 $**
T31  110   1.466E-08   2 *  DGIS *  BS6AT *  DGIR                 $**
T31  112   1.466E-08   2 *  DGIS *  BS2AT *  DGIR                 $**
T31  113   1.385E-08   3 *  BRKSD *  BRKSD                        $**
T31  114   2.989E-08   1 *  DGDR *  FIR31                         $**
T31  115   2.989E-08   1 *  DGDR *  FIR33                         $**
T31  116   2.989E-08   1 *  DGDR *  FIR32                         $**
T31  118   1.279E-08   3 *  HEDGD *  BRKSI                        $**
T31  125   1.241E-08   3 *  DGDR *  HEDGI                         $**
T31  126   2.373E-08   1 *  DGDS *  FIR33                         $**
T31  127   2.373E-08   1 *  DGDS *  FIR32                         $**
T31  131   2.373E-08   1 *  DGDS *  FIR31                         $**
T31  134   1.013E-08   1 *  BS5AT *  DGIR *  DGIR                 $**
T31  140   1.013E-08   1 *  BS6AT *  DGIR *  DGIR                 $**
T31  155   1.013E-08   1 *  BS2AT *  DGIR *  DGIR                 $**
T31  182   9.848E-09   3 *  DGDS *  HEDGI                         $**
T31  204   2.219E-08   2 *  DGIR *  FIR31 *  BRKSI                $**
T31  226   2.219E-08   2 *  DGIR *  FIR33 *  BRKSI                $**
T31  227   2.219E-08   2 *  DGIR *  FIR32 *  BRKSI                $**
T31  228   9.273E-09   1 *  BRKSI *  BRKSI *  BRKSI               $**
T31  229   9.210E-09   6 *  DGIR *  HEDGI *  BRKSI                $**
T31  230   7.257E-09   1 *  DGIR *  DC31 *  DC33                  $**
T31  231   7.257E-09   1 *  DGIR *  DC31 *  DC32                  $**
T31  232   7.257E-09   1 *  DGIR *  DC32 *  DC33                  $**
T31  233   1.606E-08   2 *  DGIS *  FIR32 *  BRKSI                $**
T31  236   1.606E-08   2 *  DGIS *  FIR33 *  BRKSI                $**
T31  239   1.606E-08   2 *  DGIS *  FIR31 *  BRKSI                $**
T31  242   6.665E-09   6 *  DGIS *  HEDGI *  BRKSI                $**
T31  244   5.304E-09   1 *  DGIS *  DGIS *  BS6AT                 $**
T31  246   5.304E-09   1 *  DGIS *  DGIS *  BS2AT                 $**
T31  247   5.304E-09   1 *  DGIS *  DGIS *  BS5AT                 $**
T31  248   1.233E-08   1 *  FIR32 *  BRKSD                        $**
T31  249   1.233E-08   1 *  FIR31 *  BRKSD                        $**
T31  250   1.233E-08   1 *  FIR33 *  BRKSD                        $**
T31  254   5.252E-09   1 *  DGIS *  DC32 *  DC33                  $**
T31  257   5.252E-09   1 *  DGIS *  DC31 *  DC32                  $**
T31  258   5.252E-09   1 *  DGIS *  DC31 *  DC33                  $**
T31  315   5.117E-09   3 *  HEDGI *  BRKSD                        $**
T31  316   1.235E-05 MAIN31 UNSHEDULED MAINTENANCE ON DIESEL 31   $I
T31  317   3.644E-03 Fraction of time in: MAIN31                  $F
T31  318   3.389E-03 Conditional system failure frequency given: MAIN31$C
T31  319   1.226E-03   2 *  DGIS *  DGIR                          $**
T31  320   8.474E-04   1 *  DGIR *  DGIR                          $**
T31  321   4.438E-04   1 *  DGIS *  DGIS                          $**
T31  322   1.648E-04   1 *  DGDR                                  $**
T31  323   1.308E-04   1 *  DGDS                                  $**
T31  324   1.223E-04   2 *  DGIR *  BRKSI                         $**
T31  325   1.110E-04   1 *  DGIR                                  $**
T31  326   8.852E-05   2 *  DGIS *  BRKSI                         $**
T31  327   6.795E-05   1 *  BRKSD                                 $**
T31  328   4.266E-05   1 *  DGIS                                  $**
T31  329   2.216E-05   1 *  BRKSI                                 $**
T31  330   1.453E-05   1 *  DGIR *  DC31                          $**
T31  333   1.453E-05   1 *  DGIR *  DC32                          $**
T31  334   1.052E-05   1 *  DGIS *  DC32                          $**
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T31   335  1.052E-05   1 *  DGIS *  DC31                    $**
T31   337  9.592E-06   2 *  DGIR *  DGDR                    $**
T31   342  7.614E-06   2 *  DGDS *  DGIR                    $**
T31   350  6.942E-06   2 *  DGIS *  DGDR                    $**
T31   351  5.510E-06   2 *  DGIS *  DGDS                    $**
T31   352  4.414E-06   1 *  BRKSI *  BRKSI                  $**
T31   354  3.956E-06   2 *  DGIR *  BRKSD                   $**
T31   358  2.863E-06   2 *  DGIS *  BRKSD                   $**
T31   360  5.282E-06   1 *  DGIR *  FIR32                   $**
T31   363  5.282E-06   1 *  DGIR *  FIR33                   $**
T31   365  2.030E-06   1 *  HEDGD                           $**
T31   375  3.822E-06   1 *  DGIS *  FIR32                   $**
T31   377  3.822E-06   1 *  DGIS *  FIR33                   $**
T31   378  1.461E-06   2 *  DGIR *  HEDGI                   $**
T31   379  1.058E-06   2 *  DGIS *  HEDGI                   $**
T31   380  1.049E-06   1 *  DC32 *  BRKSI                   $**
T31   381  1.049E-06   1 *  DC31 *  BRKSI                   $**
T31   382  7.630E-07   1 *  HEDGT                           $**
T31   383  6.923E-07   2 *  DGDR *  BRKSI                   $**
T31   384  5.496E-07   2 *  DGDS *  BRKSI                   $**
T31   385  3.479E-07   1 *  BS6AT *  DGIR                   $**
T31   386  3.479E-07   1 *  BS5AT *  DGIR                   $**
T31   388  2.855E-07   2 *  BRKSI *  BRKSD                  $**
T31   393  2.518E-07   1 *  DGIS *  BS6AT                   $**
T31   398  2.518E-07   1 *  DGIS *  BS5AT                   $**
T31   399  2.493E-07   1 *  DC31 *  DC32                    $**
T31   400  3.812E-07   1 *  FIR33 *  BRKSI                  $**
T31   401  3.812E-07   1 *  FIR32 *  BRKSI                  $**
T31   402  1.182E-07   2 *  DGIR *  HEDGD                   $**
T31   403  1.055E-07   2 *  HEDGI *  BRKSI                  $**
T31   404  8.553E-08   2 *  DGIS *  HEDGD                   $**
T31   405  8.226E-08   1 *  DGDR *  DC31                    $**
T31   406  8.226E-08   1 *  DGDR *  DC32                    $**
T31   408  6.530E-08   1 *  DGDS *  DC31                    $**
T31   409  6.530E-08   1 *  DGDS *  DC32                    $**
T31   411  4.310E-08   2 *  DGDS *  DGDR                    $**
T31   414  9.059E-08   1 *  DC32 *  FIR33                   $**
T31   416  9.059E-08   1 *  DC31 *  FIR32                   $**
T31   418  3.393E-08   1 *  DC32 *  BRKSD                   $**
T31   419  3.393E-08   1 *  DC31 *  BRKSD                   $**
T31   420  1.235E-05 MAIN32 UNSHEDULED MAINTENANCE ON DIESEL 32        $T
T31   421  3.644E-03 Fraction of time in: MAIN32                       $F
T31   422  3.389E-03 Conditional system failure frequency given: MAIN32$C
T31   423  1.226E-03   2 *  DGIS *  DGIR                    $**
T31   424  8.474E-04   1 *  DGIR *  DGIR                    $**
T31   425  4.438E-04   1 *  DGIS *  DGIS                    $**
T31   426  1.648E-04   1 *  DGDR                            $**
T31   427  1.308E-04   1 *  DGDS                            $**
T31   428  1.223E-04   2 *  DGIR *  BRKSI                   $**
T31   429  1.110E-04   1 *  DGIR                            $**
T31   430  8.852E-05   2 *  DGIS *  BRKSI                   $**
T31   431  6.795E-05   1 *  BRKSD                           $**
T31   432  4.266E-05   1 *  DGIS                            $**
T31   433  2.216E-05   1 *  BRKSI                           $**
T31   434  1.453E-05   1 *  DGIR *  DC33                    $**
T31   437  1.453E-05   1 *  DGIR *  DC31                    $**
T31   438  1.052E-05   1 *  DGIS *  DC31                    $**
T31   439  1.052E-05   1 *  DGIS *  DC33                    $**
T31   443  9.592E-06   2 *  DGIR *  DGDR                    $**
T31   446  7.614E-06   2 *  DGDS *  DGIR                    $**
T31   454  6.942E-06   2 *  DGIS *  DGDR                    $**
T31   455  5.510E-06   2 *  DGIS *  DGDS                    $**
T31   456  4.414E-06   1 *  BRKSI *  BRKSI                  $**
T31   458  3.956E-06   2 *  DGIR *  BRKSD                   $**
T31   462  2.863E-06   2 *  DGIS *  BRKSD                   $**
T31   464  5.282E-06   1 *  DGIR *  FIR31                   $**
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T31   466   5.2064E-06   1 *  DGIR *  FIR33                    $**
T31   467   2.030E-06    1 *  HEDGD                            $**
T31   479   3.822E-06    1 *  DGIS *  FIR33                    $**
T31   481   3.822E-06    1 *  DGIS *  FIR31                    $**
T31   482   1.461E-06    2 *  DGIR *  HEDGI                    $**
T31   483   1.058E-06    2 *  DGIS *  HEDGI                    $**
T31   484   1.049E-06    1 *  DC33 *  BRKSI                    $**
T31   485   1.049E-06    1 *  DC31 *  BRKSI                    $**
T31   486   7.630E-07    1 *  HEDGI                            $**
T31   487   6.923E-07    2 *  DGDR *  BRKSI                    $**
T31   488   5.496E-07    2 *  DGDS *  BRKSI                    $**
T31   489   3.479E-07    1 *  BS2AT *  DGIR                    $**
T31   490   3.479E-07    1 *  BS5AT *  DGIR                    $**
T31   492   2.855E-07    2 *  BRKSI *  BRKSD                   $**
T31   497   2.518E-07    1 *  DGIS *  BS5AT                    $**
T31   502   2.518E-07    1 *  DGIS *  BS2AT                    $**
T31   503   2.493E-07    1 *  DC31 *  DC33                     $**
T31   504   3.812E-07    1 *  FIR31 *  BRKSI                   $**
T31   505   3.812E-07    1 *  FIR33 *  BRKSI                   $**
T31   506   1.182E-07    2 *  DGIR *  HEDGD                    $**
T31   507   1.055E-07    2 *  HEDGI *  BRKSI                   $**
T31   508   8.553E-08    2 *  DGIS *  HEDGD                    $**
T31   509   8.226E-08    1 *  DGDR *  DC31                     $**
T31   510   8.226E-08    1 *  DGDR *  DC33                     $**
T31   512   6.530E-08    1 *  DGDS *  DC31                     $**
T31   513   6.530E-08    1 *  DGDS *  DC33                     $**
T31   515   4.310E-08    2 *  DGDS *  DGDR                     $**
T31   518   9.059E-08    1 *  DC33 *  FIR33                    $**
T31   520   9.059E-08    1 *  DC31 *  FIR31                    $**
T31   522   3.393E-08    1 *  DC33 *  BRKSD                    $**
T31   523   3.393E-08    1 *  DC31 *  BRKSD                    $**
T31   524   1.235E-05 MAIN33 UNSHEDULED MAINTENANCE ON DIESEL 33 $T
T31   525   3.644E-03 Fraction of time in: MAIN33               $F
T31   526   3.389E-03 Conditional system failure frequency given: MAIN33$C
T31   527   1.226E-03    2 *  DGIS *  DGIR                    $**
T31   528   8.474E-04    1 *  DGIR *  DGIR                    $**
T31   529   4.438E-04    1 *  DGIS *  DGIS                    $**
T31   530   1.648E-04    1 *  DGDR                            $**
T31   531   1.308E-04    1 *  DGDS                            $**
T31   532   1.223E-04    2 *  DGIR *  BRKSI                   $**
T31   533   1.110E-04    1 *  DGIR                            $**
T31   534   8.852E-05    2 *  DGIS *  BRKSI                   $**
T31   535   6.795E-05    1 *  BRKSD                           $**
T31   536   4.266E-05    1 *  DGIS                            $**
T31   537   2.216E-05    1 *  BRKST                           $**
T31   538   1.453E-05    1 *  DGIR *  DC33                    $**
T31   541   1.453E-05    1 *  DGIR *  DC32                    $**
T31   542   1.052E-05    1 *  DGIS *  DC32                    $**
T31   543   1.052E-05    1 *  DGIS *  DC33                    $**
T31   547   9.592E-06    2 *  DGIR *  DGDR                    $**
T31   550   7.614E-06    2 *  DGDS *  DGIR                    $**
T31   558   6.942E-06    2 *  DGIS *  DGDR                    $**
T31   559   5.510E-06    2 *  DGIS *  DGDS                    $**
T31   560   4.414E-06    1 *  BRKSI *  BRKSI                  $**
T31   562   3.956E-06    2 *  DGIR *  BRKSD                   $**
T31   566   2.863E-06    2 *  DGIS *  BRKSD                   $**
T31   568   5.282E-06    1 *  DGIR *  FIR31                   $**
T31   571   5.282E-06    1 *  DGIR *  FIR32                   $**
T31   573   2.030E-06    1 *  HEDGD                           $**
T31   583   3.822E-06    1 *  DGIS *  FIR32                   $**
T31   585   3.822E-06    1 *  DGIS *  FIR31                   $**
T31   586   1.461E-06    2 *  DGIR *  HEDGI                   $**
T31   587   1.058E-06    2 *  DGIS *  HEDGI                   $**
T31   588   1.049E-06    1 *  DC33 *  BRKSI                   $**
T31   589   1.049E-06    1 *  DC32 *  BRKSI                   $**
T31   590   7.630E-07    1 *  HEDGI                           $**
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T31   591  6.923E-07    2 *  DGDR *  BRKSI                          $**
T31   592  5.496E-07    2 *  DGDS *  BRKSI                          $**
T31   593  3.479E-07    1 *  BS2AT *  DGIR                          $**
T31   594  3.479E-07    1 *  BS6AT *  DGIR                          $**
T31   596  2.855E-07    2 *  BRKSI *  BRKSD                         $**
T31   601  2.518E-07    1 *  DGIS *  BS6AT                          $**
T31   606  2.518E-07    1 *  DGIS *  BS2AT                          $**
T31   607  2.493E-07    1 *  DC32 *  DC33                           $**
T31   608  3.812E-07    1 *  FIR31 *  BRKSI                         $**
T31   609  3.812E-07    1 *  FIR32 *  BRKSI                         $**
T31   610  1.182E-07    2 *  DGIR *  HEDGD                         $**
T31   611  1.055E-07    2 *  HEDGI *  BRKSI                         $**
T31   612  8.553E-08    2 *  DGIS *  HEDGD                         $**
T31   613  8.226E-08    1 *  DGDR *  DC32                           $**
T31   614  8.226E-08    1 *  DGDR *  DC33                           $**
T31   616  6.530E-08    1 *  DGDS *  DC32                           $**
T31   617  6.530E-08    1 *  DGDS *  DC33                           $**
T31   619  4.310E-08    2 *  DGDS *  DGDR                           $**
T31   622  9.059E-08    1 *  DC33 *  FIR32                          $**
T31   624  9.059E-08    1 *  DC32 *  FIR31                          $**
T31   626  3.393E-08    1 *  DC33 *  BRKSD                          $**
T31   627  3.393E-08    1 *  DC32 *  BRKSD                          $**
FOA     1  3.361E-05 TOTAL  OFFSITE POWER FAILED,SERVICE WATER&ACTUATIO$
FOA     2  3.361E-05 NORMAL SYSTEM NOT UNDERGOING TEST OR MAINTENANCE$ $T
FOA     3  1.000E+00 Fraction of time in: NORMAL                     $F
FOA     4  3.361E-05 Conditional system failure frequency given: NORMAL$C
FOA     5  3.228E-05    1 *  PMIS                                   $**
FOA     6  9.084E-07    3 *  PMIS *  PMDS                           $**
FOA    13  2.878E-07    1 *  PMIR                                   $**
FOA    15  6.031E-08    3 *  PMDS *  PMIR                           $**
FOA    17  2.938E-08    3 *  PMDS *  PMDS                           $**
FOA    19  2.865E-08    1 *  PMIS *  PMIS *  PMIS                   $**
FOA    20  8.098E-09    3 *  PMIS *  PMDR                           $**
FOA    21  5.706E-09    3 *  PMIS *  PMIS *  PMIR                   $**
FOA    22  5.377E-10    3 *  PMIR *  PMDR                           $**
FOA    23  5.239E-10    6 *  PMDS *  PMDR                           $**
FOA    24  4.917E-10    1 *  CBC6BT *  PMDS                         $**
FOA    76  4.917E-10    1 *  CBC6CT *  PMDS                         $**
FOA    77  4.917E-10    1 *  CBC6AT *  PMDS                         $**
FOA    78  3.788E-10    3 *  PMIS *  PMIR *  PMIR                   $**
FOI     1  1.438E-04 TOTAL  POWER TO PUMP 33 FROM BUS 5A NOT AVAILABLE$$
FOI     2  1.438E-04 NORMAL SYSTEM NOT UNDERGOING TEST OR MAINTENANCE$ $T
FOI     3  1.000E+00 Fraction of time in: NORMAL                     $F
FOI     4  1.438E-04 Conditional system failure frequency given: NORMAL$C
FOI     5  9.897E-05    1 *  PMDS                                   $**
FOI     6  3.228E-05    1 *  PMIS                                   $**
FOI    15  9.362E-06    1 *  PMIS *  PMIS                           $**
FOI    16  1.243E-06    2 *  PMIS *  PMIR                           $**
FOI    17  8.822E-07    1 *  PMDR                                   $**
FOI    18  6.056E-07    2 *  PMIS *  PMDS                           $**
FOI    19  2.878E-07    1 *  PMIR                                   $**
FOI    22  4.127E-08    1 *  PMIR *  PMIR                           $**
FOI    26  4.021E-08    2 *  PMDS *  PMIR                           $**
FOI    29  1.520E-08    1 *  CBC6BT *  PMIS                         $**
FOI    32  1.520E-08    1 *  CBC6CT *  PMIS                         $**
FOI    34  9.794E-09    1 *  PMDS *  PMDS                           $**
FOI    36  9.143E-09    1 *  BS36CT *  PMIS                         $**
FOI    37  9.143E-09    1 *  BS36BT *  PMIS                         $**
FOI    38  5.399E-09    2 *  PMIS *  PMDR                           $**
TXI     1  2.271E-03 TOTAL  OFFSITE POWER FAILED,SERVICE WATER&ACTUATIO$
TXI     2  2.271E-03 NORMAL SYSTEM NOT IN TEST OR MAINTENANCE        $T
TXI     3  1.000E+00 Fraction of time in: NORMAL                     $F
TXI     4  2.271E-03 Conditional system failure frequency given: NORMAL$C
TXI     5  1.610E-03    1 *  CB2AC                                  $**
TXI     6  6.490E-04    1 *  CB3AO                                  $**
TXI     7  1.195E-05    1 *  BS3AT                                  $**
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CTS FILE FOR 3 DAY AOT WITH REALISTIC MAINTENANCE DURATION AND TRUNCATION
OF INDIVIDUAL CUTSETS AT 1E-5

SS1      1  8.290E-01 SUCCESS STATE,                SEQ1$
SS3      1  5.024E-04 ALL 480V POWER FAILED$
SS3      2  2.793E-05  SEQ3$
SS3      3  7.591E-06  SEQ6$
SS3      4  7.591E-06  SEQ9$
SS3      5  1.204E-05  SEQ12$
SS3      6  7.591E-06  SEQ14$
SS3      7  1.204E-05  SEQ16$
SS3      8  1.204E-05  SEQ18$
SS3      9  4.156E-04  SEQ19$
SS4      1  5.266E-02 BUS 6A FAILED,                SEQ4$
SS5      1  5.266E-02 BUS 5A FAILED,                SEQ7$
SS6      1  5.278E-02 BUS 2A&3A FAILED,             SEQ13$
SS2      1  1.887E-03 BUS 3A POWER FAILED,          SEQ2$
SS8      1  3.418E-03 BUS 5A&6A,                    SEQ10$
SS0      1  3.426E-03 BUSES 2A,3A&6A FAIL,          SEQ15$
SS4      1  3.426E-03 BUSES 2A,3A&5A FAIL,          SEQ17$
SS7      1  1.199E-04 BUS 3A&5A FAILED,             SEQ8$
SS8      1  1.199E-04 BUSES 3A&6A FAIL,             SEQ5$
SS9      1  7.781E-06 BUSES 3A,5A&6A FAIL,          SEQ11$
SST      1  1.000E+00 TOTAL OF ALL SEQUENCES$
SST      2  1.887E-03  SEQ2$
SST      3  2.793E-05  SEQ3$
SST      4  5.266E-02  SEQ4$
SST      5  1.199E-04  SEQ5$
SST      6  7.591E-06  SEQ6$
SST      7  5.266E-02  SEQ7$
SST      8  1.199E-04  SEQ8$
SST      9  7.591E-06  SEQ9$
SST     10  3.418E-03  SEQ10$
SST     11  7.781E-06  SEQ11$
SST     12  1.204E-05  SEQ12$
SST     13  5.278E-02  SEQ13$
SST     14  7.591E-06  SEQ14$
SST     15  3.426E-03  SEQ15$
SST     16  1.204E-05  SEQ16$
SST     17  3.426E-03  SEQ17$
SST     18  1.204E-05  SEQ18$
SST     19  4.156E-04  SEQ19$
SST     20  8.290E-01  SEQ1$
SST     21  6.287E-04  TOTAL FOR LOSS OF ALL AC INCLUDING DG&SW FAILURES$
SSW      1  6.287E-04  TOTAL FOR LOSS OF ALL AC INCLUDING SW FAILURES $
```

```
@ BS2A1 = ZIBS1R*T24  $
@ BS3I1 = ZIBS1R*T24  $
@ BS32I = ZIBS1R*T24  $
@ BS33I = ZIBS1R*T24  $
@ BS36AI= ZIBS1R*T6  $
@ BS36BI= ZIBS1R*T6  $
@ BS36CI= ZIBS1R*T6  $
@ BS2A1 = ZIBS1R*T24  $
@ BS5A1 = ZIBS1R*T24  $
@ BS6A1 = ZIBS1R*T24  $
@ BT31I = ZIBATD*ZIBATR*T2 $
@ BT32I = ZIBATD*ZIBATR*T2 $
@ BT33I = ZIBATD*ZIBATR*T2 $
@ CB2AC = ZICB1C     $
@ CB3AD = ZICB1D  $
@ CBC6AI= ZICB1I*T6  $
@ CBC6BI= ZICB1I*T6  $
@ CBC6CI= ZICB1I*T6  $
@ DC31  = ZIBATD*ZIBATR*T2*ZIFU1R*T2*ZIBS1R*T24 $
@ DC32  = ZIBATD*ZIBATR*T2*ZIFU1R*T2*ZIBS1R*T24 $
@ DC33  = ZIBATD*ZIBATR*T2*ZIFU1R*T2*ZIBS1R*T24 $
@ FIR31 = FIREDG*TA01 $
@ FIR32 = FIREDG*TA01 $
@ FIR33 = FIREDG*TA01 $
@ FS31I = ZIFU1R*T2  $
@ FS33I = ZIFU1R*T2  $
@ FS32I = ZIFU1R*T2  $
@ HEDGI = HE1DG      $
@ HEDGD = HE2DG      $
@ HEDGT = HE3DG      $
@ FMIR  = 1 / 1 * (1-ZBFMSR) * ZIFMSR*T6$
@ FMDR  = 1 / 2 * ZBFMSR * (1-ZGFMSR) * ZIFMSR*T6$
@ FMTR  = 1 / 1 * ZBFMSR * ZGFMSR * ZIFMSR*T6$
@ DGIR  = (1-ZB3DRI)*ZIDGS1*(1-ZB3DRT)*ZIDGS2*(T6-1) $
@ DGDR  = 0.5*(1-ZGDGSR)*(ZB3DRI*ZIDGS1+ZB3DRT*ZIDGS2*(T6-1)) $
@ DGTR  = ZGDGSR*(ZB3DRI*ZIDGS1+ZB3DRT*ZIDGS2*(T6-1)) $
@ CBEGIC= ZICB1C     $
@ DGIS  = 1 / 1 * (1-ZB3DGS) * ZIDGSS$
@ DGTS  = 1 / 1 * ZB3DGS * ZGDGSS * ZIDGSS$
@ DGDS  = 1 / 2 * ZB3DGS * (1-ZGDGSS) * ZIDGSS$
@ FMIS  = 1 / 1 * (1-ZBFMSS) * ZIFMSS$
@ FMDS  = 1 / 2 * ZBFMSS * (1-ZGFMSS) * ZIFMSS$
@ FMTS  = 1 / 1 * ZBFMSS * ZGFMSS * ZIFMSS$
@ CBSFIO= 1 / 1 * (1-ZBCB1O) * ZICB1O$
@ CBSFDO= 1 / 2 * ZBCB1O * (1-ZGCB1O) * ZICB1O$
@ CBSFTO= 1 / 1 * ZBCB1O * ZGCB1O * ZICB1O$
@ CBDGIC= 1 / 1 * (1-ZBCB1C) * ZICB1C$
@ CBDGDC= 1 / 2 * ZBCB1C * (1-ZGCB1C) * ZICB1C$
@ CBDGTC= 1 / 1 * ZBCB1C * ZGCB1C * ZICB1C$
@ PRISI = (1-ZBCB1O)*ZICB1O +(1-ZBCB1C)*ZICB1C $
@ PRISD = 0.5*(ZBCB1O*(1-ZGCB1O)*ZICB1O+ZBCB1C*(1-ZGCB1C)*ZICB1C)$
@ PRIST = ZBCB1O*ZGCB1O*ZICB1O + ZBCB1C*ZGCB1C*ZICB1C $
@ TA01  = 72.       $  168. FOR 7 DAY T.S. .72. FOR 3 DAY
@ T6    = 6.        $
@ T24   = 24.       $
@ T2    = 2.         $
```

C.3 7-DAY AOT RESULTS

```
FO2     1  3.503E-03 TOTAL  POWER TO PUMPS 33&31 FROM BUSES 5A &2A NOT S
FO2     2  3.503E-03 NORMAL SYSTEM NOT UNDERGOING TEST OR MAINTENANCES ST
FO2     3  1.000E+00 Fraction of time in: NORMAL                       SF
FO2     4  3.503E-03 Conditional system failure frequency given: NORMALSC
FO2     5  3.060E-03    1 *  PMIS                                      S**
FO2     6  2.031E-04    1 *  PMIR                                      S**
FO2     7  1.979E-04    2 *  PMDS                                      S**
FO2     8  3.228E-05    1 *  PMTS                                      S**
FO2     9  4.968E-06    1 *  CBC6BT                                    S**
FO2    10  2.988E-06    1 *  BS36BT                                    S**
FO2    11  1.764E-06    2 *  PMDR                                      S**
FO2    12  2.878E-07    1 *  PMTR                                      S**
T11     1  1.813E-01 TOTAL  OFFSITE POWER FAILED,SERVICE WATER&ACTUATIOS
T11     2  1.562E-01 NORMAL SYSTEM NOT IN TEST OR MAINTENANCE          ST
T11     3  9.750E-01 Fraction of time in: NORMAL                       SF
T11     4  1.603E-01 Conditional system failure frequency given: NORMALSC
T11     5  8.733E-02    3 *  DGIR                                      S**
T11     6  6.320E-02    3 *  DGIS                                      S**
T11     7  4.492E-03    3 *  CBDGIC                                    S**
T11     8  1.811E-03    3 *  CBSPIO                                    S**
T11     9  4.943E-04    3 *  DGDR                                      S**
T11    10  4.855E-04    1 *  BT33T                                     S**
T11    11  4.855E-04    1 *  BT31T                                     S**
T11    12  4.855E-04    1 *  BT32T                                     S**
T11    13  3.924E-04    3 *  DGDS                                      S**
T11    14  1.453E-04    3 *  CBDGDC                                    S**
T11    15  1.110E-04    1 *  DGTR                                      S**
T11    16  1.814E-04    1 *  FIR31                                     S**
T11    17  1.814E-04    1 *  FIR32                                     S**
T11    18  1.814E-04    1 *  FIR33                                     S**
T11    19  7.530E-05    3 *  HEDGI                                     S**
T11    20  5.857E-05    3 *  CBSPDO                                    S**
T11    21  4.266E-05    1 *  DGTS                                      S**
T11    22  1.580E-05    1 *  CBDGTC                                    S**
T11    23  1.195E-05    1 *  BS6AT                                     S**
T11    24  1.195E-05    1 *  BS32T                                     S**
T11    25  1.195E-05    1 *  BS5AT                                     S**
T11    26  1.195E-05    1 *  BS2AT                                     S**
T11    27  1.195E-05    1 *  BS31T                                     S**
T11    28  1.195E-05    1 *  BS33T                                     S**
T11    29  6.368E-06    1 *  CBSPTO                                    S**
T11    30  6.090E-06    3 *  HEDGD                                     S**
T11    31  1.840E-06    1 *  FS32T                                     S**
T11    32  1.840E-06    1 *  FS33T                                     S**
T11    33  1.840E-06    1 *  FS31T                                     S**
T11    35  8.342E-03 MAIN31 UNSHEDULED MAINTENANCE ON DIESEL 31       ST
T11    36  8.342E-03 Fraction of time in: MAIN31                      SF
T11    37  1.000E+00 Conditional system failure frequency given: MAIN31SC
T11    38  8.342E-03 MAIN32 UNSHEDULED MAINTENANCE ON DIESEL 32       ST
T11    39  8.342E-03 Fraction of time in: MAIN32                      SF
T11    40  1.000E+00 Conditional system failure frequency given: MAIN32SC
T11    41  8.342E-03 MAIN33 UNSHEDULED MAINTENANCE ON DIESEL 33       ST
T11    42  8.342E-03 Fraction of time in: MAIN33                      SF
T11    43  1.000E+00 Conditional system failure frequency given: MAIN33SC
T21     1  1.214E-02 TOTAL  OFFSITE POWER FAILED,SERVICE WATER&ACTUATIOS
T21     2  9.453E-03 NORMAL SYSTEM NOT IN TEST OR MAINTENANCE          ST
T21     3  9.750E-01 Fraction of time in: NORMAL                       SF
T21     4  9.696E-03 Conditional system failure frequency given: NORMALSC
```

T21	5	3.879E-03	6 *	DGIS *	DGIR	S**
T21	6	2.542E-03	3 *	DGIR *	DGIR	S**
T21	7	1.331E-03	3 *	DGIS *	DGIS	S**
T21	8	4.943E-04	3 *	DGDR		S**
T21	9	3.924E-04	3 *	DGDS		S**
T21	10	2.615E-04	6 *	DGIR *	CBDGIC	S**
T21	11	1.893E-04	6 *	DGIS *	CBDGIC	S**
T21	12	1.453E-04	3 *	CBDGDC		S**
T21	13	1.110E-04	1 *	DGTR		S**
T21	14	1.054E-04	6 *	DGIR *	CBSPIO	S**
T21	15	7.629E-05	6 *	DGIS *	CBSPIO	S**
T21	16	5.857E-05	3 *	CBSPDO		S**
T21	17	4.266E-05	1 *	DGTS		S**
T21	18	2.827E-05	2 *	BT32T *	DGIR	S**
T21	19	2.827E-05	2 *	BT33T *	DGIR	S**
T21	20	2.827E-05	2 *	BT31T *	DGIR	S**
T21	21	2.046E-05	2 *	DGIS *	BT32T	S**
T21	22	2.046E-05	2 *	DGIS *	BT33T	S**
T21	23	2.046E-05	2 *	DGIS *	BT31T	S**
T21	24	1.580E-05	1 *	CBDGTC		S**
T21	25	6.726E-06	3 *	CBDGIC *	CBDGIC	S**
T21	28	6.368E-06	1 *	CBSPTO		S**
T21	29	6.090E-06	3 *	HEDGD		S**
T21	30	5.423E-06	6 *	CBDGIC *	CBSPIO	S**
T21	31	1.056E-05	2 *	DGIR *	FIR32	S**
T21	32	1.056E-05	2 *	DGIR *	FIR33	S**
T21	33	1.056E-05	2 *	DGIR *	FIR31	S**
T21	41	4.384E-06	6 *	DGIR *	HEDGI	S**
T21	54	7.644E-06	2 *	DGIS *	FIR32	S**
T21	66	7.644E-06	2 *	DGIS *	FIR31	S**
T21	78	7.644E-06	2 *	DGIS *	FIR33	S**
T21	89	3.173E-06	6 *	DGIS *	HEDGI	S**
T21	99	1.454E-06	2 *	BT33T *	CBDGIC	S**
T21	107	1.454E-06	2 *	BT32T *	CBDGIC	S**
T21	108	1.454E-06	2 *	BT31T *	CBDGIC	S**
T21	109	1.093E-06	3 *	CBSPIO *	CBSPIO	S**
T21	110	7.630E-07	1 *	HEDGT		S**
T21	115	6.958E-07	2 *	BS31T *	DGIR	S**
T21	117	6.958E-07	2 *	BS2AT *	DGIR	S**
T21	118	6.958E-07	2 *	BS32T *	DGIR	S**
T21	119	6.958E-07	2 *	BS5AT *	DGIR	S**
T21	124	6.958E-07	2 *	BS6AT *	DGIR	S**
T21	126	6.958E-07	2 *	BS33T *	DGIR	S**
T21	127	5.861E-07	2 *	BT32T *	CBSPIO	S**
T21	132	5.861E-07	2 *	BT31T *	CBSPIO	S**
T21	134	5.861E-07	2 *	BT33T *	CBSPIO	S**
T21	135	5.036E-07	2 *	DGIS *	BS31T	S**
T21	136	5.036E-07	2 *	DGIS *	BS33T	S**
T21	137	5.036E-07	2 *	DGIS *	BS2AT	S**
T21	138	5.036E-07	2 *	DGIS *	BS6AT	S**
T21	139	5.036E-07	2 *	DGIS *	BS5AT	S**
T21	140	5.036E-07	2 *	DGIS *	BS32T	S**
T21	141	2.357E-07	1 *	BT32T *	BT33T	S**
T21	142	2.357E-07	1 *	BT31T *	BT33T	S**
T21	143	2.357E-07	1 *	BT31T *	BT32T	S**
T21	144	5.434E-07	2 *	CBDGIC *	FIR33	S**
T21	145	5.434E-07	2 *	CBDGIC *	FIR31	S**
T21	146	5.434E-07	2 *	CBDGIC *	FIR32	S**
T21	149	2.255E-07	6 *	CBDGIC *	HEDGI	S**
T21	150	1.071E-07	2 *	DGIR *	FS31T	S**
T21	151	1.071E-07	2 *	DGIR *	FS32T	S**
T21	177	1.071E-07	2 *	DGIR *	FS33T	S**
T21	180	8.948E-04	MAIN31 UNSHEDULED MAINTENANCE ON DIESEL 31			ST
T21	181	8.342E-03	Fraction of time in: MAIN31			SF
T21	182	1.073E-01	Conditional system failure frequency given: MAIN31			SC
T21	183	5.822E-02	2 *	DGTR		S**

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T21   184  4.213E-02    2 *  DGIS                                          S**
T21   185  2.995E-03    2 *  CBDGIC                                        S**
T21   186  1.207E-03    2 *  CBSPIO                                        S**
T21   187  4.943E-04    3 *  DGDR                                          S**
T21   188  4.855E-04    1 *  BT32T                                         S**
T21   189  4.855E-04    1 *  BT31T                                         S**
T21   190  3.924E-04    3 *  DGDS                                          S**
T21   191  1.453E-04    3 *  CBDGDC                                        S**
T21   193  1.110E-04    1 *  DGTR                                          S**
T21   194  1.814E-04    1 *  FIR33                                         S**
T21   195  1.814E-04    1 *  FIR32                                         S**
T21   196  5.857E-05    3 *  CBSPDO                                        S**
T21   197  5.020E-05    2 *  HEDGI                                         S**
T21   198  4.266E-05    1 *  DGTS                                          S**
T21   199  1.580E-05    1 *  CBDGTC                                        S**
T21   200  1.195E-05    1 *  BS6AT                                         S**
T21   201  1.195E-05    1 *  BS32T                                         S**
T21   202  1.195E-05    1 *  BS5AT                                         S**
T21   203  1.195E-05    1 *  BS31T                                         S**
T21   204  6.368E-06    1 *  CBSPTO                                        S**
T21   205  6.090E-06    3 *  HEDGD                                         S**
T21   206  1.840E-06    1 *  FS32T                                         S**
T21   207  1.840E-06    1 *  FS31T                                         S**
T21   208  8.948E-04 MAIN32 UNSHEDULED MAINTENANCE ON DIESEL 32            ST
T21   209  8.342E-03 Fraction of time in: MAIN32                           SF
T21   210  1.073E-01 Conditional system failure frequency given: MAIN32SC
T21   211  5.822E-02    2 *  DGIR                                          S**
T21   212  4.213E-02    2 *  DGIS                                          S**
T21   213  2.995E-03    2 *  CBDGIC                                        S**
T21   214  1.207E-03    2 *  CBSPIO                                        S**
T21   215  4.943E-04    3 *  DGDR                                          S**
T21   216  4.855E-04    1 *  BT33T                                         S**
T21   217  4.855E-04    1 *  BT31T                                         S**
T21   218  3.924E-04    3 *  DGDS                                          S**
T21   219  1.453E-04    3 *  CBDGDC                                        S**
T21   221  1.110E-04    1 *  DGTR                                          S**
T21   222  1.814E-04    1 *  FIR33                                         S**
T21   223  1.814E-04    1 *  FIR31                                         S**
T21   224  5.857E-05    3 *  CBSPDO                                        S**
T21   225  5.020E-05    2 *  HEDGI                                         S**
T21   226  4.266E-05    1 *  DGTS                                          S**
T21   227  1.580E-05    1 *  CBDGTC                                        S**
T21   228  1.195E-05    1 *  BS5AT                                         S**
T21   229  1.195E-05    1 *  BS31T                                         S**
T21   230  1.195E-05    1 *  BS33T                                         S**
T21   231  1.195E-05    1 *  BS2AT                                         S**
T21   232  6.368E-06    1 *  CBSPTO                                        S**
T21   233  6.090E-06    3 *  HEDGD                                         S**
T21   234  1.840E-06    1 *  FS33T                                         S**
T21   235  1.840E-06    1 *  FS31T                                         S**
T21   236  8.948E-04 MAIN33 UNSHEDULED MAINTENANCE ON DIESEL 33            ST
T21   237  8.342E-03 Fraction of time in: MAIN33                           SF
T21   238  1.073E-01 Conditional system failure frequency given: MAIN33SC
T21   239  5.822E-02    2 *  DGIR                                          S**
T21   240  4.213E-02    2 *  DGIS                                          S**
T21   241  2.995E-03    2 *  CBDGIC                                        S**
T21   242  1.207E-03    2 *  CBSPIO                                        S**
T21   243  4.943E-04    3 *  DGDR                                          S**
T21   244  4.855E-04    1 *  BT33T                                         S**
T21   245  4.855E-04    1 *  BT32T                                         S**
T21   246  3.924E-04    3 *  DGDS                                          S**
T21   247  1.453E-04    3 *  CBDGDC                                        S**
T21   249  1.110E-04    1 *  DGTR                                          S**
T21   250  1.814E-04    1 *  FIR32                                         S**
T21   251  1.814E-04    1 *  FIR31                                         S**
T21   252  5.857E-05    3 *  CBSPDO                                        S**
```

T21	253	5.020E-05	2	*	HEDGI			
T21	254	4.266E-05	1	*	DGTS			S**
T21	255	1.580E-05	1	*	CBDGTC			S**
T21	256	1.195E-05	1	*	BS6AT			S**
T21	257	1.195E-05	1	*	BS32T			S**
T21	258	1.195E-05	1	*	BS33T			S**
T21	259	1.195E-05	1	*	BS2AT			S**
T21	260	6.368E-06	1	*	CBSPTO			S**
T21	261	6.090E-06	3	*	HEDGD			S**
T21	262	1.840E-06	1	*	FS33T			S**
T21	263	1.840E-06	1	*	FS32T			S**
T31	1	4.591E-04	TOTAL OFFSITE POWER FAILED,SERVICE WATERGACTUATIOC					C**
T31	2	3.742E-04	NORMAL SYSTEM NOT IN TEST OR MAINTENANCE					ST
T31	3	9.750E-01	Fraction of time in: NORMAL					ST
T31	4	3.839E-04	Conditional system failure frequency given: NORMALSC					
T31	5	1.110E-04	1	*	DGTR			S**
T31	6	5.355E-05	3	*	DGIS	* DGIR	* DGIR	S**
T31	7	4.266E-05	1	*	DGTS			S**
T31	8	3.875E-05	3	*	DGIS	* DGIS	* DGIR	S**
T31	9	2.467E-05	1	*	DGIR	* DGIR	* DGIR	S**
T31	10	2.216E-05	1	*	BRKST			S**
T31	11	1.439E-05	3	*	DGIR	* DGDR		S**
T31	12	1.142E-05	3	*	DGDS	* DGIR		S**
T31	13	1.041E-05	3	*	DGIS	* DGDR		S**
T31	15	9.348E-06	1	*	DGIS	* DGIS	* DGIS	S**
T31	16	8.265E-06	3	*	DGIS	* DGDS		S**
T31	17	7.730E-06	6	*	DGIS	* DGIR	* BRKSI	S**
T31	18	5.934E-06	3	*	DGIR	* BRKSD		S**
T31	19	5.341E-06	3	*	DGIR	* DGIR	* BRKSI	S**
T31	21	4.294E-06	3	*	DGIS	* BRKSD		S**
T31	22	2.797E-06	3	*	DGIS	* DGIS	* BRKSI	S**
T31	24	1.038E-06	3	*	DGDR	* BRKSI		S**
T31	25	8.243E-07	3	*	DGDS	* BRKSI		S**
T31	27	7.630E-07	1	*	HEDGT			S**
T31	28	6.124E-07	2	*	DGIS	* DGIR	* DC31	S**
T31	38	6.124E-07	2	*	DGIS	* DGIR	* DC33	S**
T31	39	6.124E-07	2	*	DGIS	* DGIR	* DC32	S**
T31	40	4.283E-07	3	*	BRKSI	* BRKSD		S**
T31	41	4.231E-07	1	*	DGIR	* DGIR	* DC32	S**
T31	42	4.231E-07	1	*	DGIR	* DGIR	* DC31	S**
T31	43	4.231E-07	1	*	DGIR	* DGIR	* DC33	S**
T31	44	3.855E-07	3	*	DGIR	* BRKSI	* BRKSI	S**
T31	46	2.789E-07	3	*	DGIS	* BRKSI	* BRKSI	S**
T31	47	2.216E-07	1	*	DGIS	* DGIS	* DC31	S**
T31	48	2.216E-07	1	*	DGIS	* DGIS	* DC32	S**
T31	49	2.216E-07	1	*	DGIS	* DGIS	* DC33	S**
T31	50	1.773E-07	3	*	DGIR	* HEDGD		S**
T31	51	1.293E-07	6	*	DGDS	* DGDR		S**
T31	53	1.283E-07	3	*	DGIS	* HEDGD		S**
T31	55	2.225E-07	2	*	DGIS	* DGIR	* FIR33	S**
T31	57	2.225E-07	2	*	DGIS	* DGIR	* FIR32	S**
T31	59	2.225E-07	2	*	DGIS	* DGIR	* FIR31	S**
T31	61	9.235E-08	6	*	DGIS	* DGIR	* HEDGI	S**
T31	63	8.226E-08	1	*	DGDR	* DC31		S**
T31	65	8.226E-08	1	*	DGDR	* DC33		S**
T31	67	8.226E-08	1	*	DGDR	* DC32		S**
T31	69	8.144E-08	3	*	DGDR	* DGDR		S**
T31	70	6.717E-08	6	*	DGDR	* BRKSD		S**
T31	71	1.537E-07	1	*	DGIR	* DGIR	* FIR33	S**
T31	72	1.537E-07	1	*	DGIR	* DGIR	* FIR32	S**
T31	73	1.537E-07	1	*	DGIR	* DGIR	* FIR31	S**
T31	74	6.530E-08	1	*	DGDS	* DC31		S**
T31	75	6.530E-08	1	*	DGDS	* DC33		S**
T31	76	6.530E-08	1	*	DGDS	* DC32		S**
T31	77	6.381E-08	3	*	DGIR	* DGIR	* HEDGI	S**
T31	78	6.107E-08	2	*	DGIR	* DC32	* BRKST	S**

T31	79	4.107E-08	2	*	DGIR	* DC31	* BRKSI	S**
T31	80	4.107E-08	2	*	DGIR	* DC31	* BRKSI	S**
T31	82	5.332E-08	6	*	DGDS	* BRKSD		S**
T31	87	5.132E-08	3	*	DGDS	* DGDS		S**
T31	92	4.420E-08	2	*	DGIS	* DC32	* BRKSI	S**
T31	93	4.420E-08	2	*	DGIS	* DC33	* BRKSI	S**
T31	94	4.420E-08	2	*	DGIS	* DC31	* BRKSI	S**
T31	95	8.052E-08	1	*	DGIS	* DGIS	* FIR33	S**
T31	96	8.052E-08	1	*	DGIS	* DGIS	* FIR31	S**
T31	97	8.052E-08	1	*	DGIS	* DGIS	* FIR32	S**
T31	98	3.393E-08	1	*	DC33	* BRKSD		S**
T31	99	3.393E-08	1	*	DC31	* BRKSD		S**
T31	102	3.393E-08	1	*	DC32	* BRKSD		S**
T31	105	3.342E-08	3	*	DGIS	* DGIS	* HEDGI	S**
T31	108	1.466E-08	2	*	DGIS	* BS5AT	* DGIR	S**
T31	110	1.466E-08	2	*	DGIS	* BS6AT	* DGIR	S**
T31	112	1.466E-08	2	*	DGIS	* BS2AT	* DGIR	S**
T31	113	1.385E-08	3	*	BRKSD	* BRKSD		S**
T31	114	2.989E-08	1	*	DGDR	* FIR31		S**
T31	115	2.989E-08	1	*	DGDR	* FIR33		S**
T31	116	2.989E-08	1	*	DGDR	* FIR32		S**
T31	118	1.279E-08	3	*	HEDGD	* BRKSI		S**
T31	125	1.241E-08	3	*	DGDR	* HEDGI		S**
T31	126	2.373E-08	1	*	DGDS	* FIR33		S**
T31	127	2.373E-08	1	*	DGDS	* FIR32		S**
T31	131	2.373E-08	1	*	DGDS	* FIR31		S**
T31	134	1.013E-08	1	*	BS5AT	* DGIR	* DGIR	S**
T31	140	1.013E-08	1	*	BS6AT	* DGIR	* DGIR	S**
T31	155	1.013E-08	1	*	BS2AT	* DGIR	* DGIR	S**
T31	182	9.848E-09	3	*	DGDS	* HEDGI		S**
T31	204	2.219E-08	2	*	DGIR	* FIR31	* BRKSI	S**
T31	226	2.219E-08	2	*	DGIR	* FIR33	* BRKSI	S**
T31	227	2.219E-08	2	*	DGIR	* FIR32	* BRKSI	S**
T31	228	9.273E-09	1	*	BRKSI	* BRKSI	* BRKSI	S**
T31	229	9.210E-09	6	*	DGIR	* HEDGI	* BRKSI	S**
T31	230	7.257E-09	1	*	DGIR	* DC31	* DC33	S**
T31	231	7.257E-09	1	*	DGIR	* DC31	* DC32	S**
T31	232	7.257E-09	1	*	DGIR	* DC32	* DC33	S**
T31	233	1.606E-08	2	*	DGIS	* FIR32	* BRKSI	S**
T31	236	1.606E-08	2	*	DGIS	* FIR33	* BRKSI	S**
T31	239	1.606E-08	2	*	DGIS	* FIR31	* BRKSI	S**
T31	242	6.665E-09	6	*	DGIS	* HEDGI	* BRKSI	S**
T31	244	5.304E-09	1	*	DGIS	* DGIS	* BS6AT	S**
T31	246	5.304E-09	1	*	DGIS	* DGIS	* BS2AT	S**
T31	247	5.304E-09	1	*	DGIS	* DGIS	* BS5AT	S**
T31	248	1.233E-08	1	*	FIR32	* BRKSD		S**
T31	249	1.233E-08	1	*	FIR31	* BRKSD		S**
T31	250	1.233E-08	1	*	FIR33	* BRKSD		S**
T31	254	5.252E-09	1	*	DGIS	* DC32	* DC33	S**
T31	257	5.252E-09	1	*	DGIS	* DC31	* DC32	S**
T31	258	5.252E-09	1	*	DGIS	* DC31	* DC33	S**
T31	315	5.117E-09	3	*	HEDGI	* BRKSD		S**
T31	316	2.827E-05	MAIN31 UNSHEDULED MAINTENANCE ON DIESEL 31					ST
T31	317	8.342E-03	Fraction of time in: MAIN31					SF
T31	318	3.389E-03	Conditional system failure frequency given: MAIN31					SC
T31	319	1.226E-03	2	*	DGIS	* DGIR		S**
T31	320	8.474E-04	1	*	DGIR	* DGIR		S**
T31	321	4.438E-04	1	*	DGIS	* DGIS		S**
T31	322	1.648E-04	1	*	DGDR			S**
T31	323	1.308E-04	1	*	DGDS			S**
T31	324	1.223E-04	2	*	DGIR	* BRKSI		S**
T31	325	1.110E-04	1	*	DGTR			S**
T31	326	8.852E-05	2	*	DGIS	* BRKSI		S**
T31	327	6.795E-05	1	*	BRKSD			S**
T31	328	4.266E-05	1	*	DGTS			S**
T31	329	2.216E-05	1	*	BRKST			S**

T31	334	1.453E-05	1	*	DGIR	*	DC31	S**
T31	335	1.453E-05	1	*	DGIR	*	DC32	S**
T31	337	1.052E-05	1	*	DGIS	*	DC32	S**
T31	338	1.052E-05	1	*	DGIS	*	DC31	S**
T31	339	9.592E-06	2	*	DGIR	*	DGDR	S**
T31	342	7.614E-06	2	*	DGDS	*	DGIR	S**
T31	350	6.942E-06	2	*	DGIS	*	DGDR	S**
T31	351	5.510E-06	2	*	DGIS	*	DGDS	S**
T31	352	4.414E-06	1	*	BRKSI	*	BRKSI	S**
T31	354	3.956E-06	2	*	DGIR	*	BRKSD	S**
T31	358	2.863E-06	2	*	DGIS	*	BRKSD	S**
T31	360	5.282E-06	1	*	DGIR	*	FIR32	S**
T31	363	5.282E-06	1	*	DGIR	*	FIR33	S**
T31	365	2.030E-06	1	*	HEDGD			S**
T31	375	3.822E-06	1	*	DGIS	*	FIR32	S**
T31	377	3.822E-06	1	*	DGIS	*	FIR33	S**
T31	378	1.461E-06	2	*	DGIR	*	HEDGI	S**
T31	379	1.058E-06	2	*	DGIS	*	HEDGI	S**
T31	380	1.049E-06	1	*	DC32	*	BRKSI	S**
T31	381	1.049E-06	1	*	DC31	*	BRKSI	S**
T31	382	7.630E-07	1	*	HEDGT			S**
T31	383	6.922E-07	2	*	DGDR	*	BRKSI	S**
T31	384	5.496E-07	2	*	DGDS	*	BRKSI	S**
T31	385	3.479E-07	1	*	BS6AT	*	DGIR	S**
T31	386	3.479E-07	1	*	BS5AT	*	DGIR	S**
T31	388	2.855E-07	2	*	BRKSI	*	BRKSD	S**
T31	393	2.518E-07	1	*	DGIS	*	BS6AT	S**
T31	398	2.518E-07	1	*	DGIS	*	BS5AT	S**
T31	399	2.493E-07	1	*	DC31	*	DC32	S**
T31	400	3.812E-07	1	*	FIR33	*	BRKSI	S**
T31	401	3.812E-07	1	*	FIR32	*	BRKSI	S**
T31	402	1.182E-07	2	*	DGIR	*	HEDGD	S**
T31	403	1.055E-07	2	*	HEDGI	*	BRKSI	S**
T31	404	8.553E-08	2	*	DGIS	*	HEDGD	S**
T31	405	8.226E-08	1	*	DGDR	*	DC31	S**
T31	406	8.226E-08	1	*	DGDR	*	DC32	S**
T31	408	6.530E-08	1	*	DGDS	*	DC31	S**
T31	409	6.530E-08	1	*	DGDS	*	DC32	S**
T31	411	4.310E-08	2	*	DGDS	*	DGDR	S**
T31	414	9.059E-08	1	*	DC32	*	FIR33	S**
T31	416	9.059E-08	1	*	DC31	*	FIR32	S**
T31	418	3.393E-08	1	*	DC32	*	BRKSD	S**
T31	419	3.393E-08	1	*	DC31	*	BRKSD	S**
T31	420	2.827E-05	MAIN32 UNSHEDULED MAINTENANCE ON DIESEL 32					ST
T31	421	8.342E-03	Fraction of time in: MAIN32					SF
T31	422	3.389E-03	Conditional system failure frequency given: MAIN32					SC
T31	423	1.226E-03	2	*	DGIS	*	DGIR	S**
T31	424	8.474E-04	1	*	DGIR	*	DGIR	S**
T31	425	4.438E-04	1	*	DGIS	*	DGIS	S**
T31	426	1.648E-04	1	*	DGDR			S**
T31	427	1.308E-04	1	*	DGDS			S**
T31	428	1.223E-04	2	*	DGIR	*	BRKSI	S**
T31	429	1.110E-04	1	*	DGTR			S**
T31	430	8.852E-05	2	*	DGIS	*	BRKSI	S**
T31	431	6.795E-05	1	*	BRKSD			S**
T31	432	4.266E-05	1	*	DGTS			S**
T31	433	2.216E-05	1	*	BRKST			S**
T31	434	1.453E-05	1	*	DGIR	*	DC33	S**
T31	437	1.453E-05	1	*	DGIR	*	DC31	S**
T31	438	1.052E-05	1	*	DGIS	*	DC31	S**
T31	439	1.052E-05	1	*	DGIS	*	DC33	S**
T31	443	9.592E-06	2	*	DGIR	*	DGDR	S**
T31	446	7.614E-06	2	*	DGDS	*	DGIR	S**
T31	454	6.942E-06	2	*	DGIS	*	DGDR	S**
T31	455	5.510E-06	2	*	DGIS	*	DGDS	S**
T31	456	4.414E-06	1	*	BRKST	*	BRKST	S**

T31	460	3.[illegible]E-06	1	*	DGIR	* BRKSD	
T31	462	2.903E-06	1	*	DGIS	* BRKSD	S**
T31	464	5.282E-06	1	*	DGIR	* FIR31	S**
T31	467	5.282E-06	1	*	DGIR	* FIR33	S**
T31	469	2.030E-06	1	*	HEDGD		S**
T31	479	3.822E-06	1	*	DGIS	* FIR33	S**
T31	481	3.822E-06	1	*	DGIS	* FIR31	S**
T31	482	1.461E-06	2	*	DGIR	* HEDGI	S**
T31	483	1.058E-06	2	*	DGIS	* HEDGI	S**
T31	484	1.049E-06	1	*	DC33	* BRKSI	S**
T31	485	1.049E-06	1	*	DC31	* BRKSI	S**
T31	486	7.630E-07	1	*	HEDGT		S**
T31	487	6.923E-07	2	*	DGDR	* BRKSI	S**
T31	488	5.496E-07	2	*	DGDS	* BRKSI	S**
T31	489	3.479E-07	1	*	BS2AT	* DGIR	S**
T31	490	3.479E-07	1	*	BS5AT	* DGIR	S**
T31	492	2.855E-07	2	*	BRKSI	* BRKSD	S**
T31	497	2.518E-07	1	*	DGIS	* BS5AT	S**
T31	502	2.518E-07	1	*	DGIS	* BS2AT	S**
T31	503	2.493E-07	1	*	DC31	* DC33	S**
T31	504	3.812E-07	1	*	FIR31	* BRKSI	S**
T31	505	3.812E-07	1	*	FIR33	* BRKSI	S**
T31	506	1.182E-07	2	*	DGIR	* HEDGD	S**
T31	507	1.055E-07	2	*	HEDGI	* BRKSI	S**
T31	508	8.553E-08	2	*	DGIS	* HEDGD	S**
T31	509	8.226E-08	1	*	DGDR	* DC31	S**
T31	510	8.226E-08	1	*	DGDR	* DC33	S**
T31	512	6.530E-08	1	*	DGDS	* DC31	S**
T31	513	6.530E-08	1	*	DGDS	* DC33	S**
T31	515	4.310E-08	2	*	DGDS	* DGDR	S**
T31	518	9.059E-08	1	*	DC33	* FIR33	S**
T31	520	9.059E-08	1	*	DC31	* FIR31	S**
T31	522	3.393E-08	1	*	DC33	* BRKSD	S**
T31	523	3.393E-08	1	*	DC31	* BRKSD	S**
T31	524	2.827E-05	MAIN33 UNSHEDULED MAINTENANCE ON DIESEL 33				S**
T31	525	8.342E-03	Fraction of time in: MAIN33				ST
T31	526	3.389E-03	Conditional system failure frequency given: MAIN33				SF
T31	527	1.226E-03	2	*	DGIS	* DGIR	SC
T31	528	8.474E-04	1	*	DGIR	* DGIR	S**
T31	529	4.438E-04	1	*	DGIS	* DGIS	S**
T31	530	1.648E-04	1	*	DGDR		S**
T31	531	1.308E-04	1	*	DGDS		S**
T31	532	1.223E-04	2	*	DGIR	* BRKSI	S**
T31	533	1.110E-04	1	*	DGTR		S**
T31	534	8.852E-05	2	*	DGIS	* BRKSI	S**
T31	535	6.795E-05	1	*	BRKSD		S**
T31	536	4.266E-05	1	*	DGTS		S**
T31	537	2.216E-05	1	*	BRKST		S**
T31	538	1.453E-05	1	*	DGIR	* DC33	S**
T31	541	1.453E-05	1	*	DGIR	* DC32	S**
T31	542	1.052E-05	1	*	DGIS	* DC32	S**
T31	543	1.052E-05	1	*	DGIS	* DC33	S**
T31	547	9.592E-06	2	*	DGIR	* DGDR	S**
T31	550	7.614E-06	2	*	DGDS	* DGIR	S**
T31	558	6.942E-06	2	*	DGIS	* DGDR	S**
T31	559	5.510E-06	2	*	DGIS	* DGDS	S**
T31	560	4.414E-06	1	*	BRKSI	* BRKSI	S**
T31	562	3.956E-06	2	*	DGIR	* BRKSD	S**
T31	566	2.863E-06	2	*	DGIS	* BRKSD	S**
T31	568	5.282E-06	1	*	DGIR	* FIR31	S**
T31	571	5.282E-06	1	*	DGIR	* FIR32	S**
T31	573	2.030E-06	1	*	HEDGD		S**
T31	583	3.822E-06	1	*	DGIS	* FIR32	S**
T31	585	3.822E-06	1	*	DGIS	* FIR31	S**
T31	586	1.461E-06	2	*	DGIR	* HEDGI	S**
T31	587	1.058E-06	2	*	DGIS	* HEDGI	S**
							S**

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T31   590  [illegible]  1 *  DG1S *  BRKSI                                  S**
T31   591  [illegible]  1 *  DG1S *  BRKSI                                  S**
T31   590  7.630E-07    1 *  HEDGT                                          S**
T31   591  6.923E-07    2 *  DGDR *  BRKSI                                  S**
T31   592  5.496E-07    1 *  DGDS *  BRKSI                                  S**
T31   593  3.479E-07    1 *  BS2AT *  DGIR                                  S**
T31   594  3.479E-07    1 *  BS6AT *  DGIR                                  S**
T31   596  2.855E-07    2 *  BRKSI *  BRKSD                                 S**
T31   601  2.518E-07    1 *  DGIS *  BS6AT                                  S**
T31   606  2.518E-07    1 *  DGIS *  BS2AT                                  S**
T31   607  2.493E-07    1 *  DC32 *  DC33                                   S**
T31   608  3.812E-07    1 *  FIR31 *  BRKSI                                 S**
T31   609  3.812E-07    1 *  FIR32 *  BRKSI                                 S**
T31   610  1.182E-07    2 *  DGIR *  HEDGD                                  S**
T31   611  1.055E-07    2 *  HEDGI *  BRKSI                                 S**
T31   612  8.553E-08    2 *  DGIS *  HEDGD                                  S**
T31   613  8.226E-08    1 *  DGDR *  DC32                                   S**
T31   614  8.226E-08    1 *  DGDR *  DC33                                   S**
T31   616  6.530E-08    1 *  DGDS *  DC32                                   S**
T31   617  6.530E-08    1 *  DGDS *  DC33                                   S**
T31   619  4.310E-08    2 *  DGDS *  DGDR                                   S**
T31   622  9.059E-08    1 *  DC33 *  FIR32                                  S**
T31   624  9.059E-08    1 *  DC32 *  FIR31                                  S**
T31   626  3.393E-08    1 *  DC33 *  BRKSD                                  S**
T31   627  3.393E-08    1 *  DC32 *  BRKSD                                  S**
FOA     1  3.361E-05 TOTAL  OFFSITE POWER FAILED,SERVICE WATER&ACTUATIOS
FOA     2  3.361E-05 NORMAL SYSTEM NOT UNDERGOING TEST OR MAINTENANCES ST
FOA     3  1.000E+00 Fraction of time in: NORMAL                           SF
FOA     4  3.361E-05 Conditional system failure frequency given: NORMALSC
FOA     5  3.228E-05    1 *  PMTS                                          S**
FOA     6  9.084E-07    3 *  PMIS *  PMDS                                  S**
FOA    13  2.878E-07    1 *  PMTR                                          S**
FOA    15  6.031E-08    3 *  PMDS *  PMIR                                  S**
FOA    17  2.938E-08    3 *  PMDS *  PMDS                                  S**
FOA    19  2.865E-08    1 *  PMIS *  PMIS *  PMIS                          S**
FOA    20  8.098E-09    3 *  PMIS *  PMDR                                  S**
FOA    21  5.706E-09    3 *  PMIS *  PMIS *  PMIR                          S**
FOA    22  5.377E-10    3 *  PMIR *  PMDR                                  S**
FOA    23  5.239E-10    6 *  PMDS *  PMDR                                  S**
FOA    24  4.917E-10    1 *  CBC6BT *  PMDS                                S**
FOA    76  4.917E-10    1 *  CBC6CT *  PMDS                                S**
FOA    77  4.917E-10    1 *  CBC6AT *  PMDS                                S**
FOA    78  3.788E-10    3 *  PMIS *  PMIR *  PMIR                          S**
FO1     1  1.438E-04 TOTAL  POWER TO PUMP 33 FROM BUS 5A NOT AVAILABLESS
FO1     2  1.438E-04 NORMAL SYSTEM NOT UNDERGOING TEST OR MAINTENANCES ST
FO1     3  1.000E+00 Fraction of time in: NORMAL                           SF
FO1     4  1.438E-04 Conditional system failure frequency given: NORMALSC
FO1     5  9.897E-05    1 *  PMDS                                          S**
FO1     6  3.228E-05    1 *  PMTS                                          S**
FO1    15  9.362E-06    1 *  PMIS *  PMIS                                  S**
FO1    16  1.243E-06    2 *  PMIS *  PMIR                                  S**
FO1    17  8.822E-07    1 *  PMDR                                          S**
FO1    18  6.056E-07    2 *  PMIS *  PMDS                                  S**
FO1    19  2.878E-07    1 *  PMTR                                          S**
FO1    22  4.127E-08    1 *  PMIR *  PMIR                                  S**
FO1    26  4.021E-08    2 *  PMDS *  PMIR                                  S**
FO1    29  1.520E-08    1 *  CBC6BT *  PMIS                                S**
FO1    32  1.520E-08    1 *  CBC6CT *  PMIS                                S**
FO1    34  9.794E-09    1 *  PMDS *  PMDS                                  S**
FO1    36  9.143E-09    1 *  BS36CT *  PMIS                                S**
FO1    37  9.143E-09    1 *  BS36BT *  PMIS                                S**
FO1    38  5.399E-09    2 *  PMIS *  PMDR                                  S**
TX1     1  2.271E-03 TOTAL  OFFSITE POWER FAILED,SERVICE WATER&ACTUATIOS
TX1     2  2.271E-03 NORMAL SYSTEM NOT IN TEST OR MAINTENANCE              ST
TX1     3  1.000E+00 Fraction of time in: NORMAL                           SF
TX1     4  2.271E-03 Conditional system failure frequency given: NORMALSC
```

```
TX1     5   1.010E-02    1 *   [illegible]
TX1     6   6.490E-04    1 *   CB3AC
TX1     7   1.195E-05    1 *   BC3AT
```

Definitions of Cutset Basic Events That Do Not Appear in the Fault Trees

PMIS	Independent Failure of a Fuel Oil Transfer Pump To Start on Demand
PMDS	Double Failure of Fuel Oil Transfer Pumps To Start on Demand
PMTS	Failure of All Three Fuel Oil Transfer Pumps To Start on Demand
PMIR	Independent Failure of Fuel Oil Pump To Run After Starting
PMDR	Double Failure of Fuel Oil Pumps To Run After Starting
PMTR	Failure of All Three Fuel Oil Pumps To Run After Starting
DGIS	Independent Failure of a Diesel Generator To Start on Demand
DGDS	Double Failure of Diesel Generators To Start on Demand
DGTS	Failure of All Three Diesel Generators To Start on Demand from a Single Cause
DGIR	Independent Failure of a Diesel Generator To Run After Starting
DGDR	Double Failure of Diesel Generators To Run After Starting
DGTR	Failure of All Three Diesel Generators To Run After Starting
BRKSI	Independent Failure of a Breaker To Close or Open on Demand
BRKSD	Double Failure of Breakers To Close or Open on Demand
BRKST	Failure of All Three Trains of Breakers To Close or Open on Demand
HEDGI	Human Error in Restoring One Diesel Generator To AUTO After Testing
HEDGD	Human Error in Restoring Two Diesel Generators To AUTO After Testing
HEDGT	Human Error in Restoring All Three Diesel Generators To AUTO After Testing
DC31	Failure of DC Power at Panel 31
DC32	Failure of DC Power at Panel 32
DC33	Failure of DC Power at Panel 33

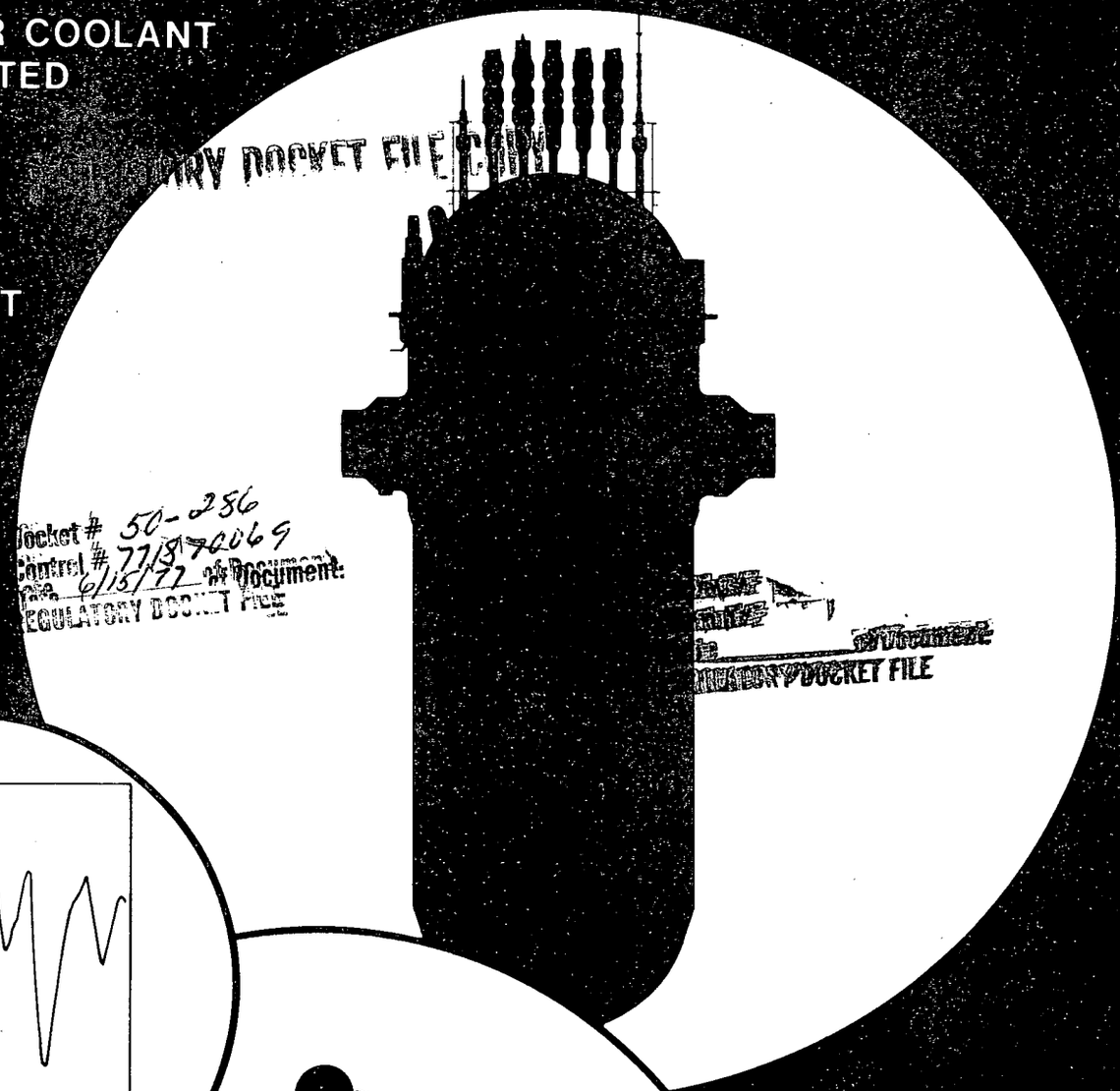
PROP

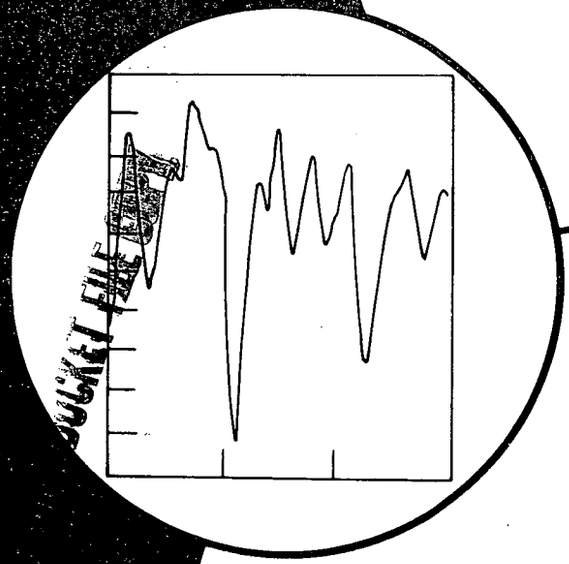
ANALYSIS OF REACTOR COOLANT SYSTEM FOR POSTULATED LOSS-OF-COOLANT ACCIDENT :

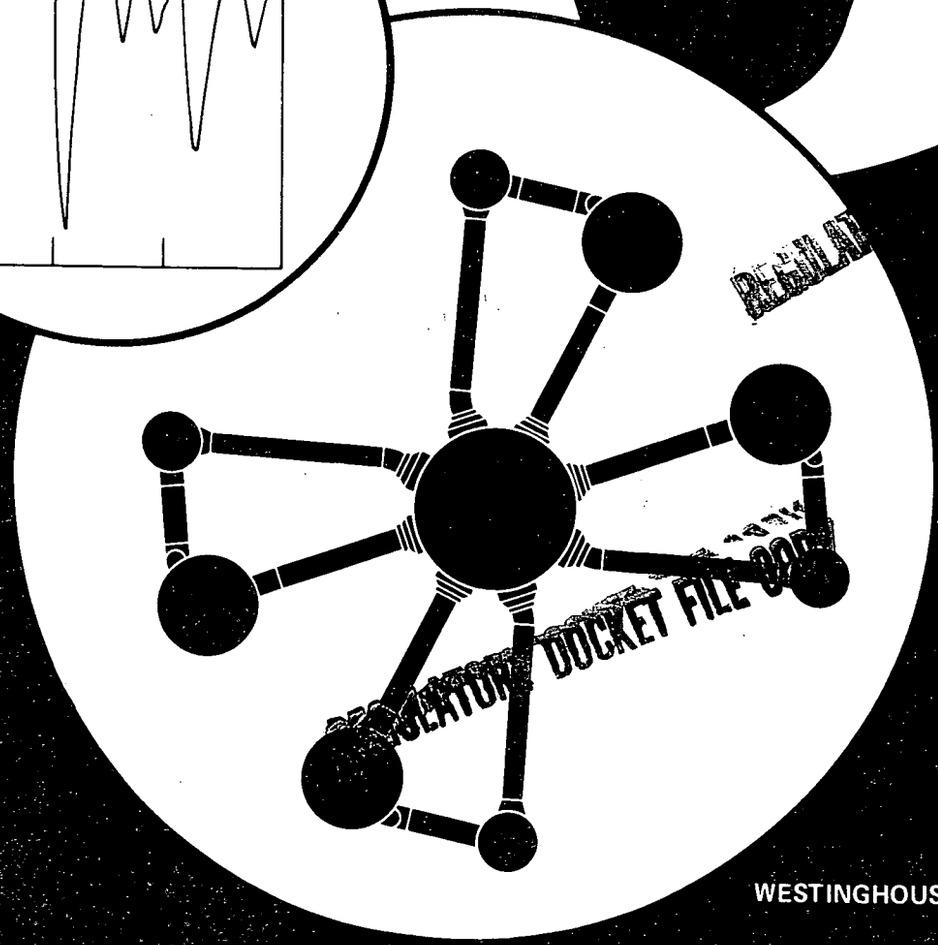
INDIAN POINT UNIT 3 NUCLEAR POWER PLANT

WCAP-9117

JUNE 1977







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WESTINGHOUSE PROPRIETARY CLASS 2

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