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Subject: **NEDO-33201, Revision 1, "ESBWR Probabilistic Risk Assessment," Sections 2 through 6**

Enclosure 1 contains the subject partial ESBWR Probabilistic Risk Assessment (PRA) document (Revision 1). The complete PRA document (including the sections transmitted herein) will be issued in accordance with the Reference 1 letter.

If you have any questions about the information provided here, please let me know.

Sincerely,

David H. Hinds
Manager, ESBWR

Reference:

1. MFN 06-015, Letter from David H. Hinds to U.S. Nuclear Regulatory Commission, *Submittal Schedule for Documents Related to ESBWR Probabilistic Risk Assessment*, January 16, 2006

D068

Enclosure:

1. MFN 06-049 – NEDO-33201, Revision 1, "ESBWR Probabilistic Risk Assessment:"
   - Section 2 – Initiating Events
   - Section 3 – Accident Sequence Analysis
   - Section 4 – System Analysis
   - Section 5 – Data Analysis
   - Section 6 – Human Reliability Analysis

cc: WD Beckner USNRC (w/o enclosures)
AE Cubbage USNRC (with enclosures)
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GB Stramback GE/San Jose (with enclosures)
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ENCLOSURE 1

MFN 06-049

NEDO-33201, Revision 1, "ESBWR Probabilistic Risk Assessment:"

- Section 2 – Initiating Events
- Section 3 – Accident Sequence Analysis
- Section 4 – System Analysis
- Section 5 – Data Analysis
- Section 6 – Human Reliability Analysis

2 INITIATING EVENTS

Contents

List of Tables

2 INITIATING EVENTS

2.1 INTRODUCTION

Event trees are used in a PRA to model discrete accident sequences. An accident sequence is comprised of an initiating event followed by challenges to system successes and failures that lead to either safe, stable plant conditions or to a plant condition that is considered unacceptable. An initiating event is any occurrence that disrupts normal plant operations sufficiently to require a reactor trip by either automatic or manual action. An initiating event may occur due to a random component failure or a human action, thus requiring plant systems to respond to maintain the unit in a safe, stable condition. The initiating event marks the starting point of the accident sequence analysis.

One of the first and basic steps in a PRA is the identification and quantification of the initiating events to be used in the sequence analysis. Initiating events have historically been broadly classified as either "internal" or "external" events. The initiating events discussed in this section are limited to at-power internal initiating events, that is, those initiating events occurring during power operation either as a direct result of equipment failure, or as the result of errors while performing maintenance, testing, or any other operator action. External initiating events (e.g., seismic events, internal floods) and initiating events during shutdown are discussed in other sections.

Initiating event analysis involves the following two major steps:

(1) Identification and grouping

(2) Frequency quantification

Each of these key steps is discussed below.

2.2 INITIATING EVENT IDENTIFICATION AND CATEGORIZATION

In order to identify the list of initiating events to be considered in the analysis, the following steps are taken:

(1) Identification of the set of initiating events applicable to the ESBWR plant by reviewing NUREG/CR-5750 (Reference 2-1)

(2) Analysis of the failure of individual ESBWR systems that could result in additional initiating events

Human error induced initiating events are considered for all of these analyses.

Individual initiating events requiring the same response from front line and auxiliary systems and operators are combined into initiating event categories. Combining initiating events into categories reduces the number of event trees that need to be developed. The four major groups of internal initiating events are:

(1) Transients

(2) Loss of preferred power (LOPP)

(3) Loss of coolant accidents (LOCA)

(4) Special initiators

These major groups are consistent with the ASME PRA Standard. The categorization of initiating events within each of these major groups is discussed below.

The postulated initiating events to be addressed in the PRA are derived from a review of BWR operating experience, as summarized in the NUREG/CR-5750 (Reference 2-1). NUREG/CR-5750 builds upon previous industry studies with similar objectives, such as EPRI Report NP-2230 (Reference 2-2) published in 1982 and NUREG/CR-3862 (Reference 2-3), published in 1985. The NUREG/CR-5750 categories are applicable, in general, to all BWR (and PWR) plants that are currently in operation. The NUREG/CR-5750 initiating event categories are listed in Table 2.2-1.

Many systems in the ESBWR design differ from those for the operating BWR plants. In addition, the ESBWR design features several innovative systems; as such, certain NUREG/CR-5750 categories are not directly applicable to the ESBWR. These are indicated in Table 2.2-1.

2.2.1 Transients

The transient initiating event categories are developed based on the following considerations:

- Effect of the initiator on feedwater and power conversion system (PCS) availability.
- Effect of the initiator on systems required to prevent core damage or containment failure.
- Successful configuration (e.g., mode of operation, number of pumps in operation) of mitigating systems.
- Effect of the initiator on operator response.

The resulting transient initiating event categories for the ESBWR PRA are as follows:

- General Transient
- Transient with Power Conversion System (PCS) Unavailable
- Loss of Feedwater
- Inadvertent Opening of SRV (IORV)

The results of this analysis and the NUREG/CR-5750 initiating events grouped into each ESBWR PRA initiating event category are summarized in Table 2.2-2.

2.2.2 Loss of Preferred Power

The Loss of Preferred Power (LOPP) initiating event category of the ESBWR PRA corresponds to the NUREG/CR-5750 category (B1) Loss of Offsite Power.

2.2.3 LOCAs

Loss of coolant accident (LOCA) initiator categories are defined based on approaches in previous BWR PRAs, plant specific configuration, and success criteria.

LOCA initiators are classified according to the following main factors:

(1) Level position: steam breaks (for pipes above Level 3) or liquid breaks (for pipes below Level 3)

(2) Break size: large, medium, or small nominal classifications are used

(3) Pipe function: Emergency Core Cooling System (ECCS) line break or non-ECCS line break (the former affects ECCS operability)

(4) Location: inside/outside containment breaks (breaks outside containment potentially can be isolated)

(5) Pipe class: LOCAs can be postulated for situations in which valves between the reactor coolant pressure boundary (RCPB) and non-RCPB segments fail, propagating high pressure to low pressure design pipes

(6) Coolability: coolable LOCAs (all the above categories) or non-coolable LOCAs (vessel rupture)

2.2.3.1 LOCAs Inside Containment

LOCAs inside containment initiators are failures of the RCPB that occur inside the containment during power operation. LOCAs inside containment are categorized into the following LOCA sizes:

- <u>Large</u>: RPV depressurizes sufficiently (without the need for additional depressurization methods) to allow GDCS injection prior to uncovering the top of active fuel (TAF).

- Medium (Steam): RPV depressurizes sufficiently (without the need for additional depressurization methods) to allow Fire Protection System (FPS) injection prior to uncovering TAF.
- Medium (Liquid): CRD insufficient makeup source. RPV depressurization required for low pressure injection.
- Small: CRD sufficient makeup source. RPV depressurization required for low pressure injection.

The lower limit of LOCAs is defined as a primary system crack or leakage small enough to be managed by normal operation water makeup and containment cooling systems. The Turbine Trip initiating event category models this level of RCPB leakage.

An analysis was performed to establish the appropriate LOCA classification for each line connected to the RCPB. Table 2.2-3 summarizes the number, the diameter, and the nozzle elevation of lines connected to the RCPB. For each line, Table 2.2-3 classifies the breaks into Large, Medium, and Small LOCA sizes according to the pipe cross-section area, and whether it is a liquid or steam break. Criteria for the classifications are:

- Pipes connected to the RPV at elevations above Level 3 are classified as steam breaks (even though a liquid phase is initially discharged through the break).
- Pipes connected to the RPV at elevations below Level 3 are classified as liquid breaks.

The Emergency Procedure Guidelines drive the operator to maintain reactor vessel level between Level 3 and Level 8 after reactor trip, so any LOCA below Level 3 results in the continual release of water through the break, provided that an injection system into the vessel is available.

As such, the LOCA categories in terms of location and diameter are as follows:

- Large (steam): >305 mm (12") dia. piping above Level 3
- Large (liquid): >305 mm (12") dia. Piping below Level 3
- Medium (steam): 264mm (10.4") – 305 mm (12") dia. piping above Level 3
- Medium (liquid): 25 mm (1") – 305 mm (12") dia. piping below Level 3
- Small (steam): <264 mm (10.4") dia. piping above Level 3
- Small (liquid): <25 mm (1") dia. piping below Level 3

The diameter of an orifice or a nozzle in a line, when it exists, is considered in the break size classification.

The initiating event categorization for LOCAs inside containment is summarized below.

Large Break LOCA

The large break LOCA is sufficiently large to depressurize the reactor to permit low pressure system injection, without the need for additional depressurization methods. The ESBWR design does not contain any piping with diameters greater than 12" below Level 3, thus, all breaks

analyzed are steam breaks, (refer to Table 2.3-3). Inadvertent opening of all DPV/SRV are also included in this group.

This initiating event category corresponds to the NUREG/CR-5750 category (G7) Large Pipe Break LOCA.

Medium Break LOCA

- Steam break case - The medium break steam LOCA is large enough to depressurize the reactor sufficiently to permit low pressure system injection (except GDCS) without the need for additional RPV depressurization methods. No ESBWR lines fall into this category (refer to Table 2.2-3).
- Liquid break case - The flow rate at reactor pressure for a medium break liquid LOCA is greater than the CRD makeup capacity. Depressurization is needed for GDCS injection to be effective. A number of ESBWR lines fall into this category (refer to Table 2.2-3)

This initiating event category corresponds to the NUREG/CR-5750 category (G6) Medium Pipe Break LOCA.

Small Break LOCA

- Steam break case - The small break steam LOCA is sufficiently small such that RPV depressurization is needed for effective low pressure injection (including LPCI and condensate). ESBWR instrument lines above Level 3 fall into this category (refer to Table 2.2-3). Inadvertent opening of a DPV is included in this group.

  The consequences of an inadvertent opening of one SRV (IORV) are similar to the consequences of a small steam LOCA; however, IORV is analyzed separately as a transient because of the steam discharge to the suppression pool versus the drywell.
- Liquid break case - CRD is a viable high pressure injection source, as the flow rate for a small break liquid LOCA is less than the CRD makeup capacity. RPV depressurization is needed for effective low pressure system injection. ESBWR instrument lines below Level 3 fall into this category (refer to Table 2.3-3).

This initiating event category corresponds to the NUREG/CR-5750 category (G3) Small Pipe Break LOCA.

Vessel Rupture

The vessel rupture initiating event category is defined as a random failure of the reactor vessel below Level 3.

2.2.3.2 LOCAs Outside Containment

LOCAs outside containment are defined as breaks in high pressure systems outside the containment. The break can be isolated by closure of the isolation valves (break isolation is addressed in the accident sequence analysis).

This initiating event category corresponds to NUREG/CR-5750 categories (K1) Steam Line Break Outside Containment and (K2) Feedwater Line Break.

2.2.3.3 Interfacing LOCAs

An interfacing LOCA is a break in a low pressure system connected to the reactor vessel as a result of a failure of the low/high pressure barrier leading to an un-isolable loss of coolant outside the containment. This initiating event category corresponds to NUREG/CR-5750 category (N1) Interfacing System LOCA.

2.2.4 Special Initiators

Special initiating events refer to plant-specific systemic malfunctions that can lead to a plant trip. A new initiating category is identified when the event is not associated with any of the categories defined before; otherwise, it is grouped into one of the defined categories and the frequency of the existing category is modified to account for the contribution of the systemic malfunction.

In general, all systems that can influence the parameters involved with the scram or isolation signals (either directly or as a consequence) are analyzed. The list of systems analyzed is as follows:

Front line systems

- Control Rod Drive System (CRD)
- Feedwater / Condensate
- Isolation Condenser System (IC)
- Depressurization System (DPV/SRV)
- Gravity Driven Cooling System (GDCS)
- Fuel and Auxiliary Pool Cooling (FAPC) System
- Reactor Water Cleanup / Shutdown Cooling System (RWCU/SDCS)
- Standby Liquid Control System (SLCS)

Support Systems

- Reactor Component Cooling Water System (RCCW)
- Turbine Component Cooling Water System (TCCW)
- Plant Service Water System (PSWS)
- Air Systems (HPNSS, Service Air, Instrument Air)
- 13.8 kVAC and 6.9 kVAC bus system
- 250VDC bus system
- Reactor Water Level Instrumentation (RWLI) System
- Drywell Cooling System

For each of these systems, the possibility for the generation of scram or isolation signals due to a spurious actuation or a variation of the system configuration resulting from a human error or hardware failure is investigated. The effect of a pipe break in these systems is also considered.

A qualitative screening analysis has been performed to eliminate errors or failures which are not credible or which do not contribute to a scram initiation or isolation function. This analysis is described in the subsections below.

2.2.4.1 Control Rod Drive System

The CRD system has one pump in operation at all times during normal plant operation. The other pump is in standby and starts automatically upon a reactor water Level 2 signal.

In normal operation the system performs the following functions:

- Charging of hydraulic control units
- Supply of purging water to the control rod drives (CRD), RWCU/SDC pumps and reactor water level reference leg instrument lines

Refer to Section 4.3 for a description and simplified diagram of the system.

The following malfunctions are considered:

a. Trip of the operating pump: No major effects are expected because at the time of the pump trip the hydraulic control units are charged and the check valve on the charging line prevents their discharge. Also, loss of purge does not impair the Fine Motion Control Rod Drive (FMCRD) function in the short term.

b. Spurious actuation of the standby pump and opening of the injection valve: This malfunction results in additional inventory of cold water entering the reactor pressure vessel (RPV) from the feedwater line. Because the feedwater system is able to regulate the injection flow (by level control) and the temperature reduction of the total flow entering the vessel is negligible when feedwater is operating, no consequences are expected from this event.

c. Injection line break downstream of the check valves (isolating CRD from RWCU line): This line is common to the injection of CRD and RWCU train A; because it belongs to RWCU, the consequences of this event are analyzed within RWCU below.

2.2.4.2 Feedwater / Condensate

The Feedwater and Condensate systems are in operation at all times during normal plant operation. Refer to Section 4.9 for a description and simplified diagrams of these systems.

The following malfunctions are considered:

a. FW controller malfunction (reactor water level increase): The FW controller is single failure proof. Therefore, the FW controller failure is much less likely to occur in the ESBWR than in current generation reactors.

   In addition, there is the added protection of a FW runback, closure signals to the high pressure makeup (CRD) flow control valves on reactor water Level 8, and trip of the FW pumps on reactor water Level 9. A scram occurs on reactor water Level 8; this event is included in the General Transient initiating event category.

In case a high reactor water level trip signal does not operate and the operator does not perform backup action, the following Main Steam Line (MSL) flooding scenarios can be postulated:

- MSL break: this event is similar to a steam LOCA event.
- MSL does not break and IC does not operate: in this case, the SRV opens and discharges water. A break of the SRV discharge might occur and cause a LOCA inside the drywell. The consequence of this event is be bounded by the Small Steam LOCA event.
- No pipe break occurs, the IC is not operating, and the SRV remains stuck open: The consequence of this event is bounded by the IORV event.

The frequency of all the above failures is estimated to be below any LOCA frequency.

b. FW controller malfunctions (reactor water level decrease): A controller malfunction that results in reduced feedwater flow is included in the General Transient initiating event category. A controller malfunction that results in loss of all feedwater flow is included in the Loss of Feedwater initiating event category.

c. Partial loss of feedwater: Malfunctions involving partial loss of the condensate or feedwater systems are included in the General Transient initiating event category.

d. Complete loss of feedwater: Malfunctions that cause complete loss of condensate or complete loss of feedwater are included in the Loss of Feedwater initiating event category.

2.2.4.3 Isolation Condensers

This system is in standby during normal plant operation. It is automatically actuated in case of reactor isolation or high reactor pressure. Refer to Section 4.2 for a description and simplified diagram of this system.

The following malfunctions are considered:

a. Spurious actuation of all four isolation condensers: the effect on the plant is an insertion of positive reactivity. The likely consequence of the event is a reactor trip. The water level changes are corrected by FW flow control. This event is included as part of the General Transient initiating event category.

b. Spurious opening of one of the twelve vent lines venting the IC to the suppression pool: each isolation condenser is equipped with a top header vent line and a bottom header 3/4 inch vent line, each with two, automatic, solenoid-operated valves in series. All valves fail closed or fail as-is.

   The automatic valves are signaled to open by high RPV pressure (above IC actuation value) and the two automatic condensate return valves open. The spurious opening of just one line produces a small LOCA with the steam flowing directly to the suppression pool and eventually leading to a high suppression pool temperature scram. This event is bounded by the IORV.

c. System pipe breaks upstream of the isolation valves: These breaks are not isolable and they produce LOCA events. This event is considered in the frequency evaluation of LOCAs inside containment (refer to Section 2.3).

d. System pipe breaks downstream from the isolation valves:

   - Significant break inside the containment: Automatic isolation valves are provided on the suction lines; if a break is sensed (by measuring the flow in the line) these valves close. If this occurs, it is expected that only a limited loss of RPV water occurs, such that no transient initiation is possible. Pipe breaks, combined with failure to isolate the line, have a very low frequency. The consequences are similar to a LOCA inside the containment, but the frequency of the event is much lower. Such events are assumed to be subsumed by the small steam LOCA initiators.

   - IC tube or pipe break outside containment: Automatic or manual break isolation is possible through the multiple leak detection systems, depending on the break size. The IC pipe break outside containment is analyzed as a separate initiating event category.

2.2.4.4 Depressurization and Safety/Relief Valves

Refer to Section 4.1 for a description and simplified diagram of this system.

For this system, only spurious actuation resulting either from operator error or from hardware failure is considered. Breaks of piping between valves and RPV nozzles are taken into account in the LOCA frequency evaluation (see Table 2.2-3).

The spurious actuation of an SRV constitutes an IORV event. An IORV is similar to a small break LOCA, but because of some important differences, a specific event tree is used. Its frequency is evaluated in Section 2.3.

The spurious actuation of only one DPV is included in the small steam LOCA initiating event category. Only the valve mechanical failure contributes to this event because the logic failure causes more than one valve to open, and thus, a different event.

The spurious actuation of all SRVs and DPVs is accounted for within the large LOCA category because of the large total flow area through the valves. The main causes for this event are discussed and quantified in Section 2.3.

2.2.4.5 Gravity Driven Cooling System

The GDCS is in standby and is automatically started by low reactor water Level 1. Refer to Section 4.6 for a description and simplified diagram of this system.

The following malfunctions are considered:

a. Spurious actuation of a squib valve: the spurious actuation of a squib valve and the failure of the in-line check valve to close produce an event similar to a GDCS line break. The event has a low probability. Also, the event is easily mitigated, because 1)

the loss of coolant is through the GDCS pool and 2) as the reactor depressurizes, one GDCS line is already operating. This event is bounded by the Medium Liquid LOCA initiating event category.

b. Spurious actuation of all squib valves: this event can occur for the same reasons as discussed earlier for the spurious opening of all DPVs; however, the frequency of this event is lower because, in this case, the check valves on the GDCS lines would need to fail to close. In this case, the event behaves like a medium steam LOCA, but with even less severe consequences than those discussed above, because all GDCS lines are already operating and the reactor is almost depressurized. Therefore, this event is not explicitly considered in the analysis.

c. Injection line break between the nozzle and the check valve: This event is a LOCA and its frequency is evaluated in Section 2.3.

2.2.4.6 Fuel and Auxiliary Pools Cooling System

This system is always in operation with one pump providing spent fuel pool cooling during plant operation. Its reconfiguration into the suppression pool cooling mode is automatic upon a high Suppression Pool temperature signal. The LPCI mode is initiated manually by the operator. Refer to Section 4.7 for a description and simplified diagram of this system.

The following malfunctions are considered:

a. Trip of the operating pump: tripping of the operating pump results in an increase of the spent fuel pool water temperature over the long term; however, the standby pump can be aligned. No effect on plant safety is expected.

b. Spurious startup of the standby pump: the startup of the standby pump has no effect on plant safety. If the related suction valves are not open, then the pump could be damaged due to overtemperature. This is a plant availability problem and not a safety problem.

c. Injection line break downstream of the check valves (isolating FAPCS from RWCU line): This line is common to the injection of FAPCS and RWCU train B; because it belongs to RWCU, the consequences of this event are analyzed within RWCU below.

2.2.4.7 Reactor Water Clean-Up System

This system is always in operation during normal plant operation with one pump working at a percentage of the rated speed to carry out the reactor water clean-up function. No automatic signals are provided for standby pump actuation or for increase of the operating pump speed. Refer to Section 4.8 for a description and simplified diagram of this system.

The following malfunctions are considered:

a. Trip of the operating pump: tripping of the operating pump does not produce an immediate effect on plant safety because only the RWCU function is impaired. The loss of the RWCU system for a long time might result in high water conductivity and require a manual plant shutdown.

b. Spurious startup of the standby pump: no effect on plant safety is expected.

c. Injection line break downstream from the check valves (isolating RWCU from FW line): this event causes loss of FW because of the diverted flow, unavailability of the RWCU trains due to high temperature in the Main Steam Tunnel, loss of the FAPCS in half of the cases (FW line A break), and loss of the CRD injection in half of the cases (FW line B break). The event behaves like a loss of FW with the unavailability of some mitigating systems.

d. RWCU line break outside of containment within Reactor Building (other than c above): this event causes loss of RWCU/SDC because of the LD&IS isolating signals, an RPV Level 2 containment IS isolating signal, and unavailability of both RWCU/SDC trains.

Breaks in the RWCU return line from the RPV lead to LOCA events. The frequency of such an event is evaluated in Section 2.3.

2.2.4.8 Standby Liquid Control System

The system is in standby during normal plant operation and is automatically actuated in response to ATWS signals. Refer to Section 4.4 for a description and simplified diagram of this system.

The following malfunctions are considered:

a. Spurious system actuation: if one of the redundant squib valves spuriously actuates, boron injection into the RPV occurs. Plant availability is affected, but not plant safety. This event is considered as part of the General Transient initiating event category.

b. Injection line break: this event causes a LOCA. Its contribution to LOCA frequency is evaluated in Section 2.3.

2.2.4.9 Complete Loss of RCCW

The Reactor Component Cooling Water System supplies cooling water to the following systems:

- CRD
- FAPCS
- RWCU/SDC
- Chilled Water System
- Instrument Air System

Refer to Section 4.10 for a description and simplified diagram of this system.

The consequences of total failure of RCCW are less severe than total failure of PSWS because BOP systems cooled by TCCW/PSWS remain available for the loss of RCCW event. However, because the consequences of this event are bounded by the Complete Loss of PSWS initiating event category, loss of RCCW is conservatively grouped together with the Complete Loss of PSWS initiator.

2.2.4.10 Complete Loss of TCCW System

Refer to Section 4.9 for a description and simplified diagram of this system.

The loss of this system results in loss of balance-of-plant (BOP) systems (i.e., a turbine trip with feedwater and condensate system failure and loss of service air system). Given the functional consequences of this event, loss of TCCW is grouped together with the Loss of Feedwater initiating event category.

2.2.4.11 Complete Loss of Plant Service Water System

Refer to Section 4.11 for a description and simplified diagram of this system.

The loss of this system produces a loss of RCCW and TCCW. The event results in the impairment of several mitigating systems (all non-safety systems, including complete loss of AC power to battery chargers). The consequences are similar to a station blackout event. This event is modeled with a separate initiating event category.

2.2.4.12 Complete Loss of Air Systems

This event consists of the simultaneous loss of HPNSS and both the instrument and service air (ISA) systems. Refer to Sections 4.12 and 4.13 for descriptions and simplified diagrams of these systems.

The following events are expected to occur in the plant as a result of complete loss of air:

- Isolation condenser condensate return valves F006A, B, C, D open. Other air-operated valves in the IC system fail as-is.
- Fuel and auxiliary pool cooling system is unavailable due to the failure of the LPCI configuration interface valves in the closed position
- MSIVs long term closure because of the discharge of the accumulators due to normal leakage

After the MSIV accumulators discharge, the event proceeds like an MSIV closure event. However, this event is not maintained as an initiator for accident sequence quantification because of the combination of the following:

(1) Indications in the control room of the changed status of the above systems

(2) Time available to the operator to shut down the plant

(3) Beneficial effect of the IC operation

(4) Low frequency of the initiating event

2.2.4.13 Loss of 13.8 kVAC or 6.9 kVAC Buses

Refer to Section 4.14 for a description and simplified diagram of the ac system.

The loss of the 13.8 or 6.9 kVAC buses of a single train produces a partial loss of plant service water system (PSWS), among other plant effects. The plant service water configuration is 2 x 100 percent capacity pumps; as such, the loss of one bus causes a partial failure of PSWS. Given the event behaves like a partial loss of PSWS event, it is not modeled as a separate initiator because the initiating event occurs only in case of failure to realign the redundant PSWS pumps (the frequency contributions of bus failure and operator error are judged not significant).

2.2.4.14 Loss of a Single 250 VDC Bus

Refer to Section 4.17 for a description and simplified diagram of the 250 DC system.

The loss of a single 250 VDC essential bus results in de-energization of one of two solenoids of the fail-open IC drain valve. The valves on the venting line to the suppression pool would not open. No effect on plant safety is expected.

The loss of a single 250 VDC non-essential bus does not produce any initiator because it does not result in the actuation of any component.

2.2.4.15 Reactor Water Level Instrumentation Failures

Failures of the RWLI system can initiate a transient event and at the same time jeopardize the operation of other mitigating systems. The failures considered are those involving an erroneous high level signal. Failures resulting in low level are already covered in other transient events in which initiation of the mitigating systems is not jeopardized.

The high level signal (Level 8) produces a trip of all feedwater pumps and closure of the turbine stop valves, resulting in a turbine trip. If the high level signal persists, it is not possible to restart the feedwater pumps and actuation of the CRD system would be inhibited.

The experience record of operating BWR plants shows that an RWLI failure could be caused by leaks in the instrumentation leg or by extreme environmental conditions, such as a high drywell temperature. The following discussion examines the effect of such phenomena, assuming the occurrence of only a single leg failure.

a. Leaks: leaks occurring in the instrumentation legs could swell the level, inducing an error in all of the connecting instruments. The ESBWR plant design incorporates one separate leg for each level instrumentation division; this means that if only one leg fails, the RWLI system can still assure correct performance (i.e., one scram signal is not generated and mitigating systems are not prevented from starting).

b. Extreme environmental conditions: a high DW temperature could be caused by accidents such as 1) LOCAs, 2) inadvertent opening of one DPV, or 3) loss of the drywell cooling system. However, the instrumentation is assumed to be designed for the maximum temperature attainable in the DW, so no instrumentation effects should occur. A possible local effect could be generated by a LOCA if the break is close to the instrumentation piping. For this case, only one division is expected to be affected, so no significant contribution to core damage frequency is expected. Safety systems (IC, GDCS, SRV) are actuated by various level sensors.

Given the above, RWLI failures are not included as an initiator for accident sequence quantification.

2.2.4.16 Loss of Drywell Cooling System

A scram is initiated when the drywell temperature increases above the Technical Specification limit. No mitigating systems are impaired. The event is similar to a spurious trip with an insignificant contribution to the spurious trip frequency. It is included in the General Transient initiating event category.

Table 2.2-1

NUREG/CR-5750 Initiating Event Categories

B Loss of Offsite Power

(B1) Loss of Offsite Power (LOSP)

C Loss of Safety-Related Bus

(C1) Loss of Vital Medium Voltage AC Bus[2]
(C2) Loss of Vital Low Voltage AC Bus[2]
(C3) Loss of Vital DC Bus

D Loss of Instrument or Control Air

(D1) Loss of Instrument or Control Air

E Loss of Safety-Related Cooling Water

(E1) Total Loss of Service Water
(E2) Partial Loss of Service Water[3]

F Steam Generator Tube Rupture

(F1) Steam Generator Tube Rupture[1]

G Loss of Coolant Accident (LOCA)/Leak

(G1) Very Small LOCA/Leak
(G2) Stuck Open: 1 Safety/Relief Valve
(G3) Small Pipe Break LOCA
(G4) Stuck Open: Pressurizer PORV[1]
(G5) Stuck Open: 2 or More Safety/Relief Valves
(G6) Medium Pipe Break LOCA
(G7) Large Pipe Break LOCA
(G8) Reactor Coolant Pump Seal LOCA: PWR[1]

H Fire

(H1) Fire

J Flood

(J1) Flood

Table 2.2-1

NUREG/CR-5750 Initiating Event Categories

K High Energy Line Break

- (K1) Steam Line Break Outside Containment
- (K2) Feedwater Line Break
- (K3) Steam Line Break Inside Containment: PWR[1]

L Total Loss of Condenser Heat Sink

- (L1) Inadvertent Closure of All MSIVs
- (L2) Loss of Condenser Vacuum
- (L3) Turbine Bypass Unavailable

N Interfacing System LOCA

- (N1) Interfacing System LOCA

P Total Loss of Feedwater Flow

- (P1) Total Loss of Feedwater Flow

Q General Transients

- (QC4) Loss of AC Instrumentation and Control Bus
- (QC5) Loss of Non-safety-related Bus
- (QG9) Primary System Leak
- (QG10) Inadvertent Open/Close: 1 Safety/Relief Valve
- (QK4) Steam or Feed Leakage
- (QL4) Loss of Nonsafety-Related Cooling Water
- (QL5) Partial Closure of MSIVs[4]
- (QL6) Condenser Leakage
- (QP2) Partial Loss of Feedwater Flow[5]
- (QP3) Total Loss of Condensate Flow
- (QP4) Partial Loss of Condensate Flow[6]
- (QP5) Excessive Feedwater Flow
- (QR0) RCS High Pressure (RPS Trip)
- (QR1) RCS Low Pressure (RPS Trip): PWR[1]
- (QR2) Loss of Primary Flow (RPS Trip): PWR[1]
- (QR3) Reactivity Control Imbalance
- (QR4) Core Power Excursion (RPS Trip)
- (QR5) Turbine Trip
- (QR6) Manual Reactor Trip
- (QR7) Other Reactor Trip (Valid RPS Trip)

Table 2.2-1

NUREG/CR-5750 Initiating Event Categories

(QR8) Spurious Reactor Trip
(QR9) Spurious Engineered Safety Feature Actuation[7]

Notes to Table 2.2-1:

1 PWR event. Not applicable to ESBWR.
2 These event categories are not applicable to the ESBWR, as the Low and Medium Voltage AC Buses in the ESBWR design are nonsafety-related (with the exception of a portion of the uninterruptible power supply system that is backed up by batteries). Low and Medium voltage AC initiators for the ESBWR are addressed by the NUREG/CR-5750 category QC5 (Loss of Non-safety-Related bus).
3 Loss of a single PSWS train does not cause a reactor trip for the ESBWR design.
4 Closure of one MSIV does not cause a reactor trip for the ESBWR design.
5 Loss of a single feedwater train does not cause a reactor trip for the ESBWR design.
6 Loss of a single condensate train does not cause a reactor trip for the ESBWR design.
7 The ESBWR design does not have high pressure standby safety injection systems, and the ESBWR low pressure safety systems cannot inject into the RPV when it is at power (due to check valves). Spurious IC actuation is considered under Special Initiators, and spurious ADS is considered in the LOCA initiator categories.

Table 2.2-2

ESBWR Transient Initiating Event Categorization

ESBWR Transient Initiating Category	Description	NUREG/CR-5750 Categories		
General Transient	Scram occurs. FW remains available or is promptly recoverable. Main condenser is available, if the mode switch is positioned in shutdown.	a.	(QG9)	Primary System Leak
		b.	(QK4)	Steam or Feed Leakage
		c.	(QL6)	Condenser Leakage
		d.	(QP5)	Excessive Feedwater Flow
		e.	(QR0)	RCS High Pressure (RPS Trip)
		f.	(QR3)	Reactivity Control Imbalance
		g.	(QR4)	Core Power Excursion (RPS Trip)
		h.	(QR5)	Turbine Trip
		i.	(QR6)	Manual Reactor Trip
		j.	(QR7)	Other Reactor Trip (Valid RPS Trip)
		k.	(QR8)	Spurious Reactor Trip
Transient with PCS Unavailable	Scram occurs. FW remains available for RPV inventory makeup. Main condenser is unavailable.	a.	(L1)	Inadvertent Closure of All MSIVs
		b.	(L2)	Loss of Condenser Vacuum
		c.	(L3)	Turbine Bypass Unavailable
Loss of Feedwater	Scram occurs. Feedwater is not available. Main condenser is unavailable due to MSIVs closure on Level 2.	a.	(P1)	Total Loss of Feedwater Flow
		b.	(QL4)	Total Loss of TCCW (subset of QL4)
		c.	(QP3)	Total Loss of Condensate Flow
IORV	Scram occurs. FW remains available. One or more safety/relief valves initially stuck open	a.	(G2)	Stuck Open: 1 Safety/Relief Valve
		b.	(QG10)	Inadvertent Open/Close: 1 Safety/ Relief Valve

Table 2.2-3

Lines Connected to Reactor Coolant Pressure Boundary (RCPB)

Line	Number of lines	mm (inches) diameter	Nozzle Elevation (mm)	Break[7,8] Type	Notes
Main Steam (MSL)	4	700 (28)[1]	22840	L	Steam break
DPV/IC	4	450 (18), 350 (14)[2]	21910	L	Steam break
DPV/MSL	4	N/A[3]	22840	S or L[6]	Steam break
SRV/MSL	18	N/A[3]	22840	S or L[6]	Steam break
FW-12"	6	300 (12)	18915	L	Steam break
22"	2	550 (22)	—	L	Steam break
RWCU/SDC	2	300 (12)	17215	L	Steam break
IC return lines	4	200 (8)	13025	M	Liquid break
GDCS	8	150 (6)[4]	10453	M	Liquid break
Equalizing lines	4	150 (6)[5]	8453	M	Liquid break
RWCU/RPV Drainlines	4	75 (3)	0	M	Liquid break
SLCS	2	50 (2)		M	Liquid break
Instrument lines above L3	4	50 (2)	>L3	S	Steam break
Instrument lines below TAF	4+2	25 (1)	<TAF	S	Liquid break
Instrument lines above TAF and below L3	4	25 (1)	TAF-L3	S	Liquid break

Notes:

1. 9.75 10^{-2} m^2 (1.05 sq. ft) throat diameter
2. 450 mm common pipe, 350 mm IC branch pipe
3. DPV directly mounted on MSL pipe
4. 75 mm (3 inches) throat diameter
5. 50 mm (2 inches) throat diameter
6. Break size depends upon whether single or multiple valves spuriously open (single DPV or SRV is Small; multiple DPVs or SRVs is Large)
7. L = Large; M = Medium; S = Small
8. Because the small and medium size steam LOCAs are consolidated, the most restrictive treatment of the two categories is used in the PRA model analysis.

2.3 INITIATING EVENTS FREQUENCY QUANTIFICATION

The initiating events are identified and grouped into initiating event categories as discussed in Section 2.2.

This section documents the frequencies calculated for each of the initiating event categories. Loss of coolant accidents (LOCA) are divided into further subcategories for more effective event tree modeling and quantification.

2.3.1 Transients

All transient frequencies are determined based on NUREG/CR-5750 results (Reference 2-1), which are based on U.S. nuclear power plant operational experience over the period 1987-1995. The resulting frequencies are summarized in Table 2.3-4 and the details are summarized below.

2.3.1.1 General Transient

The frequency of the General Transient initiating event category is quantified based on the NUREG/CR-5750 "General Transient (Q) - BWR" initiating event frequency, 1.5/yr. Those Q contributors that are included in other ESBWR PRA transient initiating event categories are subtracted out. As can be seen from Sections 2.3.1.3 and 2.3.1.4, these are:

- Total Loss of Condensate Flow (QP3) - 1.5E-2/yr
- Total Loss of TCCW (subset of QL4) - 7.5E-3/yr
- Inadvertent Open/Close: 1 Safety/Relief Valve (QG10) - non-significant contributor

The NUREG/CR-5750 "General Transient (Q) - BWR" category contributors identified in Table 2.2-1 as not applicable to the ESBWR design (QL5, QP2, and QP4) are also subtracted out. Based on Tables 4-7 and D-4 of NUREG/CR-5750, the percentage contribution to the "General Transient (Q) – BWR" frequency from these three contributors is approximately 12% (1.8E-1/yr).

Therefore, the frequency of the ESBWR PRA General Transient initiating event category is calculated as follows:

1.5/yr - 1.5E-2/yr - 7.5E-3/yr - 1.8E-1/yr = 1.30/yr

2.3.1.2 Transient With PCS Unavailable

As shown in Table 2.2-2, the ESBWR PRA Transient with PCS Unavailable initiating event category is comprised of the following contributors:

- Inadvertent Closure of All MSIVs (L1)
- Loss of Condenser Vacuum (L2)
- Turbine Bypass Unavailable (L3)`

Based on the results of NUREG/CR-5750, the frequencies of the above contributors are 1.7E-1/yr, 2.0E-1/yr, and 4.1E-3/yr, respectively. Therefore, the frequency of the ESBWR PRA Transient with PCS Unavailable initiating event category is calculated as follows:

1.7E-1/yr + 2.0E-1/yr + 4.1E-3/yr = 3.74E-1/yr

2.3.1.3 Loss of Feedwater

As shown in Table 2.2-2, the following NUREG/CR-5750 categories are grouped into the ESBWR PRA Loss of Feedwater initiating event category:

- Total Loss of Feedwater Flow (P1)
- Total Loss of Condensate Flow (QP3)
- Total Loss of TCCW (subset of QL4)

The frequency of the NUREG/CR-5750 "Total Loss of Feedwater Flow (P1)" initiating event category is 8.5E-2/yr. Appendix A of NUREG/CR-5750 notes that QP3 events are already included in the calculation of the "Total Loss of Feedwater Flow (P1)" frequency (as well as separately in the "General Transient (Q)" frequency, representing about 1% of the Q frequency).

NUREG/CR-5750 does not provide a frequency estimate for the QL4 contributor (it is part of the larger NUREG/CR-5750 category "General Transient (Q)"); however, the frequency of QL4 can be estimated from the contribution breakdowns provided in NUREG/CR-5750. Based on Tables 4-7 and D-4 of NUREG/CR-5750, the percentage contribution of QL4 to the NUREG/CR-5750 category "General Transient (Q) - BWR" is approximately 3%. The NUREG/CR-5750 QL4 encompasses both partial system failures and total system failures for various non-safety cooling water systems (turbine building cooling water, circulating water system, cooling tower systems, etc.). Based on this information, the contribution to the NUREG/CR-5750 "General Transient (Q)" frequency from the subset of QL4 involving total failure of turbine building cooling water is estimated at less than 1% (a nominal value of 0.5% is used here). This is judged reasonable. Based on these NUREG/CR-5750 results, the frequency of total loss of TCCW is estimated at 1.5/yr x 5E-3 = 7.5E-3/yr. This frequency is similar to the loss of turbine building cooling water initiating event frequencies in other U.S. BWR PRAs.

Therefore, the frequency of the ESBWR PRA Loss of Feedwater initiating event category is calculated as follows:

8.5E-2/yr + 7.5E-3/yr = 9.25E-2/yr

2.3.1.4 IORV

As shown in Table 2.2-2, the ESBWR PRA IORV initiating event category is comprised of the following contributors:

- Stuck Open: 1 Safety/Relief Valve (G2)
- Inadvertent Open/Close: 1 Safety/Relief Valve (QG10)

The frequency of the NUREG/CR-5750 "Stuck Open: 1 Safety/Relief Valve (G2) - BWR" initiating event category is 4.6E-2/yr.

NUREG/CR-5750 does not provide a frequency estimate for the QG10 contributor (it is part of the larger NUREG/CR-5750 category "'General Transient (Q)"); however, the frequency of QG10 can be estimated from the contribution breakdowns provided in NUREG/CR-5750. Based on Tables 4-7 and D-4 of NUREG/CR-5750, the percentage contribution of QG10 to the NUREG/CR-5750 category "General Transient (Q) - BWR" is <<1%. The QG10 frequency contribution is assessed here as a non-significant contributor.

Therefore, the frequency of the ESBWR PRA IORV initiating event category is estimated at 4.6E-2/yr.

2.3.2 Loss of Preferred Power (LOPP)

The frequency of the Loss of Preferred Power (LOPP) initiating event category is quantified based on the NUREG/CR-5750 "Loss of Offsite Power (B1)" initiating event frequency, 4.6E-2/yr.

Therefore, the frequency of the ESBWR PRA Loss of Preferred Power (LOPP) initiating event category is determined to be 4.6E-2/yr.

2.3.3 LOCAs

The LOCA initiators considered in the ESBWR Probabilistic Risk Assessment are:

- Breaks of the reactor coolant pressure boundary (RCPB) during normal operation
- Breaks of pipes with design pressure lower than the reactor pressure due to the malfunction of the interfacing valves (interfacing breaks)
- Vessel rupture

2.3.3.1 LOCAs Inside Containment

The frequencies of LOCAs inside containment are quantified using of the NUREG/CR-5750 mean frequencies (based on BWRs operational experience) for large, medium and small pipe breaks. For each group of ESBWR lines, the associated NUREG/CR-5750 LOCA frequency is apportioned proportionally using three different methods:

- As a function of line length
- As a function of the number of lines
- As a function of the number of line segments

The results from the three different methods are averaged to determine the final frequency used in this analysis.

Table 2.3-1 summarizes the break frequency calculations for each group of lines. Table 2.3-1 summarizes for each pipe group: the number of lines, the number of sections (assessed on the

basis of layout drawings), the frequency apportionments, and the final averaged frequencies. These data are binned into the LOCA initiator classes, as summarized in Table 2.3-2. Note that contributions from events other than pipe breaks are also included in some of the LOCA categories.

Additional LOCA Contributions

In addition to pipe breaks, the following additional events contribute to the LOCA frequencies:

	Event	Contribution To	Frequency
a.	Spurious actuation of one DPV	Medium Steam LOCA	4.9E-4
b.	Spurious actuation of all SRVs/DPVs	Large LOCA	3.2E-4

Spurious actuation of a single SRV is addressed as a separate initiating event (IORV), refer to Section 2.3.1.4.

The above two additional LOCA contributors can result from the following causes:

- Valve(s) mechanical failure
- Operator error
- Spurious generation of a level 1 water level signal

Operator errors are judged to be a non-significant contribution. The other causes contribute as follows:

a. Opening of only one DPV: only valve mechanical failure contributes to this event because logic failure produces more than one valve opening and is already taken into account in item b below.

b. Opening of all SRVs/DPVs: failure of the logic common to the other valves contributes to this event; mechanical failure of all valves can be postulated, but is statistically a non-significant contributor.

Opening of Only One DPV

Two causes found to contribute to this event:

- Spurious opening
- Shear disk rupture

A common cause failure of load drivers could result in a single spurious opening of a DPV. Assuming that the failure rate for spurious actuation is 50 percent of the total failure rate (1E-6/hr), the frequency of a CCF for load driver is:

$$0.5 \times 1E\text{-}6 \times 8760 \times 0.1 = 4.4E\text{-}4 \text{ events/year}$$

where 0.1 is the generic common cause failure factor assumed for spurious operation. Thus, the DPV spurious opening rate used is 4.4E-4 events/year.

The check valve internal rupture (shear disk rupture) failure rate is assumed; considering a verification of the integrity of the nozzle is performed at every refueling, the annual failure rate is about 4.4E-5, based on data in Appendix A of Chapter 1 of the EPRI ALWR URD (Reference 2-6).

Summing these two values results in the frequency of 4.9E-4 events/year for only one of eight DPVs spuriously opening. This is an additional contributor to the medium steam break LOCA (no FW or GDCS line break) initiator category.

Opening of All SRVs/DPVs

The operational experience of BWRs indicates that no events of more than one SRV stuck open have been observed. NUREG/CR-5750 estimates an upper bound frequency of 3.2E-4 events/year for this initiating event (NUREG/CR-5750 category G5). This is an additional contributor to the large steam break LOCA (no FW line break) initiator category.

2.3.3.2 Breaks Outside Containment

In addition to loss of coolant accidents inside containment, lines outside containment that are exposed to the high pressure of the reactor coolant pressure boundary could lead to a LOCA if they experience a break. The high pressure lines where this event can occur are:

- Main steam
- Feedwater
- RWCU
- Isolation condenser (outside containment)

The largest pipes are the main steam lines, they are also the lines with the greatest number of sections. These lines isolate automatically if a break occurs downstream from the MSIVs. The frequency for this initiating event (refer to Table 2.3-3) is obtained from NUREG/CR-4832 (Reference 2-5). This frequency applies to experiencing the steam line break, isolation of the break is addressed in the accident sequence analysis.

The feedwater pipes isolate automatically if a break occurs upstream from the containment isolation valves, but result in the unavailability of those systems/trains that inject through these lines. The frequency for this initiating event (refer to Table 2.3-3) is obtained from NUREG/CR-5750 initiating event category K2. This frequency applies to experiencing the FW line break; isolation of the break is addressed in the accident sequence analysis.

The RWCU pipes isolate automatically if a break occurs downstream from the containment isolation valves, but result in the unavailability of the train affected by the break. The frequency for this initiating event is assumed to be similar to the frequency of the feedwater lines obtained from NUREG/CR-5750.

The IC pipes outside the containment isolate automatically if a break occurs downstream from the IC isolation valves, but result in the unavailability of the IC affected by the break. A conservative estimate of the frequency for this initiating event is the LOCA frequency

apportioned for IC inside the containment in Table 2.3-1. This frequency applies to experiencing the line break; isolation of the break is addressed in the accident sequence analysis.

2.3.3.3 Vessel Rupture

The value used for the frequency of this event in industry PRAs is typically 3E-7 events/year (derived from the WASH 1400 report). It is judged that this value is applicable to older vessel designs. The adoption of improved materials, the absence of nozzles and welds at the core level, the reduction of the number of welds, the lower fluence, and the improved in-service inspection program all justify a lower value for the ESBWR. As such, vessel rupture is judged a negligible event and is not maintained as an initiator category for accident sequence quantification.

2.3.3.4 Interfacing LOCA

The interfacing LOCAs are of negligible frequency in the ESBWR design due to the numerous means of separation (i.e., check valves and air operated valves in the closed position, their opening interlocked with reactor pressure) between high and low pressure piping.

The FAPCS system (designed for low pressure) is not directly connected to the RCPB. For the low pressure core injection (LPCI) function, the system is connected to the FW line upstream of the FW isolation check valves. This FAPCS connecting line is protected by two FW isolation check valves, one testable FAPC check valve and one normally closed air operated valve (with an interlock preventing actuation at high reactor pressure). This protection is in addition to the residual structural resistance of the LPCI piping for pressure greater than the design pressure and of the greater pressure supplied by the FW pumps against the vessel pressure.

The frequency of a LOCA event due to the failure of all the above multiple (and, in many cases, independent) barriers is considered negligible. As such, interfacing LOCA is not maintained as an initiator category for accident sequence quantification.

Note that the GDCS lines connected to the RCPB are all located inside containment and do not represent potential ISLOCA scenarios. They are addressed in LOCAs inside containment (refer to Section 2.3.3.1).

2.3.4 Special Initiators

As discussed in Section 2.2.4, the only systemic malfunction maintained as a separate special initiator is Complete Loss of PSWS. All other systemic malfunctions are either included in other existing initiator categories or do not cause a plant trip.

<u>Complete Loss of PSWS</u>

The frequency of the Complete Loss of PSWS initiating event category is obtained from NUREG/CR-5750. The ESBWR Plant Service Water Systems (PSWS) is designed with a high level of redundancy and diversity provided by the Cooling Tower Makeup pumps. Reactor Water Component Cooling (RCCW), which is grouped within the Complete Loss of PSWS initiator category (refer to Section 2.2.4.9), also has a design with a high level of redundancy

considering the normal operational requirements (two out of six pumps and heat exchangers). Given the design of these ESBWR systems, the frequency estimated in NUREG/CR-5750 for Total Loss of Service Water is taken as a conservative estimate for this initiating event frequency.

2.3.5 Summary of Initiating Event Frequencies

Table 2.3-3 summarizes the frequencies of the internal events initiators used in the event tree quantification.

The initiating event frequencies developed in this analysis are based on BWR historical experience. The total initiating event frequency estimated in this analysis is judged conservative because it is greater than the design goal of less than 1 event/year, to be demonstrated in a later stage for the ESBWR by the Reliability Availability Maintenance (RAM) program.

Table 2.3-4 provides a comparison of the ESBWR PRA internal events initiator frequencies to the following industry studies:

- EPRI ALWR Utility Requirements Document (Reference 2-6)
- NUREG/CR-3862 (Reference 2-3)
- NUREG/CR-4832 (Reference 2-5)
- NUREG/CR-4550, Vol. 4 (Reference 2-7)

Table 2.3-1

Summary of Lines Connected to RPV And Quantification Of Frequency Apportionment

ID	Line	Length (m)	No. Lines	No. Sections	Apportionment Method By Length[1]	By No. Lines[2]	By No. Sections[3]	Final Frequency[4] (events/yr)	Notes
a	Main Steam (MSL)	92	4	44	6.22E-6	4.44E-6	4.13E-6	4.93E-6	Large Steam break
b	DPV line/IC	70	4	64	4.73E-6	4.44E-6	6.01E-6	5.06E-6	Large Steam break
d	FW	95	8	74	6.42E-6	8.89E-6	6.95E-6	7.42E-6	Large Steam break
e	RWCU/SDC	39	2	31	2.64E-6	2.22E-6	2.91E-6	2.59E-6	Large Steam break
f	IC return lines	12	4	40	2.83E-6	5.45E-6	8.96E-6	5.75E-6	Medium Liquid break
g	GDCS	44	8	32	1.04E-5	1.09E-5	7.16E-6	9.49E-6	Medium Liquid break
gl	Equalizing lines	11	4	12	2.60E-6	5.45E-6	2.69E-6	3.58E-6	Medium Liquid break
h	RWCU/RPV Drainlines	20	4	20	4.72E-6	5.45E-6	4.48E-6	4.89E-6	Medium Liquid break
i	SLCS	40	2	30	9.45E-6	2.73E-6	6.72E-6	6.30E-6	Medium Liquid break
j	Instrument lines above L3	50	4	100	1.14E-4	1.14E-4	1.14E-4	1.14E-4	Small Steam break
j1	Instrument lines below TAF	75	6	150	1.71E-4	1.71E-4	1.71E-4	1.71E-4	Small Liquid break
j2	Instrument lines above TAF and under L3	50	4	100	1.14E-4	1.14E-4	1.14E-4	1.14E-4	Small Liquid break

Notes to Table 2.3-1:

1 Calculated as: [(length of line) / (total length of all lines corresponding to LOCA size category)] x NUREG/CR-5750 LOCA size category frequency

2 Calculated as: [(number of individual lines) / (total number of lines corresponding to LOCA size category)] x NUREG/CR-5750 LOCA size category frequency

3 Calculated as: [(number of sections) / (total number of sections corresponding to LOCA size category)] x NUREG/CR-5750 LOCA size category frequency

4 Final frequency is the average of the three apportionment methods.

5 NUREG/CR-5750 frequencies for Large, Medium and Small BWR LOCAs: 2E-5, 3E-5, and 4E-4, respectively.

Table 2.3-2

Attribution of Line Frequencies to LOCA Categories

LOCA Category	Contributors[1, 2]	Frequency (events/yr)
Large steam LOCA (no FW line break)	a + b + e + (A)[2]	3.33E-4
Large steam LOCA in FW line	d	7.42E-6
Medium liquid LOCA (no RWCU break)	f + g + g1 + i	2.51E-5
Medium liquid LOCA in RWCU	h	4.89E-6
Small steam LOCA	j + (B)[2]	6.04E-4
Small liquid LOCA (no RWCU break)	j2	1.14E-4
Small liquid LOCA in RWCU	j1	1.71E-4
Main Steam Line Break (Outside Containment)	--	3.00E-3
Feedwater Line Break (Outside Containment)	--	3.40E-3
RWCU Line Break (Outside Containment)	--	3.40E-3
IC Line Break (Outside Containment)	--	5.06E-6

[1] Refer to Table 2.3-1 for line IDs.
[2] The additional LOCA contributors are as follows:
(A) Spurious actuation of all SRVs and DPVs (3.2E-4/yr)
(B) Spurious actuation of a single DPV (4.9E-4/yr)

Table 2.3-3

Internal Events Initiator Frequencies

Initiating Event	Frequency (events/year)	PRA Basic Event ID	PRA Basic Event Frequency (events/year)
Transients			
General Transient	1.30	%T-GEN	1.30E+0
Transient with PCS Unavailable	3.74E-1	%T-PCS	3.74E-1
Loss of Feedwater	9.25E-2	%T-FDW	9.25E-2
IORV	4.60E-2	%T-IORV	4.60E-2
Loss of Preferred Power (LOPP)	4.60E-2	%T-LOPP	4.60E-2
LOCAs Inside Containment			
Large Steam LOCA (no FW line break)	3.33E-4	%LL-S	3.33E-4
Large Steam LOCA in FW line	7.42E-6	%LL-S-FDWA	3.71E-6
		%LL-S-FDWB	3.71E-6
Medium Liquid LOCA (no RWCU break)	2.51E-5	%ML-L	2.51E-5
Medium Liquid LOCA in RWCU	4.89E-6	%ML-L-RWCU	4.89E-6
Small Steam LOCA	6.04E-4	%SL-S	6.04E-4
Small Liquid LOCA (no RWCU break)	1.14E-4	%SL-L	1.14E-4
Small Liquid LOCA in RWCU	1.71E-4	%SL-L-RWCU	1.71E-4
LOCAs Outside Containment			
Main Steam Line Break (Outside Containment)	3.00E-3	%BOC-MS	3.00E-3
Feedwater Line Break (Outside Containment)	3.40E-3	%BOC-FDWA	1.70E-3
		%BOC-FDWB	1.70E-3
RWCU Line Break (Outside Containment)	3.40E-3	%BOC-RWCU	3.40E-3
IC Line Break (Outside Containment)	5.06E-6	%BOC-IC	5.06E-6
Special Initiators			
Complete Loss of PSWS	9.70E-4	%T-SW	9.70E-4

Table 2.3-4

Comparison of ESBWR PRA Internal Events Initiating Event Frequencies to Other Studies

Initiating Event	Frequency (per year)				
	ESBWR PRA	EPRI ALWR URD	NUREG/CR-3862	NUREG/CR-4832	NUREG/CR-4550
Transients					
General Transient	1.30	2.3E+1	6.4E+1	4.5E+1	2.5E+1
Transient with PCS Unavailable	3.74E-1	4.9E-1	6.8E-1	1.54E+1	5.0E-2
Loss of Feedwater	9.25E-2	3.7E-1	7.0E-2	6.0E-1	6.0E-2
IORV	4.60E-2	n/a	1.4E-1	1.4E-1	1.9E-1
Loss of Preferred Power (LOPP)	4.60E-2	3.5E-2	8.0E-2	9.6E-2	7.9E-2
LOCAs Inside Containment					
Large Steam LOCA (no FW line break)	3.33E-4	5.8E-4	n/a	1.0E-4	1.0E-4
Large Steam LOCA in FW line	7.42E-6				
Medium Liquid LOCA (no RWCU break)	2.51E-5	n/a	n/a	3.0E-4	3.0E-4
Medium Liquid LOCA in RWCU	4.89E-6				
Small Steam LOCA	6.04E-4	5.1E-3	n/a	3.0E-2	3.0E-3
Small Liquid LOCA (no RWCU break)	1.14E-4				
Small Liquid LOCA in RWCU	1.71E-4				
LOCAs Outside Containment					
Main Steam Line Break (Outside Containment)	3.30E-3	n/a	n/a	n/a	n/a
Feedwater Line Break (Outside Containment)	3.40E-3				
RWCU Line Break (Outside Containment)	3.40E-3				

Table 2.3-4

Comparison of ESBWR PRA Internal Events Initiating Event Frequencies to Other Studies

Initiating Event	Frequency (per year)				
	ESBWR PRA	EPRI ALWR URD	NUREG/CR-3862	NUREG/CR-4832	NUREG/CR-4550
IC Line Break (Outside Containment)	5.06E-6				
Special Initiators					
Complete Loss of PSWS	9.70E-4	n/a	n/a	n/a	n/a

2.4 REFERENCES

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2-5. NUREG/CR-4832, Analysis of LaSalle Unit 2 Nuclear Power Plant: Risk Methods Integration and Evaluation Program (RMIEP), September 1992.

2-6. EPRI-ALWR Utility Requirements Document, Chapter 1, Appendix A to Volume II, PRA Key Assumptions and Groundrules, Revision 4, Issued 4/92.

2-7. NUREG/CR-4550, Vol. 4, Analysis of Core Damage Frequency: Peach Bottom, Unit 2 Internal Events, Rev. 1, August 1989.

3 ACCIDENT SEQUENCE ANALYSIS

Contents

List of Tables

3 ACCIDENT SEQUENCE ANALYSIS

3.1 INTRODUCTION AND SCOPE

The purpose of this section is to document the event trees and accident sequence analysis performed as part of the Economic Simplified Boiling Water Reactor (ESBWR) Probabilistic Risk Assessment (PRA). This section includes the basis for the event trees modeled in the internal event analysis and a description of each event tree heading. These event trees also provide the baseline models for the external events analyses presented in later sections of this report.

The event trees developed for ESBWR are based on the initiating events included in Section 2. The event tree models include the set of systems needed to mitigate each initiating event. Each event tree provides a time independent, system-based response to each initiating event. The objective of these event tree analyses is to show which system combinations result in a safe, stable state, and which ones result in core damage.

The systems modeled include both safety-related and non-safety systems are modeled using the fault tree logic that is presented in Section 4. Support systems and operator actions are modeled explicitly within each system fault tree.

The accident sequence analysis numerical results are presented in Section 7.

The event tree end states are grouped into plant damage states in order to simplify the containment analyses that is presented in Sections 8 and 21.

The event tree logic diagrams are shown at the end of this section in Appendix A.3.

3.2 EVENT TREES AND ACCIDENT SEQUENCE METHODOLOGY

3.2.1 Acceptance Criteria

The acceptance criteria of the safety functions that are required to be accomplished for safe plant operation are described in this section. These safety functions are the following:

- Criterion for Reactivity Control

The acceptance criterion is to achieve subcriticality and maintain the reactor in a subcritical state.

- Criterion for RPV Overpressure Protection

A pressure of 150 percent of the reactor coolant pressure boundary (Service Level C) is defined as the acceptance criterion for the RPV overpressure protection. This limit is used to determine the number of Safety/Relief Valves (SRVs) that are required to operate following any event, including ATWS events.

- Criterion for Core Cooling

A peak cladding temperature (PCT) of 2200°F is chosen as the criterion for establishing the adequacy of coolant inventory. This is consistent with 10 CFR 50.46 and with criteria adopted in previous PRAs.

- Criterion for Containment Heat Removal

For event sequences in which core cooling is successful utilizing Passive Systems, the containment cooling function acceptance criteria is to maintain the containment pressure below the ultimate containment pressure. If the containment fails under these conditions, the inventory of water available for the passive systems is depleted through the containment breach, and consequently core coverage would be lost without recovery of some type. In all cases, containment does not fail until at least 24 hours following the initiating event, and any subsequent core uncovery does not occur until 72 hours following the initiating event.

For sequences with successful core cooling using active water sources, containment failure does not affect continued indefinite core cooling.

3.2.2 Success Criteria

Success criteria are defined as the minimum grouping of systems, trains, or components that are required to operate in order to meet the acceptance criteria related to the safety functions identified in the previous section. The systems available for each of these functions and their success criteria are summarized in that Table 3.2-1.

3.2.3 Event Tree Development

The event tree methodology is used to represent the possible sequences of events following any one of the initiating event groups defined in Section 2. Each event tree sequence depicts a possible combination of system and operator action successes or failures leading to either the successful cooling of the core or to core damage according to the acceptance and success criteria defined in Sections 3.2.1 and 3.2.2.

The end point of each of these sequences could be either a stable and safe state of the plant (i.e., hot standby conditions), or a plant damage state (i.e., core damage) identified as an accident class. The list of accident classes used for the ESBWR plant is given in Section 3.2.4.

The event trees developed in the ESBWR PRA are presented in Appendix A.3 as follows:

(1) General Transient

(2) Transient with PCS unavailable

(2a) Transient with PCS unavailable after BOC in IC or MS

(3) Loss of Feedwater Transient

(4) Loss of Service Water System

(5) Loss of Preferred Power Transient

(6) Inadvertent Opening of a Relief Valve

(7) ATWS from General Transient or LOPP

(7a) ATWS from Loss of Preferred Power

(8) ATWS from Transient Loss of PCS

(8a) ATWS from Loss of PCS after BOC in IC or MS

(9) ATWS from Transient with Loss of Feedwater System

(10) ATWS from Transient with Loss of Service Water System

(11) ATWS from Inadvertent Opening of a RV

(11a) ATWS from Small LOCA above Reactor Core

(12) Large steam break (above L3) other than Feedwater lines

(13) Large steam break (above L3) on FDW (A) lines

(14) Large steam break (above L3) on FDW (B) line

(15) Small steam break (above L3)

(16) Medium liquid break (below L3) other than RWCU/SDC lines

(17) Medium liquid break (below L3) in RWCU/SDC lines

(18) Small liquid LOCA (below L3) other than RWCU/SDC lines

(19) Small liquid LOCA (below L3) in RWCU/SDC lines

(20) Reactor Vessel Rupture

(20a) Reactor Vessel Rupture after Loss of Preferred Power

(21) Steam break outside containment in Main Steam lines

(22) Steam break outside containment in FDW A lines

(23) Steam break outside containment in FDW B lines

(24) Large steam break outside containment in IC lines

(25) Large liquid break outside containment in RWCU/SDC lines

The specific characteristics that are taken into consideration for the development of each event tree and its functions are described in Section 3.3.

3.2.4 End States of the Accident Sequences

The event trees presented in this section identify the potential sequences that can lead to core damage. Many of the sequences have common characteristics with respect to the challenge on the containment fission product barrier. These sequences are grouped into damage classes that are analyzed in the Level 2 portion of the PRA. The end states of the accident sequences developed for the ESBWR PRA are defined to facilitate the Level 2 Containment Performance Analysis and provide the link between the Level 1 and Level 2 analyses.

The core damage sequences are grouped together based upon the overall challenge to the containment barrier. They are defined as follows:

- OK: The core is successfully cooled and the containment is intact. There is no core damage in these events.
- CD I: The containment is intact when core damage occurs and the RPV is at low pressure.
- CD II: The containment fails while the core is successfully cooled. Core damage results if the containment failure affects the core cooling. In the ESBWR, it has been demonstrated that this end state is only applicable for scenarios where core cooling is being provided solely by the passive systems; and in these cases, the core does not become uncovered until more than 72 hours from the initiating event. In that time frame, there are many potential recovery actions, including repair of failed equipment. Because of this, CD II events are not included in the baseline CDF for ESBWR. Section 11 provides a sensitivity evaluation that assesses this modeling decision. Note that the event trees presented in Appendix A.3 include this end state so that a separate set of event trees specifically for the sensitivity analysis do not need to be presented.
- CD III: The containment is intact when core damage occurs and there is high RPV pressure at the time of core damage.
- CD IV: Core damage results from an accident sequence with a failure of effective reactivity control (e.g., ATWS without SLCS). This has the potential to affect the containment in a more severe manner than the CD I and CD III because more energy is deposited into the containment prior to RPV failure. The analysis of this end state (Section 8) demonstrates that in fact, all CD IV end states could be treated as CD I or CD III (depending on the RPV pressure) without affecting the results of the containment analysis. This end state has been retained in the Level 1 analysis to more easily allow for sensitivity analyses related to reactivity control.

- CD V: The containment is bypassed at the time of core damage.

The Level 2 analysis requires further discrimination between the end states to determine specific containment challenges. For example, in CD I sequences the water level in the lower drywell is required as input to the Level 2. These sub-classes cannot be determined solely from the sequence path definitions; rather the minimal cutsets must be reviewed for specific failures to determine the applicable plant state. This information is presented in Section 7 along with the results of the Level 1 quantification.

3.2.5 Mission Time

The mission time for the ESBWR PRA is 24 hours. The design of the ESBWR is such that the onsite inventory of cooling water available and plant battery capacity can keep the core covered using passive systems for more than 72 hours. However, the simplifying assumptions made in the PRA analysis are not always applicable for mission times longer than 24 hours. For example, the PRA assumes that once the initiator has occurred, no credit will be given for repair of failed equipment. This is a conservative assumption that is reasonable for a mission time of 24 hours; it provides unreasonable results and misleading insights for a 72 hour mission.

Reference is made to the following terms in the evaluation of containment cooling adequacy:

- Short Term Cooling: Time period less than 24 hours
- Longer Term Cooling: Time period of 24 to 72 hours

In cases where the core remains cooled during the short term but conditions are not stable, a core damage end state will be assigned if there are no effective ways to stabilize the plant in the long term. An example of this is shown in the BOC-RWCU event tree (Figure A.3-25). In cases where there is successful core cooling but the broken line has not isolated, the reactor building will continue to be flooded with water from inside the containment. This flooding can disable the means to align active makeup systems. Eventually (around 72 hours), the passive water sources inside the containment will be depleted and the core will become uncovered. The CD V end state is assigned to this sequence.

The PRA presents a sensitivity analysis in Section 11 to characterize the affect of extending the mission time to 72 hours.

Table 3.2-1

Success Criteria Summary

EVENT TREE HEADING	DESCRIPTION	SUCCESS CRITERIA	NOTES[1]
ADS	Automatic Depressurization System	4 of 8 DPVs Open	• ADS sequence starts on Level 1 • SRVs do not assist in depressurization • Only Group 2 and 3 DPVs credited • Success defined as adequate depressurization to allow gravity drain systems to function
C	Reactor Protection System	(RPS or ARI signal) and Control Rod Movement	
DL	Vapor Suppression System Close	All DW/WW Vacuum Breakers close after MDS/ADS	
DS	Vapor Suppression System Open in Large and Medium LOCA	2 of 3 vacuum breakers close for pressure suppression; at least 1 of 3 vacuum breakers open to prevent excessive negative DW pressure	
I	Isolation Condensers	3 of 4 IC and all PCCS pool connections	Pool connections only needed for 72 hour mission
IA	Automatic Depressurization System Inhibition	Automatic Inhibition Actuation in ATWS	
IIC	Isolation: C Steam Line Broken	Isolation by 1 of 2 Steam Valves	
IFDW A/B	Isolation: FDW Line Broken A/B	Isolation by 1 Valve or 1 check valve	
IML	Isolation: Main Steam Line Broken	Isolation by 1of 2 MSIVs in each main steam line	
IRWCU/SDC	Isolation: RWCU Line Broken	Isolation by 1 of 2 Valves	
M	Overpressure Protection System	1 of 18 SRVs Open No ATWS	• Only 1 SRV lifts on highest spring setpoint of 8.86 MPa (1270 psig) • Success is steam dome pressure less than 13.3 MPa (1914 psig)
MA	Overpressure Protection System	9 of 18 SRVs Open ATWS	• FW Runback is successful • 9 ADS SRVs lift on highest spring setpoint of 8.86 MPa (1270 psig)

Table 3.2-1

Success Criteria Summary

EVENT TREE HEADING	DESCRIPTION	SUCCESS CRITERIA	NOTES[1]
			• Success is steam dome pressure less than 13.3 MPa (1914 psig)
MDS	Manual Depressurization System	4 of 8 DPVs Open	• Same as calculation as ADS
PA	SRV closure	All SRV reclose in ATWS	
RF	Run-back FDW	Automatic Actuation	
SL	Standby Liquid Control System	2 of 2 SLCS	
TPCS	Total Power Conversion System	1 of 12 Bypass Valves Open, 1 of 4 Steam Lines Remain Open, 1 of 4 Circulating Water Pumps, 1 of 4 Feedwater Pumps, and 1 of 4 Condensate Pumps	
UCF	High Pressure Injection Systems	2 of 2 CRD pumps or 1of 4 Feedwater Pumps	• CRD starts on Level 2 • After initial transient, core remains covered
UC	Control Rod Drive Mechanism Injection System	2 of 2 CRD pumps	• CRD starts on Level 2 • Core remains covered
U1C	CRD for RPV injection	1 of 2 CRD pumps	• CRD starts on Level 2 • Core remains covered
U1CF	High Pressure Injection Systems	1of 2 CRD pumps or 1 of 4 Feedwater pumps	• CRD starts on Level 2 • Core remains covered
U2CISHORT	CRD and IC condensate return for short time	2 of 2 CRD pumps for 15 minutes and 3 of 4 IC condensate return lines open	
UF	Feedwater Injection System	1 of 2 Feedwater pumps	
VF	Fire Protection System	1 of 1 Fire Protection System pumps inject	Design Requirement for FPS
VFL	Fire Protection System after Depressurization	1 of 1 Fire Protection System pumps inject	Design Requirement for FPS

Table 3.2-1

Success Criteria Summary

EVENT TREE HEADING	DESCRIPTION	SUCCESS CRITERIA	NOTES[1]
VG	Gravity Driven Cooling System and Equalizing Lines	2 of 8 lines and (2 of 3 GDCS pools or (1 of 3 GDCS pools and 1 of 4 Equalizing lines[2]))	• Core remains covered • If PCCS success, no equalizing lines needed • Without PCCS, core remains covered for > 72 hours with equalizing line open
VG2	Gravity Driven Cooling System and Equalizing Lines	2 of 8 lines and 2 of 3 GDCS pools and 1of 4 Equalizing lines[2]	• No core heatup • If PCCS success, no equalizing lines needed • Without PCCS, core remains covered for > 72 hours with equalizing line open
VG3	Gravity Driven Cooling System and Equalizing Lines	3 of 3 GDCS pools and 1of 4 Equalizing lines[2]	• Equalizing line opens on Level 0.5 • Core remains covered for 72 hours
VLF	Low Pressure Injection Systems	1 of 2 FAPCS pumps or 1 of 1 Fire Protection System pumps	• Core remains covered (FPS pump assumed to have the same head and flow capacity as one FAPCS pump)
VLFL	Low Pressure Injection Systems after Depressurization	1 of 2 FAPCS pumps or 1 of 1 Fire Protection System pumps	• Core remains covered (FPS pump assumed to have the same head and flow capacity as one FAPCS pump)
WC	Containment Inerting System	System vent path	2 inch vent prevents overpressure conditions in containment
WH	Reactor Water Clean Up and Shutdown Cooling System	1 of 2 RWCU/SDC	
WHA	Reactor Water Clean Up and Shutdown Cooling System	1 of 2 RWCU/SDC in ATWS	

Table 3.2-1

Success Criteria Summary

EVENT TREE HEADING	DESCRIPTION	SUCCESS CRITERIA	NOTES[1]
WL	Suppression Pool Cooling	1 of 2 FAPCS Suppression Pool cooling	
WLL	Suppression Pool Cooling after Depressurization	1 of 2 FAPCS Suppression Pool cooling	
WP	Passive Containment Cooling System	4 of 6 PCCS	• PCC Pool makeup not credited • Containment remains below design pressure for 39 hours
WT	Continued PCCS Pool Inventory	All PCCS pools connected or external makeup available from FPS.	• 4 of 6 PCCS heat exchangers function • PCC Pool makeup successful Containment remains below design pressure for more than 72 hours
XS5	Depressurization to FAPCS or FPS	5 of 10 SRVs open	• FPS pump provides injection • Core remains covered • (FPS pump assumed to have the same head and flow capacity as one FAPCS pump)

Notes for Table 3.2-1:

1) Blank field indicates that the condition is covered by the design basis of the system.

2) Some sequences indicate that 2 of 4 equalizing valves are necessary. A review of the cutsets has shown that changing this to 2 of 4 will not alter the sequence results.

3.3 EVENT TREE AND ACCIDENT SEQUENCE ANALYSIS

The event tree provides a structured analysis of the integrated response of the plant systems to any initiating event. Following an initiating event, the objective of each safety function (Section 3.2.1) is queried to determine the overall state of the plant. They are analyzed from left to right, with the functions laid out in approximately the chronological order that they will be satisfied. In the ESBWR PRA, the safety functions are further broken down to the system level to determine whether or not the function objectives are met. Finally the event tree concludes with an end state (Section 3.2.4) for each analyzed sequence.

Some of the event tree figures show a "transfer" to another event tree. For example, the failure to SCRAM following a General Transient (Figure A.3-1) is transferred to the ATWS model (Figure A.3-7). The modeling of the sequence continues on the specified tree.

At each system query, or branch, the event tree shows either success of that system or failure. The convention used in the ESBWR model is that the branch upward represents success of the system while the branch downward represents failure. A path that does not branch under a particular system heading indicates that either the state of that system can be completely determined by the path leading to that point or that the success state of that system is not relevant to the remainder of the sequence. Using this method, the resulting end states represent all of the possible outcomes as a result of the initiating event.

The frequencies of each of the end states are determined by estimating the conditional probabilities of each branch on the event tree. The probabilities are assigned based on fault tree models of each of the systems. These are described in Section 4.

In the final model representation, the sequence of headings may not retain their chronological order. The re-ordering is done to prevent the quantification code from generating non-minimal cutsets. The re-ordering does not affect the outcome of Level 1 PRA results.

The numerical results of the event trees are presented in Section 7.

Event sequences for a general transient (turbine or reactor trip initiators) are described in the following section.

For the other initiators, the sequences and headings that differ from those of the general transient are given.

The event trees for all of the internal initiating events are shown in Appendix A.3.

3.3.1 Transients

3.3.1.1 General Transient (BASE Case)

(1) Development of the General Transient Event Tree (T GEN)

Uncomplicated turbine or reactor trips are typically the most frequent initiating events at nuclear power plants. In these events, the Feedwater System and the Power Conversion System, designated the Total Power Conversion System (TPCS) in the ESBWR PRA, are initially available.

Immediately following the trip, a scram signal is generated to initiate control rod insertion. The failure to insert control rods is transferred to the specific ATWS event tree for this initiating event.

If the TPCS remains available, all the safety functions required are assured, because both the short-term and long-term core cooling functions are accomplished.

In case of TPCS failure, the Isolation Condenser (I) function is initiated by high reactor pressure or due to low water level in reactor vessel. For cases that lead to low reactor water level, Main Steam Line Isolation Valve (MSIV) closure occurs. The I function is sufficient to perform the short-term and, with all the water that is in upper pools, the long-term core cooling functions.

If the I function fails, the pressure in the reactor rises until one or more Safety Relief Valves (SRV) open on their spring setpoint. Steam is relieved to the suppression pool and makeup water is required to keep the core covered. At this point in the sequence, the reactor pressure remains high so Feedwater or the Control Rod Drive (CRD) system in high pressure injection mode could provide adequate flow to the core. HPCRD initiates automatically on low water level. If either of these systems is successful, adequate core cooling is assured without any limitations.

In the case of failure of all SRVs to open, the situation is considered as a Reactor Vessel Rupture (RVR), and it is transferred to the specific RVR event tree for this kind of initiating event. The opening of one SRV is sufficient to prevent vessel overpressure failure.

If the high pressure injection systems fail to restore water level in the RPV, low pressure injection systems will need to operate. In order to do this, depressurization of the RPV is needed. This can occur either manually using SRVs as directed by plant EOPs, or automatically via ADS.

The opening of SRVs is sufficient for reactor depressurization to allow the low pressure system injection. Either the Fuel and Auxiliary Pool Cooling System (FAPCS) in the injection mode or the Fire Protection System (FPS) in the injection mode, have the capability to successfully perform the coolant makeup function for both the short and long term. Condensate pumps could also be used to inject water to the vessel. However, because of the strong dependence with both the TPCS and FDW headings, which are already resolved as failed in these sequence paths, the condensate pumps are conservatively not credited as a separate low pressure injection heading.

If the active low pressure injection systems fail, following successful depressurization using the SRVs, ADS will automatically actuate and the passive Gravity Driven Cooling System (GDCS) will provide core inventory. If manual depressurization with SRVs fails, the ADS will actuate to depressurize using the Depressurization Valves (DPV). Then GDCS, FAPCS, or FPS can support the core cooling functions as indicated above.

For the sequences in which FAPCS or FPS provide water injection, no further systems or actions are necessary to ensure long term cooling. For the sequences where the water injection function is performed by GDCS, the core will remain covered for more than 24 hours, however to preserve the state indefinitely without recovery of any of the active systems, the containment heat removal function may be necessary. As stated in 3.2.4, the baseline PRA considers these sequences as success paths. Section 11 presents a sensitivity analysis that shows the affect of extending these sequences. The sequence paths designated as CD II are used to quantify the sensitivity.

There are multiple methods to satisfy the containment heat removal function. These include the following:

- RWCU in shutdown cooling mode
- PCCS (For successful PCCS actuation, the vacuum breakers between the drywell and the wetwell must work as designed.)
- FAPCS in suppression pool cooling mode
- Containment vent

The event tree drawing for the General Transient is shown in Figure A.3-1.

(2) Heading Descriptions

SCRAM (C)

The self-sustaining nuclear reaction is terminated by rapidly inserting control rods so that the core remains shutdown for all moderator conditions. The ESBWR scram system is capable to drive control rods into RPV by multiple means. Preferentially, the Reactor Protection System (RPS) performs the scram. The RPS can fail to insert the control rods either electrically or hydraulically. The electrical part of the RPS has a backup system, the Alternate Rod Insertion System (ARI). A second backup is provided by a FMCRD run-in of the control rods that is independent of both the electrical and hydraulic function.

PCS and FDW (TPCS)

This functional heading includes the use of both the PCS and FDW to cool down the reactor after a trip. This is the preferred way to accomplish the short-term and long-term core cooling functions.

The FDW remains available following the scram because the RPV Level 9, the setpoint for FDW pump trip, is not reached. The success criteria of this function is the operation of the FDW level control system, at least one FDW pump, one Condensate pump, one Bypass valve, and one Circulation pump with at least one steam line able to connect the RPV to the Condenser throughout the sequence mission time.

If the FDW part of this heading fails, RPV level 2 setpoint is reached and subsequently MSIV closure and initiation of IC and CRD injection occurs.

If the PCS part of the function fails, the pressure in the RPV rises and the high RPV pressure IC initiation setpoint is reached. Even if upon reaching RPV level 2 setpoint, MSIV closure is automatically initiated, the operator could reopen them promptly in order to recover the function of Bypass if it is available. Nevertheless, as a conservative assumption, this scenario is not included in the model.

Isolation Condensers (I)

Auto initiation of I function occurs in case of TPCS failure, either on low RPV water level (Level 2), closure of MSIV, or high RPV pressure.

The I function is able to prevent RPV water Level 1.5 from being reached if there is little or no leakage from the RPV. The existence of leaks present prior to the initiating event, and equal to

the maximum RCPB leak rate permitted by Technical Specifications, are judged to not result in ADS actuation during the transient.

The success criterion of this function is the operation of at least three of four ICs during the sequence mission time.

At least 1 SRV Open (M)

If the TPCS and the I function both fail, the pressure in the RPV will rise to the actuation setpoint of the SRV. The criteria for this function are the operation of at least 1 SRV automatically. Conservatively, the failure of this function is assumed that will produce a RVR.

After the opening of at least one SRV, it is not necessary to take into consideration that all of the opened SRV close properly when the pressure in the RPV decreases below the SRV. That is because from this point in the event tree onwards, no further credit is given for the I function.

High Pressure Injection Systems (U1CF)

Injection into the RPV can be provided at high pressure by the FDW or by the CRD system. FDW continues running after the initiating event and CRD system automatic initiation occurs at RPV Level 2.

FDW is successful if at least 1 FDW pump and 1 Condensate pump taking suction from the Condenser, which is replenished from the Condensate Storage Tank (CST), for the mission time. If FDW fails to keep the RPV water level above Level 2, CRD injection automatically initiates. Success of CRD for this function is the effective injection into the reactor vessel of 1 CRD pump taking suction from the CST.

RPV depressurization is directed by procedure in this case due to the rise in the water level in the suppression pool. The continuous transfer of water, from the CST to the suppression pool via the SRVs, causes the increase. Neither failure to depressurize nor the depressurization itself cause failure of the high pressure systems credited in this heading.

At least 5 SRV open (XS5)

If no high pressure injection system is available, it is necessary to depressurize the RPV by opening SRVs to permit effective FACPS or FPS injection to the RPV.

Success of this function is the manually opening of at least five of eight SRVs.

Low Pressure Injection System (VLF)

After successful XS5 depressurization, both the FAPCS and the FPS can accomplish the core cooling function when configured in the RPV injection mode. Both systems are manually actuated and it is necessary to inhibit containment isolation signals if any are present.

Success of this function is the effective operation of at least 1 train of FAPCS or FPS, operating in RPV injection mode for the duration of the sequence.

At Least 4 DPV Open Automatically (ADS)

If water level drops to Level 1, the ADS logic will automatically start a depressurization sequence. This sequence starts with the opening of SRVs and continues through the opening of the DPVs.

The success criterion for this function is to open at least 4 of 8 DPVs.

Gravity Driven Cooling Systems (VG)

If all of the active injection systems are unavailable after a successful full RPV depressurization, the passive GDCS injects water into the RPV by gravity.

The success criteria for this function is discharge of at least 2 GDCS pools or the discharge of 1 GDCS pool and the opening of at least 1 equalizing line from the suppression pool. In addition, at least 2 GDCS discharge lines must open to provide the flow path from the GDCS pools.

Low Pressure Injection System after ADS (VLFL)

If the low pressure injection system could not provide RPV makeup due to the failure of XS5, then after a successful ADS the FAPCS or the FPS can accomplish the core cooling function in case of failure of the GDCS. Both systems are manually actuated and it is also necessary to inhibit the isolation signals, RPV Level 2 and high drywell pressure, that would be present in this case.

Success of this function is the success of at least 1 train of FAPCS or FPS operating in the RPV injection mode.

RWCU/SDC (WH)

The decay heat removal function can be accomplished by the RWCU/SDC system. This function is effective only if the reactor water level is recovered at normal level above Level 3. This system with the help of the steam sent by the SRV to the suppression pool, is able to support short-term decay heat removal, until the time that the RWCU/SDC alone is sufficient to cool the water in the vessel in the long-term.

The failure of this function is the failure of the system to operate with at least 1 pump at 100 % capability during the sequence mission time. A manual action is necessary to configure the system in this mode.

Vacuum Breaker Closed (DL)

The Steam Suppression System (SSS) has vacuum breakers that open in case the pressure in the wetwell is greater than the pressure in the drywell. PCCS effectiveness in containment heat removal requires that a small pressure differential exist between the drywell and wetwell. To this end, the vacuum breakers between the DW and WW must be leak tight to maintain this small DW to WW pressure differential.

The heading success criteria represented here is that all the vacuum breakers are closed or re-close following a previous actuation.

Passive Containment Cooling System (WP)

The passive containment heat removal function can be performed by the PCCS. The PCCS is effective when the drywell pressure is greater than the wetwell pressure, i.e., all of the vacuum breakers are closed and leak tight.

The system is always open to the containment atmosphere and it has no valves that require opening. Failure of this function is the loss of effectiveness of the heat exchangers in removing the decay heat from containment atmosphere (e.g., tube plugging).

The success criterion for this function is the operation of at least 4 of 6 heat exchangers.

Long Term Containment Cooling System (WT)

PCCS or the Isolation Condensers can perform the long term containment heat removal function as long as water remains in the pools of the upper part of the containment. There is at least enough water present during operation to remove decay heat for at least 24 hours. A connection to the refueling well in the upper reactor building will automatically open to extend this inventory to at least 72 hours. This is backed up by the ability to make up water to the pools using various water systems. In the PRA, the source provided by FPS is credited because it is completely independent, including support systems, of GDCS and the PCCS automatic water makeup.

The success criteria for this function are the connection of the pools to the refueling well or adequate external water sources to the pools.

Suppression Pool Cooling after Depressurization (WLL)

If the core is cooled with GDCS, the decay heat removal function can be accomplished by the FAPCS in the suppression pool cooling mode.

Success of this function is the effective manual initiation and operation of at least 1 FAPCS train.

Vent Containment (WC)

When no containment heat removal system is available, the pressure in the containment will rise. Containment venting is directed by procedure. The actuation of this function is required to avoid the failure of the containment and to provide a means for re-sealing the containment boundary.

The success criterion for the system is manual opening of the vent line.

3.3.1.2 Transient with PCS Unavailable

This group of initiating events (T PCS) includes initiators in which the steam pathway to the condenser is unavailable.

All the functions required to mitigate the events included in this group, except the TPCS, are the same as those following the General Transient. Therefore, the event tree developed for the General Transient is also valid for this event. The only difference is that the TPCS heading is initially failed, and therefore it is removed from the event tree.

The event tree for transient with PCS unavailable initiator is shown in Figure A.3-2.

In a break outside containment in either the ICS or main steam lines occurs, and the isolation of the broken line is successful, the event sequence is identical to the T PCS scenarios. For completeness, the event tree for Transient with PCS unavailable after BOC in IC or MS is shown in Figure A.3-2a.

In the case of RPS failure following the loss of PCS event, the transfer is to the ATWS T PCS event tree.

3.3.1.3 Loss of Feedwater Transient

(1) Development of the Loss of Feedwater Event Tree (T FDW)

This group of initiators consists of the events starting with the total loss of the FDW flow.

In a loss of feedwater event, the initial water level drop is much more severe than in a general transient. It goes down below Level 1.5 almost immediately. This starts a timer sequence that allows water level to be recovered above level 1.5 within a few minutes; otherwise the ADS logic is actuated. The main consequence is that if ADS actuates, ICS cannot be used to remove decay heat.

The design basis for the loss of feedwater event is such that if 3 of 4 isolation condensers actuate and both CRD pumps start in high pressure injection mode upon receipt of Level 2 signal, water level will be restored above Level 1.5 before the timer sequence expires.

If the water level is restored, the event tree proceeds in a similar manner to the general transient, except that TPCS and FDW are not available. TPCS is not available because the MSIVs close on water Level 2.

If ADS successfully activates, CRD is able to keep the core covered; however ICS is not available for core cooling. If CRD fails, then the sequence precedes the same as the general transient branch in which ADS is successful.

If the water level drops below level 1.5 but the ADS does not successfully actuate, ICS remains available for core cooling. Additionally, if the ICS fails too, CRD and FAPCS in LPCI mode (given depressurization using the SRVs only) could still provide core cooling. The event tree allows for this course of events.

The event tree for this event is shown in Figure A.3-3.

In the case of RPS failure, the transfer is to the ATWS T FDW event tree.

(2) Heading Description

An additional two top events are added to T FDW to treat special conditions introduced by the loss of feedwater.

U2CISHORT

The requirement for success at this node is to supply sufficient RPV inventory during the initial transient to avoid the automatic RPV depressurization that could be induced due to low RPV water level. The automatic depressurization is asked at the next node. The inventory requirement only requires operation of the CRD and IC condensate return lines for approximately 15 min to achieve success. Success at this node represents the most likely course of events given the total loss of FDW.

ADS

A second ADS top event is added to the event tree after U2CISHORT. This event is to incorporate the automatic plant response of depressurization on low RPV level that would defeat the IC effectiveness.

3.3.1.4 Loss of Service Water System

(1) Development of the Loss of Service Water and System Event Tree (T SW)

This initiating event produces the failure of the Reactor Closed Cooling Water System (RCCWS) and Turbine Building Closed Cooling Water (TCCW) systems. The event is similar to a loss of the FDW system, except there are three important differences:

- The timing of the loss of RCCWS and TCCWS is not immediate because of the energy absorption available in these two systems.
- Likewise, Feedwater is not lost immediately
- Additional systems that cannot be credited following TSW are RWCU/SCS FAPCS, and CRD.

All the functions required to mitigate the events included in this group (except for those lost as a direct consequence of the initiator) are the same as those following the General Transient. Therefore, the event tree developed for the General Transient is also valid for this event. However, considering that TPCS, U1CF, WH, and WLL headings are initially failed, they are removed from the event tree. In addition, the VLF and VLFL headings are changed to the VF and VFL headings, respectively, which takes into consideration that the use of the FPS for low pressure injection is the only available system. The event tree for this event is shown in Figure A.3-4.

In the case of RPS failure, the transfer is to the ATWS T SW event tree.

(2) Heading Description

Low Pressure Fire Protection (VF)

After successful XS5 depressurization, the FPS can accomplish the core cooling function when configured in the RPV injection mode. This system is manually actuated only.

Success of this function is the success of at least 1 train of FPS, operating in the RPV injection mode for the sequence mission time.

3.3.1.5 Loss of Preferred Power Transient

The loss of the preferred power sources (T LOPP) causes a loss of feedwater. The discussion provided above relative to the loss of feedwater response remains applicable to the T LOPP event tree. In addition, the non-safety diesel generators start. However, in case of diesel failure, there is the possibility of restoration of the offsite power before the reactor water level decreases below RPV Level 1 to allow the use of the active systems given that the ICS are ineffective. The modeling of the diesel generator and the power recovery is included in the AC fault tree. There are no new scenarios associated with LOPP or SBO situations.

Therefore, the event tree developed for the Loss of Feedwater Transient is also valid for this event situation. The event tree for this event is shown in Figure A.3-5.

In the case of RPS failure, the transfer is to the ATWS T GEN LOPP event tree.

3.3.1.6 Inadvertent Opening of an RV

The Inadvertent Opening of an RV (T IORV) at power produces the need for a reactor trip when the temperature in the suppression pool increases above the allowed limit. For this initiating event, the TPCS and I functions are unavailable and the M function is guaranteed successful.

All the functions required to mitigate the events included in this group are the same as those following the General Transient. Therefore, the event tree developed for the General Transient is also valid for this event. However, considering that the TPCS and I headings are initially failed and the M heading is successful, they are removed from the event tree.

Additionally, the XS5 heading only requires 4 additional SRVs in this case; nevertheless, for simplification, the same success criteria as described in T GEN are used. The event tree for Inadvertent Opening of an RV is shown in Figure A.3-6.

In the case of RPS failure, the transfer is to the ATWS T IORV event tree.

3.3.2 Failure to Scram Following Transients

3.3.2.1 ATWS Following General Transient or LOPP (Base Case)

(1) Development of the ATWS event tree sequence transferred from Transient with TPCS available or LOPP

The sequence of events following the failure of the RPS after the initiating event of this type in the ESBWR is described below.

ATWS sequences are initiated by any event in which there is a failure of either the hydraulic or electrical control rod insertion modes. To mitigate ATWS, sodium pentaborate at high pressure (in sufficient quantity to achieve subcriticality) is injected into the reactor core region. This is done by the Standby Liquid Control System (SLCS) that stores sodium pentaborate at high pressure inside an accumulator. The SLCS is activated, automatically, on high RPV pressure or an RPV Level 2 signal in combination with Average Power Range Monitors (APRM) not down-scale signal lasting for 3 minutes.

In order to control reactivity, ESBWR also uses FDW runback and ADS inhibit functions. FDW runback reduces the power by affecting natural circulation. ADS inhibit allows adequate reactor pressure to be maintained to take credit for IC operability. The ADS inhibit signal is sealed in. Under these conditions, power generation is reduced within the cooling capability of IC and/or CRD until SLCS injection is completed.

ADS inhibit also prevents uncontrolled reactor depressurization and the subsequent GDCS injection which could lead to boron washing out of the RPV. It is assumed that without ADS inhibit the resulting boron dilution causes recriticality.

Following an ATWS with the PCS remaining available, the nuclear boiler system overpressure protection is provided by the actuation of three possible systems: SRV, Bypass, or IC.

With successful SLC injection, core cooling can be performed: (1) by the IC if all the valves that are open also close correctly, (2) by the FDW or CRD with the heat removal by the FAPCS in the cooling mode; or, (3) by RWCU/SDC if isolation signals are inhibited and the filters are bypassed. In case of failure of high pressure systems, core damage is assumed because the

reactor is depressurized, and reactivity control is not credited in preventing core damage because of the potential for boron dilution.

The long term heat removal function is similar to that for transients except that no credit is taken for PCCS, because ATWS mitigation is not carried out at low pressure, as discussed earlier. The preferred source for the residual heat removal is FAPCS, because in ATWS situations the RWCU/SDC is automatically isolated. Nevertheless, if the FAPCS system fails the isolation signal can be overridden and the filters bypassed to allow the use of the system. The General Transient event tree is extensively modified to model ATWS response by eliminating TPCS, M, U1CF, XS5, VLF, VLFL, WH, MDS, ADS, VG, DL, WT, VLL and WP headings, and including the new headings at the beginning of the tree that are described below.

This leaves two headings that remain similar to the general transient: I and WC.

The event tree for ATWS is shown in Figure A.3-7. The event tree for ATWS from Loss of Preferred Power is shown in Figure A.3-7a.

(2) Heading Description

ATWS Initiator (ATWS-GEN-LOPP)

The initiating event for the ATWS event tree is a fault tree with the general transient ANDed with the failure of the RPS and/or ARI or LOPP ANDed with failure of RPS and/or ARI.

At least 9 SRV Open (MA)

In this case, RPV pressure increases to the SRV actuation setpoint value. The success of this function is to open automatically at least 9 SRVs. Conservatively, the failure of this function is assumed to lead to core damage due to RPV rupture and re-criticality at low RPV pressure.

ADS Inhibit (IA)

The ESBWR ATWS mitigation strategy is to maintain the reactor at high pressure until a controlled depressurization can be performed. To maintain the reactor at pressure, an ADS inhibit signal is provided on: (1) high RPV pressure; or, (2) RPV water Level 2 and APRM-not-down-scale signal. This avoids the potential consequences of boron dilution associated with reactor depressurization. Conservatively, the failure of this function is assumed to lead to core damage due to failure to successfully control power.

Standby Liquid Control System (SL)

A reactor shutdown can be achieved by the SLCS injection of concentrated boron at high pressure. Actuation of the SLCS is automatic on high pressure or RPV Level 2 and APRM-not-down-scale for 3 minutes. Conservatively, no back up or long term recovery of this function is considered. The failure of this function is assumed to lead to core damage due to failure to successfully control power.

All SRVs Close (PA)

After the opening of at least 9 SRVs, it is necessary to take into consideration that all of the opened SRVs close properly when the pressure in the RPV decreases below the setpoint of the SRVs. All SRVs must be closed to give credit to the isolation condenser function I, in bringing the plant to a safe state as in the General Transient.

High Pressure Injection Systems (UCF)

The high pressure injection function can be accomplished as was indicated for the General Transient, using FDW or CRD. However, in this case, the success of the CRD requires 2 CRD pumps taking suction from the CST.

Suppression Pool Cooling (WL)

The decay heat removal function preferred for ATWS is accomplished by FAPCS in suppression pool cooling mode, if FAPCS is not previously actuated.

Success of this function is the effective operation of at least 1 FAPCS train. This operational mode of FAPCS initiates automatically upon high temperature in the suppression pool, and if the FAPCS in the injection mode is not previously actuated.

RWCU/SDC (WHA)

The decay heat removal function can be accomplished by the RWCU/SDC system, as indicated for the General Transient, but in this case it is necessary to inhibit isolation signals developed by ATWS logic and bypass the filters.

3.3.2.2 ATWS Following Transient Loss of PCS

(1) Development of the ATWS event tree sequences transferred from Transient with TPCS unavailable

The sequence of events following the failure of the RPS after the initiating event are the same as those described in Section 3.3.2.1, the ATWS following a Transient with TPCS available or LOPP. Therefore, the event tree developed for ATWS following a Transient with TPCS available or LOPP is also valid for this event, considering that a new heading, RF, is included after the MA heading. The RF heading is described below.

The event tree for ATWS following transient with loss of PCS is shown in Figure A.3-8. The event tree for ATWS from Loss of PCS after BOC in IC or MS is shown in Figure A.3-8a.

(2) Heading Description

Feedwater Pumps Run-Back (RF)

An FDW runback is an automatic function that occurs on high RPV pressure and APRM-not-down-scale signal. The FDW is run back to a no-flow condition by tripping FDW pumps. This action is necessary to limit power production in the short term following the accident, in order to keep the pressure spike in the RPV below the reference limit. Conservatively, the failure of this function is assumed to lead to core damage due to a failure to successfully control power.

3.3.2.3 ATWS Following Transient with Loss of Feedwater System

The event tree developed for ATWS sequences transferred from the General Transient event tree is also valid for this scenario. However, the UCF heading is changed to the UC heading, which requires success of two CRD pumps for high pressure injection.

Note that ADS inhibit prevents the premature RPV depressurization due to low RPV water level as a result of the loss of feedwater. This is different than the non-ATWS loss of feedwater transient accident sequences.

The event tree for ATWS following a transient with loss of feedwater system is shown in Figure A.3-9.

3.3.2.4 ATWS Following Transient with Loss of Service Water System

The event tree developed for the ATWS following a General Transient is also valid for this scenario considering that the headings UCF, WHA, WC, and WL are initially failed or are not required and they are removed from the event tree.

The event tree for ATWS following Transient with Loss of Service Water System is shown in Figure A.3-10.

3.3.2.5 ATWS Following Inadvertent Opening of an RV

The event tree developed for ATWS following a General Transient is also valid for this scenario considering that the headings PA, I, and WT are initially failed or are not required and they are removed from the event tree.

The event tree for ATWS following inadvertent opening of an RV is shown in Figure A.3-11.

3.3.2.6 ATWS from Small LOCA above Reactor Core

While this event technically begins as a loss of coolant accident, the sequence of mitigating events is the same as the ATWS IORV event.

The event tree from ATWS from small LOCA above reactor core is shown in Figure A.3-11a.

3.3.3 LOCAs

3.3.3.1 Large Steam Break (above L3) Other than Feedwater Lines (Base Case)

(1) Development of the Large Steam Break Event Tree (LL S)

A large LOCA is an event leading to a rapid loss of coolant, resulting in a rapid consequential depressurization, such that no emergency depressurization is required in order to permit the low pressure injection systems, including GDCS, to inject.

Immediately following the break, there is a drop in the RPV water level. The FDW system attempts to maintain the water level in the vessel. If FDW is not available, CRD automatically injects at RPV Level 2. FAPCS or FPS in injection mode can be manually actuated after defeating automatic isolation. As an alternative to these systems, GDCS and the equalizing lines are sufficient to provide core cooling. Because the RPV is at low pressure, it is considered that the injection system components operability will not be impaired due to high pressure, given the pump head and containment ultimate capability. When the core is cooled with GDCS, the RWCU/SDC is the preferred residual heat removal method after the water level in the vessel is restored. If RWCU/SDC is not available, core cooling requires that the LOCA blowdown energy be dissipated by the condensation of the steam that passes through the vents to the suppression pool. If the vapor suppression function is successful, the decay heat removal is accomplished by PCCS, by natural convection and steam condensation. One FAPCS system train can also accomplish the long-term heat removal. Finally, if all other heat removal systems fail, the containment vent can be initiated to reduce the pressure in the containment.

All of the functions required to mitigate the events included in this group, except for TPCS, I, XS5, ADS, VLFL, and MDS headings, are the same as those following the General Transient. Therefore, the event tree developed for the General Transient is also valid for this event, except that the TPCS and I headings are initially failed, and XS5, ADS, and VLFL headings are not required and are removed from the event tree. Also a new heading, DS heading, is included after the RPS heading, as described below.

The event tree for large steam breaks (above L3) other than feedwater lines is shown in Appendix A.3 (Figure A.3-12).

(2) Heading Description

Steam Suppression System (DS)

The Steam Suppression System has vacuum breakers that must be initially closed during the LOCA blow-down to allow steam condensation in the pool. These vacuum breakers must also subsequently open if drywell pressure decreases relative to the wetwell pressure. This would avoid negative pressure failures.

This heading takes into consideration the need of at least two of three vacuum breakers to be closed for the steam suppression function to be successful and at least one vacuum breaker to open after steam suppression to avoid containment failure due to negative pressures in the drywell.

3.3.3.2 Large Steam Breaks (above L3) in FDW (A) Line

The sequence of events subsequent to the initiating event is the same as those described in large steam breaks other than FDW lines. Therefore, the event tree developed for large steam breaks other than FDW lines is also valid for this initiating event, except that the U1CF heading is changed to U1C, and the VLF and VLFL headings are not applicable, due to the failure of FDW line A.

The FDW is assumed failed for a large break in either FDW line due to loss of FDW suction inventory.

The event tree for large steam breaks (above L3) in FDW (A) line is shown in Figure A.3-13

3.3.3.3 Large steam breaks (above L3) in FDW (B) line.

The sequence of events after the initiating event is the same as those described in large steam breaks other than FDW lines. Therefore, the event tree developed for large steam breaks other than FDW lines is also valid for this initiating event, except that the U1CF heading is not applicable due to the failure of the line B of the FDW.

This is because failure of the "B" FDW line results in the following:

- FDW is assumed failed for a large break in either FDW line due to loss of FDW suction inventory.
- CRD is failed due to the "B" FDW line failure because CRD injection is through the "B" FDW line.

The event tree for large steam breaks (above L3) in FDW (B) line is shown in Figure A.3-14.

3.3.3.4 Small Steam Breaks (above L3)

A small LOCA is an event leading to a slow loss of coolant, such that depressurization is required in order to permit the low pressure injection systems to inject. This group includes both the medium and small LOCA group included in Section 2, "PRA – Initiating Event Analysis". In this group of initiating events, it is considered that the size of the break does not affect the availability of any system that connects to the line containing the small LOCA.

All of the functions required to mitigate the events included in this group, except for TPCS and I headings, are the same as those following the General Transient. TPCS and I headings are initially failed and thus are removed from the event tree.

The event tree for small steam breaks (above L3) is shown in Figure A.3-15.

3.3.3.5 Medium Liquid Breaks (below L3) Other than RWCU/SDC Lines

(1) Development of the medium liquid breaks (below L3) other than RWCU/SDC lines.

A medium liquid LOCA is an event leading to a rapid loss of coolant, but with a smooth consequential depressurization, that allows low pressure injection system actuation, but requires that a full depressurization occurs in order to permit GDCS to inject.

In this initiating event, it is considered that the CRD pumps are not able to compensate for the inventory lost through the break. It is also considered that the FAPCS in injection mode, which takes suction from the suppression pool, is lost on suppression pool low water level, before the level of water outside the vessel can maintain the core covered. Therefore, FAPCS in the suppression pool cooling mode is not available in those cases. Finally, a greater amount of inventory must be discharged from the GDCS pool combined with equalizing lines to guarantee that the core is covered in all cases.

Accordingly, all the functions required to mitigate the events included in this group except for the TPCS and I headings, are the same as those following the General Transient. Therefore, the event tree developed for the General Transient is also valid for this event, except that the UCF heading has is changed to UF, to take into consideration that 2/2 CRD pumps operating is not enough to compensate for the leak from the break. The VLF and VLFL headings are changed to the VF and VFL, to take into consideration that FAPCS is not credited in these situations. Finally VG is changed to VG2, and is described below. TPCS and I headings are initially failed and are removed from the event tree, and a new heading is included after the RPS heading, DS heading, which is described under the large steam breaks event tree.

The event tree for this event is shown in Figure A.3-16.

(1) Heading Description

Two Gravity Driven Cooling Systems (VG2)

This function is similar to the one described in the General Transient section. However, in this case, the passive GDCS has to open two GDCS lines, discharge at least 2 GDCS pools and also one equalizing line must be opened for long-term cooling.

The success criteria for this function is the discharge of at least 2 GDCS pools and the opening of at least 1 equalizing line and functionality of 2 GDCS 150 mm dia. lines.

3.3.3.6 Medium Liquid Breaks (below L3) in RWCU/SDC Lines

The sequence of events after the initiating event is the same as described above for Medium liquid breaks. Therefore, the event tree developed for Medium liquid breaks in other lines (Section 3.3.3.5) is also valid for this initiating event, considering that the WH heading is not applicable in this case due to the break location.

The event tree for medium liquid breaks (below L3) in RWCU/SDC lines is shown in Figure A.3-17.

3.3.3.7 Small Liquid LOCA (below L3) other than RWCU/SDC Lines

All of the functions required to mitigate the events included in this group, except for the TPCS, are the same as those following the General Transient. Therefore, the structure of the event tree developed for the General Transient is modified to require that both CRD (or FDW) and ICS be successful to reach a safe condition similar to the General Transient. It is also considered that the FAPCS, which takes suction from the suppression pool, is lost on low level in the suppression pool, before the level of water outside the vessel can maintain the core cover, and that the FAPCS in the suppression cooling mode is not available in that case. Because TPCS is initially failed, it is removed from the event tree.

The event tree for small liquid LOCA (below L3) other than RWCU/SDC lines is shown in Figure A.3-18.

3.3.3.8 Small Liquid LOCA (below L3) in RWCU/SDC Lines

The sequence of events after the initiating event is the same as what is described in Section 3.3.3.7 for small liquid breaks other than RWCU/SDC lines. Therefore, the event tree developed for small liquid breaks other than in RWCU/SDC lines is also valid for this initiating event, considering that the WH heading is not applicable in this case.

The event tree for small liquid LOCA (below L3) in RWCU/SDC lines is shown in Figure A.3-19.

3.3.3.9 Reactor Vessel Rupture

A Reactor Vessel Rupture (RVR) is considered, in a conservative way, as an event leading to a rapid depressurization and a loss of coolant through a large break in the bottom of the RPV.

For this initiating event, it is considered that no active high pressure or low pressure system is able to compensate for the inventory lost through the break and maintain the level in the reactor above RPV Level 1 before core damage. Only the injection by the GDCS can provide an amount of water quickly and with enough volume to allow the level of water outside the vessel to maintain the core covered.

The event tree structure developed for medium liquid break in "other than RWCU/SDC" lines (Section 3.3.3.5) is also valid for this initiating event, considering that the UF, VF, ADS, VFL and WH headings are not applicable due to the break size and location.

The event tree for reactor vessel rupture is shown in Figure A.3-20. The event tree for Reactor Vessel Rupture after Loss of Preferred Power is shown in Figure A.3-20a.

3.3.4 Break Outside Containment

In addition to a LOCA occurring within the drywell as described in Section 3.3.3, there is also the possibility of breaks outside the containment, which could lead to loss of primary coolant if not isolated in time.

3.3.4.1 Steam Break Outside Containment in Main Steam Lines (Base Case)

(1) Development of the Steam break outside containment in Main Steam Lines Event Tree

Immediately following the break there is a drop in the RPV pressure and an isolation signal is sent to the MSIVs to close. In the case of successful isolation, the scenario develops into a T PCS. If the isolation fails, the containment is bypassed and all the functions required to mitigate the event included in this group, except for TPCS, I, WH, M, DL, WP, WT, WLL and WC headings are the same as those following the General Transients. Therefore, the event tree developed for the General Transient is also valid for this event, considering that all of the above headings are failed or are not required and are removed from the event tree. Also, a new heading is included before the RPS heading, I ML heading, with is described below.

The event tree for this event is shown in Figure A.3-21.

(2) Heading Description

Isolation of all the Steam Lines (I ML)

This heading takes into consideration the need for at least one isolation valve to close in each steam line to stop the loss of inventory outside the containment before RPV Level 1 is reached.

3.3.4.2 Steam Break Outside Containment in FDW A Line

(1) Development of the Steam break outside containment in FDW A lines Event Tree

The sequence of events after the initiating event is the same as described in steam breaks in Main Steam lines. Conservatively, credit is not given to the WH heading because the RWCU isolation condition is not easily overridden. Therefore, the event tree developed for Steam breaks in Main Steam lines is also valid for this initiating event, considering that the U1CF heading is changed to the U1C, the VLF and WH headings are not applicable, due to the failure of line A of the FDW or the isolation signal and a new heading is changed from I ML to I FDW A heading, which is described below.

The event tree for this event is shown in Figure A.3-22.

(2) Heading Description

Isolation of FDW A Line (I FDWA)

This heading takes into consideration the need for at least one isolation valve in FDW line A to prevent the loss of inventory outside the containment before, RPV Level 1 is reached.

3.3.4.3 Steam break outside containment on FDW B Lines

(1) Development of the Steam break outside containment in FDW B lines Event Tree

The sequence of events after the initiating event is the same as described in steam breaks in Main Steam lines. Conservatively, credit is not given to the WH heading because the RWCU isolation

condition is not easily overridden. Therefore, the event tree developed for steam breaks in Main Steam lines is also valid for this initiating event, considering that the U1CF and the WH headings are not applicable, due to the failure of FDW line B, or failure of the isolation signal. Also, a new heading is included before the RPS heading, I FDW B heading, which is similar to the one described for Line A.

The event tree for this event is shown in Figure A.3-23.

(2) Heading Description

Isolation of the FDW B Line (I FDWB)

This heading takes into consideration the need for at least one isolation valve to close to stop the loss of inventory outside the containment before RPV Level 1 is reached.

3.3.4.4 Large Steam Break Outside Containment in IC Lines

(1) Development of the steam break outside containment in IC lines Event Tree

RPV pressure drops immediately following the break and an isolation signal is sent to the IC valves to close. In the case of successful isolation of the affected line, the scenario develops to a T PCS but with only 3 ICs available. If the isolation function fails, the containment is open and the sequence of events following this initiating event are the same as that described in steam breaks in Main Steam lines sequences. Therefore, the event tree developed for Steam breaks in Main Steam lines is also valid for this initiating event, considering that the I ML heading is changed to I IC.

The event tree for this event is shown in Figure A.3-24.

(2) Heading Description

Isolation of the IC Line (I IC)

This heading takes into consideration the need for at least one IC isolation valve of the affected IC to close to terminate the loss of inventory outside the containment before RPV Level 1 is reached.

3.3.4.5 Large Break Outside Containment in RWCU/SDC Lines

(1) Development Event Tree for the large break outside containment in RWCU/SDC lines

An isolation signal is sent to the RWCU/SDC valves to close, immediately following the line break. This scenario develops to a General Transient but with the WH function failed in the case of successful automatic isolation. In the case of the isolation heading failure, (with failure due to a break being located below the level of the TAF of the core), and after a reactor trip and ADS function, all of the water inventory in the containment is available, (heading VG3), or in case of failure of this heading by the use of the VFL heading, allows time necessary to proceed to a manual isolation of the broken RWCU/SDC line before the core could be uncovered in a long time frame. Isolation headings, I RWCU/SDC and MI RWCU/SDC and VG3 function are described below.

The event tree is shown in Figure A.3-25.

(1) Heading Description

Isolation of the RWCU/SDC Line (I RWCU)

This heading considers the need for at least one isolation valve to close to stop the loss of inventory outside the containment before, in the worst case, RPV Level 1 is reached.

Manual Isolation of the RWCU/SDC Line (MI RWCU)

This heading considers the need that the manual isolation valve, outside the Reactor Building, in the broken line closes to stop the loss of inventory outside the containment before core damage.

Three Gravity Driven Cooling Systems (VG3)

This function is similar to the one described in the General Transient section, but in the case of failure to isolate the break outside containment, the passive GDCS is required to discharge all of the available water to the RPV by gravity from the three pools. At least one equalizing line is required to open for long-term core cooling.

The success criteria for this function are the discharge of all three GDCS pools and the opening of at least 1 equalizing line.

3.4 REFERENCES

3-1. ESBWR DCD Tier 2, Chapter 6, Engineering Safety Features, 26A6642AT, Rev. 1

3-2. ESBWR DCD Tier 2, Chapter 15, Safety Analysis, 26A6642BP Rev 1

3.3 MAAP 4.0.6 ESBWR Application and Comparison to TRACG Benchmarks; *MAAP Support of ESBWR Design Certification Document*, EPRI, Palo Alto, CA and General Electric Co.; 2005 1011712

APPENDIX A.3

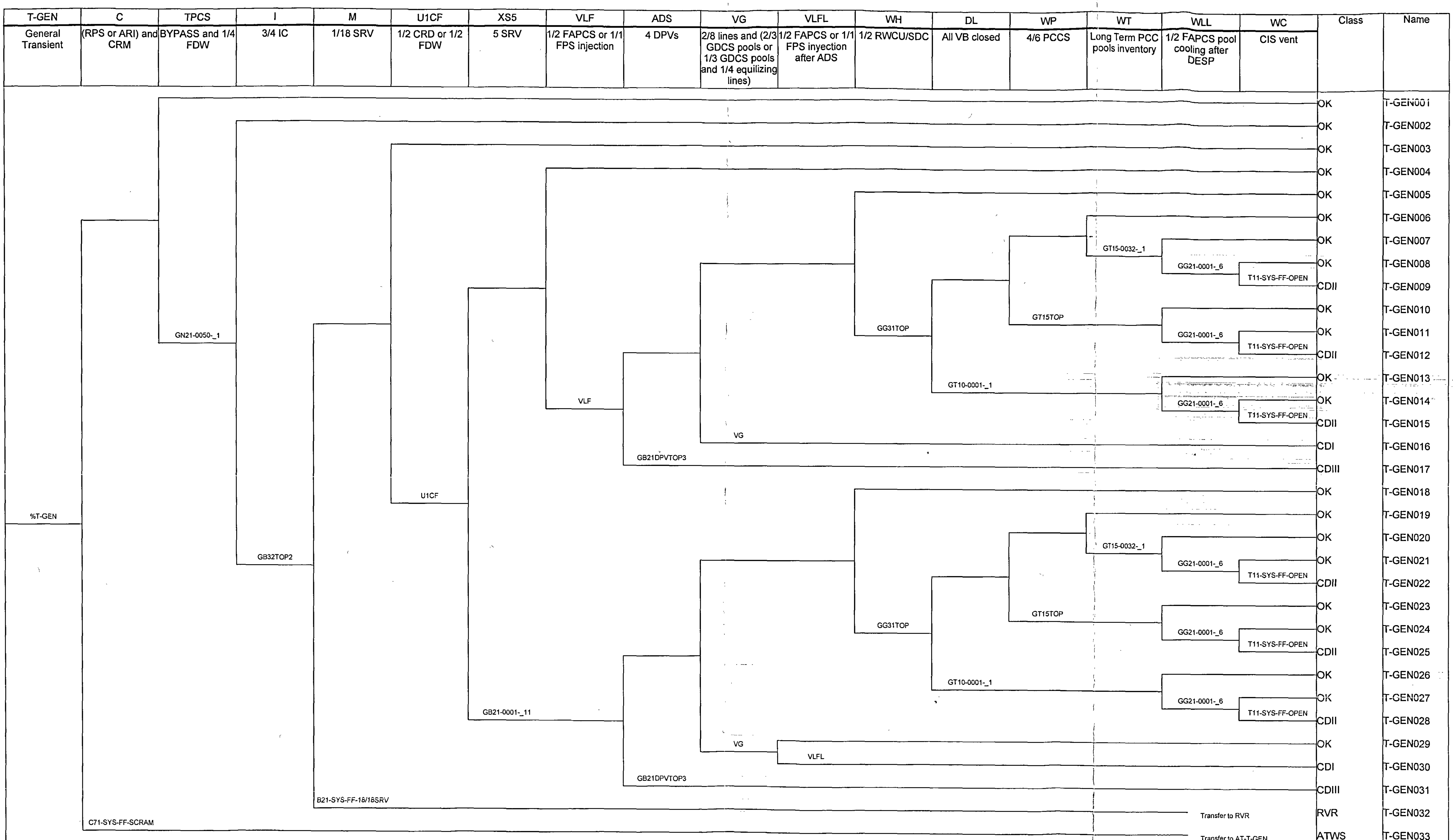


Figure A.3-1. General Transient

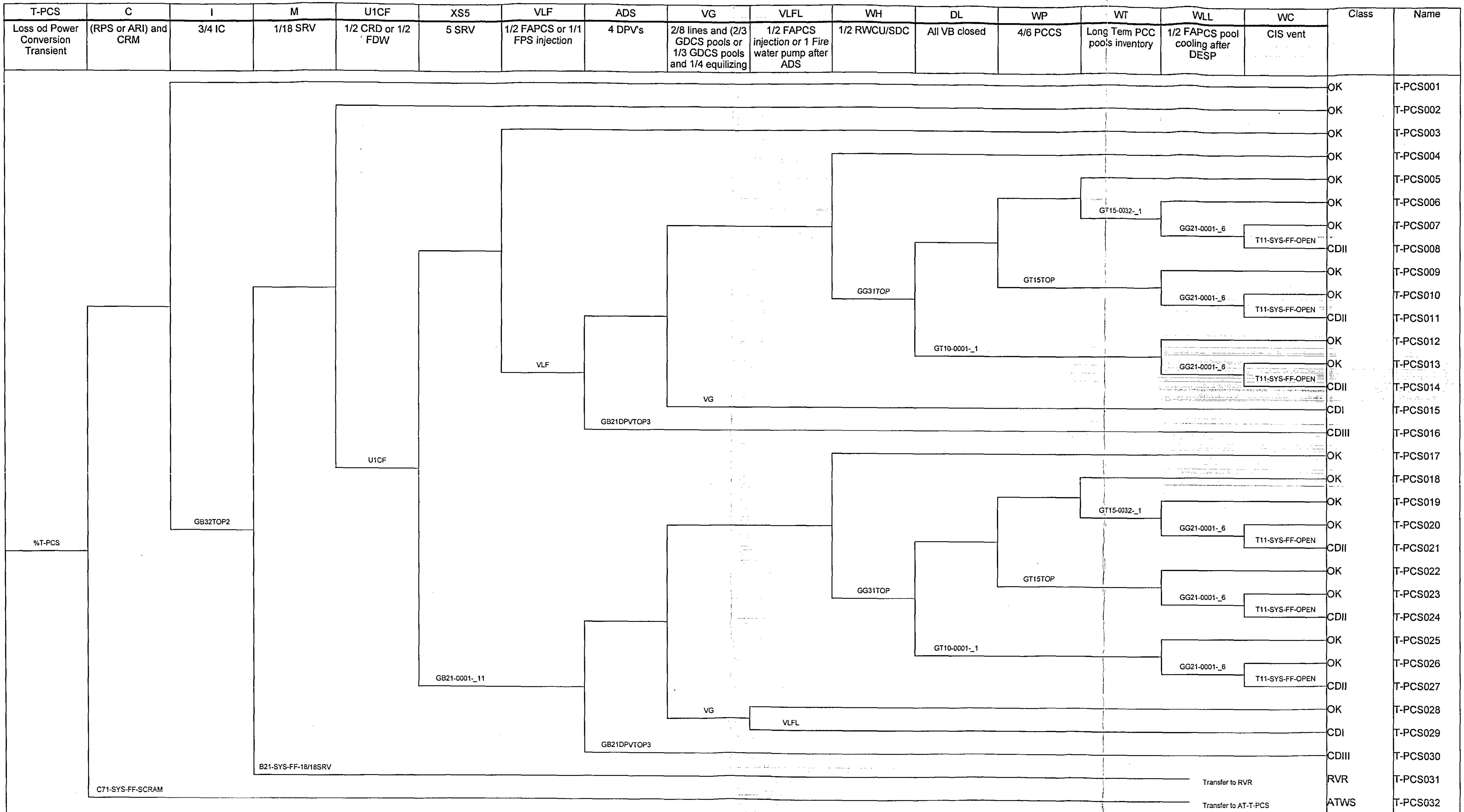


Figure A.3-2. Transient with PCS Unavailable

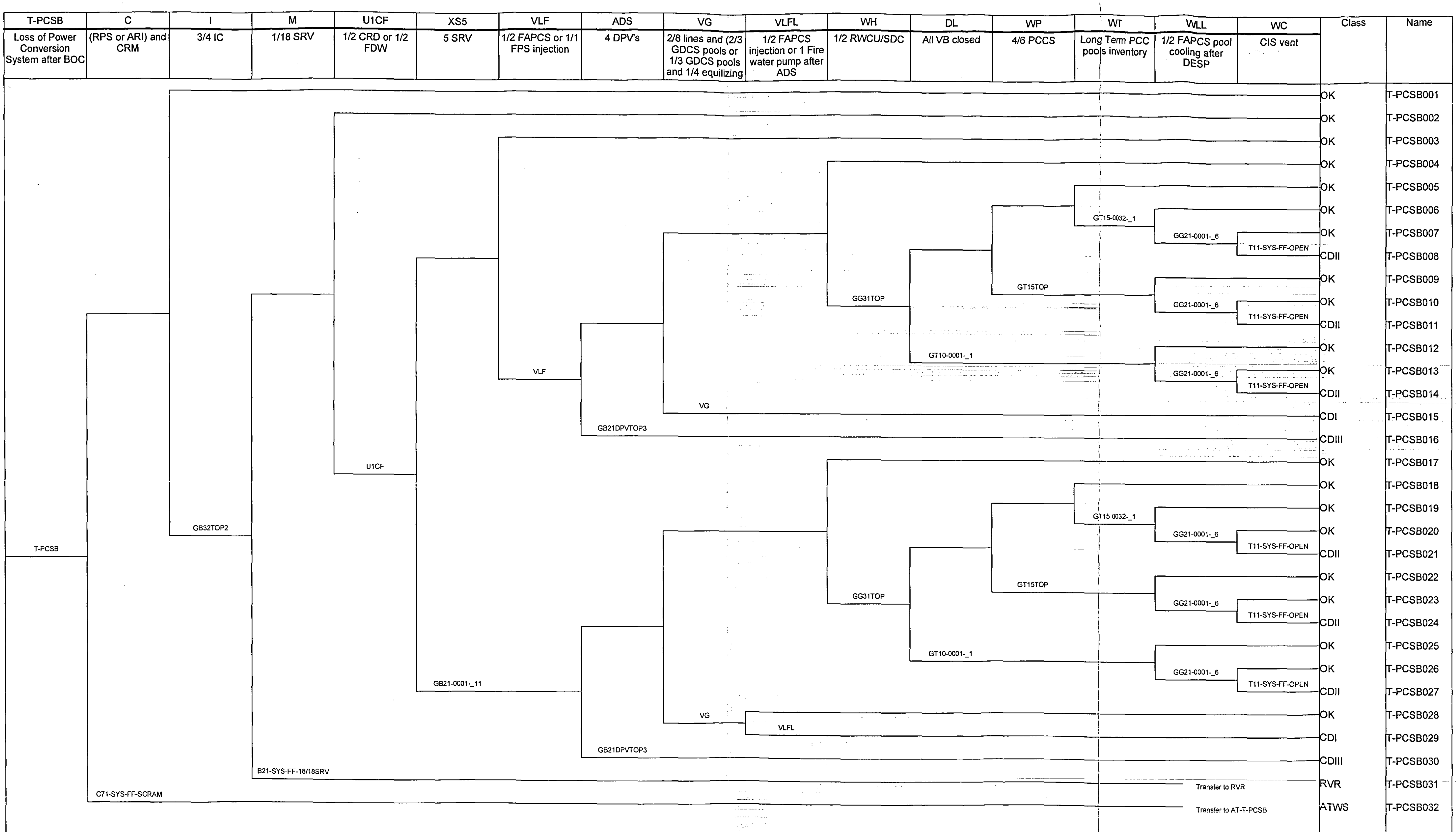


Figure A.3-2a. Transient with PCS Unavailable after BOC in IC or MS

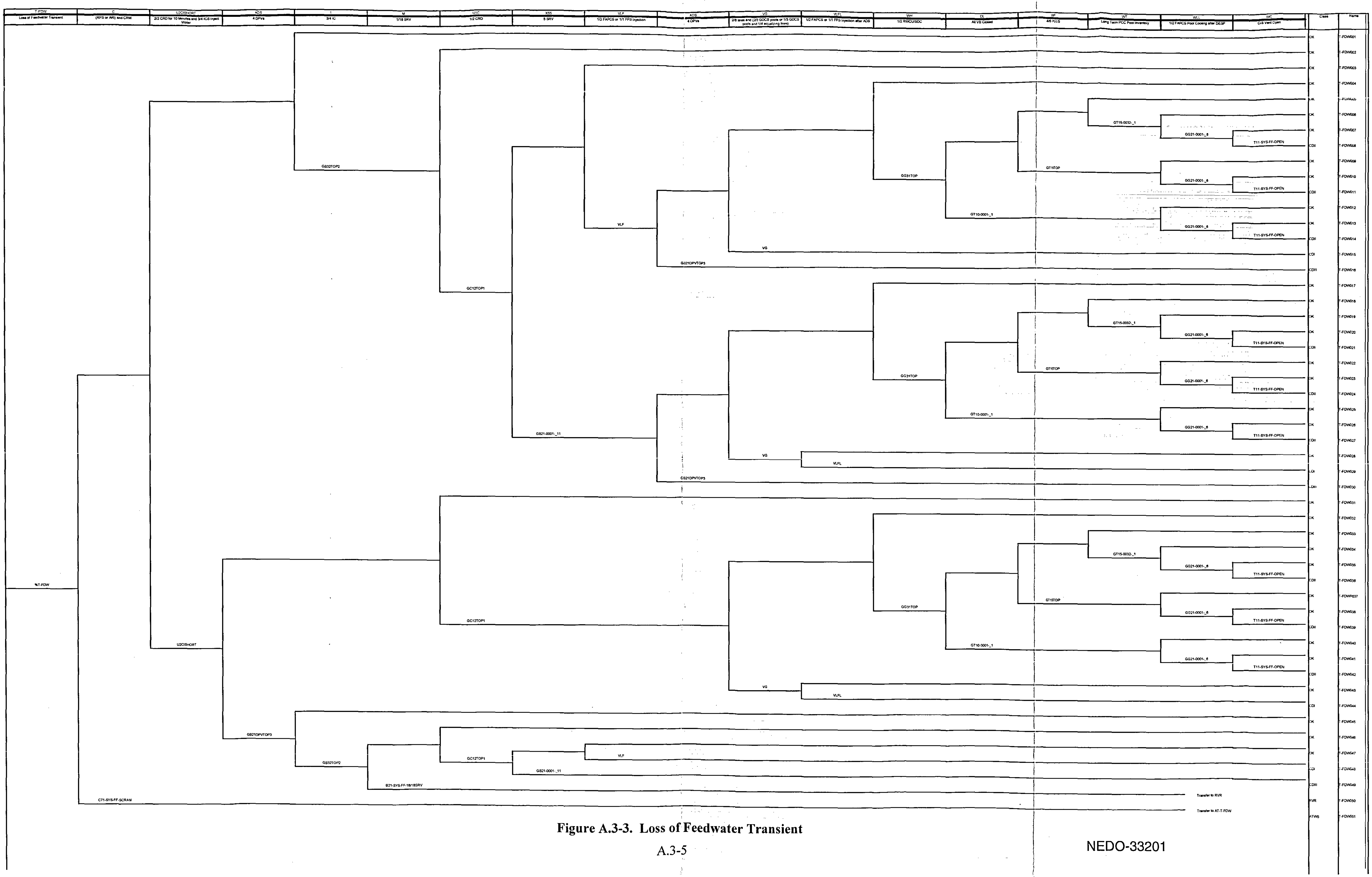


Figure A.3-3. Loss of Feedwater Transient

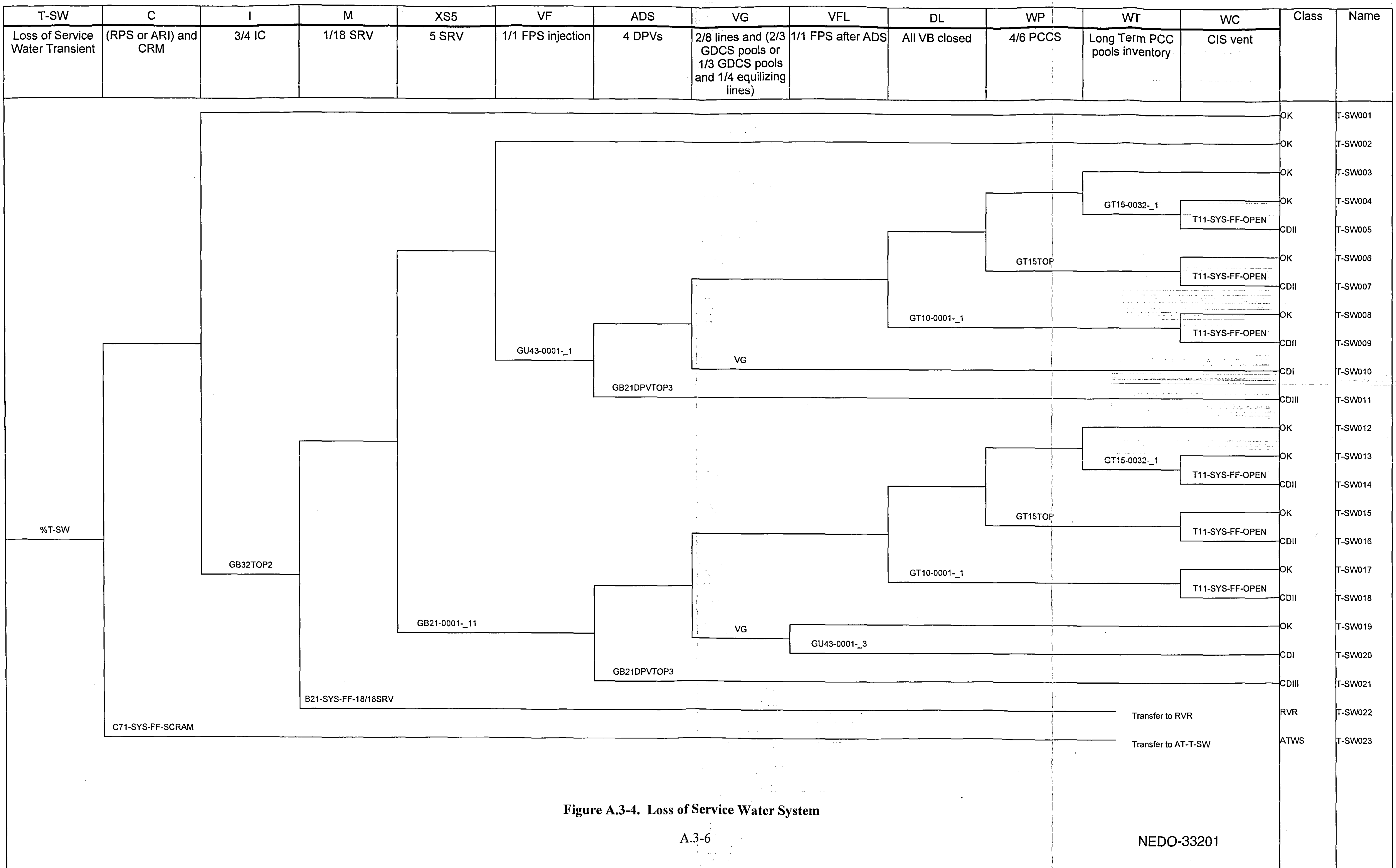


Figure A.3-4. Loss of Service Water System

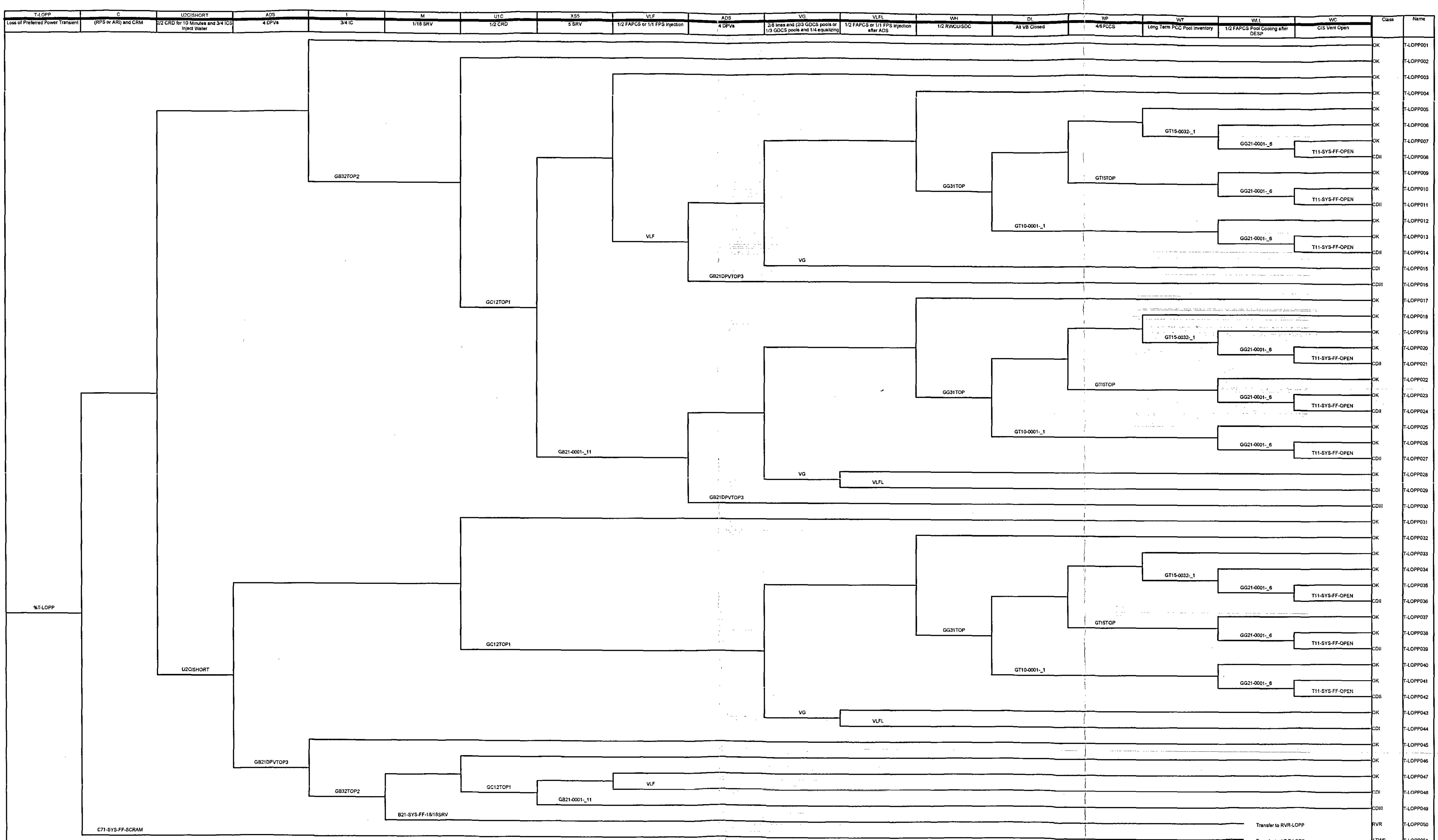


Figure A.3-5. Loss of Preferred Power Transient

T-IORV	C	U1CF	XS5	VLF	ADS	VG	VLFL	WH	DL	WP	WT	WLL	WC	Class	Name
Inadvertent Opening of a RV Transient	(RPS or ARI) and CRM	1/2 CRD or 1/2FDW	5 SRV	1/2 FAPCS or 1/1 FPS injection	4 DPV's	2/8 lines and (2/3 GDCS pools or 1/3 GDCS pools and 1/4 equilizing lines)	1/2 FAPCS or 1/1 FPS injection after ADS	1/2 RWCU/SDC	All VB closed	4/6 PCCS	Long Term PCC pools inventory	1/2 FAPCS pool cooling after DESP	CIS vent		

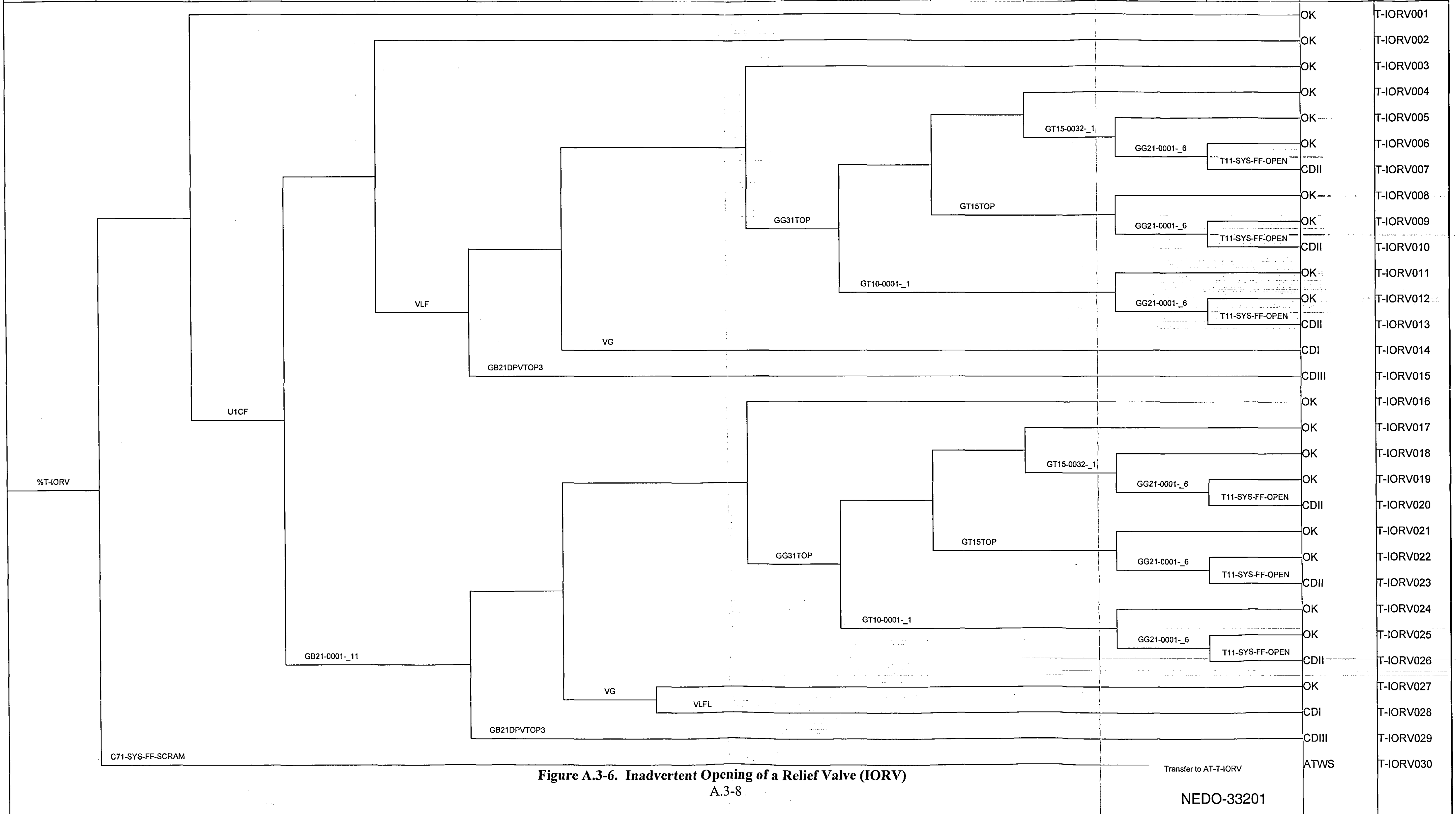


Figure A.3-6. Inadvertent Opening of a Relief Valve (IORV)

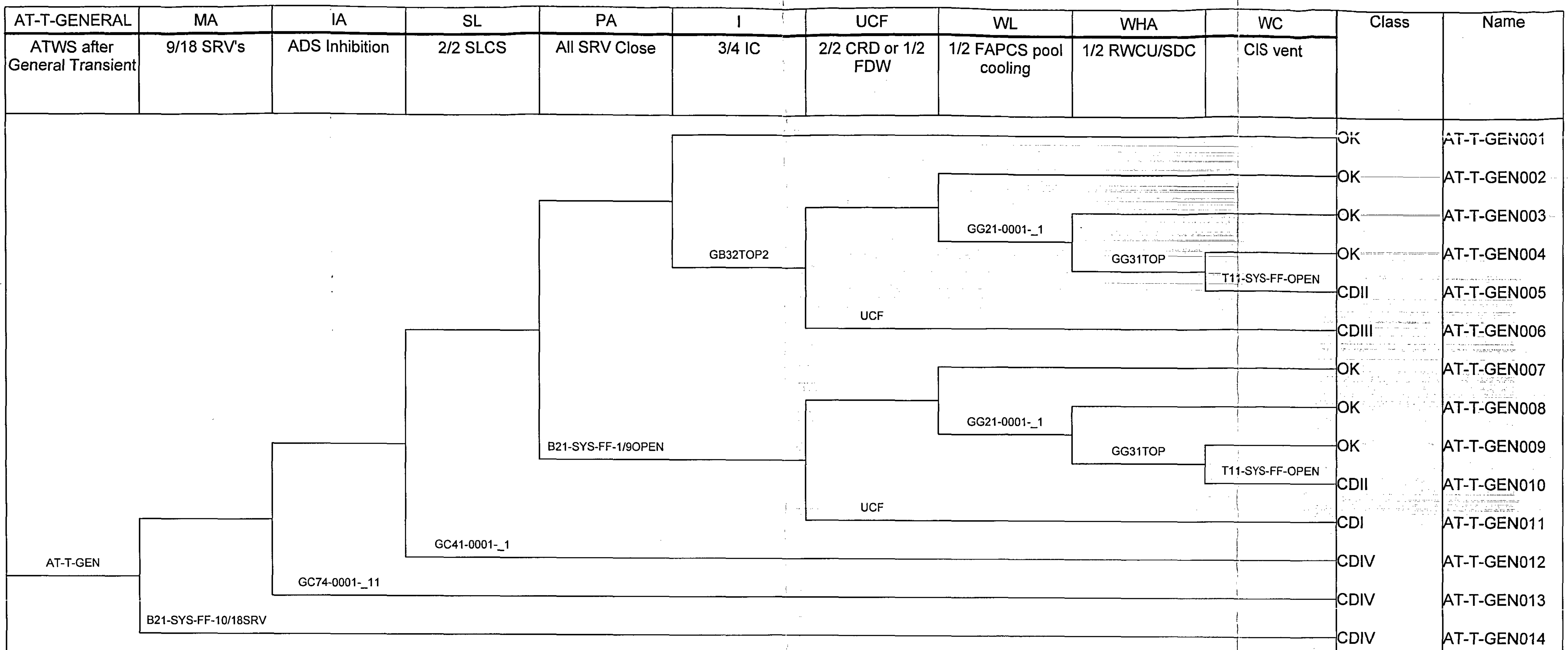


Figure A.3-7. ATWS from General Transient

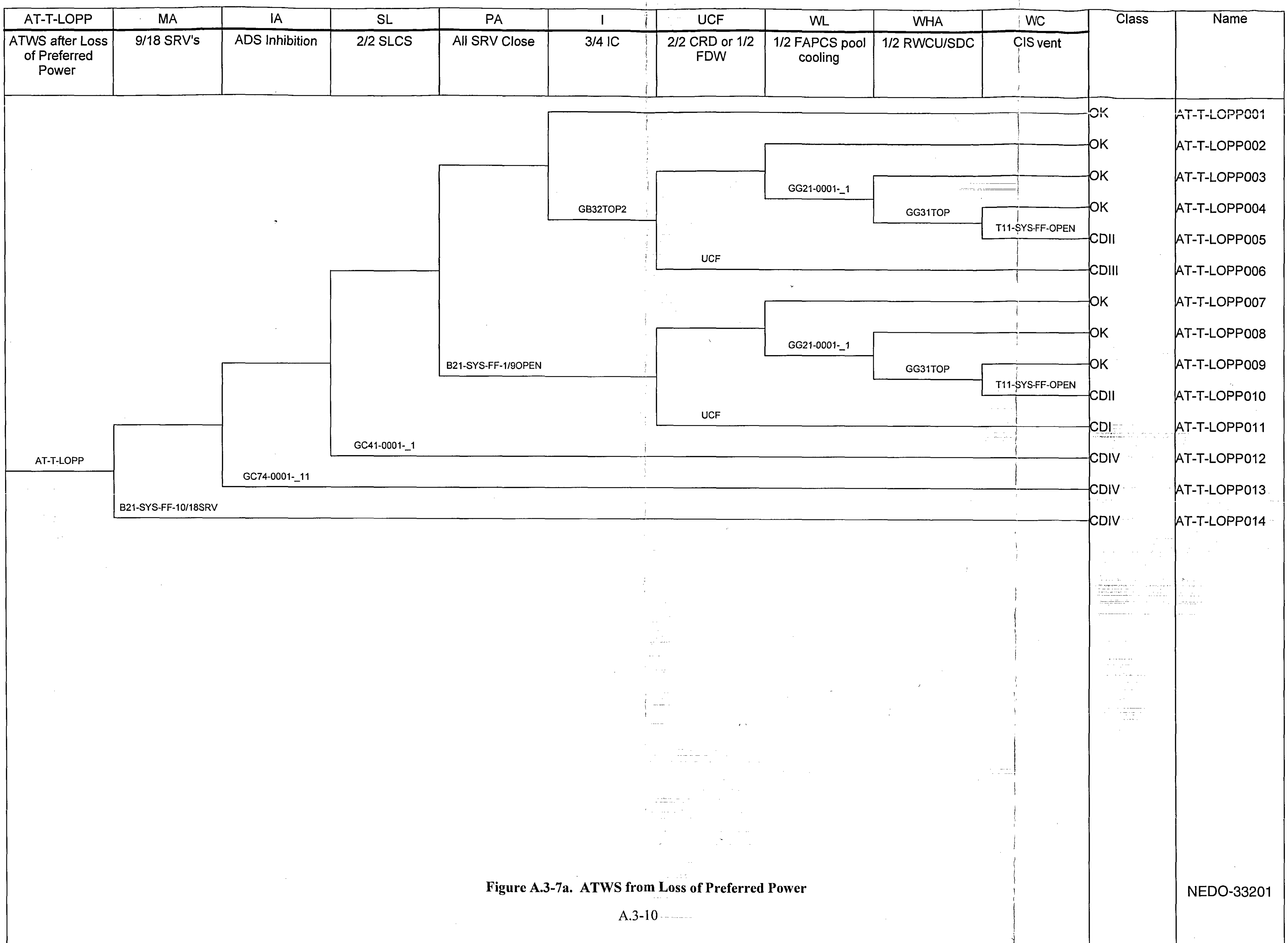


Figure A.3-7a. ATWS from Loss of Preferred Power

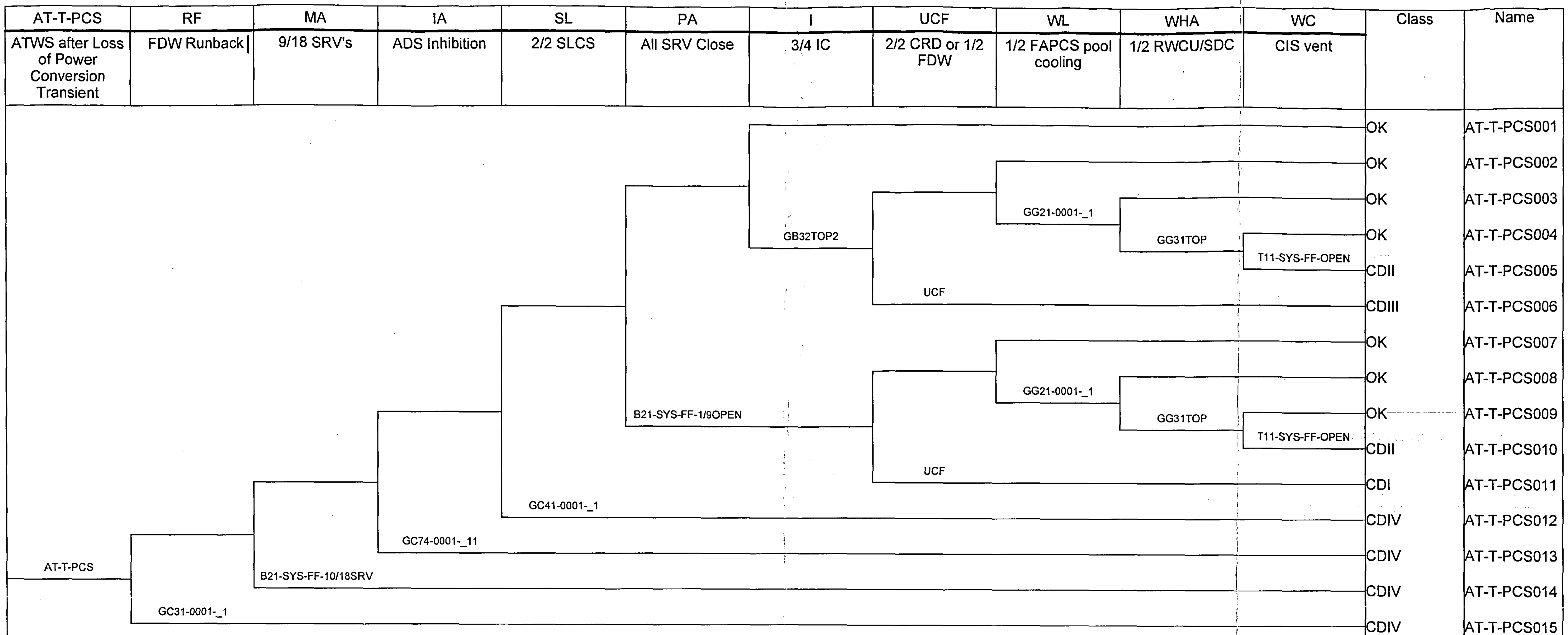


Figure A.3-8. ATWS from Transient Loss of PCS

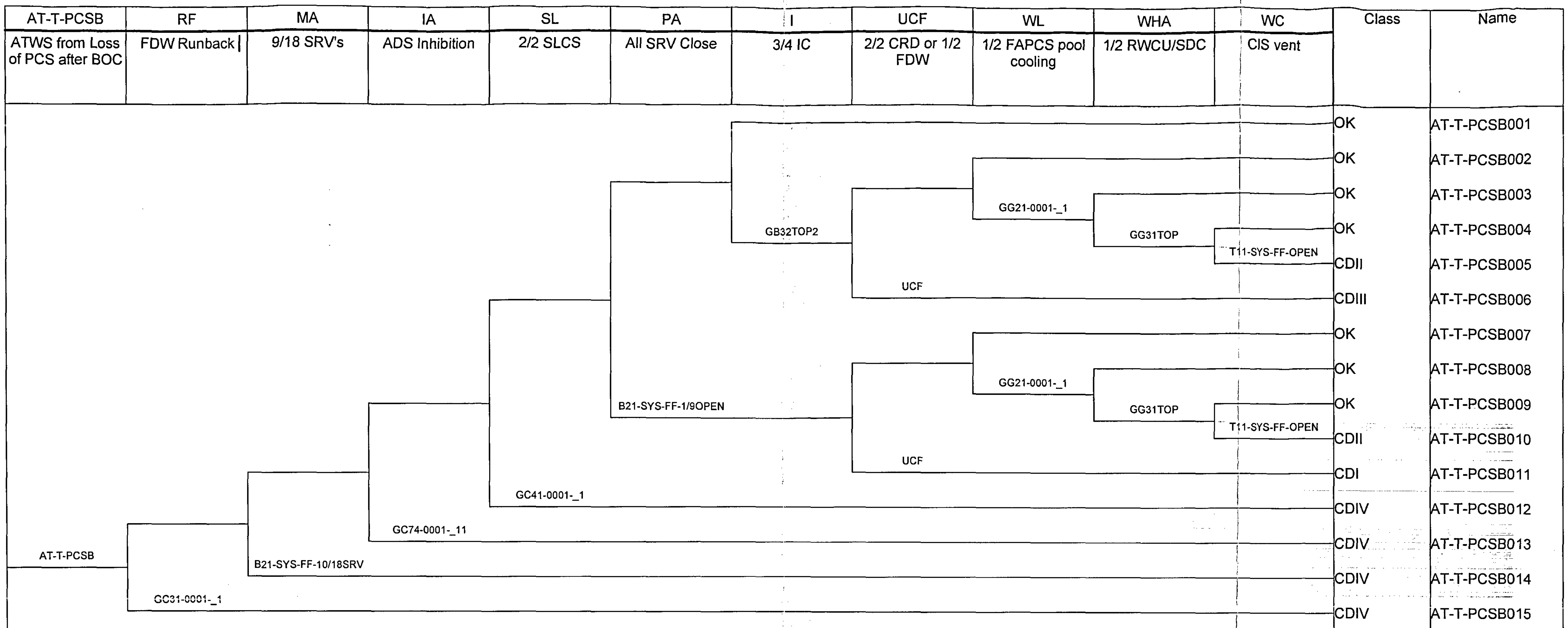
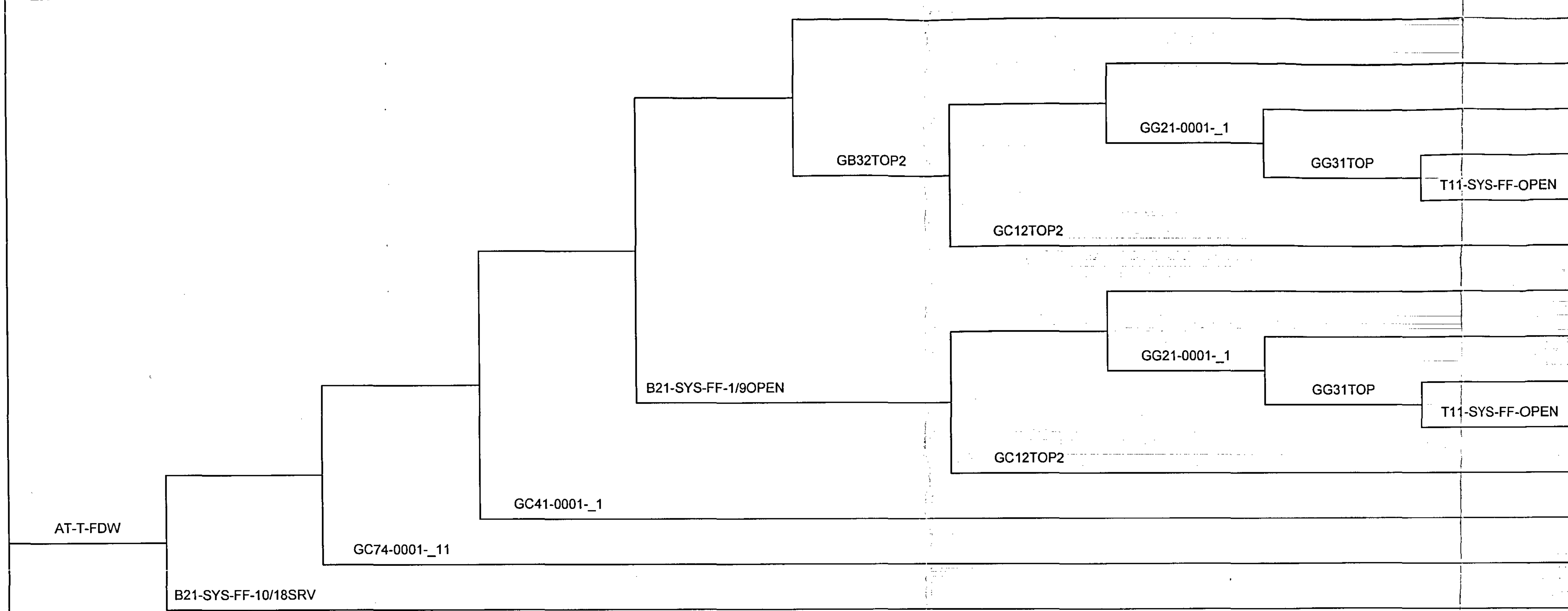


Figure A.3-8a. ATWS from Loss of PCS after BOC in IC or MS

AT-T-FDW	MA	IA	SL	PA	I	UC	WL	WHA	WC	Class	Name
ATWS after loss of FDW Transient	9/18 SRV's	ADS Inhibition	2/2 SLCS	All SRV Close	3/4 IC	2/2 CRD	1/2 FAPCS pool cooling	1/2 RWCU/SDC	CIS vent		



Class	Name
OK	AT-T-FDW001
OK	AT-T-FDW002
OK	AT-T-FDW003
OK	AT-T-FDW004
CDII	AT-T-FDW005
CDIII	AT-T-FDW006
OK	AT-T-FDW007
OK	AT-T-FDW008
OK	AT-T-FDW009
CDII	AT-T-FDW010
CDI	AT-T-FDW011
CDIV	AT-T-FDW012
CDIV	AT-T-FDW013
CDIV	AT-T-FDW014

Figure A.3-9. ATWS from Transient with Loss of Feedwater System

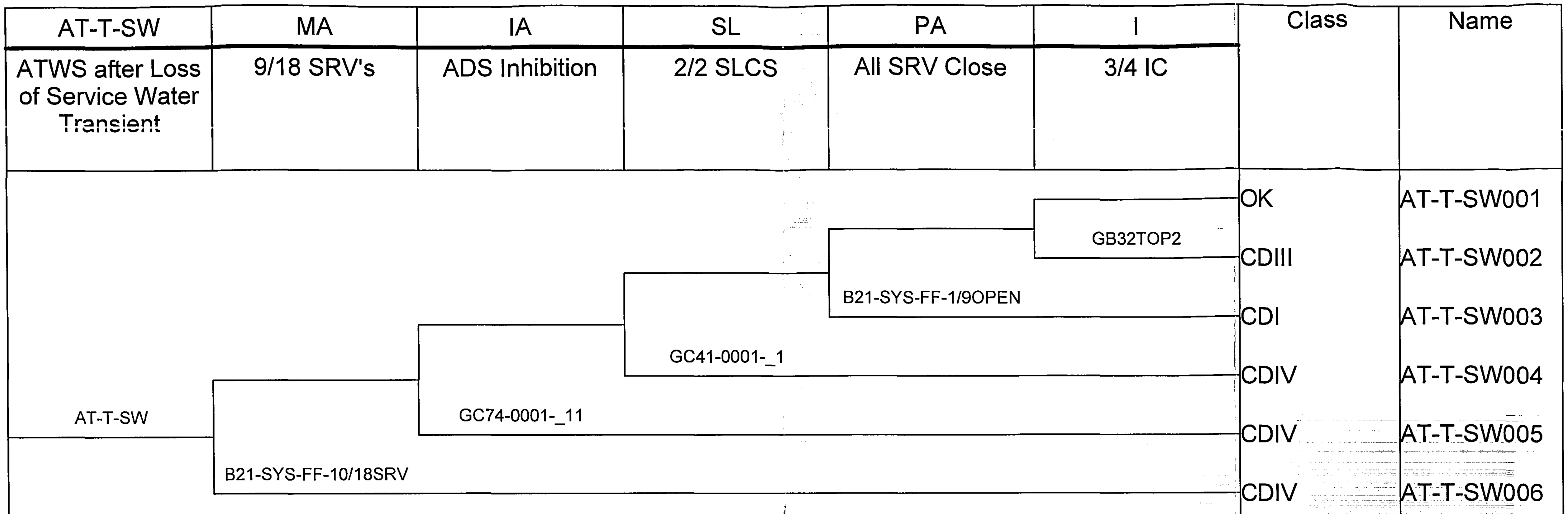


Figure A.3-10. ATWS from Loss of Service Water Transient

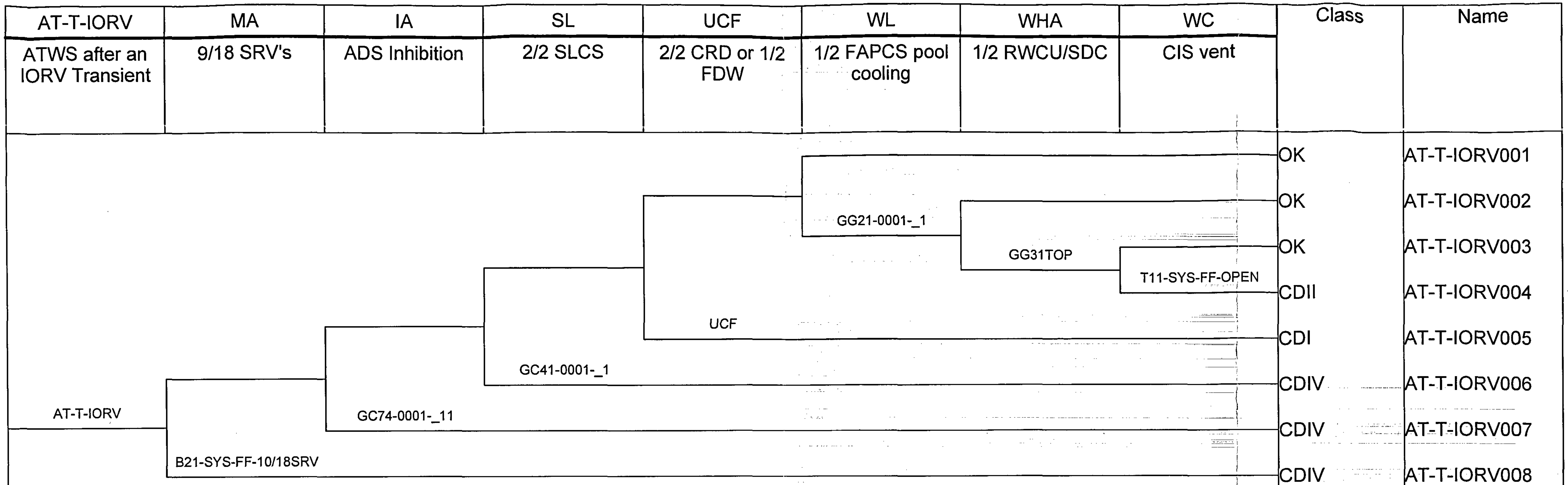
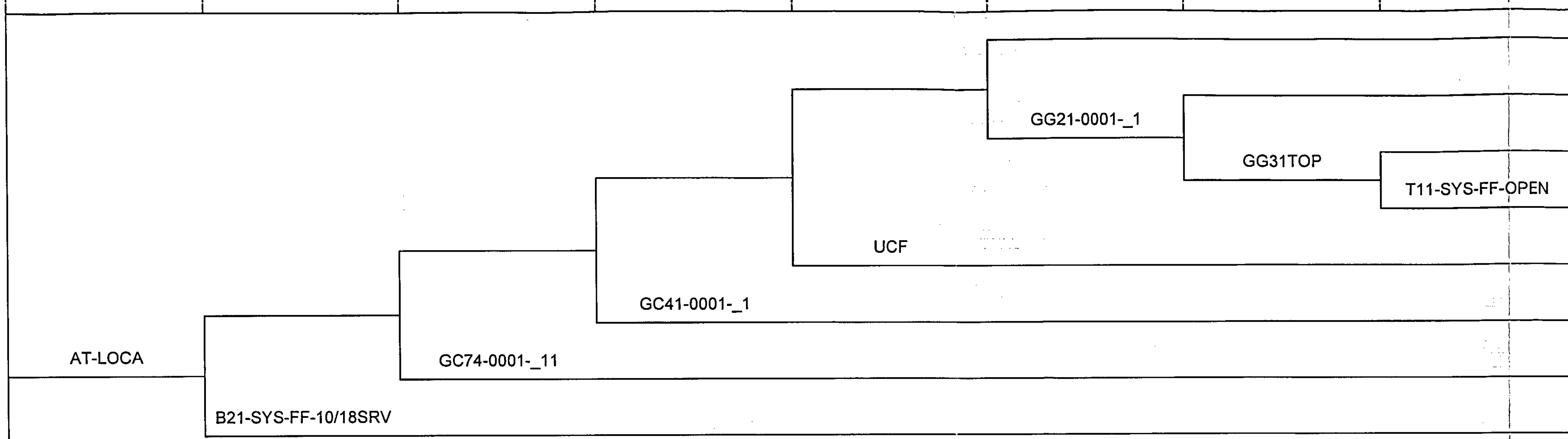


Figure A.3-11. ATWS from Inadvertent Opening of a Relief Valve

AT-LOCA	MA	IA	SL	UCF	WL	WHA	WC	Class	Name
ATWS after Small LOCA above Core	9/18 SRV's	ADS Inhibition	2/2 SLCS	2/2 CRD or 1/2 FDW	1/2 FAPCS pool cooling	1/2 RWCU/SDC	CIS vent		



Class	Name
OK	AT-LOCA001
OK	AT-LOCA002
OK	AT-LOCA003
CDII	AT-LOCA004
CDI	AT-LOCA005
CDIV	AT-LOCA006
CDIV	AT-LOCA007
CDIV	AT-LOCA008

Figure A.3-11a. ATWS from Small LOCA above Reactor Core

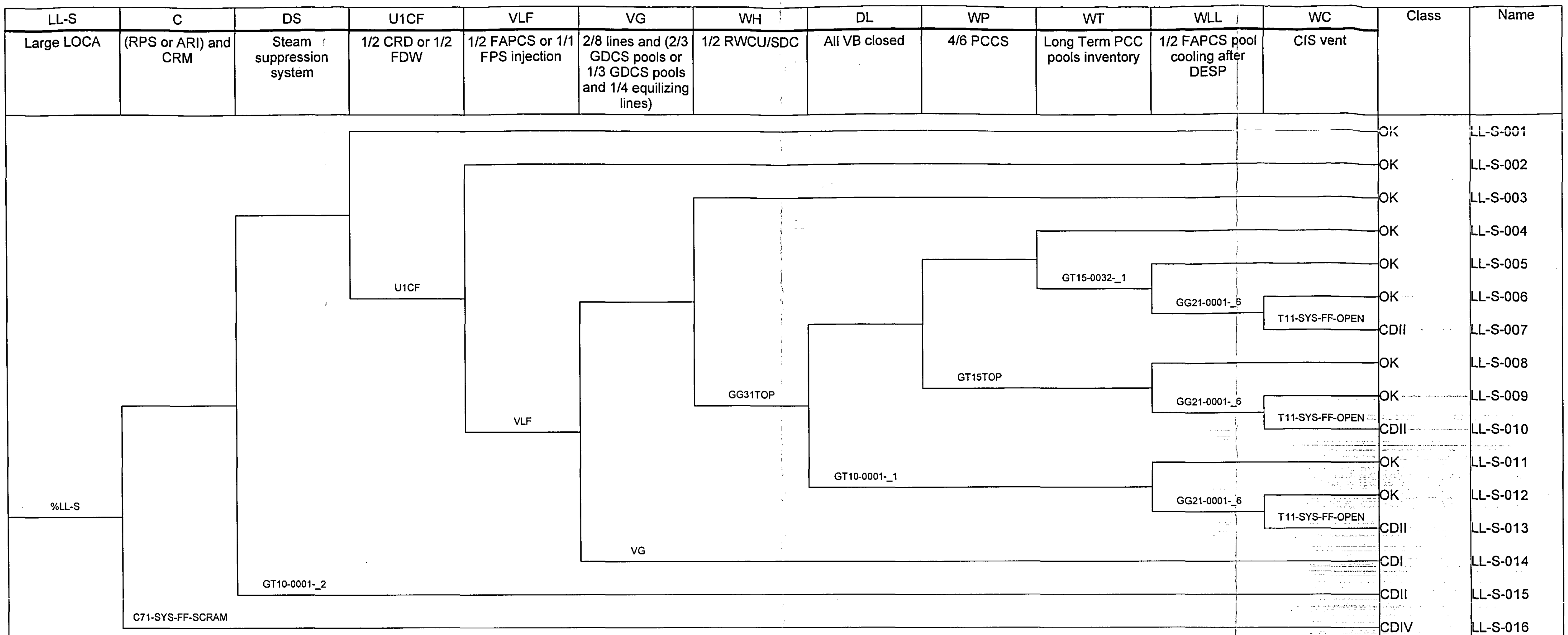


Figure A.3-12. Large Steam Breaks other than Feedwater Lines

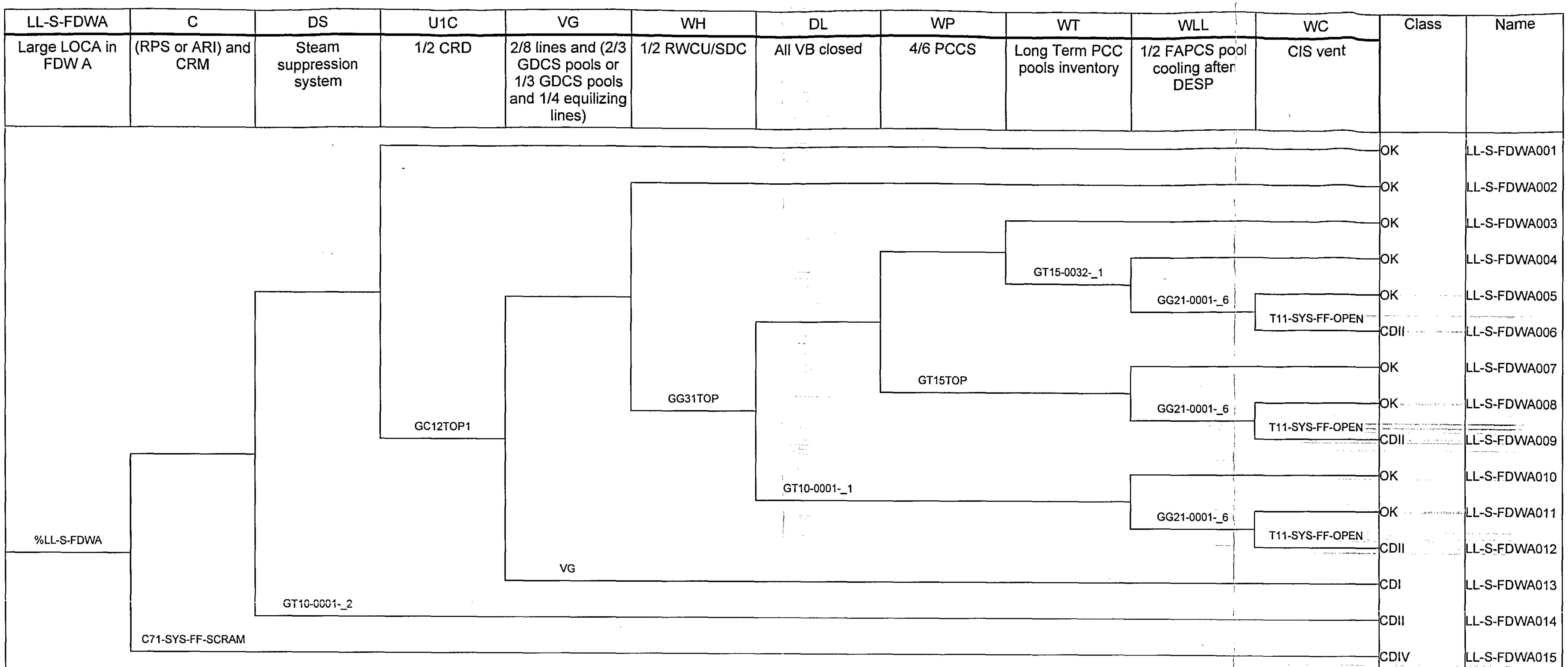


Figure A.3-13. Large Steam Break in FDW (A) Line

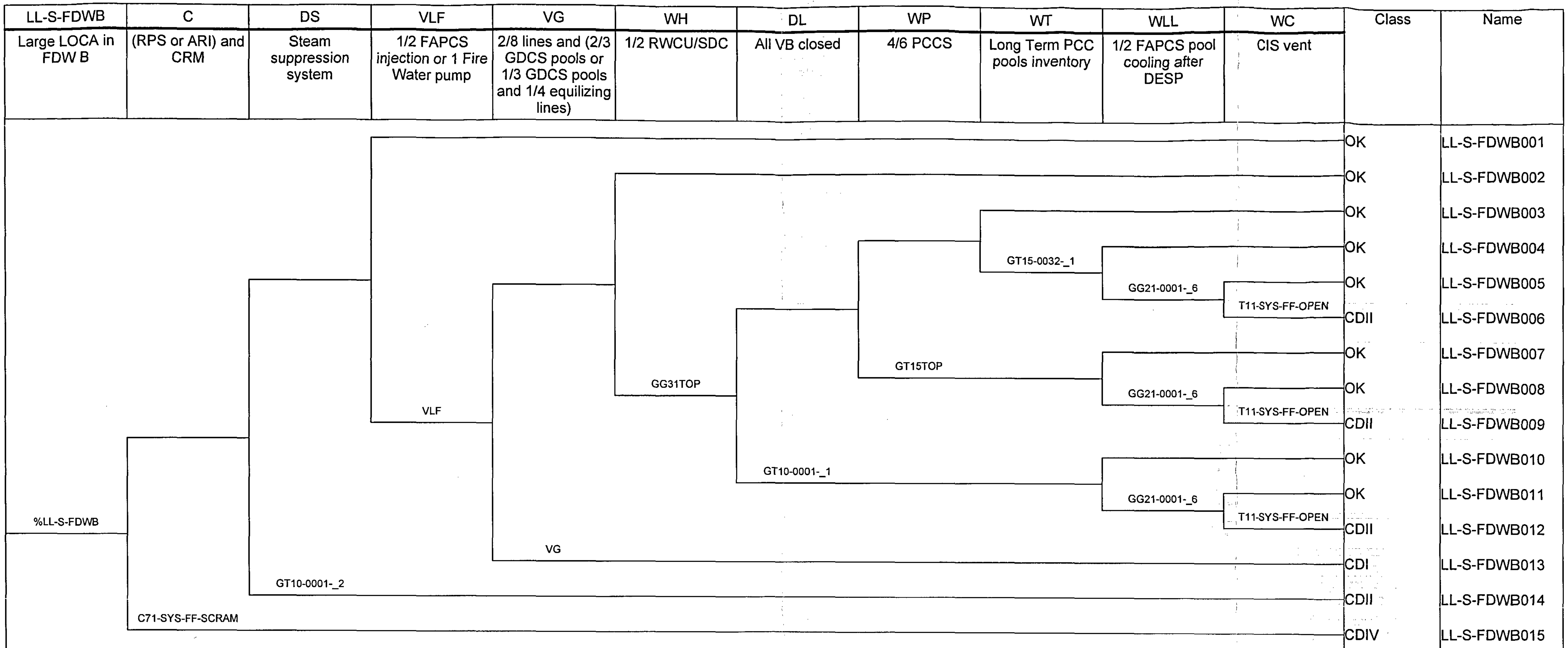


Figure A.3-14. Large Steam Break in FDW (B) Line

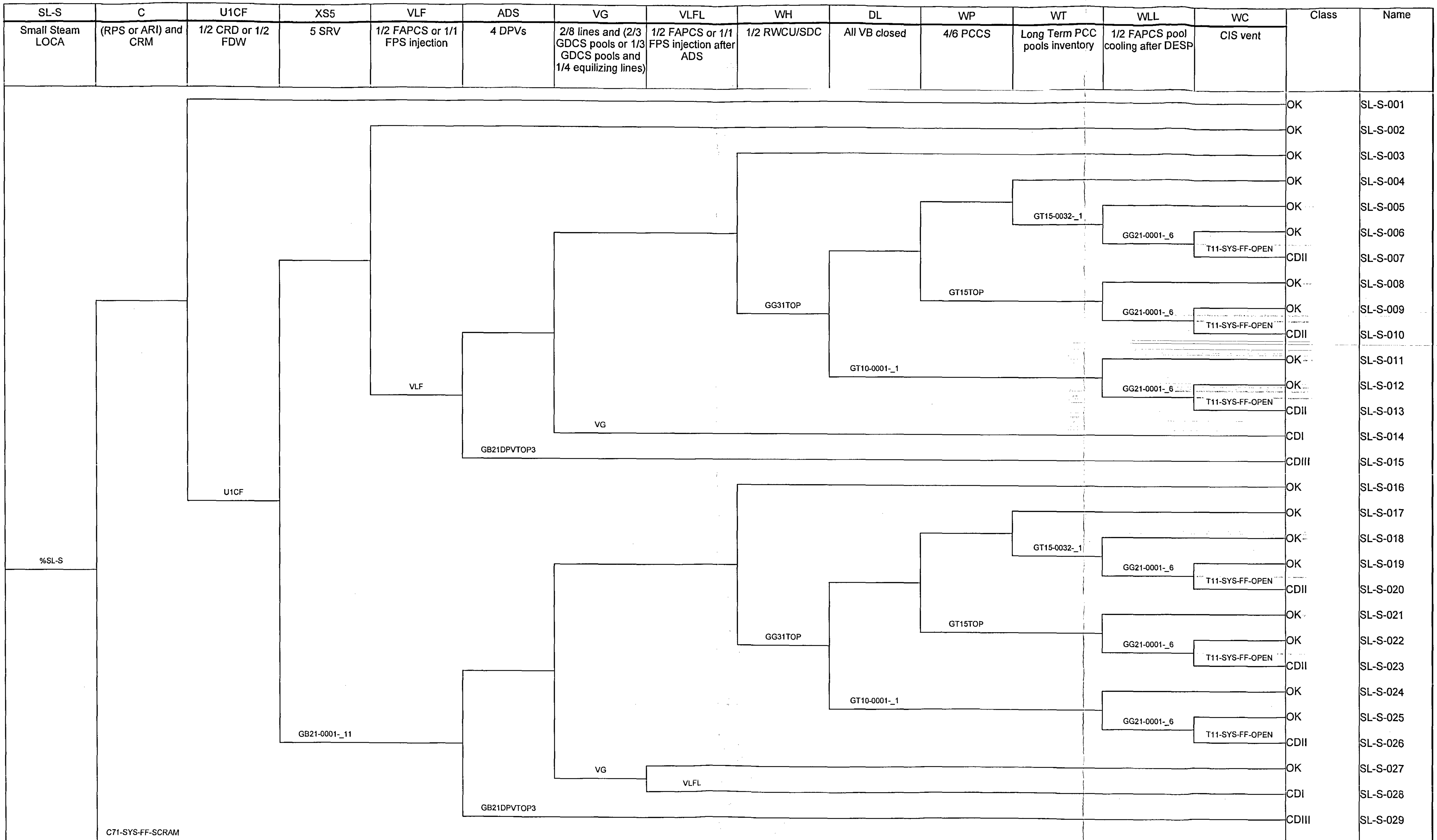


Figure A.3-15. Small Steam LOCA

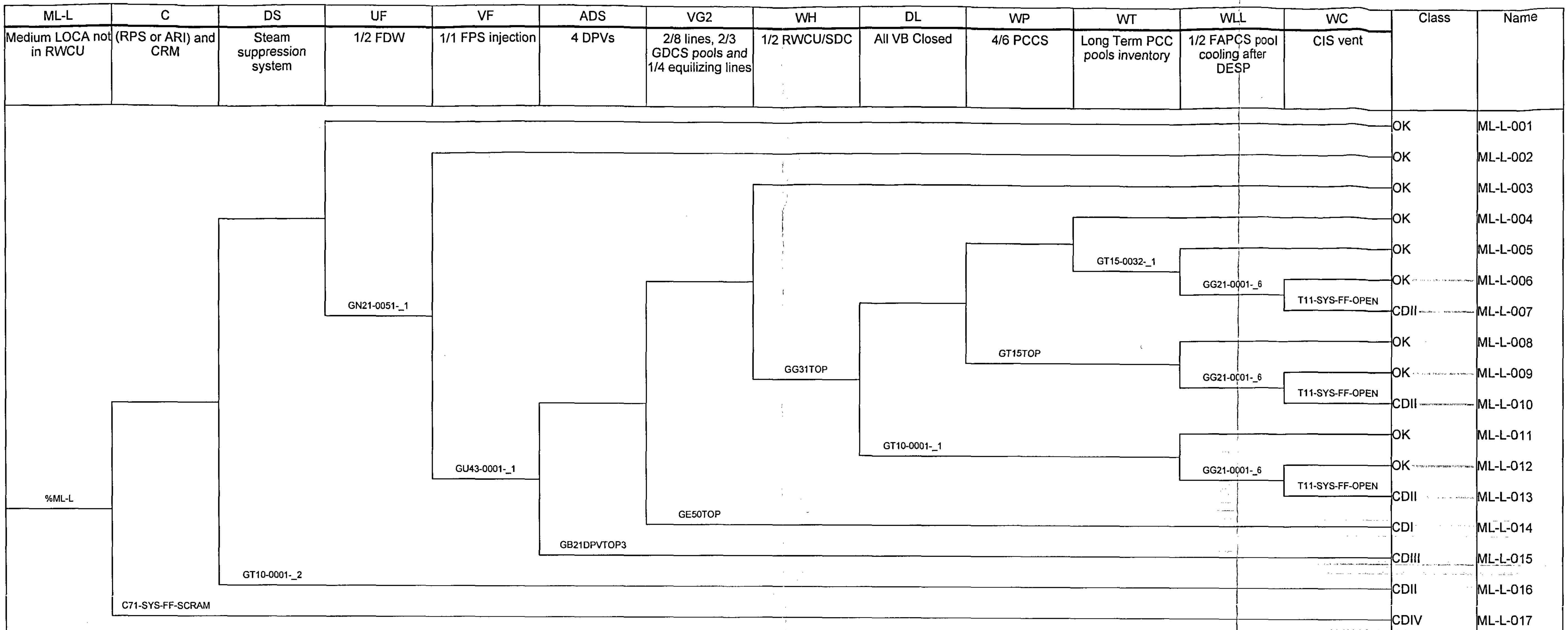


Figure A.3-16. Medium Liquid Breaks other than RWCU/SDC Lines

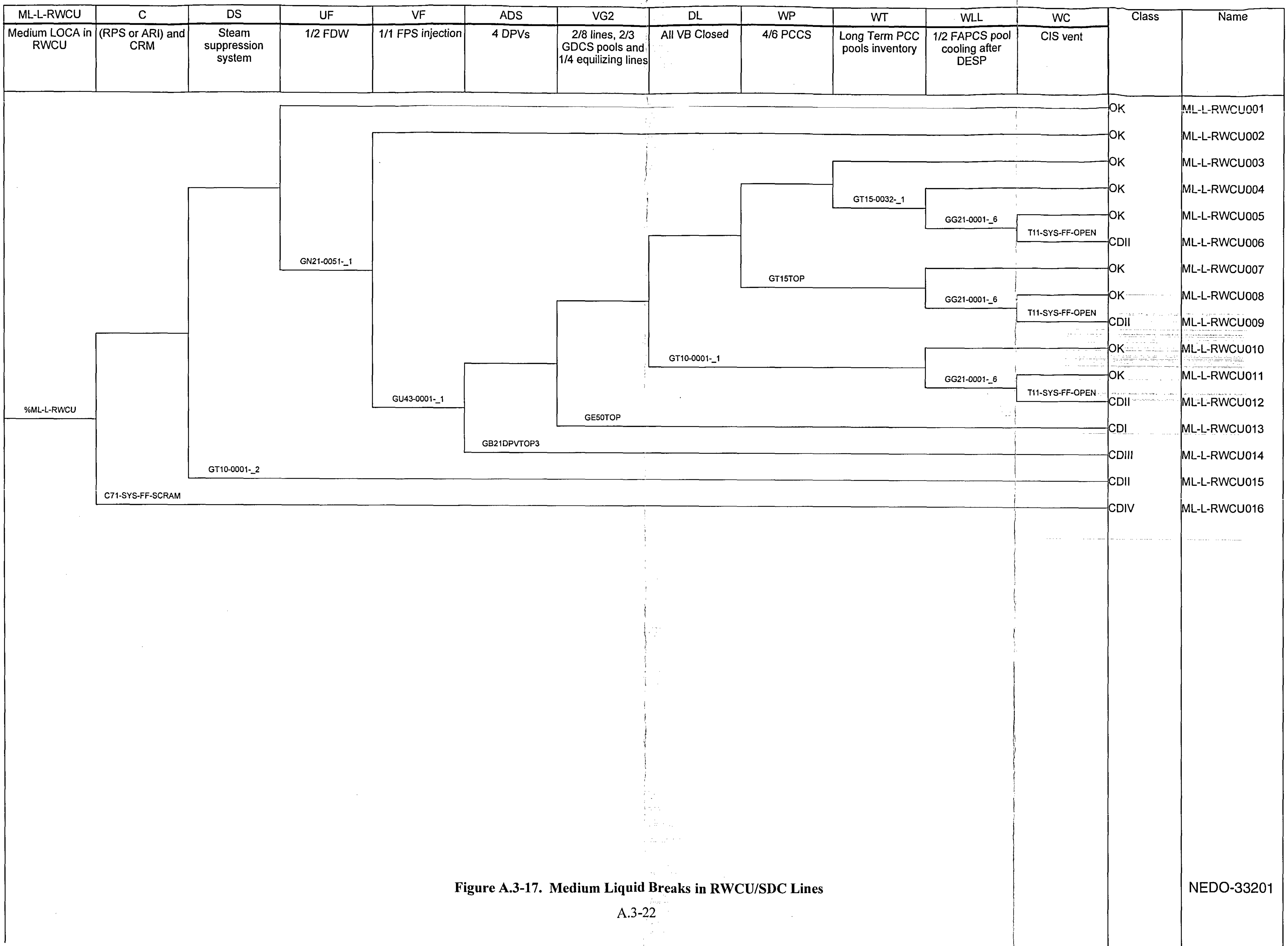


Figure A.3-17. Medium Liquid Breaks in RWCU/SDC Lines

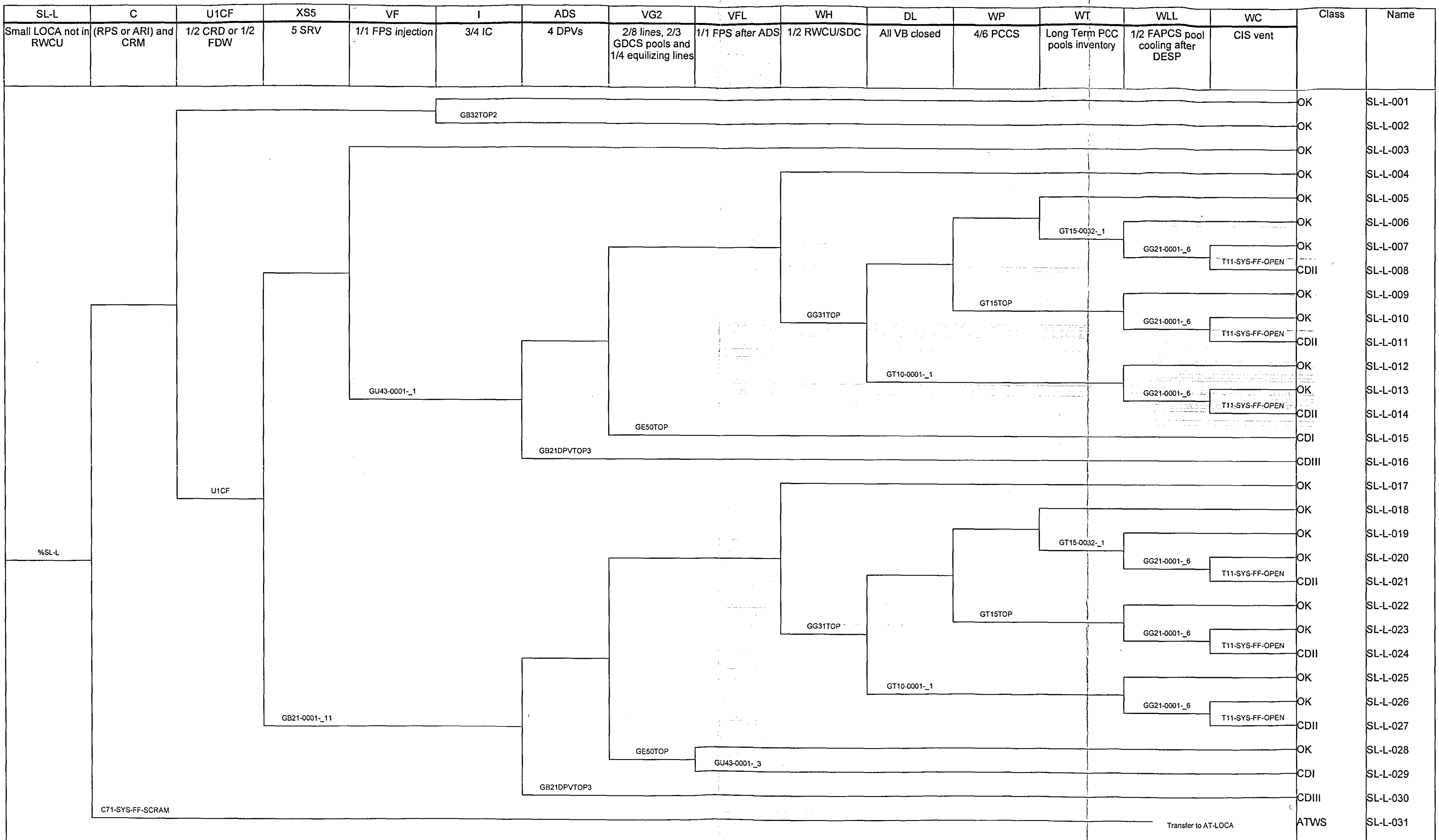


Figure A.3-18. Small Liquid LOCA

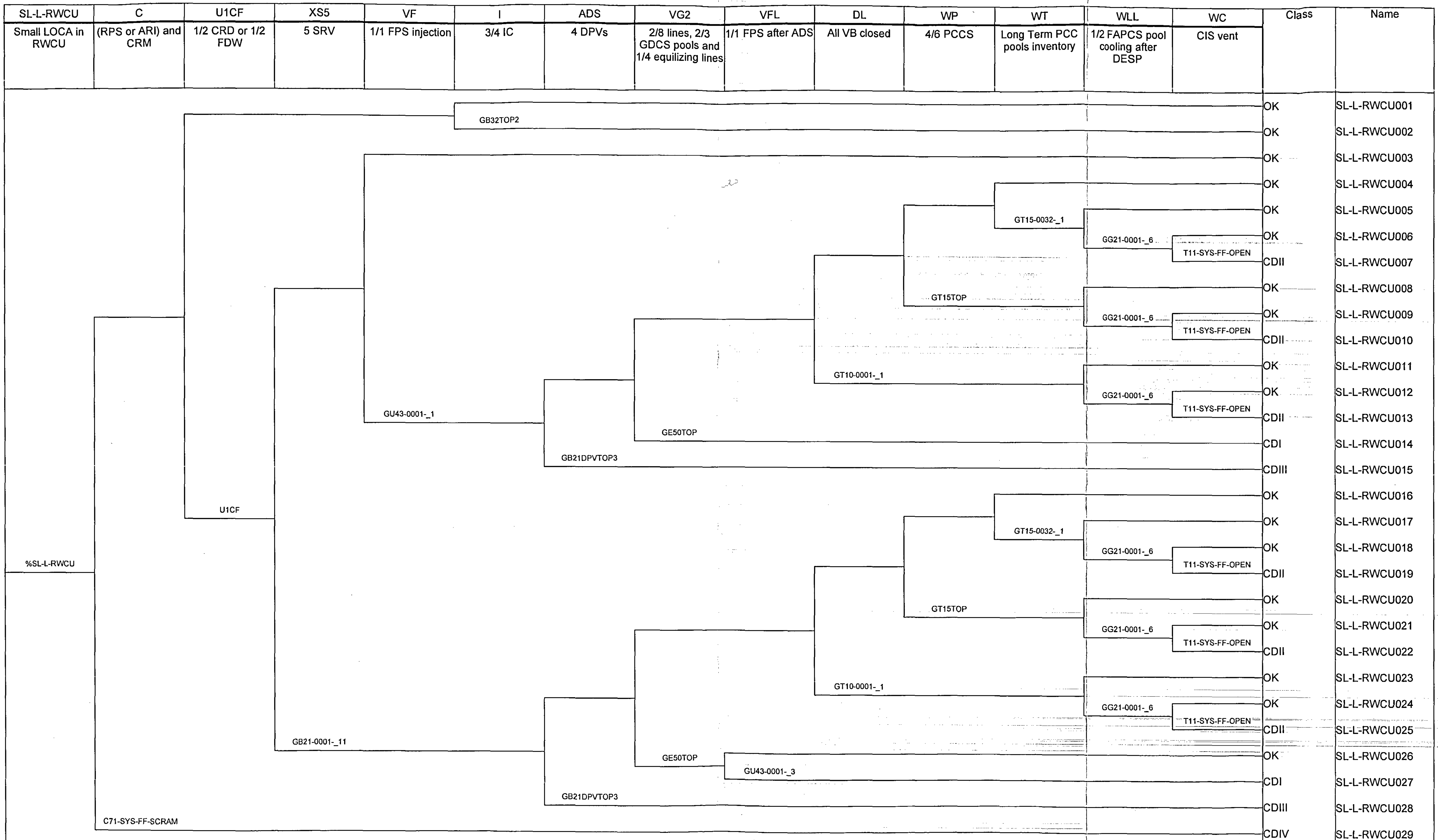


Figure A.3-19. Small Liquid LOCA in RWCU/SDC Lines

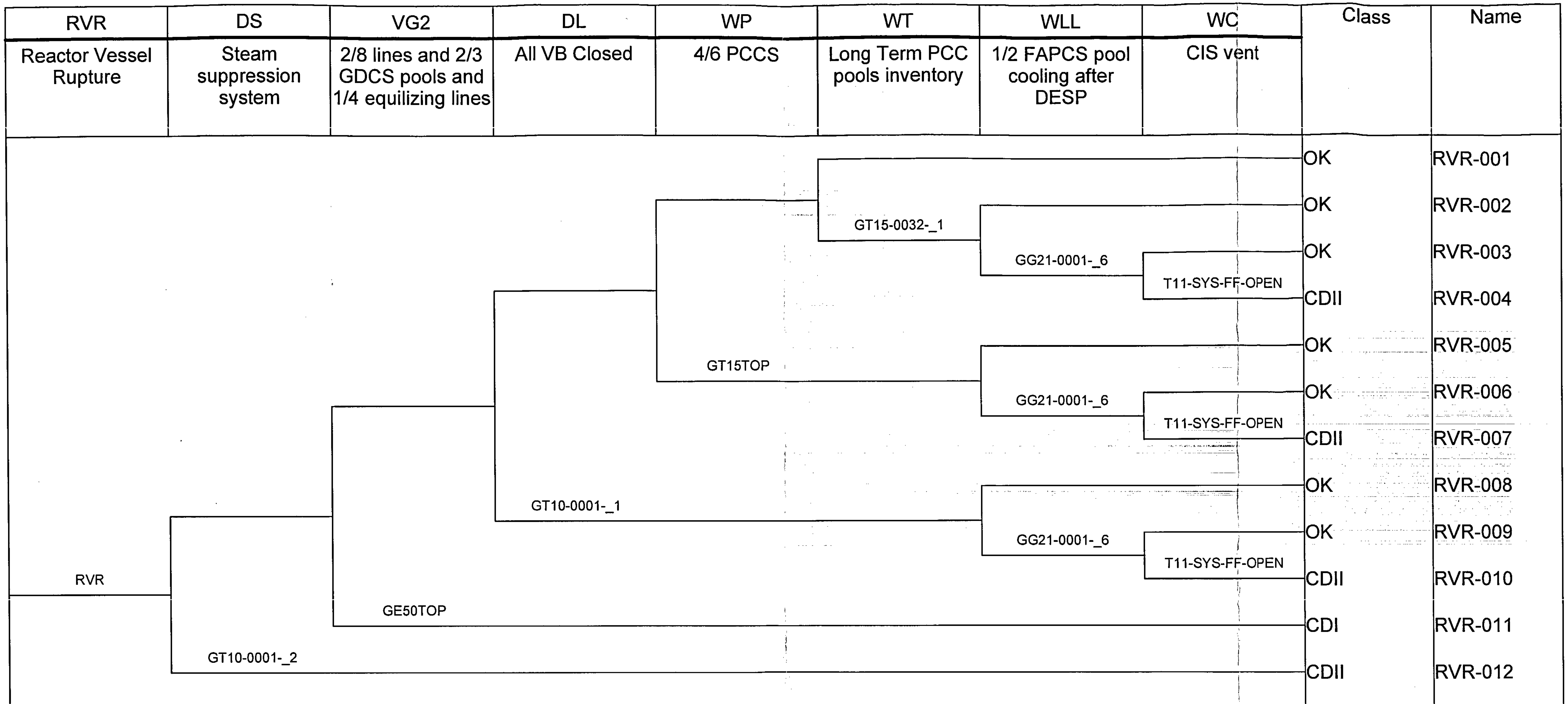


Figure A.3-20. Reactor Vessel Rupture

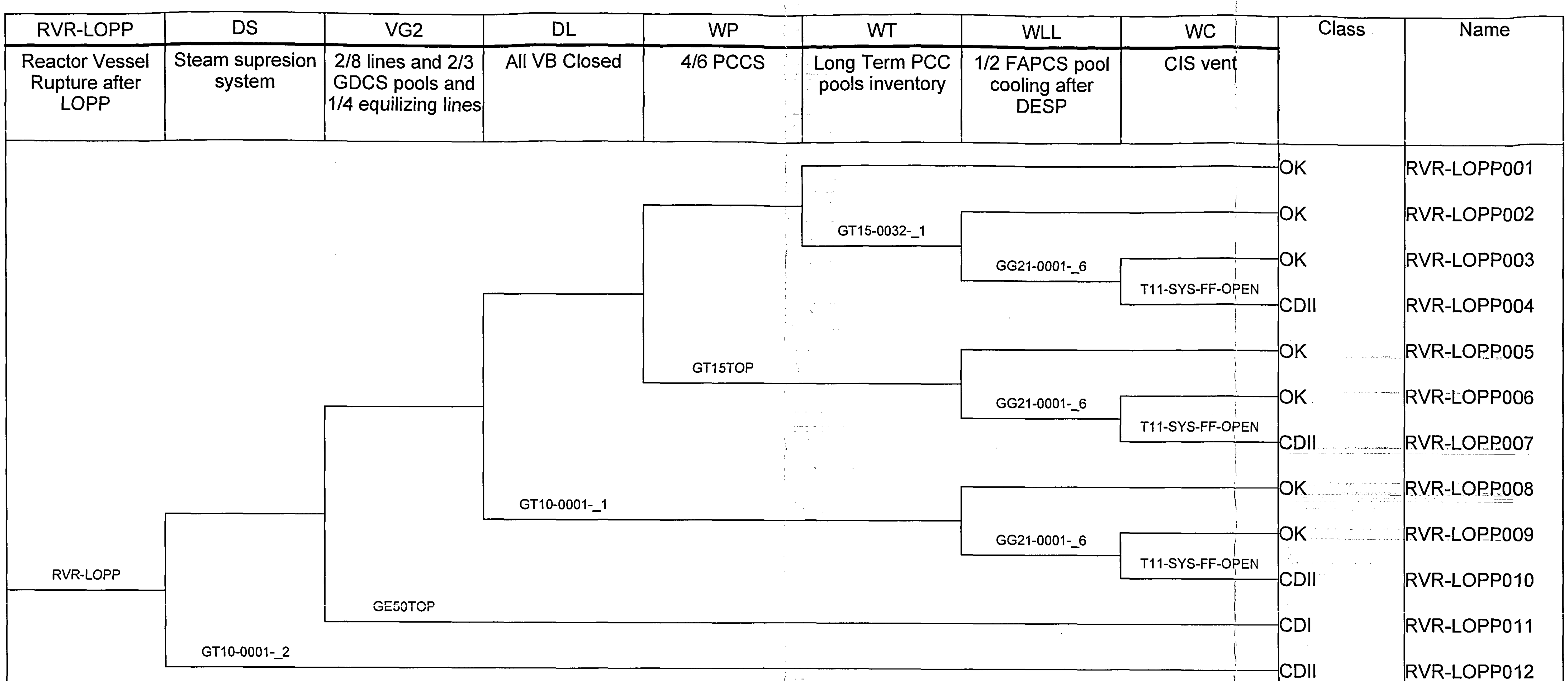
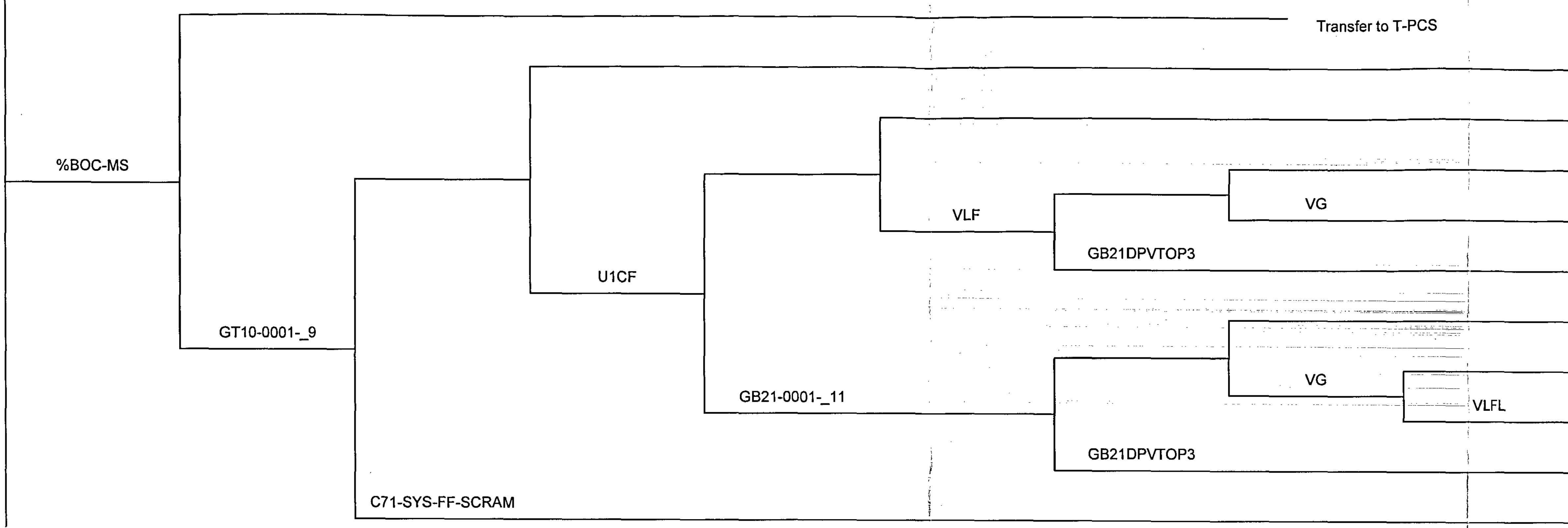


Figure A.3-20a. Reactor Vessel Rupture after Loss of Preferred Power

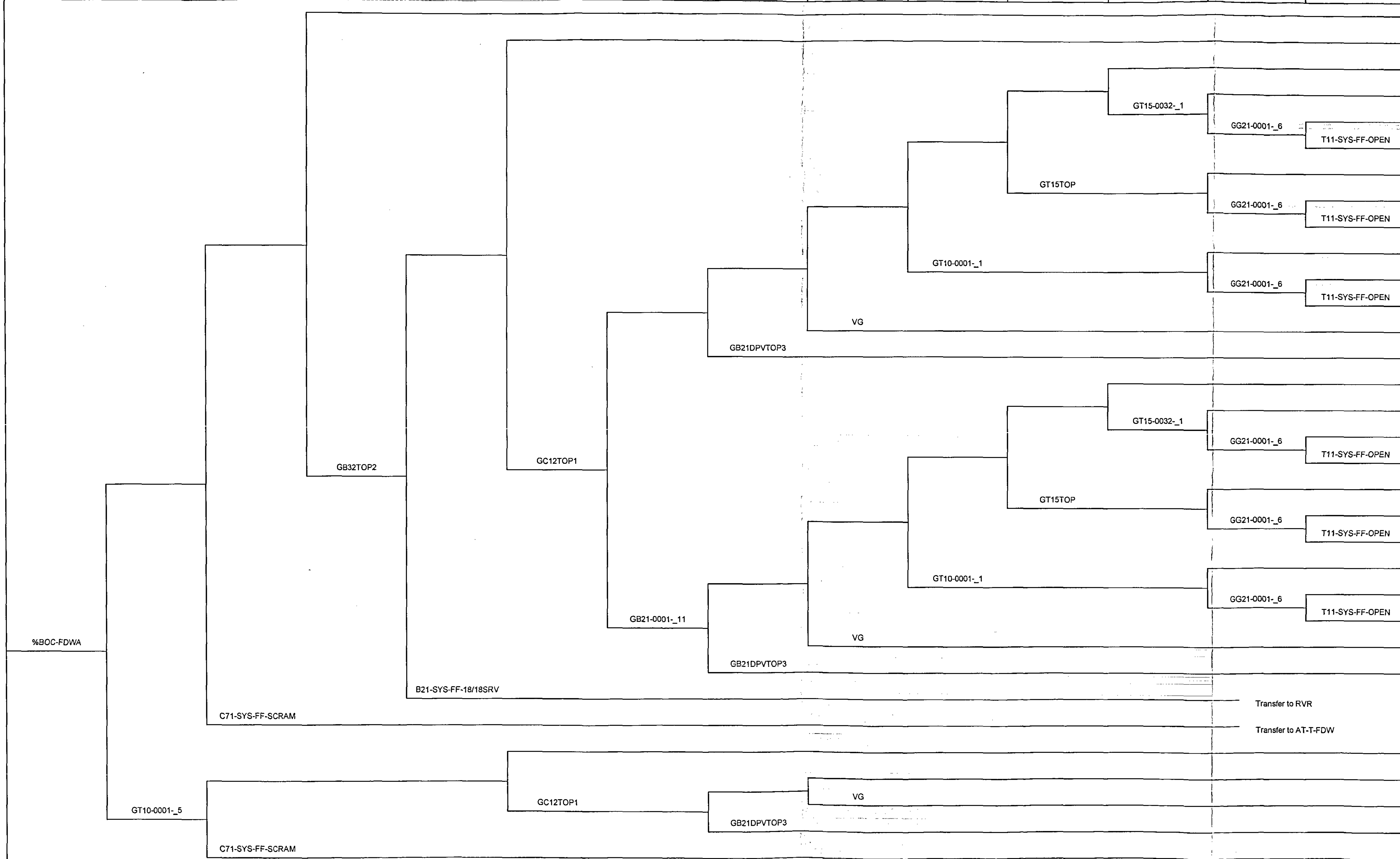
BOC MS	I ML	C	U1CF	XS5	VLF	ADS	VG	VLFL	Class	Name
Break Outside Containment in MS Line	Isolation all MSteam Line	(RPS or ARI) and CRM	1/2 CRD or 1/2 FDW	5 SRV	1/2 FAPCS or 1/1 FPS injection	4 DPVs	2/8 lines and (2/3 GDCS pools or 1/3 GDCS pools and 1/4 equilizing lines)	1/2 FAPCS or 1/1 FPS injection after ADS		



Class	Name
TPCS	BOC-MS001
OK	BOC-MS002
OK	BOC-MS003
OK	BOC-MS004
CDV	BOC-MS005
CDV	BOC-MS006
OK	BOC-MS007
OK	BOC-MS008
CDV	BOC-MS009
CDV	BOC-MS010
CDIV	BOC-MS011

Figure A.3-21. Steam Break Outside Containment on Main Steam Lines

BOC-FDWA	I FDW A	C	I	M	U1C	XS5	ADS	VG	DL	WP	WT	WLL	WC	Class	Name
Break Outside Containment on FDW A	Isolation Line A FDW	(RPS or ARI) and CRM	3/4 IC	1/18 SRV	1/2 CRD	5 SRV	4 DPVs	2/8 lines and (2/3 GDCS pools or 1/3 GDCS pools and 1/4 equilizing lines)	All VB closed	4/6 PCCS	Long Term PCC pools inventory	1/2 FAPCS pool cooling after DESP	CIS vent		



Class	Name
OK	BOC-FDWA001
OK	BOC-FDWA002
OK	BOC-FDWA003
OK	BOC-FDWA004
OK	BOC-FDWA005
CDII	BOC-FDWA006
OK	BOC-FDWA007
OK	BOC-FDWA008
CDII	BOC-FDWA009
OK	BOC-FDWA010
OK	BOC-FDWA011
CDII	BOC-FDWA012
CDI	BOC-FDWA013
CDIII	BOC-FDWA014
OK	BOC-FDWA015
OK	BOC-FDWA016
OK	BOC-FDWA017
CDII	BOC-FDWA018
OK	BOC-FDWA019
OK	BOC-FDWA020
CDII	BOC-FDWA021
OK	BOC-FDWA022
OK	BOC-FDWA023
CDII	BOC-FDWA024
CDI	BOC-FDWA025
CDIII	BOC-FDWA026
RVR	BOC-FDWA027
ATWS	BOC-FDWA028
OK	BOC-FDWA029
OK	BOC-FDWA030
CDV	BOC-FDWA031
CDV	BOC-FDWA032
CDIV	BOC-FDWA033

Figure A.3-22. Steam Break Outside Containment on FDW A Lines

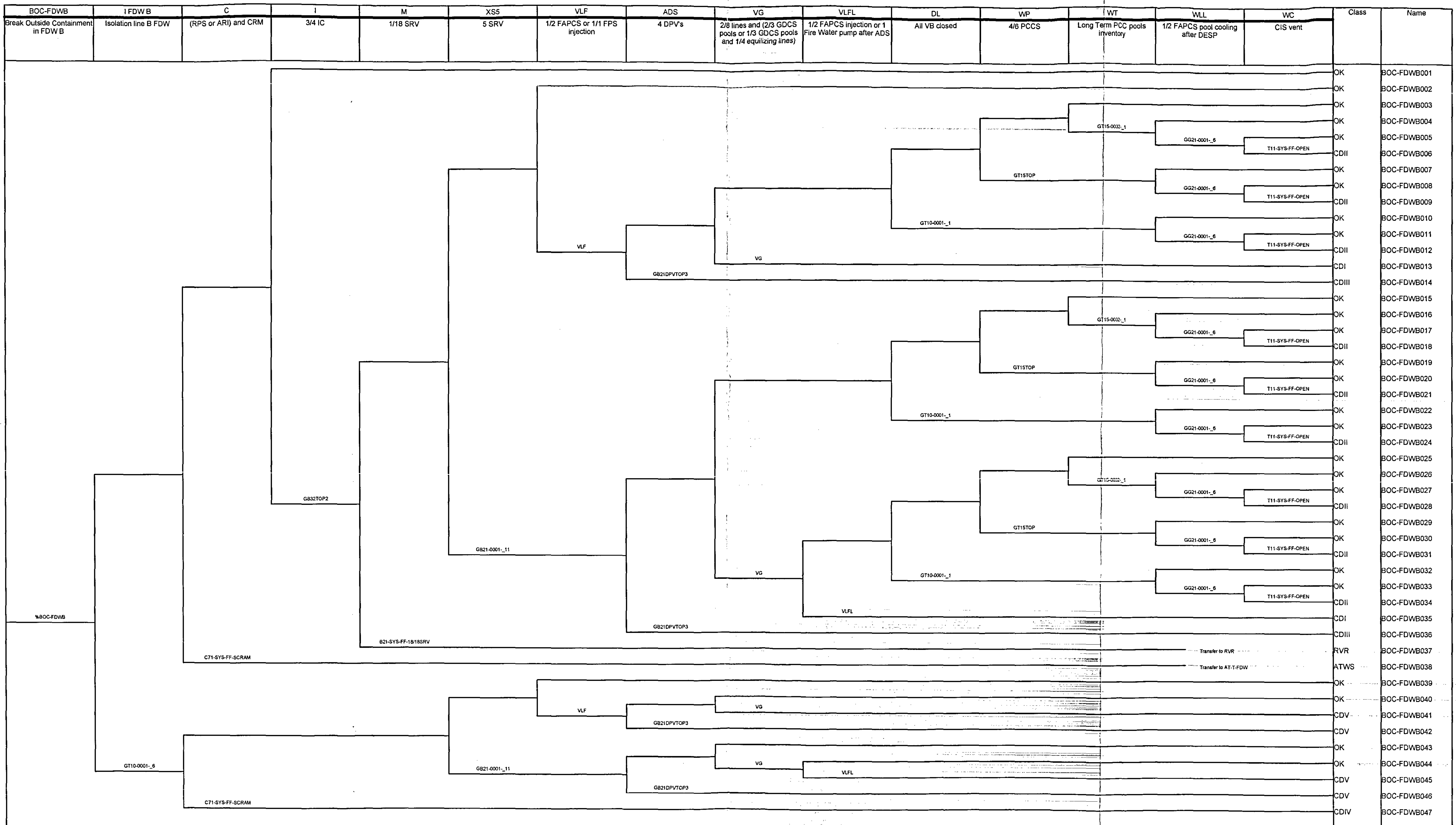
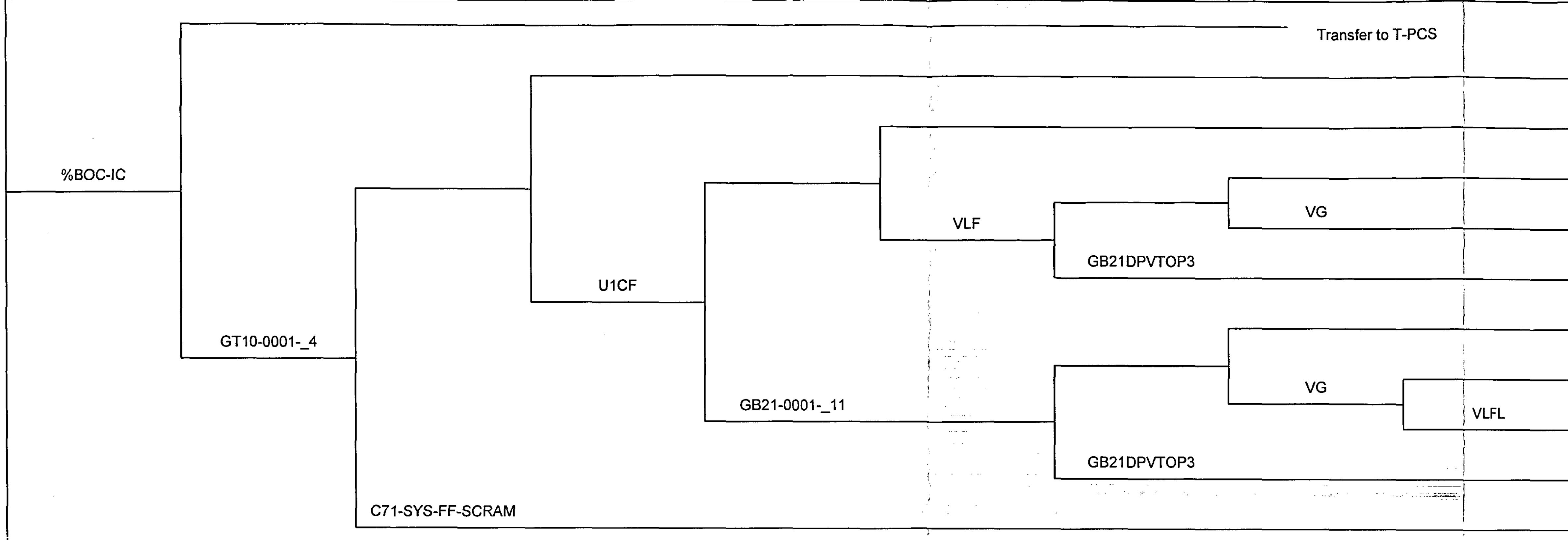


Figure A.3-23. Steam Break Outside Containment on FDW B Lines

BOC-IC	IIC	C	U1CF	XS5	VLF	ADS	VG	VLFL	Class	Name
Break Outside Containment in IC	Isolation IC Steam Line	(RPS or ARI) and CRM	1/2 CRD or 1/2 FDW	5 SRV	1/2 FAPCS or 1/1 FPS injection	4 DPV's	2/8 lines and (2/3 GDCS pools or 1/3 GDCS pools and 1/4 equilizing lines)	1/2 FAPCS or 1/1 FPS injection after ADS		



Class	Name
TPCS	BOC-IC001
OK	BOC-IC002
OK	BOC-IC003
OK	BOC-IC004
CDV	BOC-IC005
CDV	BOC-IC006
OK	BOC-IC007
OK	BOC-IC008
CDV	BOC-IC009
CDV	BOC-IC010
CDIV	BOC-IC011

Figure A.3-24. Large Liquid Break Outside Containment on IC Lines

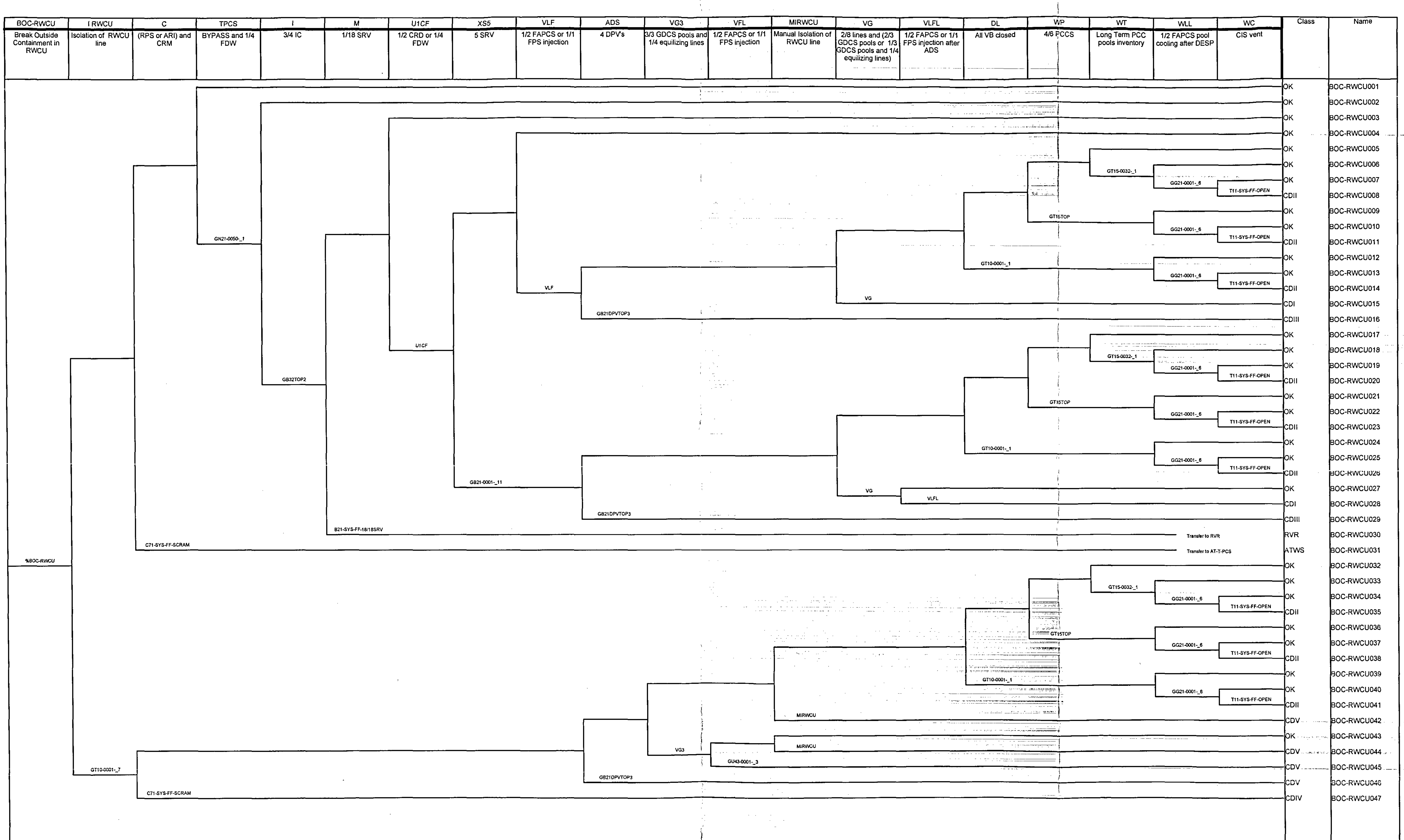


Figure A.3-25. Liquid Break Outside Containment on RWCU/SDC Lines

4 SYSTEM ANALYSIS

Contents

List of Tables

List of Figures

4 SYSTEMS ANALYSIS

4.0 INTRODUCTION

4.0.1 System Analysis Purpose

The purpose of ESBWR system analysis is to the systems modeled in the ESBWR PRA. The systems correspond to the functional headings described in Chapter 3 plus any support systems needed to accomplish those functions. Each of Sections 4.1 through 4.19 contains the following typical items:

- System Purpose
- Design Assumptions
- System Description
- Automatic and Manual Control
- System Interfaces
- System Testing
- System Maintenance
- Potential for Common Cause Failure (CCF)
- Fault Tree Analysis
- Human Interactions

The documentation of the system analysis is constructed to facilitate certification of the ESBWR design. It describes the processes used for modeling and quantification. It also includes the generic modeling assumptions. It is constructed with consideration of future updates to the ESBWR PRA and for risk informed applications involving the ESBWR.

Table 4.0-1 contains a list of the systems and the associated functions that are modeled in the ESBWR PRA. Those that are identified as "front line" appear as event tree headings.

4.0.2 Fault Trees

There is at least one fault tree file for each system function included in the PRA model. If multiple trains can perform the function, then each train is modeled. All of the logic for a particular system can be contained in a single fault tree file. In fact, this is the preferred method for the ESBWR PRA.

The fault trees are constructed using the gate and basic event naming conventions described in Appendix A.4. The fault tree database is stored in the CAFTA Database file format.

Table 4.0-1

Section Number and Fault Trees of Key ESBWR Systems

Section #	System ID	Description	Functions Modeled
Section 4.1	B21	Reactor Depressurization	Depressurization (SRV or DPV) Overpressure Protection
Section 4.2	B32	Isolation Condenser	Reactor Heat Removal SRV Leakage DPV Leakage
Section 4.3	C12	Control Rod Drive	RPV Injection at High Pressure
Section 4.4	C41	Standby Liquid Control	Boron Injection
Section 4.5	C62, C63, C71, C74	Instrument and Control	Essential Multiplexing Non-Essential Multiplexing Instrumentation (Sensors) Reactor Protection System Signals - SCRAM - Alternate Rod Insertion - Feedwater Runback - Manual Rod Insertion - ADS Inhibit
Section 4.6	E50	Gravity Driven Cooling System	RPV Injection at Low Pressure
Section 4.7	G21	Fuel & Auxiliary Pool Cooling System	Suppression Pool Cooling Low Pressure Coolant Injection Drywell Spray ICS Pool Makeup GDCS Pool Makeup
	U43	Fire Protection System	RPV Injection at Low Pressure PCCS Pool Makeup IC Pool Makeup

Table 4.0-1
Section Number and Fault Trees of Key ESBWR Systems (Continued)

Section #	System ID	Description	Functions Modeled
Section 4.8	G31	Reactor Water Cleanup and Shutdown Cooling	Shutdown Cooling
Section 4.9	N21 P22	Feedwater and Condensate	RPV Injection at High Pressure RPV Injection at Low Pressure
Section 4.10	P21	Reactor Component Cooling Water	Removes heat from systems in the drywell and Reactor Building
Section 4.11	P41	Plant Service Water	Component Cooling
Section 4.12	P52, P51	Instrument Air System and Service Air System	Valve Motive Power
Section 4.13	P54	High Pressure Nitrogen	Valve Motive Power
Section 4.14	R10, R11, R12	A.C. Electric Power	AC Power
Section 4.15	R13	Uninterruptible AC Power	AC Power
Section 4.16		Deleted / Not Used	Not Used
Section 4.17	R16	DC Power Supply	DC Power
Section 4.18	T10	Containment System	Containment Isolation Vapor Suppression
Section 4.19	T15	Passive Containment Cooling	Ultimate Heat Sink

4.1 AUTOMATIC DEPRESSURIZATION SYSTEM - (B21)

4.1.1 Purpose

In response to emergency conditions, the Automatic Depressurization System (ADS) provides automatic, effectively permanent depressurization of the reactor under a timely blowdown schedule. Once the depressurization is complete, this allows passive resupply of coolant to the reactor by the Gravity Driven Cooling System (GDCS). The depressurization is completed in time to allow GDCS injection flow to replenish core coolant and prevent uncovering the core assuming a failure of any single active component. The ADS uses depressurization valves (DPVs) together with safety-relief valves (SRVs) to achieve reactor depressurization. This function continues until the vessel pressure and temperature are nominally stabilized. For the long term, the DPVs provide a flow path for the steam to the drywell and from there to the Passive Containment Cooling System (PCCS). The SRVs involved in the ADS actuation are each piped separately to their respective quenchers located in the suppression pool to permit condensation of the discharged steam. The SRVs are also used to relieve pressure for the postulated anticipated transient without scram (ATWS) event.

4.1.2 Design Assumptions

The following assumption with respect to the design is made:

(1) Actuation logic is provided by two independent and diverse systems.

4.1.3 System Description

4.1.3.1 Hardware Configuration

The automatic depressurization system is composed of ten of eighteen safety/relief valves (SRVs) and eight depressurization valves (DPVs), together with their related instrumentation and control logic. The ten SRVs that are part of the ADS are distributed for each steam line (3-2-2-3). They have 200 mm inlets, 250 mm outlets, are spring-loaded and nitrogen operated. Ten SRVs have the capability of actuating in ADS mode or overpressure protection mode; the remaining SRVs, however, can only actuate in the overpressure protection mode.

Each ADS SRV has an individual discharge line routed to the suppression pool, ending with a submerged steam quencher. This discharge line incorporates redundant vacuum breakers within the drywell pipe run in order to limit re-flood of the line after SRV reclosure, which could result from condensation of residual steam after valve operation. Therefore, the vacuum breakers prevent water hammer and pressure instability conditions in the SRV discharge line.

The DPVs are straight through, squib-actuated, non-reclosing type valves, with a metal diaphragm (seal) which acts as a valve disk and is sheared off by two initiators (squibs) that either individually or jointly are capable of actuating the booster and, subsequently, opening the valve. The DPV has a rated discharge capacity between 862,000 and 1,060,000 kg/hr of steam at an inlet pressure of 7.48 MPa-gauge.

Fig. 4.1-1 shows a simplified diagram of the system.

4.1.3.2 System Operation

Considerable margins exist between the SRV spring setpoint pressure and the reactor operating pressure. The Isolation Condenser System (ICS) is able to keep reactor pressure vessel (RPV) pressure below the SRV spring setpoint during transient events. The depressurization function is requested when the RPV water level 1 is reached.

The automatic depressurization is performed by opening the SRVs and the DPVs. Each DPV has approximately twice the steam flow capability of an SRV. The success criteria for the depressurization function are defined in terms of SRV-equivalent valves, with the simplifying assumption that one DPV is equivalent to two SRVs.

A partial depressurization is considered in order to take into account the possibility of using low-pressure injection systems even if the GDCS cannot yet be made operable. To allow for this, at least five equivalent SRVs must open, that is five SRVs or three DPVs.

In order to depressurize to a point where the GDCS is allowed to operate, at least four equivalent DPVs must open; this can be achieved through the following alternative minimal combinations:

- 6 SRVs must open
- 4 SRVs and 2 DPV must open
- 4 DPVs must open

However, the PRA model currently only credits the last of these alternatives because long term cooling with equalizing lines requires the successful operation of 4 DPVs.

The SRVs are also called into operation during an ATWS event to prevent over pressurization of the RPV and a possible subsequent break. The success criterion for the pressure relief during ATWS is that nine of eighteen SRVs must open. In addition, during this ATWS event, the automatic initiation of ADS (SRVs and DPVs) is inhibited, automatic or manually.

4.1.3.3 Component Location

The SRVs are installed on the main steam lines. Four DPVs are installed on the steam lines, the other four DPVs are on short stub pipes coming off the RPV at approximately (slightly below) the elevation of the main steam lines, from where are branched the Isolation Condenser steam supply lines.

4.1.4 Automatic and Manual Control

The driving concept of the ADS is the ability to actuate SRVs and DPVs even if two electrical or signal divisions are lost. Optical isolators are used for the mixing of the signals and for the voting logic to provide high reliability for the signals coming from the four different divisions. A list of all the control room instrumentation and alarms is reported in Table 4.1-1.

4.1.4.1 Automatic Actuation

The ADS starts automatically upon detection of RPV Low-Low Water Level (level 1) while in the RUN mode.

Each SRV is actuated if any one of two solenoid valves operates, supplying pressurized nitrogen to the valve. The coil of each solenoid valve is connected to a configuration of load drivers that are triggered by the automatic signal.

The DPVs have wire circuits connected with two initiators and one booster. Either individually or jointly, the initiators are capable of actuating the booster and subsequently opening the valve. These firing circuits are connected to the load drivers for the automatic actuation. The configuration of the load drivers and the relays is analogous for the SRVs and the DPVs; they are arranged in such a way that a two-out-of-four actuation logic is obtained.

The ADS logic is automatically initiated when a low reactor water level signal (level 1) is present. If the RPV low water level signal is present concurrently with a high drywell pressure signal, both the main ADS timer and the high drywell pressure bypass timer are initiated. If the RPV low water level signal is present without a concurrent high drywell pressure signal, only the ADS high drywell pressure bypass timer is initiated. Upon the time-out of the ADS high drywell pressure bypass timer and concurrent with a RPV low water level signal, the main ADS timer is initiated, if not already initiated. The main ADS timer continues to completion and times out only in the continued presence of an RPV low water level signal. When the main ADS timer times out, the ADS function is initiated. The depressurization rate is limited to prevent reactor coolant inventory level swells in amounts sufficient to produce liquid carry-over along with steam in the blowdown exhaust flow.

4.1.4.2 Manual Actuation

The ten (10) SRVs that are part of the ADS mode have a third solenoid that gives the operator the possibility of opening the valve from the Control Room. This third solenoid possesses different and independent logic channels than the ones used in the ADS operation. The operator can open an SRV through a pushbutton switch; valves remain open for as long as the pushbutton switch is depressed. With this feature, the operator is able to control normal isolation transients even if, according to the design, no need should arise for such an operation.

The operator can also manually initiate the ADS function from the main control room.

4.1.4.3 Safety Actuation

The SRVs (all 18) also open in the safety mode (i.e., actuated on high RPV pressure) when reactor pressure reaches the spring setpoint value.

4.1.5 System Interfaces

The ADS shares all of the components related to the actuating signals with other safety-related systems. These include RPV water level (level 1) and ATWS inhibit signals. ADS shares four level sensors with the systems actuated on a level 2 signal. The system also requires the 250V DC power supply for the actuation logic and the load drivers.

The SRVs need pressurized nitrogen supply to open and to remain open. This is achieved through accumulators connected to the high pressure, nitrogen supply system (HPNSS), which supplies the valves accumulators. The nitrogen supply in the accumulators is sufficient to keep the SRVs open for time intervals if HPNSS supply is not available. The long-term nitrogen

supply for the SRVs is the nitrogen bottles in the HPNSS. Table 4.1-2 summarizes dependencies on the support systems by division.

4.1.6 System Testing

Testing of SRVs is possible during plant operation. It is assumed that SRV tests are scheduled at 18-months intervals on a staggered tests basis. The SRV safety function setpoints are verified at 24-months intervals for half of the SRVs. Each DPV contains two initiators and one booster. During plant operation, the integrity of the electrical circuits of the initiators is continuously monitored by a low current flowing through the wires. The signal chain, up to the output of the trip logic unit, is tested every three months. Actuating logic devices, such as load drivers, are tested monthly.

4.1.7 System Maintenance

All of the main components are within the drywell, so that no maintenance is planned during plant operation. Maintenance work on SRVs is anticipated during alternate test cycles, or every eight years. During refueling, booster and initiators of squib valves are replaced and test fired; also, an inspection is expected to verify the integrity of the mechanical parts of the DPVs.

Maintenance of logic electronic components is performed on-line if indicated by testing. Since the logic modules are solid state devices, component outages for maintenance are expected to be negligible.

4.1.8 Common Cause Failures

A high degree of redundancy is incorporated in the system design. For that reason, common cause failures (CCFs) turn out to be a potential contributor to system unavailability. The CCFs that have been identified in the system are listed in Table 4.1-5. Only the CCFs of two or three components are considered, as the results of higher combinations are negligible.

4.1.9 Fault Tree Analysis

The ADS fault tree has been evaluated to determine the system unavailability and to identify the components that contribute significantly to system unavailability.

4.1.9.1 Top Event Definitions

The top events list defined for the system is given in Table 4.1-8.

The two main fault trees are shown in the Appendix B.4.1.

4.1.9.2 Fault Tree Description

Two fault trees are developed: the first one represents the opening of four (4) of eight (8) DPVs, while the second one shows the manual opening of five (5) of the ten (10) SRVs with a depressurization function.

4.1.9.3 Human Interaction

In the fault tree relating to the manual opening of SRVs, this opening is initiated by operator action from the Control Room.

There are no local manually operated valves in the ADS system, so no misposition events are considered.

The only specific human action modeled within the DPV fault tree is the backup manual actuation of the ADS (Type C). The backup actuation is initiated in the control room through devices designed to prevent inadvertent actuation.

4.1.10 Results of Fault Tree Analysis

The definition of each basic event is reported in Table 4.1-7.

The quantification of core damage sequences implicitly includes the contribution of basic events for this system. This quantification process enables checking the global consistency of the system fault trees and their relationship with the rest of the systems modeled in the PRA.

The importance measurements obtained from core damage frequency equations, allow identification of the most relevant basic events and system component failures in an integrated context, as well as the determination of their relative importance with respect to the basic events and component failures of the other systems modeled.

4.1.11 Model Differences for 72-Hour Operation

No change is necessary for using the model with a 72-hour mission time.

4.1.12 References

4.1.1. ESBWR Design Control Document, 26A6642 Rev. 01

Table 4.1-1

Control Room Instrumentation and Alarms

Controls
Displays
Reactor vessel pressure
Reactor vessel water level
Main steam line pressure
Main condenser vacuum
Main steam line flow
Main steam line radiation (from PRMS)
SRV position
MSIV position
DPV position
Main steam line drain valve position
Position of feedwater motor operated valves within Reactor Building
Feedwater outboard isolation check valve position
Position of feedwater maintenance manual isolation valve
RPV head seal leak detection
Main steam line drain temperature
Alarms
RPV head closure seal leakage
Low reactor water level (L1, L2 and L3)
High reactor water level (L8)
High reactor water level (L9)
High SRV discharge line temperature
SRV – Open
MSIV – Closure
DPV – Open
ADS Inhibited/Auto Out of Service
ADS Logic Initiated
Valve travel failure (all feedwater motor-operated valves)

Table 4.1-2

System Dependency Matrix

	Support System								
	250 V DC Power Supply					Actuation Signal			
Component	**Type**	**R16-11**	**R16-21**	**R16-31**	**R16-41**	**C74 Div 1**	**C74 Div 2**	**C72 Div 1**	**C72 Div 2**
F004A	DPV	X			X	X			X
F004B	DPV		X	X			X	X	
F004C	DPV	X			X	X		X	
F004D	DPV		X	X			X		X
F004E	DPV	X			X	X			X
F004F	DPV		X	X			X	X	
F004G	DPV	X			X	X		X	
F004H	DPV		X	X			X		X

	Support System								
	Uninterruptible AC Power Supply				Signal Transmission (C72)				Air Supply
Component	**Type**	**R13-A1-2**	**R13-B1-2**	**R13-C1-2**	**Div A**	**Div B**	**Div C**	**Div D**	**HPNSS**
F006A	SRV	X			X				X
F006B	SRV		X			X			X
F006C	SRV			X			X		X
F006D	SRV	X						X	X
F006E	SRV		X		X				X
F006F	SRV			X		X			X
F006G	SRV	X					X		X
F006H	SRV		X					X	X
F006I	SRV			X	X				X
F006J	SRV	X				X			X

Table 4.1-3

Component Test

Component	Type	Expected Test Interval
SRVs safety function setpoints	SRV	24-month intervals for half of the SRVs
SRV tests	SRV	18-month intervals on a staggered tests basis
Signal chain	DPV	Quarterly
Actuating logic devices	DPV	Monthly
Initiators and boosters	DPV	24-months

Table 4.1-4

Component Maintenance

All of the main components are within the drywell, so that no maintenance is planned during plant operation.

Table 4.1-5
List of System Common Cause Failures

Basic Event	Prob	Description
B21-SQV-CF-DPVOPEN	1.50E-05	CCF OF DPV'S TO OPEN
B21-SQV-CF-F004AB	3.60E-05	CCF OF DPV A AND B TO OPEN
B21-SQV-CF-F004ABC	9.00E-06	CCF OF DPV A, B & C TO OPEN
B21-SQV-CF-F004ABD	9.00E-06	CCF OF DPV A, B & D TO OPEN
B21-SQV-CF-F004ABE	9.00E-06	CCF OF DPV A, B & E TO OPEN
B21-SQV-CF-F004ABF	9.00E-06	CCF OF DPV A, B & F TO OPEN
B21-SQV-CF-F004ABG	9.00E-06	CCF OF DPV A, B & G TO OPEN
B21-SQV-CF-F004ABH	9.00E-06	CCF OF DPV A, B & H TO OPEN
B21-SQV-CF-F004AC	3.60E-05	CCF OF DPV A AND C TO OPEN
B21-SQV-CF-F004ACD	9.00E-06	CCF OF DPV A, C & D TO OPEN
B21-SQV-CF-F004ACE	9.00E-06	CCF OF DPV A, C & E TO OPEN
B21-SQV-CF-F004ACF	9.00E-06	CCF OF DPV A, C & F TO OPEN
B21-SQV-CF-F004ACG	9.00E-06	CCF OF DPV A, C & G TO OPEN
B21-SQV-CF-F004ACH	9.00E-06	CCF OF DPV A, C & H TO OPEN
B21-SQV-CF-F004AD	3.60E-05	CCF OF DPV A AND D TO OPEN
B21-SQV-CF-F004ADE	9.00E-06	CCF OF DPV A, D & E TO OPEN
B21-SQV-CF-F004ADF	9.00E-06	CCF OF DPV A, D & F TO OPEN
B21-SQV-CF-F004ADG	9.00E-06	CCF OF DPV A, D & G TO OPEN
B21-SQV-CF-F004ADH	9.00E-06	CCF OF DPV A, D & H TO OPEN
B21-SQV-CF-F004AE	3.60E-05	CCF OF DPV A AND E TO OPEN
B21-SQV-CF-F004AEF	9.00E-06	CCF OF DPV A, E & F TO OPEN
B21-SQV-CF-F004AEG	9.00E-06	CCF OF DPV A, E & G TO OPEN
B21-SQV-CF-F004AEH	9.00E-06	CCF OF DPV A, E & H TO OPEN
B21-SQV-CF-F004AF	3.60E-05	CCF OF DPV A AND F TO OPEN
B21-SQV-CF-F004AFG	9.00E-06	CCF OF DPV A, F & G TO OPEN
B21-SQV-CF-F004AFH	9.00E-06	CCF OF DPV A, F & H TO OPEN
B21-SQV-CF-F004AG	3.60E-05	CCF OF DPV A AND G TO OPEN
B21-SQV-CF-F004AGH	9.00E-06	CCF OF DPV A, G & H TO OPEN
B21-SQV-CF-F004AH	3.60E-05	CCF OF DPV A AND H TO OPEN
B21-SQV-CF-F004BC	3.60E-05	CCF OF DPV B AND C TO OPEN
B21-SQV-CF-F004BCD	9.00E-06	CCF OF DPV B, C & D TO OPEN
B21-SQV-CF-F004BCE	9.00E-06	CCF OF DPV B, C & E TO OPEN
B21-SQV-CF-F004BCF	9.00E-06	CCF OF DPV B, C & F TO OPEN

Table 4.1-5

List of System Common Cause Failures

Basic Event	Prob	Description
B21-SQV-CF-F004BCG	9.00E-06	CCF OF DPV B, C & G TO OPEN
B21-SQV-CF-F004BCH	9.00E-06	CCF OF DPV B, C & H TO OPEN
B21-SQV-CF-F004BD	3.60E-05	CCF OF DPV B AND D TO OPEN
B21-SQV-CF-F004BDE	9.00E-06	CCF OF DPV B, D & E TO OPEN
B21-SQV-CF-F004BDF	9.00E-06	CCF OF DPV B, D & F TO OPEN
B21-SQV-CF-F004BDG	9.00E-06	CCF OF DPV B, D & G TO OPEN
B21-SQV-CF-F004BDH	9.00E-06	CCF OF DPV B, D & H TO OPEN
B21-SQV-CF-F004BE	3.60E-05	CCF OF DPV B AND E TO OPEN
B21-SQV-CF-F004BEF	9.00E-06	CCF OF DPV B, E & F TO OPEN
B21-SQV-CF-F004BEG	9.00E-06	CCF OF DPV B, E & G TO OPEN
B21-SQV-CF-F004BEH	9.00E-06	CCF OF DPV B, E & H TO OPEN
B21-SQV-CF-F004BF	3.60E-05	CCF OF DPV B AND F TO OPEN
B21-SQV-CF-F004BFG	9.00E-06	CCF OF DPV B, F & G TO OPEN
B21-SQV-CF-F004BFH	9.00E-06	CCF OF DPV B, F & H TO OPEN
B21-SQV-CF-F004BG	3.60E-05	CCF OF DPV B AND G TO OPEN
B21-SQV-CF-F004BGH	9.00E-06	CCF OF DPV B, G & H TO OPEN
B21-SQV-CF-F004BH	3.60E-05	CCF OF DPV B AND H TO OPEN
B21-SQV-CF-F004CD	3.60E-05	CCF OF DPV C AND D TO OPEN
B21-SQV-CF-F004CDE	9.00E-06	CCF OF DPV C, D & E TO OPEN
B21-SQV-CF-F004CDF	9.00E-06	CCF OF DPV C, D & F TO OPEN
B21-SQV-CF-F004CDG	9.00E-06	CCF OF DPV C, D & G TO OPEN
B21-SQV-CF-F004CDH	9.00E-06	CCF OF DPV C, D & H TO OPEN
B21-SQV-CF-F004CE	3.60E-05	CCF OF DPV C AND E TO OPEN
B21-SQV-CF-F004CEF	9.00E-06	CCF OF DPV C, E & F TO OPEN
B21-SQV-CF-F004CEG	9.00E-06	CCF OF DPV C, E & G TO OPEN
B21-SQV-CF-F004CEH	9.00E-06	CCF OF DPV C, E & H TO OPEN
B21-SQV-CF-F004CF	3.60E-05	CCF OF DPV C AND F TO OPEN
B21-SQV-CF-F004CFG	9.00E-06	CCF OF DPV C, F & G TO OPEN
B21-SQV-CF-F004CFH	9.00E-06	CCF OF DPV C, F & H TO OPEN
B21-SQV-CF-F004CG	3.60E-05	CCF OF DPV C AND G TO OPEN
B21-SQV-CF-F004CGH	9.00E-06	CCF OF DPV C, G & H TO OPEN
B21-SQV-CF-F004CH	3.60E-05	CCF OF DPV C AND H TO OPEN
B21-SQV-CF-F004DE	3.60E-05	CCF OF DPV D AND E TO OPEN
B21-SQV-CF-F004DEF	9.00E-06	CCF OF DPV D, E & F TO OPEN

Table 4.1-5

List of System Common Cause Failures

Basic Event	Prob	Description
B21-SQV-CF-F004DEG	9.00E-06	CCF OF DPV D, E & G TO OPEN
B21-SQV-CF-F004DEH	9.00E-06	CCF OF DPV D, E & H TO OPEN
B21-SQV-CF-F004DF	3.60E-05	CCF OF DPV D AND F TO OPEN
B21-SQV-CF-F004DFG	9.00E-06	CCF OF DPV D, F & G TO OPEN
B21-SQV-CF-F004DFH	9.00E-06	CCF OF DPV D, F & H TO OPEN
B21-SQV-CF-F004DG	3.60E-05	CCF OF DPV D AND G TO OPEN
B21-SQV-CF-F004DGH	9.00E-06	CCF OF DPV D, G & H TO OPEN
B21-SQV-CF-F004DH	3.60E-05	CCF OF DPV D AND H TO OPEN
B21-SQV-CF-F004EF	3.60E-05	CCF OF DPV E AND F TO OPEN
B21-SQV-CF-F004EFG	9.00E-06	CCF OF DPV E, F & G TO OPEN
B21-SQV-CF-F004EFH	9.00E-06	CCF OF DPV E, F & H TO OPEN
B21-SQV-CF-F004EG	3.60E-05	CCF OF DPV E AND G TO OPEN
B21-SQV-CF-F004EGH	9.00E-06	CCF OF DPV E, G & H TO OPEN
B21-SQV-CF-F004EH	3.60E-05	CCF OF DPV E AND H TO OPEN
B21-SQV-CF-F004FG	3.60E-05	CCF OF DPV F AND G TO OPEN
B21-SQV-CF-F004FGH	9.00E-06	CCF OF DPV F, G & H TO OPEN
B21-SQV-CF-F004FH	3.60E-05	CCF OF DPV F AND H TO OPEN
B21-SQV-CF-F004GH	3.60E-05	CCF OF DPV G AND H TO OPEN
B21-SRV-CF-6OPEN	1.90E-04	CCF TO OPEN 6 SRVs
C51-ACT-CF-APRMSTUCK	2.10E-07	CCF APRM DETECTORS STUCK AT POWER LEVEL

Table 4.1-6

List of System Human Errors

Basic Event	Prob	Description
B21-XHE-FO-6OPEN	1.61E-03	OPERATOR FAILS TO OPEN 6/10 SRVs
XXX-XHE-FO-DEPRESS	1.61E-01	OPERATOR FAILS TO RECOGNIZE NEED OF DEPRESSURIZATION

Table 4.1-7

List of System Basic Events

Basic Event	Prob	Description
B21-SQV-CC-F004A	3.00E-03	EXPLOSIVE VALVE DPV A FAILS TO OPERATE
B21-SQV-CC-F004B	3.00E-03	EXPLOSIVE VALVE DPV B FAILS TO OPERATE
B21-SQV-CC-F004C	3.00E-03	EXPLOSIVE VALVE DPV C FAILS TO OPERATE
B21-SQV-CC-F004D	3.00E-03	EXPLOSIVE VALVE DPV D FAILS TO OPERATE
B21-SQV-CC-F004E	3.00E-03	EXPLOSIVE VALVE DPV E FAILS TO OPERATE
B21-SQV-CC-F004F	3.00E-03	EXPLOSIVE VALVE DPV F FAILS TO OPERATE
B21-SQV-CC-F004G	3.00E-03	EXPLOSIVE VALVE DPV G FAILS TO OPERATE
B21-SQV-CC-F004H	3.00E-03	EXPLOSIVE VALVE DPV H FAILS TO OPERATE
B21-SQV-CF-DPVOPEN	1.50E-05	CCF OF DPV'S TO OPEN
B21-SQV-CF-F004AB	3.60E-05	CCF OF DPV A AND B TO OPEN
B21-SQV-CF-F004ABC	9.00E-06	CCF OF DPV A, B & C TO OPEN
B21-SQV-CF-F004ABD	9.00E-06	CCF OF DPV A, B & D TO OPEN
B21-SQV-CF-F004ABE	9.00E-06	CCF OF DPV A, B & E TO OPEN
B21-SQV-CF-F004ABF	9.00E-06	CCF OF DPV A, B & F TO OPEN
B21-SQV-CF-F004ABG	9.00E-06	CCF OF DPV A, B & G TO OPEN
B21-SQV-CF-F004ABH	9.00E-06	CCF OF DPV A, B & H TO OPEN
B21-SQV-CF-F004AC	3.60E-05	CCF OF DPV A AND C TO OPEN
B21-SQV-CF-F004ACD	9.00E-06	CCF OF DPV A, C & D TO OPEN
B21-SQV-CF-F004ACE	9.00E-06	CCF OF DPV A, C & E TO OPEN
B21-SQV-CF-F004ACF	9.00E-06	CCF OF DPV A, C & F TO OPEN
B21-SQV-CF-F004ACG	9.00E-06	CCF OF DPV A, C & G TO OPEN
B21-SQV-CF-F004ACH	9.00E-06	CCF OF DPV A, C & H TO OPEN
B21-SQV-CF-F004AD	3.60E-05	CCF OF DPV A AND D TO OPEN
B21-SQV-CF-F004ADE	9.00E-06	CCF OF DPV A, D & E TO OPEN
B21-SQV-CF-F004ADF	9.00E-06	CCF OF DPV A, D & F TO OPEN
B21-SQV-CF-F004ADG	9.00E-06	CCF OF DPV A, D & G TO OPEN
B21-SQV-CF-F004ADH	9.00E-06	CCF OF DPV A, D & H TO OPEN
B21-SQV-CF-F004AE	3.60E-05	CCF OF DPV A AND E TO OPEN
B21-SQV-CF-F004AEF	9.00E-06	CCF OF DPV A, E & F TO OPEN
B21-SQV-CF-F004AEG	9.00E-06	CCF OF DPV A, E & G TO OPEN
B21-SQV-CF-F004AEH	9.00E-06	CCF OF DPV A, E & H TO OPEN
B21-SQV-CF-F004AF	3.60E-05	CCF OF DPV A AND F TO OPEN
B21-SQV-CF-F004AFG	9.00E-06	CCF OF DPV A, F & G TO OPEN

Table 4.1-7

List of System Basic Events

Basic Event	Prob	Description
B21-SQV-CF-F004AFH	9.00E-06	CCF OF DPV A, F & H TO OPEN
B21-SQV-CF-F004AG	3.60E-05	CCF OF DPV A AND G TO OPEN
B21-SQV-CF-F004AGH	9.00E-06	CCF OF DPV A, G & H TO OPEN
B21-SQV-CF-F004AH	3.60E-05	CCF OF DPV A AND H TO OPEN
B21-SQV-CF-F004BC	3.60E-05	CCF OF DPV B AND C TO OPEN
B21-SQV-CF-F004BCD	9.00E-06	CCF OF DPV B, C & D TO OPEN
B21-SQV-CF-F004BCE	9.00E-06	CCF OF DPV B, C & E TO OPEN
B21-SQV-CF-F004BCF	9.00E-06	CCF OF DPV B, C & F TO OPEN
B21-SQV-CF-F004BCG	9.00E-06	CCF OF DPV B, C & G TO OPEN
B21-SQV-CF-F004BCH	9.00E-06	CCF OF DPV B, C & H TO OPEN
B21-SQV-CF-F004BD	3.60E-05	CCF OF DPV B AND D TO OPEN
B21-SQV-CF-F004BDE	9.00E-06	CCF OF DPV B, D & E TO OPEN
B21-SQV-CF-F004BDF	9.00E-06	CCF OF DPV B, D & F TO OPEN
B21-SQV-CF-F004BDG	9.00E-06	CCF OF DPV B, D & G TO OPEN
B21-SQV-CF-F004BDH	9.00E-06	CCF OF DPV B, D & H TO OPEN
B21-SQV-CF-F004BE	3.60E-05	CCF OF DPV B AND E TO OPEN
B21-SQV-CF-F004BEF	9.00E-06	CCF OF DPV B, E & F TO OPEN
B21-SQV-CF-F004BEG	9.00E-06	CCF OF DPV B, E & G TO OPEN
B21-SQV-CF-F004BEH	9.00E-06	CCF OF DPV B, E & H TO OPEN
B21-SQV-CF-F004BF	3.60E-05	CCF OF DPV B AND F TO OPEN
B21-SQV-CF-F004BFG	9.00E-06	CCF OF DPV B, F & G TO OPEN
B21-SQV-CF-F004BFH	9.00E-06	CCF OF DPV B, F & H TO OPEN
B21-SQV-CF-F004BG	3.60E-05	CCF OF DPV B AND G TO OPEN
B21-SQV-CF-F004BGH	9.00E-06	CCF OF DPV B, G & H TO OPEN
B21-SQV-CF-F004BH	3.60E-05	CCF OF DPV B AND H TO OPEN
B21-SQV-CF-F004CD	3.60E-05	CCF OF DPV C AND D TO OPEN
B21-SQV-CF-F004CDE	9.00E-06	CCF OF DPV C, D & E TO OPEN
B21-SQV-CF-F004CDF	9.00E-06	CCF OF DPV C, D & F TO OPEN
B21-SQV-CF-F004CDG	9.00E-06	CCF OF DPV C, D & G TO OPEN
B21-SQV-CF-F004CDH	9.00E-06	CCF OF DPV C, D & H TO OPEN
B21-SQV-CF-F004CE	3.60E-05	CCF OF DPV C AND E TO OPEN
B21-SQV-CF-F004CEF	9.00E-06	CCF OF DPV C, E & F TO OPEN
B21-SQV-CF-F004CEG	9.00E-06	CCF OF DPV C, E & G TO OPEN
B21-SQV-CF-F004CEH	9.00E-06	CCF OF DPV C, E & H TO OPEN
B21-SQV-CF-F004CF	3.60E-05	CCF OF DPV C AND F TO OPEN

Table 4.1-7

List of System Basic Events

Basic Event	Prob	Description
B21-SQV-CF-F004CFG	9.00E-06	CCF OF DPV C, F & G TO OPEN
B21-SQV-CF-F004CFH	9.00E-06	CCF OF DPV C, F & H TO OPEN
B21-SQV-CF-F004CG	3.60E-05	CCF OF DPV C AND G TO OPEN
B21-SQV-CF-F004CGH	9.00E-06	CCF OF DPV C, G & H TO OPEN
B21-SQV-CF-F004CH	3.60E-05	CCF OF DPV C AND H TO OPEN
B21-SQV-CF-F004DE	3.60E-05	CCF OF DPV D AND E TO OPEN
B21-SQV-CF-F004DEF	9.00E-06	CCF OF DPV D, E & F TO OPEN
B21-SQV-CF-F004DEG	9.00E-06	CCF OF DPV D, E & G TO OPEN
B21-SQV-CF-F004DEH	9.00E-06	CCF OF DPV D, E & H TO OPEN
B21-SQV-CF-F004DF	3.60E-05	CCF OF DPV D AND F TO OPEN
B21-SQV-CF-F004DFG	9.00E-06	CCF OF DPV D, F & G TO OPEN
B21-SQV-CF-F004DFH	9.00E-06	CCF OF DPV D, F & H TO OPEN
B21-SQV-CF-F004DG	3.60E-05	CCF OF DPV D AND G TO OPEN
B21-SQV-CF-F004DGH	9.00E-06	CCF OF DPV D, G & H TO OPEN
B21-SQV-CF-F004DH	3.60E-05	CCF OF DPV D AND H TO OPEN
B21-SQV-CF-F004EF	3.60E-05	CCF OF DPV E AND F TO OPEN
B21-SQV-CF-F004EFG	9.00E-06	CCF OF DPV E, F & G TO OPEN
B21-SQV-CF-F004EFH	9.00E-06	CCF OF DPV E, F & H TO OPEN
B21-SQV-CF-F004EG	3.60E-05	CCF OF DPV E AND G TO OPEN
B21-SQV-CF-F004EGH	9.00E-06	CCF OF DPV E, G & H TO OPEN
B21-SQV-CF-F004EH	3.60E-05	CCF OF DPV E AND H TO OPEN
B21-SQV-CF-F004FG	3.60E-05	CCF OF DPV F AND G TO OPEN
B21-SQV-CF-F004FGH	9.00E-06	CCF OF DPV F, G & H TO OPEN
B21-SQV-CF-F004FH	3.60E-05	CCF OF DPV F AND H TO OPEN
B21-SQV-CF-F004GH	3.60E-05	CCF OF DPV G AND H TO OPEN
B21-SRV-CF-6OPEN	1.90E-04	CCF TO OPEN 6 SRVs
B21-XHE-FO-6OPEN	1.61E-03	OPERATOR FAILS TO OPEN 6/10 SRVs
C51-ACT-CF-APRMSTUCK	2.10E-07	CCF APRM DETECTORS STUCK AT POWER LEVEL
XXX-XHE-FO-DEPRESS	1.61E-01	OPERATOR FAILS TO RECOGNIZE NEED OF DEPRESSURIZATION

Table 4.1-8

List of System Top Events

Top Event	**Description**
GB21DPVTOP3	5/8 DPVs FAIL TO OPEN
GB21-0001-_11	6 OUT OF 10 SRV FAIL TO OPEN MANUALLY

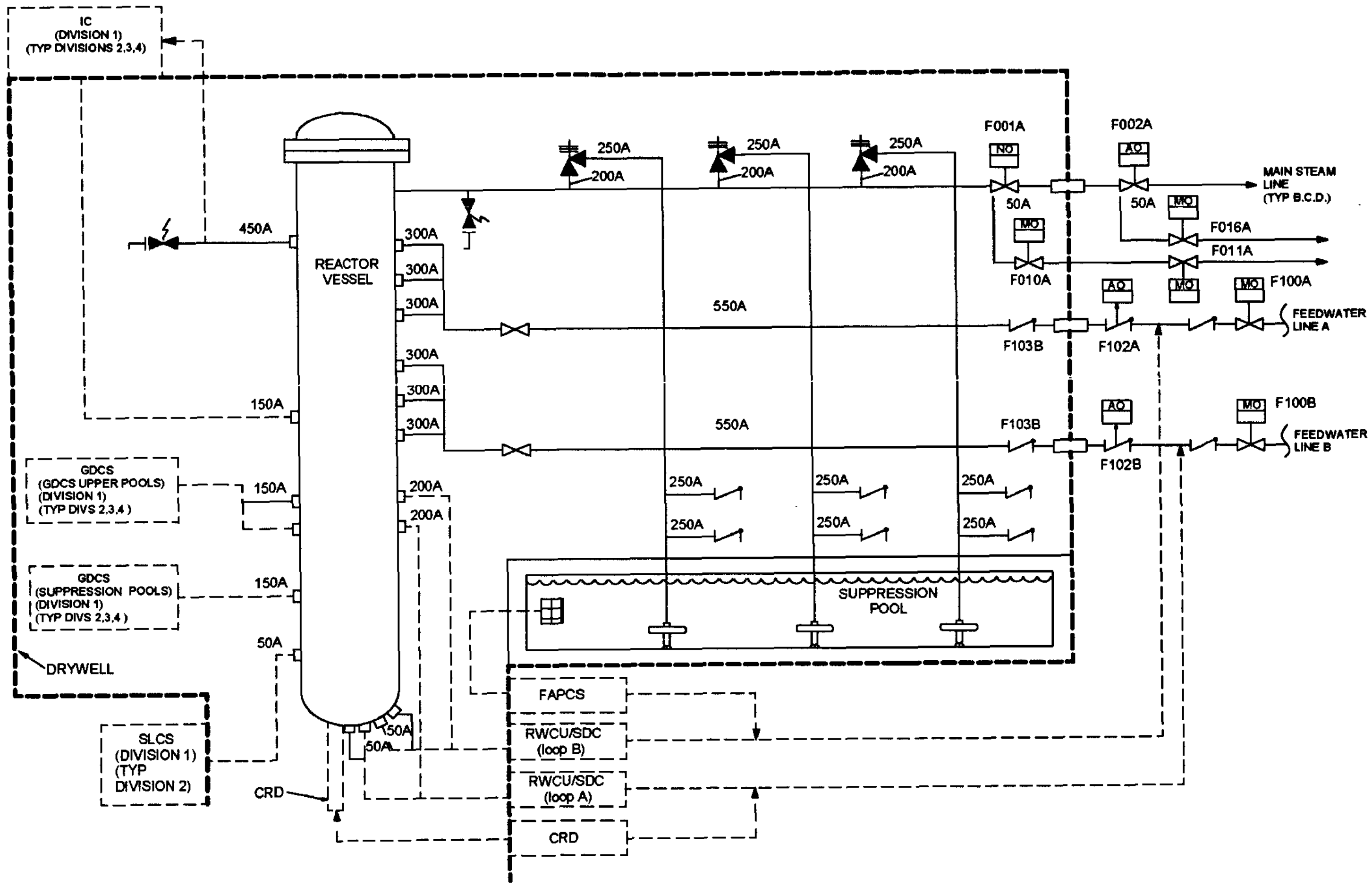


Figure 4.1-1. Simplified Process Diagram for Nuclear Boiler System

4.2 ISOLATION CONDENSER SYSTEM – (B32)

4.2.1 Purpose

The Isolation Condenser System (ICS) limits reactor pressure and temperature within an acceptable range so that safety/relief valve operation is limited and automatic reactor depressurization will not occur when the reactor becomes isolated during power operations.

The ICS is used to transfer decay and residual heat from the reactor after the reactor is shut down and isolated. This function can also be performed by the other Engineered Safety Features (ESFs) of Automatic Depressurization System (ADS) and Gravity Driven Cooling System (GDCS). ICS functions to avoid unnecessary use of these other ESFs for residual heat removal and ICS provides additional liquid inventory upon opening of the condensate return valves to initiate the system. The IC system also provides the means for initial depressurization of the reactor before ADS initiation from a low reactor water level.

The Isolation Condenser System consists of four, high pressure, independent loops, each containing a heat exchanger that condenses steam on the tube side and transfers heat to water in a large Isolation Condenser/Passive Containment Cooling pool (IC/PCC pool) that is vented to the atmosphere.

The units are located in the IC/PCC pool positioned above, and outside, the containment (drywell). The condenser, connected by piping to the reactor pressure vessel, is placed at an elevation above the source of steam (reactor vessel) and, when the steam is condensed, condensate is returned to the vessel via a condensate return pipe.

The steam side connection between the vessel and the IC is normally open and the condensate line is normally closed. This allows the isolation condenser and drain piping to fill with condensate that is maintained at a sub-cooled temperature by the IC/PCC pool water during normal reactor operation.

The isolation condenser is started into operation by draining the condensate to the reactor, thus causing steam from the reactor to fill the tubes that transfer heat to the cooler pool water.

4.2.2 Design Assumptions

The following assumptions with respect to the design are made:

(1) Two limit switches per Main Steam Line are used to generate the MSIV closure signal. Two limit switches, each one belonging to a different MSIV (inboard and outboard) on the same Main Steam Line (MSL), serve as inputs to generate the opening signals to motor-operated F005 valves, when one MSIV in each MSL is closing.

(2) A diverse initiating signal of motor-operated F005 valves is generated by a high RPV pressure > 7.447 MPa-gauge (1080 psig) for 10 seconds.

(3) One nitrogen-operated valve (F006) is present in each return condensate line. Each F006 valve is maintained closed by means of the nitrogen flowing though one of two solenoid valves, normally energized, and powered by different sources.

    Upon loss of nitrogen or power, the valves open.

Both solenoid valves have to de-energize to open the F006 valve.

The opening of either one of two load drivers in series on the power line reenergizes both solenoid valves.

Different Safety System Logic and Control (SSLC) channels are employed to open the two load drivers.

(4) Automatic initiation of the ICS F006 valves is also provided by a reactor water level 2 signal.

(5) The ICS is able to maintain reactor pressure below the safety valve operating pressure with three of four ICs in service following reactor isolation from 100% power and successful scram.

4.2.3 System Description

The systems are assumed to operate as described in Reference 4.2-1 for the ICS.

4.2.3.1 Hardware Configuration

Isolation Condenser System (ICS)

A simplified P&ID is shown in Figure 4.2-1.

The ICS consists of four high pressure, independent loops, each containing a condenser that condenses steam on the tube side and transfers heat to water in a large pool (IC/PCC pool) positioned above and outside the primary containment. The surface of the pool is vented to the atmosphere through a plant stack.

Each ICS condenser is connected by piping to the reactor pressure vessel and is placed at an elevation above the source of steam (RPV). When the steam is condensed, it returns to the vessel via a condensate return pipe.

The steam side connection between the vessel and the ICS condenser is normally open and the condensate line is normally closed. This allows the isolation condenser and drain piping to fill with condensate, which is maintained at a subcooled temperature by the pool water during normal reactor operation.

Portions of the ICS system outside the containment are located in a subcompartment of the safety-related IC/PCC pool to provide protection from missiles, tornadoes and winds. The IC steam supply pipes include flow restrictors and the IC condensate drain pipes diameter is sized such that if an IC piping or tube rupture occurs in the safety-related IC/PCC pool, flow-induced dynamic loads and pressure buildup in the IC/PCC pool would be limited by these design features.

The steam supply line is vertical and feeds two horizontal headers through four pipes. The steam line is properly insulated and enclosed in a guard pipe, which penetrates the containment roof slab, up to the distribution branching point. Guard pipes and special transition fittings are used at the locations where the IC steam supply and condensate return pipes enter the pool at the containment pressure boundary.

Two fail-as-is isolation valves in series (nitrogen-motor-operated F001 and motor-operated F002) are located in the run of steam supply line piping inboard of the containment boundary.

They are used to isolate that part of the ICS that is located outside the containment. Two different valve actuator types are used to assure flow path closure.

Steam is condensed inside vertical tubes and is collected in two lower headers. Two pipes, one from each lower header, take the condensate to the common drain line, which vertically penetrates the containment roof slab.

On the condensate return piping, two fail-as-is isolation valves in series (motor-operated F003 and nitrogen-motor-operated F004) are provided, both located inboard of the containment boundary. They are also used to isolate parts of the ICS outside the containment. Two different valve actuator types are used to assure flow path closure.

A loop seal and a condensate return valve (F006, nitrogen-operated, fail open) are located on the condensate return piping just upstream from the reactor entry point. This valve is closed during normal plant power operations. Because the steam supply line valves are normally open, condensate forms in the ICS condenser and fills up to the steam distributor, above the upper headers.

The isolation condenser operation is initiated by draining the condensate to the reactor, thus causing steam from the reactor to fill the tubes, which transfer heat to the water of the cooler pool. The motor-operated condensate return valve (F005) is opened to commence ICS operation. Whereupon the collected condensate within the condensate return line, drains into the reactor. The steam-water interface in the condenser tube bundle moves downward, below the lower headers, to a point within the main condensate return line. A similar physical process is followed if the valves initially opened are the nitrogen-operated condensate return valves (F006). The fail open nitrogen-operated condensate return bypass valve (F006) opens if the 250 V DC power or nitrogen supply are lost.

A vent line to the suppression pool is provided for both the upper and lower headers in order to remove the non-condensable gases during ICS operation.

Venting is controlled as follows: two normally closed, fail closed, solenoid-operated valves (F009 and F010) are located in the vent line from the lower headers. They can be actuated both automatically and manually; automatically, when RPV pressure is high and either of the condensate return valves is open, and manually, by the control room operator. In case of F009 and/or F010 failure, two bypass motor-operated valves, F011 and F012, (normally closed) allow the operator to vent non-condensable gases.

A vent line from the upper headers equipped with two normally closed, fail closed, solenoid-operated valves (F007 and F008) allows the operator to vent non-condensable gases, if necessary.

During normal plant operation, non-condensable gases are prone to accumulate in the ICS condenser due to hydrogen buildup from water chemistry control additions and air entrained in the feedwater. A purge line is provided to assure that the tubes are not blanketed with non-condensibles when the system is first started.

ICS Pool

The isolation condensers (IC) and the passive containment cooling (PCCS) condensers are located in the same large water pool, positioned above the drywell. The large ICS pool is

partitioned, but both the ICS and PCCS are able to draw water from the entire pool. The air and steam spaces are also common.

The pool subcompartment interconnections are as follows: the ICS and PCCS pool subcompartments are connected to the other pools below the water level by locked open valves, one for each subcompartment. These valves can be closed to isolate and drain the individual partitioned ICS pool for maintenance of the unit. All other pool subcompartments are interconnected below the pool water level.

The remote handwheels on the locked open valves extend above the water level to locations accessible to the operator.

The walls containing the airspace flow path extend above the normal water level. This enhances the flow stability and heat removal capability of the condensers by establishing a flow path for the makeup water through the lower pipes.

4.2.3.2 System Operation

During normal plant operation, the ICS subloop is on ready standby. Both steam supply isolation valves and both isolation valves on the condensate return line are in a normally open position with the condensate level in the ICS condenser extending above the upper headers. The condensate return valves are both closed, and the small vent lines from the ICS condenser top and bottom headers to the suppression pool are also closed.

Steam flow is induced from the steam distributor through the purge line by the pressure differential caused by main steam line flow. The valve status, failure mode, actuator type, pipe size, valve type, and line location are as follows:

Valve number	Status	Failure mode	Actuator type	Pipe Size mm (inches)	Valve type	Location
F001	NO	AI	NMO	350 (14)	Gate	Steam line
F002	NO	AI	MO	350 (14)	Gate	Steam line
F003	NO	AI	MO	200 (8)	Gate	Condensate to RPV
F004	NO	AI	NMO	200 (8)	Gate	Condensate to RPV
F005	NC	AI	MO	200 (8)	Gate	Condensate to RPV
F006	NC	FO	NO	200 (8)	Globe	Condensate to RPV
F007	NC	FC	SO	25 (1)	Globe	Vent line to SP
F008	NC	FC	SO	25 (1)	Globe	Vent line to SP
F009	NC	FC	SO	25 (1)	Globe	Vent line to SP
F010	NC	FC	SO	25 (1)	Globe	Vent line to SP
F011	NC	AI	MO	25 (1)	Globe	Vent line to SP
F012	NC	AI	MO	25 (1)	Globe	Vent line to SP
F013	NO	AI	MO	20(3/4)	Globe	Purge line to MSL

Legend	NO	= normally open
	NC	= normally closed
	AI	= as is
	FO	= fail open
	FC	= fail closed
	MO	= motor operated
	NMO	= nitrogen motor operated
	SO	= solenoid operated
	NO	= nitrogen operated

During refueling, the ICS condenser is isolated from the reactor; all isolation valves (F001 through F004) and all vent valves (F007 through F012) are closed.

During plant operation, when one of the ICS initiation signals (as described in Section 4.2.4) opens condensate return valve F005 or F006 with a delay of 30 seconds, operation of the ICS starts.

If, during ICS operation and after the initial transient, the RPV pressure increases above 7.516 MPa-gauge, the bottom vent valves, F009 and F010, automatically open. When the RPV pressure decreases below 7.447 MPa-gauge (reset value), and after a time delay these two valves close.

4.2.3.3 Component Location

The ICS condensers are located in a large pool positioned above, and outside, the ESBWR primary containment.

The large pool is partitioned between the ICS and PCCS condensers, but each is able to draw water from the entire pool; the air and steam space is also open to both.

The ICS condensers are extensions of the reactor coolant pressure boundary and are not isolated from it.

The piping and valves are all within the drywell. The vent valves (F007 through F012) are located in a vertical pipe run near the top of the drywell.

The radiation monitors used to detect steam leakage to the pool are installed in each IC pool exhaust passage to the atmosphere to detect IC leakage.

4.2.4 Automatic and Manual Control

The initiation signals actuate all four ICS loops at the same time by opening the F005 valves (A, B, C and D). The initiation signals are described as follows:

a. The "reactor mode switch is in run" and at least one of the inboard or outboard MSIVs position switch are less than 92% open on the four Main Steam Lines.

There are two MSIVs on each main steam line. The logic is one-out-of-two limit switches of the MSIVs on the same line plus one-out-of-two limit switches of the MSIVs on the other lines. All MSLs must be closed for ICS actuation.

b. RPV pressure (with logic two-out-of-four) > 7.447 MPa-gauge for 10 seconds or more.

c. Operator Manual Initiation.

Other initiation signals actuate all four ICS loops at the same time by opening the F006 valves (A, B, C, D). These other initiation signals are as follows:

a. Reactor water level below Level 2.

b. Operator Manual Initiation.

The condensate return valve (F006) opens automatically upon a loss of the two electrical power divisions, or on the loss of nitrogen supply, or manually, by operator action.

Initiation of the ICS automatically generates the automatic opening of valves (A, B, C, and D) for F001 through F004.

The automatic valves interconnecting the upper containment pools have a manual backup. The signal is from the water level in the pools. This gives the operators a chance to makeup with demineralized water and thus prevent opening of the valves.

Automatic actuation for the vent valves (F009 and F010) is provided by a high RPV pressure (above system actuation value) and either of the condensate return valves not fully closed (with a time delay to avoid the vents opening during the initial transient). The valves close preventing loss of inventory when the RPV pressure decreases below the 7.447 MPa-gauge reset value.

The Leak Detection and Isolation System (LD&IS) isolates each IC loop individually on high pool radiation or on high flow (as measured by high differential pressure) in the steam supply line or the condensate return line. (See Paragraph 4.1 for detailed system description).

- Four radiation sensors are installed in each IC-HX pool exhaust passages that vent air and coolant vapor to the environment. Detection of a low-level leak (radiation level above background, logic two-out-of-four) initiates an alarm. Detection of a high radiation level (exceeding site boundary limits, logic two-out-of-four) isolates the leaking isolation condenser automatically (closure of isolation valves F001 through F004). The high radiation may be due to a leak from any condenser tube and a subsequent release of noble gas to the air above the pool.
- Four redundant sets of differential Pressure Transmitters (dPT) on the steam line and another four sets on the condensate return line are used to detect a possible LOCA. A high dPT signal coming from two-out-of-four dPTs on the same line (steam or condensate) results in alarms to the operator and automatic closure of all isolation valves, rendering the affected IC inoperable.

Closure of the isolation valves (F001 through F004) and an alarm is automatic on the following signals coming from their own loop (logic two-out-of-four):

- high mass flow in the ICS steam supply line or
- high mass flow in the ICS condensate return line or

- high radiation in the IC-HX pool steam flow path

The operator cannot override the high radiation signals from the IC atmospheric vents and high differential pressure IC isolation signals.

A temperature element is provided downstream from the valves in each vent line to confirm vent-valve function and in the condensate return line, downstream from isolation valve F004.

The instrument and alarm signals reported in the control room are given in Table 4.2-1.

4.2.5 System Interfaces

Support Systems

The condensate return valve (MO F005) is a motor-operated, double disk wedge gate type valve, and designed to fail as-is upon loss of essential 480 V AC power. The condensate return valve (MO F005, A, B, C or D) for each ICS condenser is supplied as follows:

IC A	Essential 480 V AC power, Div. 1
IC B	Essential 480 V AC power, Div. 2
IC C	Essential 480 V AC power, Div. 3
IC D	Essential 480 V AC power, Div. 4

The inboard isolation valves (NMO-F001 and F004) on any ICS loop are supplied by essential 250 V DC power, Div. 2 and the High Pressure Nitrogen Gas Supply System. Nitrogen charged pneumatic accumulators supply the valves during abnormal (i.e. emergency) conditions.

The outboard isolation valves (MO-F002 and F003, A, B, C, and D) for any ICS loop are supplied by essential 250 V DC power, Div. 1.

Valve F006 (A, B, C, and D) interfaces with the SSLC which provides the initiation signals for valve opening. Table 4.2-2 reports the System Dependency Matrix for valves F006 (A, B, C, D).

The Fire Protection System is able to provide makeup water to the IC/PCC pool in the long term and it is included in the model.

4.2.6 System Testing

During normal plant operations, a quarterly surveillance test of the normally-closed valves, F005 and F006, on the ICS condensate line to the RPV is performed. The test procedure of the condensate return valve starts after the condensate return line isolation valves, F003 and F004, are closed. This avoids subjecting the condenser to unnecessary thermal heat-up and cooldown cycles. Isolation valves on the steam supply line (i.e., F001 and F002) remain open to avoid ICS depressurization. The control room operator via remote manual switches that actuate the isolation valves and the condensate return valves performs the test. Their status light verifies the opening and closure of the valves. The procedure is as follows:

- Close valves F003 and F004
- Open fully and then close valves F005/F006
- Re-open isolation valves F003 and F004 to put the ICS on stand-by condition

The isolation valves (F001, F002, F003, and F004) are tested quarterly, one at a time. If an automatic system actuation signal occurs during the test, all the valves are aligned automatically to permit the ICS to start operation.

Each vent valve (F007 through F012) is tested quarterly. These valves, in series, are opened one at a time during normal plant operation. A permissive allows the operator to open one vent valve if the other one in series is closed.

Purge line root valve F013 is tested quarterly.

Table 4.2-3 shows the test program for the system.

4.2.7 System Maintenance

Preventive maintenance actions are not expected to be performed during normal plant operation for the ICS.

Corrective maintenance for tube plugging following the detection of a tube leak is performed during refueling. After closing the isolation valves to or from the condenser, plugging of the leaking tube is performed by personnel operating from the refueling floor. Maintenance is performed from the upper and lower ends of the condensers after removal of the header covers. A remotely operated tool is used.

The pool water in the isolation condenser subcompartment is removable without emptying the entire IC/PCC pool. The individual partitioned ICS pool is isolated by closing the locked open valve interconnecting it to the other pools and emptying the compartment using a portable pump. This water is discharged into the common pool. To replenish the pool, the normally locked open valve is reopened and the water refills the pool.

Table 4.2-4 shows the test program for the system.

4.2.8 Common Cause Failures

Common cause failures within the ICS are summarized in Table 4.2-5 including the CCF of logic.

4.2.9 Fault Tree Analysis

The ICS fault trees are evaluated to determine the system unavailabilities and to identify the components that contribute significantly.

4.2.9.1 Top Event Definitions

The ICS is analyzed for the following events using the same fault tree (GB32TOP2):

- All Transients, to avoid Level 1 without RCPB leakage and to prevent lifting SRVs
- ATWS events

Table 4.2-8 reports the list of ICS top events.

4.2.9.2 Fault Tree Description

The fault tree is developed in Appendix B.4.2.

4.2.9.3 Human Interactions

Table 4.2-6 summarizes the human errors considered in the present analysis.

4.2.10 Results of Fault Tree Analysis

The fault tree results provide quantitative values of systems unavailability and the importance of specific components to that total.

The definition of each basic event is reported in Table 4.2-7.

The quantification of top events for ICS includes the contribution of basic events for this system. This quantification process enables checking the global consistency of the system fault trees and their relationship with the rest of the systems modeled in the PRA.

The importance measures obtained from core damage frequency equations, allow identification of the most relevant basic events and system component failures in an integrated context, as well as the determination of their relative importance with respect to the basic events and component failures of the other systems modeled.

4.2.11 Model Differences for 72-Hour Operation

The IC pools provide sufficient cooling water for 24 hours. To maintain the pool cooling function beyond 24 hours, it is necessary to interconnect IC/PCC and Reactor Well pools through the MOVs provided (F72HA, F72HB, F72HC, F72HD). This is an automatic action initiated on low pool level. (See Figure 4.2-2) Alternatively, the lost water can be resupplied via a manual cross tie from the Fire Protection Systems.

4.2.12 References

4.2-1. ESBWR Design Control Document, 26A6642 Rev. 01

Table 4.2-1

Control Room Instrumentation and Alarms

Controls
Displays
(6) Remote operable valves status lights
(7) A vent line element downstream of the valves to confirm vent function (these elements send signals to a temperature recorder in the control room).
Alarms
(8) High mass flow (dPT) in steam mass supply
(9) High mass flow (dPT) in condensate return line to RPV
(10) High radiation in the pool vents
(11) Remote operable valves computer alarms

Table 4.2-2

System Dependency Matrix

		Support Systems			
		Power Supply			
		R13 480 V AC			
Component	**TYPE**	**DIV 1**	**DIV 2**	**DIV 3**	**DIV 4**
F005A	MOV	X			
F005B	MOV		X		
F005C	MOV			X	
F005D	MOV				X

Table 4.2-3

Component Test

COMPONENT	TYPE	Expected test interval	Components aligned away from emergency position without automatic return logic
F005A/B/C/D	MOV	Quarterly	None
F006A/B/C/D	NMO	Quarterly	None
F001A/B/C/D	NMO	Quarterly	None
F002A/B/C/D	MOV	Quarterly	None
F003A/B/C/D	MOV	Quarterly	None
F004A/B/C/D	NMO	Quarterly	None

Table 4.2-4

Component Maintenance

No preventive actions are expected to be performed during normal plant operation.

Corrective maintenance of ICS condenser tube plugging following tube leak detection can be performed during refueling.

If there is considerable damage to some component part of the ICS or PCCS, each module of the unit is easily removable, after cutting the feed, drain and vent lines.

Table 4.2-5

List of System Common Cause Failures

Basic Event	Prob	Description
B21-LT_-CF-N001ABCD	1.20E-07	CCF OF DIVERSIFIED LEVEL 1& 2 TRANSM. 1A/B/C/D
B21-LT_-CF-N010ABCD	1.20E-07	CCF OF DIVERSIFIED LEVEL 1 & 2 TRANSM. 10A/B/C/D
B21-PT_-CF-02ALLNO	3.00E-08	CCF OF RPV PRESSURE TRANSMITTERS
B32-ACV-CF-2ICABCD	1.55E-05	CCF TO OPEN 2/4 ACV VALVES TRAINS A, B, C, D
B32-LT_-CF-LT72HA	7.20E-08	CCF 3 OUT OF FOUR A LEVEL TRANSMITTERS
B32-MOV-CF-2ICABCD	8.08E-06	CCF TO OPEN 2/4 MOV VALVES TRAINS A, B, C, D
B32-MOV-CF-F005A/B	1.44E-05	CCF TO OPERATE BETWEEN F005 A & B
B32-MOV-CF-F005A/C	1.44E-05	CCF TO OPERATE BETWEEN F005 A & C
B32-MOV-CF-F005A/D	1.44E-05	CCF TO OPERATE BETWEEN F005 A & D
B32-MOV-CF-F005B/C	1.44E-05	CCF TO OPERATE BETWEEN F005 B & C
B32-MOV-CF-F005B/D	1.44E-05	CCF TO OPERATE BETWEEN F005 B & D
B32-MOV-CF-F005C/D	1.44E-05	CCF TO OPERATE BETWEEN F005 C & D
B32-MOV-CF-F72HADOPEN	2.00E-04	CCF VALVES F72HA AND D TO OPEN
B32-MOV-CF-F72HBCOPEN	2.00E-04	CCF VALVES F72HB AND C TO OPEN
B32-PDT-CF-3ICAHIGH	9.71E-06	CCF 3/4 PDT'S ISOLATION CONDENSER A SPURIOUS ACTUATION
B32-PDT-CF-3ICBHIGH	9.71E-06	CCF 3/4 PDT'S ISOLATION CONDENSER B SPURIOUS ACTUATION
B32-PDT-CF-3ICCHIGH	9.71E-06	CCF 3/4 PDT'S ISOLATION CONDENSER C SPURIOUS ACTUATION
B32-PDT-CF-3ICDHIGH	9.71E-06	CCF 3/4 PDT'S ISOLATION CONDENSER D SPURIOUS ACTUATION
C74-DTM-CF-ALL	1.20E-05	CCF 3/4 DTM OF SSLC DIV1/2/3/4
C74-VLU-CF-ALL	3.12E-06	CCF OF VOTER LOGIC UNITS
D11-ACT-CF-3ICAHIGH	1.50E-07	CCF 3/4 RADIATION MONITORS IC-A SPURIOUS ACTUATION
D11-ACT-CF-3ICBHIGH	1.50E-07	CCF 3/4 RADIATION MONITORS IC-B SPURIOUS ACTUATION
D11-ACT-CF-3ICCHIGH	1.50E-07	CCF 3/4 RADIATION MONITORS IC-C SPURIOUS ACTUATION
D11-ACT-CF-31CDHIGH	1.50E-07	CCF ¾ RADIATION MONITORS ICD-D SPURIOUS ACTUATION
H23-EMS-CF-ALL	1.80E-06	CCF OF ESSENTIAL MULTIPLEXING SYSTEM DIV 1/2/3/4
H23-EMS-CF-ALL	9.00E-07	CCF OLF REMOTE MULTIPLEXING UNITS TO OPERATE

Table 4.2-6

List of System Human Errors

Basic Event	Prob	Description
B32-XHE-FO-F72HA	1.61E-03	OPERATOR FAILS TO OPEN VALVE F72HA
B32-XHE-FO-F72HB	1.61E-03	OPERATOR FAILS TO OPEN VALVE F72HB
B32-XHE-FO-F72HC	1.61E-03	OPERATOR FAILS TO OPEN VALVE F72HC
B32-XHE-FO-F72HD	1.61E-03	OPERATOR FAILS TO OPEN VALVE F72HD
XXX-XHE-FO-ICPCCS	1.61E-03	OPERATOR FAILS TO RECOGNIZE NEED OF MAKE UP TO IC/PCCS POOLS

Table 4.2-7 List of System Basic Events		
Basic Event	**Prob**	**Description**
B21-ACV-OO-F001A	2.00E-03	NOV F001A FAILS TO OPERATE TO DEENER. POSITION.
B21-ACV-OO-F001B	2.00E-03	NOV F001B FAILS TO OPEARTE TO DEENER. POSITION.
B21-ACV-OO-F001C	2.00E-03	NOV F001C FAILS TO OPERATE TO DEENER. POSITION.
B21-ACV-OO-F001D	2.00E-03	NOV F001D FAILS TO OPERATE TO DEENER. POSITION.
B21-ACV-OO-F002A	2.00E-03	AOV F002A FAILS TO OPERATE TO DEENER. POSTION.
B21-ACV-OO-F002B	2.00E-03	AOV F002B FAILS TO OPERATE. TO DENER. POSTION.
B21-ACV-OO-F002C	2.00E-03	AOV F002C FAILS TO OPERATE TO DEENER. POSTION.
B21-ACV-OO-F002D	2.00E-03	AOV F002D FAILS TO OPERATE TO DEENER. POSTION.
B21-LT_-CF-N001ABCD	1.20E-07	CCF OF DIVERSIFIED LEVEL 1& 2 TRANSM. 1A/B/C/D
B21-LT_-CF-N010ABCD	1.20E-07	CCF OF DIVERSIFIED LEVEL 1 & 2 TRANSM. 10A/B/C/D
B21-LT_-NO-N001A	2.40E-05	WIDE RANGE LEVEL TRANSMITTER 1A (LEVEL 1&2) FAILS
B21-LT_-NO-N001B	2.40E-05	WIDE RANGE LEVEL TRANSMITTER 1B (LEVEL 1&2) FAILS
B21-LT_-NO-N001C	2.40E-05	WIDE RANGE LEVEL TRANSMITTER 1C (LEVEL 1&2) FAILS
B21-LT_-NO-N001D	2.40E-05	WIDE RANGE LEVEL TRANSMITTER 1D (LEVEL 1&2) FAILS
B21-OR_-PG-01A	1.44E-05	ORIFICE INSTR. LINE 1A FAILS TO REMAIN OPEN (PLUG)
B21-OR_-PG-01B	1.44E-05	ORIFICE INSTR. LINE 1B FAILS TO REMAIN OPEN (PLUG)
B21-OR_-PG-01C	1.44E-05	ORIFICE INSTR. LINE 1C FAILS TO REMAIN OPEN (PLUG)
B21-OR_-PG-01D	1.44E-05	ORIFICE INSTR. LINE 1D FAILS TO REMAIN OPEN (PLUG)
B21-PT_-CF-02ALLNO	3.00E-08	CCF OF RPV PRESSURE TRANSMITTERS
B21-PT_-NO-0002A	1.15E-05	PRESSURE TRANSMITTER 0002A FAILS TO RESPOND TO CHANGE IN PRESSURE
B21-PT_-NO-0002B	1.15E-05	PRESSURE TRANSMITTER 0002B FAILS TO RESPOND TO CHANGE IN PRESSURE
B21-PT_-NO-0002C	1.15E-05	PRESSURE TRANSMITTER 0002C FAILS TO RESPOND TO CHANGE IN PRESSURE

Table 4.2-7
List of System Basic Events

Basic Event	Prob	Description
B21-PT_-NO-0002D	1.15E-05	PRESSURE TRANSMITTER 0002D FAILS TO RESPOND TO CHANGE IN PRESSURE
B32-ACV-CC-F006A	2.00E-03	AIR OPERATED VALVE F006A FAILS TO OP. TO DEENERG. POSIT.
B32-ACV-CC-F006B	2.00E-03	AIR OPERATED VALVE F006B FAILS TO OP. TO DEENERG. POSIT.
B32-ACV-CC-F006C	2.00E-03	AIR OPERATED VALVE F006A FAILS TO OP. TO DEENERG. POSIT.
B32-ACV-CC-F006D	2.00E-03	AIR OPERATED VALVE F006D FAILS TO OP. TO DEENERG. POSIT.
B32-ACV-CF-2ICABCD	1.55E-05	CCF TO OPEN 2/4 ACV VALVES TRAINS A, B, C, D
B32-LT_-CF-LT72HA	7.20E-08	CCF 3 OUT OF FOUR A LEVEL TRANSMITTERS
B32-LT_-NO-F72HADIV1	2.40E-05	LEVEL TRANSMITTER DIV 1 POOL A FAILS
B32-LT_-NO-F72HADIV2	2.40E-05	LEVEL TRANSMITTER DIV 2 POOL A FAILS
B32-LT_-NO-F72HADIV3	2.40E-05	LEVEL TRANSMITTER DIV 3 POOL A FAILS
B32-LT_-NO-F72HADIV4	2.40E-05	LEVEL TRANSMITTER DIV 4 POOL A FAILS
B32-LT_-NO-F72HBDIV1	2.40E-05	LEVEL TRANSMITTER DIV 1 POOL B FAILS
B32-LT_-NO-F72HBDIV2	2.40E-05	LEVEL TRANSMITTER DIV 2 POOL B FAILS
B32-LT_-NO-F72HBDIV3	2.40E-05	LEVEL TRANSMITTER DIV 3 POOL B FAILS
B32-LT_-NO-F72HBDIV4	2.40E-05	LEVEL TRANSMITTER DIV 4 POOL B FAILS
B32-LT_-NO-LT72HB	2.40E-05	CCF 3 OUT OF FOUR B LEVEL TRANSMITTERS
B32-MOV-CC-F005A	4.00E-03	MOTOR OPER. VALVE F005A FAILS TO OPEN
B32-MOV-CC-F005B	4.00E-03	MOTOR OPER. VALVE F005B FAILS TO OPEN
B32-MOV-CC-F005C	4.00E-03	MOTOR OPER. VALVE F005C FAILS TO OPEN
B32-MOV-CC-F005D	4.00E-03	MOTOR OPER. VALVE F005A FAILS TO OPEN
B32-MOV-CC-F72HA	4.00E-03	MOTOR OPERATED VALVE F72HA FAILS TO OPEN
B32-MOV-CC-F72HB	4.00E-03	VALVE F72HB FAILS TO OPEN
B32-MOV-CC-F72HC	4.00E-03	MOTOR OPERATED VALVE FAILS TO OPEN
B32-MOV-CC-F72HD	4.00E-03	MOTOR OPERATED VALVE FAILS TO OPEN
B32-MOV-CF-2ICABCD	8.08E-06	CCF TO OPEN 2/4 MOV VALVES TRAINS A, B, C, D
B32-MOV-CF-F005A/B	1.44E-05	CCF TO OPERATE BETWEEN F005 A & B
B32-MOV-CF-F005A/C	1.44E-05	CCF TO OPERATE BETWEEN F005 A & C
B32-MOV-CF-F005A/D	1.44E-05	CCF TO OPERATE BETWEEN F005 A & D
B32-MOV-CF-F005B/C	1.44E-05	CCF TO OPERATE BETWEEN F005 B & C
B32-MOV-CF-F005B/D	1.44E-05	CCF TO OPERATE BETWEEN F005 B & D
B32-MOV-CF-F005C/D	1.44E-05	CCF TO OPERATE BETWEEN F005 C & D
B32-MOV-CF-F72HADOPEN	2.00E-04	CCF VALVES F72HA AND D TO OPEN
B32-MOV-CF-F72HBCOPEN	2.00E-04	CCF VALVES F72HB AND C TO OPEN

Table 4.2-7
List of System Basic Events

Basic Event	Prob	Description
B32-MOV-OC-F001A	3.36E-06	MOTOR OPER. VALVE F001A FAILS TO REMAIN OPEN
B32-MOV-OC-F001B	3.36E-06	MOTOR OPER. VALVE F001B FAILS TO REMAIN OPEN
B32-MOV-OC-F001C	3.36E-06	MOTOR OPER. VALVE F001C FAILS TO REMAIN OPEN
B32-MOV-OC-F001D	3.36E-06	MOTOR OPER. VALVE F001D FAILS TO REMAIN OPEN
B32-MOV-OC-F002A	3.36E-06	MOTOR OPER. VALVE F002A FAILS TO REMAIN OPEN
B32-MOV-OC-F002B	3.36E-06	MOTOR OPER. VALVE F002B FAILS TO REMAIN OPEN
B32-MOV-OC-F002C	3.36E-06	MOTOR OPER. VALVE F002C FAILS TO REMAIN OPEN
B32-MOV-OC-F002D	3.36E-06	MOTOR OPER. VALVE F002D FAILS TO REMAIN OPEN
B32-MOV-OC-F003A	3.36E-06	MOTOR OPER. VALVE F003A FAILS TO REMAIN OPEN
B32-MOV-OC-F003B	3.36E-06	MOTOR OPER. VALVE F003B FAILS TO REMAIN OPEN
B32-MOV-OC-F003C	3.36E-06	MOTOR OPER. VALVE F003C FAILS TO REMAIN OPEN
B32-MOV-OC-F003D	3.36E-06	MOTOR OPER. VALVE F003D FAILS TO REMAIN OPEN
B32-MOV-OC-F004A	3.36E-06	MOTOR OPER. VALVE F004A FAILS TO REMAIN OPEN
B32-MOV-OC-F004B	3.36E-06	MOTOR OPER. VALVE F004B FAILS TO REMAIN OPEN
B32-MOV-OC-F004C	3.36E-06	MOTOR OPER. VALVE F004C FAILS TO REMAIN OPEN
B32-MOV-OC-F004D	3.36E-06	MOTOR OPER. VALVE F004D FAILS TO REMAIN OPEN
B32-OR_-PG-F72HADIV1	1.44E-05	ORIFICE INSTR. LINE DIV 1 FAILS TO REMAIN OPEN (PLUG)
B32-OR_-PG-F72HADIV2	1.44E-05	ORIFICE INSTR. LINE DIV 2 FAILS TO REMAIN OPEN (PLUG)
B32-OR_-PG-F72HADIV3	1.44E-05	ORIFICE INSTR. LINE DIV 3 FAILS TO REMAIN OPEN (PLUG)
B32-OR_-PG-F72HADIV4	1.44E-05	ORIFICE INSTR. LINE DIV 4 FAILS TO REMAIN OPEN (PLUG)
B32-OR_-PG-F72HBDIV1	1.44E-05	ORIFICE INSTR. LINE DIV 1FAILS TO REMAIN OPEN (PLUG)
B32-OR_-PG-F72HBDIV2	1.44E-05	ORIFICE INSTR. LINE DIV 2 FAILS TO REMAIN OPEN (PLUG)

Table 4.2-7
List of System Basic Events

Basic Event	Prob	Description
B32-OR_-PG-F72HBDIV3	1.44E-05	ORIFICE INSTR. LINE DIV 3 FAILS TO REMAIN OPEN (PLUG)
B32-OR_-PG-F72HBDIV4	1.44E-05	ORIFICE INSTR. LINE DIV 4 FAILS TO REMAIN OPEN (PLUG)
B32-PDT-CF-3ICAHIGH	9.71E-06	CCF 3/4 PDT'S ISOLATION CONDENSER A SPURIOUS ACTUATION
B32-PDT-CF-3ICBHIGH	9.71E-06	CCF 3/4 PDT'S ISOLATION CONDENSER B SPURIOUS ACTUATION
B32-PDT-CF-3ICCHIGH	9.71E-06	CCF 3/4 PDT'S ISOLATION CONDENSER C SPURIOUS ACTUATION
B32-PDT-CF-3ICDHIGH	9.71E-06	CCF 3/4 PDT'S ISOLATION CONDENSER D SPURIOUS ACTUATION
B32-RMU-FC-F72HB1	3.00E-04	REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION
B32-RMU-FC-F72HB2	3.00E-04	REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION
B32-RMU-FC-F72HC1	3.00E-04	REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION
B32-RMU-FC-F72HC2	3.00E-04	REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION
B32-SYS-TM-ICA	4.16E-02	IC "A" UNAVAILABLE [# 7]
B32-XHE-FO-F72HA	1.61E-03	OPERATOR FAILS TO OPEN VALVE F72HA
B32-XHE-FO-F72HB	1.61E-03	OPERATOR FAILS TO OPEN VALVE F72HB
B32-XHE-FO-F72HC	1.61E-03	OPERATOR FAILS TO OPEN VALVE F72HC
B32-XHE-FO-F72HD	1.61E-03	OPERATOR FAILS TO OPEN VALVE F72HD
C74-DTM-CF-ALL	1.20E-05	CCF 3/4 DTM OF SSLC DIV1/2/3/4
C74-DTM-FC-DIV1	6.00E-04	DTM OF SSLC DIV 1 FAILS TO TRIP
C74-DTM-FC-DIV2	6.00E-04	DTM OF SSLC DIV. 2 FAILS TO TRIP
C74-DTM-FC-DIV3	6.00E-04	DTM OF SSLC DIV. 3 FAILS TO TRIP
C74-DTM-FC-DIV4	6.00E-04	DTM OF SSLC DIV. 4 FAILS TO TRIP
C74-VLU-CF-ALL	3.12E-06	CCF OF VOTER LOGIC UNITS
D11-ACT-CF-3ICAHIGH	1.50E-07	CCF 3/4 RADIATION MONITORS IC-A SPURIOUS ACTUATION
D11-ACT-CF-3ICBHIGH	1.50E-07	CCF 3/4 RADIATION MONITORS IC-B SPURIOUS ACTUATION
D11-ACT-CF-3ICCHIGH	1.50E-07	CCF 3/4 RADIATION MONITORS IC-C SPURIOUS ACTUATION
D11-ACT-CF-3ICDHIGH	1.50E-07	CCF 3/4 RADIATION MONITORS IC-D SPURIOUS ACTUATION
H23-EMS-CF-ALL	1.80E-06	CCF OF ESSENTIAL MULTIPLEXING SYSTEM DIV 1/2/3/4
H23-EMS-FC-DIV1	6.00E-04	ESSENTIAL MULTIPLEXING SYSTEM DIV 1 FAILS TO FUNCTION

Table 4.2-7
List of System Basic Events

Basic Event	Prob	Description
H23-EMS-FC-DIV2	6.00E-04	ESSENTIAL MULTIPLEXING SYSTEM DIV 2 FAILS TO FUNCTION
H23-EMS-FC-DIV3	6.00E-04	ESSENTIAL MULTIPLEXING SYSTEM DIV 3 FAILS TO FUNCTION
H23-EMS-FC-DIV4	6.00E-04	ESSENTIAL MULTIPLEXING SYSTEM DIV 4 FAILS TO FUNCTION
H23-RMU-CF-ALL	9.00E-07	CCF OF REMOTE MULTIPLEXING UNITS TO OPERATE
H23-RMU-FC-0002A	3.00E-04	REMOTE MULTIPLEXING UNIT 0002A FAILS TO FUNCTION
H23-RMU-FC-0002B	3.00E-04	REMOTE MULTIPLEXING UNIT 0002B FAILS TO FUNCTION
H23-RMU-FC-0002C	3.00E-04	REMOTE MULTIPLEXING UNIT 0002C FAILS TO FUNCTION
H23-RMU-FC-0002D	3.00E-04	REMOTE MULTIPLEXING UNIT 0002D FAILS TO FUNCTION
H23-RMU-FC-F72HA1	3.00E-04	REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION
H23-RMU-FC-F72HA2	3.00E-04	REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION
H23-RMU-FC-F72HADIV1	3.00E-04	REMOTE MULTIPLEXING UNIT DIV1 FAILS TO FUNCTION
H23-RMU-FC-F72HADIV2	3.00E-04	REMOTE MULTIPLEXING UNIT DIV 2 FAILS TO FUNCTION
H23-RMU-FC-F72HADIV3	3.00E-04	REMOTE MULTIPLEXING UNIT DIV 3 FAILS TO FUNCTION
H23-RMU-FC-F72HADIV4	3.00E-04	REMOTE MULTIPLEXING UNIT DIV 4 FAILS TO FUNCTION
H23-RMU-FC-F72HBDIV1	3.00E-04	REMOTE MULTIPLEXING UNIT DIV 1 FAILURE
H23-RMU-FC-F72HBDIV2	3.00E-04	REMOTE MULTIPLEXING UNIT DIV 2 FAILURE
H23-RMU-FC-F72HBDIV3	3.00E-04	REMOTE MULTIPLEXING UNIT DIV 3 FAILURE
H23-RMU-FC-F72HBDIV4	3.00E-04	REMOTE MULTIPLEXING UNIT DIV 4 FAILURE
H23-RMU-FC-F72HD1	3.00E-04	REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION
H23-RMU-FC-F72HD2	3.00E-04	REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION
XXX-POL-RP-IC/PCC	3.00E-07	LOSS OF IC/PCC POOL WATER DUE TO BREAK DURING ACCIDENT
XXX-XHE-FO-ICPCCS	1.61E-03	OPERATOR FAILS TO RECOGNIZE NEED OF MAKE UP TO IC/PCCS POOLS

Table 4.2-8

List of System Top Events

Top Event	Description
GC32TOP2	2 OUT OF 4 IC's FAIL TO RETURN WATER TO RPV IN TRANSIENTS

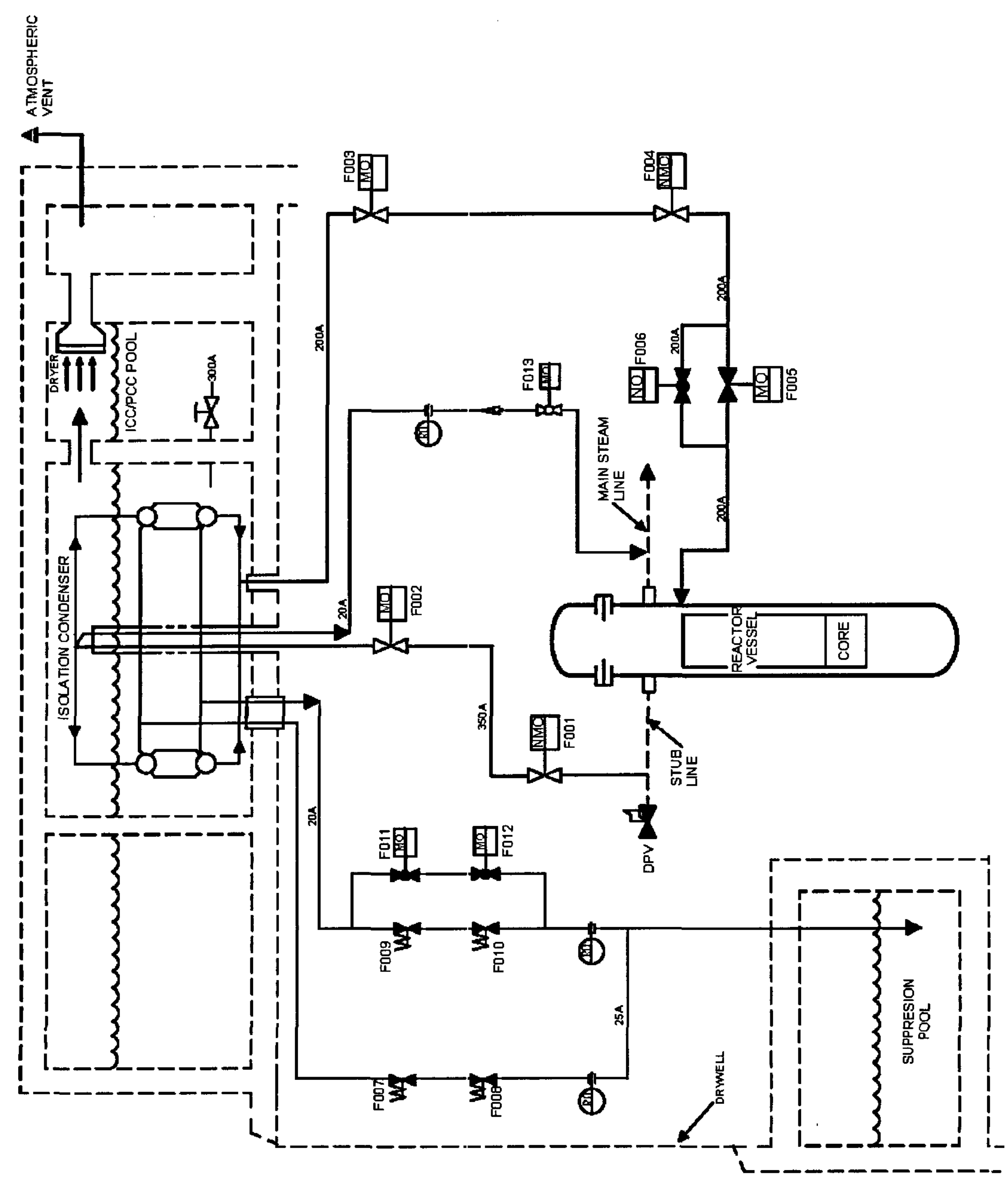


Figure 4.2-1. Simplified Process Flow Diagram for Isolation Condenser System

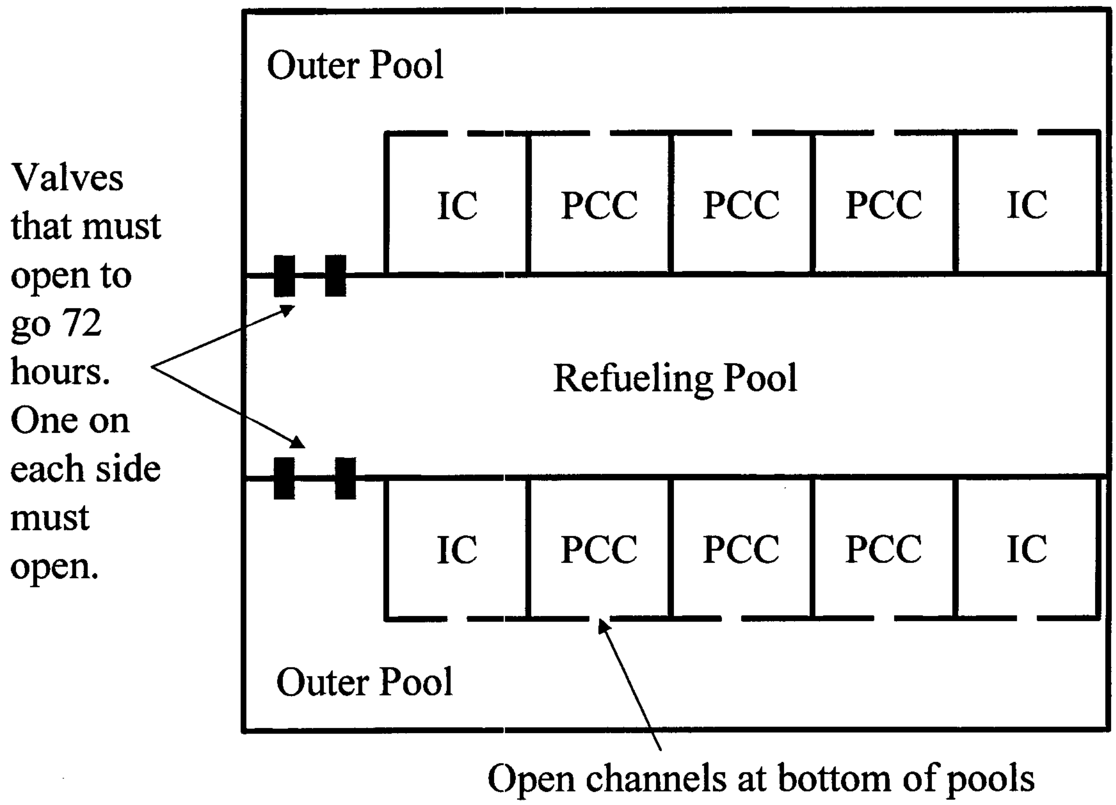


Figure 4.2-2. Schematic of the IC/PCC Pools and Interconnections

4.3 CONTROL ROD DRIVE SYSTEM - (C12)

4.3.1 Purpose

The purpose of this section is focused on the CRDS function to provide high-pressure water injection to the Reactor Pressure Vessel (RPV) in the event of loss of feedwater or other events resulting in low RPV water level. This injection function is initiated automatically by a RPV water level 2 signal.

4.3.2 Design Assumptions

The following assumptions with respect to the design are made:

(1) Failure of either the A or B flow control loops resulting in a full-open condition of valves F020A or B, results in a trip of both CRD pumps.

(2) Strainers D001A and B do not have sufficient flow capacity for CRDS in the water injection mode, and the opening of bypass valves F014A or B is required. Opening either F014A or B valves is sufficient to supply the total flow required by pumps C001A and B.

(3) CRD trains are rotated on a monthly basis.

(4) Human actuation time values are assumed consistent with ESBWR calculations.

4.3.3 System Description

The CRD System is composed of three major elements: (1) the electro-hydraulic fine motion control rod drive (FMCRD) mechanisms, (2) the hydraulic control units (HCU), and (3) the control rod drive hydraulic system (CRDHS). Figure 4.3-1 provides a general outline of the CRD System.

The CRDHS portion of CRDS supplies clean, demineralized water that is regulated and distributed to provide charging of the HCU scram accumulators and purge water flow to the FMCRDs during normal operation. The CRDHS is also the source of pressurized water for purging the Reactor Water Cleanup / Shutdown Cooling (RWCU/SDC) System pumps and Nuclear Boiler System (NBS) reactor water level reference leg instrument lines. Additionally, the CRDHS provides high pressure makeup water to the reactor during events in which the feedwater system is unable to maintain normal reactor water level. This makeup water is supplied to the reactor via a bypass line off the CRD pump discharge header that connects to the feedwater inlet piping via the RWCU/SDC return piping.

In normal plant operation, the CRDS pumps supply high-pressure water to charge the HCU accumulators, to the Fine Motion Control Rod Drive (FMCRD), to RWCU/SDC pumps, and to the reactor water level reference leg instrument lines. Upon receipt of a reactor water level 2 signal, the mode of operation changes to the RPV injection mode.

4.3.3.1 Hardware Configuration

A simplified diagram of the CRDS water injection system is shown on Figure 4.3-1. The condensate storage tank supplies the suction header of the CRDS water injection system. During normal plant operation, the CRDS water injection mode is in standby, and the CRDS is operating

in the purging HCU-charging mode using water filtered through one of the pump-suction filters, D001A and B. Upon receipt of a reactor water level 2 signal, valves F014A and B, in the redundant suction CRDS header, open to provide condensate water directly to the suction of pumps C001A and B. Under normal operating conditions, condensate water is supplied to the pump suctions through a pipe that is connected downstream of the condensate polisher. In an alternative mode, CRDS can draw condensate water directly from the condensate storage tank through a normally open manual valve (F01T) and a check valve (CV01T). The CRD system is arranged so that water is supplied from the source of higher pressure, without the need for any active change in valve positions. During losses of offsite power (when condensate pumps are unavailable), the water source is provided from the CST.

High-pressure water is discharged from each of the two pumps into a discharge header. The discharge header supplies water to the HCU accumulators, the FMCRDs, and the Reactor Water Cleanup System/Shutdown Cooling (RWCU/SDC) pumps for purge water. Other pipe runs, from each pump, supply water to the RPV through the normally closed valves, F020A and B, and to the RWCU/Shutdown Cooling (SDC) discharge piping and valves. A test line is supplied to provide means of testing the components of this run during plant operation.

In the water injection mode, the CRDS pump discharge is controlled by each of two flow control valves (F020A and B). The flow control valves are controlled by flow control loops made up of flow sensors N019A and B that provide the control input signals to the valves.

The two CRDS pumps are motor-driven, multi-stage, high-pressure, centrifugal pumps. The pump motors are driven by 6.9 kV AC power and the Reactor Component Cooling System (RCCS) water cools the pumps. All motor-operated system valves are powered by 480 V AC power.

4.3.3.2 System Operation

During normal plant operation, the CRDS is aligned with one of the two pump continuously operating to pressurize the system with water from the condensate and feedwater system and/or condensate storage tank (CST), and the associated control valves F010A or B, regulating the purge water flow to FMCRDs. During this condition, the other CRD pump is shutdown and in standby and the associated control valve is closed. Upon receipt of a reactor water level 2 signal, the CRDS shifts to the water injection mode of operation. The standby pump starts, the purge water header valve F012 and the charging water header valve F030 closes, and valves F014 A and B and F020A and B open to provide suction from condensate and a discharge path to the RPV.

The systems available for each of the required functions (identified in Section 3.2) and their success criteria are summarized in that Table 3.2-1 and discussed in detail in Section 3 of this ESBWR PRA report.

An additional requirement in the analysis is that no room cooling for the CRDS compartment is required for the first 24 hours of the accident.

4.3.3.3 System Location

All CRDS equipment, with the exception of piping from the condensate system and to the RWCU/SDC system, is located in the CRDS hydraulic compartment adjacent to the HCUs in the reactor building.

4.3.4 Automatic and Manual Control

Automatic Actuation. The CRDS is automatically aligned and initiated for water injection upon receipt of a reactor water level 2 signal. The following actions occur:

(1) Suction valves F014 A and B open,

(2) Injection-control valves F020A and B open,

(3) The standby pump starts, and

(4) The charging water header isolation valve F030 and purge water header isolation valve F012 close.

The water level 2 initiating signal is supplied by the CRDS logic. Four level transmitters on four different divisions generate the water level 2 signal. The logic for the signal transmission is two-out-of-four.

A high reactor water level 8 signal closes the flow control valves F020A and B to stop the flow to the reactor in order to prevent flooding of the main steam lines.

For accident sequences with loss of offsite power:

- The running CRD pump stops
- Circuit breakers must reclose to allow restart of the pumps
- All needed power is supplied by the on-site diesel generators

Initiation of the CRDS automatically generates the automatic opening and closing of valves F023 and F024, respectively.

Manual Actuation. As a backup to automatic initiation, the operator has the capability to manually initiate the water injection function in the event of failure of automatic initiation. For transients and small Loss-of-Coolant Accident (LOCA) events, the operator would have at least 20 minutes available for initiation of CRDS water injection to avoid automatic depressurization at L-1. Following depressurization at L-1, there would be an additional 45 minutes available before the Peak Cladding Temperature (PCT) limit would be reached. For medium and large LOCA events, the operator would have at least 45 minutes available to initiate CRDS water injection.

Instrumentation and Alarms. The instrumentation and alarm signals provided in the main control room for the CRDS water injection function are listed in Table 4.3-1.

4.3.5 System Interfaces

Support Systems. The water injection function of the CRDS interfaces with several support systems, including AC power and the Reactor Component Cooling Water System (RCCW). The CRD pump motors are driven by 6.9 kV AC power, and the system valves are operated by 480 V

AC power. The CRD pump room coolers are cooled by RCCW water. These specific dependency relationships are shown in Table 4.3-2.

Shared Components. The water injection function of the CRDS uses the same pumps (C001A and B) and water source (condensate) as the purging HCU-charging function. The automatic initiation signal uses the same reactor water level 2 signal and some of the same instrumentation and logic components as are used by other systems.

The CRDS injects high-pressure water into the RWCUS/SDCS discharge line, and shares with it and feedwater line B several check valves and isolation valves.

Spurious signal from GDCS pump stop logic trips CRDS pumps is modeled in the fault, this interface is described as follows. When in the high pressure makeup mode of operation, the CRD pumps are automatically tripped to terminate CRD System flow on receipt of low water level signals from two out of three GDCS pools. This logic is interlocked with a sealed-in low reactor water level 1 signal so that the pump trip can occur only during an accident condition, and not during normal operation.

4.3.6 System Testing

All standby system components for the CRDS water injection function are tested quarterly, including functional testing of the flow control loops. A test line to the CST from downstream of the two flow-control valves (F020A and B), together with an isolation valve on the vessel injection line provides a means of testing each of the flow control functions without injecting water into the RPV. A modulating valve in the test line allows variation of the line resistance to simulate different reactor pressures so that the flow control function can be tested over its full range of operation. If an initiation signal is received while the system is in test, the system automatically reverts to the water injection mode.

4.3.7 System Maintenance

All components of the CRDS water injection function can be maintained while the plant is in normal operation, subject to technical specification requirements and limitations. All normally open manual isolation valves are subject to being left in the closed position following maintenance. The system test isolation valve is not considered subject to misalignment following test since it is opened on receipt of an actuation signal.

4.3.8 Common Cause Failures

The following common cause component failures within the CRDS were considered in the present analysis:

Common cause failures within the CRD are summarized in Table 4.3-5 including the CCF of logic.

4.3.9 Fault Tree Analysis

Fault trees have been developed for the CRDS water injection functions for transient, LOCA, and loss of offsite-power initiating events using a success criterion of both CRDS pumps operating. Fault trees have also been constructed for a single pump (one-out-of-two) success,

with and without offsite power available. The success criteria is discussed in Section 3 of this PRA and summary table is provided in Table 3.3-1.

4.3.9.1 Top Event Definitions

Two top events are presented for the CRDS fault tree analysis:

(1) GC12TOP1 - System Fails to Provide Inventory Makeup (failure of both CRD supplies) (TRAN with leakages).

(2) GC12TOP2 - System Fails to Provide Inventory Makeup (failure of one CRD supplies) (LOCA & TRAN).

4.3.9.2 Fault Tree Description

The fault tree for GC12TOP1 is presented in Appendix B.4.3 and represents the probability that both loops of the CRD water injection function are unavailable if called upon in the event of a transient event with leakage. This function is used to support successful IC operation.

The fault tree for GC12TOP2 is presented in Appendix B.4.3 and represents the probability that either loop of the CRD water injection function is unavailable if called on in the event of LOCA or TRANSIENT requiring both CRD pumps to operate.

4.3.9.3 Human Interactions

Two types of human errors have been considered in developing the fault trees:

- Human errors in leaving normally open manual valves in closed position following maintenance.
- Human error in recovery following failure to receive an automatic initiation signal on a water level 2 condition. For this situation, the operator should manually initiate the CRDS water injection function.

These human errors are identified in Table 4.3-6.

4.3.10 Results of Fault Tree Analysis

The fault tree results provide quantitative values of system unavailability and of the importance of specific components to that total.

The definition of each basic event is reported in Table A.3-7.

The quantification of core damage sequences implicitly includes the contribution of basic event for this system. This qualification process enables checking the global consistency of the system fault trees and their relationship with the rest of the systems modeled in the PRA.

On the other hand, the importance measurements obtained from core damage frequency equations, allow identification of the most relevant basic events and system component failures in an integrated context, as well as the determination of their relative importance with respect to the basic events and component failures of the other systems modeled.

4.3.11 References

4.3-1. ESBWR Design Control Document, 26A6642 Rev. 01

Table 4.3-1

Control Room Instrumentation and Alarms

Controls
Displays
(1) CRD pump operating status (run/stop)
(2) CRD pump auxiliary lube oil pump status (run/stop)
(3) Scram valve position
(4) Flow control valve position
(5) Pump suction pressure
(6) Pump discharge pressure
(7) System flow rate
(8) Charging water header pressure
(9) Reactor/purge water header differential pressure
Alarms
(1) Low pump lube oil pressure
(2) High pump lube oil temperature
(3) Low pump suction pressure
(4) High pump suction filter differential pressure
(5) High drive water filter differential pressure
(6) High scram air header pressure
(7) Low scram air header pressure
(8) HCU trouble alarm (low HCU accumulator pressure or high accumulator water level)
(9) Low charging header pressure
(10) FMCRD control rod separation

Table 4.3-2

System Dependencies Matrix

		Support System				
		Power Supply				RCCWS
		R12 480 V AC		R11 6.9 KV AC		
Component	**Type**	**DIV A**	**DIV B**	**DIV A**	**DIV A**	
F014A	MO	X				
F014B	MO		X			
F020A	MO	X				
F020B	MO		X			
F023A	MO	X				
F023B	MO		X			
F024A	MO	X				
F024B	MO		X			
C001A	Pump			X		
C001B	Pump				X	
C001A	Oil Pump			X		X
C001B	Oil Pump				X	X

Table 4.3-3

Component Test

All components are tested quarterly.

Table 4.3-4

Component Maintenance

All components of the CRDS water injection function can be maintained while the plant is in normal operation, subject to technical specification requirements and limitations.

Table 4.3-5

System Common Cause Failures

Basic Event	Prob	Description
B21-LT_-CF-DPSWR	1.20E-07	CCF OF DPS WR LEVEL TRANSMITTERS
B21-LT_-CF-L8NO	1.20E-07	CCF LEVEL TRANSMITTERS L8 (FAILURE TO RESPOND TO CHANGE)
B21-LT_-CF-L9SPU1	1.20E-07	SPURIOUS L9 SIGNAL CCF
C12-MCB-CF-CLOSE	9.29E-05	CIRCUIT BREAKER CCF TO CLOSE
C12-MOV-CF-OPEN	1.78E-04	CCF MOV TO OPEN
C12-MPC-CR-C001AB	3.57E-06	CCF OF CRD PUMPS TO RUN
C12-MPC-CS-C001A/B	2.05E-04	CCF PUMPS TO START
C12-PT_-CF-N001A/BLOW	3.00E-08	CCF PRESSURE TRANSMITTERS IN SUCTION LINES FAIL LOW
C74-DTM-CF-DIDALL	5.50E-05	COMMON CAUSE FAILURE 3/4 DTM DID LOGIC
E50-LT_-CF-N005ABCLOW	2.40E-07	CCF 2/3 LEVEL TRANSMITTERS E50-N005A/B/C LOW
H23-EMS-CF-DIDALL	1.80E-06	CCF OF ALL DIVISION OF THE EMS
H23-RMU-CF-DIDALL	9.00E-07	CCF OF REMOTE MULTIPLEXING UNITS (DID)

Table 4.3-6
System Human Errors

Basic Event	Prob	Description
C12-XHE-FO-LEVEL2	3.22E-02	MANUAL ACTUATION FAILURE
C12-XHE-MH-F003B	1.20E-02	MISPOSITION OF VALVE F003B
C12-XHE-MH-F013A	4.80E-02	MISPOSITION OF VALVE F013A
C12-XHE-MH-F013B	4.80E-02	MISPOSITION OF VALVE F013B
C12-XHE-MH-F015A	4.80E-02	MISPOSITION OF VALVE F015A
C12-XHE-MH-F015B	4.80E-02	MISPOSITION OF VALVE F015B
C12-XHE-MH-F018A	1.20E-02	MISPOSITION OF VALVE F018A
C12-XHE-MH-F018B	1.20E-02	MISPOSITION OF VALVE F018B
C12-XHE-MH-F021A	1.20E-02	MISPOSITION OF VALVE F021A
C12-XHE-MH-F021B	1.20E-02	MISPOSITION OF VALVE F021B
P30-XHE-MH-F015	4.80E-02	MISPOSITION OF VALVE F01T

Table 4.3-7

System Basic Events

Basic Event	Prob	Description
B21-LT_-CF-DPSWR	1.20E-07	CCF OF DPS WR LEVEL TRANSMITTERS
B21-LT_-CF-L8NO	1.20E-07	CCF LEVEL TRANSMITTERS L8 (FAILURE TO RESPOND TO CHANGE)
B21-LT_-CF-L9SPU1	1.20E-07	SPURIOUS L9 SIGNAL CCF
B21-UV_-CC-F102A	1.60E-03	CHECK VALVE F102A IN FEEDWATER LINE A FAILS TO OPEN
B21-UV_-CC-F103A	1.60E-03	CHECK VALVE F103A IN FEEDWATER LINE A FAILS TO OPEN
C12-MCB-CF-CLOSE	9.29E-05	CIRCUIT BREAKER CCF TO CLOSE
C12-MCB-CO-C001A	1.20E-05	CIRCUIT BREAKER FOR C001A & OIL PUMP A OPENS SPURIOUSLY
C12-MCB-OO-C001A	1.00E-03	CIRCUIT BREAKER FOR C001A & OIL PUMP A FAILS TO CLOSE
C12-MCB-OO-C001B	1.00E-03	CIRCUIT BREAKER FOR C001B & AUX OIL PMP B FAILS TO CLOSE
C12-MOV-CC-F014A	4.00E-03	MOTOR OPER. VALVE F014A FAILS TO OPEN
C12-MOV-CC-F014B	4.00E-03	MOTOR OPER. VALVE F014B FAILS TO OPEN
C12-MOV-CC-F020A	4.00E-03	MOTOR OPER. VALVE F020A FAILS TO OPEN
C12-MOV-CC-F020B	4.00E-03	MOTOR OPER. VALVE F020B FAILS TO OPEN
C12-MOV-CF-OPEN	1.78E-04	CCF MOV TO OPEN
C12-MOV-FC-F020A	3.13E-03	FLOW CONTROL A FAILS WIDE OPEN
C12-MOV-FC-F020B	3.13E-03	FLOW CONTROL B FAILS WIDE OPEN
C12-MPC-CR-C001AB	3.57E-06	CCF OF CRD PUMPS TO RUN
C12-MPC-CS-C001A/B	2.05E-04	CCF PUMPS TO START
C12-MPC-FR-C001A	5.76E-05	MOTOR-DRIVEN PUMP C001A FAILS TO RUN, GIVEN START
C12-MPC-FR-C001B	5.76E-05	MOTOR-DRIVEN PUMP C001B FAILS TO RUN, GIVEN START
C12-MPC-FS-C001A	2.40E-03	MOTOR-DRIVEN PUMP C001A FAILS TO START
C12-MPC-FS-C001B	2.40E-03	MOTOR-DRIVEN PUMP C001B FAILS TO START
C12-MP_-CS-C001A/BOIL	2.05E-04	CCF AUX. OIL PUMPS TO START
C12-MP_-FS-C001AOIL	2.40E-03	MOTOR-DRIVEN AUX. OIL PUMP FOR C001A FAILS TO RESTART
C12-MP_-FS-C001BOIL	2.40E-03	MOTOR-DRIVEN AUX. OIL PUMP FOR C001B FAILS TO START
C12-OR_-PG-D007A	6.48E-04	ORIFICE D007A FAILS TO REMAIN OPEN (PLUG)
C12-OR_-PG-D007B	6.48E-04	ORIFICE D007B FAILS TO REMAIN OPEN (PLUG)
C12-PT_-CF-N001A/BLOW	3.00E-08	CCF PRESSURE TRANSMITTERS IN SUCTION LINES FAIL

Table 4.3-7

System Basic Events

Basic Event	Prob	Description
		LOW
C12-PT_-LO-N004A	7.92E-06	PRESSURE TRANSMITTER IN SUCTION LINE TRAIN A FAILS LOW
C12-PT_-LO-N004B	7.92E-06	PRESSURE TRANSMITTER IN SUCTION LINE TRAIN B FAILS LOW
C12-SYS-TM-TRAINB	3.00E-03	TRAIN B IN MAINTENANCE
C12-UV_-CC-F022	1.60E-03	CHECK VALVE F022 FAILS TO OPEN
C12-XHE-FO-LEVEL2	3.22E-02	MANUAL ACTUATION FAILURE
C12-XHE-MH-F003B	1.20E-02	MISPOSITION OF VALVE F003B
C12-XHE-MH-F013A	4.80E-02	MISPOSITION OF VALVE F013A
C12-XHE-MH-F013B	4.80E-02	MISPOSITION OF VALVE F013B
C12-XHE-MH-F015A	4.80E-02	MISPOSITION OF VALVE F015A
C12-XHE-MH-F015B	4.80E-02	MISPOSITION OF VALVE F015B
C12-XHE-MH-F018A	1.20E-02	MISPOSITION OF VALVE F018A
C12-XHE-MH-F018B	1.20E-02	MISPOSITION OF VALVE F018B
C12-XHE-MH-F021A	1.20E-02	MISPOSITION OF VALVE F021A
C12-XHE-MH-F021B	1.20E-02	MISPOSITION OF VALVE F021B
C74-DTM-CF-DIDALL	5.50E-05	COMMON CAUSE FAILURE 3/4 DTM DID LOGIC
E50-LT_-CF-N005ABCLOW	2.40E-07	CCF 2/3 LEVEL TRANSMITTERS E50-N005A/B/C LOW
E50-LT_-LO-N005A	1.22E-05	LEVEL TRANSMITTER E50-N005 DRIFTS LOW
E50-LT_-LO-N005B	1.22E-05	LEVEL TRANSMITTER E50-N005B DRIFTS LOW
E50-LT_-LO-N005C	1.22E-05	LEVEL TRANSMITTER E50-N005C DRIFTS LOW
H23-EMS-CF-DIDALL	1.80E-06	CCF OF ALL DIVISION OF THE EMS
H23-RMU-CF-DIDALL	9.00E-07	CCF OF REMOTE MULTIPLEXING UNITS (DID)
H23-RMU-FC-C12001	3.00E-04	RMU 001 CRD SYSTEM C.R.MANUAL ACTUAT. FAILS TO OPERATE
H23-RMU-FC-C12002	3.00E-04	RMU 002 CRD SYSTEM C.R.MANUAL ACTUAT. FAILS TO OPERATE
H23-RMU-FC-C12003	3.00E-04	RMU 003 CRD SYSTEM C.R. MANUAL ACTUAT. FAILS TO OPERATE
P30-TNK-RP-A001	2.40E-06	CONDENSATE STORAGE TANK LEAKS CATASTROPHICALLY
P30-UV_-CC-CV01T	2.00E-04	CHECK VALVE CV01T FAILS TO OPEN
P30-XHE-MH-F015	4.80E-02	MISPOSITION OF VALVE F01T

Table 4.3-8

System Top Events

Top Event	Description
GC12TOP1	LOSS OF FLOW FROM BOTH CRD PUMPS
GC12TOP2	LOSS OF FLOW FROM EITHER CRD PUMPS

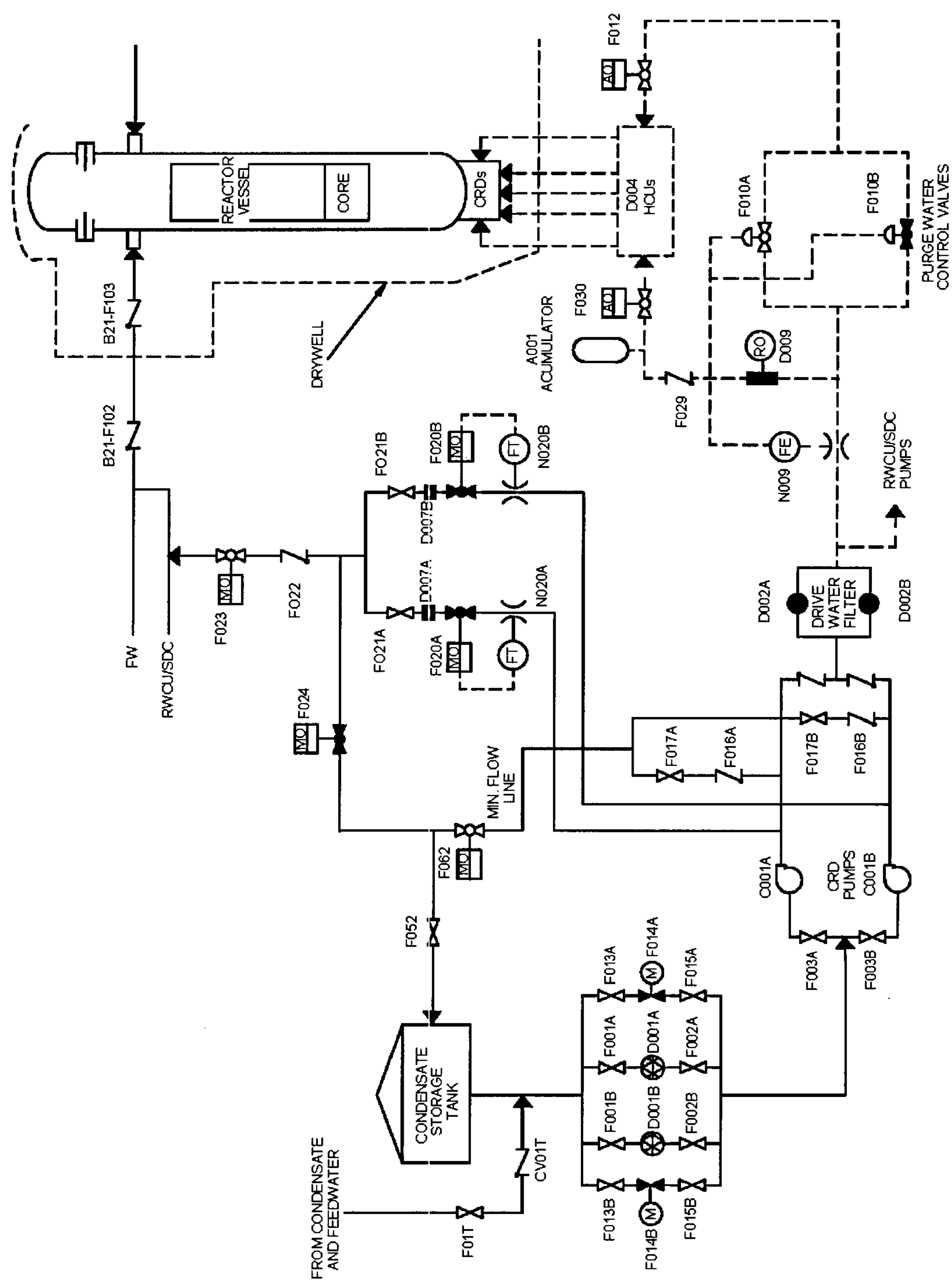


Figure 4.3-1. Simplified Process Flow Diagram for Control Rod Drive System

4.4 STANDBY LIQUID CONTROL SYSTEM - (C41)

4.4.1 Purpose

The purpose of the SLCS is to provide a backup function to the Control Rod Drives for reactivity control to assure automatic reactor shutdown from full power to subcritical given an anticipated transient without scram (ATWS).

Reactor shutdown is achieved by injection of a solution of neutron absorber sodium pentaborate inside the reactor pressure vessel (RPV), where it rapidly becomes mixed with the primary reactor coolant. No control rod movement is required. The SLCS is initiated automatically by either high reactor pressure or low reactor water level (Level 2) signals and the average power range monitor (APRM) not downscale. The operator from the control room may also initiate it manually.

4.4.2 Design Assumptions

The following design assumptions (DA) have been used for the model:

(1) Neither heat tracing in the discharge lines nor ventilation dependencies are necessary.

(2) The success criterion applied to the SLCS is that both loops are required to fulfill the safety function related to control of reactivity to prevent core damage. While the boron from a single tank is sufficient to bring the plant to hot shutdown, there are concerns about sufficient mixing in the core. Localized core damage is assumed to occur if only a single tank injects into the RPV. The localized damage releases fission products into the RPV, but does not challenge the overall coolability of the core.

(3) No maintenance is expected to occur during power operation that makes either train of the SLCS unavailable.

(4) Initially, each loop of the SLCS must be on Standby mode, with the explosive injection valves closed.

(5) For purposes of the system boundary with respect to the model, the system includes:

- Instrumentation and control system, except for the transmission of signals (acquisition, logic and actuation) of the squib valves
- Sodium Pentaborate Solution (SPBS) preparation and makeup system
- High-pressure nitrogen makeup system
- Accumulator tank vent line valves
- SPBS injection system, consisting of accumulator and valves corresponding to the injection lines

4.4.3 System Description

The SLCS consists of two loops, each one consisting of a high-pressure accumulator tank containing an enriched sodium pentaborate solution; a main discharge line containing a pair of parallel squib-actuated injection valves; an in-RPV supply header that connects to several

sparger tubes, each located inside the core bypass region; a system connections to a high-pressure, nitrogen gas supply, and associated valves, piping, local instrumentation, and control.

4.4.3.1 Hardware Configuration

A simplified diagram of the SLCS is shown on Figure 4.4-1. The sodium pentaborate solution is stored in the accumulator tanks, A001A and A001B. The discharge is through an 80 mm (3 inch nominal) line containing a locked-open isolation valve, F001A and B. Downstream of the isolation valve, a normally open, motor-operated valve (F002A and B) closes on a low-level signal from the tank to prevent nitrogen injection into the RPV. Downstream of F002A and B, the injection line divides into two parallel lines, each of which contains a normally closed explosive (squib) valve (F003A and C for loop A and F003B and D for loop B). These valves receive an open signal given the ATWS logic is satisfied. The discharge of the squib valves is routed to the RPV through two check isolation valves (F004A and B and F005A and B) and a normally open manual valve (F006A and B) inside the drywell. The position of this valve is indicated in the control room.

Pressure in the accumulator tank is maintained between 15.2 and 15.5 MPa (2200 and 2250 psi) from high-pressure cryogenic nitrogen gasification supply system. Pressure makeup is supplied through a motor-operated globe valve (F029A and B), and check valve (F028A and B). Two normally closed valves (a motor-operated valve, F014, and a solenoid valve, F013) control nitrogen makeup based on accumulator tank pressure. These charging valves (F029A and B) are operated manually, but they automatically close if the system is initiated. Accumulator tank pressure is monitored in the control room and pressure makeup can be initiated manually.

A keylock switch is provided in the control room, which operates two series high pressure air operated diaphragm valves (F507A and B and F508A and B) to vent the accumulator tank. These depressurization valves are actuated manually and automatically to prevent nitrogen from getting into the RPV.

4.4.3.2 System Operation

During normal plant operation, the system is in standby with the sodium pentaborate solution in the accumulator tanks and the tanks pressure maintained automatically between 15.2 and 15.5 MPa-gauge and a level between 2.148 and 2.188 mm. All valves in the tank discharge line are open except the four squib valves and check valves.

In the event of an ATWS, the four squib valves are fired open given an initiation signal when ATWS logic is satisfied. The SLC system automatically initiated with one of the following conditions:

a. High reactor vessel dome pressure and APRM not downscale for 3 minutes, or

b. Low reactor vessel water level (Level 2) and APRM not downscale for 3 minutes, or

c. APRM not downscale for 3 minutes following manual initiation of ARI/FMCRD run.

Note that one SLC tank is sufficient to prevent global core damage. TRACG based calculations have confirmed 1 SLC is adequate to get the reactor to hot shutdown. The squib valves can also be fired from the control room by depressing two switches simultaneously.

Following firing of the squib valves, the sodium pentaborate solution is injected into the RPV. When each tank reaches a set low value, local instrumentation closes the respective motor-operated valves F002A and B to prevent the injection of nitrogen into the RPV. The same signal that closes valve F002A and B also opens the diverse accumulator depressurization valves, F507A and B and F508A and B after a delay.

For successful operation of the system to prevent core damage, the injection of both tanks through at least one of the two ignition squib valves is necessary.

4.4.3.3 System Location

The SLCS equipment is located in a corner room outside the drywell at elevation 22,500 of the Reactor Building.

4.4.4 Automatic and Manual Control

Automatic Actuation. The SLCS is automatically initiated for sodium pentaborate injection upon receipt of an ATWS signal. The ATWS signal is supplied by the SLCS two-out-of-four logic. The ATWS signal is generated by either a reactor water level 2 or a reactor high pressure signal together with an "APRM not downscale" permissive plus a timer. Four instruments on four different divisions generate the initiating signals, and are hard-wired to dedicated analog trip modules (ATM). The outputs from the logic are hard-wired to the squib-valve firing circuits.

When the SPBS level in the accumulator tanks have reached low level, redundant accumulator level measurement instrumentation using 2-out-of-4 logic closes the shutoff valve F002A (F002B). To provide a diverse means of preventing nitrogen injection into the RPV, the nitrogen depressurization valves F507A and B, and F508A and B, are also actuated by the low SPBS level signal after a delay.

These actions prevent further discharge of effluent and thus prevent nitrogen injection into the RPV where it could adversely affect the performance of the isolation condenser system.

For accident sequences with loss of preferred power, all needed power is supplied by 250 V DC battery supply.

Manual Actuation. As a backup to automatic actuation, the operator has the capability to manually initiate the boron injection from the main control room by simultaneously depressing two switches. If automatic feedwater runback occurs successfully, the operator has a very long time available to insert boron. In the event of failure of feedwater runback, the operator's time window is much shorter (approximately 10 minutes) and therefore not credited.

Instrumentation and Alarms. The instrumentation and alarm signals provided in the main control room for the SLCS function are listed in Table 4.4-1.

4.4.5 System Interfaces

Support Systems. The only support systems required by the SLCS and associated instrumentation are the 250 V DC power supply and the nitrogen supply system. The system dependency on DC power is listed in Table 4.4-2. System operation is not affected by nitrogen supply unavailability as long as the accumulator remains within the required operational pressure band.

4.4.6 System Testing

The SLC system is designed with passive and redundant features such that minimum in-service testing is required at times other than during normally scheduled plant refueling outages. Assurance that SLC system design conditions are maintained during plant operation is accomplished by critical parameter alarms and periodic surveillances. A small, trickle current circuit is used at each squib charge, and automatic testing is done (typically every 30 minutes) to verify circuit continuity for receiving firing signals.

The SLCS is tested during plant refueling shutdowns. The system fault tree analysis is based on a test interval of two years for all SLCS equipment except valve F010, which are tested every 90 days. Generally, initiating instrumentation is also tested every 90 days. Valves not critical to system initiation including F002A and B are periodically tested (quarterly).

4.4.7 System Maintenance

No specific maintenance activities are planned or foreseen on the SLCS during normal plant operation. If necessary, all components of the SLCS can be maintained while the plant is in normal operation, subject to technical specification requirements and limitations. Mispositioning of valves F001A, F001B, F006A, and F006B is not considered an error because they are checked periodically. All normally-open manual isolation valves are subject to being left in the closed position following maintenance. The probability of this is included in the analysis.

4.4.8 Common-Cause Failures

The common-cause failures of concern in the SLCS equipment are common-cause failure of the redundant squib valves and transmitters to operate within each loop. This is included in the analysis. Common cause failures of VLU, DTM and RMU components are also considered in the model.

4.4.9 Fault Tree Analysis

The only fault tree developed for the SLCS is for a transient initiating event with failure to scram, namely ATWS. Instrumentation and logic for SLCS initiation are presented herein as separate fault trees, one tree for each squib valve initiation.

4.4.9.1 Top Event Definitions

One top event is developed for the SLCS fault tree analysis:

- GC41-0001-_1 – Long term boration fails during ATWS

4.4.9.2 Fault Tree Description

The fault tree for GC41-0001-_1 is presented in Appendix B.4.4, representing the probability that the SLCS fails to inject boron into the RPV following an ATWS. This tree includes the probability that both squib valves of each system loop fail to fire, either because of valve failure or failure to receive firing signals.

In the SLCS fault tree analysis, it is assumed that the accumulator tank pressure requires recharging at some time during the assumed two-year interval. It is further assumed that if no

corrective actions were taken, the SLCS would fail to inject sufficient boron in the event of an ATWS. This combination of assumptions may be conservative.

4.4.9.3 Human Interactions

Three types of human errors have been considered in developing the fault trees:

- Human errors in leaving normally-open manual valves in closed position following maintenance.
- Human error in failing to provide manual initiation of SLCS in the event of failure of automatic initiation.
- Human error in failing to provide manual initiation of pressure makeup to the accumulator, or to take other action, in the event of need for makeup and failure of automatic makeup.

These human errors are listed in Table 4.4-6.

4.4.10 Results of Fault Tree Analysis

The fault tree results provide quantitative values of system unavailability and of the contribution of specific components to that total.

The definition of each basic event is reported in Table 4.4-7.

The quantification of core damage sequences implicitly includes the contribution of basic events for this system. This qualification process enables the checking of the global consistency of the system fault trees and their relationship with the rest of the systems modeled in the PRA.

On the other hand, the importance measurements obtained from core damage frequency equations, allow the identification of the most relevant basic events and system component failures in an integrated context, as well as the determination of their relative importance with respect to the basic events and component failures of the other systems modeled.

4.4.11 Model Differences for 72-Hour Operation

The model is not different for a 72-hour mission time because the time required to inject the sodium pentaborate solution is very short.

4.4.12 References

4.4-1. ESBWR Design Control Document, 26A6642 Rev. 01

Table 4.4-1

Control Room Instrumentation and Alarms

Controls
Remote manual switches for shut-off valves F002A (F002B), F029A (F029B) and trace heating of the accumulator vent lines (MCR panels)
Two key-locked switches actuating squib valves F003A/C (F003B/D) (MCR panels)
Accumulator depressurization solenoid valves (MCR panels)
On/off remote manual switch for the nitrogen vaporizer B001, piston pump C001, and nitrogen gas exhaust solenoid valve F034 (Local Panels & Racks)
On/off remote manual switches for a mixer, piston pump C003, drum heating, mixing pump C002, and trace heating for accumulator vent lines (Local Panels & Racks)
Drum temperature control (Local Panels & Racks)
Displays
Accumulator level monitoring (MCR panels and Local Panels & Racks)
Accumulator pressure monitoring (MCR panels)
Nitrogen gas temperature monitoring (MCR panels and Local Panels & Racks)
Position lights indicating open/close for squib valves F003A/C (F003B/D), shut-off valves F002A (F002B) and F029A (F029B) and penetration check valves F004A (F004B) and F005A (F005B) (MCR panels)
On/off position lights for the depressurization valves vent line trace heating (MCR panels)
Pressure indication for auxiliary high pressure air system of depressurization valves (MCR panels)
The temperature of the SLC system rooms shall be monitored by the reactor building HVAC (MCR panels)
Nitrogen vaporizer inlet and outlet temperature indications (Local Panels & Racks)
Level indication of the nitrogen trap vessel A004 (Local Panels & Racks)
Pump C001 pressure monitoring (Local Panels & Racks)
Open/closed indication for the valve F007A (F007B) connecting the suction line of the mixing pump to the injection line (Local Panels & Racks)
On/off indicator for the nitrogen vaporizer B001, piston pump C001, and nitrogen gas exhaust solenoid valve F034 (Local Panels & Racks)
On/off indicators for a mixer, piston pump C003, drum heating, mixing pump C002, and trace heating for accumulator vent lines (Local Panels & Racks)
Drum temperature monitor (Local Panels & Racks)
Alarms
Accumulator level alarms (MCR panels and Local Panels & Racks)
Accumulator pressure alarms (MCR panels)
Nitrogen gas temperature alarms (MCR panels and Local Panels & Racks)
Pressure indication and alarms for auxiliary high pressure air system of depressurization valves (MCR panels)
Pump C001 cool discharge temperature and high temperature alarm (Local Panels & Racks)
Pump C001 high pressure alarm (Local Panels & Racks)
Drum temperature control alarms (Local Panels & Racks)

Table 4.4-2

System Dependencies Matrix

		Support System			
		Power Supply			
		R16 250 V DC			
Component	**Type**	**DIV 1**	**DIV 2**	**DIV 3**	**DIV4**
F003A	SQV	X			X
F003B	SQV	X			X
F003C	SQV		X	X	
F003D	SQV		X	X	

Table 4.4-3

Component Tests

Component	Type	Expected Test Interval
F003A/B/C/D	SQV	30 minutes (1)
F002A/B	MOV	Quarterly
F004A/B	UV	During plant outages
F005A/B	UV	During plant outages
F006A/B	BV	Quarterly
F013	SOV	Quarterly
F014	MOV	Quarterly
F029A/B	MOV	Quarterly
F028A/B	UV	Quarterly
F507A/B	ACV	Quarterly
F508A/B	ACV	Quarterly
F001A/B	BV	During plant outages

(1): A small, trickle current circuit shall be used to verify circuit continuity for receiving firing signals

Table 4.4-4

Component Maintenance

The SLC system and components shall be designed such that they can be maintained with relative ease and minimum maintenance time.

Table 4.4-5

List of System Common Cause Failures

Basic Event	Prob	Description
B21-LT_-CF-ATWS	1.20E-07	CCF OF DIVERSIFIED LEVEL 1& 2 TRANSM. 1A/B/C/D
B21-PT_-CF-ATWS	3.00E-08	CCF 3 OUT OF 4 RPV PRESSURE TRANSMITTERS
C41-LT_-CF-N001TALOW	2.40E-07	CCF 2 OUT OF 4 OF LEVEL TRANSMITTERS LOW
C41-LT_-CF-N001TBLOW	2.40E-07	CCF 2 OUT OF 4 LEVEL TRANSMITTERS LOW
C41-SQV-CF-F003AC	1.50E-04	CCF TO OPERATE OF SQUIB VALVES ON SLCS-A
C41-SQV-CF-F003BD	1.50E-04	CCF TO OPERATE OF SQUIB VALVES ON SLCS-B
C51-ACT-CF-SRNM	2.98E-04	CCF OF SRNM CORE FLUX CHANNELS
C51-VLU-CF-SRNM	7.48E-06	CCF 3/4 OF SRNM 2/4 VLU
C74-DTM-CF-ATWSALL	1.30E-05	CCF 3 OUT OF 4 DIGITAL TRIP MODULES
C74-VLU-CF-ATWS	3.12E-06	CCF 3/4 VOTING LOGIC UNIT ATWS DIVISIONS
C74-VLU-CF-SLCS	7.48E-06	CCF 2/2 VOTING CARD SLCS LOGIC
H23-EMS-CF-ATWSALL	1.80E-06	CCF OF ESSENTIAL MULTIPLEXING SYSTEM DIV 1/2/3/4
H23-RMU-CF-ALL	9.00E-07	CCF OF REMOTE MULTIPLEXING UNITS TO OPERATE
H23-RMU-CF-ATWSALL	9.00E-07	CCF OF REMOTE MULTIPLEXING UNITS TO OPERATE

Table 4.4-6

List of System Human Errors

Basic Event	Prob	Description
C41-XHE-FO-INI	1.77E-02	MANUAL ACTUATION FAILURE
C41-XHE-FO-INISLCS	1.77E-01	OPERATOR FAILS TO MANUALLY INITIATE SLCS (SHORT TIME)
C41-XHE-FO-OPENF002A	2.69E-01	OPERATOR FAILS TO OPEN VALVE F002A (AFTER INADV.CLOS.)
C41-XHE-FO-OPENF002B	2.69E-01	OPERATOR FAILS TO OPEN VALVE F002B (AFTER INADV.CLOS.)
C41-XHE-MH-F002A	4.03E-03	MISPOSITION OF VALVE F002A
C41-XHE-MH-F002B	4.03E-03	MISPOSITION OF VALVE F002B

Table 4.4-7

List of System Basic Events

Basic Event	Prob	Description
B21-LT_-CF-ATWS	1.20E-07	CCF OF DIVERSIFIED LEVEL 1& 2 TRANSM. 1A/B/C/D
B21-LT_-NO-ATWS1A	2.40E-05	WIDE RANGE LEVEL TRANSMITTER 1A (LEVEL 1&2) FAILS
B21-LT_-NO-ATWS1B	2.40E-05	WIDE RANGE LEVEL TRANSMITTER 1B (LEVEL 1&2) FAILS
B21-LT_-NO-ATWS1C	2.40E-05	WIDE RANGE LEVEL TRANSMITTER 1C (LEVEL 1&2) FAILS
B21-LT_-NO-ATWS1D	2.40E-05	WIDE RANGE LEVEL TRANSMITTER 1D (LEVEL 1&2) FAILS
B21-OR_-PG-01A	1.44E-05	ORIFICE INSTR. LINE 1A FAILS TO REMAIN OPEN (PLUG)
B21-OR_-PG-01B	1.44E-05	ORIFICE INSTR. LINE 1B FAILS TO REMAIN OPEN (PLUG)
B21-OR_-PG-01C	1.44E-05	ORIFICE INSTR. LINE 1C FAILS TO REMAIN OPEN (PLUG)
B21-OR_-PG-01D	1.44E-05	ORIFICE INSTR. LINE 1D FAILS TO REMAIN OPEN (PLUG)
B21-PT_-CF-ATWS	3.00E-08	CCF 3 OUT OF 4 RPV PRESSURE TRANSMITTERS
B21-PT_-NO-ATWS2A	1.15E-05	PRESSURE TRANSMITTER 0002A FAILS TO RESPOND TO CHANGE IN PRESSURE
B21-PT_-NO-ATWS2B	1.15E-05	PRESSURE TRANSMITTER 0002B FAILS TO RESPOND TO CHANGE IN PRESSURE
B21-PT_-NO-ATWS2C	1.15E-05	PRESSURE TRANSMITTER 0002C FAILS TO RESPOND TO CHANGE IN PRESSURE
B21-PT_-NO-ATWS2D	1.15E-05	PRESSURE TRANSMITTER 0002D FAILS TO RESPOND TO CHANGE IN PRESSURE
C41-LT_-CF-N001TALOW	2.40E-07	CCF 2 OUT OF 3 OF LEVEL TRANSMITTERS LOW
C41-LT_-CF-N001TBLOW	2.40E-07	CCF 2 OUT OF 3 LEVEL TRANSMITTERS LOW
C41-LT_-LO-N001AA	1.22E-05	LEVEL TRANSMITTER A TANK A FAILS LOW
C41-LT_-LO-N001AB	1.22E-05	LEVEL TRANSMITTER A TANK B FAILS LOW
C41-LT_-LO-N001BA	1.22E-05	LEVEL TRANSMITTER B TANK A FAILS LOW
C41-LT_-LO-N001BB	1.22E-05	LEVEL TRANSMITTER B TANK B FAILS LOW
C41-LT_-LO-N001CA	1.22E-05	LEVEL TRANSMITTER C TANK A FAILS LOW
C41-LT_-LO-N001CB	1.22E-05	LEVEL TRANSMITTER C TANK B FAILS LOW
C41-MOV-OC-F002A	3.36E-06	MOTOR OPER. VALVE F002A FAILS TO REMAIN OPEN
C41-MOV-OC-F002B	3.36E-06	MOTOR OPER. VALVE F002-B FAILS TO REMAIN OPEN
C41-SQV-CC-F003A	3.00E-03	EXPLOSIVE VALVE F003A FAILS TO OPERATE
C41-SQV-CC-F003B	3.00E-03	EXPLOSIVE VALVE F003B FAILS TO OPERATE
C41-SQV-CC-F003C	3.00E-03	EXPLOSIVE VALVE F003C FAILS TO OPERATE
C41-SQV-CC-F003D	3.00E-03	EXPLOSIVE VALVE F003D FAILS TO OPERATE
C41-SQV-CF-F003AC	1.50E-04	CCF TO OPERATE OF SQUIB VALVES ON SLCS-A
C41-SQV-CF-F003BD	1.50E-04	CCF TO OPERATE OF SQUIB VALVES ON SLCS-B
C41-SYS-FF-MAKEUP	1.00E-01	INVENTORY MAKE-UP BORATION FAILURE
C41-UV_-CC-F004A	1.60E-03	CHECK VALVE F004A FAILS TO OPEN

Table 4.4-7

List of System Basic Events

Basic Event	Prob	Description
C41-UV_-CC-F004B	1.60E-03	CHECK VALVE F004B FAILS TO OPEN
C41-UV_-CC-F005A	1.60E-03	CHECK VALVE F005A FAILS TO OPEN
C41-UV_-CC-F005B	1.60E-03	CHECK VALVE F005B FAILS TO OPEN
C41-XHE-FO-INI	1.77E-02	MANUAL ACTUATION FAILURE
C41-XHE-FO-INISLCS	1.77E-01	OPERATOR FAILS TO MANUALLY INITIATE SLCS (SHORT TIME)
C41-XHE-FO-OPENF002A	2.69E-01	OPERATOR FAILS TO OPEN VALVE F002A (AFTER INADV.CLOS.)
C41-XHE-FO-OPENF002B	2.69E-01	OPERATOR FAILS TO OPEN VALVE F002B (AFTER INADV.CLOS.)
C41-XHE-MH-F002A	4.03E-03	MISPOSITION OF VALVE F002A
C41-XHE-MH-F002B	4.03E-03	MISPOSITION OF VALVE F002B
C51-ACT-CF-SRNM	2.98E-04	CCF OF SRNM CORE FLUX CHANNELS
C51-ACT-LO-CHASRNM	1.90E-02	SRNM CHANNEL A FAILS
C51-ACT-LO-CHBSRNM	1.90E-02	SRNM CHANNEL B FAILS
C51-ACT-LO-CHCSRNM	1.90E-02	SRNM CHANNEL C FAILS
C51-ACT-LO-CHDSRNM	1.90E-02	SRNM CHANNEL D FAILS
C51-ACT-LO-CHESRNM	1.90E-02	SRNM CHANNEL E FAILS
C51-ACT-LO-CHFSRNM	1.90E-02	SRNM CHANNEL F FAILS
C51-ACT-LO-CHGSRNM	1.90E-02	SRNM CHANNEL G FAILS
C51-ACT-LO-CHHSRNM	1.90E-02	SRNM CHANNEL H FAILS
C51-ACT-LO-CHJSRNM	1.90E-02	SRNM CHANNEL J FAILS
C51-ACT-NO-CHL	4.32E-05	SRNM CHANNEL L FAILS
C51-VLU-CF-SRNM	7.48E-06	CCF 3/4 OF SRNM 2/4 VLU
C51-VLU-FC-DIV1	6.24E-04	SRNM DIV 1 2/4 VLU FAILS
C51-VLU-FC-DIV2	6.24E-04	SRNM DIV 2 2/4 VLU FAILS
C51-VLU-FC-DIV3	6.24E-04	SRNM DIV 3 2/4 VLU FAILS
C51-VLU-FC-DIV4	6.24E-04	SRNM DIV 4 2/4 VLU FAILS
C74-DTM-CF-ATWSALL	1.30E-05	CCF 3 OUT OF 4 DIGITAL TRIP MODULES
C74-DTM-FC-DIV1ATWS	6.00E-04	DIGITAL TRIP MODULE FAILS TO FUNCTION (ATWS)
C74-DTM-FC-DIV2ATWS	6.00E-04	DIGITAL TRIP MODULE FAILS TO FUNCTION (ATWS)
C74-DTM-FC-DIV3ATWS	6.00E-04	DIGITAL TRIP MODULE FAILS TO FUNCTION (ATWS)
C74-DTM-FC-DIV4ATWS	6.00E-04	DIGITAL TRIP MODULE FAILS TO FUNCTION
C74-VLU-CF-ATWS	3.12E-06	CCF 3/4 VOTING LOGIC UNIT ATWS DIVISSIONS
C74-VLU-CF-SLCS	7.48E-06	CCF 2/2 VOTING CARD SLCS LOGIC
C74-VLU-FC-ATWS1	6.24E-04	ATWS DIV 1 VOTING LOGIC UNIT FAILS
C74-VLU-FC-ATWS2	6.24E-04	ATWS DIV 2 VOTING LOGIC UNIT FAILS
C74-VLU-FC-ATWS3	6.24E-04	ATWS DIV 3 VOTING LOGIC UNIT FAILS

Table 4.4-7

List of System Basic Events

Basic Event	Prob	Description
C74-VLU-FC-ATWS4	6.24E-04	ATWS DIV 4 VOTING LOGIC UNIT FAILS
C74-VLU-FC-SLCS1	6.24E-04	2/4 VOTING LOGIC CARD FOR SLCS DIV 1
C74-VLU-FC-SLCS2	6.24E-04	2/4 VOTING LOGIC CARD FOR SLCS DIV 2
H23-EMS-CF-ATWSALL	1.80E-06	CCF OF ESSENTIAL MULTIPLEXING SYSTEM DIV 1/2/3/4
H23-RMU-CF-ALL	9.00E-07	CCF OF REMOTE MULTIPLEXING UNITS TO OPERATE
H23-RMU-CF-ATWSALL	9.00E-07	CCF OF REMOTE MULTIPLEXING UNITS TO OPERATE
H23-RMU-FC-001C41	3.00E-04	RMU 001 CRD SYSTEM C.R. MANUAL ACTUATION FAILS TO OPERATE
H23-RMU-FC-002C41	3.00E-04	RMU 002 CRD SYSTEM C.R. MANUAL ACTUATION FAILS TO OPERATE
H23-RMU-FC-003C41	3.00E-04	RMU 003 CRD SYSTEM C.R. MANUAL ACTUATION FAILS TO OPERATE
H23-RMU-FC-ATWS1A	3.00E-04	REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION
H23-RMU-FC-ATWS1B	3.00E-04	REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION
H23-RMU-FC-ATWS1C	3.00E-04	REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION
H23-RMU-FC-ATWS1D	3.00E-04	REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION
H23-RMU-FC-ATWS2A	3.00E-04	REMOTE MULTIPLEXING UNIT 0002A FAILS TO FUNCTION
H23-RMU-FC-ATWS2B	3.00E-04	REMOTE MULTIPLEXING UNIT 0002B FAILS TO FUNCTION
H23-RMU-FC-ATWS2C	3.00E-04	REMOTE MULTIPLEXING UNIT 0002C FAILS TO FUNCTION
H23-RMU-FC-ATWS2D	3.00E-04	REMOTE MULTIPLEXING UNIT 0002D FAILS TO FUNCTION

Table 4.4-8

List of System Top Events

Top Event	Description
GC41-0001_1	Long Term Boration Fails During ATWS

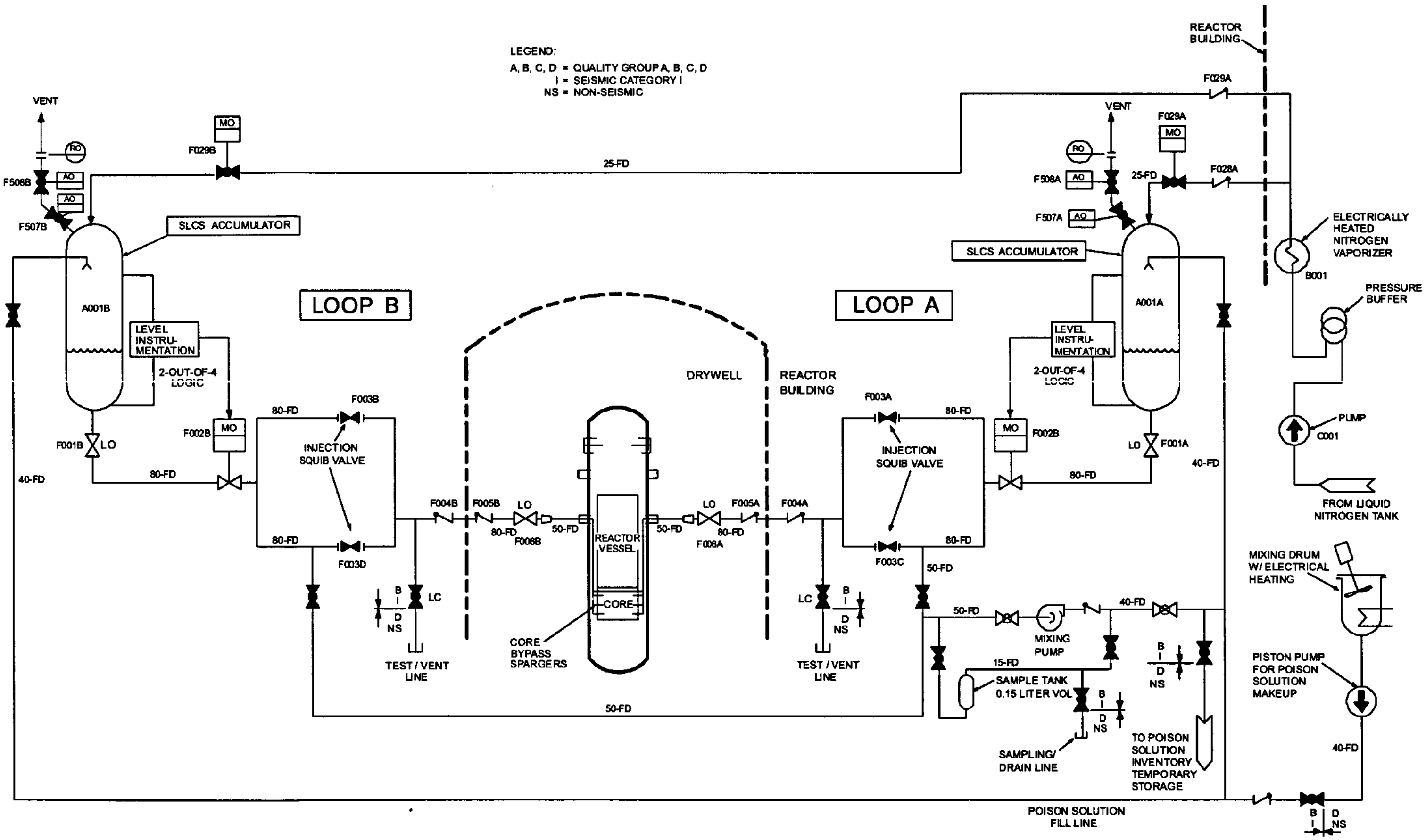


Figure 4.4-1. Simplified Process Flow Diagram for Standby Liquid Control System

4.5 INSTRUMENTATION, LOGIC AND CONTROL SYSTEM – (C62, C63, C71 and C74)

4.5.1 Purpose

The ESBWR Instrumentation, Logic and Control (I&C) System provides a centralized set of equipment for implementing safety and non-safety related logic functions.

4.5.2 Design Assumptions

The following design assumptions (DA) have been used for the model:

(1) The ESBWR Instrumentation, Logic and Control (I&C) System is made up of the following six independent subsystems:

- SSLC/ECCS subsystem (Class 1E)
- SSLC/RTIF - SCRAM subsystem (Class 1E)
- SSLC/RTIF – ATWS subsystem (Class 1E)
- DPS subsystem (Non Class 1E)
- NE RTNSS subsystem (Non class 1E)
- NE BOP subsystem (Non class 1E)

(2) The SSLC/ECCS subsystem processes the automatic and manual signals that act on systems B32, E50 (GDCS and Equalizing Lines), P54, B21 (ADS signal) and T10 (IC and RWCU isolation).

(3) The SSLC/RTIF - SCRAM subsystem processes the automatic and manual signals that act on systemT10 (MSIVs isolation), as well as the feedwater runback and inhibition ADS signals.

(4) The SSLC/RTIF – ATWS subsystem processes the automatic and manual signals that act on system C41, as well as the feedwater runback and ADS inhibits signals.

(5) The DPS subsystem processes the automatic and manual signals that act on systems B21 (ADS signal) and E50 (GDCS).

(6) The NE RTNSS subsystem processes the automatic and manual signals that act on systems C12, G21, G31, P21, P41, P52, R21 and U43.

(7) The NE BOP subsystem processes the automatic and manual signals that act on systems N21, N71, P22, P30, and P51.

(8) Each of these subsystems is comprised of the corresponding part of the E-DCIS or NE-DCIS that provides redundant and distributed control and instrumentation data communications networks to support the monitoring and control of interfacing plant systems and the logic channels (microprocessor-based, software-controlled, processing modules) located in the cabinets of the Main Control Room area.

(9) The SSLC/ECCS, SSLC/RTIF – SCRAM, SSLC/RTIF – ATWS and DPS subsystems are composed of four independent and separated instrumentation divisions I, II, III, and IV

(logic channels), while the NE RTNSS and NE BOP subsystems are made up of three independent and separated instrumentation divisions A, B and C (logic channels).

(10) The structure of the logic channels of the SSLC/ECCS, SSLC/RTIF – ATWS, DPS, NE RTNSS and NE BOP subsystems are identical.

(11) Each one of divisions I, II, III and IV of the SSLC/ECCS, SSLC/RTIF and DPS subsystems is fed electrical power from divisions I, II, III and IV Class 1E of the Uninterruptible Power Supply System (R13).

(12) Each one of the divisions A, B and C of subsystems NE RTNSS and NE BOP is powered from trains A, B and C Non Class 1E of the Uninterruptible Power Supply System (R13).

4.5.3 System Description

The Instrumentation, Logic and Control (I&C) System analysis described here refers to the system configuration shown in Figure 4.5-1.

The I&C system is designed to accomplish both essential and non-essential functions.

The essential functions are those designed for the following:

- To lead to an automatic reactor scram when plant conditions reach safety-related limits
- To provide automatic and manual actuation of essential safety systems, thus limiting the consequences of accidents
- To collect plant data and alert the operator to any abnormal plant conditions so that corrective action can be initiated to prevent a reactor scram

The non-essential functions are designed for the following:

- To provide for the automatic or manual control of the Balance of Plant (BOP) systems from the control room
- To provide manual and automatic actuation of all non-safety systems

Some basic characteristics of ESBWR I&C are reported in Reference 4.5-1.

4.5.3.1 Hardware Configuration

The logic and control functions are basically accomplished by the following systems:

- Safety System Logic & Control (SSLC)
- Essential Distributed Control and Instrumentation System (E-DCIS)
- Non-Essential Distributed Control and Instrumentation System (NE-DECIS)

The SSLC enables both the safety and non-safety systems to perform their functions and is composed of the following independent subsystems:

- SSLC/ECCS subsystem (Class 1E)
- SSLC/RTIF - SCRAM subsystem (Class 1E)
- SSLC/RTIF – ATWS subsystem (Class 1E)

- DPS subsystem (Non Class 1E)
- NE RTNSS subsystem (Non class 1E)
- NE BOP subsystem (Non class 1E)

SSLC resides in independent and separated instrumentation divisions and integrates the control logic in each division into microprocessor-based, software-controlled, processing modules located in divisional cabinets in the Main Control Room MCRB area.

Each division performs functionally identical logical operations on the process sensor signals to initiate protective action. Many sensor signals are shared by the control logic of multiple safety systems.

The main equipment in each SSLC/ECCS, DPS, NE RTNSS, and NE BOP division and the functions performed are described below:

- Digital Trip Module (DTM). Sensor channel trip decisions (comparison of input variables to programmed setpoints).
- Voter Logic Unit (VLU). The Voter Logic trains in each division are redundant but not independent modules. Each of the redundant pairs of VLUs receives the trip status from the DTMs in all four divisions and performs 2-out-of-4 and 3-out-of-4 logic to determine the actuation status for each system function. VLUs are located in main control room area SSLC/ESF cabinet (per division).
- Safety System Logic Unit (SLU). SLUs are located in each RMU. The SLUs receive actuation signals from Voter Logic Units and combines actuation signals with interlock logic permissives that implement system functional logic as defined on the logic diagrams of the affected system. Output logic is 2-out-of-2 to the device actuators. Each VLU/SLU train is defined in Plant Technical Specification as a Logic Channel. The SLUs also provides outputs, including annunciator outputs from built-in self diagnostic functions, to the operator displays and to the plant computer.
- Bypass Unit (BPU). Division-of-sensors bypass and division maintenance bypass functions that permit on-line calibration, test, and repair without causing containment isolation, or degrade ECCS or other ESF operation. Located in SSLC Test Cabinet in main control room area (per division).
- Manual switches in Control Room.

The equipment in each RTIF division is as follows:

- Digital Trip Module (DTM) that compares individual monitored variable values with trip setpoint values and for each variable sends a separate, discrete (trip/no trip) output signal to Trip Logic Units (TLUs) in all four divisions of trip logic.
- Trip Logic Unit (TLU) that performs the initiation logic, normally checking for 2-out-of-4 coincidence of trip conditions in any set of instrument channel signals coming from the four division DTMs.
- Bypass Unit (BPU) that performs bypass and interlock logic for the channel sensors bypass and the division trip logic unit bypass. It sends a separate bypass signal for all four channels to the trip logic unit in the same division for channel sensors bypass.

- Output Logic Unit (OLU) that performs division trip, seal-in, reset and trip test function. Each output logic unit receives bypass inputs from the BPU, trip inputs from the TLU of the same division and various manual inputs from switches within the same division and provides discrete trip outputs to the trip actuators in the same division.

The E-DCIS and the NE-DCIS, using fiber optic main transmission lines, provide distributed control and instrumentation data communication networks to support the monitoring and control of interfacing plant systems.

The E-DCIS has independent and separated data multiplexing divisions. Each E-DCIS division contains a redundant fiber optic network that comprises of RMUs, fiber optic signal transmission path, and isolated digital interfaces, etc. The network connects divisional Class 1E VDUs, SSLC Cabinets, Test Cabinet, and several RMUs located in each of the equipment rooms in different buildings. The network also interfaces with NE-DCIS through isolated digital interfaces. E-DCIS acquires, formats, and transmits plant sensor data and control commands within the time response requirements of the safety-related systems with which it interfaces.

The Non-Essential Distributed Control and Instrumentation System (NE-DCIS) has independent and separated data multiplexing divisions and provides redundant and distributed control and instrumentation data communications networks to support the monitoring and control of interfacing plant systems. Nonsafety-related data are processed through the NE-DCIS.

4.5.3.2 System Operation

The I&C evaluates safety system trip conditions continuously in all modes of plant operation; i.e., Run, Startup, Hot Shutdown, Cold Shutdown, and Refueling and itself operates in two modes that affect all safety systems simultaneously: Normal and Bypass.

During normal operation, the systems supported by the I&C are maintained in a standby condition and are ready to function on demand when an accident or transient event occurs. The following tasks are performed repetitively in all plant modes on data received during each scan of E-DCIS or from other sensor data sources.

The first stage of I&C operation is the comparison of the measured parameters to their setpoints. Digital or digitized input signals from E-DCIS or NE-DCIS provide the value or status of critical plant process parameters to the DTMs contained in each division cabinets. The input signals for each division are acquired from separate and independent sensor channels. At the DTMs, the value of each monitored parameter is compared to a reference setpoint stored in digital memory. For each parameter that exceeds the setpoint limit, the DTM declares a sensor channel trip. The trips are sent to coincident VLU (SSLC/ECCS, DPS, NE RTNSS, and NE BOP subsystems) or TLU (RTIF subsystems) within their own division and, by isolated interconnection, to the other subsystem divisions.

The trip outputs from the DTM are compared with the trip outputs from the DTMs of the other subsystem divisions. This function is performed, for subsystems SSLC/ECCS, DPS, NE RTNSS, and NE BOP, in parallel VLUs (one pair per system processed) and, for subsystem RTIF, in the TLU.

The VLU pairs (VLU1 and VLU2) are redundant, with a 2-out-of-2-confirmation configuration at the SLUs within the RMU. Dual SLUs with identical logic functions are connected in parallel

and simultaneously process the same sensor trip or contact closure inputs from the VLUs or other input sources.

Trip outputs from each VLU are serially multiplexed on separate communication links of E-DCIS or NE-DCIS to the SLUs in the RMUs, where a 2-out-of-2 voter determines if there is agreement between the two channels. Comparisons for voting are performed in one of the two parallel SLUs, designated as SLU A. Agreement results in processing of control and interlock signals in the identical logic of SLUs A and B, which communicate across the card file backplane. Correct performance of SLUs A and B results in output of control signals for equipment initiation or nuclear system isolation as required. Control signals to component actuators are hardwired from contact closures in the RMUs of E-DCIS or NE-DCIS to the appropriate motor control centers, switchgear, or solenoids.

Disagreement between the two channels inhibits the control output.

This arrangement prevents inadvertent equipment initiation or primary containment vessel isolation due to hardware or software failure in a single SLU. The SLUs provide device interlock logic and formulate the protective action initiation commands that are transmitted to the local area equipment actuators.

The TLU sends the trip signal to the OLU within its own division. The OLU performs division trip.

4.5.3.3 Components Location

The SSLC cabinets are located in the MCRB area.

The E-DCIS and the NE-DCIS fiber optic networks connect SSLC cabinets with the RMUs located in the equipment rooms of the different buildings.

4.5.4 Automatic and Manual Control

The following automatic and manual signals are processed through the I&C system:

Isolation Condenser System (ICS)

The B32-F005A/B/C/D and B32-F006A/B/C/D open automatically by the following signals:

(1) High reactor pressure sensed by B21-PT-002A/B/C/D pressure transmitters (if the high pressure remains for more than 10 seconds).

OR

(2) Reactor water level 2 sensed by B21-LT-N001A/B/C/D level transmitters.

OR

(3) MSIV closure, i.e., closure of all Main Steam Lines (MSL), sensed by one limit switch per valve.

The valves (B32-F72HA/B/C/D), that provide cross connection of the IC and PCC pools, to allow 72 hours of cooling by the ICS and PCCS heat exchangers, open automatically on the following signals:

(1) Low level in the pool A sensed by B32-LT-F72HA1/2/3/4 level transmitters (valves B32-F72HA/D)

OR

(2) Low level in the pool B sensed by B32-LT-F72HB1/2/3/4 level transmitters (valve B32-F72HB/C)

Operator actions are possible as backup to these automatic actuation signals. Control switches in the main control room are used for the manual backup.

These signals are processed through the SSLC/ECCS subsystem.

Automatic Depressurization System (ADS)

The DPVs and SRVs are actuated automatically by the following signal:

- Reactor water level 1 sensed by B21-LT-N001A/B/C/D and B21-LT-DPSWRA/B/C/D water level transmitters.

Operator actions are possible as backup to these automatic actuation signals. Control switches in the main control room are used for the manual backup.

This signal is processed through the SSLC/EECS and DPS subsystems.

Gravity Driven Cooling System (GDCS)

The GDCS is actuated automatically by the following signal:

- Reactor water level 1 sensed by B21-LT-N001A/B/C/D and B21-LT-DPSWRA/B/C/D water level transmitters.

Operator actions are possible as backup to these automatic actuation signals. Control switches in the main control room are used for the manual backup.

This signal is processed through the SSLC/ECCS and DPS subsystems.

High Pressure Nitrogen Supply System (HPNSS)

The essential nitrogen bottles are aligned automatically by the following signal.

- Low pressure of nitrogen sensed by P54-PT-002/003 pressure transmitters.

Operator actions are possible as backup to these automatic actuation signals. Control switches in the main control room are used for the manual backup.

This signal is processed through the SSLC/ECCS subsystem.

Main Steam Isolation Valve (MSIV)

The MSIV close automatically by the following signals:

- Reactor water level 2 sensed by B21-LT-N001A/B/C/D level transmitters.

Operator actions are possible as backup to these automatic actuation signals. Control switches in the main control room are used for the manual backup.

This signal is processed through the SSLC/RTIF-SCRAM subsystem.

Leak Detection and Isolation System (LD&IS)

The LD&IS is employed to isolate either the entire containment or a single system according to the signal received.

c. ICS isolation in case of LOCA outside containment. In that case, the line break is isolated automatically by the following signals:

- High differential pressure between steam supply line and condensate return line of the corresponding loop sensed by B32-PDT-N001/2/3/4A, B, C or D pressure differential transmitters.

  OR

- High radiation in the corresponding pool exhaust sensed by D11-ACT-1/2/3/4A, B, C or D radiation monitors.

d. RWCU isolation in case of LOCA outside containment. In that case, the line break is isolated automatically by the following signals:

- Reactor water level 2 sensed by B21-LT-N001A/B/C/D level transmitters.

  OR

- High flow in the corresponding RWCU train sensed by C21-FT-N001A/B/C/D (A) for train A or by C21-FT-N001A/B/C/D (B) for train B flow transmitters.

  OR

- High temperature in the steam tunnel sensed by C21-TT-N003A/B/C/D temperature transmitters.

Human actions are possible as backup to these automatic actuation signals. Control switches in the main control room are used for the manual backup.

These signals are processed through the SSLC/ECCS and NE RTNSS subsystems.

Standby Liquid Control System (SLCS)

The SLCS is assumed to be automatically actuated by the following signals:

(1) High reactor pressure sensed by narrow range B21-PT-ATWSA/B/C/D

OR

Reactor water level 2 sensed by wide range water B21-LT-ATWSA/B/C/D

AND

(2) Permissive of "APRM Not Downscale" signal sensed by SRNM flux detectors

Human actions are possible as backup to these automatic actuation signals. Control switches in the main control room are used for the manual backup.

These signals are processed through the SLCS/RTIF-ATWS subsystem.

ADS Inhibit

The ADS Inhibit that precludes DPV opening is assumed to be automatically actuated by the following signals:

(1) High reactor pressure sensed by B21 PT-ATWSA/B/C/D

OR

Reactor water level 2 sensed by wide range water B21-LT-ATWSA/B/C/D

AND

(2) Permissive of "APRM Not Downscale" signal sensed by SRNM flux detectors

These signals are processed through the SSLC/RTIF-ATWS subsystem.

Feedwater Runback (FWRB)

The FWRB is actuated automatically by the following signals:

- High reactor pressure sensed by narrow range B21-PT-ATWSA/B/C/D with permissive of "APRM Not Downscale" signal sensed by the Source Range Neutron Monitor (SRNM) flux detectors.

These signals are processed through the SSLC/RTIF-ATWS subsystem.

Control Rod Drive System (CRDS)

The CRDS is automatically initiated in its injection mode by the following signal:

- Reactor water level 2 sensed by B21-LT-DPSWRA/B/C/D level transmitters.

Human actions are possible as backup to these automatic actuation signals. Control switches in the main control room are used for the manual backup.

This signal is generated in Class 1E sensor channels and processed through the NE RTNSS subsystem.

Fuel and Auxiliary Pools Cooling System (FAPCS)

The FAPCS is automatically initiated in its suppression pool cooling mode by the following signal:

- High temperature in the suppression pool sensed by T62-TT-001/2/3/4 temperature transmitters.

Human actions are possible as backup to these automatic actuation signals. Control switches in the main control room are used for the manual backup.

This signal is processed through the NE RTNSS subsystem.

Standby On-Site AC Power Supply (R21)

The DGs automatically start by the following signal:

- Low voltage in bus A2 sensed by the undervoltage relay 10A11 (DGA).
- Low voltage in bus B2 sensed by the undervoltage relay 10A21 (DGB).

The startup of any one of the diesel generators leads to the automatic startup of the corresponding pumps of systems P21 and P41 that provide cooling to their respective diesel generators.

Human actions are possible as backup to these automatic actuation signals. Control switches in the main control room are used for the manual backup.

These signals are processed through the NE RTNSS subsystem.

Besides the automatic actions and the manual support indicated above, the I&C system processes manual actions from the Control Room that allows the alignment and operation of the different systems.

4.5.5 System Interfaces

The I&C system dependencies are included in the dependency matrix given in Table 4.5-2.

4.5.6 System Testing

The continuous self-diagnostics of E-DCIS and NE-DCIS automatically detect most data transmission errors and hardware failures at the card level. A comprehensive, off-line, network performance test confirms that the data transmission capability is as intended. The test provides confidence that data error rates are within specified limits, signal quality is within specifications, and the network is capable of handling the required throughput.

Most SSLC surveillance testing is included as part of surveillance testing for its supported systems, since SSLC contains the control logic for these systems. However, the following surveillance tests are unique to SSLC, since they involve functions shared by all interfacing systems:

- **Sensor Channel (Instrument Channel) Check** - This check is a visual comparison, on the MCR main control console, of the parameter indicated in one sensor channel to a similar parameter in a different sensor channel. Since redundant sets of sensors measure the same process, the indications should be reasonably close. This check is performed every shift.
- **Divisional Functional Test** - The test is performed by replacing the process signal with a test signal generated by the SSLC Surveillance Test Controller located within each divisional SSLC Test cabinet. The test signal, which can simulate the full range of an analog or digital process signal, is injected at the RMU input of E-DCIS or NE-DCIS to test the DTMs. The as-found trip setpoints are confirmed to be within their allowable values. Test signals are also injected at the SLUs to check trip logic and interlock logic response. However, VLU logic is not tested, since inputs from multiple divisions would be required. This test, performed quarterly, supplements the continuous self-diagnostic checks within each SSLC controller.
- **Comprehensive Functional Test** - This test, which is performed during an outage, verifies overall SSLC system function, computer component function, software and hardware interactions, response times, and error handling in four divisions. Successful completion of these tests establishes operability of sensor channels (instrument channels), logic channels (trip logic), and output channels (trip actuators). This end-to-end test

injects test signals simultaneously in the four divisions at the RMU inputs and thus checks the voting logic units (VLU).

- **Sensor Channel Calibration** - A sensor channel calibration or channel calibration is a complete check of the channel from the sensor output through any intervening devices and to the trip output (e.g., RMU or other signal conditioner, multiplexing network, DTM). This test verifies that a channel responds to the measured parameter within the necessary range and accuracy. This calibration is performed during outages.

4.5.7 System Maintenance

No regular maintenance is required for E-DCIS or NE-DCIS logic components. Continuous self-diagnostics in each component monitor the state of the system and each module. Fault conditions that result in detected failures are alarmed in the MCR and are traceable to the lowest replaceable module.

To SSLC components, maintenance is performed on-line by using the SSLC bypass provisions to remove components from service in one division at a time. A division-of-sensors bypass permits a DTM to be serviced, while a train bypass permits a VLU to be serviced. Sufficient channel redundancy is always maintained while the system is in bypass.

Therefore, no maintenance unavailability is considered.

4.5.8 Common-Cause Failures

The common cause failures have been grouped in Table 4.5-5.

4.5.9 Fault Tree Analysis

In relation to the functions that the Containment System has to carry out, various fault trees have been developed that allow determining the system unavailability and identifying components that contribute significantly to system unavailability.

The functions required of the system are the following:

- Signal transmission through division A of subsystem NE RTNSS.
- Signal transmission through division B of subsystem NE RTNSS.
- Signal transmission through division C of subsystem NE RTNSS.
- Signal transmission through division A of subsystem NE BOP.
- Signal transmission through division B of subsystem NE BOP.
- Signal transmission through division C of subsystem NE BOP.
- Signal transmission through division I of subsystem SSLC/ECCS.
- Signal transmission through division II of subsystem SSLC/ECCS.
- Signal transmission through division III of subsystem SSLC/ECCS.
- Signal transmission through division IV of subsystem SSLC/ECCS.
- Generation of automatic depressurization signal division I SSLC/ECCS subsystem.

- Generation of automatic depressurization signal division II SSLC/ECCS subsystem.
- Signal transmission through division I of subsystem DPS.
- Signal transmission through division II of subsystem DPS.
- Signal transmission through division III of subsystem DPS.
- Signal transmission through division IV of subsystem DPS.
- Generation of automatic depressurization signal division I DPS subsystem.
- Generation of automatic depressurization signal division II DPS subsystem.
- Inhibition of automatic depressurization signal in case of ATWS.
- Generation of feedwater runback signal in case of ATWS.

4.5.9.1 Top Event Definitions

- Gate GC62-0001-_1 represents the failure to transmit a signal through division A of subsystem NE RTNSS.
- Gate GC62-0001-_2 represents the failure to transmit a signal through division B of subsystem NE RTNSS.
- Gate GC62-0001-_3 represents the failure to transmit a signal through division C of subsystem NE RTNSS.
- Gate GC62-0001-_4 represents the failure to transmit a signal through division A of subsystem NE BOP.
- Gate GC62-0001-_5 represents the failure to transmit a signal through division B of subsystem NE BOP.
- Gate GC62-0001-_6 represents the failure to transmit a signal through division C of subsystem NE BOP.
- Gate GC74-0001-_1 represents the failure to transmit a signal through division I of subsystem SSLC/ECCS.
- Gate GC74-0001-_2 represents the failure to transmit a signal through division II of subsystem SSLC/ECCS.
- Gate GC74-0001-_3 represents the failure to transmit a signal through division III of subsystem SSLC/ECCS.
- Gate GC74-0001-_4 represents the failure to transmit a signal through division IV of subsystem SSLC/ECCS.
- Gate GC74-0001-_5 represents the failure to generate the automatic depressurization signal division I SSLC/ECCS subsystem.
- Gate GC74-0001-_6 represents the failure to generate the automatic depressurization signal division II SSLC/ECCS subsystem.

- Gate GC72-0001-_1 represents the failure to transmit a signal through division I of subsystem DPS.
- Gate GC72-0001-_2 represents the failure to transmit a signal through division II of subsystem DPS.
- Gate GC72-0001-_3 represents the failure to transmit a signal through division III of subsystem DPS.
- Gate GC72-0001-_4 represents the failure to transmit a signal through division IV of subsystem DPS.
- Gate GC72-0001-_5 represents the failure to generate the automatic depressurization signal division I DPS subsystem.
- Gate GC72-0001-_6 represents the failure to generate the automatic depressurization signal division II DPS subsystem.
- Gate GC74-0001-_11 represents the failure to inhibit the automatic depressurization signal in case of ATWS.

4.5.9.2 Model Assumptions

The following assumptions with respect to the design are made:

(1) System limits: In general and for the purpose of the PRA, the I&C system includes the components through which the logic signals run which are located between the RMUs that receive the signals of the sensor channels and send them to the DTMs and the RMUs that transmit the actuation signals related to the different components of the plant, including the RMUs. The sensor channels related to the generation of the ADS Actuation, Inhibit ADS, and Feedwater Runback signals are included within the I&C system.

(2) Within the I&C system, no generic models have been developed for signal transmission across the divisions of the SSLC/RTIF subsystem. Specific models have been built and included within the models of the systems that use said signals. These models are the following:

   - SLC actuation signal (C41 system model)
   - MSIV isolation signal (T10 Containment system models)
   - Inhibition ADS signal (I&C system models)
   - Feedwater Runback signal (I&C system models)

(3) Specific models have been developed for LOOP, and for the startup and connection signal of the DGs due to undervoltage in busbars. Models have been developed for the signal transmission through the NE RTNSS subsystem that depends only on electrical supply from batteries. The models has been developed in this manner to avoid circular logic. These models are included within the AC system models (R11).

4.5.9.3 Human Actions

The human actions considered in the fault trees are the following:

B21-XHE-FO-ADS represents the operator's failure to recognize that the automatic initiation of ADS has failed and manually initiate it.

XXX-XHE-FO-DEPRESS represents the operator's failure to recognize the need for depressurization.

Human actions in the fault trees are connected by the house-event XHOSMAN that represents operator unavailability to carry out manual actions.

4.5.10 Results of Fault Tree Analysis

The fault tree results provide quantitative values of system unavailability and of the importance of specific components to that total.

The quantification of core damage sequences implicitly includes the contribution of basic event for this system. This quantification process enables checking the global consistency of the system fault trees and their relationship with the rest of the systems modeled in the PRA.

The importance measurements obtained from core damage frequency equations, allow identification of the most relevant basic events and system component failures in an integrated context, as well as the determination of their relative importance with respect to the basic events and component failures of the other systems modeled.

4.5.11 Model Differences for 72-Hour Operation

The long-term Instrumentation, Logic and Control System operation is similar to that during the first 24 hours following a transient or LOCA. There are no fault tree model changes necessary to extend the operation to 72 hours.

4.5.12 References

4.5-1. ESBWR Design Control Document, 26A6642 Rev. 01

Table 4.5-1

Control Room Instrumentation and Alarms

Main Control Room Panel Controls
The data transmission and processing functions require no operator intervention are provided
Main Control Console Displays
Division I of sensors in bypass
Division II of sensors in bypass
Division III of sensors in bypass
Division IV of sensors in bypass
ESF loop 1 in bypass
ESF loop 2 in bypass
ESF loop 3 in bypass
ESF loop 4 in bypass
SSLC Division I controller inoperative (DTM, VLU or SLU)
SSLC Division II controller inoperative (DTM, VLU or SLU)
SSLC Division III controller inoperative (DTM, VLU or SLU)
SSLC Division IV controller inoperative (DTM, VLU or SLU)
NIM, CIM or BTM Division I inoperative
NIM, CIM or BTM Division II inoperative
NIM, CIM or BTM Division III inoperative
NIM, CIM or BTM Division IV inoperative
E-DCIS Division I diagnostic displays
E-DCIS Division II diagnostic displays
E-DCIS Division III diagnostic displays
E-DCIS Division IV diagnostic displays
NE-DCIS diagnostic displays
Main Control Room Alarms
SSLC/ESF in bypass
SSLC/ESF system trouble
E-DCIS Division I trouble
E-DCIS Division II trouble
E-DCIS Division III trouble
E-DCIS Division IV trouble
NE-DCIS alarms

Table 4.5-2

System Dependencies Matrix

COMPONENT	R13 (Class 1E)	R13 (NO 1E)
SSLC/ECCS Division I	DIV 1	
SSLC/ECCS Division II	DIV 2	
SSLC/ECCS Division III	DIV 3	
SSLC/ECCS Division IV	DIV 4	
SSLC/RTIF Division I	DIV 1	
SSLC/RTIF Division II	DIV 2	
SSLC/RTIF Division III	DIV 3	
SSLC/RTIF Division IV	DIV 4	
DPS Division I	DIV 1	
DPS Division II	DIV 2	
DPS Division III	DIV 3	
DPS Division IV	DIV 4	
NE RTNSS Division A		DIV 1
NE RTNSS Division B		DIV 2
NE RTNSS Division C		DIV 3
NE BOP Division A		DIV 1
NE BOP Division B		DIV 2
NE BOP Division C		DIV 3

Table 4.5-3

Component Tests

(See Section 4.5.6)

Table 4.5-4

Component Maintenance

N/A

Table 4.5-5

Common Cause Failure

Basic Event	Probability	Description
B21-LT_-CF-DPSWR	1.20E-07	CCF OF DPS WR LEVEL TRANSMITTERS
B21-LT_-CF-N001A/B/C/D	1.20E-07	CCF OF DIVERSIFIED LEVEL 1 & 2 TRANSM. 10A/B/C/D
C51-ACT-CF-1PRM	2.98E-04	CCF APRM NEUTRON CHANNELS
C51-ACT-CF-APRMSTUCK	2.10E-07	CCF APRM DETECTORS STUCK AT POWER LEVEL
C51-ACT-CF-SRNM	2.98E-04	CCF OF SRNM CORE FLUX CHANNELS
C51-VLU-CF-1PRM	9.30E-07	PRNM DIV I 2/4 MODULES FAILS
C51-VLU-CF-2PRM	9.30E-07	PRNM DIV II 2/4 MODULES FAILS
C51-VLU-CF-APRM	9.30E-07	CCF 2/4 MODULES APRM
C62-BYP-CF-N1EALL	1.50E-05	CCF OF BYPASS UNITS (N1E)
C62-VLU-CF-DIDALL	3.12E-05	CCF OF VOTER LOGIC UNITS
C62-VLU-CF-N1EALL	3.12E-05	CCF OF VOTER LOGIC UNITS
C72-BYP-CF-DPSALL	1.50E-06	CCF OF BYPASS UNITS
C72-DTM-CF-DPSALL	1.20E-05	CCF 3/4 DTM OF DPS DIV 1/2/3/4
C72-VLU-CF-DPSALL	3.12E-06	CCF OF VOTER LOGIC UNITS
C74-BYP-CF-ALL	1.50E-06	CCF OF BYPASS UNITS
C74-BYP-CF-DIDALL	9.00E-07	CCF OF BYPASS UNITS (DID)
C74-DTM-CF-ALL	1.20E-05	CCF 3/4 DTM OF SSLC DIV1/2/3/4
C74-VLU-CF-ALL	3.12E-06	CCF OF VOTER LOGIC UNITS
C74-VLU-CF-ATWS	3.12E-06	CCF 3/4 VOTING LOGIC UNIT ATWS
H23-EMS-CF-ALL	1.80E-06	CCF OF ESSENTIAL MULTIPLEXING SYSTEM DIV 1/2/3/4
H23-EMS-CF-DIDALL	1.80E-06	CCF OF ALL DIVISION OF THE EMS
H23-EMS-CF-DPSALL	1.80E-06	CCF OF ESSENTIAL MULTIPLEXING SYSTEM DIV 1/2/3/4
H23-EMS-CF-N1EALL	1.80E-06	CCF OF ALL DIVISION OF THE EMS
H23-RMU-CF-ALL	9.00E-07	CCF OF REMOTE MULTIPLEXING UNITS TO OPERATE
H23-RMU-CF-DIDALL	9.00E-07	CCF OF REMOTE MULTIPLEXING UNITS (DID)
H23-RMU-CF-DPSALL	9.00E-07	CCF OF REMOTE MULTIPLEXING UNITS TO OPERATE
H23-RMU-CF-N1EALL	9.00E-07	CCF OF REMOTE MULTIPLEXING UNITS (NO 1E) TO OPERATE

Table 4.5-6

Human Errors

Basic Event	Probability	Description
B21-XHE-FO-ADS	1.77E-02	OPERATOR FAILS TO RECOGNIZE NEED OR ACTUATE ADS
XXX-XHE-FO-DEPRESS	1.61E-01	OPERATOR FAILS TO RECOGNIZE NEED OF DEPRESSURIZATION

Table 4.5-7

List of System Basic Events

Basic Event	Probability	Description
B21-LT_-NO-DPSWRA	2.40E-05	DPS WIDE RANGE LEVEL TRANSMITTER A (LEVEL 1&2) FAILS
B21-LT_-NO-DPSWRB	2.40E-05	DPS WIDE RANGE LEVEL TRANSMITTER B (LEVEL 1&2) FAILS
B21-LT_-NO-DPSWRC	2.40E-05	DPS WIDE RANGE LEVEL TRANSMITTER C (LEVEL 1&2) FAILS
B21-LT_-NO-DPSWRD	2.40E-05	DPS WIDE RANGE LEVEL TRANSMITTER D (LEVEL 1&2) FAILS
B21-LT_-NO-N001A	2.40E-05	WIDE RANGE LEVEL TRANSMITTER 1A (LEVEL 1&2) FAILS
B21-LT_-NO-N001B	2.40E-05	WIDE RANGE LEVEL TRANSMITTER 1B (LEVEL 1&2) FAILS
B21-LT_-NO-N001C	2.40E-05	WIDE RANGE LEVEL TRANSMITTER 1C (LEVEL 1&2) FAILS
B21-LT_-NO-N001D	2.40E-05	WIDE RANGE LEVEL TRANSMITTER 1D (LEVEL 1&2) FAILS
B21-OR_-PG-01A	1.44E-05	ORIFICE INSTR. LINE 1A FAILS TO REMAIN OPEN (PLUG)
B21-OR_-PG-01B	1.44E-05	ORIFICE INSTR. LINE 1B FAILS TO REMAIN OPEN (PLUG)
B21-OR_-PG-01C	1.44E-05	ORIFICE INSTR. LINE 1C FAILS TO REMAIN OPEN (PLUG)
B21-OR_-PG-01D	1.44E-05	ORIFICE INSTR. LINE 1D FAILS TO REMAIN OPEN (PLUG)
C31-VLU-FC-RUNBACK	7.80E-05	C31 SYSTEM VOTER LOGIC UNIT FAILS
C51-ACT-LO-CHASRNM	1.90E-02	SRNM CHANNEL A FAILS
C51-ACT-LO-CHBSRNM	1.90E-02	SRNM CHANNEL B FAILS
C51-ACT-LO-CHCSRNM	1.90E-02	SRNM CHANNEL C FAILS
C51-ACT-LO-CHDSRNM	1.90E-02	SRNM CHANNEL D FAILS
C51-VLU-FC-1APRM	7.80E-05	APRM DIV I 2/4 MODULE FAILS
C51-VLU-FC-2APRM	7.80E-05	APRM DIV II 2/4 MODULE FAILS
C51-VLU-FC-3APRM	7.80E-05	APRM DIV III 2/4 MODULE FAILS

Table 4.5-7

List of System Basic Events

Basic Event	Probability	Description
C51-VLU-FC-4APRM	7.80E-05	APRM DIV IV 2/4 MODULE FAILS
C62-BYP-FC-DIVBN1E	3.00E-04	BYPASS UNIT DIV B (N1E) FAILS TO FUNCTION
C62-BYP-FC-DIVCN1E	3.00E-04	BYPASS UNIT DIV C (N1E) FAILS TO FUNCTION
C62-VLU-FC-ESF1ADID	6.24E-04	1ST DIV A ESF VOTER LOGIC UNIT FAILS TO FUNCTION
C62-VLU-FC-ESF1BDID	6.24E-04	1ST DIV B ESF VOTER LOGIC UNIT FAILS TO FUNCTION
C62-VLU-FC-ESF1BN1E	6.24E-04	1ST DIV B N1E ESF VOTER LOGIC UNIT FAILS TO FUNCTION
C62-VLU-FC-ESF1CDID	6.24E-04	1ST DIV C (DID) ESF VOTER LOGIC UNIT FAILS TO FUNCTION
C62-VLU-FC-ESF1CN1E	6.24E-04	1ST DIV C N1E ESF VOTER LOGIC UNIT FAILS TO FUNCTION
C62-VLU-FC-ESF2ADID	6.24E-04	2ND DIV A (DID) ESF VOTER LOGIC UNIT FAILS TO FUNCTION
C62-VLU-FC-ESF2BDID	6.24E-04	2ND DIV B (DID) ESF VOTER LOGIC UNIT FAILS TO FUNCTION
C62-VLU-FC-ESF2BN1E	6.24E-04	2ND DIV B (N1E) ESF VOTER LOGIC UNIT FAILS TO FUNCTION
C62-VLU-FC-ESF2CDID	6.24E-04	2ND DIV C (DID) ESF VOTER LOGIC UNIT FAILS TO FUNCTION
C62-VLU-FC-ESF2CN1E	6.24E-04	2ND DIV C (N1E) ESF VOTER LOGIC UNIT FAILS TO FUNCTION
C72-BYP-FC-DPSDIV1	3.00E-04	BYPASS UNIT DIV 1 FAILS TO FUNCTION
C72-BYP-FC-DPSDIV2	3.00E-04	BYPASS UNIT DIV 1 FAILS TO FUNCTION
C72-BYP-FC-DPSDIV3	3.00E-04	BYPASS UNIT DIVIII FAILS TO FUNCTION
C72-BYP-FC-DPSDIV4	3.00E-04	BYPASS UNIT DIVIV FAILS TO FUNCTION
C72-DTM-FC-DPSDIV1	6.00E-04	DTM OF DPS DIV 1 FAILS TO TRIP
C72-DTM-FC-DPSDIV2	6.00E-04	DTM OF DPV DIV 2 FAILS TO TRIP
C72-DTM-FC-DPSDIV3	6.00E-04	DTM OF DPS DIV 3 FAILS TO TRIP
C72-DTM-FC-DPSDIV4	6.00E-04	DTM OF DPS DIV 4 FAILS TO TRIP
C72-VLU-FC-DPSESF11	6.24E-04	1ST DIV 1 ESF VOTER LOGIC UNIT FAILS TO FUNCTION
C72-VLU-FC-DPSESF12	6.24E-04	1ST DIV 1 ESF VOTER LOGIC UNIT FAILS TO

Table 4.5-7

List of System Basic Events

Basic Event	Probability	Description
		FUNCTION
C72-VLU-FC-DPSESF13	6.24E-04	1ST DIV III ESF VOTER LOGIC UNIT FAILS TO FUNCTION
C72-VLU-FC-DPSESF14	6.24E-04	1ST DIV IV ESF VOTER LOGIC UNIT FAILS TO FUNCTION
C72-VLU-FC-DPSESF21	6.24E-04	2ND DIV 1 ESF VOTER LOGIC UNIT FAILS TO FUNCTION
C72-VLU-FC-DPSESF22	6.24E-04	2ND DIV 1 ESF VOTER LOGIC UNIT FAILS TO FUNCTION
C72-VLU-FC-DPSESF23	6.24E-04	2ND DIV III ESF VOTER LOGIC UNIT FAILS TO FUNCTION
C72-VLU-FC-DPSESF24	6.24E-04	2ND DIV IV ESF VOTER LOGIC UNIT FAILS TO FUNCTION
C74-BYP-FC-DIV1	3.00E-04	BYPASS UNIT DIV 1 FAILS TO FUNCTION
C74-BYP-FC-DIV2	3.00E-04	BYPASS UNIT DIV 1 FAILS TO FUNCTION
C74-BYP-FC-DIV3	3.00E-04	BYPASS UNIT DIVIII FAILS TO FUNCTION
C74-BYP-FC-DIV4	3.00E-04	BYPASS UNIT DIVIV FAILS TO FUNCTION
C74-BYP-FC-DIVADID	3.00E-04	BYPASS UNIT DIV A (DID) FAILS TO FUNCTION
C74-BYP-FC-DIVBDID	3.00E-04	BYPASS UNIT DIV B (DID) FAILS TO FUNCTION
C74-BYP-FC-DIVCDID	3.00E-04	BYPASS UNIT DIV C (DID) FAILS TO FUNCTION
C74-DTM-FC-DIV1	6.00E-04	DTM OF SSLC DIV 1 FAILS TO TRIP
C74-DTM-FC-DIV2	6.00E-04	DTM OF SSLC DIV 2 FAILS TO TRIP
C74-DTM-FC-DIV3	6.00E-04	DTM OF SSLC DIV 3 FAILS TO TRIP
C74-DTM-FC-DIV4	6.00E-04	DTM OF SSLC DIV 4 FAILS TO TRIP
C74-VLU-FC-ESF11	6.24E-04	1ST DIV 1 ESF VOTER LOGIC UNIT FAILS TO FUNCTION
C74-VLU-FC-ESF12	6.24E-04	1ST DIV 1 ESF VOTER LOGIC UNIT FAILS TO FUNCTION
C74-VLU-FC-ESF13	6.24E-04	1ST DIV III ESF VOTER LOGIC UNIT FAILS TO FUNCTION
C74-VLU-FC-ESF14	6.24E-04	1ST DIV IV ESF VOTER LOGIC UNIT FAILS TO FUNCTION
C74-VLU-FC-ESF21	6.24E-04	2ND DIV 1 ESF VOTER LOGIC UNIT FAILS TO FUNCTION

Table 4.5-7

List of System Basic Events

Basic Event	Probability	Description
C74-VLU-FC-ESF22	6.24E-04	2ND DIV 1 ESF VOTER LOGIC UNIT FAILS TO FUNCTION
C74-VLU-FC-ESF23	6.24E-04	2ND DIV III ESF VOTER LOGIC UNIT FAILS TO FUNCTION
C74-VLU-FC-ESF24	6.24E-04	2ND DIV IV ESF VOTER LOGIC UNIT FAILS TO FUNCTION
H23-EMS-FC-DIV1	6.00E-04	ESSENTIAL MULTIPLEXING SYSTEM DIV 1 FAILS TO FUNCTION
H23-EMS-FC-DIV2	6.00E-04	ESSENTIAL MULTIPLEXING SYSTEM DIV 2 FAILS TO FUNCTION
H23-EMS-FC-DIV3	6.00E-04	ESSENTIAL MULTIPLEXING SYSTEM DIV 3 FAILS TO FUNCTION
H23-EMS-FC-DIV4	6.00E-04	ESSENTIAL MULTIPLEXING SYSTEM DIV 4 FAILS TO FUNCTION
H23-EMS-FC-DIVADID	6.00E-04	ESSENTIAL MULTIPLEXING SYSTEM DIV A (DID) FAILS TO FUNCTION
H23-EMS-FC-DIVBDID	6.00E-04	ESSENTIAL MULTIPLEXING SYSTEM DIV B (DID) FAILS TO FUNCTION
H23-EMS-FC-DIVBN1E	6.00E-04	ESSENTIAL MULTIPLEXING SYSTEM DIV B (N1E) FAILS TO FUNCTION
H23-EMS-FC-DIVCDID	6.00E-04	ESSENTIAL MULTIPLEXING SYSTEM DIV C (DID) FAILS TO FUNCTION
H23-EMS-FC-DIVCN1E	6.00E-04	ESSENTIAL MULTIPLEXING SYSTEM DIV C (N1E) FAILS TO FUNCTION
H23-EMS-FC-DPSDIV1	6.00E-04	ESSENTIAL MULTIPLEXING SYSTEM DPS DIV 1 FAILS TO FUNCTION
H23-EMS-FC-DPSDIV2	6.00E-04	ESSENTIAL MULTIPLEXING SYSTEM DPS DIV 2 FAILS TO FUNCTION
H23-EMS-FC-DPSDIV3	6.00E-04	ESSENTIAL MULTIPLEXING SYSTEM DPS DIV 3 FAILS TO FUNCTION
H23-EMS-FC-DPSDIV4	6.00E-04	ESSENTIAL MULTIPLEXING SYSTEM DPS DIV 4 FAILS TO FUNCTION
H23-RMU-FC-1ADS	3.00E-04	RMU 001 FOR MANUAL ACTUATION IN CONTROL ROOM FAILS
H23-RMU-FC-2ADS	3.00E-04	RMU 002 FOR MANUAL ACTUATION IN CONTROL ROOM FAILS
H23-RMU-FC-DIV1	3.00E-04	REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION

Table 4.5-7

List of System Basic Events

Basic Event	Probability	Description
H23-RMU-FC-DIV2	3.00E-04	REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION
H23-RMU-FC-DIV3	3.00E-04	REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION
H23-RMU-FC-DIV4	3.00E-04	REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION
H23-RMU-FC-DPS1ADS	3.00E-04	RMU 001 FOR MANUAL DPS ACTUATION IN CONTROL ROOM FAILS
H23-RMU-FC-DPS2ADS	3.00E-04	RMU 002 FOR MANUAL DPS ACTUATION IN CONTROL ROOM FAILS
H23-RMU-FC-DPSDIV1	3.00E-04	REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION
H23-RMU-FC-DPSDIV2	3.00E-04	REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION
H23-RMU-FC-DPSDIV3	3.00E-04	REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION
H23-RMU-FC-DPSDIV4	3.00E-04	REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION
H23-RMU-FC-DPSESF11	3.00E-04	1ST DIV II ESF REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION
H23-RMU-FC-DPSESF12	3.00E-04	REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION
H23-RMU-FC-DPSESF13	3.00E-04	1ST DIV III ESF REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION
H23-RMU-FC-DPSESF14	3.00E-04	1ST DIV IV ESF REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION
H23-RMU-FC-DPSESF21	3.00E-04	2ND DIV 1 ESF REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION
H23-RMU-FC-DPSESF22	3.00E-04	REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION
H23-RMU-FC-DPSESF23	3.00E-04	2ND DIVIII ESF REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION
H23-RMU-FC-DPSESF24	3.00E-04	2ND DIVIII ESF REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION
H23-RMU-FC-ESF11	3.00E-04	1ST DIV II ESF REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION
H23-RMU-FC-ESF12	3.00E-04	REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION

Table 4.5-7

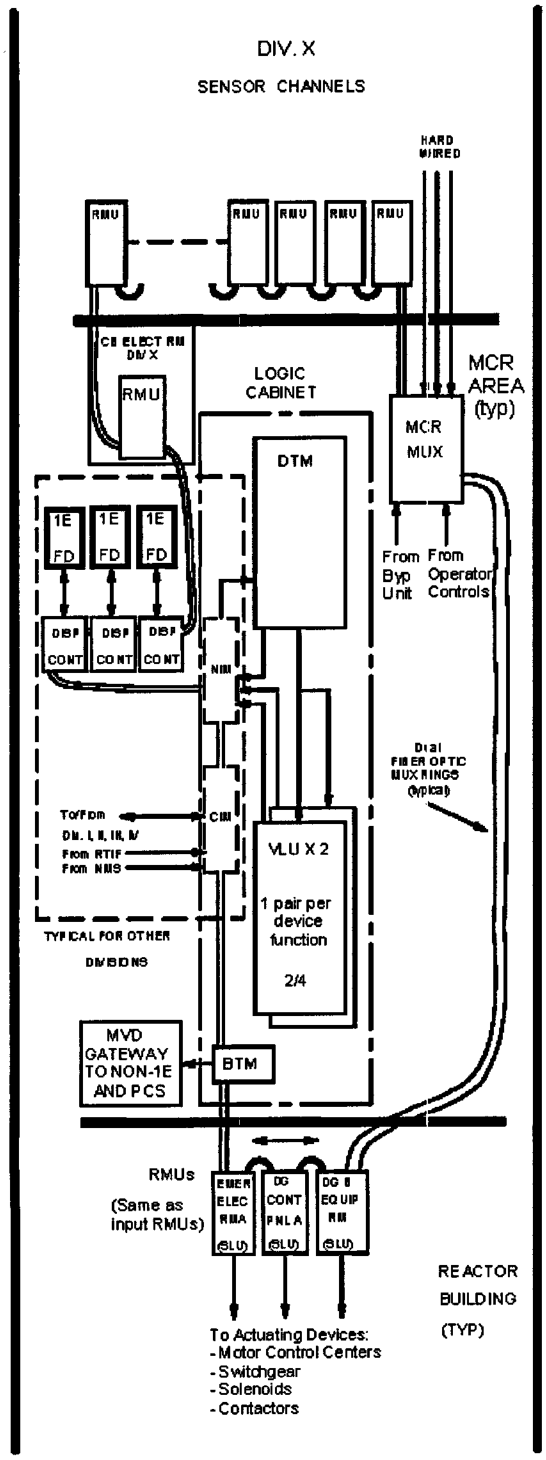
List of System Basic Events

Basic Event	Probability	Description
H23-RMU-FC-ESF13	3.00E-04	1ST DIV III ESF REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION
H23-RMU-FC-ESF14	3.00E-04	1ST DIV IV ESF REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION
H23-RMU-FC-ESF1ADID	3.00E-04	1ST DIV A (DID) ESF REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION
H23-RMU-FC-ESF1BDID	3.00E-04	1ST DIV B (DID) ESF REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION
H23-RMU-FC-ESF1BN1E	3.00E-04	1ST DIV B (N1E) ESF REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION
H23-RMU-FC-ESF1CDID	3.00E-04	1ST DIV C (DID) ESF REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION
H23-RMU-FC-ESF1CN1E	3.00E-04	1ST DIV C (N1E) ESF REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION
H23-RMU-FC-ESF21	3.00E-04	2ND DIV 1 ESF REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION
H23-RMU-FC-ESF22	3.00E-04	REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION
H23-RMU-FC-ESF23	3.00E-04	2ND DIVIII ESF REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION
H23-RMU-FC-ESF24	3.00E-04	2ND DIVIII ESF REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION
H23-RMU-FC-ESF2ADID	3.00E-04	2ND DIV A (DID) ESF REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION
H23-RMU-FC-ESF2BDID	3.00E-04	2ND DIV B (DID) ESF REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION
H23-RMU-FC-ESF2BN1E	3.00E-04	2ND DIV B (N1E) ESF REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION
H23-RMU-FC-ESF2CDID	3.00E-04	2ND DIV C DID ESF REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION
H23-RMU-FC-ESF2CN1E	3.00E-04	2ND DIV C (N1E) ESF REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION

Table 4.5-8

List of System Top Events

TOP EVENT	Description
GC31-0001-_1	FEEDWATER RUNBACK SIGNAL FAILURE
GC62-0001-_1	DIV A (NE RTNSS) SIGNAL TRANSMISSION FAILURE
GC62-0001-_2	DIV B (NE RTNSS) SIGNAL TRANSMISSION FAILURE
GC62-0001-_3	DIV C (NE RTNSS) SIGNAL TRANSMISSION FAILURE
GC62-0001-_4	DIV A (NE BOP) SIGNAL TRANSMISSION FAILURE
GC62-0001-_5	DIV B (NE BOP) SIGNAL TRANSMISSION FAILURE
GC62-0001-_6	DIV C (NE BOP) SIGNAL TRANSMISSION FAILURE
GC72-0001-_1	DPS DIV I SIGNAL TRANSMISSION FAILURE
GC72-0001-_2	DPS DIV II SIGNAL TRANSMISSION FAILURE
GC72-0001-_3	DPS DIV III SIGNAL TRANSMISSION FAILURE
GC72-0001-_4	DPS DIV IV SIGNAL TRANSMISSION FAILURE
GC72-0001-_5	LOSS OF DPS DIV 1 DPV & SRV ACTUATION SIGNAL
GC72-0001-_6	LOSS OF DPS DIV 2 DPV & SRV ACTUATION SIGNAL
GC74-0001-_1	SSLC DIV I SIGNAL TRANSMISSION FAILURE
GC74-0001-_2	SSLC DIV II SIGNAL TRANSMISSION FAILURE
GC74-0001-_3	SSLC DIV III SIGNAL TRANSMISSION FAILURE
GC74-0001-_4	SSLC DIV IV SIGNAL TRANSMISSION FAILURE
GC74-0001-_5	LOSS OF DIV 1 DPV & SRV ACTUATION SIGNAL
GC74-0001-_6	LOSS OF DIV 2 DPV & SRV ACTUATION SIGNAL
GC74-0001-_11	ADS INHIBIT FAILURE



DIV. X TYPICAL FOR :

- DIVISIONS I, II, III, IV of ESF subsystem.
- DIVISIONS A, B, C of DID subsystem.
- DIVISIONS A, B, C of NO 1E subsystem

Figure 4.5-1 (1/2). Simplified Diagram of Instrument, Logic and Control System

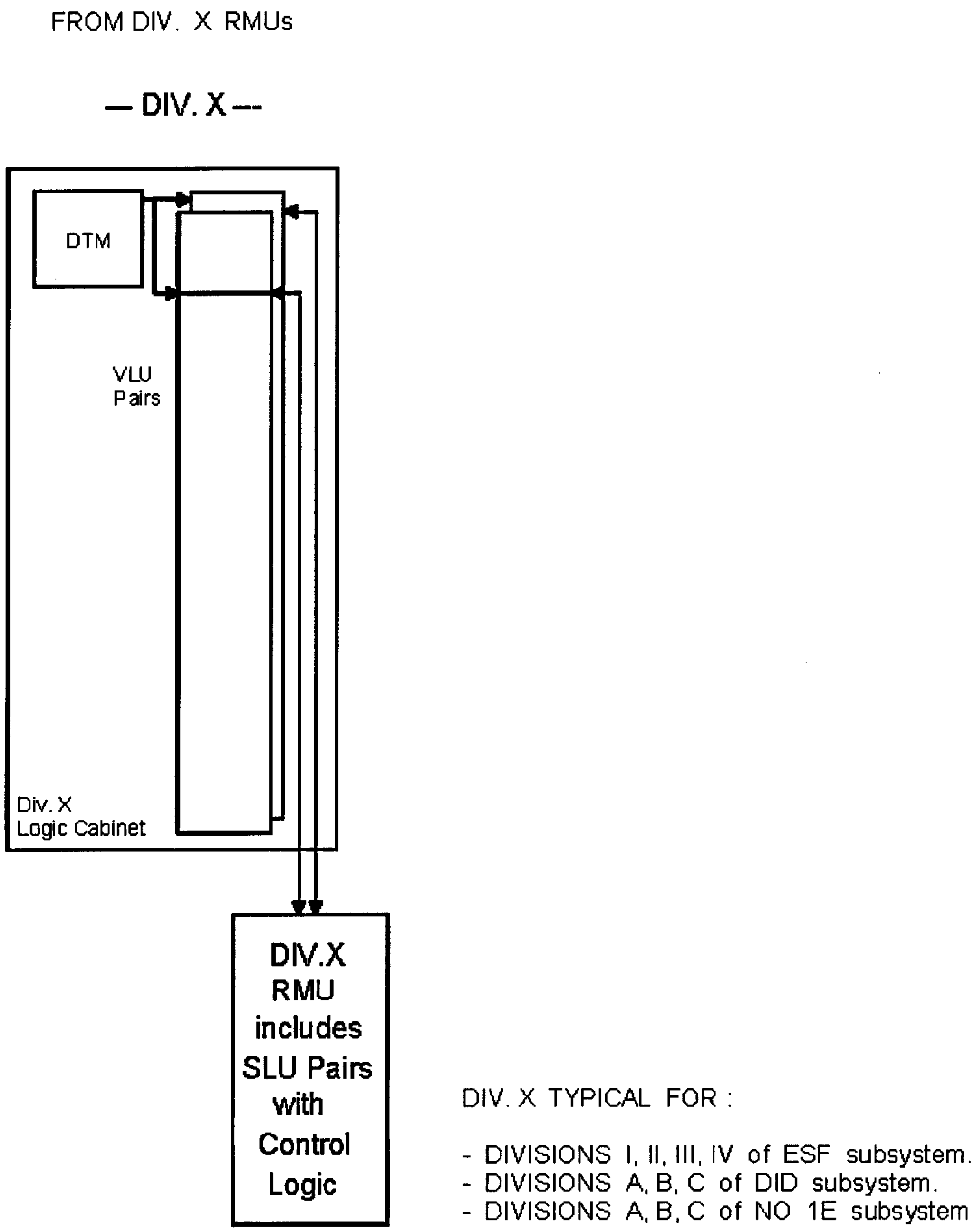


Figure 4.5-1 (2/2). Simplified Diagram of Instrument, Logic And Control System

4.6 GRAVITY-DRIVEN COOLING SYSTEM - (E50)

4.6.1 Purpose

The primary purpose of the Gravity-Driven Cooling System (GDCS) is to passively provide emergency core cooling after any event that threatens the reactor coolant inventory. Once the Nuclear Boiler System (NBS) has been depressurized via the Automatic Depressurization System (ADS), the GDCS is capable of passively injecting large volumes of water into the depressurized reactor pressure vessel (RPV) to keep the fuel covered over both short and long term time frames following system initiation.

Another function is to provide water to the lower drywell in case of a severe accident that causes RPV breach. This latter function has not been modeled in the Level 1 PRA.

In addition, the GDCS pools collect the condensate from the PCCS exchangers. GDCS includes pool water inventory, pool injection lines (main, branch secondary lines and deluge lines), suppression pool (S/P) equalizer lines, including strainers and pool piping penetrations.

The GDCS is not credited for unisolated breaks outside the containment.

4.6.2 Design Assumptions

The following assumptions with respect to the design are made:

(1) There are three elevated GDCS pools of water at drywell pressure.

(2) One 200 mm (8-inch) line (with a maintenance valve F004) carries water from each of two GDCS pools (Pools A and C), and two independent 200 mm (8-inch) lines carry water from the third GDCS pool (Pool B). These lines have a branch line that discharges into the drywell situated in the 8" pool discharge line between the manually operated valve nearest the pool (F004) and the check valve (F003). This line then branches into 3, each one with an explosive valve (F009). All three lines discharge into the upper drywell.

(3) Each of four 200 mm (8-inch) lines divides into two 150 mm (6-inch) lines. These six-inch lines each join the reactor pressure vessel at a nozzle.

(4) Each of the 150 mm (6-inch) lines has a squib valve (F002), a check valve (F003), a maintenance valve (F001), and small lines to allow testing of the check valves and flow paths.

(5) There are four 150 mm (6-inch) divisional lines (equalizing lines) to carry long-term water from the suppression pool (SP) to the RPV, and each of these lines has two maintenance valves (F005, F008), a squib valve (F006), a check valve (F007), and small lines to allow testing of check valves and flow paths.

(6) The manual valves of the RPV discharge lines and the connection to the SP are locked open.

Information regarding alarms and instrumentation is preliminary.

4.6.3 System Description

The GDCS consists of a short-term cooling subsystem and a long-term cooling subsystem, both of which provide cooling water under force of gravity to replace water inventory lost during a loss-of-coolant accident (LOCA) event and subsequent decay heat boil-off. A GDCS deluge subsystem discharges in the lower part of the upper drywell region water from GDCS for severe accident conditions.

The success criteria used in the model is summarized as follows:

- In the short term, injection is necessary through at least two of the eight GDCS 150 mm lines, and the discharge of 2 of the 3 pools.
- In the long term, at least one of the equalizing lines is to be operating to fulfill the function.

4.6.3.1 Hardware Configuration

A simplified diagram of the GDCS is shown in Figure 4.6-1. According to the design assumptions, the GDCS consists of two independent systems, the short term and the long term cooling systems. The short-term system supplies gravity-driven flow to eight separate nozzles on the vessel with suction flow from three separate GDCS pools. The long-term system supplies gravity-driven flow to four other nozzles with suction flow from the suppression pool (SP) through the equalizing lines.

Each division of the GDCS injection system consists of one 200 mm (8-inch) nominal diameter pipe (with a block valve) exiting from the GDCS pool and branching into two 150 mm (6-inch) paths, each containing one check valve, one squib valve, and one block valve. Each division of the long-term system consists of one 150 mm (6-inch) equalizing line with two block valves, a check valve, and a squib valve.

The twelve RPV injection line nozzles all contain integral flow limiters with a venturi-like shape and a minimum throat diameter of 75 mm (three inches) for short-term injection lines and 60 mm (two inches) for long-term injection lines. On each injection line, there is a locked open, manually operated maintenance valve located near the vessel nozzle and another such valve located near the water source.

In each of the 150 mm (6-inch) injection lines, the check valve is located upstream of the squib-actuated injection valve. The squib valve is designed to withstand reactor pressure without leakage during operation but, once actuated, it provides a permanent open flow path from the water source to the vessel. The check valves prevent gross reverse back flow to the pools after the squib valves are actuated if the vessel pressure is still higher than the pool pressure plus its gravity head. Once the vessel pressure has decayed below pool pressure, the differential pressure opens the check valve and allows water to begin flowing into the vessel.

The check valves are designed such that they remain partially open when zero pressure difference exists across the valve to limit core-cladding temperature. This is to minimize the potential for sticking in the closed position during long periods of non-use. Test connection lines are provided to provide a means of testing for both closing and opening operation.

The drywell-GDCS airspace has a mesh screen or equivalent to prevent the entry of debris material that might be carried into the pool, such as during a large break LOCA. A thermally

actuated deluge valve (Valves F009 on Figure 4.6-1) is connected to each of the four GDCS 200 mm (8-inch) downcomer lines in order to provide a means to flood the lower drywell cavity in the event of a core melt sequence which causes failure of the lower vessel head and allows the molten debris to reach the cavity floor.

4.6.3.2 System Operation

The GDCS begins operation following an RPV level 1 water level signal. The level 1 signal starts two sets of timers, two 150-second timers for initiation of the short-term water injection lines and two 30 minutes timers for initiation of the long-term injection lines. At 150 seconds after level 1, the eight squib valves (F002A-H) open to allow water flow from the GDCS pools to the RPV. This water flow maintains the RPV water level high enough to maintain the core submerged.

The long-term portion of GDCS begins operation 30 minutes after a level 1 signal, subject to the RPV transient water being no higher than one meter above the TAF, with opening of the four squib valves (F006A-D) on the four Suppression Pool (SP) to RPV equalizing lines. Therefore, the Level 1 RPV water level signal coupled with completion of the 30-minute timer gives the permissive for the Equalization line squib valves to fire when the RPV level reaches 1m above the Top of Active Fuel (Level 0.5). The small elevation difference between the SP and the RPV is sufficient to allow SP water to maintain RPV water level 30 minutes after shutdown.

The success criteria applied to the GDCS are that a sufficient number of GDCS lines must function in the short term and that a sufficient number of GDCS pools or SP equalizing lines are required for the long term.

In the short term, following a LOCA, GDCS lines from the GDCS pools are used to recover and maintain RPV level. In the medium and long term, the SP equalizing lines perform the RPV inventory control function while making up the following inventory losses:

- LOCA above the core:

  Evaporation losses to the drywell (Most evaporation is returned to the RPV through the isolation condensers or the passive containment cooling system (PCCS). Some moisture is vented to the SP from the PCCS.)

- Vessel bottom break

  Medium term:

  - Evaporation losses to the drywell
  - Break flow losses

  Long term:

  - Evaporation losses to the drywell

In the event that 7 of 8 GDCS pool lines fail, the SP equalizing lines alone are not sufficient to prevent core damage in the short term because of low flow due to the small available driving head. Even if the GDCS pool lines correctly operate, SP lines are necessary to maintain RPV level in the long term for some accident sequences.

Passive breaks of GDCS lines are not considered, other than as a specific LOCA initiating event, because GDCS lines are designed for full system pressure. No break due to high pressure is expected when squib valves are fired open.

4.6.3.3 Component Location

Basic components of the GDCS are located within the primary containment. The GDCS pools, piping and valves are all located in the drywell. The suppression pool is on the outer periphery of the drywell within the containment envelope. The logic elements that provide controls for the actuation of GDCS squib valves are outside primary containment and located in the corresponding four corners of the reactor building floors. Batteries that provide DC power to actuate the squib valves are located outside the containment.

The GDCS pools are located within the drywell at an elevation significantly above the top of the active core. The suppression pool water level is a few feet above the active core.

4.6.4 Automatic and Manual Control

Actuation of the GDCS is performed automatically, without the need for operator action. A backup to automatic actuation is the ability of operators to actuate the GDCS manually, if necessary.

Automatic Actuation. Automatic actuation of the GDCS is provided by an RPV level 1 water level signal (level 1). System logic then actuates the eight squib valves (F002A-H) installed in the 150 mm lines from GDCS Pools A, B, and C after a 150 sec time delay. The level 1 signal also actuates the ADS to reduce RPV pressure if other permissive logic is satisfied. (See ATWS discussion of ADS inhibit.) Also, after a longer time delay (30 min), the four squib valves (F006A-D) mounted on the SP equalizing lines are actuated, if the RPV transient water level is also less than one meter above the TAF.

The level 1 signals coming from Div. I, II, III, and IV level indicators (belonging to the Nuclear Boiler System) generate the GDCS logic divisional level 1 output signals that are sealed in for 30 minutes. Each divisional level 1 signal is passed to four different logic timers that initiate whenever two-out-of-four signals are sealed in.

The GDCS squib valves are identified in four different logic groups and two different time delay types (Table 4.6-1A). Two DC power divisions and two logic divisions are supplied for each valve to open. Each of the eight GDCS 150 mm line squib valves is similarly actuated.

Manual Actuation. The plant operator can actuate the GDCS manually if automatic actuation fails. Manual actuation, Short-Term and Long-Term (Equalizing), is interlocked to a low RPV pressure signal. Deluge squibs to flood drywell are interlocked with high-high Drywell pressure. The manual actuation circuit has four channels, one for each division. On the actuation circuitry for Type 2 valves (SP equalizing line valves), 30-minutes time delay logic is replicated to reproduce the sequence of the automatic actuation. To actuate the GDCS, the operator has to push two buttons at the same time. A signal coming from each button closes one switch for each division. If the pressure interlock switch is closed (low pressure conditions are present in the primary system), the signal remains sealed in for 30 minutes. This manual actuation process immediately fires open the valves located on the eight GDCS lines and, after 30 minutes, if the

RPV level has dropped below Level 0.5 (1 m above the TAF), actuates the SP equalizing line valves.

Instrumentation and Alarms. The instrument and alarm signals reported in the control room for the GDCS are given in Table 4.6-1B.

4.6.5 System Interfaces

The GDCS is a passive system that interfaces with two support systems and shares components with the RPV water level instrumentation and the other systems using the suppression pool. It only requires the following systems to be able to carry out its function:

- DC power supply (essential power)
- Safety System Logic and Control (SSLC)

Squib valves are fired by DC power. Dependency of each valve on specific DC power supply divisions and logic arrangement for each valve are shown in Table 4.6-2. The fault tree for loss of DC power is modeled in Section 4.17.

SSLC Divisional signals provide the automatic and manual initiating signal. Loss of the uninterruptible AC power supply system (R13) is modeled in Section 4.15.

4.6.6 System Testing

General testing of GDCS equipment is performed during refueling. Table 4.6-3 shows the test program for the system. The only valves directly operated for testing are the normally closed isolation valves on the test lines. Flow through the test lines is used to open and close check valves and to show that there is no obstruction of the RPV nozzles. Valve realignment following testing is controlled administratively. A non-intrusive magnetically coupled torque-motor together with disc position sensor are used on the check valve to test and monitor position. The torque motor and sensor provide the capability for in-service surveillance testing. With regards to model assumptions, it is assumed that this test is performed quarterly.

No unavailability events during power operation due to tests or maintenance are postulated, as there are considered to be enough administrative controls to make their contribution negligible.

4.6.7 System Maintenance

Maintenance of GDCS components is performed during refueling, every two years. There is no maintenance of components during plant operation.

4.6.8 Common Cause Failures

The GDCS provides a high degree of redundancy. That redundancy increases the relative importance of common cause failure (CCF) in overall system unavailability. The mechanical components that are more exposed to CCF events involving just the GDCS are the following:

- Orifices in injection and equalizing lines
- Squib valves
- SP suction line strainers

Common cause failures within the system, including the CCF of the logic, are summarized in Table 4.6-5.

Squib valve failure is mainly affected by failure of initiators. Common environmental conditions expose initiators to CCF due to:

- High temperature in the drywell
- Aging
- Irradiation
- Humidity
- Jet impingement

The squib valve CCFs that would affect the various modeled functions are postulated in the fault tree.

Suction line strainers plugging as a CCF can occur after a LOCA when debris is discharged into the SP via drywell to wetwell vents.

The common cause failures related to the instrumentation and logic which affect the system appear in the last part of Table 4.6-5.

4.6.9 Fault Tree Analysis

The GDCS failure tree has been evaluated to determine the system unavailability and which components contribute significantly to system unavailability.

4.6.9.1 Top Event Definitions

A TOP event has been modeled which represents short-term and long-term coolant supply. The contributions to the failure (with their corresponding gates) are the following:

- Two-of-eight GDCS lines needed, short term (failure in 7 of the 8 lines) - GE50TOP1
- Two-of-three GDCS pools needed (failure in 2 of the 3 GDCS pools), long term - GE50TOP2
- One equalizing line needed (failure in the 4 equalizing lines), long term - GE50TOP3
- One-of-three GDCS pools fails to discharge - GE50TOP4
- Three-of-three GDCS pools fail to discharge - GE50TOP5
- Two-of-three GDCS pools fail to discharge and four-of-four equalizing lines fail to open - GE50TOP6

4.6.9.2 Model Assumptions

The possibility that the LOCA occurs in one of the discharge lines in pool B, the most limiting case, is being considered, because if it happened, the discharge of this pool would not be effective, affecting 4 discharge lines.

It is assumed that check valve tests are performed quarterly (See Table 4.6-3).

The catastrophic failures of the GDCS pools are not considered, because none of them lead to the failure of the functions and their combination with other failures is highly improbable.

The Type C human actions included in the model are included in the Emergency Operating Procedures or in other Operating Procedures.

4.6.9.3 Fault Tree Description

The fault tree for GE50TOP is developed in Appendix B.4.6.

Among the dominant contributors to failure in the long term is the failure probability that none of the three equalizing lines from the SP function for long term core cooling following a level 1 signal.

4.6.9.4 Human Interactions

Human errors appear in Table 4.6-6. In the failure tree, this error is connected in a logic OR gate with a house event to allow for its inclusion in the reliability analysis The contribution to GDCS unavailability due to Locked-open Maintenance Valves mispositioning can be disregarded considering that:

- They are maneuvered only during special maintenance occasions.
- They are located inside the drywell and are locked open.
- Their status indication is reported in the control room.
- Administrative procedures assist operators in verifying valve status before each start-up.

Human actions in support of automatic actuations must be covered in the corresponding procedures.

4.6.10 Results of Fault Tree Analysis

The quantification of core damage sequences implicitly includes the contribution of basic events for this system. This quantification process enables checking the global consistency of the system fault trees and their relationship with the rest of the systems modeled in the PRA.

A summary of basic events included in the system fault tree is reported in Table 4.6-7.

On the other hand, the importance measurements obtained from core damage frequency equations, allow identification of the most relevant basic events and system component failures in an integrated context, as well as the determination of their relative importance with respect to the basic events and component failures of the other systems modeled.

4.6.11 Model Differences for 72-hour Operation

The long term GDCS operation with the core cooling water provided from the GDCS pools or through one of four suppression pool equalizer lines continues beyond 24 hours. There are no model changes necessary to extend operation to 72 hours.

4.6.12 References

4.6-1. ESBWR Design Control Document, 26A6642 Rev. 01

Table 4.6-1A

GDCS Squib Valve Grouping

	Pool A	**Pool B**	**Pool C**	**SP**
TYPE 1	F002A	F002B	F002D	
	F002E	F002F	F002H	
		F002C		
		F002G		
TYPE 2				F006A
				F006B
				F006C
				F006D

Note:

Type 1 valves actuate 150 seconds after Level 1 signal, and Type 2 valves actuate 30 minutes after Level 1 signal provided Level 0.5 is achieved (See 4.6.3.2).

Table 4.6-1B

Control Room Instrumentation And Alarms

Controls
Squib valves actuation
Displays
GDCS Pool Level
SP Pool Level
Locked-open manually operated maintenance valve status (F001A-H, F004A-D, F005A-D, F008A-D)
Squib Valve Status (F002A-H, F006A-D)
Alarms
GDCS Pool Level
SP Pool Level

Table 4.6-2

System Dependency Matrix

Component	Type	Support System Power Actuation 250 V DC (R16) DIV 1	DIV 2	DIV 3	DIV 4
F002A	Squib valve	X			X
F002B	Squib valve		X	X	
F002C	Squib valve	X			X
F002D	Squib valve		X	X	
F002E	Squib valve	X			X
F002F	Squib valve		X	X	
F002G	Squib valve	X			X
F002H	Squib valve		X	X	
F006A	Squib valve	X			X
F006B	Squib valve		X	X	
F006C	Squib valve	X			X
F006D	Squib valve		X	X	
F009A	Squib valve	X			X
F009B	Squib valve		X	X	
F009C	Squib valve	X			X
F009D	Squib valve		X	X	
F009E	Squib valve	X			X
F009F	Squib valve		X	X	
F009G	Squib valve	X			X
F009H	Squib valve		X	X	
F009I	Squib valve	X			X
F009J	Squib valve		X	X	
F009K	Squib valve	X			X
F009L	Squib valve		X	X	

Table 4.6-2

System Dependency Matrix

		Support System			
		SSLC Signal		DPS (C72)	
Component	Type	DIV 1	DIV 2	DIV 3	DIV 4
F002A	Squib valve	X			X
F002B	Squib valve		X	X	
F002C	Squib valve	X			X
F002D	Squib valve		X	X	
F002E	Squib valve	X			X
F002F	Squib valve		X	X	
F002G	Squib valve	X			X
F002H	Squib valve		X	X	
F009A	Squib valve	X			X
F009B	Squib valve		X	X	
F009C	Squib valve	X			X
F009D	Squib valve		X	X	
F009E	Squib valve	X			X
F009F	Squib valve		X	X	
F009G	Squib valve	X			X
F009H	Squib valve		X	X	
F009I	Squib valve	X			X
F009J	Squib valve		X	X	
F009K	Squib valve	X			X
F009L	Squib valve		X	X	

		Support System			
		SSLC Signal			
Component	Type	DIV 1	DIV 2	DIV 3	DIV 4
F006A	Squib valve	X			X
F006B	Squib valve		X	X	
F006C	Squib valve	X			X
F006D	Squib valve		X	X	

Table 4.6-3

Component Test

Component Type	Expected Test Interval	Components aligned away from emergency position without automatic return logic
Check valves (F003A-H)	Quarterly	Test Valves
Check Valves (F007A-D)	Quarterly	Test Valves
Maintenance valves (F001A-H, F004A-D, F005A-D, F008A-D)	24 Months	None

Note: See Section 4.6.6

Table 4.6-4

Component Maintenance

Maintenance of the GDCS components is performed during refueling, every two years. There is no maintenance of components during plant operation.

Therefore, no unavailability events during power operation due to tests or maintenance are postulated in the model, as there are considered to be sufficient administrative controls to make their contribution negligible.

Table 4.6-5

List of System Common Cause Failures

Basic Event	Prob	Description
B21-LT_-CF-N001ABCD	1.20E-07	CCF OF DIVERSIFIED LEVEL 1& 2 TRANSM. 1A/B/C/D
B21-LT_-CF-N012ABCD	7.00E-08	CCF 3/4 LEVEL TRANSMITTERS N012A/B/C/D
B21-OR_-CF-N012ABCD	4.00E-08	CCF 3/4 ORIFICES LINES 12 A/B/C/D (PLUG)
B21-PT_-CF-02HIGH	3.00E-08	CCF OF PRESSURE RPV TRANSMITTERS HIGH
C51-ACT-CF-APRMSTUCK	2.10E-07	CCF APRM DETECTORS STUCK AT POWER LEVEL
C74-DTM-CF-ALL	1.20E-05	CCF 3/4 DTM OF SSLC DIV1/2/3/4
E50-OR_-CF-4EQUA	4.00E-08	CCF OF 4 ORIFICES EQUALIZING LINES (PLUG)
E50-OR_-CF-4PLUG	7.00E-08	CCF OF 4 OR MORE ORIFICES TO PLUG
E50-OR_-CF-7PLUG	7.00E-08	CCF OF 7 ORIFICES TO PLUG
E50-OR_-CF-D001AE	7.20E-07	CCF 2/2 ORIFICES LINES A AND E (PLUG)
E50-OR_-CF-D001BCFG	7.00E-08	CCF 4/4 ORIFICES LINES B, C, F AND G (PLUG)
E50-OR_-CF-D001DH	7.20E-07	CCF 2/2 ORIFICES LINES D AND H (PLUG)
E50-OR_-CF-PLUGALL	7.20E-08	CCF OF ALL ORIFICES TO PLUG
E50-SQV-CF-EQALLOPEN	3.00E-05	CCF OF ALL 4 SQUIB VALVES TO OPEN
E50-SQV-CF-F002A/2E	3.60E-05	CCF OF SQUIB VALVES F002A/ F002E
E50-SQV-CF-F002B/2C/2F/2G	1.50E-05	CCF OF SQUIB VALVES F002B/ F002C/ F002F/ F002G
E50-SQV-CF-F002D/2H	3.60E-05	CCF OF SQUIB VALVES F002D/ F002H
E50-SQV-CF-GDCS7OPEN	1.50E-05	CCF OF 7 SQUIB VALVES IN GDCS LINES TO OPEN
E50-SQV-CF-OPENALL	1.50E-05	CCF OF ALL SQUIB VALVES TO OPEN
E50-STR-CF-SPPLUG	3.75E-04	CCF FILTER/STRAINER IN PSP TO PLUG

Table 4.6-6

List of System Human Errors

Basic Event	Prob	Description
E50-XHE-FO-EQU	1.61E-03	OPERATOR FAILS TO ACTUATE GDCS
E50-XHE-FO-GDCS	1.61E-03	OPERATOR FAILS TO ACTUATE GDCS
XXX-XHE-FO-RPVLDE	1.61E-02	OP. FAILS TO RECOG. OR CHECK THE RPV DECREASING LEVEL

Table 4.6-7 Basic Events		
Basic Event	**Prob**	**Description**
B21-LT_-CF-N001ABCD	1.20E-07	CCF OF DIVERSIFIED LEVEL 1& 2 TRANSM. 1A/B/C/D
B21-LT_-CF-N012ABCD	7.00E-08	CCF 3/4 LEVEL TRANSMITTERS N012A/B/C/D
B21-LT_-NO-N012A	2.40E-05	WIDE RANGE LEVEL TRANSMITTER 12A FAILS
B21-LT_-NO-N012B	2.40E-05	WIDE RANGE LEVEL TRANSMITTER 12B FAILS
B21-LT_-NO-N012C	2.40E-05	WIDE RANGE LEVEL TRANSMITTER 12C FAILS
B21-LT_-NO-N012D	2.40E-05	WIDE RANGE LEVEL TRANSMITTER 12D FAILS
B21-OR_-CF-N012ABCD	4.00E-08	CCF 3/4 ORIFICES LINES 12 A/B/C/D (PLUG)
B21-OR_-PG-12A	1.44E-05	ORIFICE INSTR. LINE 12A FAILS TO REMAIN OPEN (PLUG)
B21-OR_-PG-12B	1.44E-05	ORIFICE INSTR. LINE 12B FAILS TO REMAIN OPEN (PLUG)
B21-OR_-PG-12C	1.44E-05	ORIFICE INSTR. LINE 12C FAILS TO REMAIN OPEN (PLUG)
B21-OR_-PG-12D	1.44E-05	ORIFICE INSTR. LINE 12D FAILS TO REMAIN OPEN (PLUG)
B21-PT_-CF-02HIGH	3.00E-08	CCF OF PRESSURE RPV TRANSMITTERS HIGH
C51-ACT-CF-APRMSTUCK	2.10E-07	CCF APRM DETECTORS STUCK AT POWER LEVEL
C74-DTM-CF-ALL	1.20E-05	CCF 3/4 DTM OF SSLC DIV1/2/3/4
C74-DTM-FC-DIV1	6.00E-04	DTM OF SSLC DIV 1 FAILS TO TRIP
C74-DTM-FC-DIV2	6.00E-04	DTM OF SSLC DIV 2 FAILS TO TRIP
C74-DTM-FC-DIV3	6.00E-04	DTM OF SSLC DIV 3 FAILS TO TRIP
C74-DTM-FC-DIV4	6.00E-04	DTM OF SSLC DIV 4 FAILS TO TRIP
C74-SLU-CF-DLTD	1.08E-05	CCFs TO OPERATE OF DISCRETE LOGIC TIME DELAYs
C74-SLU-FC-LMU12A	9.00E-04	LMU 12A FAILURE
C74-SLU-FC-LMU12B	9.00E-04	LMU 12B FAILURE
C74-SLU-FC-LMU12C	9.00E-04	LMU 12C FAILURE
C74-SLU-FC-LMU12D	9.00E-04	LMU 12D FAILURE
E50-OR_-CF-4EQUA	4.00E-08	CCF OF 4 ORIFICES EQUALIZING LINES (PLUG)
E50-OR_-CF-4PLUG	7.00E-08	CCF OF 4 OR MORE ORIFICES TO PLUG
E50-OR_-CF-7PLUG	7.00E-08	CCF OF 7 ORIFICES TO PLUG
E50-OR_-CF-D001AE	7.20E-07	CCF 2/2 ORIFICES LINES A AND E (PLUG)
E50-OR_-CF-D001BCFG	7.00E-08	CCF 4/4 ORIFICES LINES B, C, F AND G (PLUG)
E50-OR_-CF-D001DH	7.20E-07	CCF 2/2 ORIFICES LINES D AND H (PLUG)
E50-OR_-CF-PLUGALL	7.20E-08	CCF OF ALL ORIFICES TO PLUG
E50-OR_-PG-D001A	1.44E-05	ORIFICE 001A FAILS TO REMAIN OPEN (PLUG) [# 5]
E50-OR_-PG-D001B	1.44E-05	ORIFICE 001B FAILS TO REMAIN OPEN (PLUG) [# 5]
E50-OR_-PG-D001C	1.44E-05	ORIFICE 001C FAILS TO REMAIN OPEN (PLUG) [# 5]
E50-OR_-PG-D001D	1.44E-05	ORIFICE 001D FAILS TO REMAIN OPEN (PLUG) [# 5]
E50-OR_-PG-D001E	1.44E-05	ORIFICE 001E FAILS TO REMAIN OPEN (PLUG) [# 5]
E50-OR_-PG-D001F	1.44E-05	ORIFICE 001F FAILS TO REMAIN OPEN (PLUG) [# 5]

Table 4.6-7

Basic Events

Basic Event	Prob	Description
E50-OR_-PG-D001G	1.44E-05	ORIFICE 001G FAILS TO REMAIN OPEN (PLUG) [# 5]
E50-OR_-PG-D001H	1.44E-05	ORIFICE 001H FAILS TO REMAIN OPEN (PLUG) [# 5]
E50-OR_-PG-D002A	1.44E-05	ORIFICE 002A FAILS TO REMAIN OPEN (PLUG) [# 5]
E50-OR_-PG-D002B	1.44E-05	ORIFICE 002B FAILS TO REMAIN OPEN (PLUG) [# 5]
E50-OR_-PG-D002C	1.44E-05	ORIFICE 002C FAILS TO REMAIN OPEN (PLUG) [# 5]
E50-OR_-PG-D002D	1.44E-05	ORIFICE 002D FAILS TO REMAIN OPEN (PLUG) [# 5]
E50-POL-RP-POOLA	3.00E-07	GDCS POOL A LEAKS CATASTROPHICALLY
E50-POL-RP-POOLB	3.00E-07	GDCS POOL B LEAKS CATASTROPHICALLY
E50-POL-RP-POOLC	3.00E-07	GDCS POOL C LEAKS CATASTROPHICALLY
E50-SQV-CC-F002A	3.00E-03	SQUIB VALVE F002A FAILS TO OPERATE
E50-SQV-CC-F002B	3.00E-03	SQUIB VALVE F002B FAILS TO OPERATE
E50-SQV-CC-F002C	3.00E-03	SQUIB VALVE F002C FAILS TO OPERATE
E50-SQV-CC-F002D	3.00E-03	SQUIB VALVE F002D FAILS TO OPERATE
E50-SQV-CC-F002E	3.00E-03	SQUIB VALVE F002E FAILS TO OPERATE
E50-SQV-CC-F002F	3.00E-03	SQUIB VALVE F002F FAILS TO OPERATE
E50-SQV-CC-F002G	3.00E-03	SQUIB VALVE F002G FAILS TO OPERATE
E50-SQV-CC-F002H	3.00E-03	SQUIB VALVE F002H FAILS TO OPERATE
E50-SQV-CC-F006A	6.00E-03	SQUIB VALVE F006A FAILS TO OPERATE IN EXTREME CONDITIONS
E50-SQV-CC-F006B	6.00E-03	SQUIB VALVE F006B FAILS TO OPERATE IN EXTREME CONDITIONS
E50-SQV-CC-F006C	6.00E-03	SQUIB VALVE F006C FAILS TO OPERATE IN EXTREME CONDITIONS
E50-SQV-CC-F006D	6.00E-03	SQUIB VALVE F006D FAILS TO OPERATE IN EXTREME CONDITIONS
E50-SQV-CF-4OPEN	1.50E-05	CCF OF 4 OR MORE SQUIB VALVES TO OPEN
E50-SQV-CF-EQALLOPEN	3.00E-05	CCF OF ALL 4 SQUIB VALVES TO OPEN
E50-SQV-CF-F002A/2E	3.60E-05	CCF OF SQUIB VALVES F002A/ F002E
E50-SQV-CF-F002B/2C/2F/2G	1.50E-05	CCF OF SQUIB VALVES F002B/ F002C/ F002F/ F002G
E50-SQV-CF-F002D/2H	3.60E-05	CCF OF SQUIB VALVES F002D/ F002H
E50-SQV-CF-GDCS7OPEN	1.50E-05	CCF OF 7 SQUIB VALVES IN GDCS LINES TO OPEN
E50-SQV-CF-OPENALL	1.50E-05	CCF OF ALL SQUIB VALVES TO OPEN
E50-SQV-CO-F009A	3.50E-03	SQUIB DELUGE VALVE F009A SPUR. OPENING [#7]
E50-SQV-CO-F009B	3.50E-03	SQUIB DELUGE VALVE F009B SPUR. OPENING [#7]
E50-SQV-CO-F009C	3.50E-03	SQUIB DELUGE VALVE F009C SPUR. OPENING [#7]
E50-SQV-CO-F009D	3.50E-03	SQUIB DELUGE VALVE F009D SPUR. OPENING [#7]
E50-SQV-CO-F009E	3.50E-03	SQUIB DELUGE VALVE F009E SPUR. OPENING [#7]
E50-SQV-CO-F009F	3.50E-03	SQUIB DELUGE VALVE F009F SPUR. OPENING [#7]
E50-SQV-CO-F009G	3.50E-03	SQUIB DELUGE VALVE F009G SPUR. OPENING [#7]
E50-SQV-CO-F009H	3.50E-03	SQUIB DELUGE VALVE F009H SPUR. OPENING [#7]
E50-SQV-CO-F009I	3.50E-03	SQUIB DELUGE VALVE F009I SPUR. OPENING [#7]
E50-SQV-CO-F009J	3.50E-03	SQUIB DELUGE VALVE F009J SPUR. OPENING [#7]
E50-SQV-CO-F009K	3.50E-03	SQUIB DELUGE VALVE F009K SPUR. OPENING [#7]

Table 4.6-7

Basic Events

Basic Event	Prob	Description
E50-SQV-CO-F009L	3.50E-03	SQUIB DELUGE VALVE F009L SPUR. OPENING [#7]
E50-STR-CF-SPPLUG	3.75E-04	CCF FILTER/STRAINER IN PSP TO PLUG
E50-STR-PG-K001A	1.07E-02	STRAINER/FILTER K001A PLUGS DURING OPERATION
E50-STR-PG-K001B	1.07E-02	STRAINER/FILTER K001B PLUGS DURING OPERATION
E50-STR-PG-K001C	1.07E-02	STRAINER/FILTER K001C PLUGS DURING OPERATION
E50-STR-PG-K001D	1.07E-02	STRAINER/FILTER K001D PLUGS DURING OPERATION
E50-SYS-FF-MSLOCA	3.91E-01	PROBABILITY OF MEDIUM STEAM LOCA IN GDCS LINES
E50-SYS-FF-SSLOCA	3.90E-01	PROBABILITY OF SSLOCA IN GDCS LINES
E50-UV_-OC-F003A	1.75E-03	CHECK VALVE F003A FAILS TO REMAIN OPEN OR PLUG
E50-UV_-OC-F003B	1.75E-03	CHECK VALVE F003B FAILS TO REMAIN OPEN OR PLUG
E50-UV_-OC-F003C	1.75E-03	CHECK VALVE F003C FAILS TO REMAIN OPEN OR PLUG
E50-UV_-OC-F003D	1.75E-03	CHECK VALVE F003D FAILS TO REMAIN OPEN OR PLUG
E50-UV_-OC-F003E	1.75E-03	CHECK VALVE F003E FAILS TO REMAIN OPEN OR PLUG
E50-UV_-OC-F003F	1.75E-03	CHECK VALVE F003F FAILS TO REMAIN OPEN OR PLUG
E50-UV_-OC-F003G	1.75E-03	CHECK VALVE F003G FAILS TO REMAIN OPEN OR PLUG
E50-UV_-OC-F003H	1.75E-03	CHECK VALVE F003H FAILS TO REMAIN OPEN OR PLUG
E50-UV_-OC-F007A	1.75E-03	CHECK VALVE F007A FAILS TO REMAIN OPEN OR PLUG
E50-UV_-OC-F007B	1.75E-03	CHECK VALVE F007B FAILS TO REMAIN OPEN OR PLUG
E50-UV_-OC-F007C	1.75E-03	CHECK VALVE F007C FAILS TO REMAIN OPEN OR PLUG
E50-UV_-OC-F007D	1.75E-03	CHECK VALVE F007D FAILS TO REMAIN OPEN OR PLUG
E50-XHE-FO-EQU	1.61E-03	OPERATOR FAILS TO ACTUATE GDCS
E50-XHE-FO-GDCS	1.61E-03	OPERATOR FAILS TO ACTUATE GDCS
H23-RMU-FC-CRF0061	3.00E-04	RMU DIV 1 FOR MANUAL ACTUATION IN CONTROL ROOM FAILS
H23-RMU-FC-CRF0062	3.00E-04	RMU DIV 2 FOR MANUAL ACTUATION IN CONTROL ROOM FAILS
H23-RMU-FC-CRF0063	3.00E-04	RMU DIV 3 FOR MANUAL ACTUATION IN CONTROL ROOM FAILS

Table 4.6-7

Basic Events

Basic Event	Prob	Description
H23-RMU-FC-CRF0064	3.00E-04	RMU DIV 4 FOR MANUAL ACTUATION IN CONTROL ROOM FAILS
H23-RMU-FC-DPSE503	3.00E-04	RMU DIV 3 FOR MANUAL ACTUATION IN CONTROL ROOM FAILS
H23-RMU-FC-DPSE504	3.00E-04	RMU DIV 4 FOR MANUAL ACTUATION IN CONTROL ROOM FAILS
H23-RMU-FC-E50DIV1	3.00E-04	RMU DIV 1 FOR MANUAL ACTUATION IN CONTROL ROOM FAILS
H23-RMU-FC-E50DIV2	3.00E-04	RMU DIV 2 FOR MANUAL ACTUATION IN CONTROL ROOM FAILS
T23-POL-RP-SP	3.00E-07	SUPPRESSION POOL LEAKS CATASTROPHICALLY
XXX-SYS-FF-SCRAMFOLLOW	7.80E-05	LOSS OF SCRAM FOLLOW SIGNAL. (2/4 RELAY LOGIC FAILURE
XXX-XHE-FO-RPVLDE	1.61E-02	OP. FAILS TO RECOG. OR CHECK THE RPV DECREASING LEVEL

Table 4.6-8

List of System Top Events

Top Event Name	Description
GE50TOP	2/8 LINES, 2/3 GDCS POOLS AND 1/4 EQUALIZING LINES
GE50TOP1	7/8 LINES FAIL TO INJECT INTO RPV
GE50TOP2	2/3 GDCS POOLS FAIL TO DISCHARGE
GE50TOP3	4/4 EQUALIZING LINES FAIL TO INJECT INTO RPV
GE50TOP4	1/3 GDCS POOLS FAILS TO DISCHARGE
GE50TOP5	3/3 GDCS POOLS FAIL TO DISCHARGE
GE50TOP6	2/3 GDCS POOLS FAIL TO DISCHARGE AND 4/4 EQUALIZING LINES FAILS TO OPEN

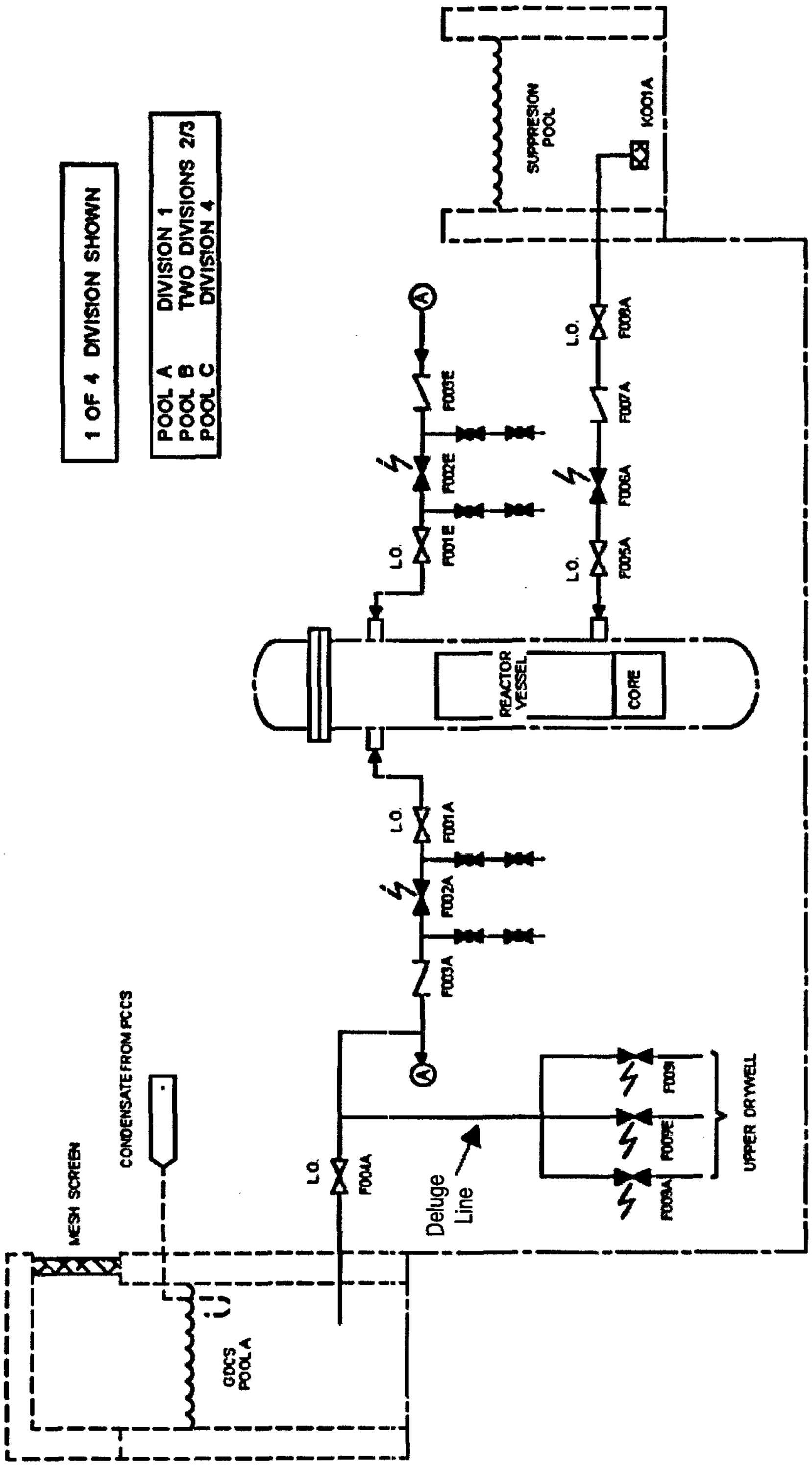


Figure 4.6-1. Simplified Process Flow Diagram for GDCS System

4.7 FUEL AND AUXILIARY POOLS COOLING SYSTEM - (G21) AND FIRE PROTECTION SYSTEM - (U43)

4.7.1 Purpose

For its non-safety related functions the Fuel and Auxiliary Pools Cooling System (FAPCS) is designed to perform pool water cooling, cleanup, and distribution to the following pools (operation in the FAPC mode) in the reactor building and auxiliary fuel building:

e. Spent Fuel Storage Pool

f. Cask Loading and Transfer Pool

g. Inclined Fuel Transfer System Lower Pool

h. Equipment Storage Pools

i. Reactor Well

j. Isolation Condenser and Passive Containment Cooling (IC/PCC) Pool

k. Gravity Driven Cooling System (GDCS) Pools

l. Suppression Pool

The FAPCS is also designated as a back-up to provide makeup water from the suppression pool to the reactor pressure vessel (RPV) through one of the main feedwater lines after the reactor has been depressurized down to approximately 5 bar (74 psi), under an accident condition, (operation in low pressure coolant injection - LPCI mode). This enables, in conjunction with the safety-relief valves in the nuclear boiler system, that the FAPCS is capable of providing backup shutdown cooling water.

The FAPCS is also used to drain the reactor well to permit removal and replacement of the drywell head and the Reactor Pressure Vessel (RPV) head during outages, and to refill the reactor well to support refueling and ultimately power generation operations.

For its safety-related functions, the FAPCS is also able to provide cooling water during the long term using a pipe connection to convey water for post loss-of-coolant accident (LOCA) recovery after 72 hours to the IC/PCC pool. It is also capable to convey water using passive-type pipe connections to the spent fuel storage pool at the end of 72 hours post-LOCA period.

For containment isolation purposes, the portions of the FAPCS that penetrate the containment are also considered to be safety-related.

The functions included in the PRA model are:

- Suppression Pool cooling mode.
- Low pressure coolant injection (LPCI mode).

It is possible to inject water through the FAPCS into the vessel from the Fire Protection System (FPS) through the line corresponding to the LPCI mode. In addition, using this system, it is possible to supply water to the upper pools (IC/PCC pool) from the FPS. Both connections are represented in the simplified diagram (Figure 4.7-1(A)). The fault tree corresponding to the

failure of these supplies, both to the vessel and to the IC/PCC pool, is also included within this system description and the associated fault tree models.

4.7.2 Design Assumptions

The following assumptions with respect to the design are made:

(1) The FAPCS automatically actuates in the suppression pool cooling (SPC) mode on a suppression pool high temperature signal (see Section 4.7.4), whenever the system has not been previously aligned for low pressure coolant injection mode.

(2) The loss of pneumatic supplies do not fail FACPS or FPS. It is assumed that the necessary measures will be taken to make air operated valves not dependent from the Instrument Air System on emergency situation.

(3) The electrical supplies are provided according to System Dependence Matrix shown in Table 4.7-2.

(4) The GDCS and suppression pools are instrumented and alarmed such that inadvertent draining of a pool would be immediately obvious to the crew and pool level would be restored.

(5) The FAPCS and FPS injection capability is adequate to provide adequate core cooling for transients given successful DPV or ADS valve operation, even if containment pressure is at the ultimate containment pressure.

(6) Information regarding to alarms and instrumentation is preliminary.

4.7.3 System Description

4.7.3.1 Hardware Configuration

Figure 4.7-1(A) shows a simplified diagram of the FAPCS for initial configuration. When the FAPCS operates in the cooling mode, water is drawn from the pools listed in 4.7.1 "a" through "e" using surface level skimmers. It is drained to skimmer surge tanks.

Figure 4.7-1(B) depicts the cooling by the RCCWS of the heat exchangers included in the FAPCS model.

A line leading from the bottom of the skimmer surge tanks A and B conveys water to be cooled or cleaned to the inlet end of a dual-train of series-arranged components. Each train consists of the following components:

- A 100 percent circulating water pump with a check valve in the discharge piping;
- A shell-and-tube-type heat exchanger on the downstream side of the pump discharge check valve (cooling flow is provided by the reactor component cooling water system);
- A filter/demineralizer unit located downstream of the heat exchanger with an inlet motor-operated valve (MOV); a parallel line containing an MOV is provided to bypass the filter/demineralizer.

Both the inlets and outlets of the trains are connected by MOVs F011A/B, F003A/B, F014A/B, and F008A/B, respectively. This arrangement allows each train to take suction flow from

different sources, and allows the train discharge flow to be routed to alternative common headers depending on whether the water flow is routed to the pools listed in 4.7.1 "a" through "e", or to other possible uses or pools (IC pools, gravity driven cooling system (GDCS) pools, suppression pools, or RWCU/SDC discharge line).

When the FAPCS operates in the LPCI or SPC mode, water is drawn from the suppression pool by means of a line emerging through the inner pool wall into the primary containment and then penetrating through the containment wall. Two air-operated gate valves (F321 and F322) located immediately outside the primary containment are provided on the line for containment isolation purposes.

The downstream piping from the outboard valves merges with the common line conveying water from the IC pools or the GDCS pools to the upstream end of the cooling/cleanup trains. A nitrogen-operated valve inside containment and a motor-operated valve outside containment isolate GDCS pools suction. (Not Modeled).

A common discharge header from the cooling/cleanup trains splits into several lines. In turn, one of those lines splits into multiple branches before penetrating the primary containment. One branch, leading to the suppression pool, contains the motor-operated gate valve, F306, outside the primary containment and the check valve, F307, inside. This branch is aligned for flow when the FAPCS operates in the SPC mode. Another branch, returning water to the GDCS, has a motor-operated gate valve outside the containment and a check valve inside. A second line discharges water to the RWCU/SDC which sends it to the feedwater system to be injected into the RPV when the FAPCS operates in the LPCI mode. This line is provided with an air-operated gate valve, F332, and an air-operated testable check valve, F333, downstream of it. Finally, an air-operated gate valve can isolate a third line returning water to the IC pool.

It is possible to inject water through the FAPCS into the vessel from the Fire Protection System (FPS), through the line corresponding to the LPCI mode. In addition, using this system, it is possible to supply water to the upper pools (IC/PCC pool) from the FPS. Both connections are represented in the simplified diagram (Figure 4.7-1(A)). The fault tree corresponding to the failure of these supplies, both to the vessel and to the IC/PCC pool, is also included within this system description and the associated fault tree models.

4.7.3.2 System Operation

The two modeled operating modes are the following:

- Suppression Pool Cooling and Cleanup Mode. Cooling and cleanup of the suppression pool is performed by drawing pool water through a line penetrating the containment and reaches the inlet of the cooling/cleanup trains. From the outlet of these, the processed water returns to a discharge point near the bottom of the suppression pool

- Low Pressure Coolant Injection (LPCI) Mode. Under accident conditions, once the reactor has been depressurized to a pressure that is below the nominal shutoff discharge head from the FAPCS pumps, logical processing enables the opening of several valves that automatically align the FAPCS to draw coolant from the suppression pool and pump this coolant into RWCU/SDC piping that leads into one of the two main feedwater lines, thus achieving a low pressure coolant injection.

During normal plant conditions, the FAPCS operates with one pump (C001A) running and the other in standby, to continuously cool, clean, and clarify the water of the fuel storage pool.

During or following a seismic event, the pool water treatment subsystem is bypassed and the cleaning function is not performed.

During other emergency conditions, the standby train can be either manually actuated to work in the LPCI mode, or automatically actuated on suppression pool water high temperature signal to work in the SPC mode. At the same time, the other train continues to operate in the FAPC mode. Table 4.7-1A lists the relevant valves of the system shown in Figure 4.7-1 and lists their status for each system operating mode, assuming train A is working and train B is in standby during normal plant conditions.

4.7.3.3 System Location

The basic components of the FAPCS are all within the fuel and reactor buildings except nitrogen-operated isolation valve F323 (GDCS pools suction) which is located inside the primary containment.

4.7.4 Automatic and Manual Control

Actuation of the FAPCS is performed manually when the system is required to operate in the LPCI mode and automatically (on suppression pool high temperature signal) when operating in the SPC mode.

If automatic actuation fails, the operator is expected to manually actuate the system in the SPC mode.

The signals that trip the FAPCS pumps are the following:

- Low suction pressure
- High/low discharge flow

Position lights for all relevant valves are provided in the control room. Instrument and alarm signals reported in the control room for the FAPCS are given in Table 4.7-1B.

The fault tree system top events are shown in Table 4.7-8.

4.7.5 System Interfaces

The FAPCS components depend on electrical, fluid, and nitrogen/air-support systems as indicated by the dependence matrix given in Table 4.7-2.

Upon loss of electric power, each system's motor-operated valve (MOV) fails "as is", and on loss of air supply, each nitrogen/air-operated valve (N/AOV) fails closed.

The FAPCS shares check valves F102A and F103A of the FDW line A with the RWCUs/SDCS.

4.7.6 System Testing

The FAPCS is non-safety related; therefore, no Technical Specifications apply. However, the following assumptions have been made:

- MOV F303, F306, AOVs F321, F322, F332, all have isolation functions and are tested quarterly.
- The MOVs and the pump of each train are tested quarterly before the operator calls the standby train into operation and the other one is stopped.
- All remaining components are tested every 24 months during refueling.
- Monthly rotation between trains has been assumed.

4.7.7 System Maintenance

Maintenance during normal plant operation is only expected for the components found failed during a test.

For all other components, scheduled maintenance is carried out during reactor refueling.

4.7.8 Common Cause Failures

Common cause failures within the system are summarized in Table 4.7-5.

4.7.9 Fault Tree Analysis

4.7.9.1 Top Event Definitions

The list of the top events used in the PRA is shown in Table 4.7-8.

Four top events have been defined for the FAPCS.

(1) GG21-0001-_1 for Both FAPCS trains fail SPC operation mode actuation.

(2) GG21-0001-_4 for Both FAPCS trains fail LPCI operation mode.

(3) GG21-0001-_5 for Both FAPCS trains LPCI operation mode after ADS.

(4) GG21-0001-_6 for Both FAPCS trains fail SPC operation mode actuation after ADS.

For Fire Protection System functions three tops have been developed:

(1) GU43-0001-_1 for U43 fails to inject water into RPV.

(2) GU43-0001-_2 for Water make up to the IC/PCCS pools from U43 (FPS) fails

(3) GU43-0001-_3 for U43 fails to inject water into RPV after ADS.

4.7.9.2 Model Assumptions

- Monthly rotation between trains is assumed.
- Failures of branch lines relevant to no-modeled functions are not taken into account.
- Failures of manual valves in the closed position (misposition) are not taken into account, except if single failures affect system function.
- FAPCS includes suction piping from the pools to the inlet of the Cooling/Cleanup Trains, including suction strainers, and piping extending from the downstream end of the Cooling/Cleanup Trains to their discharge ends in each pool, including discharge

diffusers. However, FAPCS excludes the nitrogen and air supply lines, and any equipment inside the pools not attached to FAPCS piping.

- Initially, Train A is considered to be operating in FAPCS mode and train B, on standby. The alignment of each train in each operating mode is shown in Table 4.7-1A.
- The system modeled is shown in the simplified diagram, based on P&ID 107E6299, Rev 1, and corresponds to the SBWR.
- The Type C human actions included in the model are included in the Emergency Operating Procedures or in other operating procedures.
- If a loss of power supply occurs, the circuit breaker of the pump in operation must be closed once power supply is reestablished.
- The correct operation of one of the trains, with its corresponding heat exchanger, is necessary in both SPC and LPCI operating modes, along with the proper alignment of the corresponding intake and discharge.
- For modeling purposes, failure of the automatic actuation signals in the cooling mode of the SP is included in the system limits.
- Manual valve F320 in the SP intake and manual valve F334 in the discharge to FDWA may both be subjected to maintenance, and therefore, failure due to misposition is considered.
- In the RCCWS part of heat exchanger cooling included in the model, the possibility of failure due to incorrect position of the manual valves is not considered, because it is assumed that alarms and indications in the Control Room warn the operators of improper closing of a valve before putting into operation the corresponding train.

4.7.9.3 Fault Tree Description

The following main fault trees are shown in the Appendix B.4.7. The list of the top event gates is shown in Table 4.7-8.

Four fault trees have been developed for the FAPCS:

(1) Fault tree with top event GG21-0001-_1.

(2) Fault tree with top event GG21-0001-_4.

(3) Fault tree with top event GG21-0001-_5.

(4) Fault tree with top event GG21-0001-_6.

For Fire Protection System functions, three fault trees have been developed:

(1) GU43-0001-_1 for U43 fails to inject water into RPV.

(2) GU43-0001-_2 for Water make up to the IC/PCCS pools from U43 (FPS) fails

(3) GU43-0001-_3 for U43 fails to inject water into RPV after ADS.

4.7.9.4 Human Interactions

A summary of the human errors included as basic events in the system fault trees is reported in Table 4.7-6.

In the fault trees, each one of these errors is connected in a logic OR with a House Event for purposes of sensitivity analysis.

4.7.10 Results of Fault Tree Analysis

The quantification of core damage sequences implicitly includes the contribution of basic events for this system. This quantification process enables checking the global consistency of the system fault trees and their relationship with the rest of the systems modeled in the PRA.

A summary of the basic events included in the system fault tree are reported in Table 4.7-7.

The importance measurements obtained from core damage frequency equations, allow identification of the most relevant basic events and system component failures in an integrated context, as well as the determination of their relative importance with respect to the basic events and component failures of the other systems modeled.

4.7.11 Model Differences for 72-Hour Operation

Operation of the FAPCS beyond 24 hours presents no unique problems. There are no changes to the model for operation to 72 hours other than the mission time.

4.7.12 References

4.7-1. ESBWR Design Control Document, 26A6642 Rev. 01

Table 4.7-1A

Status of the FAPCS Relevant Valves for Each System Operating Mode

Valve	Operating Modes (1) (2)		
	FAPCS	LPCI	SPC
MOV F003A	NO	NO	NO
MOV F003B	NC	NC	NC
MOV F005A	NO	NO	NO
MOV F005B	NC	NC	NC
MOV F008A	NO	NO	NO
MOV F008B	NC	NC	NC
MOV F011A	NC	NC	NC
MOV F011B	NC	Opened	Opened
MOV F013A	NC	NC	NC
MOV F013B	NC	Opened	Opened
MOV F014A	NC	NC	NC
MOV F0014B	NC	Opened	Opened
Isolation AOV F321	NC	Opened	Opened
Isolation AOV F322	NC	Opened	Opened
Isolation MOV F306	NC	NC	Opened
AOV F332	NC	Opened	NC

Notes:

(1) Assumes Train A is operating and Train B is in standby during normal plant operation

(2) AOV = Air Operated Valve
MOV = Motor Operated Valve
NC = Normally Closed
NO = Normally Open

Table 4.7-1B

Control Room Instrumentation and Alarms

Controls
IC/PCC pool water level
Make-up water supply to the skimmer surge tank
Displays
Differential pressure between suction and discharge of each pump
Water flow in each train
Temperature upstream and downstream of each heat exchanger
Temperature in the Suppression Pool
Suppression pool water level
IC/PCC pool water level
Spent fuel storage pool water level
Skimmer surge tank level
Alarms
Water flow in each train
Temperature in the Suppression Pool
Low and high suppression pool water level
Low and high skimmer surge tank water level
Low and high IC/PCC pool water level
Low and spent fuel storage pool water level

Table 4.7-2

System Dependency Matrix

		Support System (1)				
		Power Supply				IAS
		480 V AC (R13· 1E)				
Component	**Type**	**DIV 1**	**DIV 2**	**DIV 3**	**DIV 4**	
F306	MOV	X				
F321	AOV	X				X
F322	AOV		X			X
F332	AOV	X				X

		Support System		
		Power Supply		RCCWS
Component	**Type**	**6.9 kV AC (R11)**	**480 V AC (R12FB)**	
C001A	Pump	X		X
C001B	Pump	X		X
F0011A	MOV		A	
F011B	MOV		B	
F014A	MOV		A	
F014B	MOV		B	
F013A	MOV		A	
F013B	MOV		B	
F005A	MOV		A	
F005B	MOV		B	
F003A	MOV		A	
F003B	MOV		B	
F008A	MOV		A	
F008B	MOV		B	
N077A	MOV		A	
N077B	MOV		B	
F051A	MOV		A	
F051B	MOV		B	
F055A	MOV		A	
F055B	MOV		B	

(1) The FPS used as an RPV injection source or as make up to the IC/PCC pools is considered to have no support system dependencies that interface with the remainder of the plant. Therefore, no dependency matrix is required.

Table 4.7-3

Component Test

Component Type	Expected Test Interval	Components aligned away from emergency position without automatic return logic
Pumps	Quarterly	None
Active valves	Quarterly	None
Maintenance valves	24 Months	None
Note: Monthly rotation between trains has been assumed.		

Table 4.7-4

Component Maintenance

Maintenance during normal plant operation is only expected for the components found failed during a test. For all other components, scheduled maintenance is carried out during reactor refueling (expected maintenance interval: 24 months).

Table 4.7-5A

List of Common Cause Failures for FAPCS

Event Name	Unavailability	Description
B21-LT_-CF-NO01ABCDLOW	6.00E-08	CCF LEVEL TRANSMITTER L2 FAIL LOW
G21-ACV-CF-SUCTION	1.33E-05	CCF OPEN ACV SUCTION PUMPS LINE
G21-FT_-CF-N014A/BLOW	8.20E-07	CCF DISCHARGE FLOW TRANSMITTERS
G21-HX_-CF-PLUG/LEAK	1.19E-06	CCF H/Xs TO PLUG/LEAK
G21-MCB-CF-C001A/BCLOSE	9.29E-05	CCF CIRCUIT BREAKERS TO CLOSE
G21-MOV-CF-CLOSEA	6.06E-05	CCF TO CLOSE MOV TRAIN A
G21-MOV-CF-OPENA/B	8.64E-06	CCF TO OPEN MOV TRAINS A AND B
G21-MP_-CR-C001A/B	2.23E-04	CCF PUMPS TO RUN
G21-MP_-CS-C001A/B	2.56E-04	CCF PUMPS TO START
G21-PT_-CF-N002A/BLOW	5.94E-06	CCF SUCTION PRESSURE TRANSMITTERS
G21-STR-CF-SPPLUG	1.01E-03	CCF FILTER/STRAINER IN PSP TO PLUG
H23-EMS-CF-ALL	1.80E-06	CCF OF ESSENTIAL MULTIPLEXING SYSTEM DIV 1/2/3/4
T62-TT_-CF-SPALL	4.00E-08	CCF OF SUPPRESSION POOL TEMP. TRANSMITTERS

Table 4.7-5B

List of Common Cause Failures for Fps

No common cause failures have been defined for Fire Protection System.

Table 4.7-6A

List of Human Errors for FAPCS

Event Name	Unavailability	Description
G21-XHE-FO-LPCI	1.61E-03	OPERATOR FAILS TO ALIGN AND ACTUATE FAPCS IN LPCI MODE
G21-XHE-FO-LPCIADS	1.61E-02	OPERATOR FAILS TO ALIGN AND ACTUATE FAPCS IN LPCI MODE
G21-XHE-FO-SPC	1.61E-03	OPERATOR FAILS TO MANUALLY INI. FAPCS IN SPC MODE #3, #4
G21-XHE-FO-SPCADS	1.61E-02	OPERATOR FAILS TO MANUALLY INI. FAPCS IN SPC MODE AFTER ADS
G21-XHE-MH-F308	0.00E+00	MISPOSITION OF VALVE F308
G21-XHE-MH-F320	0.00E+00	MISPOSITION OF VALVE F320
G21-XHE-MH-F334	4.80E-02	MISPOSITION OF VALVE F334
XXX-XHE-FO-DEPRESS	1.61E-01	OPERATOR FAILS TO RECOGNIZE NEED OF DEPRESSURIZATION
XXX-XHE-FO-LPMAKEUP	1.61E-01	OP. FAILS TO RECOG. NEED FOR LOW PRESS. MAKEUP (LOCA)
XXX-XHE-FO-SPC	1.61E-02	OPERATOR FAILS TO RECOG. NEED FOR SPC

Table 4.7-6B

List of Human Errors for FPS

Event Name	Unavailability	Description
G21-XHE-MH-F334	4.80E-02	MISPOSITION OF VALVE F334
U43-XHE-FO-LPCI	1.61E-03	OPERATOR FAILS TO ACTUATE U43 IN LPCI MODE
U43-XHE-FO-LPCIADS	1.61E-02	OPERATOR FAILS TO ACTUATE U43 IN LPCI MODE AFTER ADS
U43-XHE-FO-MAKEUP	1.61E-02	OPERATOR FAILS TO ACTUATE U43 IN MAKE UP MODE
U43-XHE-FO-YARD	5.32E-02[(1)]	OPERATOR FAILS TO MAKE UP FROM YARD AREA
XXX-XHE-FO-DEPRESS	1.61E-01	OPERATOR FAILS TO RECOGNIZE NEED OF DEPRESSURIZATION
XXX-XHE-FO-ICPCCS	1.61E-03	OPERATOR FAILS TO RECOGNIZE NEED OF MAKE UP TO IC/PCCS POOLS
XXX-XHE-FO-LPMAKEUP	1.61E-01	OP. FAILS TO RECOG. NEED FOR LOW PRESS. MAKEUP (LOCA)

(1) The value currently used in the model and reported in Section 6 is 1.77E-03. The revised HEP of 5.32E-02 is the subject of sensitivity calculations.

Table 4.7-7A

List of Basic Events for FAPCS

Basic Event	Prob	Description
B21-LT_-CF-NO01ABCDLOW	6.00E-08	CCF LEVEL TRANSMITTER L2 FAIL LOW
B21-UV_-CC-F102A	1.60E-03	CHECK VALVE F102A IN FEEDWATER LINE A FAILS TO OPEN
B21-UV_-CC-F103A	1.60E-03	CHECK VALVE F103A IN FEEDWATER LINE A FAILS TO OPEN
C74-DTM-CF-ALL	1.20E-05	CCF 3/4 DTM OF SSLC DIV1/2/3/4
C74-DTM-FC-DIV1	6.00E-04	DTM OF SSLC DIV 1 FAILS TO TRIP
C74-DTM-FC-DIV2	6.00E-04	DTM OF SSLC DIV 2 FAILS TO TRIP
C74-DTM-FC-DIV3	6.00E-04	DTM OF SSLC DIV 3 FAILS TO TRIP
C74-DTM-FC-DIV4	6.00E-04	DTM OF SSLC DIV 4 FAILS TO TRIP
G21-ACV-CC-F321	2.00E-03	AOV F321 FAILS TO OPERATE TO NOT DEENERG.POS.
G21-ACV-CC-F322	2.00E-03	AOV F322 FAILS TO OPERATE TO NOT DEENERG.POS.
G21-ACV-CC-F332	2.00E-03	AOV F332 FAILS TO OPERATE TO NOT DEENERG.POS.
G21-ACV-CF-SUCTION	1.33E-05	CCF OPEN ACV SUCTION PUMPS LINE
G21-ACV-TM-F321/F322	8.00E-04	AOVs F321 OR F322 IN MAINTENANCE OR TEST
G21-FT_-CF-N014A/BLOW	8.20E-07	CCF DISCHARGE FLOW TRANSMITTERS
G21-FT_-LO-N014A	4.08E-05	DISCHARGE FLOW TRANSMITTER FAILS LOW
G21-FT_-LO-N014B	6.12E-04	DISCHARGE FLOW TRANSMITTER FAILS LOW
G21-HX_-CF-PLUG/LEAK	1.19E-06	CCF H/Xs TO PLUG/LEAK
G21-HX_-LK-B001A	2.40E-05	HEAT EXCHANGER B001A FAILS WHILE OPERATING
G21-HX_-LK-B001B	3.60E-04	HEAT EXCHANGER B001B FAILS WHILE OPERATING
G21-MCB-CF-C001A/BCLOSE	9.29E-05	CCF CIRCUIT BREAKERS TO CLOSE
G21-MCB-CO-C001A	1.20E-05	CIRCUIT BREAKER OF PUMP C001A OPENS SPURIOUSLY
G21-MCB-OO-C001A	1.00E-03	CIRCUIT BREAKER FAILS TO CLOSE
G21-MCB-OO-C001B	1.00E-03	CIRCUIT BREAKER OF PUMP C001B FAILS TO CLOSE
G21-MOV-CC-F011A	4.00E-03	MOTOR OPER. VALVE F011A FAILS TO OPEN
G21-MOV-CC-F011B	4.00E-03	MOTOR OPER. VALVE F011B FAILS TO OPEN
G21-MOV-CC-F013A	4.00E-03	MOTOR OPER. VALVE F013A FAILS TO OPEN
G21-MOV-CC-F013B	4.00E-03	MOTOR OPER. VALVE F013 FAILS TO OPEN
G21-MOV-CC-F014A	4.00E-03	MOTOR OPER. VALVE F014A FAILS TO OPEN
G21-MOV-CC-F014B	4.00E-03	MOTOR OPER. VALVE F014B FAILS TO OPEN

Table 4.7-7A

List of Basic Events for FAPCS

Basic Event	Prob	Description
G21-MOV-CC-F306	4.00E-03	MOTOR OPER. VALVE F306 FAILS TO OPEN
G21-MOV-CF-CLOSEA	6.06E-05	CCF TO CLOSE MOV TRAIN A
G21-MOV-CF-OPENA/B	8.64E-06	CCF TO OPEN MOV TRAINS A AND B
G21-MOV-OO-F003A	4.00E-03	MOTOR OPERATED VALVE F003A FAILS TO CLOSE
G21-MOV-OO-F008A	4.00E-03	MOTOR OPER. VALVE F008A FAILS TO CLOSE
G21-MOV-TM-F306	8.00E-04	MOV F306 IN MAINTENANCE OR TEST
G21-MP_-CR-C001A/B	2.23E-04	CCF PUMPS TO RUN
G21-MP_-CS-C001A/B	2.56E-04	CCF PUMPS TO START
G21-MP_-FR-C001A	3.59E-03	MOTOR-DRIVEN PUMP C001A FAILS TO RUN, GIVEN START
G21-MP_-FR-C001B	3.59E-03	MOTOR-DRIVEN PUMP C001B FAILS TO RUN, GIVEN START
G21-MP_-FS-C001A	3.00E-03	PUMP C001A FAILS TO START
G21-MP_-FS-C001B	3.00E-03	MOTOR-DRIVEN PUMP C001B FAILS TO START
G21-PT_-CF-N002A/BLOW	5.94E-06	CCF SUCTION PRESSURE TRANSMITTERS
G21-PT_-LO-N002A	7.92E-06	SUCTION PRESSURE TRANSMITTER FAILS LOW
G21-PT_-LO-N002B	1.19E-04	SUCTION PRESSURE TRANSMITTER FAILS LOW
G21-STR-CF-SPPLUG	1.01E-03	CCF FILTER/STRAINER IN PSP TO PLUG
G21-SYS-TM-TRAINB	3.00E-03	TRAIN B IN MAINTENANCE
G21-UV_-CC-F004B	2.00E-04	CHECK VALVE F004B FAILS TO OPEN
G21-UV_-CC-F307	1.60E-03	CHECK VALVE F307 FAILS TO OPEN
G21-UV_-CC-F331	1.60E-03	CHECK VALVE F331 FAILS TO OPEN
G21-UV_-CC-F333	1.60E-03	CHECK VALVE F333 FAILS TO OPEN
G21-UV_-CC-F348	1.60E-03	CHECK VALVE F348 FAILS TO OPEN
G21-UV_-TM-F332/333	8.00E-04	MAINTENANCE FOR CV F332 OR CV F333
G21-XHE-FO-LPCI	1.61E-03	OPERATOR FAILS TO ALIGN AND ACTUATE FAPCS IN LPCI MODE
G21-XHE-FO-LPCIADS	1.61E-02	OPERATOR FAILS TO ALIGN AND ACTUATE FAPCS IN LPCI MODE
G21-XHE-FO-SPC	1.61E-03	OPERATOR FAILS TO MANUALLY INI. FAPCS IN SPC MODE #3, #4
G21-XHE-FO-SPCADS	1.61E-02	OPERATOR FAILS TO MANUALLY INI. FAPCS IN SPC MODE AFTER ADS
G21-XHE-MH-F308	0.00E+00	MISPOSITION OF VALVE F308
G21-XHE-MH-F320	0.00E+00	MISPOSITION OF VALVE F320
G21-XHE-MH-F334	4.80E-02	MISPOSITION OF VALVE F334
H23-EMS-CF-ALL	1.80E-06	CCF OF ESSENTIAL MULTIPLEXING SYSTEM DIV 1/2/3/4

Table 4.7-7A

List of Basic Events for FAPCS

Basic Event	Prob	Description
H23-EMS-FC-DIV1	6.00E-04	ESSENTIAL MULTIPLEXING SYSTEM DIV 1 FAILS TO FUNCTION
H23-EMS-FC-DIV2	6.00E-04	ESSENTIAL MULTIPLEXING SYSTEM DIV 2 FAILS TO FUNCTION
H23-EMS-FC-DIV3	6.00E-04	ESSENTIAL MULTIPLEXING SYSTEM DIV 3 FAILS TO FUNCTION
H23-EMS-FC-DIV4	6.00E-04	ESSENTIAL MULTIPLEXING SYSTEM DIV 4 FAILS TO FUNCTION
H23-RMU-CF-ALL	9.00E-07	CCF OF REMOTE MULTIPLEXING UNITS TO OPERATE
H23-RMU-FC-1G21	3.00E-04	RMU 001 FOR FAPCS C.R. MANUAL ACTUAT. FAILS TO OPERATE
H23-RMU-FC-2G21	3.00E-04	RMU 002FOR FAPCS C.R. MANUAL ACTUAT. FAILS TO OPERATE
H23-RMU-FC-LMU9A	3.00E-04	LMU 9A FAILURE
H23-RMU-FC-LMU9B	3.00E-04	LMU 9B FAILURE
H23-RMU-FC-LMU9C	3.00E-04	LMU 9C FAILURE
H23-RMU-FC-LMU9D	3.00E-04	LMU 9D FAILURE
P21-MOV-CC-F051B	4.00E-03	MOTOR OPERATED VALVE P21-F051B FAILS TO OPEN
P21-MOV-CC-F055B	4.00E-03	MOTOR OPERATED VALVE P21-F055B FAILS TO OPEN
P21-MOV-CO-N077B	1.80E-04	MOTOR OPERATED VALVE P21-N077A FAILS TO REMAIN CLOSED
T23-POL-RP-SP	3.00E-07	SUPPRESSION POOL LEAKS CATASTROPHICALLY
T62-TT_-CF-SPALL	4.00E-08	CCF OF SUPPRESSION POOL TEMP. TRANSMITTERS
T62-TT_-NO-001	8.40E-06	SP TEMPERATURE TRANSMITTER 001 (HI TEMP.) FAILS
T62-TT_-NO-002	8.40E-06	SP TEMPERATURE TRANSMITTER 002 (HI TEMP.) FAILS
T62-TT_-NO-003	8.40E-06	SP TEMPERATURE TRANSMITTER 003 (HI TEMP.) FAILS
T62-TT_-NO-004	8.40E-06	SP TEMPERATURE TRANSMITTER 004 (HI TEMP.) FAILS
XXX-XHE-FO-DEPRESS	1.61E-01	OPERATOR FAILS TO RECOGNIZE NEED OF DEPRESSURIZATION
XXX-XHE-FO-LPMAKEUP	1.61E-01	OP. FAILS TO RECOG. NEED FOR LOW PRESS. MAKEUP (LOCA)
XXX-XHE-FO-SPC	1.61E-02	OPERATOR FAILS TO RECOG. NEED FOR SPC

Table 4.7-7B
List of Basic Events for FPS

Basic Event	Prob	Description
B21-UV_-CC-F102A	1.60E-03	CHECK VALVE F102A IN FEEDWATER LINE A FAILS TO OPEN
B21-UV_-CC-F103A	1.60E-03	CHECK VALVE F103A IN FEEDWATER LINE A FAILS TO OPEN
G21-ACV-CC-F332	2.00E-03	AOV F332 FAILS TO OPERATE TO NOT DEENERG.POS.
G21-ACV-CC-U43	2.00E-03	AIR OPERATED VALVE FAILS TO OPEN
G21-UV_-CC-F333	1.60E-03	CHECK VALVE F333 FAILS TO OPEN
G21-UV_-CC-U43	2.00E-04	CHECK VALVE FAILS TO OPEN
G21-UV_-OC-F331	2.16E-04	CHECK VALVE F331 FAILS TO CLOSE
G21-UV_-TM-F332/333	8.00E-04	MAINTENANCE FOR CV F332 OR CV F333
G21-XHE-MH-F334	4.80E-02	MISPOSITION OF VALVE F334
H23-RMU-FC-1MAKEUP	3.00E-04	RMU 001 FOR U43 C.R MANUAL ACTUATION FAILS TO OPERATE
H23-RMU-FC-1U43LPCI	3.00E-04	RMU 001 FOR U43 C.R. MANUAL ACTUATES. FAILS TO OPERATE
H23-RMU-FC-2MAKEUP	3.00E-04	RMU 002 FOR U43 C.R. MANUAL ACTUATION FAILS TO OPERATE
H23-RMU-FC-2U43LPCI	3.00E-04	RMU 002 FOR U43 C.R. MANUAL ACTUATES. FAILS TO OPERATE
U43-SYS-FF-LPCI	2.40E-02	U43 HARDWARE FAILURES
U43-SYS-FF-YARD	2.00E-03	HARDWARE FAILURES IN YARD AREA
U43-XHE-FO-LPCI	1.61E-03	OPERATOR FAILS TO ACTUATE U43 IN LPCI MODE
U43-XHE-FO-LPCIADS	1.61E-02	OPERATOR FAILS TO ACTUATE U43 IN LPCI MODE AFTER ADS
U43-XHE-FO-MAKEUP	1.61E-02	OPERATOR FAILS TO ACTUATE U43 IN MAKE UP MODE
U43-XHE-FO-YARD	5.32E-02	OPERATOR FAILS TO MAKE UP FROM YARD AREA
XXX-XHE-FO-DEPRESS	1.61E-01	OPERATOR FAILS TO RECOGNIZE NEED OF DEPRESSURIZATION
XXX-XHE-FO-ICPCCS	1.61E-03	OPERATOR FAILS TO RECOGNIZE NEED OF MAKE UP TO IC/PCCS POOLS
XXX-XHE-FO-LPMAKEUP	1.61E-01	OP. FAILS TO RECOG. NEED FOR LOW PRESS. MAKEUP (LOCA)

Table 4.7-8

List of System Top Events

Event Name	Event Tree Functional Node	Description
GG21-0001-_4	VLF	BOTH FAPCS TRAINS FAIL LPCI OP. MODE (INCLUDES DEPENDENT HEP FOR DEPRESSURIZATION)
GG21-0001-_1	WL	BOTH FAPCS TRAINS FAIL SPC OP. MODE ACTUATION (USED FOR ATWS SEQUENCES) INCLUDES CREDIT FOR AUTO INITIATION OF THE STDBY LOOP (LOOP B)
GG21-0001-_5	VLFL	BOTH FAPCS TRAINS FAIL LPCI OP. MODE AFTER ADS (NO DEPENDENT HEP)
GG21-0001-_6	WLL	BOTH FAPCS TRAINS FAIL SPC OP. MODE ACTUATION AFTER ADS (USED FOR NON-ATWS SEQUENCES) DOES NOT INCLUDE AUTOMATIC INITIATION
GU43-0001-_1	VF	U43 FAILS TO INJECT WATER INTO RPV
GU43-0001-_2	WT	WATER MAKE UP TO THE IC/PCCS POOLS FROM U43 (FPS) FAILS
GU43-0001-_3	VFL	U43 FAILS TO INJECT WATER INTO RPV AFTER ADS

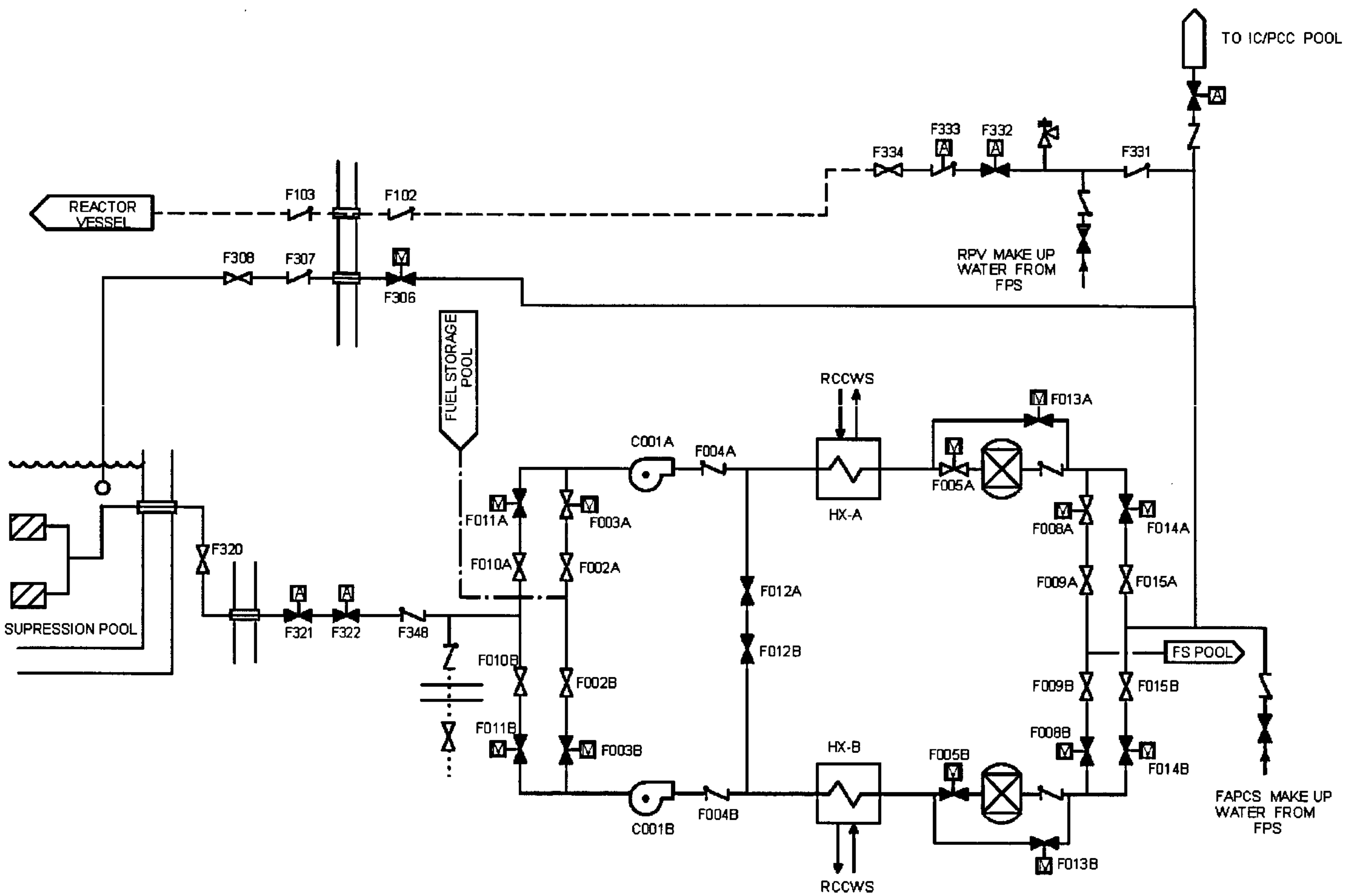


Figure 4.7-1(A). Simplified Process Flow Diagram for FAPCS System

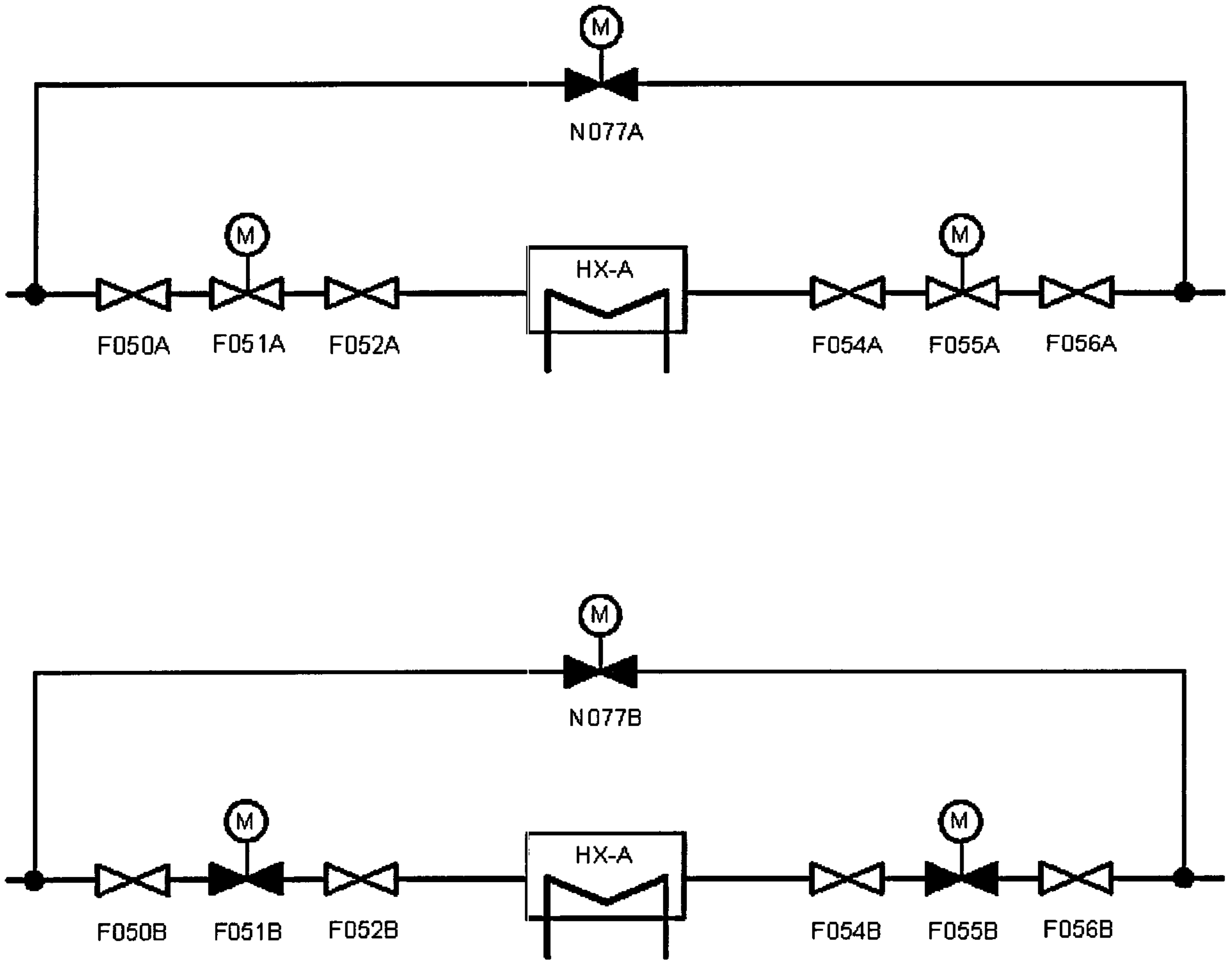


Figure 4.7-1(B). RCCWS-FAPCS Diagram

4.8 REACTOR WATER CLEANUP/SHUTDOWN COOLING SYSTEM – (G31)

4.8.1 Purpose

The Reactor Water Cleanup and Shutdown Cooling System (RWCU/SDCS) is designed:

- To maintain reactor water quality within specified limits during reactor operation (operation in RWCU mode);
- To maintain reactor pressure vessel (RPV) water level during startup or refueling and provide residual heat removal;
- To provide high-pressure cooling of the primary coolant during reactor hot standby condition in order to limit the heat transferred to the isolation condenser (IC) pools (operation in SDC mode) and to bring the plant to its cold shutdown state.

4.8.2 Design Assumptions

The following assumptions with respect to the design are made:

(1) A third air-operated isolation valve is included in each train, outside containment (F3A and F3B). It is assumed that these valves are open during normal operation in both trains, in A in operation and also in B, supposing that the other two (F005B and F006B) fulfill the isolation function.

(2) It has been assumed that the relevant measures will be taken so that the air-operated valves do not depend on the Instrument Air System in an emergency situation.

4.8.3 System Description

4.8.3.1 Hardware Configuration

Figure 4.8-1(A) shows a simplified diagram of the RWCU/SDCS.

This system consists of two independent and redundant trains of series-arranged components, each one with one regenerative heat exchanger, one non-regenerative heat exchanger, one recirculation water pump driven by adjustable speed drive, and one filter/demineralizer. Reactor coolant in each train is drawn from two points on the reactor:

- From the RPV, via the nozzles located at the top of the core chimney (main suction line);
- From small bottom head nozzles (drain line).

Reactor coolant passes first through the tube side of the regenerative heat exchanger and next through the tube side of the non-regenerative heat exchanger where it is further cooled by secondary coolant supplied by the reactor component cooling water system (RCCWS). The part of the RCCWS (HXs cooling) that has been considered as part of the RWCU/SDC for the purpose of the fault tree model is shown in Figure 4.8-1(B).

Next, the process coolant passes through the RWCU recirculation pump where its pressure is raised to above feedwater inlet pressure levels. Pump discharge next passes into the water treatment units, where it becomes demineralized via the mixed-bed type demineralizer.

Purified cool water is then recycled back through the regenerative heat exchanger and returned to the RPV via the feedwater (FW) piping.

Downstream of the water treatment unit, process flow can be totally bypassed around the regenerative heat exchanger and can also be diverted to the main condenser or to radwaste.

4.8.3.2 System Operation

During normal plant conditions, the RWCU/SDCS operates in the RWCU mode with one pump running at reduced speed (delivering a flow rate of about one percent of the normal feedwater flow) and the other one in standby.

One of the water treatment units is working and the regenerative heat exchanger is not bypassed.

During emergency plant conditions, the system is used in the SDC mode to relieve the Isolation Condenser System (ICS) load, that is, the standby train is aligned, and its pump is started.

The pump speed flow is adjusted automatically to ensure that the heat rejection rate to the RCCWS is maintained within the RCCW limitation and the RCCWS flow rate to each non-regenerative heat exchanger is increased to the maximum. The flow returning to the RPV is bypassed around the regenerative heat exchangers.

4.8.3.3 System Location

Basic components of the RWCU/SDCS are all within the reactor building except valves located inside the containment.

4.8.4 Automatic and Manual Control

Actuation of the RWCU/SDCS in the SDC mode is performed manually.

Position lights for all relevant valves are provided in the control room.

Instrumentation for flow, pressure, temperature, NPSH available, and conductivity are recorded in the main control room, along with suitable alarms.

4.8.5 System Interfaces

The RWCU/SDCS components depend on electrical, fluid, air, and nitrogen support systems such as those indicated by the dependence matrix given in Table 4.8-2.

In case of loss of electric power, MOVs fail as is. In case of loss of nitrogen supply, each NOV fails closed.

Each RWCU/SDCS train injects into a Feedwater line upstream of the containment isolation valves.

4.8.6 System Testing

The RWCU/SDCS is non-safety related; no Technical Specifications exist for it. However, it is assumed that all active train components are tested quarterly before the periodic change in train operation when the standby pump is manually actuated and the other one is stopped. Anticipated testing is described in Table 4.8-3. All remaining components are assumed to be tested every 24 months during the plant shutdown for refueling.

4.8.7 System Maintenance

Maintenance during normal plant operation is only expected to be the unscheduled maintenance of the components in each train found failed during a test. For all other components, scheduled maintenance is carried out during reactor refueling.

4.8.8 Instrumentation and Alarms

The RWCU/SDC System instrumentation for flow, pressure, temperature, NPSH available and conductivity are recorded or indicated in the main control room, along with suitable alarms. The parameters with controls, displays, or alarms in the main control room are shown in Table 4.8-1.

4.8.9 Common Cause Failures

Common Cause Failure (CCF) events are identified within the system and are listed in Table 4.8-5.

4.8.10 Fault Tree Analysis

4.8.10.1 Top Event Definitions

The list of the top events defined for the RWCU/SDCS is shown in Table 4.8-8.

The following top event has been defined for the system:

(1) GG31TOP for loss of RWCU/SDC taking into account loss-of-coolant accident (LOCA) cases.

4.8.10.2 Model Assumptions

The following assumptions with respect to the design are made:

(1) It is assumed that the trains are rotated on a monthly basis.

(2) Failures of manual valves in the closed position (misposition) are not taken into account, except if single failure affects system functions.

(3) The Type C human actions included in the model are included in the Emergency Operating Procedures or in other operating procedures.

4.8.10.3 Fault Tree Description

The fault tree is shown in annex A.

4.8.10.4 Human Interactions

Human errors are shown in Table 4.8-6. On the fault trees, these errors are connected in a logic OR with a house event for purposes of sensitivity analysis.

4.8.11 Results of Fault Tree Analysis

The quantification of core damage sequences implicitly includes the contribution of basic events for this system. This quantification process enables checking the global consistency of the system fault trees and their relationship with the rest of the systems modeled in the PRA.

A Summary of the basic events included in the system fault tree and reported in Table 4.8-7.

On the other hand, the importance measurements obtained from core damage frequency equations, allow identification of the most relevant basic events and system component failures in an integrated context, as well as the determination of their relative importance with respect to the basic events and component failures of the other systems modeled.

4.8.12 Model Differences for 72-Hour Operation

Operation of the RWCU/SDCS beyond 24 hours presents no unique problems. There are no changes to model for 72-hour operation other than the mission time.

4.8.13 References

4.8-1. ESBWR Design Control Document, 26A6642 Rev. 01

Table 4.8-1

Control Room Instrumentation And Alarms

Controls
Flow controls valves on RWCU/SDC System suction line from the mid-vessel RPV nozzle and in the bottom drain line
Pump speed
Position of the RHX shell-side bypass and inlet valves
Demineralizer automated filling, draining and resin transfer operations
Automatic pressure drop control for demineralizer system
Displays
Position lights for all relevant valves
Process flow, pressure and temperature
Flow of the RHX tube side and shell side
NPSH available
Conductivity of demineralizer influent and effluent
Position of the isolation valves
RWCU/SDC return to feedwater
Demineralizer automated filling, draining and resin transfer operations
Alarms
High pump cooling water temperature
High pump motor winding temperature
High pump room temperature
Low pump suction flow
Containment isolation valves F006A, B and F005A, B not fully open during all modes of operation
Containment isolation valves F007A and B not fully open during low pressure shutdown
Reactor water high-high temperature at NRHX tube outlet
Conductivity in excess of water quality requirements
Differential pressure measurements with alarm function for demineralizer and resin trap

Table 4.8-2

System Dependency Matrix

Component	Type	Support System: Power Supply: 480 V AC (R13· 1E) DIV 1	DIV 2	DIV 3	DIV 4	HPNSS
F006A	NOV				X	X
F006B	NOV			X		X
F007A	AOV	X				
F007B	AOV		X			
F3A	AOV	X				
F3B	AOV		X			

Component	Type	Support System: Power supply: 6.9 kV AC (R11)	480 V AC (R12)	RCCWS
C001A	Pump	X		X
C001B	Pump	X		X
F009A	MOV		X	
F009B	MOV		X	
F020A	MOV		X	
F020B	MOV		X	
F030A	MOV		X	
F030B	MOV		X	
F036A	MOV		X	
F036B	MOV		X	

Table 4.8-3

Component Test

Component Type	Expected Test Interval	Components aligned away from emergency position without automatic return logic
Pumps	Quarterly	None
Active valves	Quarterly	None
Maintenance valves	24 Months	None

Note: A monthly train rotation is assumed.

Table 4.8-4

Component Maintenance

Maintenance during normal plant operation is only expected to be the unscheduled maintenance of the components in each train found failed during a test. For all other components, scheduled maintenance is carried out during reactor refueling (expected maintenance interval: 24 months).

Table 4.8-5

List of System Common Cause Failures

Basic Event	Prob	Description
B21-LT_-CF-N001ABCDLOW	6.00E-08	CCF LEVEL TRANSMITTERS (L2) FAIL LOW
G31-ACV-CF-DEENERGA/B	3.64E-05	AOV/NOV SPURIOUS TRANSF. TO DEENERG. POSITION
G31-FT_-CF-N002ABLOW	3.06E-05	CCF SUCTION FLOW TRANSMITTERS FAIL LOW
G31-MCB-CF-CLOSE	7.62E-05	CCF CIRCUIT BREAKER TO CLOSE
G31-MOV-CF-F018/62/63A	6.06E-05	CCF 3 OUT OF 3 MOTOR OPERATED VALVES F018A, F062A AND F063A TO CLOSE
G31-MOV-CF-F018/62/63B	6.06E-05	CCF 3 OUT OF 3 MOTOR OPERATED VALVES F018B, F062B AND F063B TO CLOSE
G31-MOV-CF-OPENA	2.11E-05	MOVs (3) TRAIN A CCF TO OPEN
G31-MOV-CF-OPENA/B	8.64E-06	CCF MOV TO OPEN
G31-MOV-CF-OPENB	2.11E-05	MOVs (3) TRAIN B CCF TO OPEN
G31-MP_-CR-RUN	1.49E-05	CCF OF RWCU PUMPS TO RUN
G31-MP_-CS-C001A/B	1.96E-04	CCF TO RESTART PUMPS
H23-RMU-CF-DIDALL	9.00E-07	CCF OF REMOTE MULTIPLEXING UNITS (DID)
T64-TT_-CF-HIGH	2.28E-06	CFF TEMPERATURE TRANSMITTERS IN STEAM TUNNELFAIL HIGH

Table 4.8-6

List of System Human Errors

Basic Event	Prob	Description
G31-XHE-FO-SDC	1.77E-02	OPERATOR FAILS TO ACTUATE SDC MODE
G31-XHE-FO-SDCMSL	3.22E-02	OPERATOR FAILS TO ACTUATE SDC MODE
G31-XHE-FO-SDCSLCS	1.77E-01	OPERATOR FAILS TO ACTUATE SDC MODE AFTER SLCS ACTUATION

Table 4.8-7

List of System Basic Events

Basic Event	Prob	Description
B21-LT_-CF-N001ABCDLOW	6.00E-08	CCF LEVEL TRANSMITTERS (L2) FAIL LOW
B21-UV_-CC-F102A	1.60E-03	CHECK VALVE F102A IN FEEDWATER LINE A FAILS TO OPEN
B21-UV_-CC-F102B	1.60E-03	CHECK VALVE #1 IN FEEDWATER LINE B FAILS TO REOPEN
B21-UV_-CC-F103A	1.60E-03	CHECK VALVE F103A IN FEEDWATER LINE A FAILS TO OPEN
B21-UV_-CC-F103B	1.60E-03	CHECK VALVE #2 IN FEEDWATER LINE B FAILS TO REOPEN
G31-ACV-CC-F007A	2.00E-03	AIR OPER. VALVE F007A FAILS TO OPEN
G31-ACV-CC-F007B	2.00E-03	MOTOR OPER. VALVE F007B FAILS TO OPEN
G31-ACV-CF-DEENERGA/B	3.64E-05	AOV/NOV SPURIOUS TRANSF. TO DEENERG. POSITION
G31-ACV-OC-F006A	3.60E-06	AIR OPERATED VALVE F006A SPUR. TRANSF. TO DEENERG. POSIT.
G31-ACV-OC-F006B	5.40E-05	AIR OPERATED VALVE F006B SPUR. TRANSF. TO DEENERG. POSIT.
G31-ACV-OC-F3A	5.40E-05	AIR OPERATED VALVE F3A CLOSES SPURIOUSLY
G31-ACV-OC-F3B	5.40E-05	AIR OPERATED VALVE F3B CLOSES SPURIOUSLY
G31-FT_-CF-N002ABLOW	3.06E-05	CCF SUCTION FLOW TRANSMITTERS FAIL LOW
G31-FT_-LO-N002A	4.08E-05	FLOW TRANSMITTER N002A FAILS LOW
G31-FT_-LO-N002B	6.12E-04	SUCTION FLOW TRANSMITTER N002B FAILS LOW
G31-HX_-LK-B002A	2.40E-05	HEAT EXCHANGER A FOR RWCU/SDCS FAILS WHILE OPERATING
G31-HX_-LK-B002B	3.60E-04	HEAT EXCHANGER B FOR RWCU/SDCS FAILS WHILE OPERATING
G31-MCB-CF-CLOSE	7.62E-05	CCF CIRCUIT BREAKER TO CLOSE
G31-MCB-CO-C001A	1.20E-05	CIRCUIT BREAKER OF PUMP A OPENS SPURIOUSLY
G31-MCB-OO-C001A	1.00E-03	CIRCUIT BREAKER OF PUMP A FAILS TO RECLOSE
G31-MCB-OO-C001B	1.00E-03	CIRCUIT BREAKER OF PUMP B FAILS TO CLOSE
G31-MOV-CC-F009A	4.00E-03	MOTOR OPER. VALVE F009A FAILS TO OPEN
G31-MOV-CC-F009B	4.00E-03	MOTOR OPER. VALVE F009B FAILS TO OPEN
G31-MOV-CC-F020A	4.00E-03	MOTOR OPER. VALVE F020A FAILS TO OPEN
G31-MOV-CC-F020B	4.00E-03	MOTOR OPER. VALVE F020B FAILS TO OPEN
G31-MOV-CC-F030A	4.00E-03	MOTOR OPER. VALVE F030A FAILS TO OPEN
G31-MOV-CC-F030B	4.00E-03	AIR OPER. VALVE F030B FAILS TO OPEN
G31-MOV-CF-F018/62/63A	6.06E-05	CCF 3 OUT OF 3 MOTOR OPERATED VALVES F018A, F062A AND F063A TO CLOSE
G31-MOV-CF-F018/62/63B	6.06E-05	CCF 3 OUT OF 3 MOTOR OPERATED VALVES F018B, F062B AND F063B TO CLOSE
G31-MOV-CF-OPENA	2.11E-05	MOVs (3) TRAIN A CCF TO OPEN
G31-MOV-CF-OPENA/B	8.64E-06	CCF MOV TO OPEN
G31-MOV-CF-OPENB	2.11E-05	MOVs (3) TRAIN B CCF TO OPEN
G31-MP_-CR-RUN	1.49E-05	CCF OF RWCU PUMPS TO RUN

Table 4.8-7

List of System Basic Events

Basic Event	Prob	Description
G31-MP_-CS-C001A/B	1.96E-04	CCF TO RESTART PUMPS
G31-MP_-FR-C001A	2.40E-04	MOTOR-DRIVEN PUMP A FAILS TO RUN, GIVEN START
G31-MP_-FR-C001B	2.40E-04	MOTOR-DRIVEN PUMP B FAILS TO RUN, GIVEN START
G31-MP_-FS-C001A	2.30E-03	MOTOR-DRIVEN PUMP A FAILS TO RESTART
G31-MP_-FS-C001B	2.30E-03	MOTOR-DRIVEN PUMP B FAILS TO START
G31-OR_-PG-RWA	1.44E-05	ORIFICE A FAILS TO REMAIN OPEN (PLUG)
G31-OR_-PG-RWB	2.16E-04	ORIFICE B FAILS TO REMAIN OPEN (PLUG)
G31-SYS-TM-B	3.00E-03	RWCU/SDCS TRAIN B IN MAINTENANCE OR OUT OF SERVICE
G31-UV_-CC-F017B	2.00E-04	CHECK VALVE F017B FAILS TO OPEN
G31-UV_-CC-F035B	1.60E-03	CHECK VALVE F035B FAILS TO OPEN
G31-UV_-CC-F094B	1.60E-03	CHECK VALVE F094B FAILS TO OPEN
G31-XHE-FO-SDC	1.77E-02	OPERATOR FAILS TO ACTUATE SDC MODE
G31-XHE-FO-SDCMSL	3.22E-02	OPERATOR FAILS TO ACTUATE SDC MODE
G31-XHE-FO-SDCSLCS	1.77E-01	OPERATOR FAILS TO ACTUATE SDC MODE AFTER SLCS ACTUATION
H23-RMU-CF-DIDALL	9.00E-07	CCF OF REMOTE MULTIPLEXING UNITS (DID)
H23-RMU-FC-001G31	3.00E-04	RMU 001 FOR MANUAL ACTUATION IN CONTROL ROOM FAILS
H23-RMU-FC-002G31	3.00E-04	RMU 002 FOR MANUAL ACTUATION IN CONTROL ROOM FAILS
N21-SYS-FF-FWAL	5.00E-01	PROBABILITY OF LSLOCA IN FW TRAIN A PIPE INSIDE CONTAINMENT
N21-SYS-FF-FWBL	5.00E-01	PROBABILITY OF LSLOCA IN FW TRAIN B PIPE INSIDE CONTAINMENT
P21-ACV-CO-F042A	4.80E-07	AIR OPERATED VALVE P21-F042A SPURIOUSLY TRANSFER TO ENERGIZED POSITION
P21-ACV-CO-F042B	7.20E-06	AIR OPERATED VALVE P21-F042B SPURIOUSLY TRANSFER TO ENERGIZED POSITION
P21-MOV-CC-F039B	4.00E-03	MOTOR OPERATED VALVE P21-F039B FAILS TO OPEN
P21-MOV-CC-F040B	4.00E-03	MOTOR OPERATED VALVE P21-F040B FAILS TO OPEN
P21-MOV-OC-F039A	3.36E-06	MOTOR OPERATED VALVE P21-F039 FAILS TO REMAIN OPEN
P21-MOV-OC-F040A	3.36E-06	MOTOR OPERATED VALVE P21-F040A FAILS TO REMAIN OPEN
T64-TT_-CF-HIGH	2.28E-06	CFF TEMPERATURE TRANSMITTERS IN STEAM TUNNELFAIL HIGH

Table 4.8-8

List of System Top Events

Top Event	Description
G31TOP	LOSS OF RWCU/SDC

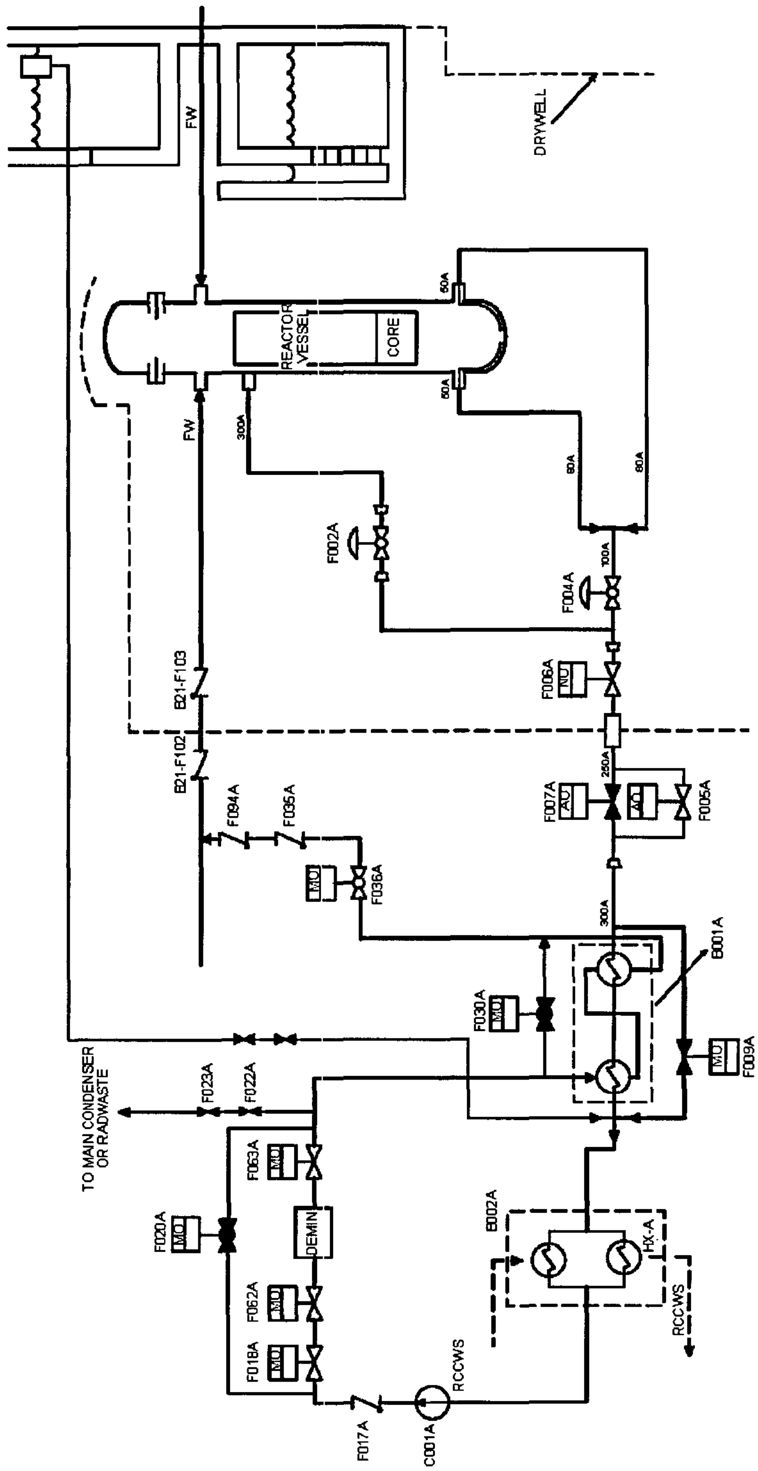


Figure 4.8-1(A). Simplified Process Flow Diagram for RWCU/SDC System

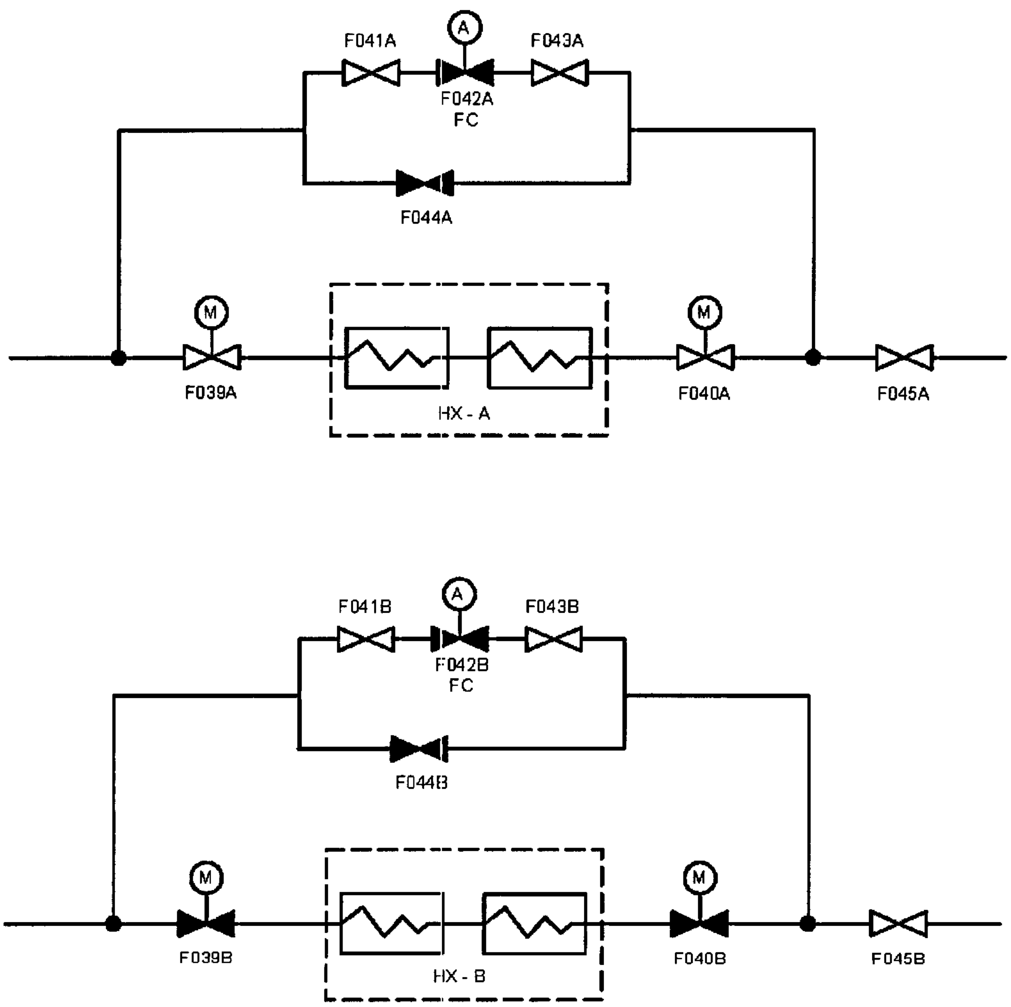


Figure 4.8-1(B). RCCWS/SDCS Simplified Process Flow Diagram

4.9 FEEDWATER AND CONDENSATE SYSTEM - (N21 and P22)

4.9.1 Purpose

This section includes the following parts of the plant: feedwater and condensate system, condenser hotwell makeup, main condenser and Circulating Water System (CIRC), steam bypass, and the Turbine Component Cooling Water system (TCCWS).

The purpose of the feedwater and condensate system is to receive condensate from the condenser hotwell and deliver feedwater to the reactor at the required flow rate, pressure, and temperature, both during normal operation and after shutdown.

The main condenser is the steam cycle heat sink, which receives and condenses the steam coming from the turbine or the steam bypass valves. It is utilized as a heat sink in the initial phase of reactor cooldown during a normal plant shutdown.

Condenser hotwell makeup from the Condensate Storage & Transfer System (CS&TS) and condensate reject to the Condensate Storage & Transfer System tank (CST) are provided to maintain condenser hotwell level. The makeup water to the CST is made through the demineralized water system.

The turbine bypass system (TBS) provides the capability to discharge steam from the main steam lines directly to the condenser.

The TCCW system provides cooling water to all turbine island auxiliary equipment.

4.9.2 Design Assumptions

The following assumptions with respect to the design are made:

(1) Based on the detail of design available, assumptions have been made in order to construct a model corresponding to the level of analysis generally adopted for this study.

(2) Valves F018 and F016 have been considered air operated valves, that fail to remain open on a loss of air supply.

4.9.3 System Description

4.9.3.1 Hardware Configuration

The feedwater and condensate system include the following main components:

- Four adjustable speed (33 to 45% each) motor-driven feedwater pumps.
- Four feedwater recirculation lines, one for each pump.
- Bypass lines for the feedwater pumps and the high-pressure heaters.
- Parallel strings, seven stages, low (four parallel strings) and high (two parallel strings) pressure feedwater heaters.
- Condensate filters and demineralizers.
- Four (33 to 37% each) percent motor-driven condensate pumps.

- One condensate recirculation line to the condenser.
- One condensate line to the CS&TS.
- One makeup line from the CST to the hotwell.

The TCCW system is composed of three 50 percent pumps, two 100 percent heat exchangers, a surge tank, and the related valves.

The current configuration for the CIRC has four 25 percent operating pumps. The turbine bypass system (TBS) has a 110 percent capacity, which allows full load reject capability without causing a reactor scram or opening any of the safety relief valves, and opens on a signal of high pressure in the steam line.

Figures 4.9-1, 2, 3, and 4 show simplified diagrams of the feedwater and condensate (Trains A and B), TCCWS, and circulating water systems, respectively, with the main components indicated.

The part of the Plant Service Water system that has been considered as part of the TCCWS for the purpose of the model is highlighted in Figure 4.9-5.

4.9.3.2 System Operation

During normal operation, three feedwater pumps and three condensate pumps are normally running at 33 percent flow. Upon a signal of low flow on the feedwater discharge line, the pump speed increases.

After a shutdown, two cases are possible:

- The system is still able to inject water at high pressure in the RPV with at least one feedwater pump and one condensate pump. If the Power Conversion System (PCS) is not available, the condenser makeup is also needed.
- The feedwater is not able to inject. In this case the operator can align the condensate pumps to provide the cooling water at low pressure with makeup from the condenser hotwell after opening the recirculation line. If the Power Conversion System (PCS) is not available, the condenser makeup is also needed.

A bypass is provided around the feedwater pumps to allow feedwater to be supplied to the reactor during startup or when the reactor is depressurized by using only the condensate pumps.

The condensate pumps take suction from the condenser hotwell and discharge into one common header, which feeds the filters, demineralizers, and auxiliary coolers. The recirculation line, downstream of the auxiliary condensers, allows the condensate pump flow to return to the main condenser, thus avoiding a condensate pump trip when the feedwater pumps stop.

The condenser hotwell level is maintained by a set of two parallel modulating air-operated valves (one for normal and one for emergency conditions). The set allows water to flow down by gravity from the CS&TS to the hotwell. Another set of valves allows for pumping water back to the CS&TS using the drain pump condenser.

Direct contact FW heater – Low pressure heater stage No. 5 is combined with a large horizontal storage tank (feedwater tank). The direct contact FW heater receives the condensate from the outlet of the low-pressure close contact heat up strings. Heating steam flows to the direct contact

FW heater to raise the temperature of the condensate to saturation level. Non-condensibles are vented through an orifice and valve assembly to the main condenser.

4.9.3.3 Component Location

All the main components and most of the piping related to this system are located within the non-safety related turbine building. Pumps of the CIRC are located in pump intake structure of the cooling tower basin.

4.9.4 Automatic and Manual Control

4.9.4.1 Automatic Control

Under normal operating conditions, system operation is automatic. The feedwater flow is regulated by the Feedwater Control system that utilizes measurements of steam flow, feedwater flow, and reactor level to regulate the feedwater pump speed. See also Section 7.7.3 of the Design Control Document, Reference 4.9-1.

After a scram, two of the three running pumps are automatically stopped in order to maintain the reactor level below Level 8.

A runback of all the feedwater pumps demand to zero is initiated upon the condition of high reactor water, Level 8. A trip of main feedwater pumps and condensate pumps is generated on high reactor water Level 9. The signal is derived from the narrow range level sensors.

An automatic and redundant level control system controls the level in all FW heaters, MS/RH drain tanks, direct contact feedwater heater and the condenser hotwells.

4.9.4.2 Manual Control

If manual recovery of automatic actuation failures is feasible, it is considered.

4.9.5 System Interfaces

Tables 4.9-2A, B and C show the dependency matrices for the feedwater and condensate, circulating water systems and TCCW, respectively.

The supporting systems are the 13.8 kV AC and 6.9 kV AC that supplies power to the pumps, the 480 V AC for MOV actuation, and the 125 V DC non-1E for the logic and the Instrument Air System (IAS) for air-operated valves.

The TCCW is a supporting system for the Feedwater and the Condensate systems, and needs the Plant Service Water System (PSWS) for cooling as well as the electrical power for the pumps (13.8 kV, 6.9 kV AC), the MOVs (480 V AC) and the logic (125 V DC).

4.9.6 System Testing

Monthly rotation of trains is assumed in Condensate, Feedwater and TCCWS.

The components on the bypass lines and the main lines (motor-operated isolation valves) are assumed to be not testable during operation.

Table 4.9-3 lists the components subject to test and their expected frequency of test.

4.9.7 System Maintenance

Maintenance of one branch at a time is allowed during normal operation for the feedwater, condensate, and TCCW systems.

4.9.8 Common Cause Failures

The possible types of common cause failures (CCFs) within the system are summarized in Table 4.9-5.

4.9.9 Fault Tree Analysis

4.9.9.1 Top Event Definitions

The following fault trees were developed:

GN21-0050-_1: PCS failure

GN21-0051-_1: High-pressure injection with feedwater fails.

GP22-0001-_1_: Loss of cooling from TCCWS System.

GN71-0001-_1: Circulating water system fails to provide condensate cooling.

4.9.9.2 Modeling Assumptions

- The system includes the condenser hotwell as well as its supply system from the condensate storage tank (included) and the turbine bypass, and the condensate and feedwater system.
- The CIRC and TCCWS are also modeled, including the cooling part of the heat exchangers corresponding to the PSWS indicated in Figure 4.9-5.
- The failure of the valves associated with the pumps operating during normal operation is not considered.
- Misalignment failures are not considered for valves associated with the pump that is in standby
- Monthly rotation of the standby train for Condensate, Feedwater and TCCWS is assumed.
- Type C human actions are included in the Emergency Operating Procedures or in other operating procedures.
- The failures of the main steam valves are considered as encompassed in the special event N21-SYS-FF-BYPASS corresponding to the failure of the turbine bypass.
- Failures of the condenser makeup system valves are considered as the cause of failure of the function.
- The failure due to maintenance of one condensate branch and of one feedwater branch is considered, without possibility of coinciding with another branch in maintenance, because the other three would be in operation if the plant were at 100% power.

(Operation at reduced power levels for maintenance on multiple trains is considered to produce negligible unavailability.)

4.9.9.3 Fault Tree Description

- Top event GN21-0050-_1 models the PCS failure. To achieve PCS success, operation of the turbine bypass is required for water supply, as well as the operation of at least one condensate pump and one feedwater pump for injection to the vessel. Condenser cooling by the CIRC is also required. However, condenser makeup is not required in this case, because the condenser is operating within the cycle.
- Top event GN21-0051-_1 models failure of high-pressure injection. Success of this function requires operation of at least one condensate pump and one feedwater pump for injection, as well as condenser water supply by gravity from the CS&TS.
- Top event GN71-0001-_1 models the circulating water system failure to provide condenser cooling. For this function to be successful, operation of at least one of the circulating water pumps is required.
- Top event GP22-0001-_1, an auxiliary system, evaluates the unavailability of the TCCW system; it is not common to any other front line system. For this function to be successful, operation of at least two of the three pumps is required, as well as operation of one of the two heat exchangers.

4.9.9.4 Human Interaction

The human interactions and their associated error probabilities that are considered in the analysis are the following as shown in Tables 4-9.6A, -6B, and –6C. No credit is taken for FW operation after runback for shutdown or ATWS conditions.

4.9.10 Results of Fault Tree Analysis

The definition of each basic event is reported in Table 4.9-7.

The quantification of core damage sequences implicitly includes the contribution of basic event for this system. This qualification process enables checking the global consistency of the system fault trees and their relationship with the rest of the systems modeled in the PRA.

On the other hand, the importance measurements obtained from core damage frequency equations, allow identification of the most relevant basic events and system component failures in an integrated context, as well as the determination of their relative importance with respect to the basic events and component failures of the other systems modeled.

4.9.11 Model Differences for 72-Hours Operation

The only change necessary for the model is the adjustment of the mission time to 72 hours.

4.9.12 References

4.9-1. ESBWR Design Control Document, 26A6642 Rev. 01

Table 4.9-1

Control Room Instrumentation and Alarms

Controls
Condensate and Feedwater flow
Condenser hotwell level
Automatic FW pump recirculation flow
Displays
Steam flow
Feedwater flow
Reactor water level
Hotwell level
CST level
FW pump suction and discharge pressure
Alarms

Table 4.9-2A

Condensate and Feedwater Dependency Matrix

		Support System				
		Power Supply				
		13.8 kV AC				
Component	**Type**	**Bus A1**	**Bus B1**	**Bus C1**	**Bus D1**	**TCCWS**
N21C001	Cond. Pump	X				X
N21C002	Cond. Pump		X			X
N21C003	Cond. Pump			X		X
N21C004	Cond. Pump				X	X
N21C010	FW Pump	X				X
N21C020	FW Pump		X			X
N21C030	FW Pump			X		X
N21C040	FW Pump				X	X

		Support System				
		Power Supply			480 V AC Non-1E	IAS
		Uninterruptible 208/120 VAC				
Component	**Type**	**R13-A2-1**	**R13-B2-1**	**R13-C1-3**		
F008	MOV				X	
F023	AOV	X				X
F026	AOV		X			X
F016	AOV			X		X
F061	MOV			X		

Table 4.9-2B

Circulating Water System Dependency Matrix

		Support System				
		Power Supply				TCCWS
		13.8 kV AC				
Component	**Type**	**Bus A1**	**Bus B1**	**Bus C1**	**Bus D1**	
C001	Pump	X				X
C002	Pump		X			X
C003	Pump			X		X
C004	Pump				X	X

Table 4.9-2C

Turbine Component Cooling Water System Dependency Matrix

		Support System		
		Power Supply		PSW
		6.9 kV AC		
Component	**Type**	**Bus A3**	**Bus B3**	
C001	Pump	X		
C002	Pump		X	
C003	Pump		X	
B001	Heat exchanger			X
B002	Heat exchanger			X

Table 4.9-3

Component Test

Component Type	Expected Test Interval	Components aligned away from emergency position without automatic return logic
F061	2 years	-
F016	2 years	-
F023	2 years	-
F026	2 years	-
F008	1 month	-
Transmitters	2 years	-

Note: monthly rotation between trains in Feedwater, Condensate and TCCWS has been assumed.

Table 4.9-4

Component Maintenance

Maintenance of one branch at time is allowed during normal operation for the feedwater, condensate and TCCW systems. The failure due to maintenance of one condensate branch and of one feedwater branch is considered, without possibility of coinciding with another branch in maintenance, because the other three would be in operation if the plant were at 100% power. (Operation at reduced power levels for maintenance on multiple trains is considered to produce negligible unavailability.).

Table 4.9-5A

Common Cause Failures for Condensate and Feedwater System

Event Name	Unavailability	Description
B21-LT_-CF-L8NO	1.20E-07	CCF LEVEL TRANSMITTERS L8 (FAILURE TO RESPOND TO CHANGE)
B21-LT_-CF-L9SPU1	1.20E-07	SPURIOUS L9 SIGNAL CCF
C62-DTM-CF-N1EALL	5.50E-05	CCF OF DIGITAL TRIP MODULES NO 1E
H23-RMU-CF-N1EALL	9.00E-07	CCF OF REMOTE MULTIPLEXING UNITS (NO 1E) TO OPERATE
N21-ACV-CF-MKUPA/B	1.08E-04	CCF TO OPERATE AOVs TRAINS A & B
N21-LT_-CF-FWTKLOW	6.00E-08	CCF OF LEVEL TRANSMITTERS (LOW) IN FW STORAGE TANK
N21-LT_-CF-FWTKNO	4.38E-05	CCF FEEDWATER STORAGE TANK LEVEL TRANSMITTERS
N21-LT_-CF-HWLOW	6.00E-08	CCF HOTWELL LEVEL TRANSMITTERS TO STOP PUMPS
N21-LT_-CF-HWNO	4.38E-05	CCF HOTWELL LEVEL TRANSMITTERS
N21-MPF-CR-RUN	3.00E-06	FEEDWATER PUMPS CCF TO RUN
N21-MP_-CR-COND	3.00E-06	CONDENSATE PUMPS CCF TO RUN

Table 4.9-5B

Common Cause Failures For Circulating Water System

Event Name	Unavailability	Description
N71-MP_-CR-PUMP	7.91E-06	CCF PUMPS CWS TO RUN
N71-STR-CF-CWS	1.07E-05	CCF STRAINER TO RUN
XXX-MP_-CR-SWS/CWS	7.91E-06	CCF PUMPS TO RUN SWS/CWS

Table 4.9-5C

Common Cause Failures For Turbine Component Cooling Water System

Event Name	Unavailability	Description
C62-DTM-CF-N1EALL	5.5E-05	CCF OF DIGITAL TRIP MODULES NO 1E
P22-MCB-CF-2ALL	9.29E-05	CCF 2 OUT OF 3 CIRCUIT BEAKERS FAIL TO CLOSE
P22-MP_-CR-C001ABC	2.40E-06	CCF TO RUN 2 PUMPS
P22-MP_-CS-2ALL	2.60E-05	CCF 2 OUT OF 3 PUMPS FAIL TO START
P22-PT_-CF-N001	1.72E-06	CCF 2/3 DISCHARGE PRESSURE TRANSMITTERS
P22-PT_-CF-N002LOW	3.00E-08	CCF SUCTION PRESSURE 2/ 3 TRANSMITTERS
P22-TT_-CF-N003LOW	2.20E-07	CCF 2/ 3 TEMPERATURE TRANSMITTERS

Table 4.9-6A

Human Errors For Feedwater And Condensate System

Event Name	Unavailability	Description
N21-XHE-FO-CONDPUMPD	2.69E-01	OPERATOR FAILS TO START CONDENSATE PUMP D
N21-XHE-FO-FWPUMPD	2.69E-01	OPERATOR FAILS TO START FEEDWATER PUMP D

Table 4.9-6B

Human Errors for Circulating Water System

No human errors have been considered

Table 4.9-6C

Human Errors for Turbine Component Cooling Water System

Event Name	Unavailability	Description
P22-XHE-FO-HXB	2.69E-01	OPERATOR FAILS TO ALIGN HX B

Table 4.9-7A

Basic Events for Feedwater and Condensate System

Event Name	Unavailability	Description
B21-LT_-CF-L8NO	1.20E-07	CCF LEVEL TRANSMITTERS L8 (FAILURE TO RESPOND TO CHANGE)
B21-LT_-CF-L9SPU1	1.20E-07	SPURIOUS L9 SIGNAL CCF
B21-LT_-NO-LVL8A	2.40E-05	LEVEL TRANSMITTER A (RX LVL 8) FAILS TO RESPOND TO CHANGE
B21-LT_-NO-LVL8B	2.40E-05	LEVEL TRANSMITTER B (RX LVL 8) FAILS TO RESPOND TO CHANGE
B21-LT_-NO-LVL8C	2.40E-05	LEVEL TRANSMITTER C (RX LVL 8) FAILS TO RESPOND TO CHANGE
C62-DTM-CF-N1EALL	5.5E-05	CCF OF DIGITAL TRIP MODULES NO 1E
C62-DTM-FC-N1EA	9.00E-04	DIGITAL TRIP MODULE TRAIN A NO 1E FAILS
C62-DTM-FC-N1EB	9.00E-04	DIGITAL TRIP MODULE TRAIN B NO 1E FAILS
C62-DTM-FC-N1EC	9.00E-04	DIGITAL TRIP MODULE TRAIN C NO 1E FAILS
H23-RMU-CF-N1EALL	9.00E-07	CCF OF REMOTE MULTIPLEXING UNITS (NO 1E) TO OPERATE
H23-RMU-FC-1CONDD	3.00E-04	RMU 001 FOR COND PUMP D MANUAL ACTUATION FAILS TO OPERATE
H23-RMU-FC-1FWD	3.00E-04	RMU 001 FOR FW PUMP D MANUAL ACTUATION FAILS TO OPERATE
H23-RMU-FC-2CONDD	3.00E-04	RMU 002 FOR COND PUMP D MANUAL ACTUATION FAILS TO OPERATE
H23-RMU-FC-2FWD	3.00E-04	RMU 002 FOR FW PUMP D MANUAL ACTUATION FAILS TO OPERATE
H23-RMU-FC-FWTKA	3.00E-04	RMU LEVEL TRANSMITTER A FW TANK FAILS
H23-RMU-FC-FWTKB	3.00E-04	RMU LEVEL TRANSMITTER B FW TANK FAILS
H23-RMU-FC-FWTKC	3.00E-04	RMU LEVEL TRANSMITTER C FW TANK FAILS
H23-RMU-FC-HWA	3.00E-04	RMU LEVEL TRANSMITTER FW TANK A FAILS
H23-RMU-FC-HWB	3.00E-04	RMU LEVEL TRANSMITTER FW TANK B FAILS
H23-RMU-FC-HWC	3.00E-04	RMU LEVEL TRANSMITTER FW TANK C FAILS
H23-RMU-FC-LVL8A	3.00E-04	RMU LEVEL TRANSMITTER A (RX LVL 8) FAILS TO FUNCTION
H23-RMU-FC-LVL8B	3.00E-04	RMU LEVEL TRANSMITTER B (RX LVL 8) FAILS TO FUNCTION
H23-RMU-FC-LVL8C	3.00E-04	RMU LEVEL TRANSMITTER C (RX LVL 8) FAILS TO FUNCTION
N21-ACV-CC-F023	1.58E-02	AIR OPERATED VALVE N21-F023 FAILS TO OPEN
N21-ACV-CC-F026	1.58E-02	AIR OPERATED VALVE N21-F026 FAILS TO OPEN

Table 4.9-7A

Basic Events for Feedwater and Condensate System

Event Name	Unavailability	Description
N21-ACV-CF-MKUPA/B	1.08E-04	CCF TO OPERATE AOVs TRAINS A & B
N21-ACV-OC-F016	1.31E-03	AIR OPERATED VALVE N21-F016 FAILS TO REMAIN OPEN
N21-ACV-OC-F018	1.31E-03	AIR OPERATED VALVE N21-F018 FAILS TO REMAIN OPEN
N21-ACV-TM-F026	8.00E-04	VALVE N21-F026 UNAVAILABLE DUE TO TEST OR MAINTENANCE
N21-LT_-CF-FWTKLOW	6.00E-08	CCF OF LEVEL TRANSMITTERS (LOW) IN FW STORAGE TANK
N21-LT_-CF-FWTKNO	4.38E-05	CCF FEEDWATER STORAGE TANK LEVEL TRANSMITTERS
N21-LT_-CF-HWLOW	6.00E-08	CCF HOTWELL LEVEL TRANSMITTERS TO STOP PUMPS
N21-LT_-CF-HWNO	4.38E-05	CCF HOTWELL LEVEL TRANSMITTERS
N21-LT_-LO-FWTKA	1.22E-05	LEVEL TRANSMITTER TRAIN A FAILS LOW
N21-LT_-LO-FWTKB	1.22E-05	LEVEL TRANSMITTER TRAIN B FAILS LOW
N21-LT_-LO-FWTKC	1.22E-05	LEVEL TRANSMITTER TRAIN C FAILS LOW
N21-LT_-LO-HWA	1.22E-05	LEVEL TRANSMITTER TRAIN A FAILS LOW
N21-LT_-LO-HWB	1.22E-05	LEVEL TRANSMITTER TRAIN B FAILS LOW
N21-LT_-LO-HWC	1.22E-05	LEVEL TRANSMITTER TRAIN C FAILS LOW
N21-LT_-NO-FWTKA	8.71E-03	LEVEL TRANSMITTER TRAIN A FAILS
N21-LT_-NO-FWTKB	8.71E-03	LEVEL TRANSMITTER TRAIN B FAILS
N21-LT_-NO-FWTKC	8.71E-03	LEVEL TRANSMITTER TRAIN C FAILS
N21-LT_-NO-HWA	8.71E-03	LEVEL TRANSMITTER TRAIN A FAILS
N21-LT_-NO-HWB	8.71E-03	LEVEL TRANSMITTER TRAIN B FAILS
N21-LT_-NO-HWC	8.71E-03	LEVEL TRANSMITTER TRAIN C FAILS
N21-MCB-CO-CONDA	1.20E-05	CIRCUIT BREAKER FOR CONDENSATE PUMP A OPENS SPURIOUSLY
N21-MCB-CO-CONDB	1.20E-05	CIRCUIT BREAKER FOR CONDENSATE PUMP B OPENS SPURIOUSLY
N21-MCB-CO-CONDC	1.20E-05	CIRCUIT BREAKER FOR CONDENSATE PUMP C OPENS SPURIOUSLY
N21-MCB-CO-FWA	1.20E-05	CIRCUIT BREAKER FOR FW PUMP A OPENS SPURIOUSLY
N21-MCB-CO-FWB	1.20E-05	CIRCUIT BREAKER FOR FW PUMP B OPENS SPURIOUSLY
N21-MCB-CO-FWC	1.20E-05	CIRCUIT BREAKER FOR FW PUMP C OPENS SPURIOUSLY
N21-MCB-CO-FWD	1.20E-05	CIRCUIT BREAKER FOR FW PUMP D OPENS SPURIOUSLY

Table 4.9-7A

Basic Events for Feedwater and Condensate System

Event Name	Unavailability	Description
N21-MCB-OO-CONDD	1.00E-03	CIRCUIT BREAKER FOR CONDENSATE PUMP D FAILS TO CLOSE
N21-MCB-OO-FWD	1.00E-03	CIRCUIT BREAKER TO FEEDWATER PUMP D FAILS TO CLOSE
N21-MOV-CC-F008	4.00E-03	MOTOR OPERATED VALVE F008 FAILS TO OPEN
N21-MOV-CC-F061	3.13E-02	MOTOR OPERATED VALVE N21-F061 FAILS TO OPEN
N21-MPF-CR-RUN	3.00E-06	FEEDWATER PUMPS CCF TO RUN
N21-MPF-FR-C001A	6.00E-04	MOTOR-DRIVEN FDWTR PUMP A FAILS TO RUN, GIVEN START
N21-MPF-FR-C001B	6.00E-04	MOTOR-DRIVEN FDWTR PUMP B FAILS TO RUN, GIVEN START
N21-MPF-FR-C001C	6.00E-04	MOTOR-DRIVEN FDWTR PUMP C FAILS TO RUN, GIVEN START
N21-MPF-FR-C001D	6.00E-04	MOTOR-DRIVEN FDWTR PUMP D FAILS TO RUN, GIVEN START
N21-MPF-FS-C001D	2.00E-03	MOTOR-DRIVEN FEEDWATER PUMP D FAILS TO RESTART
N21-MPF-TM-C001D	2.00E-03	FEEDWATER PUMP BRANCH D IN MAINTENANCE
N21-MP_-CR-COND	3.00E-06	CONDENSATE PUMPS CCF TO RUN
N21-MP_-FR-CONDA	6.00E-04	MOTOR-DRIVEN COND. PUMP A FAILS TO RUN, GIVEN START
N21-MP_-FR-CONDB	6.00E-04	MOTOR-DRIVEN COND PUMP B FAILS TO RUN, GIVEN START
N21-MP_-FR-CONDC	6.00E-04	MOTOR-DRIVEN COND PUMP C FAILS TO RUN, GIVEN START
N21-MP_-FR-CONDD	6.00E-04	MOTOR-DRIVEN PUMP D FAILS TO RUN, GIVEN START
N21-MP_-FS-CONDD	2.00E-03	MOTOR-DRIVEN CONDENSATE PUMP D FAILS TO START
N21-MP_-TM-CONDD	3.00E-03	FEEDWATER PUMP BRANCH D IN MAINTENANCE
N21-OR_-PG-FWCPRECIRD	1.44E-05	ORIFICE FOR FWP D RECIRC FAILS TO REMAIN OPEN (PLUG)
N21-STR-PG-FL001A	2.40E-04	STRAINER/FILTER FOR PMP A PLUGS DURING OPERATION
N21-STR-PG-FL001B	2.40E-04	STRAINER/FILTER FOR PMP B PLUGS DURING OPERATION
N21-STR-PG-FL001C	2.40E-04	STRAINER/FILTER FOR PMP C PLUGS DURING OPERATION
N21-STR-PG-FL001D	3.59E-03	STRAINER/FILTER FOR PMP D PLUGS DURING OPERATION

Table 4.9-7A

Basic Events for Feedwater and Condensate System

Event Name	Unavailability	Description
N21-SYS-FF-BYPASS	1.00E-02	TURBINE BYPASS FAILS
N21-UV_-CC-F008D	2.00E-04	CHECK VALVE F008D FOR CND PUMP D FAILS TO OPEN
N21-UV_-CC-F021D	2.00E-04	CHECK VALVE F021D FOR FWP D FAILS TO OPEN
N21-XHE-FO-CONDPUMPD	2.69E-01	OPERATOR FAILS TO START CONDENSATE PUMP D
N21-XHE-FO-FWPUMPD	2.69E-01	OPERATOR FAILS TO START FEEDWATER PUMP D
P30-TNK-RP-A001	2.40E-06	CONDENSATE STORAGE TANK LEAKS CATASTROPHICALLY

Table 4.9-7B

Basic Events For Circulating Water System

Event Name	Unavailability	Description
N71-MCB-CO-PUMPA	1.20E-05	CIRCUIT BREAKER FOR CIRC PUMP A OPENS SPURIOUSLY
N71-MCB-CO-PUMPB	1.20E-05	CIRCUIT BREAKER FOR CIRC PUMP B OPENS SPURIOUSLY
N71-MCB-CO-PUMPC	1.20E-05	CIRCUIT BREAKER FOR PUMP C OPENS SPURIOUSLY
N71-MCB-CO-PUMPD	1.20E-05	CIRCUIT BREAKER FOR PUMP D OPENS SPURIOUSLY
N71-MP_-CR-PUMP	7.91E-06	CCF PUMPS CWS TO RUN
N71-MP_-FR-C001A	6.00E-04	MOTOR-DRIVEN PUMP A FOR CIRC FAILS TO RUN, GIVEN START
N71-MP_-FR-C001B	6.00E-04	MOTOR-DRIVEN PUMP B FOR CIRC FAILS TO RUN, GIVEN START
N71-MP_-FR-C001C	6.00E-04	MOTOR-DRIVEN PUMP C FOR CIRC FAILS TO RUN, GIVEN START
N71-MP_-FR-C001D	6.00E-04	MOTOR-DRIVEN PUMP D FOR CIRC WATER SYS FAILS TO RUN
N71-STR-CF-CWS	1.07E-05	CCF STRAINER TO RUN
XXX-MP_-CR-SWS/CWS	7.91E-06	CCF PUMPS TO RUN SWS/CWS

Table 4.9-7C

Basic Events for Turbine Component Cooling Water System

Event Name	Unavailability	Description
C62-DTM-CF-N1EALL	5.5E-05	CCF OF DIGITAL TRIP MODULES NO 1E
C62-DTM-FC-N1EA	9.00E-04	DIGITAL TRIP MODULE TRAIN A NO 1E FAILS
C62-DTM-FC-N1EB	9.00E-04	DIGITAL TRIP MODULE TRAIN B NO 1E FAILS
C62-DTM-FC-N1EC	9.00E-04	DIGITAL TRIP MODULE TRAIN C NO 1E FAILS
H23-RMU-FC-1HXB	3.00E-04	RMU 001 FOR MANUAL ACTUATION IN CONTROL ROOM FAILS
H23-RMU-FC-2HXB	3.00E-04	RMU 002 FOR MANUAL ACTUATION IN CONTROL ROOM FAILS
H23-RMU-FC-P22N001A	3.00E-04	RMU PRESS TANSMITTER A FAILS
H23-RMU-FC-P22N001B	3.00E-04	RMU PRESS TANSMITTER B FAILS
H23-RMU-FC-P22N001C	3.00E-04	RMU PRESS TANSMITTER C FAILS
H23-RMU-FC-P22N002A	3.00E-04	RMU PRESS TRANSMITTER A FAILS
H23-RMU-FC-P22N002B	3.00E-04	RMU PRESS TRANSMITTER B FAILS
H23-RMU-FC-P22N002C	3.00E-04	RMU PRESS TRANSMITTER C FAILS
H23-RMU-FC-P22N003A	3.00E-04	RMU TRANSMITTER N003A FAILS
H23-RMU-FC-P22N003B	3.00E-04	RMU TRANSMITTER N003B FAILS
H23-RMU-FC-P22N003C	3.00E-04	RMU TRANSMITTER N003C FAILS
P22-ACV-FT-BYPASS	2.00E-03	HEAT EXCHANGERS BYPASS VALVE FAILS TO REGULATE
P22-HX_-PG-B001A	5.28E-05	HEAT EXCHANGER A FAILS
P22-HX_-PG-B001B	7.92E-04	HEAT EXCHANGER B FAILS
P22-HX_-TM-B001B	2.20E-03	HEAT EXCHANGER B IN MAINTENANCE
P22-MCB-CF-2ALL	9.29E-05	CCF 2 OUT OF 3 CIRCUIT BEAKERS FAIL TO CLOSE
P22-MCB-CO-C001A	1.20E-05	CIRCUIT BREAKER FOR TCCW PUMP A OPENS SPURIOUSLY
P22-MCB-CO-C001B	1.20E-05	CIRCUIT BREAKER FOR TCCW PUMP B OPENS SPURIOUSLY
P22-MCB-OO-C001A	1.00E-03	MEDIUM VOLTAGE CIRCUIT BREAKER (PUMP A) FAILS TO CLOSE
P22-MCB-OO-C001B	1.00E-03	MEDIUM VOLTAGE CIRCUIT BREAKER FAILS TO CLOSE
P22-MCB-OO-C001C	1.00E-03	CIRCUIT BREAKER FOR TCCW PUMP C FAILS TO CLOSE
P22-MOV-CC-HXB	4.00E-03	MOV OF HX B FAILS TO OPEN
P22-MP_-CR-C001ABC	2.40E-06	CCF TO RUN 2 PUMPS
P22-MP_-CS-2ALL	2.60E-05	CCF 2 OUT OF 3 PUMPS FAIL TO START

Table 4.9-7C

Basic Events for Turbine Component Cooling Water System

Event Name	Unavailability	Description
P22-MP_-FR-C001A	1.20E-04	MOTOR-DRIVEN PUMP A FOR TCCWS FAILS TO RUN, GIVEN START
P22-MP_-FR-C001B	1.20E-04	MOTOR-DRIVEN PUMP B FOR TCCWS FAILS TO RUN, GIVEN START
P22-MP_-FR-C001C	1.20E-04	MOTOR-DRIVEN PUMP C FOR TCCWS FAILS TO RUN, GIVEN START
P22-MP_-FS-C001A	1.30E-03	MOTOR-DRIVEN PUMP (ALL TYPES) FAILS TO START
P22-MP_-FS-C001B	1.30E-03	MOTOR-DRIVEN PUMP (ALL TYPES) FAILS TO START
P22-MP_-FS-C001C	1.30E-03	MOTOR-DRIVEN PUMP C FOR TCCWS FAILS TO START
P22-MP_-TM-C001C	2.00E-03	TCCW PUMP C IN MAINTENANCE
P22-PT_-CF-N001	1.72E-06	CCF 2/3 DISCHARGE PRESSURE TRANSMITTERS
P22-PT_-CF-N002LOW	3.00E-08	CCF SUCTION PRESSURE 2/ 3 TRANSMITTERS
P22-PT_-LO-N002A	7.92E-06	PRESSURE TRANSMITTER N002A FAILS
P22-PT_-LO-N002B	7.92E-06	PRESSURE TRANSMITTER N002B FAILS
P22-PT_-LO-N002C	1.19E-04	PRESSURE TRANSMITTER N002C FAILS
P22-PT_-NO-N001A	3.46E-04	PRESSURE TRANSMITTER NOO1A FAILS
P22-PT_-NO-N001B	3.46E-04	PRESSURE TRANSMITTER NOO1B FAILS
P22-PT_-NO-N001C	3.46E-04	PRESSURE TRANSMITTER NOO1C FAILS
P22-TNK-RP-A001	2.40E-06	TCCW SURGE TANK LEAKS CATASTROPHICALLY
P22-TT_-CF-N003LOW	2.20E-07	CCF 2/ 3 TEMPERATURE TRANSMITTERS
P22-TT_-LO-N003A	4.56E-05	TEMPERATURE TRANSMITTER N003A FAILS
P22-TT_-LO-N003B	4.56E-05	TEMPERATURE TRANSMITTER N003B FAILS
P22-TT_-LO-N003C	4.56E-05	TEMPERATURE TRANSMITTER N003C FAILS
P22-UV_-CC-F034C	2.00E-04	CHECK VALVE F034 C FAILS TO OPEN
P22-UV_-OO-F034A	1.00E-03	CHECK VALVE F034A FAILS TO CLOSE
P22-UV_-OO-F034B	1.00E-03	CHECK VALVE F034B FAILS TO CLOSE
P22-XHE-FO-HXB	2.69E-01	OPERATOR FAILS TO ALIGN HX B
P41-ACV-OC-F000A	1.08E-04	VALVE P22-F000A FAILS TO REMAIN OPEN
P41-ACV-OC-F000B	1.08E-04	VALVE P22-F000B FAILS TO REMAIN OPEN
P41-ACV-OC-F001A	1.08E-04	VALVE P22-F001A FAILS TO REMAIN OPEN
P41-ACV-OC-F001B	1.08E-04	VALVE P22-F001B FAILS TO REMAIN OPEN

Table 4.9-8

List of System Top Events

Top Event Name	Description
GN21-0050-_1	PCS FAILURE
GN21-0051-_1	HIGH PRESSURE INJECTION WITH FEEDWATER FAILS
GP22-0001-_1	LOSS OF COOLING FROM TCCW SYSTEM
GN71-0001-_1	CIRCULATING WATER SYSTEM FAILS TO PROVIDE COND. COOL.

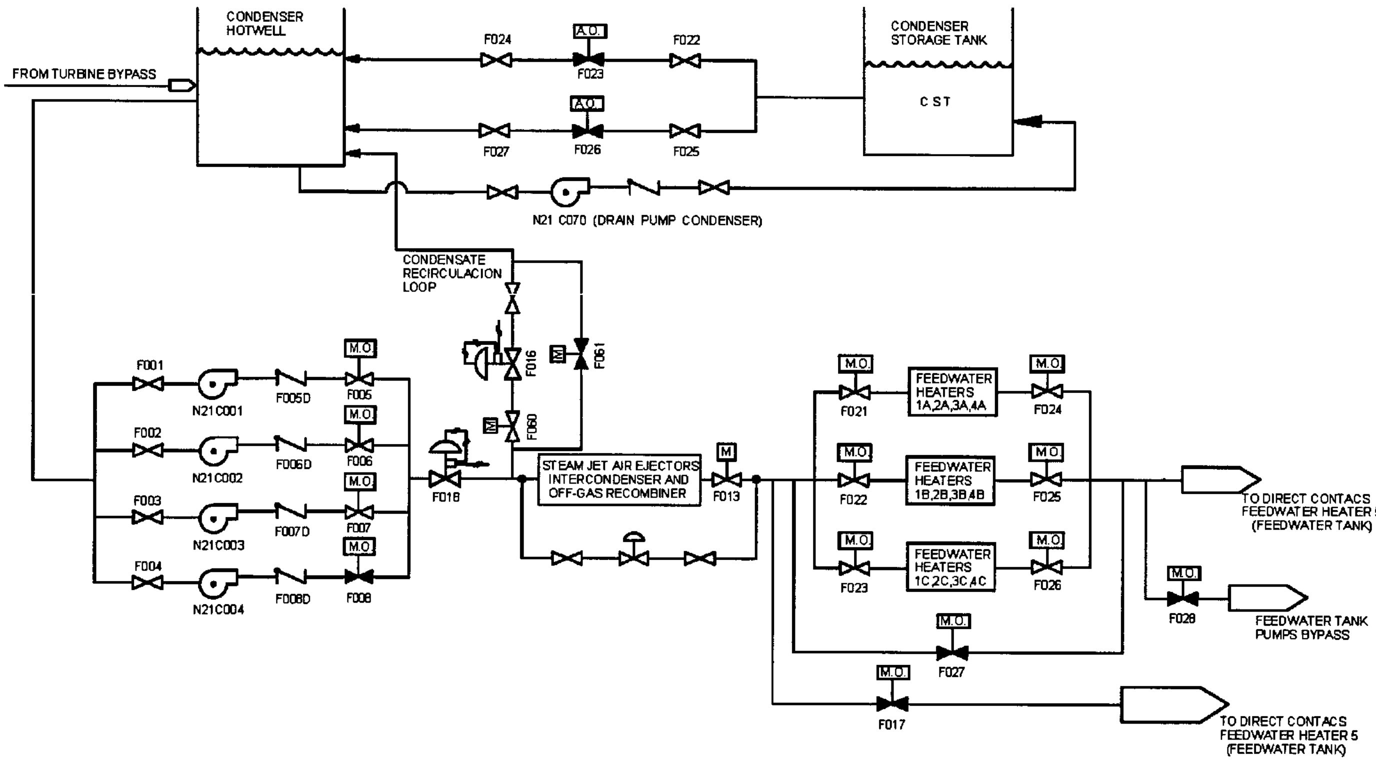


Figure 4.9-1. Condensate and Feedwater System (A) Process Flow Diagram

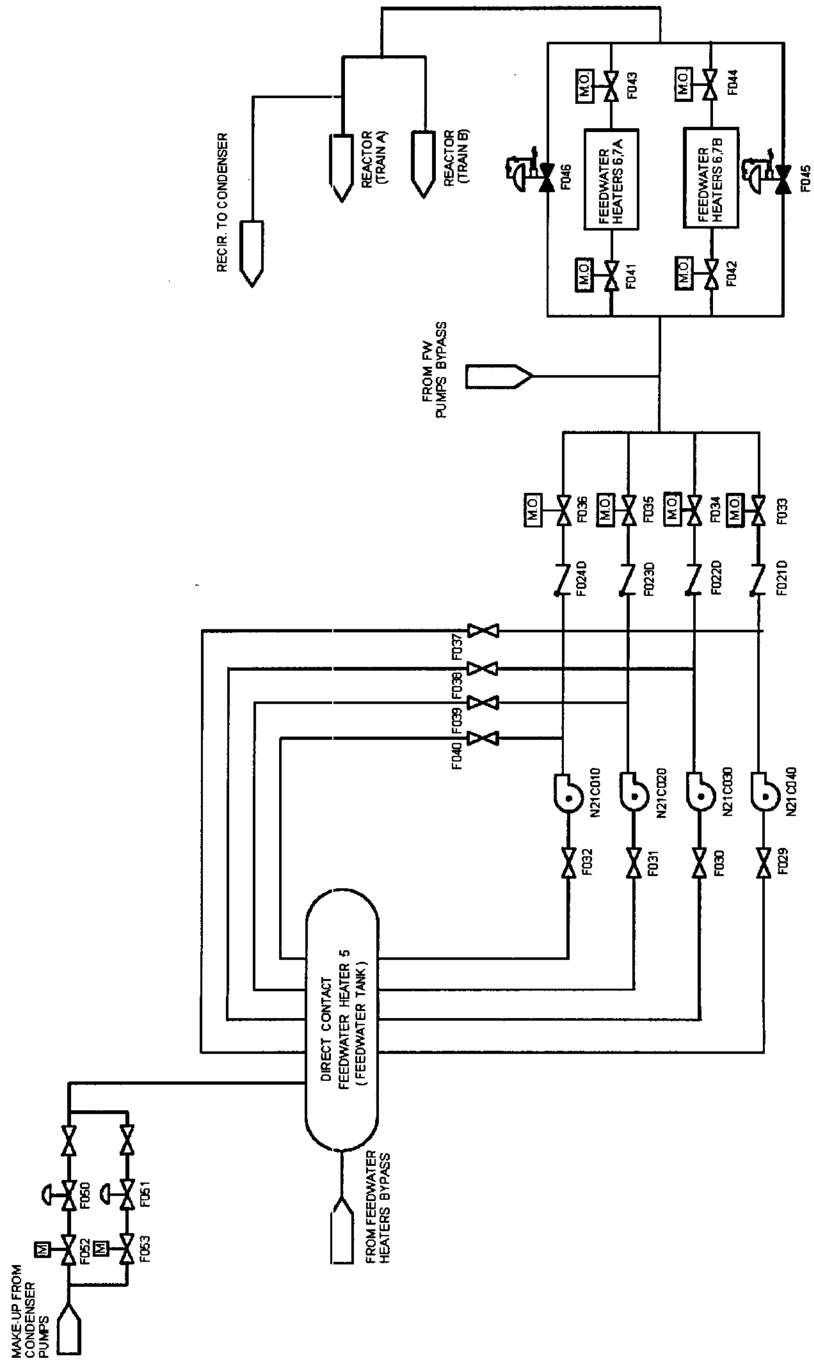


Figure 4.9-2. Condensate and Feedwater System (B) Process Flow Diagram

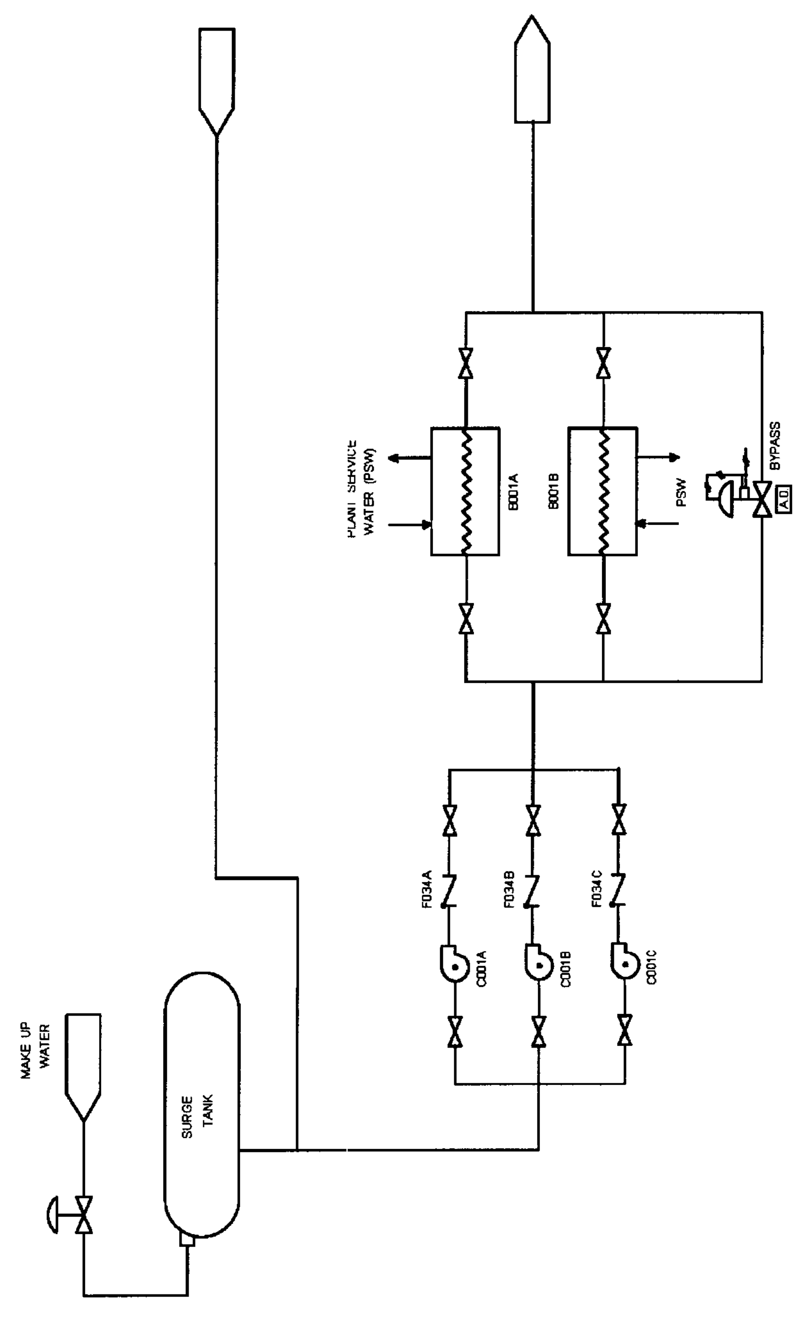


Figure 4.9-3. Turbine Component Cooling Water System Process Flow Diagram

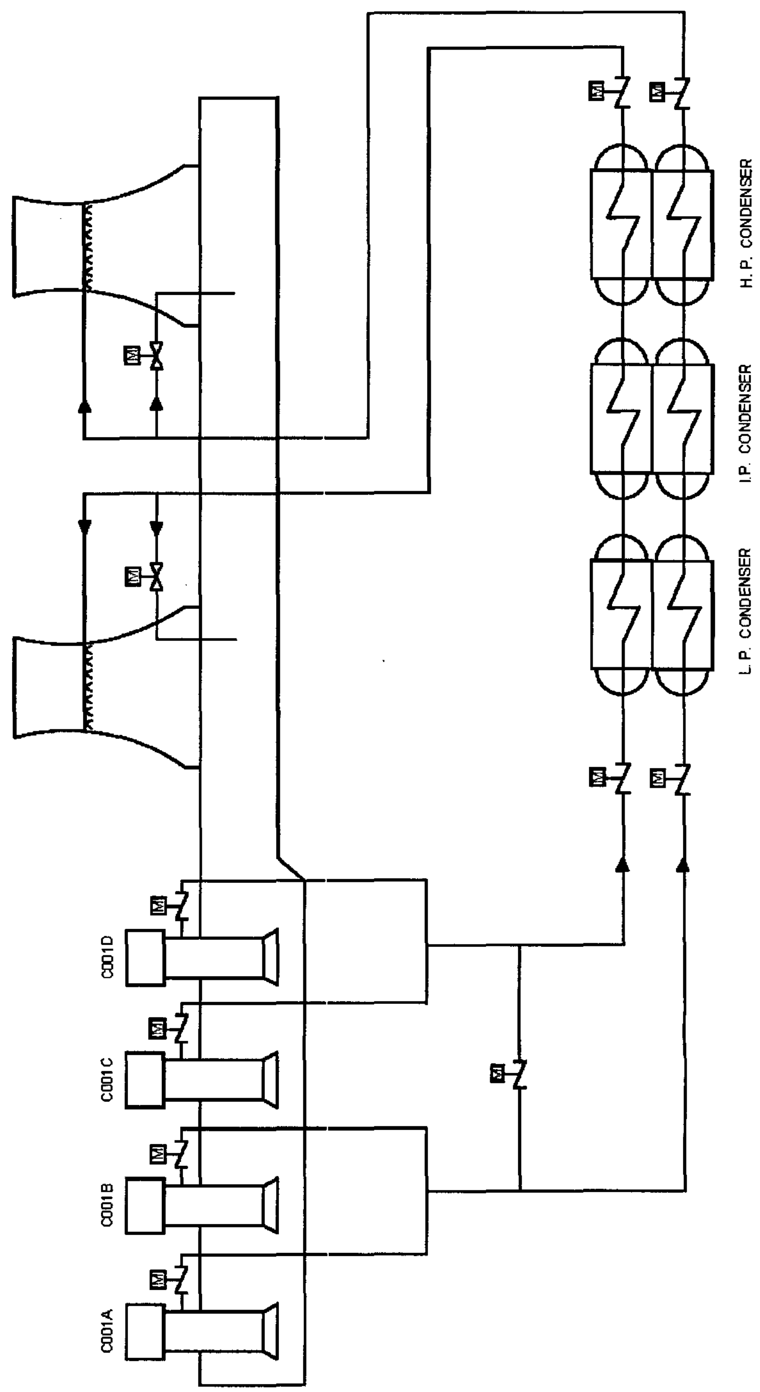


Figure 4.9-4. Circulating Water System Process Flow Diagram

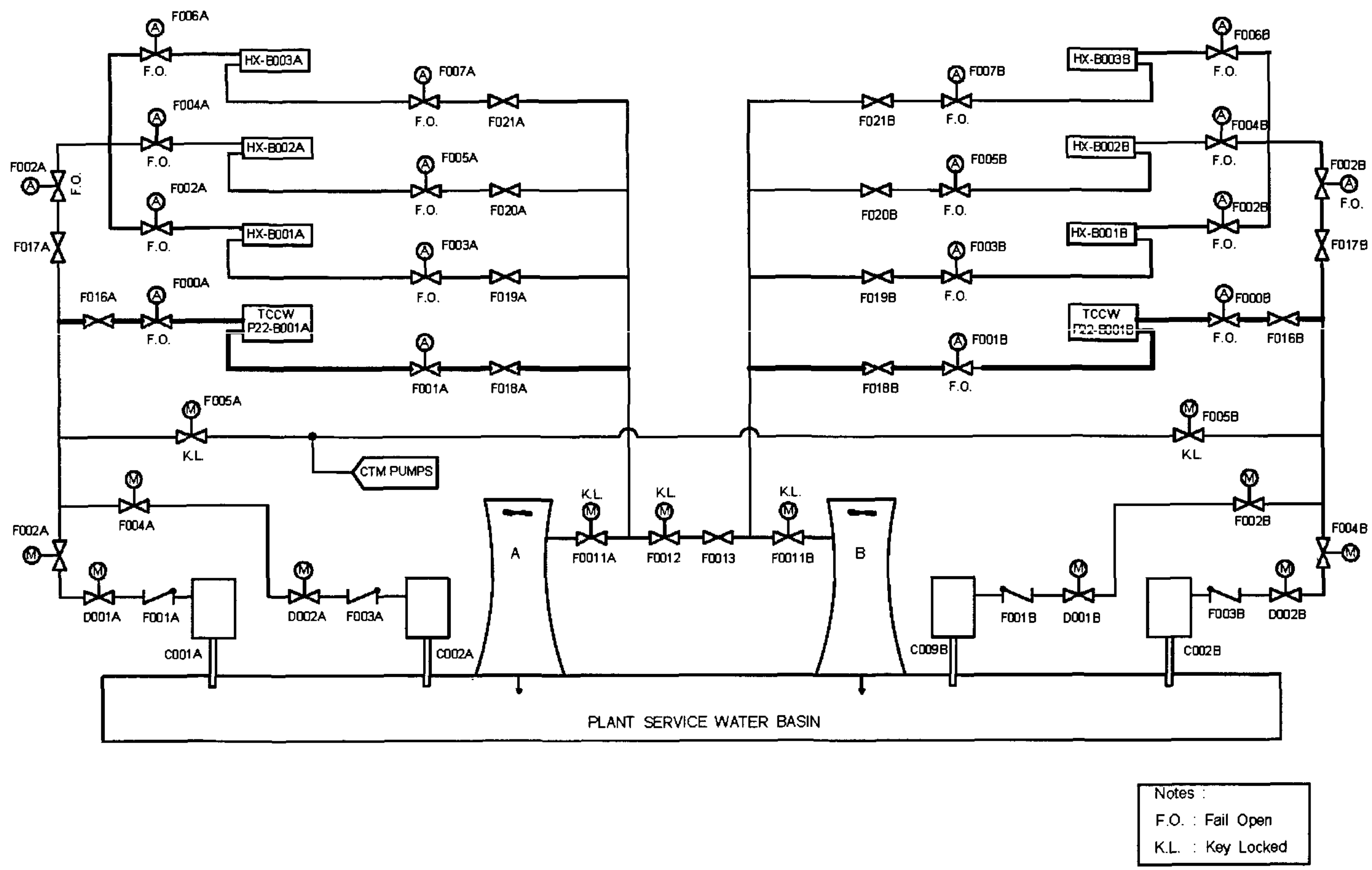


Figure 4.9-5. TCCW-PSW System

4.10 REACTOR COMPONENT COOLING WATER SYSTEM – (P21)

4.10.1 Purpose

RCCWS (P21) removes heat from systems in the drywell and Reactor Building that require cooling water during normal operation, shutdown, and hot standby, and rejects this heat to the environment using the PSW system.

Reactor Component Cooling Water System has no safety-related functions.

4.10.2 Design Assumptions

The following assumptions with respect to the design are made:

(1) The volume of water in the tanks required by Technical Specification are sufficient for water to be supplied to the pumps for 72 hours and therefore, the make up of the inventory in the surge tank using the Fire Protection System is not necessary.

(2) All the components of train A are powered from division I and those of train B from division II.

(3) The connection valves have the following uninterrupted power supply: valves P21-F010 and P21-F032 are powered from division A and valves P21-F013 and P21-F027 are powered from an uninterrupted power supply from division B.

(4) The relevant measures are taken so that the air-operated valves do not depend on the Instrument Air System in an emergency situation.

(5) In case one of the pumps fails, another pump from the same train receives a startup signal. This signal transmission within the division, is included in the model. It is also considered that the pumps can be started from the control room.

(6) In shutdown mode, 2 pumps and 2 heat exchangers are sufficient to cool the necessary loads. In the case of a LOPP, another heat exchanger and pump are required to be started to replace the train that has lost power.

(7) Room cooling is not required for first 24 hours of the accident.

(8) All loads needed for the PRA are specified/required to be cooled with at least n+1 redundancy.

4.10.3 System Description

The RCCWS analysis described here refers to the system configuration shown in the diagram of Figure 4.10.1.

4.10.3.1 Hardware Configuration

RCCWS is comprised of two interconnected divisions of closed cooling water. Each division consists of 3 pumps and 3 heat exchangers connected in parallel to a common discharge header/piping system that provides cooling water to designated coolers located in the reactor and turbine buildings.

Both trains have a common suction line from the RCCWS Surge Tank. There are manual isolation valves on the suction and discharge lines of each for maintenance.

The discharge of the pumps and the exchangers of the 2 trains are interconnected. This means that any combination of pumps and heat exchangers can fulfill the success criteria by delivering cooling water to any combination of loads.

The flow rate for each heat exchanger train is regulated by the bypass valves (P21-F022A/B) and the exchanger discharge valves (P21-F025A/B). Both valves are pneumatic. The flow through these valves regulates the temperature of the cold leg water supply temperature. As described below, it is assumed that in case of instrument air failure, air operated valves change or maintains their position in order to guarantee cooling flow. Because of this, it is assumed that heat exchanger discharge valves open, heat exchanger bypass valves close, and cross connection valves fail as is, given a loss of pneumatic supply.

The pumps are all sized for an output of 1250 m^3/hr, and the heat exchangers have a maximum design flow rate of 1250 m^3/hr.

4.10.3.2 System Operation

During normal power operation the system operates with 2 pumps and 2 heat exchangers in operation.

RCCWS cooling water is supplied to two cooling water trains during normal operation with two pumps in service and the other four pumps shall be in standby. Two heat exchangers are functioning during normal operation and the other four heat exchangers are in standby. The cross-tie valves are open during normal operation to allow operating flexibility. Major users of RCCWS water (CWS, FAPCS, and RWCU/SDC) have redundant heat exchangers on each train, and only one of these trains is in use during normal operating conditions. The heat exchangers for major users not in use have the cooling water supply automatically isolated to reduce wear on the unused heat exchanger, and reduce the required cooling water flow rate during normal operation.

In the event that the cooling water trains need to be separated, the cross-tie valves are closed and two pumps and two heat exchangers are in use in each train. If the cross-tie valves need to be closed, the CWS, FAPCS, and RWCU/SDC heat exchangers that are not required to be in operation are bypassed. The separation of trains is considered an abnormal operating condition. Opening the bypass line valves for CWS, FAPCS, and RWCU/SDC is required to keep the RCCWS pumps within their operating ranges.

During normal power operation, flow through the RWCU/SDC heat exchanger is regulated with a bypass flow control valve. This valve shall be controlled by RWCU/SDC, not RCCWS. Control of this bypass valve by RWCU/SDC shall prevent overcooling of the reactor coolant.

In shutdown mode, the configuration of the system varies depending on the initiating event that caused the scram.

- Non-LOPP events: Initially pumps 1A and 1B are operating. The two remaining pumps from each train are in standby. The water passes through the 6 HXs, which are in line, and the bypass valve regulates the flow based on the outlet temperature. This

configuration is maintained when the trip occurs. In case of an operation failure in a pump, another one from the same train automatically initiates.

All the interconnection valves of the trains are open. Valves F022A/B and valves F025A/B are also regulated by a signal from the same temperature transmitter.

- LOPP event: One pump from each train is operating when the event initiates. Consequently, the pumps trip and the 2 trains isolate by the closing of the pneumatic connection valves. The diesel generators initiate and once the power on buses is reestablished, the RCCW pumps re-initiate. The success criterion in this case requires the operation of 3 pumps for the same train, with interconnection valve openings that guarantee the delivery of the cooling flow to the consumers, whichever configuration of loads is in operation.

During shutdown/refueling RCCWS remains available for cooling associated with plant maintenance.

4.10.3.3 Components Location

The RCCWS components are located within the turbine building.

4.10.4 Automatic and Manual Control

In case of the failure of one working pump, one standby pump is automatically actuated. Manual initiation of the standby pump is also possible. Status indication for valves and pumps are expected to be in the control room.

Manual actuation of pneumatic and motorized valves can be carried out from the control room.

The flow rate through the heat exchangers is adjusted by the temperature regulation in the outlet of the heat exchangers, which acts on the bypass valves and the pneumatic valves of the heat exchanger discharge.

4.10.5 System Interfaces

The RCCWS dependencies are included in the dependency matrix given in Table 4.10-2.

4.10.6 System Testing

The RCCWS is a non-safety related system and therefore no Technical Specifications exist for it.

However, a periodic change in train operation is assumed so that the relevant train components are checked quarterly, as indicated in Table 4.10-3.

4.10.7 System Maintenance

Given the redundancy of the RCCWS system design, it is possible to carry out maintenance on pumps and/or heat exchangers during power operation.

For modeling purposes, it has been considered that maintenance can be carried out in both trains simultaneously, as long as it does not affect more than one pump or exchanger in each train.

Maintenance unavailabilities are assigned to train 2 pumps and heat exchangers as indicated in Table 4.10-4.

4.10.8 Common-Cause Failures

The common cause failures have been grouped in Table 4.10-5.

4.10.9 Fault Tree Analysis

- A fault tree is developed, whose TOP gate GP21-0001, which represents the system failures, is "Insufficient Cooling flow from RCCWS". The fault tree is shown in Appendix B.4.10.
- The TOP groups together two mutually exclusive situations:
  - Gate GP21-0001-_2 represents the system failures in normal operation and shutdown cooling.
  - Gate GP21-0001-_3 represents the system failures after a loss of preferred power (LOPP).

4.10.9.1 Top Event Definitions

- A fault tree for insufficient cooling flow from RCCWS is developed, whose TOP gate GP21-0001-_1 represents the system failure.
- The TOP includes two mutually exclusive situations:
  - Gate GP21-0001-_2 represents the system failures in normal operation and shutdown cooling. The success criterion of this part of the tree is to supply cooling water through two heat exchangers with two pumps.
  - Gate GP21-0001-_3 represents the system failures after a loss of preferred power (LOPP). In this case, the success criterion is to supply cooling water from 3 pumps in the same train. In the case of a LOPP, the house-event XHSLOSP is assigned a value of 1, therefore gate GP21-0001-_3 is cancelled. If the opposite occurs, the gate to be cancelled is GP21-0001-_3.

4.10.9.2 Model Assumptions

- System limits: For the purpose of the PRA, the RCCWS system includes suction lines from the RCCWS surge tank, pumps, cross-ties, heat exchangers, cooling lines and associated valves from PSWS and discharge lines up to RWCU/SDC, FAPCS, and CRD connections.
- Gate GP21-0001-_2 represents the system failures in normal operation and shutdown cooling. The success criterion of this part of the tree is the supply through two heat exchangers with two pumps. It is considered that initially this system is operating with one pump and one heat exchanger of every train. To guarantee cooling for consumers, independently of the train which the loads to be cooled belong to, and of the configuration of the pumps and heat exchangers, it has been considered that at least one of the ties between the trains downstream from the heat exchangers should be open.
- Gate GP21-0001-_3 represents the system failures after a loss of preferred power (LOPP). In this case the success criterion is the supply through 3 pumps. It is considered that as a consequence of the LOPP the pumps trip and the trains are isolated from each

other due to the closing of the air operated interconnection valves. The model outlines the necessity for the startup of 3 pumps in the same train. The interconnection of the trains in the part of the heat exchanger discharge which guarantees the cooling of the consumers independently of the train they belong to and the starting configuration of the pumps.

- Manual valve failures caused by mispositioning are not considered failures because the system is normally in operation, mis-positions would therefore be immediately detectable.
- RCCW is a closed circuit and the function of the tanks is to maintain the pressure in the circuit. The loss of water supply from tanks is not considered to be the cause of a system failure, because a leak would be detectable during normal operation (alarms and level indicators). Catastrophic failures of the tanks or lines are considered to be improbable compared to active component failures, and therefore, are not considered in the model.
- The possibility of obstruction in the pump suction filters is not considered because it is a clean water system, it operates in all plant modes, it is subjected to periodic tests and the periodic rotation of trains, and it is a passive failure, which makes it less probable than active failures.
- It is not considered that the motorized valves could be closed and de-energized after being manipulated because it is considered that there are indications in the control room, opening signals for the corresponding pump startup and probably once the valve manipulations have been completed, tests are performed on the flow or train rotation and therefore their erroneous position would be detected immediately.
- During power operation, a pump or heat exchanger from each train may be under maintenance. In the model, maintenance events are assigned to pumps and heat exchangers 2A and 2B.
- The two interconnecting lines of the discharge from the heat exchanger allows cooling supply flow to the consumers of any train for any combination of pumps and heat exchangers that meet the system success criteria.
- Failures in the return line valves from the consumer heat exchangers to the pump suction are not considered to cause a system failure.
- In case one of the pumps fails, another pump from the same train receives an initiation signal. It is considered that this signal is generated directly from the running pump circuit breaker. It is also considered that the pumps can be started from the control room. This human action is represented by the basic event P21-XHE-FO-STDBYPUMP.
- In case of a LOPP, standby pumps receive starting signals directly from DGs starting signal. These signals are represented under gates GR21-0025-_1 and GR21-0025-_2.
- In case of a LOPP with a malfunction of the startup of one pump in operation, the manual startup is not considered. The possibility of the manual startup is considered if the automatic startup failure of one pump in standby occurs.

4.10.9.3 Human actions

One human action is considered in the fault tree:

P21-XHE-FO-STDBYPUMP represents the operator's failure to manually start the standby pump when automatic actuation fails.

Human actions in the fault trees are connected by the house-event XHOSMAN that represents operator unavailability to carry out manual actions.

4.10.10 Results of Fault Tree Analysis

The definition of each basic event is reported in Table 4.10-7.

The fault tree results provide quantitative values of system unavailability and of the importance of specific components to that total.

The quantification of core damage sequences implicitly includes the contribution of basic event for this system. This qualification process enables checking the global consistency of the system fault trees and their relationship with the rest of the systems modeled in the PRA.

The importance measurements obtained from core damage frequency equations, allow identification of the most relevant basic events and system component failures in an integrated context, as well as the determination of their relative importance with respect to the basic events and component failures of the other systems modeled.

4.10.11 Model Differences for 72-Hour Operation

The long-term RCCWS operation is similar to that during the first 24 hours following a transient or LOCA. There are no fault tree model changes necessary to extend the operation to 72 hours.

4.10.12 References

4.10-1. ESBWR Design Control Document, 26A6642 Rev. 01

Table 4.10-1

Control Room Instrumentation and Alarms

Main Control Room Panel Controls
(1) RCCWS pump(s) start/stop and pump selection controls
(2) RCCWS heat exchanger(s) outlet valve open/close controls
(3) RCCWS supply temperature control valve(s) controls
(4) FAPC heat exchanger(s) inlet and outlet valves open/close controls
(5) CWS chiller cooling water outlet block valve controls
(6) Containment isolation valves open/close controls
(7) Non-safety-related supply MOV and AOV open/close controls
(8) RWCU/SDC heat exchanger(s) inlet valve open/close controls
(9) Makeup water valve open/close control for MWS to RCCWS surge tank(s)
CWS backup DCS supply valves open/close.
Main Control Console Displays
(1) RCCWS supply pressure
(2) RCCWS supply flow
(3) RCCWS supply/return temperature
(4) Major users pressure, temperature, and flow at inlet/outlet
(5) RCCWS surge tank(s) low and high level
(6) Pump start/stop status
(7) High water level in Turbine Building for indication of pipe break or large leak
(8) RCCWS heat exchanger(s) outlet valve open/close status
(9) CWS chiller outlet block valve position status
(10) Non-safety supply MOV and AOV open/close status
(11) RWCU/SDC heat exchanger(s) inlet valve open/close status
(12) FAPC heat exchanger(s) inlet and outlet valve open/close status
(13) Containment isolation valves open/close status
(14) Surge Tank(s) makeup isolation valve from MWS open/close status
RCCWS pump NPSH available
Main Control Room Panel Controls
(1) RCCWS supply pressure low
(2) RCCWS supply flow low
(3) RCCWS supply temperature low and high
(4) RCCWS surge tank(s) standpipe low level
(5) RCCWS surge tank(s) low and high level
(6) DCS, FAPC, CWS, and RWCU/SDC heat exchanger(s) outlet temperature high
(7) RCCWS pump motor overload or trip
(8) RCCWS/PSW logic power failure
(9) RCCWS standby pump(s) auto-start

Table 4.10-2

System Dependencies Matrix

COMPONENT	TRANSMISSION SIGNAL	6.9KV (R11)	480V (R12)	UPS (R13) (NO 1E)	IA (P52)	PSW (P41)
PUMPS C001A/2A/3A	C62 (DIV A DID)	BUS A2				
P21-F022A	C62 (DIV A DID)		DIV A	DIV A	X (2)	
HX- 1A/2A/3A						X
P21-F010/32	C62 (DIV A DID)		DIV A	DIV A	X (3)	
P21-F016A/18A/20A			DIV A			
PUMPS C001B/2B/3B		BUS B2				
P21-F022B	C62 (DIV B DID)		DIV B	DIV B	X (2)	
HX- 1B/2B/3B						X
P21-F013/27	C62 (DIV B DID)		DIV B	DIV B	X (3)	
P21-F016B/18B/20B			DIV B			
P21-F025A	C62 (DIV A DID)		DIV A	DIV A	X (1)	
P21-F025B	C62 (DIV B DID)		DIV B	DIV B	X (1)	

Notes
(1) Valves fail OPEN
(2) Valves fail CLOSED
(3) Valves fail AS IS

Table 4.10-3

Component Tests

A periodic change in train operation is assumed so that the relevant train components are checked quarterly.

Table 4.10-4
Component Maintenance

Basic Event	Probability	Description
P21-MP_-TM-C002A	2.00E-03	PUMP C002A IN MAINTENANCE
P21-MP_-TM-C002B	2.00E-03	PUMP C002B IN MAINTENANCE
P21-HX_-TM-B002A	2.20E-03	HEAT EXCHANGER B002A UNAVAILABLE DUE TO MAINTENANCE
P21-HX_-TM-B002B	2.20E-03	HEAT EXCHANGER B002B UNAVAILABLE DUE TO MAINTENANCE

Table 4.10-5

Common Cause Failure

Basic Event	Probability	Description
C62-DTM-CF-N1EALL	5.50E-05	CCF OF DIGITAL TRIP MODULES NO 1E
P21-ACV-CF-F010/13	9.00E-08	CCF AIR OPERATED VALVES F010 AND F013 TO REMAIN OPEN
P21-ACV-CF-F022/25A	5.00E-05	CCF VALV ACV F022A/ F025A TRAIN A
P21-ACV-CF-F022/25B	5.00E-05	CCF VALV ACV F022B/F025B TRAIN B
P21-ACV-CF-F027/32	4.00E-08	CCF AIR OPERATED VALVES F027 AND F032 TO REMAIN OPEN
P21-MP_-CR-3A	2.40E-06	CCF 3 PUMPS TO RUN (INTRADIVISON A)
P21-MP_-CR-TRAINAB	1.80E-05	CCF TO RUN PUMPS TRAINS A AND B
P21-MP_-CR-3B	1.20E-06	CCF 3 PUMPS TO RUN (INTRADIVISON B)
P21-MP_-CR-5ALL	6.00E-07	CCF TO RUN PUMPS TRAINS A AND B
P21-MP_-CS-2A	2.60E-05	CCF 2 PUMPS (INTRADIVISON A) TO START
P21-MP_-CS-2B	2.60E-05	CCF 2 PUMPS (INTRADIVISON B) TO START
P21-MP_-CS-TRAINAB	1.95E-04	CCF TO START PUMPS TRAINS A AND B
P21-MP_-CS-5ALL	6.50E-06	CCF TO START PUMPS DIVISIONS A AND B
P21-TT_-CF-N038A/B	4.00E-08	CCF OF TEMPERATURE XMTR

Table 4.10-6

Human Errors

Basic Event	Probability	Description
P21-XHE-FO-STDBYPUMP	2.69E-01	OP. FAILS MAN. ACT. OF STDBY PUMP WHEN AUT. ACTUATION FAIL

Table 4.10-7
System Basic Events

Basic Event	Probability	Description
C62-DTM-FC-N1EA	9.00E-04	DIGITAL TRIP MODULE TRAIN A NO 1E FAILS
C62-DTM-FC-N1EB	9.00E-04	DIGITAL TRIP MODULE TRAIN B NO 1E FAILS
H23-RMU-FC-N038B	3.00E-04	REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION
H23-RMU-FC-P21C002A1	3.00E-04	REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION
H23-RMU-FC-P21C002A2	3.00E-04	REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION
H23-RMU-FC-P21C002B1	3.00E-04	REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION
H23-RMU-FC-P21C002B2	3.00E-04	REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION
H23-RMU-FC-P21C003A1	3.00E-04	REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION
H23-RMU-FC-P21C003A2	3.00E-04	REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION
H23-RMU-FC-P21C003B1	3.00E-04	REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION
H23-RMU-FC-P21C003B2	3.00E-04	REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION
H23-RMU-FC-P21N038A	3.00E-04	REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION
P21-ACV-FT-F022A	2.00E-03	AIR OPERATED VALVE F022A FAILS TO TRANSFER
P21-ACV-FT-F022B	2.00E-03	AIR OPERATED VALVE F022B FAILS TO TRANSFER
P21-ACV-FT-F025A	2.00E-03	AIR OPERATED VALVE F025A FAILS TO TRANSFER
P21-ACV-FT-F025B	2.00E-03	AIR OPERATED VALVE F025B FAILS TO TRANSFER
P21-ACV-OC-F010	3.60E-06	AIR OPERATED VALVE F010 FAILS TO REMAIN OPEN
P21-ACV-OC-F013	3.60E-06	AIR OPERATED VALVE F013 FAILS TO REMAIN OPEN
P21-ACV-OC-F027	3.60E-06	AIR OPERATED VALVE F027 FAILS TO REMAIN OPEN
P21-ACV-OC-F032	3.60E-06	AIR OPERATED VALVE F032 FAILS TO REMAIN OPEN
P21-HX_-LK-B001A	2.40E-05	HEAT EXCHANGER B001A FAILS WHILE OPERATING
P21-HX_-LK-B001B	2.40E-05	HEAT EXCHANGER B001B FAILS WHILE OPERATING
P21-HX_-LK-B002A	7.20E-04	HEAT EXCHANGER FAILURE (LEAK OR RUPTURE)
P21-HX_-LK-B002B	7.20E-04	HEAT EXCHANGER B002B FAILS WHILE OPERATING
P21-HX_-LK-B003A	7.20E-04	HEAT EXCHANGER (LEAK OR RUPTURE)
P21-HX_-LK-B003B	7.20E-04	HEAT EXCHANGER B003B FAILS WHILE OPERATING
P21-HX_-TM-B002A	2.20E-03	HEAT EXCHANGER B002A UNAVAILABLE DUE TO MAINTENANCE
P21-HX_-TM-B002B	2.20E-03	HEAT EXCHANGER B002B UNAVAILABLE DUE TO MAINTENANCE
P21-MCB-CC-C001A	1.00E-03	MOTOR DRIVEN PUMP CIRCUIT BEAKER FAILS TO OPEN
P21-MCB-CC-C001B	1.00E-03	MOTOR DRIVEN PUMP CIRCUIT BEAKER FAILS TO OPEN

Table 4.10-7
System Basic Events

Basic Event	Probability	Description
P21-MCB-OO-C001A	1.00E-03	CIRCUIT BREAKER OF PUMP C001A FAILS TO CLOSE
P21-MCB-OO-C001B	1.00E-03	CIRCUIT BREAKER OF PM C001B FAILS TO CLOSE
P21-MCB-OO-C002A	1.00E-03	MEDIUM VOLTAGE CIRCUIT BREAKER FAILS TO CLOSE
P21-MCB-OO-C002B	1.00E-03	MEDIUM VOLTAGE CIRCUIT BREAKER FAILS TO CLOSE
P21-MCB-OO-C003A	1.00E-03	MEDIUM VOLTAGE CIRCUIT BREAKER FAILS TO CLOSE
P21-MCB-OO-C003B	1.00E-03	MEDIUM VOLTAGE CIRCUIT BREAKER FAILS TO CLOSE
P21-MOV-OC-F016A	3.36E-06	MOTOR OPERATED VALVE F016A FAILS TO REMAIN OPEN
P21-MOV-OC-F016B	3.36E-06	MOTOR OPERATED VALVE F016B FAILS TO REMAIN OPEN
P21-MOV-OC-F018A	1.01E-04	MOTOR OPERATED VALVE F018A FAILS TO REMAIN OPEN
P21-MOV-OC-F018B	1.01E-04	MOTOR OPERATED VALVE F018B FAILS TO REMAIN OPEN
P21-MOV-OC-F020A	1.01E-04	MOTOR OPERATED VALVE F020A FAILS TO REMAIN OPEN
P21-MOV-OC-F020B	1.01E-04	MOTOR OPERATED VALVE MV-F020B FAIL TO REMAIN OPEN
P21-MP_-FR-C001A	1.20E-04	MOTOR DRIVEN PUMP C001A FAILS TO RUN
P21-MP_-FR-C001B	1.20E-04	MOTOR DRIVEN PUMP C001B FAILS TO RUN
P21-MP_-FR-C002A	1.20E-04	MOTOR-DRIVEN PUMP C002A FAILS TO RUN
P21-MP_-FR-C002B	1.20E-04	MOTOR-DRIVEN PUMP C002B FAILS TO RUN
P21-MP_-FR-C003A	1.20E-04	MOTOR-DRIVEN PUMP C0003A FAILS TO RUN
P21-MP_-FR-C003B	1.20E-04	MOTOR-DRIVEN PUMP C003B FAILS TO RUN
P21-MP_-FS-C001A	1.30E-03	MOTOR DRIVEN PUMP C001A FAILS TO START
P21-MP_-FS-C001B	1.30E-03	MOTOR-DRIVEN PUMP C001B FAILS TO START
P21-MP_-FS-C002A	1.30E-03	MOTOR-DRIVEN PUMP (ALL TYPES) FAILS TO START
P21-MP_-FS-C002B	1.30E-03	MOTOR-DRIVEN PUMP C002B FAILS TO START
P21-MP_-FS-C003A	1.30E-03	MOTOR-DRIVEN PUMP C0003A FAILS TO START
P21-MP_-FS-C003B	1.30E-03	MOTOR-DRIVEN PUMP C003B FAILS TO START
P21-MP_-TM-C002A	2.00E-03	PUMP C002A IN MAINTENANCE
P21-MP_-TM-C002B	2.00E-03	PUMP C002B IN MAINTENANCE
P21-TT_-NO-N038B	8.40E-06	TEMPERATURE XMTR FAILS TO RESPOND TO CHANGE IN TEMPERATURE
P21-TT_-NO-P21N038A	8.40E-06	TEMPERATURE XMTR FAILS TO RESPOND TO CHANGE IN TEMPERATURE
P21-UV_-CC-F001A	2.00E-04	CHECK VALVE F001A FAILS TO OPEN
P21-UV_-CC-F001B	2.00E-04	CHECK VALVE F001B FAILS TO OPEN

Table 4.10-7
System Basic Events

Basic Event	Probability	Description
P21-UV_-CC-F005A	2.00E-04	CHECK VALVE F005A FAILS TO OPEN
P21-UV_-CC-F005B	2.00E-04	CHECK VALVE F005B FAILS TO OPEN
P21-UV_-CC-F007A	2.00E-04	CHECK VALVE F007A FAILS TO OPEN
P21-UV_-CC-F007B	2.00E-04	CHECK VALVE F007B FAILS TO OPEN
P41-ACV-OC-F002A	3.60E-06	AIR OPERATED VALVE MV-F002A FAIL TO REMAIN OPEN
P41-ACV-OC-F002B	3.60E-06	AIR OPERATED VALVE MV-F002B FAIL TO REMAIN OPEN
P41-ACV-OC-F003A	3.60E-06	MOTOR OPERATED VALVE FAILS TO REMAIN OPEN
P41-ACV-OC-F003B	3.60E-06	AIR OPERATED VALVE MV-F003B FAIL TO REMAIN OPEN
P41-ACV-OC-F004A	3.60E-06	AIR OPERATED VALVE MV-F004A FAIL TO REMAIN OPEN
P41-ACV-OC-F004B	3.60E-06	AIR OPERATED VALVE MV-F004B FAIL TO REMAIN OPEN
P41-ACV-OC-F005A	3.60E-06	AIR OPERATED VALVE MV-F005A FAIL TO REMAIN OPEN
P41-ACV-OC-F005B	3.60E-06	AIR OPERATED VALVE MV-F005B FAIL TO REMAIN OPEN
P41-ACV-OC-F006A	3.60E-06	AIR OPERATED VALVE MV-F006A FAIL TO REMAIN OPEN
P41-ACV-OC-F006B	3.60E-06	AIR OPERATED VALVE MV-F006B FAIL TO REMAIN OPEN
P41-ACV-OC-F007A	3.60E-06	AIR OPERATED VALVE MV-F007A FAIL TO REMAIN OPEN
P41-ACV-OC-F007B	3.60E-06	AIR OPERATED VALVE MV-F007B FAIL TO REMAIN OPEN
P41-ACV-OC-F010A	3.60E-06	AIR OPERATED VALVE P41-F010A FAILS TO REMAIN OPEN
P41-ACV-OC-F010B	3.60E-06	AIR OPERATED VALVE MV-F010B FAIL TO REMAIN OPEN

Table 4.10-8

System Top Events

TOP EVENT	Description
GP21-0001-_1	RCCWS TRAINS FAIL TO COOL THE LOADS

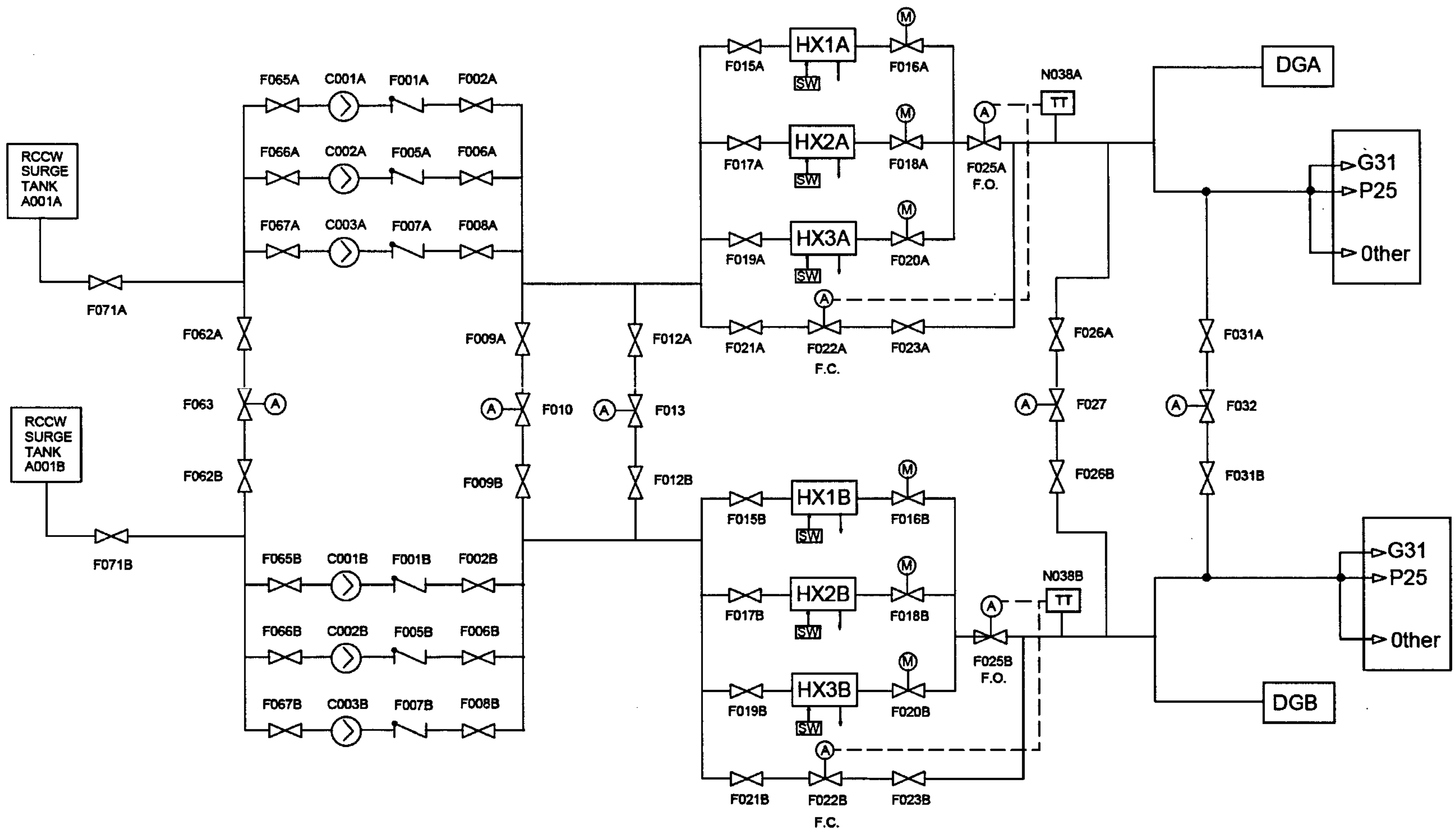


Figure 4.10-1 (1/2). Reactor Component Cooling Water System Flow Diagram

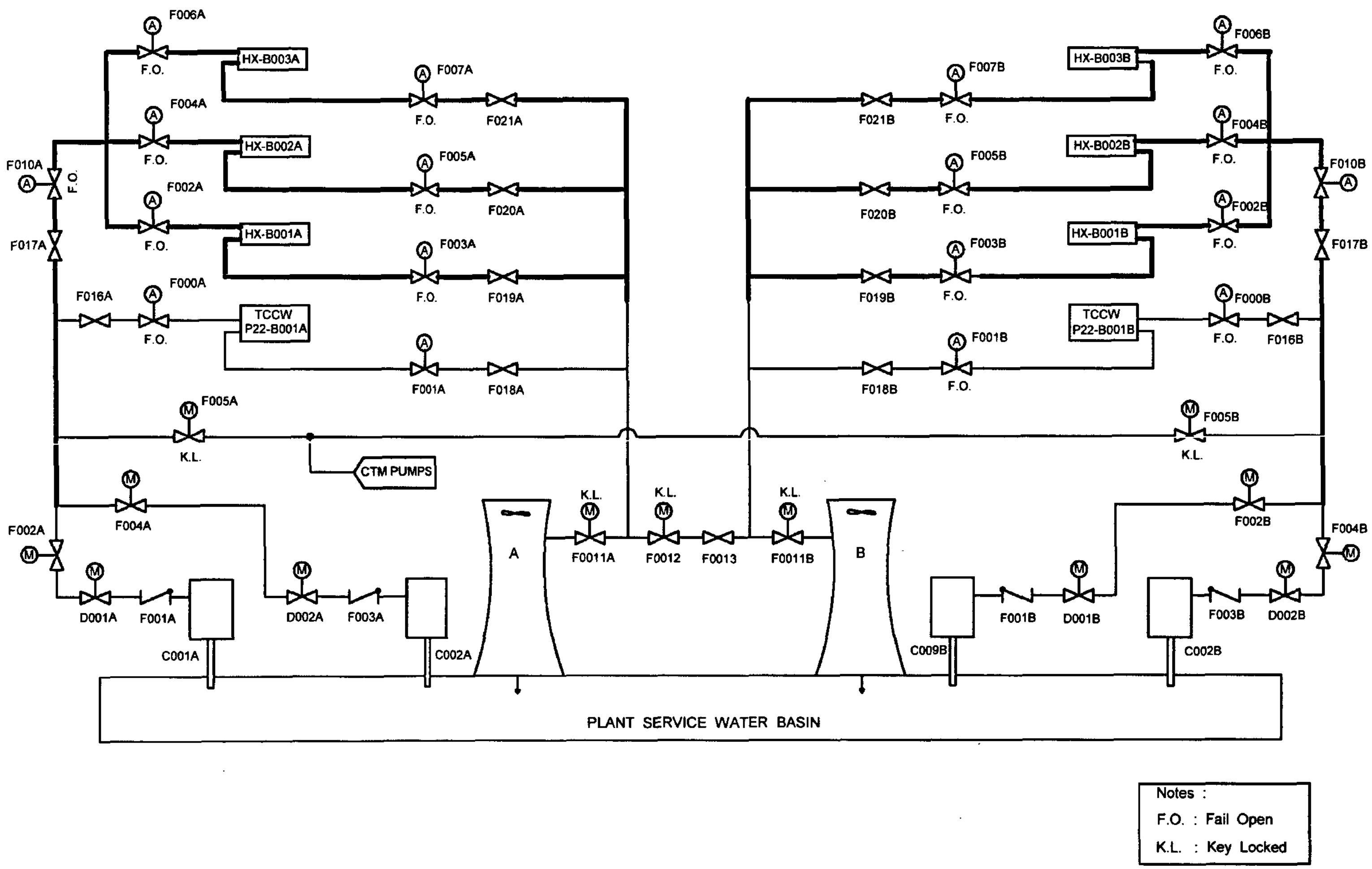


Figure 4.10-1 (2/2). Reactor Component Cooling Water System Flow Diagram

4.11 PLANT SERVICE WATER SYSTEM - (P41)

4.11.1 Purpose

PSW (P41) removes heat, during normal and shutdown operations, from the Reactor Cooling Component Water (RCCW) and Turbine Component Cooling Water (TCCW) systems and rejects this heat to the environment via two mechanical cooling towers.

Plant Service Water System has no safety-related functions.

4.11.2 Design Assumptions

The following assumptions with respect to the design are made:

(1) The normal supply source for the pumps is the Cooling Tower Makeup System (Y41). Upon a malfunction of this system, the cooling water supply to the exchangers is supplied from the PSW pumps. The malfunction of the Y41 system is currently represented by special event P41-SYS-FF-3CTMP in the event that the flow from two pumps is required (malfunction of three pumps) and by special event P41-SYS-FF-2CTMP if flow from three pumps is required (malfunction of two pumps).

(2) The volume of water in the Plant Service Water Basin is sufficient to supply water to the pumps during 72 hours, including losses through the cooling towers.

(3) All of the components of train A receive power supply from Division I, while those from train B are powered from Division II.

(4) It has been assumed that the relevant measures will be taken so that the air operated valves do not depend on the instrument air system in an emergency situation.

(5) In the event of malfunction of a pump, another pump from the same train receives an initiation signal. This signal is considered to be sent from internal feedback, therefore, it is not modeled (except for the transmission of the signal within the division, which is included).

(6) In the event of LOPP with malfunction of the startup of one pump that was in operation, no attention is paid to the manual startup from the control room. The support actuation for automatic startup is considered in the event of malfunction of the automatic startup on a pump on standby. In this case, a signal from the operating pump circuit breaker actuates the pump in standby, and if the automatic signal fails, the operator initiates the standby pump.

(7) The valves at the discharge of the pumps to the towers, F005A/B, F011A/B, F012 and F013, are locked open (key-locked).

(8) The mechanical draft cooling tower has multiple cells. Each tower cell set has a two-speed reversible 100% motor fan units or sets of 100% fans, with 50% of each tower cells powered from each electrical division.

4.11.3 System Description

The PSWS analysis described here refers to the system configuration shown in the diagram of Figure 4.11-1.

4.11.3.1 Hardware Configuration

PSW comprises two interconnected divisions of cooling water, each division consisting of 2 vertical pumps that take suction from a plant service water basin. Each pump is equipped with a self cleaning discharge strainer, discharge check valve and discharge isolation valve. The pumps discharge to a common header from which two parallel piping trains are fed. This configuration allows for increased flexibility during all operational modes and minimizes actions required in case of loss of PSWS. After passing through the RCCW and TCCW heat exchangers, the heated water from each train returns through two mechanical draft cooling towers (MCT).

The primary source of cooling water for all modes of operation are four Cooling Tower Makeup Water (CTMW) pumps. Two CTMW pumps are normally in operation sending water through P21 and P22 heat exchangers and discharging to the Main Cooling Tower basin to provide makeup water to account for evaporation losses associated with the operation of cooling towers. The backup source of cooling water when the CTMW are not in operation are PSWS pumps. Each pump is sized to provide a maximum flow rate of 4540 m^3/h (20,000 gpm).

PSWS receives electrical power from the Standby On Site AC Power Supply System via two independent buses. During LOPP, the pumps can be powered from their respective divisional non-safety related onsite standby diesel generator.

4.11.3.2 System Operation

Initially, there are two pumps in operation. It is assumed that one pump in each train provides cooling flow to two heat exchangers from the RCCW system and one heat exchanger of the TCCW system.

Given a plant trip, the system configuration changes depending on the initiating event that caused the trip:

- Non-LOPP events: operation of two pumps is required for the cooling of the loads and a cooling tower. Pumps 1A and 1B are assumed to be in operation, and the remaining two pumps are in standby. Water flows through the RCCW heat exchangers and the TCCW heat exchangers. In the event of malfunction of one pump, a different pump from the same train initiates.
- All the train interconnection valves remain open.
- LOPP events: one pump of each train is in operation when the LOPP occurs. Both pumps trip, and they restart after power is recovered. In the event of a LOPP with startup of the diesel generators, flow from three PSW pumps and one cooling tower is required.
- Motor-operated and air valves remain open.

The same success criteria applies to the pumps of the Cooling Tower Makeup System (Y41).

4.11.3.3 Components Location

The TCCW and RCCW heat exchangers are located in the Turbine Building. Therefore, the PSWS piping that is connected to these heat exchangers is routed through sections of the Turbine Building.

The PSWS pumps, discharge strainers, a section of PSWS piping, and the mechanical draft cooling towers are located in the Service and Fire Building.

4.11.4 Automatic and Manual Control

In case of failure of one working pump, one standby pump is automatically actuated. PSWS is designed for remote operation from the Main Control Room.

Manual initiation of the standby pump is also possible. Status lights for valves and pumps are expected to be in the control room.

4.11.5 System Interfaces

The PSWS functional dependencies are indicated by the dependency matrix given in Table 4.11-2.

4.11.6 System Testing

The PSWS is a non-safety related system so that no Technical Specifications exist for it.

However, a periodic change in train operation is assumed such that the relevant train components are checked quarterly, as indicated in Table 4.11-3.

No plant outage time is required for testing.

4.11.7 System Maintenance

Considering the redundancy of the PSWS, maintenance can be performed on pumps and/or heat exchangers during power operation.

As regards the models, it has been considered that maintenance can be performed on both trains, granted it is not performed simultaneously and it does not affect more than one pump or heat exchanger in each train (see Table 4.11-4).

4.11.8 Common Cause Failures

The common cause failures are set out in Table 4.11-5.

4.11.9 Fault Tree Analysis

- A fault tree has been developed. Its TOP (gate GP41-0001-_1) represents the system malfunctions with insufficient cooling flow from the PSWS.
- The TOP includes two situations that are mutually exclusive.
- Gate GP41-0001-_2 represents the system malfunctions during normal and shutdown cooling operation.
- Gate GP41-0001-_3 represents the system malfunctions after a Loss of Preferred Power (LOPP).

The LOPP event is represented with event XHOSLOSP, which would have value TRUE, so gate GP41-0001-_2 would be cancelled. Otherwise, the gate that would be cancelled would be GP41-0001-_3.

4.11.9.1 Top Event Definitions

- A fault tree has been developed with gate GP41-0001-_1 as the TOP. It represents the system failures with insufficient cooling flow from the PSWS.

4.11.9.2 Model Assumptions

- System limits: For the purpose of the PRA, PSW system includes PSW pumps, suction lines, discharge lines up to heat exchangers connections, interconnection line and associated valves, cooling towers and fan coolers. RCCW and TCCW heat exchangers, piping and valves are included in P21 and P22 models.
- Gate GP41-0001-_2 shows the system malfunctions during non-LOPP situations. The success criterion in this situation is the makeup with two pumps and cooling through a cooling tower. The system is considered to be initially aligned with a pump of each train running. The interconnection between trains must be open in order to guarantee the cooling to the consumers, regardless of the train where the loads to be cooled are included and of the configuration of the pumps and exchangers.
- Gate GP21-0001-_3 shows the system malfunctions upon a loss of preferred power (LOPP). In this case, the success criterion is the makeup with three pumps and one cooling tower. It is considered that the pumps are tripped as a consequence of the LOPP. The position of the valves is not modified in this case. The model shows the need to start up three pumps and to cool their flow by means of one tower. The connection of trains guarantees the cooling of the consumers regardless of the train they belong to and of the initial configuration of the pumps.
- In non-LOPP events the failure of one running pump is considered a mechanical failure and it is not considered recoverable and manual actions are not taken into account. The support actuation for automatic startup is considered in the event of malfunction of the automatic startup on a pump on standby. In this case, a signal directly from the operating pump breaker actuates to the pump on standby, and if the automatic signal fails, the operator should start up the pump on standby. This human action is represented by means of basic event P41-XHE-FO-STDBYPUMP.
- After a LOPP, 3 PSW pumps must initiate. In this case, it is considered that the automatic start signals are the diesel generator start signals and are represented by gates GR21-0025-_2 and GR21-0025-_1. If these signals fail, the operator initiates the pump in standby.
- No malfunctions because of incorrect positioning of manual or air operated valves are considered because the system is normally in operation with periodic rotation of the trains and the motor-operated valves locked open (key-locked). Alarms, administrative controls, etc. allow immediate detection of the improper closing of any valve.
- Loss of supply from the Plant Service Water Basin is not considered to be a cause of system malfunction because the design of the system includes supply from system Y41. This system has been represented with a basic event in each part of the tree that shows the corresponding success criterion.

- The model includes the need to have one group of fan units in one tower available for cooling.
- During power operation, one pump or one heat exchanger of each train can be under maintenance. In the model, the maintenance events are assigned to exchangers 2A or 2B and to pumps 2A or 2B, always supposing their maintenance does not coincide.
- The two interconnection lines provide flow to the consumers of any train for any combination of pumps and heat exchangers that meets the success criteria of the system.
- Air operated valves open if instrument air supply fails, so their dependency from the instrument air supply system is not modeled.
- The valves at the discharge of the pumps to the towers, F005A/B, F011A/B, F012 and F013, are locked open (key-locked). Therefore, it is considered that they cannot be in a wrong position because there are alarms, administrative controls, etc., that would allow immediate detection of the improper closing of a valve.
- In case one of the pumps fails, another pump from the same train receives an initiation signal. It is assumed that this signal is generated directly from the running pump circuit breaker. It is also assumed that the pumps can be started from the control room.
- In case of LOPP, standby pumps receive starting an initiation directly from the DGs starting signal. These signals are represented by gates GR21-0025-_1 and GR21-0025-_2.
- CTMS power is assumed to be the same supply as PSW and failure of PSW power also fails CTMS. In addition, the CTMS water source is considered not to be limiting. No other supports are required for CTMS.

4.11.9.3 Human Interactions

One human action is considered in the fault tree:

P21-XHE-FO-STDBYPUMP represents the operator fails to manually start the standby pump when automatic actuation fails.

This human action is connected to the tree by means of event XHOSMNA, which represents the availability of the operator to perform manual actuations.

4.11.10 Results of Fault Tree Analysis

The definition of each basic event is reported in Table 4.11-7.

The fault tree results provide quantitative values of system unavailability and of the importance of specific components to that total.

The quantification of core damage sequences implicitly includes the contribution of basic event for this system. This qualification process enables checking the global consistency of the system fault trees and their relationship with the rest of the systems modeled in the PRA.

On the other hand, the importance measurements obtained from core damage frequency equations, allow identification of the most relevant basic events and system component failures in an integrated context, as well as the determination of their relative importance with respect to the basic events and component failures of the other systems modeled.

4.11.11 Model Differences for 72-Hour Operation

The long term PSWS operation is similar to that during the first 24 hours following an initiating event. There are no fault tree model changes in logic necessary to extend the operation to 72 hours.

4.11.12 References

4.11-1. ESBWR Design Control Document, 26A6642 Rev. 01

Table 4.11-1

Control Room Instrumentation and Alarms

Main Control Room Panel Controls
PSW Pump 1A start / stop and control mode status
PSW Pump 2A start / stop and control mode status
PSW Pump 1B start / stop and control mode status
PSW Pump 2B start / stop and control mode status
Main Control Console Displays
PSW pump 1A motor current, winding temperature and bearing temperature
PSW pump 2A motor current, winding temperature and bearing temperature
PSW pump 1Bmotor current, winding temperature and bearing temperature
PSW pump 2Bmotor current, winding temperature and bearing temperature
PSWS discharge pressure and discharge flow
PSW pump 1A strainer differential pressure
PSW pump 2A strainer differential pressure
PSW pump 1B strainer differential pressure
PSW pump 2B strainer differential pressure
PSWS pump discharge header pressure and temperature
Motor operated valves position
Main Control Room Alarms
High differential pressure across pump discharge strainers
PSWS supply pressure below a predetermined set point
Low PSWS pump discharge flow
PSWS supply temperature above/below a predetermined setpoint
PSWS pump motor overload trip
PSWS standby pump auto-start
A significant difference between the return header flowmeter reading and the pump discharge
PSWS pump motor winding high temperature
PSWS pump motor bearing high temperature
PSWS high radioactivity level

Table 4.11-2

System Dependencies Matrix

Component	Transmission Signal C62 DID		AC Power		Uninterruptible AC		IA	Room Cooling[3]
	Div A	Div B	RH Bus A2	RH Bus B2	R13 Div A	R13 Div B B1-1		
PSW PMP C001A	X		X		X			
PSW PMP C002A	X		X		X			
PSW PMP C001B		X		X		X		
PSW PMP C002B		X		X		X		
F002A MOV	X		X		X			
F004A MOV	X		X		X			
D001A[1]	X		X		X			
D002A[1]	X		X		X			
F002A AOV	X				X		(2)	
F006A AOV	X				X		(2)	
F004A AOV	X				X		(2)	
F009A AOV	X				X		(2)	
F001A AOV	X				X		(2)	
F007A AOV	X				X		(2)	
F005A AOV	X				X		(2)	
F003A AOV	X				X		(2)	
F008A AOV	X				X		(2)	
F005A MOV	X		X		X			
FAN 1A	X		X		X			
FAN 2A	X		X		X			
CTM PMP C001A	X		X		X			
CTM PMP C002A	X		X		X			
CTM PMP C001B		X		X		X		
CTM PMP C002B		X		X		X		
F002B MOV		X				X		
F004B MOV		X				X		
D001B[1]		X				X		
D002B[1]		X				X		
F002B AOV		X				X	(2)	

Table 4.11-2

System Dependencies Matrix

Component	Transmission Signal C62 DID		AC Power		Uninterruptible AC		IA	Room Cooling(3)
	Div A	Div B	RH Bus A2	RH Bus B2	R13 Div A	R13 Div B B1-1		
F006B AOV		X				X	(2)	
F004B AOV		X				X	(2)	
F009B AOV		X				X	(2)	
F001B AOV		X				X	(2)	
F007B AOV		X				X	(2)	
F005B AOV		X				X	(2)	
F003B AOV		X				X	(2)	
F008B AOV		X				X	(2)	
F005B MOV		X		X		X		
FAN 1B		X		X		X		
FAN 2B		X		X		X		

Notes to Table 4.11-2

(1) Double basket strainer.

(2) The AOVs are provided with IA. The AOVs are fail open valves. If necessary for system operation, AOVs will be made operable by alternative means.

(3) There are no active room cooling system requirements for 72 hours.

Table 4.11-3

Component Tests

A periodic change in train operation is assumed such that the relevant train components are checked quarterly.

Table 4.11-4

Component Maintenance

Basic Event	Probability	Description
P41-MP_-TM-C002A	2.00E-03	PUMP C002A IN MAINTENANCE
P41-MP_-TM-C002B	2.00E-03	PUMP C002B IN MAINTENANCE

Table 4.11-5

Common Cause Failure

Basic Event	Probability	Description
H23-RMU-CF-P41A	3.60E-06	CCF TO OPERATERMU 001 AND RMU 002 P41 TRAIN A FOR MANUAL ACTUAT.
H23-RMU-CF-P41B	3.60E-06	CCF TO OPERATERMU 001 AND RMU 002 P41 TRAIN B FOR MANUAL ACTUAT.
P41-FAN-CR-3ALL	7.20E-07	CCF TO RUN 3 FAN UNITS
P41-FAN-CS-2ALL	7.20E-06	CCF TO START 2 FAN UNITS
P41-FAN-CS-3ALL	1.80E-06	CCF TO START 3 FAN UNITS
P41-MP_-CR-2ALL	3.39E-06	CCF TO RUN 2 PUMPS TRAINS A AND B
P41-MP_-CR-3ALL	1.17E-05	CCF TO RUN 3 PUMPS TRAINS A AND B
P41-MP_-CS-2ALL	4.29E-05	CCF TO START 2 PUMPS TRAINS A AND B
P41-MP_-CS-3ALL	6.26E-06	CCF TO START PUMPS TRAINS A AND B
P41-STR-CF-2ALL	1.07E-05	CCF 2 STRAINERS PLUGGED
P41-STR-CF-3ALL	1.07E-05	CCF 3 STRAINERS PLUGGED

Table 4.11-6

Human Errors

Basic Event	Probability	Description
P41-XHE-FO-STDBYPUMP	1.77E-02	OPER. FAILS TO MAN. ACTUATE STDBY PUMP WHEN AUT. ACT. FAIL

Table 4.11-7

List of System Basic Events

Basic Event	Probability	Description
H23-RMU-FC-P41C002A1	3.00E-04	REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION
H23-RMU-FC-P41C002A2	3.00E-04	REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION
H23-RMU-FC-P41C002B1	3.00E-04	REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION
H23-RMU-FC-P41C002B2	3.00E-04	REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION
P41-FAN-FR-0001A	2.40E-04	FAN FAILS TO RUN
P41-FAN-FR-0001B	2.40E-04	FAN FAILS TO RUN
P41-FAN-FR-0002A	2.40E-04	FAN FAILS TO RUN
P41-FAN-FR-0002B	2.40E-04	FAN FAILS TO RUN
P41-FAN-FS-0001A	6.00E-04	FAN FAILS TO START
P41-FAN-FS-0001B	6.00E-04	FAN FAILS TO START
P41-FAN-FS-0002A	6.00E-04	FAN FAILS TO START
P41-FAN-FS-0002B	6.00E-04	FAN FAILS TO START
P41-MCB-CC-C001A	1.00E-03	MEDIUM CIRCUIT BREAKER (VOLTAGE > 480 V) (FAILURE TO OPEN)
P41-MCB-CC-C001B	1.00E-03	MEDIUM CIRCUIT BREAKER (VOLTAGE > 480 V) (FAILURE TO OPEN)
P41-MCB-OO-C001A	1.00E-03	CIRCUIT BREAKER OF PUMP C001A FAILS TO CLOSE
P41-MCB-OO-C001B	1.00E-03	CIRCUIT BREAKER PUMP C001B FAILS TO CLOSE
P41-MCB-OO-C002A	1.00E-03	MEDIUM VOLTAGE CIRCUIT BREAKER FAILS TO CLOSE
P41-MCB-OO-C002B	1.00E-03	MEDIUM VOLTAGE CIRCUIT BREAKER FAILS TO CLOSE
P41-MOV-OC-F002A	3.36E-06	MOTOR OPERATED VALVE MV-F002A FAIL TO REMAIN OPEN
P41-MOV-OC-F002B	3.36E-06	MOTOR OPERATED VALVE MV-F002B FAIL TO REMAIN OPEN
P41-MOV-OC-F004A	3.36E-06	MOTOR OPERATED VALVE MV-F004A FAIL TO REMAIN OPEN
P41-MOV-OC-F004B	3.36E-06	MOTOR OPERATED VALVE MV-F004B FAIL TO REMAIN OPEN
P41-MP_-FR-C001A	7.68E-04	MOTOR DRIVEN PUMP C001A FAILS TO RUN
P41-MP_-FR-C001B	7.68E-04	MOTOR DRIVEN PUMP C001B FAILS TO RUN,
P41-MP_-FR-C002A	7.68E-04	MOTOR DRIVEN PUMP C002A FAILS TO RUN
P41-MP_-FR-C002B	7.68E-04	MOTOR-DRIVEN PUMP C002B FAILS TO RUN
P41-MP_-FS-C001A	2.40E-03	MOTOR-DRIVEN PUMP C001A FAILS TO RESTART
P41-MP_-FS-C001B	2.40E-03	MOTOR-DRIVEN PUMP C001B FAILS TO START
P41-MP_-FS-C002A	2.40E-03	MOTOR-DRIVEN PUMP C002A FAILS TO START
P41-MP_-FS-C002B	2.40E-03	MOTOR-DRIVEN PUMP C002B FAILS TO START

Table 4.11-7

List of System Basic Events

Basic Event	Probability	Description
P41-STR-PG-D01A	2.40E-04	STRAINER P41-D001 A PLUGGED
P41-STR-PG-D01B	2.40E-04	STRAINER P41-D001 B PLUGGED
P41-STR-PG-D02A	3.59E-03	STRAINER P41-D002A PLUGGED
P41-STR-PG-D02B	3.59E-03	STRAINER P41-D002B PLUGGED
P41-SYS-FF-2CTMP	5.04E-05	INSUFFICIENT FLOW FROM CTM PUMPS (2 PUMPS FAIL)
P41-SYS-FF-3CTMP	9.20E-06	INSUFFICIENT FLOW FROM CTM PUMPS (3 PUMPS FAIL)
P41-UV_-CC-F001A	2.00E-04	CHECK VALVE F001A FAILS TO OPEN
P41-UV_-CC-F001B	2.00E-04	CHECK VALVE F001B FAILS TO OPEN
P41-UV_-CC-F003A	2.00E-04	CHECK VALVE F003A FAILS TO OPEN
P41-UV_-CC-F003B	2.00E-04	CHECK VALVE F003B FAILS TO OPEN

Table 4.11-8

List of System Top Events

TOP EVENT	Description
GP41-0001-_1	PSWS FAILS TO COOL THE LOADS

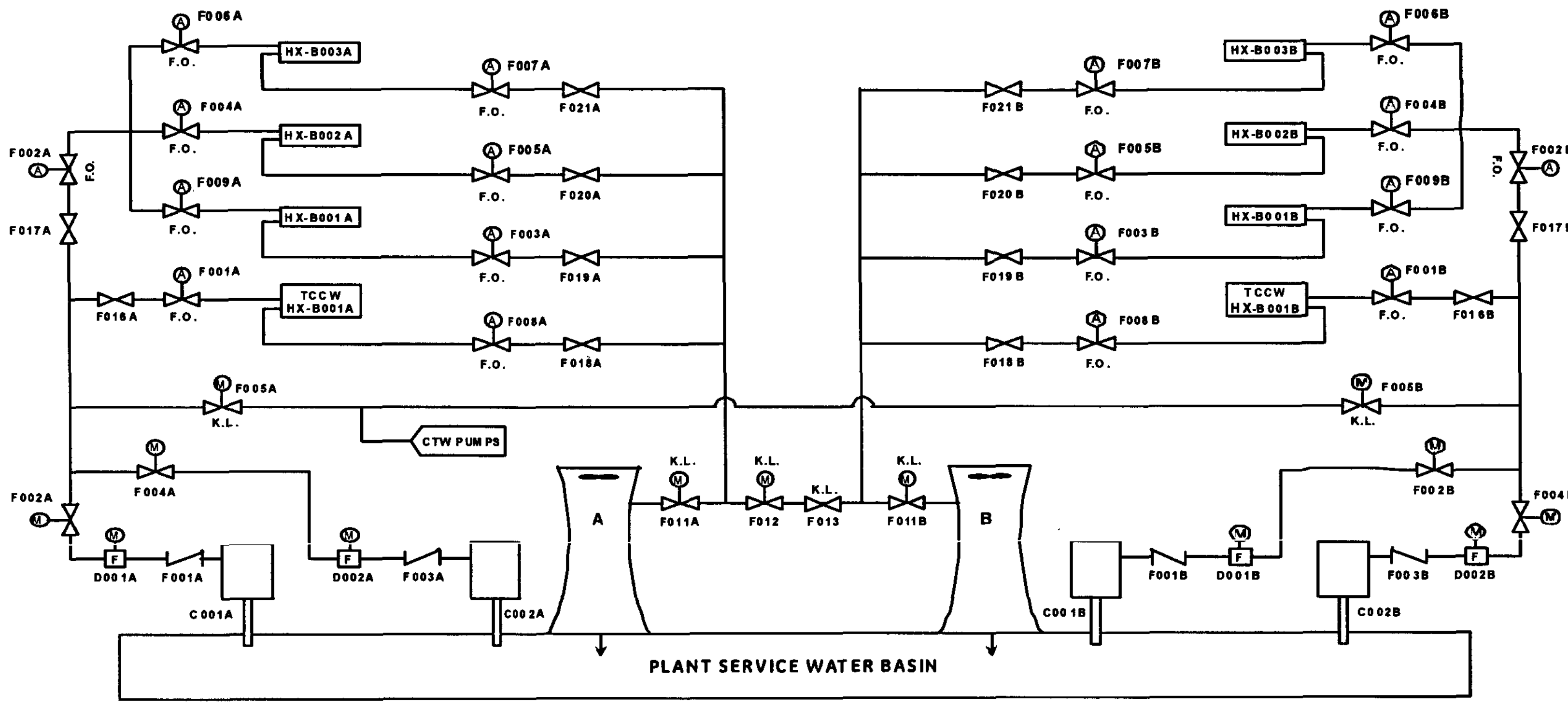


Figure 4.11-1. Plant Service Water System Simplified Flow Diagram for Plant Service Water System

4.12 INSTRUMENT AIR SYSTEM AND SERVICE AIR SYSTEM - (P51 and P52)

4.12.1 Purpose

The function of the Instrument Air System (IAS) is to provide a continuous supply of dry, oil free, filtered compressed air for pneumatic equipment, valves, controls, and instrumentation located in the following areas: areas outside of the primary containment in the Reactor Building, Turbine Building, Radwaste Building, Control Building, Fuel Storage Building, Electrical Building, Hot and Cold Machine Shop. It also supplies air to nitrogen consumers during refueling. The IAS supplies compressed air to the primary containment supply piping for non-essential instrumentation and control equipment during refueling. IAS piping transports nitrogen from the HPNSS to users inside the primary containment during normal operation. It is also used as a backup supply for the High Pressure Nitrogen Supply System (HPNSS) in case nitrogen pressure drops below the system low-pressure setpoint.

The function of the Service Air System (SAS) is to provide a continuous supply of compressed air for tank sparging, pneumatic tools, filter/demineralizer backwashing, and other services that do not require air that has been processed to the same levels as what is provided by the IAS. SAS provides a backup supply to the IAS. SAS also provides a supply of low pressure, purified compressed air for breathing air.

4.12.2 Design Assumptions

The following assumptions with respect to the design are made:

(1) The electrical supply for the dryers is assumed to be the same as for the compressors.

(2) The load/unload operation for compressor and dryer trains is assumed to be changed monthly.

4.12.3 System Description

4.12.3.1 Hardware Configuration

The IAS is a non-safety related system consisting of two 100 percent air compressor units arranged in parallel which supply air, properly filtered, cleaned, and dried, to two 50 percent capacity receivers. These, in turn, supply air to either of two 100 percent dryers whose outputs join at a common header and into a receiver/surge tank. From this point, several branches are routed to the different plant buildings and on to the individual users.

A system interconnection with the SAS is provided downstream of the air receiver and upstream of the dryers as a backup supply of compressed air. The SAS provides air automatically to the IAS via a tie line if the IAS pressure falls below a desired limit. Another interconnection via a normally closed air-operated valve is provided to supply air to the HPNSS users if the HPNSS is unavailable.

The SAS has a similar structure, including two 50 percent air compressor units, two breathing air purifiers, and related valves.

4.12.3.2 System Operation

The IAS and the SAS are continuously operating. One air compressor normally operates to feed two receivers and one filter and dryer train. The compressors operate on a load/unload sequence with one compressor selected as the lead compressor and the other in standby.

The standby compressor automatically starts when the air pressure at the receiver drops below a pre-determined set point. As the receiver pressure is returned to within normal range, the standby compressor stops and the lead unit is kept in operation. The lead and standby air compressors are switched periodically; assignment is performed at the local master control panel.

The skid of the standby dryer automatically starts when the differential pressure across the dryer, discharge pressure, or the dew point reaches the predetermined set points. The standby unit is warmed prior to start and prior to switching off an operating dryer skid. The assignment of lead or standby dryer is switched periodically and performed at the local master control panel.

4.12.3.3 Component Location

All the main components are located in the turbine building.

4.12.4 Automatic and Manual Control

4.12.4.1 Automatic Actuation

The standby compressor automatically starts when the air pressure at the receiver drops below a set point. As the receiver pressure is returned to the normal range, the standby compressor stops and the lead unit is kept in operation.

The valve in the connection line with the SAS opens automatically in the event that the receiver discharge header pressure continues to fall below a predetermined low-low pressure value.

When the high moisture switches at the operating air dryer outlets indicate high moisture or low pressure detected downstream of the afterfilter, the isolation valve upstream of the standby air dryer opens and the standby air dryer starts.

The IAS automatically switches to the standby AC power source during a loss of preferred power (LOPP).

4.12.4.2 Manual Actuation

The assignment of lead and stand-by air compressors is performed at the local master control panel.

The stand-by compressors, for both the IAS and the SAS, can be started locally and manually following a failure of the automatic actuation. The connection between the IAS and the SAS can be opened locally and manually after automatic actuation has failed.

4.12.4.3 Instrumentation and Alarms

Control room instrumentation and alarms are listed in Table 4.12-1.

4.12.5 System Interfaces

Table 4.12-2 shows a dependency matrix for the systems.

The supporting systems are the Medium Voltage Distribution System for the compressors and the dryers, the Low Voltage Distribution System for the motor operated containment isolation valves, the Uninterruptible AC Power Supply System for controls and instrumentation, the Reactor Component Cooling Water System (RCCW), which cools the IAS compressors, and the Turbine Component Cooling Water System (TCCW), which cools the SAS compressors.

4.12.6 System Testing

The SAS and IAS do not have in-service inspection requirements.

The system operational test for components normally closed to airflow is performed periodically to ensure system capability and integrity.

The only components that are subject to testing are the valves on the connection line between the IAS and the SAS and the pressure transmitters.

It is assumed that the valves are tested quarterly, while the transmitters are tested with every refueling.

The lead and stand-by compressor units follow an alternating operational cycle, so they are tested when called into operation.

4.12.7 System Maintenance

Maintenance of one compressor or one dryer at a time is possible during system operation, and the related unavailability is considered in the fault trees.

Filters are to be periodically inspected for the cleanliness, and the desiccant in the breathing air purifiers is sampled every six months to verify its useful life.

4.12.8 Common Cause Failures

Common cause failures (CCF) within the system are summarized in Table 4.12-5.

Calibration errors of the transmitters are judged to be included in the data for Common Cause Failure of the transmitters.

4.12.9 Fault Tree Analysis

4.12.9.1 Top Event Definitions

The top events considered in the study are the loss of air supply from the IAS and the loss of supply from the SAS.

4.12.9.2 Fault Tree Description

IAS and SAS fault trees have been developed to represent the loss of the instrument air supply and the loss of service air supply, Appendix B.4.12.

IAS and SAS fault trees are developed Appendix B.4.12.

4.12.9.3 Human Interaction

The following human interactions have been considered:

- Operator failure to recognize the need to align the SAS because of an IAS failure or failure when aligning
- Failure when actuating the compressors and dryers which are in standby mode

Table 4.12-6 reports the events considered with the related probabilities.

4.12.10 Results of Fault Tree Analysis

The definition of each basic event is reported in Table 4.12-7.

The quantification of core damage sequences implicitly includes the contribution of basic events for this system. This quantification process enables checking the global consistency of the system fault trees and their relationship with the rest of the systems modeled in the PRA.

On the other hand, the importance measurements obtained from core damage frequency equations, allow identification of the most relevant basic events and system component failures in an integrated context, as well as the determination of their relative importance with respect to the basic events and component failures of the other systems modeled.

4.12.11 Model Differences for 72-Hour Operation

There are no fault tree changes necessary to extend the operation to 72 hours.

4.12.12 References

4.12-1. ESBWR Design Control Document, 26A6642 Rev. 01

Table 4.12-1

Control Room Instrumentation and Alarms

Alarms (IAS)
Compressor: -High receiver air pressure -High vibration -High water level in the after cooler drip leg -High compressor outlet air temperature -Compressor low oil pressure and high oil temperature -High cooling water discharge temperature -High motor winding temperature -High motor bearing temperature -Motor overload
High temperature in the moisture separator outlet
Low receiver air pressure
High moisture content in the air dryer outlet
Low instrument air supply pressure
Standby power for IAS initiated
IAS standby dryer/filter train activated
High RCCWS temperatures
High pre-filter differential pressure
High after-filter differential pressure
Alarms (SAS)
Compressor: -High receiver air pressure -High water level in the after cooler drip leg -High compressor outlet air temperature -Compressor low oil pressure and high oil temperature -High cooling water discharge temperature
Increasing temperature in the moisture separator outlet above a predetermined setpoint
Decreasing pressure in the air receiver falling below a predetermined setpoint
Increasing moisture in the air dryer outlet rising above a predetermined setpoint
Increasing moisture in the air purifier outlet rising above a predetermined setpoint
Decreasing pressure in the air purifier outlet falling below a predetermined setpoint
Increasing pressure in the breathing air receiver rising above a predetermined setpoint
Displays (IAS)
Instrument air receiver temperature
Instrument air receiver pressure
Instrument air dryer outlet pressure
Instrument air dryer prefilter differential pressure
Instrument air dryer afterfilter differential pressure
Instrument air header pressure
Instrument air dryer outlet moisture

Table 4.14-2

System Dependency Matrix

Component	Type	Support System					
		Power Supply				Cooling System	
		480 V AC:		Uninterruptible 208/120V			
Component	Type	Train A in TB	Train B inTB	R13-A2-1	R13-B2-1	RCCWS	TCCWS
IA Dryer 1	Dryer	X		X			
IA Dryer 2	Dryer		X		X		
IA Compr 1.	Compr.	X		X		X	
IA Compr. 2	Compr.		X		X	X	
F006	AOV			X			
SA Dryer 1	Dryer	X		X			
SA Dryer 2	Dryer		X		X		
SA Compr 1.	Compr.	X		X			X
SA Compr. 2	Compr.		X		X		X
F015A	AOV			X			
F015B	AOV				X		

Table 4.12-3

Component Test

Component	Type	Expected Test Interval
F006	AOV	3 months
Transmitters	Transmitters	Refueling (24 months)

Table 4.12-4

Component Maintenance

Component	Unavailability
Compressors	2E-5
Dryers	2E-3

Table 4.12-5

System Common Cause Failures

Basic Event	Probability	Description
P52-ACV-CF-DEENERG	2.20E-05	CCF OF AOVs TO OPERATE TO OTHER THEN DEENERG. POS.
P52-ACV-CF-OPEN	1.35E-05	CCF OF AOV TO OPEN
P52-CMP-CR-C001AB	1.49E-04	CCF TO RUN COMPRESSORS LINES 1 & 2
P52-CMP-CS-C001AB	1.71E-03	CCF TO START COMPRESSORS LINES 1 & 2
P52-CMP-CS-P52/P51	1.00E-04	CCF OF P52/P51 COMPRESSORS TO START
P52-PT_-CF-P51/P52	2.59E-06	CCF OF PRESSURE TRANSMITTERS
C62-DTM-CF-N1EALL	5.50E-05	CCF OF DIGITAL TRIP MODULES NO 1E
P51-ACV-CF-OPEN	1.35E-05	CCF OF AOV TO OPEN
P52-CMP-CR-RUN	1.49E-04	CCF OF COMPRESSORS TO RUN
P52-CMP-CR-START	1.71E-03	CCF OF COMPRESSORS TO START

Table 4.12-6

System Human Errors

Basic Event	Prob	Description
P52-XHE-FO-ALIGNDRYER2	1.61E-03	OPERATOR FAILS TO ACTUATE VALVE F015B TO ALIGN DRYER LINE 2
P52-XHE-FO-ALIGNSAS	1.61E-03	OPERATOR FAILS TO ACTUATE TO ALIGN SAS
P52-XHE-FO-IAS/SAS	1.61E-02	OPER. FAILS TO REC. NEED FOR MANUAL INTERV. ON IAS/SAS
P52-XHE-FO-STDBYCOMP	1.61E-03	OPERATOR FAILS TO ACTUATE STAND-BY COMPRESSOR
P51-XHE-FO-STDBYCOMP	1.77E-02	OPERATOR FAILS TO ACTUATE STAND-BY COMPRESSOR
P52-XHE-FO-STDBYCOMP	1.61E-03	OPERATOR FAILS TO ACTUATE STAND-BY COMPRESSOR

Table 4.12-7

List of System Basic Events

Basic Event	Prob	Description
P52-XHE-FO-STDBYCOMP	1.61E-03	OPERATOR FAILS TO ACTUATE STAND-BY COMPRESSOR
P52-XHE-FO-IAS/SAS	1.61E-02	OPER. FAILS TO REC. NEED FOR MANUAL INTERV. ON IAS/SAS
P52-XHE-FO-ALIGNSAS	1.61E-03	OPERATOR FAILS TO ACTUATE TO ALIGN SAS
P52-XHE-FO-ALIGNDRYER2	1.61E-03	OPERATOR FAILS TO ACTUATE VALVE F015B TO ALIGN DRYER LINE 2
P52-UV_-CC-F002B	2.00E-04	HEATER 2B CHECK VALVE FAILS TO OPEN
P52-UV_-CC-F002A	2.00E-04	HEATER 2A CHECK VALVE FAILS TO OPEN
P52-UV_-CC-F001B	2.00E-04	HEATER 1B CHECK VALVE FAILS TO OPEN
P52-UV_-CC-F001A	2.00E-04	HEATER 1A CHECK VALVE FAILS TO OPEN
P52-TNK-RP-A001B	2.40E-06	TANK RECEIVER TKA001B LEAKS CATASTROPHICALLY
P52-TNK-RP-A001A	2.40E-06	TANK RECEIVER TKA001A LEAKS CATASTROPHICALLY
P52-STR-PG-D009C	3.59E-03	STRAINER/FILTER D009C PLUGS DURING OPERATION
P52-STR-PG-D009A	2.40E-04	STRAINER/FILTER D009A PLUGS DURING OPERATION
P52-STR-PG-D005C	3.59E-03	STRAINER/FILTER D005C PLUGS DURING OPERATION
P52-STR-PG-D005A	2.40E-04	STRAINER/FILTER D009A PLUGS DURING OPERATION
P52-STR-PG-D001B	3.59E-03	STRAINER/FILTER D001B PLUGS DURING OPERATION
P52-STR-PG-D001A	2.40E-04	STRAINER/FILTER D001A PLUGS DURING OPERATION
P52-PT_-NO-A002	5.18E-04	PRESSURE TRANSMITT. IA002 FAILS TO RESPOND TO CHANGE
P52-PT_-NO-A001	5.18E-04	PRESSURE TRANSMITT. IA001 FAILS TO RESPOND TO CHANGE
P52-PT_-CF-P51/P52	2.59E-06	CCF OF PRESSURE TRANSMITTERS
P52-HX_-PG-D007D	7.92E-04	HEATER (PRESSURIZER D007D ALL FAILURES [#2]
P52-HX_-PG-D007C	7.92E-04	HEATER (PRESSURIZER D007C ALL FAILURES [#2]
P52-HX_-PG-D007B	5.28E-05	HEATER (PRESSURIZER D007B ALL FAILURES [#2]
P52-HX_-PG-D007A	5.28E-05	HEATER (PRESSURIZER D007A ALL FAILURES [#2]
P52-HX_-PG-C001B	3.60E-04	COOLER COMPRESSOR C001B FAILS WHILE OPERATING
P52-HX_-PG-C001A	2.40E-05	COOLER COMPRESSOR C001A FAILS WHILE OPERATING
P52-DRY-TM-B002B	2.00E-05	DRYER K002B IN MAINTENANCE
P52-CMP-TM-C001B	2.00E-03	COMPRESSOR C001B IN MAINTENANCE
P52-CMP-FS-C001B	2.00E-02	MOTOR-DRIVEN AIR COMPRESS. C001B FAILS TO START
P52-CMP-FS-C001A	2.00E-02	MOTOR-DRIVEN AIR COMPRESS. C001A FAILS TO START
P52-CMP-FR-C001B	2.40E-03	MOTOR-DRIVEN AIR COMPRESS. C001B FAILS TO CONT.OPER.
P52-CMP-FR-C001A	2.40E-03	MOTOR-DRIVEN AIR COMPRESS. C001A FAILS TO CONT.OPER.
P52-CMP-CS-P52/P51	1.00E-04	CCF OF P52/P51 COMPRESSORS TO START
P52-CMP-CS-C001AB	1.71E-03	CCF TO START COMPRESSORS LINES 1 & 2
P52-CMP-CR-START	1.71E-03	CCF OF COMPRESSORS TO START

Table 4.12-7

List of System Basic Events

Basic Event	Prob	Description
P52-CMP-CR-RUN	1.49E-04	CCF OF COMPRESSORS TO RUN
P52-CMP-CR-C001AB	1.49E-04	CCF TO RUN COMPRESSORS LINES 1 & 2
P52-ACV-OC-F010F	5.40E-05	AOV FAILS F010F TO REMAIN OPEN (FOR FC VALVE)[#2]
P52-ACV-OC-F010D	5.40E-05	AOV F010D FAILS TO REMAIN OPEN (FOR FC VALVE)[#2]
P52-ACV-OC-F010C	3.60E-06	AOV FAILS F010C TO REMAIN OPEN (FOR FC VALVE)
P52-ACV-OC-F010A	3.60E-06	AOV F010A FAILS TO REMAIN OPEN (FOR FC VALVE)[#2]
P52-ACV-OC-F005B	5.40E-05	AOV F005A SPURIOUSLY TRANSFER TO ENERGIZED POSIT.
P52-ACV-OC-F005A	3.60E-06	AOV F005A SPURIOUSLY TRANSFER TO ENERGIZED POSIT.
P52-ACV-CF-OPEN	1.35E-05	CCF OF AOV TO OPEN
P52-ACV-CF-DEENERG	2.20E-05	CCF OF AOVs TO OPERATE TO OTHER THEN DEENERG. POS.
P52-ACV-CC-RTBUILD	2.00E-03	THE AOV TO RADWASTE REACTOR, AND TURB BUILD FAILS (NOFO)
P52-ACV-CC-F015B	2.00E-03	AIR OPERATED VALVE FAILS TO OPEN
P52-ACV-CC-F010F	2.00E-03	AOV F010F FAILS TO OPEN REPETITIOUSLY [#3]
P52-ACV-CC-F010D	2.00E-03	AOV F010D FAILS TO OPEN REPETITIOUSLY [#3]
P52-ACV-CC-F010C	2.00E-03	AOV F010C FAILS TO OPEN REPETITIOUSLY [#3]
P52-ACV-CC-F010A	2.00E-03	AOV F010A FAILS TO OPEN REPETITIOUSLY [#3]
P52-ACV-CC-F006	2.00E-03	AOV F006 FAILS TO OPERATE TO NOT DEENERG.POS.
P51-XHE-FO-STDBYCOMP	1.77E-02	OPERATOR FAILS TO ACTUATE STAND-BY COMPRESSOR
P51-UV_-CC-F001D	2.00E-04	DESICCANT 1D CHECK VALVE FAILS TO OPEN
P51-UV_-CC-F001C	2.00E-04	DESICCANT 1C CHECK VALVE FAILS TO OPEN
P51-UV_-CC-F001B	2.00E-04	DESICCANT 1B CHECK VALVE FAILS TO OPEN
P51-UV_-CC-F001A	2.00E-04	DESICCANT 1A CHECK VALVE FAILS TO OPEN
P51-TNK-RP-A002	2.40E-06	AIR RECEIVER TANK LEAKS CATASTROPHICALLY
P51-TNK-RP-A001B	2.40E-06	AIR RECEIVER TANK A001B LEAKS CATASTROPHICALLY
P51-TNK-RP-A001A	2.40E-06	AIR RECEIVER TANK A001A LEAKS CATASTROPHICALLY
P51-STR-PG-TK07D	3.59E-03	STRAINER/FILTER TK07D PLUGS DURING OPERATION
P51-STR-PG-TK07C	3.59E-03	STRAINER/FILTER TK07C PLUGS DURING OPERATION
P51-STR-PG-TK07B	2.40E-04	STRAINER/FILTER TK07B PLUGS DURING OPERATION
P51-STR-PG-TK07A	2.40E-04	STRAINER/FILTER TK07A PLUGS DURING OPERATION
P51-STR-PG-K002B	3.59E-03	STRAINER/FILTER K002B PLUGS DURING OPERATION
P51-STR-PG-K002A	2.40E-04	STRAINER/FILTER K002A PLUGS DURING OPERATION
P51-STR-PG-D005C	3.59E-03	STRAINER/FILTER D005C PLUGS DURING OPERATION
P51-STR-PG-D005A	2.40E-04	STRAINER/FILTER D005A PLUGS DURING OPERATION
P51-STR-PG-D001B	3.59E-03	STRAINER/FILTER D001B PLUGS DURING OPERATION
P51-STR-PG-D001A	2.40E-04	STRAINER/FILTER D001A PLUGS DURING OPERATION
P51-PT_-NO-A001	1.15E-05	PRESSURE TRANSMITT. SA001 FAILS TO RESPOND TO CHANGE
P51-HX_-PG-C001B	3.60E-04	COOLER COMPRESSOR C001B FAILS WHILE OPERATING
P51-HX_-PG-C001A	2.40E-05	COOLER COMPRESSOR C001A FAILS WHILE OPERATING
P51-DRY-TM-B002B	2.00E-05	DRYER B002B IN MAINTENANCE

Table 4.12-7 List of System Basic Events		
Basic Event	**Prob**	**Description**
P51-CMP-TM-C001B	2.00E-03	COMPRESSOR C001B IN MAINTENANCE
P51-CMP-FS-C001B	2.00E-02	MOTOR-DRIVEN AIR COMPRESS. C001B FAILS TO START
P51-CMP-FS-C001A	2.00E-02	MOTOR-DRIVEN AIR COMPRESS. C001A FAILS TO START
P51-CMP-FR-C001B	2.40E-03	MOTOR-DRIVEN AIR COMPRESS. C001B FAILS TO CONT.OPER.
P51-CMP-FR-C001A	2.40E-03	MOTOR-DRIVEN AIR COMPRESS. C001A FAILS TO CONT.OPER.
P51-ACV-OC-F010C	5.40E-05	AOV F010C FAILS TO REMAIN OPEN (FOR FC VALVE)
P51-ACV-OC-F010A	3.60E-06	AOV F010A FAILS TO REMAIN OPEN (FOR FC VALVE)
P51-ACV-CF-OPEN	1.35E-05	CCF OF AOV TO OPEN
P51-ACV-CC-F010F	2.00E-03	AOV F010F FAILS TO OPERATE TO NOT DEENERG. POSITION.
P51-ACV-CC-F010C	2.00E-03	AOV F010C FAILS TO OPERATE TO NOT DEENERG. POSITION
P51-ACV-CC-F008B	2.00E-03	AOV F08B FAILS TO OPERATE TO DEENERG. POSITION.
P51-ACV-CC-F008A	2.00E-03	AIR OPERATED VALVE F008A FAILS TO OP. TO DEENERG. POSIT.
H23-RMU-FC-SA001	3.00E-04	RMU SA001 FAILS TO OPERATE
H23-RMU-FC-IAS2	3.00E-04	RMU 002 FOR IAS C.R. MANUAL ACTUAT. FAILS TO OPERATE
H23-RMU-FC-IAS1	3.00E-04	RMU 001 FOR IAS C.R. MANUAL ACTUAT. FAILS TO OPERATE
H23-RMU-FC-IA001	3.00E-04	RMU IA001 FAILS TO OPERATE
H23-RMU-FC-2PU2	3.00E-04	RMU 2 PURIFIER 2 FAILS
H23-RMU-FC-2P51B	3.00E-04	RMU 002 FOR SAS C.R. MANUAL ACTUAT. FAILS TO OPERATE
H23-RMU-FC-2P51A	3.00E-04	RMU 002 FOR SAS C.R. MANUAL ACTUAT. FAILS TO OPERATE
H23-RMU-FC-2IA2	3.00E-04	RMU 2 IA002 FOR INPUT PARAMETER FAILS TO OPERATE
H23-RMU-FC-2DRYER2	3.00E-04	RMU 001 DRYER 2 FAIL
H23-RMU-FC-1PU2	3.00E-04	RMU 1 PURIFIER 2 FAILS
H23-RMU-FC-1P51B	3.00E-04	RMU 001 FOR SAS C.R. MANUAL ACTUAT. FAILS TO OPERATE
H23-RMU-FC-1P51A	3.00E-04	RMU 001 FOR SAS C.R. MANUAL ACTUAT. FAILS TO OPERATE
H23-RMU-FC-1DRYER2	3.00E-04	RMU 001 DRYER 2 FAIL
C74-VLU-FC-SASALIG	6.24E-04	VOTER CARD FOR SAS ALIGNMENT FAILS TO OPERATE (3M TEST)
C62-DTM-FC-N1EB	9.00E-04	DIGITAL TRIP MODULE TRAIN B NO 1E FAILS
C62-DTM-FC-N1EA	9.00E-04	DIGITAL TRIP MODULE TRAIN A NO 1E FAILS
C62-DTM-CF-N1EALL	5.50E-05	CCF OF DIGITAL TRIP MODULES NO 1E

Table 4.12-8

System Top Events

Top Event	**Description**
GP52-0001-_1	LOSS OF INSTRUMENT AIR SYSTEM
GP51-0001-_1	LOSS OF SERVICE AIR SYSTEM

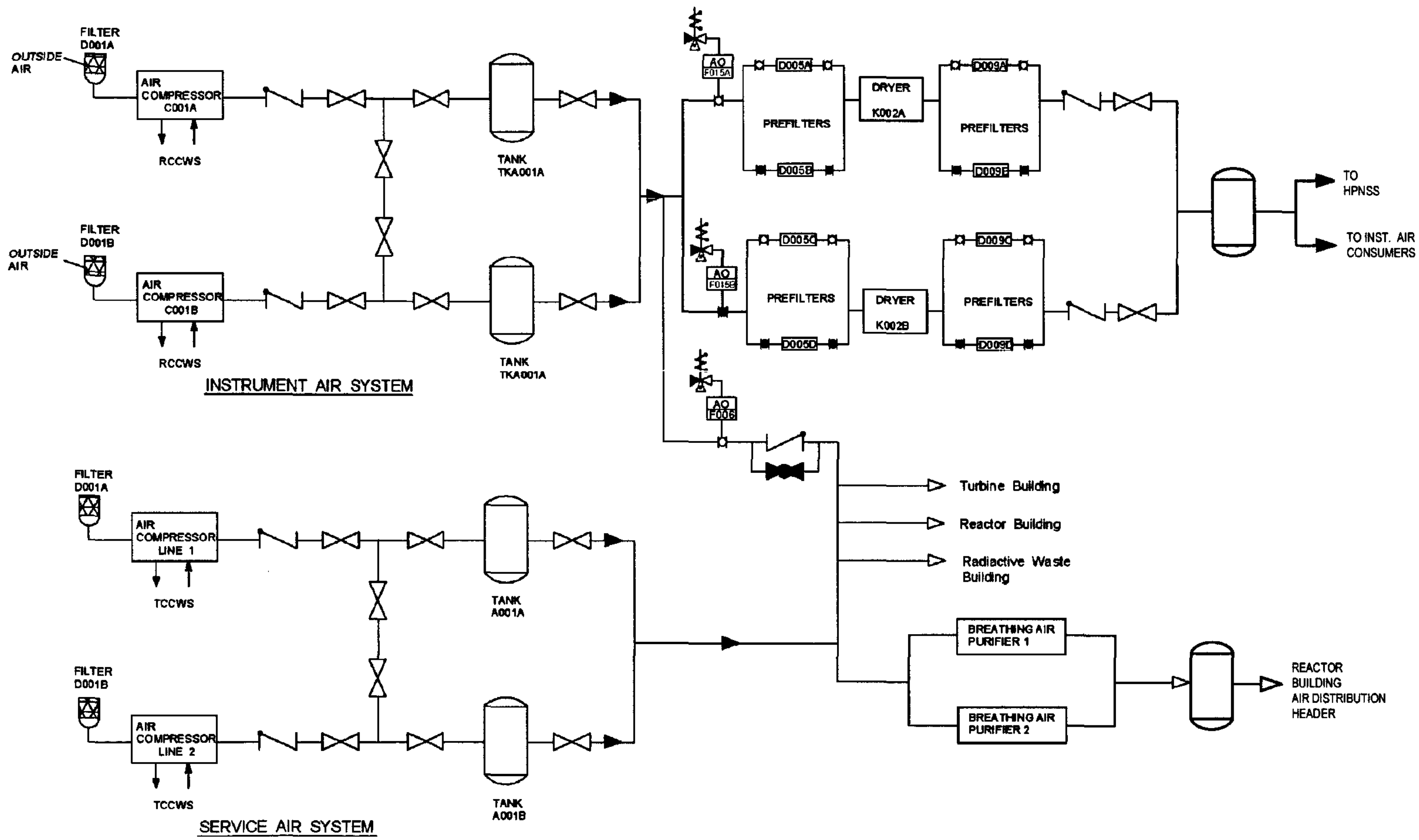


Figure 4.12-1. Simplified Process Flow Diagram for IAS and SAS

4.13 HIGH PRESSURE NITROGEN SUPPLY SYSTEM– (P54)

4.13.1 Purpose

The High Pressure Nitrogen Supply System (HPNSS) consists of distribution piping between the Containment Inerting System and the containment nitrogen users. Its function is to supply nitrogen gas for instrumentation and control systems and for pneumatic valve operators located within the primary containment. The HPNSS is a backup to the Containment Inerting System.

The containment high pressure nitrogen consumers include the ADS SRVs and their accumulators and the isolation condenser steam and condensate line isolation valve (ICIV) accumulator. The containment low pressure nitrogen consumers include the inboard MSIVs and their accumulators, the main steam drain header isolation valves, instruments, inboard RWCU containment isolation valves and the pneumatically operated valves.

4.13.2 Design Assumptions

The following assumptions with respect to the design were made:

(1) Instrumentation logic for the actuation of valves located in the high pressure portion of the HPNSS is the same type as is used for SRV operation in both designs (discrete logic components for ESBWR).

(2) The isolation valves on the lines that penetrate the primary containment are self-actuated, air-operated valves. These valves close on a loss of nitrogen pressure.

(3) Valves F003, F005 and F017 are nitrogen operated.

(4) A quarterly test of the supply from the bottles is assumed.

(5) It is assumed that valves F016A and F016B possess their own accumulator for their actuation.

4.13.3 System Description

4.13.3.1 Hardware Configuration

A simplified sketch of the HPNSS used in the analysis is shown in Figure 4.13-1. The sketch shows the interface systems needed for the HPNSS functions.

The HPNSS fulfils two functions:

(1) Supplies nitrogen gas to essential safety-related systems inside the primary containment;

(2) Supplies nitrogen gas to non-essential systems inside the primary containment.

For the first function, the nitrogen is normally obtained from a non-safety-related gas supply subsystem comprised of a liquid nitrogen storage tank that is part of the ESBWR Containment Inerting System providing nitrogen gas for containment inerting.

The two low pressure branch lines incorporate a pressure reducing station in each branch line (F014 A and B) to lower the Containment Inerting System nitrogen supply. A check valve (F015 A and B) is located downstream of each pressure reducing station to prevent contamination from traveling upstream. During refueling, the IAS provides instrument air supply to consumers in the

containment via connections to the two low pressure branch lines. As a backup, a connection to the IAS is provided in order to supply air to the non-essential nitrogen users located inside the primary containment when the nitrogen gas supply pressure drops below a preset point.

The one high pressure branch line provides clean, dry, oil-free high pressure nitrogen to the containment nitrogen consumers from either the Containment Inerting System or from two racks of nitrogen storage bottles. Each rack consists of ten or more bottles, each bottle contains a pigtail and station valve that are piped into a manifold. A pressure control valve, F012, in series with an air-operated on-off valve, is provided in the line that connects the nitrogen bottles to the valve operators inside the containment. A connection to the Containment Inerting System Supply is provided downstream of these valves.

4.13.3.2 System Operation

During normal operating conditions, only the line from the tank of the Containment Inerting System to the essential safety systems and non-essential system inside containment is open. The normal valve status is as follows:

- F001 Open
- NOV F003, F017 Open
- NOV F005 Closed

When low pressure is detected in the normal nitrogen supply line, valve F003 automatically closes and nitrogen supply is provided to essential safety systems by the nitrogen storage bottle backup system. On a low-low pressure alarm, the line supplying nitrogen to non-essential systems inside the containment is manually isolated by the operator and, as a backup, the IAS supply line is opened.

The IAS supplies instrument and quality air for the instruments and controls inside the Primary Containment Vessel during refueling outages and/or when the primary containment is open for personnel entry.

4.13.3.3 Component Location

With the exception of the Containment Inerting System Tank and the lines connected to the nitrogen users located inside the primary containment, the system components (valves, piping, etc.) are mainly located in the Reactor Building.

4.13.4 Automatic and Manual Control

4.13.4.1 Automatic Actuation

When low nitrogen gas pressure is detected by pressure transmitter PT006, pressure switch PS-001 closes NOV F003. A low nitrogen gas pressure is simultaneously detected by the pressure transmitter (PT-002) causing NOV F005 to open and thus connecting to the nitrogen gas bottle supply.

No automatic actuation is provided for the portion of the system feeding the low pressure nitrogen consumers inside the containment; only a low pressure alarm in the control room is

available for the operator. Operator action is therefore required in order to close the normal and bottled nitrogen supplying lines and to align the backup from Instrumental Air System.

4.13.4.2 Manual Actuation

The following assumptions with respect to the design were made:

(1) Operation of valves and associated equipment used for the system functions can be performed by manual actuation of switches located in the main control room (MCR).

4.13.4.3 Instrumentation and Alarms

Table 4.13-1 shows the alarms and indications located in the MCR.

4.13.5 System Interfaces

The only supporting-system interface is with the electrical system.

In case of loss of the HPNSS, the IAS supplies filtered dry air to non-essential containment pneumatic users.

HPNSS supplies nitrogen to operate valves F003, F005 and F017.

Table 4.13-2 reports the system dependency matrix assumed for the analysis.

4.13.6 System Testing

The high pressure nitrogen isolation valves are tested by manual actuation of a switch located in the control room and by observation of associated position indication lights. Operation of valves and associated equipment used to switch from the non-safety to safety nitrogen supply are also tested by manual actuation of a switch located in the control room and by observation of the associated position indication lights. Periodic tests of the check valves and accumulators are conducted to assure valve operability. The HPNSS nitrogen supply pressure for the SRVs is verified at monthly intervals to assure that the valves are capable of performing their intended functions. A system operational test is performed by isolating the Containment Inerting System supply line and allowing the nitrogen pressure to decrease. The HPNSS responds to a predetermined low pressure by opening the appropriate valves and allowing HPNSS backup nitrogen supply. In addition, Containment Inerting System isolation also occurs at this predetermined low nitrogen pressure. Table 4.13-3 reports the expected test frequency of the components considered in the analysis.

4.13.7 System Maintenance

The HPNSS is designed for on-line maintenance to the maximum extent practical. All major components have manual isolation valves to permit maintenance activities without having to shut down the HPNSS. Table 4.13-4 lists the on-line maintenance activities.

4.13.8 Common Cause Failures

Common cause failures (CCFs) within the system are summarized in Table 4.13-5.

4.13.9 Fault Tree Analysis

The HPNSS fault tree is evaluated to determine the system unavailability and the components contributing significantly to system unavailability.

4.13.9.1 Top Event Definitions

Because of the two different functions of the HPNSS, the following two top events are defined:

- Loss of the HPNSS to high pressure nitrogen consumers inside primary containment (safety relief valves of Nuclear Boiler System (NBS) (B21) and nitrogen motor-operated valves of IC (B32)), Fault Tree Top event GP54-0001-_1.
- Loss of HPNSS/air to the low pressure nitrogen consumers inside primary containment, Fault Tree Top event GP54-0001-_2.

4.13.9.2 Fault Tree Description

The fault tree for GP54-0001-_1 shows the unavailability of both the normal and the essential HPNSS.

The fault tree for GP54-0001-_2 shows the unavailability of both the normal HPNSS and the IAS used as a backup supply.

Both fault trees are shown in the Appendix B.4.13.

4.13.9.3 Human Interactions

The following human actions are accounted for in the fault trees:

- Operator failure to manually open valves F005 when automatic opening fails.
- Misposition of valve F003 causes loss of nitrogen for Containment Inerting System supply line.

Table 4.13-6 reports a summary of system mispositions and operator actions considered in the analysis.

4.13.10 Results of Fault Tree Analysis

The definition of each basic event for the HPNSS fault tree is reported in Table 4.13-7.

The quantification of core damage sequences implicitly includes the contribution of basic events for this system. This quantification process enables checking the global consistency of the system fault trees and their relationship with the rest of the systems modeled in the PRA.

On the other hand, the importance measurements obtained from core damage frequency equations, allow the identification of the most relevant basic events and system component failures in an integrated context, as well as the determination of their relative importance with respect to the basic events and component failures of the other systems modeled.

4.13.11 Model Differences for 72-Hour Operation

There are no changes to the model for operation for 72 hours other than the missing time.

4.13.12 References

4.13-1. ESBWR Design Control Document, 26A6642 Rev. 01

Table 4.13-1

Control Room Instrumentation and Alarms

Displays
Nitrogen storage bottle rack pressure
Containment Inerting System line header pressure
Low line header pressure in the Division 1 low pressure supply branch
Low line header pressure in the Division 2 low pressure supply branch
High pressure branch line header pressure
Alarms
Low nitrogen storage bottle rack pressure
Low line header pressure in Division 1 low pressure supply branch
Low line header pressure in Division 1 low pressure supply branch
High line header pressure in Division 1 low pressure supply branch
Low line header pressure in Division 2 low pressure supply branch
High line header pressure in Division 2 low pressure supply branch
Low line header pressure in the high pressure supply branch
High line header pressure in the high pressure supply branch

Table 4.13-2

System Dependency Matrix

		Support System				
		Power Supply				Air Supply
		Uninterruptible AC Power Supply System (class 1E)				
Component	**Type**	**208-120 V DIV 1 (R13-11-2)**	**208-120 V DIV 2 (R13-21-2)**	**480 V DIV 1 (R13-11)**	**480 V DIV2 (R13-21)**	
F016A	AOV			X		
F016B	AOV				X	
F003	AOV	X				X
F005	AOV	X				X
F017	AOV	X				X

Table 4.13-3

Component Test

Component	Type	Expected Test Interval
F005	AOV	Quarterly
F012	CPV	Quarterly
Pressure switch	PS	Quarterly
Pressure transmitter	PT	Quarterly

Table 4.13-4

Component Maintenance

Component maintenance has not been included in the model.

Table 4.13-5

System Common Cause Failures

Basic Event	Prob	Description
P54-CPV-CF-CONTROL	1.57E-04	CCF OF PRESSURE CONTROL VALVES FAILURES

Table 4.13-6

System Human Errors

Basic Event	Prob	Description
P54-XHE-FO-OPENF005	1.77E-02	OPERATOR FAILS TO MANUALLY OPEN VALVE F005
P54-XHE-MH-F003	4.00E-03	INADVERTENT MISPOSITION OF VALVE F003

Table 4.13-7

System Basic Events

Basic Event	Prob	Description
H23-RMU-FC-P54F005	3.00E-04	ATM VALVE F005 FAILS TO TRIP
H23-RMU-FC-P54PT2	3.00E-04	REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION
P54-ACV-CC-F005	2.00E-03	AIR OPERATED VALVE F005 FAILS TO OPEN
P54-ACV-OC-F016A	3.60E-06	AIR OPER. VALVE F016A SPUR. CLOSE
P54-ACV-OC-F016B	3.60E-06	AIR OPER. VALVE F016B SPUR. CLOSE
P54-ACV-OO-F003	2.00E-03	AIR OPERATED VALVE F003 FAILS TO CLOSE
P54-CPV-CF-CONTROL	1.57E-04	CCF OF PRESSURE CONTROL VALVES FAILURES
P54-CPV-FC-F012	3.13E-03	REGULATING PRESSURE VALVE F012 ALL MODES FAILURE
P54-CPV-FC-F014A	6.96E-05	REGULATING PRESSURE VALVE F014A ALL MODES FAILURE
P54-CPV-FC-F014B	6.96E-05	REGULATING PRESSURE VALVE F014B ALL MODES FAILURE
P54-CPV-FC-F015	6.96E-05	REGULATING PRESSURE VALVE F015 ALL MODES FAILURE
P54-PSF-RP-ESSENT	4.12E-06	PIPE SECTION TO ESSENT. SYSTEMS LEAKS OR PLUGS
P54-PSF-RP-NONESSENT	4.12E-06	PIPE SECTION TO NON ESSENT. USERS LEAKS OR PLUGS (#2)
P54-PS_-CO-PS001	1.19E-04	PRESSURE SWITCH PS001 (PT001) OPERATES SPURIOUSLY
P54-PT_-NO-002	5.18E-04	PRESSURE TRANSMITT. PT002 FAILS TO RESPOND TO CHANGE
P54-PT_-NO-006	5.18E-04	PRESSURE TRANSMITT. PT006 FAILS TO RESPOND TO CHANGE
P54-TNK-RP-A001	2.40E-06	TANK A001 LEAKS CATASTROPHICALLY
P54-UV_-OO-F004	1.00E-03	CHECK VALVE F004 FAILS TO CLOSE
P54-XHE-FO-OPENF005	1.77E-02	OPERATOR FAILS TO MANUALLY OPEN VALVE F005
P54-XHE-MH-F003	4.00E-03	INADVERTENT MISPOSITION OF VALVE F003

Table 4.13-8

System Top Events

Top Event	Description
GP54-0001-_1	LOSS OF HIGH PRESS. NIT. GAS SUPPLY SYST. TO HIGH PRESS. CONSUMERS
GP54-0001-_2	LOSS OF NITROGEN TO LOW PRESSURE USERS INSIDE P.C.

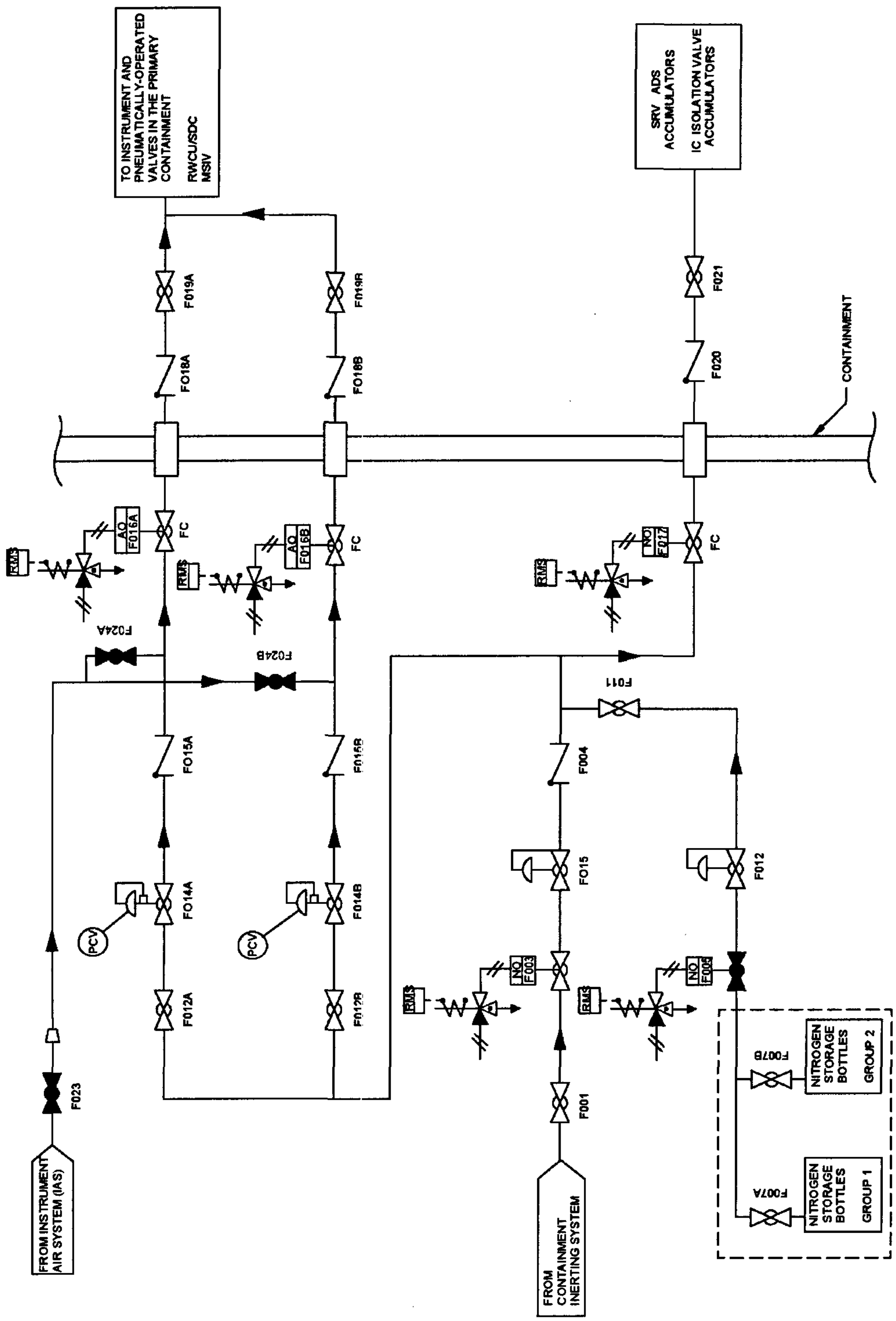


Figure 4.13-1. Simplified Process Flow Diagram for HPNSS

4.14 A.C. ELECTRIC POWER SYSTEM – (R10, R11 and R12)

4.14.1 System Purpose

To ensure satisfactory operation of the plant equipment, the main Diesel Generator and Off-site Power System supply electrical power to the Medium Voltage AC System, which consists of 13.8 kV PG (plant generation) buses and 6.9 kV PIP (Plant Investment Protection) buses. PG loads are divided into four non-safety buses (A1, B1, C1, and D1) and are needed during startup, normal operation, and normal shutdown. The 6.9 kV PIP loads are divided into four non-safety buses (A2, A3, B2, B3) and are the auxiliary and service loads that must remain operational. These buses are backed up with on-site non-safety-related diesel generators.

The Low Voltage AC Power System supplies electric power at 480V and consists of non-safety buses that are normally powered from the PG buses and non-safety buses that are normally powered from the 6.9 kV PIP buses. Four of the buses (A31, B31, C31, D31) are Class 1E divisions and are fed from the two 6.9 kV PIP buses (A2 and B2) that are backed up by on-site non-safety related diesel generators.

The Instrumentation and Control (I&C) Power Supply System provides non-vital low voltage AC power for operation of instrumentation and control system loads and other important plant loads. Receiving 480 V and supplying 208-120 V.

4.14.2 Design Assumptions

The following design assumptions with respect to the design are made:

(1) It is assumed that the diesel generators are tested every three months.

(2) It is assumed that the buses that can be powered either by bus A2 or by bus B2 (A31, B31, C31, D31 and C23) change their current supply every three months.

(3) It is assumed that no preventive maintenance actions performed during the normal operation of the plant. Nevertheless, a corrective maintenance could be done if required.

4.14.3 System Description

4.14.3.1 Hardware Configuration

Figure 4.14-1, Simplified Electrical One-line Diagram, shows the principal components of the system.

The Off-site Power System supply the plant from two electrically independent and physically separated off-site power sources:

- "Normal" (or preferred) source via the unit auxiliary transformer
- "Alternate" (or reserve) source via the reserve auxiliary transformers

During normal plant operation, the main plant generator supplies the plant loads through two auxiliary transformers. These transformers have two output voltage levels:

- 13.8kv which feeds two buses for PG loads (either buses A1 and C1 or buses B1 and D1)
- 6.9kv which feeds PIP buses (bus A2 or B2)

The utility power grid is the normal preferred power supply when the turbine generator is tripped. Off-site power via two reserve transformers, similar to the auxiliaries, is the alternate or reserve power supply.

The four PG buses (A1, B1, C1, D1) supply power to the largest pumps (feedwater, circulating water and condensate) and to the power centers of the different buildings that supply low voltage power to users via 13.8kV and 480V transformers.

Generally, the 6.9 kV buses (A2, A3, B2, B3) directly feed motor loads larger than approximately 250 kW and supply power to the power centers of the different buildings via 6.9kV/480V transformers.

The safety-related portion of the low voltage system consists of four Distribution Panels (DP) (A31, B31, C31, D31), which are fed from PIP buses (A2 and B2), and provide power to the safety-related battery chargers and regulating transformers. These DP are provided with plug-in connections for transportable AC generators, which provide a convenient and secure means of restoring long-term power to the plant safety and selected non-safety loads following a loss of all other sources.

The I&C Power Supply system is comprised of five subsystems. Each Subsystem is powered through a regulatory transformer at a ratio of 480V/208-120V. Four of the subsystems are supplied by power center buses A31, B31, C31 and D31, with a power rating of 50kVA. The fifth is supplied by power center DCIS swing bus C23 with a power rating of 150 kVA.

The Standby Onsite AC Power Supply System (SPSS) consists of two independent and redundant non-safety related diesel generator units. This system is designed to supply safety-related AC power to the plant permanent non-safety loads and to the DP when the normal preferred and alternate preferred AC sources are not available. Diesel generators are connected to the PIP buses A2 and B2.

4.14.3.2 System Operation

The 13.8kV and 6.9kV power distribution system receives power from the unit auxiliary transformers. During normal power operation, the unit auxiliary switchgear buses receive power from the main generator through the generator breaker and the unit auxiliary transformers.

If the main generator trips, the low voltage generator breaker opens and power to the unit auxiliary transformers is backfed from the normal preferred power (utility power grid). When a failure occurs in an auxiliary transformer or in a medium voltage busbar, plant shutdown does not result. The electric loads are transferred from the preferred power supply to the reserve power supply. In this situation, the plant is capable of restoring the production of energy in a short time.

During loss of preferred power (LOPP), the medium voltage AC power system supplies power from the on-site standby AC power system to selected medium voltage loads and selected portions of the medium and low voltage AC power systems.

During station blackout conditions, low voltage AC power system supplies power from transportable AC generators to selected PIP loads and safety-related buses of the low voltage AC power system and selected low voltage loads.

The I&C Power Supply System supplies constant regulated voltage power from the low voltage AC power system to its connected I&C loads. During LOPP conditions, the system is powered from the on-site power system.

4.14.3.3 System Location

The switchgear of the 13.8 kV and 6.9 kV are located in the electrical building.

The load centers consist of transformers and associated low voltage switchgear, and are located in the electrical building, control building, turbine building, fuel building, cooling tower building, pump house building, service water building, water treatment building and radwaste building.

Whenever practical, MCCs, distribution transformers, and distribution panels are located in the proximity of the loads.

The four class 1E isolation buses (A31, B31, C31, D31) are located in the Control Building.

Each diesel generator unit with its dedicated auxiliaries is located within its own room in the electric building

4.14.4 Automatic and Manual Control

Both breakers, in alternate and reserve transformers connection lines to the medium voltage power generation buses independently and automatically transfer to the alternate feed that has been verified for proper voltage and frequency. The transfer scheme is automatic in either direction and occurs any time the bus loses power. If both feeds have power, the transfer is manual, synchronized and fast, or manual and slow. If the fast transfer fails, then a slow (dead bus) transfer is automatically initiated. However originated, the slow bus automatic transfer verifies bus voltage less than 10-30% before closing the source breaker.

With both source breakers in "auto", each 6.9 kV bus individually and automatically transfers to its standby generator. The transfer scheme is automatic in the direction of the standby diesel generator and occurs any time a bus loses power and only after proper voltage and frequency have been verified. The loads are automatically sequenced on the diesels to allow the diesel generator's voltage regulator and speed control system to maintain voltage and frequency within the design range of all automatically connected loads. The return of source power to any non-diesel generator feeder is manual and synchronized.

It is possible to periodically test each standby diesel generator by manually or automatically synchronizing it to its associated medium voltage bus and loading the diesel to its rated capacity while the bus is powered from either of its incoming power feeds.

4.14.5 System Interfaces

The Medium Voltage AC Power System begins at the low voltage terminals of the unit auxiliary and reserve transformers, and at the output terminals of the sources breakers of the plant On-site Standby AC Power System. The system ends at the high voltage terminals of the power center (unit substation) transformers and the input terminals of the medium voltage loads.

The Low Voltage AC Power System begins at the high voltage terminals of the power center transformers, and at the output terminals of the sources breakers of the plant low voltage on-site

standby AC power sources. The system ends at the input terminals of low voltage loads and the boundaries of other systems.

The I&C Power Supply System begins at the input terminals of the regulating transformers and it ends at the input terminals of the system loads.

To start the diesel-generator and connect it to the bus, Direct and Uninterruptible Power Supply Systems are required.

Table 4.14-2 shows the assumed system dependencies.

4.14.6 System Testing

The electrical system design permits operability testing, during normal station operation, of components that are not normally exercised.

Provisions are made for system isolation so as to preclude unacceptable interference of system testing with unit operation. Continuous indication is provided to monitor the conditions of the systems undergoing testing.

The diesel-generators are started and manually loaded every three months; the automatic startup and loading sequence is tested during every refueling. Automatic transfer to the alternate-preferred power source is tested every refueling. Voltage availability on the alternate preferred source is checked each week.

Table 4.14-3 shows the component tests for the AC system.

4.14.7 System Maintenance

Electrical System components are designed and installed to facilitate maintenance during normal plant operation or plant scheduled shutdown.

The equipment and components of the Standby Onsite AC Power Supply System are designed for easy inspection and maintenance during operation.

Only corrective maintenance of buses can be performed.

4.14.8 Potential for Common Cause Failure

Generic CCF of the circuit breakers has been taken into account as follows:

- Spurious opening CCFs are judged to be negligible for 6.9 kV and 13.8 kV.
- CCFs to open or close are conservatively included in the fault tree model, even if the involved circuit breakers operate in different conditions.

Several CCFs have been taking into account about Diesel Generators function:

- Start, load, and run.
- Logic and feed.
- Motor driven fuel transfer loads.

CCFs are summarized in Table 4.14-5.

4.14.9 Fault Tree Analysis

4.14.9.1 Top Event Definition

A fault tree was developed for each of the 13.8kV and 6.9kV buses, for several 480V load centers and for several 480V downstream motor-control center buses. All the fault trees model the failure to supply power for 72 hours.

4.14.9.2 Fault Tree Description

Fault trees GR10-0001-_1 to GR10-0001-_4 model the loss of power of the four 13.8 kV PG load buses.

Fault trees GR11-0001-_1 to GR11-0001-_4 model the loss of power of the four 6.9 kV PIP load buses.

Fault trees GR12-0001-_1 to GR12-0001-_19 model the loss of power of nineteen 480V power center buses.

Fault trees are shown in the Appendix B.4.14.

4.14.9.3 Human Interactions

No human actions have been included in the AC Power System fault tree model, see Table 4.14-6.

4.14.10 Results of Fault Tree Analysis

The definition of each basic event is reported in Table 4.14-7.

The quantification of core damage sequences implicitly includes the contribution of basic event for this system. This quantification process enables checking the global consistency of the system fault trees and their relationship with the rest of the systems modeled in the PRA.

On the other hand, the importance measurements obtained from core damage frequency equations, allow identification of the most relevant basic events and system component failures in an integrated context, as well as the determination of their relative importance with respect to the basic events and component failures of the other systems modeled.

4.14.11 Model Differences for 72-Hour Operation

There are no changes to the model for operation to 72 hours other than the mission time.

4.14.12 References

4.14-1. ESBWR Design Control Document, 26A6642 Rev. 01

Table 4.14-1

Control Room Instrumentation and Alarms

Controls
Displays (Standby On-site AC Power Supply System)
Diesel engine running
D/G trouble
D/G controls not in Auto
G main breaker trip
D/G maintenance mode
D/G parallel mode
D/G overspeed
Engine failed to start
Generator Differential relay
Reverse power relay
Field relay
Overcurrent relay
Lock-out relay operated
Overvoltage relay
Ground relay
Overtemperature relay
Undervoltage relay
Frequency relay
Engine speed
Engine hour meter
Generator output voltage
Current
Active power output
Reactive power output
Displays (Electric Power Distribution System)
Switchgear breaker load currents
Source bus currents
Switchgear bus voltages
Switchgear bus frequency
Alarms

Table 4.14-2

System Dependency Matrix

		Support System					
		Power Supply					
Component	**Type**	**500kV (XFRM-A)**	**500kV (XFRM-B)**	**230kV (XFRM-C)**	**230kV (XFRM-D)**	**Diesel Generator A**	**Diesel Generator B**
BUS A1	BUS	X		X			
BUS B1	BUS		X		X		
BUS C1	BUS	X		X			
BUS D1	BUS		X		X		
BUS A2	BUS	X		X		X	
BUS B2	BUS		X		X		X

		Support System					
		Power Supply					
Component	**Type**	**BUS A1**	**BUS B1**	**BUS A2**	**BUS B2**	**BUS A3**	**BUS B3**
BUS A3	BUS			X			
BUS B3	BUS				X		
TRAIN A IN TB (NO 1E)	BUS	X					
TRAIN B IN TB (NO 1E)	BUS		X				
BUS A2-01A	BUS			X			
BUS A2-02A	BUS			X			
BUS A2-04A	BUS			X			
BUS A3-01A	BUS					X	
BUS A3-02A	BUS					X	
TRAIN A IN TB (DID)	BUS					X	
BUS B2-01B	BUS				X		
BUS B2-02B	BUS				X		
BUS B2-04B	BUS				X		
BUS B3-01B	BUS						X
BUS B3-02B	BUS						X
TRAIN B IN TB (DID)	BUS						X
BUS A31	BUS			X	X		
BUS B31	BUS			X	X		
BUS C31	BUS			X	X		
BUS D31	BUS			X	X		
BUS C23	BUS			X	X		

		Support System	
		Power Supply	
Component	Type	125 VDC Control Power BUS A3	125 VDC Control Power BUS B3
BUS A1	BUS	X	
BUS B1	BUS		X
BUS C1	BUS	X	
BUS D1	BUS		X
BUS A2	BUS	X	
BUS B2	BUS		X
BUS A3	BUS	X	
BUS B3	BUS		X
TRAIN A IN TB (NO 1E)	BUS	X	
TRAIN B IN TB (NO 1E)	BUS		X
BUS A2-01A	BUS	X	
BUS A2-02A	BUS	X	
BUS A2-04A	BUS	X	
BUS A3-01A	BUS	X	
BUS A3-02A	BUS	X	
TRAIN A IN TB (DID)	BUS	X	
BUS B2-01B	BUS		X
BUS B2-02B	BUS		X
BUS B2-04B	BUS		X
BUS B3-01B	BUS		X
BUS B3-02B	BUS		X
TRAIN B IN TB (DID)	BUS		X
BUS A31	BUS	X	
BUS B31	BUS		X
BUS C31	BUS	X	
BUS D31	BUS		X
BUS C23	BUS	X	

Table 4.14-3

Component Tests

Component	Expected Test Interval
Diesel generator manually started	3 months
Automatic startup and loading sequence	Refueling (2 years)
Automatic transfer to the alternate preferred power source	Refueling (2 years)
Alternate preferred power source voltage level	1 week

Table 4.14-4

Component Maintenance

No preventive maintenance actions are expected to be performed during normal plant operation. Only corrective maintenance can be performed.

Table 4.14-5

System Common Cause Failures

Basic Event	Prob	Description
R10-MCB-CF-138CLOSE	7.43E-04	CCF CIRCUIT BREAKERS TO CLOSE
C62-VLU-CF-DIDALL	3.12E-05	CCF OF VOTER LOGIC UNITS
C74-BYP-CF-DIDALL	9.00E-07	CCF OF BYPASS UNITS (DID)
H23-EMS-CF-DIDALL	1.80E-06	CCF OF ALL DIVISION OF THE EMS
H23-RMU-CF-DIDALL	9.00E-07	CCF OF REMOTE MULTIPLEXING UNITS (DID)
P21-MP_-CR-TRAINA	1.20E-06	CCF TO RUN RCCW PUMPS TRAIN A
P21-MP_-CR-TRAINB	1.20E-06	CCF TO RUN RCCW PUMPS TRAIN B
P21-MP_-CS-TRAINA	1.20E-06	CCF TO START RCCW PUMPS TRAIN A
P21-MP_-CS-TRAINB	1.30E-05	CCF TO START RCCW PUMPS TRAIN B
R11-MCB-CF-69CLOSE	9.29E-05	CCF CIRCUIT BREAKERS 6.9 KV TO CLOSE
R21-DG_-CR-ALLDG	4.44E-03	CCF OF DIESEL GENERATORS TO RUN
R21-DG_-CS-ALLDG	8.52E-04	CCF OF DIESEL GENERATORS TO START AND LOAD
R21-MP_-CR-FUELTRANS	3.72E-05	CCF TO RUN MOTOR-DRIVEN FUEL TRANSFER PUMPS
R21-MP_-CS-FUELTRANS	1.71E-04	CCF TO START MOTOR-DRIVEN FUEL TRANSFER PUMPS
R12-LCB-CF-480CLOSE	2.79E-05	CCF CIRCUIT BREAKERS 480 V AC TO CLOSE

Table 4.14-6

System Human Errors

No human actions have been included in the fault tree model.

Table 4.14-7

List of System Basic Events

Basic Event	Prob	Description
R10-BAC-LP-R10A1	4.80E-06	BUS R10-A1 FAILS DURING OPERATION
R10-BAC-LP-R10B1	4.80E-06	BUS R10-B1 FAILS DURING OPERATION
R10-BAC-LP-R10C1	4.80E-06	BUS R10-C1 FAILS DURING OPERATION
R10-BAC-LP-R10D1	4.80E-06	BUS R10-D1 FAILS DURING OPERATION
R10-BAC-TM-R10A1	4.80E-06	13,8 KV AC BUS R10-A1-IN MAINTENANCE
R10-BAC-TM-R10B1	4.80E-06	13,8 KV AC BUS R10-B1-IN MAINTENANCE
R10-BAC-TM-R10C1	4.80E-06	13,8 KV AC BUS R10-C1-IN MAINTENANCE
R10-BAC-TM-R10D1	4.80E-06	13,8 KV AC BUS R10-D1-IN MAINTENANCE
R10-MCB-CC-XFRMAA1	7.96E-03	CIRCUIT BREAKER FROM XFRM-A FAILS TO OPEN
R10-MCB-CC-XFRMAC1	7.96E-03	CIRCUIT BREAKER FROM XFRM-A FAILS TO OPEN
R10-MCB-CC-XFRMBB1	7.96E-03	CIRCUIT BREAKER FROM XFRM-B FAILS TO OPEN
R10-MCB-CC-XFRMBD1	7.96E-03	CIRCUIT BREAKER FROM XFRM-B FAILS TO OPEN
R10-MCB-CF-138CLOSE	7.43E-04	CCF CIRCUIT BREAKERS TO CLOSE
R10-MCB-CO-XFRMAA1	1.20E-05	CIRCUIT BREAKER FROM XFRM-A OPENS SPURIOUSLY
R10-MCB-CO-XFRMAC1	1.20E-05	CIRCUIT BREAKER FROM XFRM-A OPENS SPURIOUSLY
R10-MCB-CO-XFRMBB1	1.20E-05	CIRCUIT BREAKER FROM XFRM-B OPENS SPURIOUSLY
R10-MCB-CO-XFRMBD1	1.20E-05	CIRCUIT BREAKER FROM XFRM-B OPENS SPURIOUSLY
R10-MCB-OO-XFRMCA1	7.96E-03	CIRCUIT BREAKER FROM XFRM-C FAILS TO CLOSE
R10-MCB-OO-XFRMCC1	7.96E-03	CIRCUIT BREAKER FROM XFRM-C FAILS TO CLOSE
R10-MCB-OO-XFRMDB1	7.96E-03	CIRCUIT BREAKER FROM XFRM-D FAILS TO CLOSE
R10-MCB-OO-XFRMDD1	7.96E-03	CIRCUIT BREAKER FROM XFRM-D FAILS TO CLOSE
R10-XFH-LP-XFRMA	2.88E-05	TRANSFORMER XFRM-A (HIGH VOLTAGE) FAILS TO OPERATE
R10-XFH-LP-XFRMB	2.88E-05	TRANSFORMER XFRM-B (HIGH VOLTAGE) FAILS TO OPERATE
R10-XFH-LP-XFRMC	2.88E-05	TRANSFORMER XFRM-C FAILS TO OPERATE
R10-XFH-LP-XFRMD	2.88E-05	TRANSFORMER XFRM-D FAILS TO OPERATE
R10-XFH-TM-XFRMA	1.00E-04	TRANSFORMER XFRM-A IN MAINTENANCE
R10-XFH-TM-XFRMB	1.00E-04	TRANSFORMER XFRM-B IN MAINTENANCE
R10-XFH-TM-XFRMC	1.00E-04	TRANSFORMER XFRM-C IN MAINTENANCE
R10-XFH-TM-XFRMD	1.00E-04	TRANSFORMER XFRM-D IN MAINTENANCE
R11-SYS-FF-NOREC	6.13E-01	FAILURE IN OFFSITE POWER RECOVERY

Table 4.14-7

List of System Basic Events

Basic Event	Prob	Description
C62-VLU-CF-DIDALL	3.12E-05	CCF OF VOTER LOGIC UNITS
C62-VLU-FC-ESF1ADID	6.24E-04	1ST DIV A ESF VOTER LOGIC UNIT FAILS TO FUNCTION
C62-VLU-FC-ESF1BDID	6.24E-04	1ST DIV B ESF VOTER LOGIC UNIT FAILS TO FUNCTION
C62-VLU-FC-ESF2ADID	6.24E-04	2ND DIV A (DID) ESF VOTER LOGIC UNIT FAILS TO FUNCTION
C62-VLU-FC-ESF2BDID	6.24E-04	2ND DIV B (DID) ESF VOTER LOGIC UNIT FAILS TO FUNCTION
C74-BYP-CF-DIDALL	9.00E-07	CCF OF BYPASS UNITS (DID)
C74-BYP-FC-DIVADID	3.00E-04	BYPASS UNIT DIV A (DID) FAILS TO FUNCTION
C74-BYP-FC-DIVBDID	3.00E-04	BYPASS UNIT DIV B (DID) FAILS TO FUNCTION
H23-EMS-CF-DIDALL	1.80E-06	CCF OF ALL DIVISION OF THE EMS
H23-EMS-FC-DIVADID	6.00E-04	ESSENTIAL MULTIPLEXING SYSTEM DIV A (DID) FAILS TO FUNCTION
H23-EMS-FC-DIVBDID	6.00E-04	ESSENTIAL MULTIPLEXING SYSTEM DIV B (DID) FAILS TO FUNCTION
H23-RMU-CF-DIDALL	9.00E-07	CCF OF REMOTE MULTIPLEXING UNITS (DID)
H23-RMU-FC-10A11	3.00E-04	REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION
H23-RMU-FC-10A21	3.00E-04	REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION
H23-RMU-FC-ESF1ADID	3.00E-04	1ST DIV A (DID) ESF REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION
H23-RMU-FC-ESF1BDID	3.00E-04	1ST DIV B (DID) ESF REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION
H23-RMU-FC-ESF2ADID	3.00E-04	2ND DIV A (DID) ESF REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION
H23-RMU-FC-ESF2BDID	3.00E-04	2ND DIV B (DID) ESF REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION
H23-RMU-FC-R101	3.00E-04	DTM/TLU 001 OR MUX INTERFACE FAIL TO TRIP (2Y TEST)
H23-RMU-FC-R102	3.00E-04	DTM/TLU 002 OR MUX INTERFACE FAIL TO TRIP (2Y TEST)
P21-MCB-OO-C001A	1.00E-03	CIRCUIT BREAKER OF PUMP C001A FAILS TO CLOSE
P21-MCB-OO-C001B	1.00E-03	CIRCUIT BREAKER OF PM C001B FAILS TO CLOSE
P21-MCB-OO-C002A	1.00E-03	MEDIUM VOLTAGE CIRCUIT BREAKER FAILS TO CLOSE
P21-MCB-OO-C002B	1.00E-03	MEDIUM VOLTAGE CIRCUIT BREAKER FAILS TO CLOSE
P21-MCB-OO-C003A	1.00E-03	MEDIUM VOLTAGE CIRCUIT BREAKER FAILS TO CLOSE

Table 4.14-7

List of System Basic Events

Basic Event	Prob	Description
P21-MCB-OO-C003B	1.00E-03	MEDIUM VOLTAGE CIRCUIT BREAKER FAILS TO CLOSE
P21-MP_-CR-TRAINA	1.20E-06	CCF TO RUN RCCW PUMPS TRAIN A
P21-MP_-CR-TRAINB	1.20E-06	CCF TO RUN RCCW PUMPS TRAIN B
P21-MP_-CS-TRAINA	1.20E-06	CCF TO START RCCW PUMPS TRAIN A
P21-MP_-CS-TRAINB	1.30E-05	CCF TO START RCCW PUMPS TRAIN B
P21-MP_-FR-C001A	1.20E-04	MOTOR DRIVEN PUMP C001A FAILS TO RUN
P21-MP_-FR-C001B	1.20E-04	MOTOR DRIVEN PUMP C001B FAILS TO RUN
P21-MP_-FR-C002A	1.20E-04	MOTOR-DRIVEN PUMP C002A FAILS TO RUN
P21-MP_-FR-C002B	1.20E-04	MOTOR-DRIVEN PUMP C002B FAILS TO RUN
P21-MP_-FR-C003A	1.20E-04	MOTOR-DRIVEN PUMP C0003A FAILS TO RUN
P21-MP_-FR-C003B	1.20E-04	MOTOR-DRIVEN PUMP C003B FAILS TO RUN
P21-MP_-FS-C001A	1.30E-03	MOTOR DRIVEN PUMP C001A FAILS TO START
P21-MP_-FS-C001B	1.30E-03	MOTOR-DRIVEN PUMP C001B FAILS TO START
P21-MP_-FS-C002A	1.30E-03	MOTOR-DRIVEN PUMP (ALL TYPES) FAILS TO START
P21-MP_-FS-C002B	1.30E-03	MOTOR-DRIVEN PUMP C002B FAILS TO START
P21-MP_-FS-C003A	1.30E-03	MOTOR-DRIVEN PUMP C0003A FAILS TO START
P21-MP_-FS-C003B	1.30E-03	MOTOR-DRIVEN PUMP C003B FAILS TO START
P21-MP_-TM-C002A	2.00E-03	PUMP C002A IN MAINTENANCE
P21-MP_-TM-C002B	2.00E-03	PUMP C002B IN MAINTENANCE
P21-UV_-CC-F001A	2.00E-04	CHECK VALVE F001A FAILS TO OPEN
P21-UV_-CC-F001B	2.00E-04	CHECK VALVE F001B FAILS TO OPEN
P21-UV_-CC-F005A	2.00E-04	CHECK VALVE F005A FAILS TO OPEN
P21-UV_-CC-F005B	2.00E-04	CHECK VALVE F005B FAILS TO OPEN
P21-UV_-CC-F007A	2.00E-04	CHECK VALVE F007A FAILS TO OPEN
P21-UV_-CC-F007B	2.00E-04	CHECK VALVE F007B FAILS TO OPEN
R10-BAC-LP-230KVMAIN	4.80E-06	230 KV MAIN DISTRIBUTION FAILS DURING OPERATION
R10-BAC-LP-500KVMAIN	4.80E-06	500 KV MAIN DISTRIBUTION BUS FAILS DURING OPERATION
R10-CBU-FC-PRE230KV	7.20E-05	230 KV POWER TRANSMISSION LINE FAILS
R10-CBU-FC-PRE500KV	7.20E-05	500KV TRANSMISSION LINE FAILS
R10-SYS-FF-230KV	5.00E-04	230 KV SWITCHYARD FAILS DURING OPEATION
R10-SYS-FF-500KV	1.20E-06	500KV SWITCHYARD FAILS DURING OPERATION
R10-SYS-TM-230KV	1.00E-02	230 KV SWITCHYARD IN MAINTENANCE
R10-XFH-LP-XFRMA	2.88E-05	TRANSFORMER XFRM-A (HIGH VOLTAGE) FAILS TO OPERATE

Table 4.14-7

List of System Basic Events

Basic Event	Prob	Description
R10-XFH-LP-XFRMB	2.88E-05	TRANSFORMER XFRM-B (HIGH VOLTAGE) FAILS TO OPERATE
R10-XFH-LP-XFRMC	2.88E-05	TRANSFORMER XFRM-C FAILS TO OPERATE
R10-XFH-LP-XFRMD	2.88E-05	TRANSFORMER XFRM-D FAILS TO OPERATE
R10-XFH-TM-XFRMA	1.00E-04	TRANSFORMER XFRM-A IN MAINTENANCE
R10-XFH-TM-XFRMB	1.00E-04	TRANSFORMER XFRM-B IN MAINTENANCE
R10-XFH-TM-XFRMC	1.00E-04	TRANSFORMER XFRM-C IN MAINTENANCE
R10-XFH-TM-XFRMD	1.00E-04	TRANSFORMER XFRM-D IN MAINTENANCE
R11-BAC-LP-R11A2	4.80E-06	BUS R11-A2 FAILS DURING OPERATION
R11-BAC-LP-R11B2	4.80E-06	BUS R11-B2 FAILS DURING OPERATION
R11-BAC-TM-R11A2	4.80E-06	6.9 KV AC BUS R11-A2 IN MANTENANCE
R11-BAC-TM-R11B2	4.80E-06	6.9 KV AC BUS R11-B2 IN MANTENANCE
R11-MCB-CC-XFRMAA2	7.96E-03	CIRCUIT BREAKER FROM XFRM-A FAILS TO OPEN
R11-MCB-CC-XFRMBB2	7.96E-03	CIRCUIT BREAKER FROM XFRM-B FAILS TO OPEN
R11-MCB-CF-69CLOSE	9.29E-05	CCF CIRCUIT BREAKERS 6.9 KV TO CLOSE
R11-MCB-CO-XFRMAA2	1.20E-05	CIRCUIT BREAKER FROM XFRM-A OPENS SPURIOUSLY
R11-MCB-CO-XFRMBB2	1.20E-05	CIRCUIT BREAKER FROM XFRM-B OPENS SPURIOUSLY
R11-MCB-OO-XFRMCA2	7.96E-03	CIRCUIT BREAKER FROM XFRM-C FAILS TO CLOSE
R11-MCB-OO-XFRMDB2	7.96E-03	CIRCUIT BREAKER FROM XFRM-D FAILS TO CLOSE
R11-SYS-FF-NOREC	6.13E-01	FAILURE IN OFFSITE POWER RECOVERY
R13-BAC-LP-R13A1	4.80E-06	BUS R13-A1 FAILS DURING OPERATION
R13-BAC-LP-R13A11	4.80E-06	BUS R13-A1-1 FAILS DURING OPERATION
R13-BAC-LP-R13A2	4.80E-06	BUS R13-A2 FAILS DURING OPERATION
R13-BAC-LP-R13A21	4.80E-06	BUS R13-A2-1 FAILS DURING OPERATION
R13-BAC-LP-R13B1	4.80E-06	BUS R13-B1 FAILS DURING OPERATION
R13-BAC-LP-R13B11	4.80E-06	BUS R13-B1-1 FAILS DURING OPERATION
R13-BAC-LP-R13B2	4.80E-06	BUS R13-B2 FAILS DURING OPERATION
R13-BAC-LP-R13B21	4.80E-06	BUS R13-B2-1 FAILS DURING OPERATION
R13-DIO-FC-R16A1R13A1	1.43E-06	DIODE FROM R16-A1 FAILS TO OPERATE
R13-DIO-FC-R16A1R13A2	1.43E-06	DIODE FROM R16-A2 FAILS TO OPERATE
R13-DIO-FC-R16A1R13B1	1.43E-06	DIODE FROM R16-B1 FAILS TO OPERATE
R13-DIO-FC-R16A1R13B2	1.43E-06	DIODE FROM R16-B2 FAILS TO OPERATE
R13-INV-FC-R13A1	4.80E-04	INVERTER TO R13-A1 FAILS
R13-INV-FC-R13A2	4.80E-04	INVERTER TO R13-A2 FAILS
R13-INV-FC-R13B1	4.80E-04	INVERTER TO R13-B1 FAILS

Table 4.14-7

List of System Basic Events

Basic Event	Prob	Description
R13-INV-FC-R13B2	4.80E-04	INVERTER TO R13-B2 FAILS
R13-LCB-CO-FR13A11	1.44E-05	CIRCUIT BREAKER OPENS SPURIOUSLY
R13-LCB-CO-FR13A21	1.44E-05	CIRCUIT BREAKER OPENS SPURIOUSLY
R13-LCB-CO-FR13B11	1.44E-05	CIRCUIT BREAKER OPENS SPURIOUSLY
R13-LCB-CO-FR13B21	1.44E-05	CIRCUIT BREAKER OPENS SPURIOUSLY
R13-LCB-CO-R13A11	1.44E-05	CIRCUIT BREAKER OPENS SPURIOUSLY
R13-LCB-CO-R13A21	1.44E-05	CIRCUIT BREAKER OPENS SPURIOUSLY
R13-LCB-CO-R13B11	1.44E-05	CIRCUIT BREAKER OPENS SPURIOUSLY
R13-LCB-CO-R13B21	1.44E-05	CIRCUIT BREAKER OPENS SPURIOUSLY
R13-LCB-CO-R16A1R13A1	1.44E-05	CIRCUIT BREAKER FROM R16-A1 OPENS SPURIOUSLY
R13-LCB-CO-R16A1R13A2	1.44E-05	CIRCUIT BREAKER FROM R16-A2 OPENS SPURIOUSLY
R13-LCB-CO-R16A1R13B1	1.44E-05	CIRCUIT BREAKER FROM R16-B1 OPENS SPURIOUSLY
R13-LCB-CO-R16A1R13B2	1.44E-05	CIRCUIT BREAKER FROM R16-B2 OPENS SPURIOUSLY
R13-LCB-CO-TOR13A1	1.44E-05	CIRCUIT BREAKER TO R13-A1 OPENS SPURIOUSLY
R13-LCB-CO-TOR13A2	1.44E-05	CIRCUIT BREAKER TO R13-A2 OPENS SPURIOUSLY
R13-LCB-CO-TOR13B1	1.44E-05	CIRCUIT BREAKER TO R13-B1 OPENS SPURIOUSLY
R13-LCB-CO-TOR13B2	1.44E-05	CIRCUIT BREAKER TO R13-B2 OPENS SPURIOUSLY
R13-XFL-LP-R13A11	1.92E-05	TRANSFORMER FAILS DURING OPERATION
R13-XFL-LP-R13A21	1.92E-05	TRANSFORMER FAILS DURING OPERATION
R13-XFL-LP-R13B11	1.92E-05	TRANSFORMER FAILS DURING OPERATION
R13-XFL-LP-R13B21	1.92E-05	TRANSFORMER FAILS DURING OPERATION
R16-BDC-LP-R16A	4.80E-06	DC BUS R16-A FAILS DURING OPERATION
R16-BDC-LP-R16A1	4.80E-06	DC BUS R16-A1 FAILS DURING OPERATION
R16-BDC-LP-R16A2	4.80E-06	DC BUS R16-A2 FAILS DURING OPERATION
R16-BDC-LP-R16B	4.80E-06	DC BUS R16-B FAILS DURING OPERATION
R16-BDC-LP-R16B1	4.80E-06	DC BUS R16-B1 FAILS DURING OPERATION
R16-BDC-LP-R16B2	4.80E-06	DC BUS R16-B2 FAILS DURING OPERATION
R16-BDC-TM-R16A	4.80E-06	DC BUS R16-A IN MAINTENANCE
R16-BDC-TM-R16A1	4.80E-06	DC BUS R16-A1 IN MAINTENANCE
R16-BDC-TM-R16A2	4.80E-06	DC BUS R16-A2 IN MAINTENANCE
R16-BDC-TM-R16B	4.80E-06	DC BUS R16-B IN MAINTENANCE
R16-BDC-TM-R16B1	4.80E-06	DC BUS R16-B1 IN MAINTENANCE
R16-BDC-TM-R16B2	4.80E-06	DC BUS R16-B2 IN MAINTENANCE

Table 4.14-7

List of System Basic Events

Basic Event	Prob	Description
R16-BT_-LP-R16BTA2	5.00E-04	BATTERY R16-BTA2 FAILS TO PROVIDE OUTPUT
R16-BT_-LP-R16BTB1	5.00E-04	BATTERY R16-BTB1 FAILS TO PROVIDE OUTPUT
R16-BT_-TM-R16BTA2	1.00E-03	BATTERY R16-BTA2 IN TEST
R16-BT_-TM-R16BTB1	1.00E-03	BATTERY R16-BTB1 IN TEST
R16-LCB-CO-FROMR16BTA2	1.44E-05	CIRCUIT BREAKER FROM R16-BTA2 OPENS SPURIOUSLY
R16-LCB-CO-FROMR16BTB1	1.44E-05	CIRCUIT BREAKER FROM R16-BTB1 OPENS SPURIOUSLY
R21-DG_-CR-ALLDG	4.44E-03	CCF OF DIESEL GENERATORS TO RUN
R21-DG_-CS-ALLDG	8.52E-04	CCF OF DIESEL GENERATORS TO START AND LOAD
R21-DG_-FR-DGA	5.60E-02	DIESEL GENERATOR "A" FAILS TO RUN GIVEN START
R21-DG_-FR-DGB	5.60E-02	DIESEL GENERATOR "B" FAILS TO RUN GIVEN START
R21-DG_-FS-DGA	1.40E-02	DIESEL GENERATOR "A" FAILS TO START
R21-DG_-FS-DGB	1.40E-02	D/G "B" FAILS TO START AND LOAD
R21-DG_-TM-DGA	6.00E-03	STANDBY DIESEL GENERATOR "A" IN MAINTENANCE
R21-DG_-TM-DGB	6.00E-03	STANDBY DIESEL GENERATOR "B" IN MAINTENANCE
R21-MCB-OO-DGAR11A2	1.00E-03	CIRCUIT BREAKER FROM DG-A TO R11-A2 FAILS TO CLOSE
R21-MCB-OO-DGBR11B2	1.00E-03	CIRCUIT BREAKER FROM DG-B TO R11-B2 FAILS TO CLOSE
R21-MP_-CR-FUELTRANS	3.72E-05	CCF TO RUN MOTOR-DRIVEN FUEL TRANSFER PUMPS
R21-MP_-CS-FUELTRANS	1.71E-04	CCF TO START MOTOR-DRIVEN FUEL TRANSFER PUMPS
R21-SYS-FC-AIRDG4	1.00E-03	AIR STARTING SYSTEM FAILURE [#13]
R21-SYS-FC-AIRDG5	1.00E-03	AIR STARTING SYSTEM FAILURE
R21-SYS-FC-FUELDG4	4.00E-03	FUEL OIL STORAGE & TRANSFER SYSTEM FAILURE [#14]
R21-SYS-FC-FUELDG5	4.00E-03	FUEL OIL STORAGE & TRANSFER SYSTEM FAILURE [#14]
R22-MCB-CC-1LOAD1	7.96E-03	CIRCUIT BREAKER TO LOAD 1 FAILS TO OPEN
R22-MCB-CC-1LOAD2	7.96E-03	CIRCUIT BREAKER TO LOAD 2 FAILS TO OPEN
R22-MCB-CC-1LOAD3	7.96E-03	CIRCUIT BREAKER TO LOAD 3 FAILS TO OPEN
R22-MCB-CC-1LOAD4	7.96E-03	CIRCUIT BREAKER TO LOAD 4 FAILS TO OPEN
R22-MCB-CC-1LOAD5	7.96E-03	CIRCUIT BREAKER TO LOAD 5 FAILS TO OPEN
R22-MCB-CC-2LOAD1	7.96E-03	CIRCUIT BREAKER TO LOAD 1 FAILS TO OPEN

Table 4.14-7

List of System Basic Events

Basic Event	Prob	Description
R22-MCB-CC-2LOAD2	7.96E-03	CIRCUIT BREAKER TO LOAD 2 FAILS TO OPEN
R22-MCB-CC-2LOAD3	7.96E-03	CIRCUIT BREAKER TO LOAD 3 FAILS TO OPEN
R22-MCB-CC-2LOAD4	7.96E-03	CIRCUIT BREAKER TO LOAD 4 FAILS TO OPEN
R22-MCB-CC-2LOAD5	7.96E-03	CIRCUIT BREAKER TO LOAD 5 FAILS TO OPEN
R22-RE_-FD-10A11	8.00E-04	UNDERVOLTAGE RELAY FOR R22-10A11 FAILS TO OPERATE
R22-RE_-FD-10A21	8.00E-04	UNDERVOLTAGE RELAY SENSING VOLTAGE ON BUS 10A21 FAILS
R11-MCB-CO-A2A3	1.20E-05	CIRCUIT BREAKER FROM R11-A2 OPENS SPURIOUSLY
R11-MCB-CO-B2B3	1.20E-05	CIRCUIT BREAKER FROM R11-B2 OPENS SPURIOUSLY
R12-BAC-LP-R12A201A	4.80E-06	BUS R12-A2-01A FAILS DURING OPERATION
R12-BAC-LP-R12A202A	4.80E-06	BUS R12-A2-02A FAILS DURING OPERATION
R12-BAC-LP-R12A204A	4.80E-06	BUS R12-A2-04A FAILS DURING OPERATION
R12-BAC-LP-R12A301A	4.80E-06	BUS R12-A3-01A FAILS DURING OPERATION
R12-BAC-LP-R12A302A	4.80E-06	BUS R12-A3-02A FAILS DURING OPERATION
R12-BAC-LP-R12A31	4.80E-06	BUS R12-A31 FAILS DURING OPERATION
R12-BAC-LP-R12B201B	4.80E-06	BUS R12-B2-01B FAILS DURING OPERATION
R12-BAC-LP-R12B202B	4.80E-06	BUS R12-B2-02B FAILS DURING OPERATION
R12-BAC-LP-R12B204B	4.80E-06	BUS R12-B2-04B FAILS DURING OPERATION
R12-BAC-LP-R12B301B	4.80E-06	BUS R12-B3-01B FAILS DURING OPERATION
R12-BAC-LP-R12B302B	4.80E-06	BUS R12-B3-02B FAILS DURING OPERATION
R12-BAC-LP-R12B31	4.80E-06	BUS R12-B31 FAILS DURING OPERATION
R12-BAC-LP-R12C23	4.80E-06	BUS R12-C23 FAILS DURING OPERATION
R12-BAC-LP-R12C31	4.80E-06	BUS R12-C31 FAILS DURING OPERATION
R12-BAC-LP-R12D31	4.80E-06	BUS R12-D31 FAILS DURING OPERATION
R12-BAC-LP-R12TBAN1E	4.80E-06	BUS TRAIN A IN TB (NO 1E) FAILS DURING OPERATION
R12-BAC-LP-R12TBARTNSS	4.80E-06	BUS TRAIN A IN TB (RTNSS) FAILS DURING OPERATION
R12-BAC-LP-R12TBBN1E	4.80E-06	BUS TRAIN B IN TB (NO 1E) FAILS DURING OPERATION
R12-BAC-LP-R12TBBRTNSS	4.80E-06	BUS TRAIN B IN TB (RTNSS) FAILS DURING OPERATION
R12-BAC-TM-R12A201A	4.80E-06	BUS R12-A2-01A IN MAINTENANCE
R12-BAC-TM-R12A202A	4.80E-06	BUS R12-A2-02A IN MAINTENANCE
R12-BAC-TM-R12A204A	4.80E-06	BUS R12-A2-04A IN MAINTENANCE
R12-BAC-TM-R12A301A	4.80E-06	BUS R12-A3-01A IN MAINTENANCE

Table 4.14-7

List of System Basic Events

Basic Event	Prob	Description
R12-BAC-TM-R12A302A	4.80E-06	BUS R12-A3-02A IN MAINTENANCE
R12-BAC-TM-R12A31	4.80E-06	BUS R12-A31 IN MAINTENANCE
R12-BAC-TM-R12B201B	4.80E-06	BUS R12-B2-01B IN MAINTENANCE
R12-BAC-TM-R12B202B	4.80E-06	BUS R12-B2-02B IN MAINTENANCE
R12-BAC-TM-R12B204B	4.80E-06	BUS R12-B2-04B IN MAINTENANCE
R12-BAC-TM-R12B301B	4.80E-06	BUS R12-B3-01B IN MAINTENANCE
R12-BAC-TM-R12B302B	4.80E-06	BUS R12-B3-02B IN MAINTENANCE
R12-BAC-TM-R12B31	4.80E-06	BUS R12-B31 IN MAINTENANCE
R12-BAC-TM-R12C23	4.80E-06	BUS R12-C23 IN MAINTENANCE
R12-BAC-TM-R12C31	4.80E-06	BUS R12-C31 IN MAINTENANCE
R12-BAC-TM-R12D31	4.80E-06	BUS R12-D31 IN MAINTENANCE
R12-BAC-TM-R12TBAN1E	4.80E-06	BUS TRAIN A IN TB (NO 1E) MAINTENANCE
R12-BAC-TM-R12TBARTNSS	4.80E-06	BUS TRAIN A IN TB (RTNSS) MAINTENANCE
R12-BAC-TM-R12TBBN1E	4.80E-06	BUS TRAIN B IN TB (NO 1E) MAINTENANCE
R12-BAC-TM-R12TBBRTNSS	4.80E-06	BUS TRAIN B IN TB (RTNSS) MAINTENANCE
R12-LCB-CC-A2R12A31	5.00E-04	CIRCUIT BREAKER IN BUS R12-A31 FROM BUS R11-A2 FAILS TO OPEN
R12-LCB-CC-A2R12B31	5.00E-04	CIRCUIT BREAKER IN BUS R12-B31 FROM BUS R11-A2 FAILS TO OPEN
R12-LCB-CC-A2R12C23	5.00E-04	CIRCUIT BREAKER IN BUS R12-C23 FROM BUS R11-A2 FAILS TO OPEN
R12-LCB-CC-A2R12C31	5.00E-04	CIRCUIT BREAKER IN BUS R12-C31 FROM BUS R11-A2 FAILS TO OPEN
R12-LCB-CC-A2R12D31	5.00E-04	CIRCUIT BREAKER IN BUS R12-D31 FROM BUS R11-A2 FAILS TO OPEN
R12-LCB-CF-480CLOSE	2.79E-05	CCF CIRCUIT BREAKERS 480 V AC TO CLOSE
R12-LCB-CO-A2R12A201A	1.44E-05	CIRCUIT BREAKER IN R12-A2-01A OPENS SPURIOUSLY
R12-LCB-CO-A2R12A202A	1.44E-05	CIRCUIT BREAKER IN R12-A2-02A OPENS SPURIOUSLY
R12-LCB-CO-A2R12A204A	1.44E-05	CIRCUIT BREAKER IN R12-A2-04A OPENS SPURIOUSLY
R12-LCB-CO-A2R12A31	1.44E-05	CIRCUIT BREAKER IN BUS R12-A31 FROM BUS R11-A2 OPENS SPURIOUSLY
R12-LCB-CO-A2R12B31	1.44E-05	CIRCUIT BREAKER IN BUS R12-B31 FROM BUS R11-A2 OPENS SPURIOUSLY
R12-LCB-CO-A2R12C23	1.44E-05	CIRCUIT BREAKER IN BUS R12-C23 FROM BUS R11-A2 OPENS SPURIOUSLY
R12-LCB-CO-A2R12C31	1.44E-05	CIRCUIT BREAKER IN BUS R12-C31 FROM BUS R11-A2 OPENS SPURIOUSLY

Table 4.14-7

List of System Basic Events

Basic Event	Prob	Description
R12-LCB-CO-A2R12D31	1.44E-05	CIRCUIT BREAKER IN BUS R12-D31 FROM BUS R11-A2 OPENS SPURIOUSLY
R12-LCB-CO-A2R12TBAN1E	1.44E-05	CIRCUIT BREAKER IN BUS TRAIN A IN TB (NO 1E) OPENS SPURIOUSLY
R12-LCB-CO-A3R12A301A	1.44E-05	CIRCUIT BREAKER IN R12-A3-01A OPENS SPURIOUSLY
R12-LCB-CO-A3R12A302A	1.44E-05	CIRCUIT BREAKER IN R12-A3-02A OPENS SPURIOUSLY
R12-LCB-CO-A3R12TBARTNSS	1.44E-05	CIRCUIT BREAKER IN BUS TRAIN A IN TB (RTNSS) OPENS SPURIOUSLY
R12-LCB-CO-B2R12B202B	1.44E-05	CIRCUIT BREAKER IN R12-B2-02B OPENS SPURIOUSLY
R12-LCB-CO-B2R12B204B	1.44E-05	CIRCUIT BREAKER IN R12-B2-04B OPENS SPURIOUSLY
R12-LCB-CO-B3R12B201B	1.44E-05	CIRCUIT BREAKER IN R12-B2-01B OPENS SPURIOUSLY
R12-LCB-CO-B3R12B301B	1.44E-05	CIRCUIT BREAKER IN R12-B3-01B OPENS SPURIOUSLY
R12-LCB-CO-B3R12B302B	1.44E-05	CIRCUIT BREAKER IN R12-B3-02B OPENS SPURIOUSLY
R12-LCB-CO-B3R12TBBN1E	1.44E-05	CIRCUIT BREAKER IN BUS TRAIN B IN TB (NO 1E) OPENS SPURIOUSLY
R12-LCB-CO-B3R12TBBRTNSS	1.44E-05	CIRCUIT BREAKER IN BUS TRAIN B IN TB (RTNSS) OPENS SPURIOUSLY
R12-LCB-CO-FA2R12A201A	1.44E-05	CIRCUIT BREAKER FROM BUS R11-A1 OPENS SPURIOUSLY
R12-LCB-CO-FA2R12A202A	1.44E-05	CIRCUIT BREAKER FROM BUS R11-A2 OPENS SPURIOUSLY
R12-LCB-CO-FA2R12A204A	1.44E-05	CIRCUIT BREAKER FROM BUS R11-A2 OPENS SPURIOUSLY
R12-LCB-CO-FA2R12A31	1.44E-05	CIRCUIT BREAKER FROM BUS R11-A2 OPENS SPURIOUSLY
R12-LCB-CO-FA2R12B31	1.44E-05	CIRCUIT BREAKER FROM BUS R11-A2 OPENS SPURIOUSLY
R12-LCB-CO-FA2R12C23	1.44E-05	CIRCUIT BREAKER FROM BUS R11-A2 OPENS SPURIOUSLY
R12-LCB-CO-FA2R12C31	1.44E-05	CIRCUIT BREAKER FROM BUS R11-A2 OPENS SPURIOUSLY
R12-LCB-CO-FA2R12D31	1.44E-05	CIRCUIT BREAKER FROM BUS R11-A2 OPENS SPURIOUSLY
R12-LCB-CO-FA2R12TBAN1E	1.44E-05	CIRCUIT BREAKER FROM BUS R10-A1 OPENS SPURIOUSLY

Table 4.14-7

List of System Basic Events

Basic Event	Prob	Description
R12-LCB-CO-FA3R12A301A	1.44E-05	CIRCUIT BREAKER FROM BUS R11-A3 OPENS SPURIOUSLY
R12-LCB-CO-FA3R12A302A	1.44E-05	CIRCUIT BREAKER FROM BUS R11-A3 OPENS SPURIOUSLY
R12-LCB-CO-FA3R12TBARTNSS	1.44E-05	CIRCUIT BREAKER FROM BUS R11-A3 OPENS SPURIOUSLY
R12-LCB-CO-FB2R12A31	1.44E-05	CIRCUIT BREAKER FROM BUS R11-B2 OPENS SPURIOUSLY
R12-LCB-CO-FB2R12B202B	1.44E-05	CIRCUIT BREAKER FROM BUS R11-B2 OPENS SPURIOUSLY
R12-LCB-CO-FB2R12B204B	1.44E-05	CIRCUIT BREAKER FROM BUS R11-B2 OPENS SPURIOUSLY
R12-LCB-CO-FB2R12B31	1.44E-05	CIRCUIT BREAKER FROM BUS R11-B2 OPENS SPURIOUSLY
R12-LCB-CO-FB2R12C23	1.44E-05	CIRCUIT BREAKER FROM BUS R11-B2 OPENS SPURIOUSLY
R12-LCB-CO-FB2R12C31	1.44E-05	CIRCUIT BREAKER FROM BUS R11-B2 OPENS SPURIOUSLY
R12-LCB-CO-FB2R12D31	1.44E-05	CIRCUIT BREAKER FROM BUS R11-B2 OPENS SPURIOUSLY
R12-LCB-CO-FB3R12B201B	1.44E-05	CIRCUIT BREAKER FROM BUS R11-B2 OPENS SPURIOUSLY
R12-LCB-CO-FB3R12B301B	1.44E-05	CIRCUIT BREAKER FROM BUS R11-B3 OPENS SPURIOUSLY
R12-LCB-CO-FB3R12B302B	1.44E-05	CIRCUIT BREAKER FROM BUS R11-B3 OPENS SPURIOUSLY
R12-LCB-CO-FB3R12TBBN1E	1.44E-05	CIRCUIT BREAKER FROM BUS R10-B1 OPENS SPURIOUSLY
R12-LCB-CO-FB3R12TBBRTNSS	1.44E-05	CIRCUIT BREAKER FROM BUS R11-B3 OPENS SPURIOUSLY
R12-LCB-OO-B2R12A31	3.00E-04	CIRCUIT BREAKER IN BUS R11-A31 FAILS TO CLOSE
R12-LCB-OO-B2R12B31	3.00E-04	CIRCUIT BREAKER IN BUS R11-B31 FAILS TO CLOSE
R12-LCB-OO-B2R12C23	3.00E-04	CIRCUIT BREAKER IN BUS R11-C23 FAILS TO CLOSE
R12-LCB-OO-B2R12C31	3.00E-04	CIRCUIT BREAKER IN BUS R11-C31 FAILS TO CLOSE
R12-LCB-OO-B2R12D31	3.00E-04	CIRCUIT BREAKER IN BUS R11-D31 FAILS TO CLOSE
R12-XFL-LP-A2R12A31	1.92E-05	TRANSFORMER FROM R11-A2 TO R12-A31 FAILS TO OPERATE
R12-XFL-LP-A2R12B31	1.92E-05	TRANSFORMER FROM R11-A2 TO R12-B31 FAILS TO OPERATE
R12-XFL-LP-A2R12C23	1.92E-05	TRANSFORMER FROM R11-A2 TO R12-C23 FAILS TO OPERATE

Table 4.14-7

List of System Basic Events

Basic Event	Prob	Description
R12-XFL-LP-A2R12C31	1.92E-05	TRANSFORMER FROM R11-A2 TO R12-C31 FAILS TO OPERATE
R12-XFL-LP-A2R12D31	1.92E-05	TRANSFORMER FROM R11-A2 TO R12-D31 FAILS TO OPERATE
R12-XFL-LP-B2R12A31	1.92E-05	TRANSFORMER FROM R11-B2 TO R12-A31 FAILS TO OPERATE
R12-XFL-LP-B2R12B31	1.92E-05	TRANSFORMER FROM R11-B2 TO R12-B31 FAILS TO OPERATE
R12-XFL-LP-B2R12C23	1.92E-05	TRANSFORMER FROM R11-B2 TO R12-C23 FAILS TO OPERATE
R12-XFL-LP-B2R12C31	1.92E-05	TRANSFORMER FROM R11-B2 TO R12-C31 FAILS TO OPERATE
R12-XFL-LP-B2R12D31	1.92E-05	TRANSFORMER FROM R11-B2 TO R12-D31 FAILS TO OPERATE
R12-XFL-LP-R12A201A	1.92E-05	TRANSFORMER TO R12-A2-01AFAILS TO OPERATE
R12-XFL-LP-R12A202A	1.92E-05	TRANSFORMER TO R12-A2-02AFAILS TO OPERATE
R12-XFL-LP-R12A204A	1.92E-05	TRANSFORMER TO R12-A2-04A FAILS TO OPERATE
R12-XFL-LP-R12A301A	1.92E-05	TRANSFORMER TO R12-A3-01AFAILS TO OPERATE
R12-XFL-LP-R12A302A	1.92E-05	TRANSFORMER TO R12-A3-02AFAILS TO OPERATE
R12-XFL-LP-R12B201B	1.92E-05	TRANSFORMER TO R12-B2-01B FAILS TO OPERATE
R12-XFL-LP-R12B202B	1.92E-05	TRANSFORMER TO R12-B2-02B FAILS TO OPERATE
R12-XFL-LP-R12B204B	1.92E-05	TRANSFORMER TO R12-B2-04B FAILS TO OPERATE
R12-XFL-LP-R12B301B	1.92E-05	TRANSFORMER TO R12-B3-01B FAILS TO OPERATE
R12-XFL-LP-R12B302B	1.92E-05	TRANSFORMER TO R12-B3-02B FAILS TO OPERATE
R12-XFL-LP-R12TBAN1E	1.92E-05	TRANSFORMER TO BUS TRAIN A IN TB (NO 1E) FAILS TO OPERATE
R12-XFL-LP-R12TBARTNSS	1.92E-05	TRANSFORMER TO BUS TRAIN A IN TB (RTNSS) FAILS TO OPERATE
R12-XFL-LP-R12TBBN1E	1.92E-05	TRANSFORMER TO BUS TRAIN B IN TB (NO 1E) FAILS TO OPERATE
R12-XFL-LP-R12TBBRTNSS	1.92E-05	TRANSFORMER TO BUS TRAIN B IN TB (RTNSS) FAILS TO OPERATE

Table 4.14-8

System Top Events

Top Event	Description
GR10-0001-_1	LOSS OF 13.8 KV AC FROM BUS R10-A1
GR10-0001-_2	LOSS OF 13.8 KV AC FROM BUS R10-B1
GR10-0001-_3	LOSS OF 13.8 KV AC FROM BUS R10-C1
GR10-0001-_4	LOSS OF 13.8 KV AC FROM BUS R10-D1
GR11-0001-_1	LOSS OF 6.9 KV AC FROM BUS R11-A2
GR11-0001-_2	LOSS OF 6.9 KV AC FROM BUS R11-B2
GR11-0001-_3	LOSS OF 6.9 KV AC FROM BUS R11-A3
GR11-0001-_4	LOSS OF 6.9 KV AC FROM BUS R11-B3
GR12-0001-_1	LOSS OF 480 V AC FROM BUS R12-A31
GR12-0001-_2	LOSS OF 480 V AC FROM BUS R12-B31
GR12-0001-_3	LOSS OF 480 V AC FROM BUS R12-C31
GR12-0001-_4	LOSS OF 480 V AC FROM BUS R12-D31
GR12-0001-_5	LOSS OF 480 V AC FROM BUS R12-C23
GR12-0001-_6	LOSS OF 480 V AC FROM BUS R12-A3-01A
GR12-0001-_7	LOSS OF 480 V AC FROM BUS R12-A3-02A
GR12-0001-_8	LOSS OF 480 V AC FROM BUS R12-A2-02A
GR12-0001-_9	LOSS OF 480 V AC FROM BUS R12-B3-01B
GR12-0001-_10	LOSS OF 480 V AC FROM BUS R12-B3-02B
GR12-0001-_11	LOSS OF 480 V AC FROM BUS R12-B2-02B
GR12-0001-_12	LOSS OF 480 V AC FROM BUS R12-A2-04A (FUEL BUILDING)
GR12-0001-_13	LOSS OF 480 V AC FROM BUS R12-B2-04B (FUEL BUILDING)
GR12-0001-_14	LOSS OF 480 V AC FROM TRAIN A IN TB (DID)
GR12-0001-_15	LOSS OF 480 V AC FROM TRAIN B IN TB (DID)
GR12-0001-_16	LOSS OF 480 V AC FROM TRAIN A IN TB (NO 1E)
GR12-0001-_17	LOSS OF 480 V AC FROM TRAIN B IN TB (NO 1E)
GR12-0001-_18	LOSS OF 480 V AC FROM BUS R12-A2-01A
GR12-0001-_19	LOSS OF 480 V AC FROM BUS R12-B2-01B

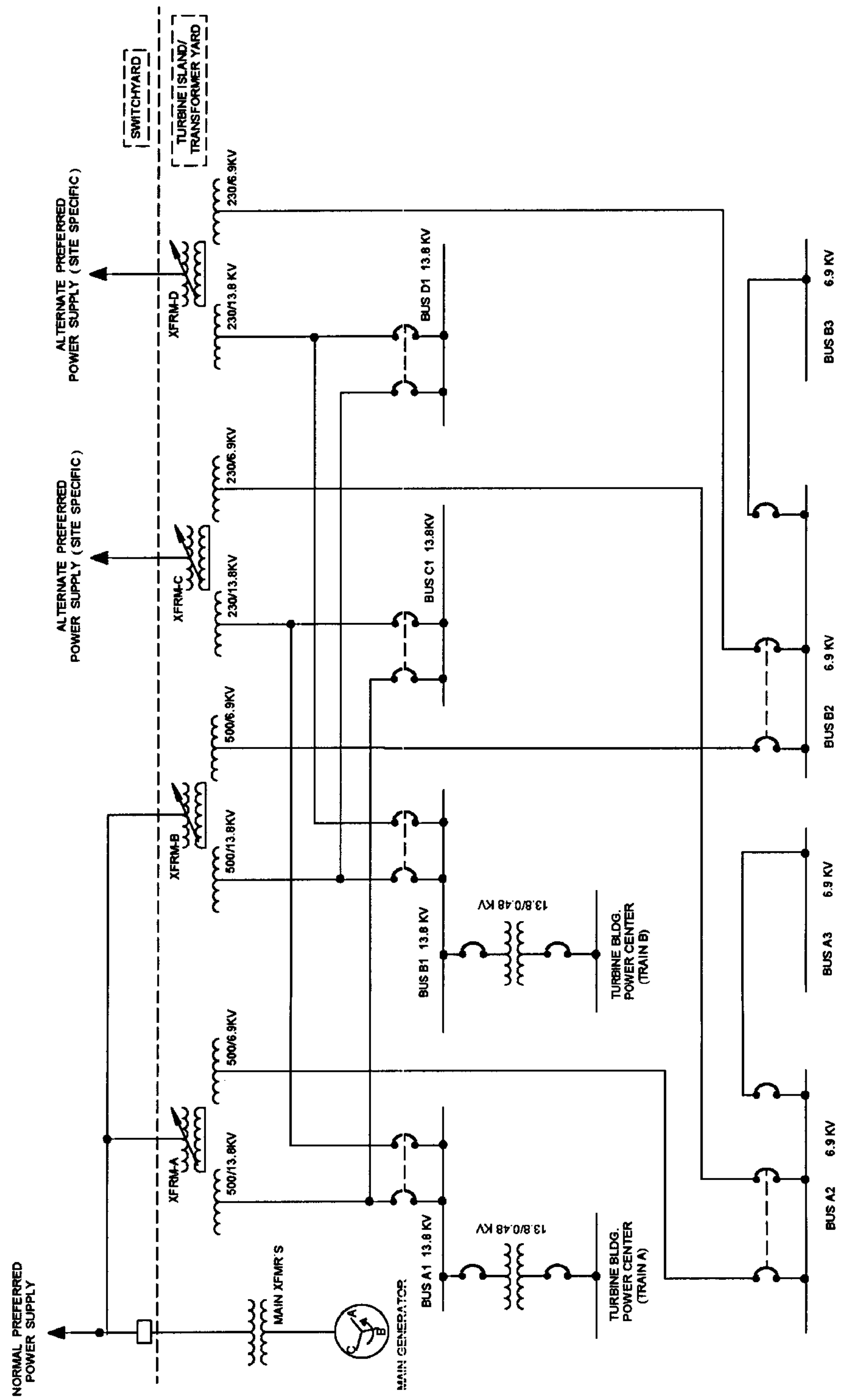


Figure 4.14-1A. A.C. Electric Power System One-line Simplified Diagram

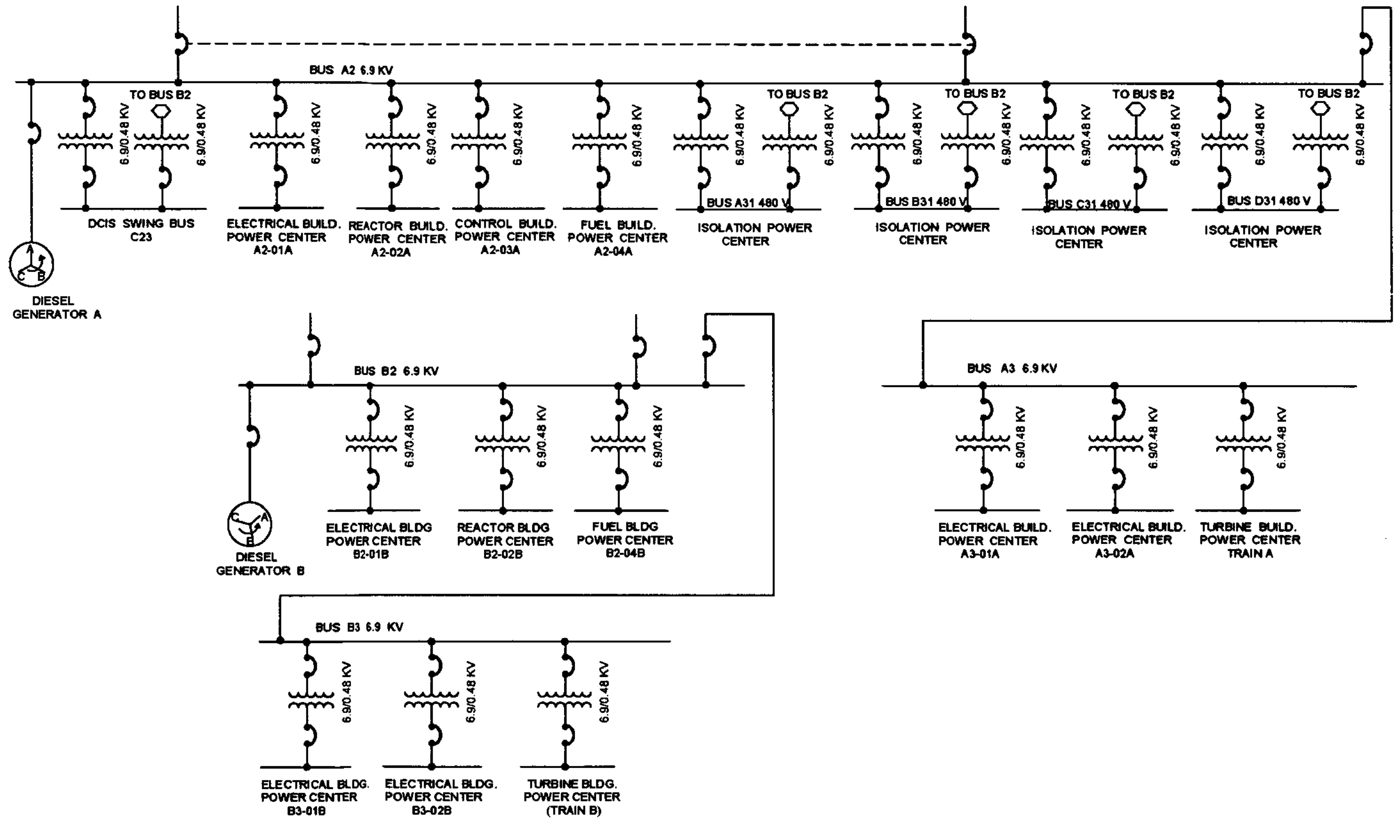


Figure 4.14-1B. A.C. Electric Power System One-line Simplified Diagram

4.15 UNINTERRUPTIBLE AC POWER SUPPLY SYSTEM – (R13)

4.15.1 System Purpose

This system provides continuous and reliable uninterruptible low voltage AC power for instrument loads, computer systems and other important plant loads, including safety-related loads (supplied from safety-related system) and non-safety-related load (supplied from non-safety-related system). This system is required for plant start-up, normal operation, and normal or emergency shutdown.

4.15.2 Design Assumptions

The following assumption with respect to the design is made:

(1) It is assumed that preventive and corrective maintenance actions that can make a bus unavailable are avoided while the plant is at power.

4.15.3 System Description

4.15.3.1 Hardware Configuration

Figure 4.15-1, shows the principal components of this system.

The safety-related Uninterruptible Power Supply consists of four divisions. Division 1 and 2 include two separate units. One unit supplies 120 V single-phase power and the other unit supplies 480 V AC three-phase power. Divisions 3 and 4 supply 480 V AC three-phase power. Each unit has two power supplies. The main source is from 250 VDC. The auxiliary source is through a voltage regulatory transformer supplied by 480 VAC.

There are five non-safety related uninterruptible power supply systems. Three of them receive 480 V AC and 250 V DC power and supply 480 V AC, while the other two receive 480 V AC and 125 V DC power and supply 120 V AC.

In the systems that are a long distance away from the DC power system batteries, the uninterruptible power can be supplied by a modularized Uninterruptible Power Supply (UPS) that includes batteries and battery chargers.

4.15.3.2 System Operation

During plant start-up, normal operation, normal and emergency shutdown, and during plant outages, the Uninterruptible Power Supply System inverters receive rectified DC power through the battery charger with the batteries floating on line, while supplying constant voltage and constant frequency to its connected loads.

During station blackout conditions the system inverters automatically and without interruption, supply constant voltage and constant frequency AC power from the DC power system or the UPSs batteries, whichever applies, to its connected loads.

When the DC input is lost, the AC input is switched. A static transfer switch, capable of operating within ½ cycle of 60 Hz, automatically switches the inverter output to a regulating transformer when the inverter portion of the supply fails. Prior to the static transfer switch operation, the inverter is kept in synchronism with the bypass source.

4.15.3.3 System Location

The safety-related Uninterruptible Power Supply System (UPSS) is located in the Reactor Building.

The non-safety-related 120V AC power system is located in the Electrical Building.

4.15.4 Automatic and Manual Control

Appropriate manual and automatic controls are provided to maintain the operating parameters and systems within prescribed operating ranges and, specifically, to permit the following operations:

- Automatic and manual transfer to the alternate source
- Automatic and manual re-transfer back to the normal source

Table 4.15-1 lists the signals and alarms that are assumed to be needed.

4.15.5 System Interfaces

The UPSS begins at the input terminals of the inverters and regulating transformers and ends at the input terminals of the system's loads. For AC power provided by a modularized UPSS, complete with battery chargers, the system begins at the input terminals of the UPSS battery charger and alternate source.

The Low Voltage AC power supply system provides power to the battery chargers and regulating transformers, and for operation of their auxiliary equipment, such as cooling fans, heaters, etc.

The DC power supply system provides power to inverters.

The instrumentation and control systems provide remote monitoring and control capabilities.

Table 4.15-2 shows the assumed system dependencies.

4.15.6 System Testing

Periodic tests of the UPSS are conducted in accordance with normal power plant requirements for demonstrating system and component operability and integrity.

Table 4.15-3 shows the assumed component tests.

4.15.7 System Maintenance

A maintenance switch parallels the static transfer switch to allow maintenance of the inverter/static transfer switch while continuing power to the vital loads. It is possible to throw the maintenance switch while the inverter and loads are operating.

The equipment and components of the UPSS are designed for easy inspection and maintenance during plant operation.

4.15.8 Potential for Common Cause Failure (CCF)

Potential CCFs are considered negligible because the system has a continuous operation, continuous surveillance and its preferred alignment is with the DC power supply system.

4.15.9 Fault Tree Analysis

4.15.9.1 Top Event Definition

A fault tree is developed for each one of the safety-related and non-safety-related buses.

Top events are listed in Table 4.15-8

4.15.9.2 Fault Tree Description

Eighteen fault trees are developed to reflect the failure of each class 1E buses:

- Fault trees GR13-0001-_1 to GR13-0001-_8 model the failures of the 208/120V AC buses, for 24 h. supply.
- Fault trees GR13-0001-_9 and GR13-0001-_10 model the failures of the 120V AC buses, for 72 h. supply.
- Fault trees GR13-0001-_11 to GR13-0001-_18 model the failures of the 480V AC buses, for 24 h. supply.

The rest of the fault trees relate to the non-class 1E buses:

- Fault trees GR13-0001-_19 to GR13-0001-_21, GR13-0001-_23 to GR13-0001-_25 and GR13-0001-_27 model the failures of the 208/120V AC buses.
- Fault trees GR13-0001-_22, GR13-0001-_26, GR13-0001-_28 and GR13-0001-_29 model the failures of the 120V AC buses.

4.15.9.3 Human Interactions

There is no human action included in the model.

4.15.10 Results of Fault Tree Analysis

The definition of each basic event is reported in Table 4.15-7.

The quantification of core damage sequences implicitly includes the contribution of basic events for this system. This quantification process enables checking the global consistency of the system fault trees and their relationship with the rest of the systems modeled in the PRA.

On the other hand, the importance measurements obtained from core damage frequency equations, allow identification of the most relevant basic events and system component failures in an integrated context, as well as the determination of their relative importance with respect to the basic events and component failures of the other systems modeled.

4.15.11 Model Differences for 72-Hour Operation

There are no changes to the model for operation to 72 hours other than the mission time.

4.15.12 References

4.15-1. ESBWR Design Control Document, 26A6642 Rev. 01

Table 4.15-1

Control Room Instrumentation and Alarms

Controls
Displays
Inverters input voltages
Alarms

Table 4.15-2

System Dependency Matrix

		Support System									
		Power Supply									
		250 V DC class 1E (busses)						480 V A.C. (busses)			
Component	**Type**	**11**	**12**	**21**	**22**	**31**	**41**	**A31**	**B31**	**C31**	**D31**
Bus 11-1	Bus	X						X			
Bus 11-2	Bus	X						X			
Bus 21-1	Bus			X					X		
Bus 21-2	Bus			X					X		
Bus 31-1	Bus					X				X	
Bus 31-2	Bus					X				X	
Bus 41-1	Bus						X				X
Bus 41-2	Bus						X				X
Bus 12	Bus		X					X			
Bus 22	Bus				X				X		
Bus 11-3	Bus	X						X			
Bus 11-4	Bus	X						X			
Bus 21-3	Bus			X					X		
Bus 21-4	Bus			X					X		
Bus 31-3	Bus					X				X	
Bus 31-4	Bus					X				X	
Bus 41-3	Bus						X				X
Bus 41-4	Bus						X				X

		Support System										
		Power Supply										
		250 V DC no class 1E (busses)					480 V A.C. (busses)					
Component	**Type**	**A1**	**A2**	**B1**	**B2**	**C**	**A2-02A**	**A3-01A**	**A3-02A**	**B3-02B**	**B3-01B**	**C23**
Bus A1-1	Bus	X						X	X			
Bus A1-2	Bus	X						X	X			
Bus A2-1	Bus		X					X	X			
Bus A2-2	Bus		X					X	X			
Bus B1-1	Bus			X						X	X	
Bus B1-2	Bus			X						X	X	
Bus B2-1	Bus				X					X	X	
Bus B2-2	Bus				X					X	X	
Bus C-1	Bus					X	X					X
Bus C-2	Bus					X	X					X
Bus C-3	Bus					X	X					X

Table 4.15-3

Component Tests

Component	**Expected Test Interval**
Transfer switch	3 months

Table 4.15-4

Component Maintenance

No preventive maintenance actions are expected to be performed during normal plant operation that can cause loss of power in a bus.

Table 4.15-5

System Common Cause Failures

Common cause failures have been considered negligible

Table 4.15-6

System Human Errors

No human actions have been included in the fault tree model.

Table 4.15-7

System Basic Events

Top Event	Description
GR13-0001-_1	LOSS OF 208/120 V AC FROM BUS R13-11-1
GR13-0001-_2	LOSS OF 208/120 V AC FROM BUS R13-11-2
GR13-0001-_3	LOSS OF 208/120 V AC FROM BUS R13-21-1
GR13-0001-_4	LOSS OF 208/120 V AC FROM BUS R13-21-2
GR13-0001-_5	LOSS OF 208/120 V AC FROM BUS R13-31-1
GR13-0001-_6	LOSS OF 208/120 V AC FROM BUS R13-31-2
GR13-0001-_7	LOSS OF 208/120 V AC FROM BUS R13-41-1
GR13-0001-_8	LOSS OF 208/120 V AC FROM BUS R13-41-2
GR13-0001-_9	LOSS OF 120 V AC FROM R13-12
GR13-0001-_10	LOSS OF 120 V AC FROM R13-22
GR13-0001-_11	LOSS OF 480 V AC FROM BUS R13-11-3
GR13-0001-_12	LOSS OF 480 V AC FROM BUS R13-11-4
GR13-0001-_13	LOSS OF 480 V AC FROM R13-21-3
GR13-0001-_14	LOSS OF 480 V AC FROM R13-21-4
GR13-0001-_15	LOSS OF 480 V AC FROM R13-31-3
GR13-0001-_16	LOSS OF 480 V AC FROM R13-31-4
GR13-0001-_17	LOSS OF 480 V AC FROM R13-41-3
GR13-0001-_18	LOSS OF 480 V AC FROM R13-41-4
GR13-0001-_19	LOSS OF 208/120 V AC FROM BUS R13-A1-1
GR13-0001-_20	LOSS OF 208/120 V AC FROM BUS R13-A1-2
GR13-0001-_21	LOSS OF 208/120 V AC FROM BUS R13-A2-1
GR13-0001-_22	LOSS OF 120 V AC FROM BUS R13-A2-2
GR13-0001-_23	LOSS OF 208/120 V AC FROM BUS R13-B1-1
GR13-0001-_24	LOSS OF 208/120 V AC FROM BUS R13-B1-2
GR13-0001-_25	LOSS OF 208/120 V AC FROM BUS R13-B2-1
GR13-0001-_26	LOSS OF 120 V AC FROM BUS R13-B2-2
GR13-0001-_27	LOSS OF 208/120 V AC FROM BUS R13-C1-1
GR13-0001-_28	LOSS OF 120 V AC FROM BUS R13-C1-2
GR13-0001-_29	LOSS OF 120 V AC FROM BUS R13-C1-3

Table 4.15-8

System Top Events

Top Event	Description
GR13-0001-_1	LOSS OF 208/120 V AC FROM BUS R13-11-1
GR13-0001-_2	LOSS OF 208/120 V AC FROM BUS R13-11-2
GR13-0001-_3	LOSS OF 208/120 V AC FROM BUS R13-21-1
GR13-0001-_4	LOSS OF 208/120 V AC FROM BUS R13-21-2
GR13-0001-_5	LOSS OF 208/120 V AC FROM BUS R13-31-1
GR13-0001-_6	LOSS OF 208/120 V AC FROM BUS R13-31-2
GR13-0001-_7	LOSS OF 208/120 V AC FROM BUS R13-41-1
GR13-0001-_8	LOSS OF 208/120 V AC FROM BUS R13-41-2
GR13-0001-_9	LOSS OF 120 V AC FROM R13-12
GR13-0001-_10	LOSS OF 120 V AC FROM R13-22
GR13-0001-_11	LOSS OF 480 V AC FROM BUS R13-11-3
GR13-0001-_12	LOSS OF 480 V AC FROM BUS R13-11-4
GR13-0001-_13	LOSS OF 480 V AC FROM R13-21-3
GR13-0001-_14	LOSS OF 480 V AC FROM R13-21-4
GR13-0001-_15	LOSS OF 480 V AC FROM R13-31-3
GR13-0001-_16	LOSS OF 480 V AC FROM R13-31-4
GR13-0001-_17	LOSS OF 480 V AC FROM R13-41-3
GR13-0001-_18	LOSS OF 480 V AC FROM R13-41-4
GR13-0001-_19	LOSS OF 208/120 V AC FROM BUS R13-A1-1
GR13-0001-_20	LOSS OF 208/120 V AC FROM BUS R13-A1-2
GR13-0001-_21	LOSS OF 208/120 V AC FROM BUS R13-A2-1
GR13-0001-_22	LOSS OF 120 V AC FROM BUS R13-A2-2
GR13-0001-_23	LOSS OF 208/120 V AC FROM BUS R13-B1-1
GR13-0001-_24	LOSS OF 208/120 V AC FROM BUS R13-B1-2
GR13-0001-_25	LOSS OF 208/120 V AC FROM BUS R13-B2-1
GR13-0001-_26	LOSS OF 120 V AC FROM BUS R13-B2-2
GR13-0001-_27	LOSS OF 208/120 V AC FROM BUS R13-C1-1
GR13-0001-_28	LOSS OF 120 V AC FROM BUS R13-C1-2
GR13-0001-_29	LOSS OF 120 V AC FROM BUS R13-C1-3

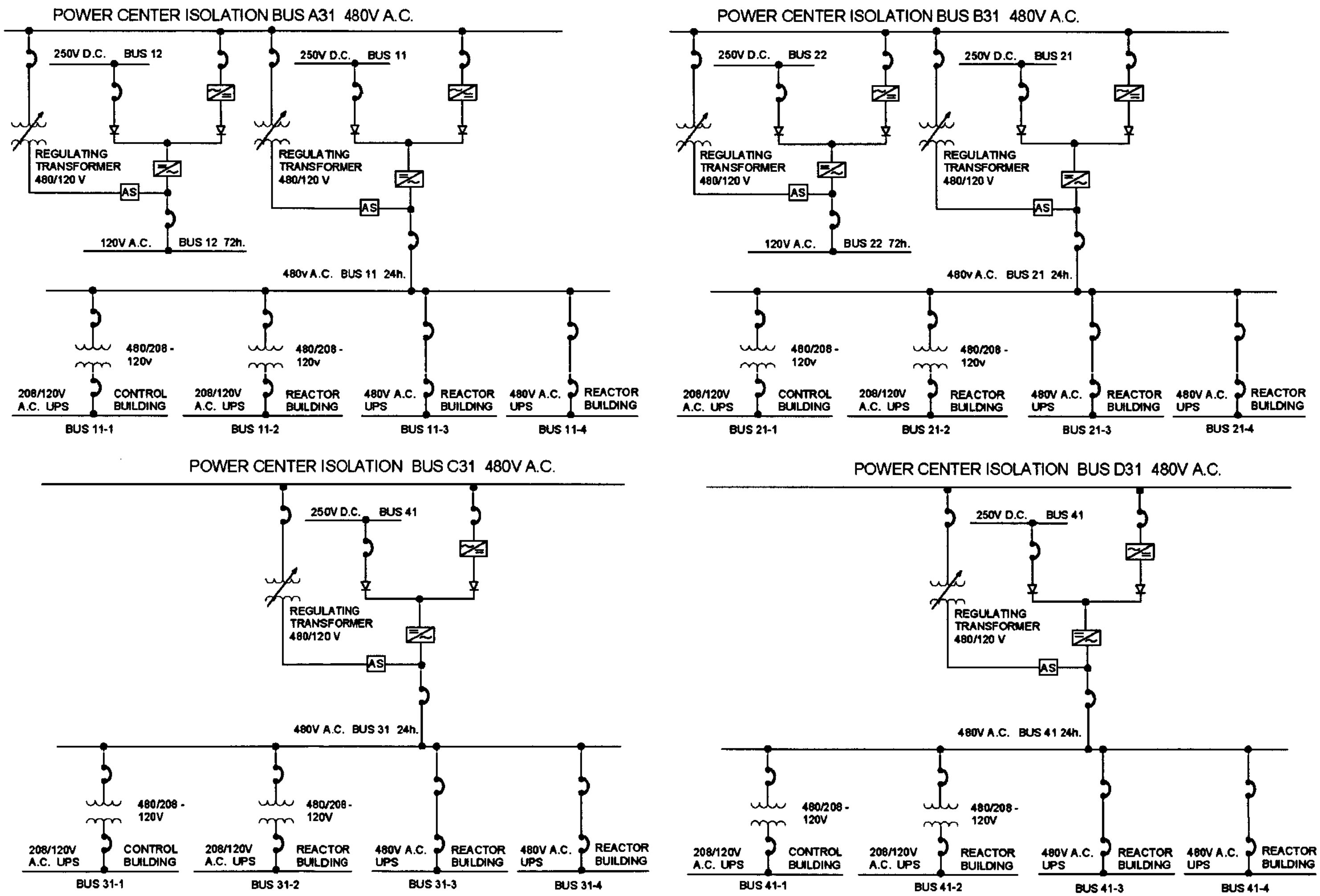


Figure 4.15-1A. Uninterruptible A.C. Power Supply System One Line Diagram

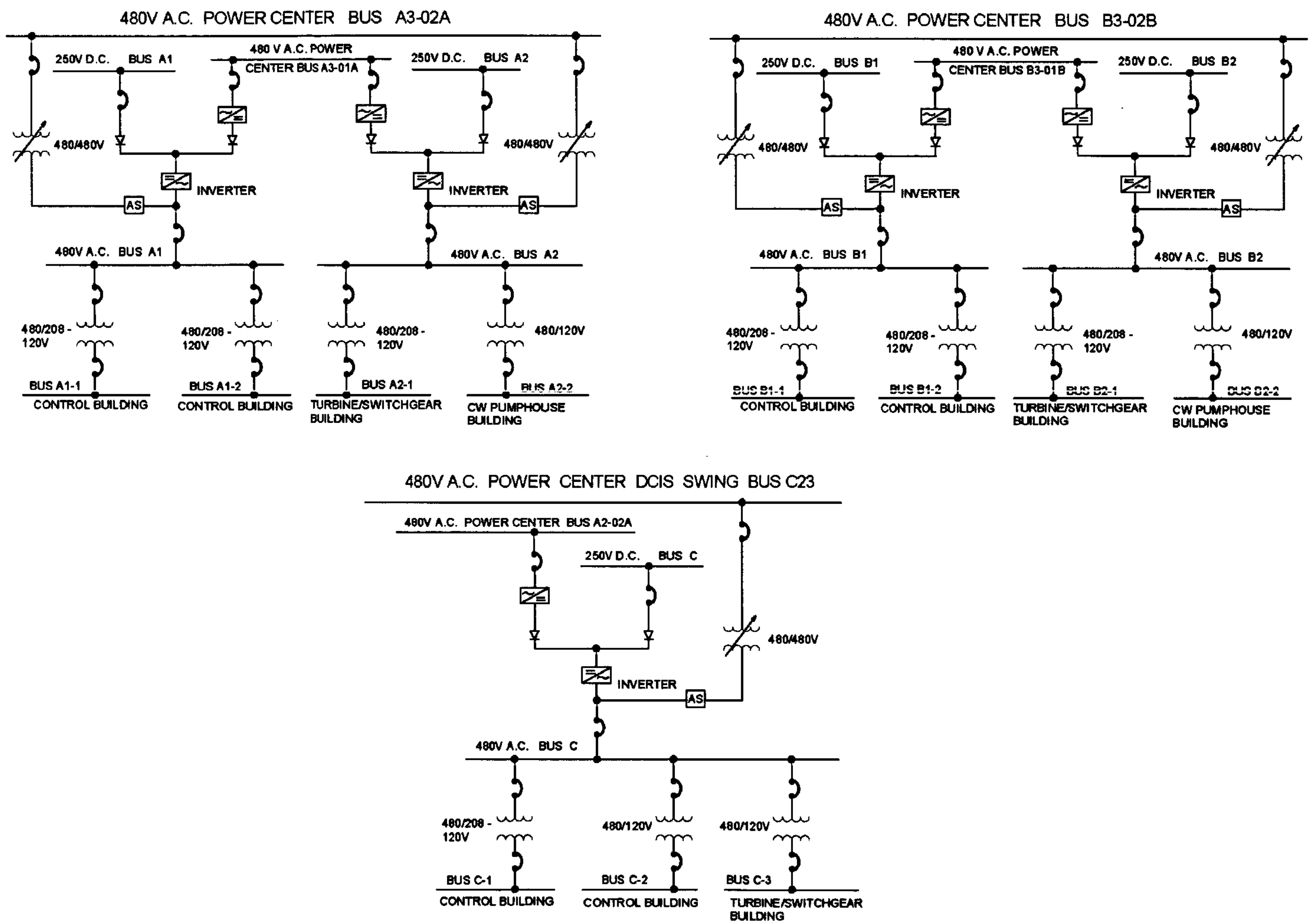


Figure 4.15-1B. Uninterruptible A.C. Power Supply System One Line Diagram

4.16 N/A SECTION 4.16 HAS BEEN DELETED FROM THE PRA

4.17 DIRECT CURRENT POWER SUPPLY SYSTEM - (R16)

4.17.1 System Purpose

The system provides power to the safety-related plant controls and instrumentation required for emergency reactor shutdown and other safety related functions. It also supplies power to non-safety related loads through 250V DC divisions with the necessary isolation between the safety and the non-safety grade part of the system. The non-safety is separated from the safety during normal operation.

4.17.2 Design Assumptions

The following assumptions with respect to the design are made:

(1) The plug-in power source to supply the 480V AC MCCs is available long term. No human action is modeled as far as system alignment is concerned. The system is assumed to be always aligned and does not need automatic actuation or human action.

(2) It is assumed that the only maintenance performed to a busbar is corrective maintenance after its failure.

(3) It is assumed that adequate cooling is needed and available in battery charger room.

4.17.3 System Description

4.17.3.1 Hardware Configuration

The safety related DC distribution system is arranged in four divisional class 1E 250V DC power supplies. Each DC train consists of a battery, battery charger, and DC distribution panels. Divisions 1 and 2 have two separate DC systems. One of the systems has a battery sized to provide power for a 24-hour period. The other system has a battery sized to provide power for a 72-hour period.

Non-class 1E DC power is arranged in three 250V DC trains. The safety and non-safety battery chargers are supplied from the Motor Control Centers (MCCs) fed by diesel generator buses.

In the event of loss of all AC supplies (including diesel generators), divisional batteries supply all the safety related loads. Non-class 1E batteries are sized to provide power to protections, controls, and instrumentation loads for two hours.

Following discharge of the batteries, the battery chargers are able to supply the normal system loads and at the same time recharge the batteries. The battery charger is arranged so that the associated battery can be charged on line at an equalizing charge rate while the normal battery loads are disconnected from the battery and carried by the normal battery charger.

Each distribution panel contains disconnect switches protected by fuses, ground fault detection, and alarm devices.

An alarm located within the control room alerts the operator if the battery connection switch is inadvertently left open after test or maintenance.

Battery rooms are served by a flow-through ventilation system to remove the small amount of hydrogen produced during the charging of the batteries.

Figure 4.17-1 shows the system arrangement.

4.17.3.2 System Operation

The batteries and the battery chargers are always connected to the distribution panel during normal operation. In fault conditions, the automatic opening of the circuit breaker connecting the battery charger isolates each division.

During station blackout conditions and whenever the battery charger output is unavailable, the DC Power Supply System automatically and without interruption supplies DC power from the batteries to its connected loads.

Fuses protect battery chargers and batteries from overcurrent.

4.17.3.3 System Location

Safety related batteries, battery chargers, and related motor control centers and power centers are located in the reactor building.

The DC batteries in each division are installed in separate rooms, apart from the power distribution equipment, such as the chargers and the power center.

Non-safety related 250 V DC systems are located in Electrical Building.

4.17.4 Automatic and Manual Control

There is no logic driven disconnection in case of battery charger failure. In case of a fault to ground, overcurrent protection is assured by fuses and by the overcurrent protection device located inside the circuit breaker connecting the battery charger to the 480 V AC MCC. All switching has to be done locally by the operator through manual switches.

4.17.5 System Interfaces

The system begins at the source terminals of the plant battery chargers. It ends at the input terminals of the plant DC loads (motors, control loads, etc.) and at the DC input terminals of the inverters of the Uninterruptible AC Power Supply System.

The 250V DC division interfaces with the related 480V AC buses at the MCC level.

Battery rooms are served by a flow-through ventilation system to avoid hydrogen concentration during battery charging. In case of a loss of AC power, the battery ceases to charge so the ventilation is not needed.

System dependencies are reported in Table 4.17-2.

4.17.6 System Testing

The non-class 1E and class 1E battery testing is assumed to be the same. Battery voltage is verified weekly. Electrolyte level and density is checked every month.

A complete battery test with a 24-hour and 72-hour discharge at nominal current and a complete recharge is performed at each refueling.

The output of the battery charger and correct alignment of the charger switches is tested as part of the battery discharge test because the charger has to restore the battery charge. Consequently, a misposition of the switch connecting the battery charger is not credible.

4.17.7 System Maintenance

The battery maintenance requires disconnection from the distribution panel, but misposition after maintenance is not credible because an alarm alerts the control room operator.

4.17.8 Potential for Common Cause Failure

Battery chargers, batteries, and the fuses connecting the batteries to the distribution panel are subject to Common Cause Failure (CCF). The batteries are the most critical, since, in some accident sequences involving loss of preferred power, the power from the battery chargers is not expected, they are no longer powered.

CCF data estimated results are summarized in Table 4.17-5.

4.17.9 Fault Tree Analysis

4.17.9.1 Top Event Definitions

A fault tree is developed for each of the 250V DC (class 1E and non class 1E) divisional trains.

The fault trees for non-class 1E trains model the failure to supply power for two hours, which is the design discharge time. They are only used for short-term non-safety related systems alignment.

All top events are listed in Table 4.17-8.

4.17.9.2 Fault Tree Description

Fault trees take into account internal failures and dependency on Low Voltage AC Power System.

Fault trees are shown in the Appendix B.4.17.

4.17.9.3 Human Interaction

No human action is modeled as far as system alignment is concerned. The system is always aligned and does not need automatic actuation or human action. Misposition is possible after a battery test, but a disconnection is alarmed in the control room, so no misposition is taken into account.

4.17.10 Results of Fault Tree Analysis

The quantification of core damage sequences implicitly includes the contribution of basic events for this system. This quantification process enables checking the global consistency of the system fault trees and their relationship with the rest of the systems modeled in the PRA.

The definition of each basic event is reported in Table 4.17-7.

On the other hand, the importance measurements obtained from core damage frequency equations, allow identification of the most relevant basic events and system component failures

in an integrated context, as well as the determination of their relative importance with respect to the basic events and component failures of the other systems modeled.

4.17.11 Model Differences for 72-Hour Operation

For the class 1E 250V DC power supply, the model differences due to a 72-hour or 24-hour mission time are mainly due to running failures and spurious operation.

4.17.12 References

4.17-1. ESBWR Design Control Document, 26A6642 Rev. 01

Table 4.17-1

Control Room Instrumentation and Alarms

Controls
Displays
Divisions Voltage
Battery chargers output current and voltage
CBs position indication
Alarms
Loss of Voltage to a Division
Battery charger failure
Battery discharging
Fault to ground

Table 4.17-2

System Dependency Matrix

		Support System			
		Power Supply			
		480 V AC MCC			
Component (250 V 1E)	**Type**	**(R12-A31)**	**(R12-B31)**	**(R12-C31)**	**(R12-D31)**
BYC11	Battery. Charger.	X			
BYC12	Battery. Charger.	X			
BYC21	Battery. Charger.		X		
BYC22	Battery. Charger.		X		
BYC31	Battery. Charger.			X	
BYC41	Battery. Charger.				X

		Support System		
		Power Supply		
		480 V AC MCC		
Component (250 V NO 1E)	**Type**	**(R12-A201A)**	**(R12-B201A)**	**(R12-C23)**
BYCA1	Battery. Charger.	X		
BYCA2	Battery. Charger.	X		
BYCB1	Battery. Charger.		X	
BYCB2	Battery. Charger.		X	
BYCC	Battery. Charger.			X

Table 4.17-3

Component Test

Component	Expected test interval
Batteries voltage	1 week
Electrolyte level and density	1 month
Complete battery test (discharge and recharge)	Refueling (24 months)

Table 4.17-4

Component Maintenance

No preventive maintenance actions are expected to be performed during normal plant operation. Only corrective maintenance can be performed.

Table 4.17-5

System Common Cause Failures

Basic Event	Prob	Description
R16-BT_-CF-ALLBATT	9.00E-06	BATTERY CCF #2
R16-BT_-CF-BATT11&12	9.50E-07	BATTERY 11 & 12 CCF
R16-BT_-CF-BATT11&21	9.50E-07	BATTERY 11 & 21 CCF
R16-BT_-CF-BATT11&22	9.50E-07	BATTERY 11 & 22 CCF
R16-BT_-CF-BATT11&31	9.50E-07	BATTERY 11 & 31 CCF
R16-BT_-CF-BATT11&41	9.50E-07	BATTERY 11 & 41 CCF
R16-BT_-CF-BATT12&21	9.50E-07	BATTERY 12 & 21 CCF
R16-BT_-CF-BATT12&22	9.50E-07	BATTERY 12 & 22 CCF
R16-BT_-CF-BATT12&31	9.50E-07	BATTERY 12 & 31 CCF
R16-BT_-CF-BATT12&41	9.50E-07	BATTERY 12 & 41 CCF
R16-BT_-CF-BATT21&22	9.50E-07	BATTERY 21 & 22 CCF
R16-BT_-CF-BATT21&31	9.50E-07	BATTERY 21 & 31 CCF
R16-BT_-CF-BATT21&41	9.50E-07	BATTERY 21 & 41 CCF
R16-BT_-CF-BATT22&31	9.50E-07	BATTERY 22 & 31 CCF
R16-BT_-CF-BATT22&41	9.50E-07	BATTERY 41 & 22 CCF
R16-BT_-CF-BATT31&41	9.50E-07	BATTERY 31 & 41 CCF
R16-BT_-CF-BATTA1A2	1.53E-06	BATTERY A1 & A2 CCF
R16-BT_-CF-BATTA1B1	1.53E-06	BATTERY A1 & B1 CCF
R16-BT_-CF-BATTA1B2	1.53E-06	BATTERY A1 & B2 CCF
R16-BT_-CF-BATTA1C	1.53E-06	BATTERY A1 & C CCF
R16-BT_-CF-BATTA2B1	1.53E-06	BATTERY A2 & B1 CCF
R16-BT_-CF-BATTA2B2	1.53E-06	BATTERY A2 & B2 CCF
R16-BT_-CF-BATTA2C	1.53E-06	BATTERY A2 & C CCF
R16-BT_-CF-BATTB1B2	1.53E-06	BATTERY B1 & B2 CCF
R16-BT_-CF-BATTB1C	1.53E-06	BATTERY B1 & C CCF
R16-BT_-CF-BATTB2C	1.53E-06	BATTERY B2 & C CCF

Table 4.17-6

System Human Errors

No human actions have been included in the fault tree model.

Table 4.17-7

System Basic Events

Basic Event	Prob	Description
R16-BDC-LP-R1611	4.80E-06	DC BUS R16-11 FAILS DURING OPERATION
R16-BDC-LP-R1612	4.80E-06	DC BUS R16-12 FAILS DURING OPERATION
R16-BDC-LP-R1621	4.80E-06	DC BUS R16-21 FAILS DURING OPERATION
R16-BDC-LP-R1622	4.80E-06	DC BUS R16-22 FAILS DURING OPERATION
R16-BDC-LP-R1631	4.80E-06	DC BUS R16-31 FAILS DURING OPERATION
R16-BDC-LP-R1641	4.80E-06	DC BUS R16-41 FAILS DURING OPERATION
R16-BDC-LP-R16A1	4.80E-06	DC BUS R16-A1 FAILS DURING OPERATION
R16-BDC-LP-R16A2	4.80E-06	DC BUS R16-A2 FAILS DURING OPERATION
R16-BDC-LP-R16B1	4.80E-06	DC BUS R16-B1 FAILS DURING OPERATION
R16-BDC-LP-R16B2	4.80E-06	DC BUS R16-B2 FAILS DURING OPERATION
R16-BDC-LP-R16C	4.80E-06	DC BUS R16-C FAILS DURING OPERATION
R16-BDC-TM-R1611	4.80E-06	DC BUS R16-11 IN MAINTENANCE
R16-BDC-TM-R1612	4.80E-06	DC BUS R16-12 IN MAINTENANCE
R16-BDC-TM-R1621	4.80E-06	DC BUS R16-21 IN MAINTENANCE
R16-BDC-TM-R1622	4.80E-06	DC BUS R16-22 IN MAINTENANCE
R16-BDC-TM-R1631	4.80E-06	DC BUS R16-31 IN MAINTENANCE
R16-BDC-TM-R1641	4.80E-06	DC BUS R16-41 IN MAINTENANCE
R16-BDC-TM-R16A1	4.80E-06	DC BUS R16-A1 IN MAINTENANCE
R16-BDC-TM-R16A2	4.80E-06	DC BUS R16-A2 IN MAINTENANCE
R16-BDC-TM-R16B1	4.80E-06	DC BUS R16-B1 IN MAINTENANCE
R16-BDC-TM-R16B2	4.80E-06	DC BUS R16-B2 IN MAINTENANCE
R16-BDC-TM-R16C	4.80E-06	DC BUS R16-C IN MAINTENANCE
R16-BT_-CF-ALLBATT	9.00E-06	BATTERY CCF FOR ALL 250 VDC BATTERIES
R16-BT_-CF-BATT11&12	9.50E-07	BATTERY 11 & 12 CCF
R16-BT_-CF-BATT11&21	9.50E-07	BATTERY 11 & 21 CCF
R16-BT_-CF-BATT11&22	9.50E-07	BATTERY 11 & 22 CCF
R16-BT_-CF-BATT11&31	9.50E-07	BATTERY 11 & 31 CCF
R16-BT_-CF-BATT11&41	9.50E-07	BATTERY 11 & 41 CCF
R16-BT_-CF-BATT12&21	9.50E-07	BATTERY 12 & 21 CCF
R16-BT_-CF-BATT12&22	9.50E-07	BATTERY 12 & 22 CCF
R16-BT_-CF-BATT12&31	9.50E-07	BATTERY 12 & 31 CCF
R16-BT_-CF-BATT12&41	9.50E-07	BATTERY 12 & 41 CCF
R16-BT_-CF-BATT21&22	9.50E-07	BATTERY 21 & 22 CCF
R16-BT_-CF-BATT21&31	9.50E-07	BATTERY 21 & 31 CCF
R16-BT_-CF-BATT21&41	9.50E-07	BATTERY 21 & 41 CCF
R16-BT_-CF-BATT22&31	9.50E-07	BATTERY 22 & 31 CCF
R16-BT_-CF-BATT22&41	9.50E-07	BATTERY 41 & 22 CCF
R16-BT_-CF-BATT31&41	9.50E-07	BATTERY 31 & 41 CCF
R16-BT_-CF-BATTA1A2	1.53E-06	BATTERY A1 & A2 CCF
R16-BT_-CF-BATTA1B1	1.53E-06	BATTERY A1 & B1 CCF
R16-BT_-CF-BATTA1B2	1.53E-06	BATTERY A1 & B2 CCF
R16-BT_-CF-BATTA1C	1.53E-06	BATTERY A1 & C CCF
R16-BT_-CF-BATTA2B1	1.53E-06	BATTERY A2 & B1 CCF
R16-BT_-CF-BATTA2B2	1.53E-06	BATTERY A2 & B2 CCF

Table 4.17-7

System Basic Events

Basic Event	Prob	Description
R16-BT_-CF-BATTA2C	1.53E-06	BATTERY A2 & C CCF
R16-BT_-CF-BATTB1B2	1.53E-06	BATTERY B1 & B2 CCF
R16-BT_-CF-BATTB1C	1.53E-06	BATTERY B1 & C CCF
R16-BT_-CF-BATTB2C	1.53E-06	BATTERY B2 & C CCF
R16-BT_-LP-R16BT11	5.00E-04	BATTERY R16-BT11 FAILS TO PROVIDE OUTPUT
R16-BT_-LP-R16BT12	5.00E-04	BATTERY DE2BY001 FAILS TO PROVIDE OUTPUT
R16-BT_-LP-R16BT21	5.00E-04	BATTERY DE3BY001 FAILS TO PROVIDE OUTPUT
R16-BT_-LP-R16BT22	5.00E-04	BATTERY R16-BT22 FAILS TO PROVIDE OUTPUT
R16-BT_-LP-R16BT31	5.00E-04	BATTERY R16-BT31 FAILS TO PROVIDE OUTPUT
R16-BT_-LP-R16BT41	5.00E-04	BATTERY R16-BT41 FAILS TO PROVIDE OUTPUT
R16-BT_-LP-R16BTA1	5.00E-04	BATTERY R16-BTA1 FAILS TO PROVIDE OUTPUT
R16-BT_-LP-R16BTA2	5.00E-04	BATTERY R16-BTA2 FAILS TO PROVIDE OUTPUT
R16-BT_-LP-R16BTB1	5.00E-04	BATTERY R16-BTB1 FAILS TO PROVIDE OUTPUT
R16-BT_-LP-R16BTB2	5.00E-04	BATTERY R16-BTB2 FAILS TO PROVIDE OUTPUT
R16-BT_-LP-R16BTC	5.00E-04	BATTERY R16-BTC FAILS TO PROVIDE OUTPUT
R16-BT_-TM-R16BT11	1.00E-03	BATTERY R16-BT11 IN TEST.
R16-BT_-TM-R16BT12	1.00E-03	BATTERY R16-BT12 IN TEST
R16-BT_-TM-R16BT21	1.00E-03	BATTERY R16-BT21 IN TEST
R16-BT_-TM-R16BT22	1.00E-03	BATTERY R16-BT22 IN TEST
R16-BT_-TM-R16BT31	1.00E-03	BATTERY R16-BT31 IN TEST
R16-BT_-TM-R16BT41	1.00E-03	BATTERY R16-BT41 IN TEST
R16-BT_-TM-R16BTA1	1.00E-03	BATTERY R16-BTA1 IN TEST
R16-BT_-TM-R16BTA2	1.00E-03	BATTERY R16-BTA2 IN TEST
R16-BT_-TM-R16BTB1	1.00E-03	BATTERY R16-BTB1 IN TEST
R16-BT_-TM-R16BTB2	1.00E-03	BATTERY R16-BTB2 IN TEST
R16-BT_-TM-R16BTC	1.00E-03	BATTERY R16-BTC IN TEST
R16-BYC-LP-R16BYC11	1.68E-04	BATTERY CHARGER R16-BYC11 FAILS TO MAINTAIN OUTPUT
R16-BYC-LP-R16BYC12	1.68E-04	BATTERY CHARGER R16-BYC12 FAILS TO MAINTAIN OUTPUT
R16-BYC-LP-R16BYC21	1.68E-04	BATTERY CHARGER R16-BYC21 FAILS TO MAINTAIN OUTPUT
R16-BYC-LP-R16BYC22	1.68E-04	BATTERY CHARGER R16-BYC22 FAILS TO MAINTAIN OUTPUT
R16-BYC-LP-R16BYC31	1.68E-04	BATTERY CHARGER R16-BYC31 FAILS TO MAINTAIN OUTPUT
R16-BYC-LP-R16BYC41	1.68E-04	BATTERY CHARGER R16-BYC41 FAILS TO MAINTAIN OUTPUT
R16-BYC-LP-R16BYCA1	1.68E-04	BATTERY CHARGER R16-BYCA1 FAILS TO MAINTAIN OUTPUT
R16-BYC-LP-R16BYCA2	1.68E-04	BATTERY CHARGER R16-BYCA2 FAILS TO MAINTAIN OUTPUT
R16-BYC-LP-R16BYCB1	1.68E-04	BATTERY CHARGER R16-BYCB1 FAILS TO MAINTAIN OUTPUT
R16-BYC-LP-R16BYCB2	1.68E-04	BATTERY CHARGER R16-BYCB2 FAILS TO MAINTAIN OUTPUT

Table 4.17-7

System Basic Events

Basic Event	Prob	Description
R16-BYC-LP-R16BYCC	1.68E-04	BATTERY CHARGER R16-BYCC FAILS TO MAINTAIN OUTPUT
R16-BYC-TM-R16BYC11	3.00E-04	BATTERY CHARGER R16-BYC11 IN TEST
R16-BYC-TM-R16BYC12	3.00E-04	BATTERY CHARGER R16-BYC12 IN TEST
R16-BYC-TM-R16BYC21	3.00E-04	BATTERY CHARGER R16-BYC21 IN TEST
R16-BYC-TM-R16BYC22	3.00E-04	BATTERY CHARGER R16-BYC22 IN TEST
R16-BYC-TM-R16BYC31	3.00E-04	BATTERY CHARGER R16-BYC31 IN TEST
R16-BYC-TM-R16BYC41	3.00E-04	BATTERY CHARGER R16-BYC41 IN TEST
R16-BYC-TM-R16BYCA1	3.00E-04	BATTERY CHARGER R16-BYCA1 IN TEST
R16-BYC-TM-R16BYCA2	3.00E-04	BATTERY CHARGER R16-BYCA2 IN TEST
R16-BYC-TM-R16BYCB1	3.00E-04	BATTERY CHARGER R16-BYCB1 IN TEST
R16-BYC-TM-R16BYCB2	3.00E-04	BATTERY CHARGER R16-BYCB2 IN TEST
R16-BYC-TM-R16BYCC	3.00E-04	BATTERY CHARGER R16-BYCC IN TEST
R16-LCB-CO-FROMR16BT11	1.44E-05	CIRCUIT BREAKER FROM R16-BT11 OPENS SPURIOUSLY
R16-LCB-CO-FROMR16BT12	1.44E-05	CIRCUIT BREAKER FROM R16-BT12 OPENS SPURIOUSLY
R16-LCB-CO-FROMR16BT21	1.44E-05	CIRCUIT BREAKER FROM R16-BT21 OPENS SPURIOUSLY
R16-LCB-CO-FROMR16BT22	1.44E-05	CIRCUIT BREAKER FROM R16-BT22 OPENS SPURIOUSLY
R16-LCB-CO-FROMR16BT31	1.44E-05	CIRCUIT BREAKER FROM R16-BT31 OPENS SPURIOUSLY
R16-LCB-CO-FROMR16BT41	1.44E-05	CIRCUIT BREAKER FROM R16-BT41 OPENS SPURIOUSLY
R16-LCB-CO-FROMR16BTA1	1.44E-05	CIRCUIT BREAKER FROM R16-BTA1 OPENS SPURIOUSLY
R16-LCB-CO-FROMR16BTA2	1.44E-05	CIRCUIT BREAKER FROM R16-BTA2 OPENS SPURIOUSLY
R16-LCB-CO-FROMR16BTB1	1.44E-05	CIRCUIT BREAKER FROM R16-BTB1 OPENS SPURIOUSLY
R16-LCB-CO-FROMR16BTB2	1.44E-05	CIRCUIT BREAKER FROM R16-BTB2 OPENS SPURIOUSLY
R16-LCB-CO-FROMR16BTC	1.44E-05	CIRCUIT BREAKER FROM R16-BTC OPENS SPURIOUSLY
R16-LCB-CO-TOR1611	1.44E-05	BATT. CHARG. R16-BYC11 OUTPUT BREAKER OPENS SPURIOUSLY
R16-LCB-CO-TOR1612	1.44E-05	BATT. CHARG. R16-BYC12 OUTPUT BREAKER OPENS SPURIOUSLY
R16-LCB-CO-TOR1621	1.44E-05	BATT. CHARG. R16-BYC21 OUTPUT BREAKER OPENS SPURIOUSLY
R16-LCB-CO-TOR1622	1.44E-05	BATT. CHARG. R16-BYC22 OUTPUT BREAKER OPENS SPURIOUSLY
R16-LCB-CO-TOR1631	1.44E-05	BATT. CHARG. R16-BYC31 OUTPUT BREAKER OPENS SPURIOUSLY
R16-LCB-CO-TOR1641	1.44E-05	BATT. CHARG. R16-BYC41 OUTPUT BREAKER OPENS SPURIOUSLY

Table 4.17-7

System Basic Events

Basic Event	Prob	Description
R16-LCB-CO-TOR16A1	1.44E-05	BATT. CHARG. R16-BYCA1 OUTPUT BREAKER OPENS SPURIOUSLY
R16-LCB-CO-TOR16A2	1.44E-05	BATT. CHARG. R16-BYCA2 OUTPUT BREAKER OPENS SPURIOUSLY
R16-LCB-CO-TOR16B1	1.44E-05	BATT. CHARG. R16-BYCB1 OUTPUT BREAKER OPENS SPURIOUSLY
R16-LCB-CO-TOR16B2	1.44E-05	BATT. CHARG. R16-BYCB2 OUTPUT BREAKER OPENS SPURIOUSLY
R16-LCB-CO-TOR16BYC11	1.44E-05	480V FEEDER BREAKER TO R16-BYC11 OPENS SPURIOUSLY
R16-LCB-CO-TOR16BYC12	1.44E-05	480V FEEDER BREAKER TO R16-BYC12 OPENS SPURIOUSLY
R16-LCB-CO-TOR16BYC21	1.44E-05	480V FEEDER BREAKER TO R16-BYC21 OPENS SPURIOUSLY
R16-LCB-CO-TOR16BYC22	1.44E-05	480V FEEDER BREAKER TO R16-BYC22 OPENS SPURIOUSLY
R16-LCB-CO-TOR16BYC31	1.44E-05	480V FEEDER BREAKER TO R16-BYC31 OPENS SPURIOUSLY
R16-LCB-CO-TOR16BYC41	1.44E-05	480V FEEDER BREAKER TO R16-BYC41 OPENS SPURIOUSLY
R16-LCB-CO-TOR16BYCA1	1.44E-05	480V FEEDER BREAKER TO R16-BYCA1 OPENS SPURIOUSLY
R16-LCB-CO-TOR16BYCA2	1.44E-05	480V FEEDER BREAKER TO R16-BYCA2 OPENS SPURIOUSLY
R16-LCB-CO-TOR16BYCB1	1.44E-05	480V FEEDER BREAKER TO R16-BYCB1 OPENS SPURIOUSLY
R16-LCB-CO-TOR16BYCB2	1.44E-05	480V FEEDER BREAKER TO R16-BYCB2 OPENS SPURIOUSLY
R16-LCB-CO-TOR16BYCC	1.44E-05	480V FEEDER BREAKER TO R16-BYCC OPENS SPURIOUSLY
R16-LCB-CO-TOR16C	1.44E-05	BATT. CHARG. R16-BYCC OUTPUT BREAKER OPENS SPURIOUSLY

Table 4.17-8

System Top Events

Top Event	Description
GR42-0001-_1	LOSS OF POWER FROM 250V DC 1E BUS R16-11
GR42-0001-_2	LOSS OF POWER FROM 250V DC 1E BUS R16-12
GR42-0001-_3	LOSS OF POWER FROM 250V DC 1E BUS R16-21
GR42-0001-_4	LOSS OF POWER FROM 250V DC 1E BUS R16-22
GR42-0001-_5	LOSS OF POWER FROM 250V DC 1E BUS R16-31
GR42-0001-_6	LOSS OF POWER FROM 250V DC 1E BUS R16-41
GR42-0001-_7	LOSS OF POWER FROM 250V DC NO 1E BUS R16-A1
GR42-0001-_8	LOSS OF POWER FROM 250V DC NO 1E BUS R16-A2
GR42-0001-_9	LOSS OF POWER FROM 250V DC NO 1E BUS R16-B1
GR42-0001-_10	LOSS OF POWER FROM 250V DC NO 1E BUS R16-B2
GR42-0001-_11	LOSS OF POWER FROM 250V DC NO 1E BUS R16-C

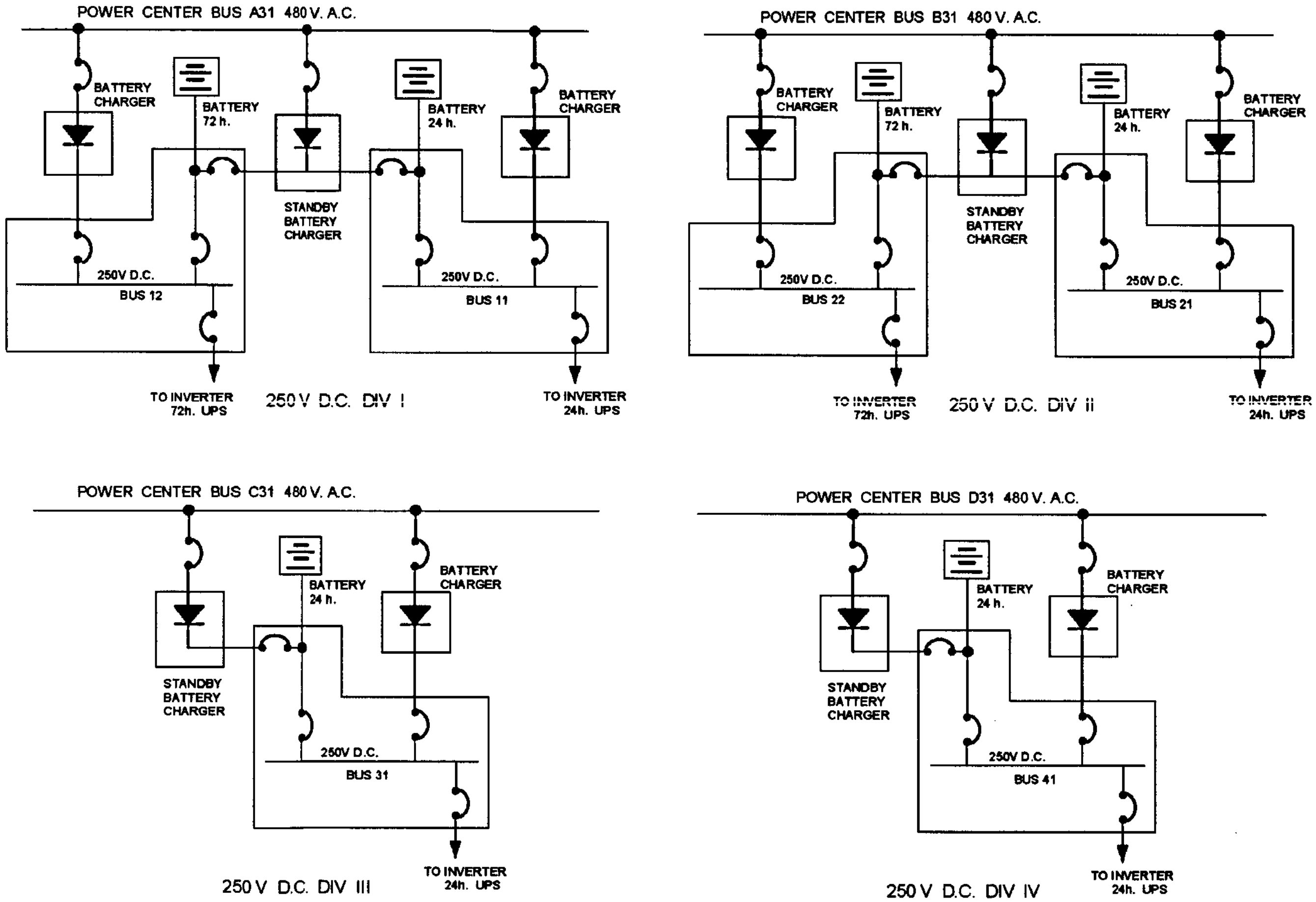


Figure 4.17-1A. Simplified One-line Diagram for 250 V DC Class 1E System

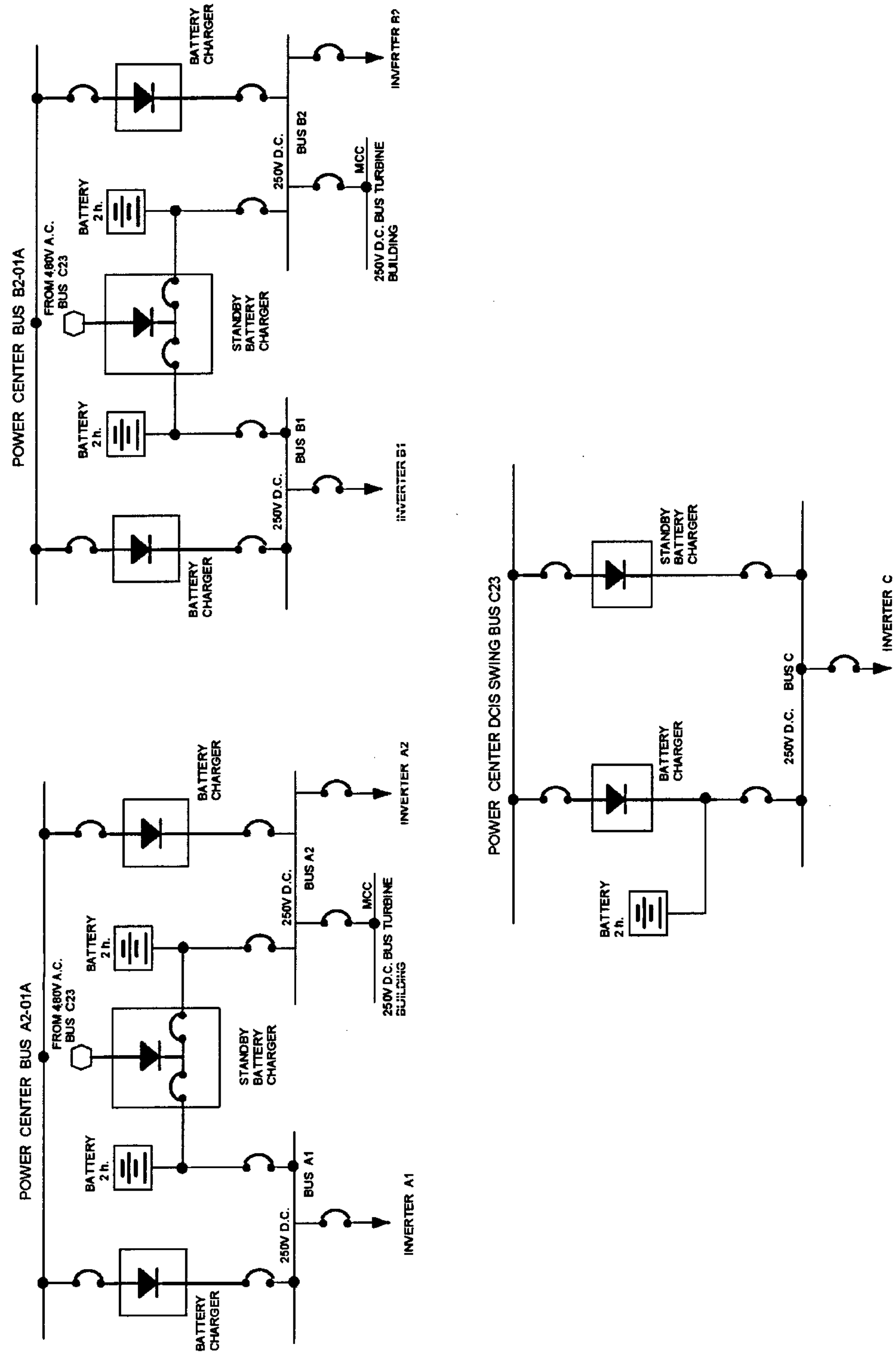


Figure 4.17-1B. Simplified One-line Diagram for 250 V DC Non-Class 1E System

4.18 CONTAINMENT SYSTEM - (TI0)

4.18.1 Purpose

The function of the containment system is to limit the fission product release from the core to the environment and to provide a leak tight vessel enclosing the Reactor Pressure Vessel (RPV) and associated equipment.

4.18.2 Design Assumptions

The following assumptions with respect to the design were made:

(1) It is assumed that vacuum breakers 1, 2, and 3 are supplied with 250 V DC class 1E from DIV. I, DIV. II and DIV. III, respectively.

(2) It is assumed that manual action in support of closure of the vacuum breakers is possible from the Control Room and two vacuum breakers closure signal propagates through divisions I and II of the ECCS logic of the SSLC system.

(3) It is assumed that valve B32-F001A receives automatic isolation signals from DIV. I and DIV. II of the ECCS logic of the SSLC and that the solenoid actuated by DIV. I receives 208/120 V AC uninterruptible power supply DIV. I, class 1E, and the solenoid actuated by DIV. II receives 208/120 V AC uninterruptible power supply DIV. II, class 1E. If automatic signals fail, it is assumed that it is possible for the crew to close the valve remotely from the Control Room.

(4) It is assumed that valve B32-F002A receives automatic isolation signals from DIV I of the ECCS logic or the SSLC and that its motor is fed by 480 V AC uninterruptible power supply DIV. I, class 1E. If automatic signals fail, it is assumed that it is possible for the crew to close the valve remotely from the Control Room.

(5) It is assumed that valve G31-F005A receives automatic isolation signals from DIV. I of the ECCS logic of the SSLC and that the electrical supply to the valve motor is 480 V AC uninterruptible power supply DIV. I, class 1E. If automatic signals fail, it is assumed that it is possible for the crew to close the valve remotely from the Control Room.

(6) It is assumed that valve G31-F006A receives automatic isolation signals from DIV. II of the ECCS logic of the SSLC. If automatic signals fail, it is assumed that it is possible for the crew to close the valve remotely from the Control Room.

(7) It is assumed that valves B21-F001A / B / C / D receive automatic isolation signals from DIV. I of the RTIF-scram logic of the SSLC. If automatic signals fail, it is assumed that it is possible for the crew to close the valves remotely from the Control Room.

(8) It is assumed that valves B21-F002A / B / C / D receive automatic isolation signals from DIV. II of the RTIF-scram logic of the SSLC. If automatic signals fail, it is assumed that it is possible for the crew to close the valves remotely from the Control Room.

(9) It is assumed that the logic channels DIV. I, II, III and IV of the RTIF logic of the SSLC are fed from 208/120 V AC uninterruptible power supply DIV. I, II, III and IV class 1E, respectively.

(10) It is assumed that there is a third valve (G31-F3A or B) in the suction line of each train of the RWCU system. These valves are located, respectively, downstream of the valves G31-F005/7A or B, depending on the train. They are air operated valves that are normally open that fail closed. These valves isolate the line automatically due to the same isolation signals that actuate the valves G31-F005/6/7A or B in the same train. These automatic signals are transmitted by the NE-RTNSS logic sub-system and can be manually overridden.

4.18.3 System Description

The Containment System is comprised of the drywell (DW), suppression pool (SP), wetwell (WW) gas space, and the vent system. The vent system and the Passive Cooling Containment Cooling System (PCCS) vent lines establish flow paths from the drywell to the suppression pool.

In addition, the wetwell-to-drywell vacuum breakers establish a flow path from the wetwell gas space to the drywell for the purpose of limiting the maximum differential pressure that could exist between the wetwell gas space and the drywell. The containment is inerted with nitrogen during normal plant operation.

The containment vessel is a reinforced concrete vessel that has an internal steel liner providing the leak-tight containment boundary.

The Containment System analysis described here refers to the system configuration shown in the diagram of Figure 4.18-1.

4.18.3.1 Hardware Configuration

The containment system mainly consists of the following components:

Drywell (DW)

The DW is made up of two volumes, the upper DW and the lower DW, which are geometrically separated by the Reactor Pressure Vessel (RPV) support skirt and pedestal. The two DW volumes are connected by open flow paths between the upper and lower drywell regions through the RPV support skirt.

Suppression Chamber (SC)

The SC, also referred to as the wetwell, is made up of a water volume (suppression pool) and a gas volume above the pool.

The suppression pool is a large body of water that absorbs energy by condensing steam from Safety Relief Valves (SRV) discharges and postulated pipe breaks. The suppression pool also serves as a source of reactor makeup water. The SP also serves to retain radioactive materials routed to it with the blowdown flow.

DW/SC Connecting Vents

The SC is connected to the DW by a vent system, which includes twelve vent modules. These vent modules are built into the vertical cylindrical wall, which separates the upper DW from the SC.

Spillover Pipes

The ESBWR spillover function provides a DW to SC connection for transferring water from the DW to the suppression pool. Spillover is accomplished by ten pipes, which are built into the vent wall. If water ascending through the DW annulus following a postulated LOCA reaches the entrance of the spillover pipes, it flows to the suppression pool. These lines are fitted with valves that open at the same time as the equalizing lines.

Containment Isolation System

The Containment Isolation System provides protection against release of radioactive materials to the environment as a result of accidents occurring in systems or components within the containment. Protection is provided by isolation of lines and ducts that penetrate the containment boundary.

The Containment Isolation System consists of the valves that are required to close and the portion of the instrumentation, from sensor to the actuation device that generates containment isolation signals (isolation logic) during an accident in which containment integrity is necessary. In the analysis, only the isolation of LOCAs outside containment in IC pipes, RWCU pipes, main steam (MS) pipes, or Feedwater pipes are justified.

Vacuum Relief

The ESBWR design provides a vacuum relief function to limit the magnitude of a negative pressure differential between the DW and the SC. The vacuum relief function is accomplished by three DW/SC vacuum breakers installed in the diaphragm floor. These vacuum breakers operate passively in response to a negative DW-to-SC to pressure gradient and is otherwise held closed by combination of gravity and the normally positive DW-to-SC pressure gradient. Each vacuum breaker is equipped with a DC motor–operated valve which provides isolation capability if the vacuum breaker sticks open or leaks in its closed position. Four position sensors are located around the disk periphery to provide the plant operator with confirmation that the disk is securely seated.

Vent

At the outer wall of the containment structural boundary there is a pipeline forming part of the Containment Inerting System normally isolated capable of venting the suppression pool air volume to the Reactor Building HVAC if required. The bleed line is normally closed by air operated valves that are only opened by operator action under emergency procedures to vent overpressure if required.

4.18.3.2 System Operation

The containment is inerted prior to reactor heatup for startup from an external source before hydrotest. During shutdown and plant outages, pre-entry purge is provided with the establishment of clean breathable atmosphere throughout the containment. The Containment Inerting System (CIS) (T31) provides the nitrogen inerting prior to plant startup and the nitrogen pre-entry purging with breathable atmosphere during shutdowns and plant outages.

During plant operation nitrogen makeup is also provided by CIS. The CIS maintains the drywell and wetwell pressures slightly above the reactor building pressure to ensure that that there is no air leakage from reactor building to the containment. The differential pressure setpoint is selected

such that a positive containment differential pressure can be maintained without excessive wasteful inerting with nitrogen. Following a postulated LOCA, high-energy fluids from the RPV pressurize the DW. In the early portion of the post –LOCA transient, the DW pressure is relieved by flow of the non-condensibles and steam through the main vent system to the suppression pool, where the steam is condensed. In the long term, steam generated by decay power flows to the PCCS where its latent heat is transferred via PCCS or IC Heat Exchangers to the IC/PCC pool.

In case of a LOCA outside containment, the Containment Isolation System actuates closing the open lines that penetrate the containment boundary.

4.18.3.3 Components Location

The Containment System components are located within the reactor building, drywell and the steam tunnel.

4.18.4 Automatic and Manual Control

In case of a LOCA outside containment automatic actuation of containment isolation valves is initiated. The actuation signals considered in the isolation of these LOCAs are listed by type of LOCA as follows:

<u>IC pipe breaks</u>

- High radiation in the IC pool
- High flow (differential pressure) in steam supply line
- High flow (differential pressure) in condensate return line

<u>Main Steam line breaks</u>

- Reactor water level 2
- Main steam line high flow rate
- Turbine inlet low pressure

<u>Feedwater line breaks</u>

No automatic actuation is required for feedwater isolation valves (check valves).

RWCU line breaks

- Reactor water level 2
- High flow rate in the RWCU train
- High temperature in the steam tunnel

A remote manual (from the control room) actuation is provided for all isolation valves with automatic closure. Neither automatic nor manual actuation is provided for the self-actuated isolation valves on main feedwater lines.

4.18.5 System Interfaces

The Containment System dependencies are included in the dependency matrix given in Table 4.18-2.

4.18.6 System Testing

Closure of the MSIVs is tested monthly. The isolation function of the check valves located in the feedwater lines is tested during each refueling outage.

RWCU containment isolation valves G31-F005A/B and G31-F006A/B are closed each month when the train is changed.

Closure of the containment isolation valves is done quarterly.

IC steam isolation valves B32-F001A/B/C/D and B32-F002A/B/C/D are tested every three months.

The tests performed during power operation on components included in the fault trees do not affect their availabilities relative to the modeled functions.

4.18.7 System Maintenance

The performance of maintenance on the system components located inside the containment during power operation is not assumed in this model, because the line is isolated during the maintenance.

Maintenance performed on the containment isolation valves during power operation does not make them unavailable to carryout their penetration isolation functions.

4.18.8 Common-Cause Failures

The common cause failures have been grouped in Table 4.18-5.

4.18.9 Fault Tree Analysis

Various fault trees have been developed to allow the determination of the system unavailability and to identify components that contribute significantly to system unavailability of the different containment system functions.

The following systems functions are required:

- Isolation of vacuum breaker leaks
- Steam suppression in the pool after a significant RPV depressurization. This includes the need for at least 2 of 3 vacuum breakers to be closed for the steam suppression function to be successful and at least one vacuum breaker able to open after steam suppression to avoid containment failure due to depressurization.
- Isolation of IC pipe breaks outside containment.
- Isolation of MSL breaks outside containment.
- Isolation of Feedwater pipe breaks outside containment
- Isolation of RWCU pipe breaks outside containment

4.18.9.1 Top Event Definitions

The corresponding fault trees have been developed for the above-mentioned functions. Their TOPS are indicated below:

- Gate GT10-0001-_1 represents the failure to isolate vacuum breaker leaks.
- Gate GT10-0001-_2 represents the failure of the steam suppression in the pool after a significant RPV depressurization.
- Gate GT10-0001-_4 represents the failure to isolate IC pipe breaks outside containment.
- Gate GT10-0001-_5 represents the failure to isolate main Feedwater line A breaks outside containment.
- Gate GT10-0001-_6 represents the failure to isolate main Feedwater line B breaks outside containment.
- Gate GT10-0001-_7 represents the failure to isolate RWCU pipe breaks outside containment in the operating train.
- Gate GT10-0001-_9 represents the failure to isolate main steam pipe breaks outside containment.

4.18.9.2 Model Assumptions

- System boundary: For purposes of the PRA, the Containment System includes the drywell, the suppression chamber, the DW/SC connecting vents, the spillover pipes, the containment isolation system, the vacuum relief valves, the containment overpressure protection system, the containment isolation valves B32-F001A, B32-F002A, B21-F001A/B/C/D, B21-F002A/B/C/D, B21-F102A/B, B21-F103A/B, G31-F005A, G31-F006A and the sensor and logic channels (RTIF) related to the automatic and manual actuations of these components.
- RWCU Train A is the train operating during power operation and that Train B is isolated from the RPV.
- The nitrogen or air stored in their corresponding accumulators is sufficient to close the air-operated containment isolation valves, and therefore, that supply from the High Pressure Nitrogen (P54) or Instrument Air (P52) systems is not necessary.
- In the event of a LOCA outside containment due to ruptures in the Isolation Condenser System, only the failure upon isolation of loop A of the system has been modeled. The behavior of loops B, C and D is similar.

4.18.9.3 Human actions

The human actions considered in the fault trees are collected in Table 4.18-6

T10-XHE-FO-CLOSE represents the operator's failure to manually close the vacuum breakers.

T10-XHE-FO-CLOSEIVS represents the operator's failure to manually close the isolation valves in case of a LOCA outside containment when automatic actuation fails.

Human actions in the fault trees are connected by the house-event XHOSMAN that represents operator unavailability to carry out manual actions.

4.18.10 Results of Fault Tree Analysis

The fault tree results provide quantitative values of system unavailability and of the importance of specific components to that total.

The quantification of core damage sequences implicitly includes the contribution of basic event for this system. This justification process enables checking the global consistency of the system fault trees and their relationship with the rest of the systems modeled in the PRA.

In addition, the importance measurements obtained from core damage frequency equations, allow identification of the most relevant basic events and system component failures in an integrated context, as well as the determination of their relative importance with respect to the basic events and component failures of the other systems modeled.

4.18.11 Model Differences for 72-Hour Operation

The long-term Containment System operation is similar to that during the first 24 hours following a transient or LOCA. There are no fault tree model changes necessary to extend the operation to 72 hours.

4.18.12 References

4.18-1. ESBWR Design Control Document, 26A6642 Rev. 01

Table 4.18-1

Control Room Instrumentation and Alarms

Main Control Room Panel Controls
Vacuum breakers closure
B32-F001A / B / C / D open / close
B32-F002A / B / C / D open / close
G31-F3A / B open / close
G31-F005A / B open / close
G31-F006A / B open / close
B21- F001A / B / C / D open / close
B21- F002A / B / C / D open / close
Main Control Console Displays
DW temperature
DW pressure
Differential pressure DW to SC and DW to outside containment
DW oxygen and hydrogen concentrations
DW radiation level
SC gas space temperature
SC gas space pressure
Differential pressure SC to outside containment
SC oxygen and hydrogen concentrations
SC radiation level
Suppression pool temperature
Suppression pool level
DW water level
Vacuum breakers SC to DW open/close position indication
B32-F001A / B / C / D position open / close
B32-F002A / B / C / D position open / close
G31-F005A / B position open / close
G31-F006A / B position open / close
B21- F001A / B / C / D position open / close
B21- F002A / B / C / D position open / close

Main Control Room Alarms
DW temperature high
DW pressure high
DW oxygen and hydrogen concentrations high
DW radiation level high
SC gas space temperature high
SC gas space pressure high
Differential pressure SC to outside containment
SC oxygen and hydrogen concentrations high
SC radiation level high
Suppression pool temperature high
Suppression pool level low

Table 4.18-2

System Dependencies Matrix

COMPONENT	TRANSMISSION SIGNAL	R16	R13 (Class 1E)	R13 (No Class 1E)
VB-1	C74 (DIV I AND II)	DIV 1		
VB-2	C74 (DIV I AND II)	DIV 2		
VB-3	C74 (DIV I AND II)	DIV 3		
B32-F001A	C74 (DIV I AND II)			
B32-F002A	C74 (DIV I)		DIV 1	
B32-N001A			DIV 1	
B32-N002A			DIV 2	
B32-N003A			DIV 3	
B32-N004A			DIV 4	
D11-N001A			DIV 1	
D11-N002A			DIV 2	
D11-N003A			DIV 3	
D11-N004A			DIV 4	
G31-F005A			DIV 1	
G31-F3A	C62(DIV A)			DIV. A

Table 4.18-3

Component Tests

See Section 4.18.6

Table 4.18-4

Component Maintenance

N/A

Table 4.18-5

Common Cause Failure

Basic Event	Probability	Description
B21-ACV-CF-MSIVCLOSE	1.45E-05	CCF OF AOV (MSIV) TO CLOSE
B21-FT_-CF-MSLA	3.00E-08	CCF 3/4 FLOW TRANSMITTERS MSL "A"
B21-FT_-CF-MSLB	3.00E-08	CCF 3/4 FLOW TRANSMITTERS MSL "B"
B21-FT_-CF-MSLC	3.00E-08	CCF 3/4 FLOW TRANSMITTERS MSL "C"
B21-FT_-CF-MSLD	3.00E-08	CCF 3/4 FLOW TRANSMITTERS MSL "D"
B21-LT_-CF-N001ABCD	1.20E-07	CCF OF DIVERSIFIED LEVEL 1& 2 TRANSM. 1A/B/C/D
B21-PT_-CF-MSL	3.00E-08	CCF 3/4 PRESSURE TRANSMITTERS MSL
B21-UV_-CF-102/3A	4.00E-04	CCF OF CHECK VALVES F103A AND F102A TO CLOSE
B21-UV_-CF-102/3B	4.00E-04	CCF OF CHECK VALVES F103B AND F102B TO CLOSE
B32-PDT-CF-ICA	1.62E-05	CCF OF PRESSURE DIFF. TRANSMITTERS IN IC-A NO OUTPUT SIGNAL
C21-FT_-CF-N001ABCDA	3.00E-08	CCF 3/4 FLOW TRANSMITTERS RWCU TRAIN A
C21-TT_-CF-N003ABCD	2.00E-08	CCF 3/4 STEAM TUNNEL TEMPERATURE TRANSMITTERS
C62-DTM-CF-DIDALL	5.50E-05	COMMON CAUSE FAILURE 3/4 DTM DID LOGIC
C74-DTM-CF-ALL	1.20E-05	CCF 3/4 DTM OF SSLC DIV1/2/3/4
C74-DTM-CF-RTIFALL	1.20E-05	CCF 3/4 DTM OF SSLC/RTIF DIV1/2/3/4
C74-SLU-CF-OLU	2.70E-06	CCF 3/4 OLU IN SSLC/RTIF DIV 1/2/3/4
C74-SLU-CF-TLU	2.70E-06	CCF 3/4 TLU IN SSLC/RTIF DIV 1/2/3/4
C74-VLU-CF-LD&IS	3.12E-06	CCF VOTING LOGIC CARDS 2/4 LD&IS
D11-ACT-CF-ICA	9.71E-06	CCF OF RADIATION MONITORS IN IC-A POOL (NO OUTPUT)
T10-VB_-CF-CLOSED	2.00E-06	CCF 2 OF 3 VB FAIL TO REMAIN CLOSED
T10-VB_-CF-OPEN	1.00E-06	CCF 3 OF 3 VB FAIL TO OPEN

Table 4.18-6

Human Errors

Basic Event	Probability	Description
T10-XHE-FO-CLOSE	1.77E-02	Operator Fails To Close Vacuum Breaker
T10-XHE-FO-CLOSEIVS	1.77E-02	Operator Fails To Manually Close Isolation Valves

Table 4.18-7

List of System Basic Events

Basic Event	Probability	Description
C74-SLU-FC-TLURTIF2	9.00E-04	TLU OF SSLC/RTIF DIV 2 FAILS
C74-SLU-FC-TLURTIF3	9.00E-04	TLU OF SSLC/RTIF DIV 3 FAILS
C74-SLU-FC-TLURTIF4	9.00E-04	TLU OF SSLC/RTIF DIV 4 FAILS
C74-VLU-FC-LD&IS1	6.24E-04	2/4 VOTING LOGIC CARD LD&IS DIV.1 FAILURE
C74-VLU-FC-LD&IS2	6.24E-04	2/4 VOTING LOGIC CARD LD&IS DIV.2 FAILURE
D11-ACT-NO-1A	1.94E-03	RADIATION MONITOR 1A ON IC A FAILS TO RESPOND TO CHANGE
D11-ACT-NO-2A	1.94E-03	RADIATION MONITOR 2A ON IC A FAILS TO RESPOND TO CHANGE
D11-ACT-NO-3A	1.94E-03	RADIATION MONITOR 3A ON IC A FAILS TO RESPOND TO CHANGE
D11-ACT-NO-4A	1.94E-03	RADIATION MONITOR 4A ON IC A FAILS TO RESPOND TO CHANGE
H23-RMU-FC-1ICA1	3.00E-04	RMU 001 FROM C.R. FAILS
H23-RMU-FC-1ICA2	3.00E-04	RMU 001 FROM C.R. FAILS
H23-RMU-FC-1VB	3.00E-04	RMU 001 FOR T10 C.R. MANUAL ACTUAT. FAILS TO OPERATE
H23-RMU-FC-2ICA1	3.00E-04	RMU 002 FROM C.R. FAILS
H23-RMU-FC-2ICA2	3.00E-04	RMU 002 FROM C.R. FAILS
H23-RMU-FC-2VB	3.00E-04	RMU 002 FOR T10 C.R. MANUAL ACTUAT. FAILS TO OPERATE
H23-RMU-FC-ACT1A	3.00E-04	LMU 10 A FAILURE
H23-RMU-FC-ACT2A	3.00E-04	LMU 10B FAILURE
H23-RMU-FC-ACT3A	3.00E-04	LMU 10C FAILURE
H23-RMU-FC-PDT1A	3.00E-04	LMU 6A FAILURE
H23-RMU-FC-PDT2A	3.00E-04	LMU 6B FAILURE
H23-RMU-FC-PDT3A	3.00E-04	LMU 6C FAILURE
H23-RMU-FC-PDT4A	3.00E-04	LMU 6D FAILURE
T10-VB_-LK-VB1	1.00E-04	PROBABILITY OF LEAK IN VACUUM BREAKER 1
T10-VB_-LK-VB2	1.00E-04	PROBABILITY OF LEAK IN VACUUM BREAKER 2
T10-VB_-LK-VB3	1.00E-04	PROBABILITY OF LEAK IN VACUUM BREAKER 3
T10-VB_-OO-VB1	1.00E-04	VACUUM BREAKER 1 FAILS TO CLOSE

Table 4.18-7

List of System Basic Events

Basic Event	Probability	Description
T10-VB_-OO-VB2	1.00E-04	VACUUM BREAKER 2 FAILS TO CLOSE
T10-VB_-OO-VB3	1.00E-04	VACUUM BREAKER 3 FAILS TO CLOSE
B21-ACV-OO-F001A	2.00E-03	NOV F001A FAILS TO OPERATE TO DEENER. POSITION.
B21-ACV-OO-F001B	2.00E-03	NOV F001B FAILS TO OPEARTE TO DEENER. POSITION.
B21-ACV-OO-F001C	2.00E-03	NOV F001C FAILS TO OPERATE TO DEENER. POSITION.
B21-ACV-OO-F001D	2.00E-03	NOV F001D FAILS TO OPERATE TO DEENER. POSITION.
B21-ACV-OO-F002A	2.00E-03	AOV F002A FAILS TO OPERATE TO DEENER. POSTION.
B21-ACV-OO-F002B	2.00E-03	AOV F002B FAILS TO OPERATE. TO DENER. POSTION.
B21-ACV-OO-F002C	2.00E-03	AOV F002C FAILS TO OPERATE TO DEENER. POSTION.
B21-ACV-OO-F002D	2.00E-03	AOV F002D FAILS TO OPERATE TO DEENER. POSTION.
B21-UV_-OO-102B	7.96E-03	CHECK VALVE F102B FAILS TO CLOSE
B21-UV_-OO-103B	7.96E-03	CHECK VALVE F103B FAILS TO CLOSE
B21-UV_-OO-F102A	7.96E-03	CHECK VALVE F102A FAILS TO CLOSE
B21-UV_-OO-F103A	7.96E-03	CHECK VALVE F103A FAILS TO CLOSE
B32-ACV-OO-F001A	2.00E-03	MSIV F001A VALVE FAILS TO CLOSE
B32-MOV-OO-F002A	4.00E-03	SOLID STATE LOAD DRIVER LD002 FAILS TO CLOSE
B32-PDT-NO-N001A	3.23E-03	PRESSURE TRANSMITT. 1A IC "A" FAILS TO RESPOND TO CHANGE
B32-PDT-NO-N002A	3.23E-03	PRESSURE TRANSMITT. 2A IC "A" FAILS TO RESPOND TO CHANGE
B32-PDT-NO-N003A	3.23E-03	PRESSURE TRANSMITT. 3A IC "A" FAILS TO RESPOND TO CHANGE
B32-PDT-NO-N004A	3.23E-03	PRESSURE TRANSMITT. 4A IC "A" FAILS TO RESPOND TO CHANGE
C74-DTM-FC-DIV1	6.00E-04	DTM OF SSLC DIV 1 FAILS TO TRIP
C74-DTM-FC-DIV2	6.00E-04	DTM OF SSLC DIV. 2 FAILS TO TRIP
C74-DTM-FC-DIV3	6.00E-04	DTM OF SSLC DIV. 3 FAILS TO TRIP
C74-DTM-FC-DIV4	6.00E-04	DTM OF SSLC DIV. 4 FAILS TO TRIP

Table 4.18-7

List of System Basic Events

Basic Event	Probability	Description
C74-SLU-FC-LMU10D	9.00E-04	LMU 10 D FAILURE
C74-SLU-FC-OLURTIF1	9.00E-04	OLU OF SSLC/RTIF DIV 1 FAILS
C74-SLU-FC-OLURTIF2	9.00E-04	OLU OF SSLC/RTIF DIV 2 FAILS
C74-SLU-FC-OLURTIF3	9.00E-04	OLU OF SSLC/RTIF DIV 3 FAILS
C74-SLU-FC-OLURTIF4	9.00E-04	OLU OF SSLC/RTIF DIV 4 FAILS
C74-SLU-FC-TLURTIF1	9.00E-04	TLU OF SSLC/RTIF DIV 1 FAILS

Table 4.18-8

System Top Events

TOP EVENT	Description
GT10-0001-_1	ISOLATION OF VB LEAKS FAILS
GT10-0001-_2	STEAM SUPRESSION FUNCTION FAILURE
GT10-0001-_4	ICS ISOLATION FAILURE LOCA OUTSIDE CONTAINMENT
GT10-0001-_5	MAIN FEEDWATER LINE A ISOLATION FAILURE
GT10-0001-_6	MAIN FEEDWATER LINE B ISOLATION FAILURE
GT10-0001-_7	RWCU/SDC ISOLATION FAILURE LOCA IN TRAIN A OUTSIDE CONT.
GT10-0001-_9	MSL ISOLATION FAILURE LOCA OUTSIDE CONTAINMENT

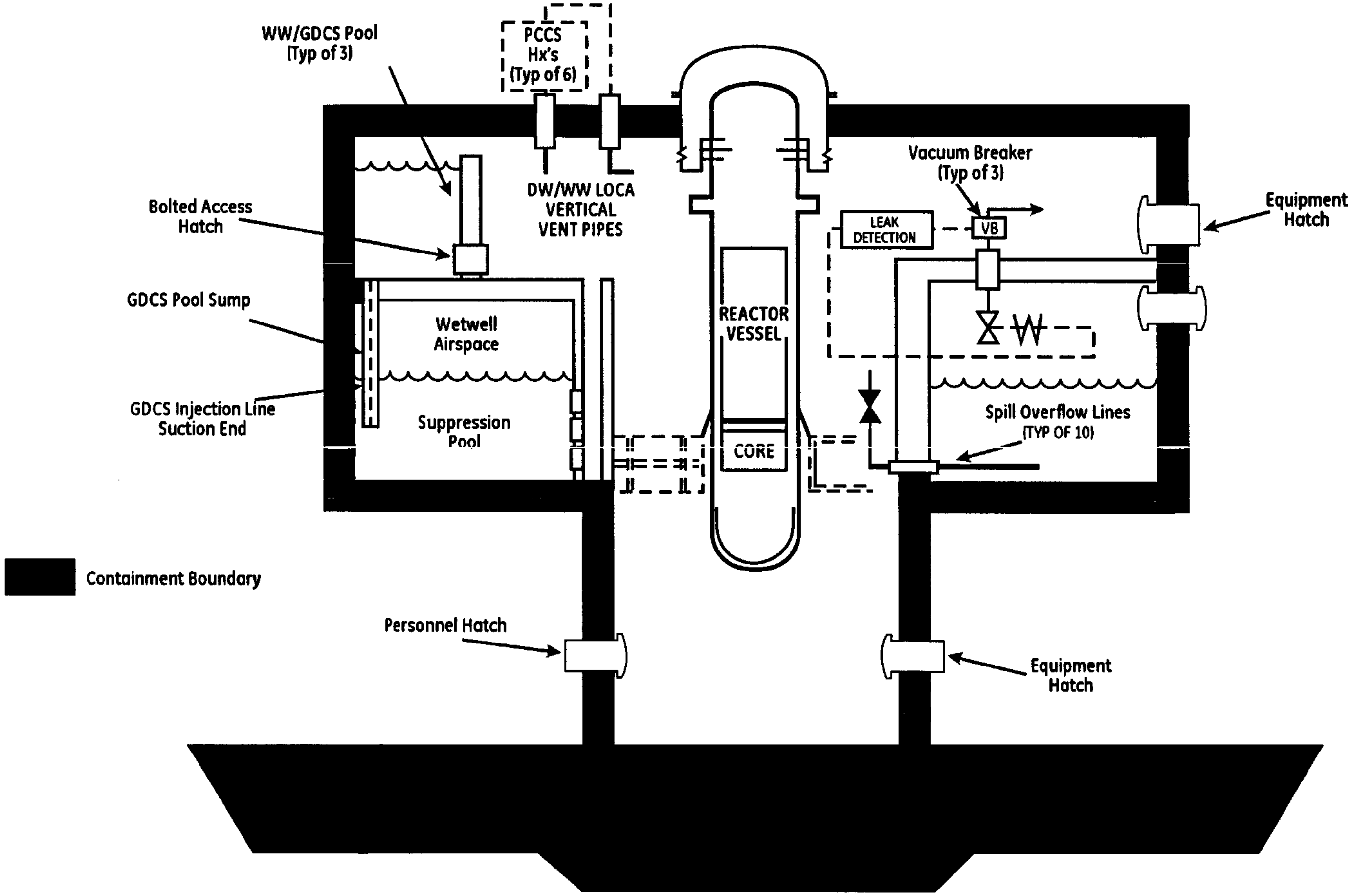
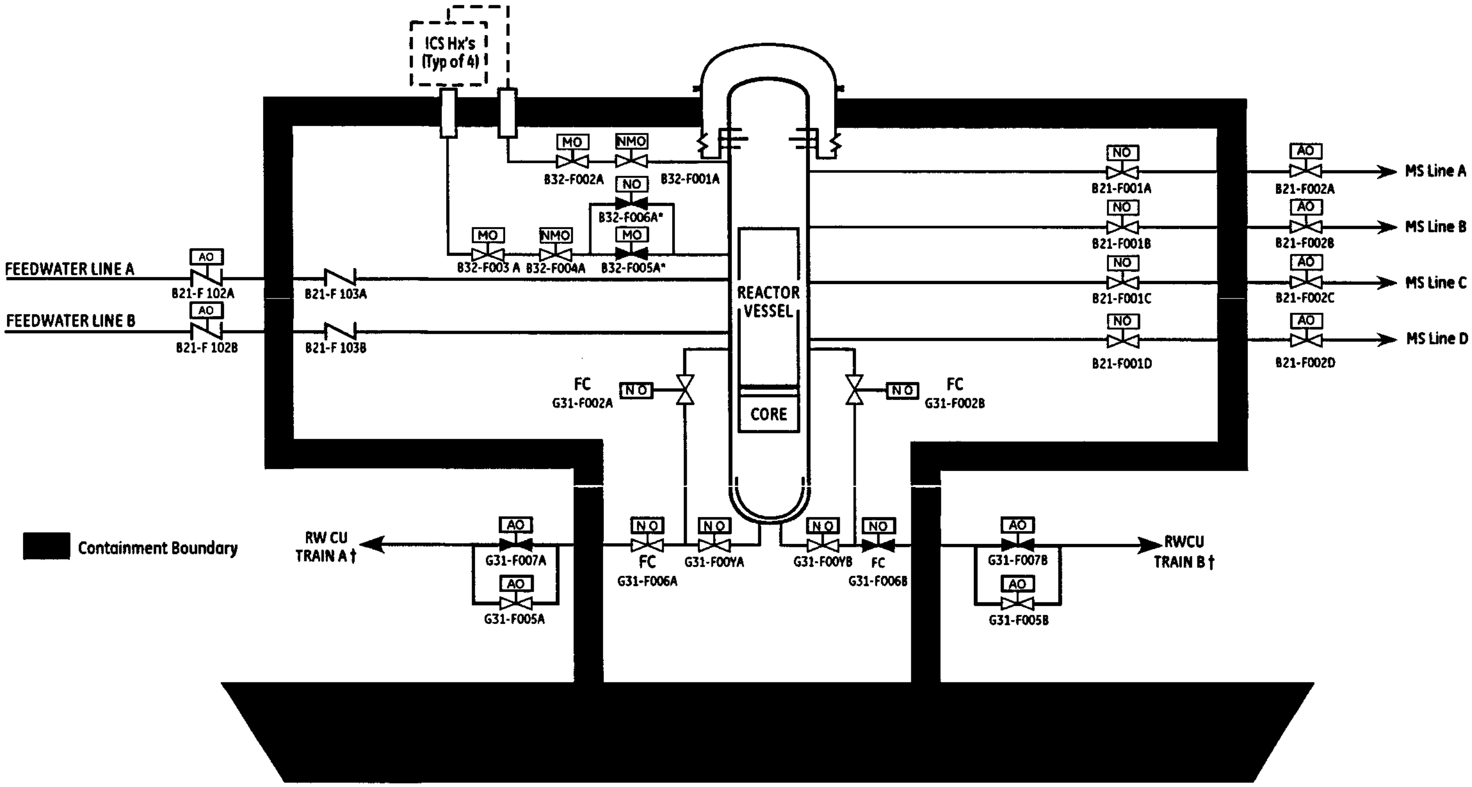


Figure 4.18-1 (1/2). Containment System Simplified Diagram



* Not containment isolation valves. Shown for clarity.

† Upper and lower RWCU paths actually have separate penetrations. For PRA purposes the model is functionally similar.

Figure 4.18-1 (2/2). Containment System Simplified Flow Diagram

4.19 PASSIVE CONTAINMENT COOLING SYSTEM - (T15)

4.19.1 Purpose

The PCCS is a safety-related passive-acting containment heat removal system that maintains the containment within its design pressure and design temperature limits for design basis accidents (DBAs). The PCCS consists of six (6) independent loops, each loop arranged as a closed-loop configuration containing a heat exchanger (PCCS condenser), supply piping to bring containment steam-gas mixture to the loop heat exchanger, discharge piping to return condensed steam back into the containment, and vent piping to recycle non-condensable gas back inside the containment. The condensed steam is drained to the Gravity Driven Cooling System (GDCS) pool and the gas is vented through a line that is submerged in the suppression pool. The heat exchangers are positioned in the lower-most region of a large, elevated, common, ambient pressure pool - Isolation Condenser/Passive Containment Cooling (IC/PCC) Pool - that warms and ultimately boils-down, with exhaust vapor discharged to the plant stack as containment heat removal proceeds following a LOCA. The heat exchangers are open-type drum-and-tube-bundle exchangers, configured into a dual-module arrangement and operated by a combination of buoyancy, pressure and condensation-driven natural circulation processes.

A schematic diagram of PCCS is shown in Figure 4.19-1. The PCCS is classified as an Engineered Safety Feature (ESF). PCCS piping conveys containment steam/non-condensable (nitrogen) mixture to the upper drums of each HX module. Heat is moved to the IC/PCC pool by condensing the steam component inside the vertical tubes. As bulk pool water warms and eventually boils, secondary (non-radioactive) steam is vented through moisture separators to the surroundings.

Condensate drains from the tubes into the HX module lower drums, where it is collected and drained to the GDCS pool. Loop seals in these drain lines insure that PCCS inflow is via the steam supply line to the top of the HXs. Non-condensable gas along with a small proportion of water vapor is piped to a discharge point within the SP and provides continuous purging of any non-condensable gases accumulating within the HX tube bundle regions.

This system design needs no isolation valves, as the HX modules and piping, as extensions of the safety-related containment, are designed for pressures of approximately twice the containment design pressure, and are designed to match the containment design temperature. No actuation valves are needed, since both condensate and non-condensable vent points discharge into containment spaces/volumes, and thus, the system is always available (i.e., in "ready standby" condition). Since it does not have any valves, the system starts into operation immediately following a LOCA event and limits containment pressure to less than its design pressure for at least 72 hours after a LOCA without operator action. The PCCS loops are initially driven by the pressure difference created between the containment drywell and the suppression pool during a LOCA and then by gravity drainage of steam condensed in the tubes, so they require no sensing, control, logic or power-actuated devices to function. In general, PCCS operation is characterized by steam and non-condensable gases entering the HX, condensation of the steam with drain flow to the GDCS pool, and collection of the non-condensable gases in the lower portion of the HX tubes and lower headers with periodic, naturally-occurring venting to the WW. In the long term, when virtually all non-condensable gas has been purged to the WW, the operation of the HX is

characterized by an interface within the tubes with almost pure steam above the interface and a rich mixture of non-condensable gases and steam below the interface. The interface gradually moves upward to compensate for the decreasing decay heat generation rate.

4.19.2 Design Assumptions

The following assumptions with respect to the design were made:

(1) Water in the IC/PCC pools provides the necessary cooling for greater than 24 hours.

(2) Connections with a makeup or cooling system are also provided as a back up to ensure cooling for up to 72 hours.

4.19.3 System Description

The system is assumed to operate as described in Reference 4.19-1.

4.19.3.1 Hardware Configuration

Passive Containment Cooling System (PCCS)

The PCCS consists of six (6), low pressure, independent loops, each containing a condenser located in the same large, interconnected IC/PCC pools as the isolation condensers. A simplified diagram is shown in Figure 4.19-1.

The PCCS operates by natural recirculation. Each PCCS loop has no valves; therefore, the system is always in "ready standby."

Each PCCS condenser is open to the primary containment and receives a steam-gas mixture directly from the drywell. The condensate is drained to the Gravity Driven Cooling System (GDCS) pool and the gas is vented through a discharge line, which is submerged in the pressure suppression pool. The water is returned directly to the RPV through the opened GDCS injection lines.

IC/PCC Pool

The isolation condensers and the passive containment cooling condensers are located in the same large interconnected IC/PCC water pools positioned outside the containment and above the drywell. The large IC/PCC pools are partitioned, but both the IC and PCC are able to draw water from the entire pool; the air and steam space are also common. See Figure 4.19-2.

The pool subcompartment interconnections are as follows: The PCCS pool subcompartments are connected to the outer pool below the water level by locked open valves, one for each subcompartment. These valves can be closed to isolate and drain the individual partitioned PCC pool for maintenance of the unit. The remote handwheels on the locked open valves extend above the water level to locations accessible to the operator. All other pool subcompartments are interconnected below the pool water level. Cross connects between the two outer pools are via normally closed valves.

The walls containing the airspace flow path extend above the normal water level; this enhances the flow stability and heat removal capability of the condensers by establishing a flow path for the make-up water through the lower pipes.

4.19.3.2 System Operation

During normal plant operation, each PCCS subloop is in "ready standby". The design basis analysis shows that the PCCS can maintain containment below the design pressure for 39 hours without opening the connection to the reactor well. The design requirement is that this time is greater than 24 hours.

Following a LOCA event, the PCCS receives a steam-gas supply directly from the drywell; it does not have any valves. Noncondensibles, together with steam vapor, enter the PCCS condenser where steam condenses inside vertical tubes that allow the condensate collected in the lower header to be discharged later to the GDCS pools. The noncondensibles are then purged to the wetwell through the large vent line.

PCCS effectiveness in containment heat removal requires that a small pressure differential exist between the drywell and wetwell. To this end, the vacuum breakers and wetwells between the DW and WW must be leak tight to maintain this small DW to WW pressure differential.

4.19.3.3 Component Location

Both the ICS and PCCS condenser are located in multiple, large, interconnected pools positioned above, and outside the ESBWR primary containment (drywell).

The large pool is partitioned between the ICS and PCCS condensers, but each is able to draw water from the entire pool; the air and steam space is also open to both.

The PCCS condensers are extensions of the containment boundary.

4.19.4 Automatic and Manual Control

The PCCS does not have instrumentation; Control logic is not needed for successful PCCS.

The automatic valves interconnecting the upper containment pools (Reactor Well and IC/PCC Pools) have a manual backup. Pool water level indication is provided and is used by the operators to indicate when manual initiation of makeup with demineralized water is needed. Manual makeup is thus used to prevent automatic opening of the valves. Make-up water is also available from the Fire Protection System.

4.19.5 Control Room Instrumentation and Alarms

The PCCS is a passive system and does not require instrumentation to initiate its operation. Nevertheless, for the long-term replenishing of the pools, the water level is monitored and alarmed..

A high and low water level alarm, measuring the common pool area is provided as a part of the FAPCS system.

4.19.6 System Interfaces

Support Systems

The system does not require any support system for the modeled function, in the first 24 hours. Water is required for long-term makeup (72h). This appears in the PCCS fault tree model in Appendix B.4.19 as a transfer to the isolation condenser logic.

The Fire Protection System is able to provide makeup water to the IC/PCC pools in the long term and it has been considered in the PCCS fault tree model (transfer to the isolation condenser fault tree).

The Fuel and Auxiliary Pools Cooling System (FAPCS), which provides for the cooling/clean-up of IC/PCC pool water, is a supporting system that does not enter into the fault tree analysis for post accident mitigation.

4.19.7 System Testing

The PCCS System is tested during refueling outages, with an expected interval between tests of 24 months.

4.19.8 System Maintenance

No preventive maintenance actions are expected to be performed during normal plant operation for the PCCS.

Corrective maintenance for tube plugging following the detection of a tube leak is performed during refueling. If there is considerable damage to some component part of the condenser, each module is easily removable after cutting the connecting feed, drain, and vent lines.

The pool water in each isolation condenser or PCC condenser subcompartment is removable without emptying the entire ICS/PCCS pool. The individual partitioned PCC pool is isolated by closing the locked open valve interconnecting it to the other pools and emptying the compartment using a portable pump. This water is discharged into the common pool. To replenish the pool, the normally locked open valve is reopened and the water refills the pool.

4.19.9 Common Cause Failures

Heat exchanger common cause failures within the PCCS are included in the model.

4.19.10 Fault Tree Analysis

The PCCS fault tree is evaluated to determine the system unavailabilities and to identify the components that contribute significantly.

4.19.10.1 Top Event Definitions

The PCCS is analyzed for the following top events:

- Containment Heat Removal Function (Top Event GT15TOP: 3/6 PCCS fail).
- Loss of Pool Water 72 H (Top Event GT15-0032-_1).

Table 4.19-8 reports the list of PCCS top events.

4.19.10.2 Model Assumptions

The success criteria considered is the operation of four (4) of the six (6) heat exchangers. To maintain the cooling function up to 72 hours long-term make-up would be necessary.

Unavailabilities for more than 24 hours due to testing or at power maintenance are not credible.

For purposes of the model, the PCCS includes pool subcompartment interconnections, and excludes pool makeup and water recirculation system. Subcompartment interconnections are normally open and passive and failure is not credible. Failure of water supply up to 72h appears in the model (in Top event GT15-0032-_1) as a transfer to the IC system fault tree, however.

It is necessary for the vacuum breakers to close in order to establish the required differential pressure through the PCCS, and intermittent operation is acceptable. The failure of the vacuum breaker valves of the SP are considered in a separate model (see Section 4.18 of this report).

The system is capable of passively performing its function for at least 24 hours. It is capable of performing its function for longer periods if the IC/PCC pools are refilled. It is assumed that the action of replenishment of inventory is a procedurized action.

The Type C human actions included in the model are included in the Emergency Operating Procedures as well as in other Operating Procedures

4.19.10.3 Fault Tree Description

The fault tree is shown in Appendix B.4.19.

4.19.11 Results of Fault Tree Analysis

The quantification of core damage sequences implicitly includes the contribution of the basic events for this system. This quantification process enables checking the global consistency of the system fault trees and their relationship with the rest of the systems modeled in the PRA.

A summary of the basic events included in the system fault tree are reported in the Table 4.19-7.

The importance measurements obtained from core damage frequency equations allow the identification of the most relevant basic events and system component failures in an integrated context, as well as the determination of their relative importance with respect to the basic events and component failures of the other systems modeled.

4.19.12 Model Differences for 72-Hour Operation

The IC/PCC pools provide sufficient cooling water for 24 hours. To maintain the cooling function beyond that time, it is necessary to interconnect the two outer IC/PCC pools and Reactor Well or to make up the loss of water from the Fire Protection System.

4.19.13 References

4.19-1. ESBWR Design Control Document, 26A6642 Rev. 01

Table 4.19-1

Control Room Instrumentation and Alarms

Note: See 4.19.5

Table 4.19-2

System Dependency Matrix

The system does not require a support system for the modeled function, except for the long-term system when the Fire Protection System or power to the interconnected valves could be necessary. (See 4.19.6)

Table 4.19-3

Component Test

The system is tested during refueling, with an expected interval of 24 months between tests.

Table 4.19-4

Component Maintenance

No preventive maintenance actions are expected to be performed during normal plant operation for the PCCS. See 4.19.8.

Table 4.19-5

List of System Common Cause Failures

Basic Event	Prob	Description
T15-HX_-CF-PLUG	4.36E-05	CCF OF THREE PCCS HX'S

Table 4.19-6

List of System Human Errors

The human errors for pool makeup are included by transfers to the IC system fault tree. See IC discussion, Section 4.2.

Table 4.19-7

List of System Basic Events

Basic Event	Probability	Description
T10-VB_-LK-VBKRS	8.00E-04	LEAKAGE OF THE VACUUM BREAKERS IN DW/WW [# 9]
T15-HX_-CF-PLUG	4.36E-05	CCF OF THREE PCCS HX'S
T15-HX_-PG-B001A	1.90E-02	HEAT EXCHANGER B001A (PLUGGED)
T15-HX_-PG-B001B	1.90E-02	HEAT EXCHANGER B001B (PLUGGED)
T15-HX_-PG-B001C	1.90E-02	HEAT EXCHANGER B001C (PLUGGED)
T15-HX_-PG-B001D	1.90E-02	HEAT EXCHANGER B001D (PLUGGED)
T15-HX_-PG-B001E	1.90E-02	HEAT EXCHANGER B001E (PLUGGED)
T15-HX_-PG-B001F	1.90E-02	HEAT EXCHANGER B001F (PLUGGED)
XXX-POL-RP-IC/PCC	3.00E-07	LOSS OF IC/PCC POOL WATER DUE TO BREAK DURING ACCIDENT

Table 4.19-8

List of System Top Events

Top Event Name	Description
GT15TOP	3/6 PCCS FAIL
GT15-0032-_1	LOSS OF POOL WATER (72 H)

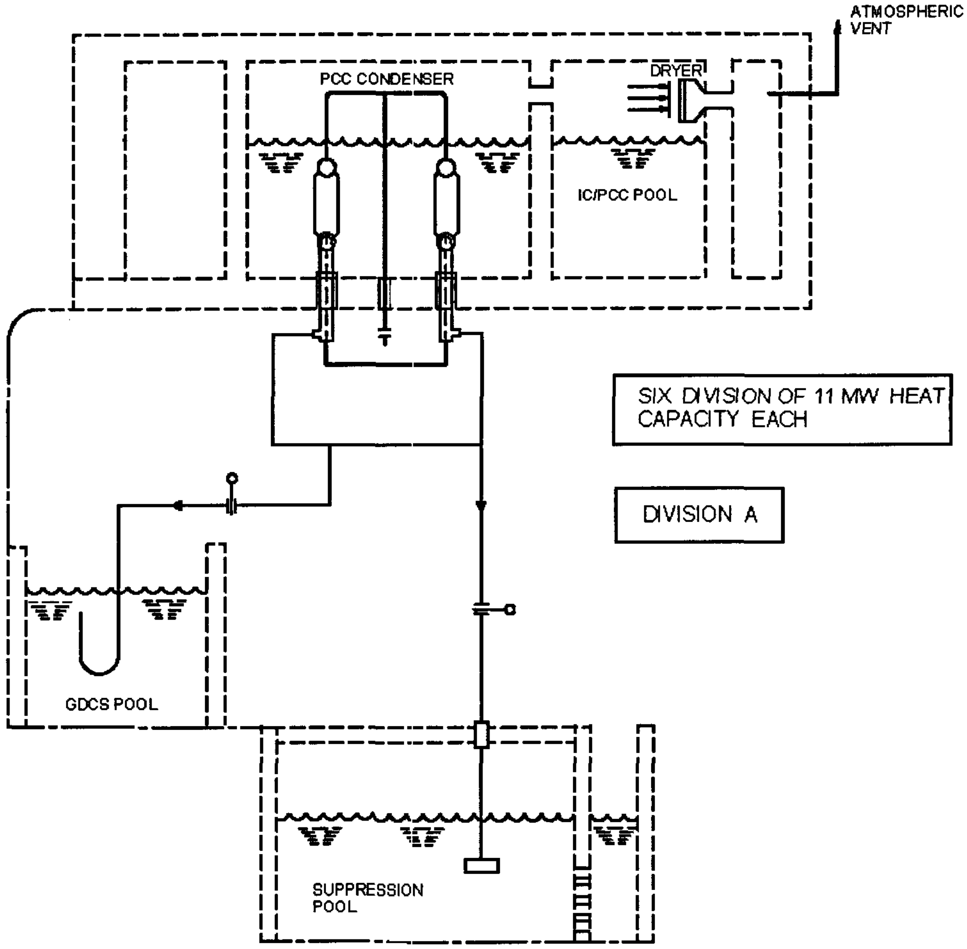


Figure 4.19-1. Simplified Process Flow Diagram for PCCS System

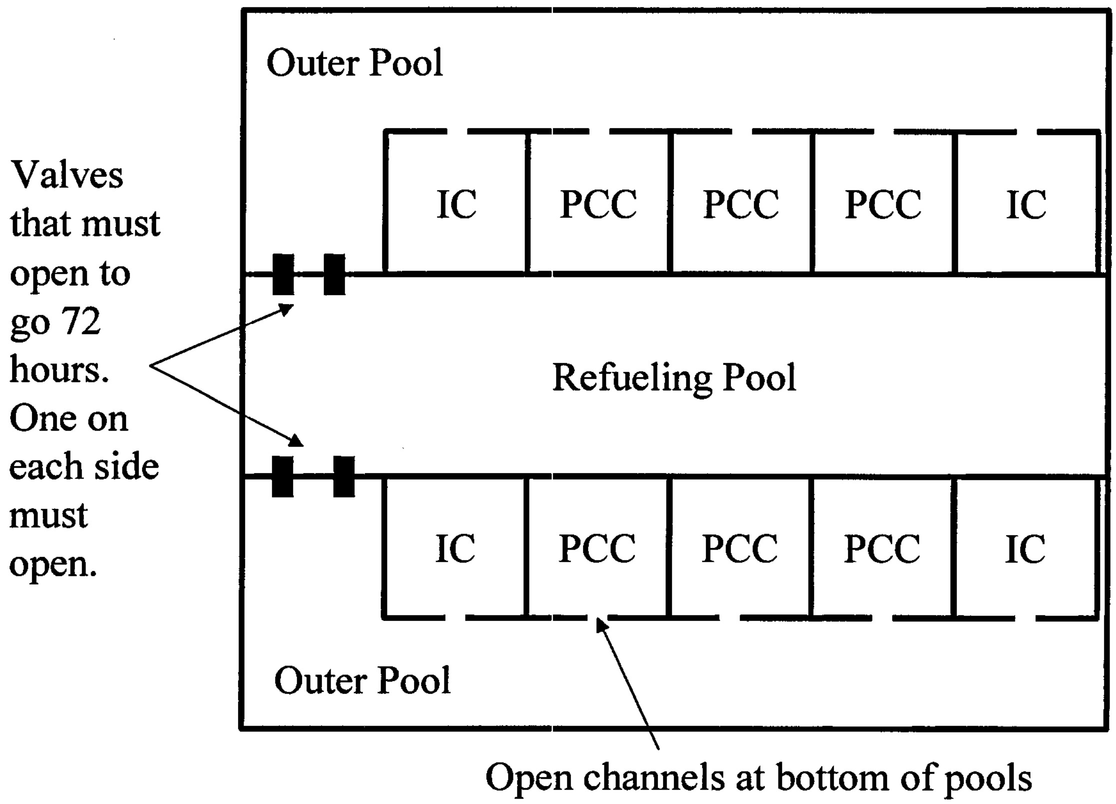


Figure 4.19-2. Schematic of the IC/PCC Pools and Interconnections

Appendix 4.A

Appendix 4.A-1

4.A-1 Initiating Event Naming Convention

Basic events that represent initiating events shall be formatted as follows:

%AAAAAA

Where AAAAA is a descriptive identifier of up to 31 characters.

4.A-2 Basic Event Naming Convention

Basic events that represent individual components shall be named as follows:

XXX-YYY-ZZ-AAAAA

Where the fields are defined as:

XXX	System ID
YYY	Component Type Code
ZZ	Failure Mode
AAAAA	Information to identify the specific component. This should match the identifier on the system sketch, excluding the component code. Use as many digits as necessary up to a total of 21 for this field. The maximum number of characters for the basic event is 32.

Common cause basic events use a similar convention, except that field AAAAA contains the combination of equipment in the CCF group preceded by the number of components in the group. For example, CCF of 3 of 6 GDCS valves F002A, F002B, and F002D would be:

E50-SQV-CF-6F002ABD

Some systems and recoveries may be modeled as undeveloped events. These are named using the same convention, with the following codes:

XXX	System ID
YYY	Use the code "SYS"
ZZ	For an undeveloped system, use "FF". For a recovery action use "NR".
AAAAA	For an undeveloped system, provide a short description of the system.

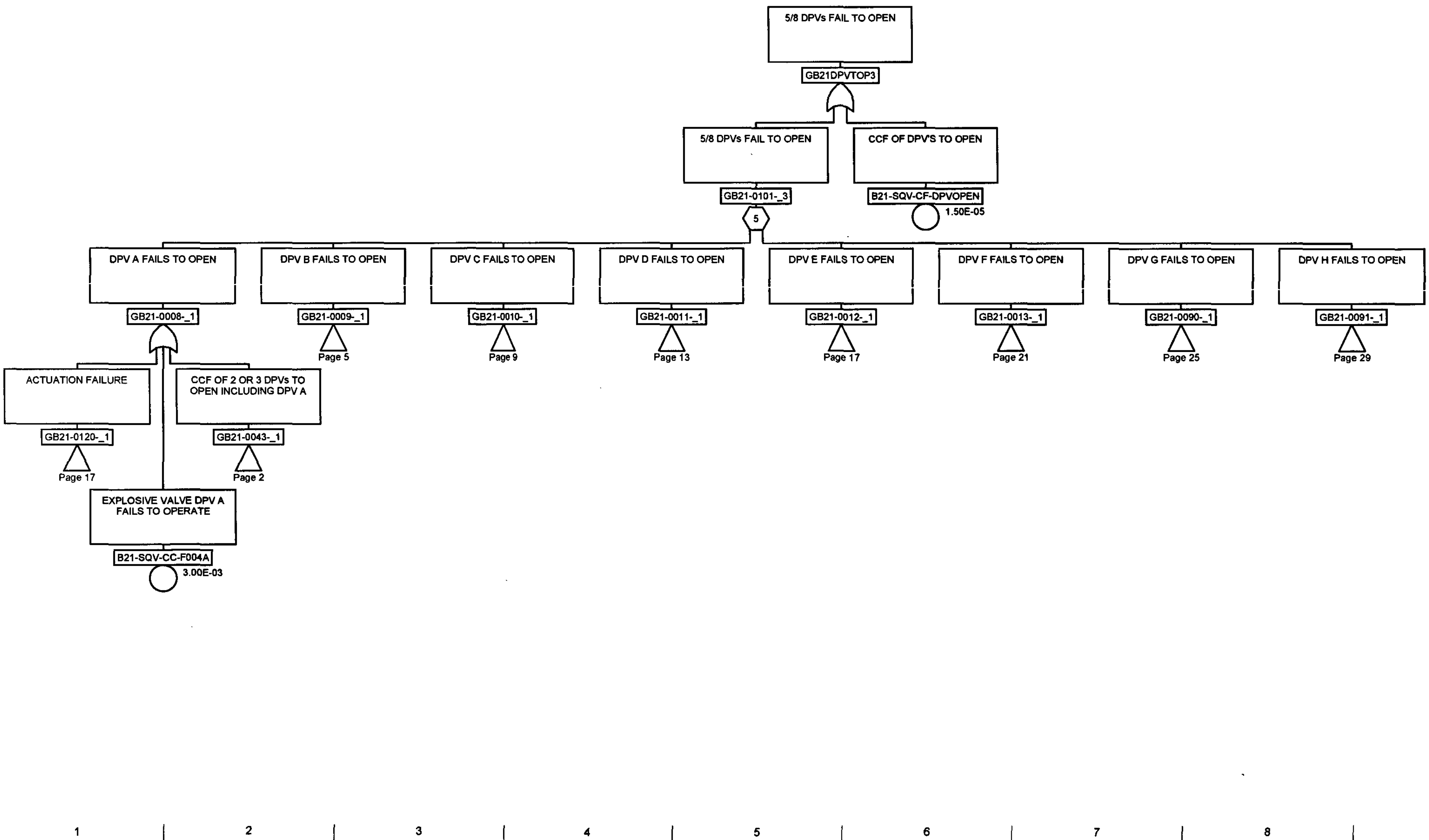
Appendix 4.B
Fault Tree Diagrams

Appendix B Contents

Appendix B.4.1-1

Automatic Depressurization System

Fault Tree



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GB21DPVTOP3
5/8 DPVs FAIL TO OPEN
GB21-0101-_3
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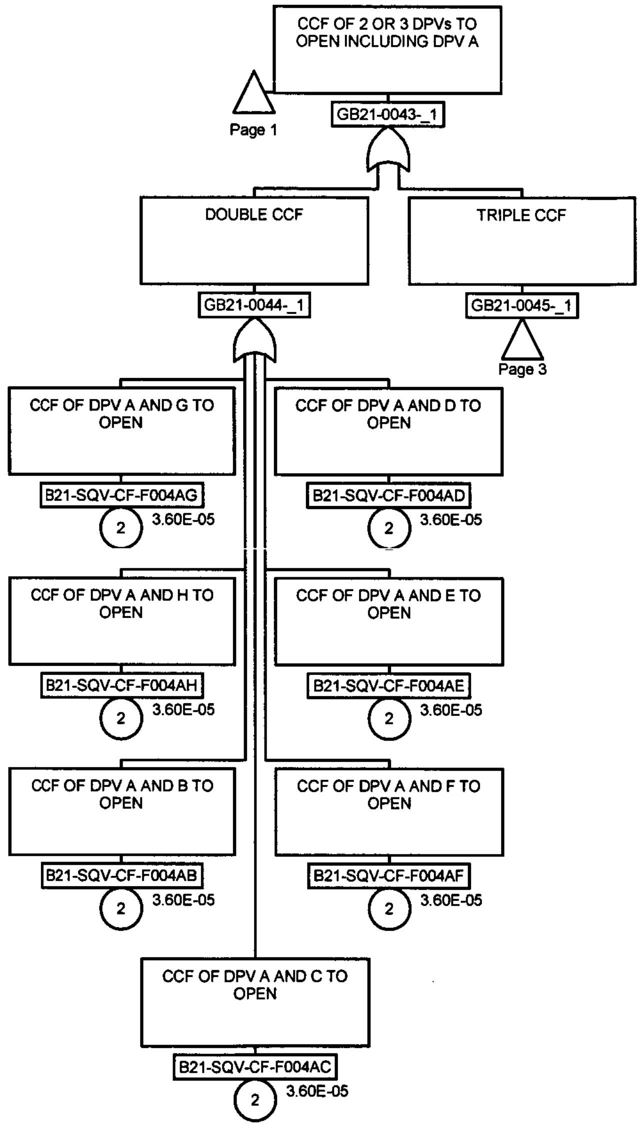
CCF OF DPV'S TO OPEN
B21-SQV-CF-DPVOPEN
1.50E-05
DPV A FAILS TO OPEN
GB21-0008-_1
DPV B FAILS TO OPEN
GB21-0009-_1
Page 5
DPV C FAILS TO OPEN
GB21-0010-_1
Page 9
DPV D FAILS TO OPEN
GB21-0011-_1
Page 13
DPV E FAILS TO OPEN
GB21-0012-_1
Page 17
DPV F FAILS TO OPEN
GB21-0013-_1
Page 21
DPV G FAILS TO OPEN
GB21-0090-_1
Page 25
DPV H FAILS TO OPEN
GB21-0091-_1
Page 29
ACTUATION FAILURE
GB21-0120-_1
Page 17
CCF OF 2 OR 3 DPVs TO OPEN INCLUDING DPV A
GB21-0043-_1
Page 2
EXPLOSIVE VALVE DPV A FAILS TO OPERATE
B21-SQV-CC-F004A
3.00E-03
1
2
3
4
5
6
7
8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DOUBLE CCF
GB21-0044-_1
TRIPLE CCF
GB21-0045-_1
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CCF OF DPV A AND G TO OPEN
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2
3.60E-05
CCF OF DPV A AND D TO OPEN
B21-SQV-CF-F004AD
2
3.60E-05
CCF OF DPV A AND H TO OPEN
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2
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CCF OF DPV A AND E TO OPEN
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3.60E-05
CCF OF DPV A AND B TO OPEN
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2
3.60E-05
CCF OF DPV A AND F TO OPEN
B21-SQV-CF-F004AF
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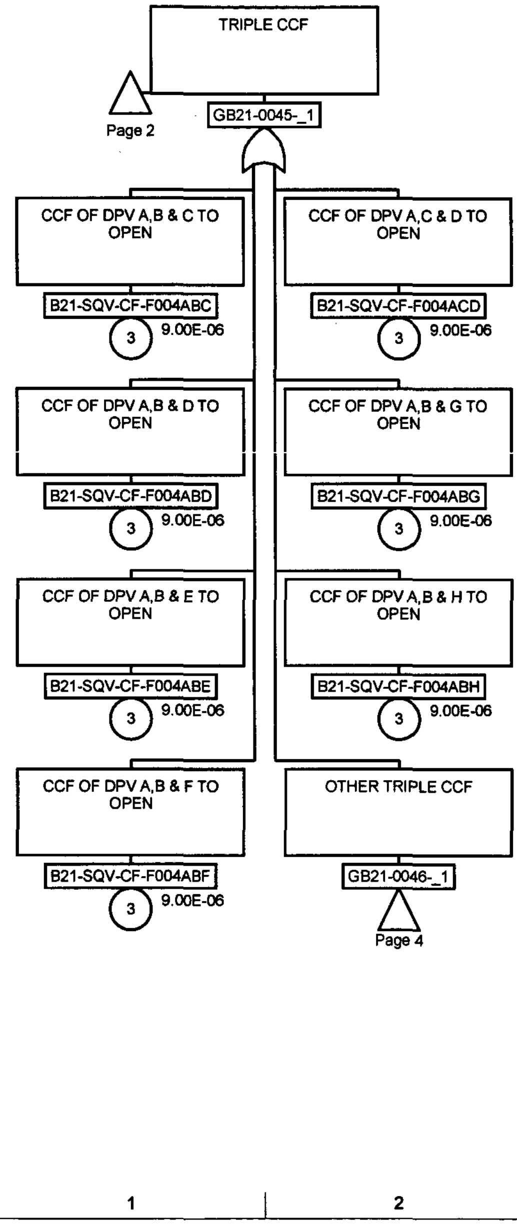
1
2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B21-SQV-CF-F004ACD
3
9.00E-06
CCF OF DPV A,B & D TO OPEN
B21-SQV-CF-F004ABD
3
9.00E-06
CCF OF DPV A,B & G TO OPEN
B21-SQV-CF-F004ABG
3
9.00E-06
CCF OF DPV A,B & E TO OPEN
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CCF OF DPV A,B & H TO OPEN
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CCF OF DPV A,B & F TO OPEN
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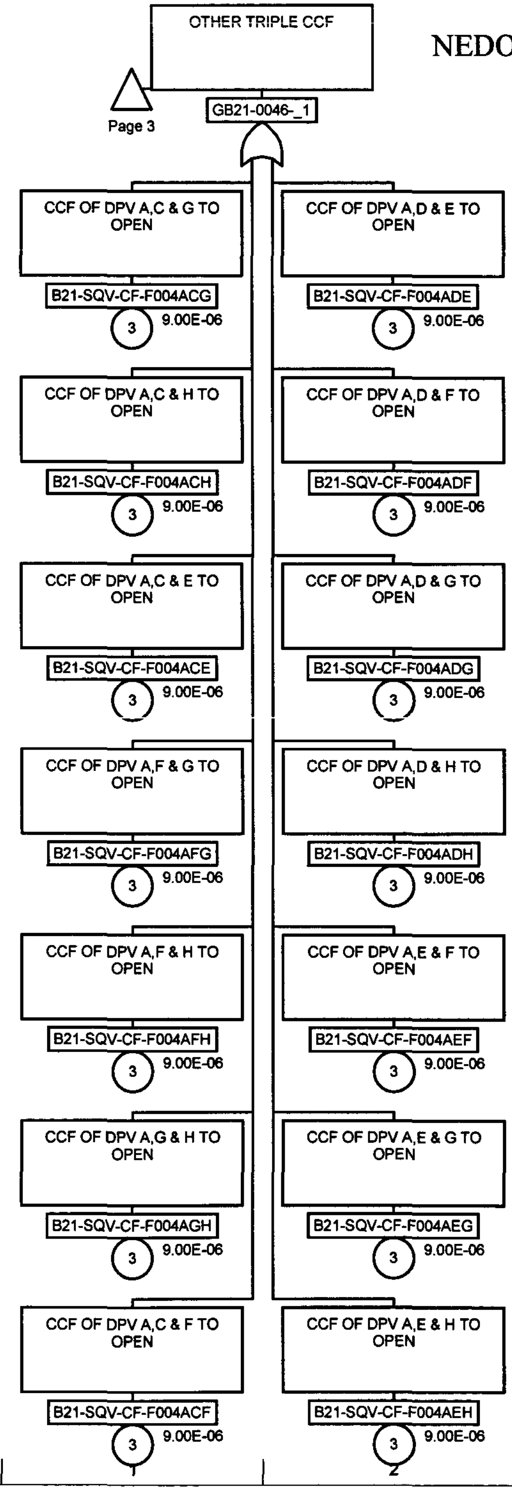
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CCF OF DPV A,D & E TO OPEN
B21-SQV-CF-F004ADE
3
9.00E-06
CCF OF DPV A,C & H TO OPEN
B21-SQV-CF-F004ACH
3
9.00E-06
CCF OF DPV A,D & F TO OPEN
B21-SQV-CF-F004ADF
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9.00E-06
CCF OF DPV A,C & E TO OPEN
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3
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CCF OF DPV A,D & G TO OPEN
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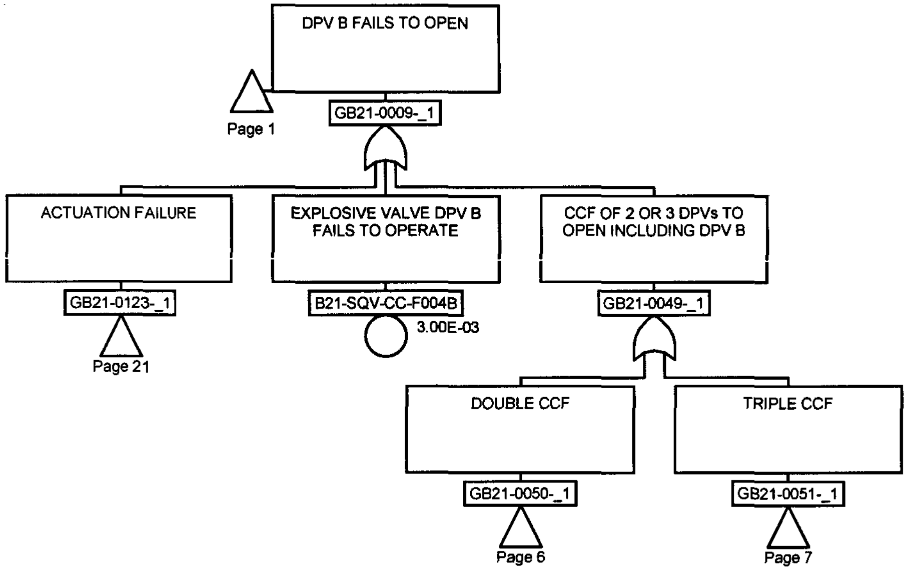
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ACTUATION FAILURE
GB21-0123-_1
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3.00E-03
CCF OF 2 OR 3 DPVs TO OPEN INCLUDING DPV B
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DOUBLE CCF
GB21-0050-_1
Page 6
TRIPLE CCF
GB21-0051-_1
Page 7

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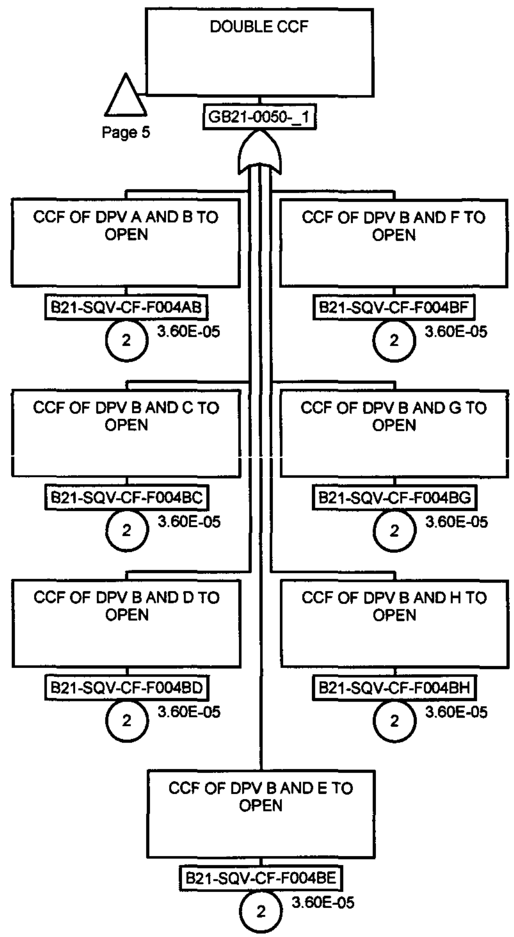
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3.60E-05
CCF OF DPV B AND G TO OPEN
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CCF OF DPV B AND D TO OPEN
B21-SQV-CF-F004BD
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CCF OF DPV B AND H TO OPEN
B21-SQV-CF-F004BH
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3.60E-05
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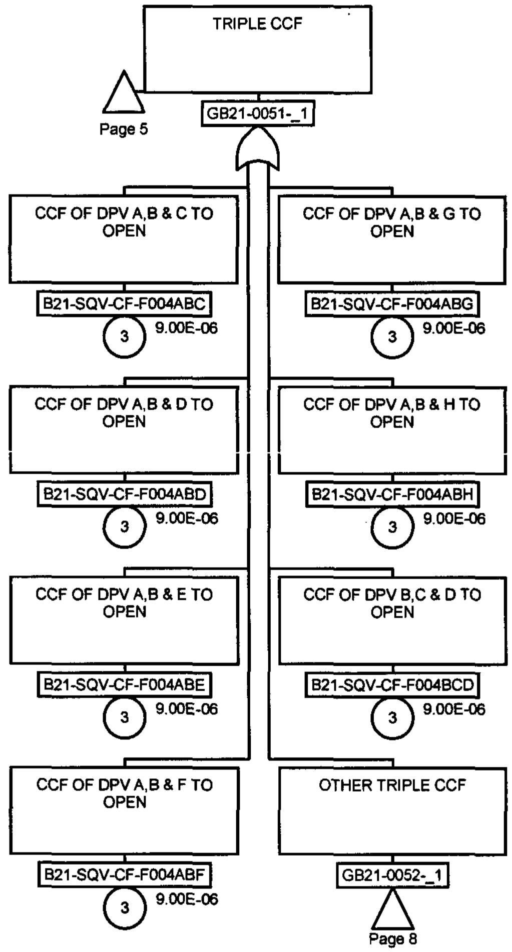
2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CCF OF DPV A,B & F TO OPEN
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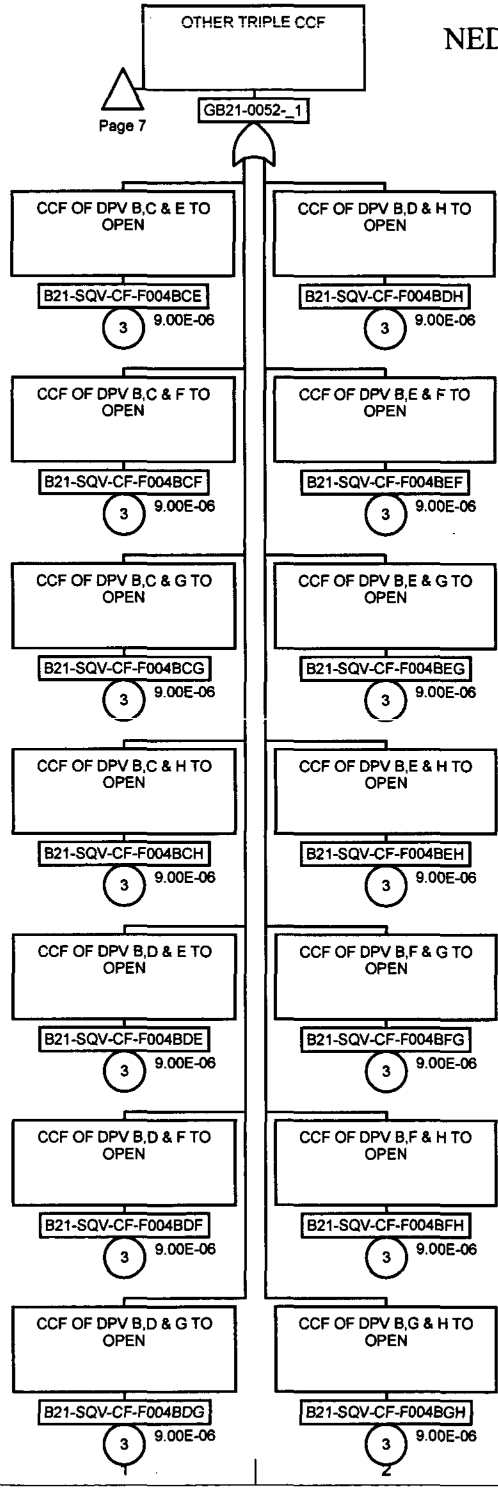
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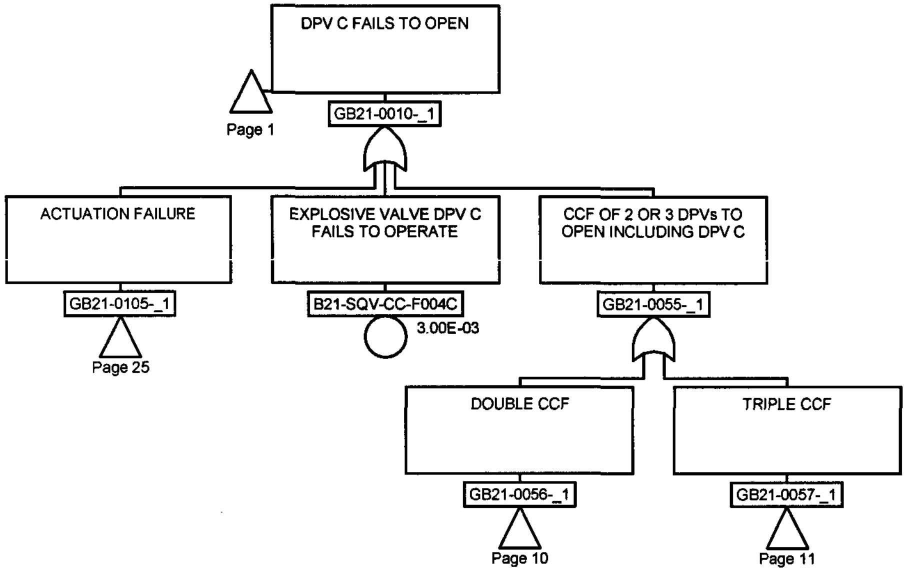
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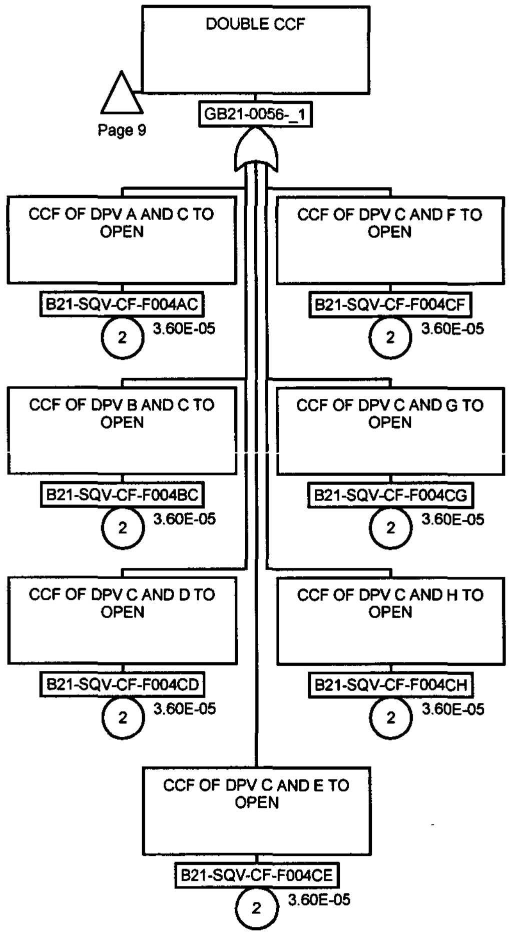
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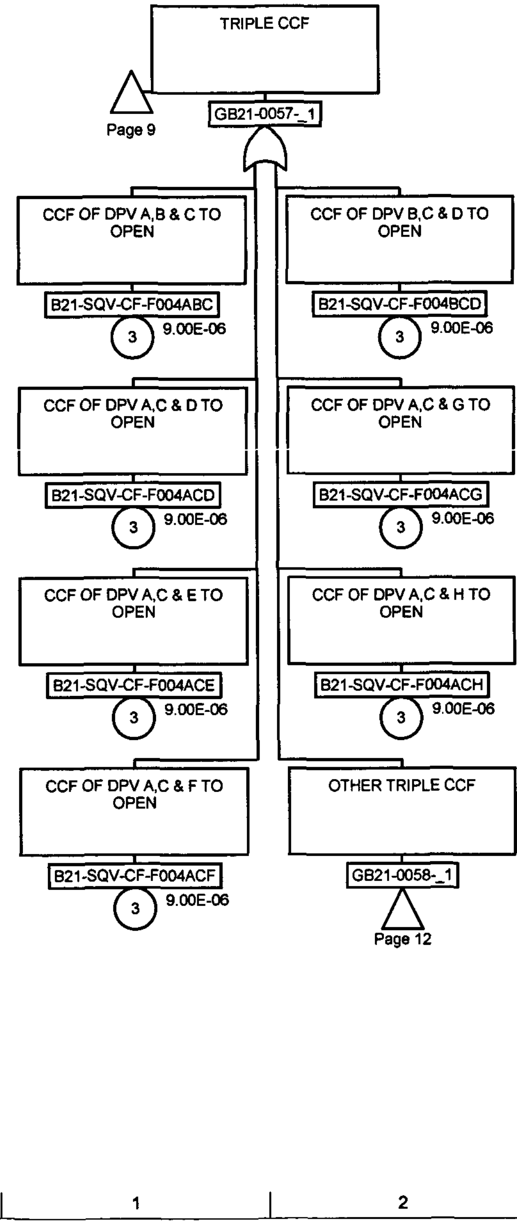
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9.00E-06
CCF OF DPV A,C & E TO OPEN
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CCF OF DPV A,C & F TO OPEN
B21-SQV-CF-F004ACF
3
9.00E-06
OTHER TRIPLE CCF
GB21-0058-_1
Page 12
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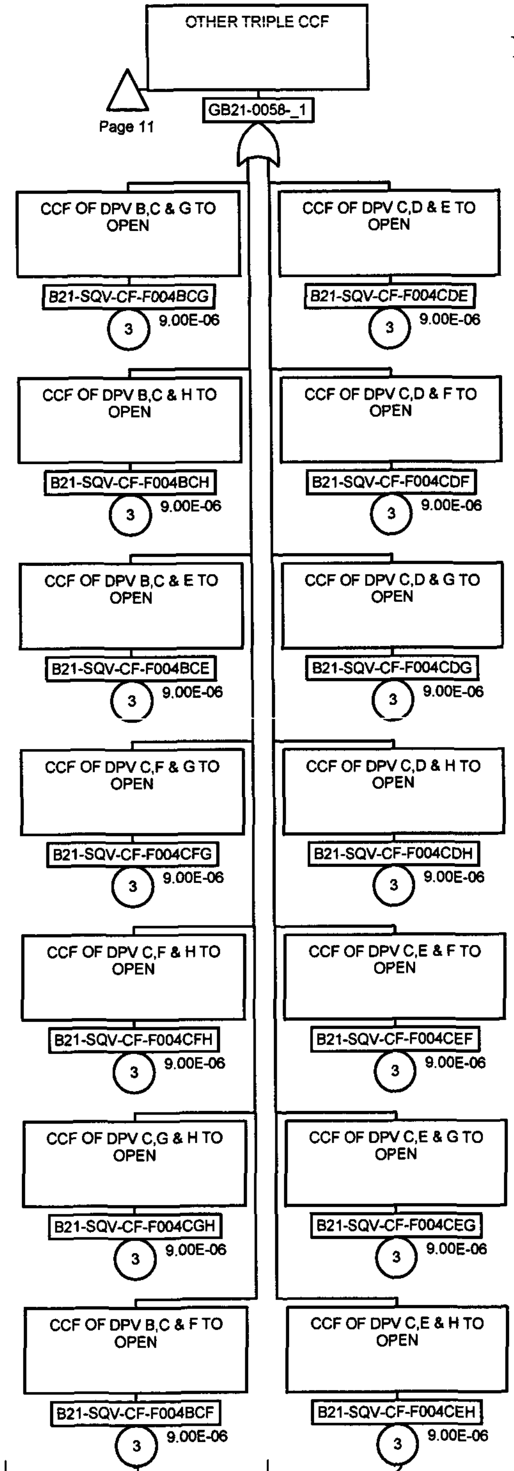
OTHER TRIPLE CCF
GB21-0058-_1
Page 11
CCF OF DPV B,C & G TO OPEN
B21-SQV-CF-F004BCG
3
9.00E-06
CCF OF DPV C,D & E TO OPEN
B21-SQV-CF-F004CDE
3
9.00E-06
CCF OF DPV B,C & H TO OPEN
B21-SQV-CF-F004BCH
3
9.00E-06
CCF OF DPV C,D & F TO OPEN
B21-SQV-CF-F004CDF
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9.00E-06
CCF OF DPV B,C & E TO OPEN
B21-SQV-CF-F004BCE
3
9.00E-06
CCF OF DPV C,D & G TO OPEN
B21-SQV-CF-F004CDG
3
9.00E-06
CCF OF DPV C,F & G TO OPEN
B21-SQV-CF-F004CFG
3
9.00E-06
CCF OF DPV C,D & H TO OPEN
B21-SQV-CF-F004CDH
3
9.00E-06
CCF OF DPV C,F & H TO OPEN
B21-SQV-CF-F004CFH
3
9.00E-06
CCF OF DPV C,E & F TO OPEN
B21-SQV-CF-F004CEF
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9.00E-06
CCF OF DPV C,G & H TO OPEN
B21-SQV-CF-F004CGH
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9.00E-06
CCF OF DPV C,E & G TO OPEN
B21-SQV-CF-F004CEG
3
9.00E-06
CCF OF DPV B,C & F TO OPEN
B21-SQV-CF-F004BCF
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CCF OF DPV C,E & H TO OPEN
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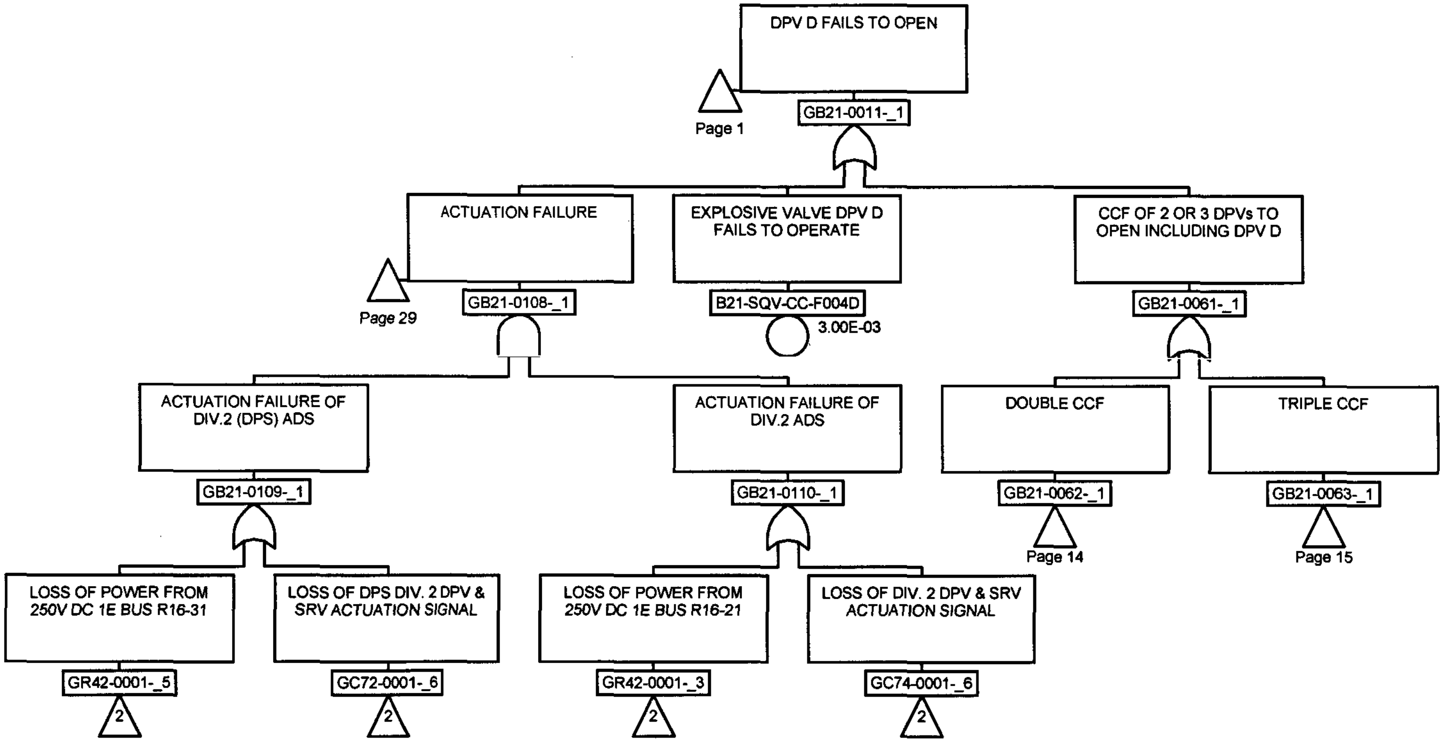
DPV D FAILS TO OPEN
Page 1
GB21-0011-_1
ACTUATION FAILURE
Page 29
GB21-0108-_1
EXPLOSIVE VALVE DPV D FAILS TO OPERATE
B21-SQV-CC-F004D
3.00E-03
CCF OF 2 OR 3 DPVs TO OPEN INCLUDING DPV D
GB21-0061-_1
ACTUATION FAILURE OF DIV.2 (DPS) ADS
GB21-0109-_1
ACTUATION FAILURE OF DIV.2 ADS
GB21-0110-_1
DOUBLE CCF
GB21-0062-_1
Page 14
TRIPLE CCF
GB21-0063-_1
Page 15
LOSS OF POWER FROM 250V DC 1E BUS R16-31
GR42-0001-_5
2
LOSS OF DPS DIV. 2 DPV & SRV ACTUATION SIGNAL
GC72-0001-_6
2
LOSS OF POWER FROM 250V DC 1E BUS R16-21
GR42-0001-_3
2
LOSS OF DIV. 2 DPV & SRV ACTUATION SIGNAL
GC74-0001-_6
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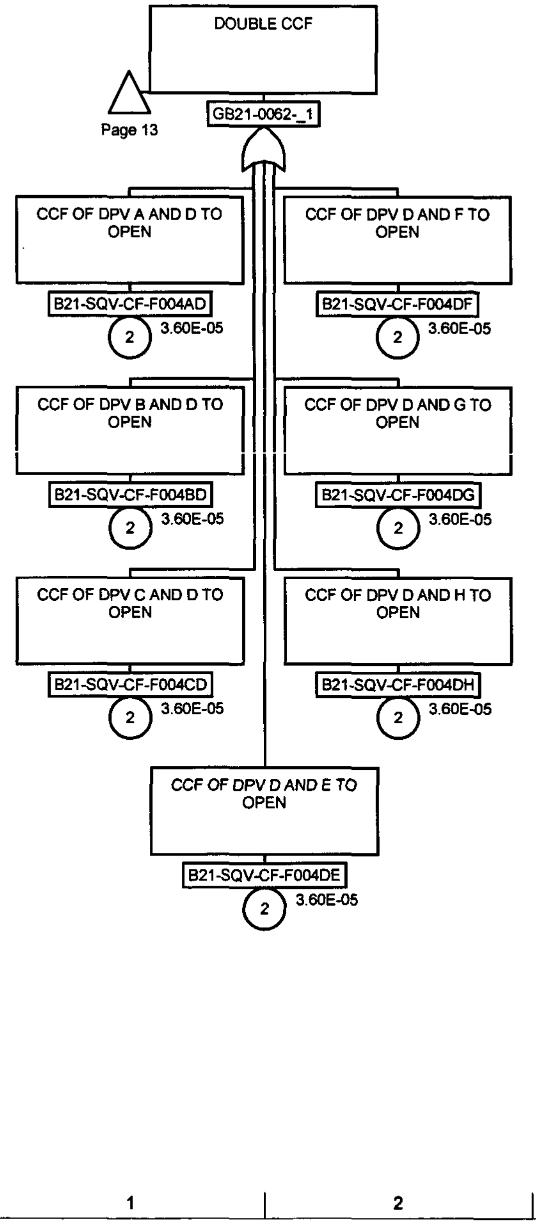
DOUBLE CCF
GB21-0062-_1
Page 13
CCF OF DPV A AND D TO OPEN
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3.60E-05
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B21-SQV-CF-F004DF
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3.60E-05
CCF OF DPV B AND D TO OPEN
B21-SQV-CF-F004BD
2
3.60E-05
CCF OF DPV D AND G TO OPEN
B21-SQV-CF-F004DG
2
3.60E-05
CCF OF DPV C AND D TO OPEN
B21-SQV-CF-F004CD
2
3.60E-05
CCF OF DPV D AND H TO OPEN
B21-SQV-CF-F004DH
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CCF OF DPV D AND E TO OPEN
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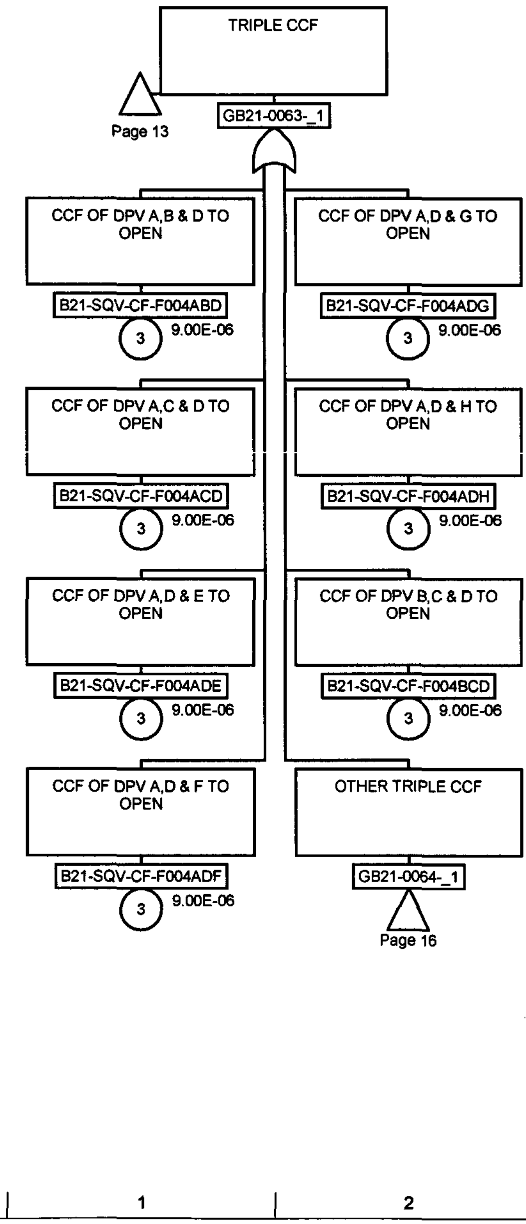
TRIPLE CCF
GB21-0063-_1
Page 13
CCF OF DPV A,B & D TO OPEN
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9.00E-06
CCF OF DPV A,D & G TO OPEN
B21-SQV-CF-F004ADG
3
9.00E-06
CCF OF DPV A,C & D TO OPEN
B21-SQV-CF-F004ACD
3
9.00E-06
CCF OF DPV A,D & H TO OPEN
B21-SQV-CF-F004ADH
3
9.00E-06
CCF OF DPV A,D & E TO OPEN
B21-SQV-CF-F004ADE
3
9.00E-06
CCF OF DPV B,C & D TO OPEN
B21-SQV-CF-F004BCD
3
9.00E-06
CCF OF DPV A,D & F TO OPEN
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GB21-0064-_1
Page 16
1
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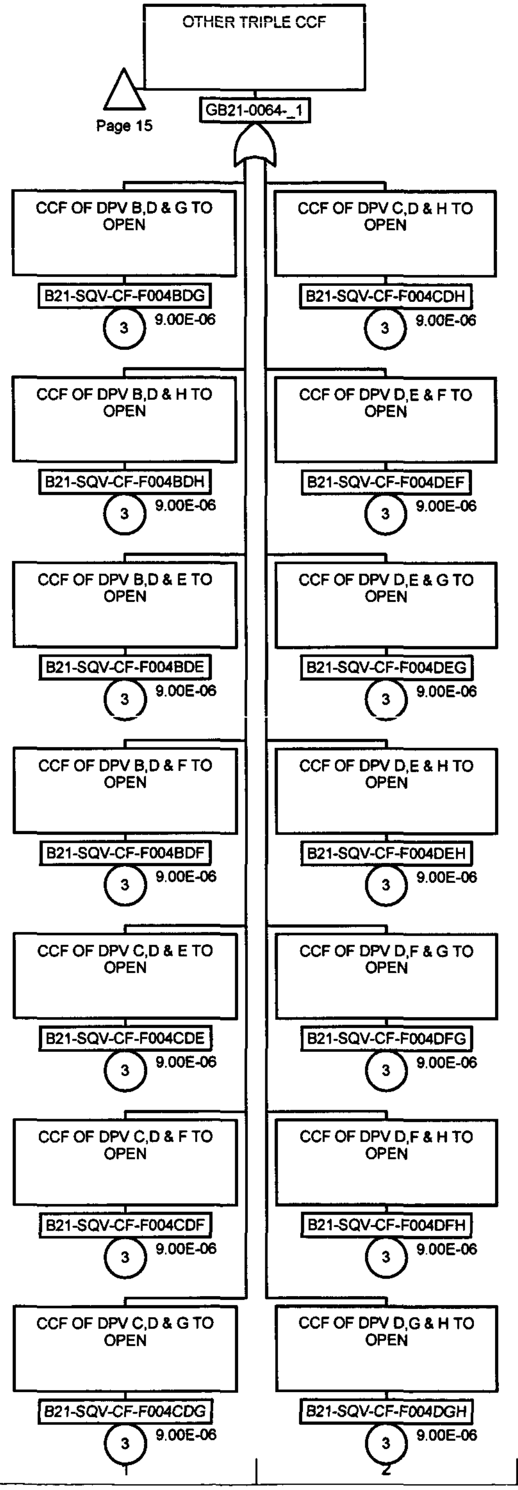
OTHER TRIPLE CCF
GB21-0064-_1
Page 15
CCF OF DPV B,D & G TO OPEN
B21-SQV-CF-F004BDG
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9.00E-06
CCF OF DPV C,D & H TO OPEN
B21-SQV-CF-F004CDH
3
9.00E-06
CCF OF DPV B,D & H TO OPEN
B21-SQV-CF-F004BDH
3
9.00E-06
CCF OF DPV D,E & F TO OPEN
B21-SQV-CF-F004DEF
3
9.00E-06
CCF OF DPV B,D & E TO OPEN
B21-SQV-CF-F004BDE
3
9.00E-06
CCF OF DPV D,E & G TO OPEN
B21-SQV-CF-F004DEG
3
9.00E-06
CCF OF DPV B,D & F TO OPEN
B21-SQV-CF-F004BDF
3
9.00E-06
CCF OF DPV D,E & H TO OPEN
B21-SQV-CF-F004DEH
3
9.00E-06
CCF OF DPV C,D & E TO OPEN
B21-SQV-CF-F004CDE
3
9.00E-06
CCF OF DPV D,F & G TO OPEN
B21-SQV-CF-F004DFG
3
9.00E-06
CCF OF DPV C,D & F TO OPEN
B21-SQV-CF-F004CDF
3
9.00E-06
CCF OF DPV D,F & H TO OPEN
B21-SQV-CF-F004DFH
3
9.00E-06
CCF OF DPV C,D & G TO OPEN
B21-SQV-CF-F004CDG
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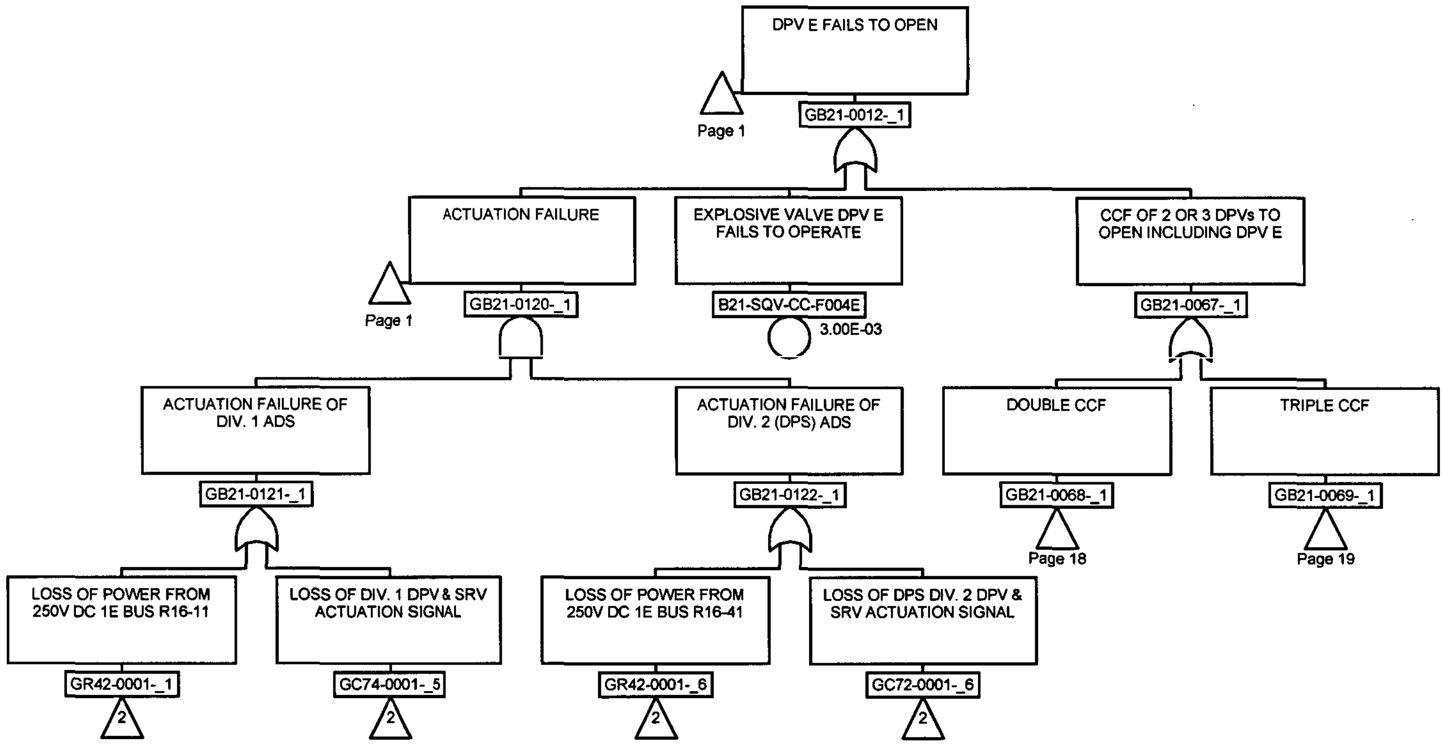
2


DPV E FAILS TO OPEN
Page 1
GB21-0012-_1
ACTUATION FAILURE
Page 1
GB21-0120-_1
EXPLOSIVE VALVE DPV E FAILS TO OPERATE
B21-SQV-CC-F004E
3.00E-03
CCF OF 2 OR 3 DPVs TO OPEN INCLUDING DPV E
GB21-0067-_1
ACTUATION FAILURE OF DIV. 1 ADS
GB21-0121-_1
ACTUATION FAILURE OF DIV. 2 (DPS) ADS
GB21-0122-_1
DOUBLE CCF
GB21-0068-_1
Page 18
TRIPLE CCF
GB21-0069-_1
Page 19
LOSS OF POWER FROM 250V DC 1E BUS R16-11
GR42-0001-_1
2
LOSS OF DIV. 1 DPV & SRV ACTUATION SIGNAL
GC74-0001-_5
2
LOSS OF POWER FROM 250V DC 1E BUS R16-41
GR42-0001-_6
2
LOSS OF DPS DIV. 2 DPV & SRV ACTUATION SIGNAL
GC72-0001-_6
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3
4
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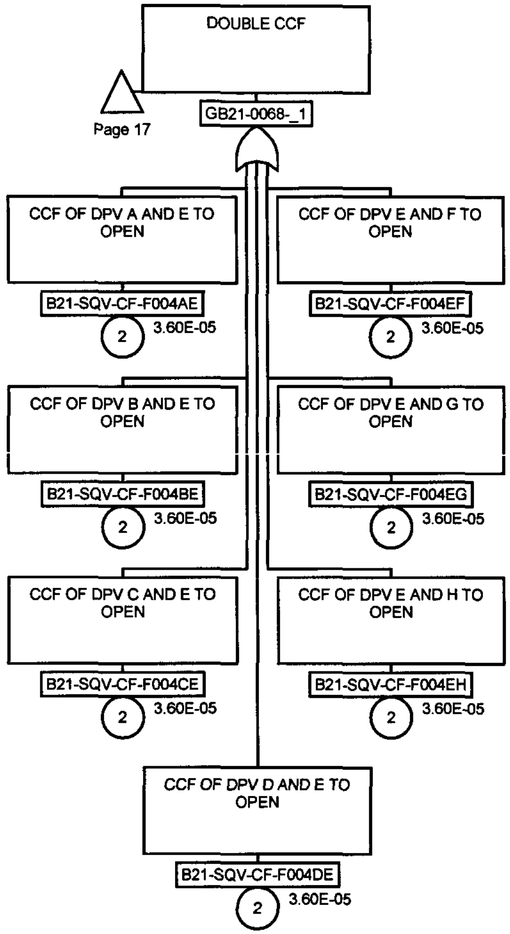
DOUBLE CCF
GB21-0068-_1
Page 17
CCF OF DPV A AND E TO OPEN
B21-SQV-CF-F004AE
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3.60E-05
CCF OF DPV E AND F TO OPEN
B21-SQV-CF-F004EF
2
3.60E-05
CCF OF DPV B AND E TO OPEN
B21-SQV-CF-F004BE
2
3.60E-05
CCF OF DPV E AND G TO OPEN
B21-SQV-CF-F004EG
2
3.60E-05
CCF OF DPV C AND E TO OPEN
B21-SQV-CF-F004CE
2
3.60E-05
CCF OF DPV E AND H TO OPEN
B21-SQV-CF-F004EH
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3.60E-05
CCF OF DPV D AND E TO OPEN
B21-SQV-CF-F004DE
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3.60E-05
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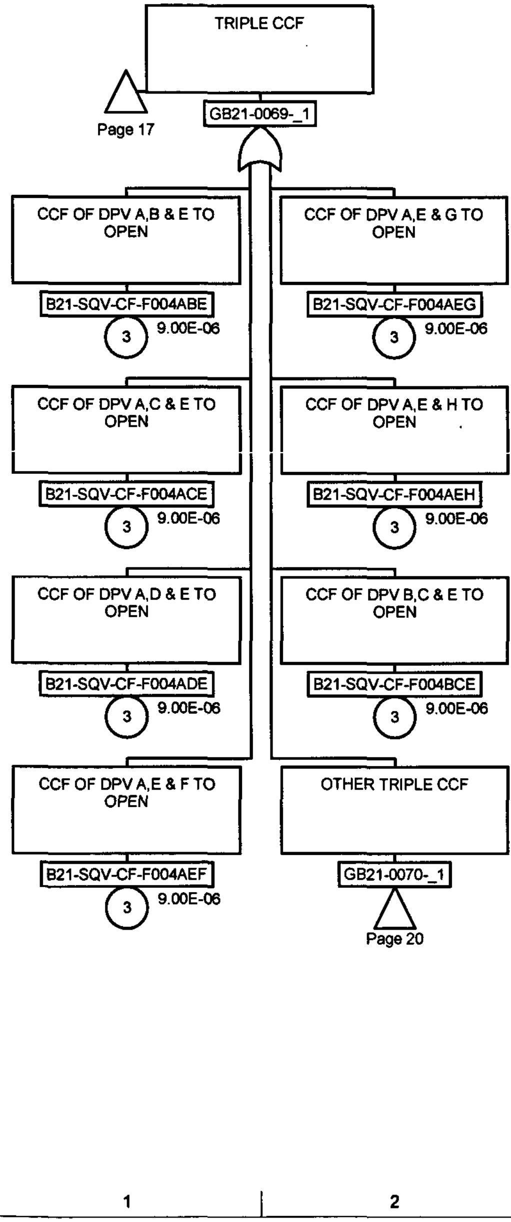
2


TRIPLE CCF
GB21-0069-_1
Page 17
CCF OF DPV A,B & E TO OPEN
B21-SQV-CF-F004ABE
3
9.00E-06
CCF OF DPV A,E & G TO OPEN
B21-SQV-CF-F004AEG
3
9.00E-06
CCF OF DPV A,C & E TO OPEN
B21-SQV-CF-F004ACE
3
9.00E-06
CCF OF DPV A,E & H TO OPEN
B21-SQV-CF-F004AEH
3
9.00E-06
CCF OF DPV A,D & E TO OPEN
B21-SQV-CF-F004ADE
3
9.00E-06
CCF OF DPV B,C & E TO OPEN
B21-SQV-CF-F004BCE
3
9.00E-06
CCF OF DPV A,E & F TO OPEN
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9.00E-06
OTHER TRIPLE CCF
GB21-0070-_1
Page 20
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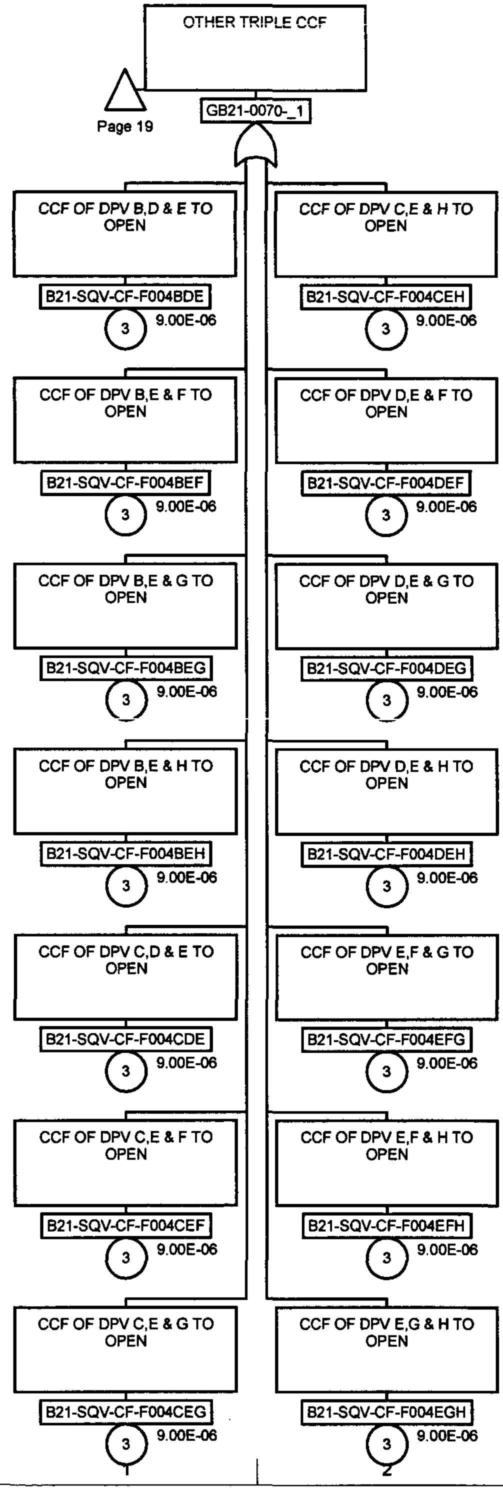
OTHER TRIPLE CCF
GB21-0070-_1
Page 19
CCF OF DPV B,D & E TO OPEN
B21-SQV-CF-F004BDE
9.00E-06
CCF OF DPV C,E & H TO OPEN
B21-SQV-CF-F004CEH
9.00E-06
CCF OF DPV B,E & F TO OPEN
B21-SQV-CF-F004BEF
9.00E-06
CCF OF DPV D,E & F TO OPEN
B21-SQV-CF-F004DEF
9.00E-06
CCF OF DPV B,E & G TO OPEN
B21-SQV-CF-F004BEG
9.00E-06
CCF OF DPV D,E & G TO OPEN
B21-SQV-CF-F004DEG
9.00E-06
CCF OF DPV B,E & H TO OPEN
B21-SQV-CF-F004BEH
9.00E-06
CCF OF DPV D,E & H TO OPEN
B21-SQV-CF-F004DEH
9.00E-06
CCF OF DPV C,D & E TO OPEN
B21-SQV-CF-F004CDE
9.00E-06
CCF OF DPV E,F & G TO OPEN
B21-SQV-CF-F004EFG
9.00E-06
CCF OF DPV C,E & F TO OPEN
B21-SQV-CF-F004CEF
9.00E-06
CCF OF DPV E,F & H TO OPEN
B21-SQV-CF-F004EFH
9.00E-06
CCF OF DPV C,E & G TO OPEN
B21-SQV-CF-F004CEG
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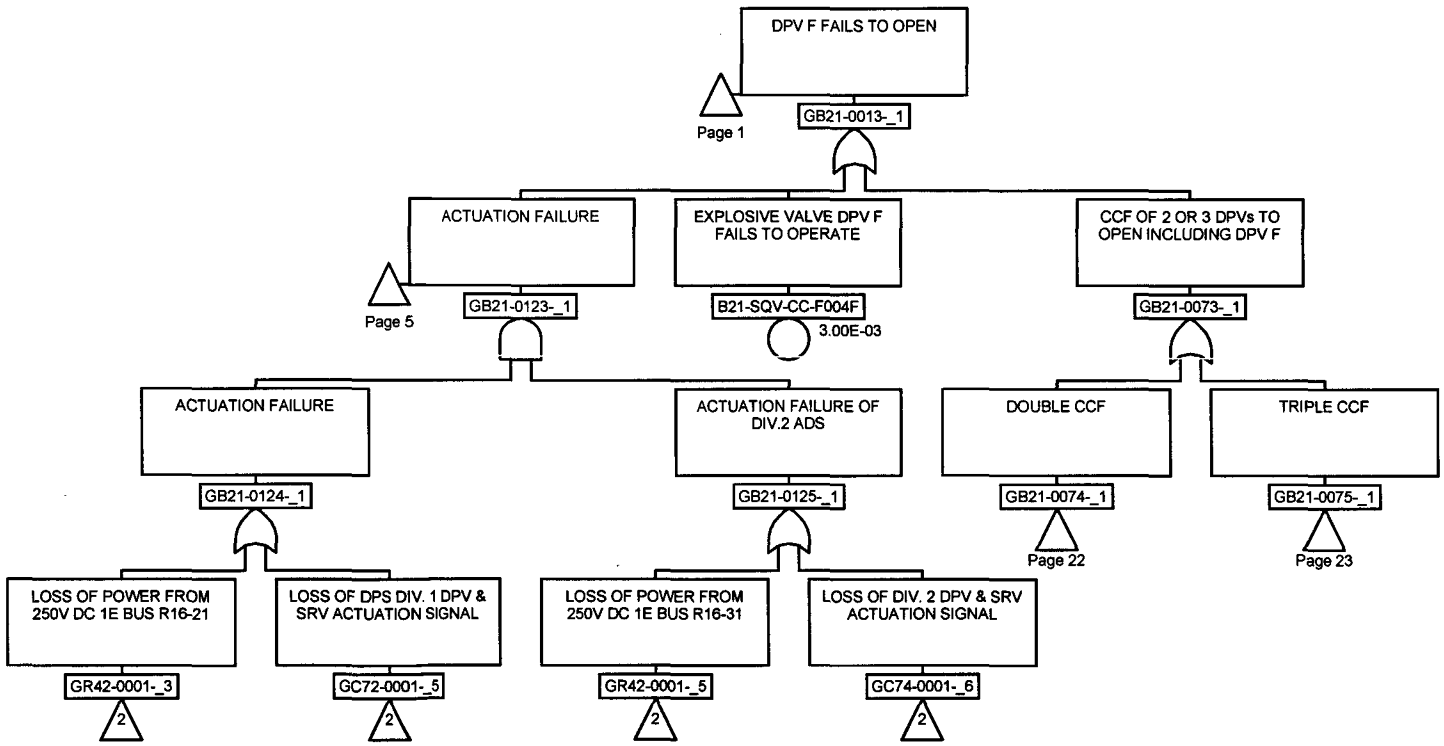
2


DPV F FAILS TO OPEN
Page 1
GB21-0013-_1
ACTUATION FAILURE
Page 5
GB21-0123-_1
EXPLOSIVE VALVE DPV F FAILS TO OPERATE
B21-SQV-CC-F004F
3.00E-03
CCF OF 2 OR 3 DPVs TO OPEN INCLUDING DPV F
GB21-0073-_1
ACTUATION FAILURE
GB21-0124-_1
ACTUATION FAILURE OF DIV.2 ADS
GB21-0125-_1
DOUBLE CCF
GB21-0074-_1
Page 22
TRIPLE CCF
GB21-0075-_1
Page 23
LOSS OF POWER FROM 250V DC 1E BUS R16-21
GR42-0001-_3
2
LOSS OF DPS DIV. 1 DPV & SRV ACTUATION SIGNAL
GC72-0001-_5
2
LOSS OF POWER FROM 250V DC 1E BUS R16-31
GR42-0001-_5
2
LOSS OF DIV. 2 DPV & SRV ACTUATION SIGNAL
GC74-0001-_6
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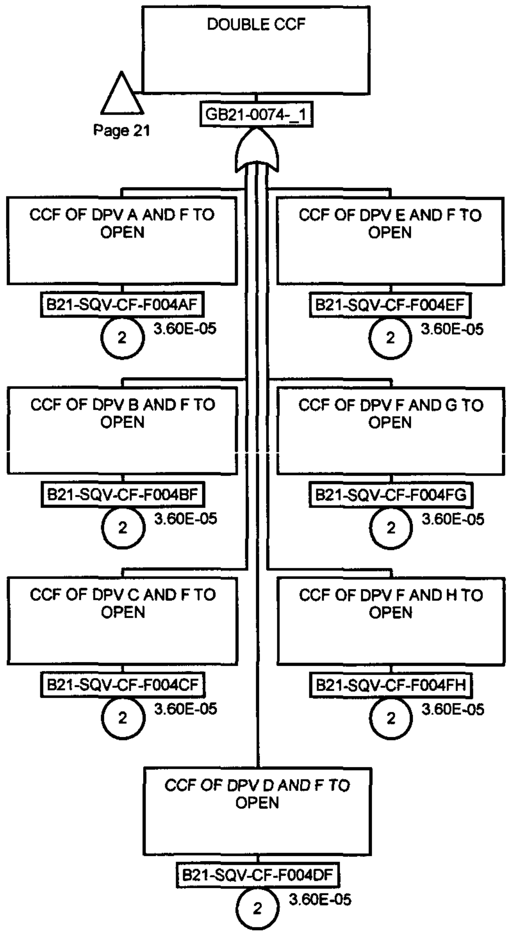
DOUBLE CCF
Page 21
GB21-0074-_1
CCF OF DPV A AND F TO OPEN
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3.60E-05
CCF OF DPV E AND F TO OPEN
B21-SQV-CF-F004EF
2
3.60E-05
CCF OF DPV B AND F TO OPEN
B21-SQV-CF-F004BF
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3.60E-05
CCF OF DPV F AND G TO OPEN
B21-SQV-CF-F004FG
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3.60E-05
CCF OF DPV C AND F TO OPEN
B21-SQV-CF-F004CF
2
3.60E-05
CCF OF DPV F AND H TO OPEN
B21-SQV-CF-F004FH
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CCF OF DPV D AND F TO OPEN
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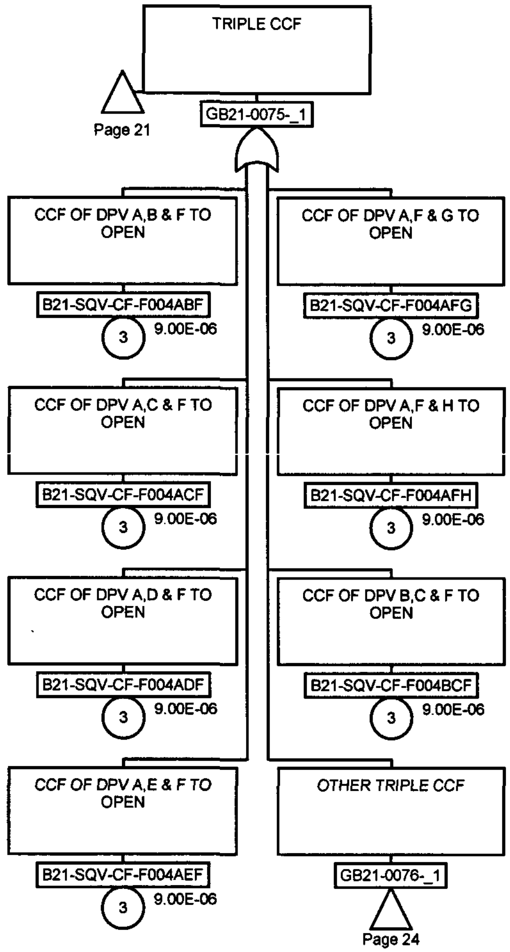
2


TRIPLE CCF
GB21-0075-_1
Page 21
CCF OF DPV A,B & F TO OPEN
B21-SQV-CF-F004ABF
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9.00E-06
CCF OF DPV A,F & G TO OPEN
B21-SQV-CF-F004AFG
3
9.00E-06
CCF OF DPV A,C & F TO OPEN
B21-SQV-CF-F004ACF
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9.00E-06
CCF OF DPV A,F & H TO OPEN
B21-SQV-CF-F004AFH
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CCF OF DPV A,D & F TO OPEN
B21-SQV-CF-F004ADF
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9.00E-06
CCF OF DPV B,C & F TO OPEN
B21-SQV-CF-F004BCF
3
9.00E-06
CCF OF DPV A,E & F TO OPEN
B21-SQV-CF-F004AEF
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9.00E-06
OTHER TRIPLE CCF
GB21-0076-_1
Page 24
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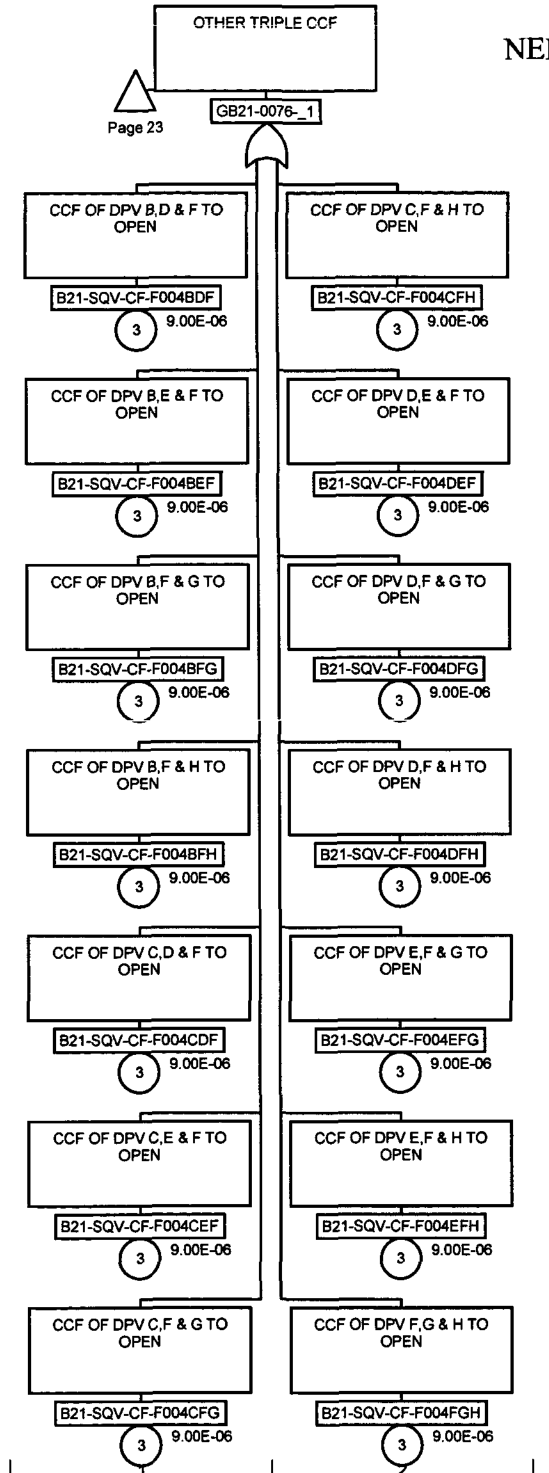
OTHER TRIPLE CCF
GB21-0076-_1
Page 23
CCF OF DPV B,D & F TO OPEN
B21-SQV-CF-F004BDF
9.00E-06
CCF OF DPV C,F & H TO OPEN
B21-SQV-CF-F004CFH
9.00E-06
CCF OF DPV B,E & F TO OPEN
B21-SQV-CF-F004BEF
9.00E-06
CCF OF DPV D,E & F TO OPEN
B21-SQV-CF-F004DEF
9.00E-06
CCF OF DPV B,F & G TO OPEN
B21-SQV-CF-F004BFG
9.00E-06
CCF OF DPV D,F & G TO OPEN
B21-SQV-CF-F004DFG
9.00E-06
CCF OF DPV B,F & H TO OPEN
B21-SQV-CF-F004BFH
9.00E-06
CCF OF DPV D,F & H TO OPEN
B21-SQV-CF-F004DFH
9.00E-06
CCF OF DPV C,D & F TO OPEN
B21-SQV-CF-F004CDF
9.00E-06
CCF OF DPV E,F & G TO OPEN
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CCF OF DPV C,E & F TO OPEN
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CCF OF DPV E,F & H TO OPEN
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9.00E-06
CCF OF DPV C,F & G TO OPEN
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CCF OF DPV F,G & H TO OPEN
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9.00E-06
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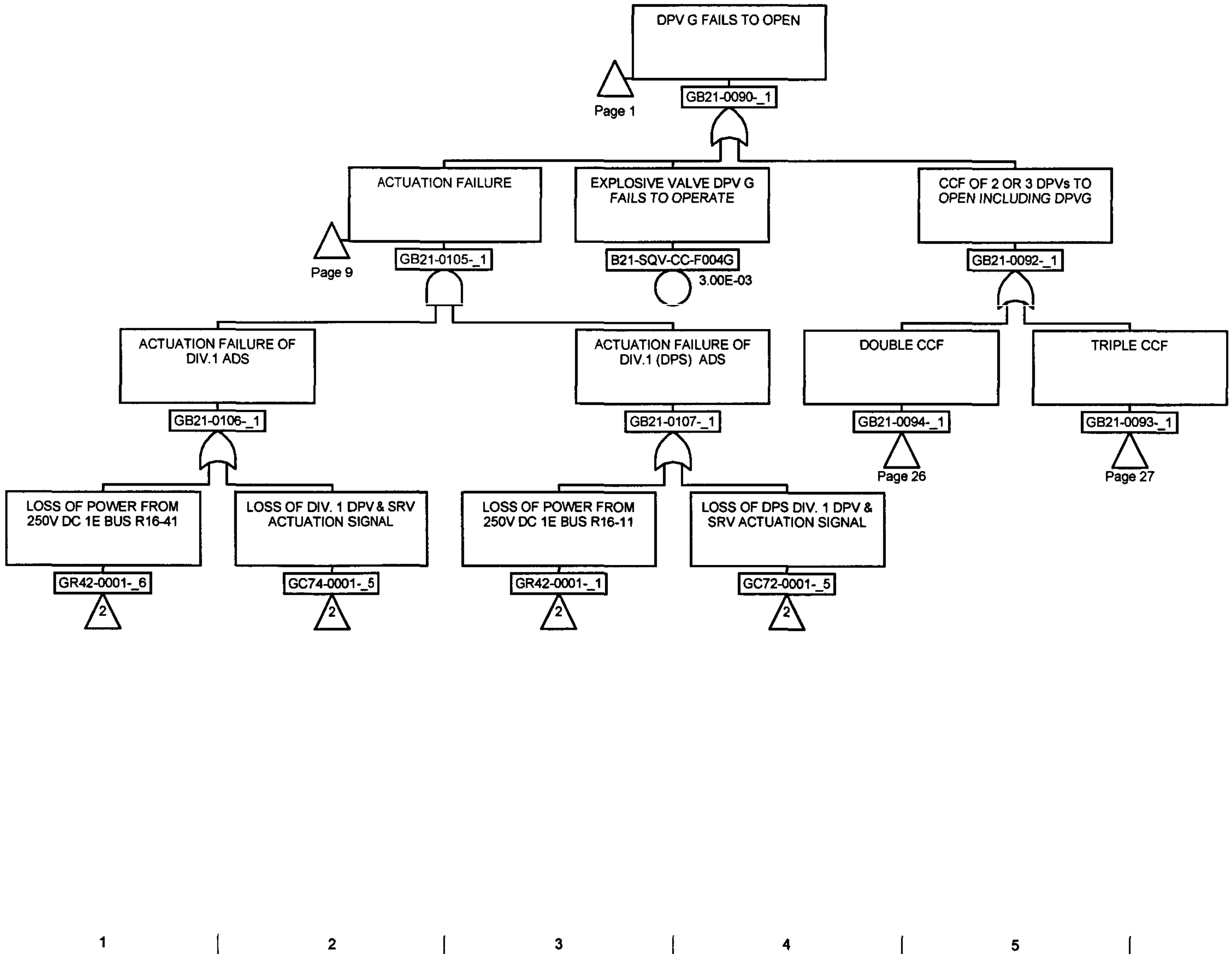
2


DPV G FAILS TO OPEN
Page 1
GB21-0090-_1
ACTUATION FAILURE
Page 9
GB21-0105-_1
EXPLOSIVE VALVE DPV G FAILS TO OPERATE
B21-SQV-CC-F004G
3.00E-03
CCF OF 2 OR 3 DPVs TO OPEN INCLUDING DPVG
GB21-0092-_1
ACTUATION FAILURE OF DIV.1 ADS
GB21-0106-_1
ACTUATION FAILURE OF DIV.1 (DPS) ADS
GB21-0107-_1
DOUBLE CCF
GB21-0094-_1
Page 26
TRIPLE CCF
GB21-0093-_1
Page 27
LOSS OF POWER FROM 250V DC 1E BUS R16-41
GR42-0001-_6
2
LOSS OF DIV. 1 DPV & SRV ACTUATION SIGNAL
GC74-0001-_5
2
LOSS OF POWER FROM 250V DC 1E BUS R16-11
GR42-0001-_1
2
LOSS OF DPS DIV. 1 DPV & SRV ACTUATION SIGNAL
GC72-0001-_5
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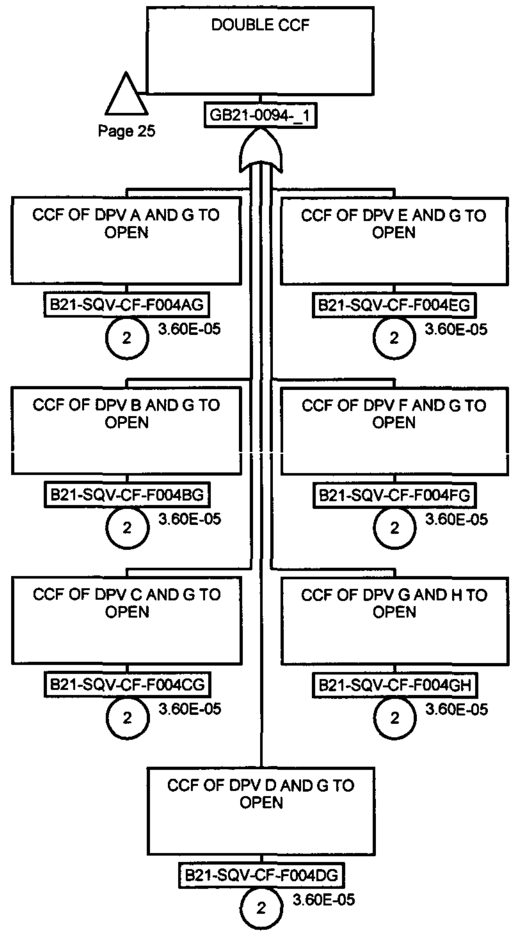
DOUBLE CCF
GB21-0094-_1
Page 25
CCF OF DPV A AND G TO OPEN
B21-SQV-CF-F004AG
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3.60E-05
CCF OF DPV E AND G TO OPEN
B21-SQV-CF-F004EG
2
3.60E-05
CCF OF DPV B AND G TO OPEN
B21-SQV-CF-F004BG
2
3.60E-05
CCF OF DPV F AND G TO OPEN
B21-SQV-CF-F004FG
2
3.60E-05
CCF OF DPV C AND G TO OPEN
B21-SQV-CF-F004CG
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3.60E-05
CCF OF DPV G AND H TO OPEN
B21-SQV-CF-F004GH
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CCF OF DPV D AND G TO OPEN
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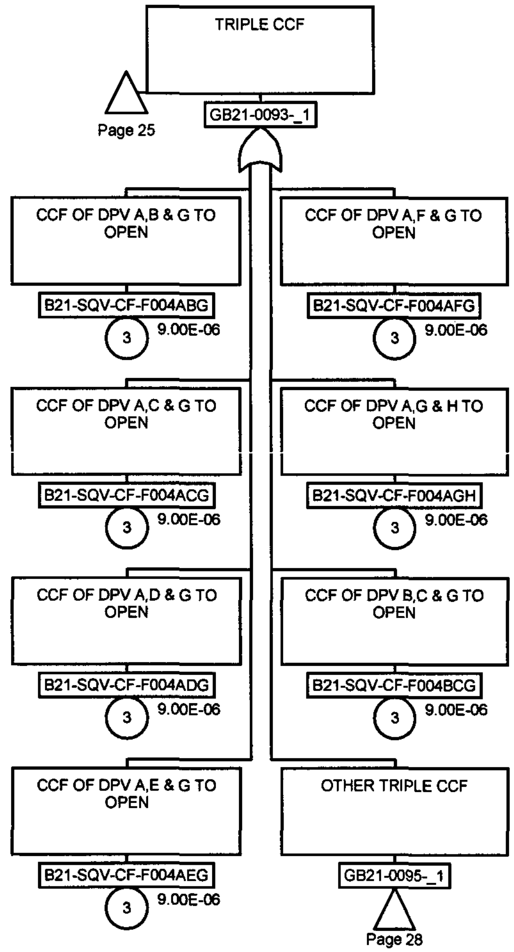
2


TRIPLE CCF
Page 25
GB21-0093-_1
CCF OF DPV A,B & G TO OPEN
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CCF OF DPV A,F & G TO OPEN
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3
9.00E-06
CCF OF DPV A,C & G TO OPEN
B21-SQV-CF-F004ACG
3
9.00E-06
CCF OF DPV A,G & H TO OPEN
B21-SQV-CF-F004AGH
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CCF OF DPV A,D & G TO OPEN
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3
9.00E-06
CCF OF DPV B,C & G TO OPEN
B21-SQV-CF-F004BCG
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9.00E-06
CCF OF DPV A,E & G TO OPEN
B21-SQV-CF-F004AEG
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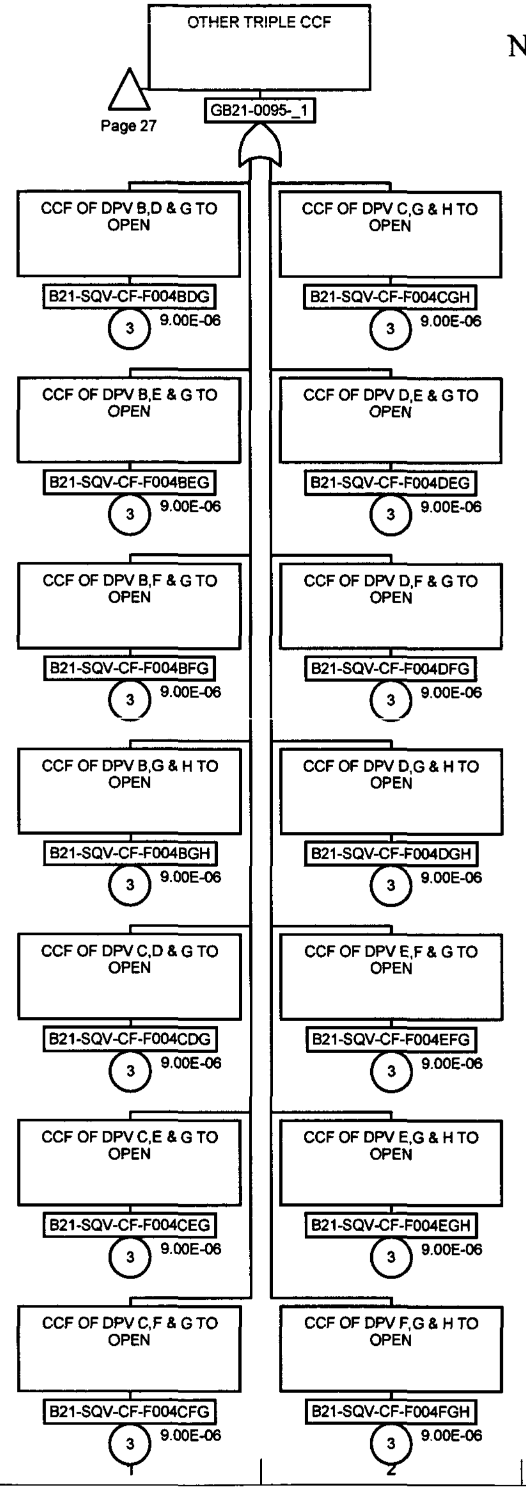
9.00E-06
OTHER TRIPLE CCF
GB21-0095-_1
Page 28
1
2


OTHER TRIPLE CCF
GB21-0095-_1
Page 27
CCF OF DPV B,D & G TO OPEN
B21-SQV-CF-F004BDG
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9.00E-06
CCF OF DPV C,G & H TO OPEN
B21-SQV-CF-F004CGH
3
9.00E-06
CCF OF DPV B,E & G TO OPEN
B21-SQV-CF-F004BEG
3
9.00E-06
CCF OF DPV D,E & G TO OPEN
B21-SQV-CF-F004DEG
3
9.00E-06
CCF OF DPV B,F & G TO OPEN
B21-SQV-CF-F004BFG
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9.00E-06
CCF OF DPV D,F & G TO OPEN
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CCF OF DPV B,G & H TO OPEN
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CCF OF DPV D,G & H TO OPEN
B21-SQV-CF-F004DGH
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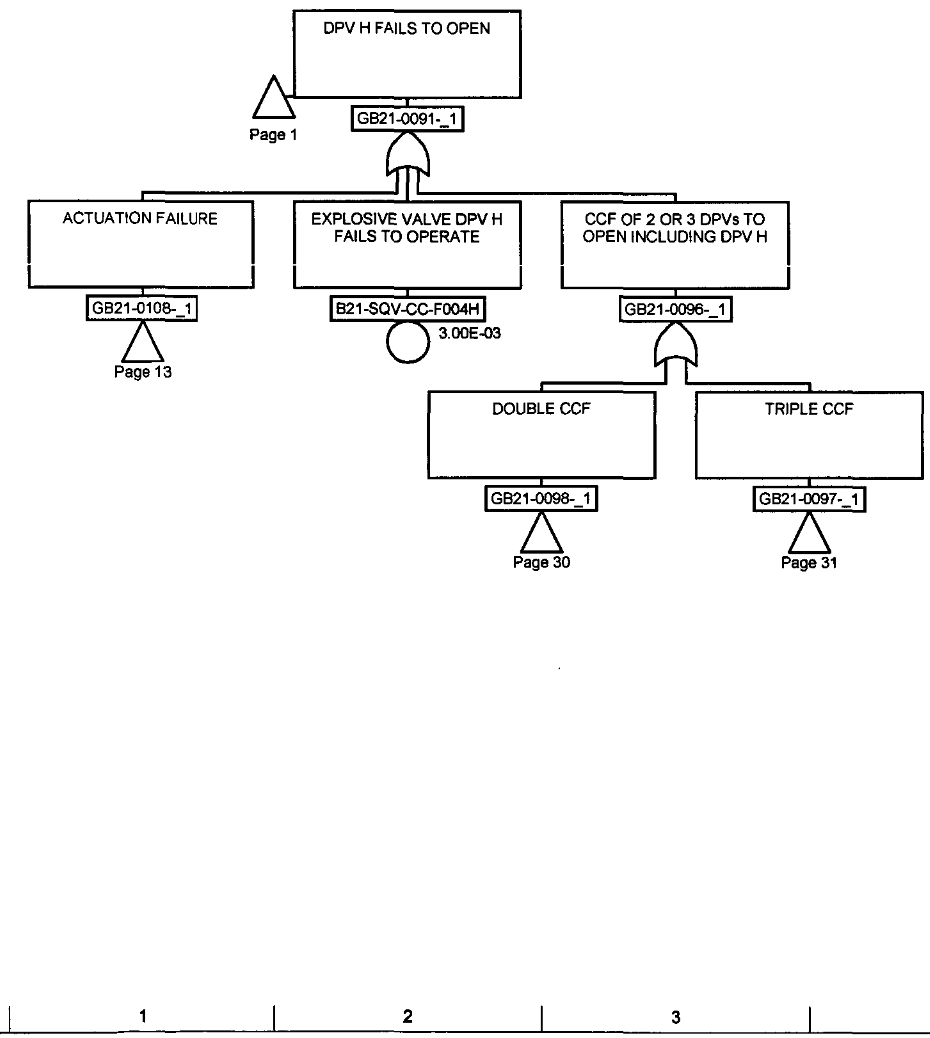
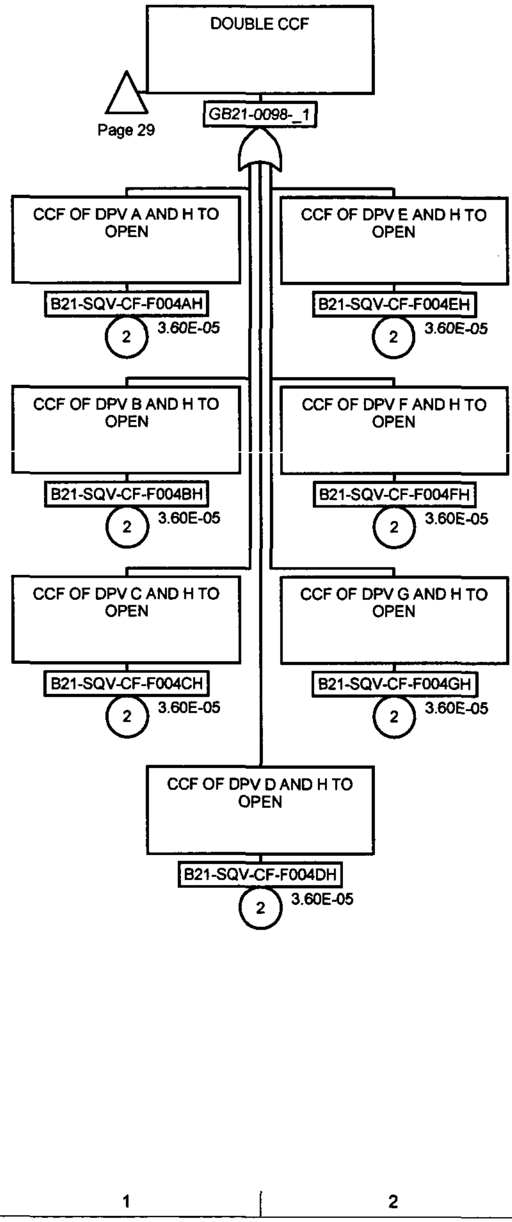
9.00E-06
CCF OF DPV C,D & G TO OPEN
B21-SQV-CF-F004CDG
3
9.00E-06
CCF OF DPV E,F & G TO OPEN
B21-SQV-CF-F004EFG
3
9.00E-06
CCF OF DPV C,E & G TO OPEN
B21-SQV-CF-F004CEG
3
9.00E-06
CCF OF DPV E,G & H TO OPEN
B21-SQV-CF-F004EGH
3
9.00E-06
CCF OF DPV C,F & G TO OPEN
B21-SQV-CF-F004CFG
3
9.00E-06
CCF OF DPV F,G & H TO OPEN
B21-SQV-CF-F004FGH
3
9.00E-06
1
2


DPV H FAILS TO OPEN
Page 1
GB21-0091-_1
ACTUATION FAILURE
GB21-0108-_1
Page 13
EXPLOSIVE VALVE DPV H FAILS TO OPERATE
B21-SQV-CC-F004H
3.00E-03
CCF OF 2 OR 3 DPVs TO OPEN INCLUDING DPV H
GB21-0096-_1
DOUBLE CCF
GB21-0098-_1
Page 30
TRIPLE CCF
GB21-0097-_1
Page 31
1
2
3


DOUBLE CCF
Page 29
GB21-0098-_1
CCF OF DPV A AND H TO OPEN
B21-SQV-CF-F004AH
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3.60E-05
CCF OF DPV E AND H TO OPEN
B21-SQV-CF-F004EH
2
3.60E-05
CCF OF DPV B AND H TO OPEN
B21-SQV-CF-F004BH
2
3.60E-05
CCF OF DPV F AND H TO OPEN
B21-SQV-CF-F004FH
2
3.60E-05
CCF OF DPV C AND H TO OPEN
B21-SQV-CF-F004CH
2
3.60E-05
CCF OF DPV G AND H TO OPEN
B21-SQV-CF-F004GH
2
3.60E-05
CCF OF DPV D AND H TO OPEN
B21-SQV-CF-F004DH
2
3.60E-05
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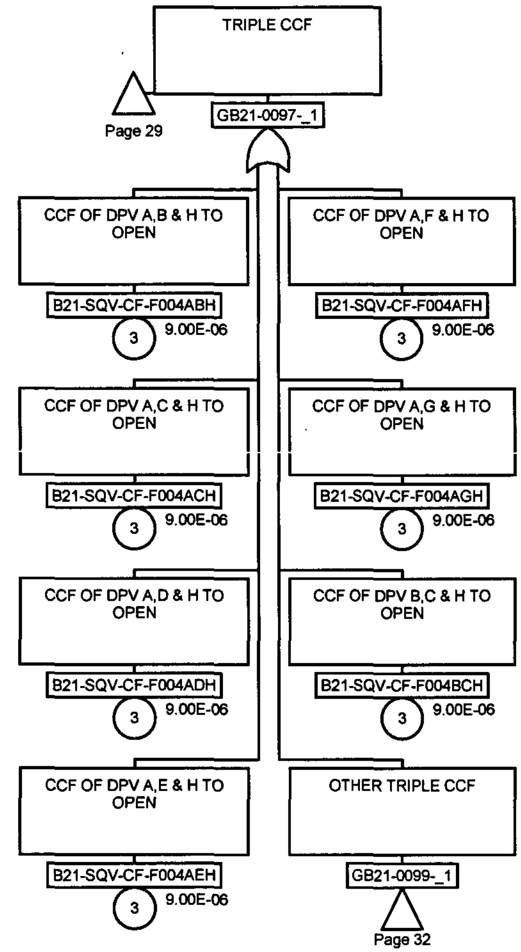
2


TRIPLE CCF
GB21-0097-_1
Page 29
CCF OF DPV A,B & H TO OPEN
B21-SQV-CF-F004ABH
3
9.00E-06
CCF OF DPV A,F & H TO OPEN
B21-SQV-CF-F004AFH
3
9.00E-06
CCF OF DPV A,C & H TO OPEN
B21-SQV-CF-F004ACH
3
9.00E-06
CCF OF DPV A,G & H TO OPEN
B21-SQV-CF-F004AGH
3
9.00E-06
CCF OF DPV A,D & H TO OPEN
B21-SQV-CF-F004ADH
3
9.00E-06
CCF OF DPV B,C & H TO OPEN
B21-SQV-CF-F004BCH
3
9.00E-06
CCF OF DPV A,E & H TO OPEN
B21-SQV-CF-F004AEH
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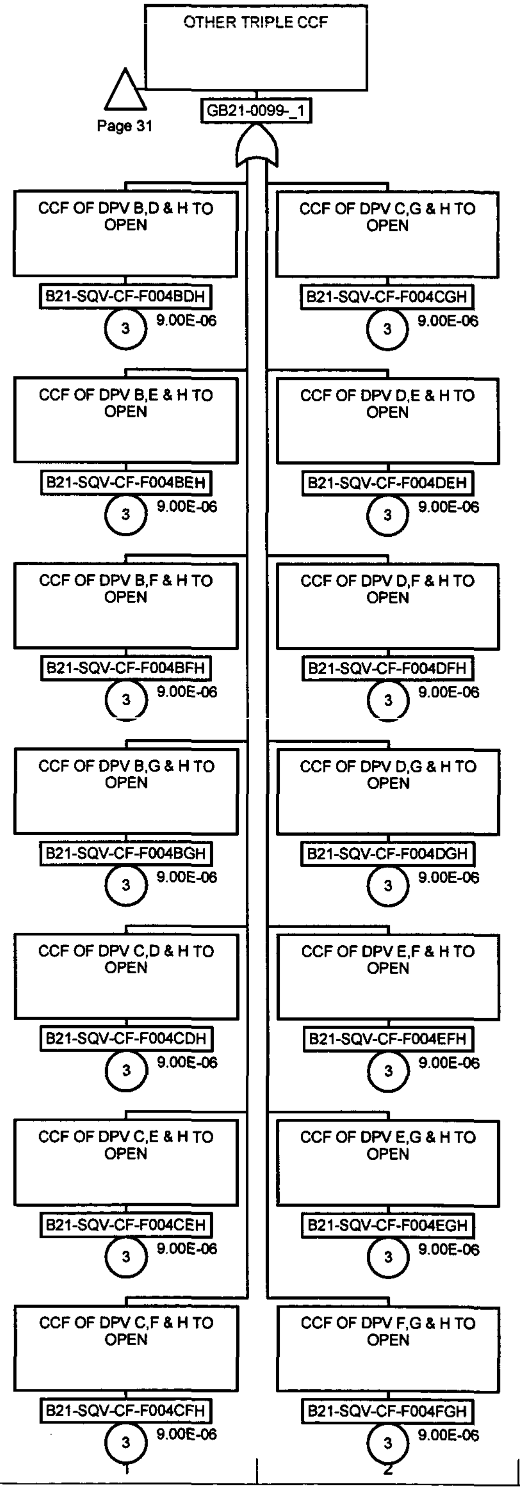
9.00E-06
OTHER TRIPLE CCF
GB21-0099-_1
Page 32
1
2


OTHER TRIPLE CCF
GB21-0099-_1
Page 31
CCF OF DPV B,D & H TO OPEN
B21-SQV-CF-F004BDH
3
9.00E-06
CCF OF DPV C,G & H TO OPEN
B21-SQV-CF-F004CGH
3
9.00E-06
CCF OF DPV B,E & H TO OPEN
B21-SQV-CF-F004BEH
3
9.00E-06
CCF OF DPV D,E & H TO OPEN
B21-SQV-CF-F004DEH
3
9.00E-06
CCF OF DPV B,F & H TO OPEN
B21-SQV-CF-F004BFH
3
9.00E-06
CCF OF DPV D,F & H TO OPEN
B21-SQV-CF-F004DFH
3
9.00E-06
CCF OF DPV B,G & H TO OPEN
B21-SQV-CF-F004BGH
3
9.00E-06
CCF OF DPV D,G & H TO OPEN
B21-SQV-CF-F004DGH
3
9.00E-06
CCF OF DPV C,D & H TO OPEN
B21-SQV-CF-F004CDH
3
9.00E-06
CCF OF DPV E,F & H TO OPEN
B21-SQV-CF-F004EFH
3
9.00E-06
CCF OF DPV C,E & H TO OPEN
B21-SQV-CF-F004CEH
3
9.00E-06
CCF OF DPV E,G & H TO OPEN
B21-SQV-CF-F004EGH
3
9.00E-06
CCF OF DPV C,F & H TO OPEN
B21-SQV-CF-F004CFH
3
9.00E-06
CCF OF DPV F,G & H TO OPEN
B21-SQV-CF-F004FGH
3
9.00E-06
1
2

Name	Page	Zone	Name	Page	Zone	Name	Page	Zone
B21-SQV-CC-F004A	1	2	B21-SQV-CF-F004ADG	4	2	B21-SQV-CF-F004BDF	8	1
B21-SQV-CC-F004B	5	2	B21-SQV-CF-F004ADG	15	2	B21-SQV-CF-F004BDF	16	1
B21-SQV-CC-F004C	9	2	B21-SQV-CF-F004ADG	27	1	B21-SQV-CF-F004BDF	24	1
B21-SQV-CC-F004D	13	3	B21-SQV-CF-F004ADH	4	2	B21-SQV-CF-F004BDG	8	1
B21-SQV-CC-F004E	17	3	B21-SQV-CF-F004ADH	15	2	B21-SQV-CF-F004BDG	16	1
B21-SQV-CC-F004F	21	3	B21-SQV-CF-F004ADH	31	1	B21-SQV-CF-F004BDG	28	1
B21-SQV-CC-F004G	25	3	B21-SQV-CF-F004AE	2	2	B21-SQV-CF-F004BDH	8	2
B21-SQV-CC-F004H	29	2	B21-SQV-CF-F004AE	18	1	B21-SQV-CF-F004BDH	16	1
B21-SQV-CF-DPVOPEN	1	6	B21-SQV-CF-F004AEF	4	2	B21-SQV-CF-F004BDH	32	1
B21-SQV-CF-F004AB	2	1	B21-SQV-CF-F004AEF	19	1	B21-SQV-CF-F004BE	6	2
B21-SQV-CF-F004AB	6	1	B21-SQV-CF-F004AEF	23	1	B21-SQV-CF-F004BE	18	1
B21-SQV-CF-F004ABC	3	1	B21-SQV-CF-F004AEG	4	2	B21-SQV-CF-F004BEF	8	2
B21-SQV-CF-F004ABC	7	1	B21-SQV-CF-F004AEG	19	2	B21-SQV-CF-F004BEF	20	1
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B21-SQV-CF-F004ABD	7	1	B21-SQV-CF-F004AEH	19	2	B21-SQV-CF-F004BEG	20	1
B21-SQV-CF-F004ABD	15	1	B21-SQV-CF-F004AEH	31	1	B21-SQV-CF-F004BEG	28	1
B21-SQV-CF-F004ABE	3	1	B21-SQV-CF-F004AF	2	2	B21-SQV-CF-F004BEH	8	2
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B21-SQV-CF-F004ABE	19	1	B21-SQV-CF-F004AFG	4	1	B21-SQV-CF-F004BEH	32	1
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B21-SQV-CF-F004ABF	7	1	B21-SQV-CF-F004AFG	27	2	B21-SQV-CF-F004BF	22	1
B21-SQV-CF-F004ABF	23	1	B21-SQV-CF-F004AFH	4	1	B21-SQV-CF-F004BFG	8	2
B21-SQV-CF-F004ABG	3	2	B21-SQV-CF-F004AFH	23	2	B21-SQV-CF-F004BFG	24	1
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B21-SQV-CF-F004ABG	27	1	B21-SQV-CF-F004AG	2	1	B21-SQV-CF-F004BFH	8	2
B21-SQV-CF-F004ABH	3	2	B21-SQV-CF-F004AG	26	1	B21-SQV-CF-F004BFH	24	1
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B21-SQV-CF-F004AC	2	2	B21-SQV-CF-F004AGH	31	2	B21-SQV-CF-F004BG	26	1
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B21-SQV-CF-F004ACF	11	1	B21-SQV-CF-F004BCE	12	1	B21-SQV-CF-F004CDE	16	1
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B21-SQV-CF-F004ACG	11	2	B21-SQV-CF-F004BCF	12	1	B21-SQV-CF-F004CDF	16	1
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B21-SQV-CF-F004AD	14	1	B21-SQV-CF-F004BCH	12	1	B21-SQV-CF-F004CDH	16	2
B21-SQV-CF-F004ADE	4	2	B21-SQV-CF-F004BCH	31	2	B21-SQV-CF-F004CDH	32	1
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B21-SQV-CF-F004CEG	20	1	B21-SQV-CF-F004EG	18	2	GB21-0064- 1	16	2
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B21-SQV-CF-F004CEH	12	2	B21-SQV-CF-F004EGH	20	2	GB21-0068- 1	17	5
B21-SQV-CF-F004CEH	20	2	B21-SQV-CF-F004EGH	28	2	GB21-0068- 1	18	2
B21-SQV-CF-F004CEH	32	1	B21-SQV-CF-F004EGH	32	2	GB21-0069- 1	17	6
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B21-SQV-CF-F004CFH	24	2	B21-SQV-CF-F004FGH	32	2	GB21-0075- 1	21	6
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B21-SQV-CF-F004CG	26	1	B21-SQV-CF-F004GH	26	2	GB21-0076- 1	24	2
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B21-SQV-CF-F004DEF	16	2	GB21-0011- 1	13	4	GB21-0094- 1	25	5
B21-SQV-CF-F004DEF	20	2	GB21-0012- 1	1	6	GB21-0094- 1	26	2
B21-SQV-CF-F004DEF	24	2	GB21-0012- 1	17	4	GB21-0095- 1	27	2
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B21-SQV-CF-F004DGH	16	2	GB21-0055- 1	9	3	GB21-0110- 1	13	4
B21-SQV-CF-F004DGH	28	2	GB21-0056- 1	9	3	GB21-0120- 1	1	1
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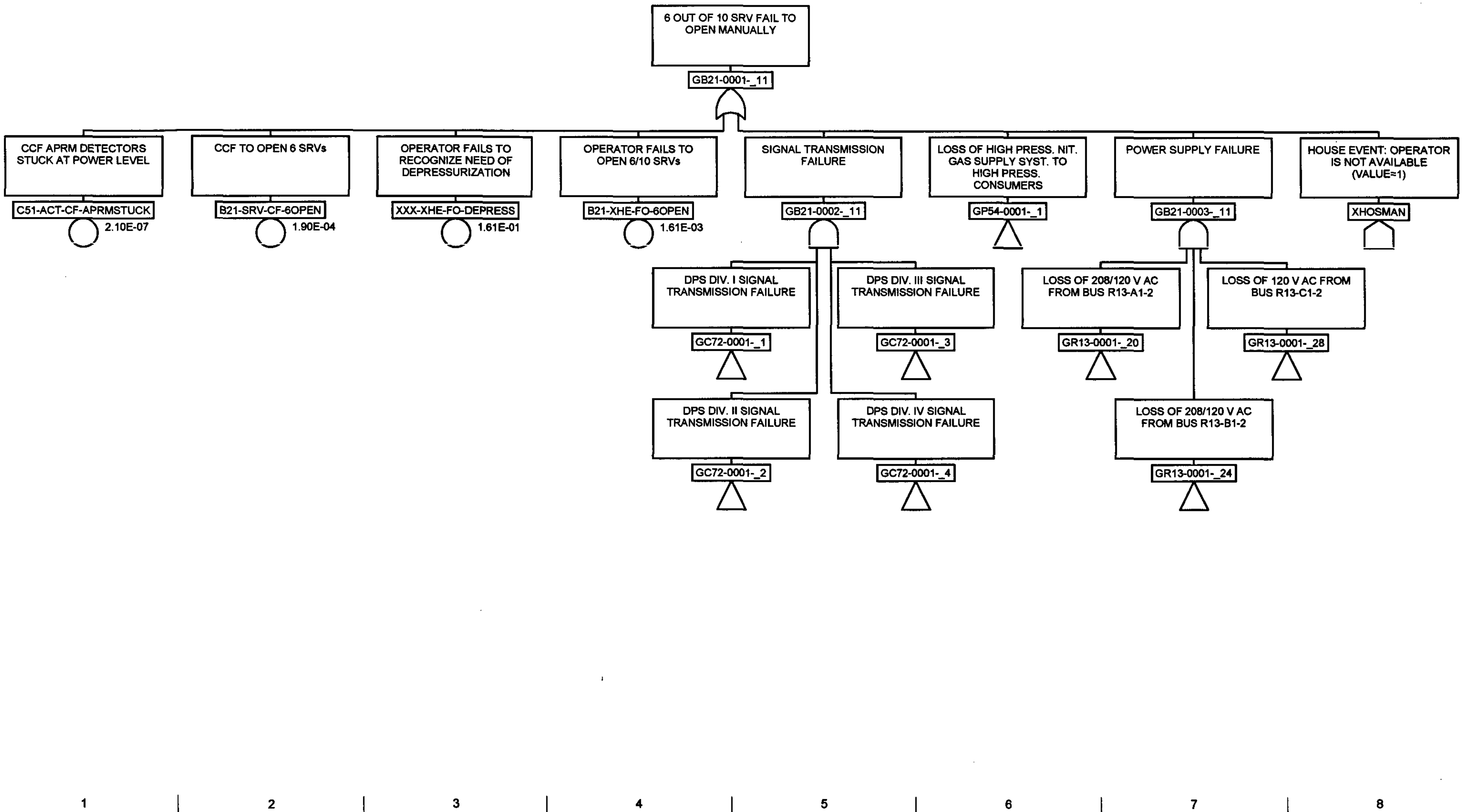
B21-SQV-CF-F004EFG	20	2	GB21-0061- 1	13	5	GB21-0124- 1	21	2
B21-SQV-CF-F004EFG	24	2	GB21-0062- 1	13	5	GB21-0125- 1	21	4
B21-SQV-CF-F004EFG	28	2	GB21-0062- 1	14	2	GB21DPVTOP3	1	5
B21-SQV-CF-F004EFH	20	2	GB21-0063- 1	13	6	GC72-0001- 5	21	2
B21-SQV-CF-F004EFH	24	2	GB21-0063-_1	15	2	GC72-0001-_5	25	4

Name	Page	Zone	Name	Page	Zone	Name	Page	Zone
GC72-0001- 6	13	2						
GC72-0001- 6	17	4						
GC74-0001- 5	17	2						
GC74-0001- 5	25	2						
GC74-0001- 6	13	4						
GC74-0001- 6	21	4						
GR42-0001- 1	17	1						
GR42-0001- 1	25	3						
GR42-0001- 3	13	3						
GR42-0001- 3	21	1						
GR42-0001- 5	13	1						
GR42-0001- 5	21	3						
GR42-0001- 6	17	3						
GR42-0001-_6	25	1						

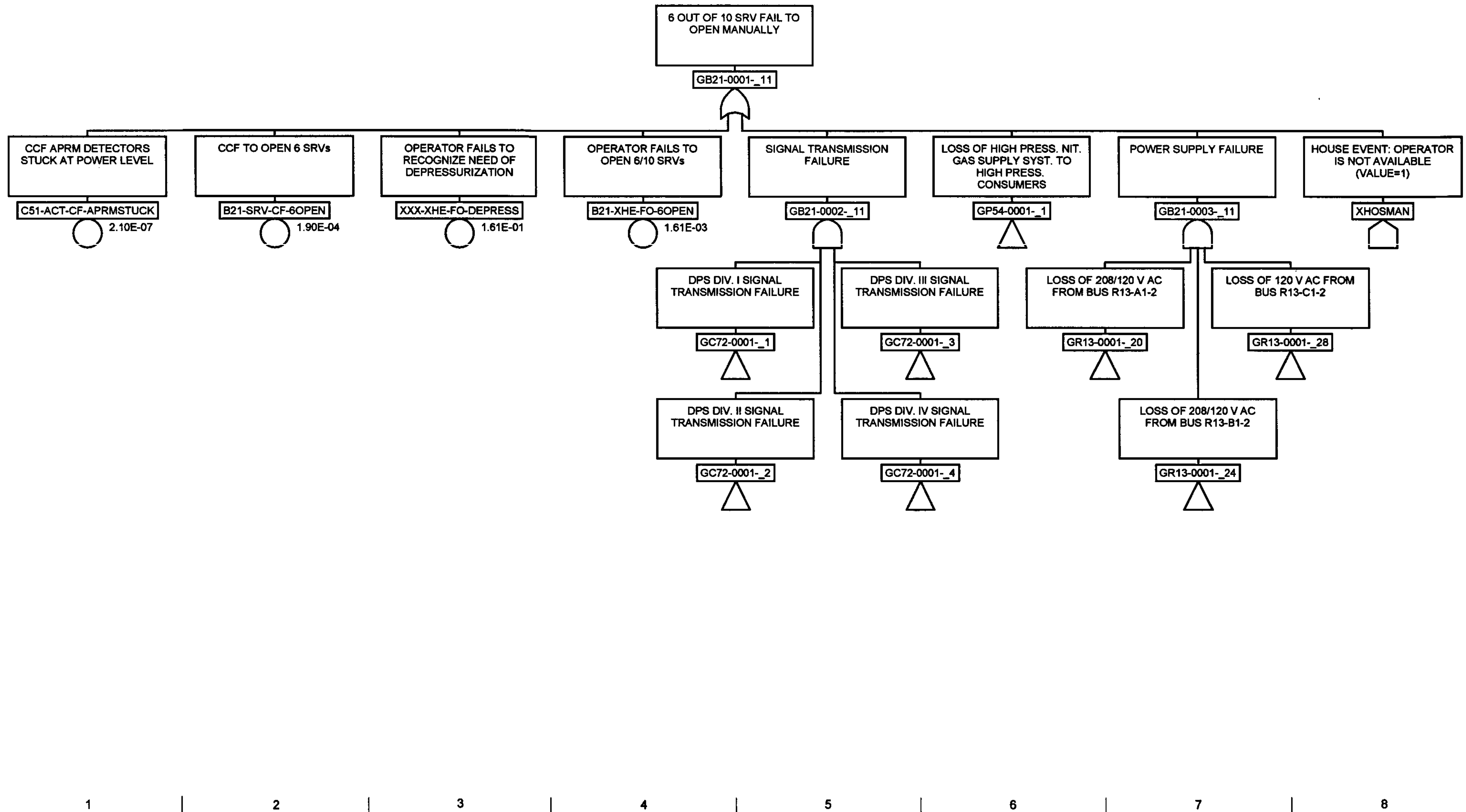
Appendix B.4.1-2
Automatic Depressurization System

Fault Tree


6 OUT OF 10 SRV FAIL TO OPEN MANUALLY
GB21-0001-_11
CCF APRM DETECTORS STUCK AT POWER LEVEL
C51-ACT-CF-APRMSTUCK
2.10E-07
CCF TO OPEN 6 SRVs
B21-SRV-CF-6OPEN
1.90E-04
OPERATOR FAILS TO RECOGNIZE NEED OF DEPRESSURIZATION
XXX-XHE-FO-DEPRESS
1.61E-01
OPERATOR FAILS TO OPEN 6/10 SRVs
B21-XHE-FO-6OPEN
1.61E-03
SIGNAL TRANSMISSION FAILURE
GB21-0002-_11
LOSS OF HIGH PRESS. NIT. GAS SUPPLY SYST. TO HIGH PRESS. CONSUMERS
GP54-0001-_1
POWER SUPPLY FAILURE
GB21-0003-_11
HOUSE EVENT: OPERATOR IS NOT AVAILABLE (VALUE=1)
XHOSMAN
DPS DIV. I SIGNAL TRANSMISSION FAILURE
GC72-0001-_1
DPS DIV. III SIGNAL TRANSMISSION FAILURE
GC72-0001-_3
DPS DIV. II SIGNAL TRANSMISSION FAILURE
GC72-0001-_2
DPS DIV. IV SIGNAL TRANSMISSION FAILURE
GC72-0001-_4
LOSS OF 208/120 V AC FROM BUS R13-A1-2
GR13-0001-_20
LOSS OF 120 V AC FROM BUS R13-C1-2
GR13-0001-_28
LOSS OF 208/120 V AC FROM BUS R13-B1-2
GR13-0001-_24
1
2
3
4
5
6
7
8

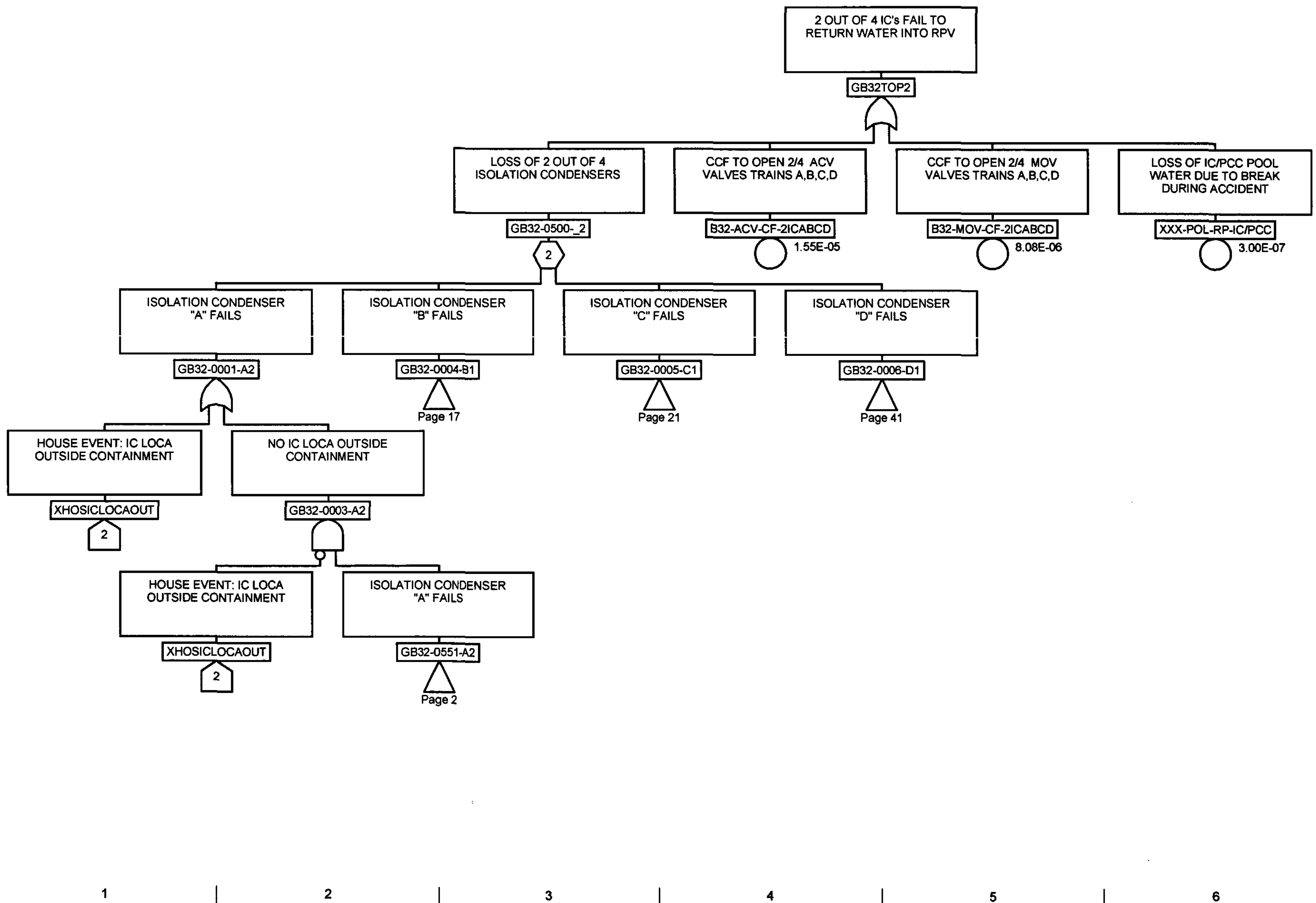
Name	Page	Zone	Name	Page	Zone	Name	Page	Zone
B21-SRV-CF-6OPEN	1	2						
B21-XHE-FO-6OPEN	1	4						
C51-ACT-CF-APRMSTUCK	1	1						
GB21-0001- 11	1	5						
GB21-0002- 11	1	5						
GB21-0003- 11	1	7						
GC72-0001- 1	1	5						
GC72-0001- 2	1	5						
GC72-0001- 3	1	6						
GC72-0001- 4	1	6						
GP54-0001- 1	1	6						
GR13-0001- 20	1	7						
GR13-0001- 24	1	7						
GR13-0001-_28	1	8						
XHOSMAN	1	8						
XXX-XHE-FO-DEPRESS	1	3						

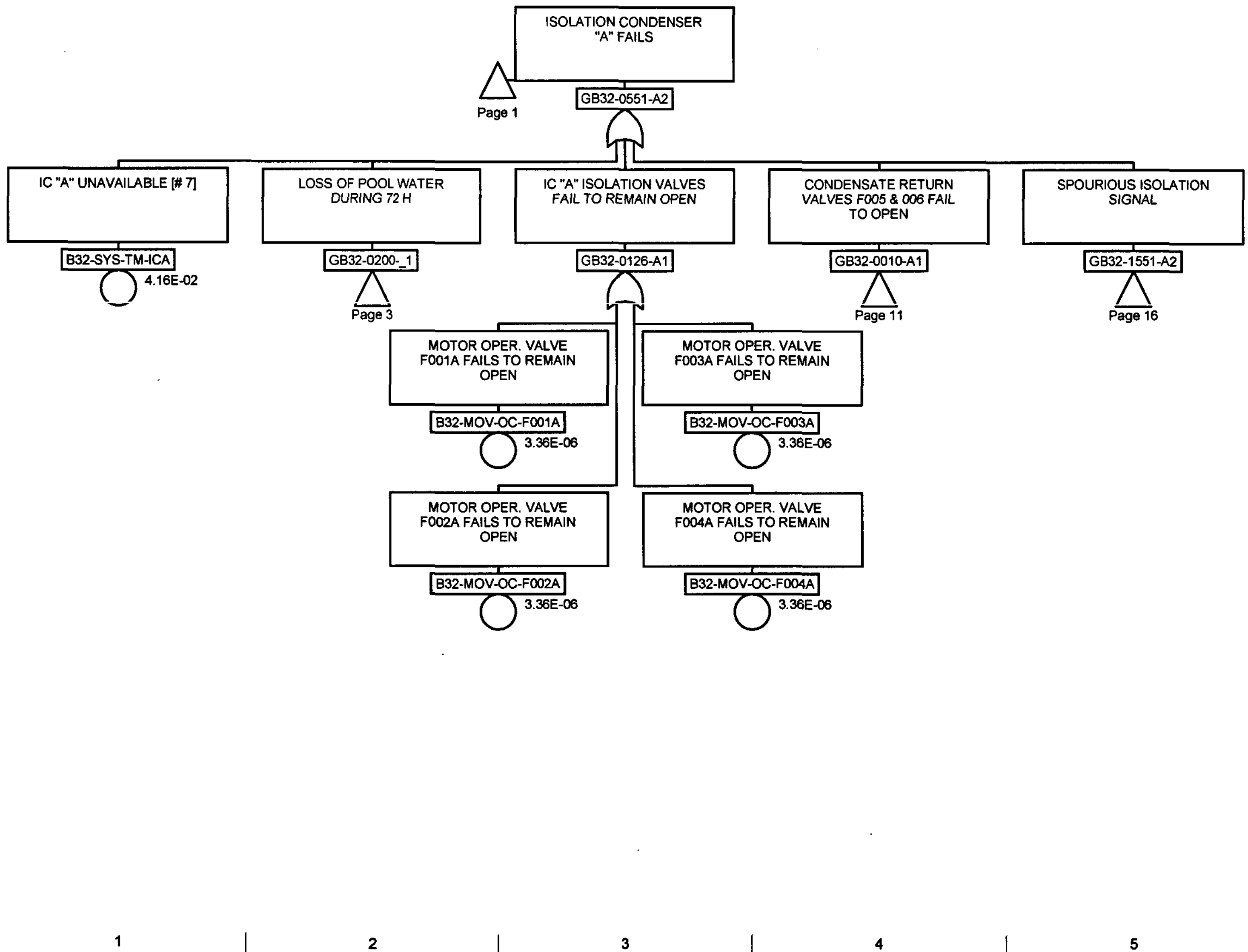
Appendix B.4.1-2
Automatic Depressurization System
Fault Tree

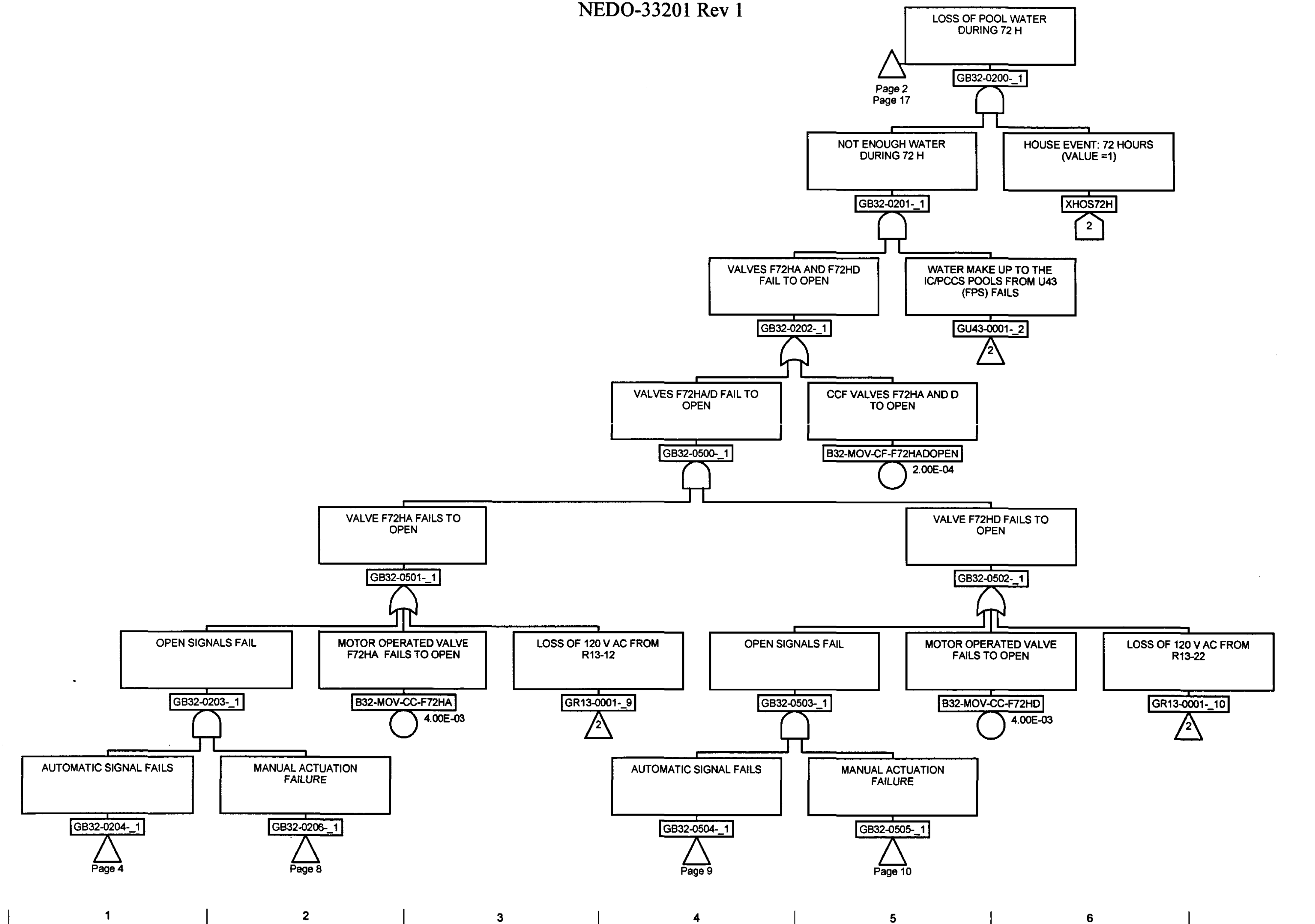

6 OUT OF 10 SRV FAIL TO OPEN MANUALLY
GB21-0001-_11
CCF APRM DETECTORS STUCK AT POWER LEVEL
C51-ACT-CF-APRMSTUCK
2.10E-07
CCF TO OPEN 6 SRVs
B21-SRV-CF-6OPEN
1.90E-04
OPERATOR FAILS TO RECOGNIZE NEED OF DEPRESSURIZATION
XXX-XHE-FO-DEPRESS
1.61E-01
OPERATOR FAILS TO OPEN 6/10 SRVs
B21-XHE-FO-6OPEN
1.61E-03
SIGNAL TRANSMISSION FAILURE
GB21-0002-_11
LOSS OF HIGH PRESS. NIT. GAS SUPPLY SYST. TO HIGH PRESS. CONSUMERS
GP54-0001-_1
POWER SUPPLY FAILURE
GB21-0003-_11
HOUSE EVENT: OPERATOR IS NOT AVAILABLE (VALUE=1)
XHOSMAN
DPS DIV. I SIGNAL TRANSMISSION FAILURE
GC72-0001-_1
DPS DIV. III SIGNAL TRANSMISSION FAILURE
GC72-0001-_3
DPS DIV. II SIGNAL TRANSMISSION FAILURE
GC72-0001-_2
DPS DIV. IV SIGNAL TRANSMISSION FAILURE
GC72-0001-_4
LOSS OF 208/120 V AC FROM BUS R13-A1-2
GR13-0001-_20
LOSS OF 120 V AC FROM BUS R13-C1-2
GR13-0001-_28
LOSS OF 208/120 V AC FROM BUS R13-B1-2
GR13-0001-_24
1
2
3
4
5
6
7
8

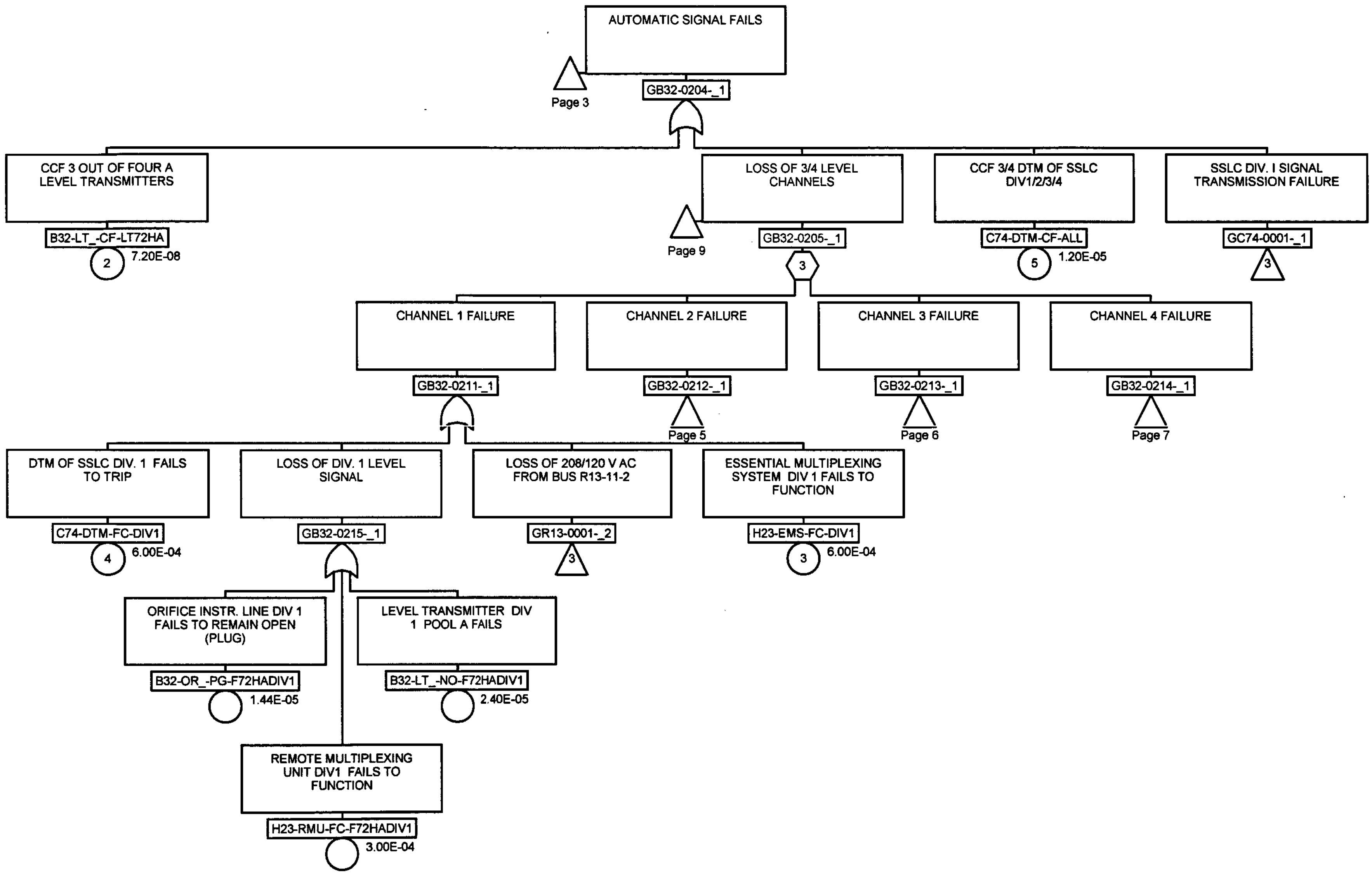
Name	Page	Zone	Name	Page	Zone	Name	Page	Zone
B21-SRV-CF-6OPEN	1	2						
B21-XHE-FO-6OPEN	1	4						
C51-ACT-CF-APRMSTUCK	1	1						
GB21-0001- 11	1	5						
GB21-0002- 11	1	5						
GB21-0003- 11	1	7						
GC72-0001- 1	1	5						
GC72-0001- 2	1	5						
GC72-0001- 3	1	6						
GC72-0001- 4	1	6						
GP54-0001- 1	1	6						
GR13-0001- 20	1	7						
GR13-0001- 24	1	7						
GR13-0001-_28	1	8						
XHOSMAN	1	8						
XXX-XHE-FO-DEPRESS	1	3						

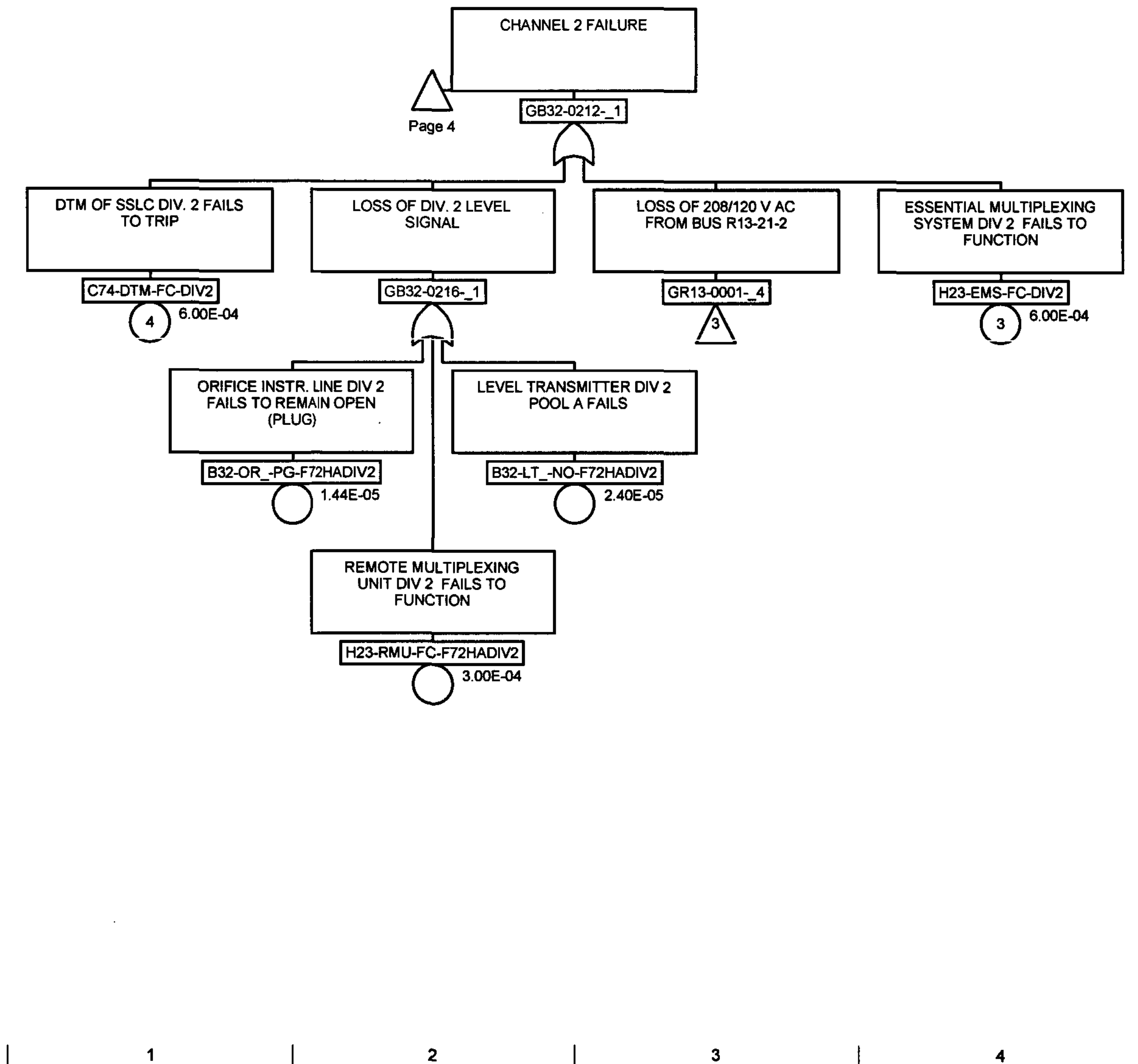
Appendix B.4.2
Isolation Condenser System
Fault Tree

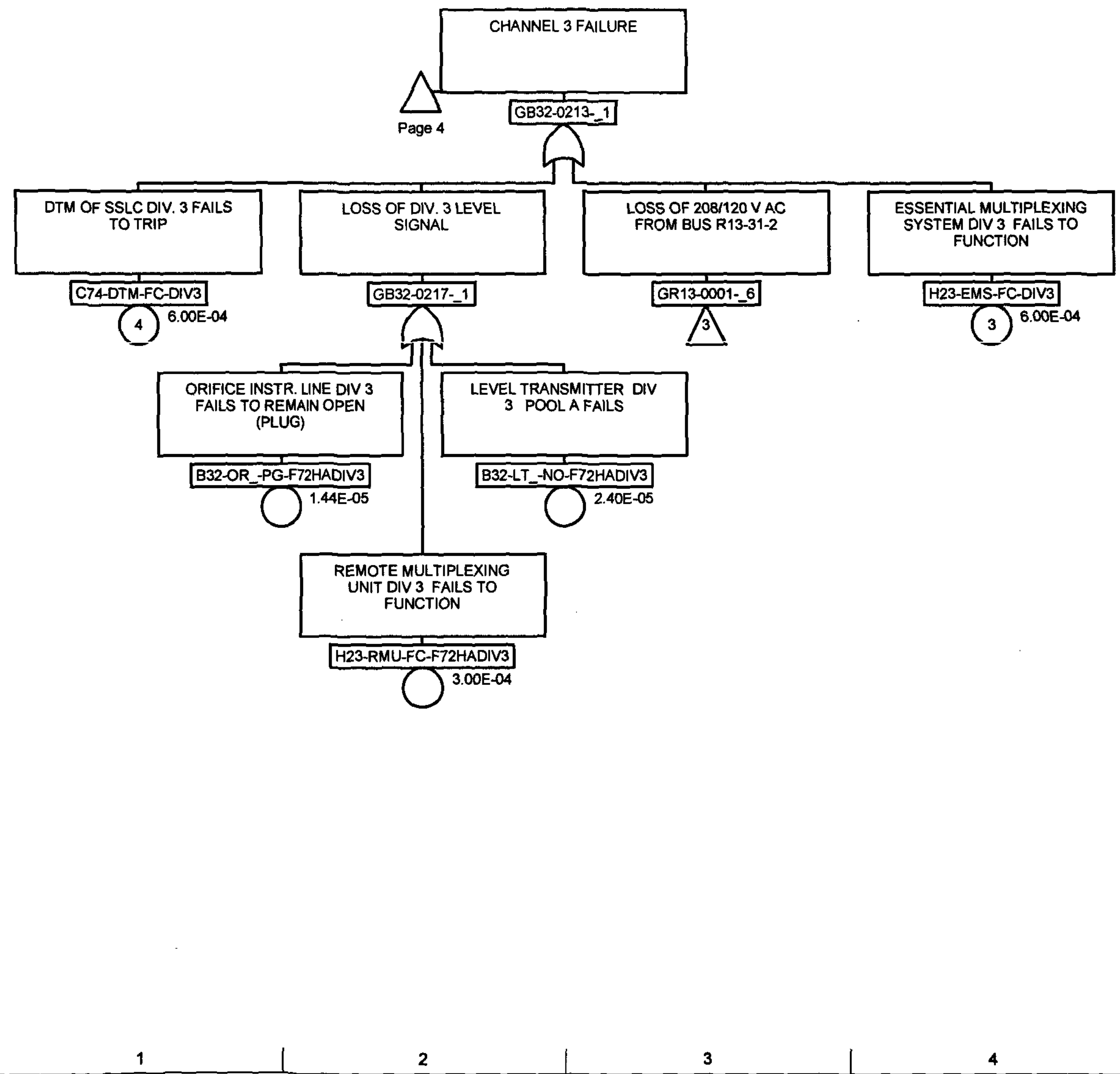

2 OUT OF 4 IC's FAIL TO RETURN WATER INTO RPV
GB32TOP2
LOSS OF 2 OUT OF 4 ISOLATION CONDENSERS
GB32-0500-_2
2
CCF TO OPEN 2/4 ACV VALVES TRAINS A,B,C,D
B32-ACV-CF-2ICABCD
1.55E-05
CCF TO OPEN 2/4 MOV VALVES TRAINS A,B,C,D
B32-MOV-CF-2ICABCD
8.08E-06
LOSS OF IC/PCC POOL WATER DUE TO BREAK DURING ACCIDENT
XXX-POL-RP-IC/PCC
3.00E-07
ISOLATION CONDENSER "A" FAILS
GB32-0001-A2
ISOLATION CONDENSER "B" FAILS
GB32-0004-B1
Page 17
ISOLATION CONDENSER "C" FAILS
GB32-0005-C1
Page 21
ISOLATION CONDENSER "D" FAILS
GB32-0006-D1
Page 41
HOUSE EVENT: IC LOCA OUTSIDE CONTAINMENT
XHOSICLOCAOUT
2
NO IC LOCA OUTSIDE CONTAINMENT
GB32-0003-A2
HOUSE EVENT: IC LOCA OUTSIDE CONTAINMENT
XHOSICLOCAOUT
2
ISOLATION CONDENSER "A" FAILS
GB32-0551-A2
Page 2
1
2
3
4
5
6

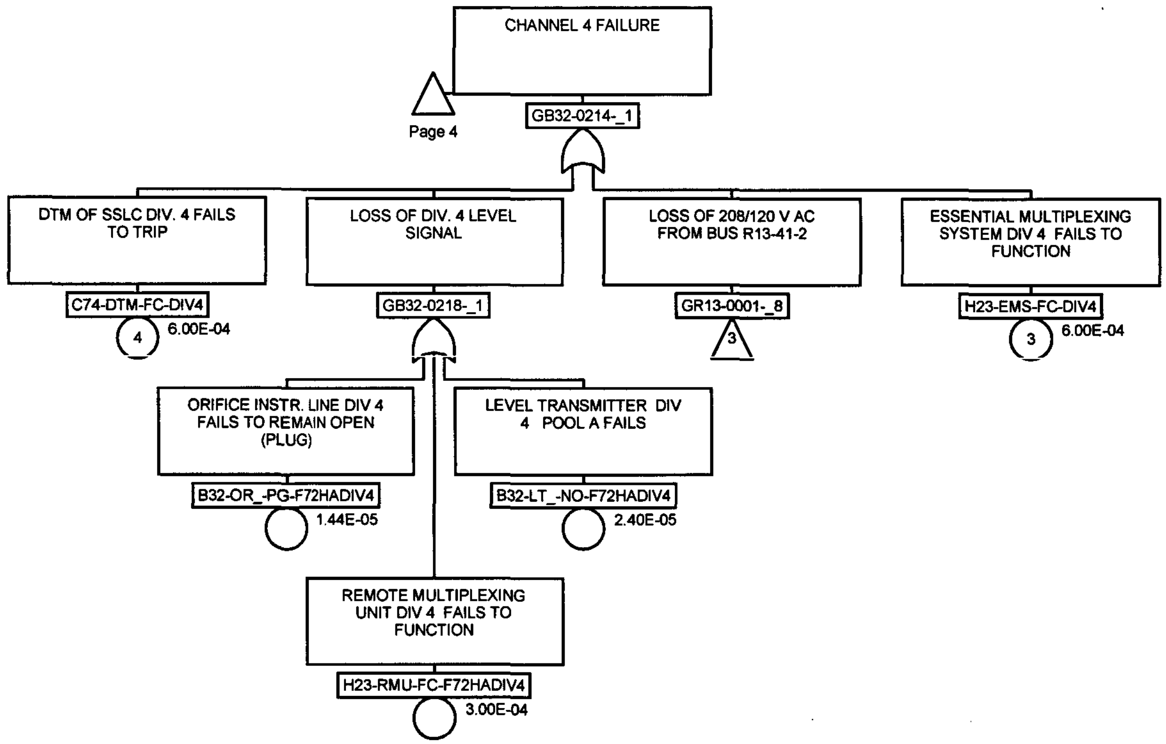

ISOLATION CONDENSER "A" FAILS
GB32-0551-A2
Page 1
IC "A" UNAVAILABLE [# 7]
B32-SYS-TM-ICA
4.16E-02
LOSS OF POOL WATER DURING 72 H
GB32-0200-_1
Page 3
IC "A" ISOLATION VALVES FAIL TO REMAIN OPEN
GB32-0126-A1
CONDENSATE RETURN VALVES F005 & 006 FAIL TO OPEN
GB32-0010-A1
Page 11
SPOURIOUS ISOLATION SIGNAL
GB32-1551-A2
Page 16
MOTOR OPER. VALVE F001A FAILS TO REMAIN OPEN
B32-MOV-OC-F001A
3.36E-06
MOTOR OPER. VALVE F003A FAILS TO REMAIN OPEN
B32-MOV-OC-F003A
3.36E-06
MOTOR OPER. VALVE F002A FAILS TO REMAIN OPEN
B32-MOV-OC-F002A
3.36E-06
MOTOR OPER. VALVE F004A FAILS TO REMAIN OPEN
B32-MOV-OC-F004A
3.36E-06
1
2
3
4
5

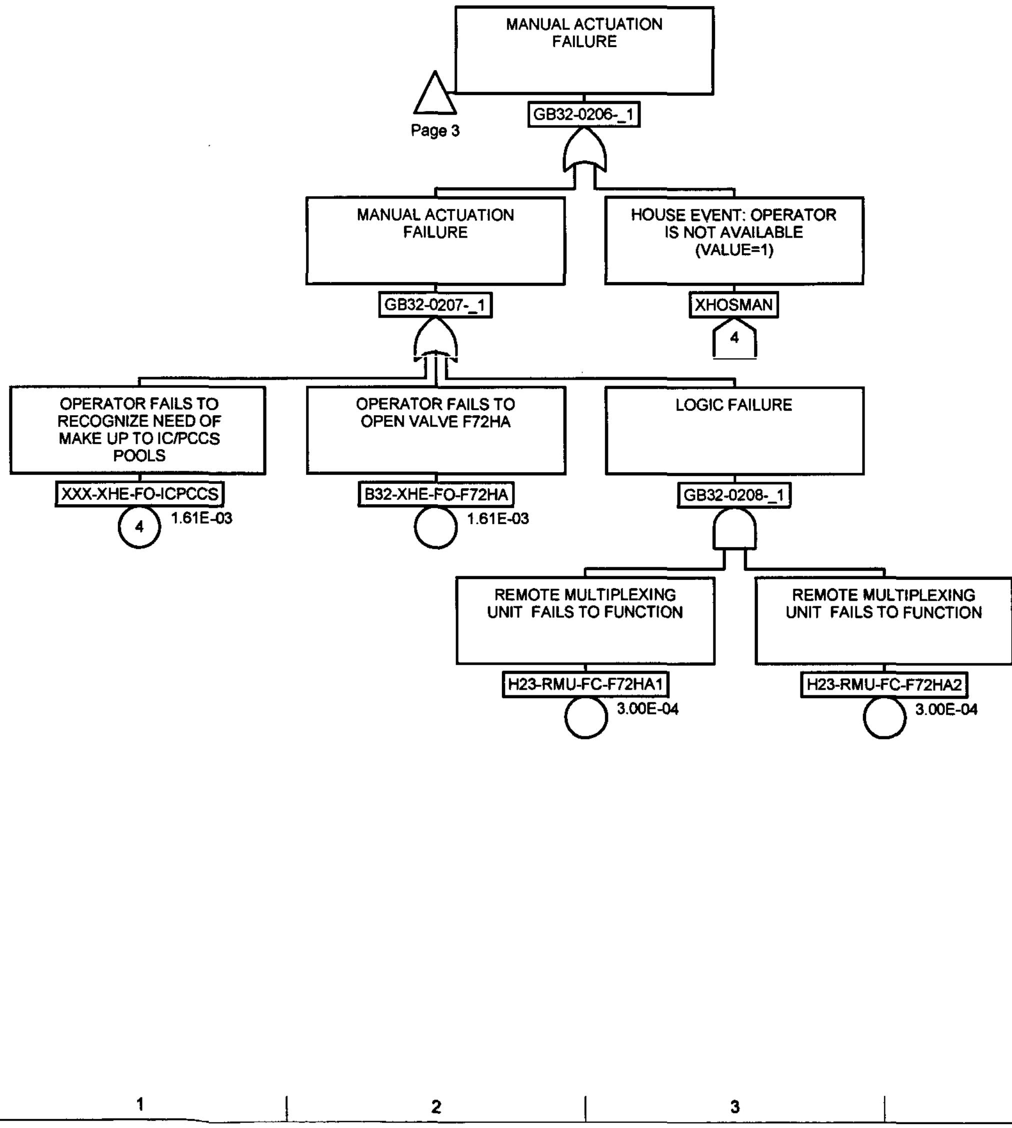

LOSS OF POOL WATER DURING 72 H
GB32-0200-_1
Page 2
Page 17
NOT ENOUGH WATER DURING 72 H
GB32-0201-_1
HOUSE EVENT: 72 HOURS (VALUE =1)
XHOS72H
2
VALVES F72HA AND F72HD FAIL TO OPEN
GB32-0202-_1
WATER MAKE UP TO THE IC/PCCS POOLS FROM U43 (FPS) FAILS
GU43-0001-_2
2
VALVES F72HA/D FAIL TO OPEN
GB32-0500-_1
CCF VALVES F72HA AND D TO OPEN
B32-MOV-CF-F72HADOPEN
2.00E-04
VALVE F72HA FAILS TO OPEN
GB32-0501-_1
VALVE F72HD FAILS TO OPEN
GB32-0502-_1
OPEN SIGNALS FAIL
GB32-0203-_1
MOTOR OPERATED VALVE F72HA FAILS TO OPEN
B32-MOV-CC-F72HA
4.00E-03
LOSS OF 120 V AC FROM R13-12
GR13-0001-_9
2
OPEN SIGNALS FAIL
GB32-0503-_1
MOTOR OPERATED VALVE FAILS TO OPEN
B32-MOV-CC-F72HD
4.00E-03
LOSS OF 120 V AC FROM R13-22
GR13-0001-_10
2
AUTOMATIC SIGNAL FAILS
GB32-0204-_1
Page 4
MANUAL ACTUATION FAILURE
GB32-0206-_1
Page 8
AUTOMATIC SIGNAL FAILS
GB32-0504-_1
Page 9
MANUAL ACTUATION FAILURE
GB32-0505-_1
Page 10
1
2
3
4
5
6

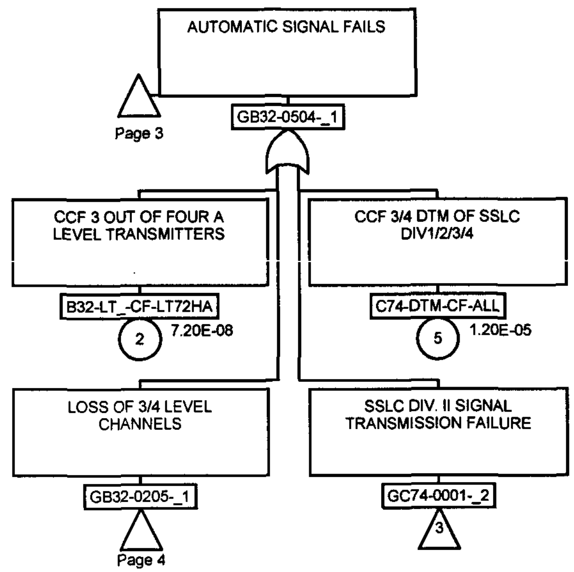

AUTOMATIC SIGNAL FAILS
GB32-0204-_1
Page 3
CCF 3 OUT OF FOUR A LEVEL TRANSMITTERS
B32-LT_-CF-LT72HA
2
7.20E-08
LOSS OF 3/4 LEVEL CHANNELS
Page 9
GB32-0205-_1
3
CCF 3/4 DTM OF SSLC DIV1/2/3/4
C74-DTM-CF-ALL
5
1.20E-05
SSLC DIV. I SIGNAL TRANSMISSION FAILURE
GC74-0001-_1
3
CHANNEL 1 FAILURE
GB32-0211-_1
CHANNEL 2 FAILURE
GB32-0212-_1
Page 5
CHANNEL 3 FAILURE
GB32-0213-_1
Page 6
CHANNEL 4 FAILURE
GB32-0214-_1
Page 7
DTM OF SSLC DIV. 1 FAILS TO TRIP
C74-DTM-FC-DIV1
4
6.00E-04
LOSS OF DIV. 1 LEVEL SIGNAL
GB32-0215-_1
LOSS OF 208/120 V AC FROM BUS R13-11-2
GR13-0001-_2
3
ESSENTIAL MULTIPLEXING SYSTEM DIV 1 FAILS TO FUNCTION
H23-EMS-FC-DIV1
3
6.00E-04
ORIFICE INSTR. LINE DIV 1 FAILS TO REMAIN OPEN (PLUG)
B32-OR_-PG-F72HADIV1
1.44E-05
LEVEL TRANSMITTER DIV 1 POOL A FAILS
B32-LT_-NO-F72HADIV1
2.40E-05
REMOTE MULTIPLEXING UNIT DIV1 FAILS TO FUNCTION
H23-RMU-FC-F72HADIV1
3.00E-04


CHANNEL 2 FAILURE
GB32-0212-_1
Page 4
DTM OF SSLC DIV. 2 FAILS TO TRIP
C74-DTM-FC-DIV2
4
6.00E-04
LOSS OF DIV. 2 LEVEL SIGNAL
GB32-0216-_1
LOSS OF 208/120 V AC FROM BUS R13-21-2
GR13-0001-_4
3
ESSENTIAL MULTIPLEXING SYSTEM DIV 2 FAILS TO FUNCTION
H23-EMS-FC-DIV2
3
6.00E-04
ORIFICE INSTR. LINE DIV 2 FAILS TO REMAIN OPEN (PLUG)
B32-OR_-PG-F72HADIV2
1.44E-05
LEVEL TRANSMITTER DIV 2 POOL A FAILS
B32-LT_-NO-F72HADIV2
2.40E-05
REMOTE MULTIPLEXING UNIT DIV 2 FAILS TO FUNCTION
H23-RMU-FC-F72HADIV2
3.00E-04
1
2
3
4

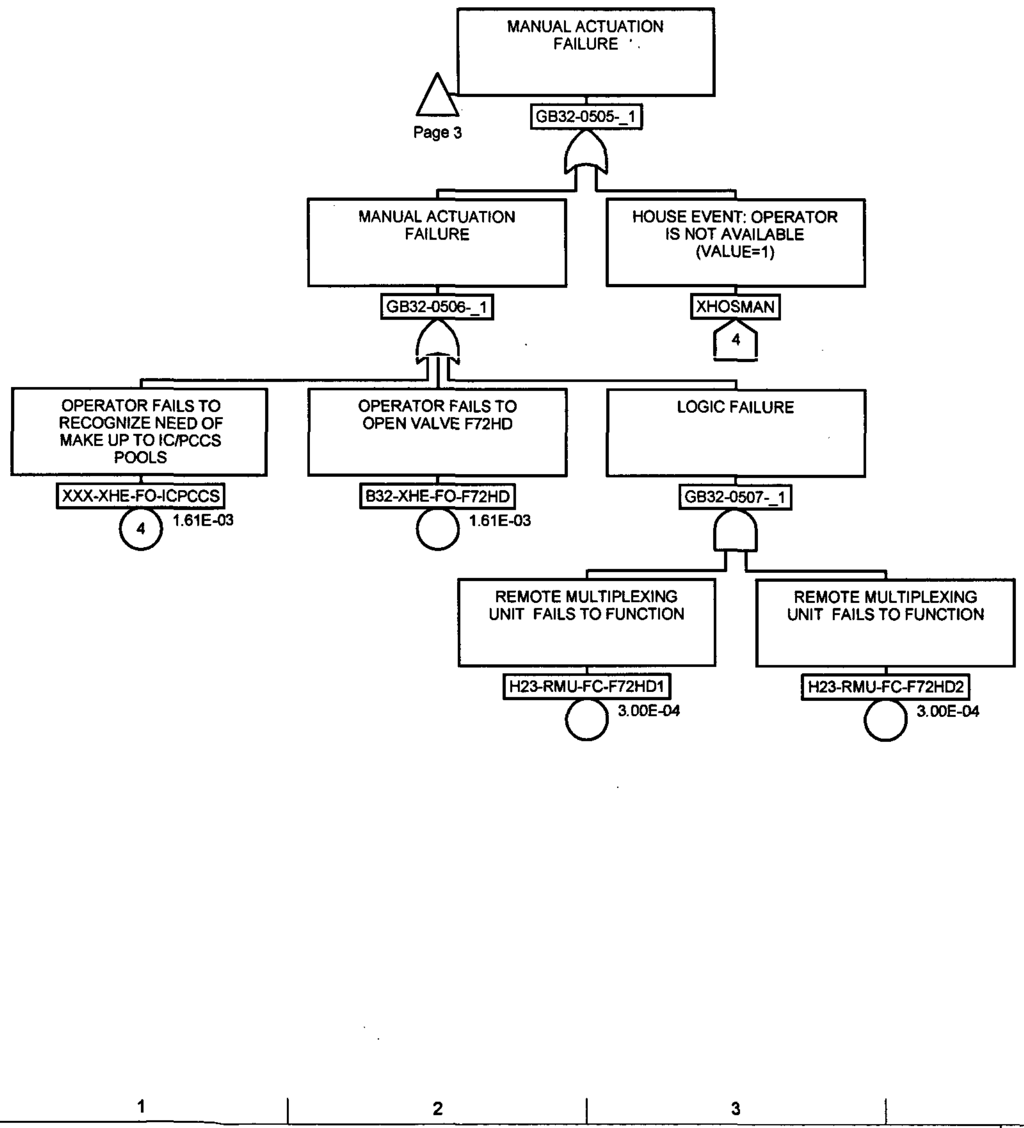

CHANNEL 3 FAILURE
Page 4
GB32-0213-_1
DTM OF SSLC DIV. 3 FAILS TO TRIP
C74-DTM-FC-DIV3
4
6.00E-04
LOSS OF DIV. 3 LEVEL SIGNAL
GB32-0217-_1
LOSS OF 208/120 V AC FROM BUS R13-31-2
GR13-0001-_6
3
ESSENTIAL MULTIPLEXING SYSTEM DIV 3 FAILS TO FUNCTION
H23-EMS-FC-DIV3
3
6.00E-04
ORIFICE INSTR. LINE DIV 3 FAILS TO REMAIN OPEN (PLUG)
B32-OR_-PG-F72HADIV3
1.44E-05
LEVEL TRANSMITTER DIV 3 POOL A FAILS
B32-LT_-NO-F72HADIV3
2.40E-05
REMOTE MULTIPLEXING UNIT DIV 3 FAILS TO FUNCTION
H23-RMU-FC-F72HADIV3
3.00E-04
1
2
3
4

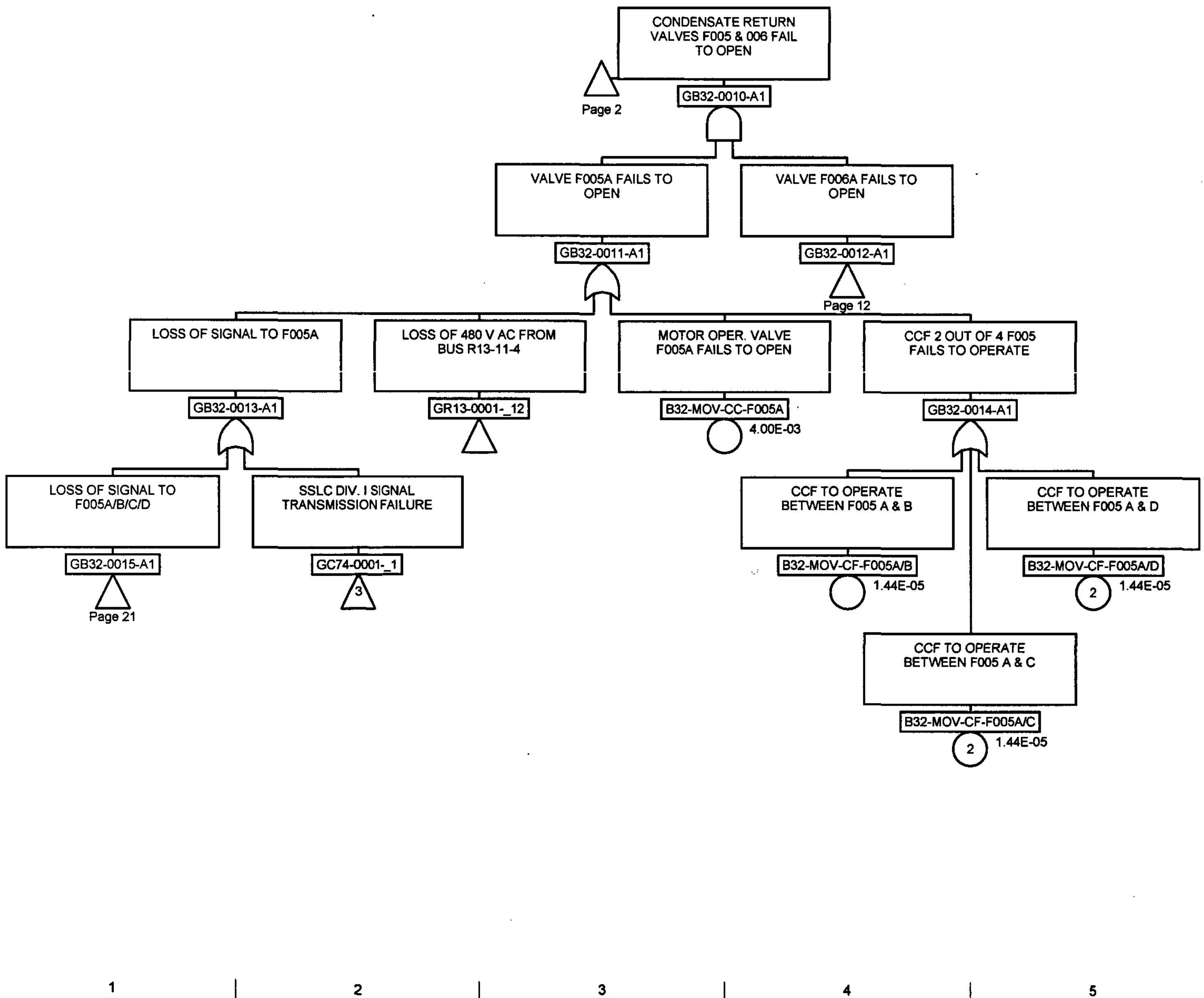

CHANNEL 4 FAILURE
GB32-0214-_1
Page 4
DTM OF SSLC DIV. 4 FAILS TO TRIP
C74-DTM-FC-DIV4
4
6.00E-04
LOSS OF DIV. 4 LEVEL SIGNAL
GB32-0218-_1
LOSS OF 208/120 V AC FROM BUS R13-41-2
GR13-0001-_8
3
ESSENTIAL MULTIPLEXING SYSTEM DIV 4 FAILS TO FUNCTION
H23-EMS-FC-DIV4
3
6.00E-04
ORIFICE INSTR. LINE DIV 4 FAILS TO REMAIN OPEN (PLUG)
B32-OR_-PG-F72HADIV4
1.44E-05
LEVEL TRANSMITTER DIV 4 POOL A FAILS
B32-LT_-NO-F72HADIV4
2.40E-05
REMOTE MULTIPLEXING UNIT DIV 4 FAILS TO FUNCTION
H23-RMU-FC-F72HADIV4
3.00E-04
1
2
3
4

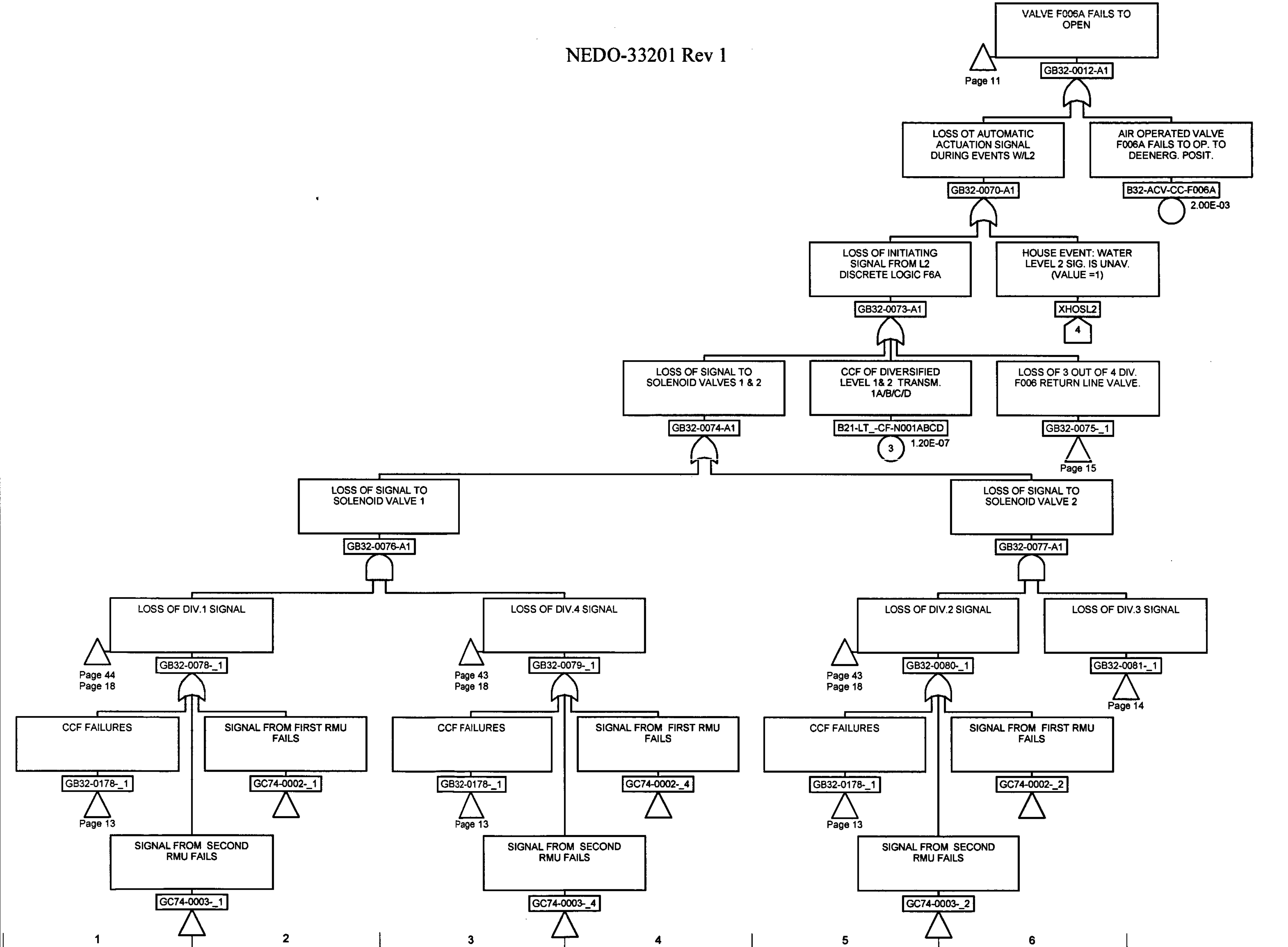

MANUAL ACTUATION FAILURE
Page 3
GB32-0206-_1
MANUAL ACTUATION FAILURE
GB32-0207-_1
HOUSE EVENT: OPERATOR IS NOT AVAILABLE (VALUE=1)
XHOSMAN
4
OPERATOR FAILS TO RECOGNIZE NEED OF MAKE UP TO IC/PCCS POOLS
XXX-XHE-FO-ICPCCS
4
1.61E-03
OPERATOR FAILS TO OPEN VALVE F72HA
B32-XHE-FO-F72HA
1.61E-03
LOGIC FAILURE
GB32-0208-_1
REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION
H23-RMU-FC-F72HA1
3.00E-04
REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION
H23-RMU-FC-F72HA2
3.00E-04
1
2
3

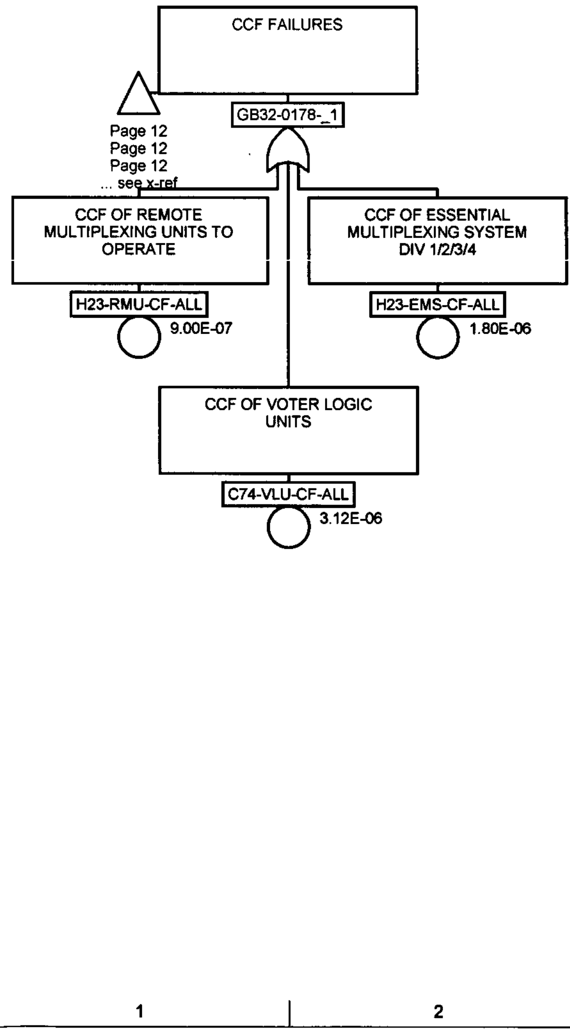

AUTOMATIC SIGNAL FAILS
GB32-0504-_1
Page 3
CCF 3 OUT OF FOUR A LEVEL TRANSMITTERS
B32-LT_-CF-LT72HA
2
7.20E-08
CCF 3/4 DTM OF SSLC DIV1/2/3/4
C74-DTM-CF-ALL
5
1.20E-05
LOSS OF 3/4 LEVEL CHANNELS
GB32-0205-_1
Page 4
SSLC DIV. II SIGNAL TRANSMISSION FAILURE
GC74-0001-_2
3

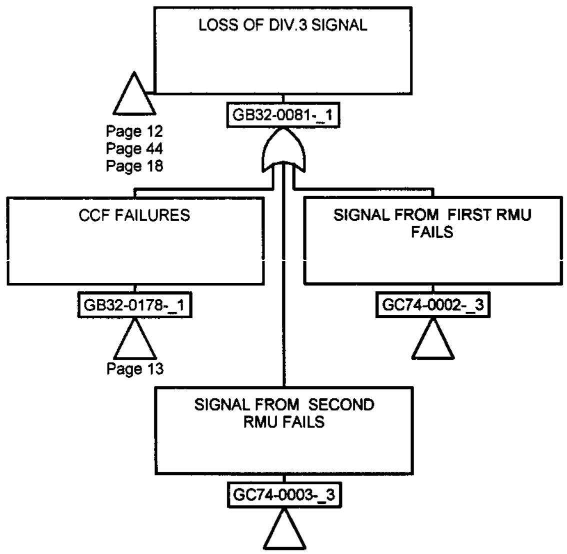
1 | 2

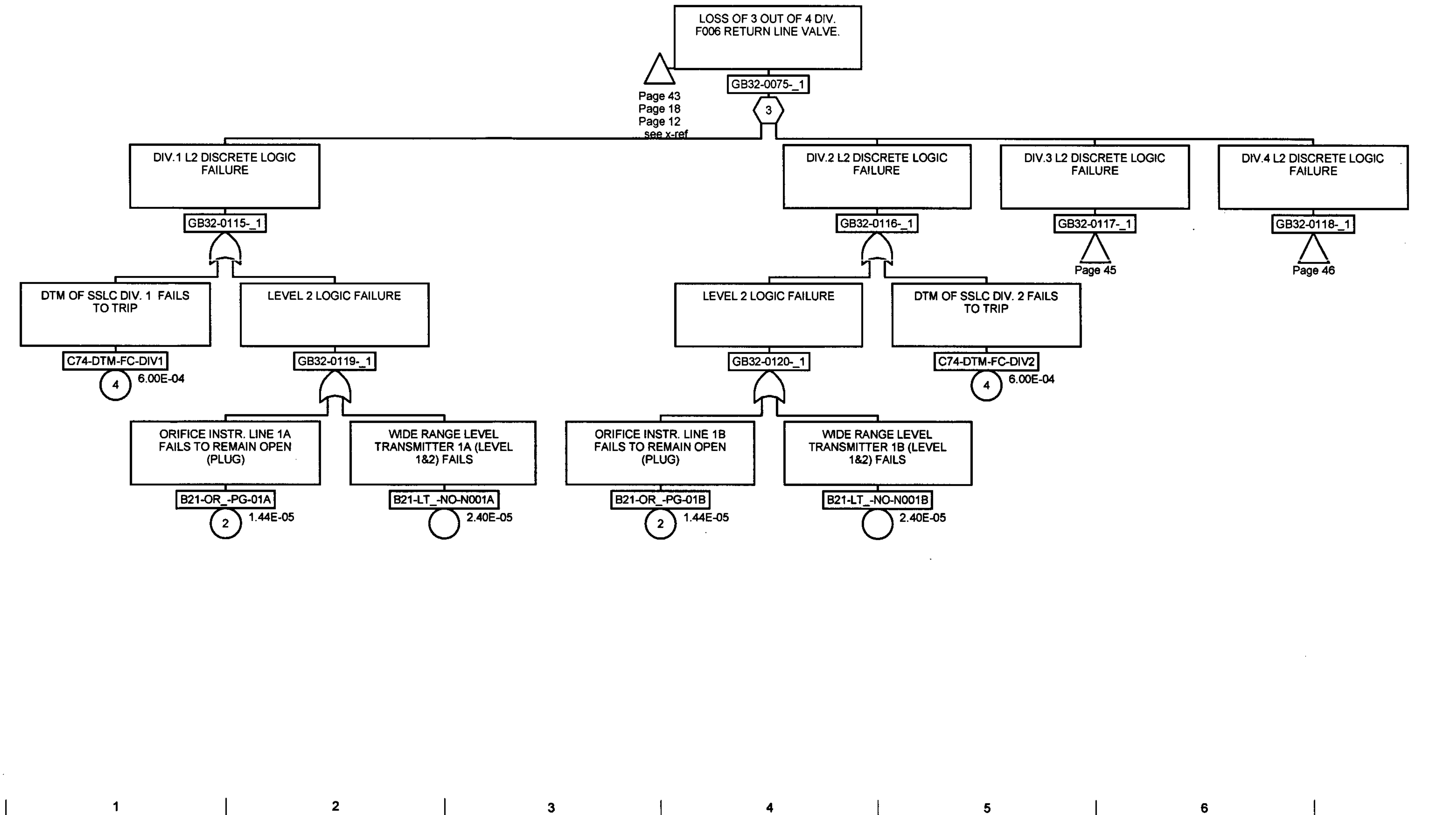

MANUAL ACTUATION FAILURE
GB32-0505-_1
Page 3
MANUAL ACTUATION FAILURE
GB32-0506-_1
HOUSE EVENT: OPERATOR IS NOT AVAILABLE (VALUE=1)
XHOSMAN
4
OPERATOR FAILS TO RECOGNIZE NEED OF MAKE UP TO IC/PCCS POOLS
XXX-XHE-FO-ICPCCS
4
1.61E-03
OPERATOR FAILS TO OPEN VALVE F72HD
B32-XHE-FO-F72HD
1.61E-03
LOGIC FAILURE
GB32-0507-_1
REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION
H23-RMU-FC-F72HD1
3.00E-04
REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION
H23-RMU-FC-F72HD2
3.00E-04
1
2
3

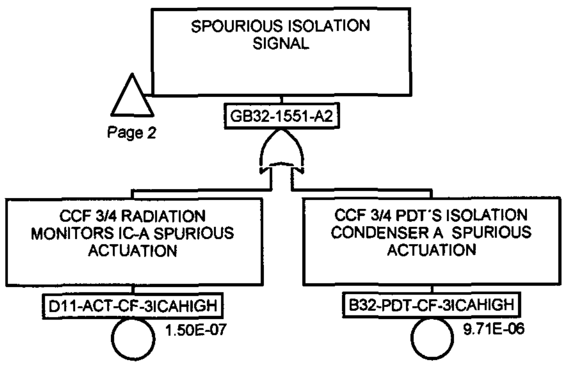

CONDENSATE RETURN VALVES F005 & 006 FAIL TO OPEN
Page 2
GB32-0010-A1
VALVE F005A FAILS TO OPEN
GB32-0011-A1
VALVE F006A FAILS TO OPEN
GB32-0012-A1
Page 12
LOSS OF SIGNAL TO F005A
GB32-0013-A1
LOSS OF 480 V AC FROM BUS R13-11-4
GR13-0001-_12
MOTOR OPER. VALVE F005A FAILS TO OPEN
B32-MOV-CC-F005A
4.00E-03
CCF 2 OUT OF 4 F005 FAILS TO OPERATE
GB32-0014-A1
LOSS OF SIGNAL TO F005A/B/C/D
GB32-0015-A1
Page 21
SSLC DIV. I SIGNAL TRANSMISSION FAILURE
GC74-0001-_1
3
CCF TO OPERATE BETWEEN F005 A & B
B32-MOV-CF-F005A/B
1.44E-05
CCF TO OPERATE BETWEEN F005 A & D
B32-MOV-CF-F005A/D
2
1.44E-05
CCF TO OPERATE BETWEEN F005 A & C
B32-MOV-CF-F005A/C
2
1.44E-05
1
2
3
4
5


VALVE F006A FAILS TO OPEN
GB32-0012-A1
Page 11
LOSS OT AUTOMATIC ACTUATION SIGNAL DURING EVENTS W/L2
GB32-0070-A1
AIR OPERATED VALVE F006A FAILS TO OP. TO DEENERG. POSIT.
B32-ACV-CC-F006A
2.00E-03
LOSS OF INITIATING SIGNAL FROM L2 DISCRETE LOGIC F6A
GB32-0073-A1
HOUSE EVENT: WATER LEVEL 2 SIG. IS UNAV. (VALUE =1)
XHOSL2
4
LOSS OF SIGNAL TO SOLENOID VALVES 1 & 2
GB32-0074-A1
CCF OF DIVERSIFIED LEVEL 1& 2 TRANSM. 1A/B/C/D
B21-LT_-CF-N001ABCD
3
1.20E-07
LOSS OF 3 OUT OF 4 DIV. F006 RETURN LINE VALVE.
GB32-0075-_1
Page 15
LOSS OF SIGNAL TO SOLENOID VALVE 1
GB32-0076-A1
LOSS OF SIGNAL TO SOLENOID VALVE 2
GB32-0077-A1
LOSS OF DIV.1 SIGNAL
GB32-0078-_1
Page 44
Page 18
LOSS OF DIV.4 SIGNAL
GB32-0079-_1
Page 43
Page 18
LOSS OF DIV.2 SIGNAL
GB32-0080-_1
Page 43
Page 18
LOSS OF DIV.3 SIGNAL
GB32-0081-_1
Page 14
CCF FAILURES
GB32-0178-_1
Page 13
SIGNAL FROM FIRST RMU FAILS
GC74-0002-_1
SIGNAL FROM SECOND RMU FAILS
GC74-0003-_1
CCF FAILURES
GB32-0178-_1
Page 13
SIGNAL FROM FIRST RMU FAILS
GC74-0002-_4
SIGNAL FROM SECOND RMU FAILS
GC74-0003-_4
CCF FAILURES
GB32-0178-_1
Page 13
SIGNAL FROM FIRST RMU FAILS
GC74-0002-_2
SIGNAL FROM SECOND RMU FAILS
GC74-0003-_2
1
2
3
4
5
6

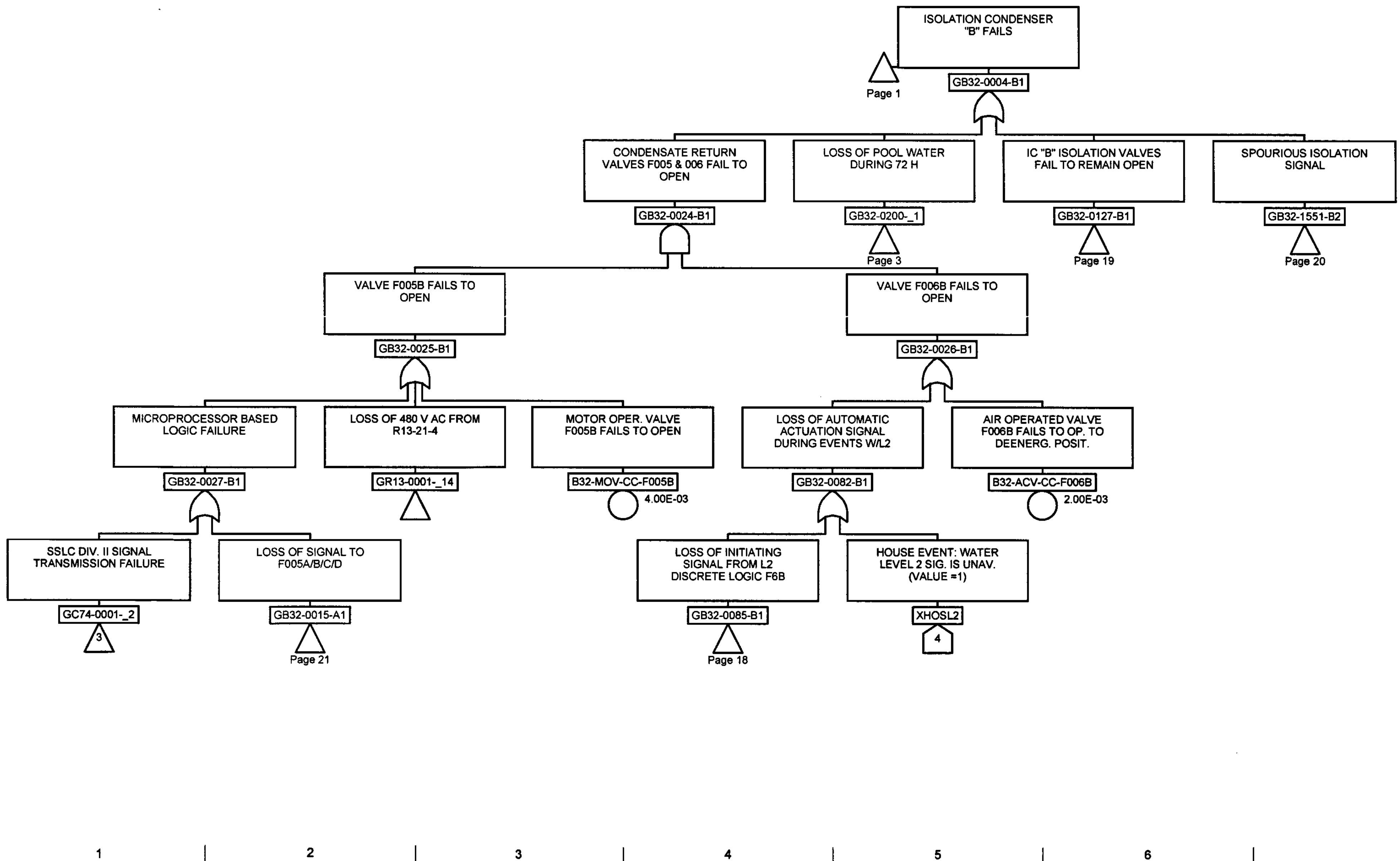

CCF FAILURES
GB32-0178-_1
Page 12
Page 12
Page 12
... see x-ref
CCF OF REMOTE MULTIPLEXING UNITS TO OPERATE
H23-RMU-CF-ALL
9.00E-07
CCF OF ESSENTIAL MULTIPLEXING SYSTEM DIV 1/2/3/4
H23-EMS-CF-ALL
1.80E-06
CCF OF VOTER LOGIC UNITS
C74-VLU-CF-ALL
3.12E-06
1
2

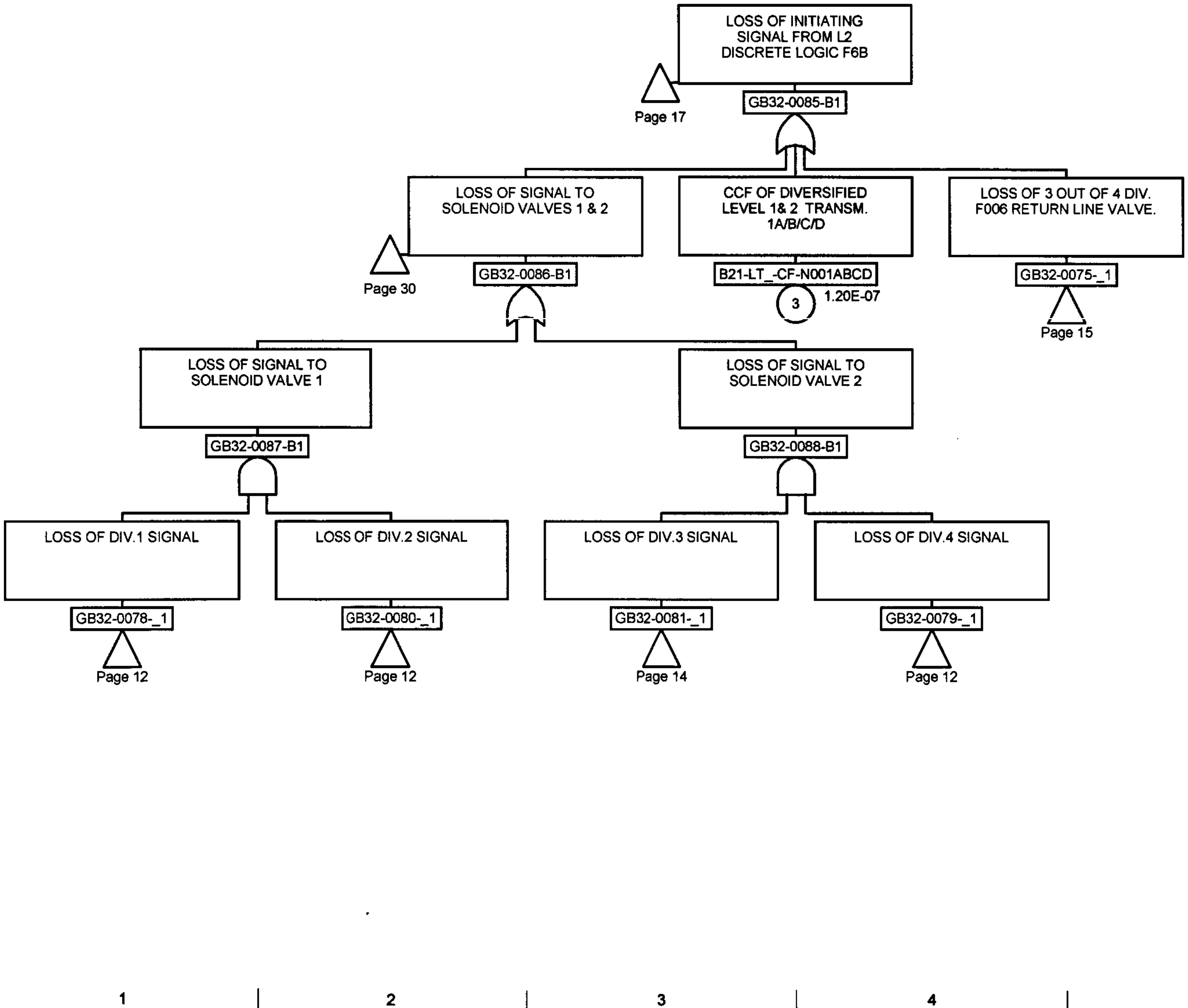

LOSS OF DIV.3 SIGNAL
GB32-0081-_1
Page 12
Page 44
Page 18
CCF FAILURES
GB32-0178-_1
Page 13
SIGNAL FROM FIRST RMU FAILS
GC74-0002-_3
SIGNAL FROM SECOND RMU FAILS
GC74-0003-_3

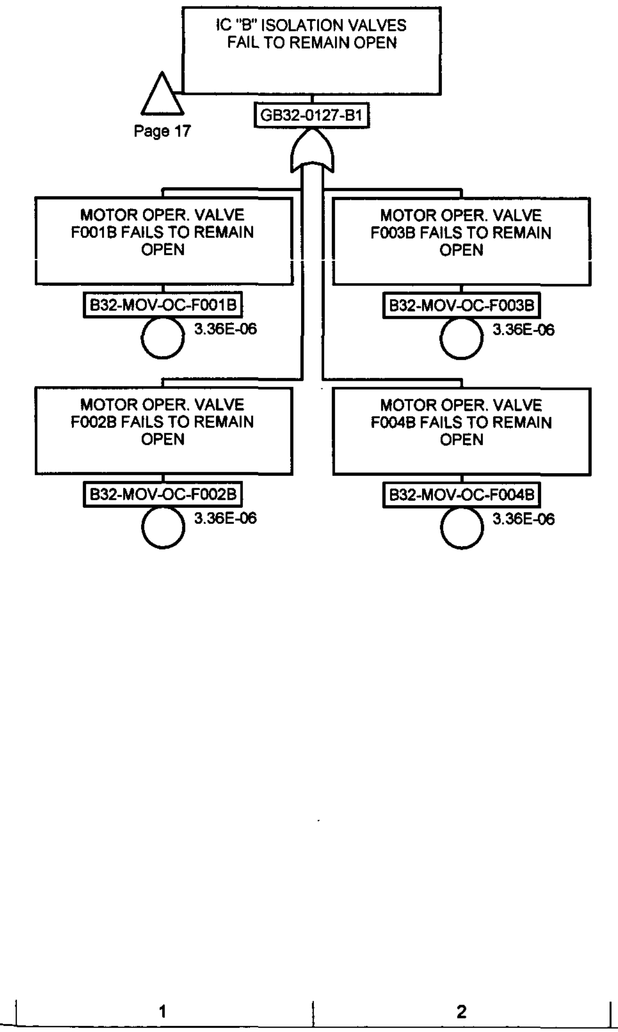

LOSS OF 3 OUT OF 4 DIV. F006 RETURN LINE VALVE.
GB32-0075-_1
3
Page 43
Page 18
Page 12
see x-ref
DIV.1 L2 DISCRETE LOGIC FAILURE
GB32-0115-_1
DIV.2 L2 DISCRETE LOGIC FAILURE
GB32-0116-_1
DIV.3 L2 DISCRETE LOGIC FAILURE
GB32-0117-_1
Page 45
DIV.4 L2 DISCRETE LOGIC FAILURE
GB32-0118-_1
Page 46
DTM OF SSLC DIV. 1 FAILS TO TRIP
C74-DTM-FC-DIV1
4
6.00E-04
LEVEL 2 LOGIC FAILURE
GB32-0119-_1
LEVEL 2 LOGIC FAILURE
GB32-0120-_1
DTM OF SSLC DIV. 2 FAILS TO TRIP
C74-DTM-FC-DIV2
4
6.00E-04
ORIFICE INSTR. LINE 1A FAILS TO REMAIN OPEN (PLUG)
B21-OR_-PG-01A
2
1.44E-05
WIDE RANGE LEVEL TRANSMITTER 1A (LEVEL 1&2) FAILS
B21-LT_-NO-N001A
2.40E-05
ORIFICE INSTR. LINE 1B FAILS TO REMAIN OPEN (PLUG)
B21-OR_-PG-01B
2
1.44E-05
WIDE RANGE LEVEL TRANSMITTER 1B (LEVEL 1&2) FAILS
B21-LT_-NO-N001B
2.40E-05
1
2
3
4
5
6


SPOURIOUS ISOLATION SIGNAL
GB32-1551-A2
Page 2
CCF 3/4 RADIATION MONITORS IC-A SPURIOUS ACTUATION
D11-ACT-CF-3ICAHIGH
1.50E-07
CCF 3/4 PDT'S ISOLATION CONDENSER A SPURIOUS ACTUATION
B32-PDT-CF-3ICAHIGH
9.71E-06

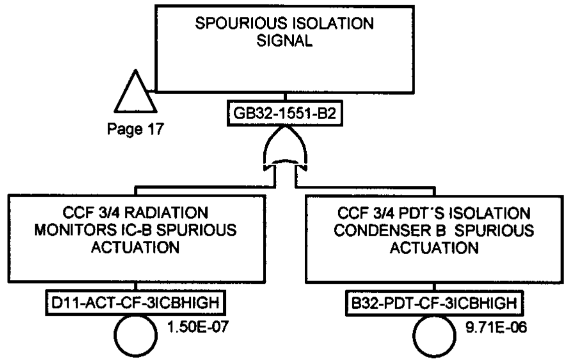
1 2

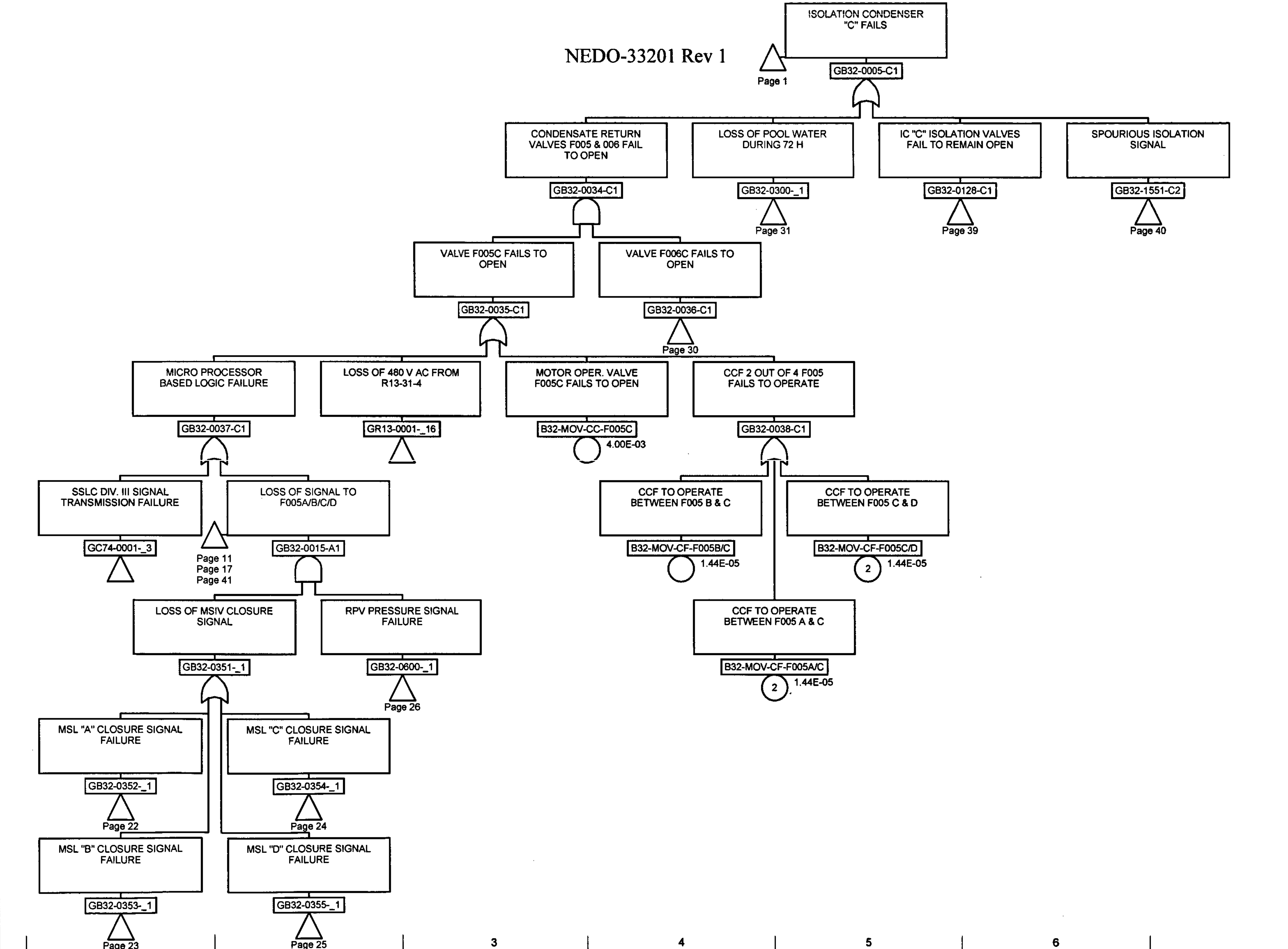

ISOLATION CONDENSER "B" FAILS
Page 1
GB32-0004-B1
CONDENSATE RETURN VALVES F005 & 006 FAIL TO OPEN
GB32-0024-B1
LOSS OF POOL WATER DURING 72 H
GB32-0200-_1
Page 3
IC "B" ISOLATION VALVES FAIL TO REMAIN OPEN
GB32-0127-B1
Page 19
SPOURIOUS ISOLATION SIGNAL
GB32-1551-B2
Page 20
VALVE F005B FAILS TO OPEN
GB32-0025-B1
VALVE F006B FAILS TO OPEN
GB32-0026-B1
MICROPROCESSOR BASED LOGIC FAILURE
GB32-0027-B1
LOSS OF 480 V AC FROM R13-21-4
GR13-0001-_14
MOTOR OPER. VALVE F005B FAILS TO OPEN
B32-MOV-CC-F005B
4.00E-03
LOSS OF AUTOMATIC ACTUATION SIGNAL DURING EVENTS W/L2
GB32-0082-B1
AIR OPERATED VALVE F006B FAILS TO OP. TO DEENERG. POSIT.
B32-ACV-CC-F006B
2.00E-03
SSLC DIV. II SIGNAL TRANSMISSION FAILURE
GC74-0001-_2
3
LOSS OF SIGNAL TO F005A/B/C/D
GB32-0015-A1
Page 21
LOSS OF INITIATING SIGNAL FROM L2 DISCRETE LOGIC F6B
GB32-0085-B1
Page 18
HOUSE EVENT: WATER LEVEL 2 SIG. IS UNAV. (VALUE =1)
XHOSL2
4
1
2
3
4
5
6

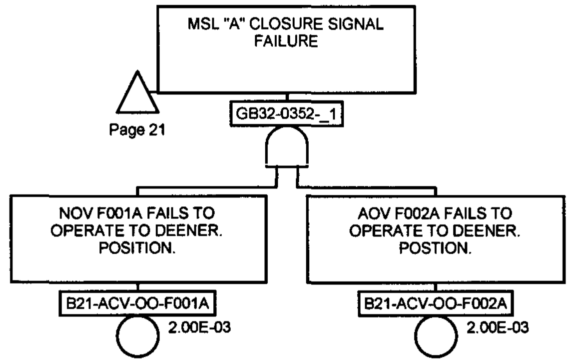

LOSS OF INITIATING SIGNAL FROM L2 DISCRETE LOGIC F6B
GB32-0085-B1
Page 17
LOSS OF SIGNAL TO SOLENOID VALVES 1 & 2
GB32-0086-B1
Page 30
CCF OF DIVERSIFIED LEVEL 1& 2 TRANSM. 1A/B/C/D
B21-LT_-CF-N001ABCD
3
1.20E-07
LOSS OF 3 OUT OF 4 DIV. F006 RETURN LINE VALVE.
GB32-0075-_1
Page 15
LOSS OF SIGNAL TO SOLENOID VALVE 1
GB32-0087-B1
LOSS OF SIGNAL TO SOLENOID VALVE 2
GB32-0088-B1
LOSS OF DIV.1 SIGNAL
GB32-0078-_1
Page 12
LOSS OF DIV.2 SIGNAL
GB32-0080-_1
Page 12
LOSS OF DIV.3 SIGNAL
GB32-0081-_1
Page 14
LOSS OF DIV.4 SIGNAL
GB32-0079-_1
Page 12
1
2
3
4

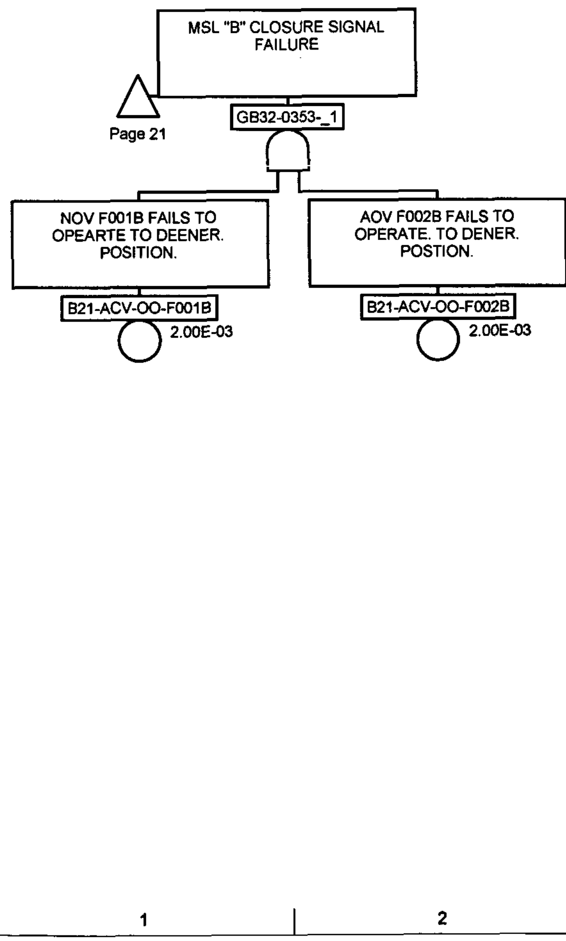


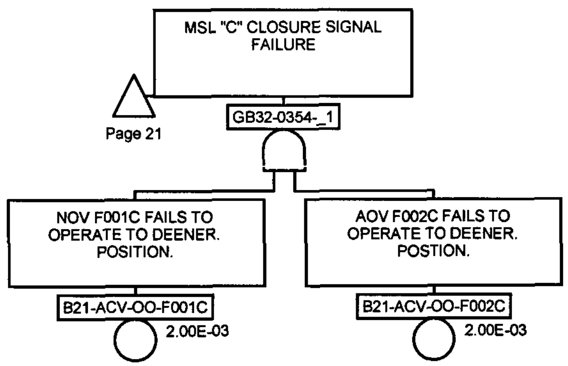
IC "B" ISOLATION VALVES FAIL TO REMAIN OPEN
Page 17
GB32-0127-B1
MOTOR OPER. VALVE F001B FAILS TO REMAIN OPEN
B32-MOV-OC-F001B
3.36E-06
MOTOR OPER. VALVE F003B FAILS TO REMAIN OPEN
B32-MOV-OC-F003B
3.36E-06
MOTOR OPER. VALVE F002B FAILS TO REMAIN OPEN
B32-MOV-OC-F002B
3.36E-06
MOTOR OPER. VALVE F004B FAILS TO REMAIN OPEN
B32-MOV-OC-F004B
3.36E-06
1
2


SPOURIOUS ISOLATION SIGNAL
Page 17
GB32-1551-B2
CCF 3/4 RADIATION MONITORS IC-B SPURIOUS ACTUATION
D11-ACT-CF-3ICBHIGH
1.50E-07
CCF 3/4 PDT'S ISOLATION CONDENSER B SPURIOUS ACTUATION
B32-PDT-CF-3ICBHIGH
9.71E-06
1
2

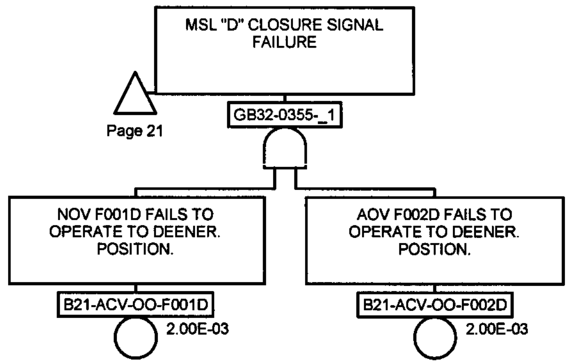

ISOLATION CONDENSER "C" FAILS
GB32-0005-C1
Page 1
CONDENSATE RETURN VALVES F005 & 006 FAIL TO OPEN
GB32-0034-C1
LOSS OF POOL WATER DURING 72 H
GB32-0300-_1
Page 31
IC "C" ISOLATION VALVES FAIL TO REMAIN OPEN
GB32-0128-C1
Page 39
SPOURIOUS ISOLATION SIGNAL
GB32-1551-C2
Page 40
VALVE F005C FAILS TO OPEN
GB32-0035-C1
VALVE F006C FAILS TO OPEN
GB32-0036-C1
Page 30
MICRO PROCESSOR BASED LOGIC FAILURE
GB32-0037-C1
LOSS OF 480 V AC FROM R13-31-4
GR13-0001-_16
MOTOR OPER. VALVE F005C FAILS TO OPEN
B32-MOV-CC-F005C
4.00E-03
CCF 2 OUT OF 4 F005 FAILS TO OPERATE
GB32-0038-C1
SSLC DIV. III SIGNAL TRANSMISSION FAILURE
GC74-0001-_3
Page 11
Page 17
Page 41
LOSS OF SIGNAL TO F005A/B/C/D
GB32-0015-A1
CCF TO OPERATE BETWEEN F005 B & C
B32-MOV-CF-F005B/C
1.44E-05
CCF TO OPERATE BETWEEN F005 C & D
B32-MOV-CF-F005C/D
2
1.44E-05
LOSS OF MSIV CLOSURE SIGNAL
GB32-0351-_1
RPV PRESSURE SIGNAL FAILURE
GB32-0600-_1
Page 26
CCF TO OPERATE BETWEEN F005 A & C
B32-MOV-CF-F005A/C
2
1.44E-05
MSL "A" CLOSURE SIGNAL FAILURE
GB32-0352-_1
Page 22
MSL "C" CLOSURE SIGNAL FAILURE
GB32-0354-_1
Page 24
MSL "B" CLOSURE SIGNAL FAILURE
GB32-0353-_1
Page 23
MSL "D" CLOSURE SIGNAL FAILURE
GB32-0355-_1
Page 25
3
4
5
6

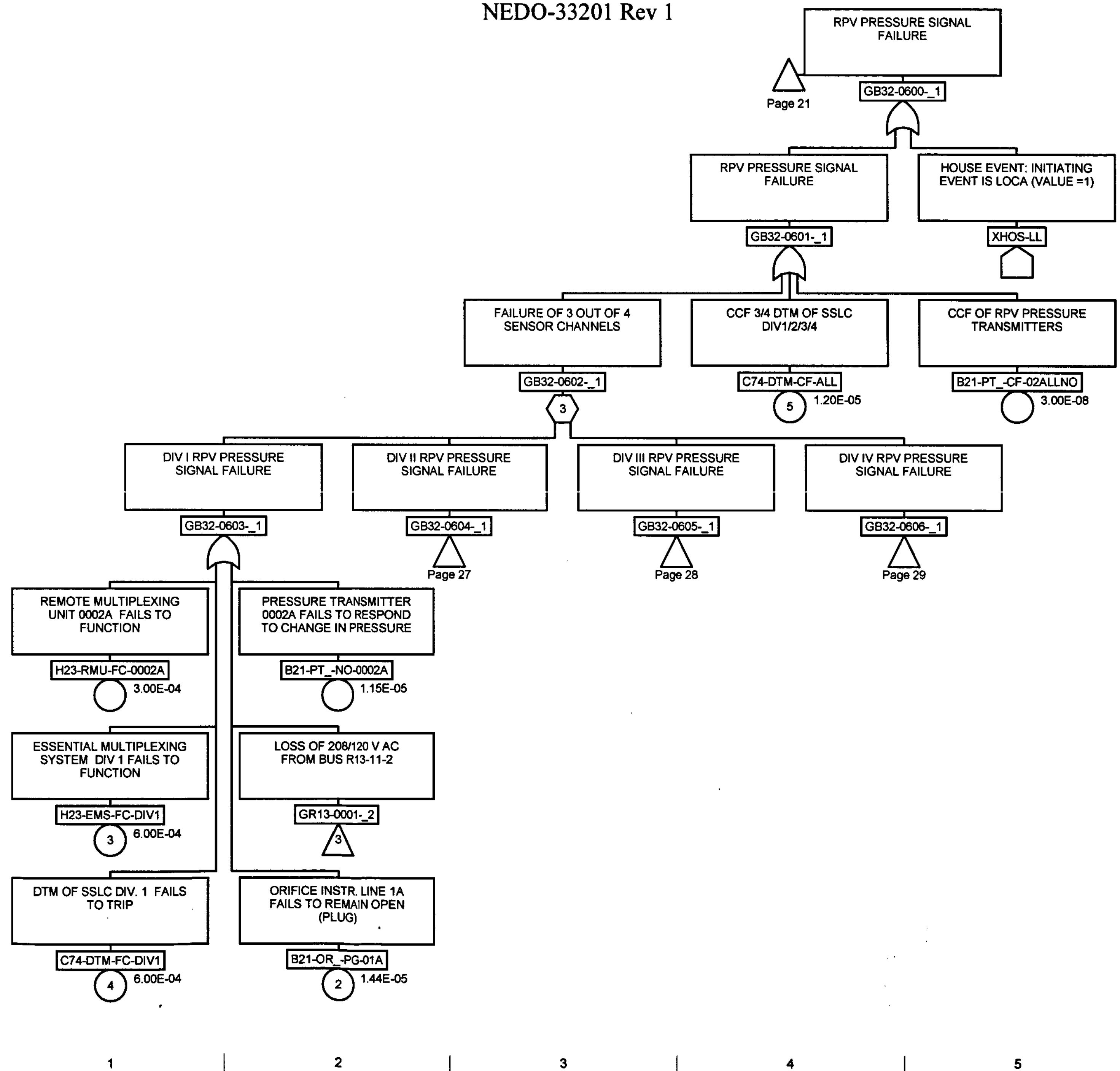

MSL "A" CLOSURE SIGNAL FAILURE
Page 21
GB32-0352-_1
NOV F001A FAILS TO OPERATE TO DEENER. POSITION.
AOV F002A FAILS TO OPERATE TO DEENER. POSTION.
B21-ACV-OO-F001A
2.00E-03
B21-ACV-OO-F002A
2.00E-03
1
2

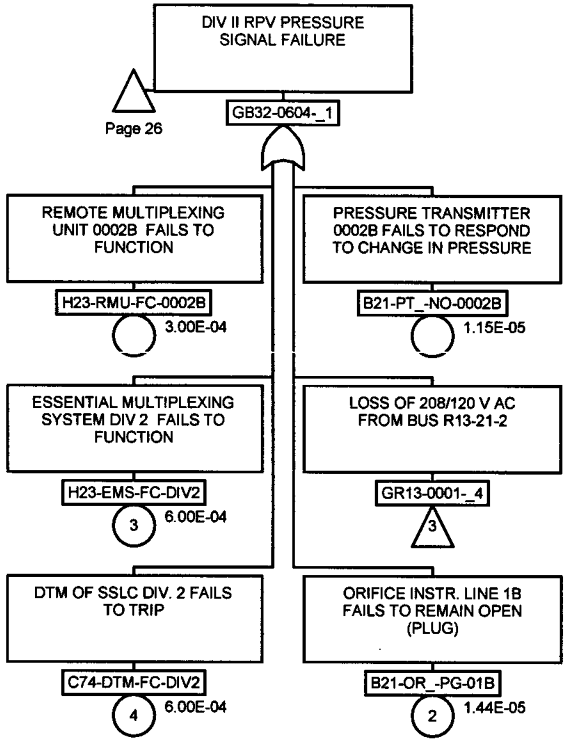

MSL "B" CLOSURE SIGNAL FAILURE
GB32-0353-_1
Page 21
NOV F001B FAILS TO OPEARTE TO DEENER. POSITION.
B21-ACV-OO-F001B
2.00E-03
AOV F002B FAILS TO OPERATE. TO DENER. POSTION.
B21-ACV-OO-F002B
2.00E-03
1
2

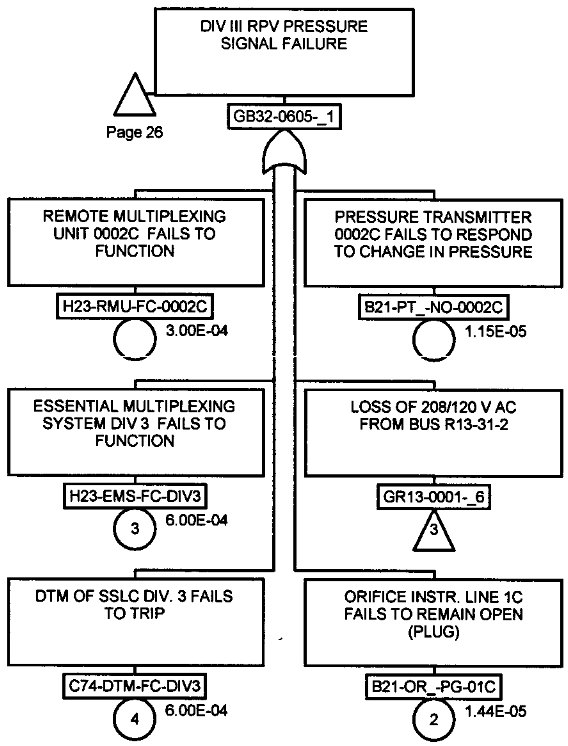

MSL "C" CLOSURE SIGNAL FAILURE
GB32-0354-_1
Page 21
NOV F001C FAILS TO OPERATE TO DEENER. POSITION.
B21-ACV-OO-F001C
2.00E-03
AOV F002C FAILS TO OPERATE TO DEENER. POSTION.
B21-ACV-OO-F002C
2.00E-03

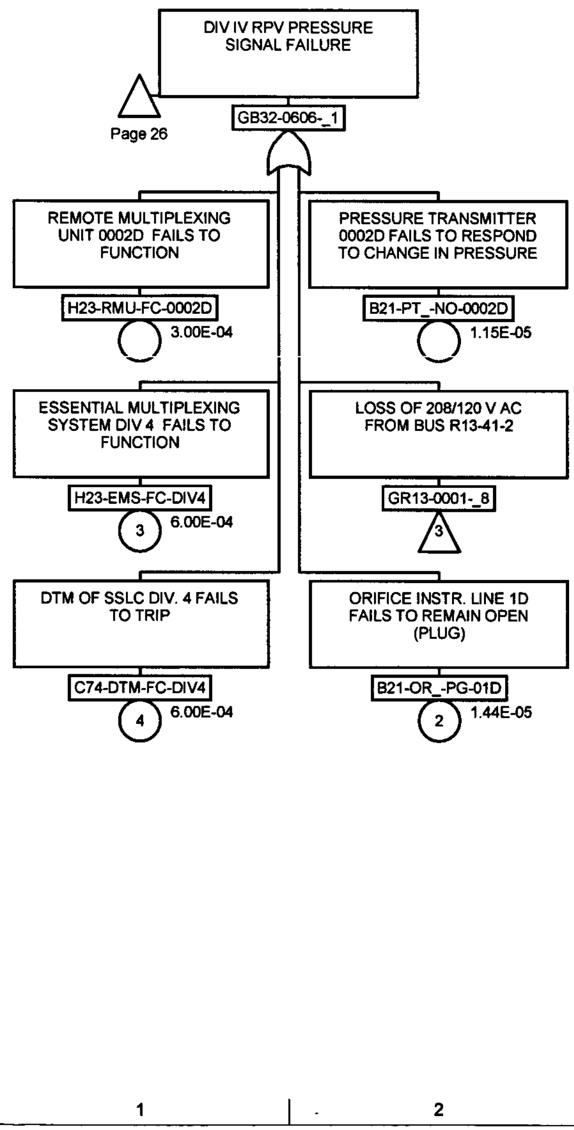
1 2

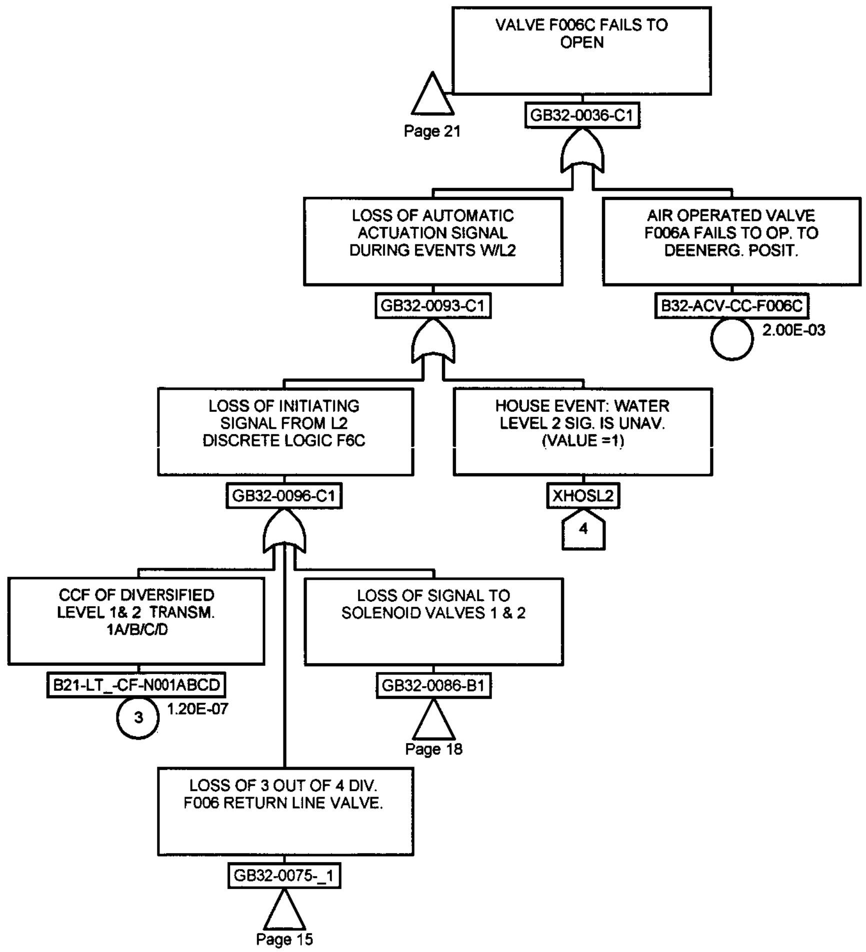

MSL "D" CLOSURE SIGNAL FAILURE
Page 21
GB32-0355-_1
NOV F001D FAILS TO OPERATE TO DEENER. POSITION.
AOV F002D FAILS TO OPERATE TO DEENER. POSTION.
B21-ACV-OO-F001D
2.00E-03
B21-ACV-OO-F002D
2.00E-03
1
2

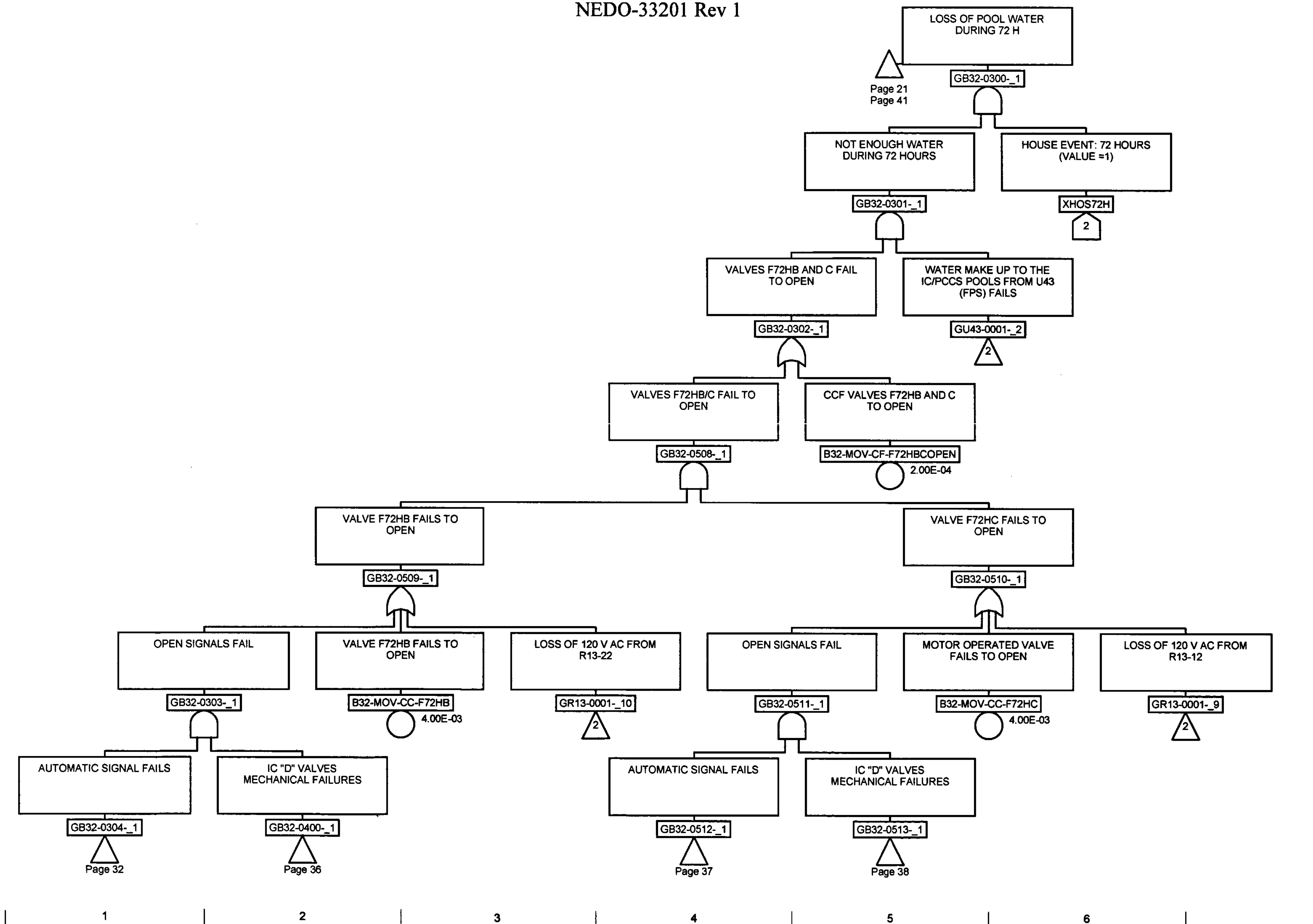

RPV PRESSURE SIGNAL FAILURE
GB32-0600-_1
Page 21
RPV PRESSURE SIGNAL FAILURE
GB32-0601-_1
HOUSE EVENT: INITIATING EVENT IS LOCA (VALUE =1)
XHOS-LL
FAILURE OF 3 OUT OF 4 SENSOR CHANNELS
GB32-0602-_1
3
CCF 3/4 DTM OF SSLC DIV1/2/3/4
C74-DTM-CF-ALL
5
1.20E-05
CCF OF RPV PRESSURE TRANSMITTERS
B21-PT_-CF-02ALLNO
3.00E-08
DIV I RPV PRESSURE SIGNAL FAILURE
GB32-0603-_1
DIV II RPV PRESSURE SIGNAL FAILURE
GB32-0604-_1
Page 27
DIV III RPV PRESSURE SIGNAL FAILURE
GB32-0605-_1
Page 28
DIV IV RPV PRESSURE SIGNAL FAILURE
GB32-0606-_1
Page 29
REMOTE MULTIPLEXING UNIT 0002A FAILS TO FUNCTION
H23-RMU-FC-0002A
3.00E-04
PRESSURE TRANSMITTER 0002A FAILS TO RESPOND TO CHANGE IN PRESSURE
B21-PT_-NO-0002A
1.15E-05
ESSENTIAL MULTIPLEXING SYSTEM DIV 1 FAILS TO FUNCTION
H23-EMS-FC-DIV1
3
6.00E-04
LOSS OF 208/120 V AC FROM BUS R13-11-2
GR13-0001-_2
3
DTM OF SSLC DIV. 1 FAILS TO TRIP
C74-DTM-FC-DIV1
4
6.00E-04
ORIFICE INSTR. LINE 1A FAILS TO REMAIN OPEN (PLUG)
B21-OR_-PG-01A
2
1.44E-05
1
2
3
4
5


DIV II RPV PRESSURE SIGNAL FAILURE
Page 26
GB32-0604-_1
REMOTE MULTIPLEXING UNIT 0002B FAILS TO FUNCTION
H23-RMU-FC-0002B
3.00E-04
PRESSURE TRANSMITTER 0002B FAILS TO RESPOND TO CHANGE IN PRESSURE
B21-PT_-NO-0002B
1.15E-05
ESSENTIAL MULTIPLEXING SYSTEM DIV 2 FAILS TO FUNCTION
H23-EMS-FC-DIV2
3
6.00E-04
LOSS OF 208/120 V AC FROM BUS R13-21-2
GR13-0001-_4
3
DTM OF SSLC DIV. 2 FAILS TO TRIP
C74-DTM-FC-DIV2
4
6.00E-04
ORIFICE INSTR. LINE 1B FAILS TO REMAIN OPEN (PLUG)
B21-OR_-PG-01B
2
1.44E-05
1
2

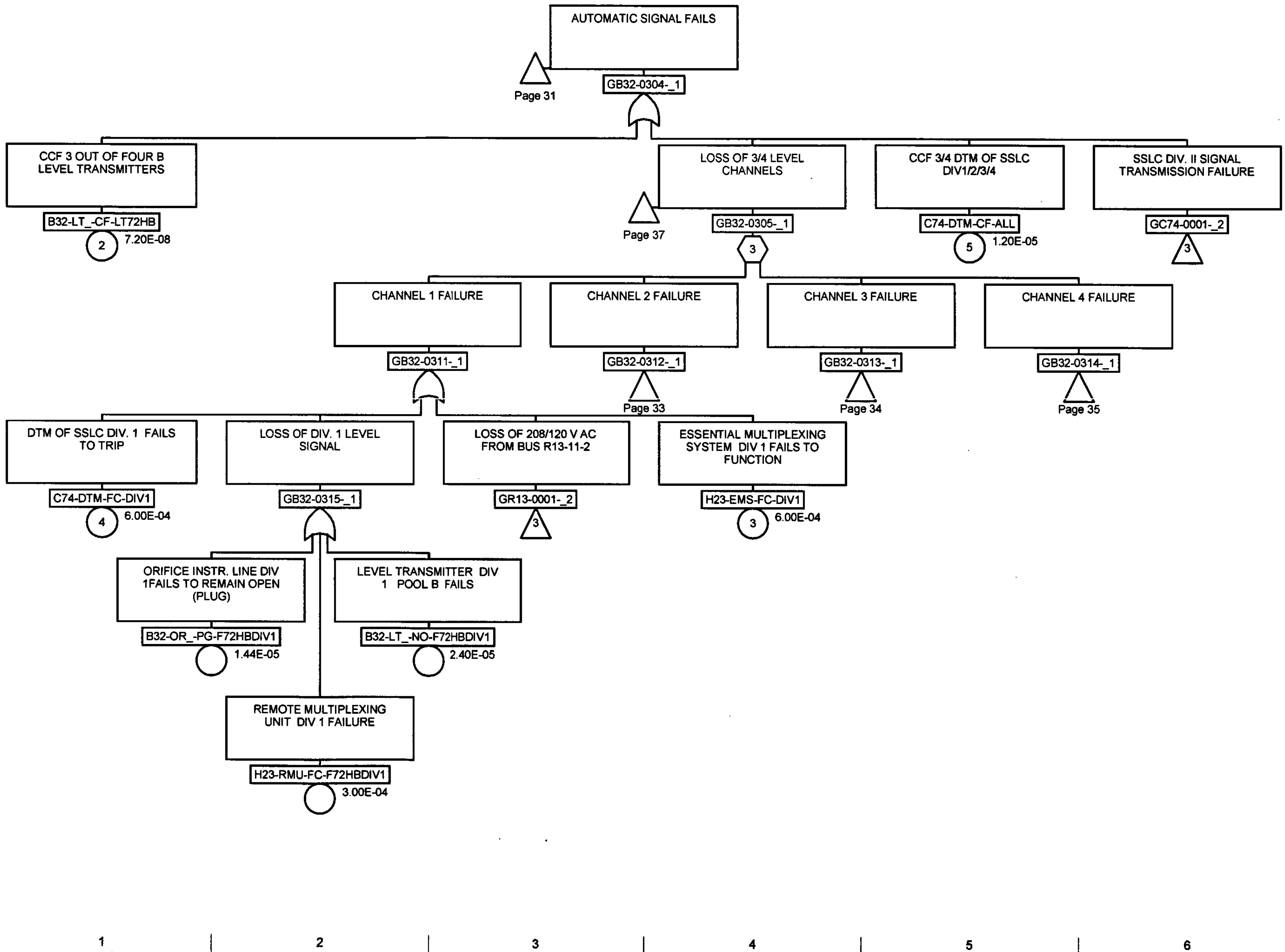

DIV III RPV PRESSURE SIGNAL FAILURE
Page 26
GB32-0605-_1
REMOTE MULTIPLEXING UNIT 0002C FAILS TO FUNCTION
H23-RMU-FC-0002C
3.00E-04
PRESSURE TRANSMITTER 0002C FAILS TO RESPOND TO CHANGE IN PRESSURE
B21-PT_-NO-0002C
1.15E-05
ESSENTIAL MULTIPLEXING SYSTEM DIV 3 FAILS TO FUNCTION
H23-EMS-FC-DIV3
3
6.00E-04
LOSS OF 208/120 V AC FROM BUS R13-31-2
GR13-0001-_6
3
DTM OF SSLC DIV. 3 FAILS TO TRIP
C74-DTM-FC-DIV3
4
6.00E-04
ORIFICE INSTR. LINE 1C FAILS TO REMAIN OPEN (PLUG)
B21-OR_-PG-01C
2
1.44E-05
1
2


DIV IV RPV PRESSURE SIGNAL FAILURE
GB32-0606-_1
Page 26
REMOTE MULTIPLEXING UNIT 0002D FAILS TO FUNCTION
H23-RMU-FC-0002D
3.00E-04
PRESSURE TRANSMITTER 0002D FAILS TO RESPOND TO CHANGE IN PRESSURE
B21-PT_-NO-0002D
1.15E-05
ESSENTIAL MULTIPLEXING SYSTEM DIV 4 FAILS TO FUNCTION
H23-EMS-FC-DIV4
3
6.00E-04
LOSS OF 208/120 V AC FROM BUS R13-41-2
GR13-0001-_8
3
DTM OF SSLC DIV. 4 FAILS TO TRIP
C74-DTM-FC-DIV4
4
6.00E-04
ORIFICE INSTR. LINE 1D FAILS TO REMAIN OPEN (PLUG)
B21-OR_-PG-01D
2
1.44E-05
1
2


VALVE F006C FAILS TO OPEN
Page 21
GB32-0036-C1
LOSS OF AUTOMATIC ACTUATION SIGNAL DURING EVENTS W/L2
GB32-0093-C1
AIR OPERATED VALVE F006A FAILS TO OP. TO DEENERG. POSIT.
B32-ACV-CC-F006C
2.00E-03
LOSS OF INITIATING SIGNAL FROM L2 DISCRETE LOGIC F6C
GB32-0096-C1
HOUSE EVENT: WATER LEVEL 2 SIG. IS UNAV. (VALUE =1)
XHOSL2
4
CCF OF DIVERSIFIED LEVEL 1& 2 TRANSM. 1A/B/C/D
B21-LT_-CF-N001ABCD
3
1.20E-07
LOSS OF SIGNAL TO SOLENOID VALVES 1 & 2
GB32-0086-B1
Page 18
LOSS OF 3 OUT OF 4 DIV. F006 RETURN LINE VALVE.
GB32-0075-_1
Page 15
1
2
3



LOSS OF POOL WATER DURING 72 H
GB32-0300-_1
Page 21
Page 41
NOT ENOUGH WATER DURING 72 HOURS
GB32-0301-_1
HOUSE EVENT: 72 HOURS (VALUE =1)
XHOS72H
2
VALVES F72HB AND C FAIL TO OPEN
GB32-0302-_1
WATER MAKE UP TO THE IC/PCCS POOLS FROM U43 (FPS) FAILS
GU43-0001-_2
2
VALVES F72HB/C FAIL TO OPEN
GB32-0508-_1
CCF VALVES F72HB AND C TO OPEN
B32-MOV-CF-F72HBCOPEN
2.00E-04
VALVE F72HB FAILS TO OPEN
GB32-0509-_1
VALVE F72HC FAILS TO OPEN
GB32-0510-_1
OPEN SIGNALS FAIL
GB32-0303-_1
VALVE F72HB FAILS TO OPEN
B32-MOV-CC-F72HB
4.00E-03
LOSS OF 120 V AC FROM R13-22
GR13-0001-_10
2
OPEN SIGNALS FAIL
GB32-0511-_1
MOTOR OPERATED VALVE FAILS TO OPEN
B32-MOV-CC-F72HC
4.00E-03
LOSS OF 120 V AC FROM R13-12
GR13-0001-_9
2
AUTOMATIC SIGNAL FAILS
GB32-0304-_1
Page 32
IC "D" VALVES MECHANICAL FAILURES
GB32-0400-_1
Page 36
AUTOMATIC SIGNAL FAILS
GB32-0512-_1
Page 37
IC "D" VALVES MECHANICAL FAILURES
GB32-0513-_1
Page 38
1
2
3
4
5
6


AUTOMATIC SIGNAL FAILS
GB32-0304-_1
Page 31
CCF 3 OUT OF FOUR B LEVEL TRANSMITTERS
B32-LT_-CF-LT72HB
2
7.20E-08
LOSS OF 3/4 LEVEL CHANNELS
Page 37
GB32-0305-_1
3
CCF 3/4 DTM OF SSLC DIV1/2/3/4
C74-DTM-CF-ALL
5
1.20E-05
SSLC DIV. II SIGNAL TRANSMISSION FAILURE
GC74-0001-_2
3
CHANNEL 1 FAILURE
GB32-0311-_1
CHANNEL 2 FAILURE
GB32-0312-_1
Page 33
CHANNEL 3 FAILURE
GB32-0313-_1
Page 34
CHANNEL 4 FAILURE
GB32-0314-_1
Page 35
DTM OF SSLC DIV. 1 FAILS TO TRIP
C74-DTM-FC-DIV1
4
6.00E-04
LOSS OF DIV. 1 LEVEL SIGNAL
GB32-0315-_1
LOSS OF 208/120 V AC FROM BUS R13-11-2
GR13-0001-_2
3
ESSENTIAL MULTIPLEXING SYSTEM DIV 1 FAILS TO FUNCTION
H23-EMS-FC-DIV1
3
6.00E-04
ORIFICE INSTR. LINE DIV 1FAILS TO REMAIN OPEN (PLUG)
B32-OR_-PG-F72HBDIV1
1.44E-05
LEVEL TRANSMITTER DIV 1 POOL B FAILS
B32-LT_-NO-F72HBDIV1
2.40E-05
REMOTE MULTIPLEXING UNIT DIV 1 FAILURE
H23-RMU-FC-F72HBDIV1
3.00E-04
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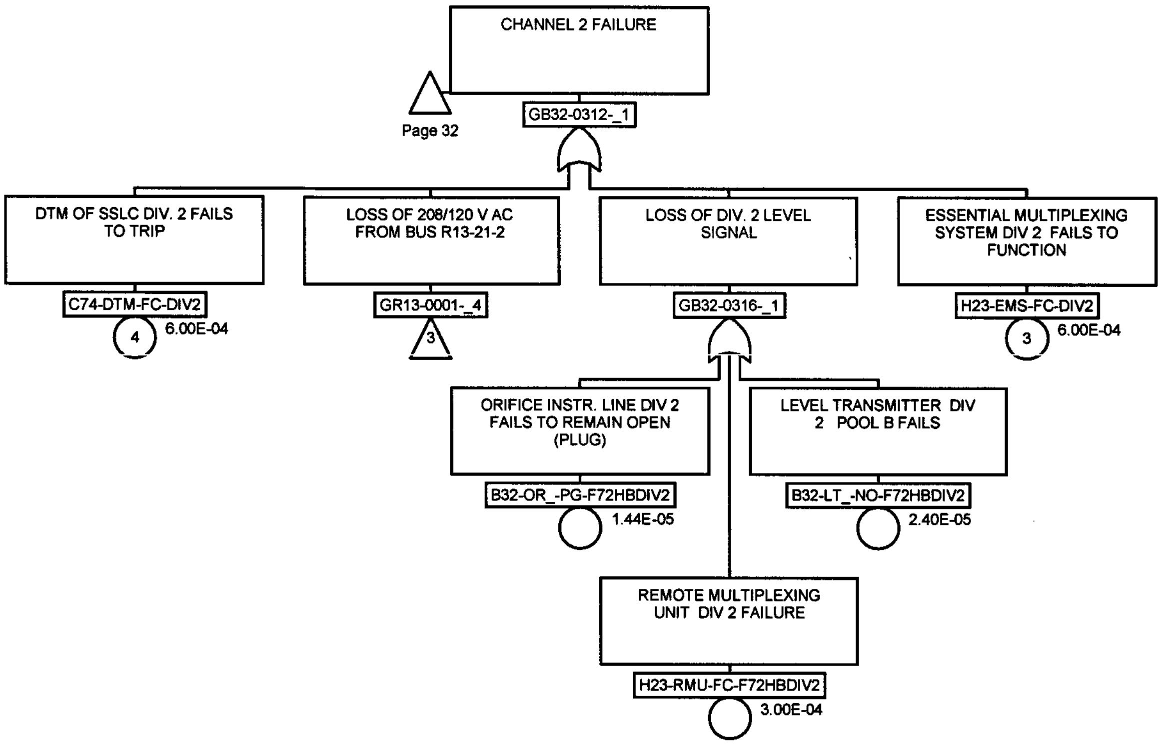
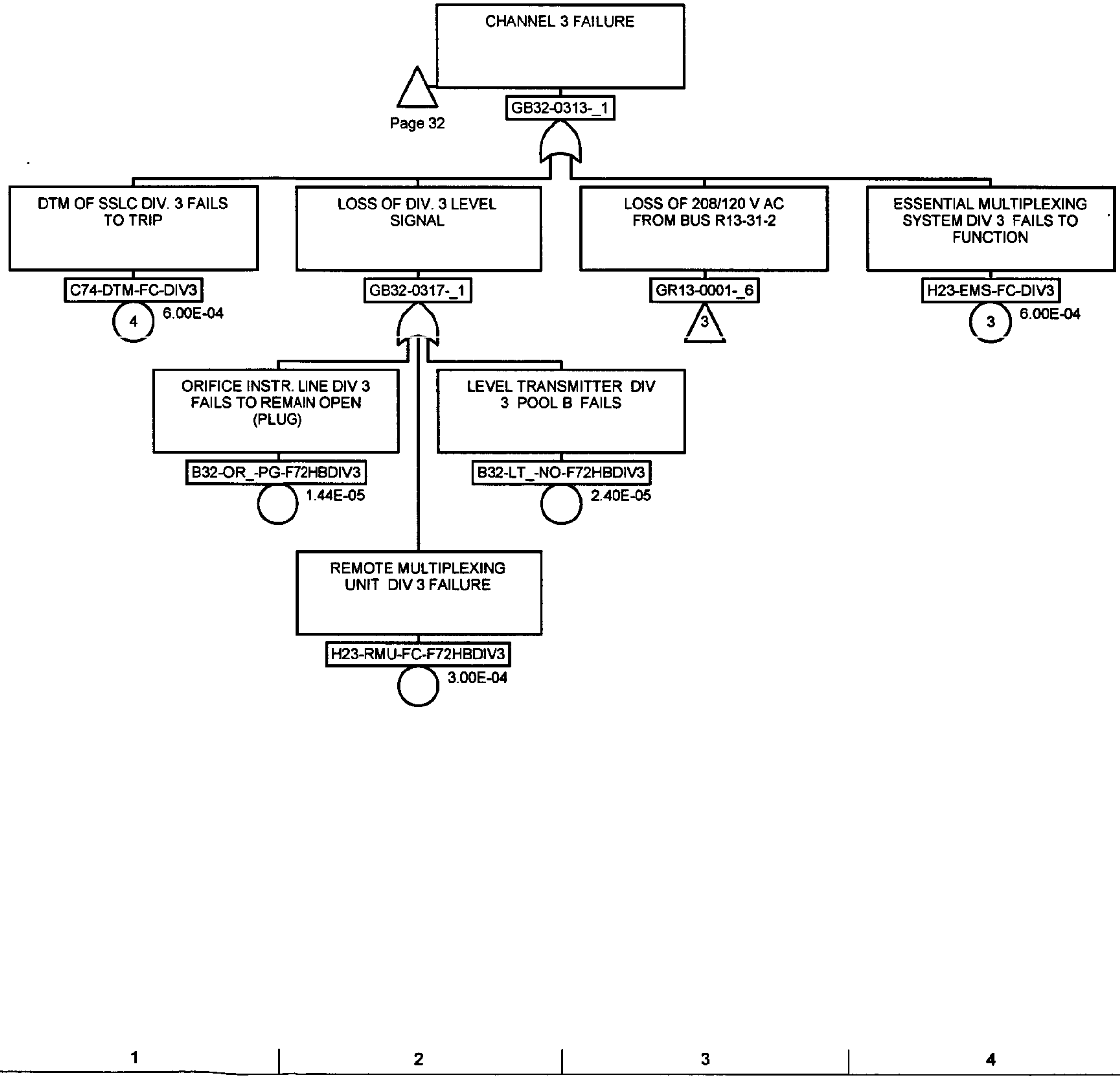
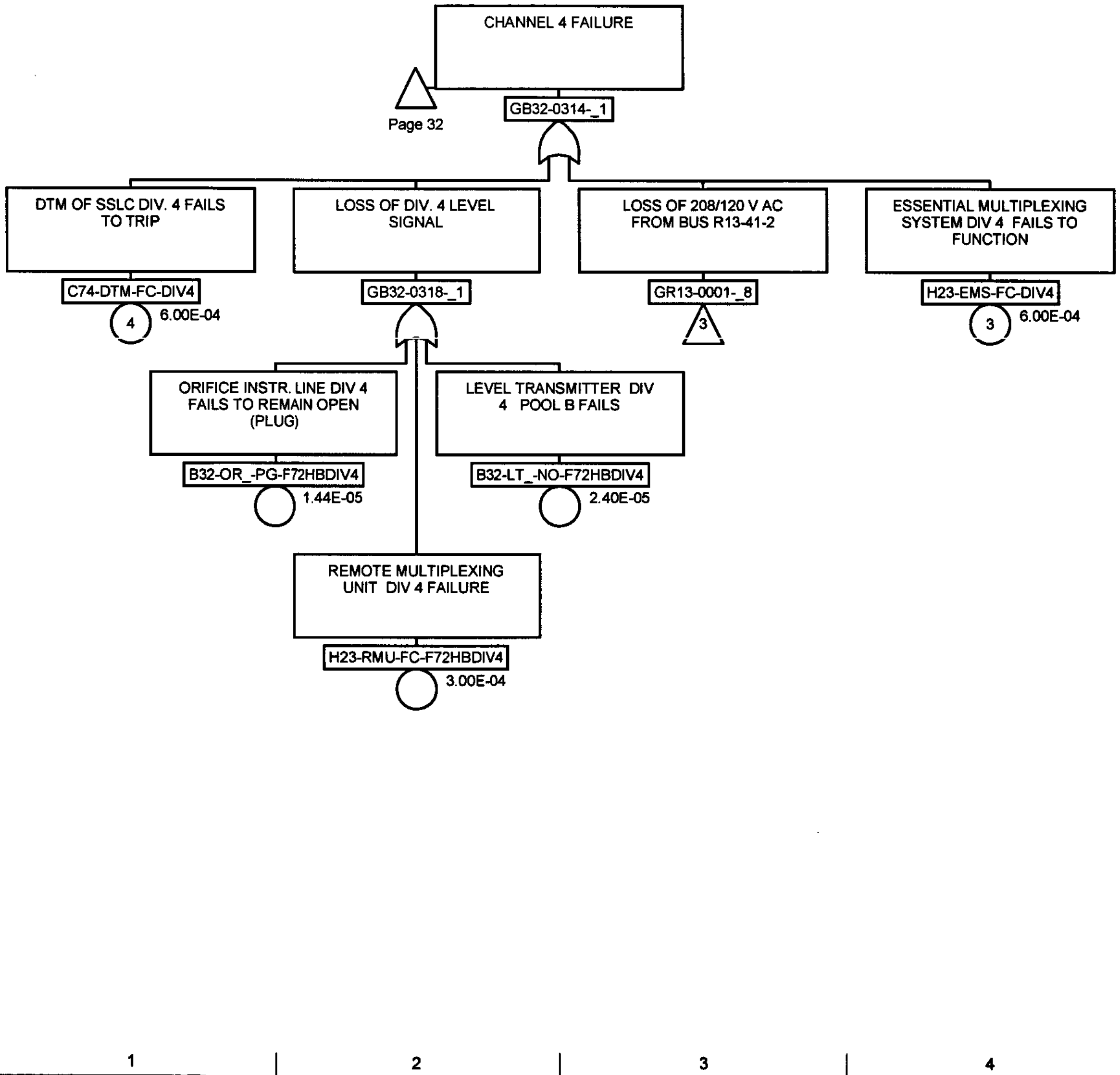
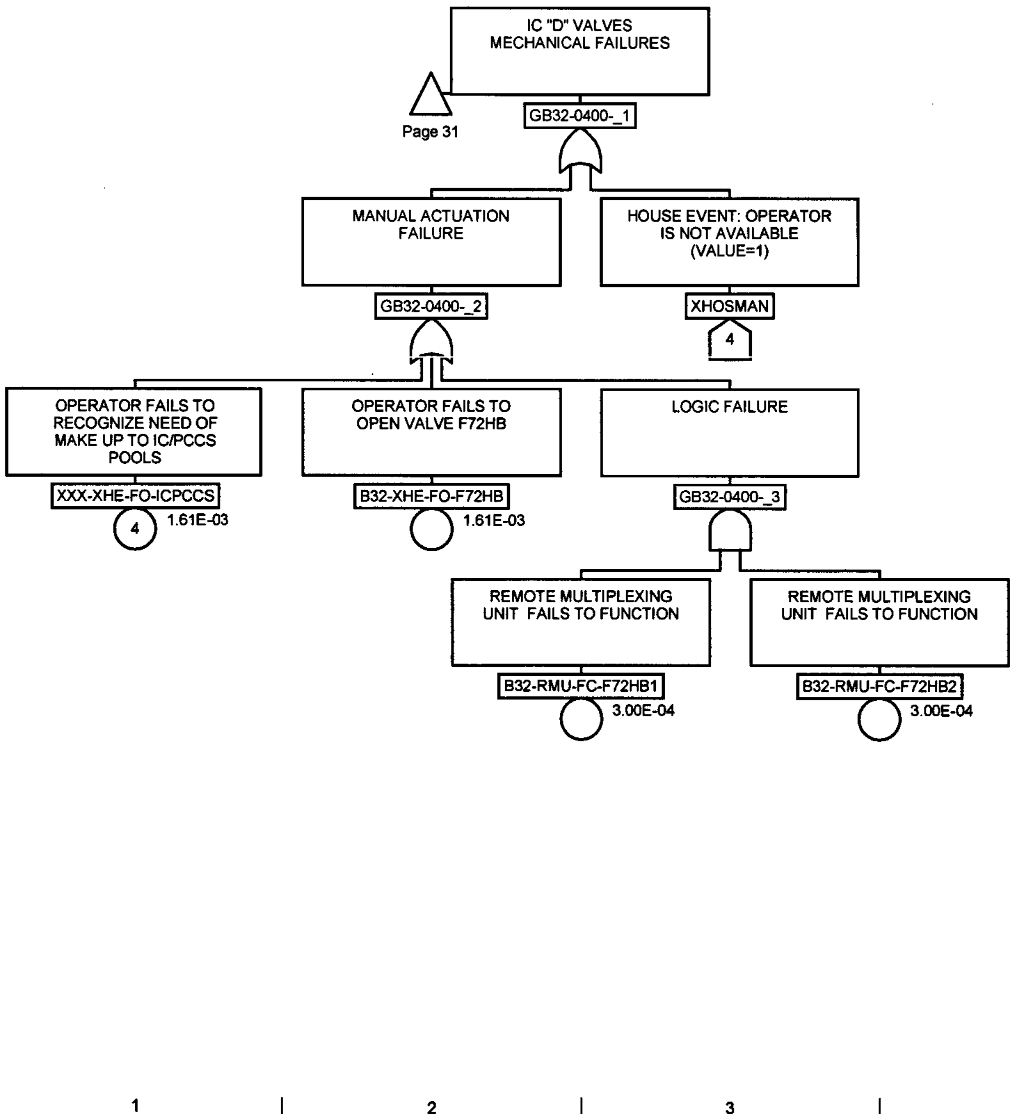
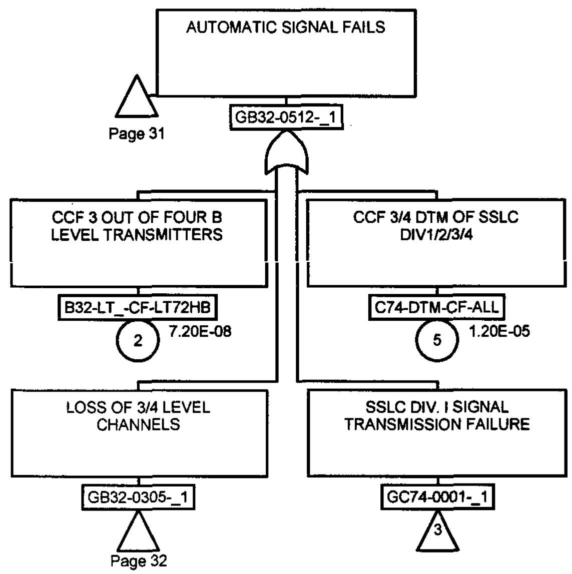
2
3
4
5
6

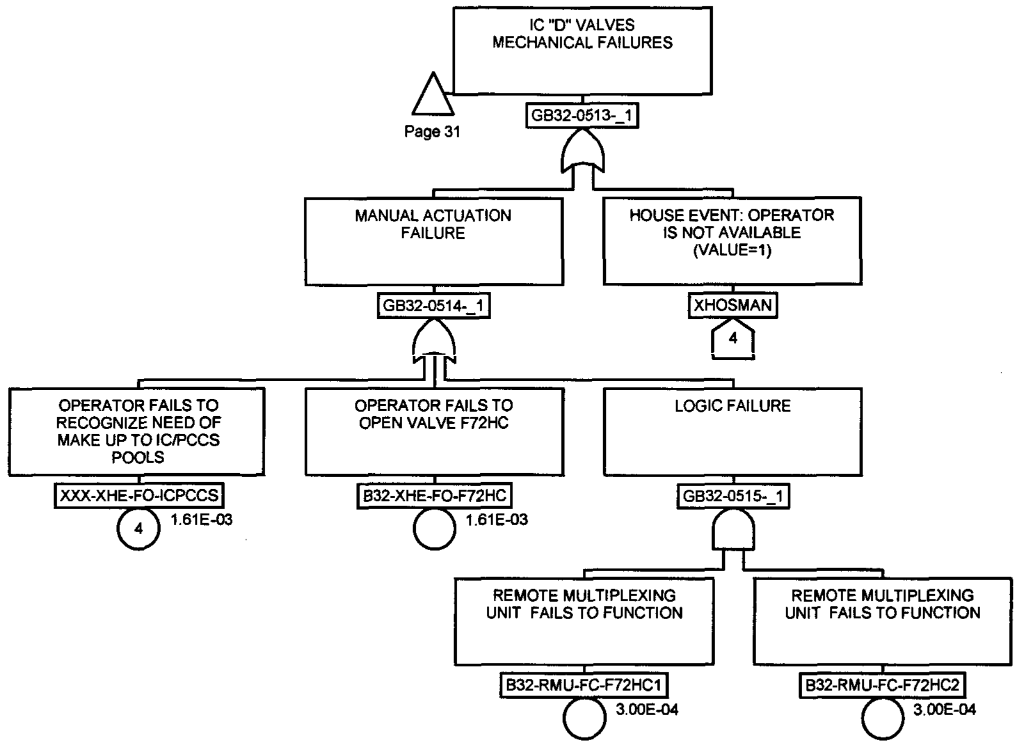

CHANNEL 2 FAILURE
GB32-0312-_1
Page 32
DTM OF SSLC DIV. 2 FAILS TO TRIP
C74-DTM-FC-DIV2
4
6.00E-04
LOSS OF 208/120 V AC FROM BUS R13-21-2
GR13-0001-_4
3
LOSS OF DIV. 2 LEVEL SIGNAL
GB32-0316-_1
ESSENTIAL MULTIPLEXING SYSTEM DIV 2 FAILS TO FUNCTION
H23-EMS-FC-DIV2
3
6.00E-04
ORIFICE INSTR. LINE DIV 2 FAILS TO REMAIN OPEN (PLUG)
B32-OR_-PG-F72HBDIV2
1.44E-05
LEVEL TRANSMITTER DIV 2 POOL B FAILS
B32-LT_-NO-F72HBDIV2
2.40E-05
REMOTE MULTIPLEXING UNIT DIV 2 FAILURE
H23-RMU-FC-F72HBDIV2
3.00E-04
1
2
3
4

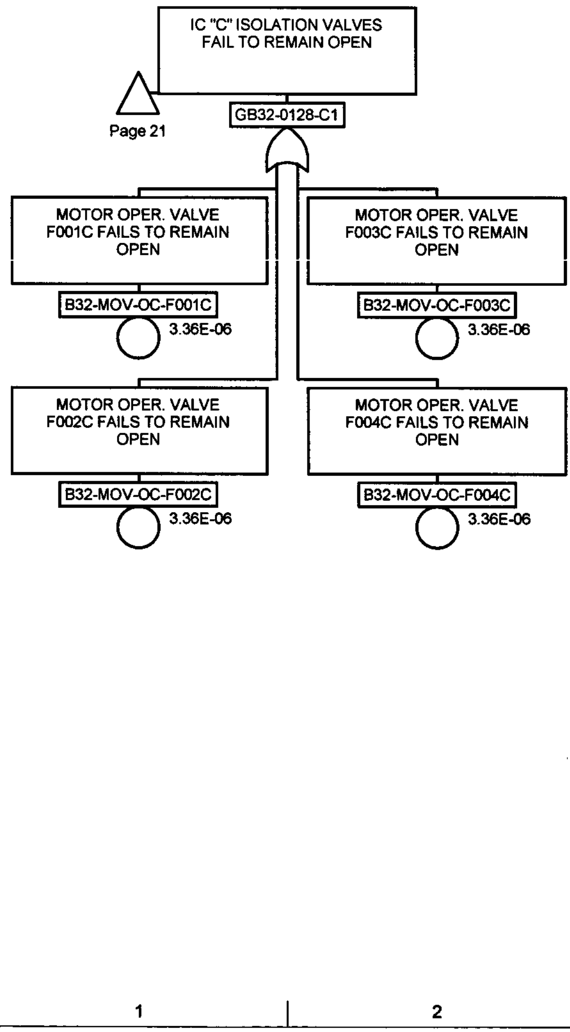

CHANNEL 3 FAILURE
GB32-0313-_1
Page 32
DTM OF SSLC DIV. 3 FAILS TO TRIP
C74-DTM-FC-DIV3
4
6.00E-04
LOSS OF DIV. 3 LEVEL SIGNAL
GB32-0317-_1
LOSS OF 208/120 V AC FROM BUS R13-31-2
GR13-0001-_6
3
ESSENTIAL MULTIPLEXING SYSTEM DIV 3 FAILS TO FUNCTION
H23-EMS-FC-DIV3
3
6.00E-04
ORIFICE INSTR. LINE DIV 3 FAILS TO REMAIN OPEN (PLUG)
B32-OR_-PG-F72HBDIV3
1.44E-05
LEVEL TRANSMITTER DIV 3 POOL B FAILS
B32-LT_-NO-F72HBDIV3
2.40E-05
REMOTE MULTIPLEXING UNIT DIV 3 FAILURE
H23-RMU-FC-F72HBDIV3
3.00E-04
1
2
3
4


CHANNEL 4 FAILURE
GB32-0314-_1
Page 32
DTM OF SSLC DIV. 4 FAILS TO TRIP
C74-DTM-FC-DIV4
4
6.00E-04
LOSS OF DIV. 4 LEVEL SIGNAL
GB32-0318-_1
LOSS OF 208/120 V AC FROM BUS R13-41-2
GR13-0001-_8
3
ESSENTIAL MULTIPLEXING SYSTEM DIV 4 FAILS TO FUNCTION
H23-EMS-FC-DIV4
3
6.00E-04
ORIFICE INSTR. LINE DIV 4 FAILS TO REMAIN OPEN (PLUG)
B32-OR_-PG-F72HBDIV4
1.44E-05
LEVEL TRANSMITTER DIV 4 POOL B FAILS
B32-LT_-NO-F72HBDIV4
2.40E-05
REMOTE MULTIPLEXING UNIT DIV 4 FAILURE
H23-RMU-FC-F72HBDIV4
3.00E-04
1
2
3
4


IC "D" VALVES MECHANICAL FAILURES
GB32-0400-_1
Page 31
MANUAL ACTUATION FAILURE
GB32-0400-_2
HOUSE EVENT: OPERATOR IS NOT AVAILABLE (VALUE=1)
XHOSMAN
4
OPERATOR FAILS TO RECOGNIZE NEED OF MAKE UP TO IC/PCCS POOLS
XXX-XHE-FO-ICPCCS
4
1.61E-03
OPERATOR FAILS TO OPEN VALVE F72HB
B32-XHE-FO-F72HB
1.61E-03
LOGIC FAILURE
GB32-0400-_3
REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION
B32-RMU-FC-F72HB1
3.00E-04
REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION
B32-RMU-FC-F72HB2
3.00E-04
1
2
3


AUTOMATIC SIGNAL FAILS
GB32-0512-_1
Page 31
CCF 3 OUT OF FOUR B LEVEL TRANSMITTERS
B32-LT_-CF-LT72HB
2
7.20E-08
CCF 3/4 DTM OF SSLC DIV1/2/3/4
C74-DTM-CF-ALL
5
1.20E-05
LOSS OF 3/4 LEVEL CHANNELS
GB32-0305-_1
Page 32
SSLC DIV. I SIGNAL TRANSMISSION FAILURE
GC74-0001-_1
3
1
2


IC "D" VALVES MECHANICAL FAILURES
Page 31
GB32-0513-_1
MANUAL ACTUATION FAILURE
HOUSE EVENT: OPERATOR IS NOT AVAILABLE (VALUE=1)
GB32-0514-_1
XHOSMAN
4
OPERATOR FAILS TO RECOGNIZE NEED OF MAKE UP TO IC/PCCS POOLS
OPERATOR FAILS TO OPEN VALVE F72HC
LOGIC FAILURE
XXX-XHE-FO-ICPCCS
4
1.61E-03
B32-XHE-FO-F72HC
1.61E-03
GB32-0515-_1
REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION
REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION
B32-RMU-FC-F72HC1
3.00E-04
B32-RMU-FC-F72HC2
3.00E-04
1
2
3


IC "C" ISOLATION VALVES FAIL TO REMAIN OPEN
GB32-0128-C1
Page 21
MOTOR OPER. VALVE F001C FAILS TO REMAIN OPEN
B32-MOV-OC-F001C
3.36E-06
MOTOR OPER. VALVE F003C FAILS TO REMAIN OPEN
B32-MOV-OC-F003C
3.36E-06
MOTOR OPER. VALVE F002C FAILS TO REMAIN OPEN
B32-MOV-OC-F002C
3.36E-06
MOTOR OPER. VALVE F004C FAILS TO REMAIN OPEN
B32-MOV-OC-F004C
3.36E-06
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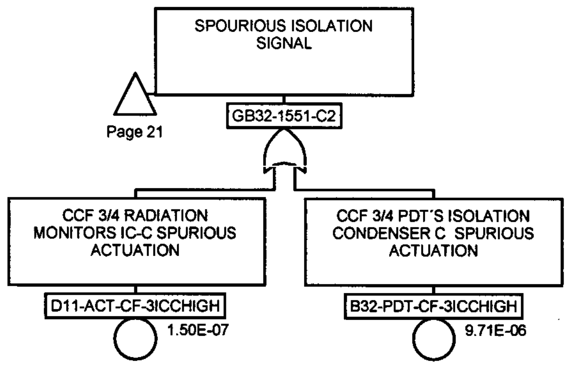
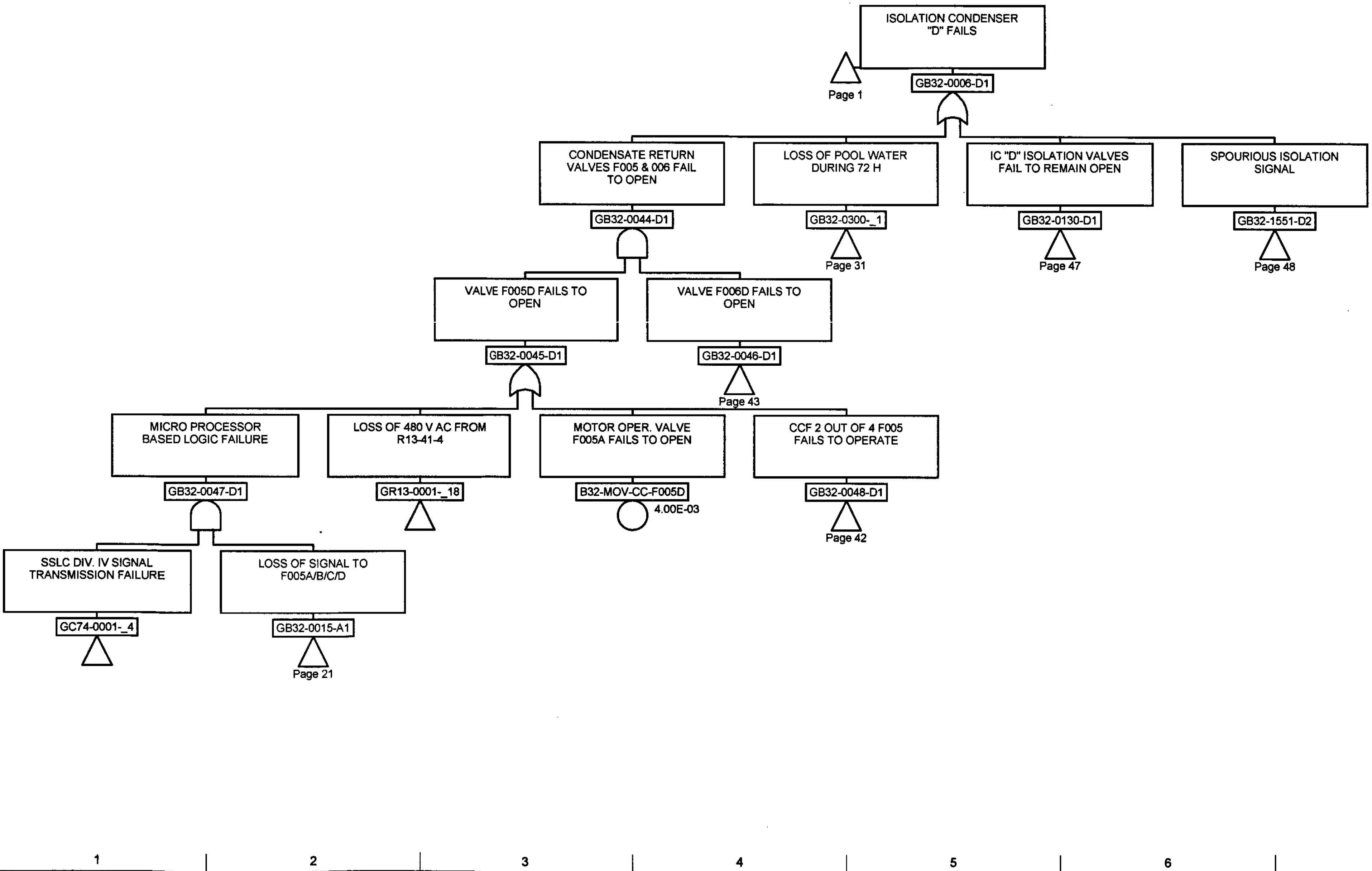
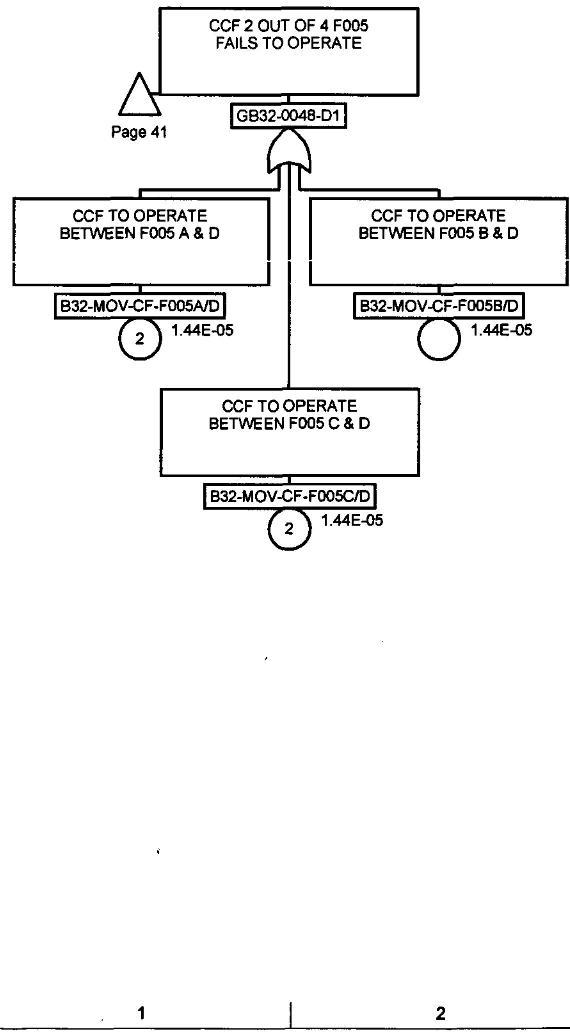

SPOURIOUS ISOLATION SIGNAL
Page 21
GB32-1551-C2
CCF 3/4 RADIATION MONITORS IC-C SPURIOUS ACTUATION
D11-ACT-CF-3ICCHIGH
1.50E-07
CCF 3/4 PDT'S ISOLATION CONDENSER C SPURIOUS ACTUATION
B32-PDT-CF-3ICCHIGH
9.71E-06


ISOLATION CONDENSER "D" FAILS
Page 1
GB32-0006-D1
CONDENSATE RETURN VALVES F005 & 006 FAIL TO OPEN
GB32-0044-D1
LOSS OF POOL WATER DURING 72 H
GB32-0300-_1
Page 31
IC "D" ISOLATION VALVES FAIL TO REMAIN OPEN
GB32-0130-D1
Page 47
SPOURIOUS ISOLATION SIGNAL
GB32-1551-D2
Page 48
VALVE F005D FAILS TO OPEN
GB32-0045-D1
VALVE F006D FAILS TO OPEN
GB32-0046-D1
Page 43
MICRO PROCESSOR BASED LOGIC FAILURE
GB32-0047-D1
LOSS OF 480 V AC FROM R13-41-4
GR13-0001-_18
MOTOR OPER. VALVE F005A FAILS TO OPEN
B32-MOV-CC-F005D
4.00E-03
CCF 2 OUT OF 4 F005 FAILS TO OPERATE
GB32-0048-D1
Page 42
SSLC DIV. IV SIGNAL TRANSMISSION FAILURE
GC74-0001-_4
LOSS OF SIGNAL TO F005A/B/C/D
GB32-0015-A1
Page 21
1
2
3
4
5
6


CCF 2 OUT OF 4 F005
FAILS TO OPERATE
Page 41
GB32-0048-D1
CCF TO OPERATE
BETWEEN F005 A & D
B32-MOV-CF-F005A/D
2
1.44E-05
CCF TO OPERATE
BETWEEN F005 B & D
B32-MOV-CF-F005B/D
1.44E-05
CCF TO OPERATE
BETWEEN F005 C & D
B32-MOV-CF-F005C/D
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1.44E-05
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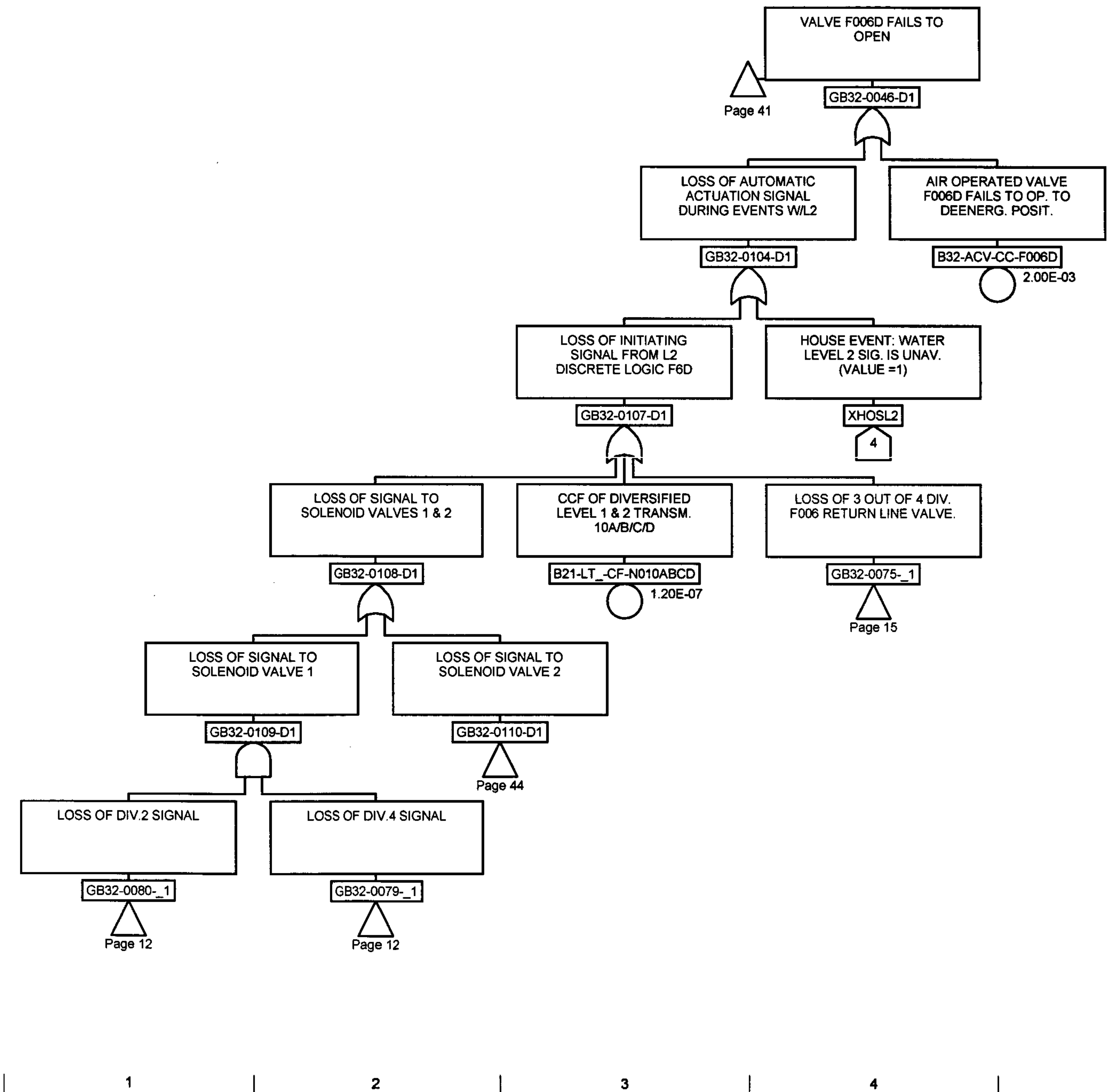
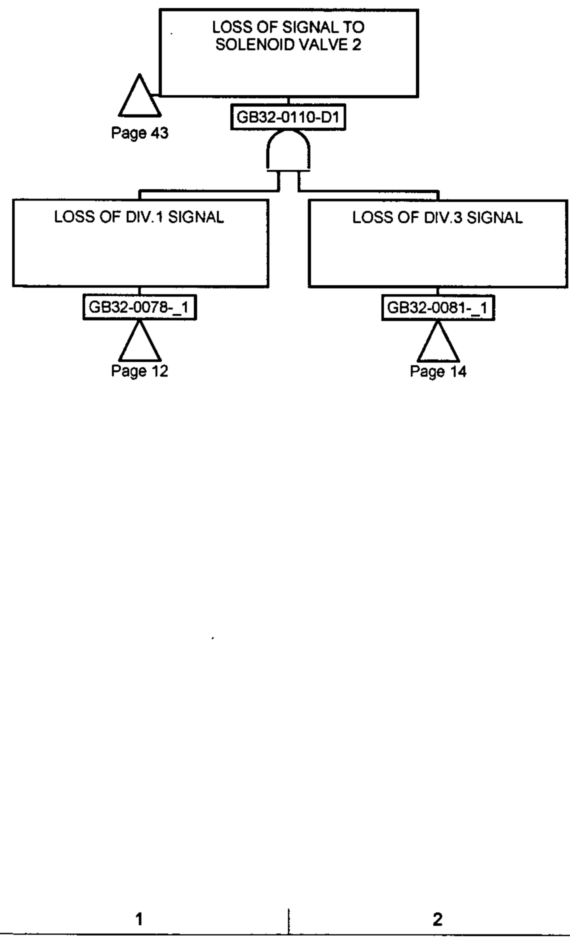
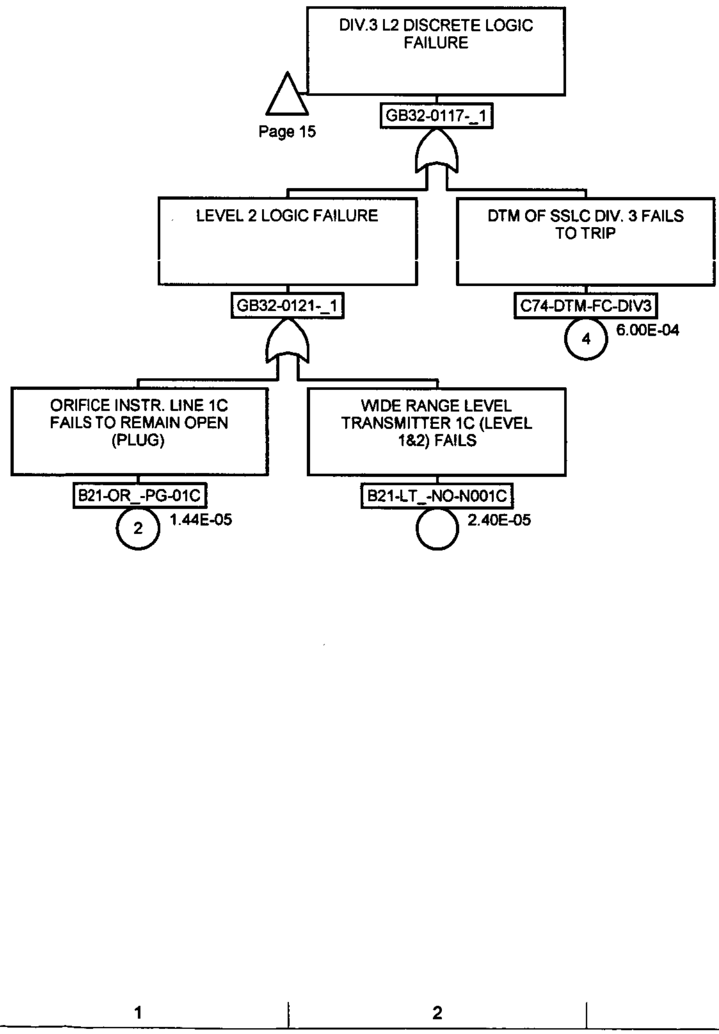
2


VALVE F006D FAILS TO OPEN
Page 41
GB32-0046-D1
LOSS OF AUTOMATIC ACTUATION SIGNAL DURING EVENTS W/L2
GB32-0104-D1
AIR OPERATED VALVE F006D FAILS TO OP. TO DEENERG. POSIT.
B32-ACV-CC-F006D
2.00E-03
LOSS OF INITIATING SIGNAL FROM L2 DISCRETE LOGIC F6D
GB32-0107-D1
HOUSE EVENT: WATER LEVEL 2 SIG. IS UNAV. (VALUE =1)
XHOSL2
4
LOSS OF SIGNAL TO SOLENOID VALVES 1 & 2
GB32-0108-D1
CCF OF DIVERSIFIED LEVEL 1 & 2 TRANSM. 10A/B/C/D
B21-LT_-CF-N010ABCD
1.20E-07
LOSS OF 3 OUT OF 4 DIV. F006 RETURN LINE VALVE.
GB32-0075-_1
Page 15
LOSS OF SIGNAL TO SOLENOID VALVE 1
GB32-0109-D1
LOSS OF SIGNAL TO SOLENOID VALVE 2
GB32-0110-D1
Page 44
LOSS OF DIV.2 SIGNAL
GB32-0080-_1
Page 12
LOSS OF DIV.4 SIGNAL
GB32-0079-_1
Page 12
1
2
3
4


LOSS OF SIGNAL TO SOLENOID VALVE 2
Page 43
GB32-0110-D1
LOSS OF DIV.1 SIGNAL
LOSS OF DIV.3 SIGNAL
GB32-0078-_1
GB32-0081-_1
Page 12
Page 14
1
2


DIV.3 L2 DISCRETE LOGIC FAILURE
GB32-0117-_1
Page 15
LEVEL 2 LOGIC FAILURE
GB32-0121-_1
DTM OF SSLC DIV. 3 FAILS TO TRIP
C74-DTM-FC-DIV3
4
6.00E-04
ORIFICE INSTR. LINE 1C FAILS TO REMAIN OPEN (PLUG)
B21-OR_-PG-01C
2
1.44E-05
WIDE RANGE LEVEL TRANSMITTER 1C (LEVEL 1&2) FAILS
B21-LT_-NO-N001C
2.40E-05
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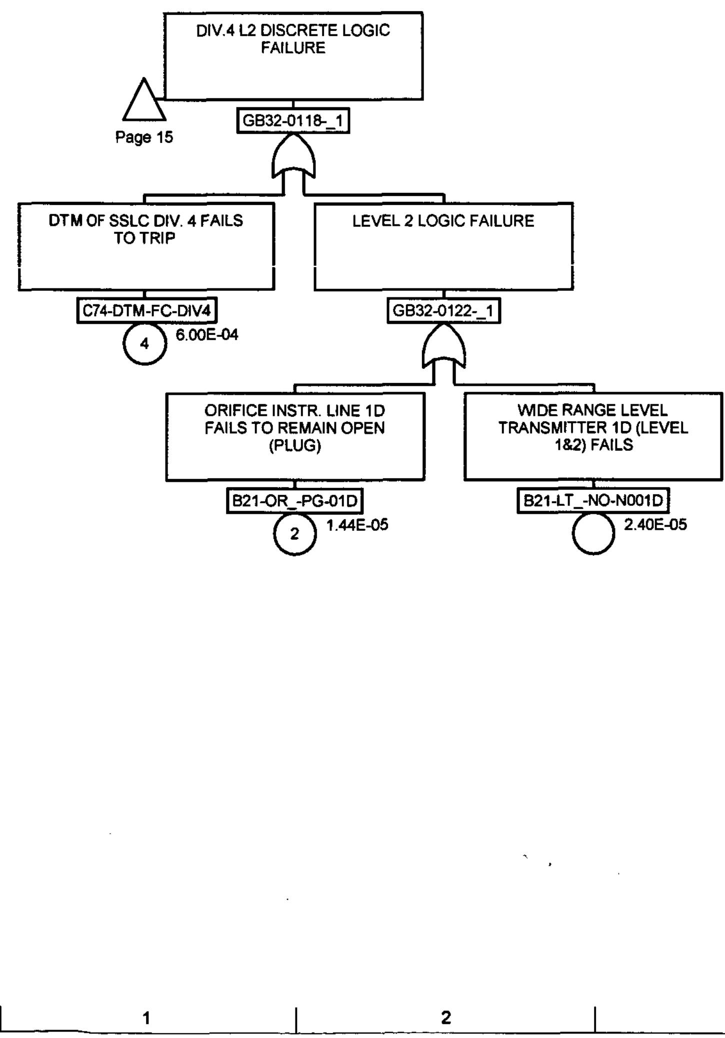
2


DIV.4 L2 DISCRETE LOGIC FAILURE
Page 15
GB32-0118-_1
DTM OF SSLC DIV. 4 FAILS TO TRIP
C74-DTM-FC-DIV4
4
6.00E-04
LEVEL 2 LOGIC FAILURE
GB32-0122-_1
ORIFICE INSTR. LINE 1D FAILS TO REMAIN OPEN (PLUG)
B21-OR_-PG-01D
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1.44E-05
WIDE RANGE LEVEL TRANSMITTER 1D (LEVEL 1&2) FAILS
B21-LT_-NO-N001D
2.40E-05
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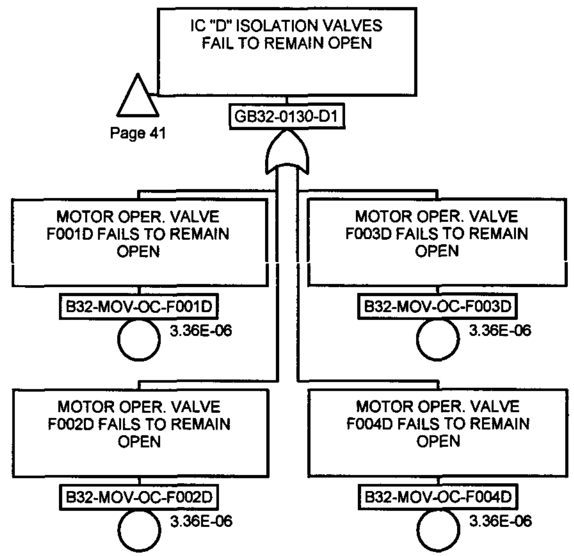
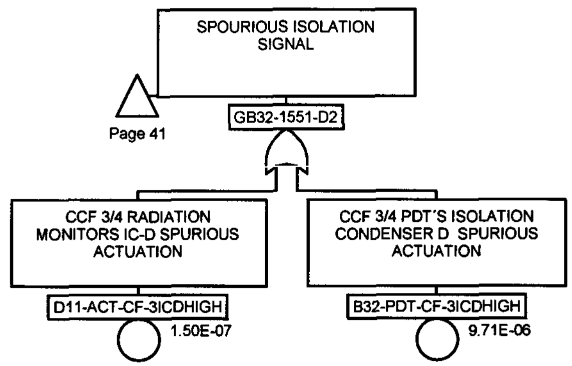
2


IC "D" ISOLATION VALVES FAIL TO REMAIN OPEN
GB32-0130-D1
Page 41
MOTOR OPER. VALVE F001D FAILS TO REMAIN OPEN
B32-MOV-OC-F001D
3.36E-06
MOTOR OPER. VALVE F003D FAILS TO REMAIN OPEN
B32-MOV-OC-F003D
3.36E-06
MOTOR OPER. VALVE F002D FAILS TO REMAIN OPEN
B32-MOV-OC-F002D
3.36E-06
MOTOR OPER. VALVE F004D FAILS TO REMAIN OPEN
B32-MOV-OC-F004D
3.36E-06


SPOURIOUS ISOLATION SIGNAL
GB32-1551-D2
Page 41
CCF 3/4 RADIATION MONITORS IC-D SPURIOUS ACTUATION
D11-ACT-CF-3ICDHIGH
1.50E-07
CCF 3/4 PDT'S ISOLATION CONDENSER D SPURIOUS ACTUATION
B32-PDT-CF-3ICDHIGH
9.71E-06
1
2

Name	Page	Zone	Name	Page	Zone	Name	Page	Zone
B21-ACV-OO-F001A	22	1	B32-MOV-CF-2ICABCD	1	5	C74-DTM-FC-DIV1	4	1
B21-ACV-OO-F001B	23	1	B32-MOV-CF-F005A/B	11	4	C74-DTM-FC-DIV1	15	1
B21-ACV-OO-F001C	24	1	B32-MOV-CF-F005A/C	11	5	C74-DTM-FC-DIV1	26	1
B21-ACV-OO-F001D	25	1	B32-MOV-CF-F005A/C	21	5	C74-DTM-FC-DIV1	32	1
B21-ACV-OO-F002A	22	2	B32-MOV-CF-F005A/D	11	5	C74-DTM-FC-DIV2	5	1
B21-ACV-OO-F002B	23	2	B32-MOV-CF-F005A/D	42	1	C74-DTM-FC-DIV2	15	5
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B21-ACV-OO-F002D	25	2	B32-MOV-CF-F005B/D	42	2	C74-DTM-FC-DIV2	33	1
B21-LT -CF-N001ABCD	12	5	B32-MOV-CF-F005C/D	21	5	C74-DTM-FC-DIV3	6	1
B21-LT -CF-N001ABCD	18	3	B32-MOV-CF-F005C/D	42	2	C74-DTM-FC-DIV3	28	1
B21-LT -CF-N001ABCD	30	1	B32-MOV-CF-F72HADOPEN	3	5	C74-DTM-FC-DIV3	34	1
B21-LT -CF-N010ABCD	43	3	B32-MOV-CF-F72HBCOPEN	31	5	C74-DTM-FC-DIV3	45	3
B21-LT -NO-N001A	15	3	B32-MOV-OC-F001A	2	3	C74-DTM-FC-DIV4	7	1
B21-LT -NO-N001B	15	5	B32-MOV-OC-F001B	19	1	C74-DTM-FC-DIV4	29	1
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B21-OR -PG-01B	15	4	B32-MOV-OC-F002C	39	1	D11-ACT-CF-3ICBHIGH	20	1
B21-OR -PG-01B	27	2	B32-MOV-OC-F002D	47	1	D11-ACT-CF-3ICCHIGH	40	1
B21-OR -PG-01C	28	2	B32-MOV-OC-F003A	2	4	D11-ACT-CF-3ICDHIGH	48	1
B21-OR -PG-01C	45	1	B32-MOV-OC-F003B	19	2	GB32-0001-A2	1	2
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B21-PT -CF-02ALLNO	26	5	B32-MOV-OC-F004A	2	4	GB32-0004-B1	17	5
B21-PT -NO-0002A	26	2	B32-MOV-OC-F004B	19	2	GB32-0005-C1	1	4
B21-PT -NO-0002B	27	2	B32-MOV-OC-F004C	39	2	GB32-0005-C1	21	5
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B21-PT -NO-0002D	29	2	B32-OR -PG-F72HADIV1	4	2	GB32-0006-D1	41	5
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B32-ACV-CF-2ICABCD	1	4	B32-OR -PG-F72HBDIV2	33	3	GB32-0012-A1	12	6
B32-LT -CF-LT72HA	4	1	B32-OR -PG-F72HBDIV3	34	2	GB32-0013-A1	11	2
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B32-LT -NO-F72HADIV1	4	3	B32-PDT-CF-3ICCHIGH	40	2	GB32-0015-A1	21	2
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B32-LT -NO-F72HBDIV1	32	3	B32-RMU-FC-F72HC1	38	3	GB32-0026-B1	17	5
B32-LT -NO-F72HBDIV2	33	4	B32-RMU-FC-F72HC2	38	4	GB32-0027-B1	17	2
B32-LT -NO-F72HBDIV3	34	3	B32-SYS-TM-ICA	2	1	GB32-0034-C1	21	3
B32-LT -NO-F72HBDIV4	35	3	B32-XHE-FO-F72HA	8	2	GB32-0035-C1	21	3
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B32-MOV-CC-F72HA	3	3	C74-DTM-CF-ALL	9	2	GB32-0044-D1	41	3
B32-MOV-CC-F72HB	31	3	C74-DTM-CF-ALL	26	4	GB32-0045-D1	41	3
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B32-MOV-CC-F72HD	3	6	C74-DTM-CF-ALL	37	2	GB32-0046-D1	43	4

Name	Page	Zone	Name	Page	Zone	Name	Page	Zone
GB32-0047-D1	41	2	GB32-0128-C1	21	5	GB32-0318- 1	35	2
GB32-0048-D1	41	5	GB32-0128-C1	39	2	GB32-0351- 1	21	2
GB32-0048-D1	42	2	GB32-0130-D1	41	5	GB32-0352- 1	21	1
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GB32-0074-A1	12	4	GB32-0178- 1	12	3	GB32-0353- 1	23	2
GB32-0075- 1	12	6	GB32-0178- 1	12	5	GB32-0354- 1	21	2
GB32-0075- 1	15	4	GB32-0178- 1	13	2	GB32-0354- 1	24	2
GB32-0075- 1	18	4	GB32-0178- 1	14	1	GB32-0355- 1	21	2
GB32-0075- 1	30	2	GB32-0200- 1	2	2	GB32-0355- 1	25	2
GB32-0075- 1	43	4	GB32-0200- 1	3	5	GB32-0400- 1	31	2
GB32-0076-A1	12	2	GB32-0200- 1	17	5	GB32-0400- 1	36	3
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GB32-0081- 1	14	2	GB32-0211- 1	4	3	GB32-0506- 1	10	2
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GB32-0104-D1	43	3	GB32-0300- 1	31	5	GB32-0551-A2	1	3
GB32-0107-D1	43	3	GB32-0300- 1	41	4	GB32-0551-A2	2	3
GB32-0108-D1	43	2	GB32-0301- 1	31	5	GB32-0600- 1	21	3
GB32-0109-D1	43	2	GB32-0302- 1	31	4	GB32-0600- 1	26	4
GB32-0110-D1	43	3	GB32-0303- 1	31	2	GB32-0601- 1	26	4
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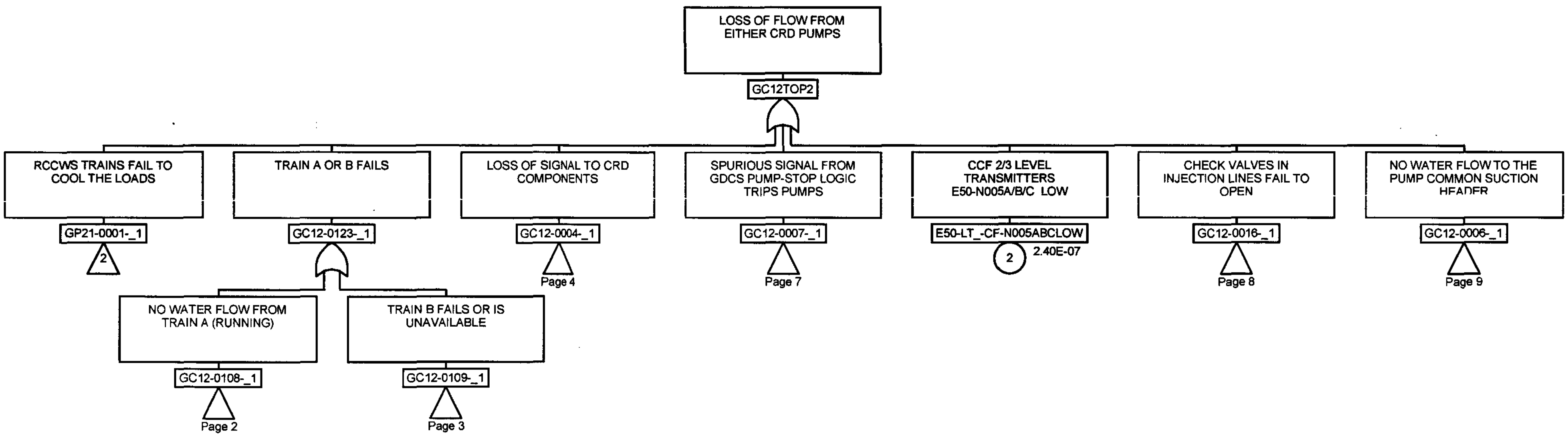
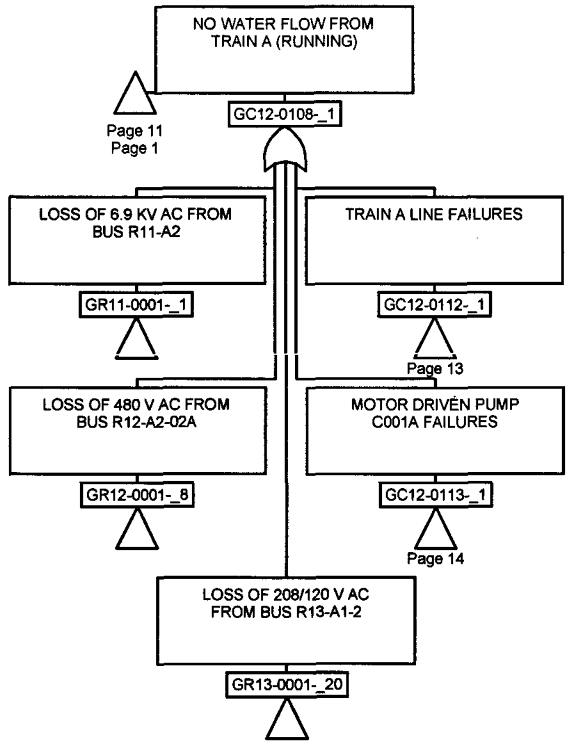
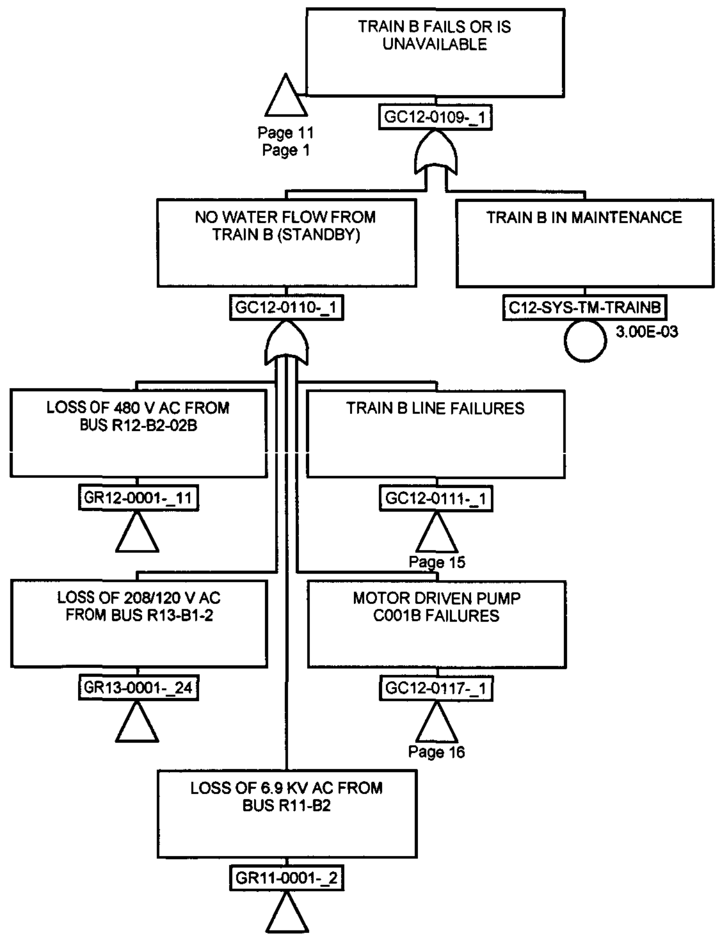
GB32-0115- 1	15	2	GB32-0304- 1	32	4	GB32-0603- 1	26	2
GB32-0116- 1	15	5	GB32-0305- 1	32	4	GB32-0604- 1	26	3
GB32-0117- 1	15	6	GB32-0305- 1	37	1	GB32-0604- 1	27	2
GB32-0117- 1	45	2	GB32-0311- 1	32	3	GB32-0605- 1	26	4
GB32-0118- 1	15	7	GB32-0312- 1	32	4	GB32-0605- 1	28	2
GB32-0118- 1	46	2	GB32-0312- 1	33	3	GB32-0606- 1	26	5
GB32-0119- 1	15	2	GB32-0313- 1	32	5	GB32-0606- 1	29	2
GB32-0120- 1	15	4	GB32-0313- 1	34	3	GB32-1551-A2	2	5
GB32-0121- 1	45	2	GB32-0314- 1	32	6	GB32-1551-A2	16	2
GB32-0122- 1	46	2	GB32-0314- 1	35	3	GB32-1551-B2	17	7
GB32-0126-A1	2	3	GB32-0315- 1	32	2	GB32-1551-B2	20	2
GB32-0127-B1	17	6	GB32-0316- 1	33	3	GB32-1551-C2	21	6
GB32-0127-B1	19	2	GB32-0317- 1	34	2	GB32-1551-C2	40	2

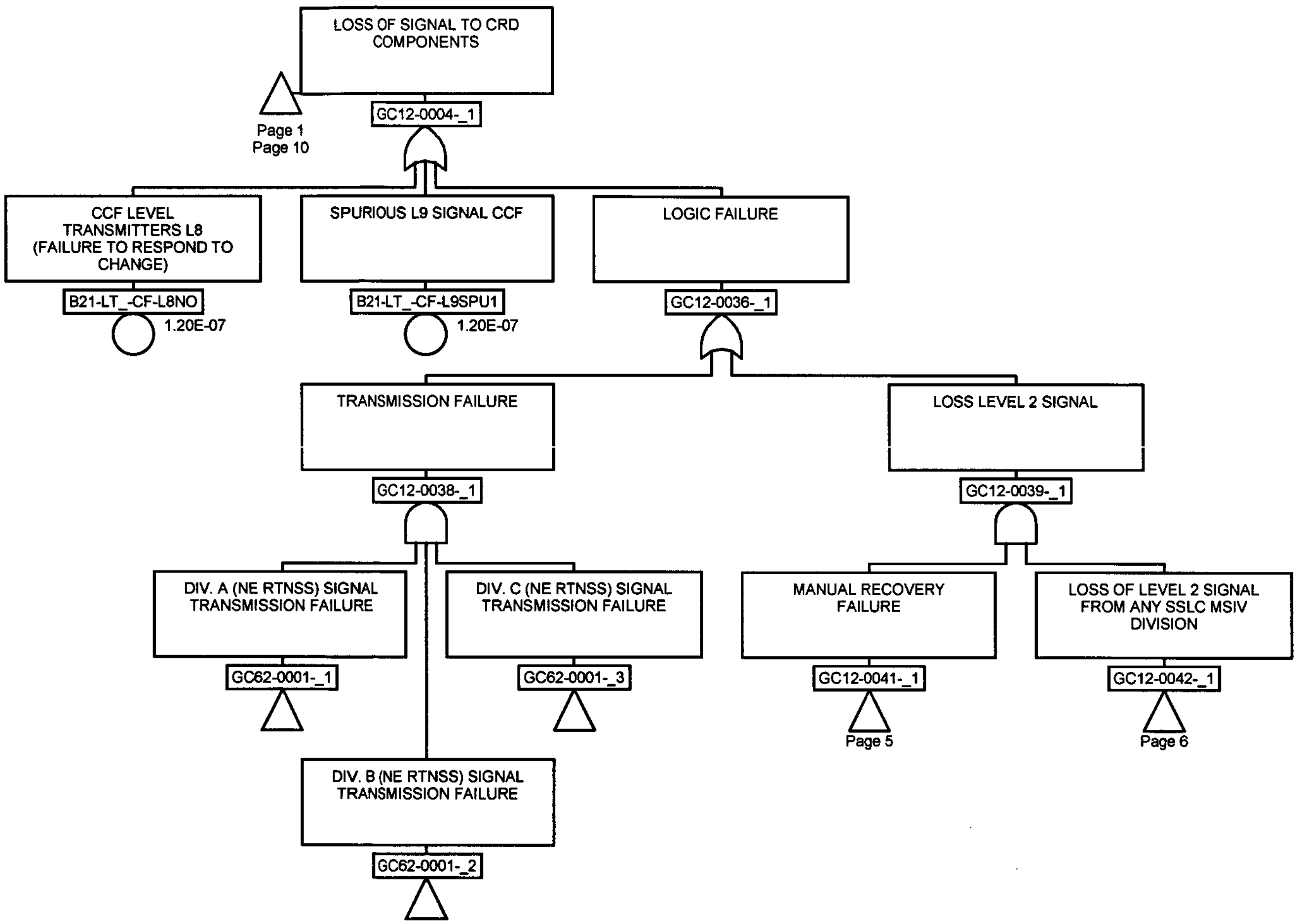
Name	Page	Zone	Name	Page	Zone	Name	Page	Zone
GB32-1551-D2	41	6	H23-RMU-CF-ALL	13	1			
GB32-1551-D2	48	2	H23-RMU-FC-0002A	26	1			
GB32TOP2	1	4	H23-RMU-FC-0002B	27	1			
GC74-0001- 1	4	6	H23-RMU-FC-0002C	28	1			
GC74-0001- 1	11	2	H23-RMU-FC-0002D	29	1			
GC74-0001- 1	37	2	H23-RMU-FC-F72HA1	8	3			
GC74-0001- 2	9	2	H23-RMU-FC-F72HA2	8	4			
GC74-0001- 2	17	1	H23-RMU-FC-F72HADIV1	4	2			
GC74-0001- 2	32	6	H23-RMU-FC-F72HADIV2	5	2			
GC74-0001- 3	21	1	H23-RMU-FC-F72HADIV3	6	2			
GC74-0001- 4	41	1	H23-RMU-FC-F72HADIV4	7	2			
GC74-0002- 1	12	2	H23-RMU-FC-F72HBDIV1	32	2			
GC74-0002- 2	12	6	H23-RMU-FC-F72HBDIV2	33	3			
GC74-0002- 3	14	2	H23-RMU-FC-F72HBDIV3	34	2			
GC74-0002- 4	12	4	H23-RMU-FC-F72HBDIV4	35	2			
GC74-0003- 1	12	2	H23-RMU-FC-F72HD1	10	3			
GC74-0003- 2	12	6	H23-RMU-FC-F72HD2	10	4			
GC74-0003- 3	14	2	XHOS-LL	26	5			
GC74-0003- 4	12	4	XHOS72H	3	6			
GR13-0001- 10	3	7	XHOS72H	31	6			
GR13-0001- 10	31	4	XHOSICLOCAOUT	1	1			
GR13-0001- 12	11	3	XHOSICLOCAOUT	1	2			
GR13-0001- 14	17	3	XHOSL2	12	6			
GR13-0001- 16	21	3	XHOSL2	17	5			
GR13-0001- 18	41	3	XHOSL2	30	3			
GR13-0001- 2	4	3	XHOSL2	43	4			
GR13-0001- 2	26	2	XHOSMAN	8	3			
GR13-0001- 2	32	3	XHOSMAN	10	3			
GR13-0001- 4	5	3	XHOSMAN	36	3			
GR13-0001- 4	27	2	XHOSMAN	38	3			
GR13-0001- 4	33	2	XXX-POL-RP-IC/PCC	1	6			
GR13-0001- 6	6	3	XXX-XHE-FO-ICPCCS	8	1			
GR13-0001- 6	28	2	XXX-XHE-FO-ICPCCS	10	1			
GR13-0001- 6	34	3	XXX-XHE-FO-ICPCCS	36	1			
GR13-0001- 8	7	3	XXX-XHE-FO-ICPCCS	38	1			
GR13-0001- 8	29	2						
GR13-0001- 8	35	3						
GR13-0001- 9	3	4						
GR13-0001- 9	31	7						
GU43-0001- 2	3	5						
GU43-0001- 2	31	5						
H23-EMS-CF-ALL	13	2						
H23-EMS-FC-DIV1	4	4						
H23-EMS-FC-DIV1	26	1						
H23-EMS-FC-DIV1	32	4						
H23-EMS-FC-DIV2	5	4						
H23-EMS-FC-DIV2	27	1						
H23-EMS-FC-DIV2	33	4						
H23-EMS-FC-DIV3	6	4						
H23-EMS-FC-DIV3	28	1						
H23-EMS-FC-DIV3	34	4						
H23-EMS-FC-DIV4	7	4						
H23-EMS-FC-DIV4	29	1						
H23-EMS-FC-DIV4	35	4						

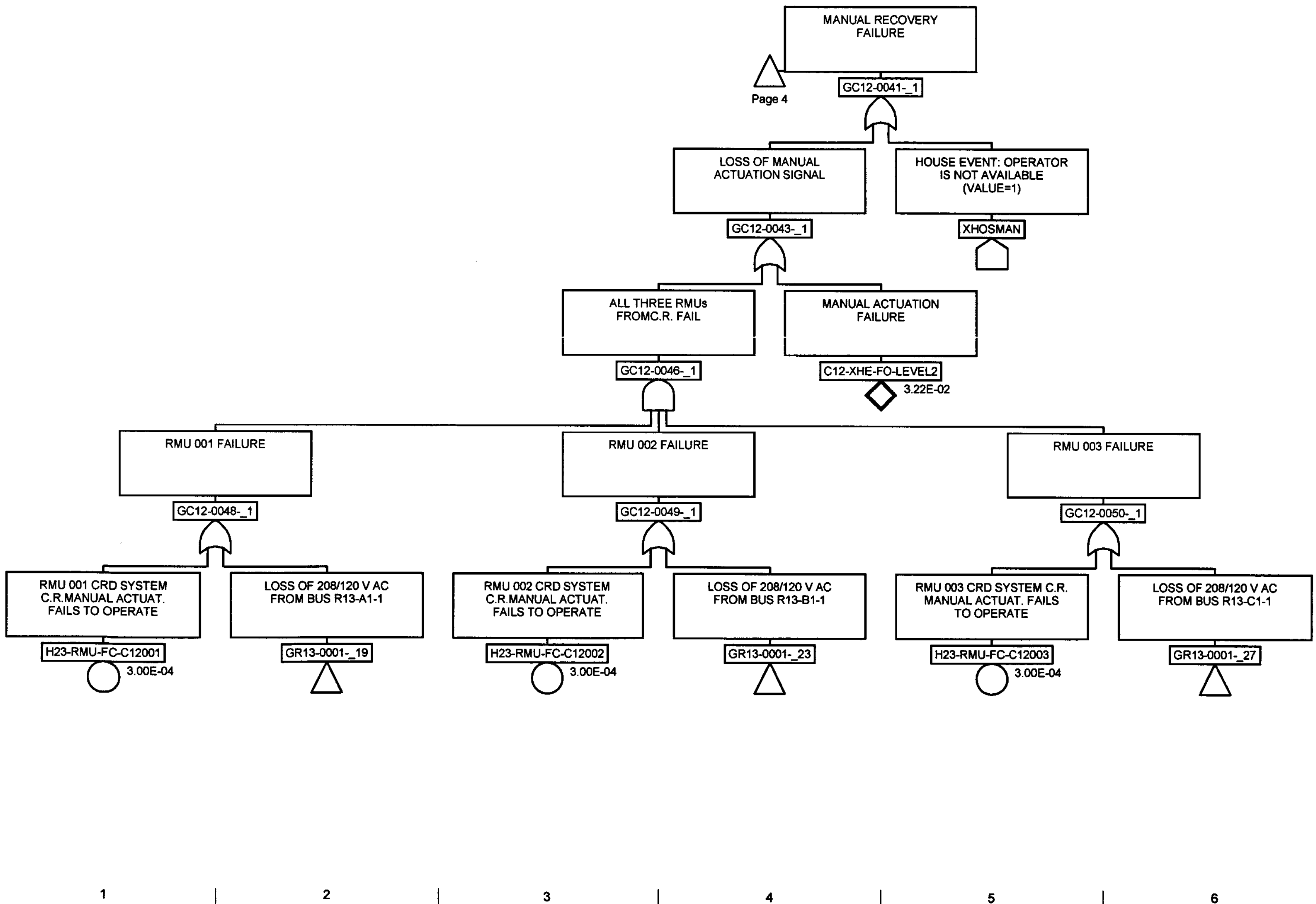
Appendix B.4.3
Control Rod Drive System
Fault Tree

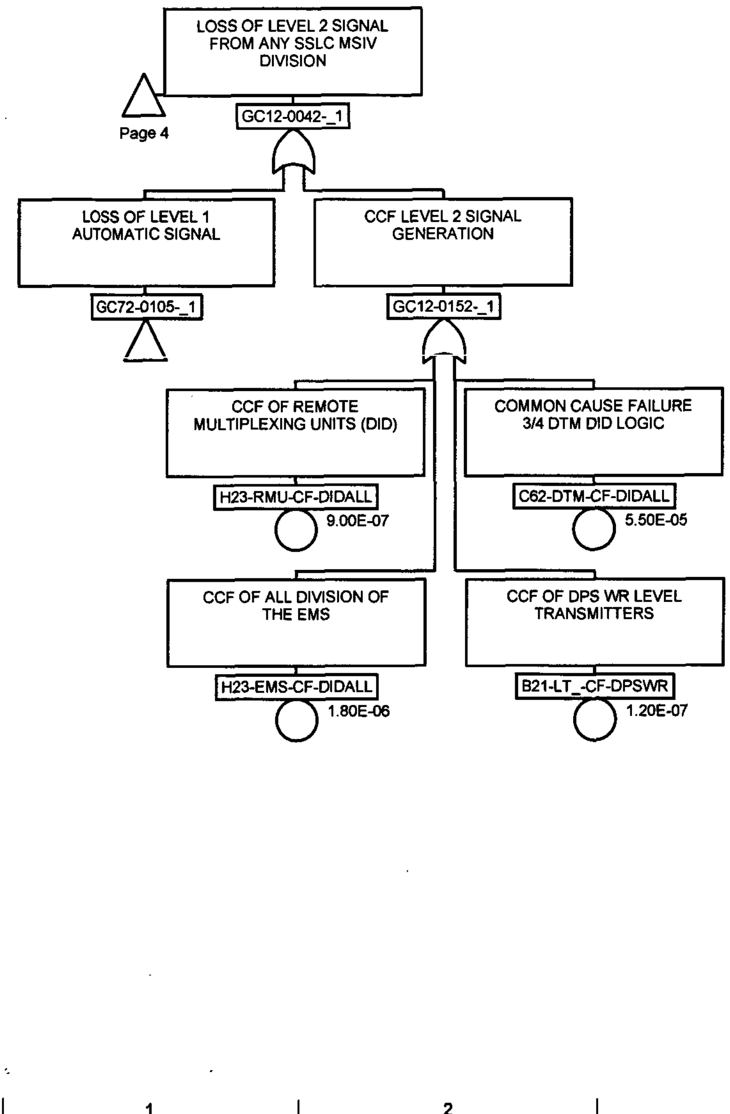

LOSS OF FLOW FROM EITHER CRD PUMPS
GC12TOP2
RCCWS TRAINS FAIL TO COOL THE LOADS
GP21-0001-_1
2
TRAIN A OR B FAILS
GC12-0123-_1
NO WATER FLOW FROM TRAIN A (RUNNING)
GC12-0108-_1
Page 2
TRAIN B FAILS OR IS UNAVAILABLE
GC12-0109-_1
Page 3
LOSS OF SIGNAL TO CRD COMPONENTS
GC12-0004-_1
Page 4
SPURIOUS SIGNAL FROM GDCS PUMP-STOP LOGIC TRIPS PUMPS
GC12-0007-_1
Page 7
CCF 2/3 LEVEL TRANSMITTERS E50-N005A/B/C LOW
E50-LT_-CF-N005ABCLOW
2
2.40E-07
CHECK VALVES IN INJECTION LINES FAIL TO OPEN
GC12-0016-_1
Page 8
NO WATER FLOW TO THE PUMP COMMON SUCTION
GC12-0006-_1
Page 9

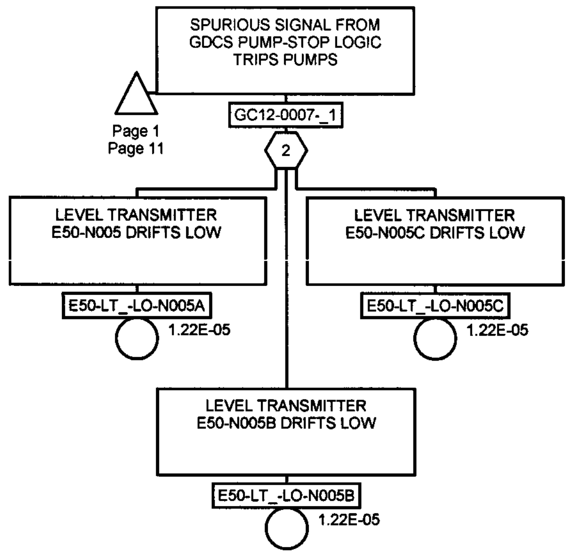

NO WATER FLOW FROM TRAIN A (RUNNING)
GC12-0108-_1
Page 11
Page 1
LOSS OF 6.9 KV AC FROM BUS R11-A2
GR11-0001-_1
TRAIN A LINE FAILURES
GC12-0112-_1
Page 13
LOSS OF 480 V AC FROM BUS R12-A2-02A
GR12-0001-_8
MOTOR DRIVEN PUMP C001A FAILURES
GC12-0113-_1
Page 14
LOSS OF 208/120 V AC FROM BUS R13-A1-2
GR13-0001-_20
1
2


TRAIN B FAILS OR IS UNAVAILABLE
GC12-0109-_1
Page 11
Page 1
NO WATER FLOW FROM TRAIN B (STANDBY)
GC12-0110-_1
TRAIN B IN MAINTENANCE
C12-SYS-TM-TRAINB
3.00E-03
LOSS OF 480 V AC FROM BUS R12-B2-02B
GR12-0001-_11
TRAIN B LINE FAILURES
GC12-0111-_1
Page 15
LOSS OF 208/120 V AC FROM BUS R13-B1-2
GR13-0001-_24
MOTOR DRIVEN PUMP C001B FAILURES
GC12-0117-_1
Page 16
LOSS OF 6.9 KV AC FROM BUS R11-B2
GR11-0001-_2
1
2

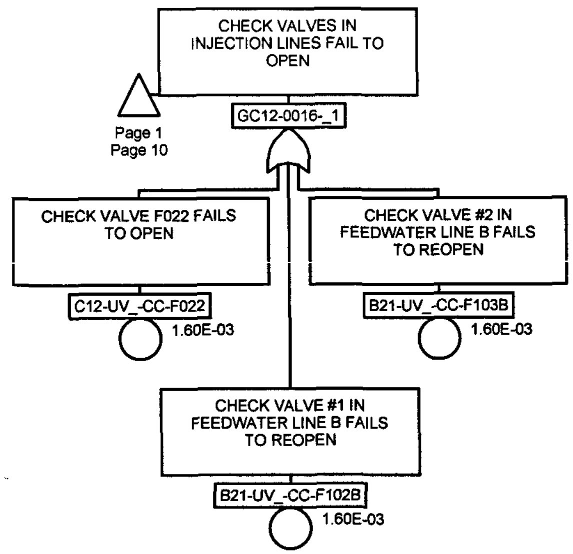

LOSS OF SIGNAL TO CRD COMPONENTS
GC12-0004-_1
Page 1
Page 10
CCF LEVEL TRANSMITTERS L8 (FAILURE TO RESPOND TO CHANGE)
B21-LT_-CF-L8NO
1.20E-07
SPURIOUS L9 SIGNAL CCF
B21-LT_-CF-L9SPU1
1.20E-07
LOGIC FAILURE
GC12-0036-_1
TRANSMISSION FAILURE
GC12-0038-_1
LOSS LEVEL 2 SIGNAL
GC12-0039-_1
DIV. A (NE RTNSS) SIGNAL TRANSMISSION FAILURE
GC62-0001-_1
DIV. C (NE RTNSS) SIGNAL TRANSMISSION FAILURE
GC62-0001-_3
MANUAL RECOVERY FAILURE
GC12-0041-_1
Page 5
LOSS OF LEVEL 2 SIGNAL FROM ANY SSLC MSIV DIVISION
GC12-0042-_1
Page 6
DIV. B (NE RTNSS) SIGNAL TRANSMISSION FAILURE
GC62-0001-_2
1
2
3
4

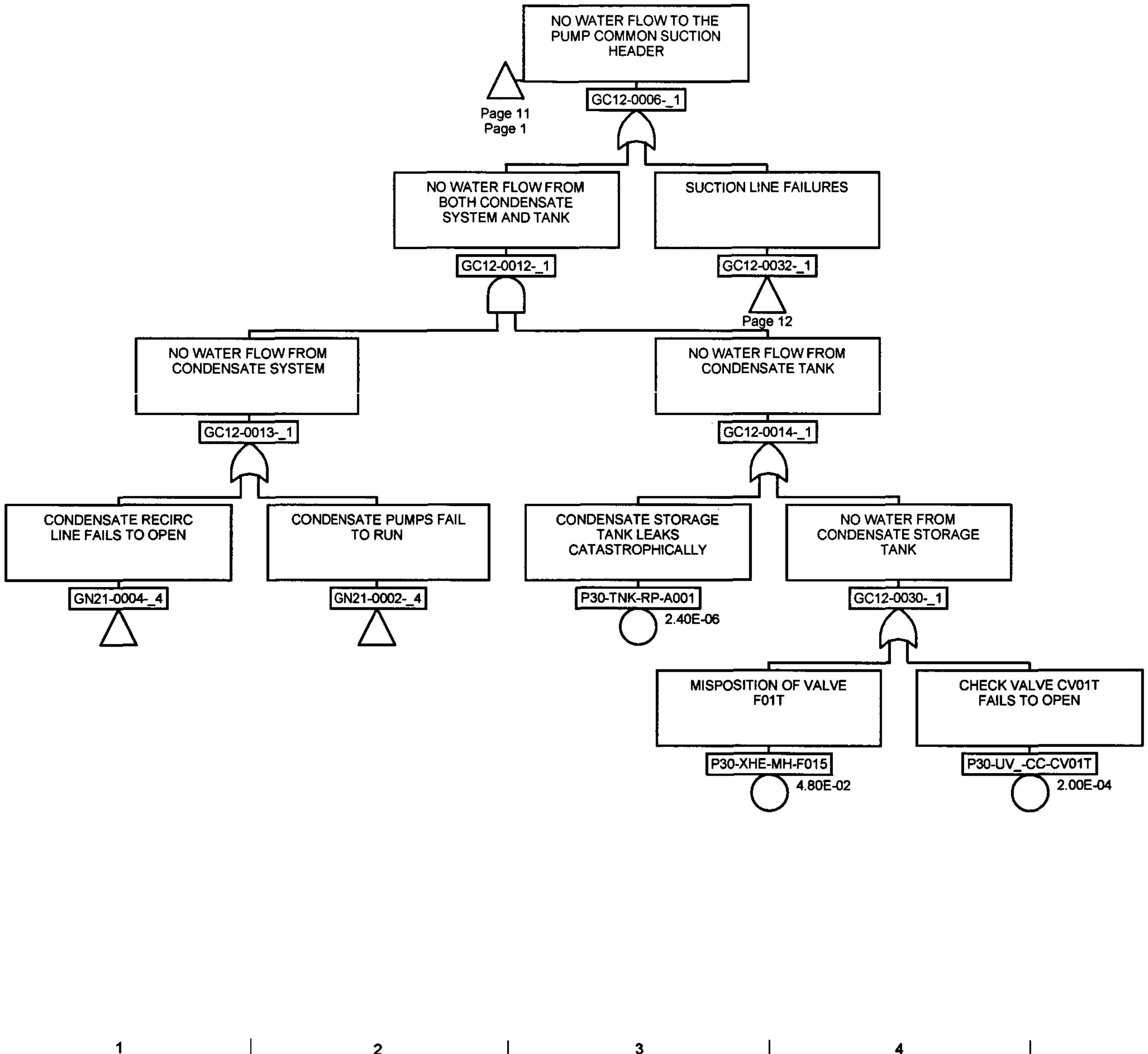

MANUAL RECOVERY FAILURE
GC12-0041-_1
Page 4
LOSS OF MANUAL ACTUATION SIGNAL
GC12-0043-_1
HOUSE EVENT: OPERATOR IS NOT AVAILABLE (VALUE=1)
XHOSMAN
ALL THREE RMUs FROMC.R. FAIL
GC12-0046-_1
MANUAL ACTUATION FAILURE
C12-XHE-FO-LEVEL2
3.22E-02
RMU 001 FAILURE
GC12-0048-_1
RMU 002 FAILURE
GC12-0049-_1
RMU 003 FAILURE
GC12-0050-_1
RMU 001 CRD SYSTEM C.R.MANUAL ACTUAT. FAILS TO OPERATE
H23-RMU-FC-C12001
3.00E-04
LOSS OF 208/120 V AC FROM BUS R13-A1-1
GR13-0001-_19
RMU 002 CRD SYSTEM C.R.MANUAL ACTUAT. FAILS TO OPERATE
H23-RMU-FC-C12002
3.00E-04
LOSS OF 208/120 V AC FROM BUS R13-B1-1
GR13-0001-_23
RMU 003 CRD SYSTEM C.R. MANUAL ACTUAT. FAILS TO OPERATE
H23-RMU-FC-C12003
3.00E-04
LOSS OF 208/120 V AC FROM BUS R13-C1-1
GR13-0001-_27
1
2
3
4
5
6

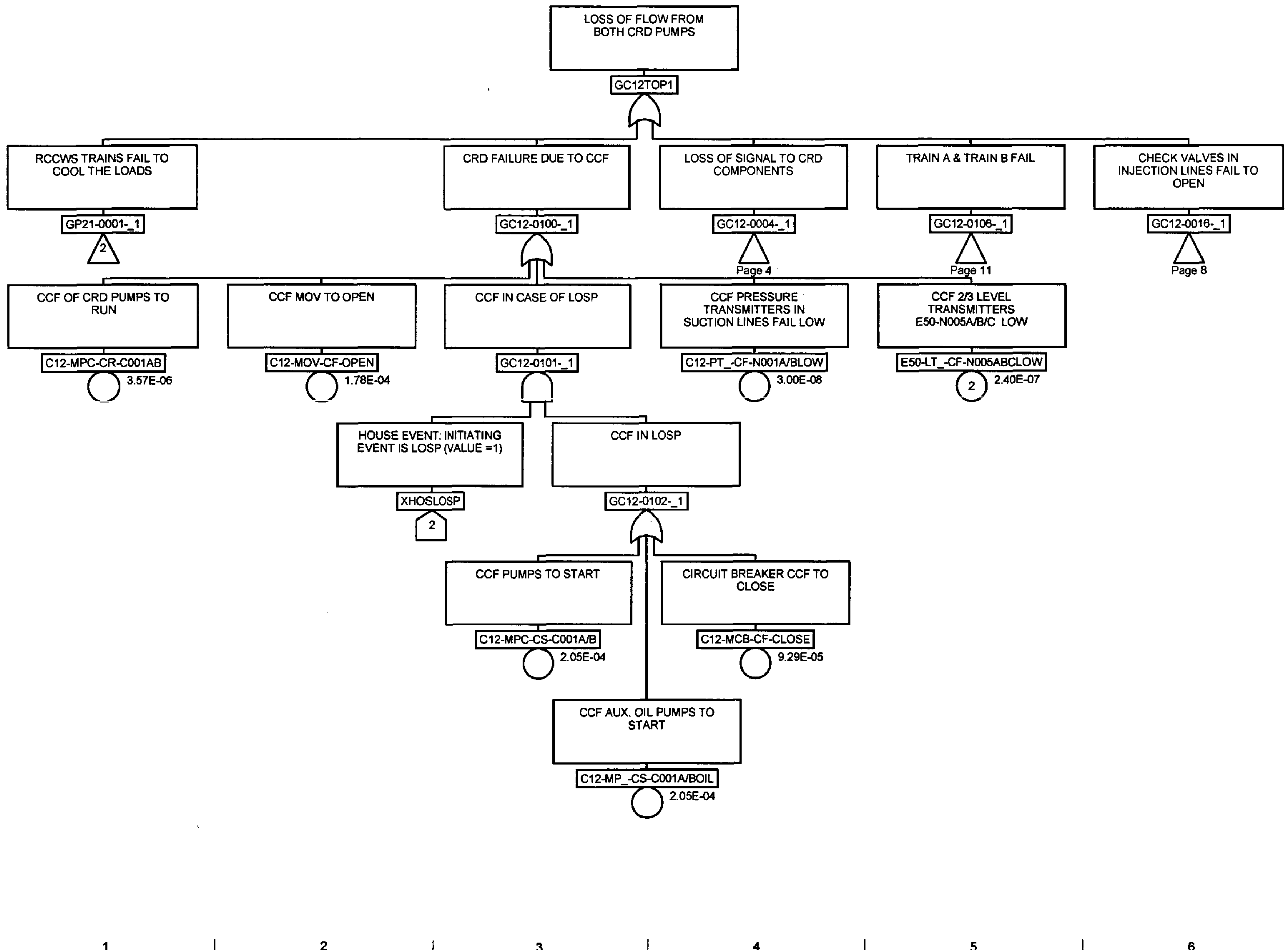

LOSS OF LEVEL 2 SIGNAL FROM ANY SSLC MSIV DIVISION
GC12-0042-_1
Page 4
LOSS OF LEVEL 1 AUTOMATIC SIGNAL
GC72-0105-_1
CCF LEVEL 2 SIGNAL GENERATION
GC12-0152-_1
CCF OF REMOTE MULTIPLEXING UNITS (DID)
H23-RMU-CF-DIDALL
9.00E-07
COMMON CAUSE FAILURE 3/4 DTM DID LOGIC
C62-DTM-CF-DIDALL
5.50E-05
CCF OF ALL DIVISION OF THE EMS
H23-EMS-CF-DIDALL
1.80E-06
CCF OF DPS WR LEVEL TRANSMITTERS
B21-LT_-CF-DPSWR
1.20E-07
1
2

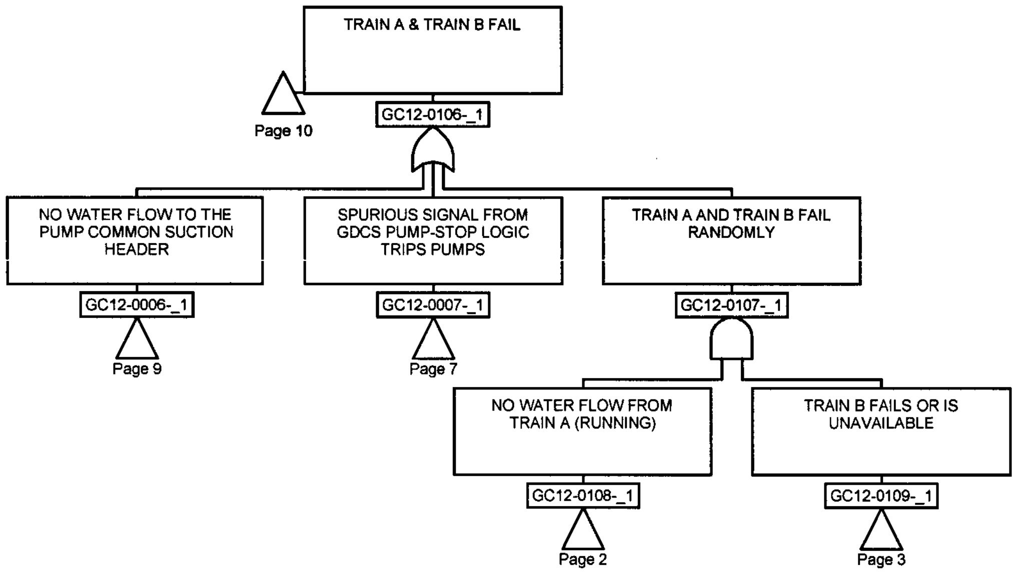

SPURIOUS SIGNAL FROM GDCS PUMP-STOP LOGIC TRIPS PUMPS
GC12-0007-_1
Page 1
Page 11
2
LEVEL TRANSMITTER E50-N005 DRIFTS LOW
E50-LT_-LO-N005A
1.22E-05
LEVEL TRANSMITTER E50-N005C DRIFTS LOW
E50-LT_-LO-N005C
1.22E-05
LEVEL TRANSMITTER E50-N005B DRIFTS LOW
E50-LT_-LO-N005B
1.22E-05

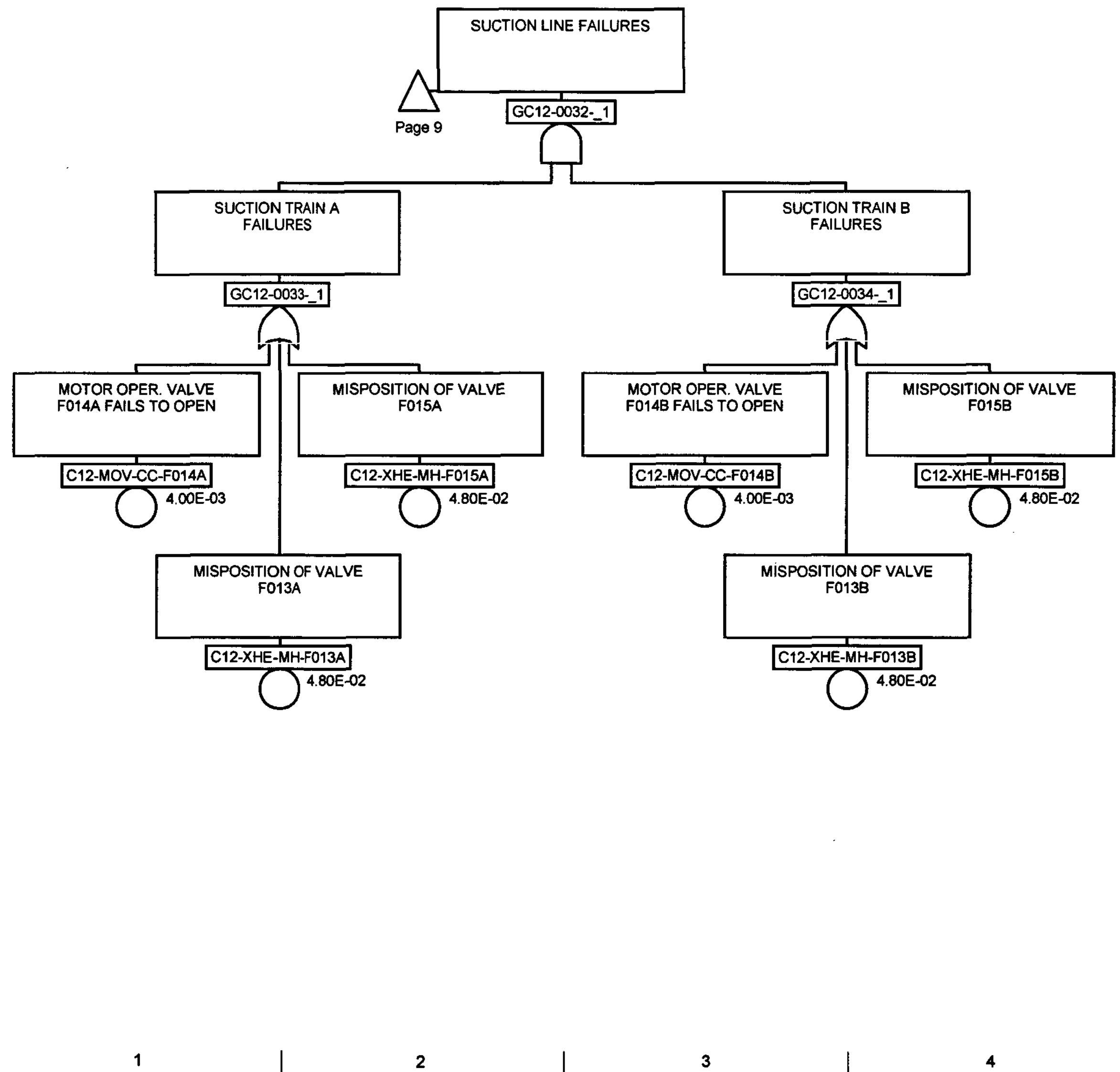
1	2

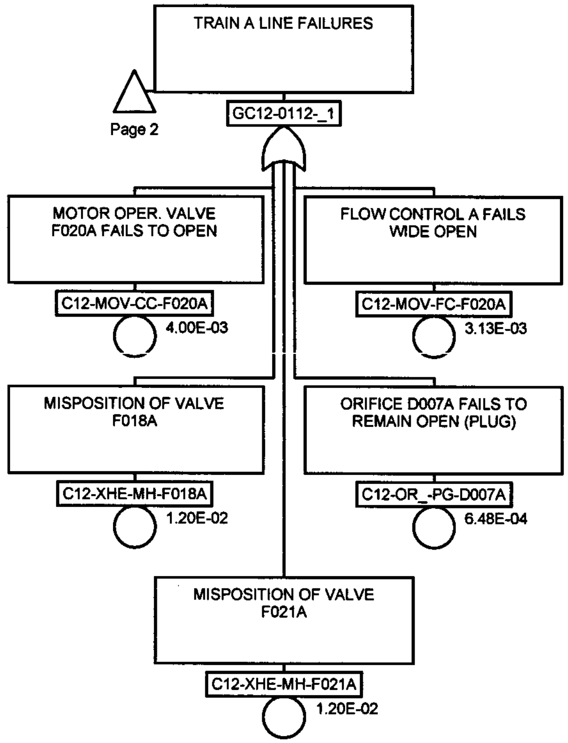

CHECK VALVES IN INJECTION LINES FAIL TO OPEN
GC12-0016-_1
Page 1
Page 10
CHECK VALVE F022 FAILS TO OPEN
C12-UV_-CC-F022
1.60E-03
CHECK VALVE #2 IN FEEDWATER LINE B FAILS TO REOPEN
B21-UV_-CC-F103B
1.60E-03
CHECK VALVE #1 IN FEEDWATER LINE B FAILS TO REOPEN
B21-UV_-CC-F102B
1.60E-03

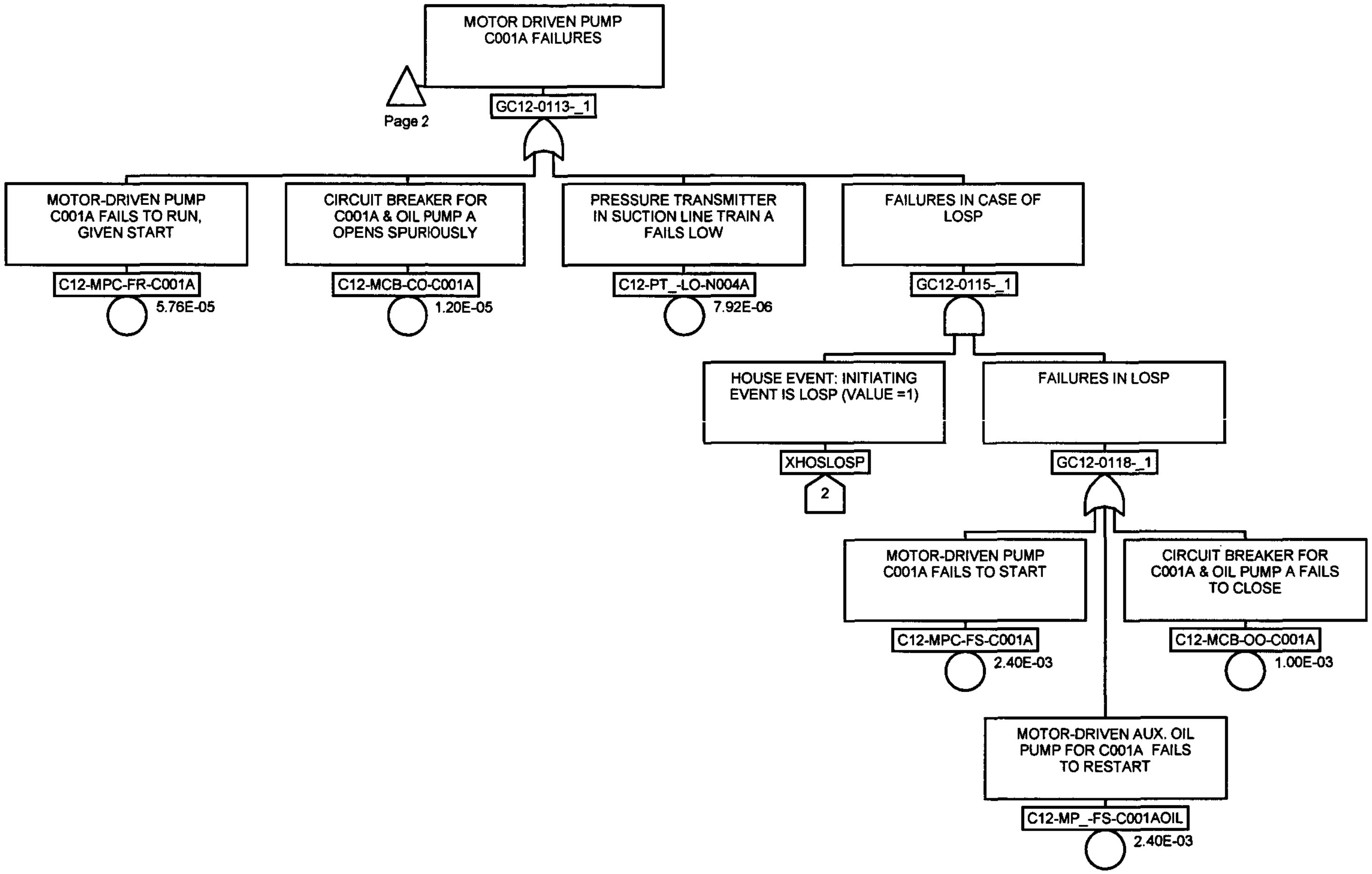

NO WATER FLOW TO THE PUMP COMMON SUCTION HEADER
GC12-0006-_1
Page 11
Page 1
NO WATER FLOW FROM BOTH CONDENSATE SYSTEM AND TANK
GC12-0012-_1
SUCTION LINE FAILURES
GC12-0032-_1
Page 12
NO WATER FLOW FROM CONDENSATE SYSTEM
GC12-0013-_1
NO WATER FLOW FROM CONDENSATE TANK
GC12-0014-_1
CONDENSATE RECIRC LINE FAILS TO OPEN
GN21-0004-_4
CONDENSATE PUMPS FAIL TO RUN
GN21-0002-_4
CONDENSATE STORAGE TANK LEAKS CATASTROPHICALLY
P30-TNK-RP-A001
2.40E-06
NO WATER FROM CONDENSATE STORAGE TANK
GC12-0030-_1
MISPOSITION OF VALVE F01T
P30-XHE-MH-F015
4.80E-02
CHECK VALVE CV01T FAILS TO OPEN
P30-UV_-CC-CV01T
2.00E-04
1
2
3
4

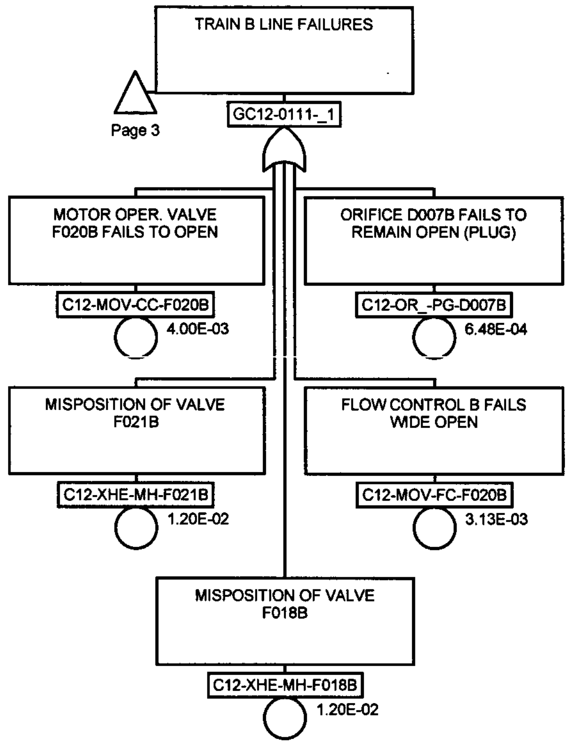

LOSS OF FLOW FROM BOTH CRD PUMPS
GC12TOP1
RCCWS TRAINS FAIL TO COOL THE LOADS
GP21-0001-_1
2
CRD FAILURE DUE TO CCF
GC12-0100-_1
LOSS OF SIGNAL TO CRD COMPONENTS
GC12-0004-_1
Page 4
TRAIN A & TRAIN B FAIL
GC12-0106-_1
Page 11
CHECK VALVES IN INJECTION LINES FAIL TO OPEN
GC12-0016-_1
Page 8
CCF OF CRD PUMPS TO RUN
C12-MPC-CR-C001AB
3.57E-06
CCF MOV TO OPEN
C12-MOV-CF-OPEN
1.78E-04
CCF IN CASE OF LOSP
GC12-0101-_1
CCF PRESSURE TRANSMITTERS IN SUCTION LINES FAIL LOW
C12-PT_-CF-N001A/BLOW
3.00E-08
CCF 2/3 LEVEL TRANSMITTERS E50-N005A/B/C LOW
E50-LT_-CF-N005ABCLOW
2
2.40E-07
HOUSE EVENT: INITIATING EVENT IS LOSP (VALUE =1)
XHOSLOSP
2
CCF IN LOSP
GC12-0102-_1
CCF PUMPS TO START
C12-MPC-CS-C001A/B
2.05E-04
CIRCUIT BREAKER CCF TO CLOSE
C12-MCB-CF-CLOSE
9.29E-05
CCF AUX. OIL PUMPS TO START
C12-MP_-CS-C001A/BOIL
2.05E-04
1
2
3
4
5
6

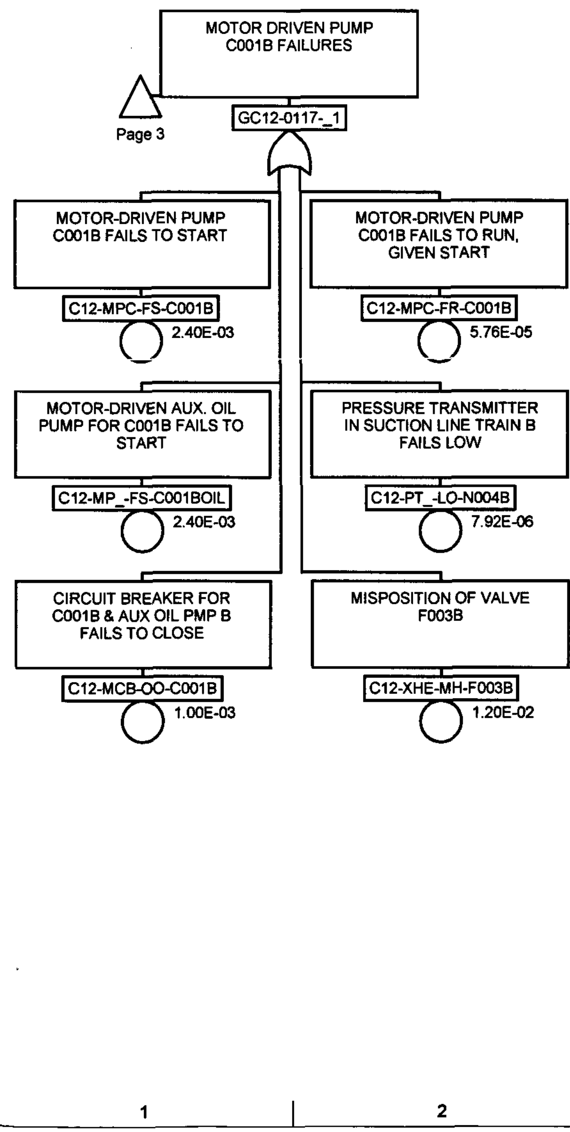

TRAIN A & TRAIN B FAIL
GC12-0106-_1
Page 10
NO WATER FLOW TO THE PUMP COMMON SUCTION HEADER
GC12-0006-_1
Page 9
SPURIOUS SIGNAL FROM GDCS PUMP-STOP LOGIC TRIPS PUMPS
GC12-0007-_1
Page 7
TRAIN A AND TRAIN B FAIL RANDOMLY
GC12-0107-_1
NO WATER FLOW FROM TRAIN A (RUNNING)
GC12-0108-_1
Page 2
TRAIN B FAILS OR IS UNAVAILABLE
GC12-0109-_1
Page 3


SUCTION LINE FAILURES
GC12-0032-_1
Page 9
SUCTION TRAIN A FAILURES
GC12-0033-_1
SUCTION TRAIN B FAILURES
GC12-0034-_1
MOTOR OPER. VALVE F014A FAILS TO OPEN
C12-MOV-CC-F014A
4.00E-03
MISPOSITION OF VALVE F015A
C12-XHE-MH-F015A
4.80E-02
MISPOSITION OF VALVE F013A
C12-XHE-MH-F013A
4.80E-02
MOTOR OPER. VALVE F014B FAILS TO OPEN
C12-MOV-CC-F014B
4.00E-03
MISPOSITION OF VALVE F015B
C12-XHE-MH-F015B
4.80E-02
MISPOSITION OF VALVE F013B
C12-XHE-MH-F013B
4.80E-02
1
2
3
4


TRAIN A LINE FAILURES
GC12-0112-_1
Page 2
MOTOR OPER. VALVE F020A FAILS TO OPEN
C12-MOV-CC-F020A
4.00E-03
FLOW CONTROL A FAILS WIDE OPEN
C12-MOV-FC-F020A
3.13E-03
MISPOSITION OF VALVE F018A
C12-XHE-MH-F018A
1.20E-02
ORIFICE D007A FAILS TO REMAIN OPEN (PLUG)
C12-OR_-PG-D007A
6.48E-04
MISPOSITION OF VALVE F021A
C12-XHE-MH-F021A
1.20E-02
1
2


MOTOR DRIVEN PUMP C001A FAILURES
Page 2
GC12-0113-_1
MOTOR-DRIVEN PUMP C001A FAILS TO RUN, GIVEN START
C12-MPC-FR-C001A
5.76E-05
CIRCUIT BREAKER FOR C001A & OIL PUMP A OPENS SPURIOUSLY
C12-MCB-CO-C001A
1.20E-05
PRESSURE TRANSMITTER IN SUCTION LINE TRAIN A FAILS LOW
C12-PT_-LO-N004A
7.92E-06
FAILURES IN CASE OF LOSP
GC12-0115-_1
HOUSE EVENT: INITIATING EVENT IS LOSP (VALUE =1)
XHOSLOSP
2
FAILURES IN LOSP
GC12-0118-_1
MOTOR-DRIVEN PUMP C001A FAILS TO START
C12-MPC-FS-C001A
2.40E-03
CIRCUIT BREAKER FOR C001A & OIL PUMP A FAILS TO CLOSE
C12-MCB-OO-C001A
1.00E-03
MOTOR-DRIVEN AUX. OIL PUMP FOR C001A FAILS TO RESTART
C12-MP_-FS-C001AOIL
2.40E-03


TRAIN B LINE FAILURES
Page 3
GC12-0111-_1
MOTOR OPER. VALVE F020B FAILS TO OPEN
C12-MOV-CC-F020B
4.00E-03
ORIFICE D007B FAILS TO REMAIN OPEN (PLUG)
C12-OR_-PG-D007B
6.48E-04
MISPOSITION OF VALVE F021B
C12-XHE-MH-F021B
1.20E-02
FLOW CONTROL B FAILS WIDE OPEN
C12-MOV-FC-F020B
3.13E-03
MISPOSITION OF VALVE F018B
C12-XHE-MH-F018B
1.20E-02
1
2

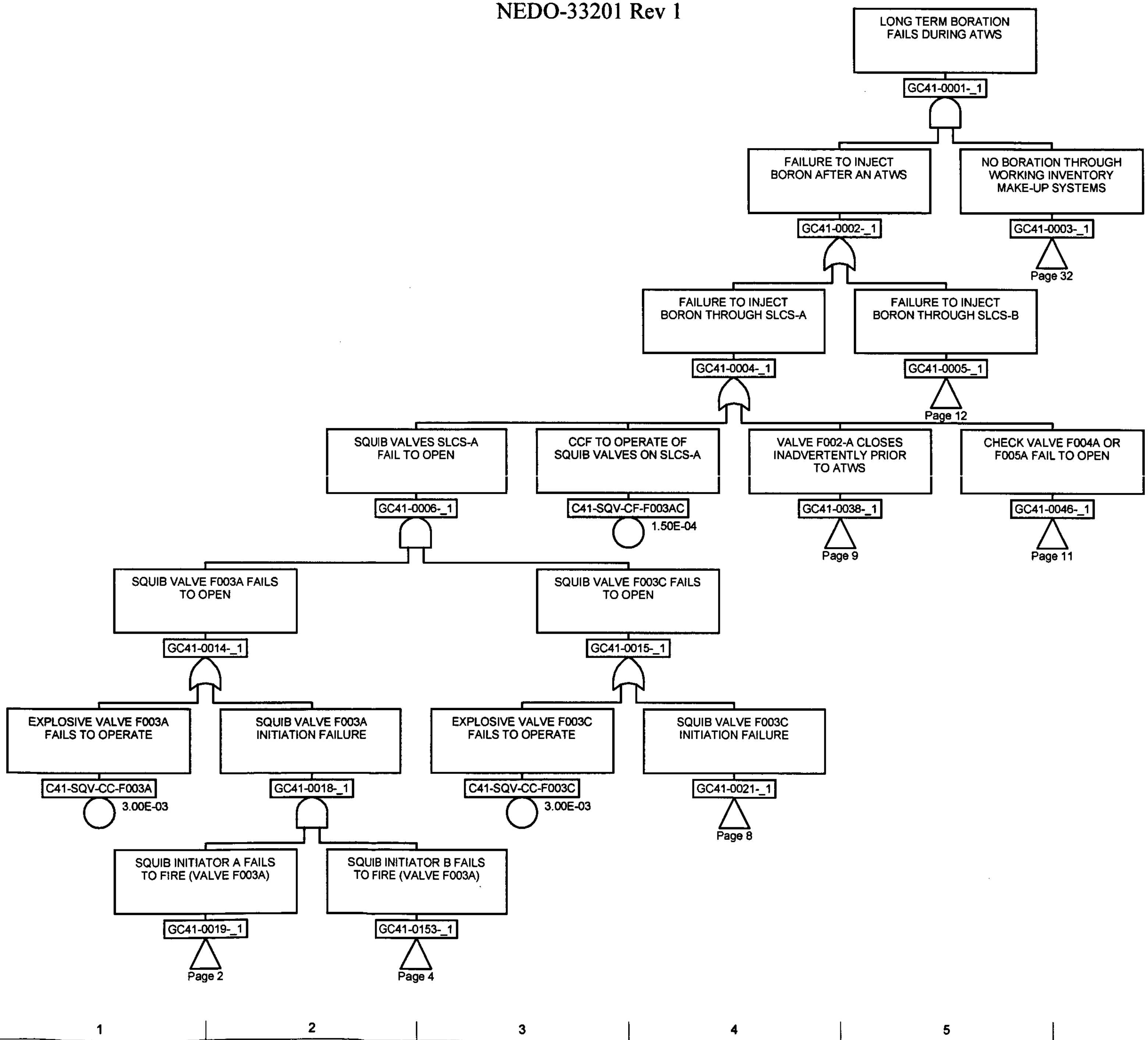

MOTOR DRIVEN PUMP C001B FAILURES
GC12-0117-_1
Page 3
MOTOR-DRIVEN PUMP C001B FAILS TO START
C12-MPC-FS-C001B
2.40E-03
MOTOR-DRIVEN PUMP C001B FAILS TO RUN, GIVEN START
C12-MPC-FR-C001B
5.76E-05
MOTOR-DRIVEN AUX. OIL PUMP FOR C001B FAILS TO START
C12-MP_-FS-C001BOIL
2.40E-03
PRESSURE TRANSMITTER IN SUCTION LINE TRAIN B FAILS LOW
C12-PT_-LO-N004B
7.92E-06
CIRCUIT BREAKER FOR C001B & AUX OIL PMP B FAILS TO CLOSE
C12-MCB-OO-C001B
1.00E-03
MISPOSITION OF VALVE F003B
C12-XHE-MH-F003B
1.20E-02
1
2

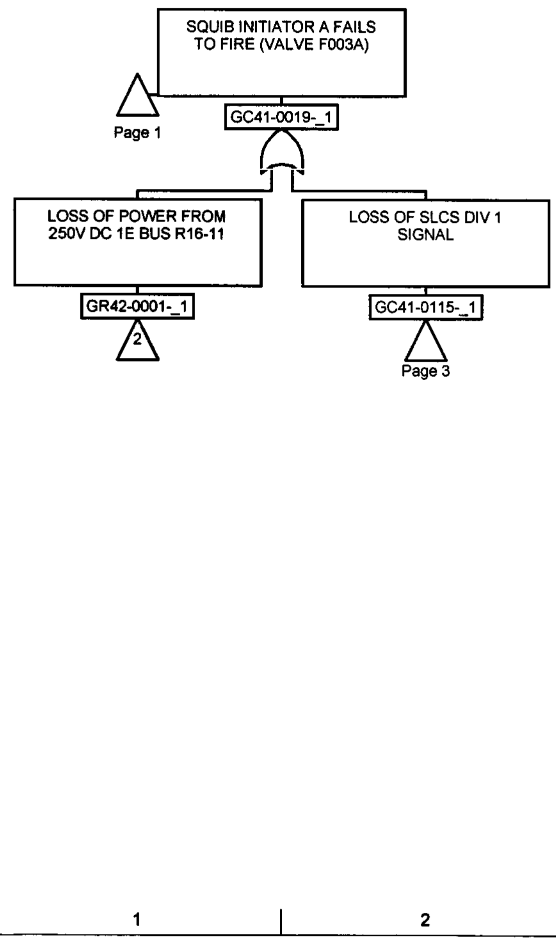
Name	Page	Zone
B21-LT -CF-DPSWR	6	3
B21-LT -CF-L8NO	4	1
B21-LT -CF-L9SPU1	4	2
B21-UV -CC-F102B	8	2
B21-UV -CC-F103B	8	2
C12-MCB-CF-CLOSE	10	4
C12-MCB-CO-C001A	14	2
C12-MCB-OO-C001A	14	5
C12-MCB-OO-C001B	16	1
C12-MOV-CC-F014A	12	1
C12-MOV-CC-F014B	12	3
C12-MOV-CC-F020A	13	1
C12-MOV-CC-F020B	15	1
C12-MOV-CF-OPEN	10	2
C12-MOV-FC-F020A	13	2
C12-MOV-FC-F020B	15	2
C12-MPC-CR-C001AB	10	1
C12-MPC-CS-C001A/B	10	3
C12-MPC-FR-C001A	14	1
C12-MPC-FR-C001B	16	2
C12-MPC-FS-C001A	14	4
C12-MPC-FS-C001B	16	1
C12-MP -CS-C001A/BOIL	10	4
C12-MP -FS-C001AOIL	14	5
C12-MP -FS-C001BOIL	16	1
C12-OR -PG-D007A	13	2
C12-OR -PG-D007B	15	2
C12-PT -CF-N001A/BLOW	10	4
C12-PT -LO-N004A	14	3
C12-PT -LO-N004B	16	2
C12-SYS-TM-TRAINB	3	3
C12-UV -CC-F022	8	1
C12-XHE-FO-LEVEL2	5	4
C12-XHE-MH-F003B	16	2
C12-XHE-MH-F013A	12	2
C12-XHE-MH-F013B	12	4
C12-XHE-MH-F015A	12	2
C12-XHE-MH-F015B	12	4
C12-XHE-MH-F018A	13	1
C12-XHE-MH-F018B	15	2
C12-XHE-MH-F021A	13	2
C12-XHE-MH-F021B	15	1
C62-DTM-CF-DIDALL	6	3
E50-LT -CF-N005ABCLOW	1	5
E50-LT -CF-N005ABCLOW	10	5
E50-LT -LO-N005A	7	1
E50-LT -LO-N005B	7	2
E50-LT -LO-N005C	7	2
GC12-0004- 1	1	3
GC12-0004- 1	4	2
GC12-0004- 1	10	4
GC12-0006- 1	1	7
GC12-0006- 1	9	3
GC12-0006-_1	11	1

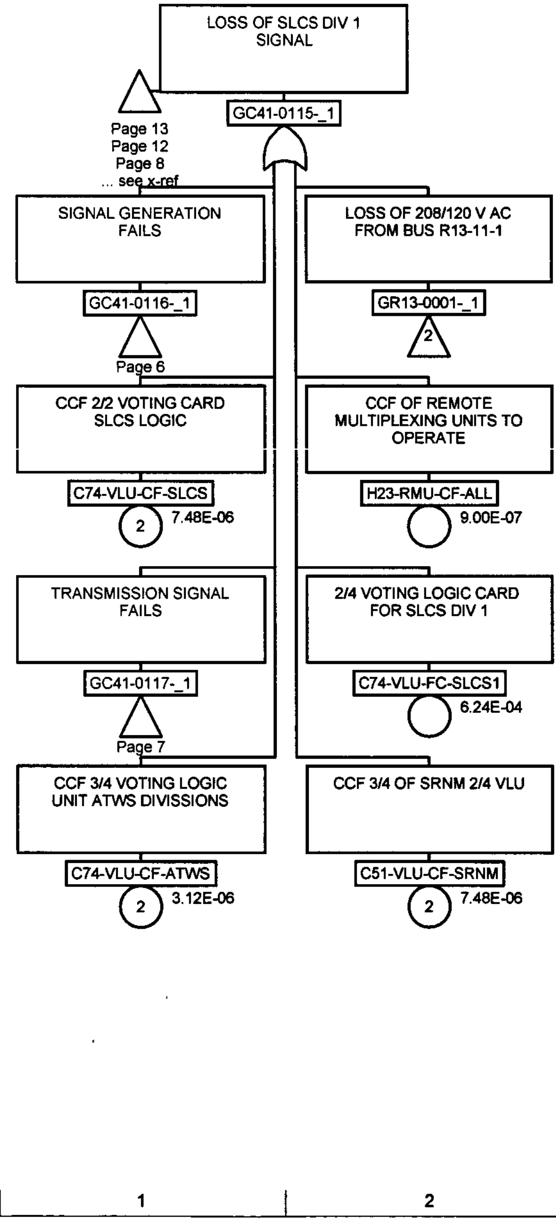
Name	Page	Zone
GC12-0007- 1	1	4
GC12-0007- 1	7	2
GC12-0007- 1	11	2
GC12-0012- 1	9	2
GC12-0013- 1	9	2
GC12-0014- 1	9	4
GC12-0016- 1	1	6
GC12-0016- 1	8	2
GC12-0016- 1	10	6
GC12-0030- 1	9	4
GC12-0032- 1	9	3
GC12-0032- 1	12	2
GC12-0033- 1	12	2
GC12-0034- 1	12	4
GC12-0036- 1	4	3
GC12-0038- 1	4	2
GC12-0039- 1	4	4
GC12-0041- 1	4	4
GC12-0041- 1	5	4
GC12-0042- 1	4	5
GC12-0042- 1	6	2
GC12-0043- 1	5	4
GC12-0046- 1	5	3
GC12-0048- 1	5	2
GC12-0049- 1	5	4
GC12-0050- 1	5	6
GC12-0100- 1	10	3
GC12-0101- 1	10	3
GC12-0102- 1	10	4
GC12-0106- 1	10	5
GC12-0106- 1	11	2
GC12-0107- 1	11	3
GC12-0108- 1	1	2
GC12-0108- 1	2	2
GC12-0108- 1	11	3
GC12-0109- 1	1	3
GC12-0109- 1	3	2
GC12-0109- 1	11	4
GC12-0110- 1	3	2
GC12-0111- 1	3	2
GC12-0111- 1	15	2
GC12-0112- 1	2	2
GC12-0112- 1	13	2
GC12-0113- 1	2	2
GC12-0113- 1	14	3
GC12-0115- 1	14	4
GC12-0117- 1	3	2
GC12-0117- 1	16	2
GC12-0118- 1	14	5
GC12-0123- 1	1	2
GC12-0152-_1	6	2
GC12TOP1	10	4
GC12TOP2	1	4
GC62-0001-_1	4	2

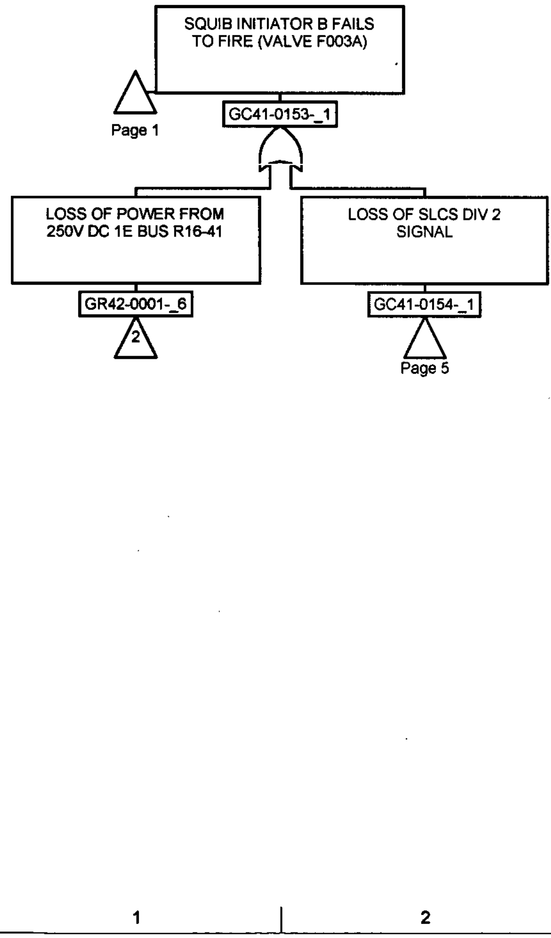
Name	Page	Zone
GC62-0001- 2	4	2
GC62-0001- 3	4	3
GC72-0105- 1	6	1
GN21-0002- 4	9	2
GN21-0004- 4	9	1
GP21-0001- 1	1	1
GP21-0001- 1	10	1
GR11-0001- 1	2	1
GR11-0001- 2	3	2
GR12-0001- 11	3	1
GR12-0001- 8	2	1
GR13-0001- 19	5	2
GR13-0001- 20	2	2
GR13-0001- 23	5	4
GR13-0001- 24	3	1
GR13-0001- 27	5	6
H23-EMS-CF-DIDALL	6	2
H23-RMU-CF-DIDALL	6	2
H23-RMU-FC-C12001	5	1
H23-RMU-FC-C12002	5	3
H23-RMU-FC-C12003	5	5
P30-TNK-RP-A001	9	3
P30-UV -CC-CV01T	9	5
P30-XHE-MH-F015	9	4
XHOSLOSP	10	3
XHOSLOSP	14	4
XHOSMAN	5	5

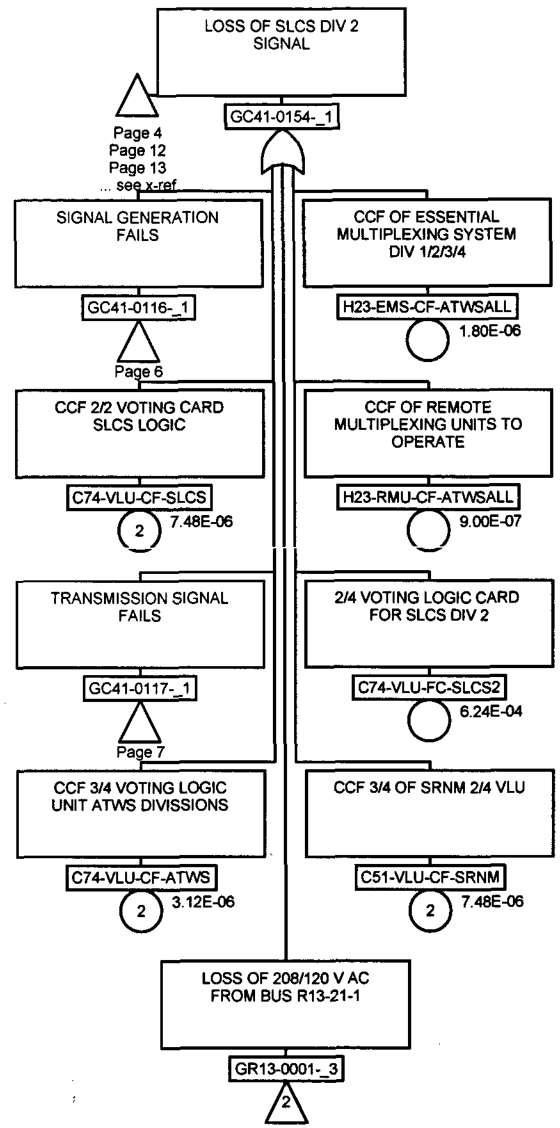
Appendix B.4.4 Standby Liquid Control System Fault Tree

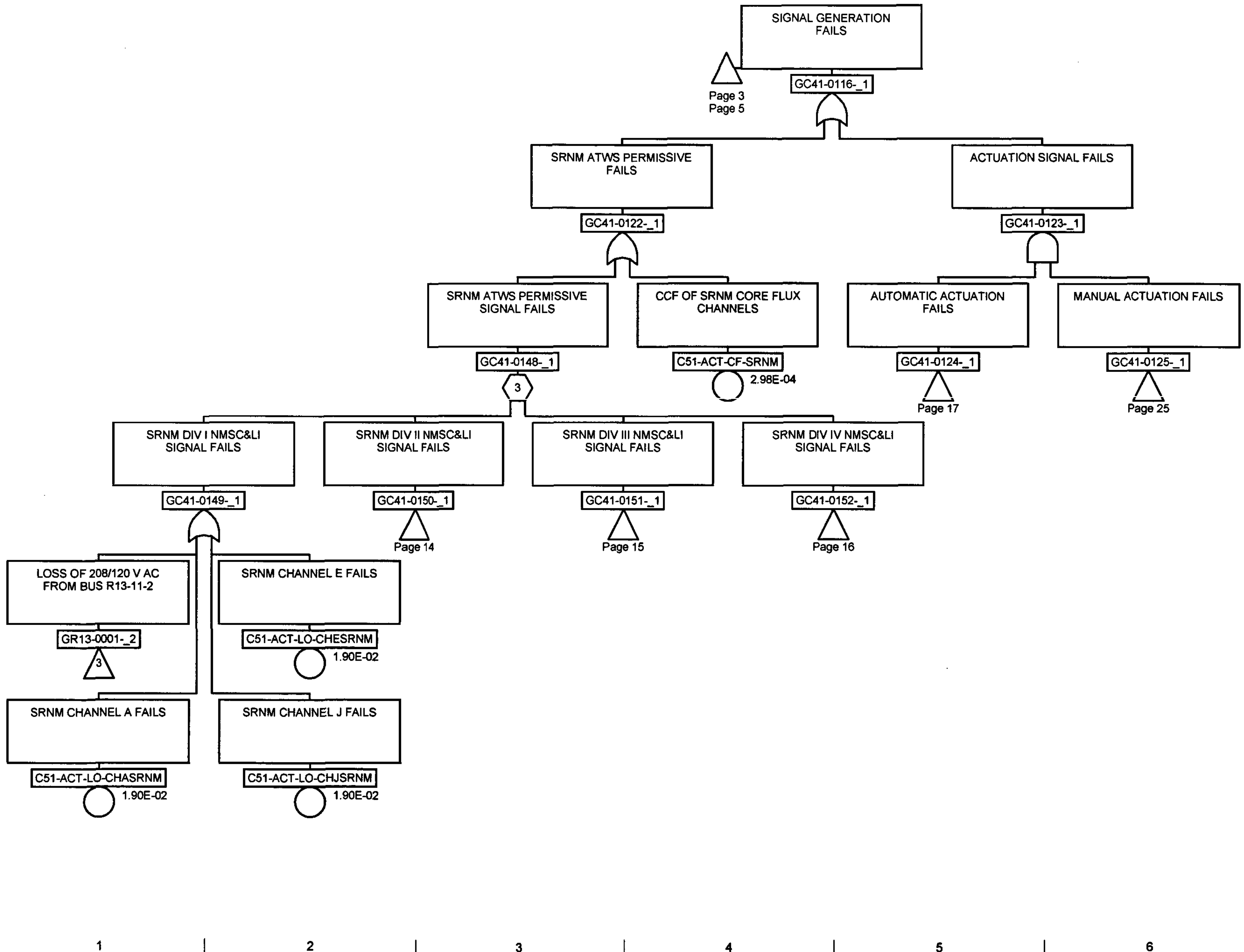

LONG TERM BORATION FAILS DURING ATWS
GC41-0001-_1
FAILURE TO INJECT BORON AFTER AN ATWS
GC41-0002-_1
NO BORATION THROUGH WORKING INVENTORY MAKE-UP SYSTEMS
GC41-0003-_1
Page 32
FAILURE TO INJECT BORON THROUGH SLCS-A
GC41-0004-_1
FAILURE TO INJECT BORON THROUGH SLCS-B
GC41-0005-_1
Page 12
SQUIB VALVES SLCS-A FAIL TO OPEN
GC41-0006-_1
CCF TO OPERATE OF SQUIB VALVES ON SLCS-A
C41-SQV-CF-F003AC
1.50E-04
VALVE F002-A CLOSES INADVERTENTLY PRIOR TO ATWS
GC41-0038-_1
Page 9
CHECK VALVE F004A OR F005A FAIL TO OPEN
GC41-0046-_1
Page 11
SQUIB VALVE F003A FAILS TO OPEN
GC41-0014-_1
SQUIB VALVE F003C FAILS TO OPEN
GC41-0015-_1
EXPLOSIVE VALVE F003A FAILS TO OPERATE
C41-SQV-CC-F003A
3.00E-03
SQUIB VALVE F003A INITIATION FAILURE
GC41-0018-_1
EXPLOSIVE VALVE F003C FAILS TO OPERATE
C41-SQV-CC-F003C
3.00E-03
SQUIB VALVE F003C INITIATION FAILURE
GC41-0021-_1
Page 8
SQUIB INITIATOR A FAILS TO FIRE (VALVE F003A)
GC41-0019-_1
Page 2
SQUIB INITIATOR B FAILS TO FIRE (VALVE F003A)
GC41-0153-_1
Page 4
1
2
3
4
5

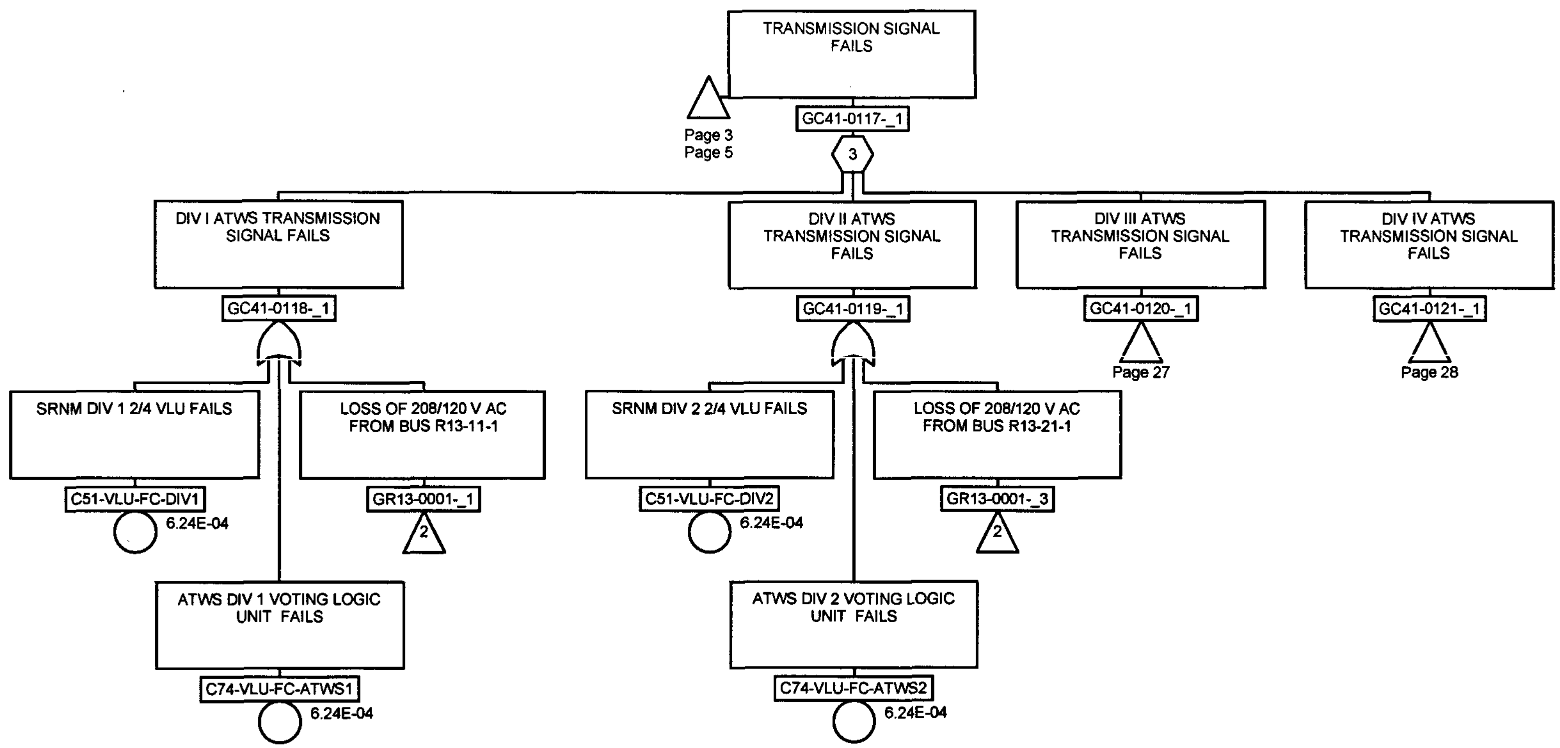

SQUIB INITIATOR A FAILS TO FIRE (VALVE F003A)
GC41-0019-_1
Page 1
LOSS OF POWER FROM 250V DC 1E BUS R16-11
GR42-0001-_1
2
LOSS OF SLCS DIV 1 SIGNAL
GC41-0115-_1
Page 3
1
2

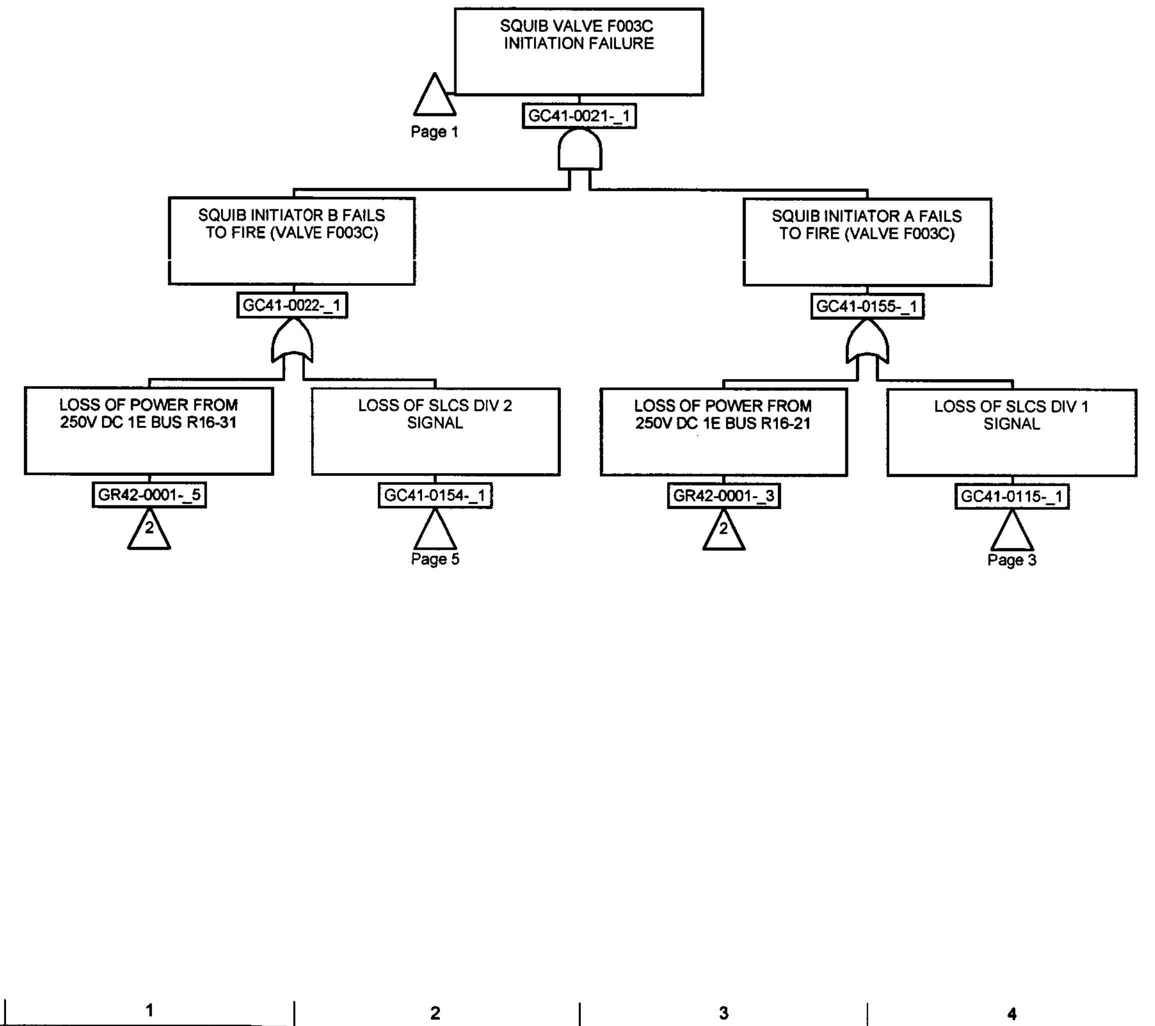

LOSS OF SLCS DIV 1 SIGNAL
GC41-0115-_1
Page 13
Page 12
Page 8
... see x-ref
SIGNAL GENERATION FAILS
GC41-0116-_1
Page 6
LOSS OF 208/120 V AC FROM BUS R13-11-1
GR13-0001-_1
2
CCF 2/2 VOTING CARD SLCS LOGIC
C74-VLU-CF-SLCS
2
7.48E-06
CCF OF REMOTE MULTIPLEXING UNITS TO OPERATE
H23-RMU-CF-ALL
9.00E-07
TRANSMISSION SIGNAL FAILS
GC41-0117-_1
Page 7
2/4 VOTING LOGIC CARD FOR SLCS DIV 1
C74-VLU-FC-SLCS1
6.24E-04
CCF 3/4 VOTING LOGIC UNIT ATWS DIVISSIONS
C74-VLU-CF-ATWS
2
3.12E-06
CCF 3/4 OF SRNM 2/4 VLU
C51-VLU-CF-SRNM
2
7.48E-06
1
2

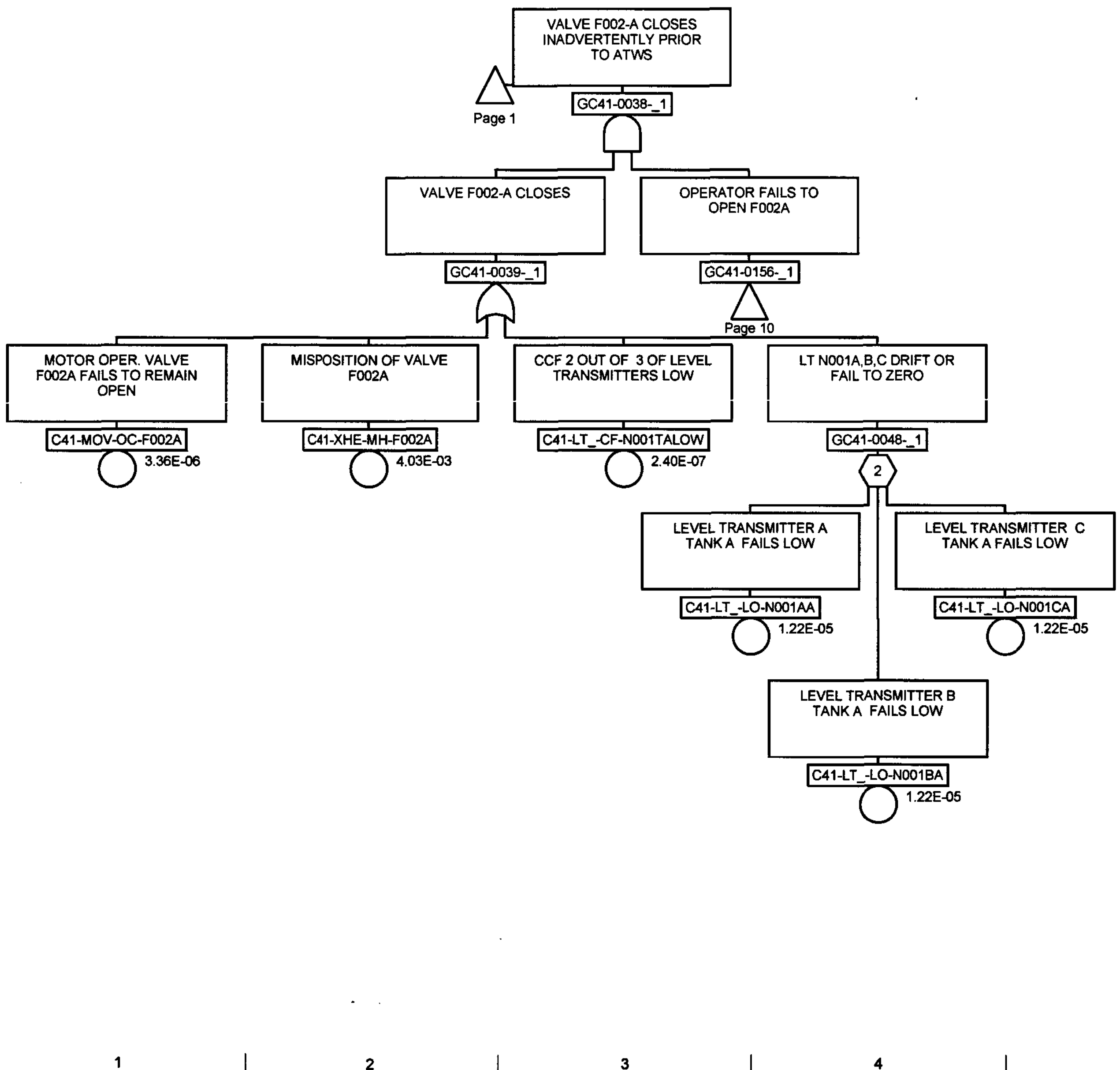

SQUIB INITIATOR B FAILS TO FIRE (VALVE F003A)
GC41-0153-_1
Page 1
LOSS OF POWER FROM 250V DC 1E BUS R16-41
GR42-0001-_6
2
LOSS OF SLCS DIV 2 SIGNAL
GC41-0154-_1
Page 5
1
2

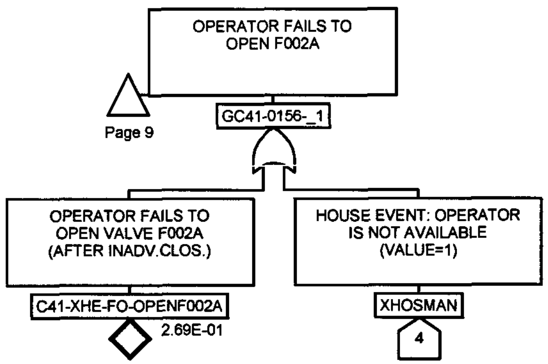

LOSS OF SLCS DIV 2 SIGNAL
GC41-0154-_1
Page 4
Page 12
Page 13
... see x-ref
SIGNAL GENERATION FAILS
GC41-0116-_1
Page 6
CCF OF ESSENTIAL MULTIPLEXING SYSTEM DIV 1/2/3/4
H23-EMS-CF-ATWSALL
1.80E-06
CCF 2/2 VOTING CARD SLCS LOGIC
C74-VLU-CF-SLCS
2
7.48E-06
CCF OF REMOTE MULTIPLEXING UNITS TO OPERATE
H23-RMU-CF-ATWSALL
9.00E-07
TRANSMISSION SIGNAL FAILS
GC41-0117-_1
Page 7
2/4 VOTING LOGIC CARD FOR SLCS DIV 2
C74-VLU-FC-SLCS2
6.24E-04
CCF 3/4 VOTING LOGIC UNIT ATWS DIVISSIONS
C74-VLU-CF-ATWS
2
3.12E-06
CCF 3/4 OF SRNM 2/4 VLU
C51-VLU-CF-SRNM
2
7.48E-06
LOSS OF 208/120 V AC FROM BUS R13-21-1
GR13-0001-_3
2
1
2

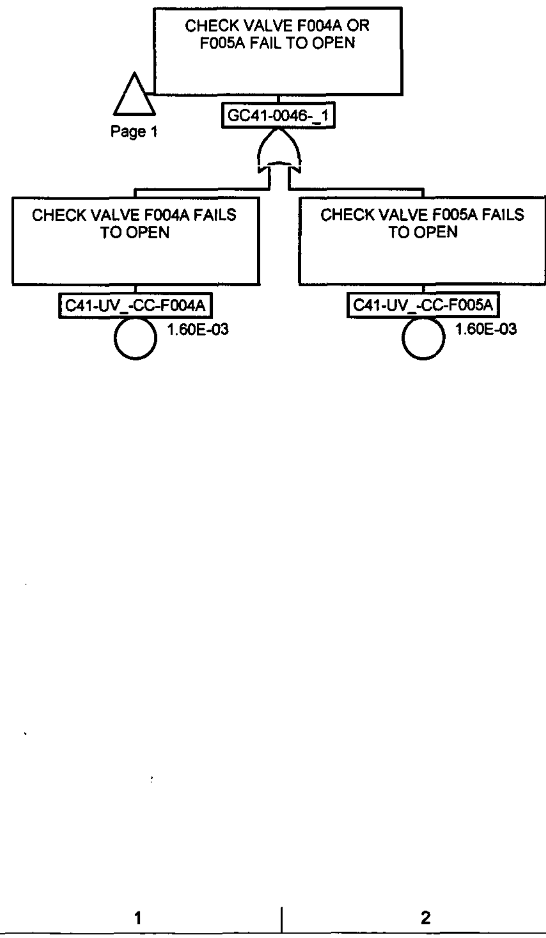

SIGNAL GENERATION FAILS
GC41-0116-_1
Page 3
Page 5
SRNM ATWS PERMISSIVE FAILS
GC41-0122-_1
ACTUATION SIGNAL FAILS
GC41-0123-_1
SRNM ATWS PERMISSIVE SIGNAL FAILS
GC41-0148-_1
3
CCF OF SRNM CORE FLUX CHANNELS
C51-ACT-CF-SRNM
2.98E-04
AUTOMATIC ACTUATION FAILS
GC41-0124-_1
Page 17
MANUAL ACTUATION FAILS
GC41-0125-_1
Page 25
SRNM DIV I NMSC&LI SIGNAL FAILS
GC41-0149-_1
SRNM DIV II NMSC&LI SIGNAL FAILS
GC41-0150-_1
Page 14
SRNM DIV III NMSC&LI SIGNAL FAILS
GC41-0151-_1
Page 15
SRNM DIV IV NMSC&LI SIGNAL FAILS
GC41-0152-_1
Page 16
LOSS OF 208/120 V AC FROM BUS R13-11-2
GR13-0001-_2
3
SRNM CHANNEL E FAILS
C51-ACT-LO-CHESRNM
1.90E-02
SRNM CHANNEL A FAILS
C51-ACT-LO-CHASRNM
1.90E-02
SRNM CHANNEL J FAILS
C51-ACT-LO-CHJSRNM
1.90E-02
1
2
3
4
5
6

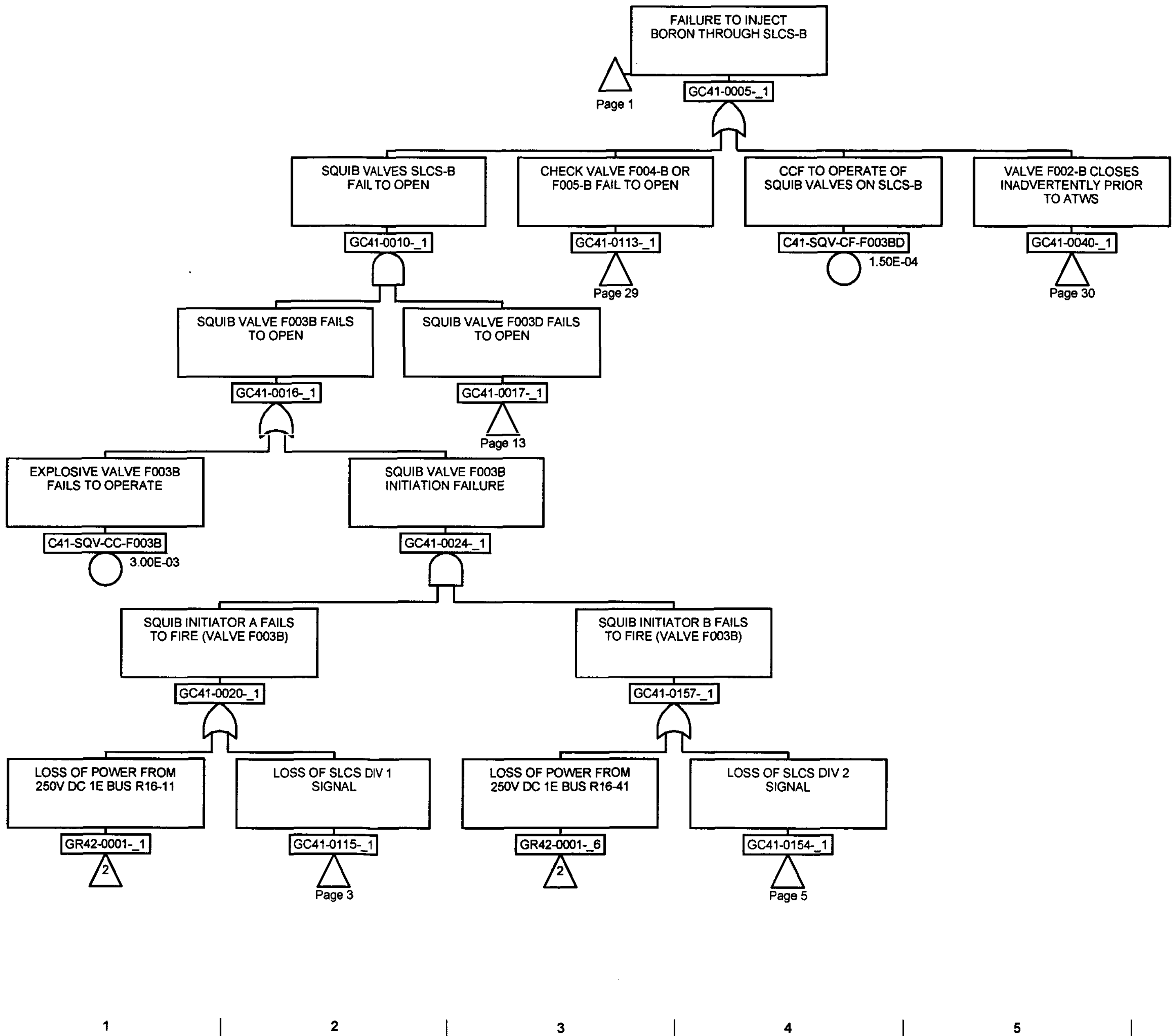

TRANSMISSION SIGNAL FAILS
GC41-0117-_1
Page 3
Page 5
3
DIV I ATWS TRANSMISSION SIGNAL FAILS
GC41-0118-_1
DIV II ATWS TRANSMISSION SIGNAL FAILS
GC41-0119-_1
DIV III ATWS TRANSMISSION SIGNAL FAILS
GC41-0120-_1
Page 27
DIV IV ATWS TRANSMISSION SIGNAL FAILS
GC41-0121-_1
Page 28
SRNM DIV 1 2/4 VLU FAILS
C51-VLU-FC-DIV1
6.24E-04
LOSS OF 208/120 V AC FROM BUS R13-11-1
GR13-0001-_1
2
SRNM DIV 2 2/4 VLU FAILS
C51-VLU-FC-DIV2
6.24E-04
LOSS OF 208/120 V AC FROM BUS R13-21-1
GR13-0001-_3
2
ATWS DIV 1 VOTING LOGIC UNIT FAILS
C74-VLU-FC-ATWS1
6.24E-04
ATWS DIV 2 VOTING LOGIC UNIT FAILS
C74-VLU-FC-ATWS2
6.24E-04
1
2
3
4
5

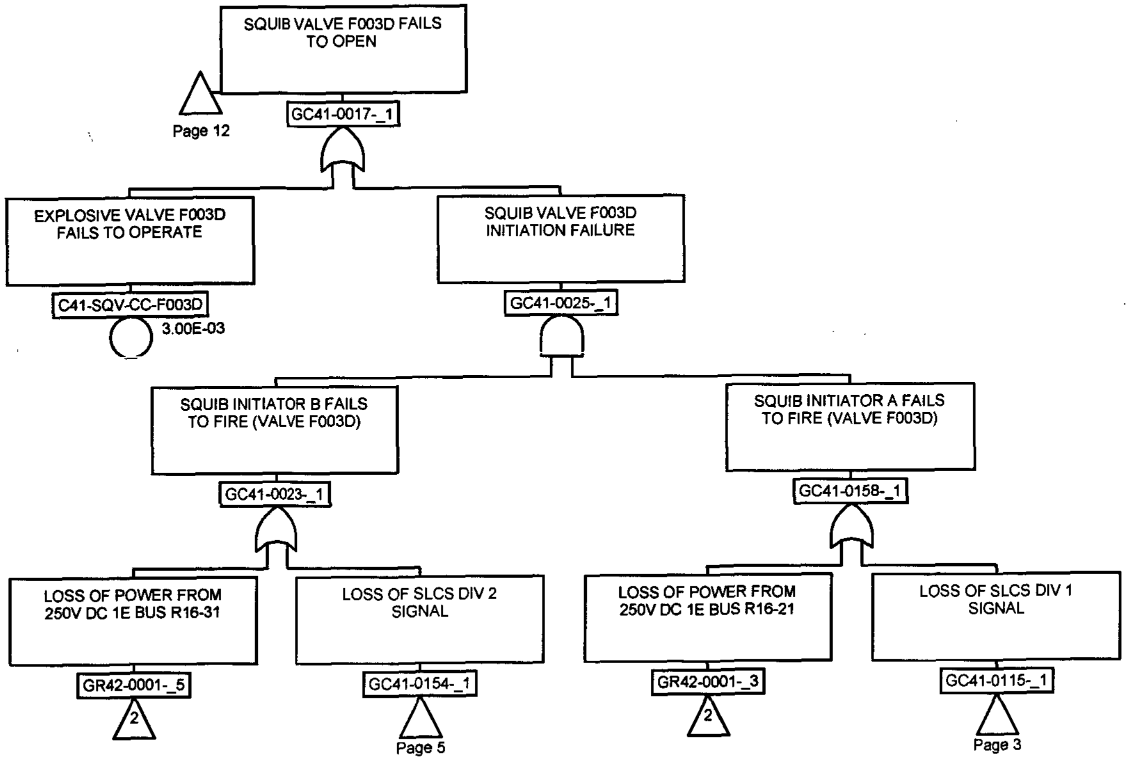

SQUIB VALVE F003C INITIATION FAILURE
GC41-0021-_1
Page 1
SQUIB INITIATOR B FAILS TO FIRE (VALVE F003C)
GC41-0022-_1
SQUIB INITIATOR A FAILS TO FIRE (VALVE F003C)
GC41-0155-_1
LOSS OF POWER FROM 250V DC 1E BUS R16-31
GR42-0001-_5
2
LOSS OF SLCS DIV 2 SIGNAL
GC41-0154-_1
Page 5
LOSS OF POWER FROM 250V DC 1E BUS R16-21
GR42-0001-_3
2
LOSS OF SLCS DIV 1 SIGNAL
GC41-0115-_1
Page 3
1
2
3
4

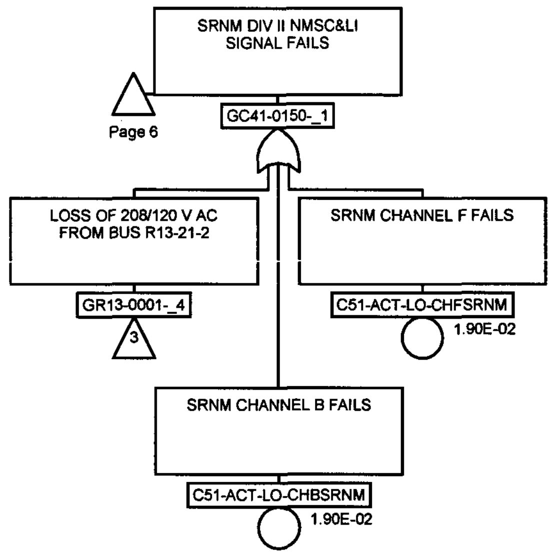

VALVE F002-A CLOSES INADVERTENTLY PRIOR TO ATWS
GC41-0038-_1
Page 1
VALVE F002-A CLOSES
GC41-0039-_1
OPERATOR FAILS TO OPEN F002A
GC41-0156-_1
Page 10
MOTOR OPER. VALVE F002A FAILS TO REMAIN OPEN
C41-MOV-OC-F002A
3.36E-06
MISPOSITION OF VALVE F002A
C41-XHE-MH-F002A
4.03E-03
CCF 2 OUT OF 3 OF LEVEL TRANSMITTERS LOW
C41-LT_-CF-N001TALOW
2.40E-07
LT N001A,B,C DRIFT OR FAIL TO ZERO
GC41-0048-_1
2
LEVEL TRANSMITTER A TANK A FAILS LOW
C41-LT_-LO-N001AA
1.22E-05
LEVEL TRANSMITTER C TANK A FAILS LOW
C41-LT_-LO-N001CA
1.22E-05
LEVEL TRANSMITTER B TANK A FAILS LOW
C41-LT_-LO-N001BA
1.22E-05
1
2
3
4

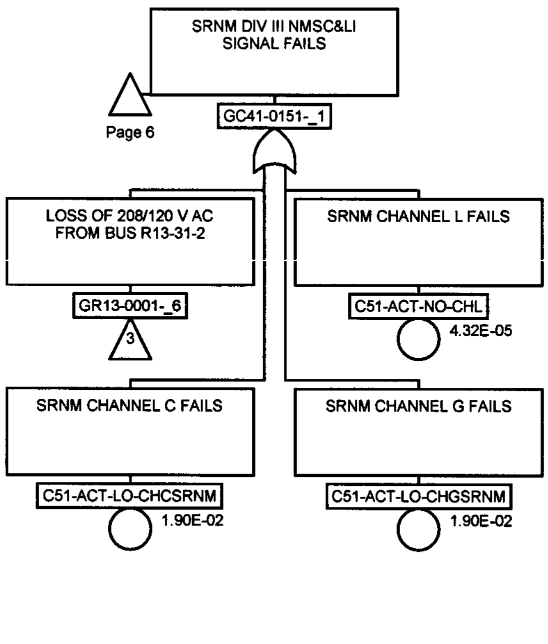

OPERATOR FAILS TO OPEN F002A
GC41-0156-_1
Page 9
OPERATOR FAILS TO OPEN VALVE F002A (AFTER INADV.CLOS.)
C41-XHE-FO-OPENF002A
2.69E-01
HOUSE EVENT: OPERATOR IS NOT AVAILABLE (VALUE=1)
XHOSMAN
4

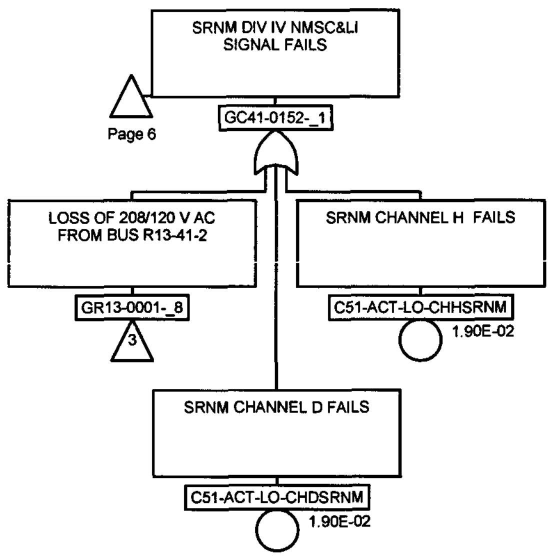

CHECK VALVE F004A OR F005A FAIL TO OPEN
Page 1
GC41-0046-_1
CHECK VALVE F004A FAILS TO OPEN
CHECK VALVE F005A FAILS TO OPEN
C41-UV_-CC-F004A
1.60E-03
C41-UV_-CC-F005A
1.60E-03
1
2

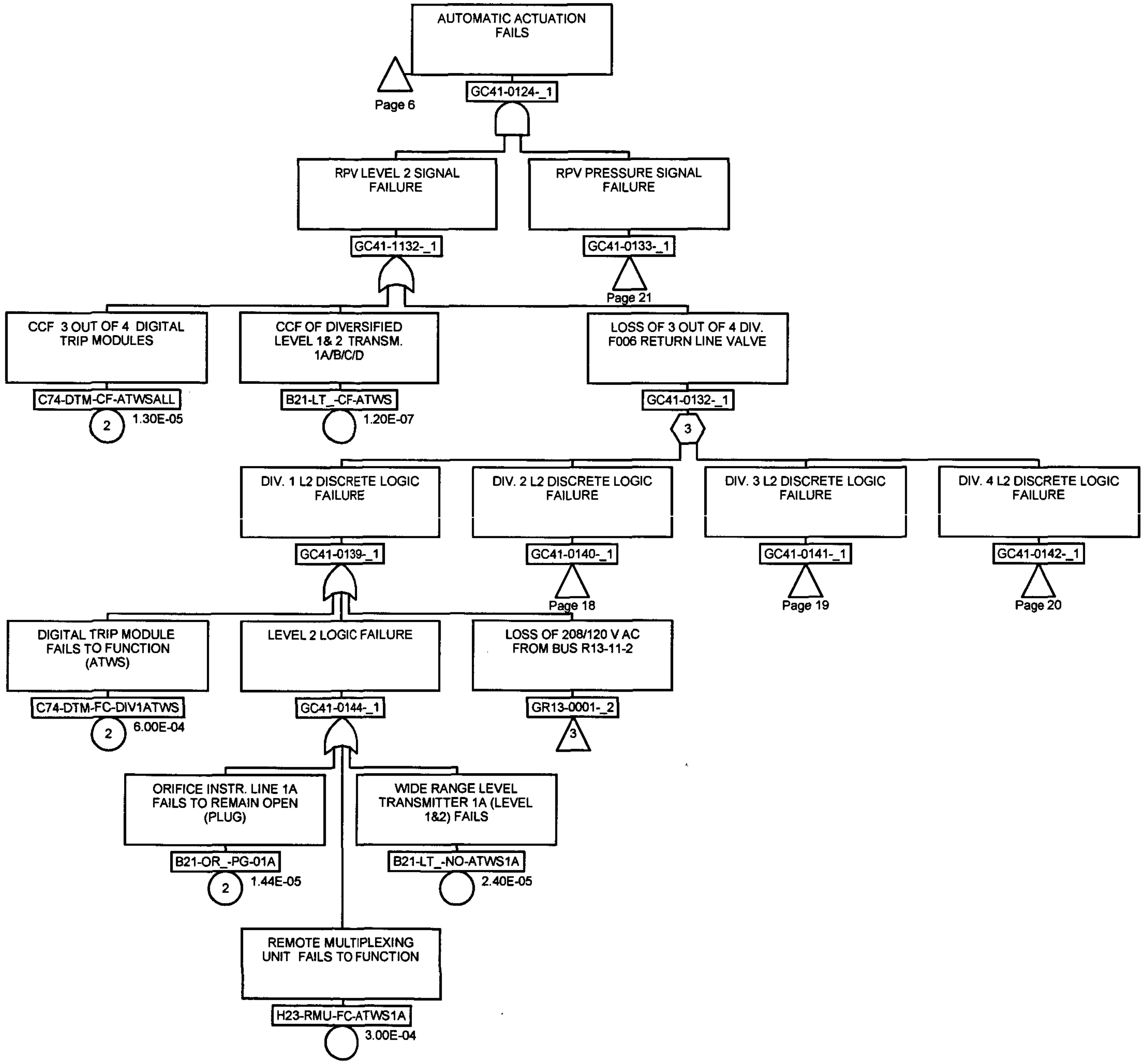

FAILURE TO INJECT BORON THROUGH SLCS-B
Page 1
GC41-0005-_1
SQUIB VALVES SLCS-B FAIL TO OPEN
GC41-0010-_1
CHECK VALVE F004-B OR F005-B FAIL TO OPEN
GC41-0113-_1
Page 29
CCF TO OPERATE OF SQUIB VALVES ON SLCS-B
C41-SQV-CF-F003BD
1.50E-04
VALVE F002-B CLOSES INADVERTENTLY PRIOR TO ATWS
GC41-0040-_1
Page 30
SQUIB VALVE F003B FAILS TO OPEN
GC41-0016-_1
SQUIB VALVE F003D FAILS TO OPEN
GC41-0017-_1
Page 13
EXPLOSIVE VALVE F003B FAILS TO OPERATE
C41-SQV-CC-F003B
3.00E-03
SQUIB VALVE F003B INITIATION FAILURE
GC41-0024-_1
SQUIB INITIATOR A FAILS TO FIRE (VALVE F003B)
GC41-0020-_1
SQUIB INITIATOR B FAILS TO FIRE (VALVE F003B)
GC41-0157-_1
LOSS OF POWER FROM 250V DC 1E BUS R16-11
GR42-0001-_1
2
LOSS OF SLCS DIV 1 SIGNAL
GC41-0115-_1
Page 3
LOSS OF POWER FROM 250V DC 1E BUS R16-41
GR42-0001-_6
2
LOSS OF SLCS DIV 2 SIGNAL
GC41-0154-_1
Page 5
1
2
3
4
5

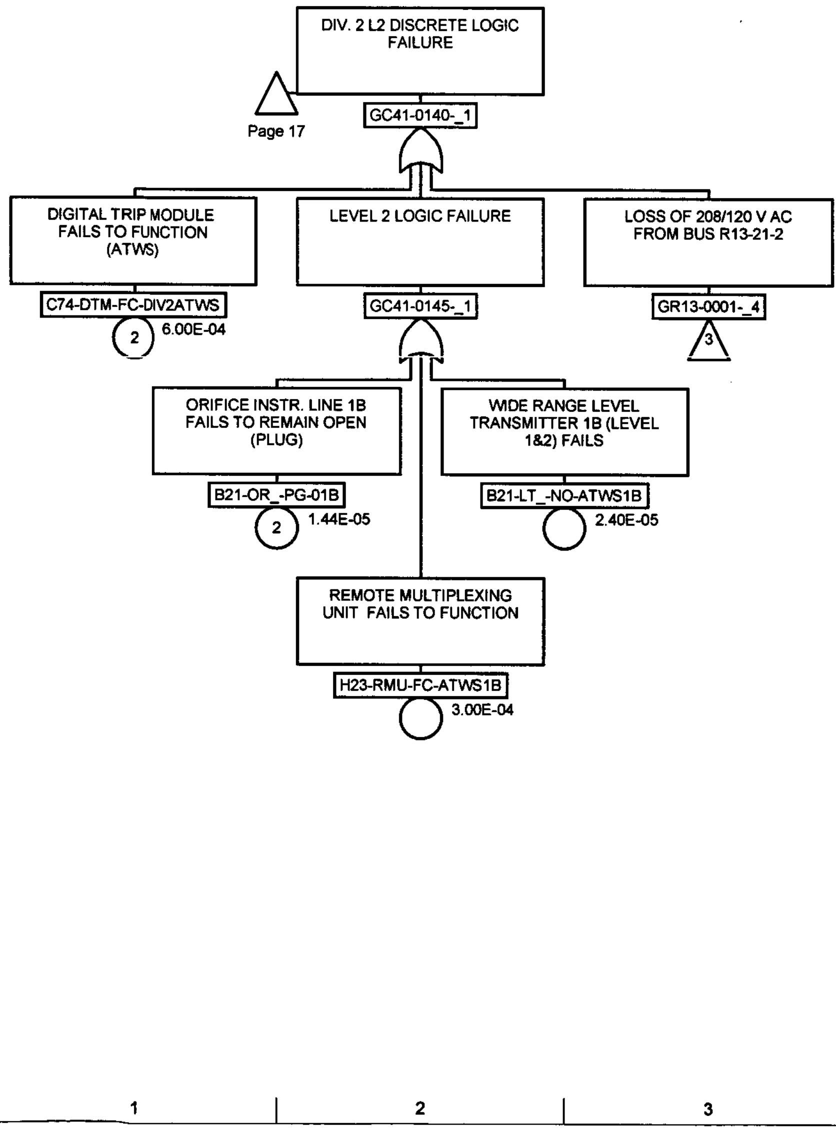

SQUIB VALVE F003D FAILS TO OPEN
Page 12
GC41-0017-_1
EXPLOSIVE VALVE F003D FAILS TO OPERATE
C41-SQV-CC-F003D
3.00E-03
SQUIB VALVE F003D INITIATION FAILURE
GC41-0025-_1
SQUIB INITIATOR B FAILS TO FIRE (VALVE F003D)
GC41-0023-_1
SQUIB INITIATOR A FAILS TO FIRE (VALVE F003D)
GC41-0158-_1
LOSS OF POWER FROM 250V DC 1E BUS R16-31
GR42-0001-_5
2
LOSS OF SLCS DIV 2 SIGNAL
GC41-0154-_1
Page 5
LOSS OF POWER FROM 250V DC 1E BUS R16-21
GR42-0001-_3
2
LOSS OF SLCS DIV 1 SIGNAL
GC41-0115-_1
Page 3
1
2
3
4

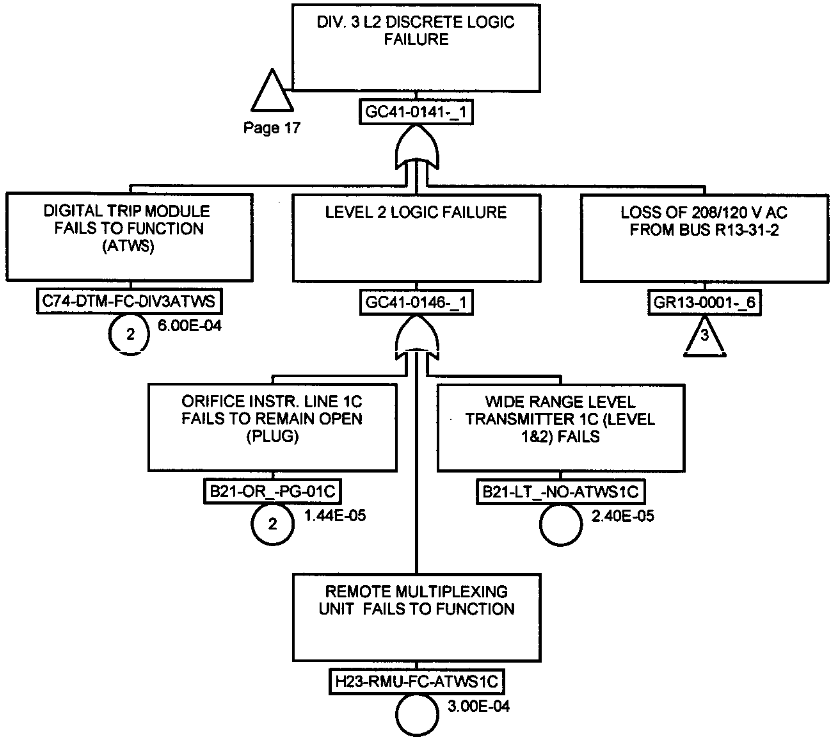

SRNM DIV II NMSC&LI SIGNAL FAILS
Page 6
GC41-0150-_1
LOSS OF 208/120 V AC FROM BUS R13-21-2
GR13-0001-_4
3
SRNM CHANNEL F FAILS
C51-ACT-LO-CHFSRNM
1.90E-02
SRNM CHANNEL B FAILS
C51-ACT-LO-CHBSRNM
1.90E-02

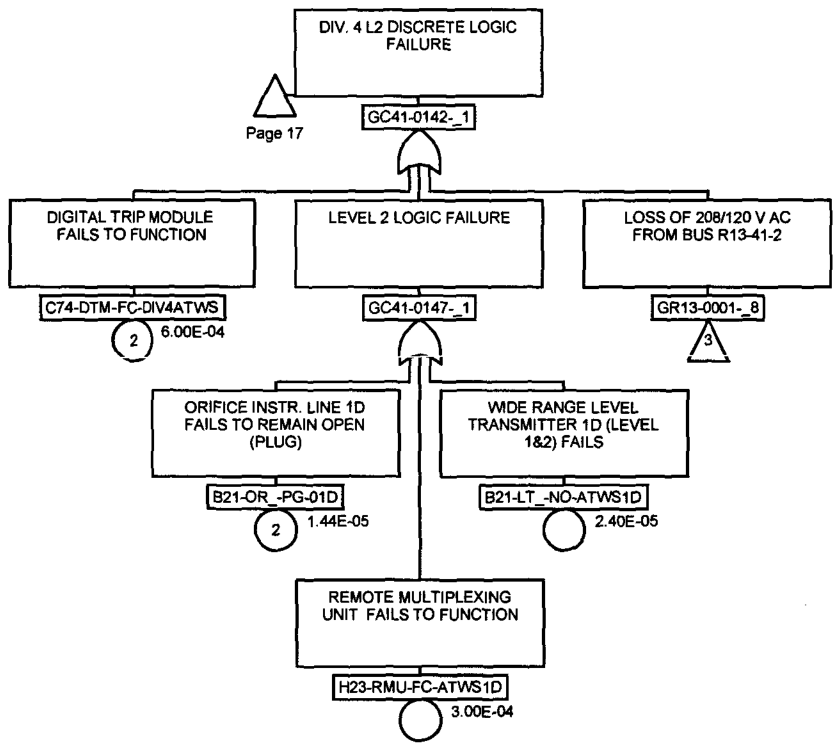

SRNM DIV III NMSC&LI SIGNAL FAILS
Page 6
GC41-0151-_1
LOSS OF 208/120 V AC FROM BUS R13-31-2
GR13-0001-_6
3
SRNM CHANNEL L FAILS
C51-ACT-NO-CHL
4.32E-05
SRNM CHANNEL C FAILS
C51-ACT-LO-CHCSRNM
1.90E-02
SRNM CHANNEL G FAILS
C51-ACT-LO-CHGSRNM
1.90E-02
1
2

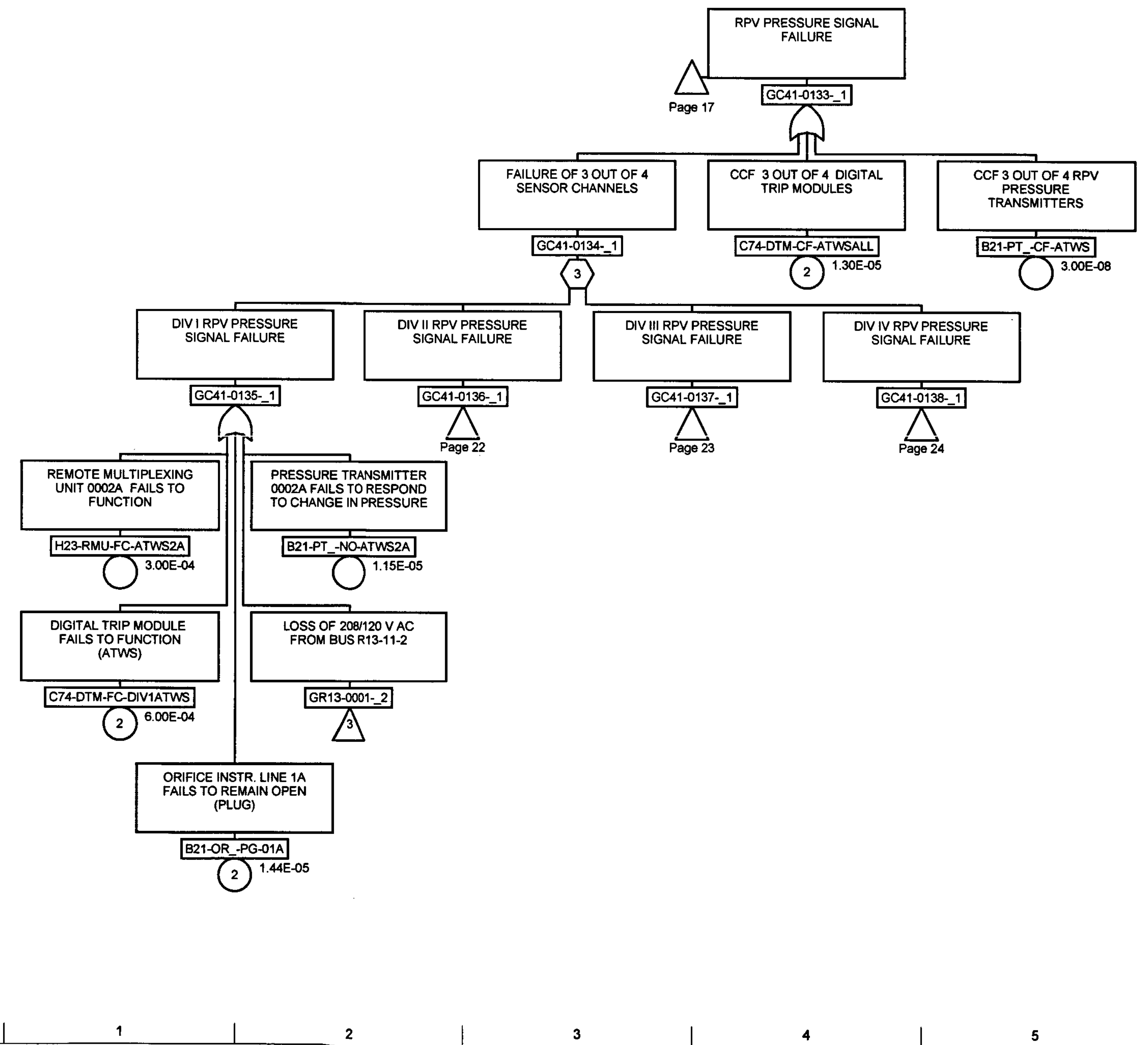

SRNM DIV IV NMSC&LI SIGNAL FAILS
GC41-0152-_1
Page 6
LOSS OF 208/120 V AC FROM BUS R13-41-2
GR13-0001-_8
3
SRNM CHANNEL H FAILS
C51-ACT-LO-CHHSRNM
1.90E-02
SRNM CHANNEL D FAILS
C51-ACT-LO-CHDSRNM
1.90E-02

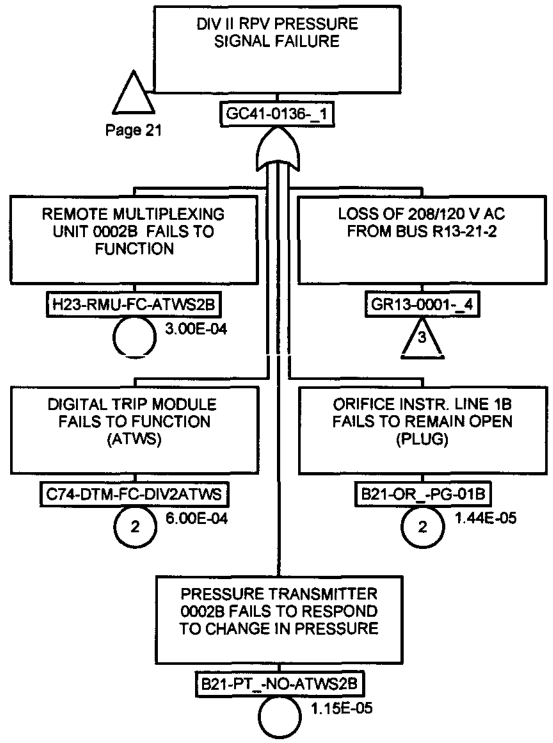

AUTOMATIC ACTUATION FAILS
GC41-0124-_1
Page 6
RPV LEVEL 2 SIGNAL FAILURE
GC41-1132-_1
RPV PRESSURE SIGNAL FAILURE
GC41-0133-_1
Page 21
CCF 3 OUT OF 4 DIGITAL TRIP MODULES
C74-DTM-CF-ATWSALL
2
1.30E-05
CCF OF DIVERSIFIED LEVEL 1& 2 TRANSM. 1A/B/C/D
B21-LT_-CF-ATWS
1.20E-07
LOSS OF 3 OUT OF 4 DIV. F006 RETURN LINE VALVE
GC41-0132-_1
3
DIV. 1 L2 DISCRETE LOGIC FAILURE
GC41-0139-_1
DIV. 2 L2 DISCRETE LOGIC FAILURE
GC41-0140-_1
Page 18
DIV. 3 L2 DISCRETE LOGIC FAILURE
GC41-0141-_1
Page 19
DIV. 4 L2 DISCRETE LOGIC FAILURE
GC41-0142-_1
Page 20
DIGITAL TRIP MODULE FAILS TO FUNCTION (ATWS)
C74-DTM-FC-DIV1ATWS
2
6.00E-04
LEVEL 2 LOGIC FAILURE
GC41-0144-_1
LOSS OF 208/120 V AC FROM BUS R13-11-2
GR13-0001-_2
3
ORIFICE INSTR. LINE 1A FAILS TO REMAIN OPEN (PLUG)
B21-OR_-PG-01A
2
1.44E-05
WIDE RANGE LEVEL TRANSMITTER 1A (LEVEL 1&2) FAILS
B21-LT_-NO-ATWS1A
2.40E-05
REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION
H23-RMU-FC-ATWS1A
3.00E-04
1
2
3
4
5

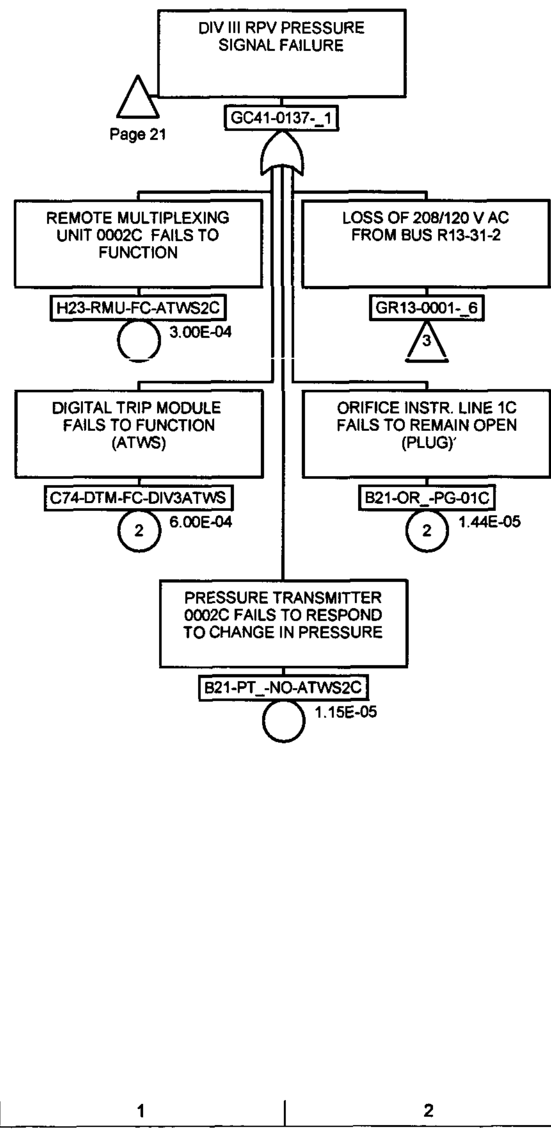

DIV. 2 L2 DISCRETE LOGIC FAILURE
GC41-0140-_1
Page 17
DIGITAL TRIP MODULE FAILS TO FUNCTION (ATWS)
C74-DTM-FC-DIV2ATWS
2
6.00E-04
LEVEL 2 LOGIC FAILURE
GC41-0145-_1
LOSS OF 208/120 V AC FROM BUS R13-21-2
GR13-0001-_4
3
ORIFICE INSTR. LINE 1B FAILS TO REMAIN OPEN (PLUG)
B21-OR_-PG-01B
2
1.44E-05
WIDE RANGE LEVEL TRANSMITTER 1B (LEVEL 1&2) FAILS
B21-LT_-NO-ATWS1B
2.40E-05
REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION
H23-RMU-FC-ATWS1B
3.00E-04
1
2
3

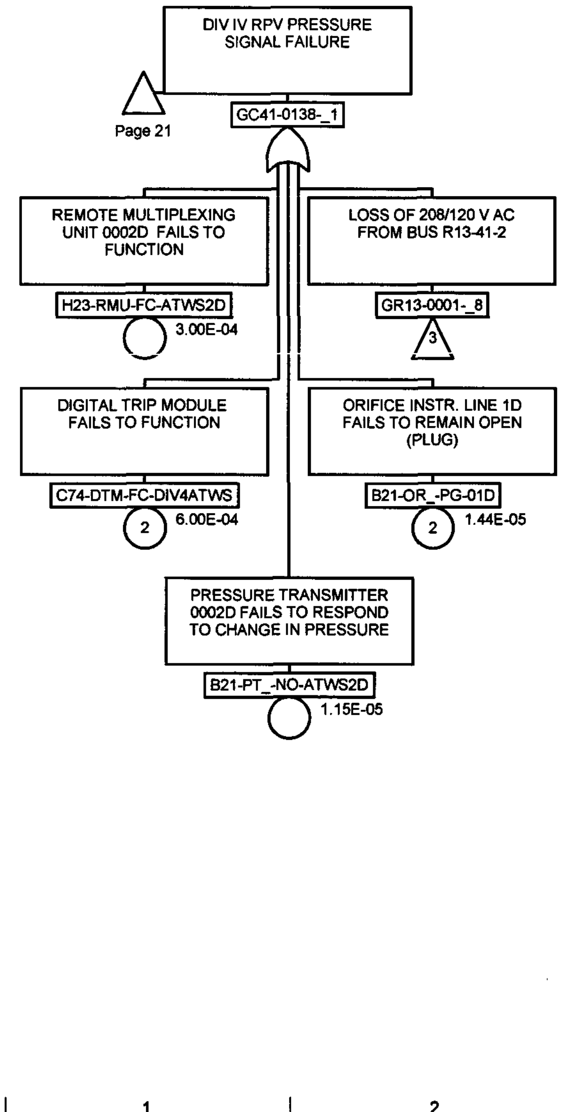

DIV. 3 L2 DISCRETE LOGIC FAILURE
GC41-0141-_1
Page 17
DIGITAL TRIP MODULE FAILS TO FUNCTION (ATWS)
C74-DTM-FC-DIV3ATWS
2
6.00E-04
LEVEL 2 LOGIC FAILURE
GC41-0146-_1
LOSS OF 208/120 V AC FROM BUS R13-31-2
GR13-0001-_6
3
ORIFICE INSTR. LINE 1C FAILS TO REMAIN OPEN (PLUG)
B21-OR_-PG-01C
2
1.44E-05
WIDE RANGE LEVEL TRANSMITTER 1C (LEVEL 1&2) FAILS
B21-LT_-NO-ATWS1C
2.40E-05
REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION
H23-RMU-FC-ATWS1C
3.00E-04
1
2
3

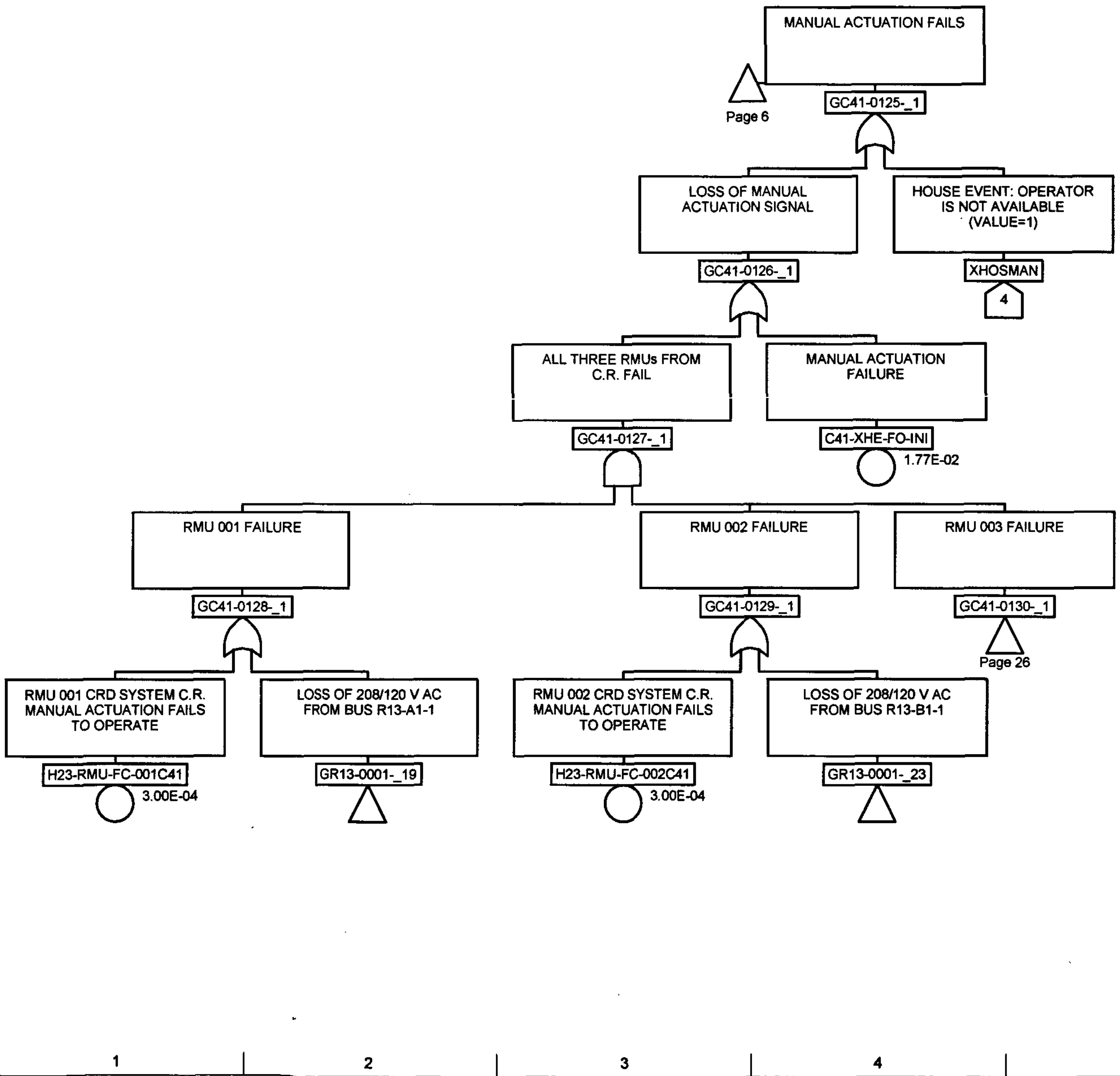

DIV. 4 L2 DISCRETE LOGIC FAILURE
Page 17
GC41-0142-_1
DIGITAL TRIP MODULE FAILS TO FUNCTION
C74-DTM-FC-DIV4ATWS
2
6.00E-04
LEVEL 2 LOGIC FAILURE
GC41-0147-_1
LOSS OF 208/120 V AC FROM BUS R13-41-2
GR13-0001-_8
3
ORIFICE INSTR. LINE 1D FAILS TO REMAIN OPEN (PLUG)
B21-OR_-PG-01D
2
1.44E-05
WIDE RANGE LEVEL TRANSMITTER 1D (LEVEL 1&2) FAILS
B21-LT_-NO-ATWS1D
2.40E-05
REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION
H23-RMU-FC-ATWS1D
3.00E-04

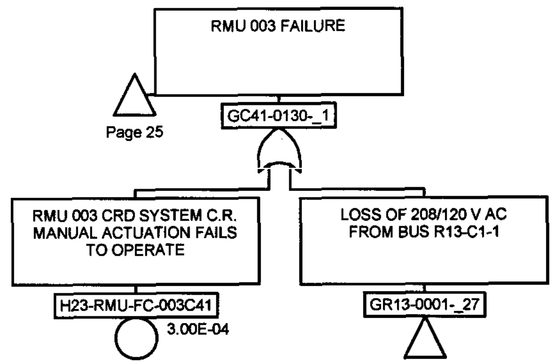

RPV PRESSURE SIGNAL FAILURE
GC41-0133-_1
Page 17
FAILURE OF 3 OUT OF 4 SENSOR CHANNELS
GC41-0134-_1
3
CCF 3 OUT OF 4 DIGITAL TRIP MODULES
C74-DTM-CF-ATWSALL
2
1.30E-05
CCF 3 OUT OF 4 RPV PRESSURE TRANSMITTERS
B21-PT_-CF-ATWS
3.00E-08
DIV I RPV PRESSURE SIGNAL FAILURE
GC41-0135-_1
DIV II RPV PRESSURE SIGNAL FAILURE
GC41-0136-_1
Page 22
DIV III RPV PRESSURE SIGNAL FAILURE
GC41-0137-_1
Page 23
DIV IV RPV PRESSURE SIGNAL FAILURE
GC41-0138-_1
Page 24
REMOTE MULTIPLEXING UNIT 0002A FAILS TO FUNCTION
H23-RMU-FC-ATWS2A
3.00E-04
PRESSURE TRANSMITTER 0002A FAILS TO RESPOND TO CHANGE IN PRESSURE
B21-PT_-NO-ATWS2A
1.15E-05
DIGITAL TRIP MODULE FAILS TO FUNCTION (ATWS)
C74-DTM-FC-DIV1ATWS
2
6.00E-04
LOSS OF 208/120 V AC FROM BUS R13-11-2
GR13-0001-_2
3
ORIFICE INSTR. LINE 1A FAILS TO REMAIN OPEN (PLUG)
B21-OR_-PG-01A
2
1.44E-05
1
2
3
4
5

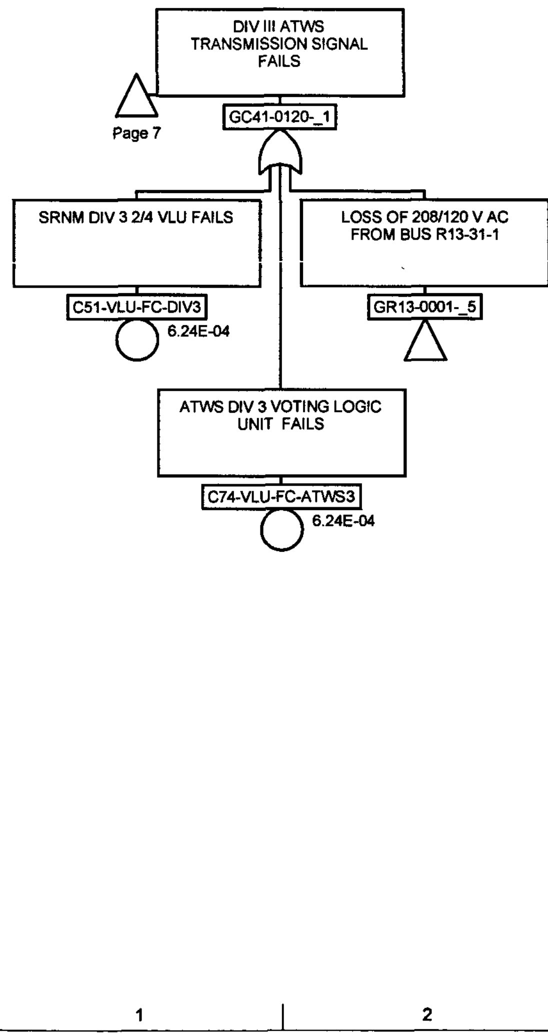

DIV II RPV PRESSURE SIGNAL FAILURE
GC41-0136-_1
Page 21
REMOTE MULTIPLEXING UNIT 0002B FAILS TO FUNCTION
H23-RMU-FC-ATWS2B
3.00E-04
LOSS OF 208/120 V AC FROM BUS R13-21-2
GR13-0001-_4
3
DIGITAL TRIP MODULE FAILS TO FUNCTION (ATWS)
C74-DTM-FC-DIV2ATWS
2
6.00E-04
ORIFICE INSTR. LINE 1B FAILS TO REMAIN OPEN (PLUG)
B21-OR_-PG-01B
2
1.44E-05
PRESSURE TRANSMITTER 0002B FAILS TO RESPOND TO CHANGE IN PRESSURE
B21-PT_-NO-ATWS2B
1.15E-05

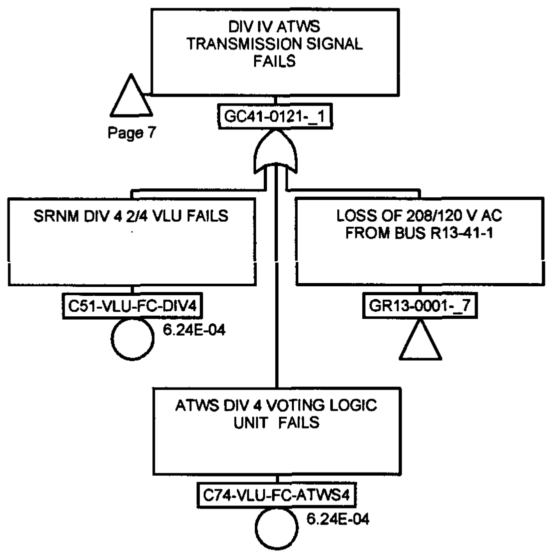

DIV III RPV PRESSURE SIGNAL FAILURE
GC41-0137-_1
Page 21
REMOTE MULTIPLEXING UNIT 0002C FAILS TO FUNCTION
H23-RMU-FC-ATWS2C
3.00E-04
LOSS OF 208/120 V AC FROM BUS R13-31-2
GR13-0001-_6
3
DIGITAL TRIP MODULE FAILS TO FUNCTION (ATWS)
C74-DTM-FC-DIV3ATWS
2
6.00E-04
ORIFICE INSTR. LINE 1C FAILS TO REMAIN OPEN (PLUG)
B21-OR_-PG-01C
2
1.44E-05
PRESSURE TRANSMITTER 0002C FAILS TO RESPOND TO CHANGE IN PRESSURE
B21-PT_-NO-ATWS2C
1.15E-05
1
2

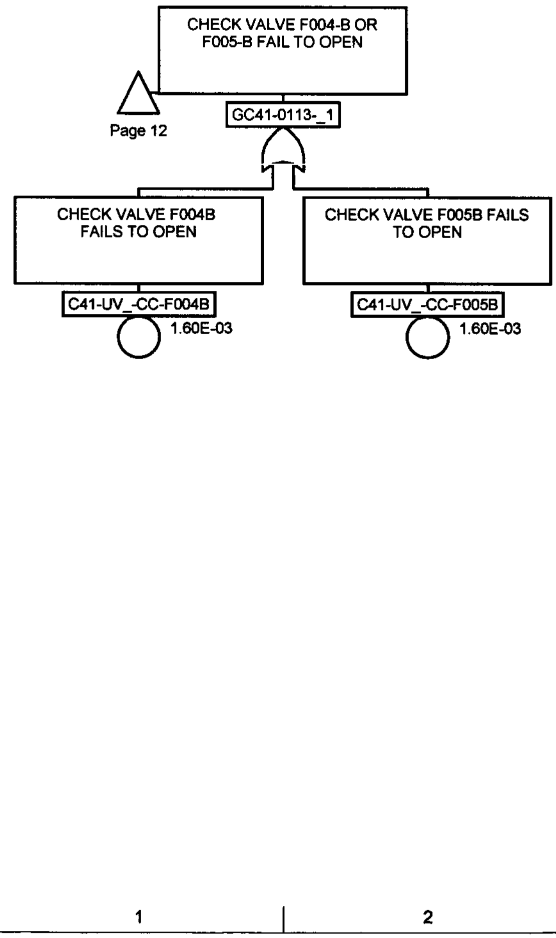

DIV IV RPV PRESSURE SIGNAL FAILURE
GC41-0138-_1
Page 21
REMOTE MULTIPLEXING UNIT 0002D FAILS TO FUNCTION
H23-RMU-FC-ATWS2D
3.00E-04
LOSS OF 208/120 V AC FROM BUS R13-41-2
GR13-0001-_8
3
DIGITAL TRIP MODULE FAILS TO FUNCTION
C74-DTM-FC-DIV4ATWS
2
6.00E-04
ORIFICE INSTR. LINE 1D FAILS TO REMAIN OPEN (PLUG)
B21-OR_-PG-01D
2
1.44E-05
PRESSURE TRANSMITTER 0002D FAILS TO RESPOND TO CHANGE IN PRESSURE
B21-PT_-NO-ATWS2D
1.15E-05
1
2

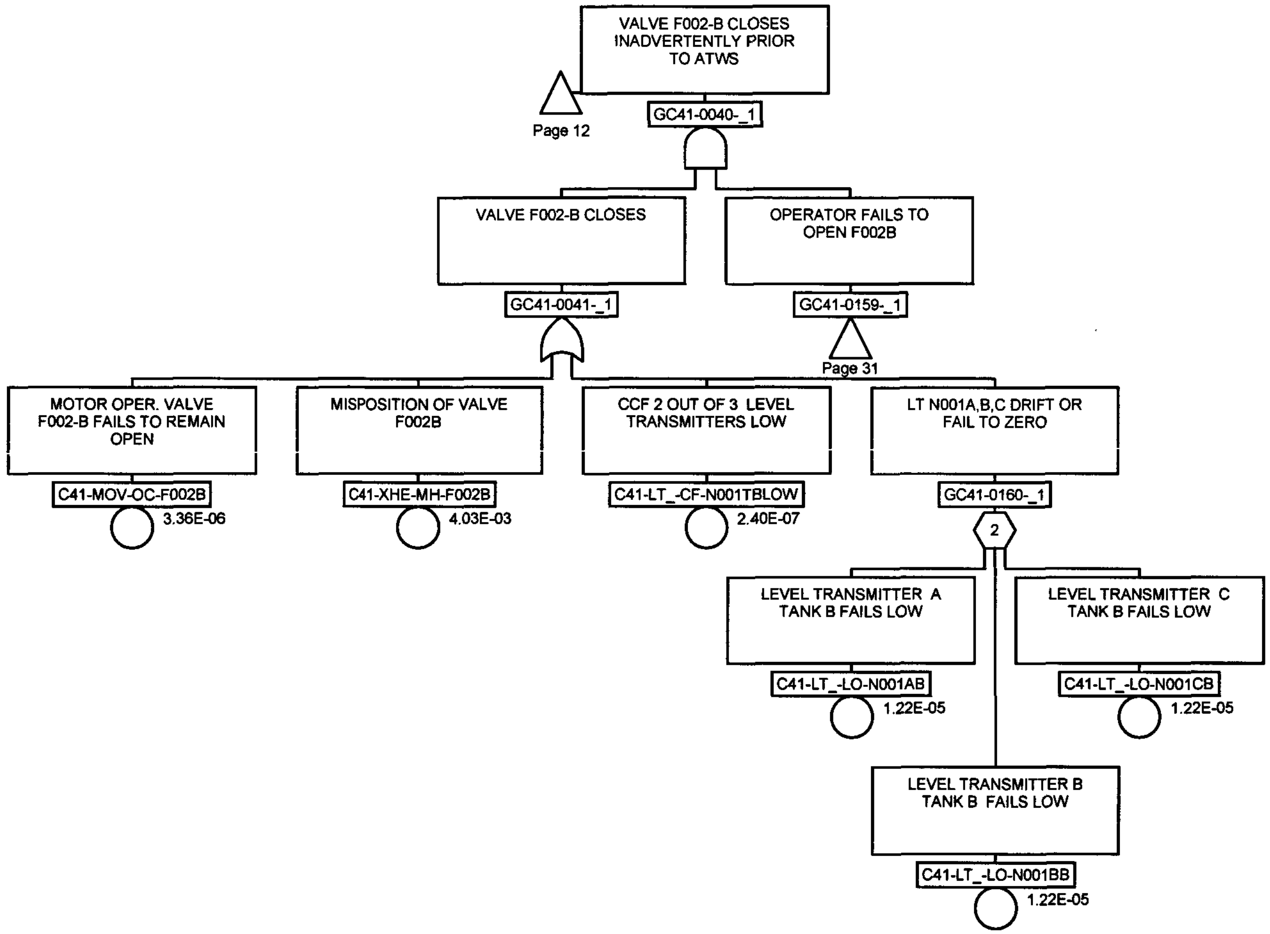

MANUAL ACTUATION FAILS
Page 6
GC41-0125-_1
LOSS OF MANUAL ACTUATION SIGNAL
GC41-0126-_1
HOUSE EVENT: OPERATOR IS NOT AVAILABLE (VALUE=1)
XHOSMAN
4
ALL THREE RMUs FROM C.R. FAIL
GC41-0127-_1
MANUAL ACTUATION FAILURE
C41-XHE-FO-INI
1.77E-02
RMU 001 FAILURE
GC41-0128-_1
RMU 002 FAILURE
GC41-0129-_1
RMU 003 FAILURE
GC41-0130-_1
Page 26
RMU 001 CRD SYSTEM C.R. MANUAL ACTUATION FAILS TO OPERATE
H23-RMU-FC-001C41
3.00E-04
LOSS OF 208/120 V AC FROM BUS R13-A1-1
GR13-0001-_19
RMU 002 CRD SYSTEM C.R. MANUAL ACTUATION FAILS TO OPERATE
H23-RMU-FC-002C41
3.00E-04
LOSS OF 208/120 V AC FROM BUS R13-B1-1
GR13-0001-_23
1
2
3
4

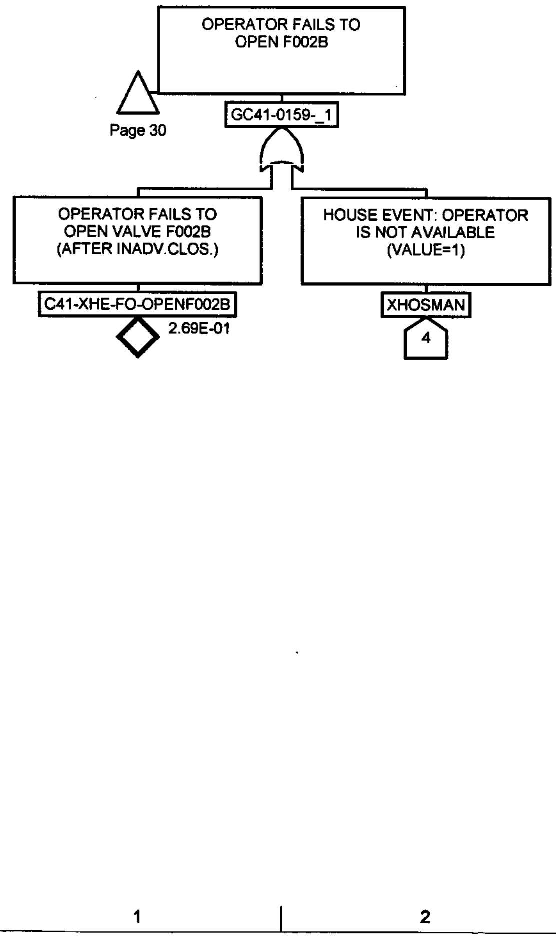

RMU 003 FAILURE
GC41-0130-_1
Page 25
RMU 003 CRD SYSTEM C.R. MANUAL ACTUATION FAILS TO OPERATE
H23-RMU-FC-003C41
3.00E-04
LOSS OF 208/120 V AC FROM BUS R13-C1-1
GR13-0001-_27

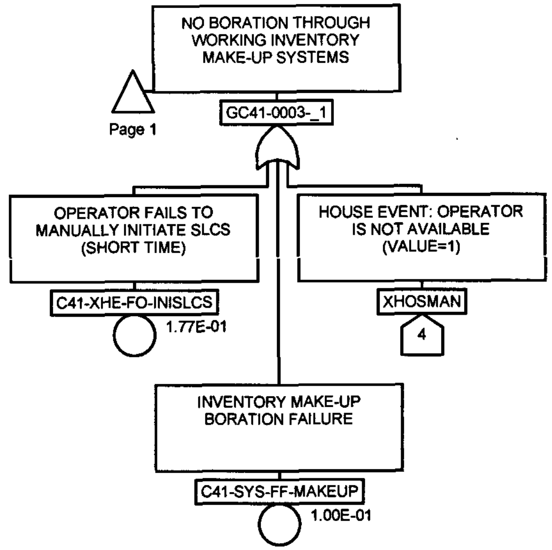

DIV III ATWS TRANSMISSION SIGNAL FAILS
GC41-0120-_1
Page 7
SRNM DIV 3 2/4 VLU FAILS
C51-VLU-FC-DIV3
6.24E-04
LOSS OF 208/120 V AC FROM BUS R13-31-1
GR13-0001-_5
ATWS DIV 3 VOTING LOGIC UNIT FAILS
C74-VLU-FC-ATWS3
6.24E-04
1
2


DIV IV ATWS TRANSMISSION SIGNAL FAILS
GC41-0121-_1
Page 7
SRNM DIV 4 2/4 VLU FAILS
C51-VLU-FC-DIV4
6.24E-04
LOSS OF 208/120 V AC FROM BUS R13-41-1
GR13-0001-_7
ATWS DIV 4 VOTING LOGIC UNIT FAILS
C74-VLU-FC-ATWS4
6.24E-04
1
2


CHECK VALVE F004-B OR F005-B FAIL TO OPEN
GC41-0113-_1
Page 12
CHECK VALVE F004B FAILS TO OPEN
C41-UV_-CC-F004B
1.60E-03
CHECK VALVE F005B FAILS TO OPEN
C41-UV_-CC-F005B
1.60E-03
1
2


VALVE F002-B CLOSES INADVERTENTLY PRIOR TO ATWS
GC41-0040-_1
Page 12
VALVE F002-B CLOSES
GC41-0041-_1
OPERATOR FAILS TO OPEN F002B
GC41-0159-_1
Page 31
MOTOR OPER. VALVE F002-B FAILS TO REMAIN OPEN
C41-MOV-OC-F002B
3.36E-06
MISPOSITION OF VALVE F002B
C41-XHE-MH-F002B
4.03E-03
CCF 2 OUT OF 3 LEVEL TRANSMITTERS LOW
C41-LT_-CF-N001TBLOW
2.40E-07
LT N001A,B,C DRIFT OR FAIL TO ZERO
GC41-0160-_1
2
LEVEL TRANSMITTER A TANK B FAILS LOW
C41-LT_-LO-N001AB
1.22E-05
LEVEL TRANSMITTER C TANK B FAILS LOW
C41-LT_-LO-N001CB
1.22E-05
LEVEL TRANSMITTER B TANK B FAILS LOW
C41-LT_-LO-N001BB
1.22E-05

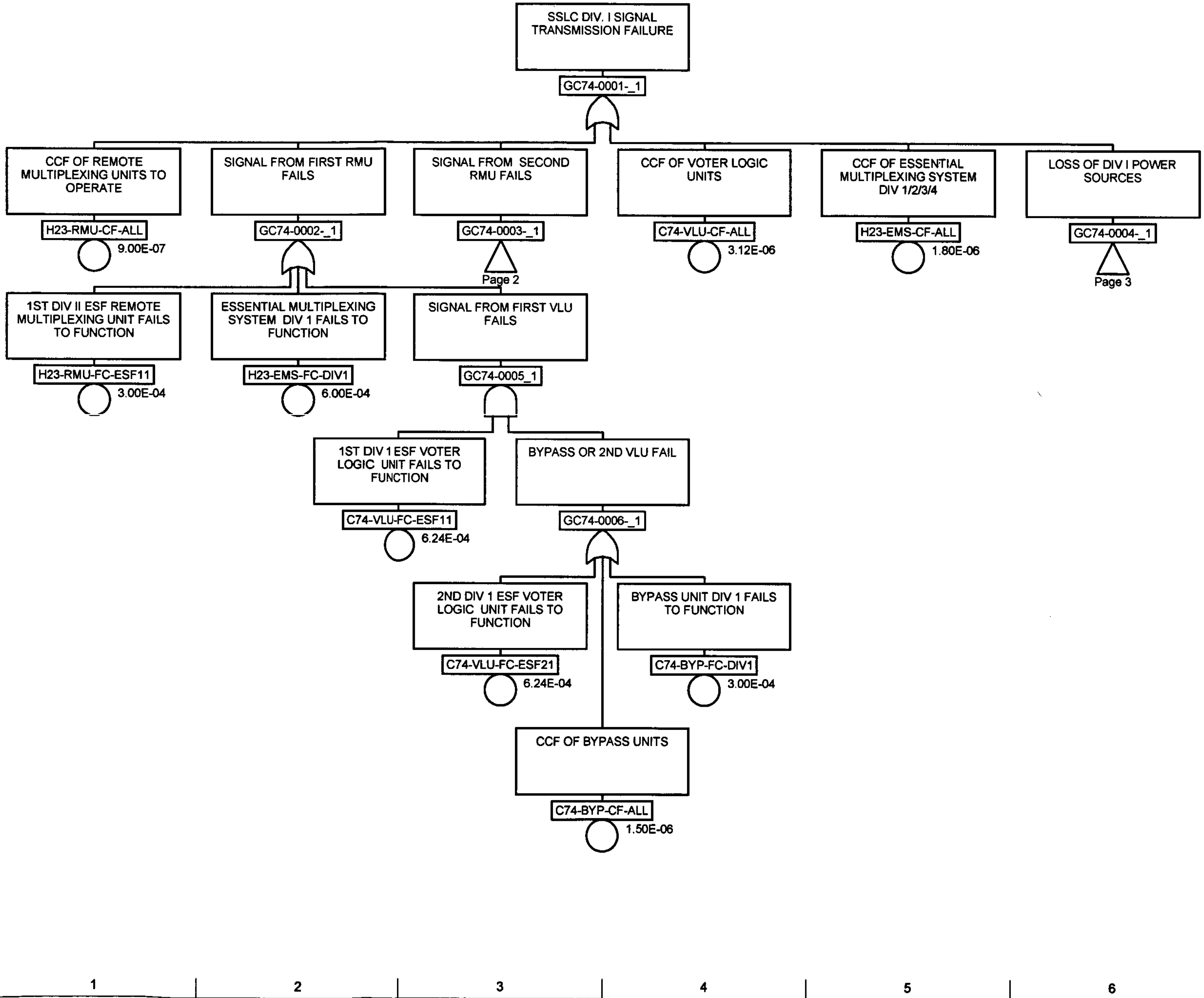

OPERATOR FAILS TO OPEN F002B
Page 30
GC41-0159-_1
OPERATOR FAILS TO OPEN VALVE F002B (AFTER INADV.CLOS.)
C41-XHE-FO-OPENF002B
2.69E-01
HOUSE EVENT: OPERATOR IS NOT AVAILABLE (VALUE=1)
XHOSMAN
4
1
2

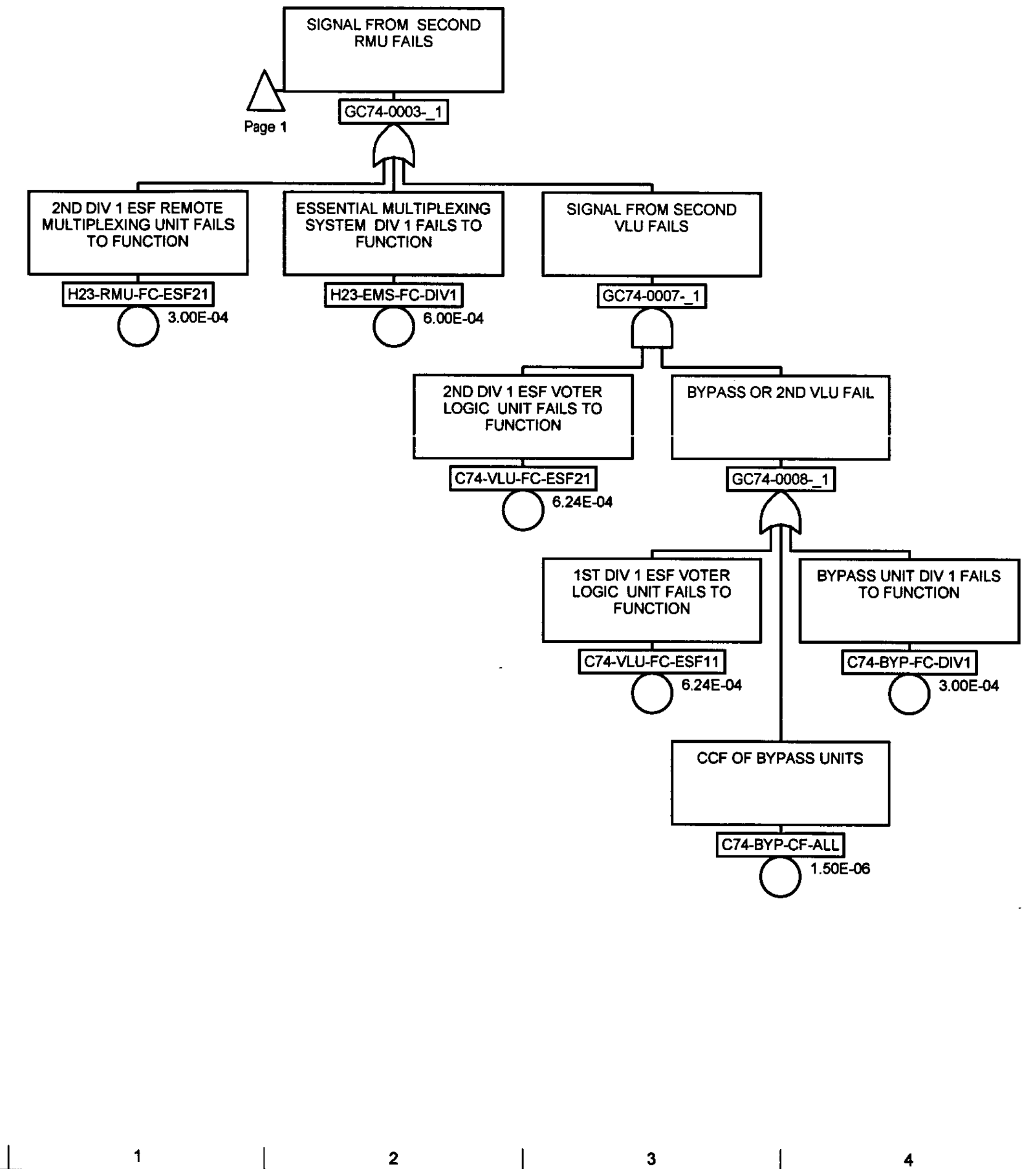

NO BORATION THROUGH WORKING INVENTORY MAKE-UP SYSTEMS
GC41-0003-_1
Page 1
OPERATOR FAILS TO MANUALLY INITIATE SLCS (SHORT TIME)
C41-XHE-FO-INISLCS
1.77E-01
HOUSE EVENT: OPERATOR IS NOT AVAILABLE (VALUE=1)
XHOSMAN
4
INVENTORY MAKE-UP BORATION FAILURE
C41-SYS-FF-MAKEUP
1.00E-01

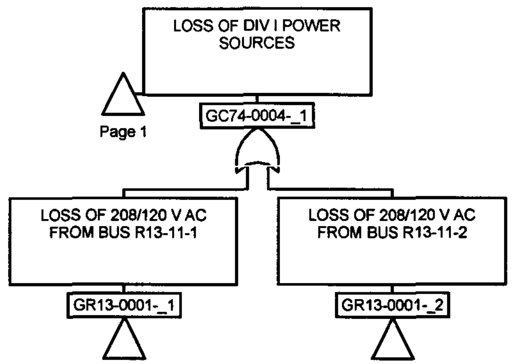
Name	Page	Zone	Name	Page	Zone
B21-LT -CF-ATWS	17	2	C51-ACT-LO-CHJSRNM	6	2
B21-LT -NO-ATWS1A	17	3	C51-ACT-NO-CHL	15	2
B21-LT -NO-ATWS1B	18	3	C51-VLU-CF-SRNM	3	2
B21-LT -NO-ATWS1C	19	3	C51-VLU-CF-SRNM	5	2
B21-LT -NO-ATWS1D	20	3	C51-VLU-FC-DIV1	7	1
B21-OR -PG-01A	17	2	C51-VLU-FC-DIV2	7	3
B21-OR -PG-01A	21	2	C51-VLU-FC-DIV3	27	1
B21-OR -PG-01B	18	2	C51-VLU-FC-DIV4	28	1
B21-OR -PG-01B	22	2	C74-DTM-CF-ATWSALL	17	1
B21-OR -PG-01C	19	2	C74-DTM-CF-ATWSALL	21	4
B21-OR -PG-01C	23	2	C74-DTM-FC-DIV1ATWS	17	1
B21-OR -PG-01D	20	2	C74-DTM-FC-DIV1ATWS	21	1
B21-OR -PG-01D	24	2	C74-DTM-FC-DIV2ATWS	18	1
B21-PT -CF-ATWS	21	5	C74-DTM-FC-DIV2ATWS	22	1
B21-PT -NO-ATWS2A	21	2	C74-DTM-FC-DIV3ATWS	19	1
B21-PT -NO-ATWS2B	22	2	C74-DTM-FC-DIV3ATWS	23	1
B21-PT -NO-ATWS2C	23	2	C74-DTM-FC-DIV4ATWS	20	1
B21-PT -NO-ATWS2D	24	2	C74-DTM-FC-DIV4ATWS	24	1
C41-LT -CF-N001TALOW	9	3	C74-VLU-CF-ATWS	3	1
C41-LT -CF-N001TBLOW	30	3	C74-VLU-CF-ATWS	5	1
C41-LT -LO-N001AA	9	4	C74-VLU-CF-SLCS	3	1
C41-LT -LO-N001AB	30	4	C74-VLU-CF-SLCS	5	1
C41-LT -LO-N001BA	9	4	C74-VLU-FC-ATWS1	7	2
C41-LT -LO-N001BB	30	4	C74-VLU-FC-ATWS2	7	4
C41-LT -LO-N001CA	9	5	C74-VLU-FC-ATWS3	27	2
C41-LT -LO-N001CB	30	5	C74-VLU-FC-ATWS4	28	2
C41-MOV-OC-F002A	9	1	C74-VLU-FC-SLCS1	3	2
C41-MOV-OC-F002B	30	1	C74-VLU-FC-SLCS2	5	2
C41-SQV-CC-F003A	1	1	GC41-0001- 1	1	5
C41-SQV-CC-F003B	12	1	GC41-0002- 1	1	5
C41-SQV-CC-F003C	1	3	GC41-0003- 1	1	6
C41-SQV-CC-F003D	13	1	GC41-0003- 1	32	2
C41-SQV-CF-F003AC	1	4	GC41-0004- 1	1	4
C41-SQV-CF-F003BD	12	4	GC41-0005- 1	1	5
C41-SYS-FF-MAKEUP	32	2	GC41-0005- 1	12	4
C41-UV -CC-F004A	11	1	GC41-0006- 1	1	3
C41-UV -CC-F004B	29	1	GC41-0010- 1	12	2
C41-UV -CC-F005A	11	2	GC41-0014- 1	1	2
C41-UV -CC-F005B	29	2	GC41-0015- 1	1	4
C41-XHE-FO-INI	25	4	GC41-0016- 1	12	2
C41-XHE-FO-INISLCS	32	1	GC41-0017- 1	12	3
C41-XHE-FO-OPENF002A	10	1	GC41-0017- 1	13	2
C41-XHE-FO-OPENF002B	31	1	GC41-0018- 1	1	2
C41-XHE-MH-F002A	9	2	GC41-0019- 1	1	2
C41-XHE-MH-F002B	30	2	GC41-0019- 1	2	2
C51-ACT-CF-SRNM	6	4	GC41-0020- 1	12	2
C51-ACT-LO-CHASRNM	6	1	GC41-0021- 1	1	4
C51-ACT-LO-CHBSRNM	14	2	GC41-0021- 1	8	3
C51-ACT-LO-CHCSRNM	15	1	GC41-0022- 1	8	2
C51-ACT-LO-CHDSRNM	16	2	GC41-0023- 1	13	2
C51-ACT-LO-CHESRNM	6	2	GC41-0024- 1	12	3
C51-ACT-LO-CHFSRNM	14	2	GC41-0025- 1	13	3
C51-ACT-LO-CHGSRNM	15	2	GC41-0038- 1	1	5
C51-ACT-LO-CHHSRNM	16	2	GC41-0038-_1	9	3

Name	Page	Zone	Name	Page	Zone
GC41-0039- 1	9	3	GC41-0142- 1	17	5
GC41-0040- 1	12	5	GC41-0142- 1	20	2
GC41-0040- 1	30	3	GC41-0144- 1	17	2
GC41-0041- 1	30	3	GC41-0145- 1	18	2
GC41-0046- 1	1	6	GC41-0146- 1	19	2
GC41-0046- 1	11	2	GC41-0147- 1	20	2
GC41-0048- 1	9	4	GC41-0148- 1	6	3
GC41-0113- 1	12	3	GC41-0149- 1	6	2
GC41-0113- 1	29	2	GC41-0150- 1	6	3
GC41-0115- 1	2	2	GC41-0150- 1	14	2
GC41-0115- 1	3	2	GC41-0151- 1	6	4
GC41-0115- 1	8	4	GC41-0151- 1	15	2
GC41-0115- 1	12	2	GC41-0152- 1	6	5
GC41-0115- 1	13	4	GC41-0152- 1	16	2
GC41-0116- 1	3	1	GC41-0153- 1	1	3
GC41-0116- 1	5	1	GC41-0153- 1	4	2
GC41-0116- 1	6	5	GC41-0154- 1	4	2
GC41-0117- 1	3	1	GC41-0154- 1	5	2
GC41-0117- 1	5	1	GC41-0154- 1	8	2
GC41-0117- 1	7	4	GC41-0154- 1	12	4
GC41-0118- 1	7	2	GC41-0154- 1	13	2
GC41-0119- 1	7	4	GC41-0155- 1	8	4
GC41-0120- 1	7	5	GC41-0156- 1	9	4
GC41-0120- 1	27	2	GC41-0156- 1	10	2
GC41-0121- 1	7	6	GC41-0157- 1	12	4
GC41-0121- 1	28	2	GC41-0158- 1	13	4
GC41-0122- 1	6	4	GC41-0159- 1	30	4
GC41-0123- 1	6	6	GC41-0159- 1	31	2
GC41-0124- 1	6	5	GC41-0160- 1	30	4
GC41-0124- 1	17	3	GC41-1132- 1	17	2
GC41-0125- 1	6	6	GR13-0001- 1	3	2
GC41-0125- 1	25	4	GR13-0001- 1	7	2
GC41-0126- 1	25	4	GR13-0001- 19	25	2
GC41-0127- 1	25	3	GR13-0001- 2	6	1
GC41-0128- 1	25	2	GR13-0001- 2	17	3
GC41-0129- 1	25	4	GR13-0001- 2	21	2
GC41-0130- 1	25	5	GR13-0001- 23	25	4
GC41-0130- 1	26	2	GR13-0001- 27	26	2
GC41-0132- 1	17	4	GR13-0001- 3	5	2
GC41-0133- 1	17	3	GR13-0001- 3	7	4
GC41-0133- 1	21	4	GR13-0001- 4	14	1
GC41-0134- 1	21	3	GR13-0001- 4	18	3
GC41-0135- 1	21	2	GR13-0001- 4	22	2
GC41-0136- 1	21	3	GR13-0001- 5	27	2
GC41-0136- 1	22	2	GR13-0001- 6	15	1
GC41-0137- 1	21	4	GR13-0001- 6	19	3
GC41-0137- 1	23	2	GR13-0001- 6	23	2
GC41-0138- 1	21	5	GR13-0001- 7	28	2
GC41-0138- 1	24	2	GR13-0001- 8	16	1
GC41-0139- 1	17	2	GR13-0001- 8	20	3
GC41-0140- 1	17	3	GR13-0001- 8	24	2
GC41-0140- 1	18	2	GR42-0001- 1	2	1
GC41-0141- 1	17	4	GR42-0001- 1	12	1
GC41-0141-_1	19	2	GR42-0001-_3	8	3

Appendix B.4.5-1
Instrument Logic & Control System
Fault Tree

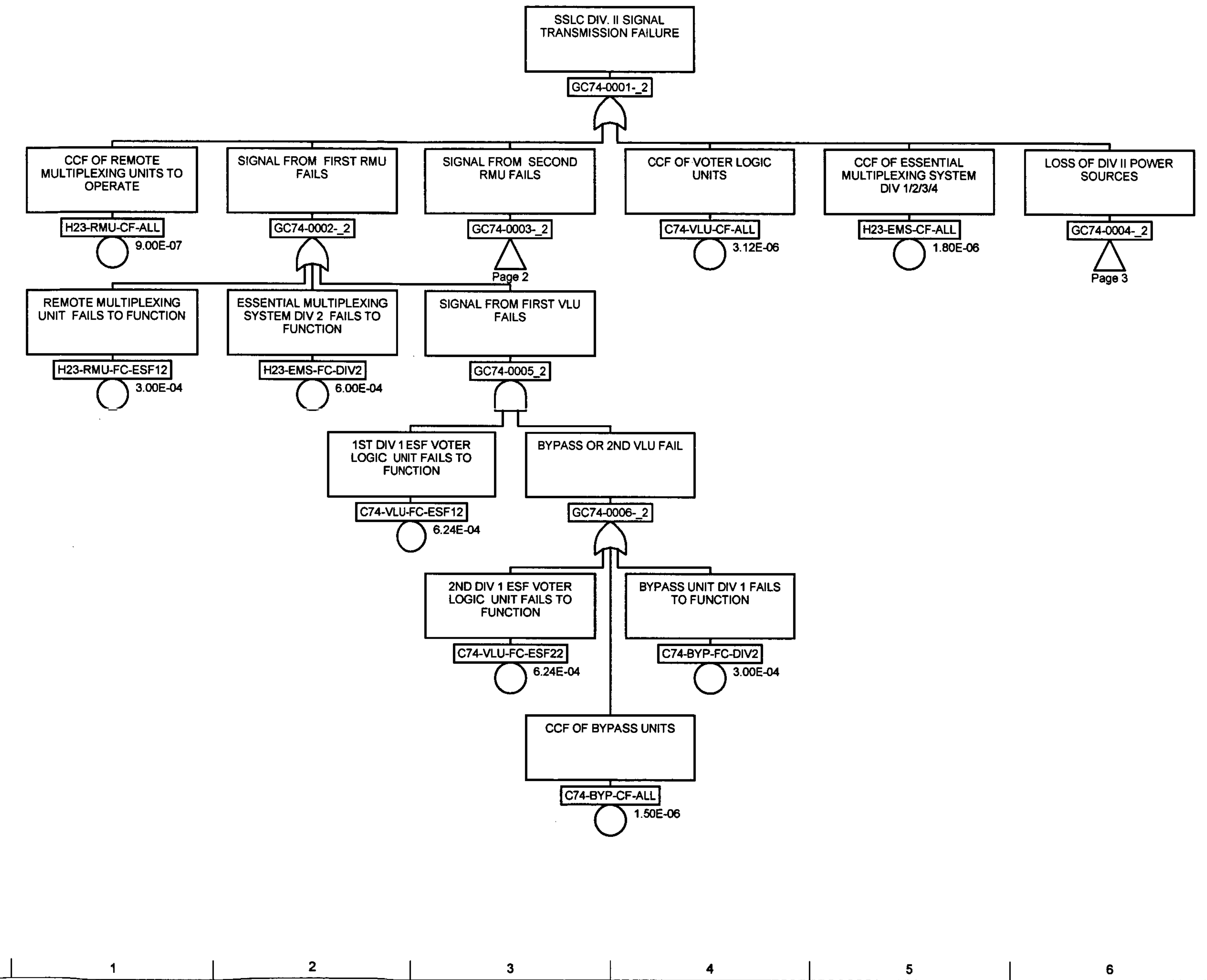

SSLC DIV. I SIGNAL TRANSMISSION FAILURE
GC74-0001-_1
CCF OF REMOTE MULTIPLEXING UNITS TO OPERATE
H23-RMU-CF-ALL
9.00E-07
SIGNAL FROM FIRST RMU FAILS
GC74-0002-_1
SIGNAL FROM SECOND RMU FAILS
GC74-0003-_1
Page 2
CCF OF VOTER LOGIC UNITS
C74-VLU-CF-ALL
3.12E-06
CCF OF ESSENTIAL MULTIPLEXING SYSTEM DIV 1/2/3/4
H23-EMS-CF-ALL
1.80E-06
LOSS OF DIV I POWER SOURCES
GC74-0004-_1
Page 3
1ST DIV II ESF REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION
H23-RMU-FC-ESF11
3.00E-04
ESSENTIAL MULTIPLEXING SYSTEM DIV 1 FAILS TO FUNCTION
H23-EMS-FC-DIV1
6.00E-04
SIGNAL FROM FIRST VLU FAILS
GC74-0005_1
1ST DIV 1 ESF VOTER LOGIC UNIT FAILS TO FUNCTION
C74-VLU-FC-ESF11
6.24E-04
BYPASS OR 2ND VLU FAIL
GC74-0006-_1
2ND DIV 1 ESF VOTER LOGIC UNIT FAILS TO FUNCTION
C74-VLU-FC-ESF21
6.24E-04
BYPASS UNIT DIV 1 FAILS TO FUNCTION
C74-BYP-FC-DIV1
3.00E-04
CCF OF BYPASS UNITS
C74-BYP-CF-ALL
1.50E-06
1
2
3
4
5
6


SIGNAL FROM SECOND RMU FAILS
GC74-0003-_1
Page 1
2ND DIV 1 ESF REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION
H23-RMU-FC-ESF21
3.00E-04
ESSENTIAL MULTIPLEXING SYSTEM DIV 1 FAILS TO FUNCTION
H23-EMS-FC-DIV1
6.00E-04
SIGNAL FROM SECOND VLU FAILS
GC74-0007-_1
2ND DIV 1 ESF VOTER LOGIC UNIT FAILS TO FUNCTION
C74-VLU-FC-ESF21
6.24E-04
BYPASS OR 2ND VLU FAIL
GC74-0008-_1
1ST DIV 1 ESF VOTER LOGIC UNIT FAILS TO FUNCTION
C74-VLU-FC-ESF11
6.24E-04
BYPASS UNIT DIV 1 FAILS TO FUNCTION
C74-BYP-FC-DIV1
3.00E-04
CCF OF BYPASS UNITS
C74-BYP-CF-ALL
1.50E-06
1
2
3
4

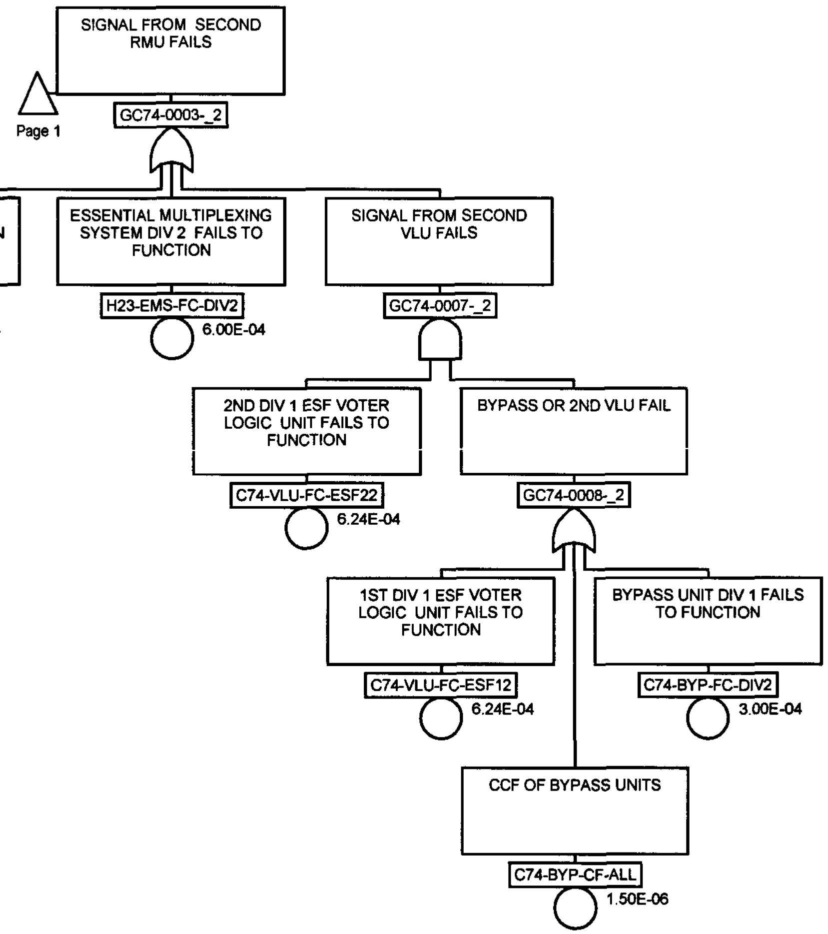

LOSS OF DIV I POWER SOURCES
GC74-0004-_1
Page 1
LOSS OF 208/120 V AC FROM BUS R13-11-1
GR13-0001-_1
LOSS OF 208/120 V AC FROM BUS R13-11-2
GR13-0001-_2

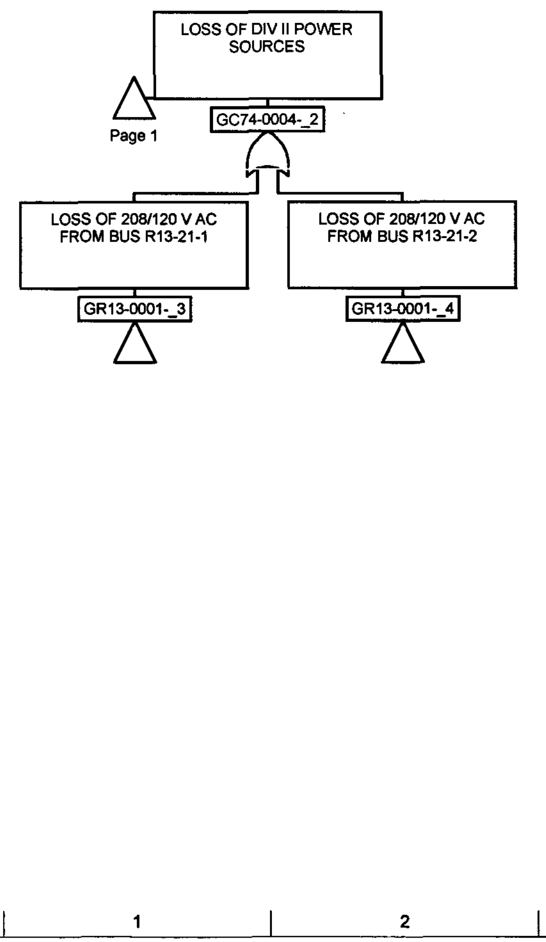
Appendix B.4.5-2

I&C Systems - C74 SSLC - DIV II SIGNAL TRANSMISSION FAILURE



SSLC DIV. II SIGNAL TRANSMISSION FAILURE
GC74-0001-_2
CCF OF REMOTE MULTIPLEXING UNITS TO OPERATE
H23-RMU-CF-ALL
9.00E-07
SIGNAL FROM FIRST RMU FAILS
GC74-0002-_2
SIGNAL FROM SECOND RMU FAILS
GC74-0003-_2
Page 2
CCF OF VOTER LOGIC UNITS
C74-VLU-CF-ALL
3.12E-06
CCF OF ESSENTIAL MULTIPLEXING SYSTEM DIV 1/2/3/4
H23-EMS-CF-ALL
1.80E-06
LOSS OF DIV II POWER SOURCES
GC74-0004-_2
Page 3
REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION
H23-RMU-FC-ESF12
3.00E-04
ESSENTIAL MULTIPLEXING SYSTEM DIV 2 FAILS TO FUNCTION
H23-EMS-FC-DIV2
6.00E-04
SIGNAL FROM FIRST VLU FAILS
GC74-0005_2
1ST DIV 1 ESF VOTER LOGIC UNIT FAILS TO FUNCTION
C74-VLU-FC-ESF12
6.24E-04
BYPASS OR 2ND VLU FAIL
GC74-0006-_2
2ND DIV 1 ESF VOTER LOGIC UNIT FAILS TO FUNCTION
C74-VLU-FC-ESF22
6.24E-04
BYPASS UNIT DIV 1 FAILS TO FUNCTION
C74-BYP-FC-DIV2
3.00E-04
CCF OF BYPASS UNITS
C74-BYP-CF-ALL
1.50E-06
1
2
3
4
5
6

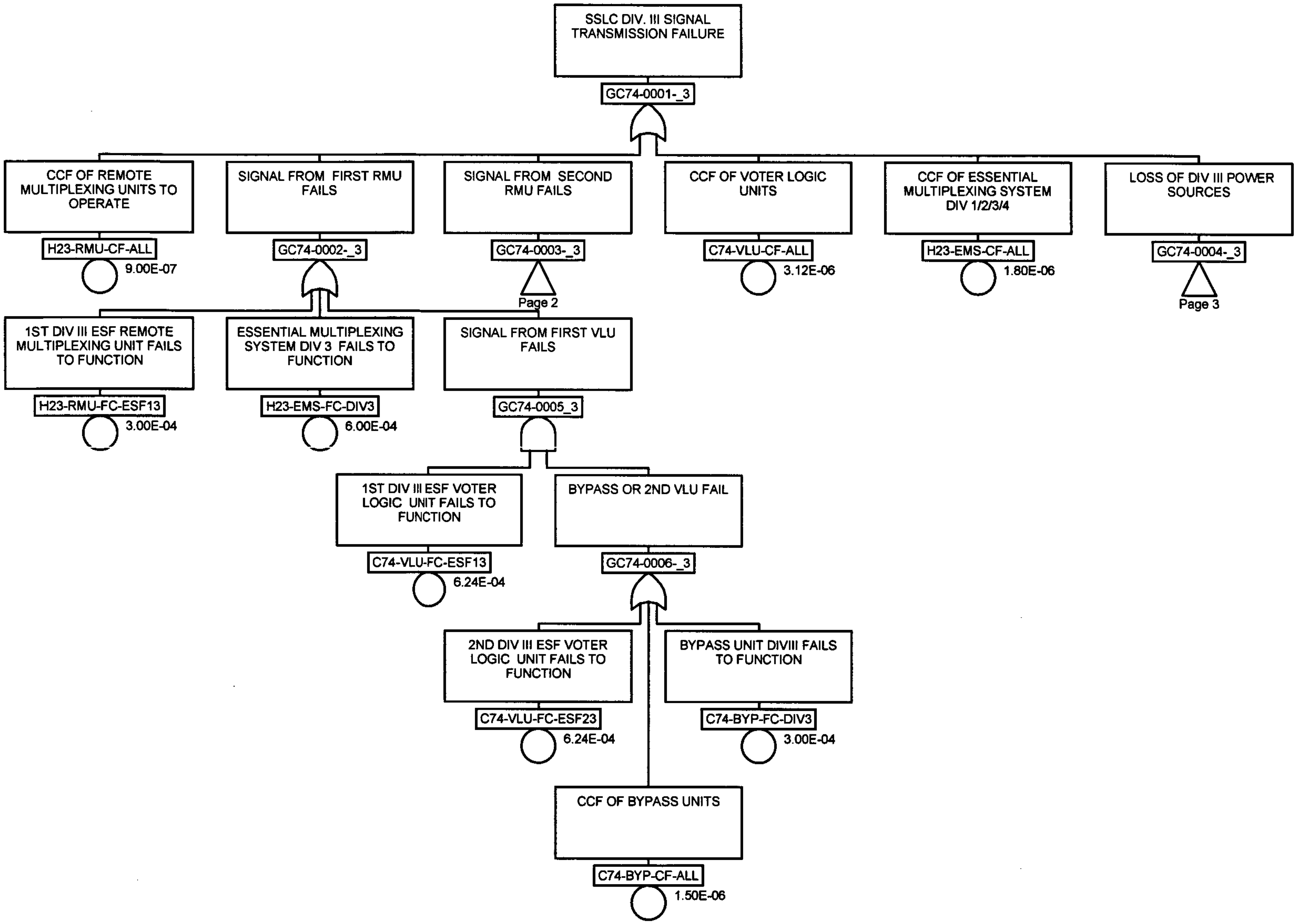

SIGNAL FROM SECOND RMU FAILS
GC74-0003-_2
Page 1
REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION
H23-RMU-FC-ESF22
3.00E-04
ESSENTIAL MULTIPLEXING SYSTEM DIV 2 FAILS TO FUNCTION
H23-EMS-FC-DIV2
6.00E-04
SIGNAL FROM SECOND VLU FAILS
GC74-0007-_2
2ND DIV 1 ESF VOTER LOGIC UNIT FAILS TO FUNCTION
C74-VLU-FC-ESF22
6.24E-04
BYPASS OR 2ND VLU FAIL
GC74-0008-_2
1ST DIV 1 ESF VOTER LOGIC UNIT FAILS TO FUNCTION
C74-VLU-FC-ESF12
6.24E-04
BYPASS UNIT DIV 1 FAILS TO FUNCTION
C74-BYP-FC-DIV2
3.00E-04
CCF OF BYPASS UNITS
C74-BYP-CF-ALL
1.50E-06

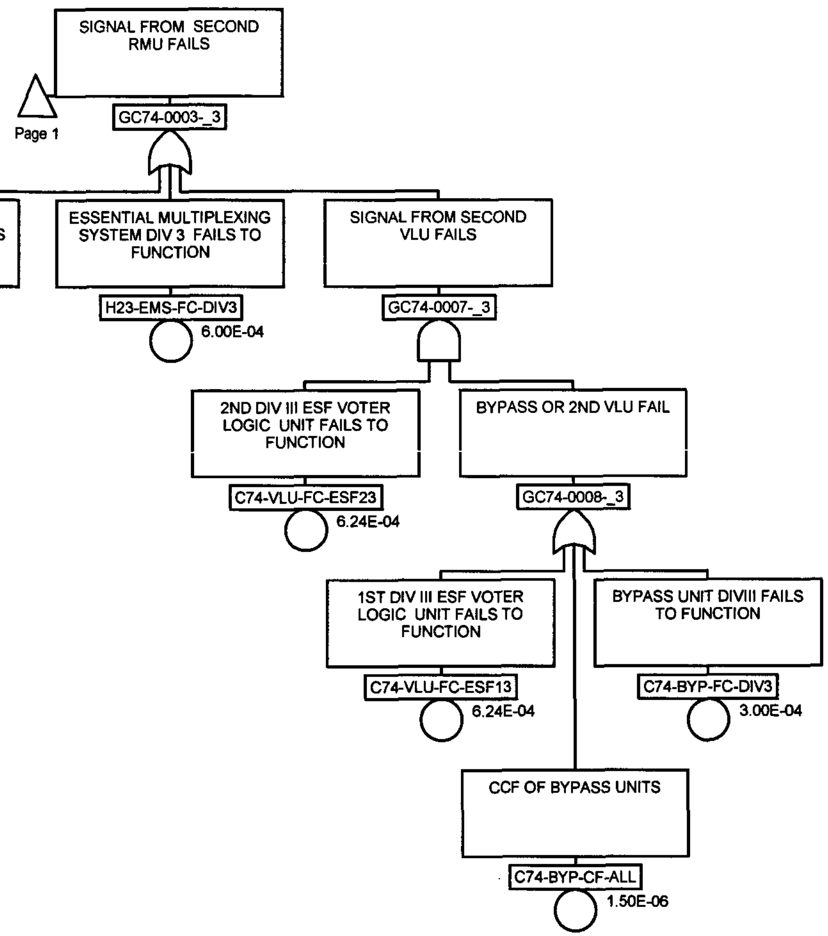

LOSS OF DIV II POWER SOURCES
Page 1
GC74-0004-_2
LOSS OF 208/120 V AC FROM BUS R13-21-1
GR13-0001-_3
LOSS OF 208/120 V AC FROM BUS R13-21-2
GR13-0001-_4
1
2

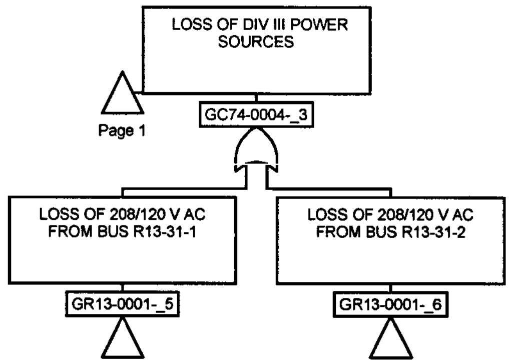
Name	Page	Zone	Name	Page	Zone	Name	Page	Zone
C74-BYP-CF-ALL	1	4						
C74-BYP-CF-ALL	2	4						
C74-BYP-FC-DIV2	1	4						
C74-BYP-FC-DIV2	2	4						
C74-VLU-CF-ALL	1	4						
C74-VLU-FC-ESF12	1	3						
C74-VLU-FC-ESF12	2	3						
C74-VLU-FC-ESF22	1	3						
C74-VLU-FC-ESF22	2	3						
GC74-0001- 2	1	4						
GC74-0002- 2	1	2						
GC74-0003- 2	1	3						
GC74-0003- 2	2	2						
GC74-0004- 2	1	6						
GC74-0004- 2	3	2						
GC74-0005 2	1	3						
GC74-0006- 2	1	4						
GC74-0007- 2	2	3						
GC74-0008- 2	2	4						
GR13-0001- 3	3	1						
GR13-0001- 4	3	2						
H23-EMS-CF-ALL	1	5						
H23-EMS-FC-DIV2	1	2						
H23-EMS-FC-DIV2	2	2						
H23-RMU-CF-ALL	1	1						
H23-RMU-FC-ESF12	1	1						
H23-RMU-FC-ESF22	2	1						

Appendix B.4.5-3

I&C Systems - C74 SSLC - DIV III SIGNAL TRANSMISSION FAILURE


SSLC DIV. III SIGNAL TRANSMISSION FAILURE
GC74-0001-_3
CCF OF REMOTE MULTIPLEXING UNITS TO OPERATE
H23-RMU-CF-ALL
9.00E-07
SIGNAL FROM FIRST RMU FAILS
GC74-0002-_3
SIGNAL FROM SECOND RMU FAILS
GC74-0003-_3
Page 2
CCF OF VOTER LOGIC UNITS
C74-VLU-CF-ALL
3.12E-06
CCF OF ESSENTIAL MULTIPLEXING SYSTEM DIV 1/2/3/4
H23-EMS-CF-ALL
1.80E-06
LOSS OF DIV III POWER SOURCES
GC74-0004-_3
Page 3
1ST DIV III ESF REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION
H23-RMU-FC-ESF13
3.00E-04
ESSENTIAL MULTIPLEXING SYSTEM DIV 3 FAILS TO FUNCTION
H23-EMS-FC-DIV3
6.00E-04
SIGNAL FROM FIRST VLU FAILS
GC74-0005_3
1ST DIV III ESF VOTER LOGIC UNIT FAILS TO FUNCTION
C74-VLU-FC-ESF13
6.24E-04
BYPASS OR 2ND VLU FAIL
GC74-0006-_3
2ND DIV III ESF VOTER LOGIC UNIT FAILS TO FUNCTION
C74-VLU-FC-ESF23
6.24E-04
BYPASS UNIT DIVIII FAILS TO FUNCTION
C74-BYP-FC-DIV3
3.00E-04
CCF OF BYPASS UNITS
C74-BYP-CF-ALL
1.50E-06

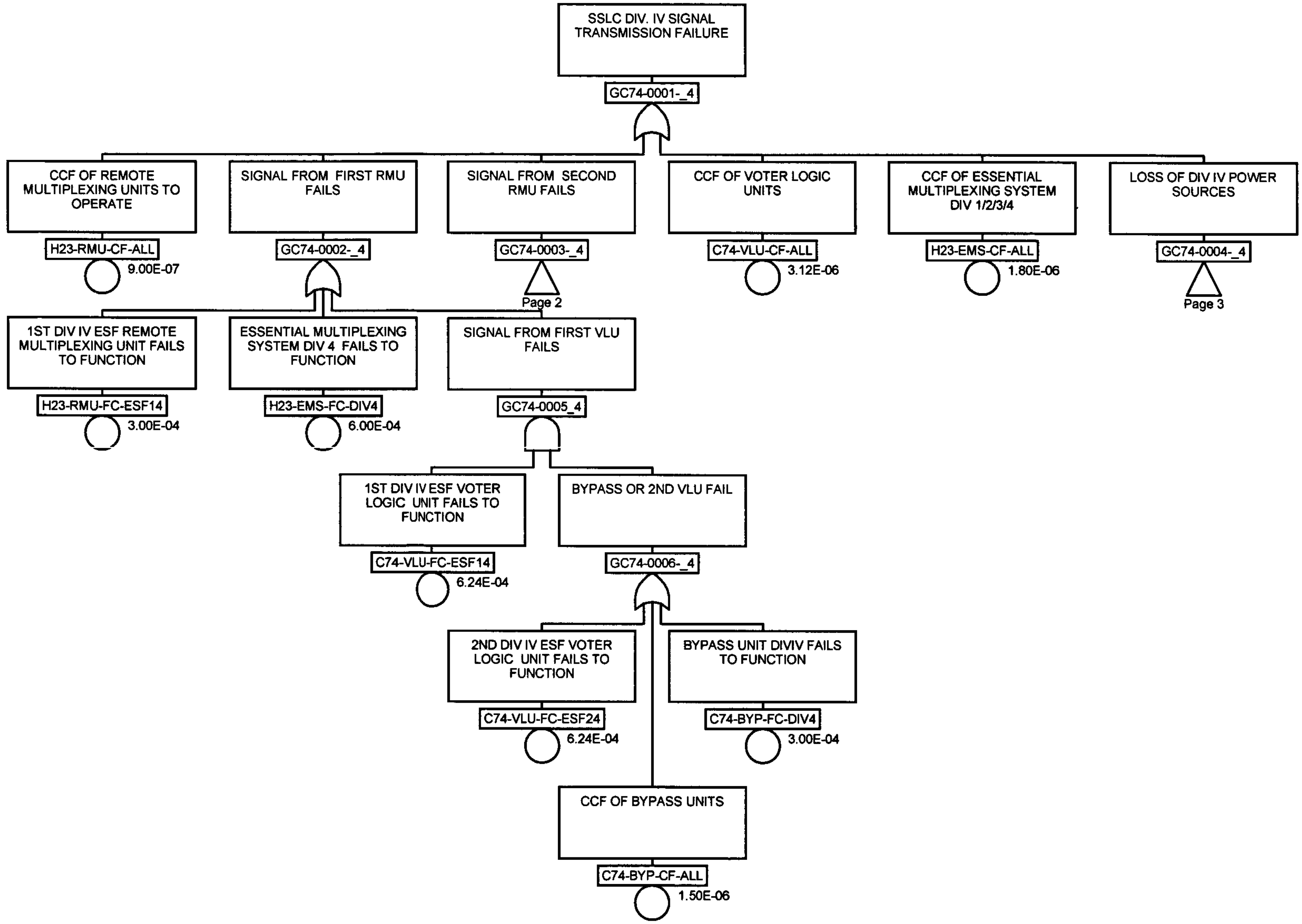

SIGNAL FROM SECOND RMU FAILS
Page 1
GC74-0003-_3
2ND DIVIII ESF REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION
H23-RMU-FC-ESF23
3.00E-04
ESSENTIAL MULTIPLEXING SYSTEM DIV 3 FAILS TO FUNCTION
H23-EMS-FC-DIV3
6.00E-04
SIGNAL FROM SECOND VLU FAILS
GC74-0007-_3
2ND DIV III ESF VOTER LOGIC UNIT FAILS TO FUNCTION
C74-VLU-FC-ESF23
6.24E-04
BYPASS OR 2ND VLU FAIL
GC74-0008-_3
1ST DIV III ESF VOTER LOGIC UNIT FAILS TO FUNCTION
C74-VLU-FC-ESF13
6.24E-04
BYPASS UNIT DIVIII FAILS TO FUNCTION
C74-BYP-FC-DIV3
3.00E-04
CCF OF BYPASS UNITS
C74-BYP-CF-ALL
1.50E-06


LOSS OF DIV III POWER SOURCES
Page 1
GC74-0004-_3
LOSS OF 208/120 V AC FROM BUS R13-31-1
GR13-0001-_5
LOSS OF 208/120 V AC FROM BUS R13-31-2
GR13-0001-_6

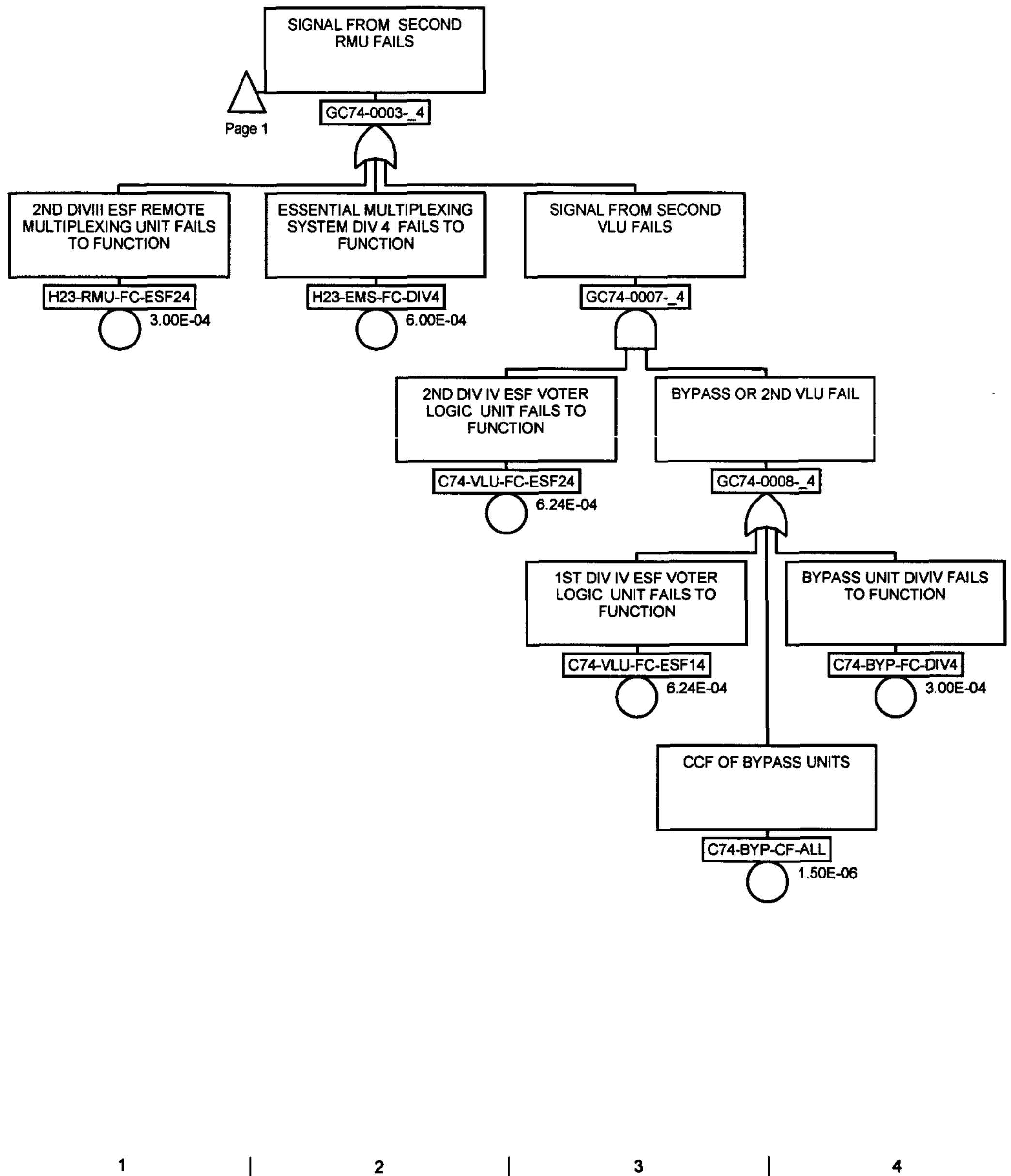
Name	Page	Zone	Name	Page	Zone	Name	Page	Zone
C74-BYP-CF-ALL	1	4						
C74-BYP-CF-ALL	2	4						
C74-BYP-FC-DIV3	1	4						
C74-BYP-FC-DIV3	2	4						
C74-VLU-CF-ALL	1	4						
C74-VLU-FC-ESF13	1	3						
C74-VLU-FC-ESF13	2	3						
C74-VLU-FC-ESF23	1	3						
C74-VLU-FC-ESF23	2	3						
GC74-0001- 3	1	4						
GC74-0002- 3	1	2						
GC74-0003- 3	1	3						
GC74-0003- 3	2	2						
GC74-0004- 3	1	6						
GC74-0004- 3	3	2						
GC74-0005 3	1	3						
GC74-0006- 3	1	4						
GC74-0007- 3	2	3						
GC74-0008- 3	2	4						
GR13-0001- 5	3	1						
GR13-0001- 6	3	2						
H23-EMS-CF-ALL	1	5						
H23-EMS-FC-DIV3	1	2						
H23-EMS-FC-DIV3	2	2						
H23-RMU-CF-ALL	1	1						
H23-RMU-FC-ESF13	1	1						
H23-RMU-FC-ESF23	2	1						

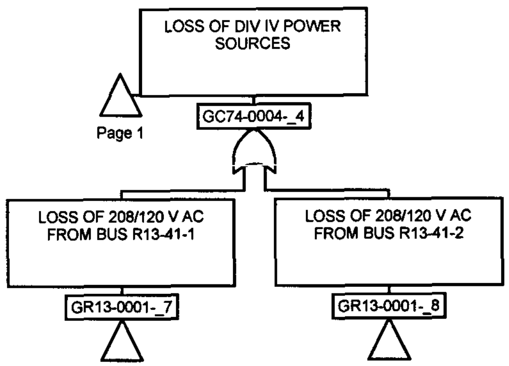
Appendix B.4.5-4

I&C Systems - C74 SSLC - DIV IV SIGNAL TRANSMISSION FAILURE


SSLC DIV. IV SIGNAL TRANSMISSION FAILURE
GC74-0001-_4
CCF OF REMOTE MULTIPLEXING UNITS TO OPERATE
H23-RMU-CF-ALL
9.00E-07
SIGNAL FROM FIRST RMU FAILS
GC74-0002-_4
SIGNAL FROM SECOND RMU FAILS
GC74-0003-_4
Page 2
CCF OF VOTER LOGIC UNITS
C74-VLU-CF-ALL
3.12E-06
CCF OF ESSENTIAL MULTIPLEXING SYSTEM DIV 1/2/3/4
H23-EMS-CF-ALL
1.80E-06
LOSS OF DIV IV POWER SOURCES
GC74-0004-_4
Page 3
1ST DIV IV ESF REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION
H23-RMU-FC-ESF14
3.00E-04
ESSENTIAL MULTIPLEXING SYSTEM DIV 4 FAILS TO FUNCTION
H23-EMS-FC-DIV4
6.00E-04
SIGNAL FROM FIRST VLU FAILS
GC74-0005_4
1ST DIV IV ESF VOTER LOGIC UNIT FAILS TO FUNCTION
C74-VLU-FC-ESF14
6.24E-04
BYPASS OR 2ND VLU FAIL
GC74-0006-_4
2ND DIV IV ESF VOTER LOGIC UNIT FAILS TO FUNCTION
C74-VLU-FC-ESF24
6.24E-04
BYPASS UNIT DIVIV FAILS TO FUNCTION
C74-BYP-FC-DIV4
3.00E-04
CCF OF BYPASS UNITS
C74-BYP-CF-ALL
1.50E-06

1 2 3 4 5 6

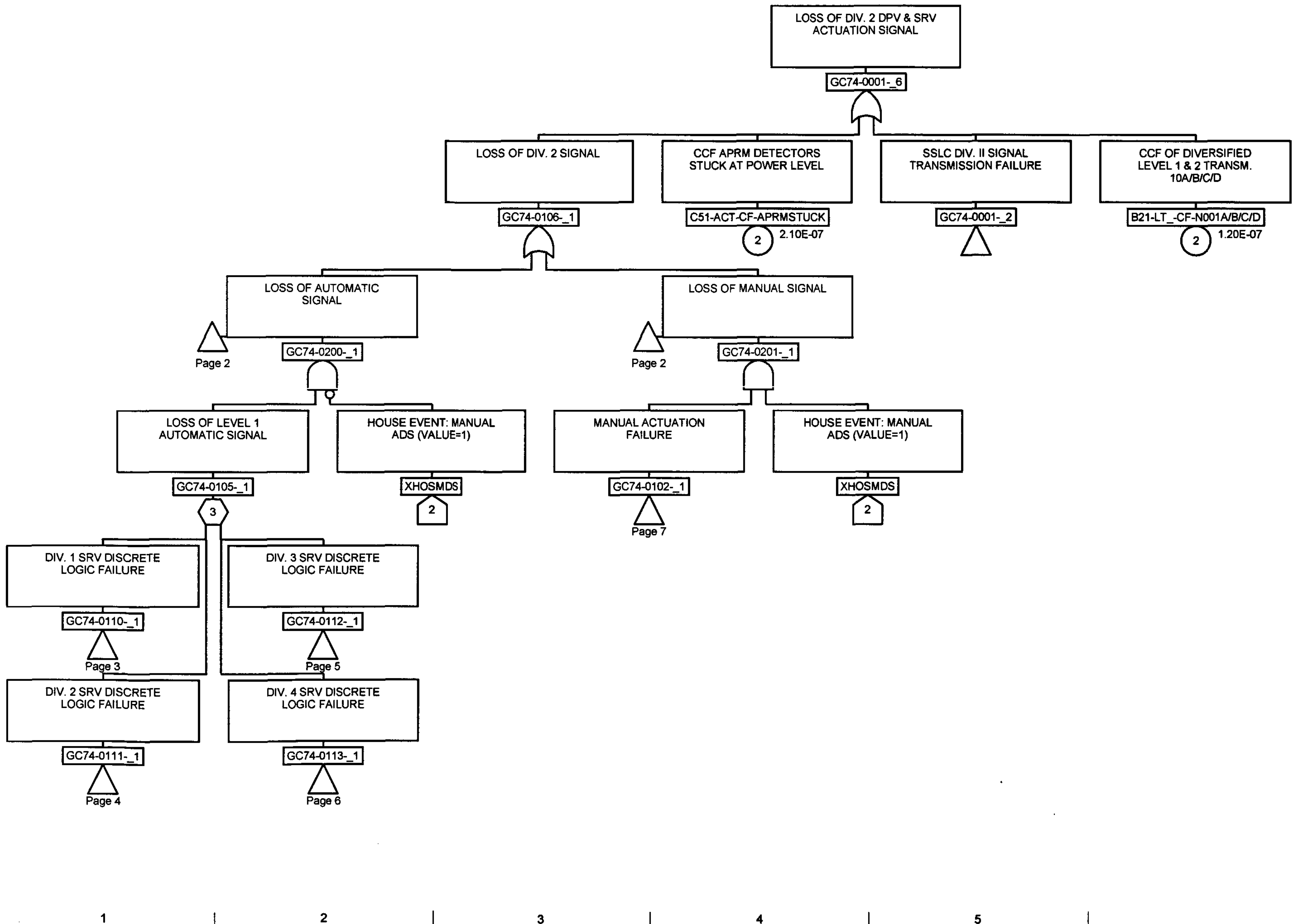

SIGNAL FROM SECOND RMU FAILS
GC74-0003-_4
Page 1
2ND DIVIII ESF REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION
H23-RMU-FC-ESF24
3.00E-04
ESSENTIAL MULTIPLEXING SYSTEM DIV 4 FAILS TO FUNCTION
H23-EMS-FC-DIV4
6.00E-04
SIGNAL FROM SECOND VLU FAILS
GC74-0007-_4
2ND DIV IV ESF VOTER LOGIC UNIT FAILS TO FUNCTION
C74-VLU-FC-ESF24
6.24E-04
BYPASS OR 2ND VLU FAIL
GC74-0008-_4
1ST DIV IV ESF VOTER LOGIC UNIT FAILS TO FUNCTION
C74-VLU-FC-ESF14
6.24E-04
BYPASS UNIT DIVIV FAILS TO FUNCTION
C74-BYP-FC-DIV4
3.00E-04
CCF OF BYPASS UNITS
C74-BYP-CF-ALL
1.50E-06
1
2
3
4

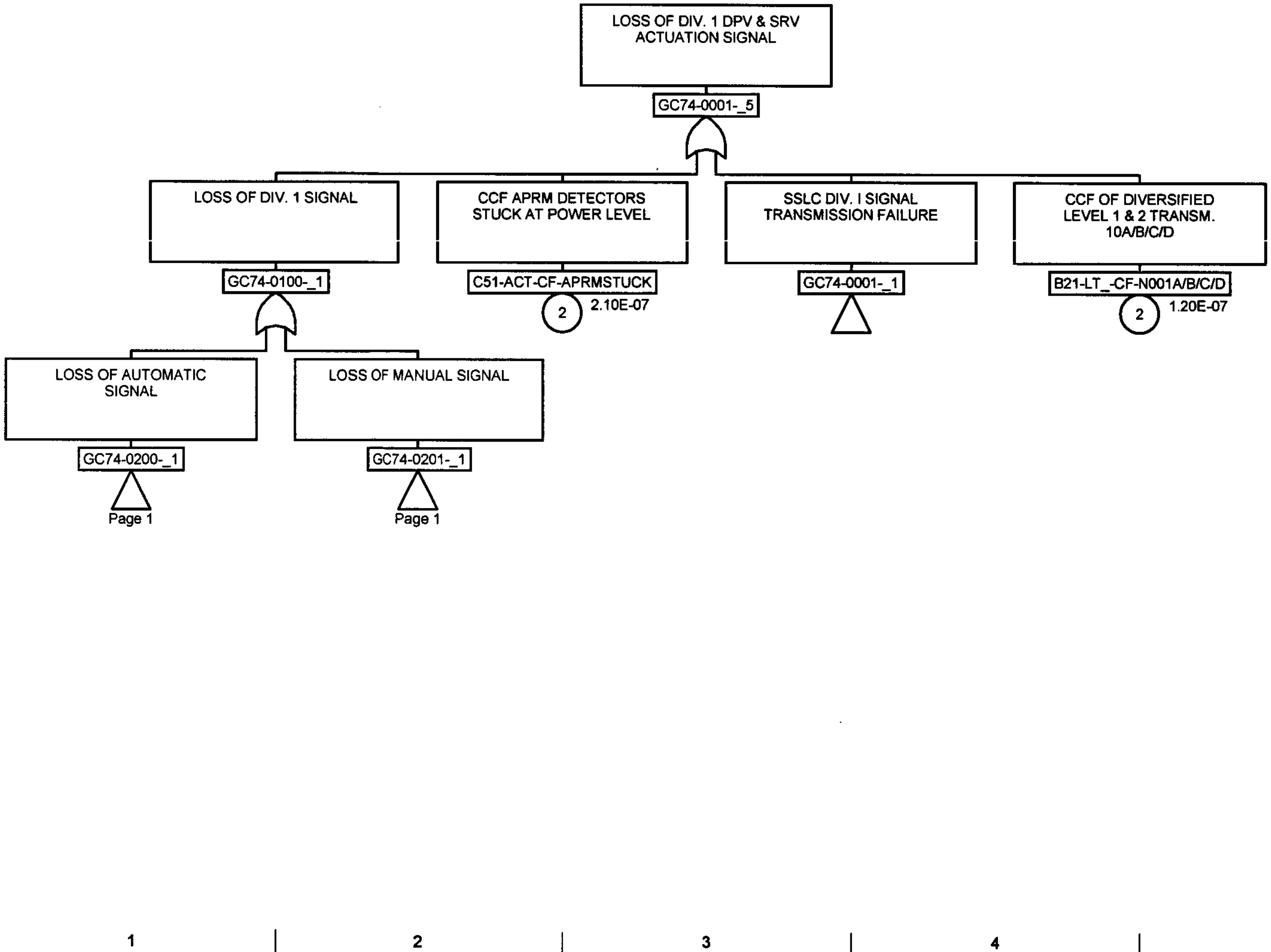

LOSS OF DIV IV POWER SOURCES
Page 1
GC74-0004-_4
LOSS OF 208/120 V AC FROM BUS R13-41-1
LOSS OF 208/120 V AC FROM BUS R13-41-2
GR13-0001-_7
GR13-0001-_8

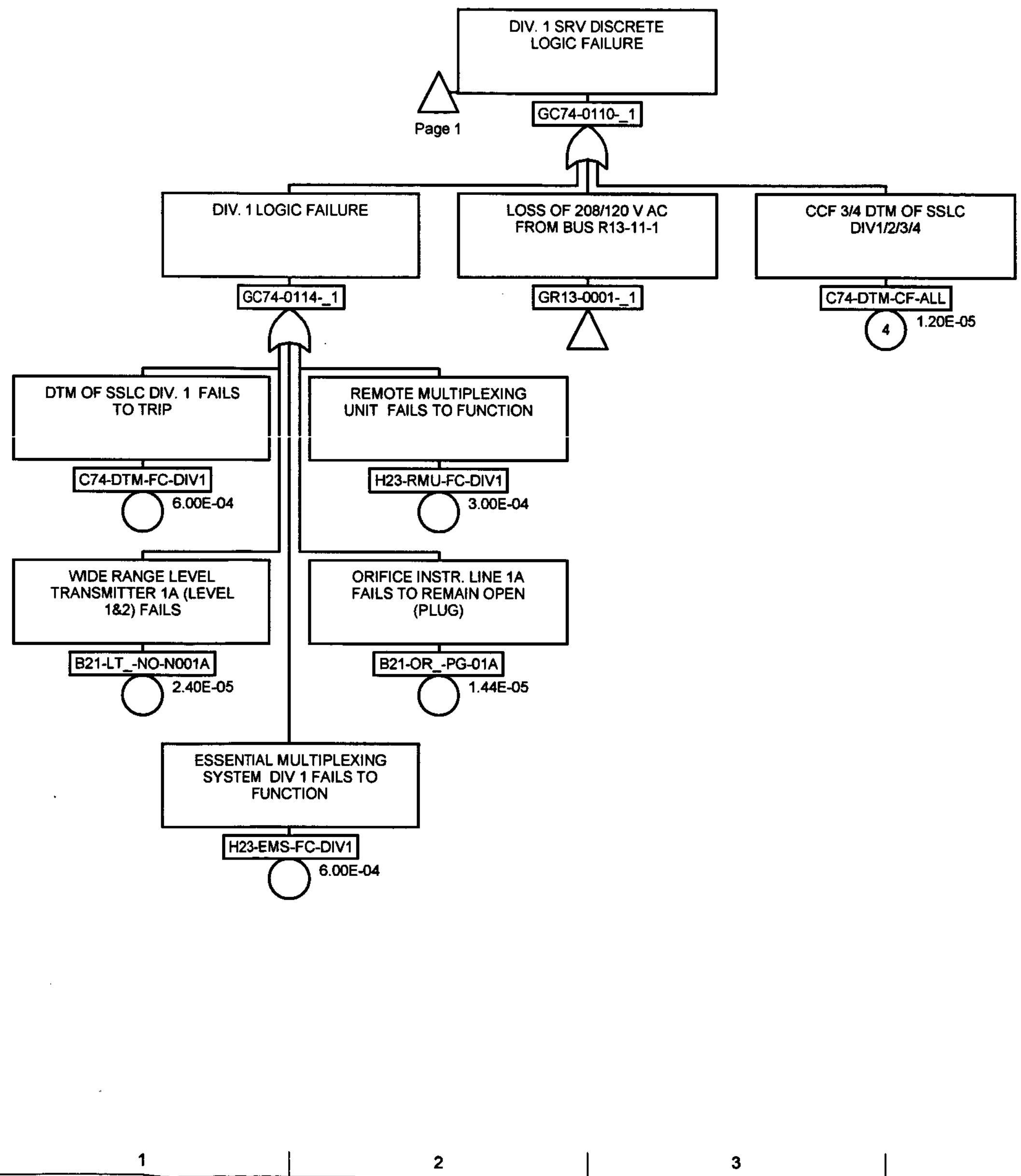
Name	Page	Zone	Name	Page	Zone	Name	Page	Zone
C74-BYP-CF-ALL	1	4						
C74-BYP-CF-ALL	2	4						
C74-BYP-FC-DIV4	1	4						
C74-BYP-FC-DIV4	2	4						
C74-VLU-CF-ALL	1	4						
C74-VLU-FC-ESF14	1	3						
C74-VLU-FC-ESF14	2	3						
C74-VLU-FC-ESF24	1	3						
C74-VLU-FC-ESF24	2	3						
GC74-0001- 4	1	4						
GC74-0002- 4	1	2						
GC74-0003- 4	1	3						
GC74-0003- 4	2	2						
GC74-0004- 4	1	6						
GC74-0004- 4	3	2						
GC74-0005 4	1	3						
GC74-0006- 4	1	4						
GC74-0007- 4	2	3						
GC74-0008- 4	2	4						
GR13-0001- 7	3	1						
GR13-0001- 8	3	2						
H23-EMS-CF-ALL	1	5						
H23-EMS-FC-DIV4	1	2						
H23-EMS-FC-DIV4	2	2						
H23-RMU-CF-ALL	1	1						
H23-RMU-FC-ESF14	1	1						
H23-RMU-FC-ESF24	2	1						

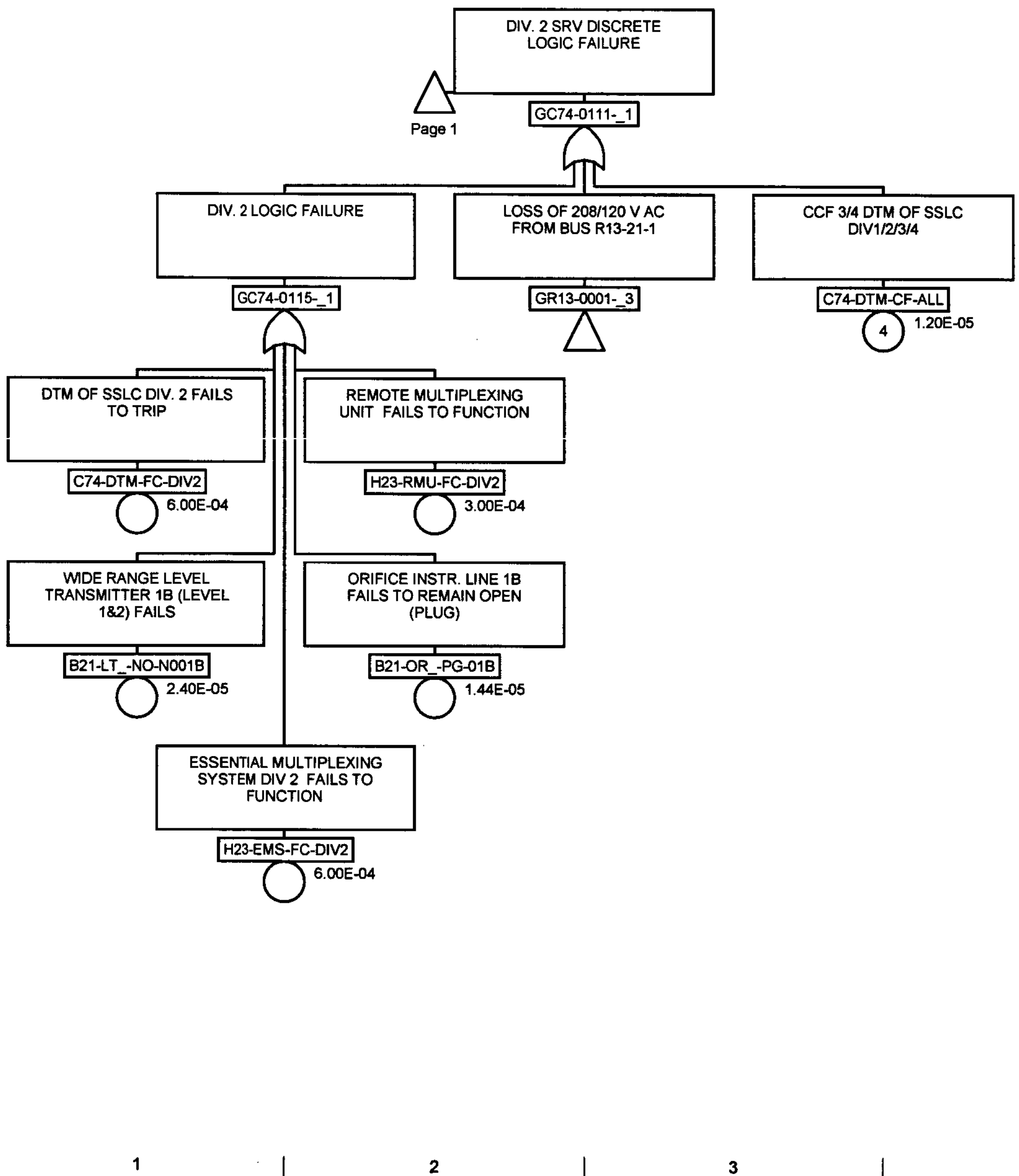
Appendix B.4.5-5

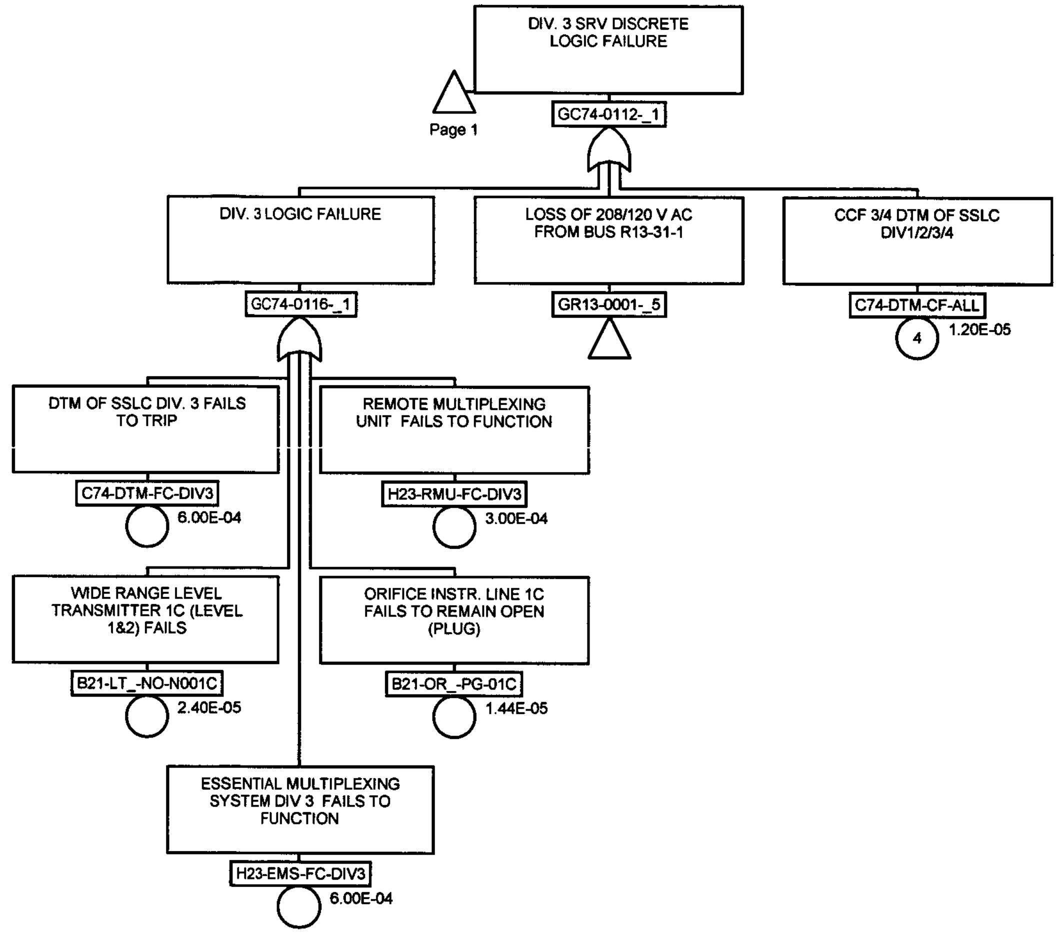
I&C Systems - C74 Auto Depressurization Signal (ADS)

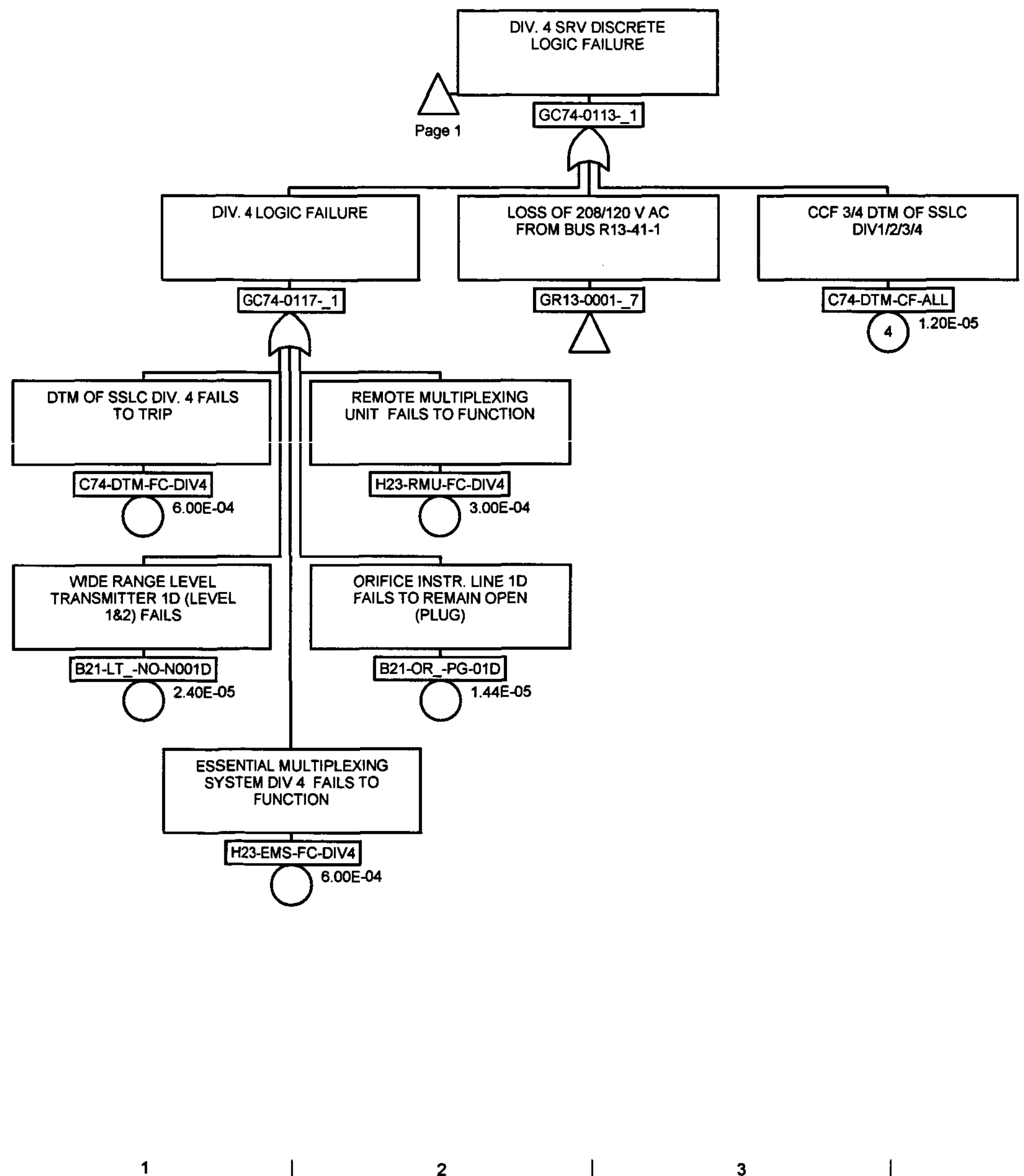

LOSS OF DIV. 2 DPV & SRV ACTUATION SIGNAL
GC74-0001-_6
LOSS OF DIV. 2 SIGNAL
GC74-0106-_1
CCF APRM DETECTORS STUCK AT POWER LEVEL
C51-ACT-CF-APRMSTUCK
2
2.10E-07
SSLC DIV. II SIGNAL TRANSMISSION FAILURE
GC74-0001-_2
CCF OF DIVERSIFIED LEVEL 1 & 2 TRANSM. 10A/B/C/D
B21-LT_-CF-N001A/B/C/D
2
1.20E-07
LOSS OF AUTOMATIC SIGNAL
Page 2
GC74-0200-_1
LOSS OF MANUAL SIGNAL
Page 2
GC74-0201-_1
LOSS OF LEVEL 1 AUTOMATIC SIGNAL
GC74-0105-_1
3
HOUSE EVENT: MANUAL ADS (VALUE=1)
XHOSMDS
2
MANUAL ACTUATION FAILURE
GC74-0102-_1
Page 7
HOUSE EVENT: MANUAL ADS (VALUE=1)
XHOSMDS
2
DIV. 1 SRV DISCRETE LOGIC FAILURE
GC74-0110-_1
Page 3
DIV. 3 SRV DISCRETE LOGIC FAILURE
GC74-0112-_1
Page 5
DIV. 2 SRV DISCRETE LOGIC FAILURE
GC74-0111-_1
Page 4
DIV. 4 SRV DISCRETE LOGIC FAILURE
GC74-0113-_1
Page 6
1
2
3
4
5

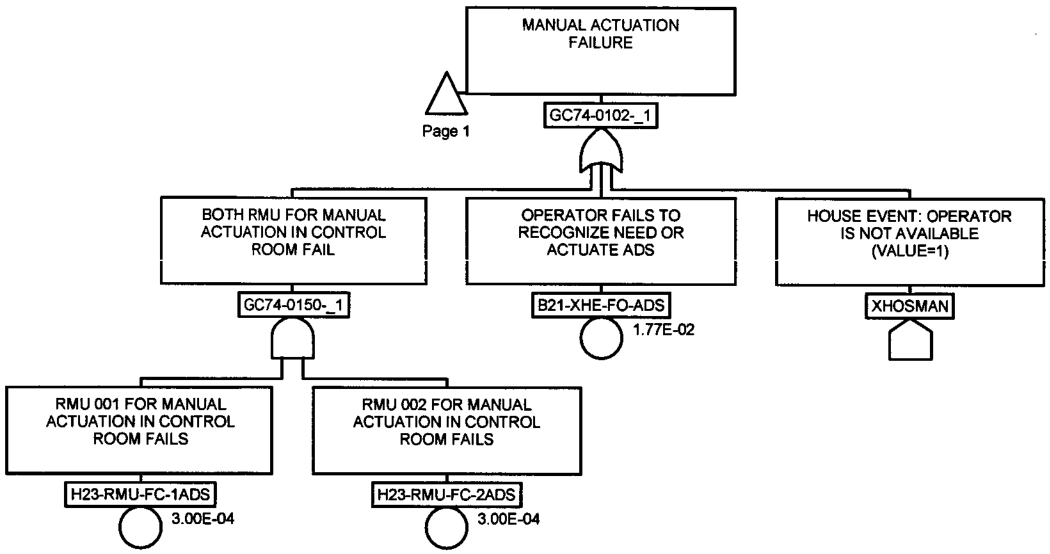

LOSS OF DIV. 1 DPV & SRV ACTUATION SIGNAL
GC74-0001-_5
LOSS OF DIV. 1 SIGNAL
GC74-0100-_1
CCF APRM DETECTORS STUCK AT POWER LEVEL
C51-ACT-CF-APRMSTUCK
2
2.10E-07
SSLC DIV. I SIGNAL TRANSMISSION FAILURE
GC74-0001-_1
CCF OF DIVERSIFIED LEVEL 1 & 2 TRANSM. 10A/B/C/D
B21-LT_-CF-N001A/B/C/D
2
1.20E-07
LOSS OF AUTOMATIC SIGNAL
GC74-0200-_1
Page 1
LOSS OF MANUAL SIGNAL
GC74-0201-_1
Page 1
1
2
3
4


DIV. 1 SRV DISCRETE LOGIC FAILURE
GC74-0110-_1
Page 1
DIV. 1 LOGIC FAILURE
GC74-0114-_1
LOSS OF 208/120 V AC FROM BUS R13-11-1
GR13-0001-_1
CCF 3/4 DTM OF SSLC DIV1/2/3/4
C74-DTM-CF-ALL
4
1.20E-05
DTM OF SSLC DIV. 1 FAILS TO TRIP
C74-DTM-FC-DIV1
6.00E-04
REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION
H23-RMU-FC-DIV1
3.00E-04
WIDE RANGE LEVEL TRANSMITTER 1A (LEVEL 1&2) FAILS
B21-LT_-NO-N001A
2.40E-05
ORIFICE INSTR. LINE 1A FAILS TO REMAIN OPEN (PLUG)
B21-OR_-PG-01A
1.44E-05
ESSENTIAL MULTIPLEXING SYSTEM DIV 1 FAILS TO FUNCTION
H23-EMS-FC-DIV1
6.00E-04
1
2
3


DIV. 2 SRV DISCRETE LOGIC FAILURE
GC74-0111-_1
Page 1
DIV. 2 LOGIC FAILURE
GC74-0115-_1
LOSS OF 208/120 V AC FROM BUS R13-21-1
GR13-0001-_3
CCF 3/4 DTM OF SSLC DIV1/2/3/4
C74-DTM-CF-ALL
4
1.20E-05
DTM OF SSLC DIV. 2 FAILS TO TRIP
C74-DTM-FC-DIV2
6.00E-04
REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION
H23-RMU-FC-DIV2
3.00E-04
WIDE RANGE LEVEL TRANSMITTER 1B (LEVEL 1&2) FAILS
B21-LT_-NO-N001B
2.40E-05
ORIFICE INSTR. LINE 1B FAILS TO REMAIN OPEN (PLUG)
B21-OR_-PG-01B
1.44E-05
ESSENTIAL MULTIPLEXING SYSTEM DIV 2 FAILS TO FUNCTION
H23-EMS-FC-DIV2
6.00E-04
1
2
3


DIV. 3 SRV DISCRETE LOGIC FAILURE
GC74-0112-_1
Page 1
DIV. 3 LOGIC FAILURE
GC74-0116-_1
LOSS OF 208/120 V AC FROM BUS R13-31-1
GR13-0001-_5
CCF 3/4 DTM OF SSLC DIV1/2/3/4
C74-DTM-CF-ALL
4
1.20E-05
DTM OF SSLC DIV. 3 FAILS TO TRIP
C74-DTM-FC-DIV3
6.00E-04
REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION
H23-RMU-FC-DIV3
3.00E-04
WIDE RANGE LEVEL TRANSMITTER 1C (LEVEL 1&2) FAILS
B21-LT_-NO-N001C
2.40E-05
ORIFICE INSTR. LINE 1C FAILS TO REMAIN OPEN (PLUG)
B21-OR_-PG-01C
1.44E-05
ESSENTIAL MULTIPLEXING SYSTEM DIV 3 FAILS TO FUNCTION
H23-EMS-FC-DIV3
6.00E-04
1
2
3

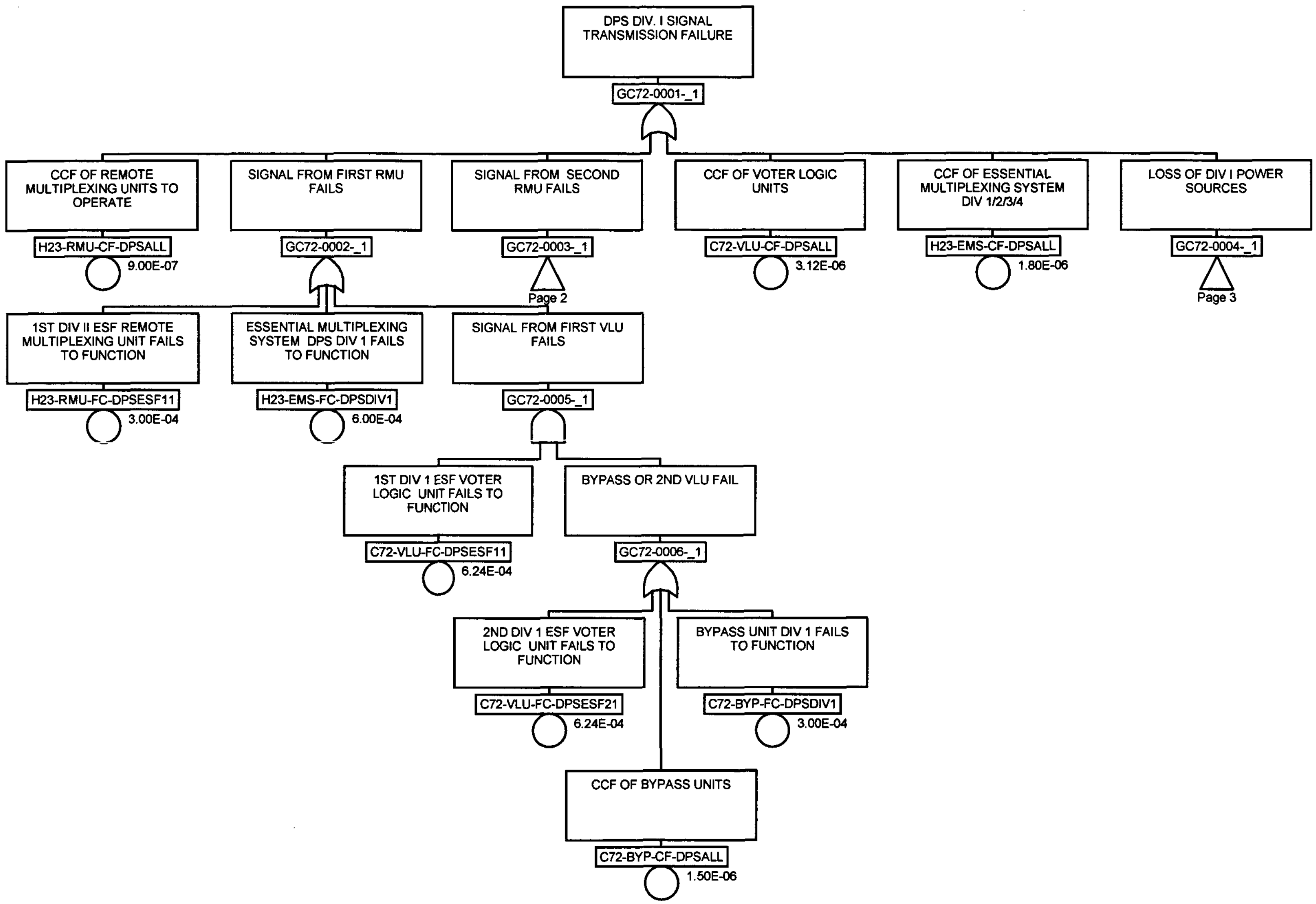

DIV. 4 SRV DISCRETE LOGIC FAILURE
Page 1
GC74-0113-_1
DIV. 4 LOGIC FAILURE
GC74-0117-_1
LOSS OF 208/120 V AC FROM BUS R13-41-1
GR13-0001-_7
CCF 3/4 DTM OF SSLC DIV1/2/3/4
C74-DTM-CF-ALL
4
1.20E-05
DTM OF SSLC DIV. 4 FAILS TO TRIP
C74-DTM-FC-DIV4
6.00E-04
REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION
H23-RMU-FC-DIV4
3.00E-04
WIDE RANGE LEVEL TRANSMITTER 1D (LEVEL 1&2) FAILS
B21-LT_-NO-N001D
2.40E-05
ORIFICE INSTR. LINE 1D FAILS TO REMAIN OPEN (PLUG)
B21-OR_-PG-01D
1.44E-05
ESSENTIAL MULTIPLEXING SYSTEM DIV 4 FAILS TO FUNCTION
H23-EMS-FC-DIV4
6.00E-04
1
2
3

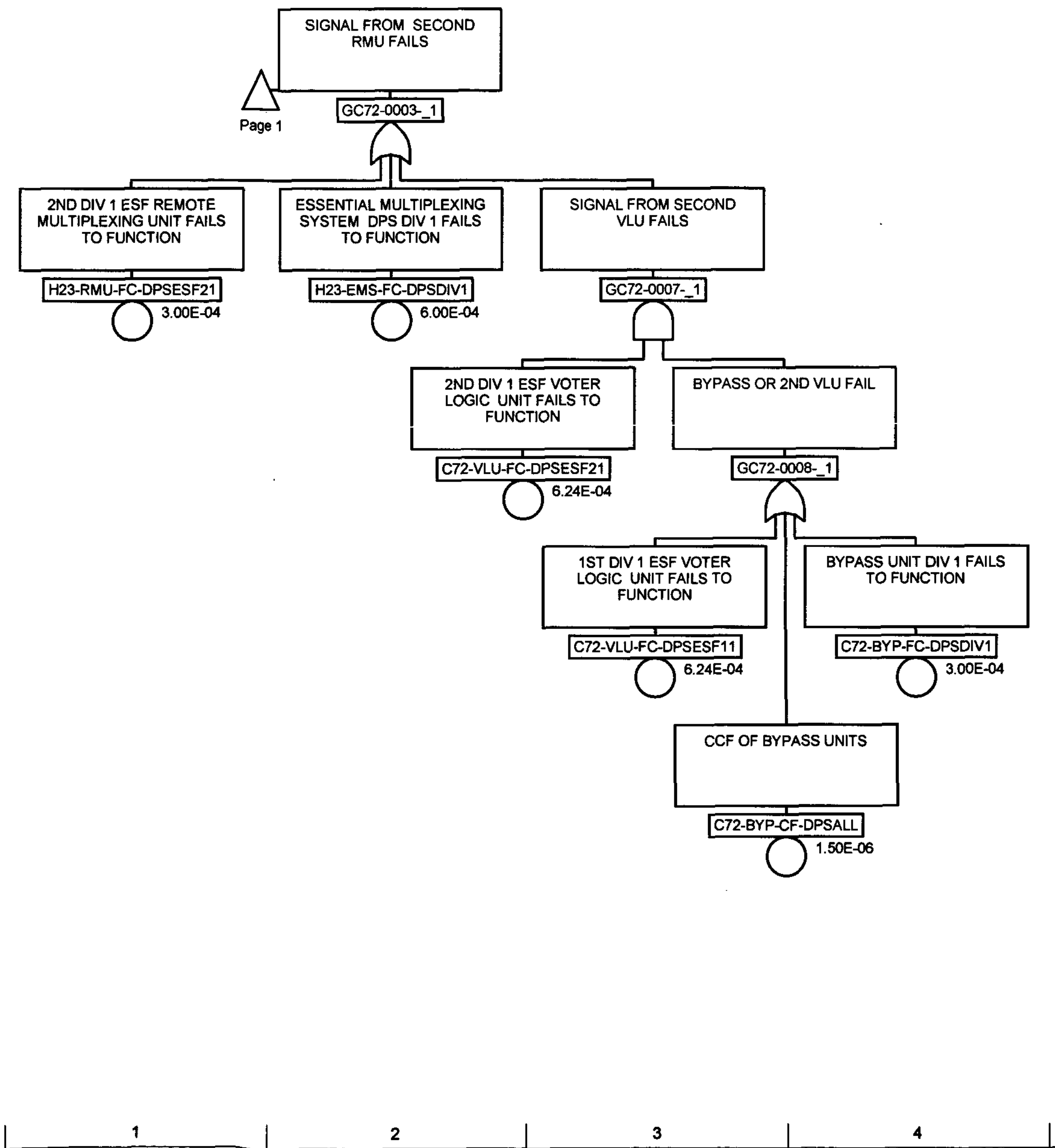

MANUAL ACTUATION FAILURE
Page 1
GC74-0102-_1
BOTH RMU FOR MANUAL ACTUATION IN CONTROL ROOM FAIL
GC74-0150-_1
OPERATOR FAILS TO RECOGNIZE NEED OR ACTUATE ADS
B21-XHE-FO-ADS
1.77E-02
HOUSE EVENT: OPERATOR IS NOT AVAILABLE (VALUE=1)
XHOSMAN
RMU 001 FOR MANUAL ACTUATION IN CONTROL ROOM FAILS
H23-RMU-FC-1ADS
3.00E-04
RMU 002 FOR MANUAL ACTUATION IN CONTROL ROOM FAILS
H23-RMU-FC-2ADS
3.00E-04
1
2
3

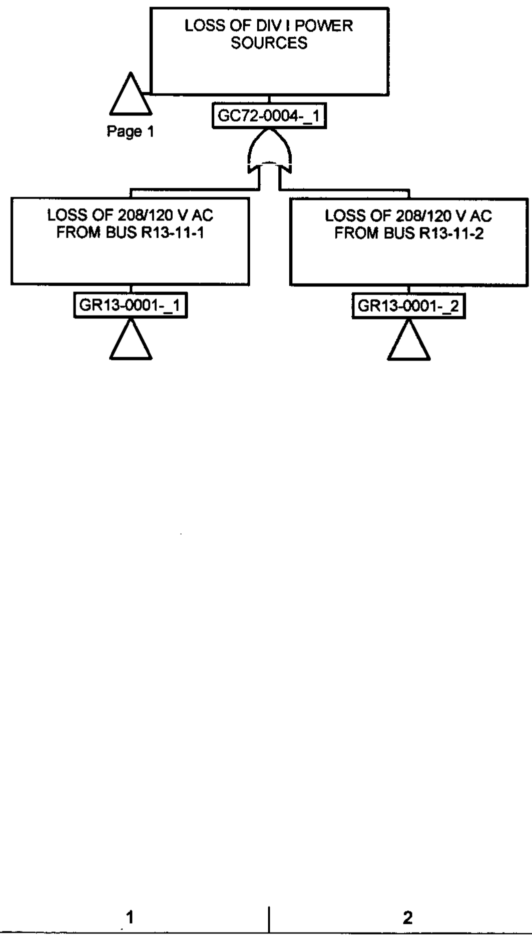
Name	Page	Zone
B21-LT -CF-N001A/B/C/D	1	6
B21-LT -CF-N001A/B/C/D	2	5
B21-LT -NO-N001A	3	1
B21-LT -NO-N001B	4	1
B21-LT -NO-N001C	5	1
B21-LT -NO-N001D	6	1
B21-OR -PG-01A	3	2
B21-OR -PG-01B	4	2
B21-OR -PG-01C	5	2
B21-OR -PG-01D	6	2
B21-XHE-FO-ADS	7	3
C51-ACT-CF-APRMSTUCK	1	4
C51-ACT-CF-APRMSTUCK	2	3
C74-DTM-CF-ALL	3	4
C74-DTM-CF-ALL	4	4
C74-DTM-CF-ALL	5	4
C74-DTM-CF-ALL	6	4
C74-DTM-FC-DIV1	3	1
C74-DTM-FC-DIV2	4	1
C74-DTM-FC-DIV3	5	1
C74-DTM-FC-DIV4	6	1
GC74-0001- 1	2	4
GC74-0001- 2	1	5
GC74-0001- 5	2	3
GC74-0001- 6	1	4
GC74-0100- 1	2	2
GC74-0102- 1	1	4
GC74-0102- 1	7	2
GC74-0105- 1	1	2
GC74-0106- 1	1	3
GC74-0110- 1	1	1
GC74-0110- 1	3	2
GC74-0111- 1	1	1
GC74-0111- 1	4	2
GC74-0112- 1	1	2
GC74-0112- 1	5	2
GC74-0113- 1	1	2
GC74-0113- 1	6	2
GC74-0114- 1	3	2
GC74-0115- 1	4	2
GC74-0116- 1	5	2
GC74-0117- 1	6	2
GC74-0150- 1	7	2
GC74-0200- 1	1	2
GC74-0200- 1	2	1
GC74-0201- 1	1	4
GC74-0201- 1	2	2
GR13-0001- 1	3	3
GR13-0001- 3	4	3
GR13-0001- 5	5	3
GR13-0001- 7	6	3
H23-EMS-FC-DIV1	3	2
H23-EMS-FC-DIV2	4	2
H23-EMS-FC-DIV3	5	2
H23-EMS-FC-DIV4	6	2
H23-RMU-FC-1ADS	7	1
H23-RMU-FC-2ADS	7	2
H23-RMU-FC-DIV1	3	2
H23-RMU-FC-DIV2	4	2
H23-RMU-FC-DIV3	5	2
H23-RMU-FC-DIV4	6	2
XHOSMAN	7	4
XHOSMDS	1	3
XHOSMDS	1	5

Appendix B.4.5-6

I&C Systems - C72 - DPS DIV I SIGNAL TRANSMISSION FAILURE


DPS DIV. I SIGNAL TRANSMISSION FAILURE
GC72-0001-_1
CCF OF REMOTE MULTIPLEXING UNITS TO OPERATE
H23-RMU-CF-DPSALL
9.00E-07
SIGNAL FROM FIRST RMU FAILS
GC72-0002-_1
SIGNAL FROM SECOND RMU FAILS
GC72-0003-_1
Page 2
CCF OF VOTER LOGIC UNITS
C72-VLU-CF-DPSALL
3.12E-06
CCF OF ESSENTIAL MULTIPLEXING SYSTEM DIV 1/2/3/4
H23-EMS-CF-DPSALL
1.80E-06
LOSS OF DIV I POWER SOURCES
GC72-0004-_1
Page 3
1ST DIV II ESF REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION
H23-RMU-FC-DPSESF11
3.00E-04
ESSENTIAL MULTIPLEXING SYSTEM DPS DIV 1 FAILS TO FUNCTION
H23-EMS-FC-DPSDIV1
6.00E-04
SIGNAL FROM FIRST VLU FAILS
GC72-0005-_1
1ST DIV 1 ESF VOTER LOGIC UNIT FAILS TO FUNCTION
C72-VLU-FC-DPSESF11
6.24E-04
BYPASS OR 2ND VLU FAIL
GC72-0006-_1
2ND DIV 1 ESF VOTER LOGIC UNIT FAILS TO FUNCTION
C72-VLU-FC-DPSESF21
6.24E-04
BYPASS UNIT DIV 1 FAILS TO FUNCTION
C72-BYP-FC-DPSDIV1
3.00E-04
CCF OF BYPASS UNITS
C72-BYP-CF-DPSALL
1.50E-06

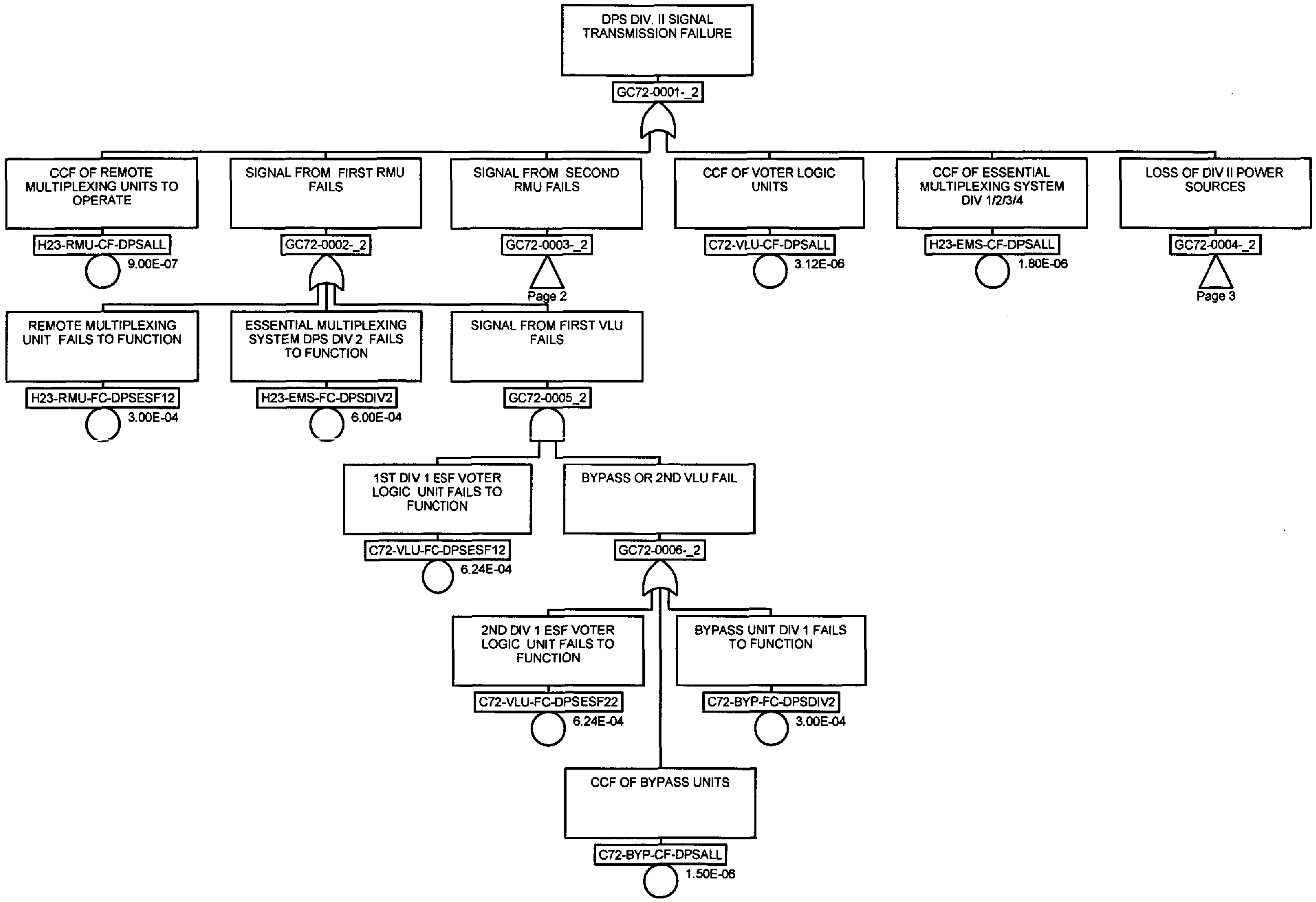

SIGNAL FROM SECOND RMU FAILS
GC72-0003-_1
Page 1
2ND DIV 1 ESF REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION
H23-RMU-FC-DPSESF21
3.00E-04
ESSENTIAL MULTIPLEXING SYSTEM DPS DIV 1 FAILS TO FUNCTION
H23-EMS-FC-DPSDIV1
6.00E-04
SIGNAL FROM SECOND VLU FAILS
GC72-0007-_1
2ND DIV 1 ESF VOTER LOGIC UNIT FAILS TO FUNCTION
C72-VLU-FC-DPSESF21
6.24E-04
BYPASS OR 2ND VLU FAIL
GC72-0008-_1
1ST DIV 1 ESF VOTER LOGIC UNIT FAILS TO FUNCTION
C72-VLU-FC-DPSESF11
6.24E-04
BYPASS UNIT DIV 1 FAILS TO FUNCTION
C72-BYP-FC-DPSDIV1
3.00E-04
CCF OF BYPASS UNITS
C72-BYP-CF-DPSALL
1.50E-06
1
2
3
4


LOSS OF DIV I POWER SOURCES
Page 1
GC72-0004-_1
LOSS OF 208/120 V AC FROM BUS R13-11-1
LOSS OF 208/120 V AC FROM BUS R13-11-2
GR13-0001-_1
GR13-0001-_2
1
2

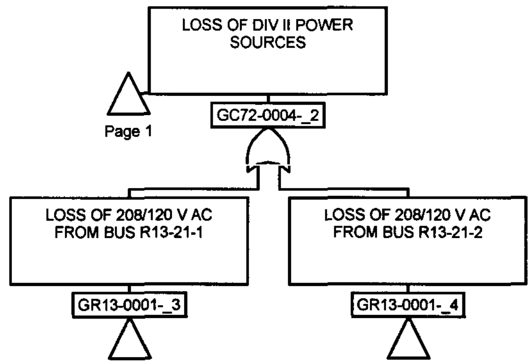
NEDO-33201 Rev 1

Appendix B.4.5-7

I&C Systems - C72 - DPS DIV II SIGNAL TRANSMISSION FAILURE


DPS DIV. II SIGNAL TRANSMISSION FAILURE
GC72-0001-_2
CCF OF REMOTE MULTIPLEXING UNITS TO OPERATE
H23-RMU-CF-DPSALL
9.00E-07
SIGNAL FROM FIRST RMU FAILS
GC72-0002-_2
SIGNAL FROM SECOND RMU FAILS
GC72-0003-_2
Page 2
CCF OF VOTER LOGIC UNITS
C72-VLU-CF-DPSALL
3.12E-06
CCF OF ESSENTIAL MULTIPLEXING SYSTEM DIV 1/2/3/4
H23-EMS-CF-DPSALL
1.80E-06
LOSS OF DIV II POWER SOURCES
GC72-0004-_2
Page 3
REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION
H23-RMU-FC-DPSESF12
3.00E-04
ESSENTIAL MULTIPLEXING SYSTEM DPS DIV 2 FAILS TO FUNCTION
H23-EMS-FC-DPSDIV2
6.00E-04
SIGNAL FROM FIRST VLU FAILS
GC72-0005_2
1ST DIV 1 ESF VOTER LOGIC UNIT FAILS TO FUNCTION
C72-VLU-FC-DPSESF12
6.24E-04
BYPASS OR 2ND VLU FAIL
GC72-0006-_2
2ND DIV 1 ESF VOTER LOGIC UNIT FAILS TO FUNCTION
C72-VLU-FC-DPSESF22
6.24E-04
BYPASS UNIT DIV 1 FAILS TO FUNCTION
C72-BYP-FC-DPSDIV2
3.00E-04
CCF OF BYPASS UNITS
C72-BYP-CF-DPSALL
1.50E-06

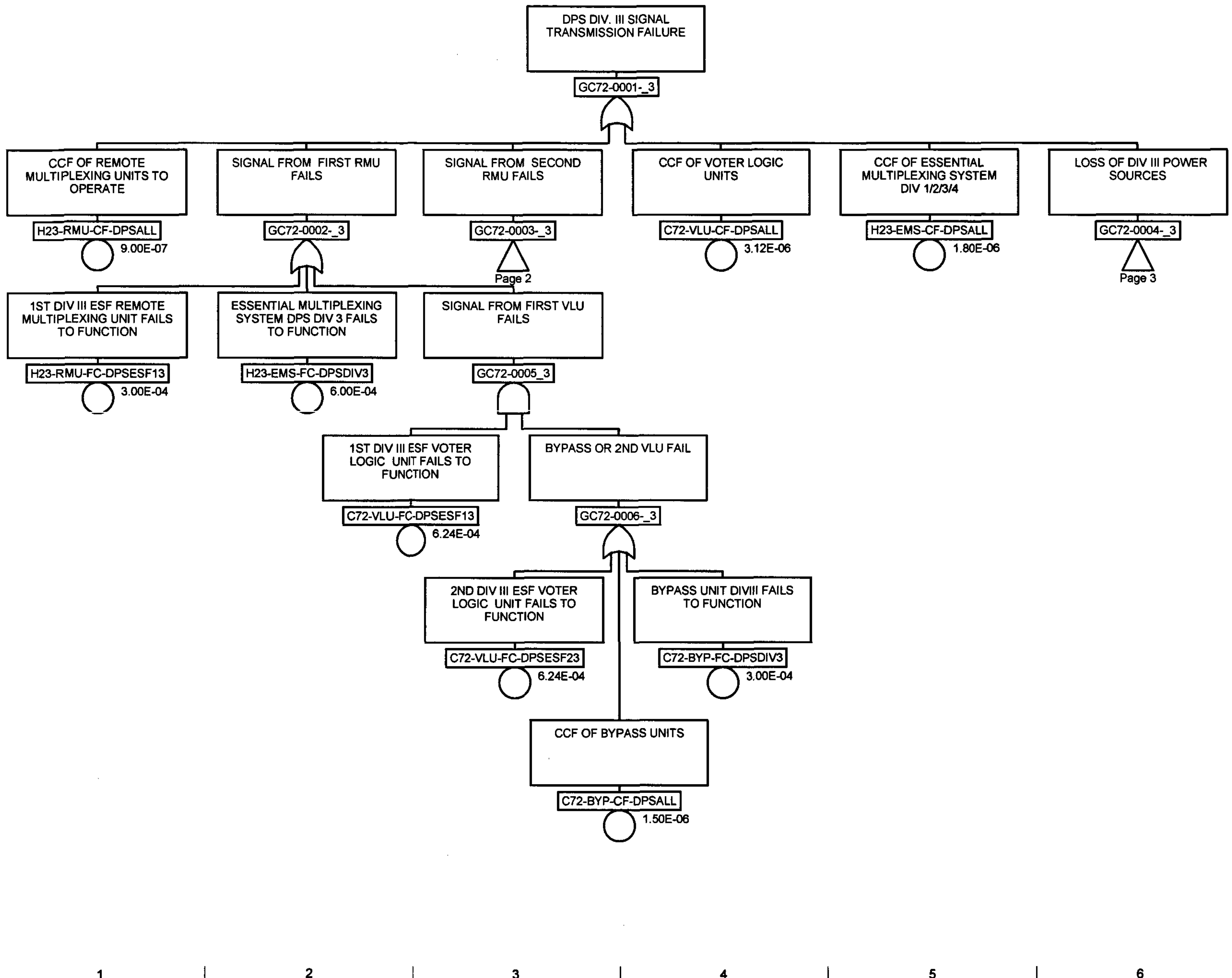
1 2 3 4 5 6

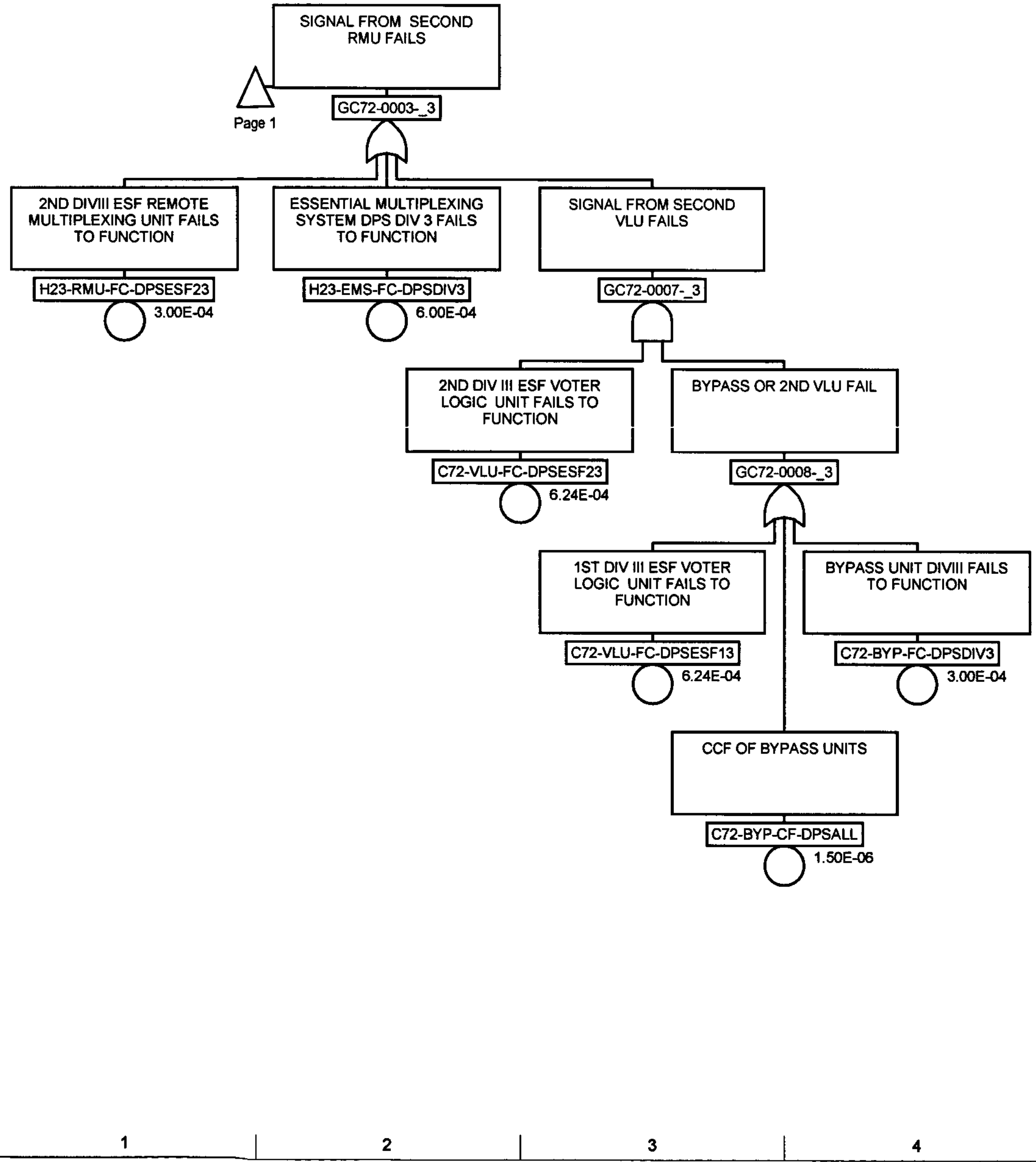

LOSS OF DIV II POWER SOURCES
GC72-0004-_2
Page 1
LOSS OF 208/120 V AC FROM BUS R13-21-1
GR13-0001-_3
LOSS OF 208/120 V AC FROM BUS R13-21-2
GR13-0001-_4
1
2

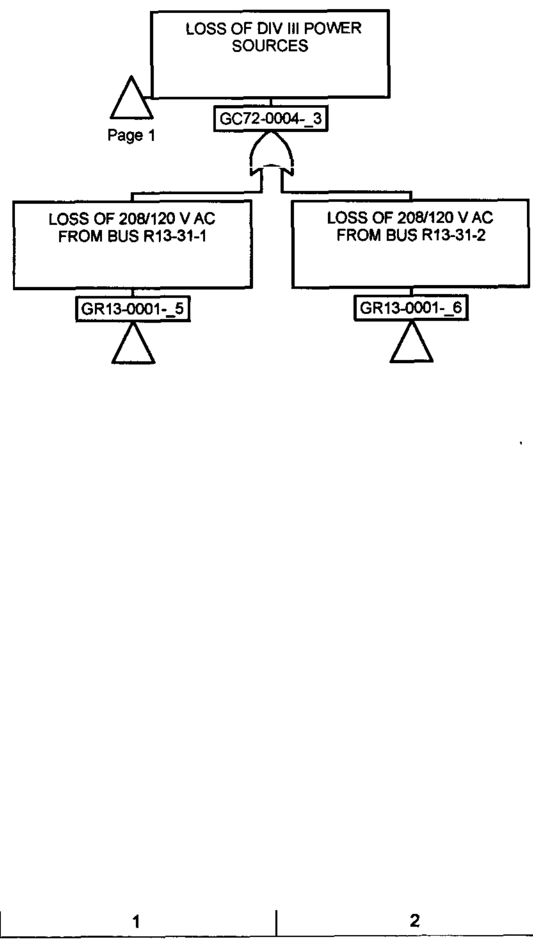
Name	Page	Zone	Name	Page	Zone	Name	Page	Zone
C72-BYP-CF-DPSALL	1	4						
C72-BYP-CF-DPSALL	2	4						
C72-BYP-FC-DPSDIV2	1	4						
C72-BYP-FC-DPSDIV2	2	4						
C72-VLU-CF-DPSALL	1	4						
C72-VLU-FC-DPSESF12	1	3						
C72-VLU-FC-DPSESF12	2	3						
C72-VLU-FC-DPSESF22	1	3						
C72-VLU-FC-DPSESF22	2	3						
GC72-0001- 2	1	4						
GC72-0002- 2	1	2						
GC72-0003- 2	1	3						
GC72-0003- 2	2	2						
GC72-0004- 2	1	6						
GC72-0004- 2	3	2						
GC72-0005 2	1	3						
GC72-0006- 2	1	4						
GC72-0007- 2	2	3						
GC72-0008- 2	2	4						
GR13-0001- 3	3	1						
GR13-0001- 4	3	2						
H23-EMS-CF-DPSALL	1	5						
H23-EMS-FC-DPSDIV2	1	2						
H23-EMS-FC-DPSDIV2	2	2						
H23-RMU-CF-DPSALL	1	1						
H23-RMU-FC-DPSESF12	1	1						
H23-RMU-FC-DPSESF22	2	1						

Appendix B.4.5-8

I&C Systems - C72 - DPS DIV III SIGNAL TRANSMISSION FAILURE


DPS DIV. III SIGNAL TRANSMISSION FAILURE
GC72-0001-_3
CCF OF REMOTE MULTIPLEXING UNITS TO OPERATE
H23-RMU-CF-DPSALL
9.00E-07
SIGNAL FROM FIRST RMU FAILS
GC72-0002-_3
SIGNAL FROM SECOND RMU FAILS
GC72-0003-_3
Page 2
CCF OF VOTER LOGIC UNITS
C72-VLU-CF-DPSALL
3.12E-06
CCF OF ESSENTIAL MULTIPLEXING SYSTEM DIV 1/2/3/4
H23-EMS-CF-DPSALL
1.80E-06
LOSS OF DIV III POWER SOURCES
GC72-0004-_3
Page 3
1ST DIV III ESF REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION
H23-RMU-FC-DPSESF13
3.00E-04
ESSENTIAL MULTIPLEXING SYSTEM DPS DIV 3 FAILS TO FUNCTION
H23-EMS-FC-DPSDIV3
6.00E-04
SIGNAL FROM FIRST VLU FAILS
GC72-0005_3
1ST DIV III ESF VOTER LOGIC UNIT FAILS TO FUNCTION
C72-VLU-FC-DPSESF13
6.24E-04
BYPASS OR 2ND VLU FAIL
GC72-0006-_3
2ND DIV III ESF VOTER LOGIC UNIT FAILS TO FUNCTION
C72-VLU-FC-DPSESF23
6.24E-04
BYPASS UNIT DIVIII FAILS TO FUNCTION
C72-BYP-FC-DPSDIV3
3.00E-04
CCF OF BYPASS UNITS
C72-BYP-CF-DPSALL
1.50E-06
1
2
3
4
5
6

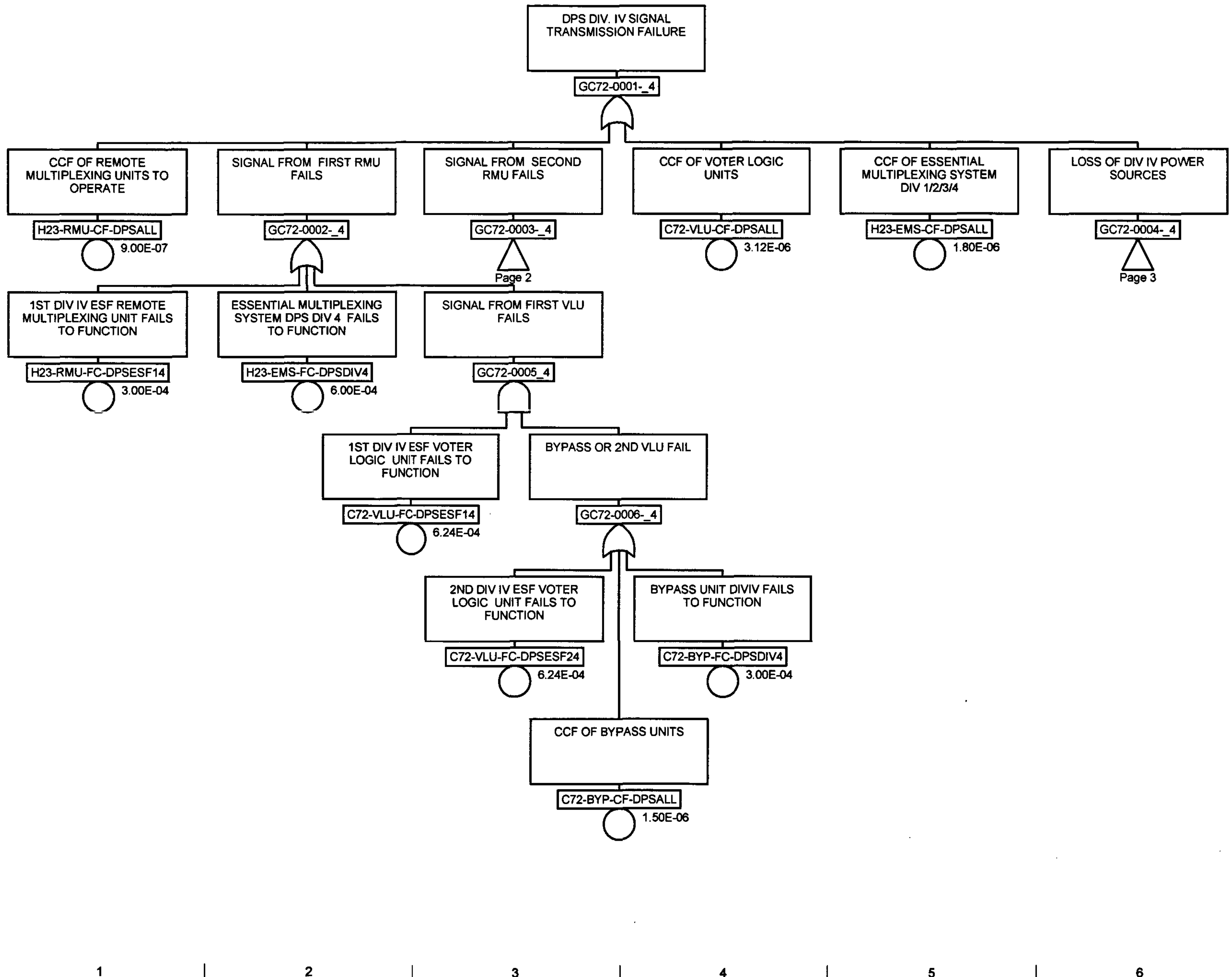

SIGNAL FROM SECOND RMU FAILS
GC72-0003-_3
Page 1
2ND DIVIII ESF REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION
H23-RMU-FC-DPSESF23
3.00E-04
ESSENTIAL MULTIPLEXING SYSTEM DPS DIV 3 FAILS TO FUNCTION
H23-EMS-FC-DPSDIV3
6.00E-04
SIGNAL FROM SECOND VLU FAILS
GC72-0007-_3
2ND DIV III ESF VOTER LOGIC UNIT FAILS TO FUNCTION
C72-VLU-FC-DPSESF23
6.24E-04
BYPASS OR 2ND VLU FAIL
GC72-0008-_3
1ST DIV III ESF VOTER LOGIC UNIT FAILS TO FUNCTION
C72-VLU-FC-DPSESF13
6.24E-04
BYPASS UNIT DIVIII FAILS TO FUNCTION
C72-BYP-FC-DPSDIV3
3.00E-04
CCF OF BYPASS UNITS
C72-BYP-CF-DPSALL
1.50E-06
1
2
3
4

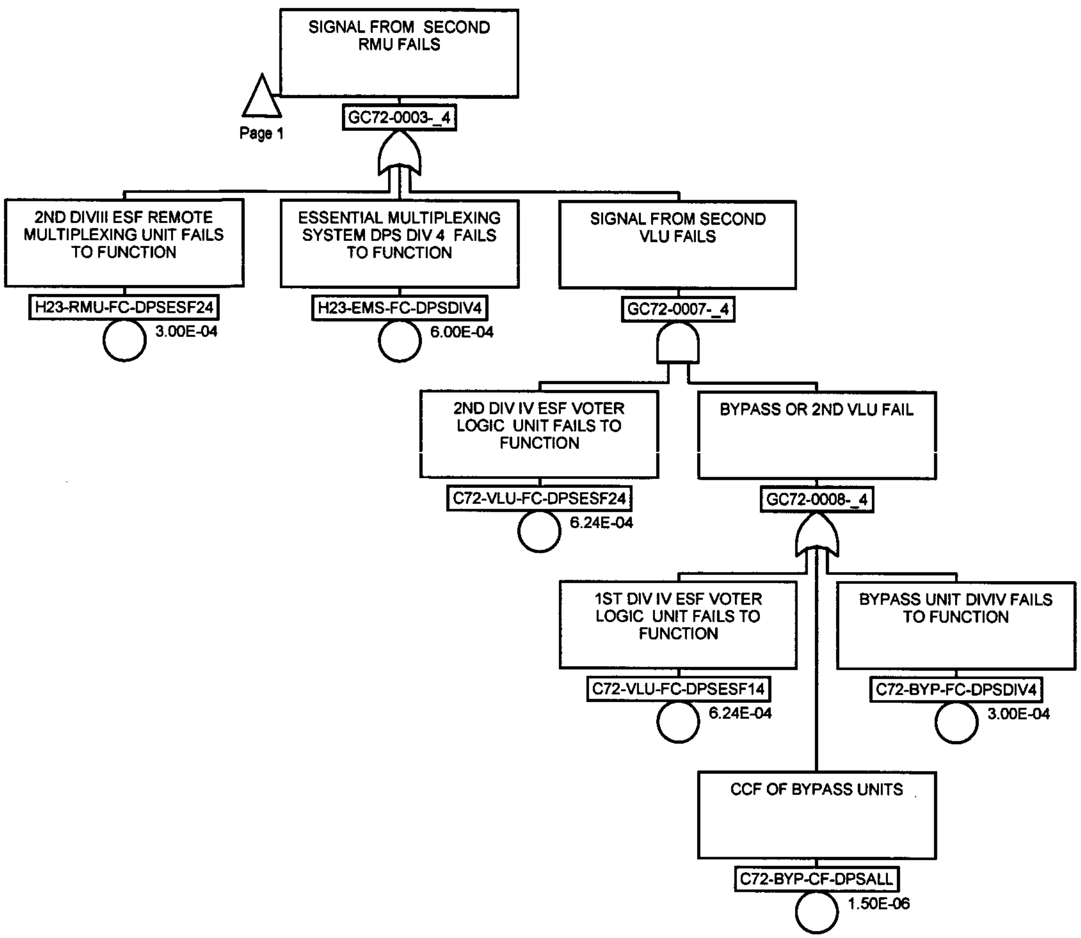

LOSS OF DIV III POWER SOURCES
GC72-0004-_3
Page 1
LOSS OF 208/120 V AC FROM BUS R13-31-1
GR13-0001-_5
LOSS OF 208/120 V AC FROM BUS R13-31-2
GR13-0001-_6
1
2

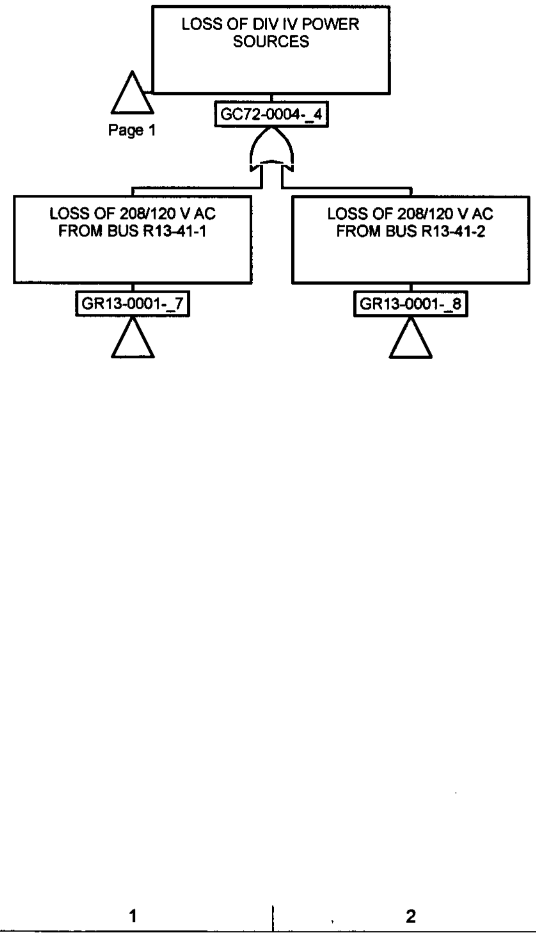
Name	Page	Zone	Name	Page	Zone	Name	Page	Zone
C72-BYP-CF-DPSALL	1	4						
C72-BYP-CF-DPSALL	2	4						
C72-BYP-FC-DPSDIV3	1	4						
C72-BYP-FC-DPSDIV3	2	4						
C72-VLU-CF-DPSALL	1	4						
C72-VLU-FC-DPSESF13	1	3						
C72-VLU-FC-DPSESF13	2	3						
C72-VLU-FC-DPSESF23	1	3						
C72-VLU-FC-DPSESF23	2	3						
GC72-0001- 3	1	4						
GC72-0002- 3	1	2						
GC72-0003- 3	1	3						
GC72-0003- 3	2	2						
GC72-0004- 3	1	6						
GC72-0004- 3	3	2						
GC72-0005 3	1	3						
GC72-0006- 3	1	4						
GC72-0007- 3	2	3						
GC72-0008- 3	2	4						
GR13-0001- 5	3	1						
GR13-0001- 6	3	2						
H23-EMS-CF-DPSALL	1	5						
H23-EMS-FC-DPSDIV3	1	2						
H23-EMS-FC-DPSDIV3	2	2						
H23-RMU-CF-DPSALL	1	1						
H23-RMU-FC-DPSESF13	1	1						
H23-RMU-FC-DPSESF23	2	1						

Appendix B.4.5-9

I&C Systems - C72 - DPS DIV IV SIGNAL TRANSMISSION FAILURE


DPS DIV. IV SIGNAL TRANSMISSION FAILURE
GC72-0001-_4
CCF OF REMOTE MULTIPLEXING UNITS TO OPERATE
H23-RMU-CF-DPSALL
9.00E-07
SIGNAL FROM FIRST RMU FAILS
GC72-0002-_4
SIGNAL FROM SECOND RMU FAILS
GC72-0003-_4
Page 2
CCF OF VOTER LOGIC UNITS
C72-VLU-CF-DPSALL
3.12E-06
CCF OF ESSENTIAL MULTIPLEXING SYSTEM DIV 1/2/3/4
H23-EMS-CF-DPSALL
1.80E-06
LOSS OF DIV IV POWER SOURCES
GC72-0004-_4
Page 3
1ST DIV IV ESF REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION
H23-RMU-FC-DPSESF14
3.00E-04
ESSENTIAL MULTIPLEXING SYSTEM DPS DIV 4 FAILS TO FUNCTION
H23-EMS-FC-DPSDIV4
6.00E-04
SIGNAL FROM FIRST VLU FAILS
GC72-0005_4
1ST DIV IV ESF VOTER LOGIC UNIT FAILS TO FUNCTION
C72-VLU-FC-DPSESF14
6.24E-04
BYPASS OR 2ND VLU FAIL
GC72-0006-_4
2ND DIV IV ESF VOTER LOGIC UNIT FAILS TO FUNCTION
C72-VLU-FC-DPSESF24
6.24E-04
BYPASS UNIT DIVIV FAILS TO FUNCTION
C72-BYP-FC-DPSDIV4
3.00E-04
CCF OF BYPASS UNITS
C72-BYP-CF-DPSALL
1.50E-06
1
2
3
4
5
6

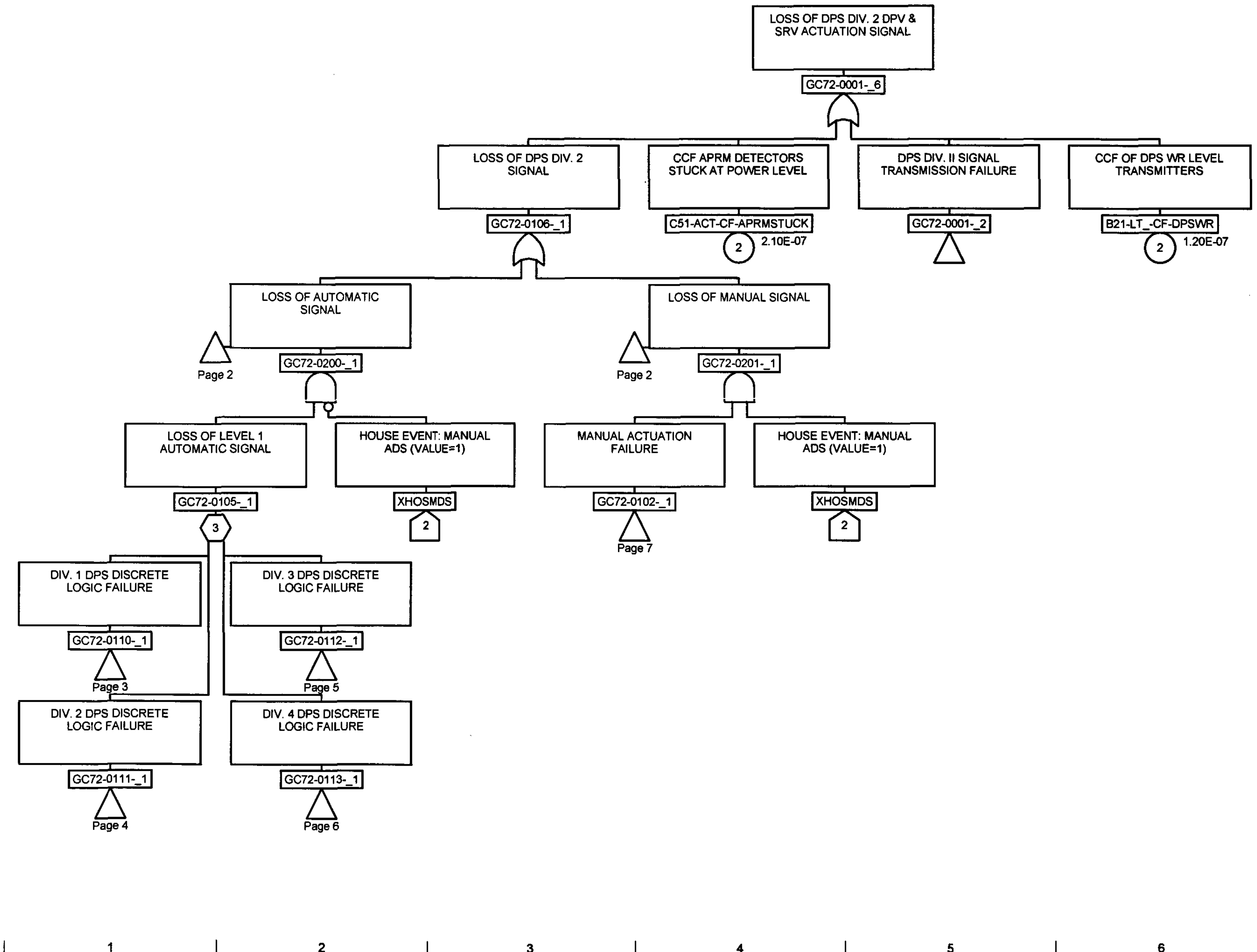

SIGNAL FROM SECOND RMU FAILS
GC72-0003-_4
Page 1
2ND DIVIII ESF REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION
H23-RMU-FC-DPSESF24
3.00E-04
ESSENTIAL MULTIPLEXING SYSTEM DPS DIV 4 FAILS TO FUNCTION
H23-EMS-FC-DPSDIV4
6.00E-04
SIGNAL FROM SECOND VLU FAILS
GC72-0007-_4
2ND DIV IV ESF VOTER LOGIC UNIT FAILS TO FUNCTION
C72-VLU-FC-DPSESF24
6.24E-04
BYPASS OR 2ND VLU FAIL
GC72-0008-_4
1ST DIV IV ESF VOTER LOGIC UNIT FAILS TO FUNCTION
C72-VLU-FC-DPSESF14
6.24E-04
BYPASS UNIT DIVIV FAILS TO FUNCTION
C72-BYP-FC-DPSDIV4
3.00E-04
CCF OF BYPASS UNITS
C72-BYP-CF-DPSALL
1.50E-06
1
2
3
4

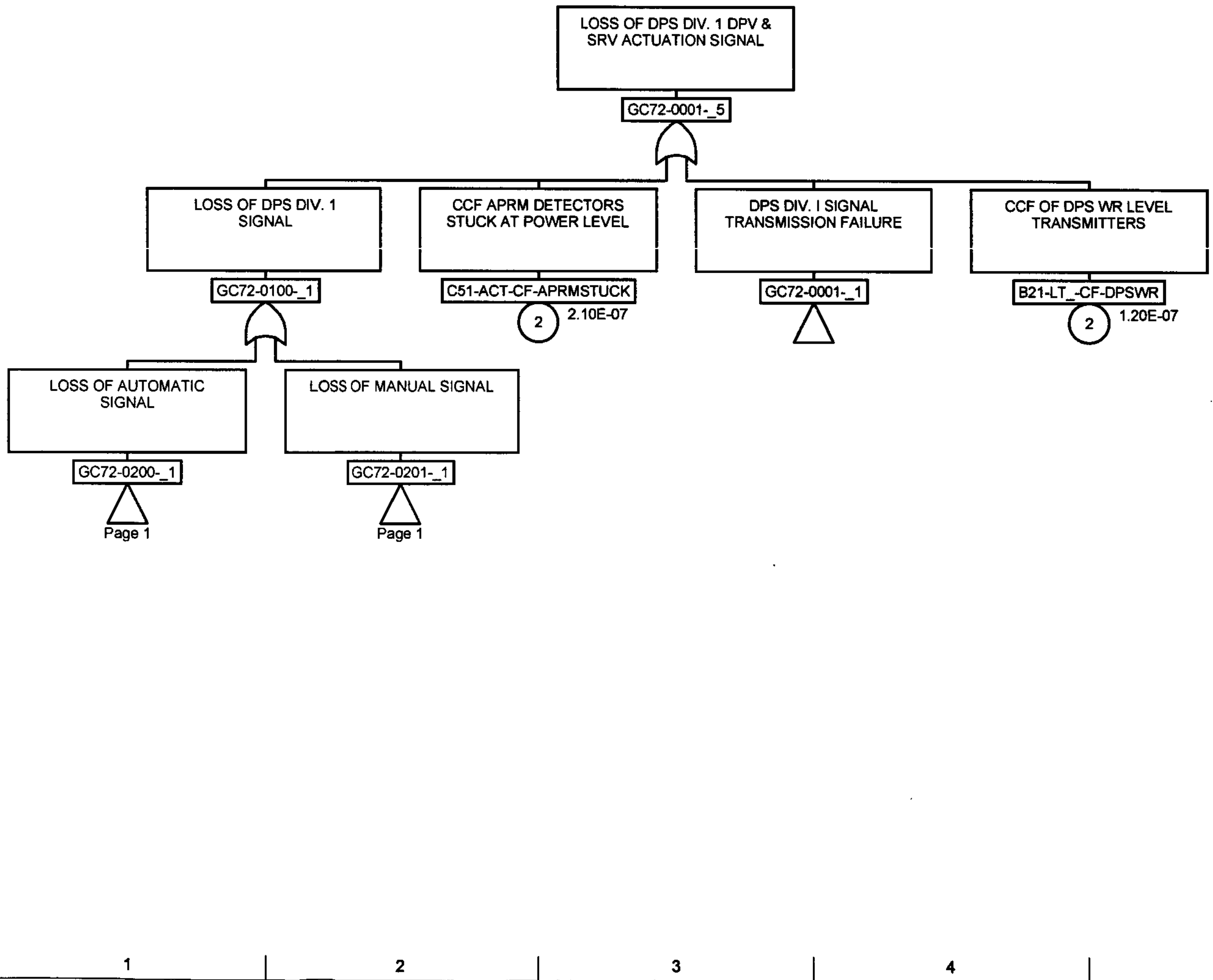

LOSS OF DIV IV POWER SOURCES
Page 1
GC72-0004-_4
LOSS OF 208/120 V AC FROM BUS R13-41-1
GR13-0001-_7
LOSS OF 208/120 V AC FROM BUS R13-41-2
GR13-0001-_8
1
2

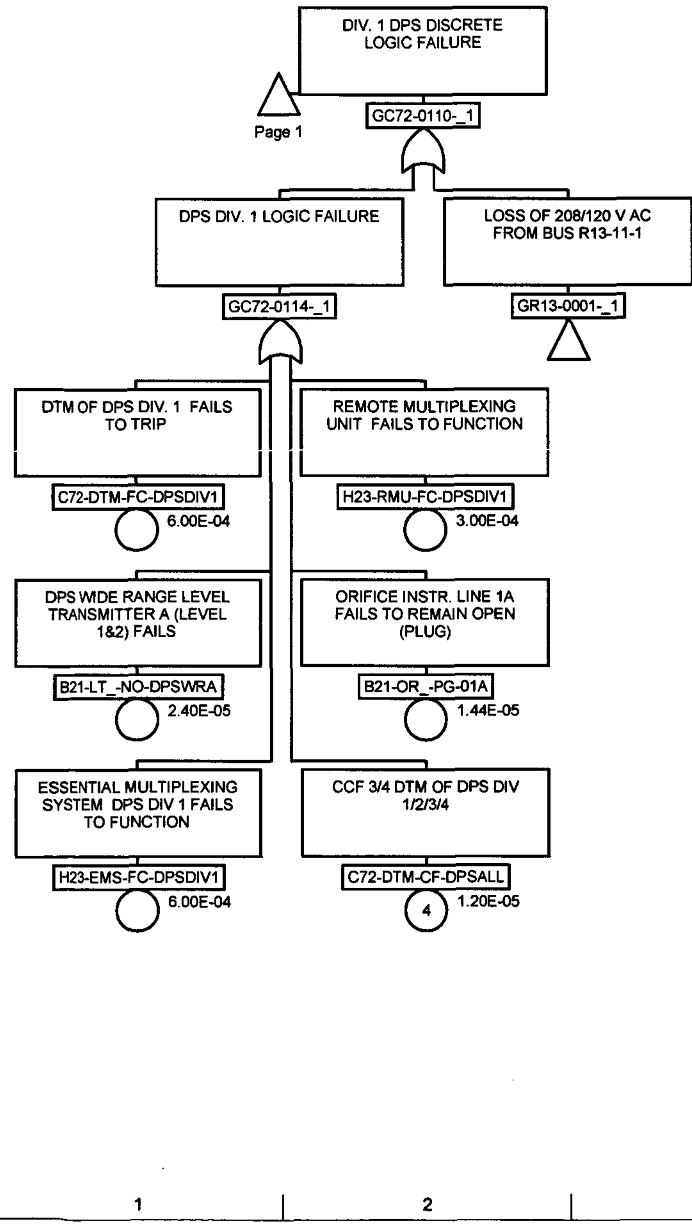
Name	Page	Zone	Name	Page	Zone	Name	Page	Zone
C72-BYP-CF-DPSALL	1	4						
C72-BYP-CF-DPSALL	2	4						
C72-BYP-FC-DPSDIV4	1	4						
C72-BYP-FC-DPSDIV4	2	4						
C72-VLU-CF-DPSALL	1	4						
C72-VLU-FC-DPSESF14	1	3						
C72-VLU-FC-DPSESF14	2	3						
C72-VLU-FC-DPSESF24	1	3						
C72-VLU-FC-DPSESF24	2	3						
GC72-0001- 4	1	4						
GC72-0002- 4	1	2						
GC72-0003- 4	1	3						
GC72-0003- 4	2	2						
GC72-0004- 4	1	6						
GC72-0004- 4	3	2						
GC72-0005 4	1	3						
GC72-0006- 4	1	4						
GC72-0007- 4	2	3						
GC72-0008- 4	2	4						
GR13-0001- 7	3	1						
GR13-0001- 8	3	2						
H23-EMS-CF-DPSALL	1	5						
H23-EMS-FC-DPSDIV4	1	2						
H23-EMS-FC-DPSDIV4	2	2						
H23-RMU-CF-DPSALL	1	1						
H23-RMU-FC-DPSESF14	1	1						
H23-RMU-FC-DPSESF24	2	1						

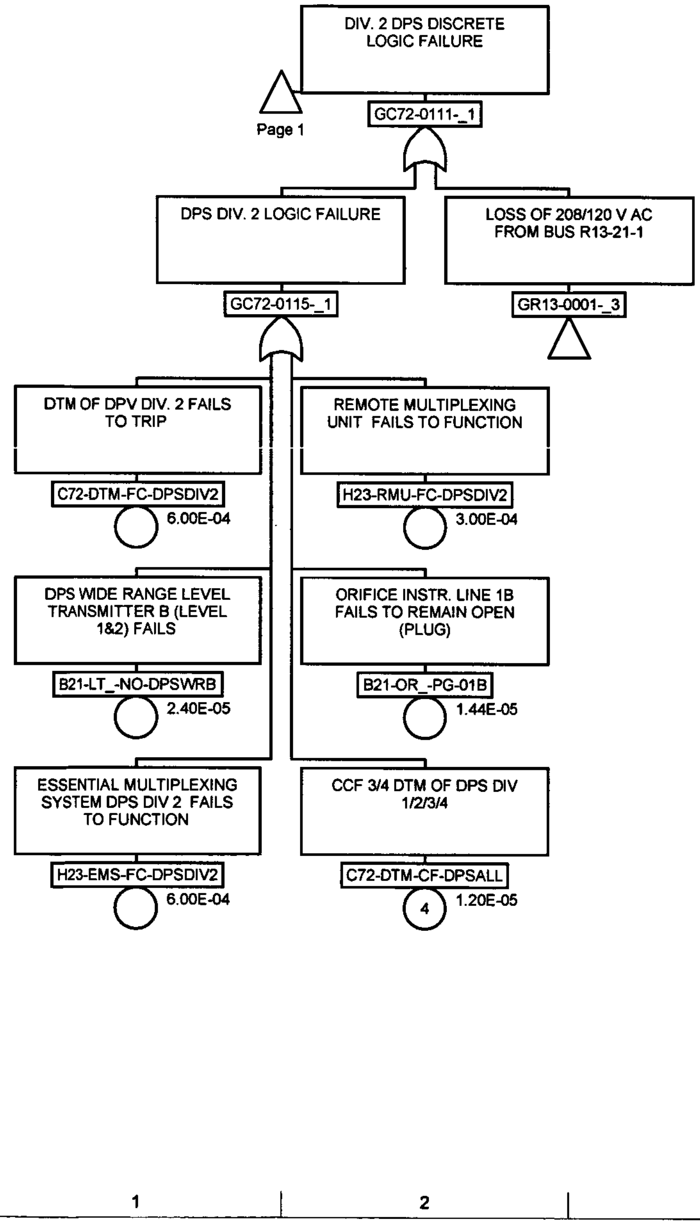
Appendix B.4.5-10

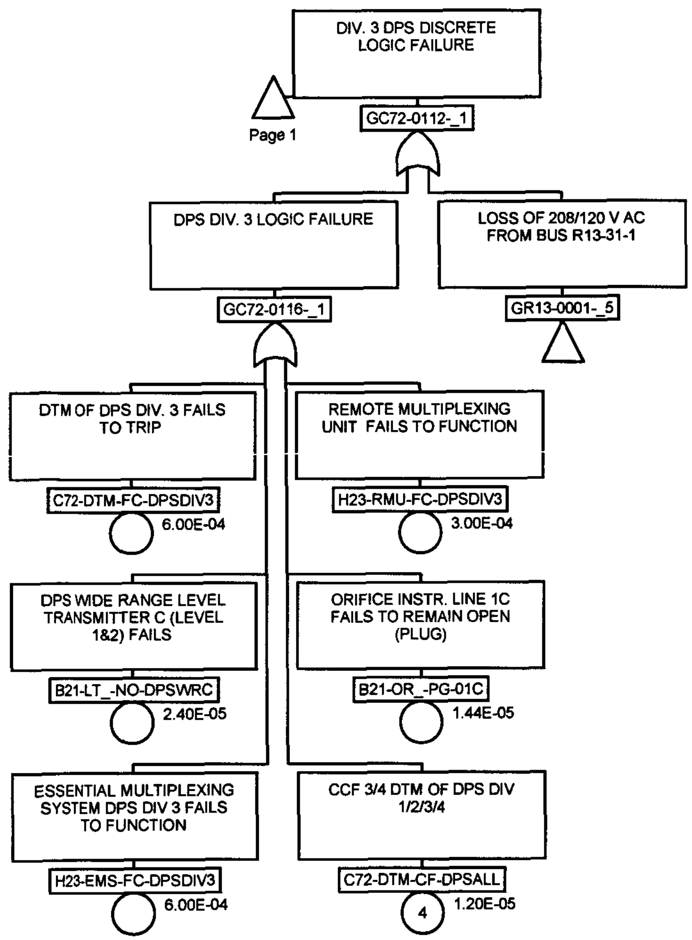
I&C-C72-LOSS OF DIV. 2 DPV & SRV ACTUATION SIGNAL

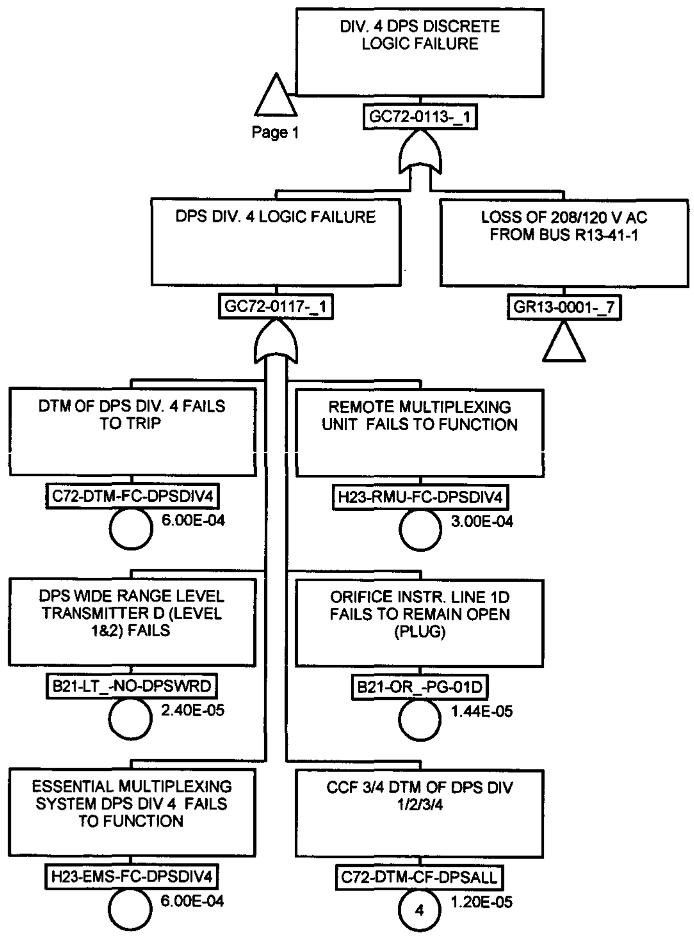

LOSS OF DPS DIV. 2 DPV & SRV ACTUATION SIGNAL
GC72-0001-_6
LOSS OF DPS DIV. 2 SIGNAL
GC72-0106-_1
CCF APRM DETECTORS STUCK AT POWER LEVEL
C51-ACT-CF-APRMSTUCK
2
2.10E-07
DPS DIV. II SIGNAL TRANSMISSION FAILURE
GC72-0001-_2
CCF OF DPS WR LEVEL TRANSMITTERS
B21-LT_-CF-DPSWR
2
1.20E-07
LOSS OF AUTOMATIC SIGNAL
Page 2
GC72-0200-_1
LOSS OF MANUAL SIGNAL
Page 2
GC72-0201-_1
LOSS OF LEVEL 1 AUTOMATIC SIGNAL
GC72-0105-_1
3
HOUSE EVENT: MANUAL ADS (VALUE=1)
XHOSMDS
2
MANUAL ACTUATION FAILURE
GC72-0102-_1
Page 7
HOUSE EVENT: MANUAL ADS (VALUE=1)
XHOSMDS
2
DIV. 1 DPS DISCRETE LOGIC FAILURE
GC72-0110-_1
Page 3
DIV. 3 DPS DISCRETE LOGIC FAILURE
GC72-0112-_1
Page 5
DIV. 2 DPS DISCRETE LOGIC FAILURE
GC72-0111-_1
Page 4
DIV. 4 DPS DISCRETE LOGIC FAILURE
GC72-0113-_1
Page 6
1
2
3
4
5
6

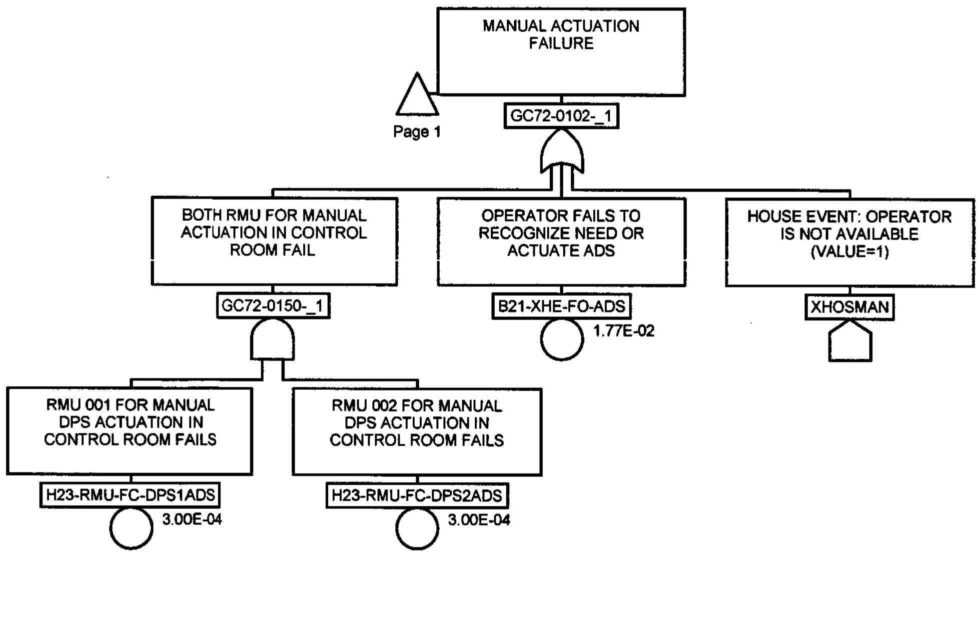

LOSS OF DPS DIV. 1 DPV & SRV ACTUATION SIGNAL
GC72-0001-_5
LOSS OF DPS DIV. 1 SIGNAL
GC72-0100-_1
CCF APRM DETECTORS STUCK AT POWER LEVEL
C51-ACT-CF-APRMSTUCK
2
2.10E-07
DPS DIV. I SIGNAL TRANSMISSION FAILURE
GC72-0001-_1
CCF OF DPS WR LEVEL TRANSMITTERS
B21-LT_-CF-DPSWR
2
1.20E-07
LOSS OF AUTOMATIC SIGNAL
GC72-0200-_1
Page 1
LOSS OF MANUAL SIGNAL
GC72-0201-_1
Page 1
1
2
3
4


DIV. 1 DPS DISCRETE LOGIC FAILURE
GC72-0110-_1
Page 1
DPS DIV. 1 LOGIC FAILURE
GC72-0114-_1
LOSS OF 208/120 V AC FROM BUS R13-11-1
GR13-0001-_1
DTM OF DPS DIV. 1 FAILS TO TRIP
C72-DTM-FC-DPSDIV1
6.00E-04
REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION
H23-RMU-FC-DPSDIV1
3.00E-04
DPS WIDE RANGE LEVEL TRANSMITTER A (LEVEL 1&2) FAILS
B21-LT_-NO-DPSWRA
2.40E-05
ORIFICE INSTR. LINE 1A FAILS TO REMAIN OPEN (PLUG)
B21-OR_-PG-01A
1.44E-05
ESSENTIAL MULTIPLEXING SYSTEM DPS DIV 1 FAILS TO FUNCTION
H23-EMS-FC-DPSDIV1
6.00E-04
CCF 3/4 DTM OF DPS DIV 1/2/3/4
C72-DTM-CF-DPSALL
4
1.20E-05
1
2


DIV. 2 DPS DISCRETE LOGIC FAILURE
GC72-0111-_1
Page 1
DPS DIV. 2 LOGIC FAILURE
GC72-0115-_1
LOSS OF 208/120 V AC FROM BUS R13-21-1
GR13-0001-_3
DTM OF DPV DIV. 2 FAILS TO TRIP
C72-DTM-FC-DPSDIV2
6.00E-04
REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION
H23-RMU-FC-DPSDIV2
3.00E-04
DPS WIDE RANGE LEVEL TRANSMITTER B (LEVEL 1&2) FAILS
B21-LT_-NO-DPSWRB
2.40E-05
ORIFICE INSTR. LINE 1B FAILS TO REMAIN OPEN (PLUG)
B21-OR_-PG-01B
1.44E-05
ESSENTIAL MULTIPLEXING SYSTEM DPS DIV 2 FAILS TO FUNCTION
H23-EMS-FC-DPSDIV2
6.00E-04
CCF 3/4 DTM OF DPS DIV 1/2/3/4
C72-DTM-CF-DPSALL
4
1.20E-05
1
2


DIV. 3 DPS DISCRETE LOGIC FAILURE
Page 1
GC72-0112-_1
DPS DIV. 3 LOGIC FAILURE
GC72-0116-_1
LOSS OF 208/120 V AC FROM BUS R13-31-1
GR13-0001-_5
DTM OF DPS DIV. 3 FAILS TO TRIP
C72-DTM-FC-DPSDIV3
6.00E-04
REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION
H23-RMU-FC-DPSDIV3
3.00E-04
DPS WIDE RANGE LEVEL TRANSMITTER C (LEVEL 1&2) FAILS
B21-LT_-NO-DPSWRC
2.40E-05
ORIFICE INSTR. LINE 1C FAILS TO REMAIN OPEN (PLUG)
B21-OR_-PG-01C
1.44E-05
ESSENTIAL MULTIPLEXING SYSTEM DPS DIV 3 FAILS TO FUNCTION
H23-EMS-FC-DPSDIV3
6.00E-04
CCF 3/4 DTM OF DPS DIV 1/2/3/4
C72-DTM-CF-DPSALL
4
1.20E-05
1
2

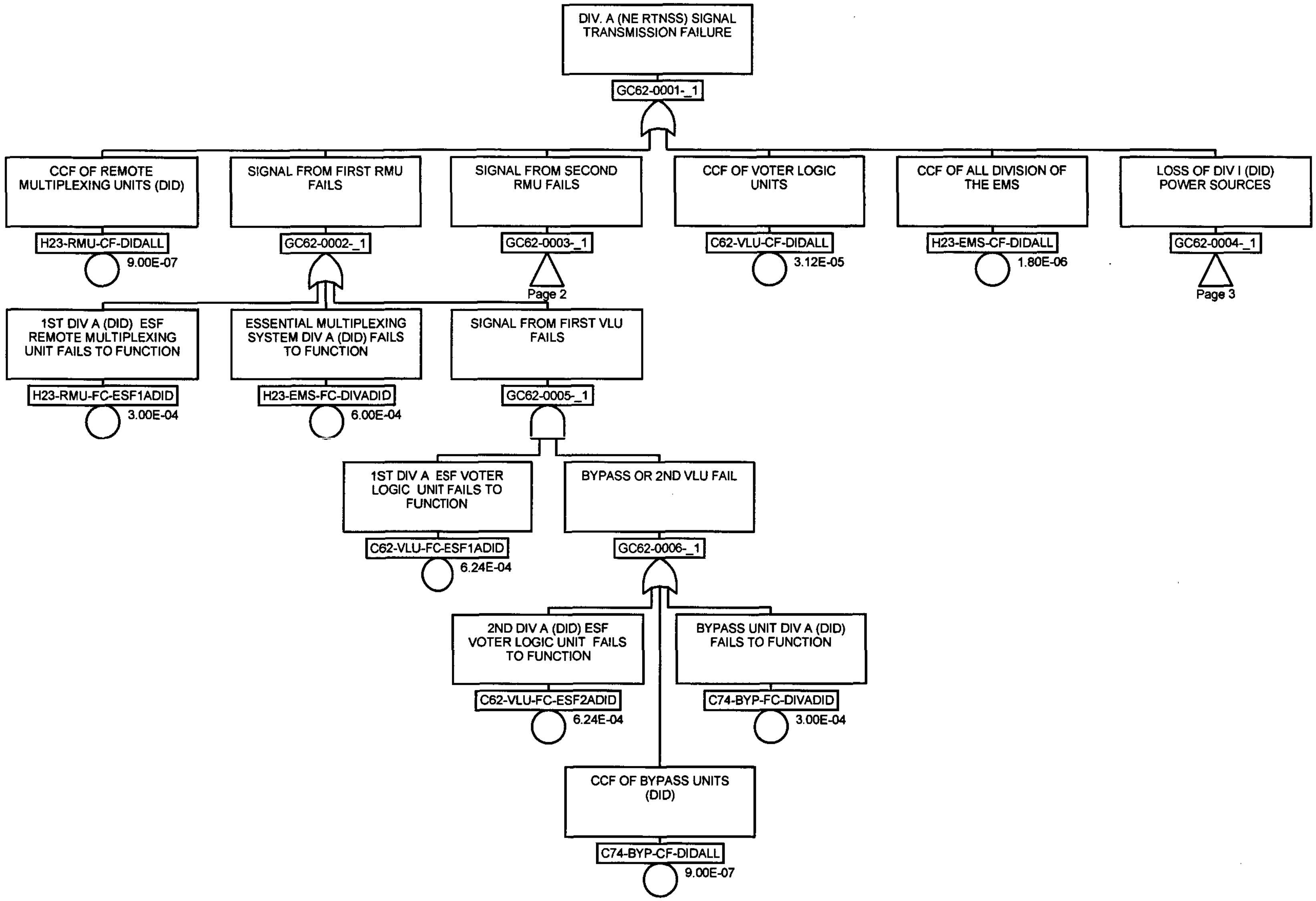

DIV. 4 DPS DISCRETE LOGIC FAILURE
GC72-0113-_1
Page 1
DPS DIV. 4 LOGIC FAILURE
GC72-0117-_1
LOSS OF 208/120 V AC FROM BUS R13-41-1
GR13-0001-_7
DTM OF DPS DIV. 4 FAILS TO TRIP
C72-DTM-FC-DPSDIV4
6.00E-04
REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION
H23-RMU-FC-DPSDIV4
3.00E-04
DPS WIDE RANGE LEVEL TRANSMITTER D (LEVEL 1&2) FAILS
B21-LT_-NO-DPSWRD
2.40E-05
ORIFICE INSTR. LINE 1D FAILS TO REMAIN OPEN (PLUG)
B21-OR_-PG-01D
1.44E-05
ESSENTIAL MULTIPLEXING SYSTEM DPS DIV 4 FAILS TO FUNCTION
H23-EMS-FC-DPSDIV4
6.00E-04
CCF 3/4 DTM OF DPS DIV 1/2/3/4
C72-DTM-CF-DPSALL
4
1.20E-05
1
2

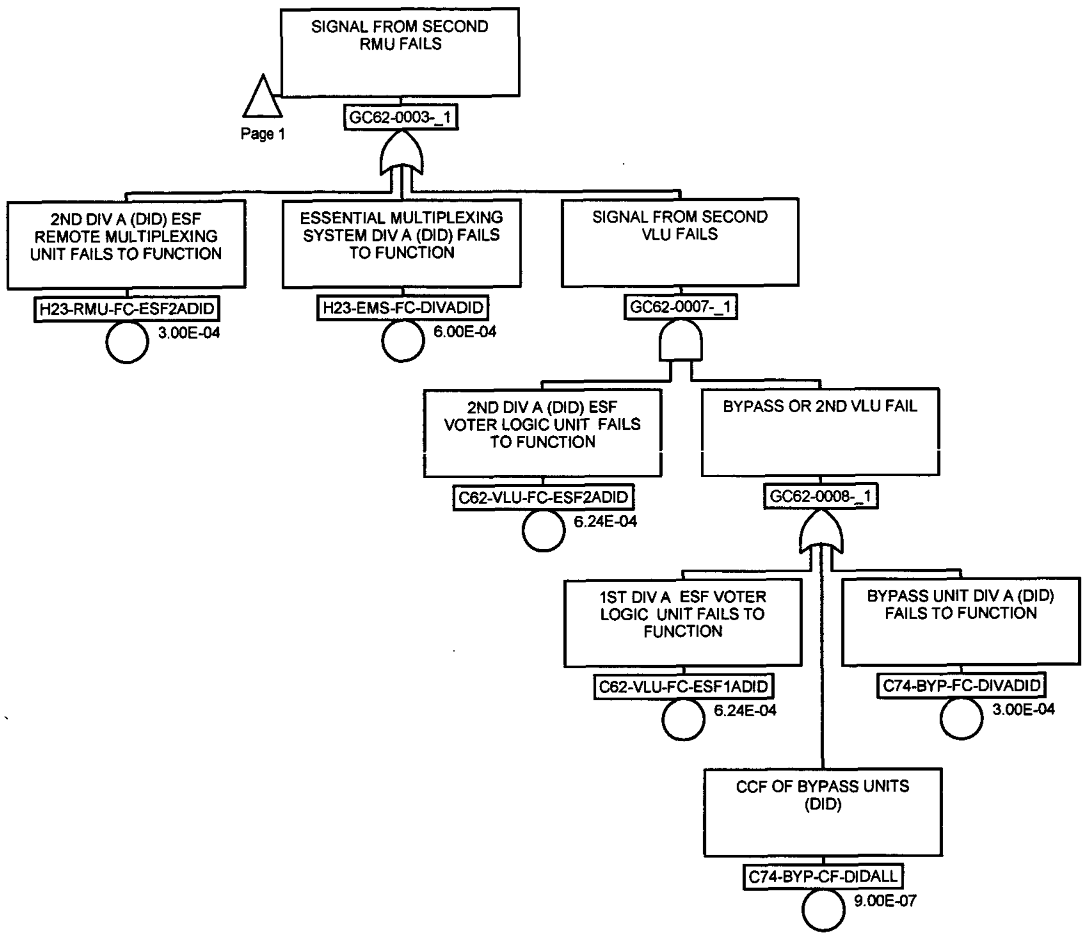

MANUAL ACTUATION FAILURE
Page 1
GC72-0102-_1
BOTH RMU FOR MANUAL ACTUATION IN CONTROL ROOM FAIL
GC72-0150-_1
OPERATOR FAILS TO RECOGNIZE NEED OR ACTUATE ADS
B21-XHE-FO-ADS
1.77E-02
HOUSE EVENT: OPERATOR IS NOT AVAILABLE (VALUE=1)
XHOSMAN
RMU 001 FOR MANUAL DPS ACTUATION IN CONTROL ROOM FAILS
H23-RMU-FC-DPS1ADS
3.00E-04
RMU 002 FOR MANUAL DPS ACTUATION IN CONTROL ROOM FAILS
H23-RMU-FC-DPS2ADS
3.00E-04
1
2
3

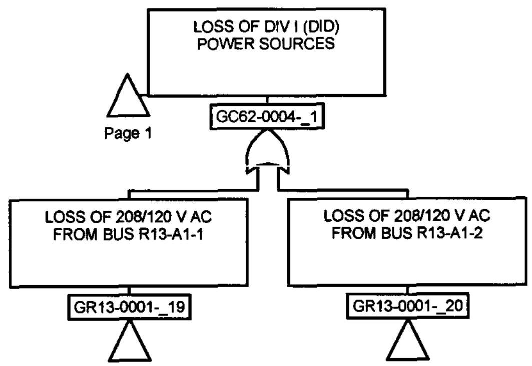
Name	Page	Zone
B21-LT -CF-DPSWR	1	6
B21-LT -CF-DPSWR	2	5
B21-LT -NO-DPSWRA	3	1
B21-LT -NO-DPSWRB	4	1
B21-LT -NO-DPSWRC	5	1
B21-LT -NO-DPSWRD	6	1
B21-OR -PG-01A	3	2
B21-OR -PG-01B	4	2
B21-OR -PG-01C	5	2
B21-OR -PG-01D	6	2
B21-XHE-FO-ADS	7	3
C51-ACT-CF-APRMSTUCK	1	4
C51-ACT-CF-APRMSTUCK	2	3
C72-DTM-CF-DPSALL	3	2
C72-DTM-CF-DPSALL	4	2
C72-DTM-CF-DPSALL	5	2
C72-DTM-CF-DPSALL	6	2
C72-DTM-FC-DPSDIV1	3	1
C72-DTM-FC-DPSDIV2	4	1
C72-DTM-FC-DPSDIV3	5	1
C72-DTM-FC-DPSDIV4	6	1
GC72-0001- 1	2	4
GC72-0001- 2	1	5
GC72-0001- 5	2	3
GC72-0001- 6	1	5
GC72-0100- 1	2	2
GC72-0102- 1	1	4
GC72-0102- 1	7	3
GC72-0105- 1	1	2
GC72-0106- 1	1	3
GC72-0110- 1	1	1
GC72-0110- 1	3	2
GC72-0111- 1	1	1
GC72-0111- 1	4	2
GC72-0112- 1	1	2
GC72-0112- 1	5	2
GC72-0113- 1	1	2
GC72-0113- 1	6	2
GC72-0114- 1	3	2
GC72-0115- 1	4	2
GC72-0116- 1	5	2
GC72-0117- 1	6	2
GC72-0150- 1	7	2
GC72-0200- 1	1	2
GC72-0200- 1	2	1
GC72-0201- 1	1	4
GC72-0201- 1	2	2
GR13-0001- 1	3	3
GR13-0001- 3	4	3
GR13-0001- 5	5	3
GR13-0001- 7	6	3
H23-EMS-FC-DPSDIV1	3	1
H23-EMS-FC-DPSDIV2	4	1
H23-EMS-FC-DPSDIV3	5	1
H23-EMS-FC-DPSDIV4	6	1
H23-RMU-FC-DPS1ADS	7	1
H23-RMU-FC-DPS2ADS	7	2
H23-RMU-FC-DPSDIV1	3	2
H23-RMU-FC-DPSDIV2	4	2
H23-RMU-FC-DPSDIV3	5	2
H23-RMU-FC-DPSDIV4	6	2
XHOSMAN	7	4
XHOSMDS	1	3
XHOSMDS	1	5

Appendix B.4.5-11

I&C Systems - C62 - DIV A SIGNAL TRANSMISSION FAILURE

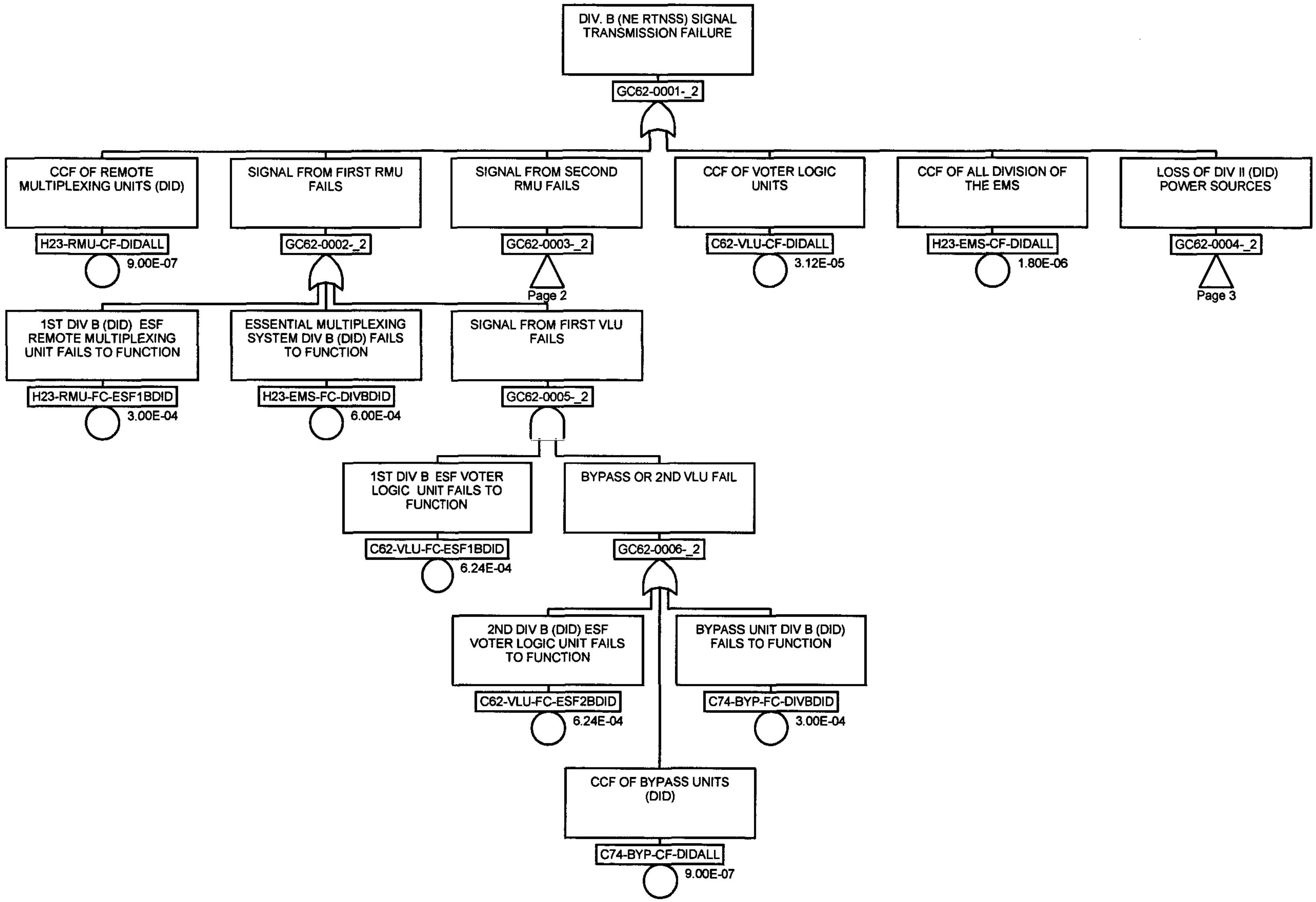

DIV. A (NE RTNSS) SIGNAL TRANSMISSION FAILURE
GC62-0001-_1
CCF OF REMOTE MULTIPLEXING UNITS (DID)
H23-RMU-CF-DIDALL
9.00E-07
SIGNAL FROM FIRST RMU FAILS
GC62-0002-_1
SIGNAL FROM SECOND RMU FAILS
GC62-0003-_1
Page 2
CCF OF VOTER LOGIC UNITS
C62-VLU-CF-DIDALL
3.12E-05
CCF OF ALL DIVISION OF THE EMS
H23-EMS-CF-DIDALL
1.80E-06
LOSS OF DIV I (DID) POWER SOURCES
GC62-0004-_1
Page 3
1ST DIV A (DID) ESF REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION
H23-RMU-FC-ESF1ADID
3.00E-04
ESSENTIAL MULTIPLEXING SYSTEM DIV A (DID) FAILS TO FUNCTION
H23-EMS-FC-DIVADID
6.00E-04
SIGNAL FROM FIRST VLU FAILS
GC62-0005-_1
1ST DIV A ESF VOTER LOGIC UNIT FAILS TO FUNCTION
C62-VLU-FC-ESF1ADID
6.24E-04
BYPASS OR 2ND VLU FAIL
GC62-0006-_1
2ND DIV A (DID) ESF VOTER LOGIC UNIT FAILS TO FUNCTION
C62-VLU-FC-ESF2ADID
6.24E-04
BYPASS UNIT DIV A (DID) FAILS TO FUNCTION
C74-BYP-FC-DIVADID
3.00E-04
CCF OF BYPASS UNITS (DID)
C74-BYP-CF-DIDALL
9.00E-07
1
2
3
4
5
6

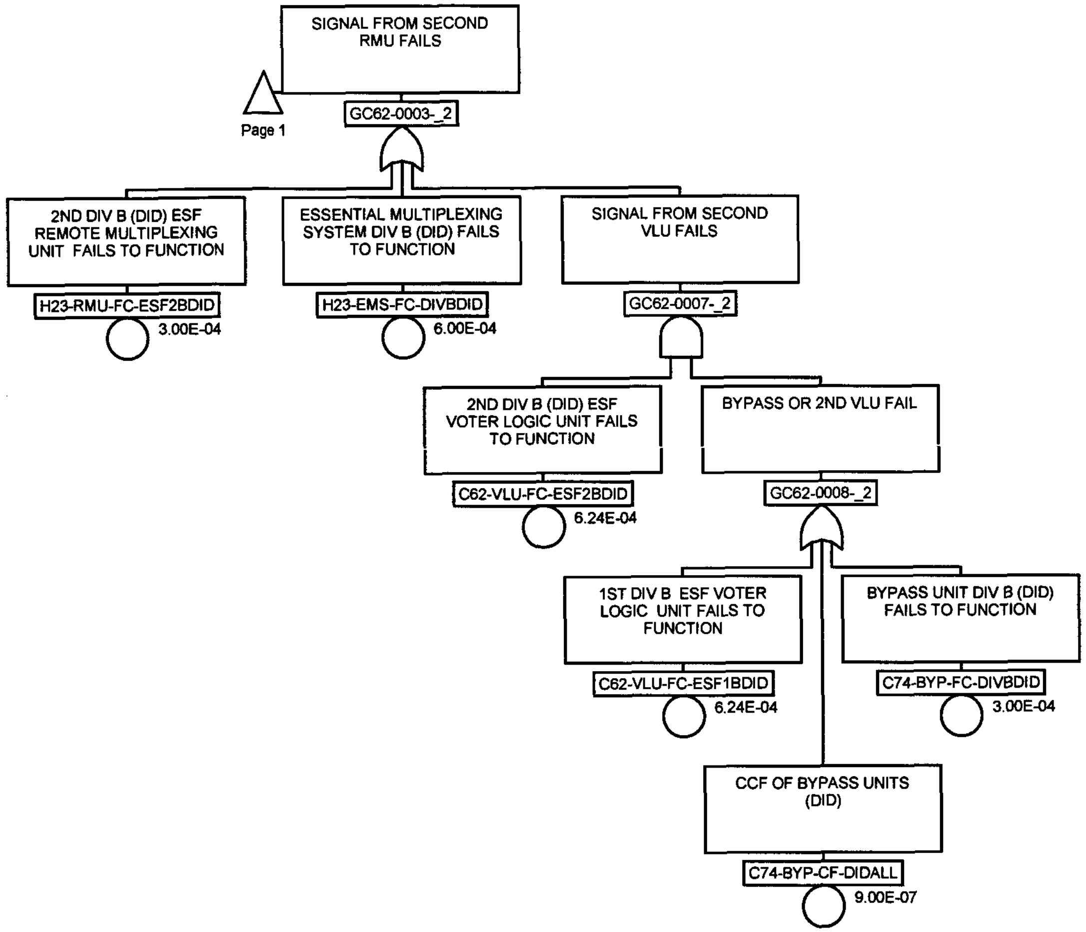

SIGNAL FROM SECOND RMU FAILS
GC62-0003-_1
Page 1
2ND DIV A (DID) ESF REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION
H23-RMU-FC-ESF2ADID
3.00E-04
ESSENTIAL MULTIPLEXING SYSTEM DIV A (DID) FAILS TO FUNCTION
H23-EMS-FC-DIVADID
6.00E-04
SIGNAL FROM SECOND VLU FAILS
GC62-0007-_1
2ND DIV A (DID) ESF VOTER LOGIC UNIT FAILS TO FUNCTION
C62-VLU-FC-ESF2ADID
6.24E-04
BYPASS OR 2ND VLU FAIL
GC62-0008-_1
1ST DIV A ESF VOTER LOGIC UNIT FAILS TO FUNCTION
C62-VLU-FC-ESF1ADID
6.24E-04
BYPASS UNIT DIV A (DID) FAILS TO FUNCTION
C74-BYP-FC-DIVADID
3.00E-04
CCF OF BYPASS UNITS (DID)
C74-BYP-CF-DIDALL
9.00E-07

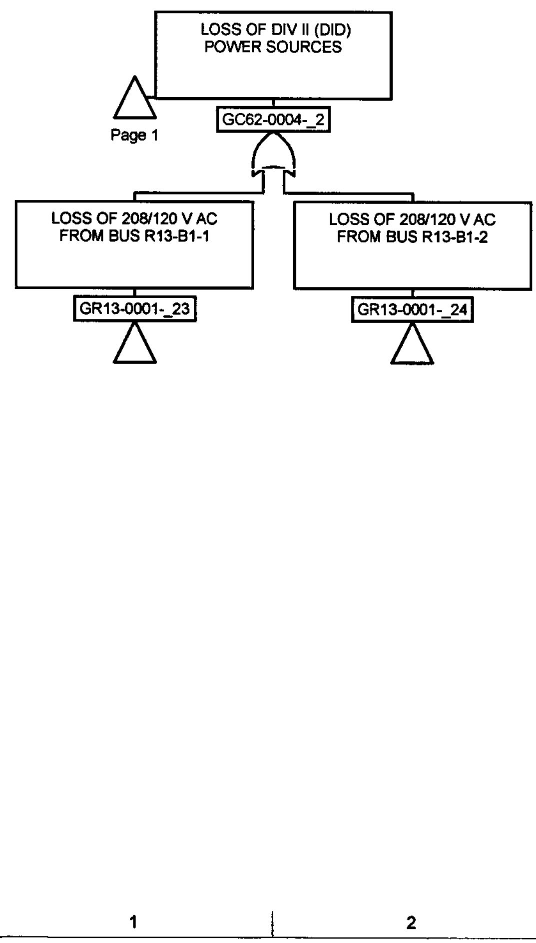

LOSS OF DIV I (DID)
POWER SOURCES
GC62-0004-_1
Page 1
LOSS OF 208/120 V AC
FROM BUS R13-A1-1
GR13-0001-_19
LOSS OF 208/120 V AC
FROM BUS R13-A1-2
GR13-0001-_20

Appendix B.4.5-12

I&C Systems - C62 - DIV B SIGNAL TRANSMISSION FAILURE


DIV. B (NE RTNSS) SIGNAL TRANSMISSION FAILURE
GC62-0001-_2
CCF OF REMOTE MULTIPLEXING UNITS (DID)
H23-RMU-CF-DIDALL
9.00E-07
SIGNAL FROM FIRST RMU FAILS
GC62-0002-_2
SIGNAL FROM SECOND RMU FAILS
GC62-0003-_2
Page 2
CCF OF VOTER LOGIC UNITS
C62-VLU-CF-DIDALL
3.12E-05
CCF OF ALL DIVISION OF THE EMS
H23-EMS-CF-DIDALL
1.80E-06
LOSS OF DIV II (DID) POWER SOURCES
GC62-0004-_2
Page 3
1ST DIV B (DID) ESF REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION
H23-RMU-FC-ESF1BDID
3.00E-04
ESSENTIAL MULTIPLEXING SYSTEM DIV B (DID) FAILS TO FUNCTION
H23-EMS-FC-DIVBDID
6.00E-04
SIGNAL FROM FIRST VLU FAILS
GC62-0005-_2
1ST DIV B ESF VOTER LOGIC UNIT FAILS TO FUNCTION
C62-VLU-FC-ESF1BDID
6.24E-04
BYPASS OR 2ND VLU FAIL
GC62-0006-_2
2ND DIV B (DID) ESF VOTER LOGIC UNIT FAILS TO FUNCTION
C62-VLU-FC-ESF2BDID
6.24E-04
BYPASS UNIT DIV B (DID) FAILS TO FUNCTION
C74-BYP-FC-DIVBDID
3.00E-04
CCF OF BYPASS UNITS (DID)
C74-BYP-CF-DIDALL
9.00E-07
1
2
3
4
5
6

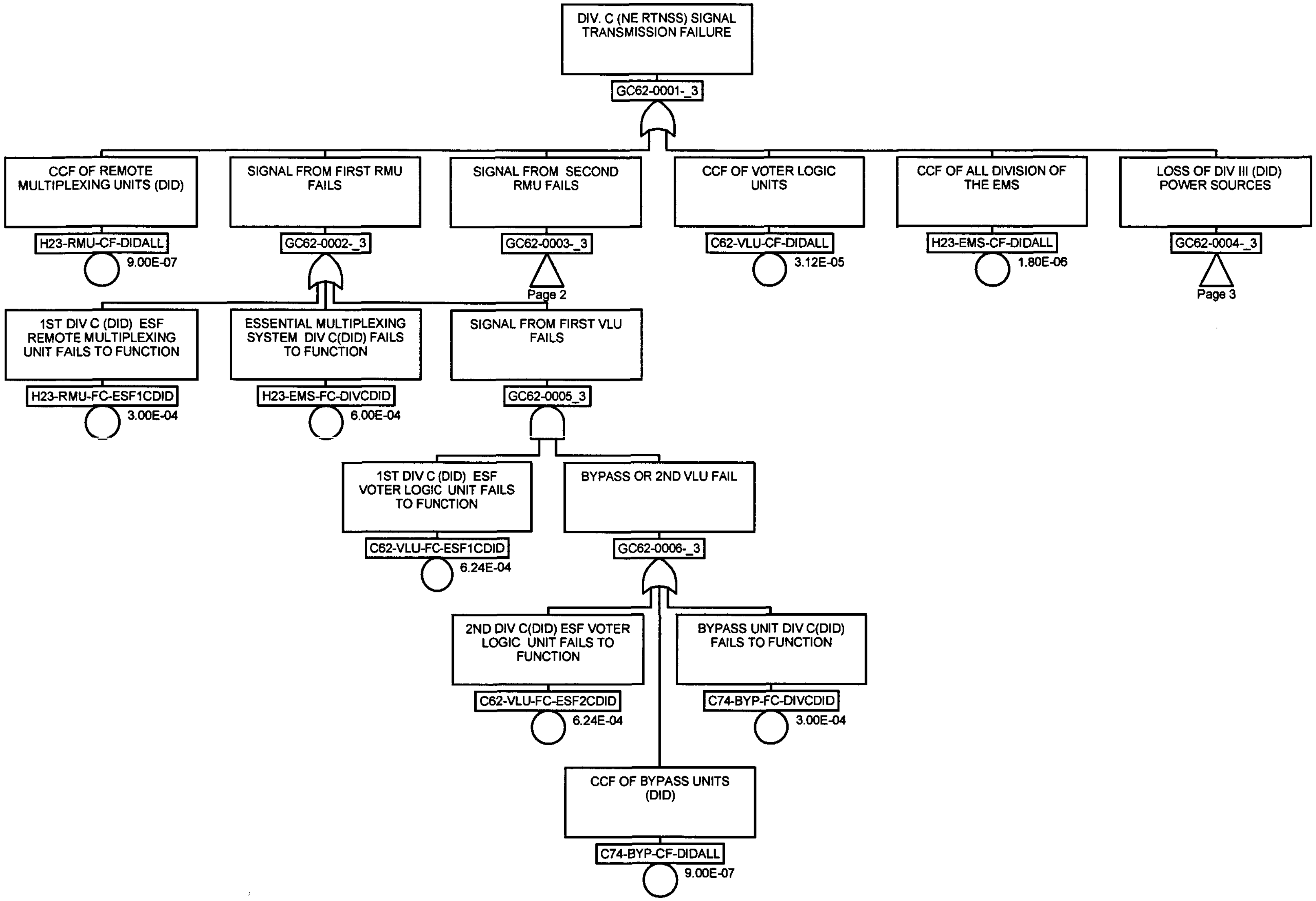

SIGNAL FROM SECOND RMU FAILS
Page 1
GC62-0003-_2
2ND DIV B (DID) ESF REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION
H23-RMU-FC-ESF2BDID
3.00E-04
ESSENTIAL MULTIPLEXING SYSTEM DIV B (DID) FAILS TO FUNCTION
H23-EMS-FC-DIVBDID
6.00E-04
SIGNAL FROM SECOND VLU FAILS
GC62-0007-_2
2ND DIV B (DID) ESF VOTER LOGIC UNIT FAILS TO FUNCTION
C62-VLU-FC-ESF2BDID
6.24E-04
BYPASS OR 2ND VLU FAIL
GC62-0008-_2
1ST DIV B ESF VOTER LOGIC UNIT FAILS TO FUNCTION
C62-VLU-FC-ESF1BDID
6.24E-04
BYPASS UNIT DIV B (DID) FAILS TO FUNCTION
C74-BYP-FC-DIVBDID
3.00E-04
CCF OF BYPASS UNITS (DID)
C74-BYP-CF-DIDALL
9.00E-07

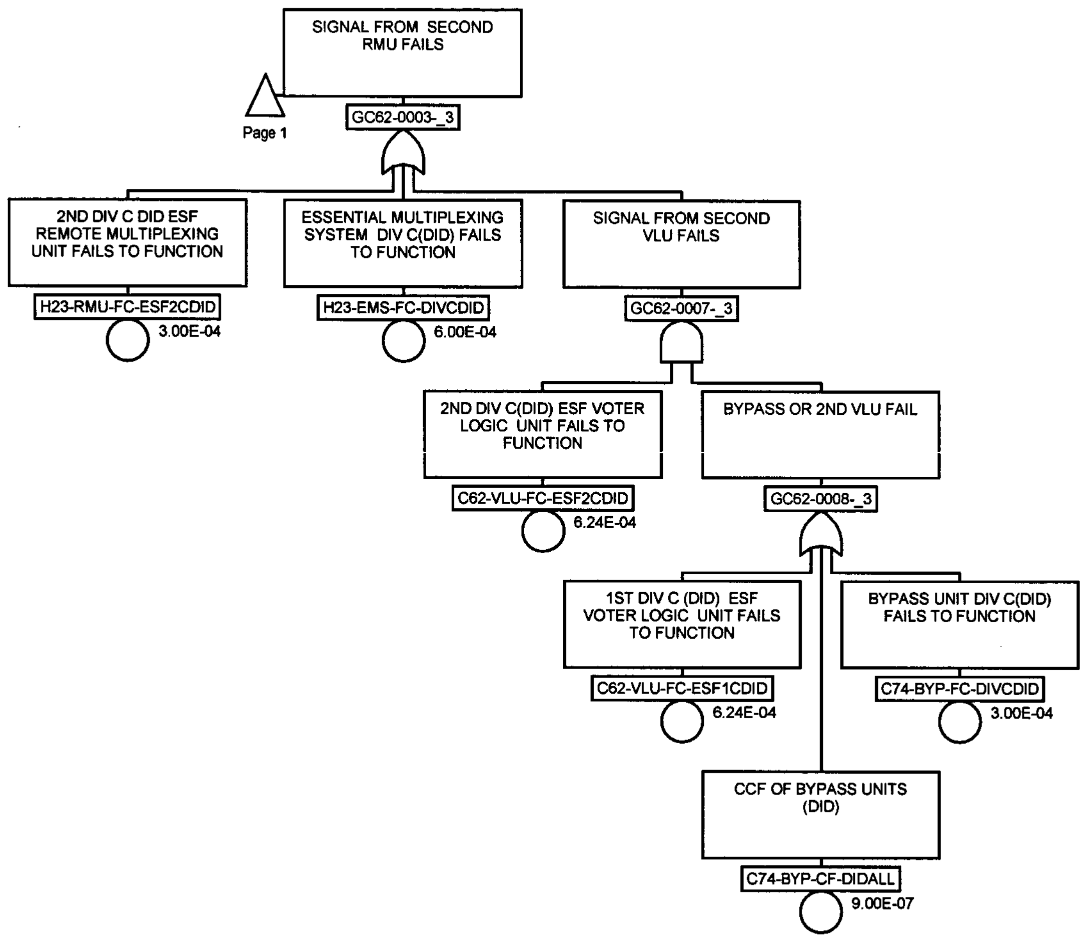

LOSS OF DIV II (DID)
POWER SOURCES
GC62-0004-_2
Page 1
LOSS OF 208/120 V AC
FROM BUS R13-B1-1
GR13-0001-_23
LOSS OF 208/120 V AC
FROM BUS R13-B1-2
GR13-0001-_24
1
2

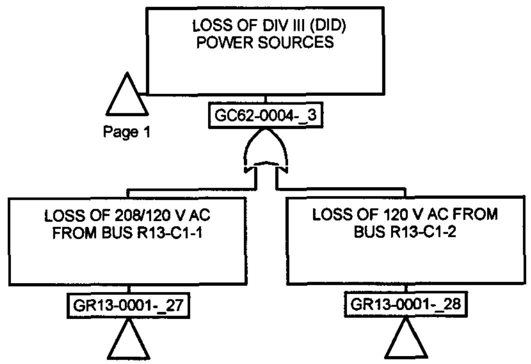
Name	Page	Zone	Name	Page	Zone	Name	Page	Zone
C62-VLU-CF-DIDALL	1	4						
C62-VLU-FC-ESF1BDID	1	3						
C62-VLU-FC-ESF1BDID	2	3						
C62-VLU-FC-ESF2BDID	1	3						
C62-VLU-FC-ESF2BDID	2	3						
C74-BYP-CF-DIDALL	1	4						
C74-BYP-CF-DIDALL	2	4						
C74-BYP-FC-DIVBDID	1	4						
C74-BYP-FC-DIVBDID	2	4						
GC62-0001- 2	1	4						
GC62-0002- 2	1	2						
GC62-0003- 2	1	3						
GC62-0003- 2	2	2						
GC62-0004- 2	1	6						
GC62-0004- 2	3	2						
GC62-0005- 2	1	3						
GC62-0006- 2	1	4						
GC62-0007- 2	2	3						
GC62-0008- 2	2	4						
GR13-0001- 23	3	1						
GR13-0001- 24	3	2						
H23-EMS-CF-DIDALL	1	5						
H23-EMS-FC-DIVBDID	1	2						
H23-EMS-FC-DIVBDID	2	2						
H23-RMU-CF-DIDALL	1	1						
H23-RMU-FC-ESF1BDID	1	1						
H23-RMU-FC-ESF2BDID	2	1						

Appendix B.4.5-13

I&C Systems - C62 - DIV C SIGNAL TRANSMISSION FAILURE


DIV. C (NE RTNSS) SIGNAL TRANSMISSION FAILURE
GC62-0001-_3
CCF OF REMOTE MULTIPLEXING UNITS (DID)
H23-RMU-CF-DIDALL
9.00E-07
SIGNAL FROM FIRST RMU FAILS
GC62-0002-_3
SIGNAL FROM SECOND RMU FAILS
GC62-0003-_3
Page 2
CCF OF VOTER LOGIC UNITS
C62-VLU-CF-DIDALL
3.12E-05
CCF OF ALL DIVISION OF THE EMS
H23-EMS-CF-DIDALL
1.80E-06
LOSS OF DIV III (DID) POWER SOURCES
GC62-0004-_3
Page 3
1ST DIV C (DID) ESF REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION
H23-RMU-FC-ESF1CDID
3.00E-04
ESSENTIAL MULTIPLEXING SYSTEM DIV C(DID) FAILS TO FUNCTION
H23-EMS-FC-DIVCDID
6.00E-04
SIGNAL FROM FIRST VLU FAILS
GC62-0005_3
1ST DIV C (DID) ESF VOTER LOGIC UNIT FAILS TO FUNCTION
C62-VLU-FC-ESF1CDID
6.24E-04
BYPASS OR 2ND VLU FAIL
GC62-0006-_3
2ND DIV C(DID) ESF VOTER LOGIC UNIT FAILS TO FUNCTION
C62-VLU-FC-ESF2CDID
6.24E-04
BYPASS UNIT DIV C(DID) FAILS TO FUNCTION
C74-BYP-FC-DIVCDID
3.00E-04
CCF OF BYPASS UNITS (DID)
C74-BYP-CF-DIDALL
9.00E-07
1
2
3
4
5
6


SIGNAL FROM SECOND RMU FAILS
GC62-0003-_3
Page 1
2ND DIV C DID ESF REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION
H23-RMU-FC-ESF2CDID
3.00E-04
ESSENTIAL MULTIPLEXING SYSTEM DIV C(DID) FAILS TO FUNCTION
H23-EMS-FC-DIVCDID
6.00E-04
SIGNAL FROM SECOND VLU FAILS
GC62-0007-_3
2ND DIV C(DID) ESF VOTER LOGIC UNIT FAILS TO FUNCTION
C62-VLU-FC-ESF2CDID
6.24E-04
BYPASS OR 2ND VLU FAIL
GC62-0008-_3
1ST DIV C (DID) ESF VOTER LOGIC UNIT FAILS TO FUNCTION
C62-VLU-FC-ESF1CDID
6.24E-04
BYPASS UNIT DIV C(DID) FAILS TO FUNCTION
C74-BYP-FC-DIVCDID
3.00E-04
CCF OF BYPASS UNITS (DID)
C74-BYP-CF-DIDALL
9.00E-07
1
2
3
4

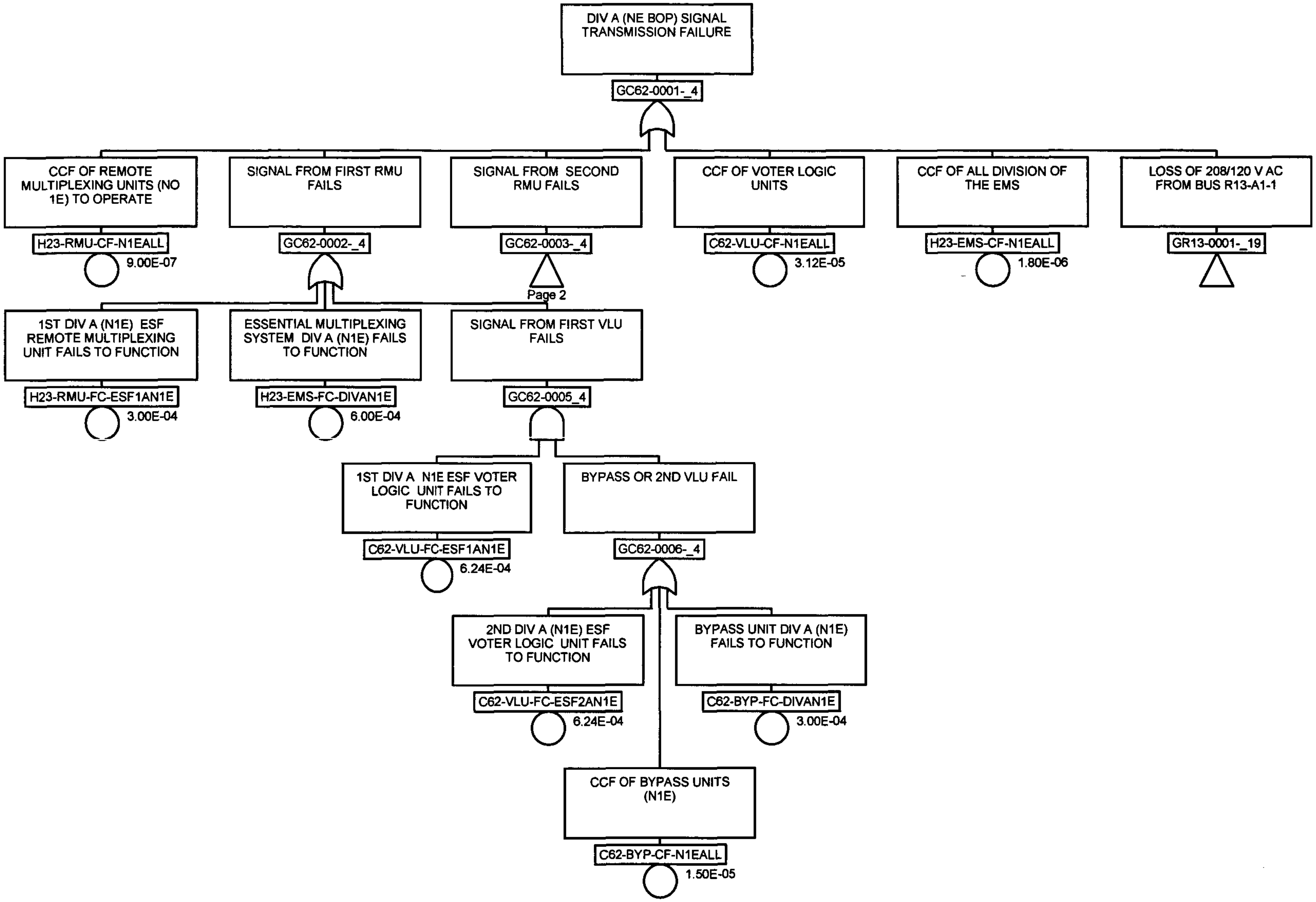


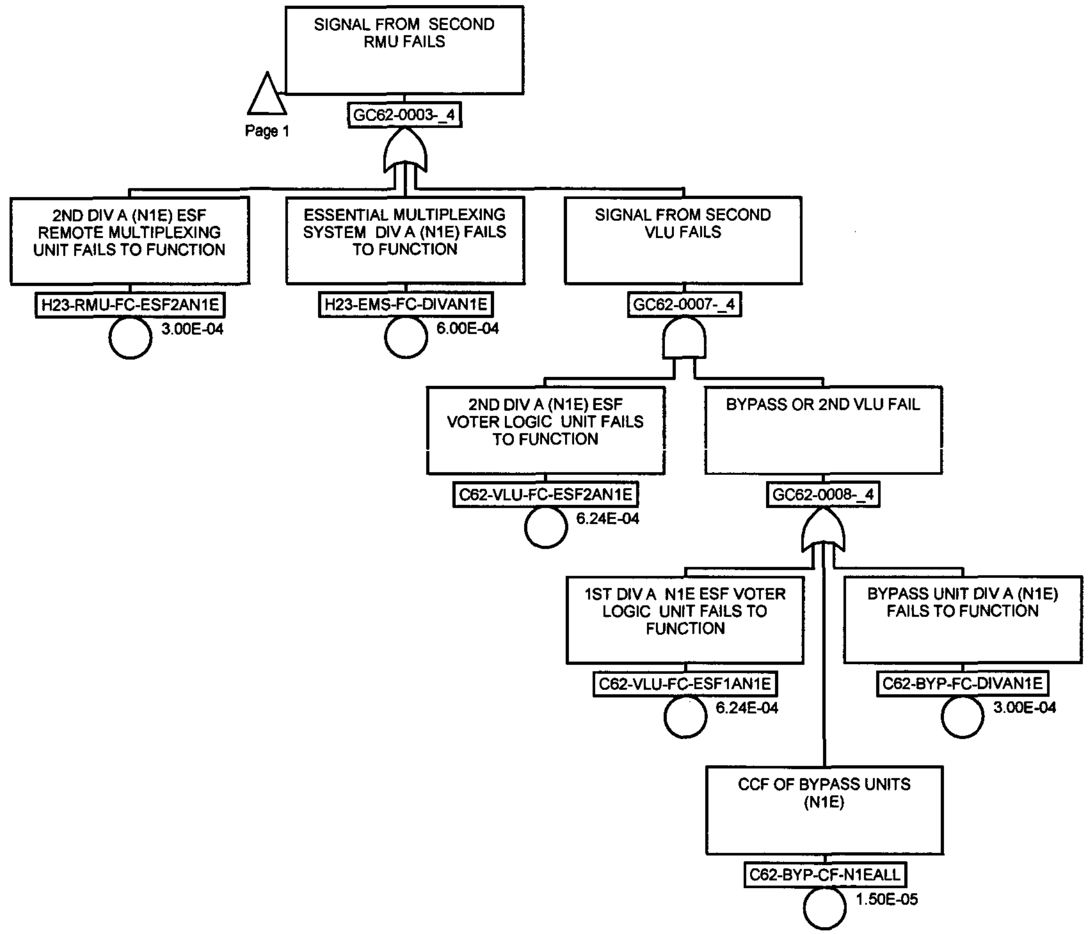
LOSS OF DIV III (DID) POWER SOURCES
Page 1
GC62-0004-_3
LOSS OF 208/120 V AC FROM BUS R13-C1-1
GR13-0001-_27
LOSS OF 120 V AC FROM BUS R13-C1-2
GR13-0001-_28

Name	Page	Zone	Name	Page	Zone	Name	Page	Zone
C62-VLU-CF-DIDALL	1	4						
C62-VLU-FC-ESF1CDID	1	3						
C62-VLU-FC-ESF1CDID	2	3						
C62-VLU-FC-ESF2CDID	1	3						
C62-VLU-FC-ESF2CDID	2	3						
C74-BYP-CF-DIDALL	1	4						
C74-BYP-CF-DIDALL	2	4						
C74-BYP-FC-DIVCDID	1	4						
C74-BYP-FC-DIVCDID	2	4						
GC62-0001- 3	1	4						
GC62-0002- 3	1	2						
GC62-0003- 3	1	3						
GC62-0003- 3	2	2						
GC62-0004- 3	1	6						
GC62-0004- 3	3	2						
GC62-0005 3	1	3						
GC62-0006- 3	1	4						
GC62-0007- 3	2	3						
GC62-0008- 3	2	4						
GR13-0001- 27	3	1						
GR13-0001- 28	3	2						
H23-EMS-CF-DIDALL	1	5						
H23-EMS-FC-DIVCDID	1	2						
H23-EMS-FC-DIVCDID	2	2						
H23-RMU-CF-DIDALL	1	1						
H23-RMU-FC-ESF1CDID	1	1						
H23-RMU-FC-ESF2CDID	2	1						

Appendix B.4.5-14

I&C - C62 - DIV A NE-BOP SIGNAL TRANSMISSION FAILURE

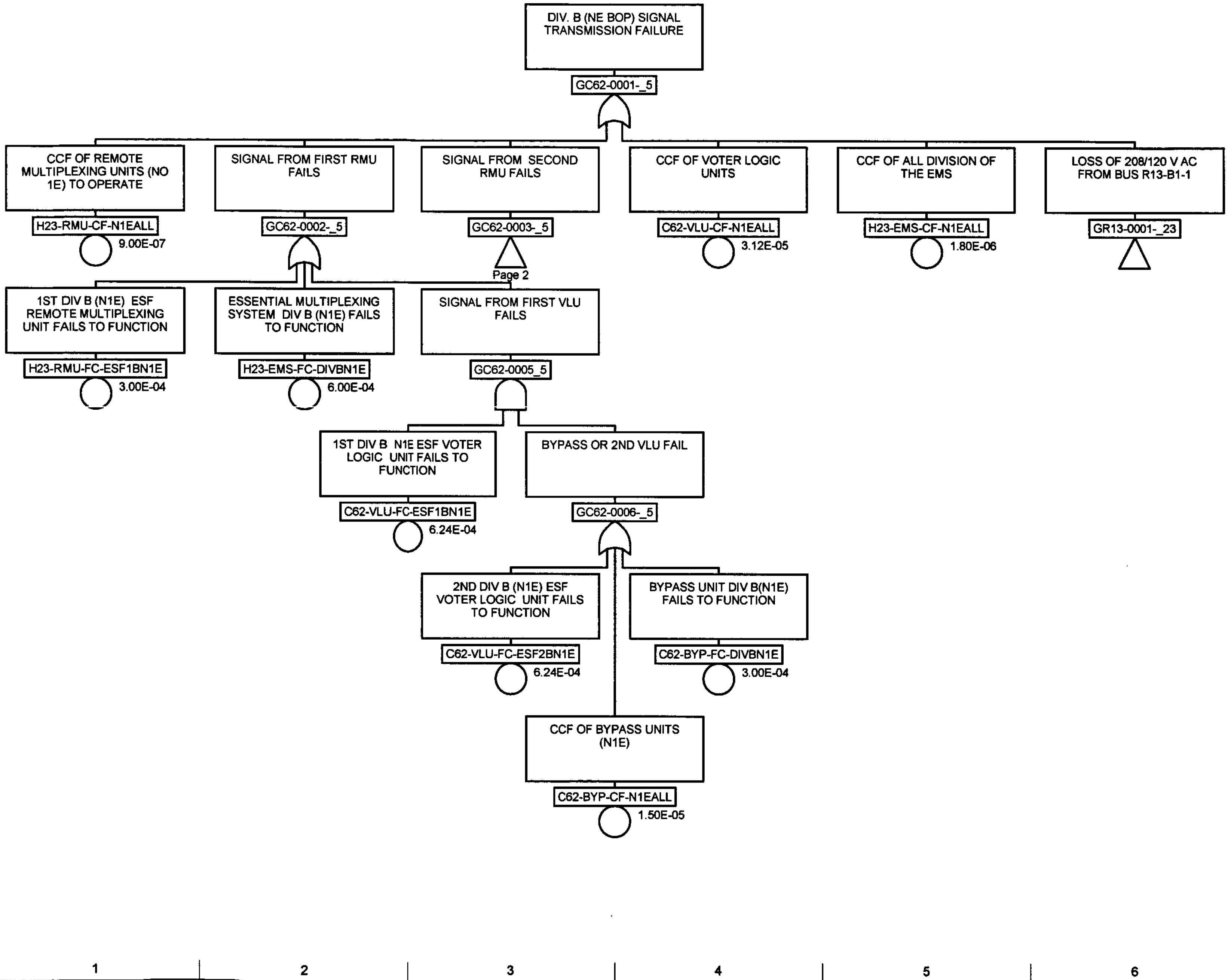

DIV A (NE BOP) SIGNAL TRANSMISSION FAILURE
GC62-0001-_4
CCF OF REMOTE MULTIPLEXING UNITS (NO 1E) TO OPERATE
H23-RMU-CF-N1EALL
9.00E-07
SIGNAL FROM FIRST RMU FAILS
GC62-0002-_4
SIGNAL FROM SECOND RMU FAILS
GC62-0003-_4
Page 2
CCF OF VOTER LOGIC UNITS
C62-VLU-CF-N1EALL
3.12E-05
CCF OF ALL DIVISION OF THE EMS
H23-EMS-CF-N1EALL
1.80E-06
LOSS OF 208/120 V AC FROM BUS R13-A1-1
GR13-0001-_19
1ST DIV A (N1E) ESF REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION
H23-RMU-FC-ESF1AN1E
3.00E-04
ESSENTIAL MULTIPLEXING SYSTEM DIV A (N1E) FAILS TO FUNCTION
H23-EMS-FC-DIVAN1E
6.00E-04
SIGNAL FROM FIRST VLU FAILS
GC62-0005_4
1ST DIV A N1E ESF VOTER LOGIC UNIT FAILS TO FUNCTION
C62-VLU-FC-ESF1AN1E
6.24E-04
BYPASS OR 2ND VLU FAIL
GC62-0006-_4
2ND DIV A (N1E) ESF VOTER LOGIC UNIT FAILS TO FUNCTION
C62-VLU-FC-ESF2AN1E
6.24E-04
BYPASS UNIT DIV A (N1E) FAILS TO FUNCTION
C62-BYP-FC-DIVAN1E
3.00E-04
CCF OF BYPASS UNITS (N1E)
C62-BYP-CF-N1EALL
1.50E-05
1
2
3
4
5
6

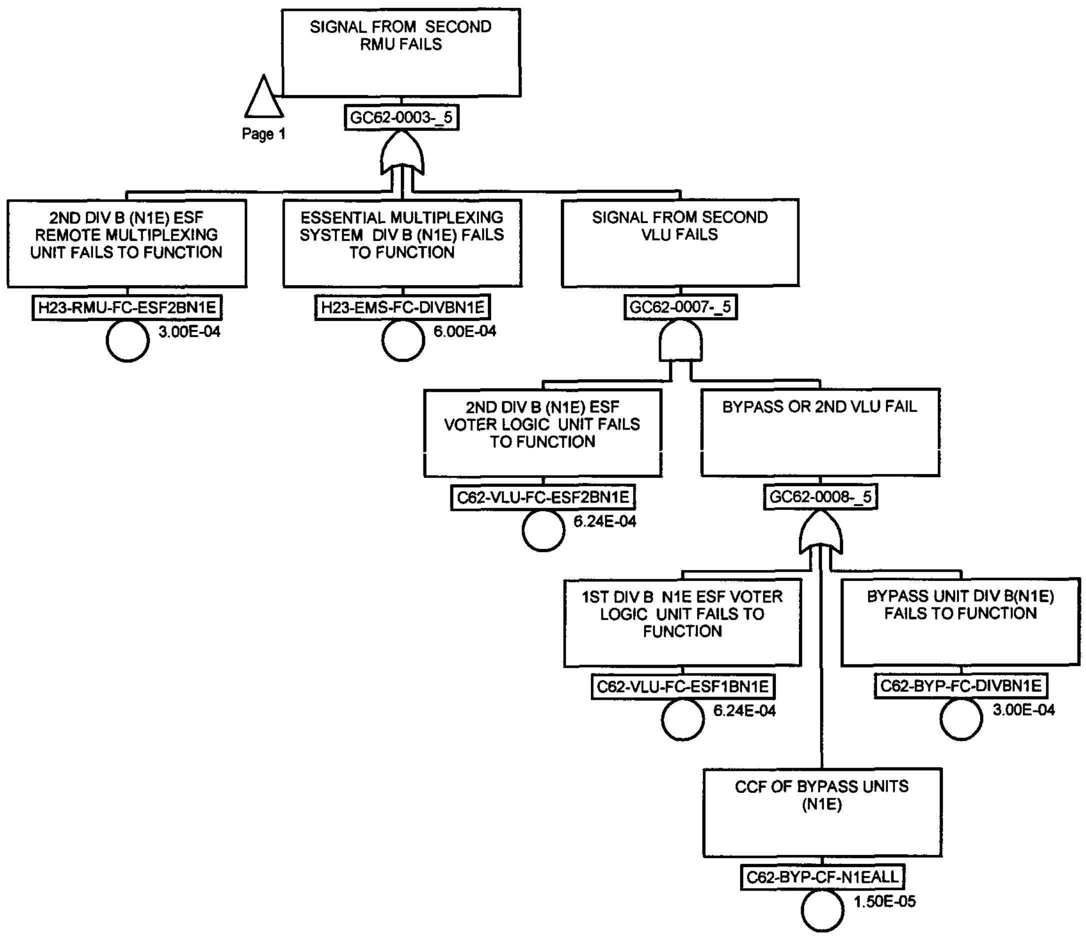

SIGNAL FROM SECOND RMU FAILS
GC62-0003-_4
Page 1
2ND DIV A (N1E) ESF REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION
H23-RMU-FC-ESF2AN1E
3.00E-04
ESSENTIAL MULTIPLEXING SYSTEM DIV A (N1E) FAILS TO FUNCTION
H23-EMS-FC-DIVAN1E
6.00E-04
SIGNAL FROM SECOND VLU FAILS
GC62-0007-_4
2ND DIV A (N1E) ESF VOTER LOGIC UNIT FAILS TO FUNCTION
C62-VLU-FC-ESF2AN1E
6.24E-04
BYPASS OR 2ND VLU FAIL
GC62-0008-_4
1ST DIV A N1E ESF VOTER LOGIC UNIT FAILS TO FUNCTION
C62-VLU-FC-ESF1AN1E
6.24E-04
BYPASS UNIT DIV A (N1E) FAILS TO FUNCTION
C62-BYP-FC-DIVAN1E
3.00E-04
CCF OF BYPASS UNITS (N1E)
C62-BYP-CF-N1EALL
1.50E-05
1
2
3
4

Name	Page	Zone	Name	Page	Zone	Name	Page	Zone
C62-BYP-CF-N1EALL	1	4						
C62-BYP-CF-N1EALL	2	4						
C62-BYP-FC-DIVAN1E	1	4						
C62-BYP-FC-DIVAN1E	2	4						
C62-VLU-CF-N1EALL	1	4						
C62-VLU-FC-ESF1AN1E	1	3						
C62-VLU-FC-ESF1AN1E	2	3						
C62-VLU-FC-ESF2AN1E	1	3						
C62-VLU-FC-ESF2AN1E	2	3						
GC62-0001- 4	1	4						
GC62-0002- 4	1	2						
GC62-0003- 4	1	3						
GC62-0003- 4	2	2						
GC62-0005 4	1	3						
GC62-0006- 4	1	4						
GC62-0007- 4	2	3						
GC62-0008- 4	2	4						
GR13-0001- 19	1	6						
H23-EMS-CF-N1EALL	1	5						
H23-EMS-FC-DIVAN1E	1	2						
H23-EMS-FC-DIVAN1E	2	2						
H23-RMU-CF-N1EALL	1	1						
H23-RMU-FC-ESF1AN1E	1	1						
H23-RMU-FC-ESF2AN1E	2	1						

Appendix B.4.5-15

I&C - C62 - DIV B NE-BOP SIGNAL TRANSMISSION FAILURE

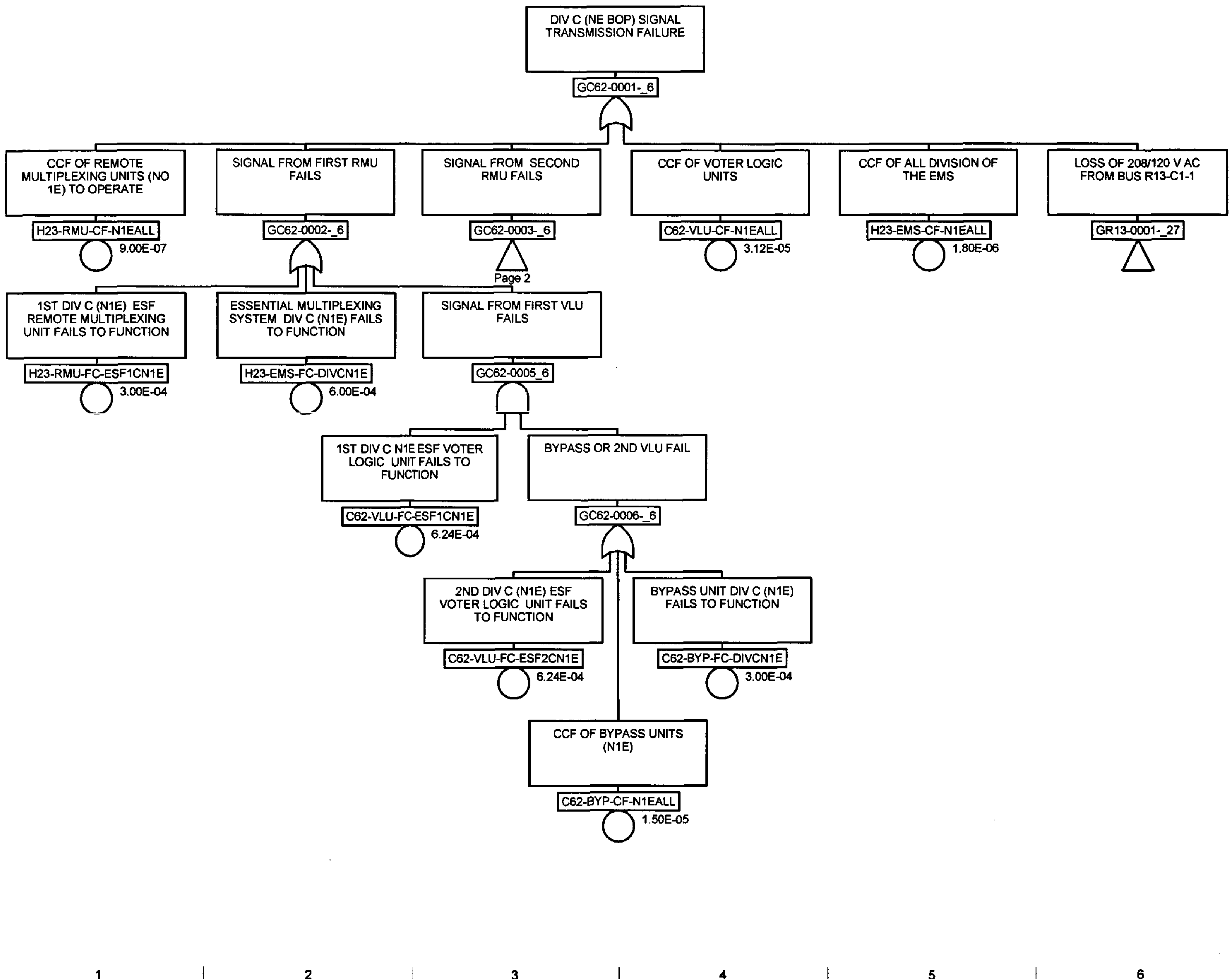

DIV. B (NE BOP) SIGNAL TRANSMISSION FAILURE
GC62-0001-_5
CCF OF REMOTE MULTIPLEXING UNITS (NO 1E) TO OPERATE
H23-RMU-CF-N1EALL
9.00E-07
SIGNAL FROM FIRST RMU FAILS
GC62-0002-_5
SIGNAL FROM SECOND RMU FAILS
GC62-0003-_5
Page 2
CCF OF VOTER LOGIC UNITS
C62-VLU-CF-N1EALL
3.12E-05
CCF OF ALL DIVISION OF THE EMS
H23-EMS-CF-N1EALL
1.80E-06
LOSS OF 208/120 V AC FROM BUS R13-B1-1
GR13-0001-_23
1ST DIV B (N1E) ESF REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION
H23-RMU-FC-ESF1BN1E
3.00E-04
ESSENTIAL MULTIPLEXING SYSTEM DIV B (N1E) FAILS TO FUNCTION
H23-EMS-FC-DIVBN1E
6.00E-04
SIGNAL FROM FIRST VLU FAILS
GC62-0005_5
1ST DIV B N1E ESF VOTER LOGIC UNIT FAILS TO FUNCTION
C62-VLU-FC-ESF1BN1E
6.24E-04
BYPASS OR 2ND VLU FAIL
GC62-0006-_5
2ND DIV B (N1E) ESF VOTER LOGIC UNIT FAILS TO FUNCTION
C62-VLU-FC-ESF2BN1E
6.24E-04
BYPASS UNIT DIV B(N1E) FAILS TO FUNCTION
C62-BYP-FC-DIVBN1E
3.00E-04
CCF OF BYPASS UNITS (N1E)
C62-BYP-CF-N1EALL
1.50E-05
1
2
3
4
5
6

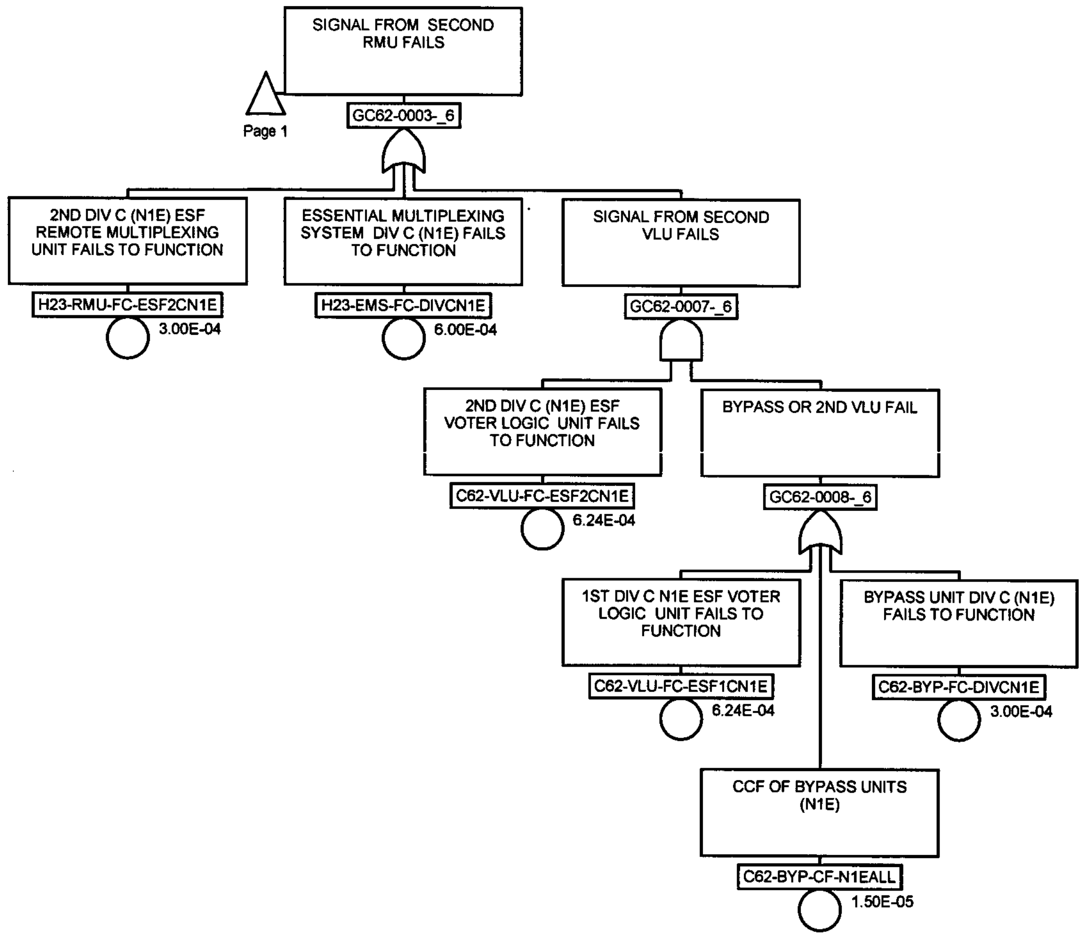


SIGNAL FROM SECOND RMU FAILS
GC62-0003-_5
Page 1
2ND DIV B (N1E) ESF REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION
H23-RMU-FC-ESF2BN1E
3.00E-04
ESSENTIAL MULTIPLEXING SYSTEM DIV B (N1E) FAILS TO FUNCTION
H23-EMS-FC-DIVBN1E
6.00E-04
SIGNAL FROM SECOND VLU FAILS
GC62-0007-_5
2ND DIV B (N1E) ESF VOTER LOGIC UNIT FAILS TO FUNCTION
C62-VLU-FC-ESF2BN1E
6.24E-04
BYPASS OR 2ND VLU FAIL
GC62-0008-_5
1ST DIV B N1E ESF VOTER LOGIC UNIT FAILS TO FUNCTION
C62-VLU-FC-ESF1BN1E
6.24E-04
BYPASS UNIT DIV B(N1E) FAILS TO FUNCTION
C62-BYP-FC-DIVBN1E
3.00E-04
CCF OF BYPASS UNITS (N1E)
C62-BYP-CF-N1EALL
1.50E-05
1
2
3
4

Appendix B.4.5-16

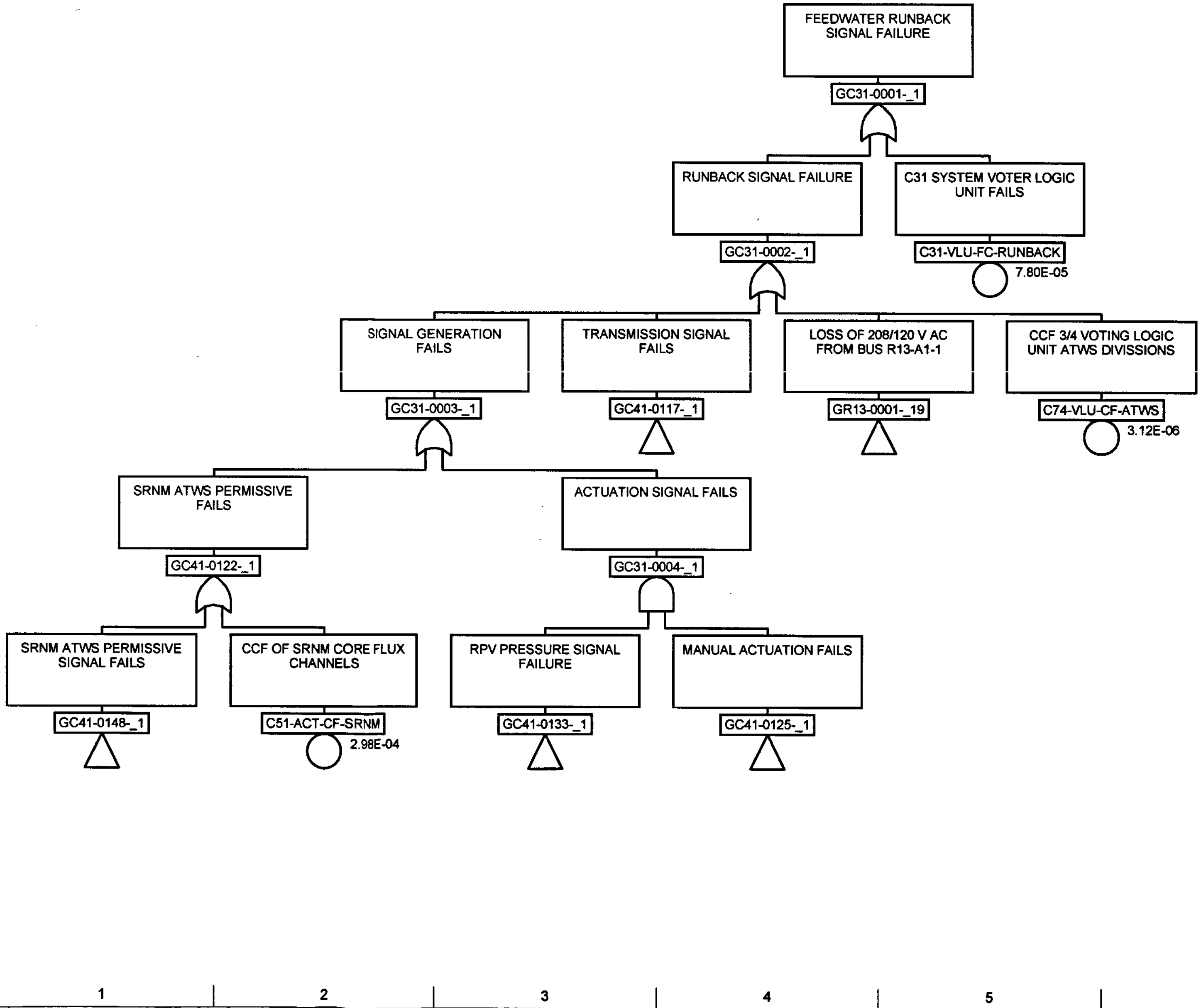
I&C - C62 - DIV C NE-BOP SIGNAL TRANSMISSION FAILURE


DIV C (NE BOP) SIGNAL TRANSMISSION FAILURE
GC62-0001-_6
CCF OF REMOTE MULTIPLEXING UNITS (NO 1E) TO OPERATE
H23-RMU-CF-N1EALL
9.00E-07
SIGNAL FROM FIRST RMU FAILS
GC62-0002-_6
SIGNAL FROM SECOND RMU FAILS
GC62-0003-_6
Page 2
CCF OF VOTER LOGIC UNITS
C62-VLU-CF-N1EALL
3.12E-05
CCF OF ALL DIVISION OF THE EMS
H23-EMS-CF-N1EALL
1.80E-06
LOSS OF 208/120 V AC FROM BUS R13-C1-1
GR13-0001-_27
1ST DIV C (N1E) ESF REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION
H23-RMU-FC-ESF1CN1E
3.00E-04
ESSENTIAL MULTIPLEXING SYSTEM DIV C (N1E) FAILS TO FUNCTION
H23-EMS-FC-DIVCN1E
6.00E-04
SIGNAL FROM FIRST VLU FAILS
GC62-0005_6
1ST DIV C N1E ESF VOTER LOGIC UNIT FAILS TO FUNCTION
C62-VLU-FC-ESF1CN1E
6.24E-04
BYPASS OR 2ND VLU FAIL
GC62-0006-_6
2ND DIV C (N1E) ESF VOTER LOGIC UNIT FAILS TO FUNCTION
C62-VLU-FC-ESF2CN1E
6.24E-04
BYPASS UNIT DIV C (N1E) FAILS TO FUNCTION
C62-BYP-FC-DIVCN1E
3.00E-04
CCF OF BYPASS UNITS (N1E)
C62-BYP-CF-N1EALL
1.50E-05
1
2
3
4
5
6


SIGNAL FROM SECOND RMU FAILS
Page 1
GC62-0003-_6
2ND DIV C (N1E) ESF REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION
H23-RMU-FC-ESF2CN1E
3.00E-04
ESSENTIAL MULTIPLEXING SYSTEM DIV C (N1E) FAILS TO FUNCTION
H23-EMS-FC-DIVCN1E
6.00E-04
SIGNAL FROM SECOND VLU FAILS
GC62-0007-_6
2ND DIV C (N1E) ESF VOTER LOGIC UNIT FAILS TO FUNCTION
C62-VLU-FC-ESF2CN1E
6.24E-04
BYPASS OR 2ND VLU FAIL
GC62-0008-_6
1ST DIV C N1E ESF VOTER LOGIC UNIT FAILS TO FUNCTION
C62-VLU-FC-ESF1CN1E
6.24E-04
BYPASS UNIT DIV C (N1E) FAILS TO FUNCTION
C62-BYP-FC-DIVCN1E
3.00E-04
CCF OF BYPASS UNITS (N1E)
C62-BYP-CF-N1EALL
1.50E-05

Appendix B.4.5-17

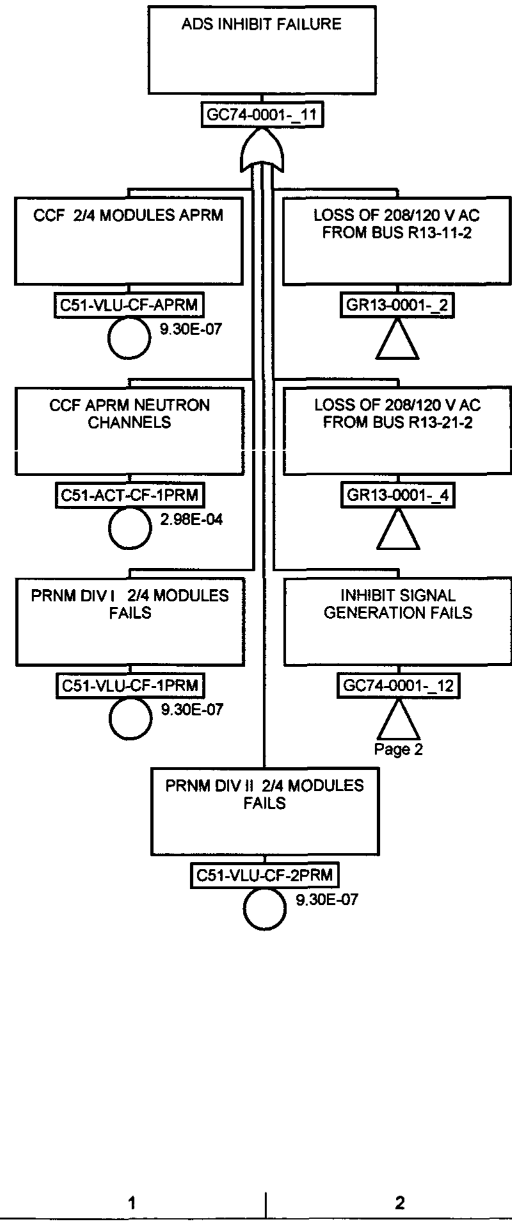
I&C Systems - C31 - FEEDWATER RUNBACK SIGNAL FAILURE

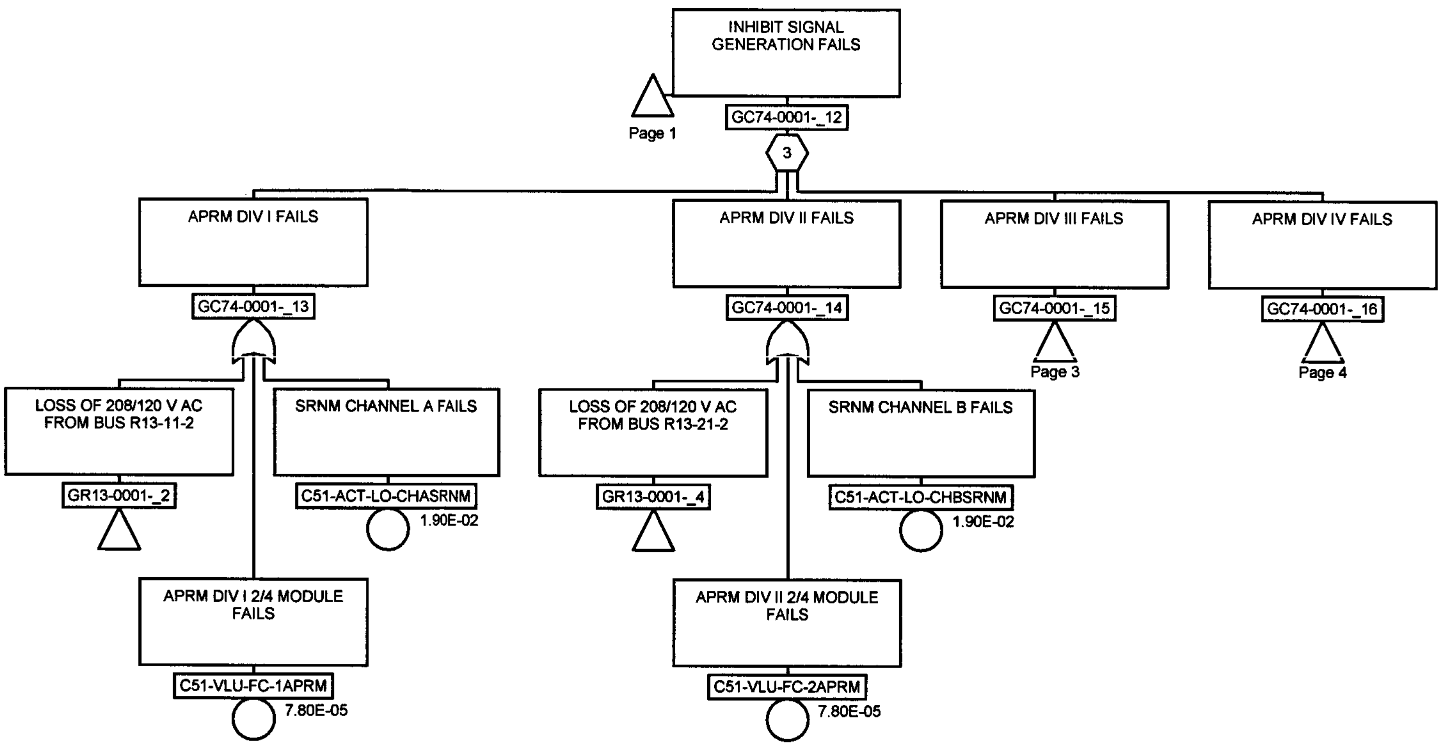

FEEDWATER RUNBACK SIGNAL FAILURE
GC31-0001-_1
RUNBACK SIGNAL FAILURE
GC31-0002-_1
C31 SYSTEM VOTER LOGIC UNIT FAILS
C31-VLU-FC-RUNBACK
7.80E-05
SIGNAL GENERATION FAILS
GC31-0003-_1
TRANSMISSION SIGNAL FAILS
GC41-0117-_1
LOSS OF 208/120 V AC FROM BUS R13-A1-1
GR13-0001-_19
CCF 3/4 VOTING LOGIC UNIT ATWS DIVISSIONS
C74-VLU-CF-ATWS
3.12E-06
SRNM ATWS PERMISSIVE FAILS
GC41-0122-_1
ACTUATION SIGNAL FAILS
GC31-0004-_1
SRNM ATWS PERMISSIVE SIGNAL FAILS
GC41-0148-_1
CCF OF SRNM CORE FLUX CHANNELS
C51-ACT-CF-SRNM
2.98E-04
RPV PRESSURE SIGNAL FAILURE
GC41-0133-_1
MANUAL ACTUATION FAILS
GC41-0125-_1
1
2
3
4
5

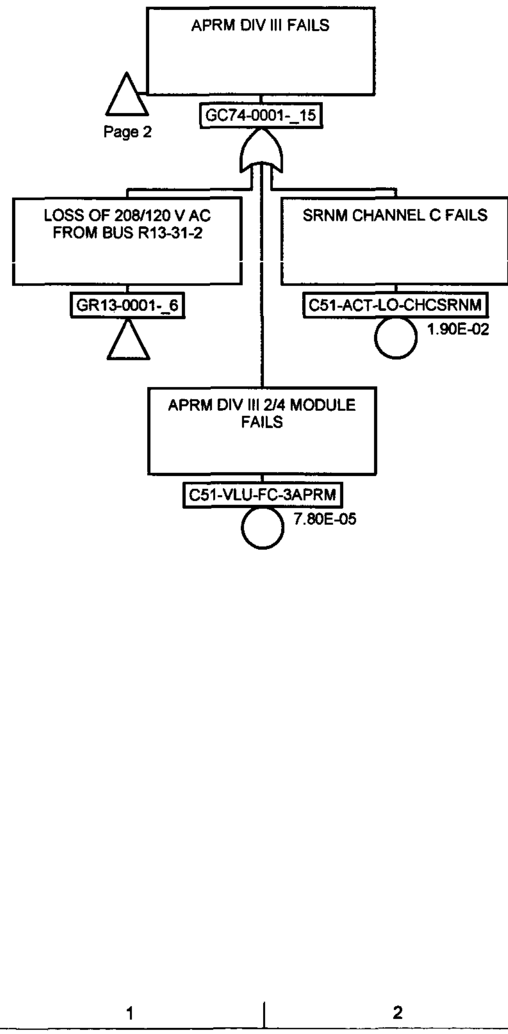
Name	Page	Zone	Name	Page	Zone
C31-VLU-FC-RUNBACK	1	5			
C51-ACT-CF-SRNM	1	2			
C74-VLU-CF-ATWS	1	5			
GC31-0001- 1	1	4			
GC31-0002- 1	1	4			
GC31-0003- 1	1	2			
GC31-0004- 1	1	4			
GC41-0117- 1	1	3			
GC41-0122- 1	1	2			
GC41-0125- 1	1	4			
GC41-0133- 1	1	3			
GC41-0148- 1	1	1			
GR13-0001-_19	1	4			

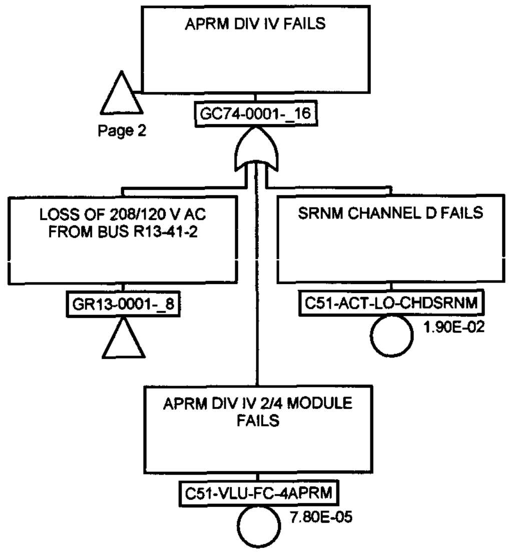
Appendix B.4.5-18

I&C System - C74 - ADS INHIBIT FAILURE


ADS INHIBIT FAILURE
GC74-0001-_11
CCF 2/4 MODULES APRM
C51-VLU-CF-APRM
9.30E-07
LOSS OF 208/120 V AC FROM BUS R13-11-2
GR13-0001-_2
CCF APRM NEUTRON CHANNELS
C51-ACT-CF-1PRM
2.98E-04
LOSS OF 208/120 V AC FROM BUS R13-21-2
GR13-0001-_4
PRNM DIV I 2/4 MODULES FAILS
C51-VLU-CF-1PRM
9.30E-07
INHIBIT SIGNAL GENERATION FAILS
GC74-0001-_12
Page 2
PRNM DIV II 2/4 MODULES FAILS
C51-VLU-CF-2PRM
9.30E-07
1
2

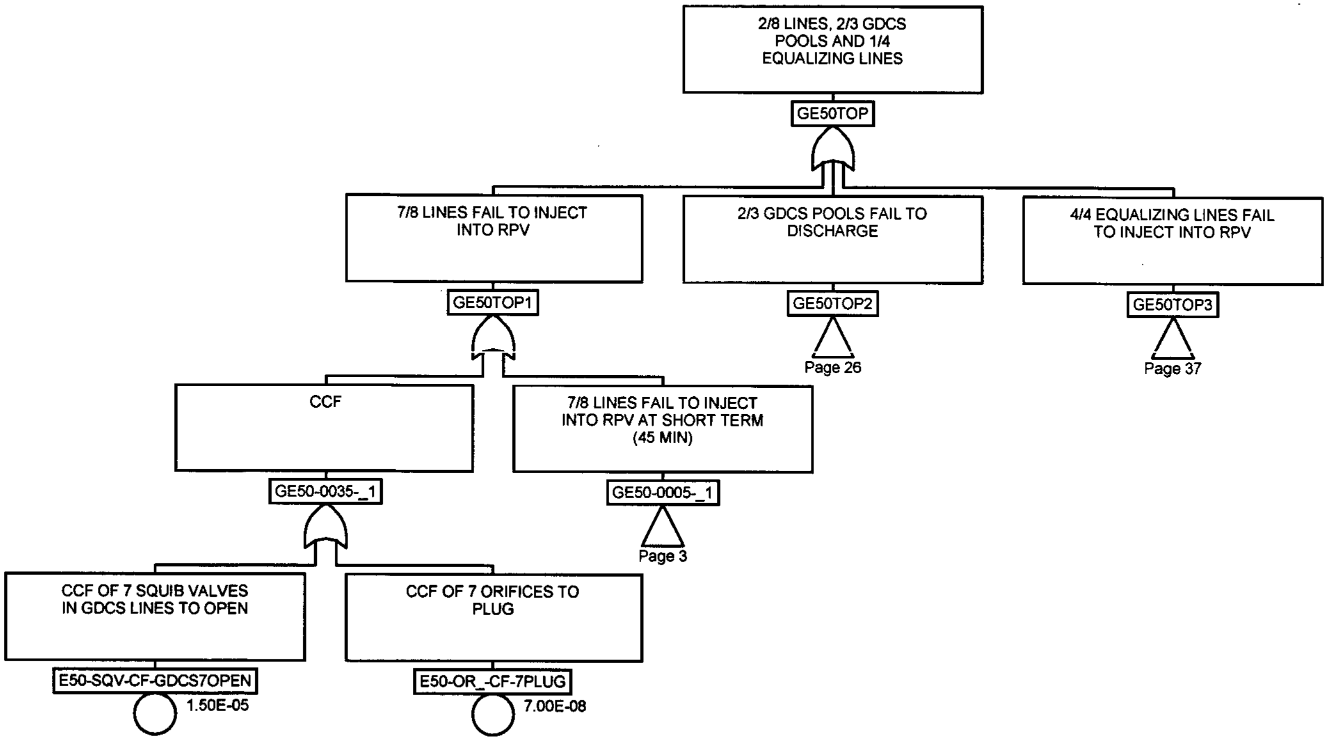

INHIBIT SIGNAL GENERATION FAILS
GC74-0001-_12
Page 1
3
APRM DIV I FAILS
GC74-0001-_13
APRM DIV II FAILS
GC74-0001-_14
APRM DIV III FAILS
GC74-0001-_15
Page 3
APRM DIV IV FAILS
GC74-0001-_16
Page 4
LOSS OF 208/120 V AC FROM BUS R13-11-2
GR13-0001-_2
SRNM CHANNEL A FAILS
C51-ACT-LO-CHASRNM
1.90E-02
LOSS OF 208/120 V AC FROM BUS R13-21-2
GR13-0001-_4
SRNM CHANNEL B FAILS
C51-ACT-LO-CHBSRNM
1.90E-02
APRM DIV I 2/4 MODULE FAILS
C51-VLU-FC-1APRM
7.80E-05
APRM DIV II 2/4 MODULE FAILS
C51-VLU-FC-2APRM
7.80E-05
1
2
3
4
5

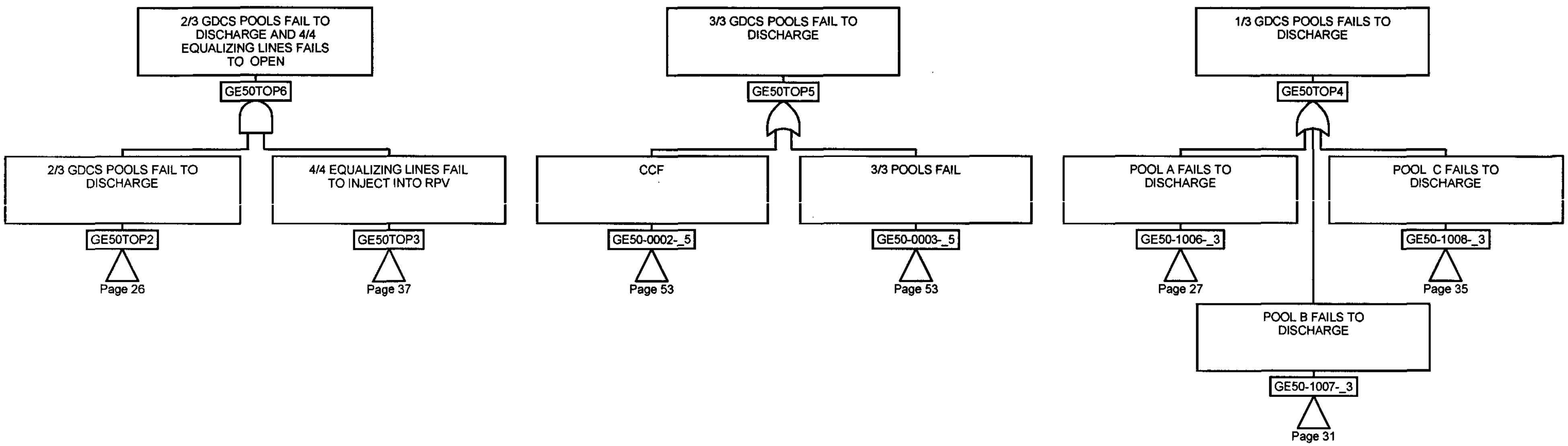

APRM DIV III FAILS
Page 2
GC74-0001-_15
LOSS OF 208/120 V AC FROM BUS R13-31-2
GR13-0001-_6
SRNM CHANNEL C FAILS
C51-ACT-LO-CHCSRNM
1.90E-02
APRM DIV III 2/4 MODULE FAILS
C51-VLU-FC-3APRM
7.80E-05
1
2

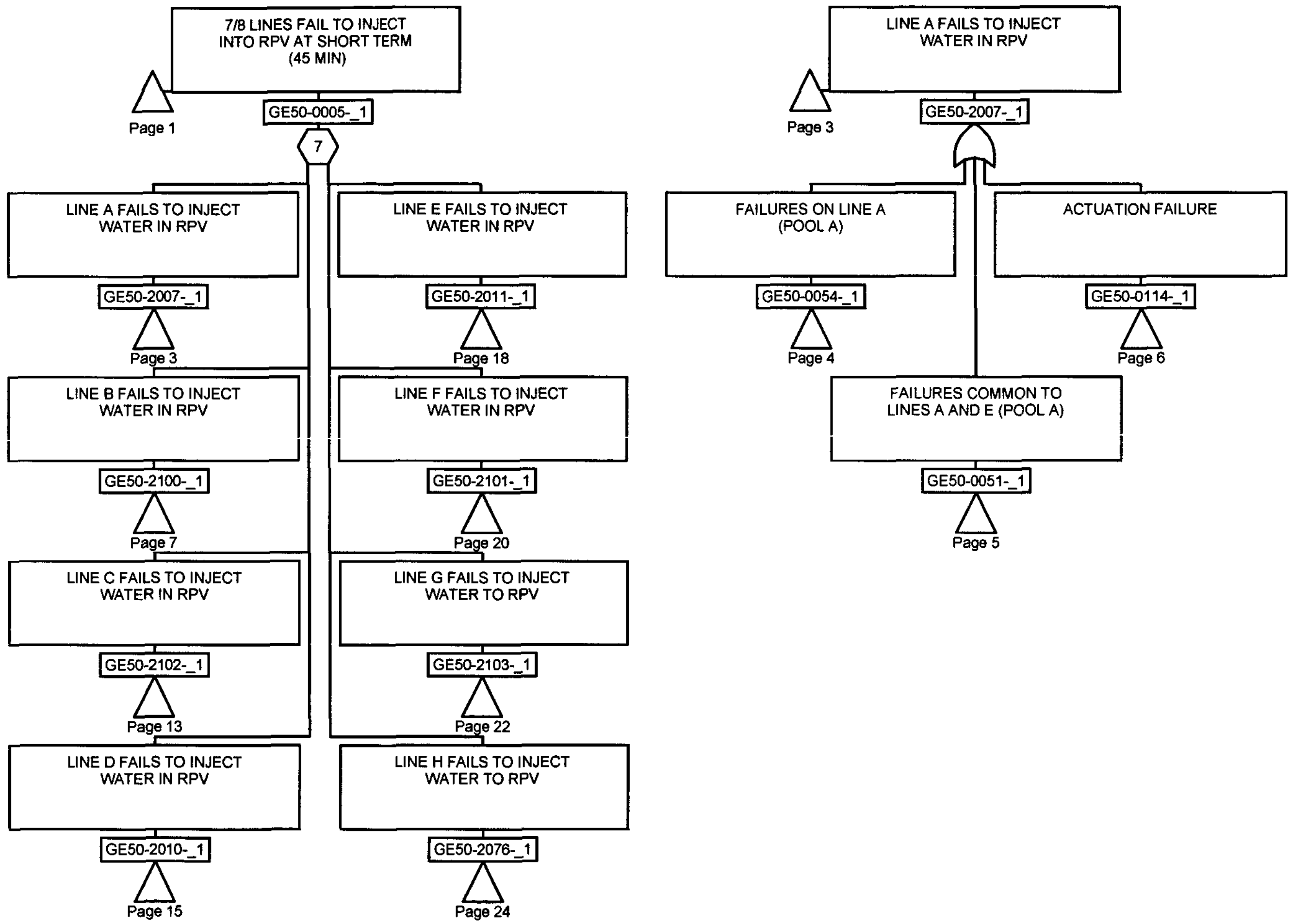

APRM DIV IV FAILS
GC74-0001-_16
Page 2
LOSS OF 208/120 V AC FROM BUS R13-41-2
GR13-0001-_8
SRNM CHANNEL D FAILS
C51-ACT-LO-CHDSRNM
1.90E-02
APRM DIV IV 2/4 MODULE FAILS
C51-VLU-FC-4APRM
7.80E-05

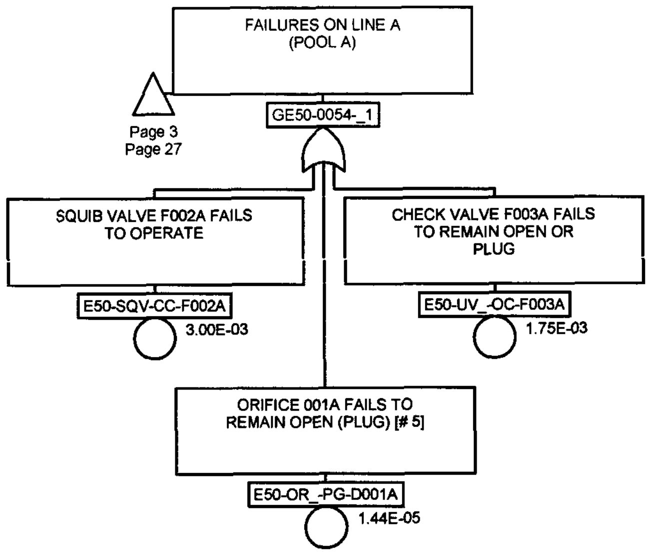
Name	Page	Zone	Name	Page	Zone	Name	Page	Zone
C51-ACT-CF-1PRM	1	1						
C51-ACT-LO-CHASRNM	2	2						
C51-ACT-LO-CHBSRNM	2	4						
C51-ACT-LO-CHCSRNM	3	2						
C51-ACT-LO-CHDSRNM	4	2						
C51-VLU-CF-1PRM	1	1						
C51-VLU-CF-2PRM	1	2						
C51-VLU-CF-APRM	1	1						
C51-VLU-FC-1APRM	2	2						
C51-VLU-FC-2APRM	2	4						
C51-VLU-FC-3APRM	3	2						
C51-VLU-FC-4APRM	4	2						
GC74-0001- 11	1	2						
GC74-0001- 12	1	2						
GC74-0001- 12	2	3						
GC74-0001- 13	2	2						
GC74-0001- 14	2	4						
GC74-0001- 15	2	5						
GC74-0001- 15	3	2						
GC74-0001- 16	2	6						
GC74-0001- 16	4	2						
GR13-0001- 2	1	2						
GR13-0001- 2	2	1						
GR13-0001- 4	1	2						
GR13-0001- 4	2	3						
GR13-0001- 6	3	1						
GR13-0001-_8	4	1						

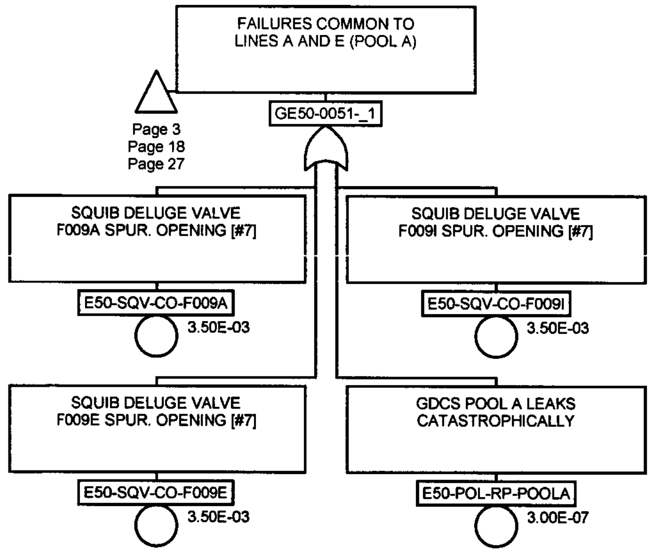
Appendix B.4.6 Gravity Driven Cooling SystemFault Tree

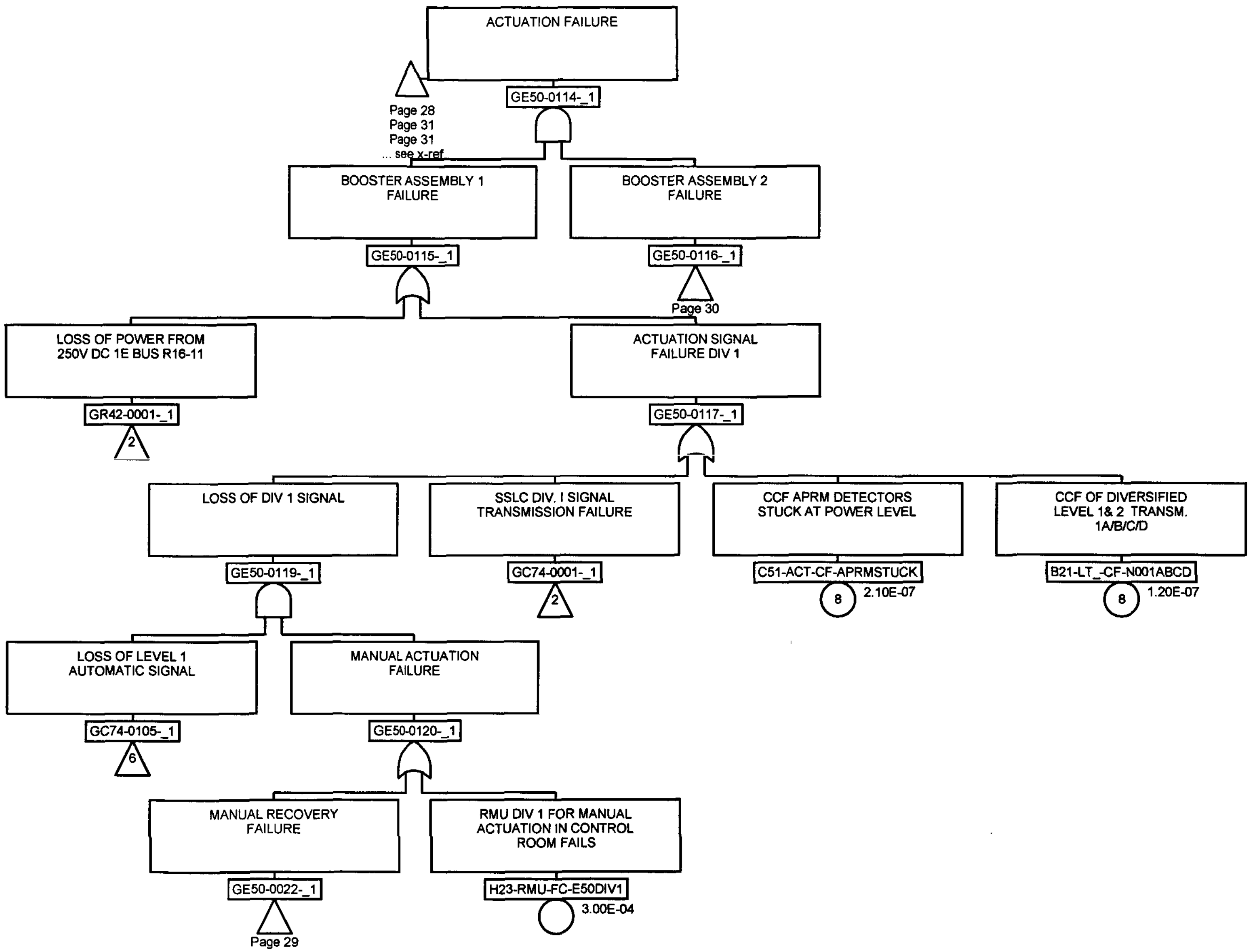

2/8 LINES, 2/3 GDCS POOLS AND 1/4 EQUALIZING LINES
GE50TOP
7/8 LINES FAIL TO INJECT INTO RPV
GE50TOP1
2/3 GDCS POOLS FAIL TO DISCHARGE
GE50TOP2
Page 26
4/4 EQUALIZING LINES FAIL TO INJECT INTO RPV
GE50TOP3
Page 37
CCF
GE50-0035-_1
7/8 LINES FAIL TO INJECT INTO RPV AT SHORT TERM (45 MIN)
GE50-0005-_1
Page 3
CCF OF 7 SQUIB VALVES IN GDCS LINES TO OPEN
E50-SQV-CF-GDCS7OPEN
1.50E-05
CCF OF 7 ORIFICES TO PLUG
E50-OR_-CF-7PLUG
7.00E-08

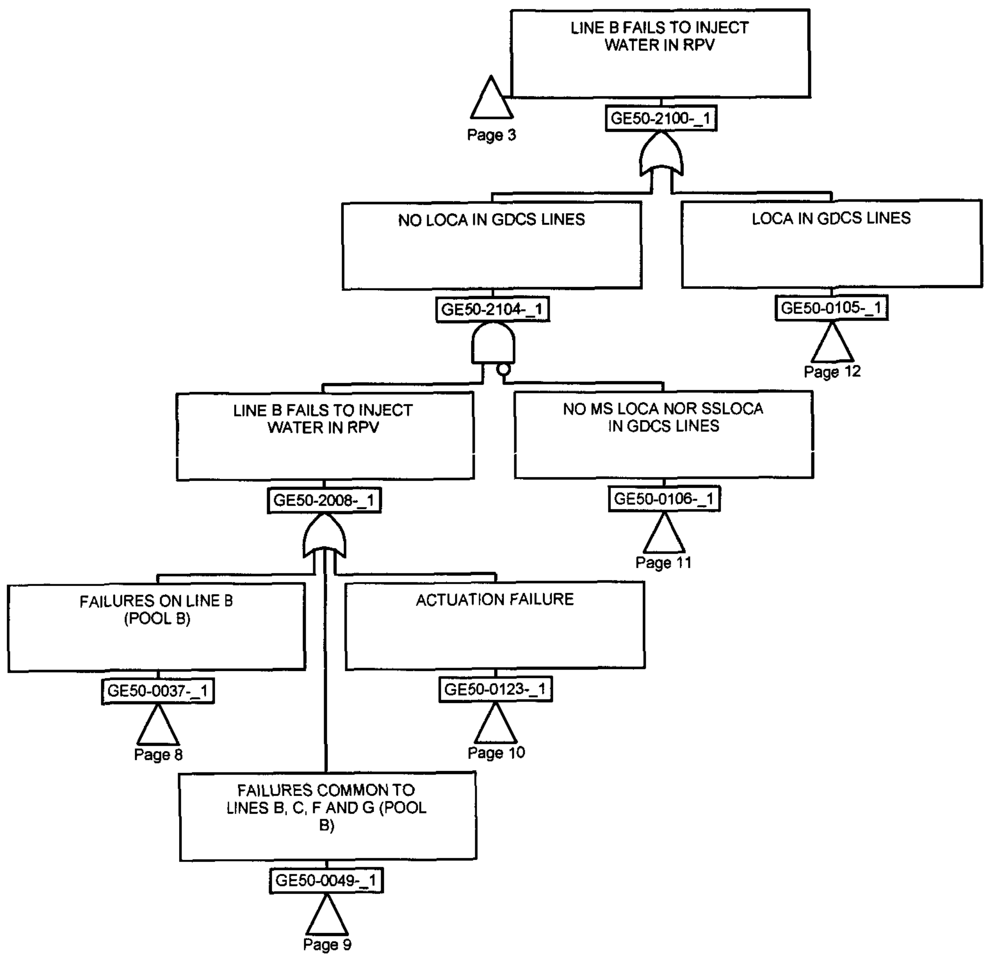

2/3 GDCS POOLS FAIL TO DISCHARGE AND 4/4 EQUALIZING LINES FAILS TO OPEN
GE50TOP6
2/3 GDCS POOLS FAIL TO DISCHARGE
GE50TOP2
Page 26
4/4 EQUALIZING LINES FAIL TO INJECT INTO RPV
GE50TOP3
Page 37
3/3 GDCS POOLS FAIL TO DISCHARGE
GE50TOP5
CCF
GE50-0002-_5
Page 53
3/3 POOLS FAIL
GE50-0003-_5
Page 53
1/3 GDCS POOLS FAILS TO DISCHARGE
GE50TOP4
POOL A FAILS TO DISCHARGE
GE50-1006-_3
Page 27
POOL C FAILS TO DISCHARGE
GE50-1008-_3
Page 35
POOL B FAILS TO DISCHARGE
GE50-1007-_3
Page 31

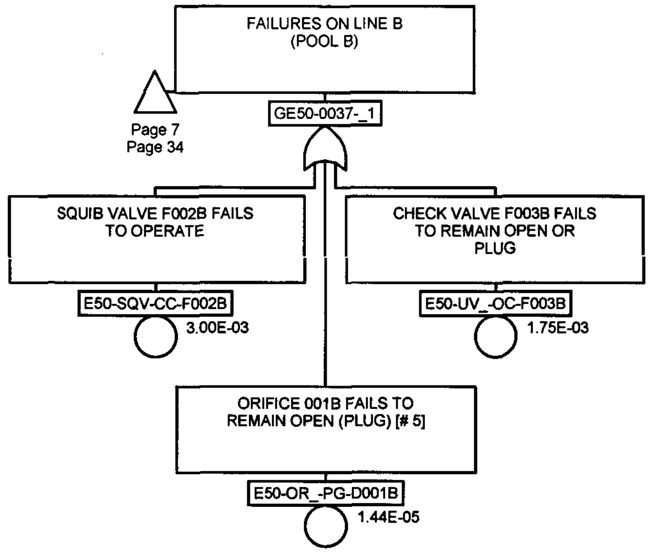

7/8 LINES FAIL TO INJECT INTO RPV AT SHORT TERM (45 MIN)
GE50-0005-_1
Page 1
7
LINE A FAILS TO INJECT WATER IN RPV
GE50-2007-_1
Page 3
LINE B FAILS TO INJECT WATER IN RPV
GE50-2100-_1
Page 7
LINE C FAILS TO INJECT WATER IN RPV
GE50-2102-_1
Page 13
LINE D FAILS TO INJECT WATER IN RPV
GE50-2010-_1
Page 15
LINE E FAILS TO INJECT WATER IN RPV
GE50-2011-_1
Page 18
LINE F FAILS TO INJECT WATER IN RPV
GE50-2101-_1
Page 20
LINE G FAILS TO INJECT WATER TO RPV
GE50-2103-_1
Page 22
LINE H FAILS TO INJECT WATER TO RPV
GE50-2076-_1
Page 24
LINE A FAILS TO INJECT WATER IN RPV
GE50-2007-_1
Page 3
FAILURES ON LINE A (POOL A)
GE50-0054-_1
Page 4
ACTUATION FAILURE
GE50-0114-_1
Page 6
FAILURES COMMON TO LINES A AND E (POOL A)
GE50-0051-_1
Page 5

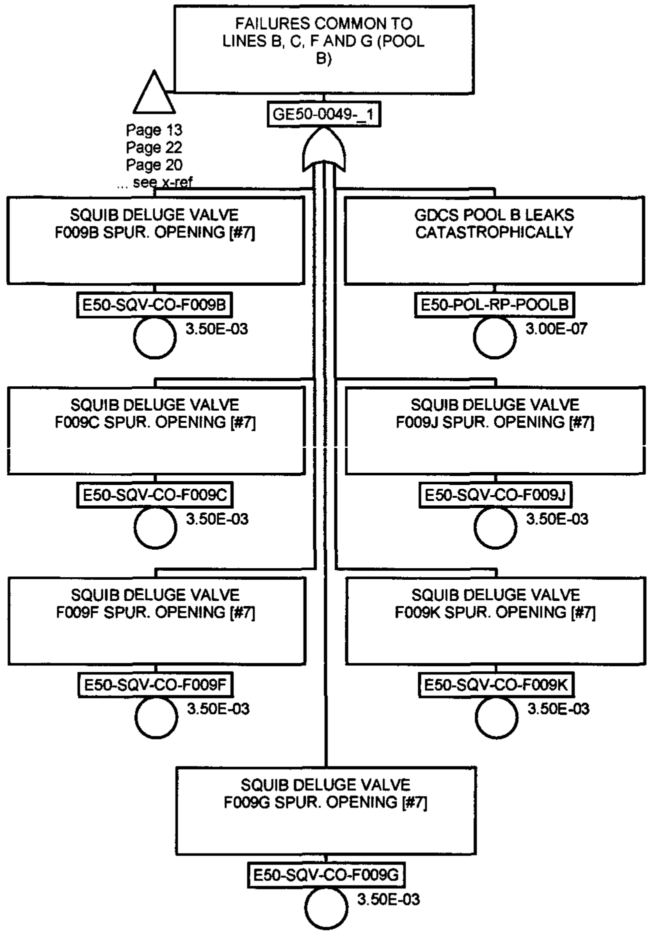

FAILURES ON LINE A (POOL A)
GE50-0054-_1
Page 3
Page 27
SQUIB VALVE F002A FAILS TO OPERATE
E50-SQV-CC-F002A
3.00E-03
CHECK VALVE F003A FAILS TO REMAIN OPEN OR PLUG
E50-UV_-OC-F003A
1.75E-03
ORIFICE 001A FAILS TO REMAIN OPEN (PLUG) [# 5]
E50-OR_-PG-D001A
1.44E-05

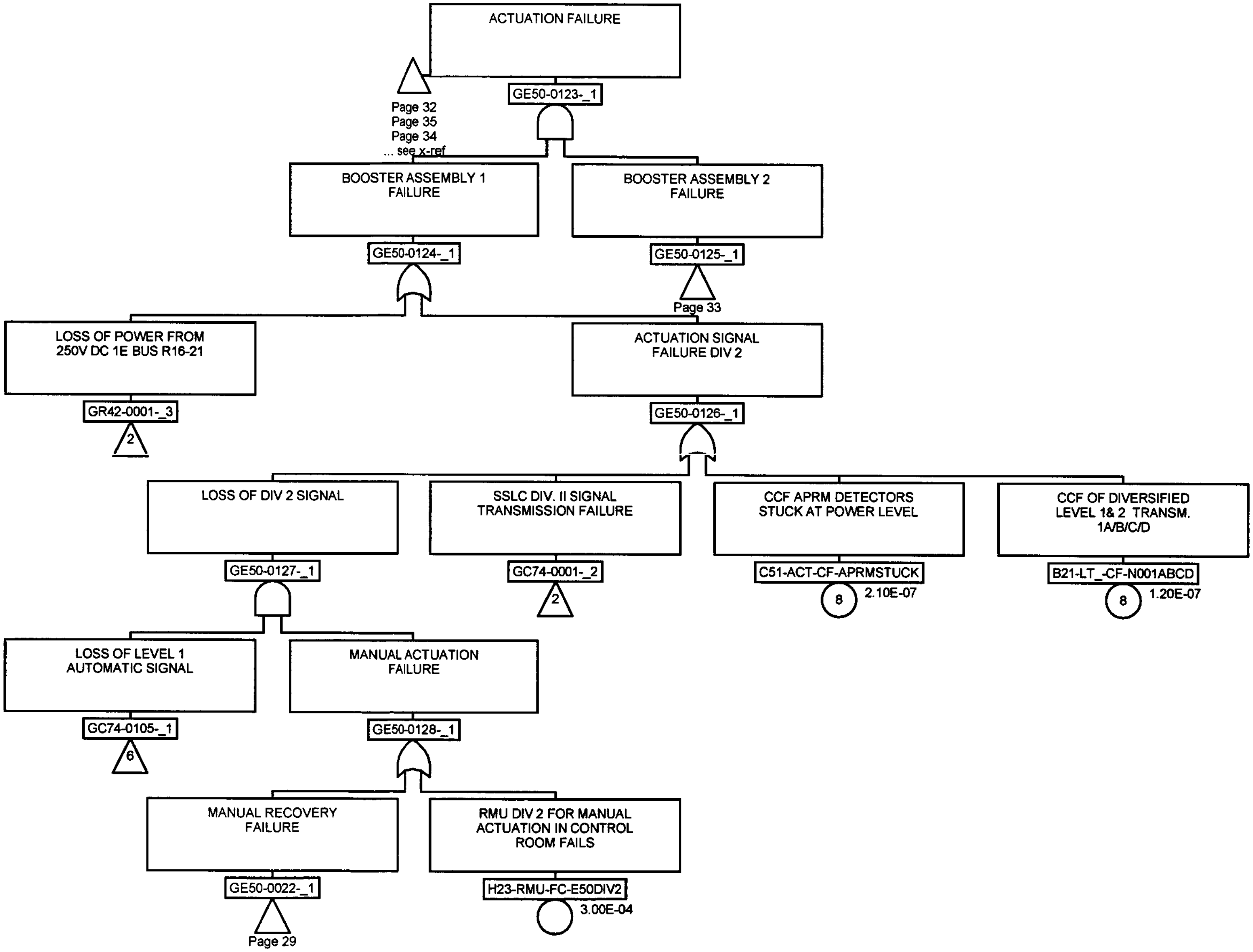

FAILURES COMMON TO LINES A AND E (POOL A)
GE50-0051-_1
Page 3
Page 18
Page 27
SQUIB DELUGE VALVE F009A SPUR. OPENING [#7]
E50-SQV-CO-F009A
3.50E-03
SQUIB DELUGE VALVE F009I SPUR. OPENING [#7]
E50-SQV-CO-F009I
3.50E-03
SQUIB DELUGE VALVE F009E SPUR. OPENING [#7]
E50-SQV-CO-F009E
3.50E-03
GDCS POOL A LEAKS CATASTROPHICALLY
E50-POL-RP-POOLA
3.00E-07

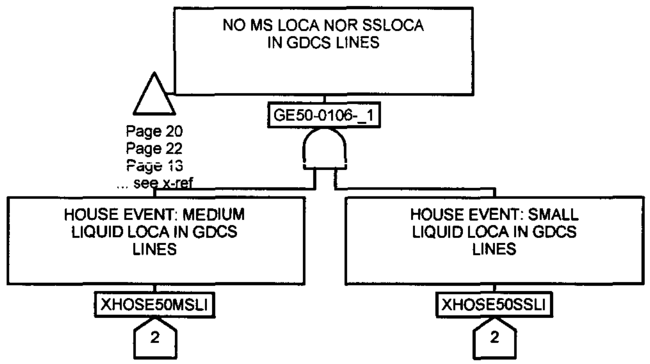

ACTUATION FAILURE
GE50-0114-_1
Page 28
Page 31
Page 31
... see x-ref
BOOSTER ASSEMBLY 1 FAILURE
GE50-0115-_1
BOOSTER ASSEMBLY 2 FAILURE
GE50-0116-_1
Page 30
LOSS OF POWER FROM 250V DC 1E BUS R16-11
GR42-0001-_1
2
ACTUATION SIGNAL FAILURE DIV 1
GE50-0117-_1
LOSS OF DIV 1 SIGNAL
GE50-0119-_1
SSLC DIV. I SIGNAL TRANSMISSION FAILURE
GC74-0001-_1
2
CCF APRM DETECTORS STUCK AT POWER LEVEL
C51-ACT-CF-APRMSTUCK
8
2.10E-07
CCF OF DIVERSIFIED LEVEL 1& 2 TRANSM. 1A/B/C/D
B21-LT_-CF-N001ABCD
8
1.20E-07
LOSS OF LEVEL 1 AUTOMATIC SIGNAL
GC74-0105-_1
6
MANUAL ACTUATION FAILURE
GE50-0120-_1
MANUAL RECOVERY FAILURE
GE50-0022-_1
Page 29
RMU DIV 1 FOR MANUAL ACTUATION IN CONTROL ROOM FAILS
H23-RMU-FC-E50DIV1
3.00E-04

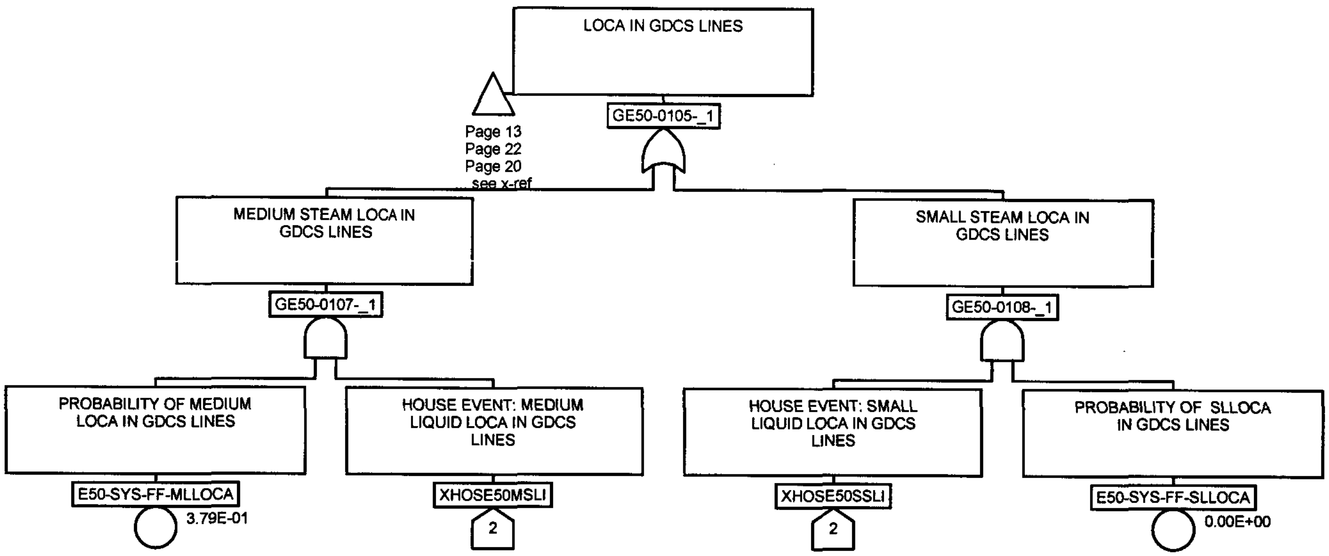

LINE B FAILS TO INJECT WATER IN RPV
Page 3
GE50-2100-_1
NO LOCA IN GDCS LINES
LOCA IN GDCS LINES
GE50-2104-_1
GE50-0105-_1
Page 12
LINE B FAILS TO INJECT WATER IN RPV
NO MS LOCA NOR SSLOCA IN GDCS LINES
GE50-2008-_1
GE50-0106-_1
Page 11
FAILURES ON LINE B (POOL B)
ACTUATION FAILURE
GE50-0037-_1
Page 8
GE50-0123-_1
Page 10
FAILURES COMMON TO LINES B, C, F AND G (POOL B)
GE50-0049-_1
Page 9

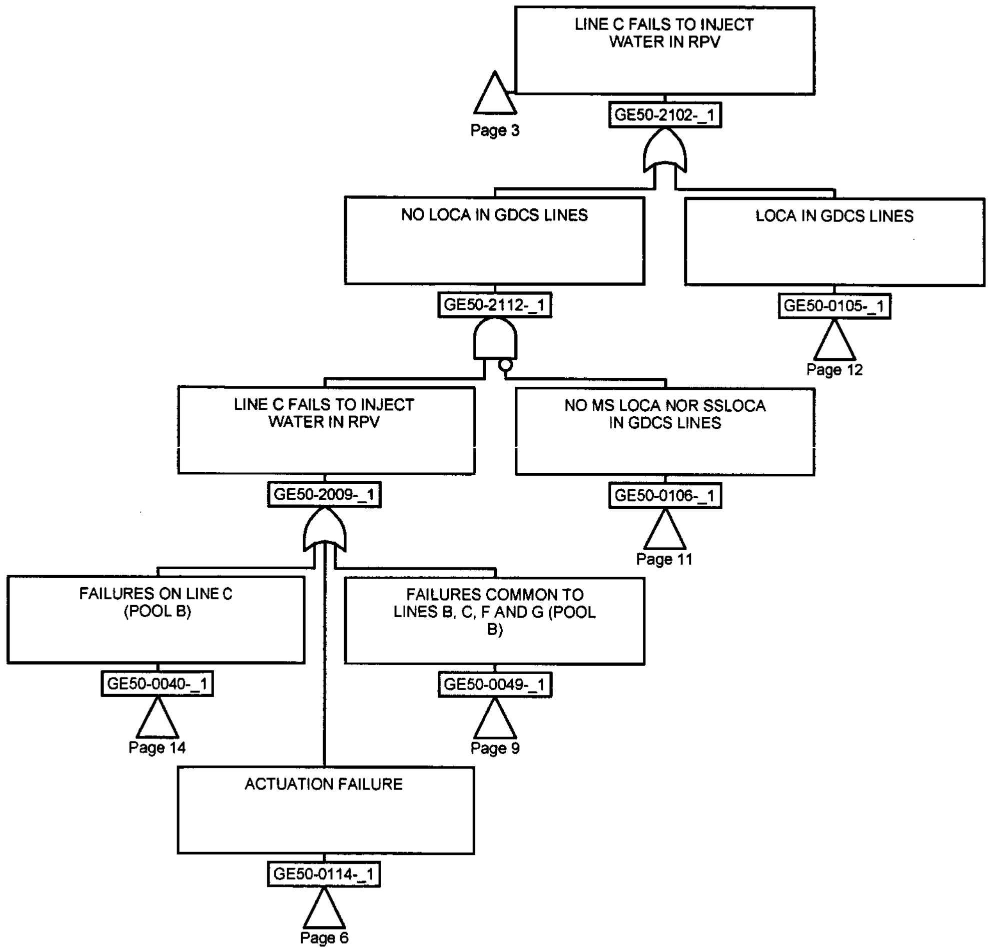

FAILURES ON LINE B
(POOL B)
GE50-0037-_1
Page 7
Page 34
SQUIB VALVE F002B FAILS
TO OPERATE
E50-SQV-CC-F002B
3.00E-03
CHECK VALVE F003B FAILS
TO REMAIN OPEN OR
PLUG
E50-UV_-OC-F003B
1.75E-03
ORIFICE 001B FAILS TO
REMAIN OPEN (PLUG) [# 5]
E50-OR_-PG-D001B
1.44E-05

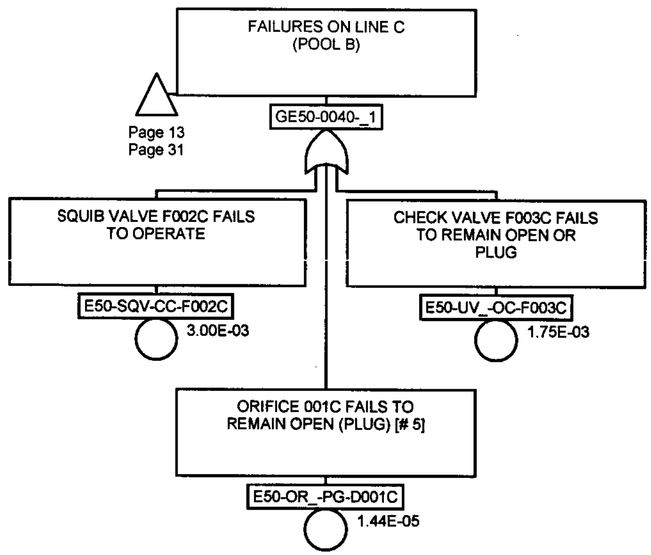

FAILURES COMMON TO LINES B, C, F AND G (POOL B)
GE50-0049-_1
Page 13
Page 22
Page 20
... see x-ref
SQUIB DELUGE VALVE F009B SPUR. OPENING [#7]
E50-SQV-CO-F009B
3.50E-03
GDCS POOL B LEAKS CATASTROPHICALLY
E50-POL-RP-POOLB
3.00E-07
SQUIB DELUGE VALVE F009C SPUR. OPENING [#7]
E50-SQV-CO-F009C
3.50E-03
SQUIB DELUGE VALVE F009J SPUR. OPENING [#7]
E50-SQV-CO-F009J
3.50E-03
SQUIB DELUGE VALVE F009F SPUR. OPENING [#7]
E50-SQV-CO-F009F
3.50E-03
SQUIB DELUGE VALVE F009K SPUR. OPENING [#7]
E50-SQV-CO-F009K
3.50E-03
SQUIB DELUGE VALVE F009G SPUR. OPENING [#7]
E50-SQV-CO-F009G
3.50E-03

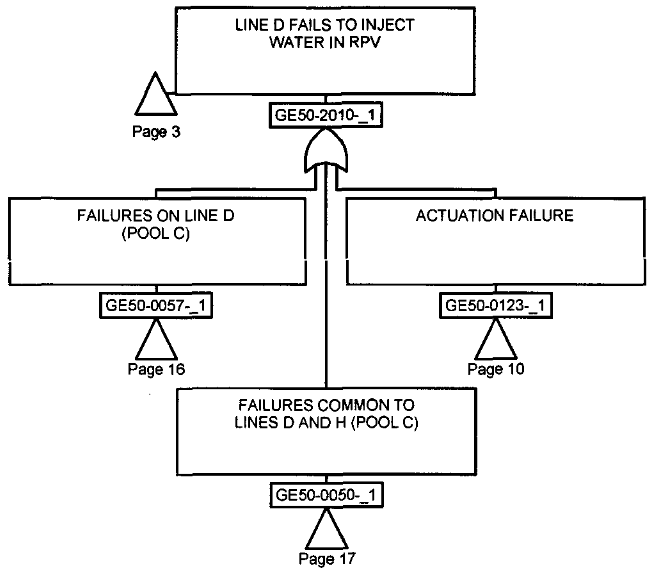

ACTUATION FAILURE
GE50-0123-_1
Page 32
Page 35
Page 34
... see x-ref
BOOSTER ASSEMBLY 1 FAILURE
GE50-0124-_1
BOOSTER ASSEMBLY 2 FAILURE
GE50-0125-_1
Page 33
LOSS OF POWER FROM 250V DC 1E BUS R16-21
GR42-0001-_3
2
ACTUATION SIGNAL FAILURE DIV 2
GE50-0126-_1
LOSS OF DIV 2 SIGNAL
GE50-0127-_1
SSLC DIV. II SIGNAL TRANSMISSION FAILURE
GC74-0001-_2
2
CCF APRM DETECTORS STUCK AT POWER LEVEL
C51-ACT-CF-APRMSTUCK
8
2.10E-07
CCF OF DIVERSIFIED LEVEL 1& 2 TRANSM. 1A/B/C/D
B21-LT_-CF-N001ABCD
8
1.20E-07
LOSS OF LEVEL 1 AUTOMATIC SIGNAL
GC74-0105-_1
6
MANUAL ACTUATION FAILURE
GE50-0128-_1
MANUAL RECOVERY FAILURE
GE50-0022-_1
Page 29
RMU DIV 2 FOR MANUAL ACTUATION IN CONTROL ROOM FAILS
H23-RMU-FC-E50DIV2
3.00E-04

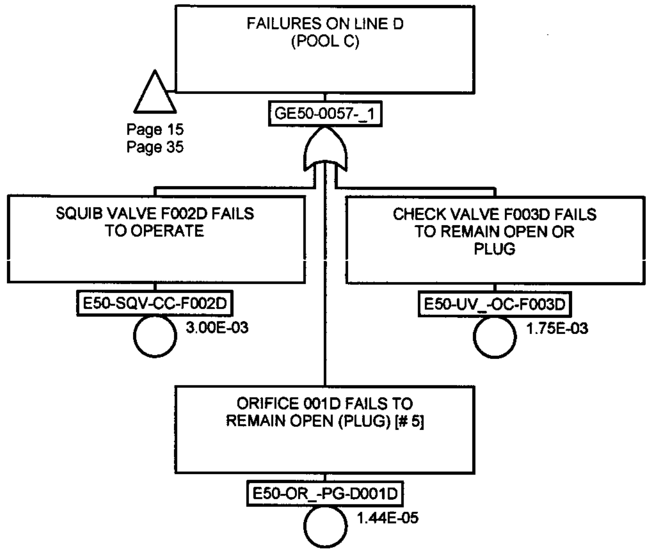

NO MS LOCA NOR SSLOCA IN GDCS LINES
GE50-0106-_1
Page 20
Page 22
Page 13
... see x-ref
HOUSE EVENT: MEDIUM LIQUID LOCA IN GDCS LINES
XHOSE50MSLI
2
HOUSE EVENT: SMALL LIQUID LOCA IN GDCS LINES
XHOSE50SSLI
2

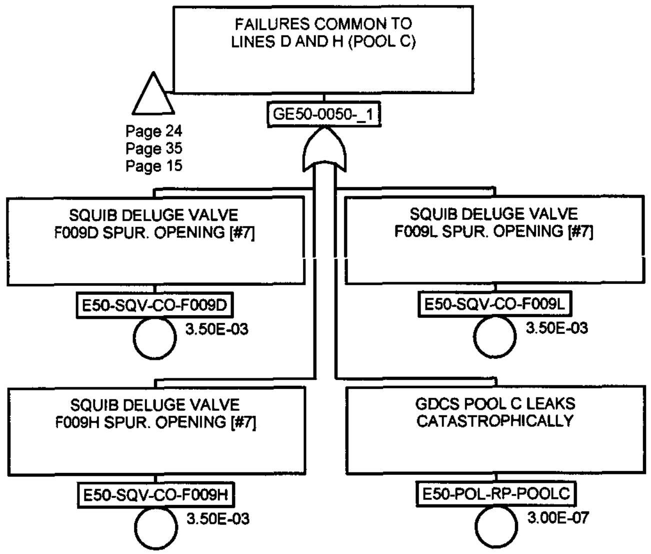

LOCA IN GDCS LINES
GE50-0105-_1
Page 13
Page 22
Page 20
see x-ref
MEDIUM STEAM LOCA IN GDCS LINES
GE50-0107-_1
SMALL STEAM LOCA IN GDCS LINES
GE50-0108-_1
PROBABILITY OF MEDIUM LOCA IN GDCS LINES
E50-SYS-FF-MLLOCA
3.79E-01
HOUSE EVENT: MEDIUM LIQUID LOCA IN GDCS LINES
XHOSE50MSLI
2
HOUSE EVENT: SMALL LIQUID LOCA IN GDCS LINES
XHOSE50SSLI
2
PROBABILITY OF SLLOCA IN GDCS LINES
E50-SYS-FF-SLLOCA
0.00E+00

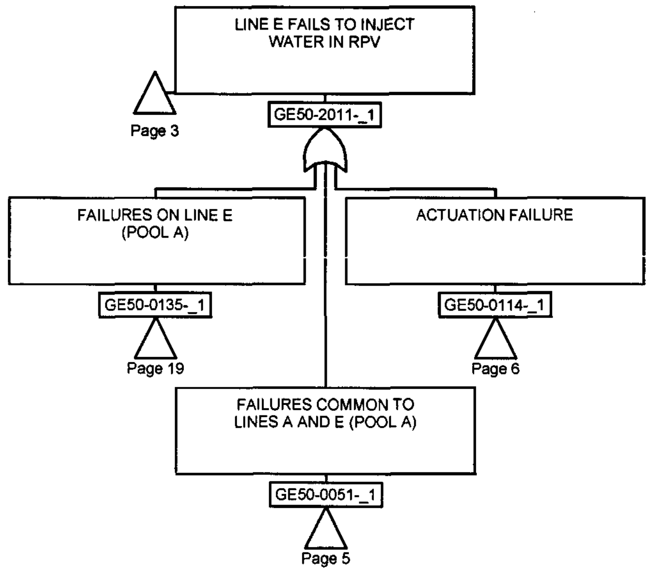

LINE C FAILS TO INJECT WATER IN RPV
Page 3
GE50-2102-_1
NO LOCA IN GDCS LINES
LOCA IN GDCS LINES
GE50-2112-_1
GE50-0105-_1
Page 12
LINE C FAILS TO INJECT WATER IN RPV
NO MS LOCA NOR SSLOCA IN GDCS LINES
GE50-2009-_1
GE50-0106-_1
Page 11
FAILURES ON LINE C (POOL B)
FAILURES COMMON TO LINES B, C, F AND G (POOL B)
GE50-0040-_1
Page 14
GE50-0049-_1
Page 9
ACTUATION FAILURE
GE50-0114-_1
Page 6

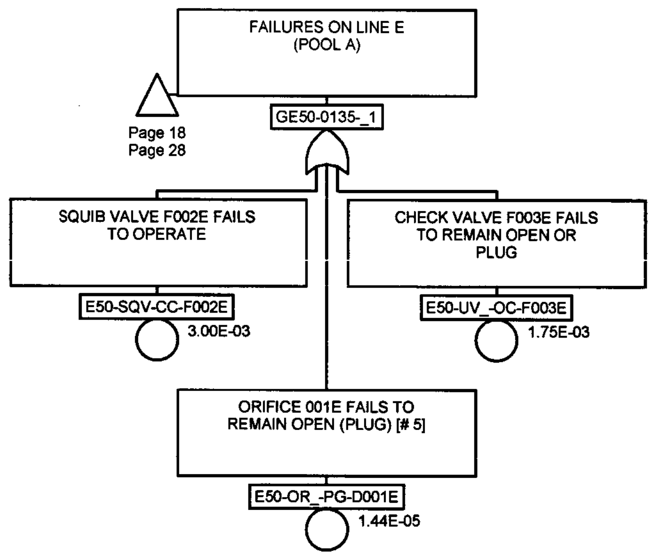

FAILURES ON LINE C
(POOL B)
GE50-0040-_1
Page 13
Page 31
SQUIB VALVE F002C FAILS
TO OPERATE
E50-SQV-CC-F002C
3.00E-03
CHECK VALVE F003C FAILS
TO REMAIN OPEN OR
PLUG
E50-UV_-OC-F003C
1.75E-03
ORIFICE 001C FAILS TO
REMAIN OPEN (PLUG) [# 5]
E50-OR_-PG-D001C
1.44E-05

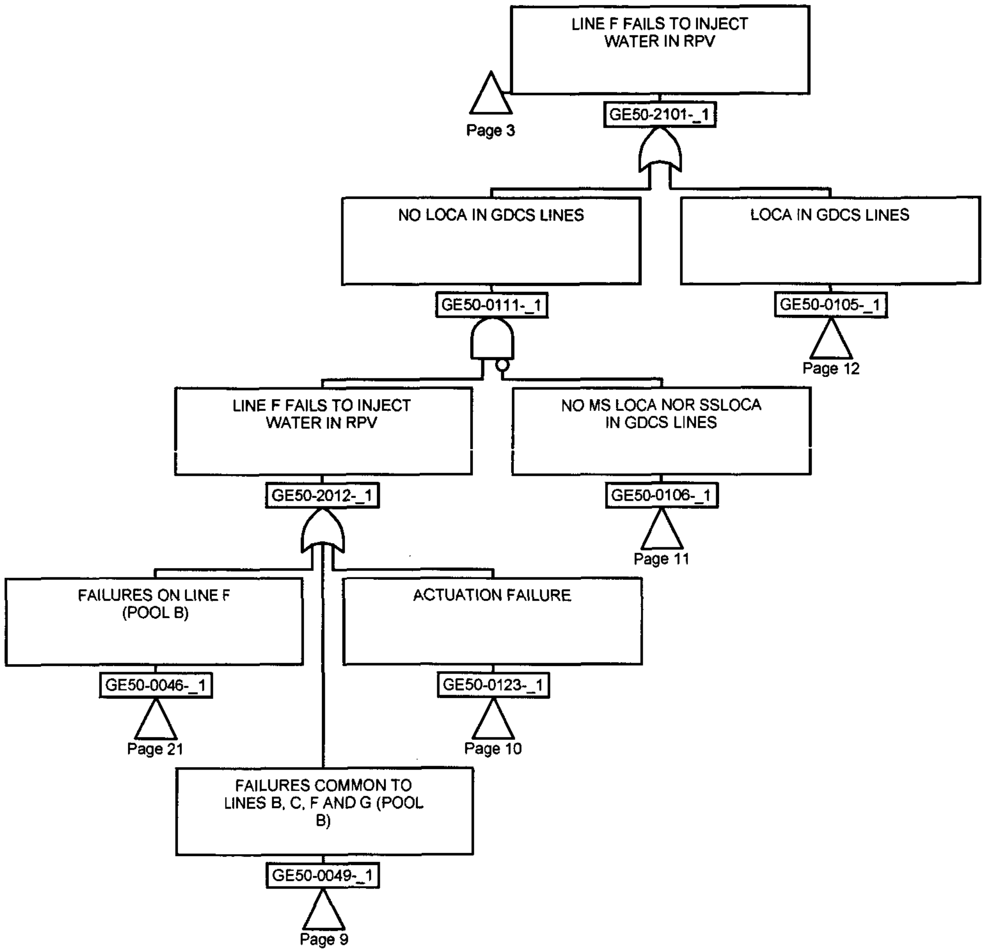

LINE D FAILS TO INJECT WATER IN RPV
GE50-2010-_1
Page 3
FAILURES ON LINE D (POOL C)
GE50-0057-_1
Page 16
ACTUATION FAILURE
GE50-0123-_1
Page 10
FAILURES COMMON TO LINES D AND H (POOL C)
GE50-0050-_1
Page 17

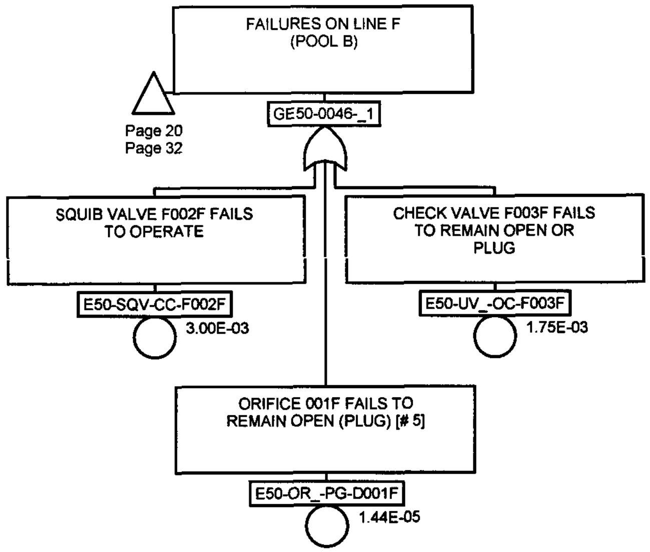

FAILURES ON LINE D
(POOL C)
Page 15
Page 35
GE50-0057-_1
SQUIB VALVE F002D FAILS
TO OPERATE
E50-SQV-CC-F002D
3.00E-03
CHECK VALVE F003D FAILS
TO REMAIN OPEN OR
PLUG
E50-UV_-OC-F003D
1.75E-03
ORIFICE 001D FAILS TO
REMAIN OPEN (PLUG) [# 5]
E50-OR_-PG-D001D
1.44E-05

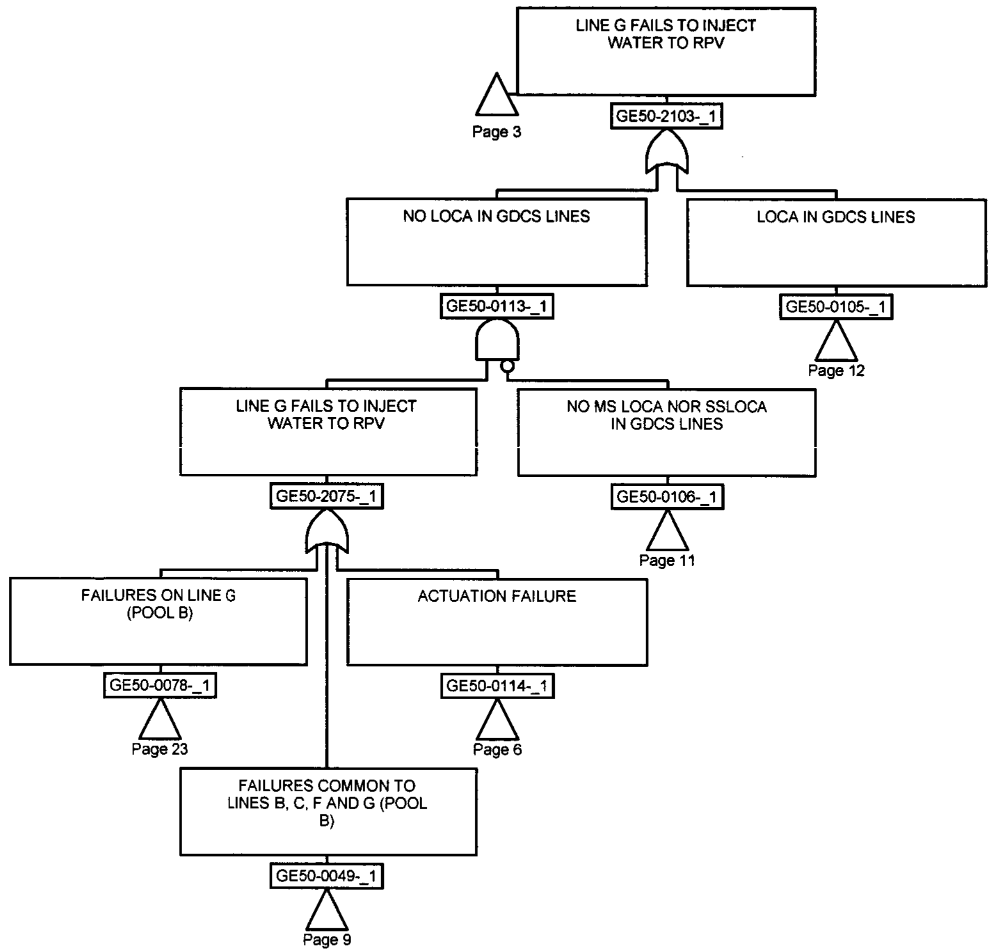

FAILURES COMMON TO
LINES D AND H (POOL C)
GE50-0050-_1
Page 24
Page 35
Page 15
SQUIB DELUGE VALVE
F009D SPUR. OPENING [#7]
E50-SQV-CO-F009D
3.50E-03
SQUIB DELUGE VALVE
F009L SPUR. OPENING [#7]
E50-SQV-CO-F009L
3.50E-03
SQUIB DELUGE VALVE
F009H SPUR. OPENING [#7]
E50-SQV-CO-F009H
3.50E-03
GDCS POOL C LEAKS
CATASTROPHICALLY
E50-POL-RP-POOLC
3.00E-07

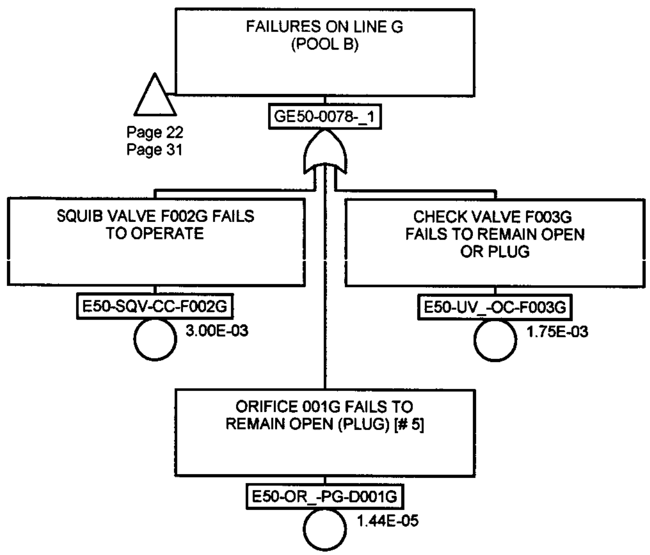

LINE E FAILS TO INJECT WATER IN RPV
GE50-2011-_1
Page 3
FAILURES ON LINE E (POOL A)
GE50-0135-_1
Page 19
ACTUATION FAILURE
GE50-0114-_1
Page 6
FAILURES COMMON TO LINES A AND E (POOL A)
GE50-0051-_1
Page 5

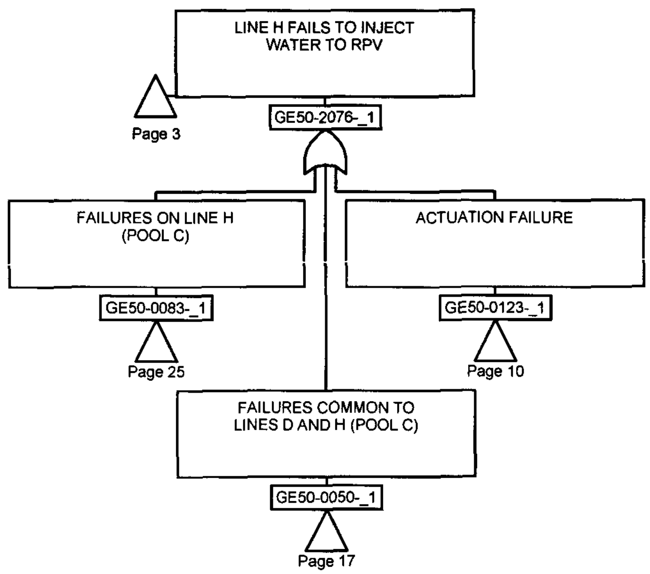

FAILURES ON LINE E
(POOL A)
GE50-0135-_1
Page 18
Page 28
SQUIB VALVE F002E FAILS TO OPERATE
E50-SQV-CC-F002E
3.00E-03
CHECK VALVE F003E FAILS TO REMAIN OPEN OR PLUG
E50-UV_-OC-F003E
1.75E-03
ORIFICE 001E FAILS TO REMAIN OPEN (PLUG) [# 5]
E50-OR_-PG-D001E
1.44E-05

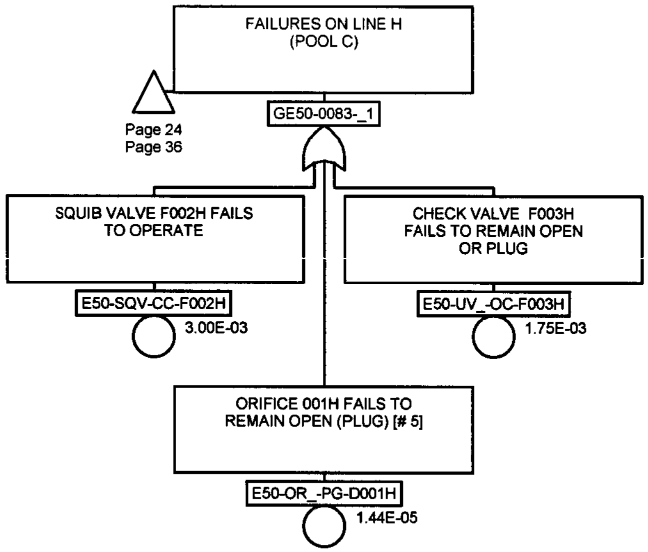

LINE F FAILS TO INJECT WATER IN RPV
GE50-2101-_1
Page 3
NO LOCA IN GDCS LINES
GE50-0111-_1
LOCA IN GDCS LINES
GE50-0105-_1
Page 12
LINE F FAILS TO INJECT WATER IN RPV
GE50-2012-_1
NO MS LOCA NOR SSLOCA IN GDCS LINES
GE50-0106-_1
Page 11
FAILURES ON LINE F (POOL B)
GE50-0046-_1
Page 21
ACTUATION FAILURE
GE50-0123-_1
Page 10
FAILURES COMMON TO LINES B, C, F AND G (POOL B)
GE50-0049-_1
Page 9

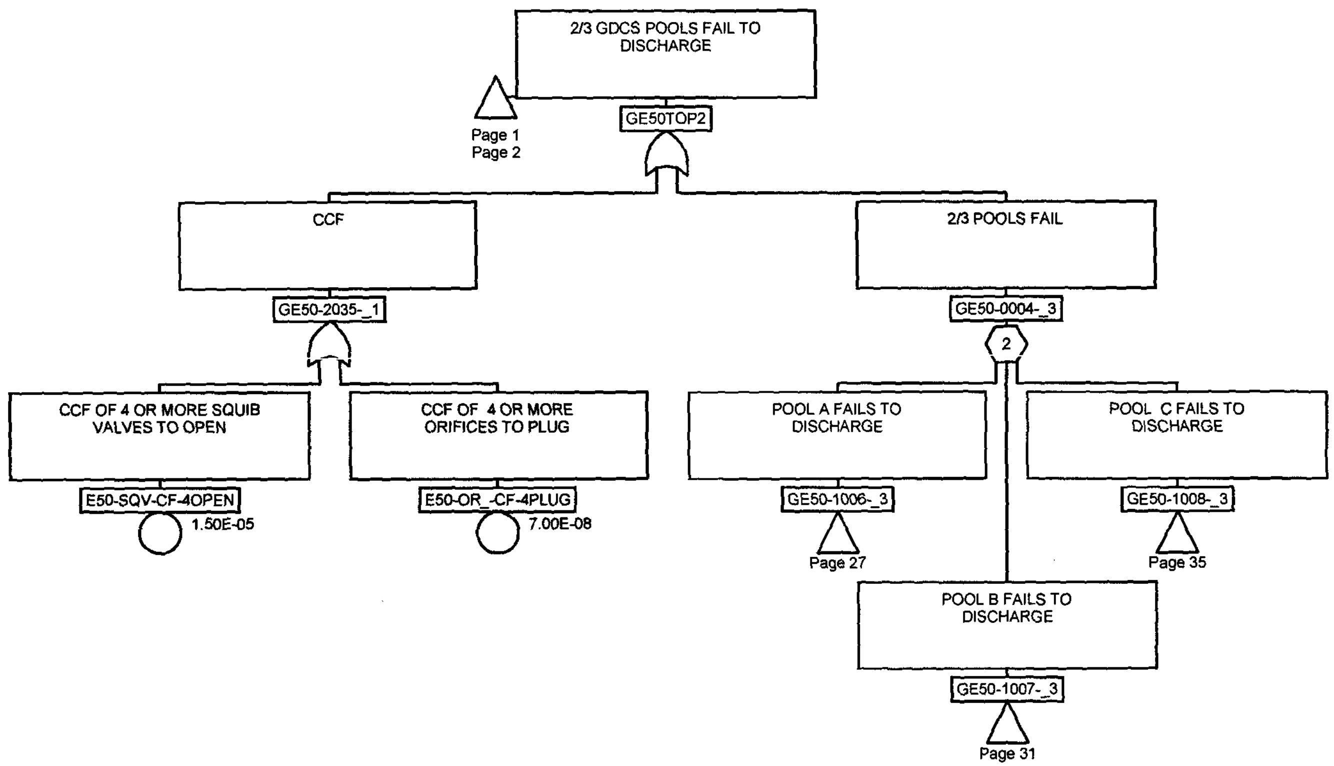

FAILURES ON LINE F
(POOL B)
GE50-0046-_1
Page 20
Page 32
SQUIB VALVE F002F FAILS
TO OPERATE
E50-SQV-CC-F002F
3.00E-03
CHECK VALVE F003F FAILS
TO REMAIN OPEN OR
PLUG
E50-UV_-OC-F003F
1.75E-03
ORIFICE 001F FAILS TO
REMAIN OPEN (PLUG) [# 5]
E50-OR_-PG-D001F
1.44E-05

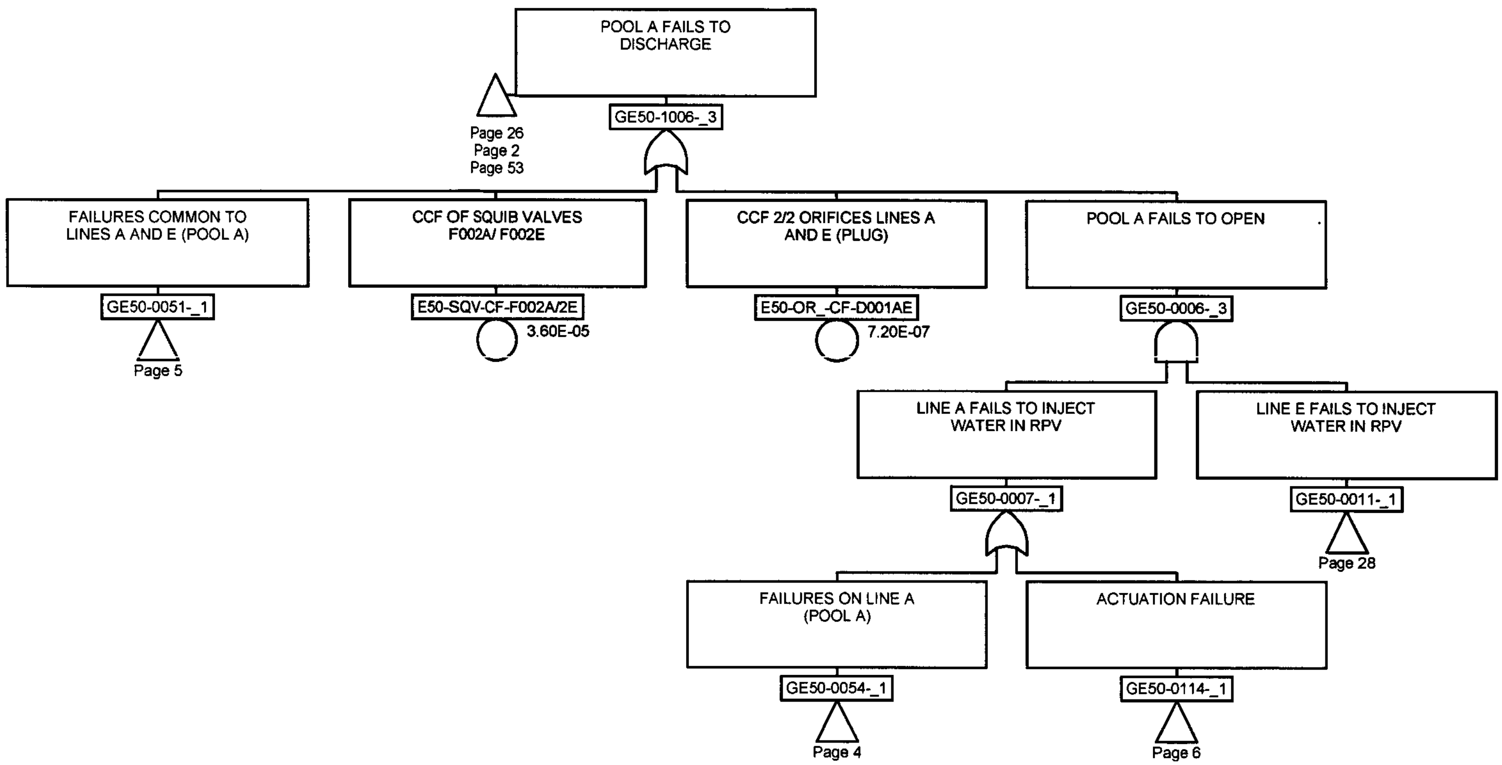

LINE G FAILS TO INJECT WATER TO RPV
GE50-2103-_1
Page 3
NO LOCA IN GDCS LINES
GE50-0113-_1
LOCA IN GDCS LINES
GE50-0105-_1
Page 12
LINE G FAILS TO INJECT WATER TO RPV
GE50-2075-_1
NO MS LOCA NOR SSLOCA IN GDCS LINES
GE50-0106-_1
Page 11
FAILURES ON LINE G (POOL B)
GE50-0078-_1
Page 23
ACTUATION FAILURE
GE50-0114-_1
Page 6
FAILURES COMMON TO LINES B, C, F AND G (POOL B)
GE50-0049-_1
Page 9

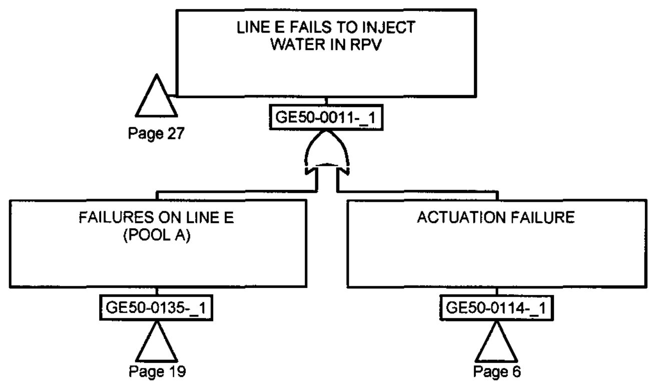

FAILURES ON LINE G
(POOL B)
GE50-0078-_1
Page 22
Page 31
SQUIB VALVE F002G FAILS
TO OPERATE
E50-SQV-CC-F002G
3.00E-03
CHECK VALVE F003G
FAILS TO REMAIN OPEN
OR PLUG
E50-UV_-OC-F003G
1.75E-03
ORIFICE 001G FAILS TO
REMAIN OPEN (PLUG) [# 5]
E50-OR_-PG-D001G
1.44E-05

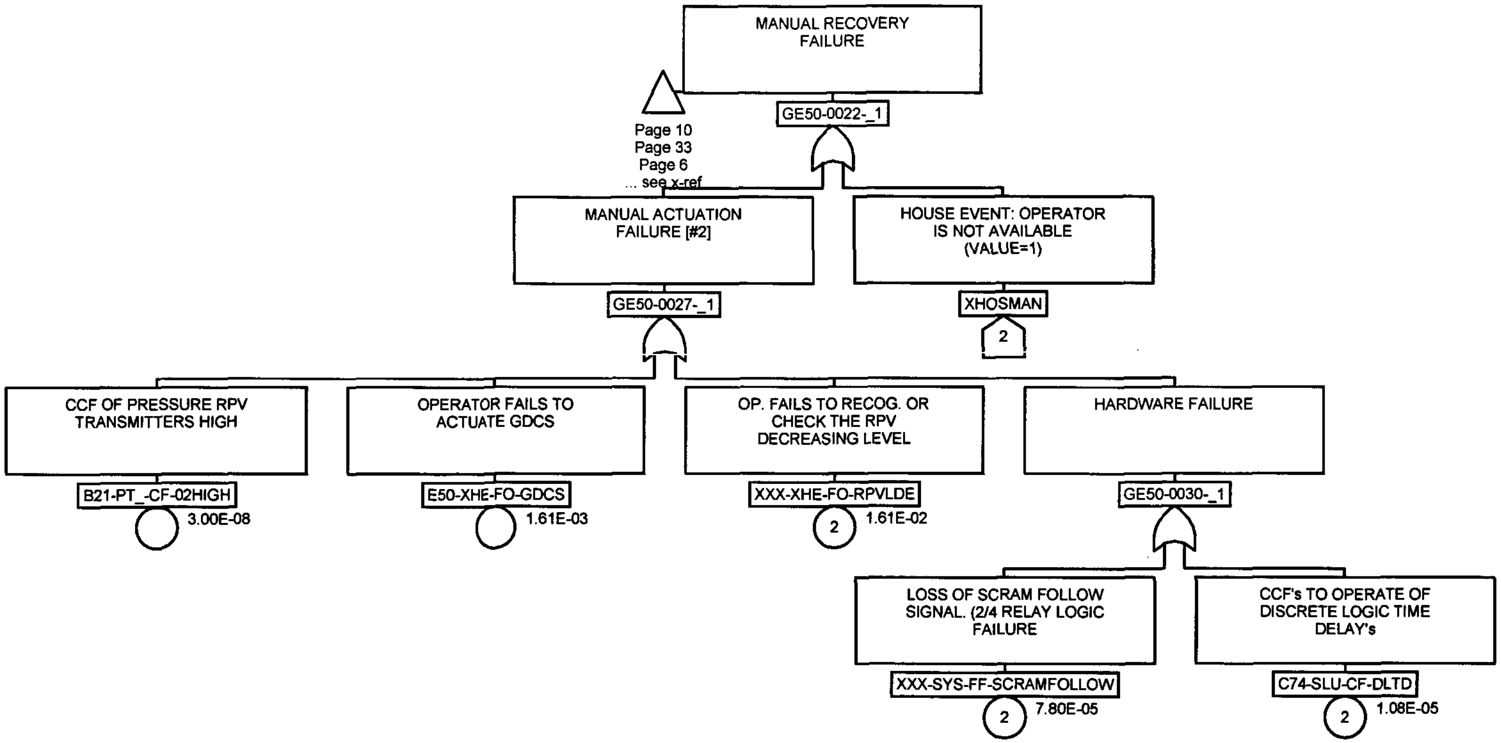

LINE H FAILS TO INJECT WATER TO RPV
GE50-2076-_1
Page 3
FAILURES ON LINE H (POOL C)
GE50-0083-_1
Page 25
ACTUATION FAILURE
GE50-0123-_1
Page 10
FAILURES COMMON TO LINES D AND H (POOL C)
GE50-0050-_1
Page 17

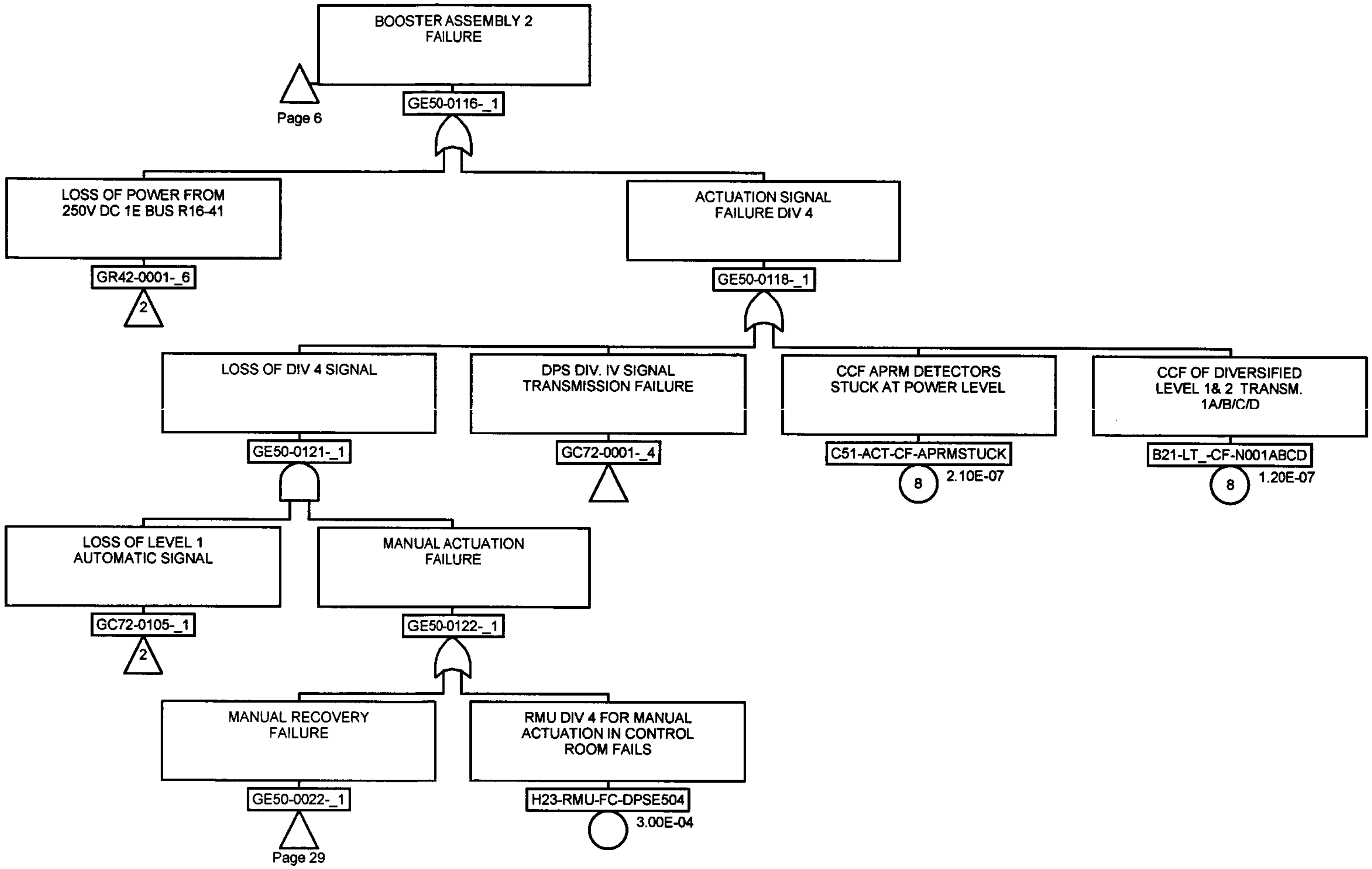

FAILURES ON LINE H
(POOL C)
GE50-0083-_1
Page 24
Page 36
SQUIB VALVE F002H FAILS
TO OPERATE
E50-SQV-CC-F002H
3.00E-03
CHECK VALVE F003H
FAILS TO REMAIN OPEN
OR PLUG
E50-UV_-OC-F003H
1.75E-03
ORIFICE 001H FAILS TO
REMAIN OPEN (PLUG) [# 5]
E50-OR_-PG-D001H
1.44E-05

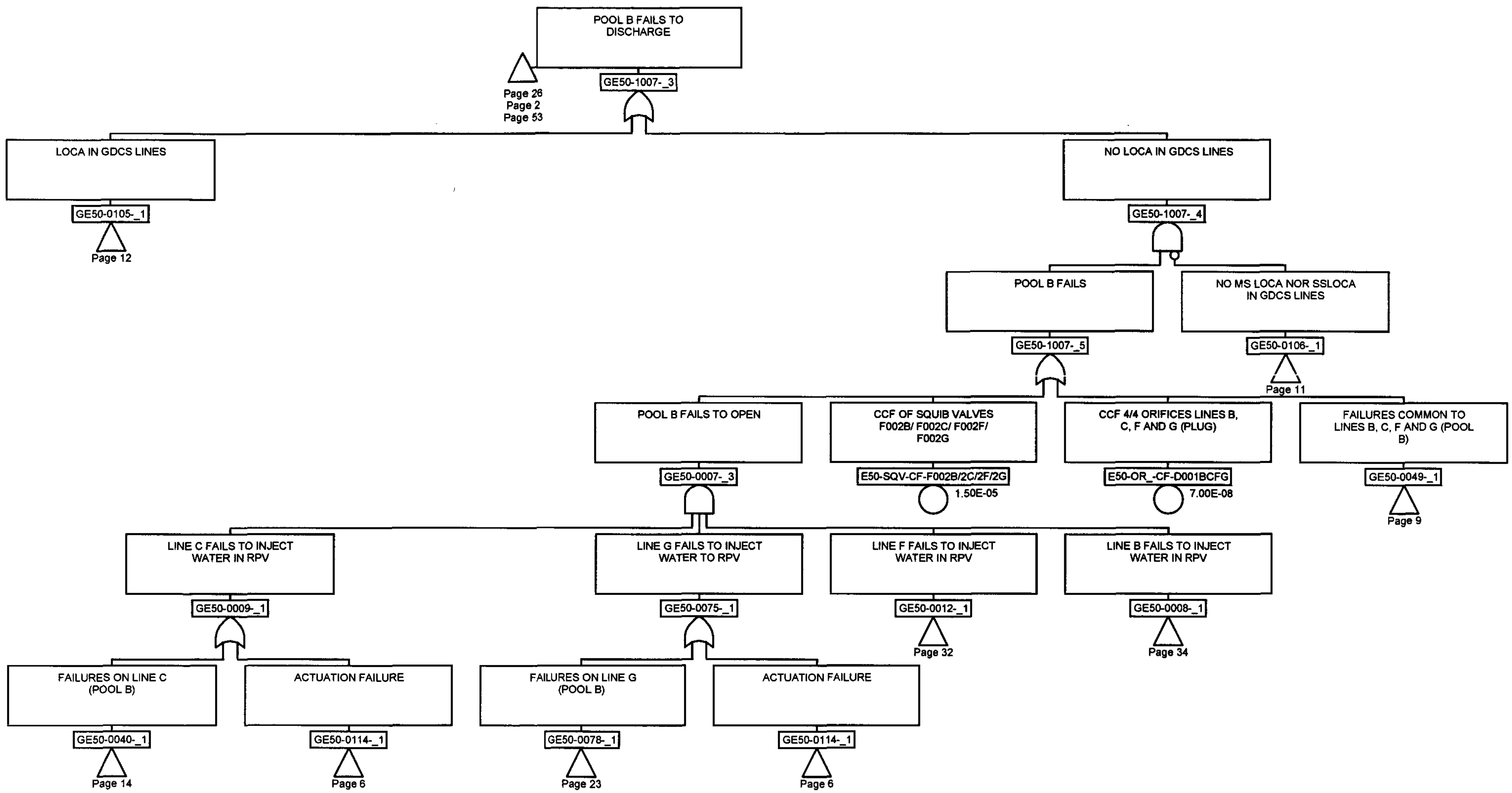

2/3 GDCS POOLS FAIL TO DISCHARGE
GE50TOP2
Page 1
Page 2
CCF
GE50-2035-_1
2/3 POOLS FAIL
GE50-0004-_3
2
CCF OF 4 OR MORE SQUIB VALVES TO OPEN
E50-SQV-CF-4OPEN
1.50E-05
CCF OF 4 OR MORE ORIFICES TO PLUG
E50-OR_-CF-4PLUG
7.00E-08
POOL A FAILS TO DISCHARGE
GE50-1006-_3
Page 27
POOL C FAILS TO DISCHARGE
GE50-1008-_3
Page 35
POOL B FAILS TO DISCHARGE
GE50-1007-_3
Page 31

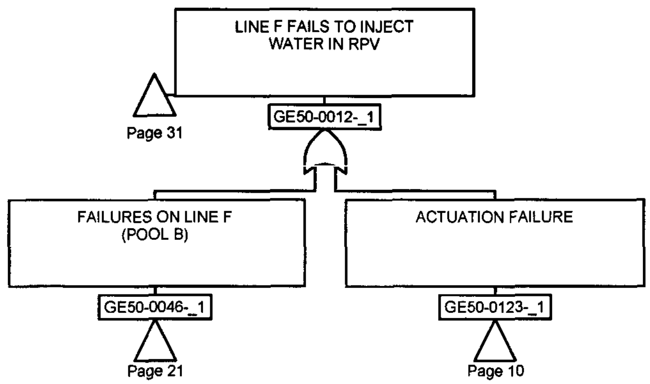

POOL A FAILS TO DISCHARGE
GE50-1006-_3
Page 26
Page 2
Page 53
FAILURES COMMON TO LINES A AND E (POOL A)
GE50-0051-_1
Page 5
CCF OF SQUIB VALVES F002A/ F002E
E50-SQV-CF-F002A/2E
3.60E-05
CCF 2/2 ORIFICES LINES A AND E (PLUG)
E50-OR_-CF-D001AE
7.20E-07
POOL A FAILS TO OPEN
GE50-0006-_3
LINE A FAILS TO INJECT WATER IN RPV
GE50-0007-_1
LINE E FAILS TO INJECT WATER IN RPV
GE50-0011-_1
Page 28
FAILURES ON LINE A (POOL A)
GE50-0054-_1
Page 4
ACTUATION FAILURE
GE50-0114-_1
Page 6

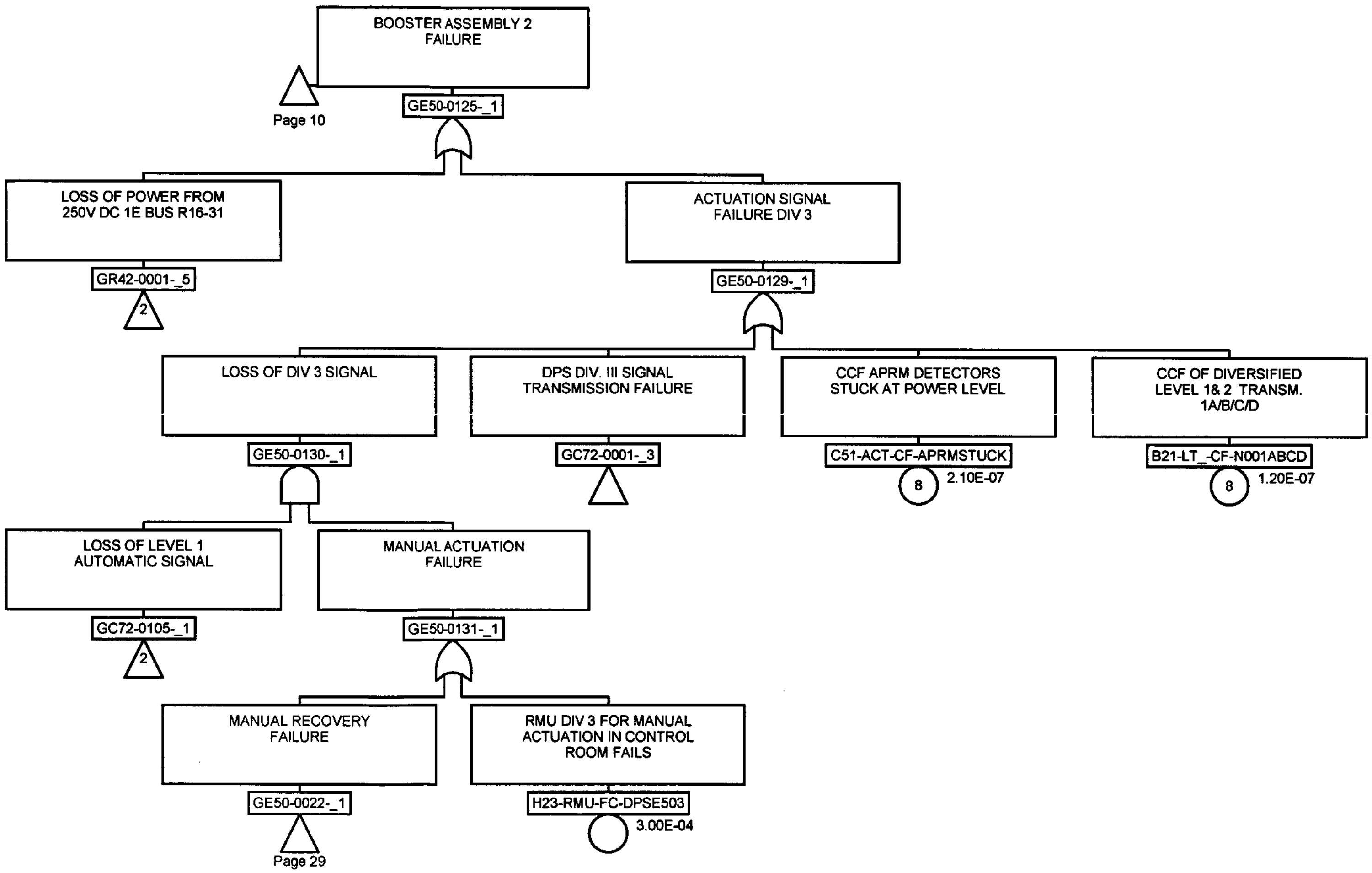

LINE E FAILS TO INJECT WATER IN RPV
GE50-0011-_1
Page 27
FAILURES ON LINE E (POOL A)
GE50-0135-_1
Page 19
ACTUATION FAILURE
GE50-0114-_1
Page 6

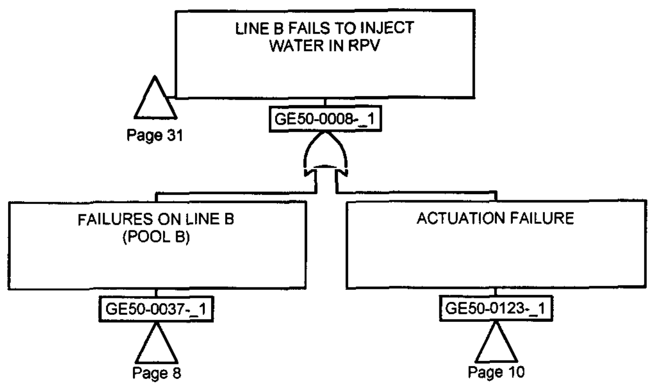

MANUAL RECOVERY FAILURE
GE50-0022-_1
Page 10
Page 33
Page 6
... see x-ref
MANUAL ACTUATION FAILURE [#2]
GE50-0027-_1
HOUSE EVENT: OPERATOR IS NOT AVAILABLE (VALUE=1)
XHOSMAN
2
CCF OF PRESSURE RPV TRANSMITTERS HIGH
B21-PT_-CF-02HIGH
3.00E-08
OPERATOR FAILS TO ACTUATE GDCS
E50-XHE-FO-GDCS
1.61E-03
OP. FAILS TO RECOG. OR CHECK THE RPV DECREASING LEVEL
XXX-XHE-FO-RPVLDE
2
1.61E-02
HARDWARE FAILURE
GE50-0030-_1
LOSS OF SCRAM FOLLOW SIGNAL. (2/4 RELAY LOGIC FAILURE
XXX-SYS-FF-SCRAMFOLLOW
2
7.80E-05
CCF's TO OPERATE OF DISCRETE LOGIC TIME DELAY's
C74-SLU-CF-DLTD
2
1.08E-05

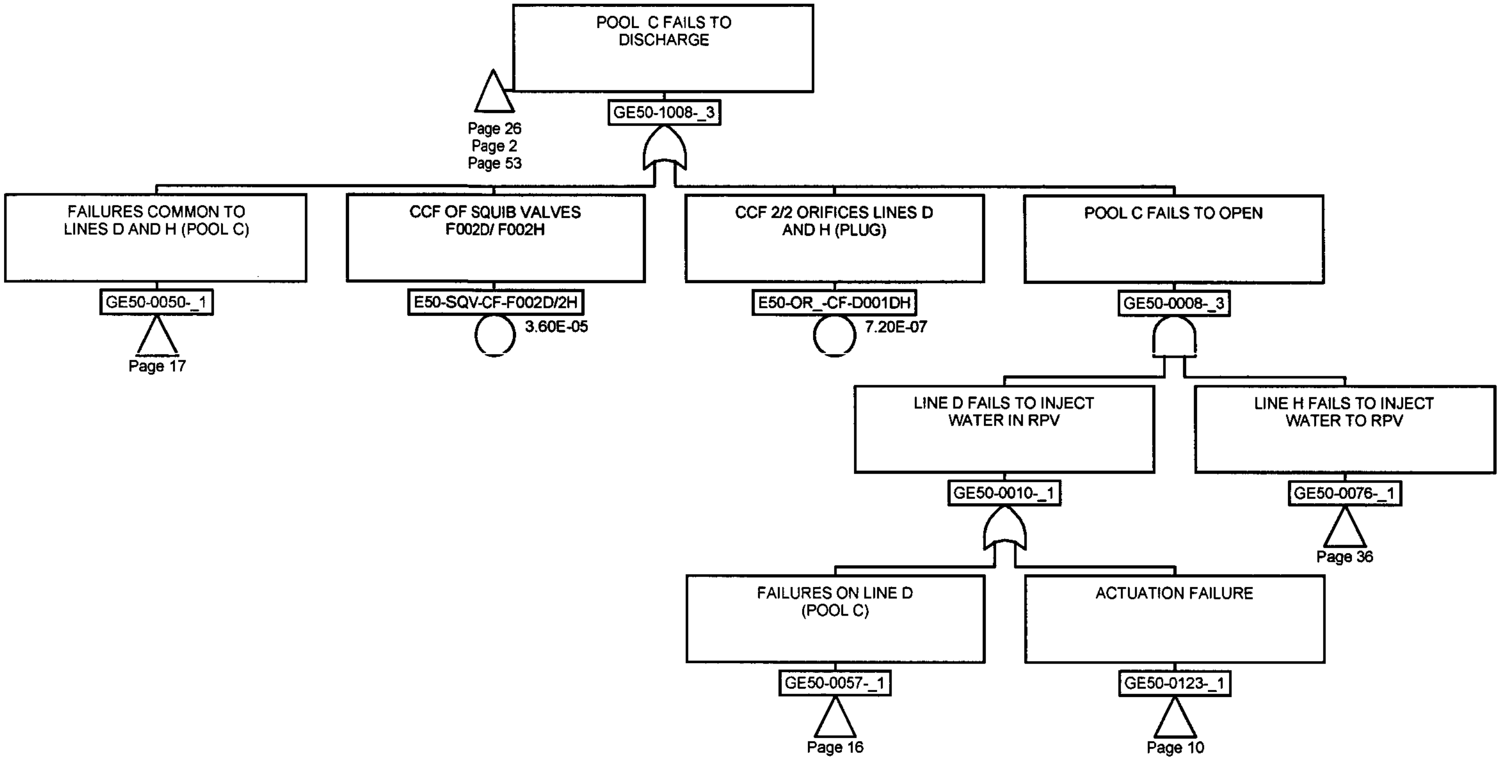

BOOSTER ASSEMBLY 2 FAILURE
Page 6
GE50-0116-_1
LOSS OF POWER FROM 250V DC 1E BUS R16-41
GR42-0001-_6
2
ACTUATION SIGNAL FAILURE DIV 4
GE50-0118-_1
LOSS OF DIV 4 SIGNAL
GE50-0121-_1
DPS DIV. IV SIGNAL TRANSMISSION FAILURE
GC72-0001-_4
CCF APRM DETECTORS STUCK AT POWER LEVEL
C51-ACT-CF-APRMSTUCK
8
2.10E-07
CCF OF DIVERSIFIED LEVEL 1& 2 TRANSM. 1A/B/C/D
B21-LT_-CF-N001ABCD
8
1.20E-07
LOSS OF LEVEL 1 AUTOMATIC SIGNAL
GC72-0105-_1
2
MANUAL ACTUATION FAILURE
GE50-0122-_1
MANUAL RECOVERY FAILURE
GE50-0022-_1
Page 29
RMU DIV 4 FOR MANUAL ACTUATION IN CONTROL ROOM FAILS
H23-RMU-FC-DPSE504
3.00E-04

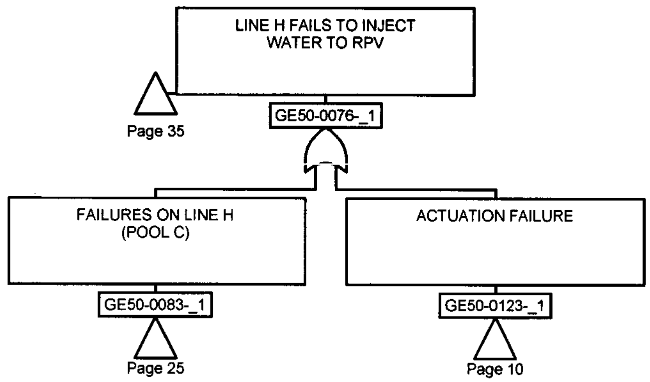

POOL B FAILS TO DISCHARGE
GE50-1007-_3
Page 26
Page 2
Page 53
LOCA IN GDCS LINES
GE50-0105-_1
Page 12
NO LOCA IN GDCS LINES
GE50-1007-_4
POOL B FAILS
GE50-1007-_5
NO MS LOCA NOR SSLOCA IN GDCS LINES
GE50-0106-_1
Page 11
POOL B FAILS TO OPEN
GE50-0007-_3
CCF OF SQUIB VALVES F002B/ F002C/ F002F/ F002G
E50-SQV-CF-F002B/2C/2F/2G
1.50E-05
CCF 4/4 ORIFICES LINES B, C, F AND G (PLUG)
E50-OR_-CF-D001BCFG
7.00E-08
FAILURES COMMON TO LINES B, C, F AND G (POOL B)
GE50-0049-_1
Page 9
LINE C FAILS TO INJECT WATER IN RPV
GE50-0009-_1
LINE G FAILS TO INJECT WATER TO RPV
GE50-0075-_1
LINE F FAILS TO INJECT WATER IN RPV
GE50-0012-_1
Page 32
LINE B FAILS TO INJECT WATER IN RPV
GE50-0008-_1
Page 34
FAILURES ON LINE C (POOL B)
GE50-0040-_1
Page 14
ACTUATION FAILURE
GE50-0114-_1
Page 6
FAILURES ON LINE G (POOL B)
GE50-0078-_1
Page 23
ACTUATION FAILURE
GE50-0114-_1
Page 6

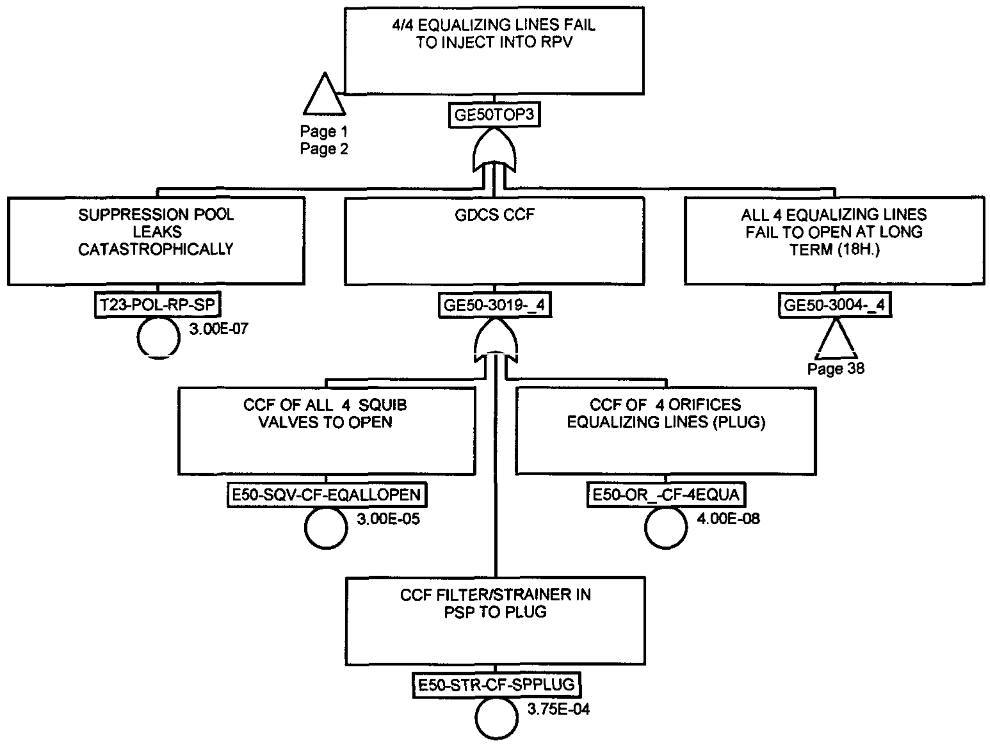

LINE F FAILS TO INJECT WATER IN RPV
Page 31
GE50-0012-_1
FAILURES ON LINE F (POOL B)
ACTUATION FAILURE
GE50-0046-_1
GE50-0123-_1
Page 21
Page 10

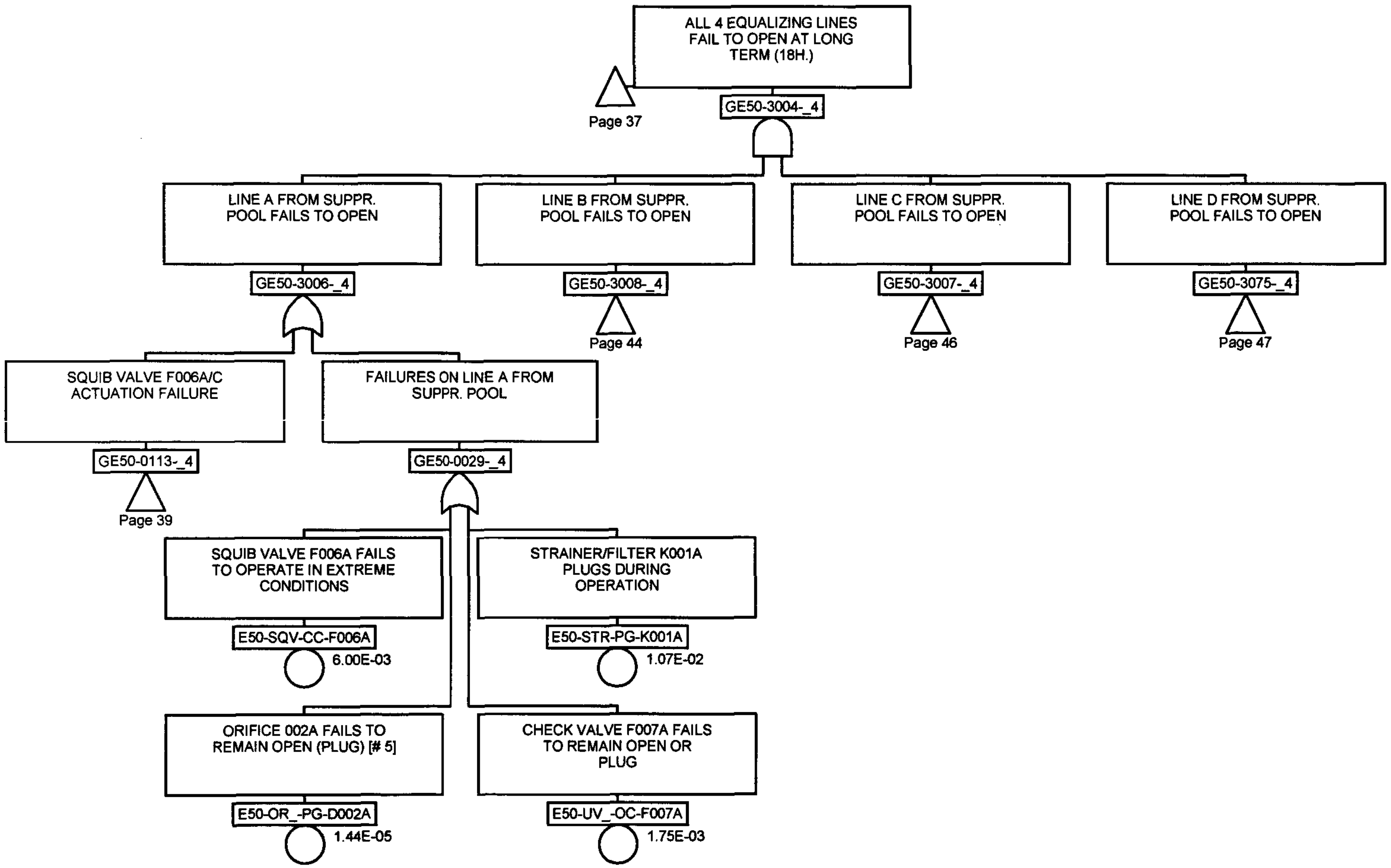

BOOSTER ASSEMBLY 2 FAILURE
Page 10
GE50-0125-_1
LOSS OF POWER FROM 250V DC 1E BUS R16-31
GR42-0001-_5
2
ACTUATION SIGNAL FAILURE DIV 3
GE50-0129-_1
LOSS OF DIV 3 SIGNAL
GE50-0130-_1
DPS DIV. III SIGNAL TRANSMISSION FAILURE
GC72-0001-_3
CCF APRM DETECTORS STUCK AT POWER LEVEL
C51-ACT-CF-APRMSTUCK
8
2.10E-07
CCF OF DIVERSIFIED LEVEL 1& 2 TRANSM. 1A/B/C/D
B21-LT_-CF-N001ABCD
8
1.20E-07
LOSS OF LEVEL 1 AUTOMATIC SIGNAL
GC72-0105-_1
2
MANUAL ACTUATION FAILURE
GE50-0131-_1
MANUAL RECOVERY FAILURE
GE50-0022-_1
Page 29
RMU DIV 3 FOR MANUAL ACTUATION IN CONTROL ROOM FAILS
H23-RMU-FC-DPSE503
3.00E-04

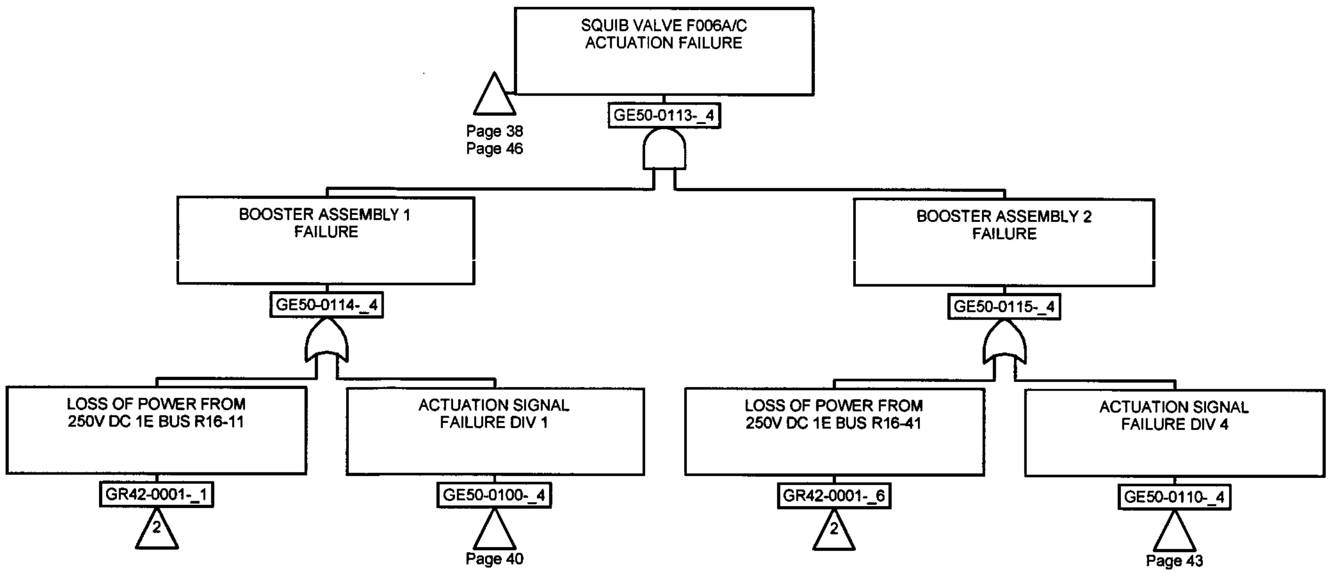

LINE B FAILS TO INJECT WATER IN RPV
Page 31
GE50-0008-_1
FAILURES ON LINE B (POOL B)
ACTUATION FAILURE
GE50-0037-_1
GE50-0123-_1
Page 8
Page 10

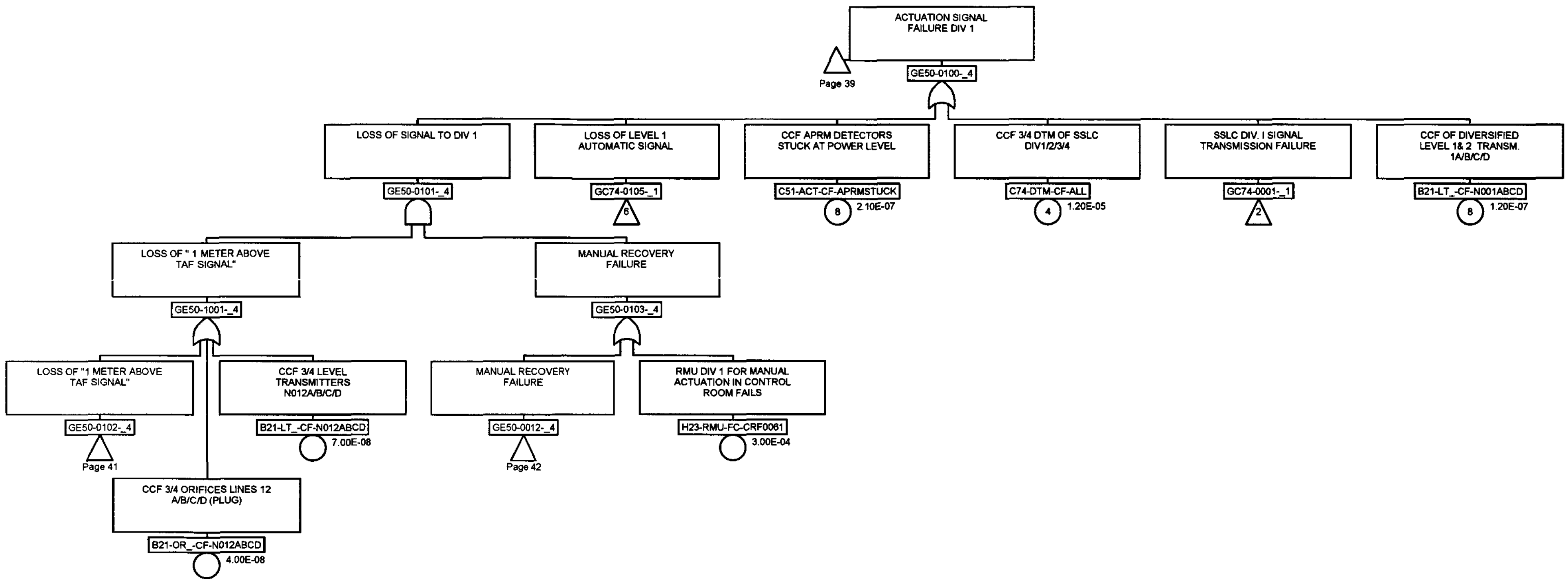

POOL C FAILS TO DISCHARGE
GE50-1008-_3
Page 26
Page 2
Page 53
FAILURES COMMON TO LINES D AND H (POOL C)
GE50-0050-_1
Page 17
CCF OF SQUIB VALVES F002D/ F002H
E50-SQV-CF-F002D/2H
3.60E-05
CCF 2/2 ORIFICES LINES D AND H (PLUG)
E50-OR_-CF-D001DH
7.20E-07
POOL C FAILS TO OPEN
GE50-0008-_3
LINE D FAILS TO INJECT WATER IN RPV
GE50-0010-_1
LINE H FAILS TO INJECT WATER TO RPV
GE50-0076-_1
Page 36
FAILURES ON LINE D (POOL C)
GE50-0057-_1
Page 16
ACTUATION FAILURE
GE50-0123-_1
Page 10


LINE H FAILS TO INJECT WATER TO RPV
GE50-0076-_1
Page 35
FAILURES ON LINE H (POOL C)
GE50-0083-_1
Page 25
ACTUATION FAILURE
GE50-0123-_1
Page 10

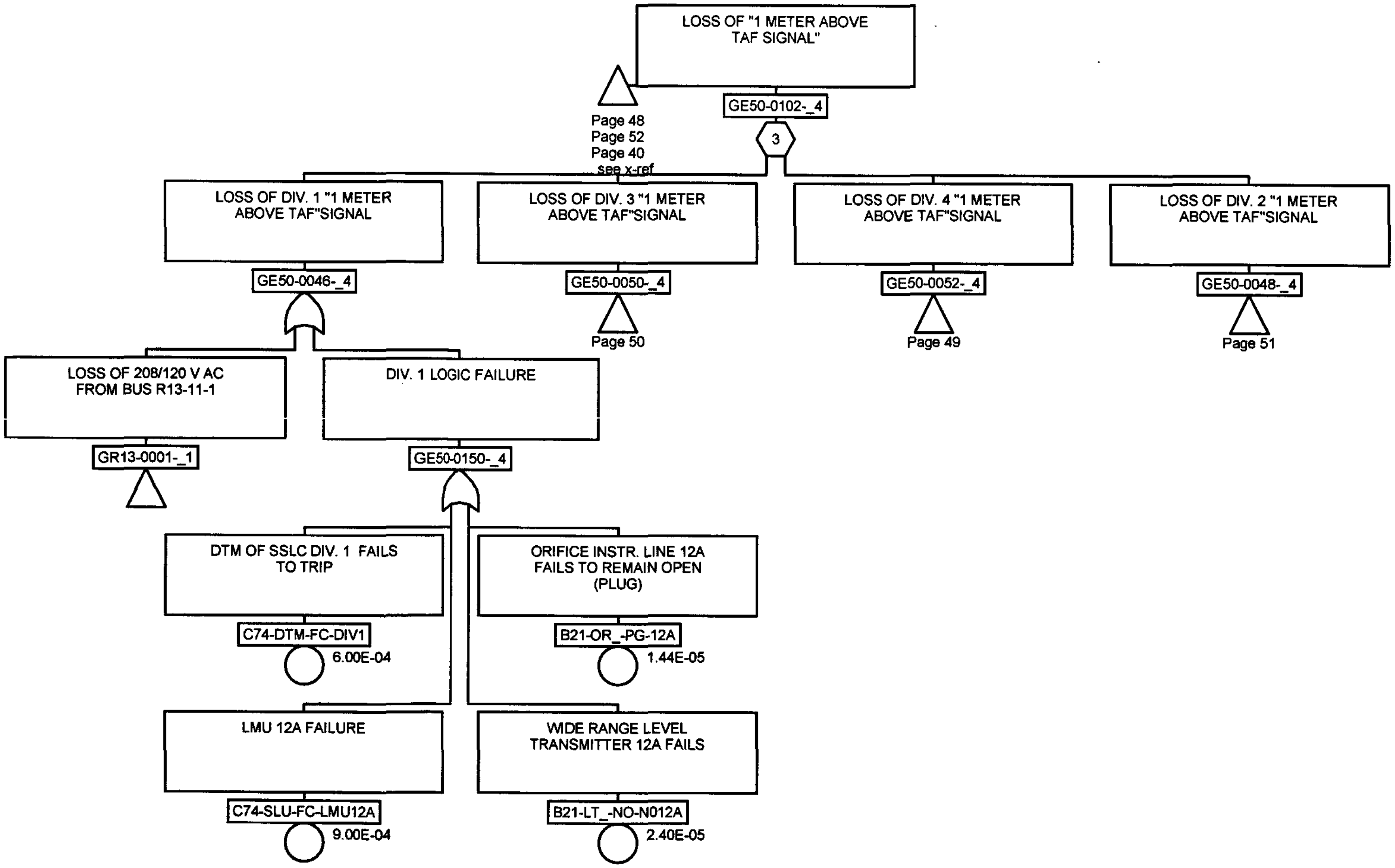

4/4 EQUALIZING LINES FAIL TO INJECT INTO RPV
GE50TOP3
Page 1
Page 2
SUPPRESSION POOL LEAKS CATASTROPHICALLY
T23-POL-RP-SP
3.00E-07
GDCS CCF
GE50-3019-_4
ALL 4 EQUALIZING LINES FAIL TO OPEN AT LONG TERM (18H.)
GE50-3004-_4
Page 38
CCF OF ALL 4 SQUIB VALVES TO OPEN
E50-SQV-CF-EQALLOPEN
3.00E-05
CCF OF 4 ORIFICES EQUALIZING LINES (PLUG)
E50-OR_-CF-4EQUA
4.00E-08
CCF FILTER/STRAINER IN PSP TO PLUG
E50-STR-CF-SPPLUG
3.75E-04

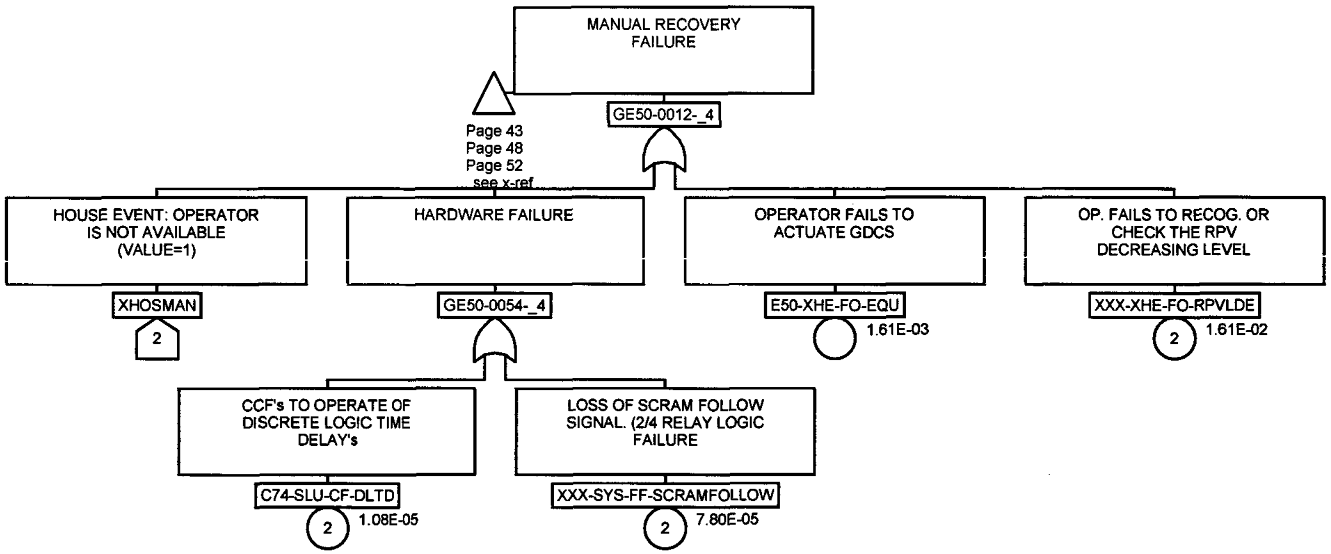

ALL 4 EQUALIZING LINES FAIL TO OPEN AT LONG TERM (18H.)
Page 37
GE50-3004-_4
LINE A FROM SUPPR. POOL FAILS TO OPEN
GE50-3006-_4
LINE B FROM SUPPR. POOL FAILS TO OPEN
GE50-3008-_4
Page 44
LINE C FROM SUPPR. POOL FAILS TO OPEN
GE50-3007-_4
Page 46
LINE D FROM SUPPR. POOL FAILS TO OPEN
GE50-3075-_4
Page 47
SQUIB VALVE F006A/C ACTUATION FAILURE
GE50-0113-_4
Page 39
FAILURES ON LINE A FROM SUPPR. POOL
GE50-0029-_4
SQUIB VALVE F006A FAILS TO OPERATE IN EXTREME CONDITIONS
E50-SQV-CC-F006A
6.00E-03
STRAINER/FILTER K001A PLUGS DURING OPERATION
E50-STR-PG-K001A
1.07E-02
ORIFICE 002A FAILS TO REMAIN OPEN (PLUG) [# 5]
E50-OR_-PG-D002A
1.44E-05
CHECK VALVE F007A FAILS TO REMAIN OPEN OR PLUG
E50-UV_-OC-F007A
1.75E-03

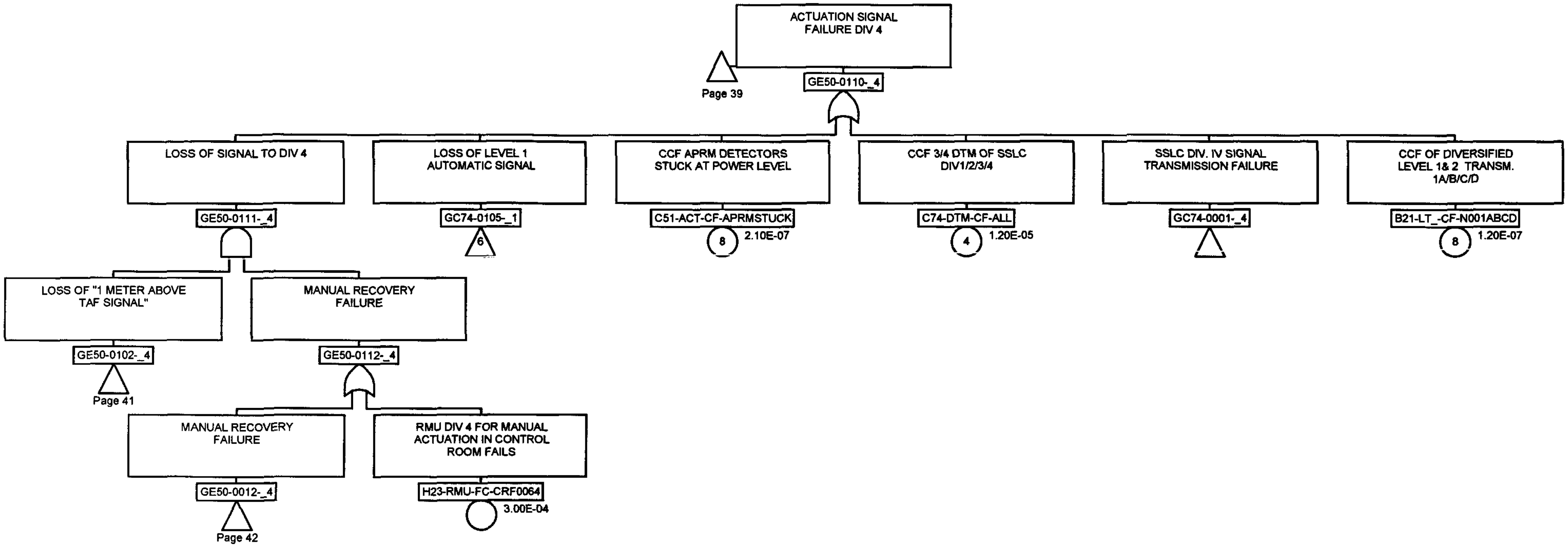

SQUIB VALVE F006A/C
ACTUATION FAILURE
GE50-0113-_4
Page 38
Page 46
BOOSTER ASSEMBLY 1
FAILURE
GE50-0114-_4
BOOSTER ASSEMBLY 2
FAILURE
GE50-0115-_4
LOSS OF POWER FROM
250V DC 1E BUS R16-11
GR42-0001-_1
2
ACTUATION SIGNAL
FAILURE DIV 1
GE50-0100-_4
Page 40
LOSS OF POWER FROM
250V DC 1E BUS R16-41
GR42-0001-_6
2
ACTUATION SIGNAL
FAILURE DIV 4
GE50-0110-_4
Page 43

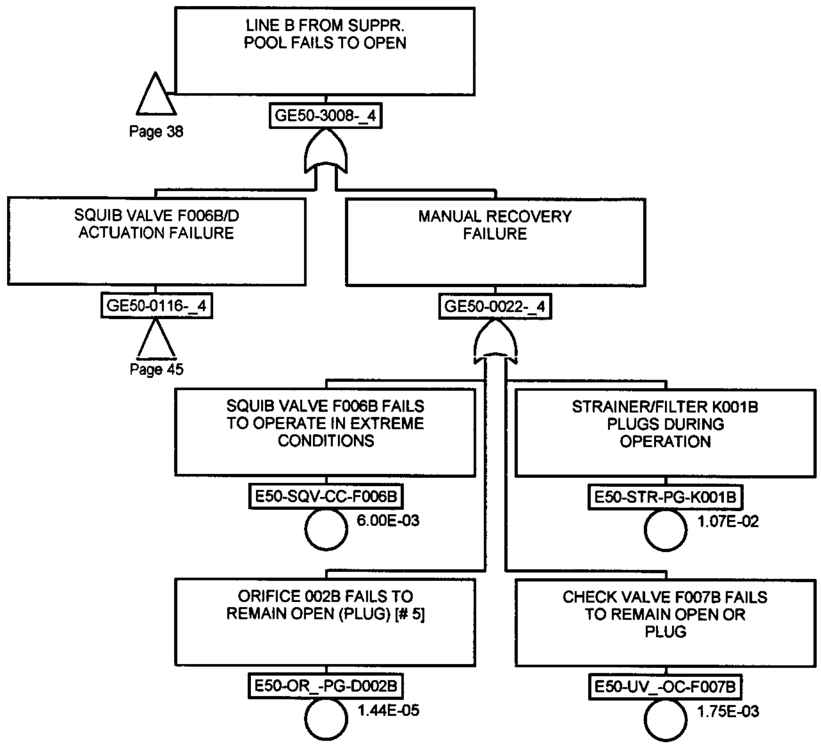


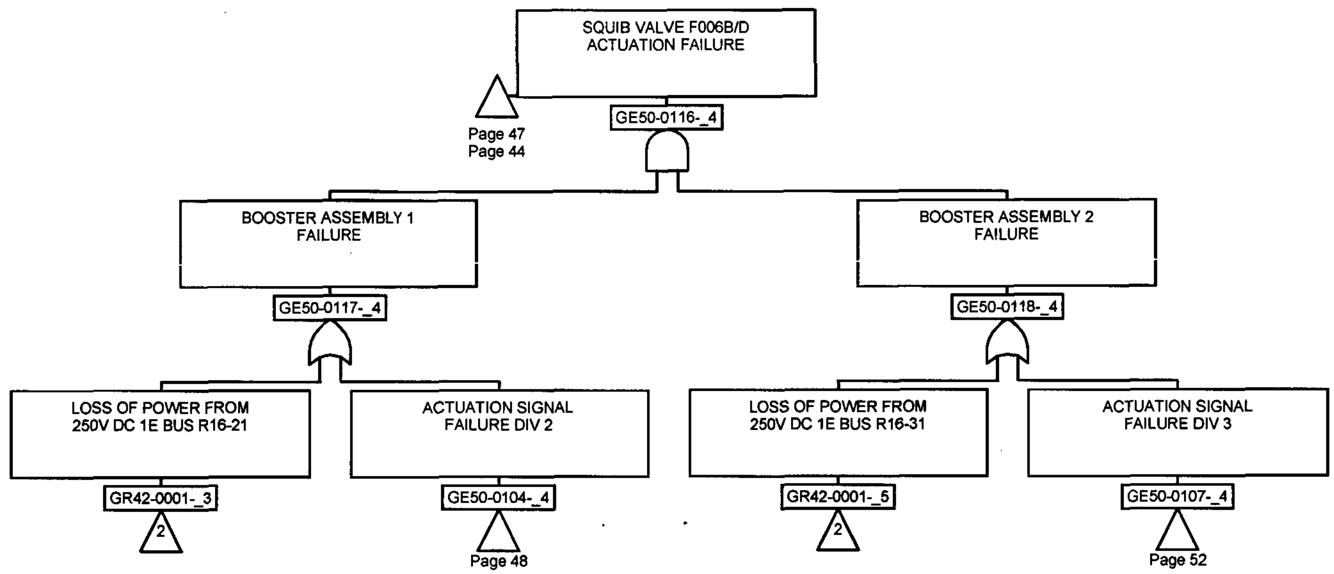
ACTUATION SIGNAL FAILURE DIV 1
GE50-0100-_4
Page 39
LOSS OF SIGNAL TO DIV 1
GE50-0101-_4
LOSS OF LEVEL 1 AUTOMATIC SIGNAL
GC74-0105-_1
6
CCF APRM DETECTORS STUCK AT POWER LEVEL
C51-ACT-CF-APRMSTUCK
8
2.10E-07
CCF 3/4 DTM OF SSLC DIV1/2/3/4
C74-DTM-CF-ALL
4
1.20E-05
SSLC DIV. I SIGNAL TRANSMISSION FAILURE
GC74-0001-_1
2
CCF OF DIVERSIFIED LEVEL 1& 2 TRANSM. 1A/B/C/D
B21-LT_-CF-N001ABCD
8
1.20E-07
LOSS OF " 1 METER ABOVE TAF SIGNAL"
GE50-1001-_4
MANUAL RECOVERY FAILURE
GE50-0103-_4
LOSS OF "1 METER ABOVE TAF SIGNAL"
GE50-0102-_4
Page 41
CCF 3/4 LEVEL TRANSMITTERS N012A/B/C/D
B21-LT_-CF-N012ABCD
7.00E-08
MANUAL RECOVERY FAILURE
GE50-0012-_4
Page 42
RMU DIV 1 FOR MANUAL ACTUATION IN CONTROL ROOM FAILS
H23-RMU-FC-CRF0061
3.00E-04
CCF 3/4 ORIFICES LINES 12 A/B/C/D (PLUG)
B21-OR_-CF-N012ABCD
4.00E-08

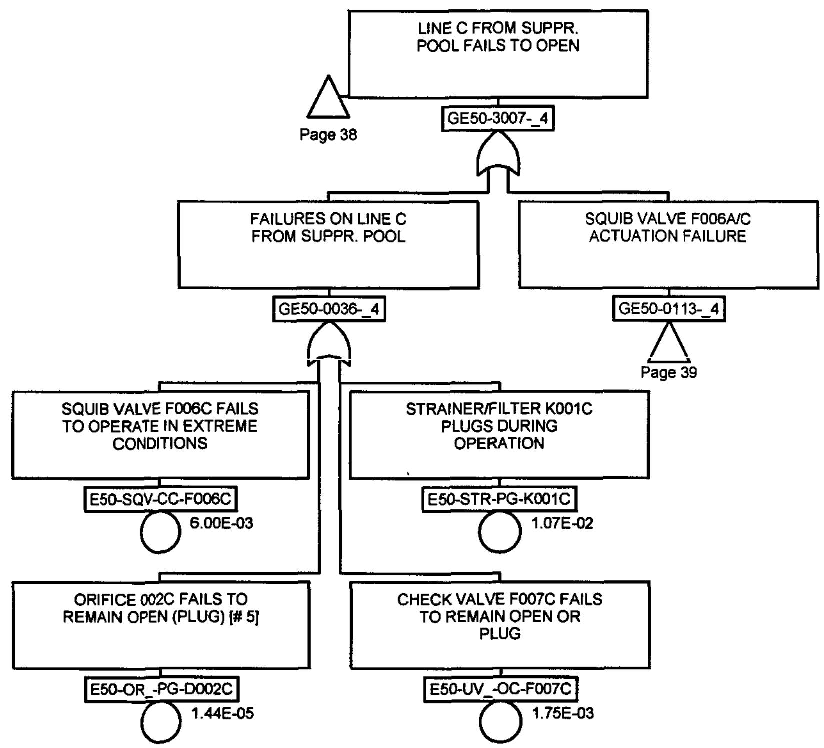

LOSS OF "1 METER ABOVE TAF SIGNAL"
GE50-0102-_4
Page 48
Page 52
Page 40
see x-ref
3
LOSS OF DIV. 1 "1 METER ABOVE TAF"SIGNAL
GE50-0046-_4
LOSS OF DIV. 3 "1 METER ABOVE TAF"SIGNAL
GE50-0050-_4
Page 50
LOSS OF DIV. 4 "1 METER ABOVE TAF"SIGNAL
GE50-0052-_4
Page 49
LOSS OF DIV. 2 "1 METER ABOVE TAF"SIGNAL
GE50-0048-_4
Page 51
LOSS OF 208/120 V AC FROM BUS R13-11-1
GR13-0001-_1
DIV. 1 LOGIC FAILURE
GE50-0150-_4
DTM OF SSLC DIV. 1 FAILS TO TRIP
C74-DTM-FC-DIV1
6.00E-04
ORIFICE INSTR. LINE 12A FAILS TO REMAIN OPEN (PLUG)
B21-OR_-PG-12A
1.44E-05
LMU 12A FAILURE
C74-SLU-FC-LMU12A
9.00E-04
WIDE RANGE LEVEL TRANSMITTER 12A FAILS
B21-LT_-NO-N012A
2.40E-05

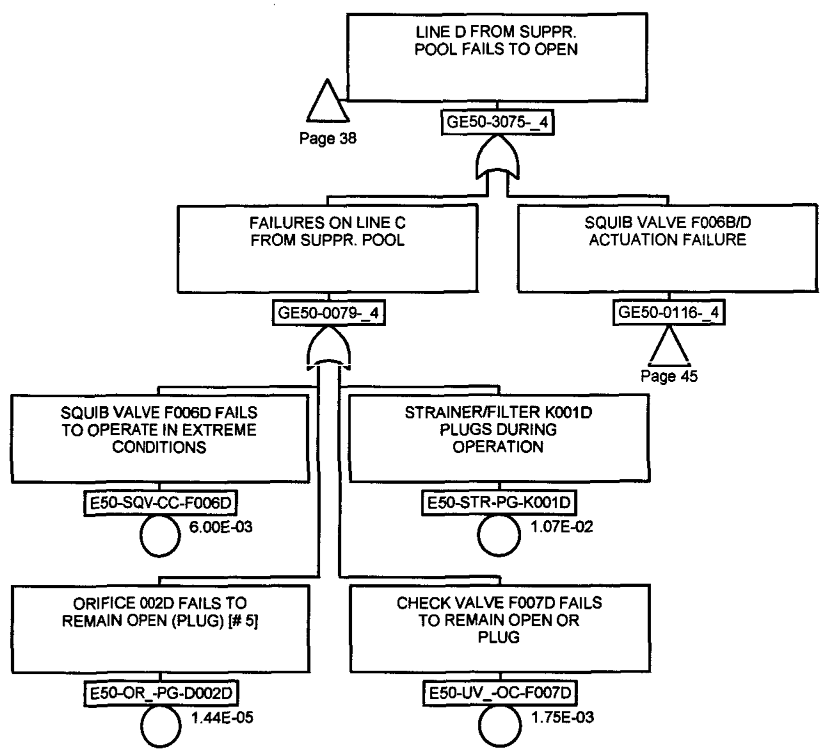

MANUAL RECOVERY FAILURE
GE50-0012-_4
Page 43
Page 48
Page 52
see x-ref
HOUSE EVENT: OPERATOR IS NOT AVAILABLE (VALUE=1)
XHOSMAN
2
HARDWARE FAILURE
GE50-0054-_4
OPERATOR FAILS TO ACTUATE GDCS
E50-XHE-FO-EQU
1.61E-03
OP. FAILS TO RECOG. OR CHECK THE RPV DECREASING LEVEL
XXX-XHE-FO-RPVLDE
2
1.61E-02
CCF's TO OPERATE OF DISCRETE LOGIC TIME DELAY's
C74-SLU-CF-DLTD
2
1.08E-05
LOSS OF SCRAM FOLLOW SIGNAL. (2/4 RELAY LOGIC FAILURE
XXX-SYS-FF-SCRAMFOLLOW
2
7.80E-05


ACTUATION SIGNAL FAILURE DIV 4
GE50-0110-_4
Page 39
LOSS OF SIGNAL TO DIV 4
GE50-0111-_4
LOSS OF LEVEL 1 AUTOMATIC SIGNAL
GC74-0105-_1
6
CCF APRM DETECTORS STUCK AT POWER LEVEL
C51-ACT-CF-APRMSTUCK
8
2.10E-07
CCF 3/4 DTM OF SSLC DIV1/2/3/4
C74-DTM-CF-ALL
4
1.20E-05
SSLC DIV. IV SIGNAL TRANSMISSION FAILURE
GC74-0001-_4
CCF OF DIVERSIFIED LEVEL 1& 2 TRANSM. 1A/B/C/D
B21-LT_-CF-N001ABCD
8
1.20E-07
LOSS OF "1 METER ABOVE TAF SIGNAL"
GE50-0102-_4
Page 41
MANUAL RECOVERY FAILURE
GE50-0112-_4
MANUAL RECOVERY FAILURE
GE50-0012-_4
Page 42
RMU DIV 4 FOR MANUAL ACTUATION IN CONTROL ROOM FAILS
H23-RMU-FC-CRF0064
3.00E-04

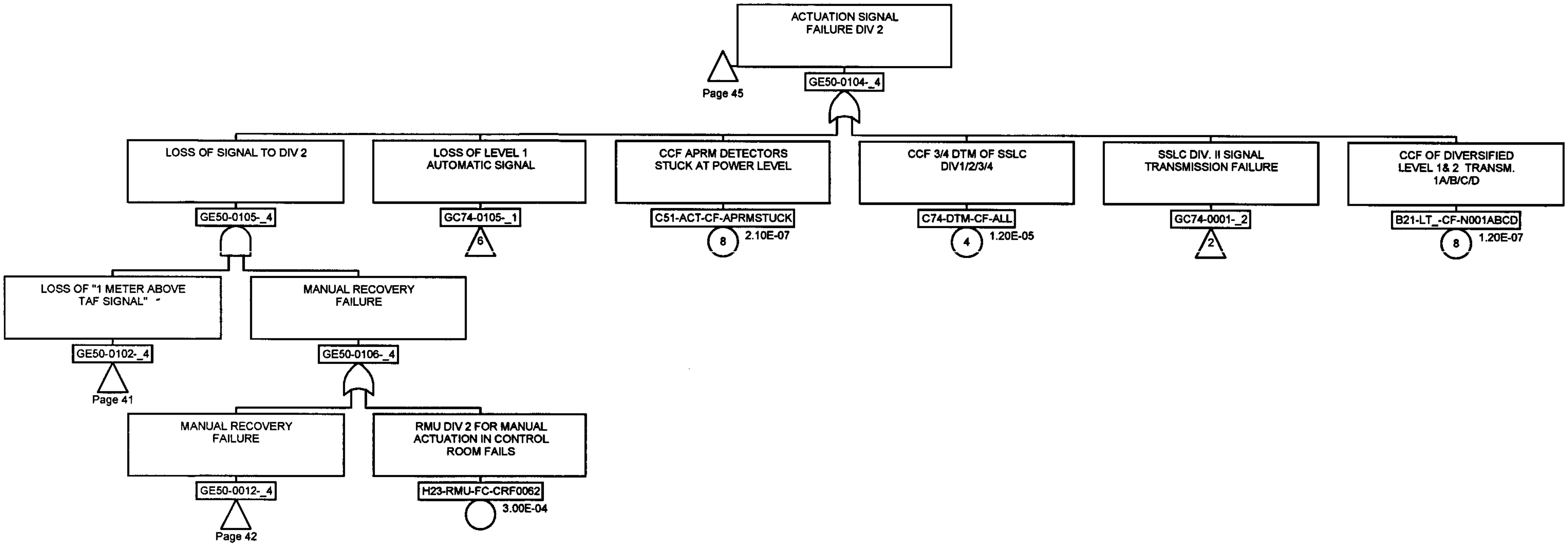

LINE B FROM SUPPR. POOL FAILS TO OPEN
GE50-3008-_4
Page 38
SQUIB VALVE F006B/D ACTUATION FAILURE
GE50-0116-_4
Page 45
MANUAL RECOVERY FAILURE
GE50-0022-_4
SQUIB VALVE F006B FAILS TO OPERATE IN EXTREME CONDITIONS
E50-SQV-CC-F006B
6.00E-03
STRAINER/FILTER K001B PLUGS DURING OPERATION
E50-STR-PG-K001B
1.07E-02
ORIFICE 002B FAILS TO REMAIN OPEN (PLUG) [# 5]
E50-OR_-PG-D002B
1.44E-05
CHECK VALVE F007B FAILS TO REMAIN OPEN OR PLUG
E50-UV_-OC-F007B
1.75E-03

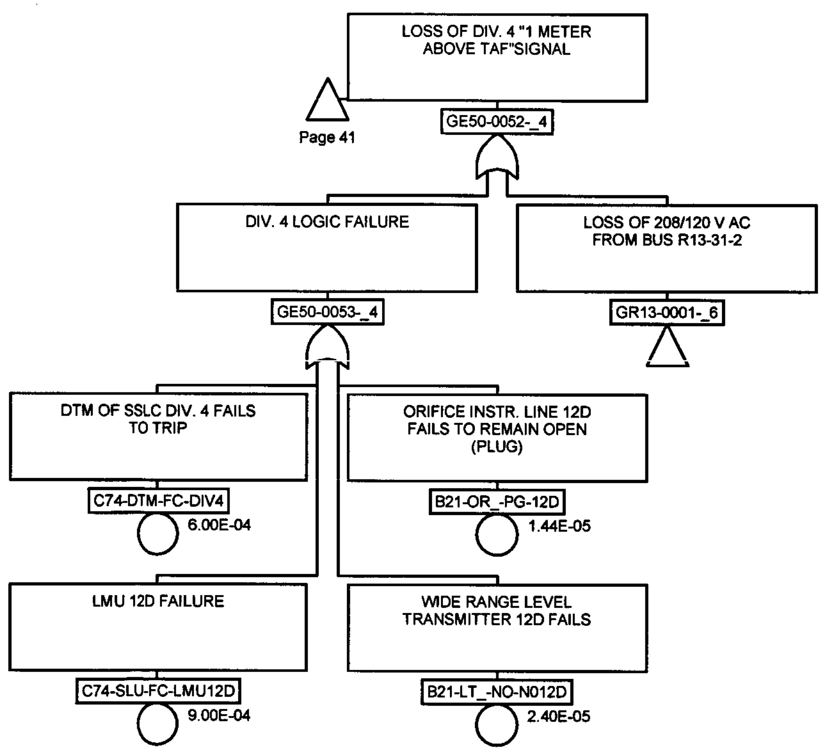

SQUIB VALVE F006B/D ACTUATION FAILURE
GE50-0116-_4
Page 47
Page 44
BOOSTER ASSEMBLY 1 FAILURE
GE50-0117-_4
BOOSTER ASSEMBLY 2 FAILURE
GE50-0118-_4
LOSS OF POWER FROM 250V DC 1E BUS R16-21
GR42-0001-_3
2
ACTUATION SIGNAL FAILURE DIV 2
GE50-0104-_4
Page 48
LOSS OF POWER FROM 250V DC 1E BUS R16-31
GR42-0001-_5
2
ACTUATION SIGNAL FAILURE DIV 3
GE50-0107-_4
Page 52

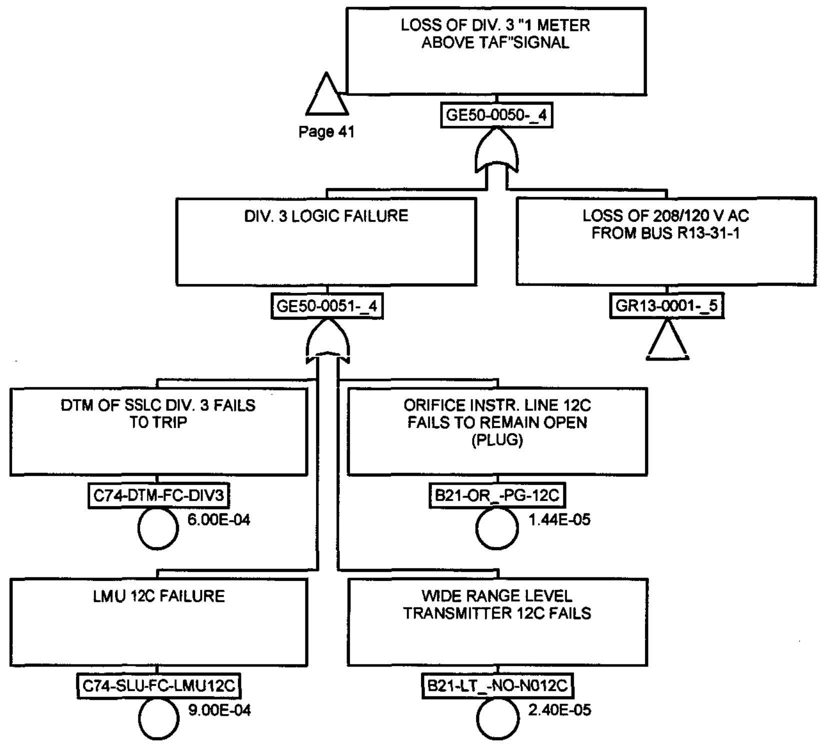

LINE C FROM SUPPR. POOL FAILS TO OPEN
Page 38
GE50-3007-_4
FAILURES ON LINE C FROM SUPPR. POOL
GE50-0036-_4
SQUIB VALVE F006A/C ACTUATION FAILURE
GE50-0113-_4
Page 39
SQUIB VALVE F006C FAILS TO OPERATE IN EXTREME CONDITIONS
E50-SQV-CC-F006C
6.00E-03
STRAINER/FILTER K001C PLUGS DURING OPERATION
E50-STR-PG-K001C
1.07E-02
ORIFICE 002C FAILS TO REMAIN OPEN (PLUG) [# 5]
E50-OR_-PG-D002C
1.44E-05
CHECK VALVE F007C FAILS TO REMAIN OPEN OR PLUG
E50-UV_-OC-F007C
1.75E-03

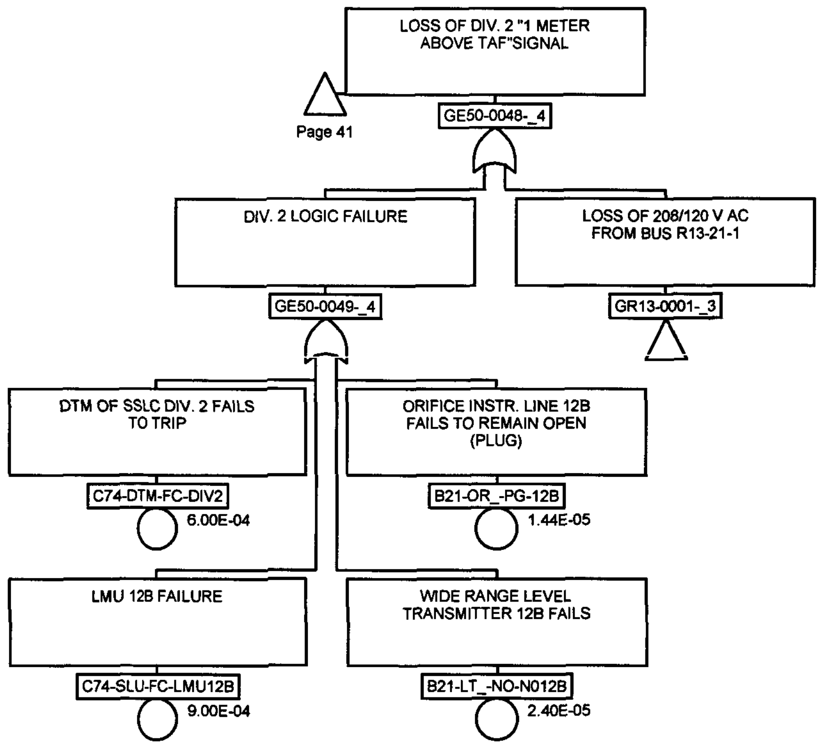


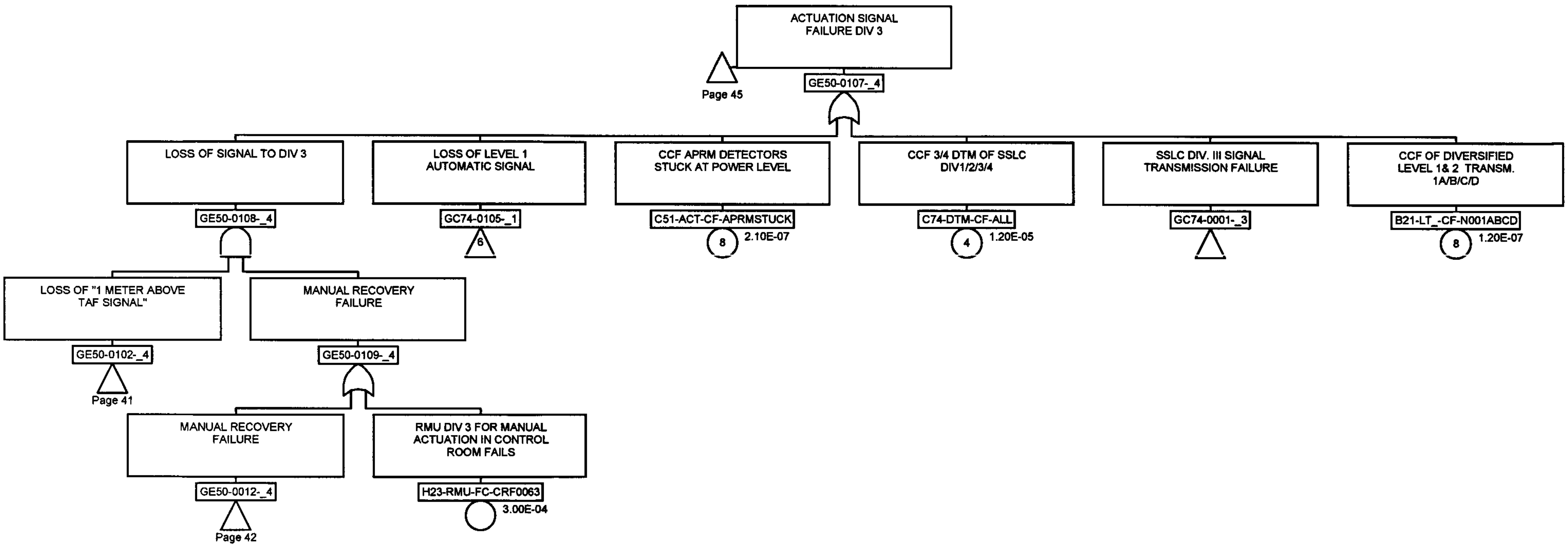
LINE D FROM SUPPR. POOL FAILS TO OPEN
GE50-3075-_4
Page 38
FAILURES ON LINE C FROM SUPPR. POOL
GE50-0079-_4
SQUIB VALVE F006B/D ACTUATION FAILURE
GE50-0116-_4
Page 45
SQUIB VALVE F006D FAILS TO OPERATE IN EXTREME CONDITIONS
E50-SQV-CC-F006D
6.00E-03
STRAINER/FILTER K001D PLUGS DURING OPERATION
E50-STR-PG-K001D
1.07E-02
ORIFICE 002D FAILS TO REMAIN OPEN (PLUG) [# 5]
E50-OR_-PG-D002D
1.44E-05
CHECK VALVE F007D FAILS TO REMAIN OPEN OR PLUG
E50-UV_-OC-F007D
1.75E-03

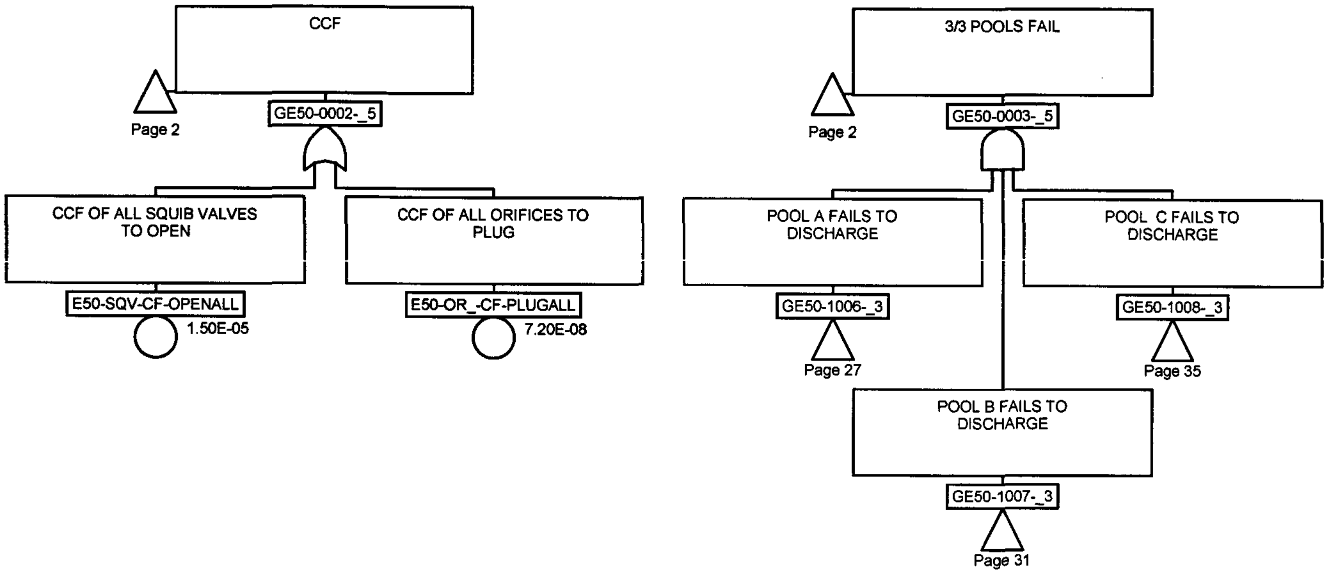

ACTUATION SIGNAL FAILURE DIV 2
GE50-0104-_4
Page 45
LOSS OF SIGNAL TO DIV 2
GE50-0105-_4
LOSS OF LEVEL 1 AUTOMATIC SIGNAL
GC74-0105-_1
6
CCF APRM DETECTORS STUCK AT POWER LEVEL
C51-ACT-CF-APRMSTUCK
8
2.10E-07
CCF 3/4 DTM OF SSLC DIV1/2/3/4
C74-DTM-CF-ALL
4
1.20E-05
SSLC DIV. II SIGNAL TRANSMISSION FAILURE
GC74-0001-_2
2
CCF OF DIVERSIFIED LEVEL 1& 2 TRANSM. 1A/B/C/D
B21-LT_-CF-N001ABCD
8
1.20E-07
LOSS OF "1 METER ABOVE TAF SIGNAL"
GE50-0102-_4
Page 41
MANUAL RECOVERY FAILURE
GE50-0106-_4
MANUAL RECOVERY FAILURE
GE50-0012-_4
Page 42
RMU DIV 2 FOR MANUAL ACTUATION IN CONTROL ROOM FAILS
H23-RMU-FC-CRF0062
3.00E-04


LOSS OF DIV. 4 "1 METER ABOVE TAF"SIGNAL
GE50-0052-_4
Page 41
DIV. 4 LOGIC FAILURE
GE50-0053-_4
LOSS OF 208/120 V AC FROM BUS R13-31-2
GR13-0001-_6
DTM OF SSLC DIV. 4 FAILS TO TRIP
C74-DTM-FC-DIV4
6.00E-04
ORIFICE INSTR. LINE 12D FAILS TO REMAIN OPEN (PLUG)
B21-OR_-PG-12D
1.44E-05
LMU 12D FAILURE
C74-SLU-FC-LMU12D
9.00E-04
WIDE RANGE LEVEL TRANSMITTER 12D FAILS
B21-LT_-NO-N012D
2.40E-05


LOSS OF DIV. 3 "1 METER ABOVE TAF"SIGNAL
GE50-0050-_4
Page 41
DIV. 3 LOGIC FAILURE
GE50-0051-_4
LOSS OF 208/120 V AC FROM BUS R13-31-1
GR13-0001-_5
DTM OF SSLC DIV. 3 FAILS TO TRIP
C74-DTM-FC-DIV3
6.00E-04
ORIFICE INSTR. LINE 12C FAILS TO REMAIN OPEN (PLUG)
B21-OR_-PG-12C
1.44E-05
LMU 12C FAILURE
C74-SLU-FC-LMU12C
9.00E-04
WIDE RANGE LEVEL TRANSMITTER 12C FAILS
B21-LT_-NO-N012C
2.40E-05


LOSS OF DIV. 2 "1 METER ABOVE TAF"SIGNAL
GE50-0048-_4
Page 41
DIV. 2 LOGIC FAILURE
GE50-0049-_4
LOSS OF 208/120 V AC FROM BUS R13-21-1
GR13-0001-_3
DTM OF SSLC DIV. 2 FAILS TO TRIP
C74-DTM-FC-DIV2
6.00E-04
ORIFICE INSTR. LINE 12B FAILS TO REMAIN OPEN (PLUG)
B21-OR_-PG-12B
1.44E-05
LMU 12B FAILURE
C74-SLU-FC-LMU12B
9.00E-04
WIDE RANGE LEVEL TRANSMITTER 12B FAILS
B21-LT_-NO-N012B
2.40E-05


ACTUATION SIGNAL FAILURE DIV 3
Page 45
GE50-0107-_4
LOSS OF SIGNAL TO DIV 3
GE50-0108-_4
LOSS OF LEVEL 1 AUTOMATIC SIGNAL
GC74-0105-_1
6
CCF APRM DETECTORS STUCK AT POWER LEVEL
C51-ACT-CF-APRMSTUCK
8
2.10E-07
CCF 3/4 DTM OF SSLC DIV1/2/3/4
C74-DTM-CF-ALL
4
1.20E-05
SSLC DIV. III SIGNAL TRANSMISSION FAILURE
GC74-0001-_3
CCF OF DIVERSIFIED LEVEL 1& 2 TRANSM. 1A/B/C/D
B21-LT_-CF-N001ABCD
8
1.20E-07
LOSS OF "1 METER ABOVE TAF SIGNAL"
GE50-0102-_4
Page 41
MANUAL RECOVERY FAILURE
GE50-0109-_4
MANUAL RECOVERY FAILURE
GE50-0012-_4
Page 42
RMU DIV 3 FOR MANUAL ACTUATION IN CONTROL ROOM FAILS
H23-RMU-FC-CRF0063
3.00E-04


CCF
Page 2
GE50-0002-_5
CCF OF ALL SQUIB VALVES TO OPEN
E50-SQV-CF-OPENALL
1.50E-05
CCF OF ALL ORIFICES TO PLUG
E50-OR_-CF-PLUGALL
7.20E-08
3/3 POOLS FAIL
Page 2
GE50-0003-_5
POOL A FAILS TO DISCHARGE
GE50-1006-_3
Page 27
POOL C FAILS TO DISCHARGE
GE50-1008-_3
Page 35
POOL B FAILS TO DISCHARGE
GE50-1007-_3
Page 31

Name	Page	Zone
B21-LT -CF-N001ABCD	6	5
B21-LT -CF-N001ABCD	10	5
B21-LT -CF-N001ABCD	30	5
B21-LT -CF-N001ABCD	33	5
B21-LT -CF-N001ABCD	40	7
B21-LT -CF-N001ABCD	43	7
B21-LT -CF-N001ABCD	48	7
B21-LT -CF-N001ABCD	52	7
B21-LT -CF-N012ABCD	40	2
B21-LT -NO-N012A	41	3
B21-LT -NO-N012B	51	2
B21-LT -NO-N012C	50	2
B21-LT -NO-N012D	49	2
B21-OR -CF-N012ABCD	40	2
B21-OR -PG-12A	41	3
B21-OR -PG-12B	51	2
B21-OR -PG-12C	50	2
B21-OR -PG-12D	49	2
B21-PT -CF-02HIGH	29	1
C51-ACT-CF-APRMSTUCK	6	4
C51-ACT-CF-APRMSTUCK	10	4
C51-ACT-CF-APRMSTUCK	30	4
C51-ACT-CF-APRMSTUCK	33	4
C51-ACT-CF-APRMSTUCK	40	4
C51-ACT-CF-APRMSTUCK	43	4
C51-ACT-CF-APRMSTUCK	48	4
C51-ACT-CF-APRMSTUCK	52	4
C74-DTM-CF-ALL	40	5
C74-DTM-CF-ALL	43	5
C74-DTM-CF-ALL	48	5
C74-DTM-CF-ALL	52	5
C74-DTM-FC-DIV1	41	2
C74-DTM-FC-DIV2	51	1
C74-DTM-FC-DIV3	50	1
C74-DTM-FC-DIV4	49	1
C74-SLU-CF-DLTD	29	5
C74-SLU-CF-DLTD	42	2
C74-SLU-FC-LMU12A	41	2
C74-SLU-FC-LMU12B	51	1
C74-SLU-FC-LMU12C	50	1
C74-SLU-FC-LMU12D	49	1
E50-OR -CF-4EQUA	37	3
E50-OR -CF-4PLUG	26	2
E50-OR -CF-7PLUG	1	2
E50-OR -CF-D001AE	27	3
E50-OR -CF-D001BCFG	31	5
E50-OR -CF-D001DH	35	3
E50-OR -CF-PLUGALL	53	2
E50-OR -PG-D001A	4	2
E50-OR -PG-D001B	8	2
E50-OR -PG-D001C	14	2
E50-OR -PG-D001D	16	2
E50-OR -PG-D001E	19	2
E50-OR -PG-D001F	21	2
E50-OR -PG-D001G	23	2
E50-OR -PG-D001H	25	2
E50-OR -PG-D002A	38	2
E50-OR -PG-D002B	44	2
E50-OR -PG-D002C	46	1
E50-OR -PG-D002D	47	1
E50-POL-RP-POOLA	5	2
E50-POL-RP-POOLB	9	2
E50-POL-RP-POOLC	17	2
E50-SQV-CC-F002A	4	1
E50-SQV-CC-F002B	8	1
E50-SQV-CC-F002C	14	1
E50-SQV-CC-F002D	16	1
E50-SQV-CC-F002E	19	1
E50-SQV-CC-F002F	21	1
E50-SQV-CC-F002G	23	1
E50-SQV-CC-F002H	25	1
E50-SQV-CC-F006A	38	2
E50-SQV-CC-F006B	44	2
E50-SQV-CC-F006C	46	1
E50-SQV-CC-F006D	47	1
E50-SQV-CF-4OPEN	26	1
E50-SQV-CF-EQALLOPEN	37	2
E50-SQV-CF-F002A/2E	27	2
E50-SQV-CF-F002B/2C/2F/2G	31	4
E50-SQV-CF-F002D/2H	35	2
E50-SQV-CF-GDCS7OPEN	1	1
E50-SQV-CF-OPENALL	53	1
E50-SQV-CO-F009A	5	1
E50-SQV-CO-F009B	9	1
E50-SQV-CO-F009C	9	1
E50-SQV-CO-F009D	17	1
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E50-SQV-CO-F009F	9	1
E50-SQV-CO-F009G	9	2
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E50-SQV-CO-F009J	9	2
E50-SQV-CO-F009K	9	2
E50-SQV-CO-F009L	17	2
E50-STR-CF-SPPLUG	37	2
E50-STR-PG-K001A	38	3
E50-STR-PG-K001B	44	3
E50-STR-PG-K001C	46	2
E50-STR-PG-K001D	47	2
E50-SYS-FF-MLLOCA	12	1
E50-SYS-FF-SLLOCA	12	4
E50-UV -OC-F003A	4	2
E50-UV -OC-F003B	8	2
E50-UV -OC-F003C	14	2
E50-UV -OC-F003D	16	2
E50-UV -OC-F003E	19	2
E50-UV -OC-F003F	21	2
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E50-UV -OC-F007D	47	2
E50-XHE-FO-EQU	42	3
E50-XHE-FO-GDCS	29	2
GC72-0001- 3	33	3
GC72-0001- 4	30	3
GC72-0105- 1	30	1
GC72-0105- 1	33	1
GC74-0001- 1	6	3
GC74-0001- 1	40	6
GC74-0001- 2	10	3
GC74-0001- 2	48	6
GC74-0001- 3	52	6
GC74-0001- 4	43	6
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GC74-0105- 1	52	3
GE50-0002- 5	2	3
GE50-0002- 5	53	2
GE50-0003- 5	2	4
GE50-0003- 5	53	4
GE50-0004- 3	26	4
GE50-0005- 1	1	3
GE50-0005- 1	3	2
GE50-0006- 3	27	4
GE50-0007- 1	27	4
GE50-0007- 3	31	3
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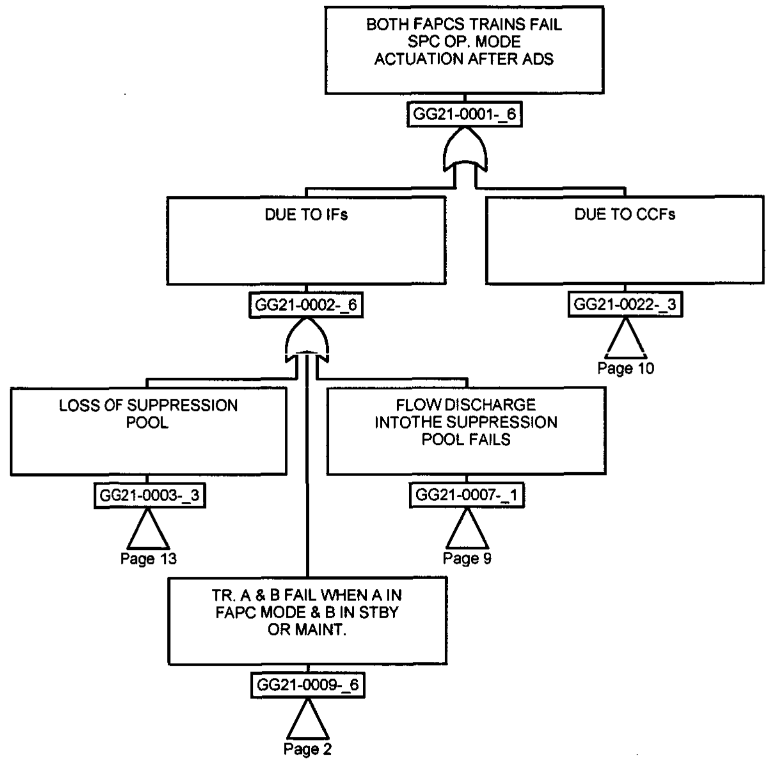
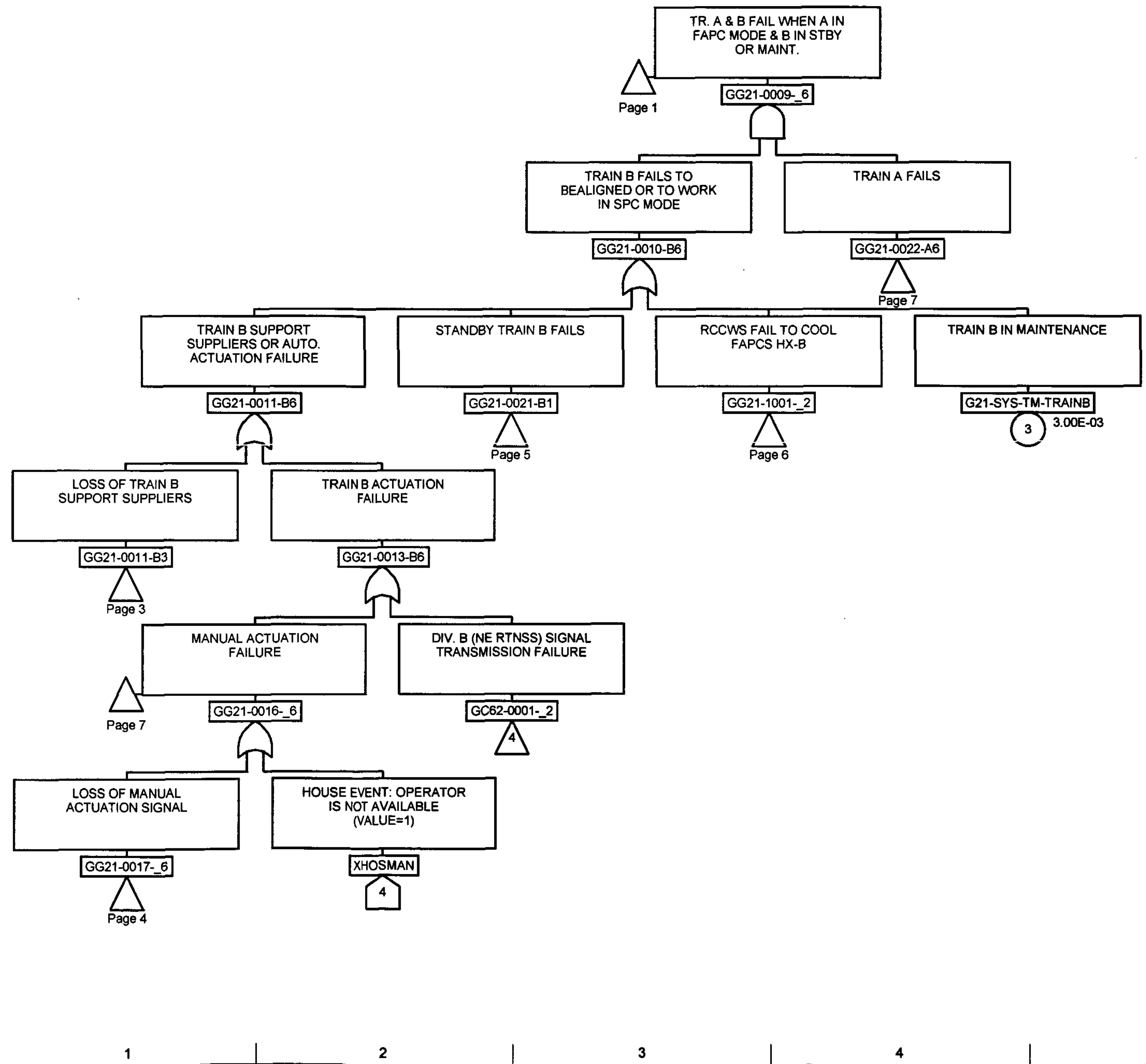
GE50-0010- 1	35	4
GE50-0011- 1	27	5
GE50-0011- 1	28	2
GE50-0012- 1	31	5
GE50-0012- 1	32	2
GE50-0012- 4	40	3
GE50-0012- 4	42	3
GE50-0012- 4	43	2
GE50-0012- 4	48	2
GE50-0012- 4	52	2
GE50-0022- 1	6	2
GE50-0022- 1	10	2
GE50-0022- 1	29	3
GE50-0022- 1	30	2
GE50-0022- 1	33	2
GE50-0022- 4	44	2
GE50-0027- 1	29	3

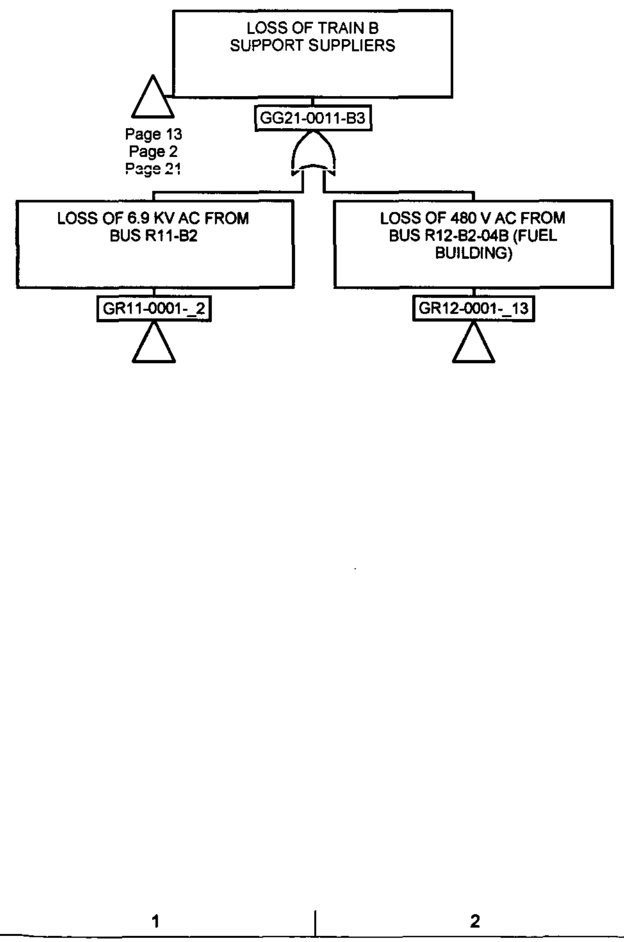
Name	Page	Zone	Name	Page	Zone	Name	Page	Zone
GE50-0029- 4	38	2	GE50-0100- 4	39	2	GE50-0116- 4	44	1
GE50-0030- 1	29	4	GE50-0100- 4	40	5	GE50-0116- 4	45	2
GE50-0035- 1	1	2	GE50-0101- 4	40	2	GE50-0116- 4	47	3
GE50-0036- 4	46	2	GE50-0102- 4	40	1	GE50-0117- 1	6	3
GE50-0037- 1	7	1	GE50-0102- 4	41	3	GE50-0117- 4	45	2
GE50-0037- 1	8	2	GE50-0102- 4	43	1	GE50-0118- 1	30	3
GE50-0037- 1	34	1	GE50-0102- 4	48	1	GE50-0118- 4	45	4
GE50-0040- 1	13	1	GE50-0102- 4	52	1	GE50-0119- 1	6	2
GE50-0040- 1	14	2	GE50-0103- 4	40	4	GE50-0120- 1	6	2
GE50-0040- 1	31	1	GE50-0104- 4	45	2	GE50-0121- 1	30	2
GE50-0046- 1	20	1	GE50-0104- 4	48	4	GE50-0122- 1	30	2
GE50-0046- 1	21	2	GE50-0105- 1	7	3	GE50-0123- 1	7	2
GE50-0046- 1	32	1	GE50-0105- 1	12	2	GE50-0123- 1	10	2
GE50-0046- 4	41	2	GE50-0105- 1	13	3	GE50-0123- 1	15	2
GE50-0048- 4	41	5	GE50-0105- 1	20	3	GE50-0123- 1	20	2
GE50-0048- 4	51	2	GE50-0105- 1	22	3	GE50-0123- 1	24	2
GE50-0049- 1	7	2	GE50-0105- 1	31	1	GE50-0123- 1	32	2
GE50-0049- 1	9	2	GE50-0105- 4	48	2	GE50-0123- 1	34	2
GE50-0049- 1	13	2	GE50-0106- 1	7	3	GE50-0123- 1	35	4
GE50-0049- 1	20	2	GE50-0106- 1	11	2	GE50-0123- 1	36	2
GE50-0049- 1	22	2	GE50-0106- 1	13	3	GE50-0124- 1	10	2
GE50-0049- 1	31	6	GE50-0106- 1	20	3	GE50-0125- 1	10	3
GE50-0049- 4	51	2	GE50-0106- 1	22	3	GE50-0125- 1	33	2
GE50-0050- 1	15	2	GE50-0106- 1	31	6	GE50-0126- 1	10	3
GE50-0050- 1	17	2	GE50-0106- 4	48	2	GE50-0127- 1	10	2
GE50-0050- 1	24	2	GE50-0107- 1	12	2	GE50-0128- 1	10	2
GE50-0050- 1	35	1	GE50-0107- 4	45	4	GE50-0129- 1	33	3
GE50-0050- 4	41	3	GE50-0107- 4	52	4	GE50-0130- 1	33	2
GE50-0050- 4	50	2	GE50-0108- 1	12	4	GE50-0131- 1	33	2
GE50-0051- 1	3	4	GE50-0108- 4	52	2	GE50-0135- 1	18	1
GE50-0051- 1	5	2	GE50-0109- 4	52	2	GE50-0135- 1	19	2
GE50-0051- 1	18	2	GE50-0110- 4	39	4	GE50-0135- 1	28	1
GE50-0051- 1	27	1	GE50-0110- 4	43	4	GE50-0150- 4	41	2
GE50-0051- 4	50	2	GE50-0111- 1	20	2	GE50-1001- 4	40	2
GE50-0052- 4	41	4	GE50-0111- 4	43	2	GE50-1006- 3	2	5
GE50-0052- 4	49	2	GE50-0112- 4	43	2	GE50-1006- 3	26	3
GE50-0053- 4	49	2	GE50-0113- 1	22	2	GE50-1006- 3	27	3
GE50-0054- 1	3	3	GE50-0113- 4	38	1	GE50-1006- 3	53	3
GE50-0054- 1	4	2	GE50-0113- 4	39	2	GE50-1007- 3	2	6
GE50-0054- 1	27	3	GE50-0113- 4	46	3	GE50-1007- 3	26	4
GE50-0054- 4	42	2	GE50-0114- 1	3	4	GE50-1007- 3	31	3
GE50-0057- 1	15	1	GE50-0114- 1	6	2	GE50-1007- 3	53	4
GE50-0057- 1	16	2	GE50-0114- 1	13	2	GE50-1007- 4	31	5
GE50-0057- 1	35	3	GE50-0114- 1	18	2	GE50-1007- 5	31	5
GE50-0075- 1	31	4	GE50-0114- 1	22	2	GE50-1008- 3	2	6
GE50-0076- 1	35	5	GE50-0114- 1	27	4	GE50-1008- 3	26	4
GE50-0076- 1	36	2	GE50-0114- 1	28	2	GE50-1008- 3	35	3
GE50-0078- 1	22	1	GE50-0114- 1	31	2	GE50-1008- 3	53	4
GE50-0078- 1	23	2	GE50-0114- 1	31	4	GE50-2007- 1	3	1
GE50-0078- 1	31	3	GE50-0114- 4	39	2	GE50-2007- 1	3	4
GE50-0079- 4	47	2	GE50-0115- 1	6	2	GE50-2008- 1	7	2
GE50-0083- 1	24	1	GE50-0115- 4	39	4	GE50-2009- 1	13	2
GE50-0083- 1	25	2	GE50-0116- 1	6	3	GE50-2010- 1	3	1
GE50-0083-_1	36	1	GE50-0116-_1	30	2	GE50-2010-_1	15	2

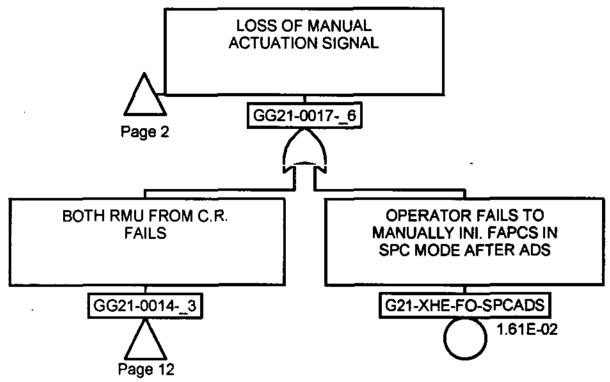
Name	Page	Zone
GE50-2011- 1	3	2
GE50-2011- 1	18	2
GE50-2012- 1	20	2
GE50-2035- 1	26	2
GE50-2075- 1	22	2
GE50-2076- 1	3	2
GE50-2076- 1	24	2
GE50-2100- 1	3	1
GE50-2100- 1	7	2
GE50-2101- 1	3	2
GE50-2101- 1	20	2
GE50-2102- 1	3	1
GE50-2102- 1	13	2
GE50-2103- 1	3	2
GE50-2103- 1	22	2
GE50-2104- 1	7	2
GE50-2112- 1	13	2
GE50-3004- 4	37	3
GE50-3004- 4	38	3
GE50-3006- 4	38	2
GE50-3007- 4	38	4
GE50-3007- 4	46	2
GE50-3008- 4	38	3
GE50-3008- 4	44	2
GE50-3019- 4	37	2
GE50-3075- 4	38	5
GE50-3075- 4	47	2
GE50TOP	1	3
GE50TOP1	1	2
GE50TOP2	1	3
GE50TOP2	2	1
GE50TOP2	26	2
GE50TOP3	1	4
GE50TOP3	2	2
GE50TOP3	37	2
GE50TOP4	2	6
GE50TOP5	2	4
GE50TOP6	2	2
GR13-0001- 1	41	1
GR13-0001- 3	51	3
GR13-0001- 5	50	3
GR13-0001- 6	49	3
GR42-0001- 1	6	1
GR42-0001- 1	39	1
GR42-0001- 3	10	1
GR42-0001- 3	45	1
GR42-0001- 5	33	1
GR42-0001- 5	45	3
GR42-0001- 6	30	1
GR42-0001- 6	39	3
H23-RMU-FC-CRF0061	40	4
H23-RMU-FC-CRF0062	48	3
H23-RMU-FC-CRF0063	52	3
H23-RMU-FC-CRF0064	43	3
H23-RMU-FC-DPSE503	33	3
H23-RMU-FC-DPSE504	30	3
H23-RMU-FC-E50DIV1	6	3
H23-RMU-FC-E50DIV2	10	3
T23-POL-RP-SP	37	1
XHOSE50MSLI	11	1
XHOSE50MSLI	12	2
XHOSE50SSLI	11	2
XHOSE50SSLI	12	3
XHOSMAN	29	4
XHOSMAN	42	1
XXX-SYS-FF-SCRAMFOLLOW	29	4
XXX-SYS-FF-SCRAMFOLLOW	42	3
XXX-XHE-FO-RPVLDE	29	3
XXX-XHE-FO-RPVLDE	42	4

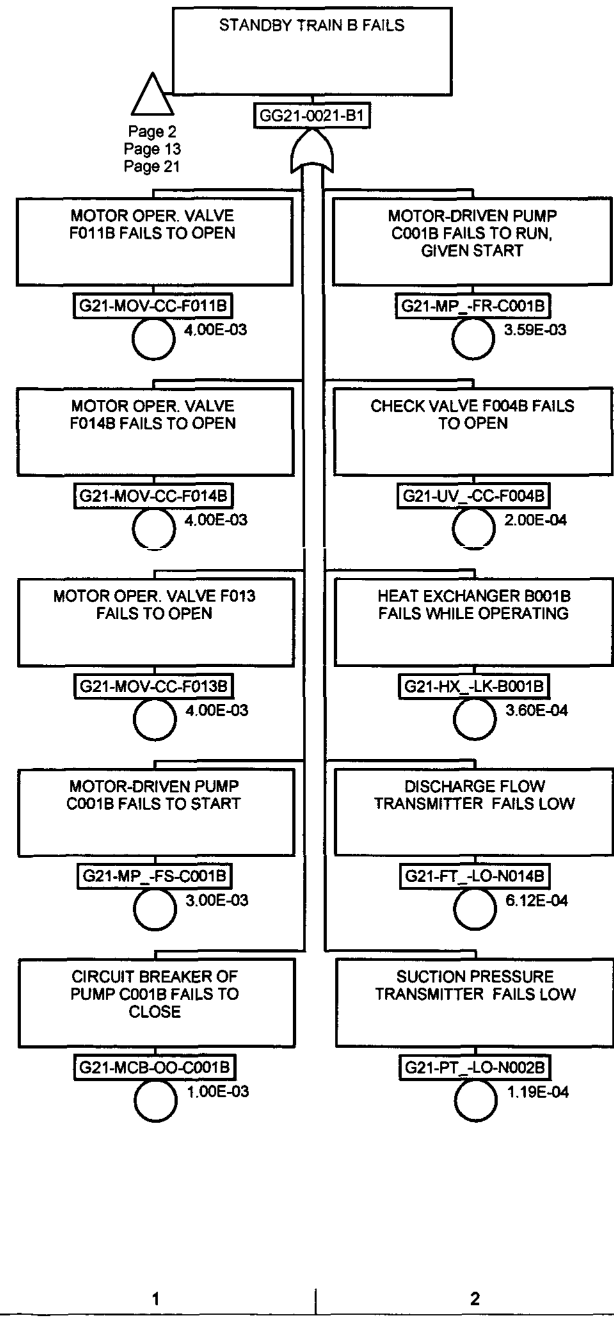
Appendix B.4.7-1 FUEL AND AUXILIARY POOLS COOLING SYSTEM - (G21) Fault Tree

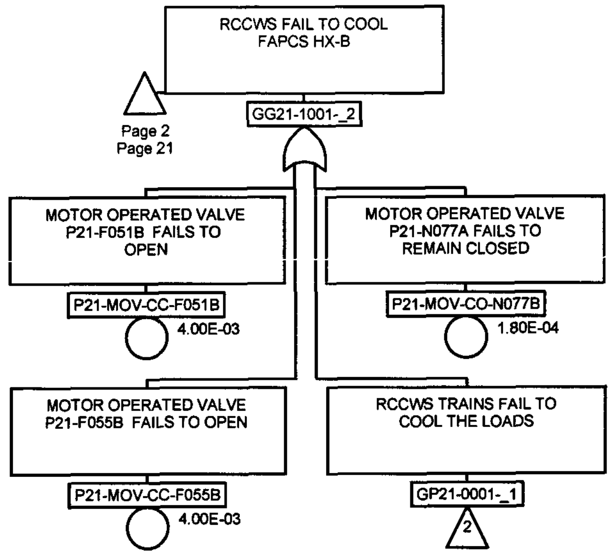

BOTH FAPCS TRAINS FAIL
SPC OP. MODE
ACTUATION AFTER ADS
GG21-0001-_6
DUE TO IFs
GG21-0002-_6
DUE TO CCFs
GG21-0022-_3
Page 10
LOSS OF SUPPRESSION
POOL
GG21-0003-_3
Page 13
FLOW DISCHARGE
INTOTHE SUPPRESSION
POOL FAILS
GG21-0007-_1
Page 9
TR. A & B FAIL WHEN A IN
FAPC MODE & B IN STBY
OR MAINT.
GG21-0009-_6
Page 2


TR. A & B FAIL WHEN A IN FAPC MODE & B IN STBY OR MAINT.
GG21-0009-_6
Page 1
TRAIN B FAILS TO BEALIGNED OR TO WORK IN SPC MODE
GG21-0010-B6
TRAIN A FAILS
GG21-0022-A6
Page 7
TRAIN B SUPPORT SUPPLIERS OR AUTO. ACTUATION FAILURE
GG21-0011-B6
STANDBY TRAIN B FAILS
GG21-0021-B1
Page 5
RCCWS FAIL TO COOL FAPCS HX-B
GG21-1001-_2
Page 6
TRAIN B IN MAINTENANCE
G21-SYS-TM-TRAINB
3
3.00E-03
LOSS OF TRAIN B SUPPORT SUPPLIERS
GG21-0011-B3
Page 3
TRAIN B ACTUATION FAILURE
GG21-0013-B6
MANUAL ACTUATION FAILURE
GG21-0016-_6
Page 7
DIV. B (NE RTNSS) SIGNAL TRANSMISSION FAILURE
GC62-0001-_2
4
LOSS OF MANUAL ACTUATION SIGNAL
GG21-0017-_6
Page 4
HOUSE EVENT: OPERATOR IS NOT AVAILABLE (VALUE=1)
XHOSMAN
4
1
2
3
4

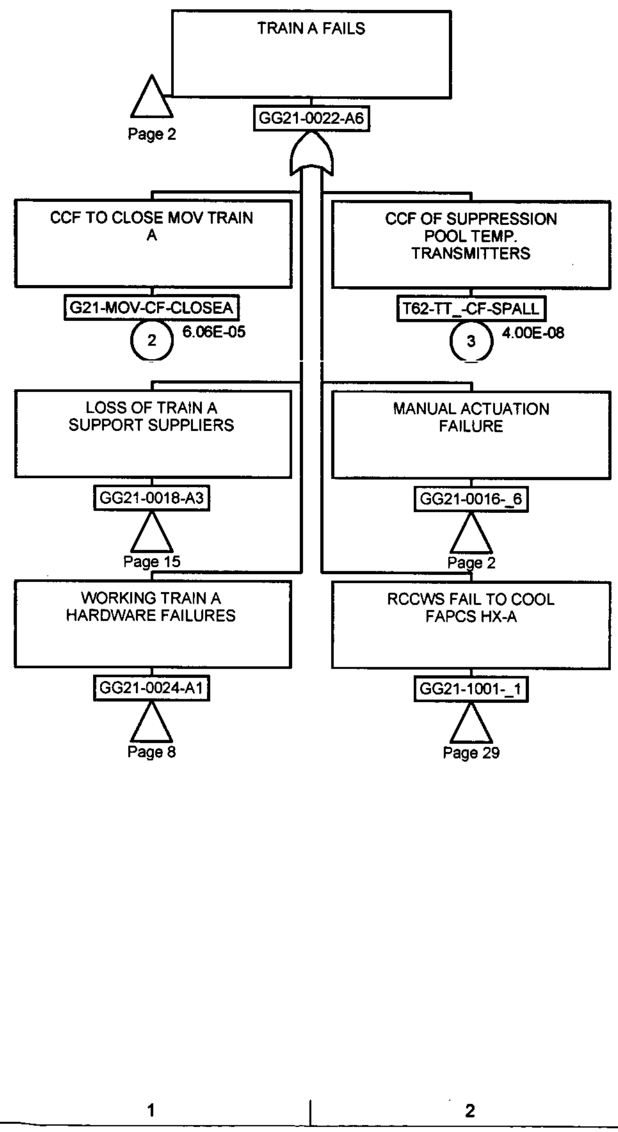

LOSS OF TRAIN B SUPPORT SUPPLIERS
GG21-0011-B3
Page 13
Page 2
Page 21
LOSS OF 6.9 KV AC FROM BUS R11-B2
GR11-0001-_2
LOSS OF 480 V AC FROM BUS R12-B2-04B (FUEL BUILDING)
GR12-0001-_13
1
2

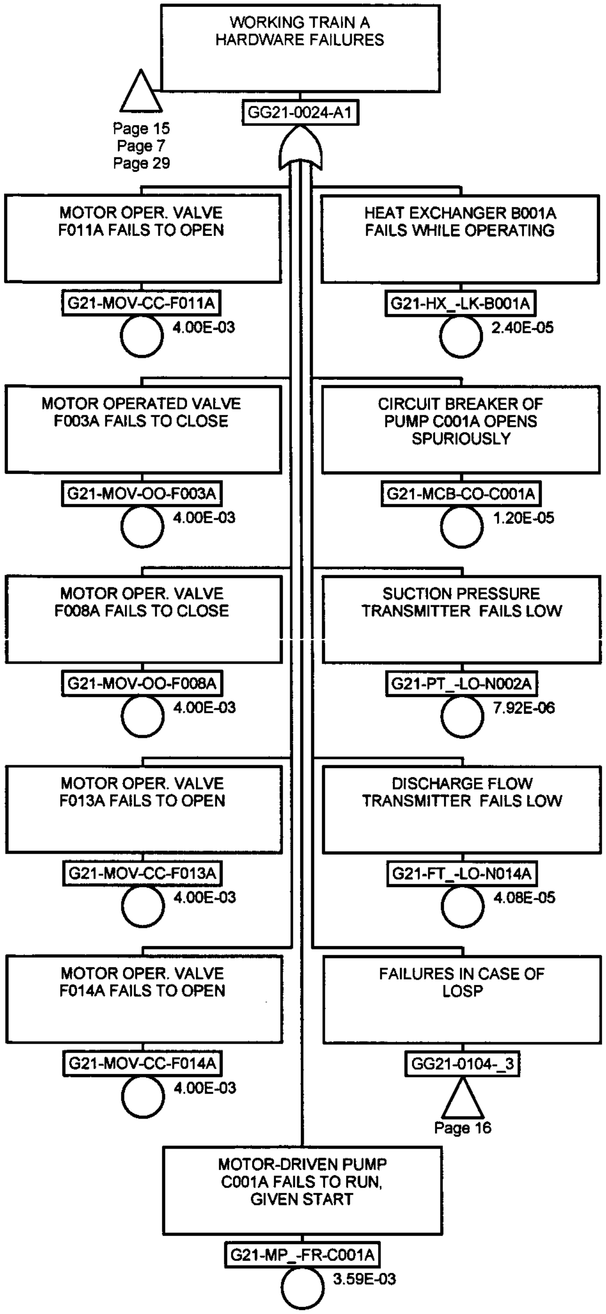

LOSS OF MANUAL ACTUATION SIGNAL
GG21-0017-_6
Page 2
BOTH RMU FROM C.R. FAILS
GG21-0014-_3
Page 12
OPERATOR FAILS TO MANUALLY INI. FAPCS IN SPC MODE AFTER ADS
G21-XHE-FO-SPCADS
1.61E-02

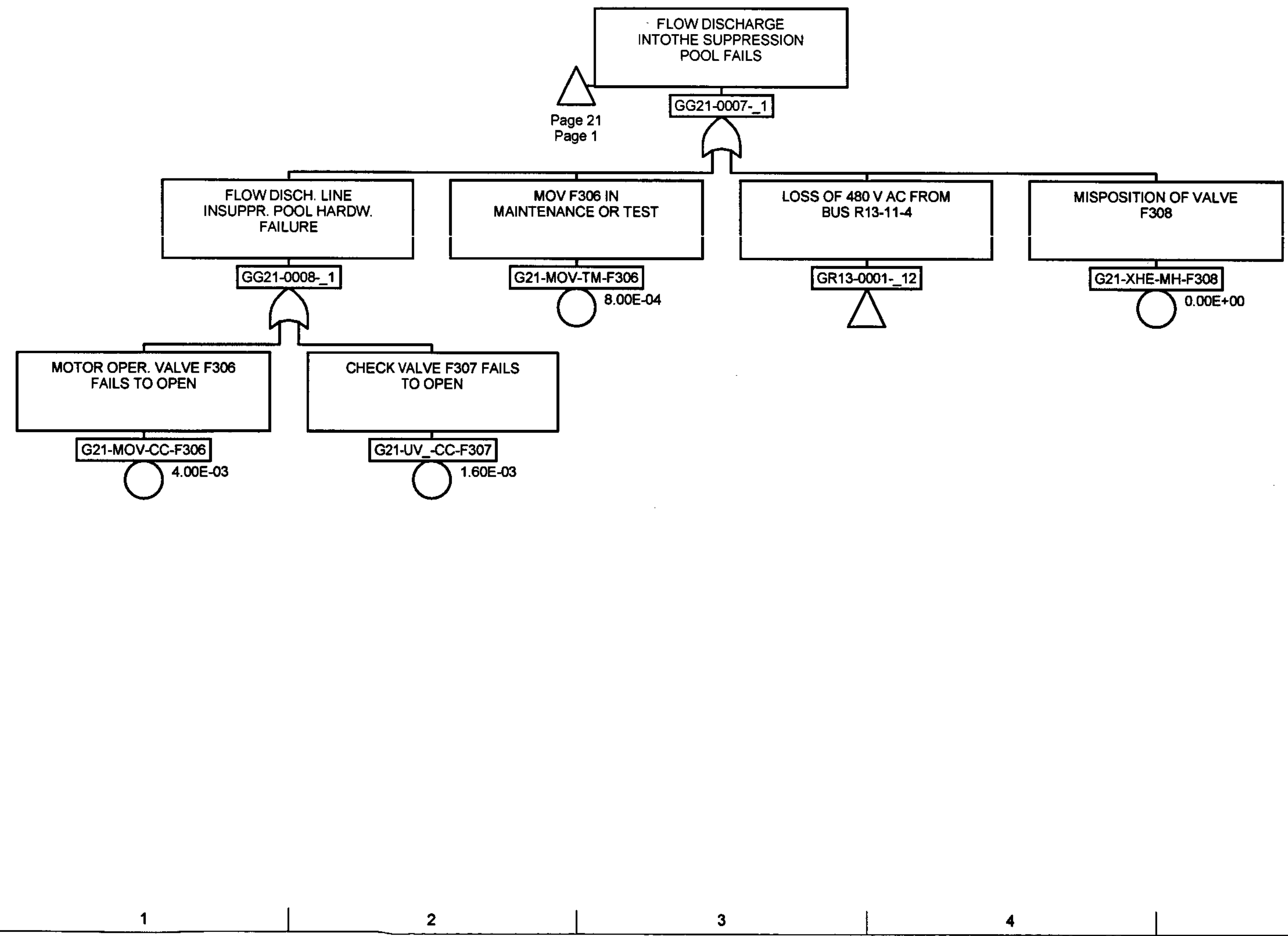

STANDBY TRAIN B FAILS
GG21-0021-B1
Page 2
Page 13
Page 21
MOTOR OPER. VALVE F011B FAILS TO OPEN
G21-MOV-CC-F011B
4.00E-03
MOTOR-DRIVEN PUMP C001B FAILS TO RUN, GIVEN START
G21-MP_-FR-C001B
3.59E-03
MOTOR OPER. VALVE F014B FAILS TO OPEN
G21-MOV-CC-F014B
4.00E-03
CHECK VALVE F004B FAILS TO OPEN
G21-UV_-CC-F004B
2.00E-04
MOTOR OPER. VALVE F013 FAILS TO OPEN
G21-MOV-CC-F013B
4.00E-03
HEAT EXCHANGER B001B FAILS WHILE OPERATING
G21-HX_-LK-B001B
3.60E-04
MOTOR-DRIVEN PUMP C001B FAILS TO START
G21-MP_-FS-C001B
3.00E-03
DISCHARGE FLOW TRANSMITTER FAILS LOW
G21-FT_-LO-N014B
6.12E-04
CIRCUIT BREAKER OF PUMP C001B FAILS TO CLOSE
G21-MCB-OO-C001B
1.00E-03
SUCTION PRESSURE TRANSMITTER FAILS LOW
G21-PT_-LO-N002B
1.19E-04
1
2

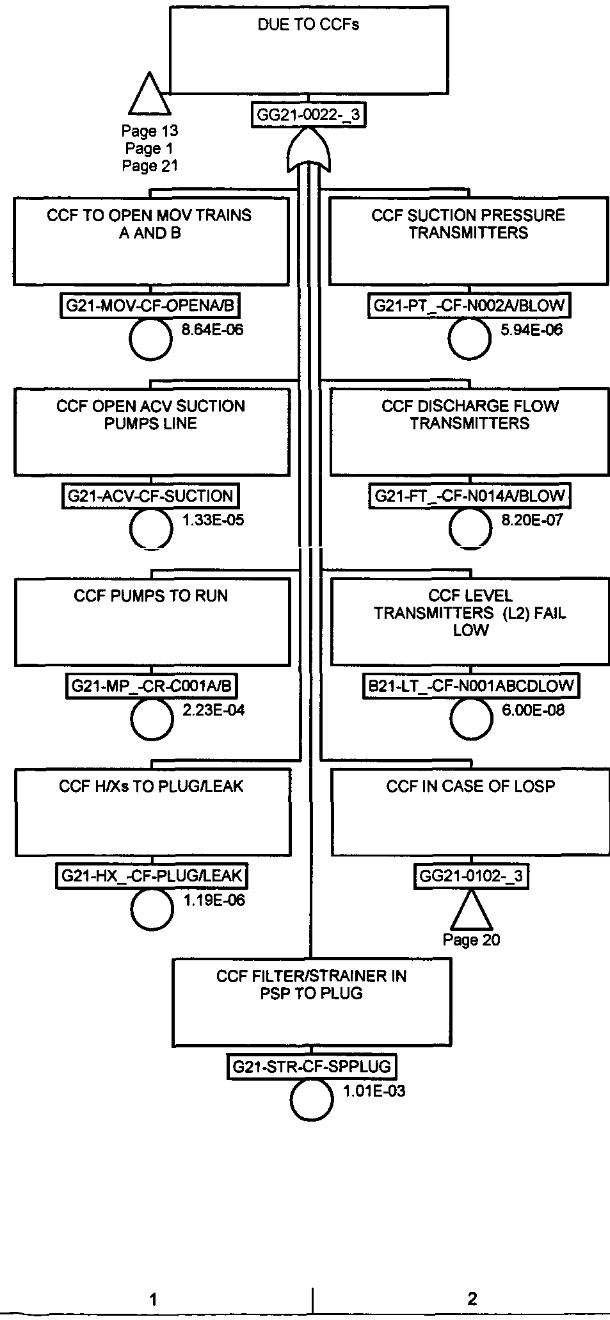

RCCWS FAIL TO COOL FAPCS HX-B
GG21-1001-_2
Page 2
Page 21
MOTOR OPERATED VALVE P21-F051B FAILS TO OPEN
P21-MOV-CC-F051B
4.00E-03
MOTOR OPERATED VALVE P21-N077A FAILS TO REMAIN CLOSED
P21-MOV-CO-N077B
1.80E-04
MOTOR OPERATED VALVE P21-F055B FAILS TO OPEN
P21-MOV-CC-F055B
4.00E-03
RCCWS TRAINS FAIL TO COOL THE LOADS
GP21-0001-_1
2

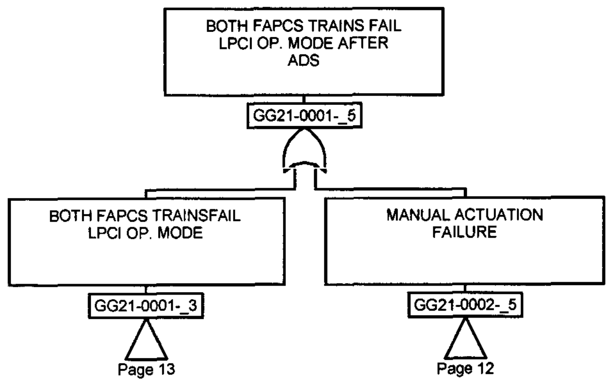
1 2

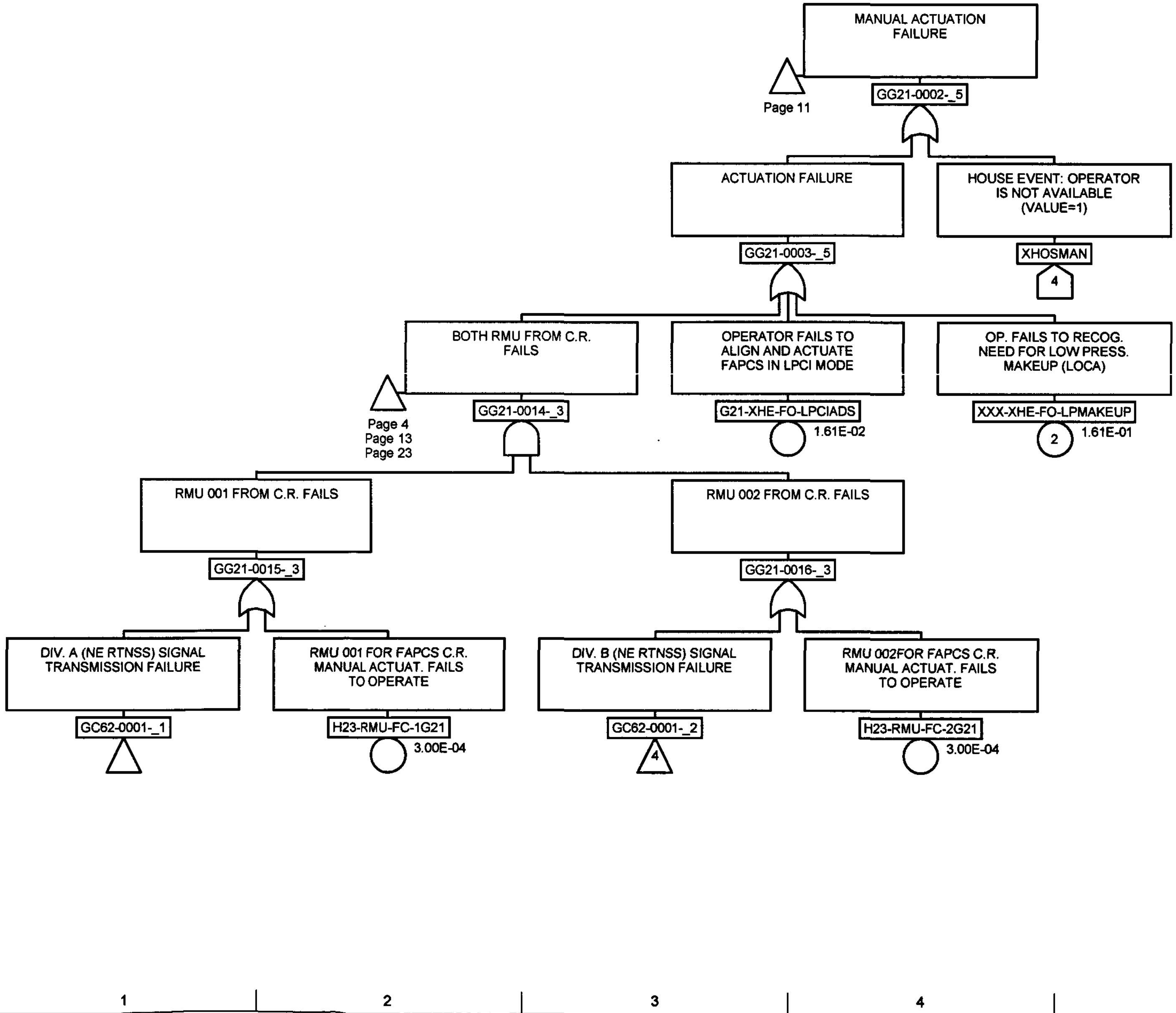

TRAIN A FAILS
GG21-0022-A6
Page 2
CCF TO CLOSE MOV TRAIN A
G21-MOV-CF-CLOSEA
2
6.06E-05
CCF OF SUPPRESSION POOL TEMP. TRANSMITTERS
T62-TT_-CF-SPALL
3
4.00E-08
LOSS OF TRAIN A SUPPORT SUPPLIERS
GG21-0018-A3
Page 15
MANUAL ACTUATION FAILURE
GG21-0016-_6
Page 2
WORKING TRAIN A HARDWARE FAILURES
GG21-0024-A1
Page 8
RCCWS FAIL TO COOL FAPCS HX-A
GG21-1001-_1
Page 29
1
2

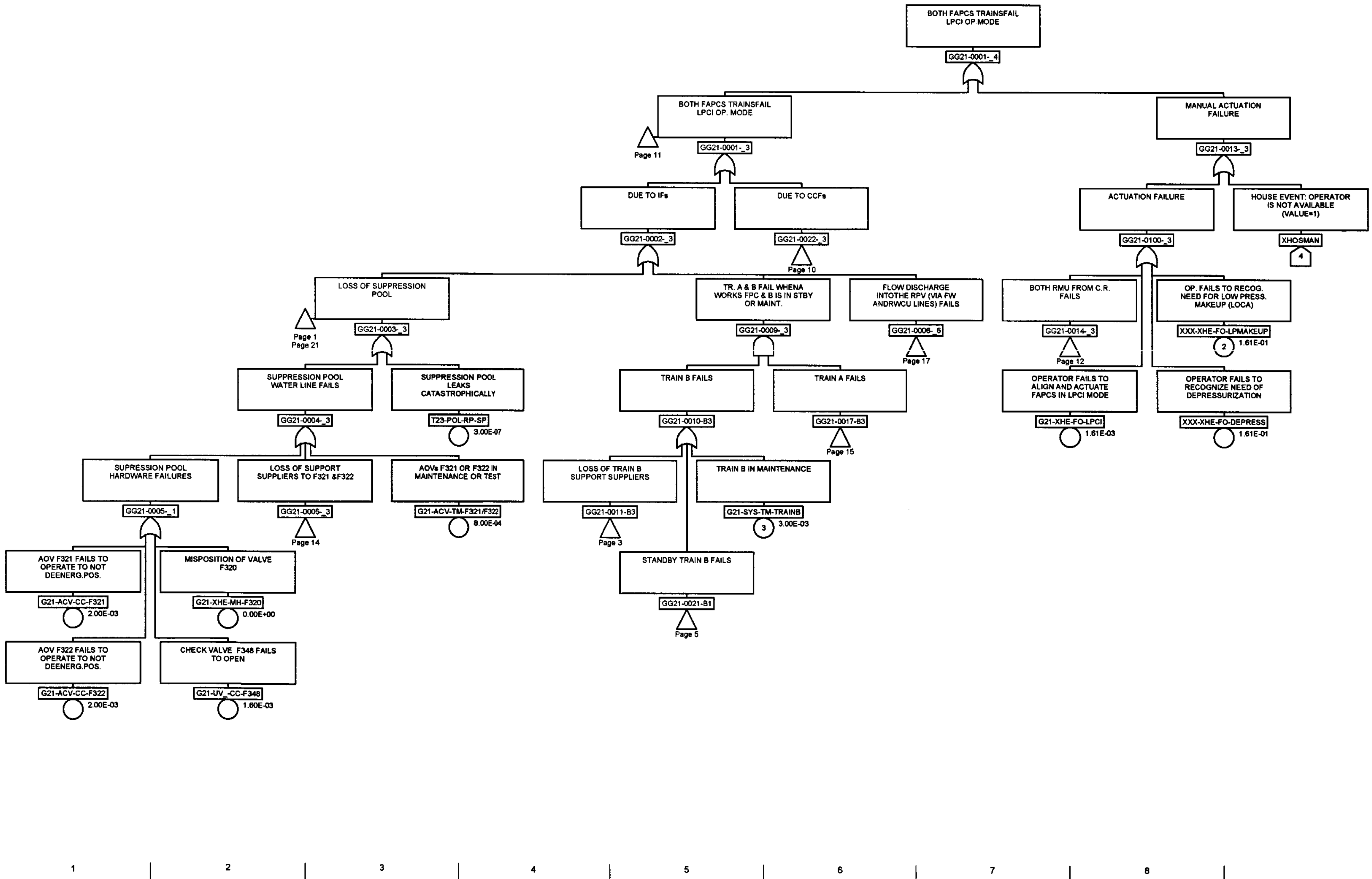

WORKING TRAIN A HARDWARE FAILURES
GG21-0024-A1
Page 15
Page 7
Page 29
MOTOR OPER. VALVE F011A FAILS TO OPEN
G21-MOV-CC-F011A
4.00E-03
HEAT EXCHANGER B001A FAILS WHILE OPERATING
G21-HX_-LK-B001A
2.40E-05
MOTOR OPERATED VALVE F003A FAILS TO CLOSE
G21-MOV-OO-F003A
4.00E-03
CIRCUIT BREAKER OF PUMP C001A OPENS SPURIOUSLY
G21-MCB-CO-C001A
1.20E-05
MOTOR OPER. VALVE F008A FAILS TO CLOSE
G21-MOV-OO-F008A
4.00E-03
SUCTION PRESSURE TRANSMITTER FAILS LOW
G21-PT_-LO-N002A
7.92E-06
MOTOR OPER. VALVE F013A FAILS TO OPEN
G21-MOV-CC-F013A
4.00E-03
DISCHARGE FLOW TRANSMITTER FAILS LOW
G21-FT_-LO-N014A
4.08E-05
MOTOR OPER. VALVE F014A FAILS TO OPEN
G21-MOV-CC-F014A
4.00E-03
FAILURES IN CASE OF LOSP
GG21-0104-_3
Page 16
MOTOR-DRIVEN PUMP C001A FAILS TO RUN, GIVEN START
G21-MP_-FR-C001A
3.59E-03
1
2

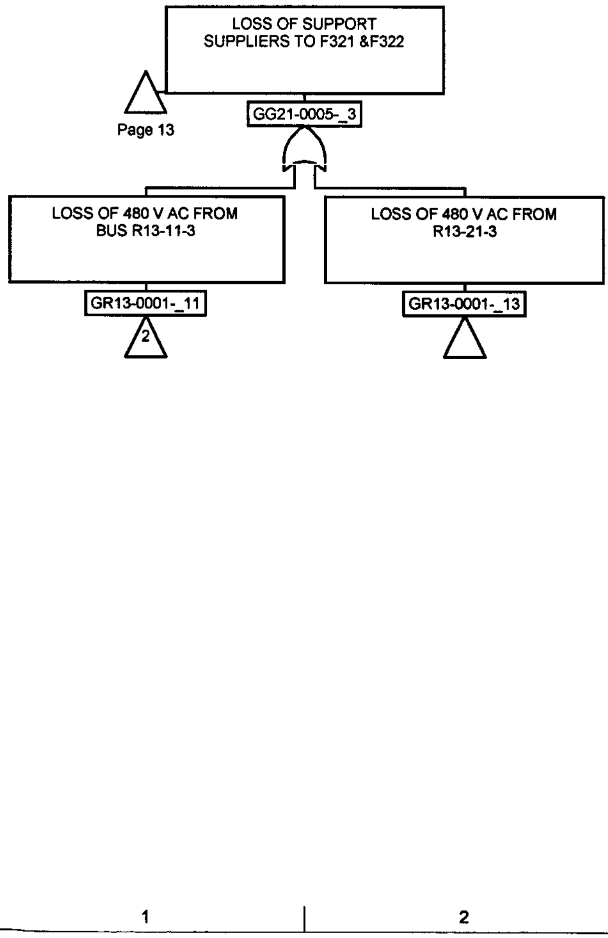

FLOW DISCHARGE INTOTHE SUPPRESSION POOL FAILS
GG21-0007-_1
Page 21
Page 1
FLOW DISCH. LINE INSUPPR. POOL HARDW. FAILURE
GG21-0008-_1
MOV F306 IN MAINTENANCE OR TEST
G21-MOV-TM-F306
8.00E-04
LOSS OF 480 V AC FROM BUS R13-11-4
GR13-0001-_12
MISPOSITION OF VALVE F308
G21-XHE-MH-F308
0.00E+00
MOTOR OPER. VALVE F306 FAILS TO OPEN
G21-MOV-CC-F306
4.00E-03
CHECK VALVE F307 FAILS TO OPEN
G21-UV_-CC-F307
1.60E-03
1
2
3
4

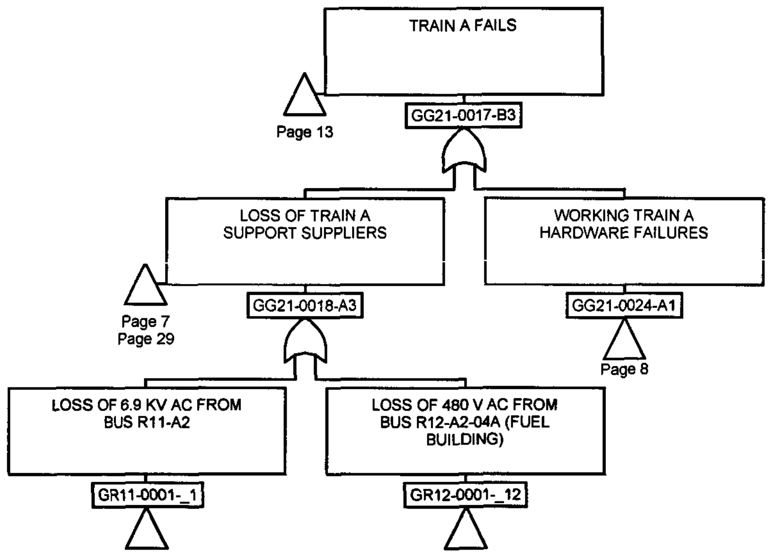

DUE TO CCFs
GG21-0022-_3
Page 13
Page 1
Page 21
CCF TO OPEN MOV TRAINS A AND B
G21-MOV-CF-OPENA/B
8.64E-06
CCF SUCTION PRESSURE TRANSMITTERS
G21-PT_-CF-N002A/BLOW
5.94E-06
CCF OPEN ACV SUCTION PUMPS LINE
G21-ACV-CF-SUCTION
1.33E-05
CCF DISCHARGE FLOW TRANSMITTERS
G21-FT_-CF-N014A/BLOW
8.20E-07
CCF PUMPS TO RUN
G21-MP_-CR-C001A/B
2.23E-04
CCF LEVEL TRANSMITTERS (L2) FAIL LOW
B21-LT_-CF-N001ABCDLOW
6.00E-08
CCF H/Xs TO PLUG/LEAK
G21-HX_-CF-PLUG/LEAK
1.19E-06
CCF IN CASE OF LOSP
GG21-0102-_3
Page 20
CCF FILTER/STRAINER IN PSP TO PLUG
G21-STR-CF-SPPLUG
1.01E-03
1
2

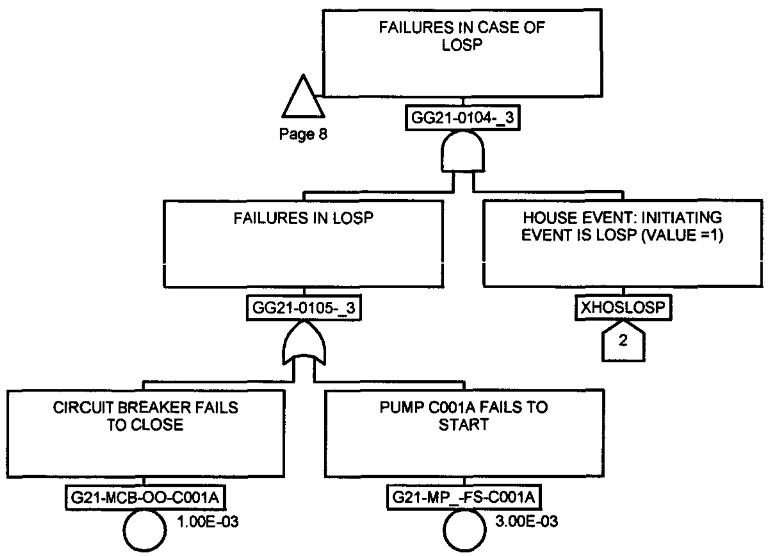

BOTH FAPCS TRAINS FAIL
LPCI OP. MODE AFTER
ADS
GG21-0001-_5
BOTH FAPCS TRAINSFAIL
LPCI OP. MODE
GG21-0001-_3
Page 13
MANUAL ACTUATION
FAILURE
GG21-0002-_5
Page 12

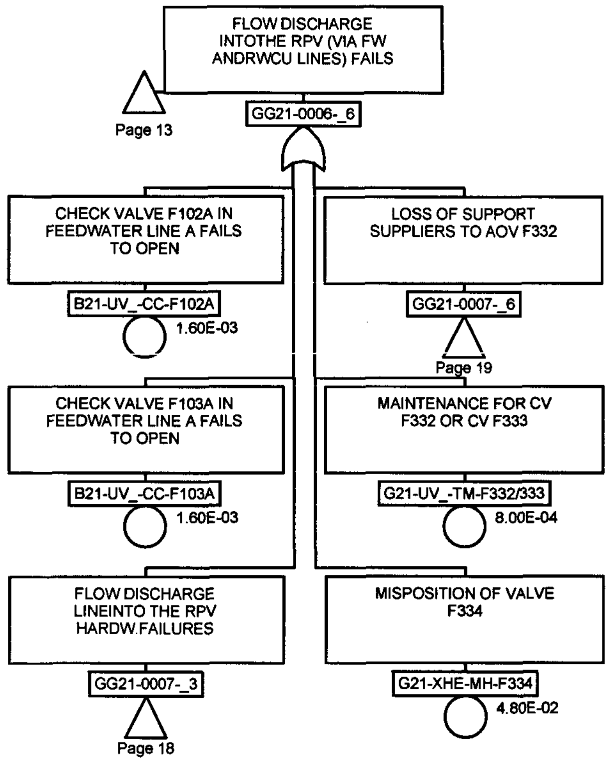

MANUAL ACTUATION FAILURE
GG21-0002-_5
Page 11
ACTUATION FAILURE
GG21-0003-_5
HOUSE EVENT: OPERATOR IS NOT AVAILABLE (VALUE=1)
XHOSMAN
4
BOTH RMU FROM C.R. FAILS
GG21-0014-_3
Page 4
Page 13
Page 23
OPERATOR FAILS TO ALIGN AND ACTUATE FAPCS IN LPCI MODE
G21-XHE-FO-LPCIADS
1.61E-02
OP. FAILS TO RECOG. NEED FOR LOW PRESS. MAKEUP (LOCA)
XXX-XHE-FO-LPMAKEUP
2
1.61E-01
RMU 001 FROM C.R. FAILS
GG21-0015-_3
RMU 002 FROM C.R. FAILS
GG21-0016-_3
DIV. A (NE RTNSS) SIGNAL TRANSMISSION FAILURE
GC62-0001-_1
RMU 001 FOR FAPCS C.R. MANUAL ACTUAT. FAILS TO OPERATE
H23-RMU-FC-1G21
3.00E-04
DIV. B (NE RTNSS) SIGNAL TRANSMISSION FAILURE
GC62-0001-_2
4
RMU 002FOR FAPCS C.R. MANUAL ACTUAT. FAILS TO OPERATE
H23-RMU-FC-2G21
3.00E-04
1
2
3
4

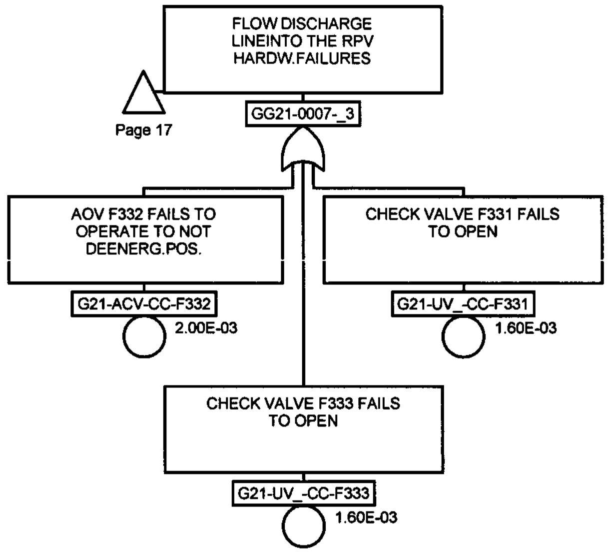

BOTH FAPCS TRAINSFAIL LPCI OP.MODE
GG21-0001-_4
BOTH FAPCS TRAINSFAIL LPCI OP. MODE
Page 11
GG21-0001-_3
MANUAL ACTUATION FAILURE
GG21-0013-_3
DUE TO IFs
GG21-0002-_3
DUE TO CCFs
GG21-0022-_3
Page 10
ACTUATION FAILURE
GG21-0100-_3
HOUSE EVENT: OPERATOR IS NOT AVAILABLE (VALUE=1)
XHOSMAN
4
LOSS OF SUPPRESSION POOL
Page 1
Page 21
GG21-0003-_3
TR. A & B FAIL WHENA WORKS FPC & B IS IN STBY OR MAINT.
GG21-0009-_3
FLOW DISCHARGE INTOTHE RPV (VIA FW ANDRWCU LINES) FAILS
GG21-0006-_6
Page 17
BOTH RMU FROM C.R. FAILS
GG21-0014-_3
Page 12
OP. FAILS TO RECOG. NEED FOR LOW PRESS. MAKEUP (LOCA)
XXX-XHE-FO-LPMAKEUP
2
1.61E-01
SUPPRESSION POOL WATER LINE FAILS
GG21-0004-_3
SUPPRESSION POOL LEAKS CATASTROPHICALLY
T23-POL-RP-SP
3.00E-07
TRAIN B FAILS
GG21-0010-B3
TRAIN A FAILS
GG21-0017-B3
Page 15
OPERATOR FAILS TO ALIGN AND ACTUATE FAPCS IN LPCI MODE
G21-XHE-FO-LPCI
1.61E-03
OPERATOR FAILS TO RECOGNIZE NEED OF DEPRESSURIZATION
XXX-XHE-FO-DEPRESS
1.61E-01
SUPRESSION POOL HARDWARE FAILURES
GG21-0005-_1
LOSS OF SUPPORT SUPPLIERS TO F321 &F322
GG21-0005-_3
Page 14
AOVs F321 OR F322 IN MAINTENANCE OR TEST
G21-ACV-TM-F321/F322
8.00E-04
LOSS OF TRAIN B SUPPORT SUPPLIERS
GG21-0011-B3
Page 3
TRAIN B IN MAINTENANCE
G21-SYS-TM-TRAINB
3
3.00E-03
AOV F321 FAILS TO OPERATE TO NOT DEENERG.POS.
G21-ACV-CC-F321
2.00E-03
MISPOSITION OF VALVE F320
G21-XHE-MH-F320
0.00E+00
STANDBY TRAIN B FAILS
GG21-0021-B1
Page 5
AOV F322 FAILS TO OPERATE TO NOT DEENERG.POS.
G21-ACV-CC-F322
2.00E-03
CHECK VALVE F348 FAILS TO OPEN
G21-UV_-CC-F348
1.60E-03
1
2
3
4
5
6
7
8

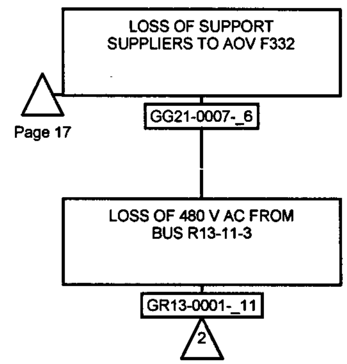

LOSS OF SUPPORT SUPPLIERS TO F321 &F322
Page 13
GG21-0005-_3
LOSS OF 480 V AC FROM BUS R13-11-3
GR13-0001-_11
2
LOSS OF 480 V AC FROM R13-21-3
GR13-0001-_13
1
2

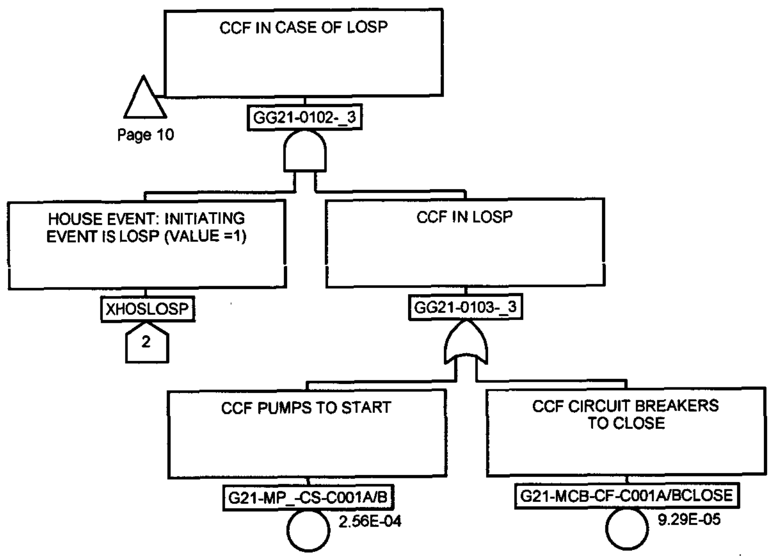

TRAIN A FAILS
GG21-0017-B3
Page 13
LOSS OF TRAIN A SUPPORT SUPPLIERS
GG21-0018-A3
Page 7
Page 29
WORKING TRAIN A HARDWARE FAILURES
GG21-0024-A1
Page 8
LOSS OF 6.9 KV AC FROM BUS R11-A2
GR11-0001-_1
LOSS OF 480 V AC FROM BUS R12-A2-04A (FUEL BUILDING)
GR12-0001-_12
1
2

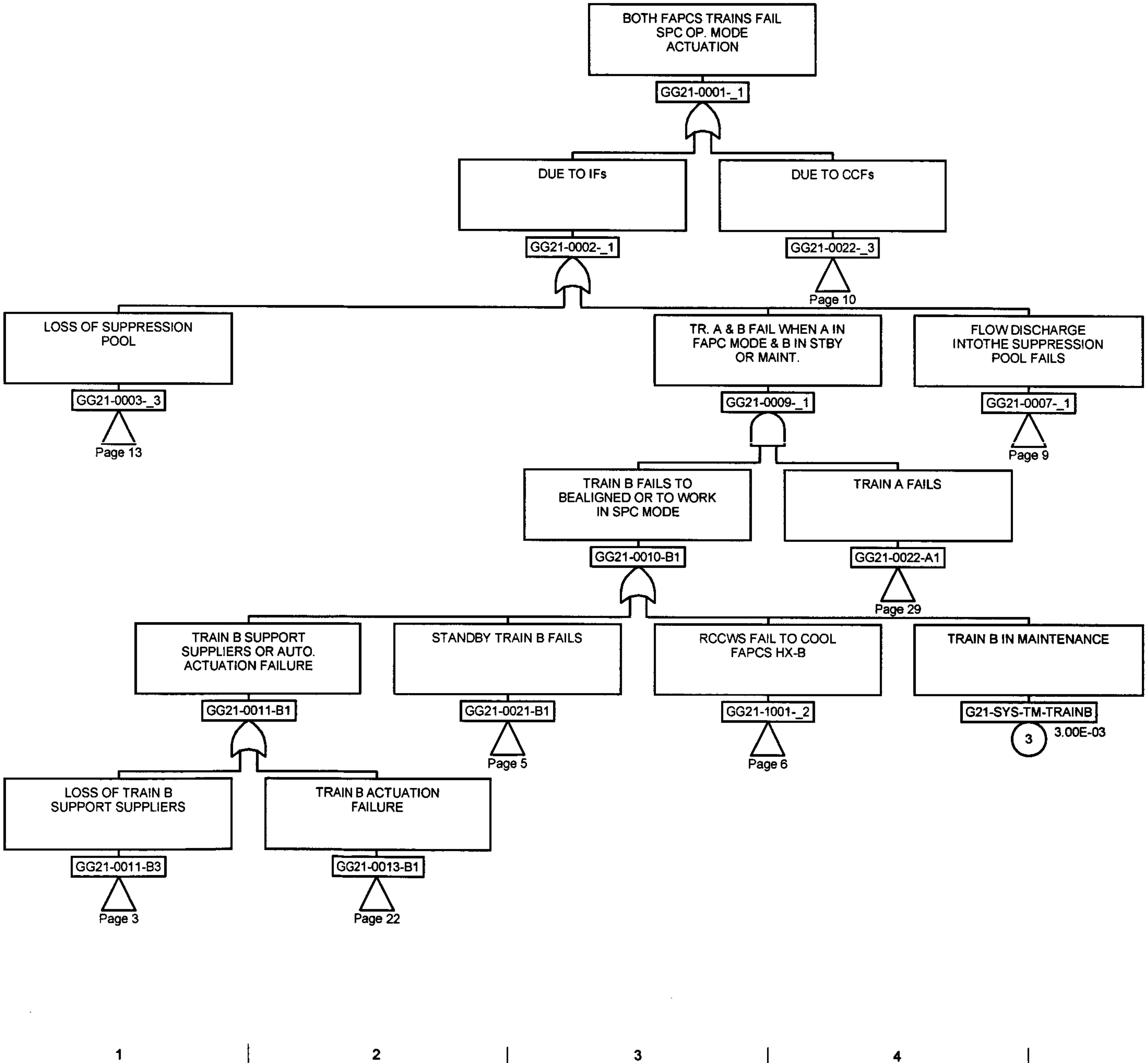

FAILURES IN CASE OF LOSP
GG21-0104-_3
Page 8
FAILURES IN LOSP
GG21-0105-_3
HOUSE EVENT: INITIATING EVENT IS LOSP (VALUE =1)
XHOSLOSP
2
CIRCUIT BREAKER FAILS TO CLOSE
G21-MCB-OO-C001A
1.00E-03
PUMP C001A FAILS TO START
G21-MP_-FS-C001A
3.00E-03
1
2

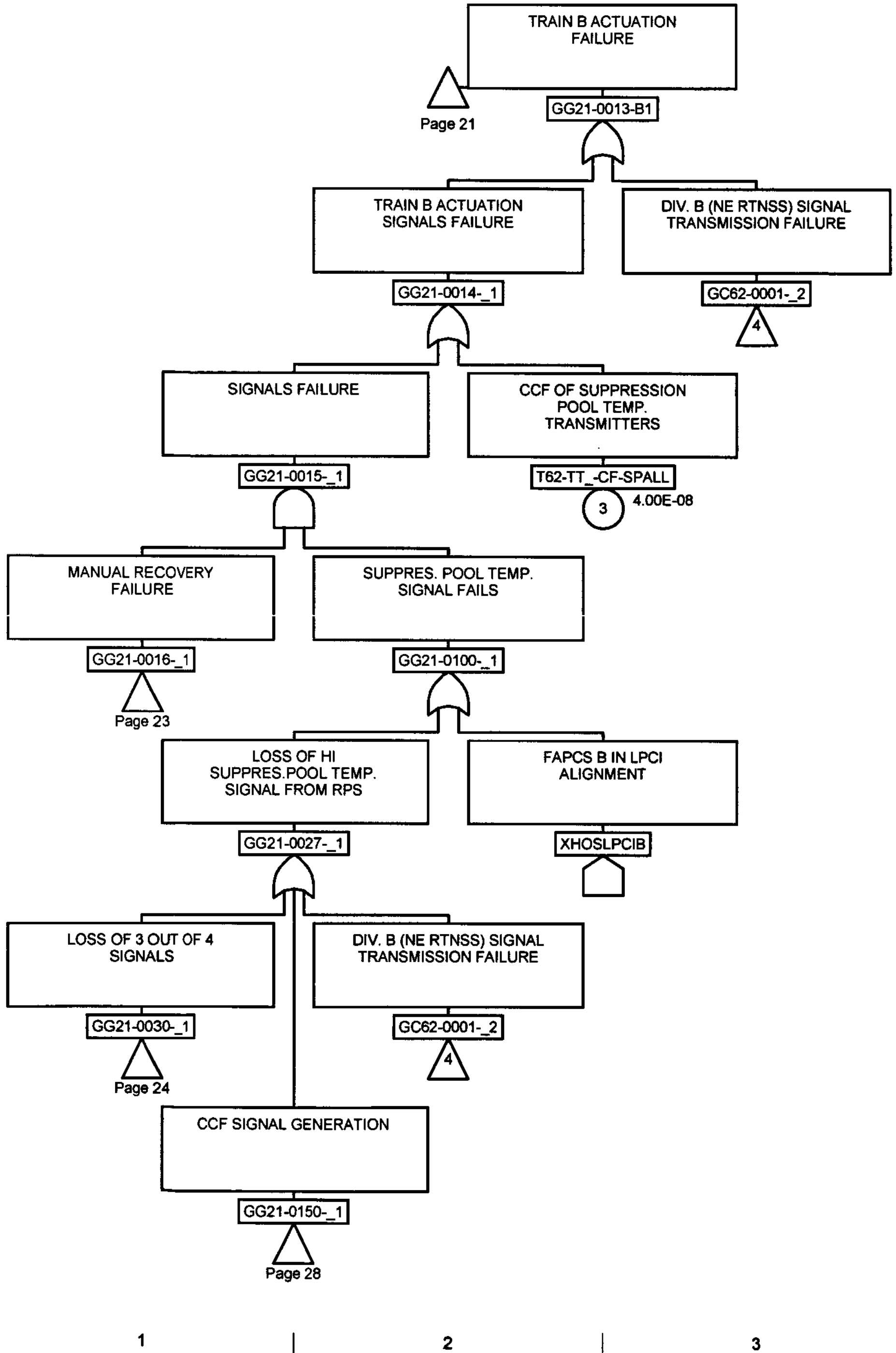

FLOW DISCHARGE
INTOTHE RPV (VIA FW
ANDRWCU LINES) FAILS
GG21-0006-_6
Page 13
CHECK VALVE F102A IN
FEEDWATER LINE A FAILS
TO OPEN
B21-UV_-CC-F102A
1.60E-03
LOSS OF SUPPORT
SUPPLIERS TO AOV F332
GG21-0007-_6
Page 19
CHECK VALVE F103A IN
FEEDWATER LINE A FAILS
TO OPEN
B21-UV_-CC-F103A
1.60E-03
MAINTENANCE FOR CV
F332 OR CV F333
G21-UV_-TM-F332/333
8.00E-04
FLOW DISCHARGE
LINEINTO THE RPV
HARDW.FAILURES
GG21-0007-_3
Page 18
MISPOSITION OF VALVE
F334
G21-XHE-MH-F334
4.80E-02
1
2

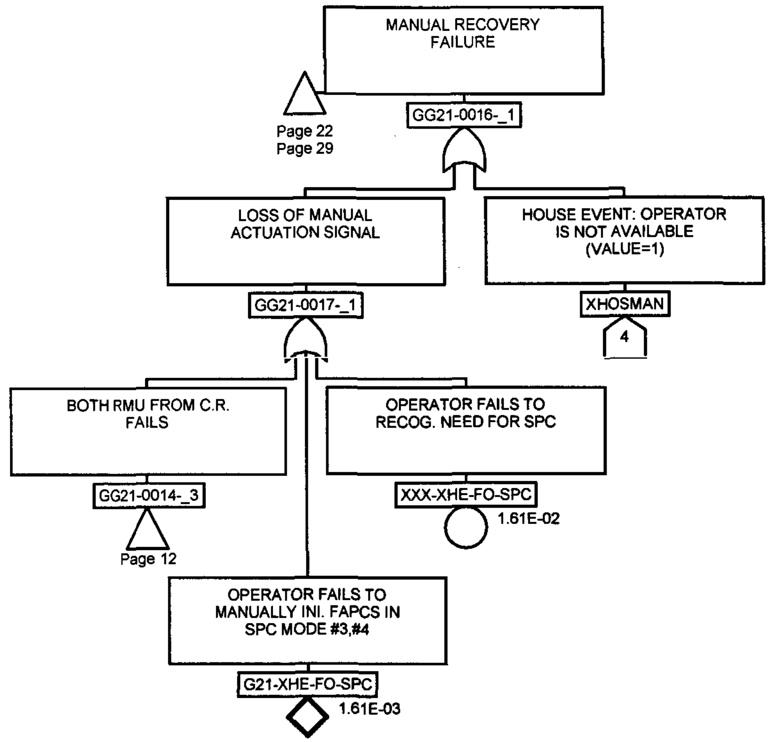

FLOW DISCHARGE LINEINTO THE RPV HARDW.FAILURES
Page 17
GG21-0007-_3
AOV F332 FAILS TO OPERATE TO NOT DEENERG.POS.
G21-ACV-CC-F332
2.00E-03
CHECK VALVE F331 FAILS TO OPEN
G21-UV_-CC-F331
1.60E-03
CHECK VALVE F333 FAILS TO OPEN
G21-UV_-CC-F333
1.60E-03
1
2

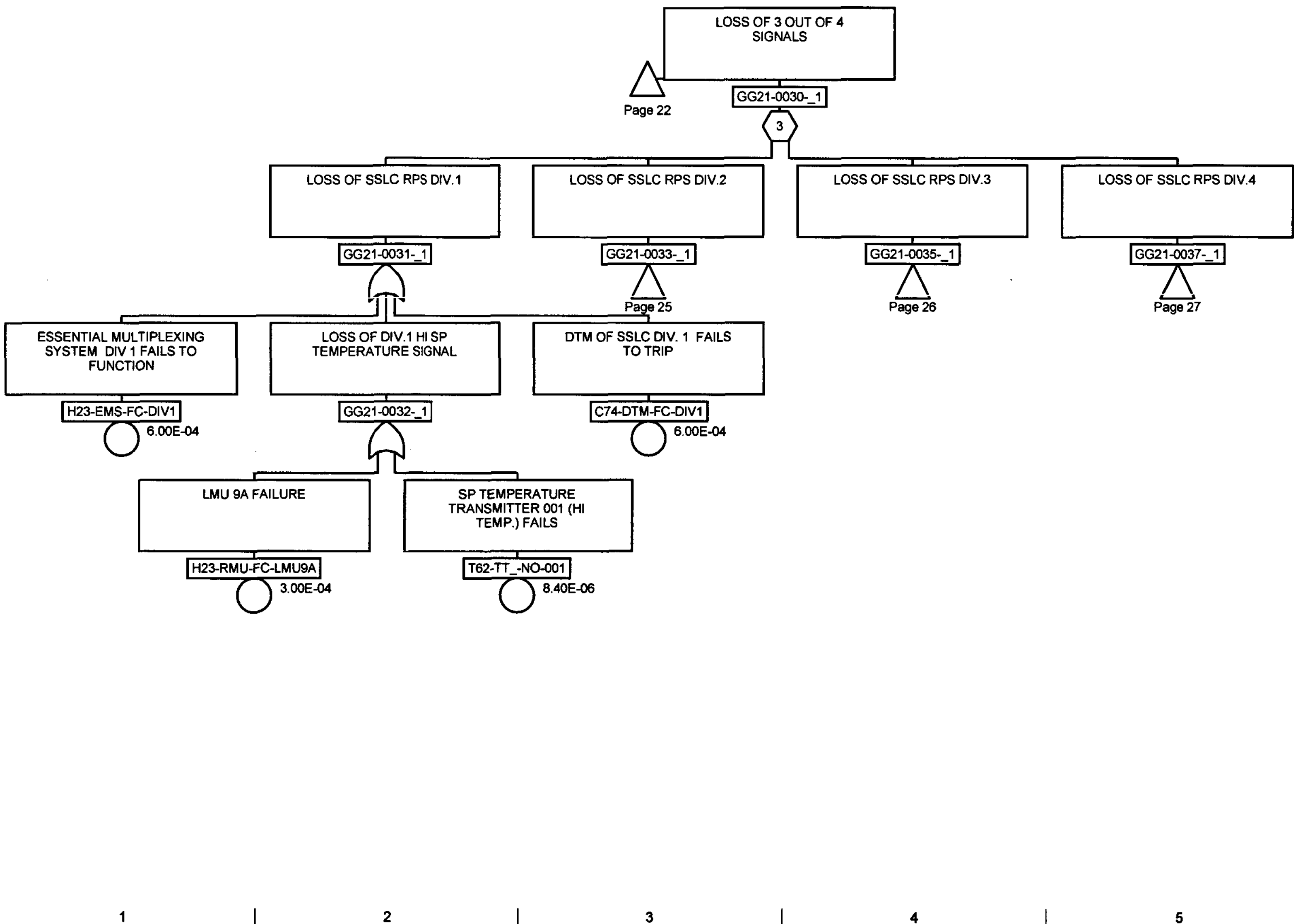

LOSS OF SUPPORT SUPPLIERS TO AOV F332
GG21-0007-_6
Page 17
LOSS OF 480 V AC FROM BUS R13-11-3
GR13-0001-_11
2
1

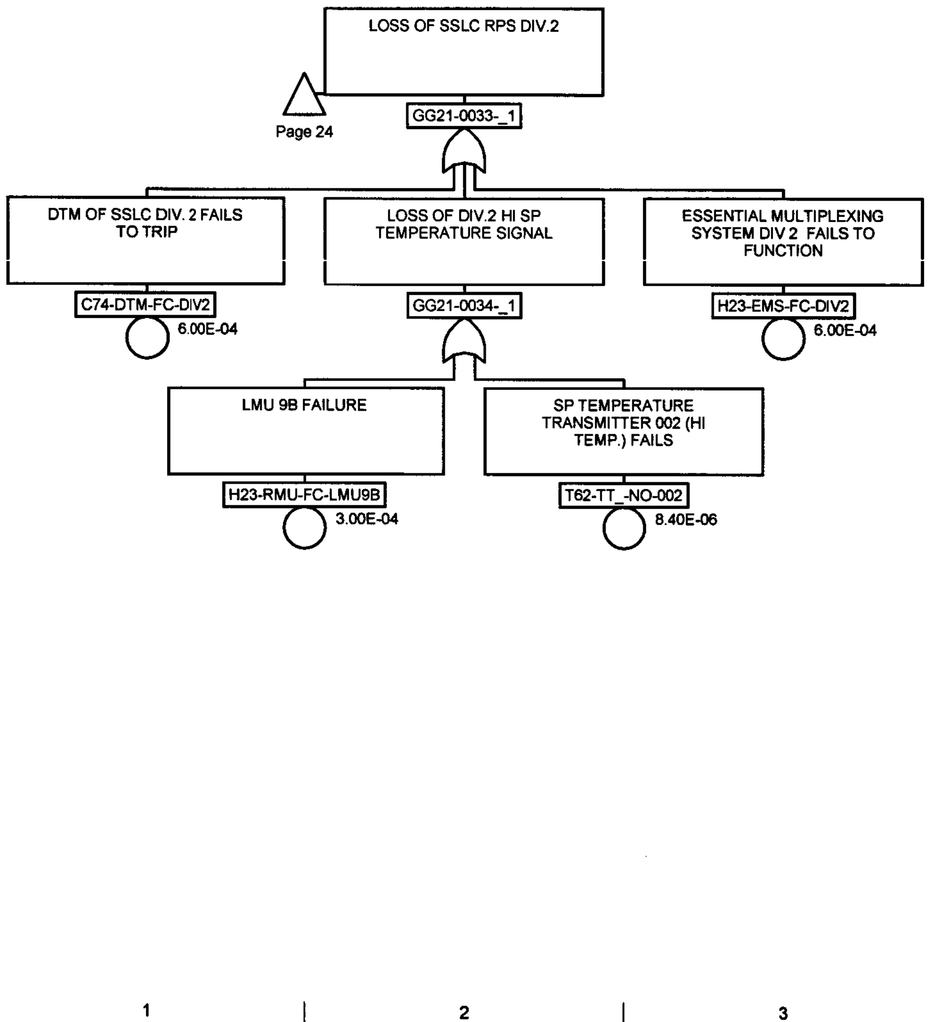

CCF IN CASE OF LOSP
GG21-0102-_3
Page 10
HOUSE EVENT: INITIATING EVENT IS LOSP (VALUE =1)
XHOSLOSP
2
CCF IN LOSP
GG21-0103-_3
CCF PUMPS TO START
G21-MP_-CS-C001A/B
2.56E-04
CCF CIRCUIT BREAKERS TO CLOSE
G21-MCB-CF-C001A/BCLOSE
9.29E-05

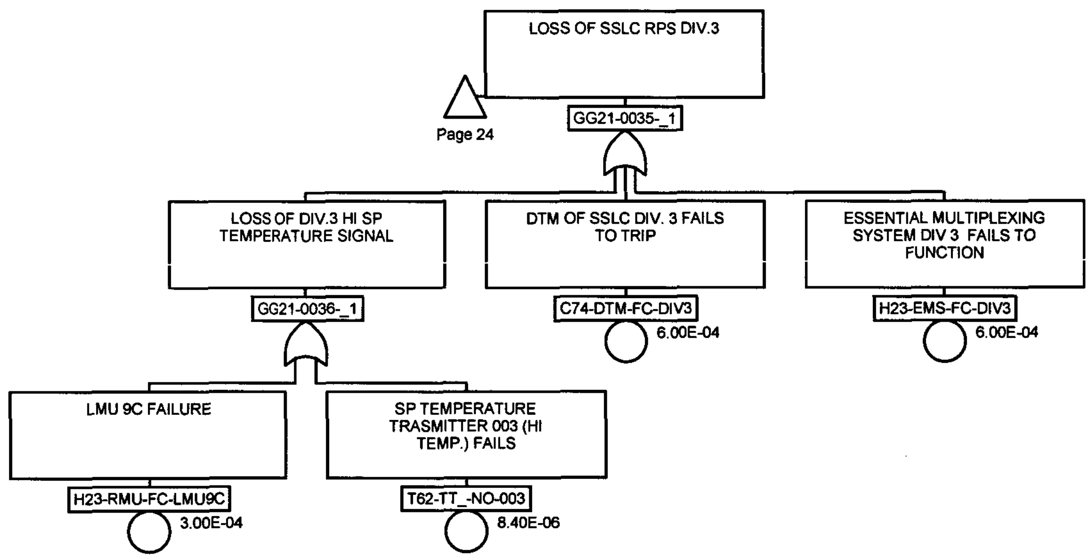

BOTH FAPCS TRAINS FAIL SPC OP. MODE ACTUATION
GG21-0001-_1
DUE TO IFs
GG21-0002-_1
DUE TO CCFs
GG21-0022-_3
Page 10
LOSS OF SUPPRESSION POOL
GG21-0003-_3
Page 13
TR. A & B FAIL WHEN A IN FAPC MODE & B IN STBY OR MAINT.
GG21-0009-_1
FLOW DISCHARGE INTOTHE SUPPRESSION POOL FAILS
GG21-0007-_1
Page 9
TRAIN B FAILS TO BEALIGNED OR TO WORK IN SPC MODE
GG21-0010-B1
TRAIN A FAILS
GG21-0022-A1
Page 29
TRAIN B SUPPORT SUPPLIERS OR AUTO. ACTUATION FAILURE
GG21-0011-B1
STANDBY TRAIN B FAILS
GG21-0021-B1
Page 5
RCCWS FAIL TO COOL FAPCS HX-B
GG21-1001-_2
Page 6
TRAIN B IN MAINTENANCE
G21-SYS-TM-TRAINB
3
3.00E-03
LOSS OF TRAIN B SUPPORT SUPPLIERS
GG21-0011-B3
Page 3
TRAIN B ACTUATION FAILURE
GG21-0013-B1
Page 22
1
2
3
4

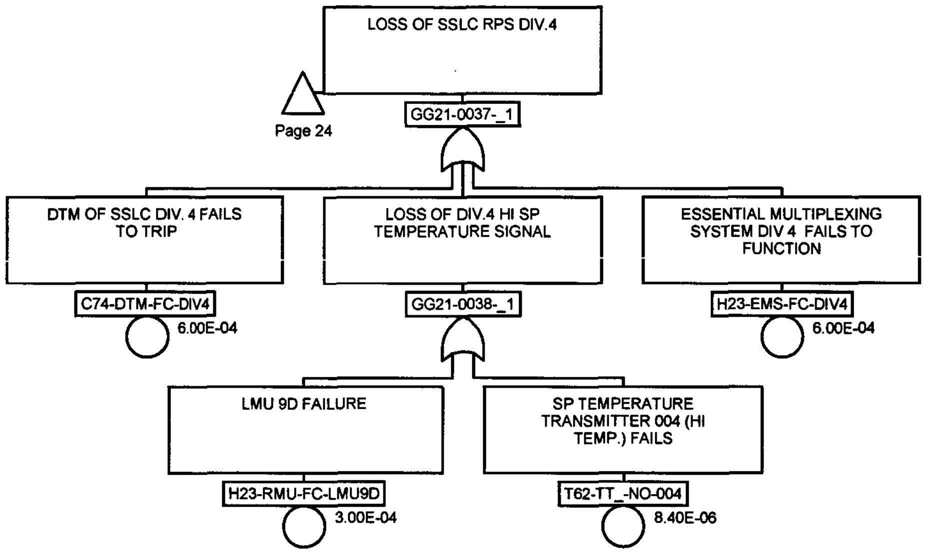

TRAIN B ACTUATION FAILURE
Page 21
GG21-0013-B1
TRAIN B ACTUATION SIGNALS FAILURE
GG21-0014-_1
DIV. B (NE RTNSS) SIGNAL TRANSMISSION FAILURE
GC62-0001-_2
4
SIGNALS FAILURE
GG21-0015-_1
CCF OF SUPPRESSION POOL TEMP. TRANSMITTERS
T62-TT_-CF-SPALL
3
4.00E-08
MANUAL RECOVERY FAILURE
GG21-0016-_1
Page 23
SUPPRES. POOL TEMP. SIGNAL FAILS
GG21-0100-_1
LOSS OF HI SUPPRES.POOL TEMP. SIGNAL FROM RPS
GG21-0027-_1
FAPCS B IN LPCI ALIGNMENT
XHOSLPCIB
LOSS OF 3 OUT OF 4 SIGNALS
GG21-0030-_1
Page 24
DIV. B (NE RTNSS) SIGNAL TRANSMISSION FAILURE
GC62-0001-_2
4
CCF SIGNAL GENERATION
GG21-0150-_1
Page 28
1
2
3

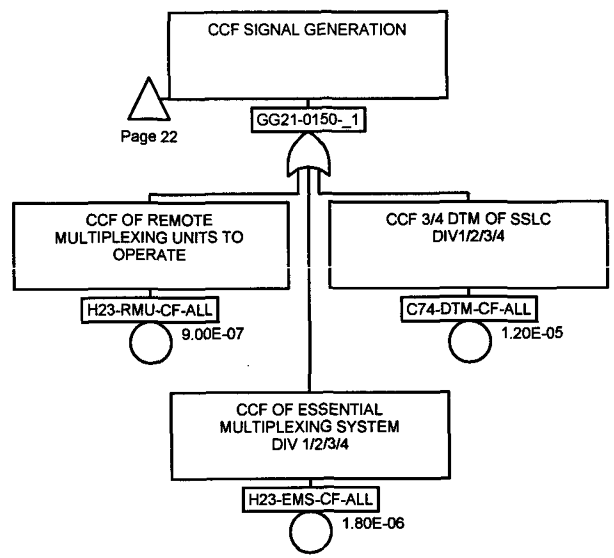

MANUAL RECOVERY FAILURE
Page 22
Page 29
GG21-0016-_1
LOSS OF MANUAL ACTUATION SIGNAL
HOUSE EVENT: OPERATOR IS NOT AVAILABLE (VALUE=1)
GG21-0017-_1
XHOSMAN
4
BOTH RMU FROM C.R. FAILS
OPERATOR FAILS TO RECOG. NEED FOR SPC
GG21-0014-_3
Page 12
XXX-XHE-FO-SPC
1.61E-02
OPERATOR FAILS TO MANUALLY INI. FAPCS IN SPC MODE #3,#4
G21-XHE-FO-SPC
1.61E-03

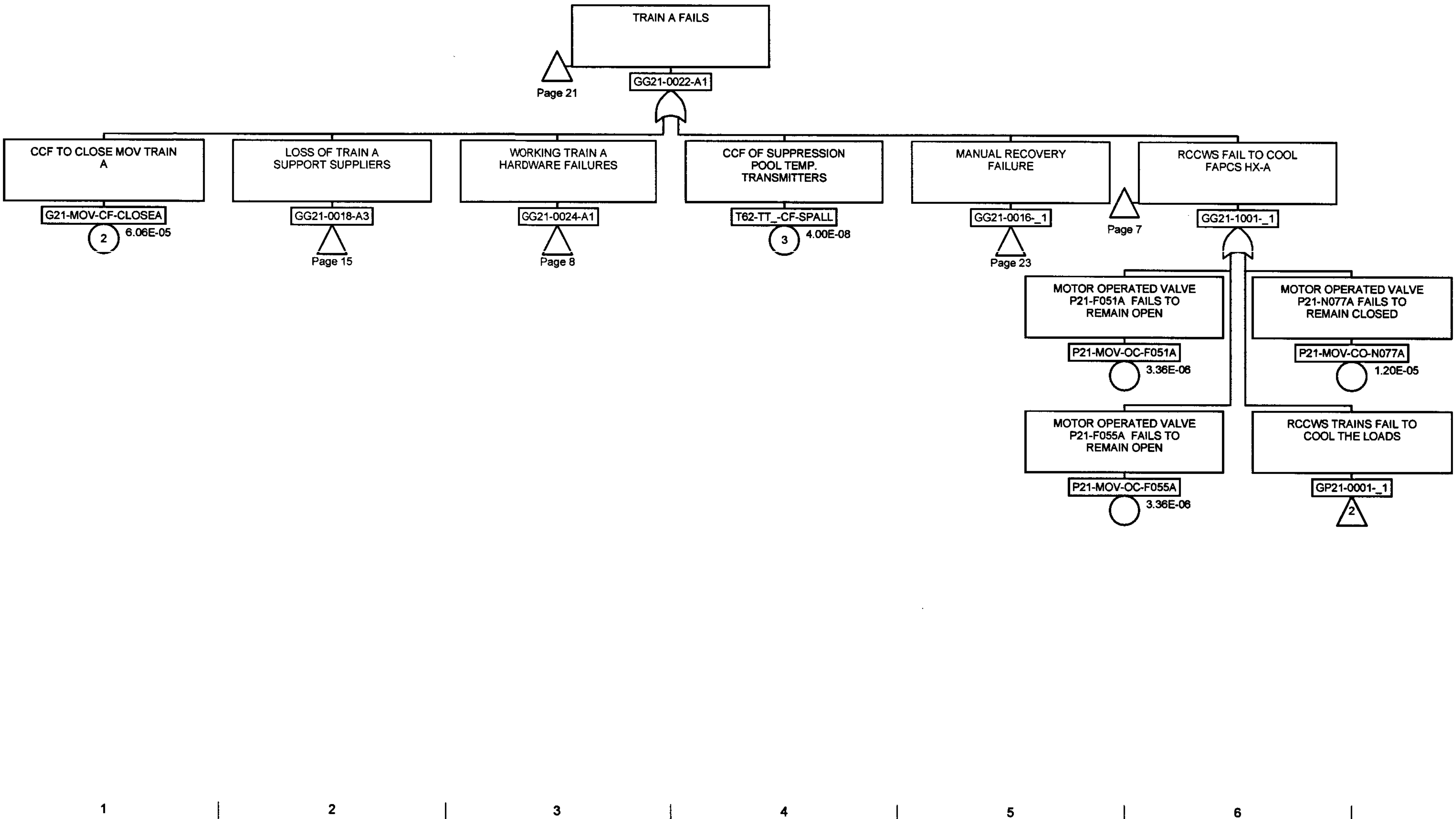

LOSS OF 3 OUT OF 4 SIGNALS
GG21-0030-_1
Page 22
3
LOSS OF SSLC RPS DIV.1
GG21-0031-_1
LOSS OF SSLC RPS DIV.2
GG21-0033-_1
Page 25
LOSS OF SSLC RPS DIV.3
GG21-0035-_1
Page 26
LOSS OF SSLC RPS DIV.4
GG21-0037-_1
Page 27
ESSENTIAL MULTIPLEXING SYSTEM DIV 1 FAILS TO FUNCTION
H23-EMS-FC-DIV1
6.00E-04
LOSS OF DIV.1 HI SP TEMPERATURE SIGNAL
GG21-0032-_1
DTM OF SSLC DIV. 1 FAILS TO TRIP
C74-DTM-FC-DIV1
6.00E-04
LMU 9A FAILURE
H23-RMU-FC-LMU9A
3.00E-04
SP TEMPERATURE TRANSMITTER 001 (HI TEMP.) FAILS
T62-TT_-NO-001
8.40E-06
1
2
3
4
5


LOSS OF SSLC RPS DIV.2
GG21-0033-_1
Page 24
DTM OF SSLC DIV. 2 FAILS TO TRIP
C74-DTM-FC-DIV2
6.00E-04
LOSS OF DIV.2 HI SP TEMPERATURE SIGNAL
GG21-0034-_1
ESSENTIAL MULTIPLEXING SYSTEM DIV 2 FAILS TO FUNCTION
H23-EMS-FC-DIV2
6.00E-04
LMU 9B FAILURE
H23-RMU-FC-LMU9B
3.00E-04
SP TEMPERATURE TRANSMITTER 002 (HI TEMP.) FAILS
T62-TT_-NO-002
8.40E-06
1
2
3


LOSS OF SSLC RPS DIV.3
Page 24
GG21-0035-_1
LOSS OF DIV.3 HI SP TEMPERATURE SIGNAL
DTM OF SSLC DIV. 3 FAILS TO TRIP
ESSENTIAL MULTIPLEXING SYSTEM DIV 3 FAILS TO FUNCTION
GG21-0036-_1
C74-DTM-FC-DIV3
6.00E-04
H23-EMS-FC-DIV3
6.00E-04
LMU 9C FAILURE
SP TEMPERATURE TRASMITTER 003 (HI TEMP.) FAILS
H23-RMU-FC-LMU9C
3.00E-04
T62-TT_-NO-003
8.40E-06


LOSS OF SSLC RPS DIV.4
GG21-0037-_1
Page 24
DTM OF SSLC DIV. 4 FAILS TO TRIP
C74-DTM-FC-DIV4
6.00E-04
LOSS OF DIV.4 HI SP TEMPERATURE SIGNAL
GG21-0038-_1
ESSENTIAL MULTIPLEXING SYSTEM DIV 4 FAILS TO FUNCTION
H23-EMS-FC-DIV4
6.00E-04
LMU 9D FAILURE
H23-RMU-FC-LMU9D
3.00E-04
SP TEMPERATURE TRANSMITTER 004 (HI TEMP.) FAILS
T62-TT_-NO-004
8.40E-06


CCF SIGNAL GENERATION
GG21-0150-_1
Page 22
CCF OF REMOTE MULTIPLEXING UNITS TO OPERATE
H23-RMU-CF-ALL
9.00E-07
CCF 3/4 DTM OF SSLC DIV1/2/3/4
C74-DTM-CF-ALL
1.20E-05
CCF OF ESSENTIAL MULTIPLEXING SYSTEM DIV 1/2/3/4
H23-EMS-CF-ALL
1.80E-06
1
2



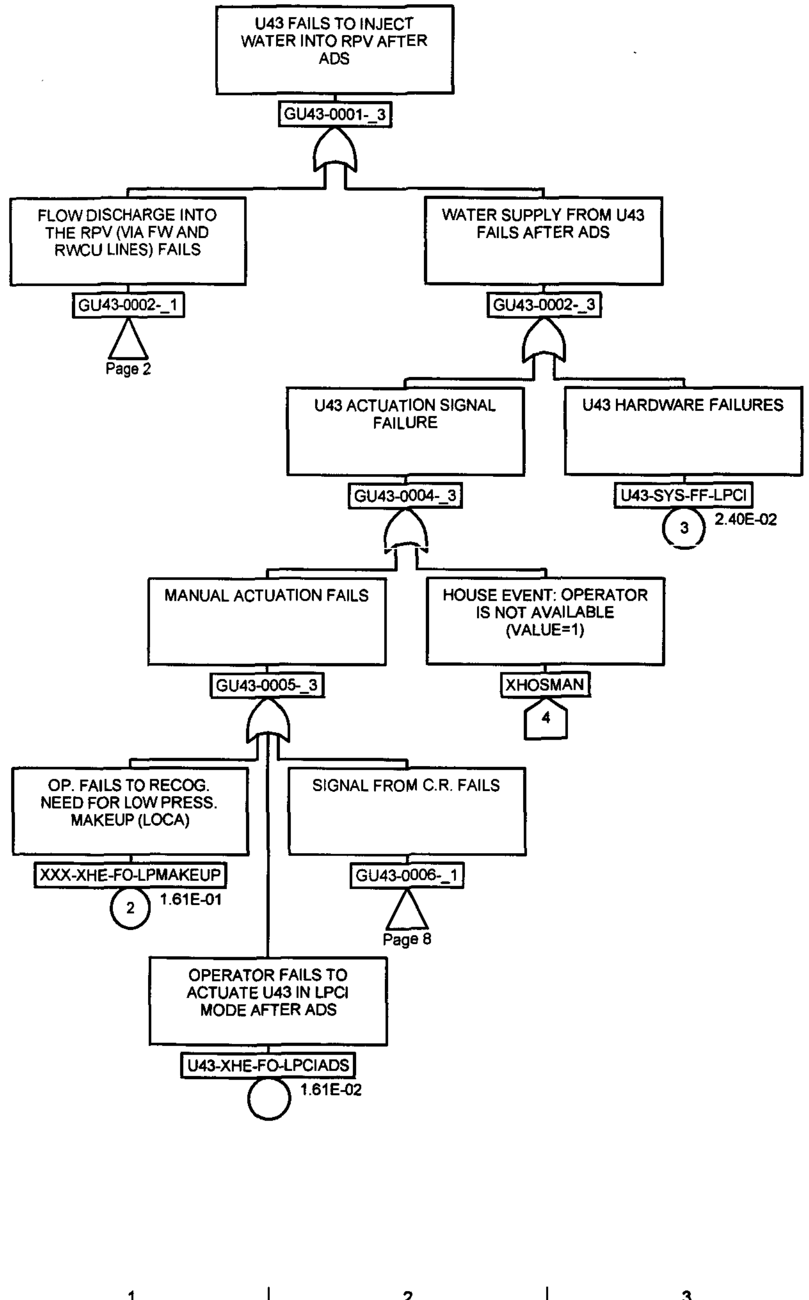
TRAIN A FAILS
GG21-0022-A1
Page 21
CCF TO CLOSE MOV TRAIN A
G21-MOV-CF-CLOSEA
2
6.06E-05
LOSS OF TRAIN A SUPPORT SUPPLIERS
GG21-0018-A3
Page 15
WORKING TRAIN A HARDWARE FAILURES
GG21-0024-A1
Page 8
CCF OF SUPPRESSION POOL TEMP. TRANSMITTERS
T62-TT_-CF-SPALL
3
4.00E-08
MANUAL RECOVERY FAILURE
GG21-0016-_1
Page 23
Page 7
RCCWS FAIL TO COOL FAPCS HX-A
GG21-1001-_1
MOTOR OPERATED VALVE P21-F051A FAILS TO REMAIN OPEN
P21-MOV-OC-F051A
3.36E-06
MOTOR OPERATED VALVE P21-N077A FAILS TO REMAIN CLOSED
P21-MOV-CO-N077A
1.20E-05
MOTOR OPERATED VALVE P21-F055A FAILS TO REMAIN OPEN
P21-MOV-OC-F055A
3.36E-06
RCCWS TRAINS FAIL TO COOL THE LOADS
GP21-0001-_1
2
1
2
3
4
5
6

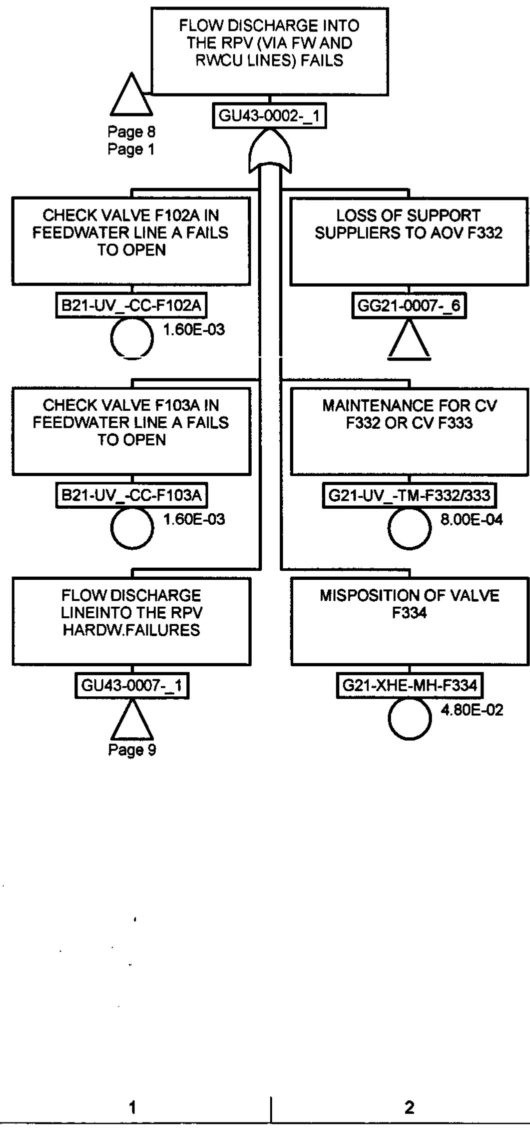
Name	Page	Zone	Name	Page	Zone
B21-LT -CF-N001ABCDLOW	10	2	G21-UV -TM-F332/333	17	2
B21-UV -CC-F102A	17	1	G21-XHE-FO-LPCI	13	8
B21-UV -CC-F103A	17	1	G21-XHE-FO-LPCIADS	12	4
C74-DTM-CF-ALL	28	2	G21-XHE-FO-SPC	23	2
C74-DTM-FC-DIV1	24	3	G21-XHE-FO-SPCADS	4	2
C74-DTM-FC-DIV2	25	1	G21-XHE-MH-F308	9	5
C74-DTM-FC-DIV3	26	3	G21-XHE-MH-F320	13	2
C74-DTM-FC-DIV4	27	1	G21-XHE-MH-F334	17	2
G21-ACV-CC-F321	13	1	GC62-0001- 1	12	1
G21-ACV-CC-F322	13	1	GC62-0001- 2	2	3
G21-ACV-CC-F332	18	1	GC62-0001- 2	12	3
G21-ACV-CF-SUCTION	10	1	GC62-0001- 2	22	2
G21-ACV-TM-F321/F322	13	4	GC62-0001- 2	22	3
G21-FT -CF-N014A/BLOW	10	2	GG21-0001- 1	21	3
G21-FT -LO-N014A	8	2	GG21-0001- 3	11	1
G21-FT -LO-N014B	5	2	GG21-0001- 3	13	5
G21-HX -CF-PLUG/LEAK	10	1	GG21-0001- 4	13	7
G21-HX -LK-B001A	8	2	GG21-0001- 5	11	2
G21-HX -LK-B001B	5	2	GG21-0001- 6	1	2
G21-MCB-CF-C001A/BCLOSE	20	3	GG21-0002- 1	21	3
G21-MCB-CO-C001A	8	2	GG21-0002- 3	13	5
G21-MCB-OO-C001A	16	1	GG21-0002- 5	11	2
G21-MCB-OO-C001B	5	1	GG21-0002- 5	12	4
G21-MOV-CC-F011A	8	1	GG21-0002- 6	1	2
G21-MOV-CC-F011B	5	1	GG21-0003- 3	1	1
G21-MOV-CC-F013A	8	1	GG21-0003- 3	13	3
G21-MOV-CC-F013B	5	1	GG21-0003- 3	21	1
G21-MOV-CC-F014A	8	1	GG21-0003- 5	12	3
G21-MOV-CC-F014B	5	1	GG21-0004- 3	13	3
G21-MOV-CC-F306	9	1	GG21-0005- 1	13	2
G21-MOV-CF-CLOSEA	7	1	GG21-0005- 3	13	3
G21-MOV-CF-CLOSEA	29	1	GG21-0005- 3	14	2
G21-MOV-CF-OPENA/B	10	1	GG21-0006- 6	13	6
G21-MOV-OO-F003A	8	1	GG21-0006- 6	17	2
G21-MOV-OO-F008A	8	1	GG21-0007- 1	1	2
G21-MOV-TM-F306	9	3	GG21-0007- 1	9	3
G21-MP -CR-C001A/B	10	1	GG21-0007- 1	21	4
G21-MP -CS-C001A/B	20	2	GG21-0007- 3	17	1
G21-MP -FR-C001A	8	2	GG21-0007- 3	18	2
G21-MP -FR-C001B	5	2	GG21-0007- 6	17	2
G21-MP -FS-C001A	16	2	GG21-0007- 6	19	1
G21-MP -FS-C001B	5	1	GG21-0008- 1	9	2
G21-PT -CF-N002A/BLOW	10	2	GG21-0009- 1	21	3
G21-PT -LO-N002A	8	2	GG21-0009- 3	13	5
G21-PT -LO-N002B	5	2	GG21-0009- 6	1	2
G21-STR-CF-SPPLUG	10	2	GG21-0009- 6	2	3
G21-SYS-TM-TRAINB	2	5	GG21-0010-B1	21	3
G21-SYS-TM-TRAINB	13	6	GG21-0010-B3	13	5
G21-SYS-TM-TRAINB	21	5	GG21-0010-B6	2	3
G21-UV -CC-F004B	5	2	GG21-0011-B1	21	2
G21-UV -CC-F307	9	2	GG21-0011-B3	2	1
G21-UV -CC-F331	18	2	GG21-0011-B3	3	2
G21-UV -CC-F333	18	2	GG21-0011-B3	13	5
G21-UV_-CC-F348	13	2	GG21-0011-B3	21	1

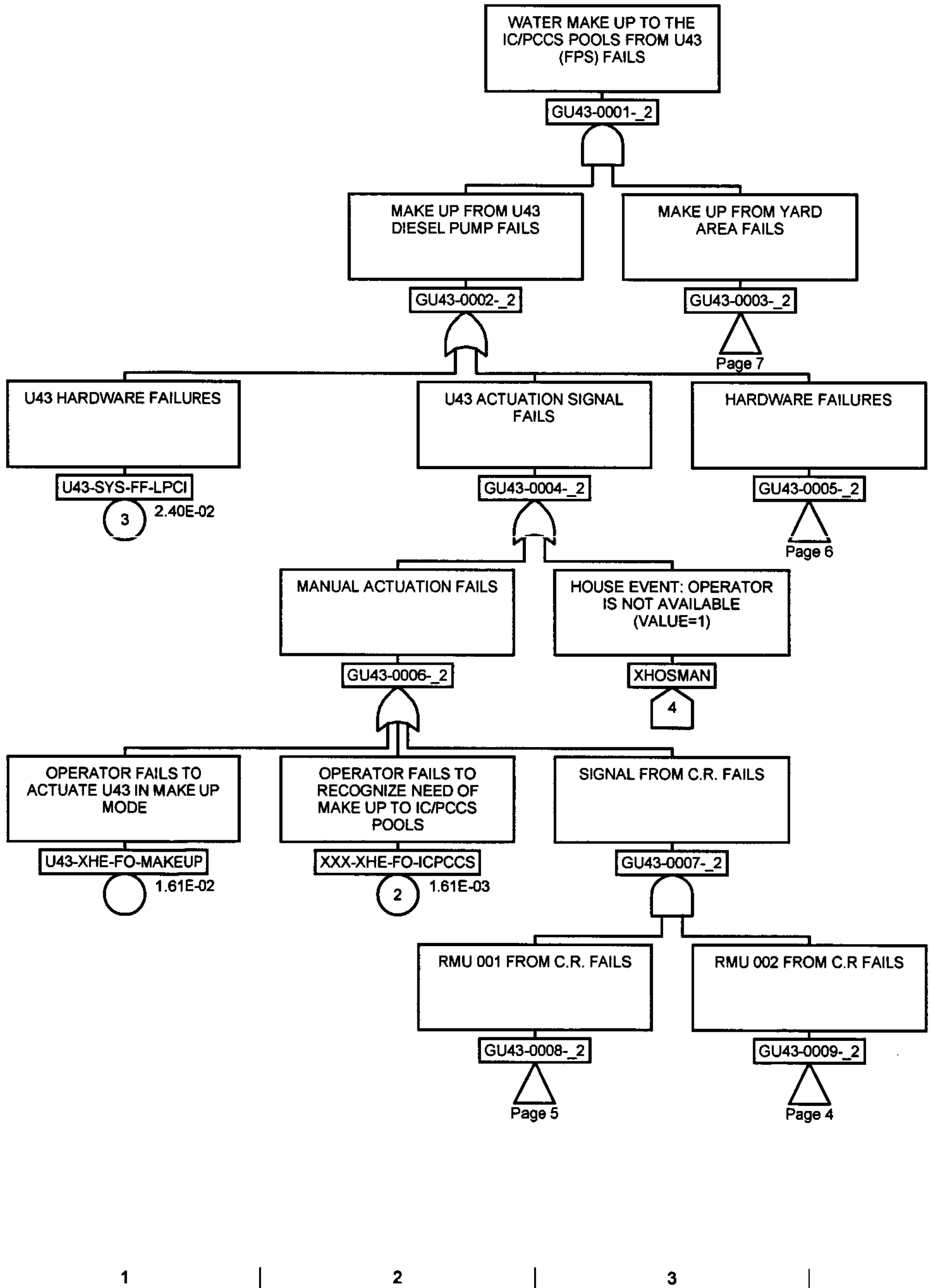
Name	Page	Zone	Name	Page	Zone
GG21-0011-B6	2	2	GG21-0037- 1	27	2
GG21-0013-B1	21	2	GG21-0038- 1	27	2
GG21-0013-B1	22	2	GG21-0100- 1	22	2
GG21-0013-B6	2	2	GG21-0100- 3	13	8
GG21-0013- 3	13	8	GG21-0102- 3	10	2
GG21-0014- 1	22	2	GG21-0102- 3	20	2
GG21-0014- 3	4	1	GG21-0103- 3	20	2
GG21-0014- 3	12	3	GG21-0104- 3	8	2
GG21-0014- 3	13	7	GG21-0104- 3	16	2
GG21-0014- 3	23	1	GG21-0105- 3	16	2
GG21-0015- 1	22	2	GG21-0150- 1	22	2
GG21-0015- 3	12	2	GG21-0150- 1	28	2
GG21-0016- 1	22	1	GG21-1001- 1	7	2
GG21-0016- 1	23	2	GG21-1001- 1	29	6
GG21-0016- 1	29	5	GG21-1001- 2	2	4
GG21-0016- 3	12	4	GG21-1001- 2	6	2
GG21-0016- 6	2	2	GG21-1001- 2	21	4
GG21-0016- 6	7	2	GP21-0001- 1	6	2
GG21-0017-B3	13	6	GP21-0001- 1	29	7
GG21-0017-B3	15	2	GR11-0001- 1	15	1
GG21-0017- 1	23	2	GR11-0001- 2	3	1
GG21-0017- 6	2	1	GR12-0001- 12	15	2
GG21-0017- 6	4	2	GR12-0001- 13	3	2
GG21-0018-A3	7	1	GR13-0001- 11	14	1
GG21-0018-A3	15	2	GR13-0001- 11	19	1
GG21-0018-A3	29	2	GR13-0001- 12	9	4
GG21-0021-B1	2	3	GR13-0001- 13	14	2
GG21-0021-B1	5	2	H23-EMS-CF-ALL	28	2
GG21-0021-B1	13	5	H23-EMS-FC-DIV1	24	1
GG21-0021-B1	21	3	H23-EMS-FC-DIV2	25	3
GG21-0022-A1	21	4	H23-EMS-FC-DIV3	26	4
GG21-0022-A1	29	4	H23-EMS-FC-DIV4	27	3
GG21-0022-A6	2	4	H23-RMU-CF-ALL	28	1
GG21-0022-A6	7	2	H23-RMU-FC-1G21	12	2
GG21-0022- 3	1	3	H23-RMU-FC-2G21	12	4
GG21-0022- 3	10	2	H23-RMU-FC-LMU9A	24	2
GG21-0022- 3	13	6	H23-RMU-FC-LMU9B	25	2
GG21-0022- 3	21	4	H23-RMU-FC-LMU9C	26	1
GG21-0024-A1	7	1	H23-RMU-FC-LMU9D	27	2
GG21-0024-A1	8	2	P21-MOV-CC-F051B	6	1
GG21-0024-A1	15	3	P21-MOV-CC-F055B	6	1
GG21-0024-A1	29	3	P21-MOV-CO-N077A	29	7
GG21-0027- 1	22	2	P21-MOV-CO-N077B	6	2
GG21-0030- 1	22	1	P21-MOV-OC-F051A	29	6
GG21-0030- 1	24	4	P21-MOV-OC-F055A	29	6
GG21-0031- 1	24	2	T23-POL-RP-SP	13	4
GG21-0032- 1	24	2	T62-TT -CF-SPALL	7	2
GG21-0033- 1	24	3	T62-TT -CF-SPALL	22	3
GG21-0033- 1	25	2	T62-TT -CF-SPALL	29	4
GG21-0034- 1	25	2	T62-TT -NO-001	24	3
GG21-0035- 1	24	4	T62-TT -NO-002	25	3
GG21-0035- 1	26	3	T62-TT -NO-003	26	2
GG21-0036- 1	26	2	T62-TT -NO-004	27	3
GG21-0037- 1	24	5	XHOSLOSP	16	3

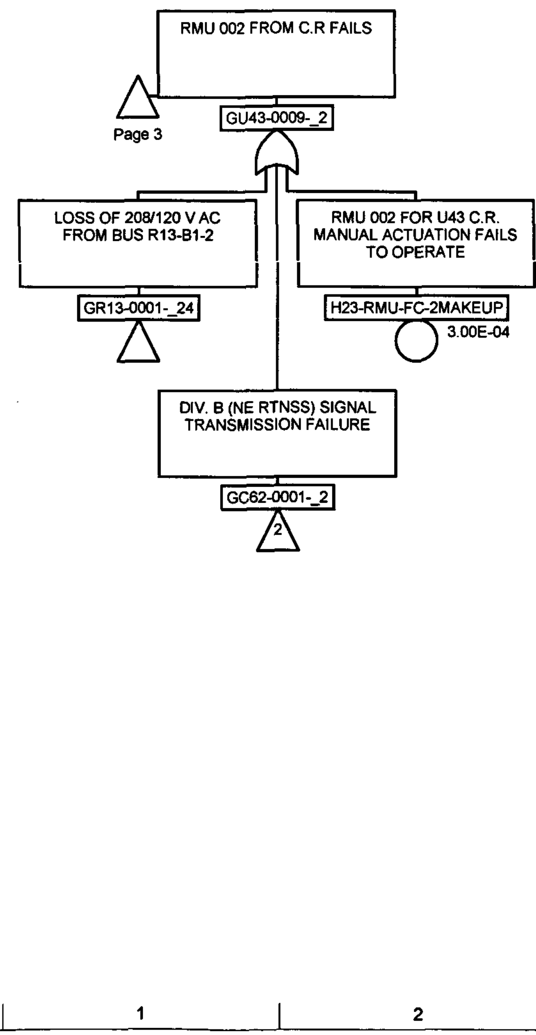
Name	Page	Zone	Name	Page	Zone
XHOSLOSP	20	1			
XHOSLPCIB	22	3			
XHOSMAN	2	2			
XHOSMAN	12	4			
XHOSMAN	13	9			
XHOSMAN	23	3			
XXX-XHE-FO-DEPRESS	13	9			
XXX-XHE-FO-LPMAKEUP	12	5			
XXX-XHE-FO-LPMAKEUP	13	8			
XXX-XHE-FO-SPC	23	2			

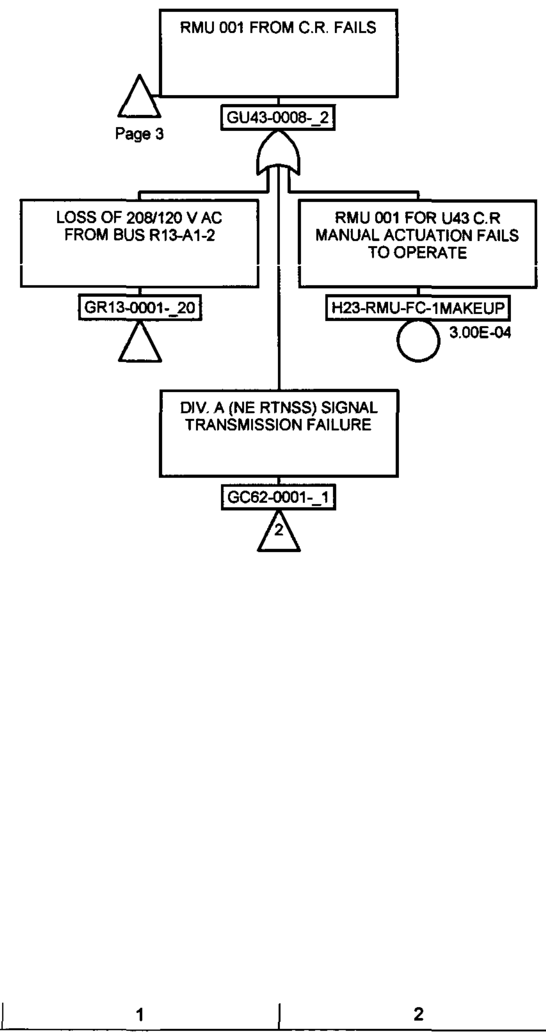
Appendix B.4.7-2
Fire Protection Protection System U43
Fault Tree

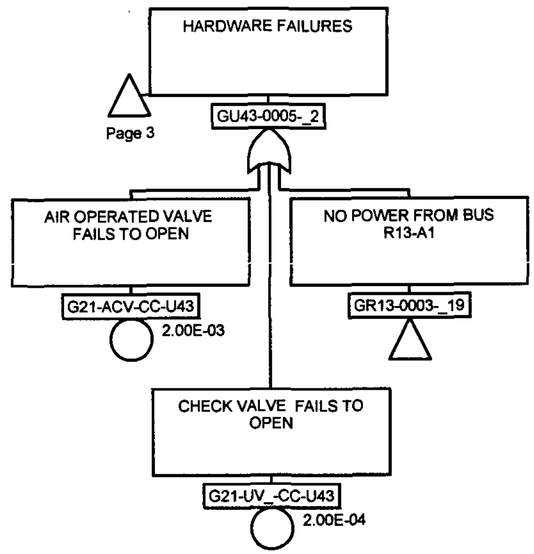

U43 FAILS TO INJECT WATER INTO RPV AFTER ADS
GU43-0001-_3
FLOW DISCHARGE INTO THE RPV (VIA FW AND RWCU LINES) FAILS
GU43-0002-_1
Page 2
WATER SUPPLY FROM U43 FAILS AFTER ADS
GU43-0002-_3
U43 ACTUATION SIGNAL FAILURE
GU43-0004-_3
U43 HARDWARE FAILURES
U43-SYS-FF-LPCI
3
2.40E-02
MANUAL ACTUATION FAILS
GU43-0005-_3
HOUSE EVENT: OPERATOR IS NOT AVAILABLE (VALUE=1)
XHOSMAN
4
OP. FAILS TO RECOG. NEED FOR LOW PRESS. MAKEUP (LOCA)
XXX-XHE-FO-LPMAKEUP
2
1.61E-01
SIGNAL FROM C.R. FAILS
GU43-0006-_1
Page 8
OPERATOR FAILS TO ACTUATE U43 IN LPCI MODE AFTER ADS
U43-XHE-FO-LPCIADS
1.61E-02
1
2
3

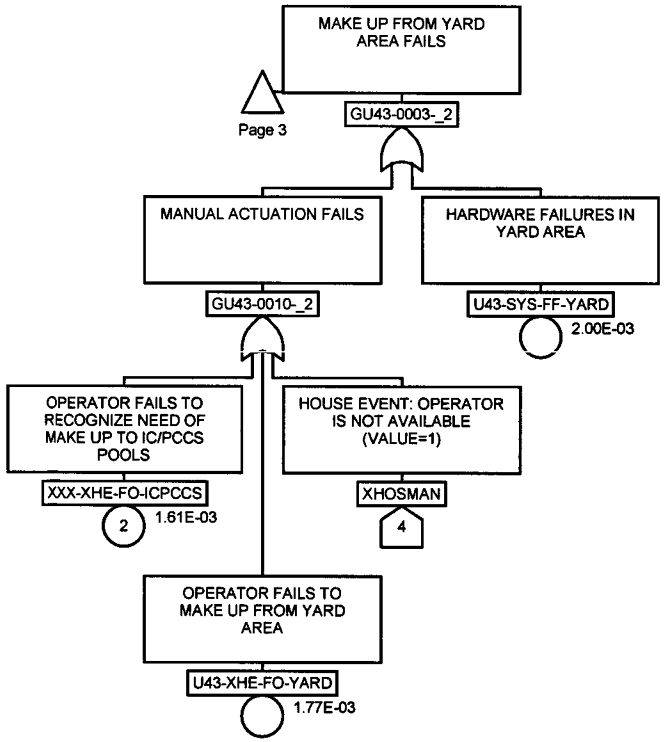

FLOW DISCHARGE INTO THE RPV (VIA FW AND RWCU LINES) FAILS
GU43-0002-_1
Page 8
Page 1
CHECK VALVE F102A IN FEEDWATER LINE A FAILS TO OPEN
B21-UV_-CC-F102A
1.60E-03
LOSS OF SUPPORT SUPPLIERS TO AOV F332
GG21-0007-_6
CHECK VALVE F103A IN FEEDWATER LINE A FAILS TO OPEN
B21-UV_-CC-F103A
1.60E-03
MAINTENANCE FOR CV F332 OR CV F333
G21-UV_-TM-F332/333
8.00E-04
FLOW DISCHARGE LINEINTO THE RPV HARDW.FAILURES
GU43-0007-_1
Page 9
MISPOSITION OF VALVE F334
G21-XHE-MH-F334
4.80E-02
1
2

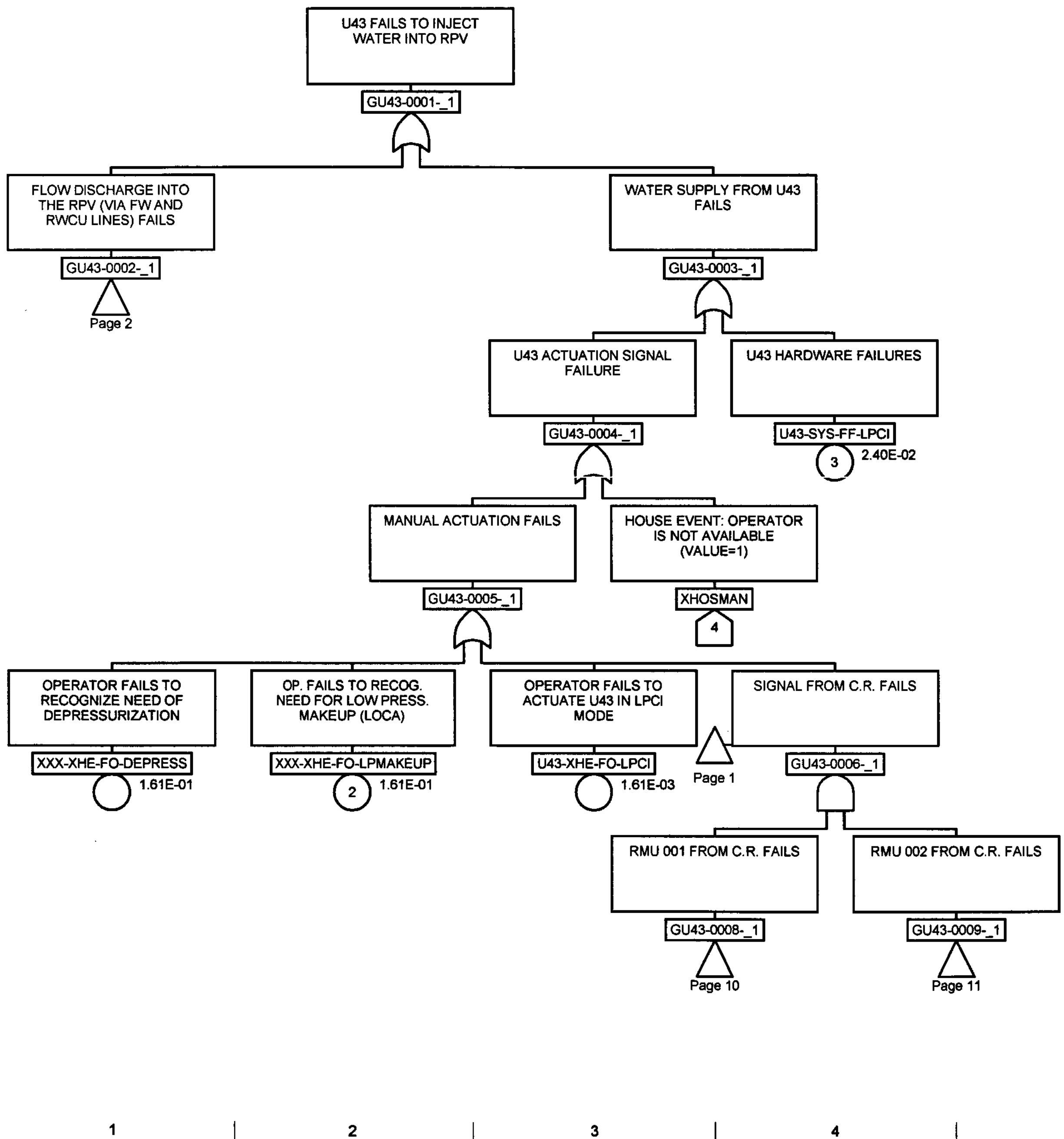

WATER MAKE UP TO THE IC/PCCS POOLS FROM U43 (FPS) FAILS
GU43-0001-_2
MAKE UP FROM U43 DIESEL PUMP FAILS
GU43-0002-_2
MAKE UP FROM YARD AREA FAILS
GU43-0003-_2
Page 7
U43 HARDWARE FAILURES
U43-SYS-FF-LPCI
3
2.40E-02
U43 ACTUATION SIGNAL FAILS
GU43-0004-_2
HARDWARE FAILURES
GU43-0005-_2
Page 6
MANUAL ACTUATION FAILS
GU43-0006-_2
HOUSE EVENT: OPERATOR IS NOT AVAILABLE (VALUE=1)
XHOSMAN
4
OPERATOR FAILS TO ACTUATE U43 IN MAKE UP MODE
U43-XHE-FO-MAKEUP
1.61E-02
OPERATOR FAILS TO RECOGNIZE NEED OF MAKE UP TO IC/PCCS POOLS
XXX-XHE-FO-ICPCCS
2
1.61E-03
SIGNAL FROM C.R. FAILS
GU43-0007-_2
RMU 001 FROM C.R. FAILS
GU43-0008-_2
Page 5
RMU 002 FROM C.R FAILS
GU43-0009-_2
Page 4
1
2
3

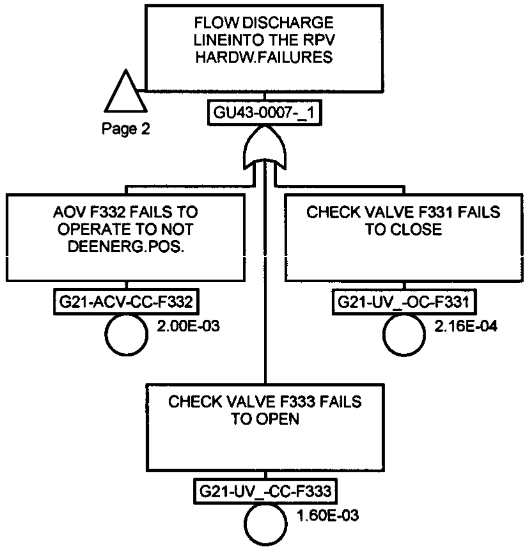

RMU 002 FROM C.R FAILS
Page 3
GU43-0009-_2
LOSS OF 208/120 V AC FROM BUS R13-B1-2
GR13-0001-_24
RMU 002 FOR U43 C.R. MANUAL ACTUATION FAILS TO OPERATE
H23-RMU-FC-2MAKEUP
3.00E-04
DIV. B (NE RTNSS) SIGNAL TRANSMISSION FAILURE
GC62-0001-_2
2
1
2

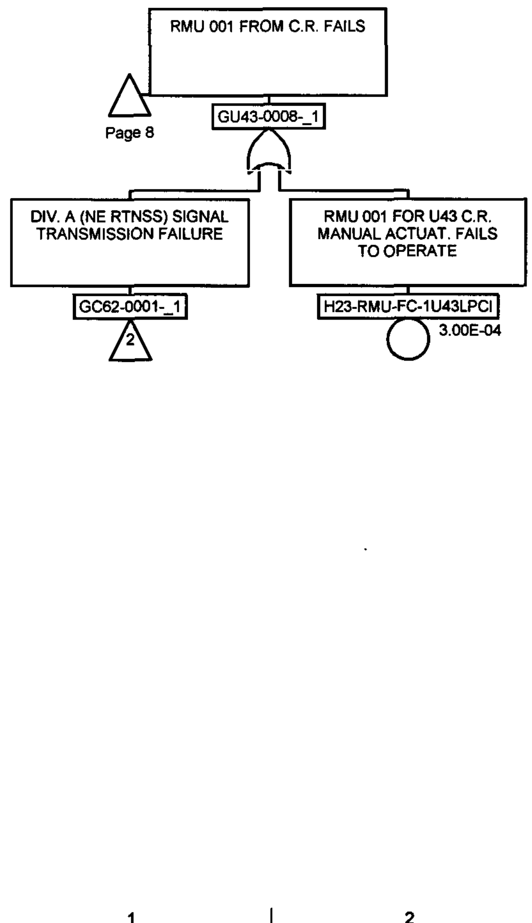

RMU 001 FROM C.R. FAILS
GU43-0008-_2
Page 3
LOSS OF 208/120 V AC FROM BUS R13-A1-2
GR13-0001-_20
RMU 001 FOR U43 C.R MANUAL ACTUATION FAILS TO OPERATE
H23-RMU-FC-1MAKEUP
3.00E-04
DIV. A (NE RTNSS) SIGNAL TRANSMISSION FAILURE
GC62-0001-_1
2
1
2

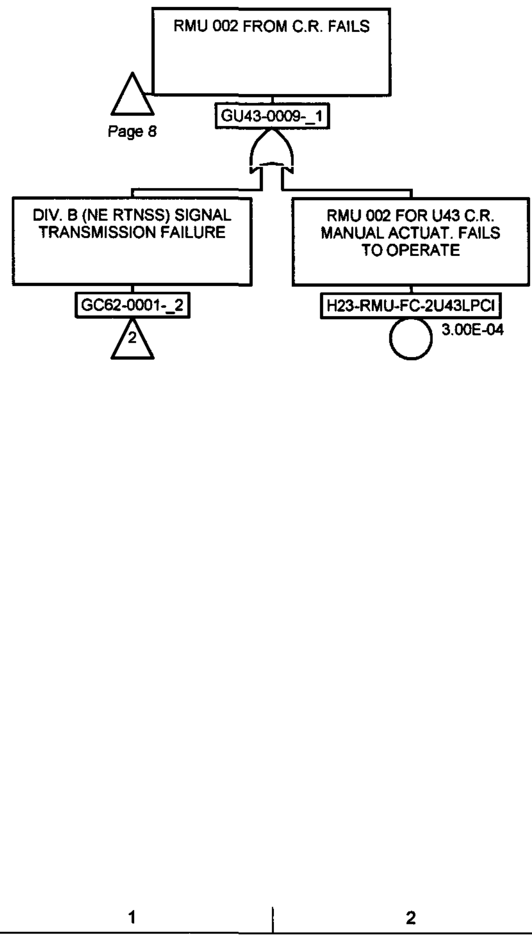

HARDWARE FAILURES
Page 3
GU43-0005-_2
AIR OPERATED VALVE FAILS TO OPEN
G21-ACV-CC-U43
2.00E-03
NO POWER FROM BUS R13-A1
GR13-0003-_19
CHECK VALVE FAILS TO OPEN
G21-UV_-CC-U43
2.00E-04


MAKE UP FROM YARD AREA FAILS
GU43-0003-_2
Page 3
MANUAL ACTUATION FAILS
GU43-0010-_2
HARDWARE FAILURES IN YARD AREA
U43-SYS-FF-YARD
2.00E-03
OPERATOR FAILS TO RECOGNIZE NEED OF MAKE UP TO IC/PCCS POOLS
XXX-XHE-FO-ICPCCS
2
1.61E-03
HOUSE EVENT: OPERATOR IS NOT AVAILABLE (VALUE=1)
XHOSMAN
4
OPERATOR FAILS TO MAKE UP FROM YARD AREA
U43-XHE-FO-YARD
1.77E-03
1
2


U43 FAILS TO INJECT WATER INTO RPV
GU43-0001-_1
FLOW DISCHARGE INTO THE RPV (VIA FW AND RWCU LINES) FAILS
GU43-0002-_1
Page 2
WATER SUPPLY FROM U43 FAILS
GU43-0003-_1
U43 ACTUATION SIGNAL FAILURE
GU43-0004-_1
U43 HARDWARE FAILURES
U43-SYS-FF-LPCI
3
2.40E-02
MANUAL ACTUATION FAILS
GU43-0005-_1
HOUSE EVENT: OPERATOR IS NOT AVAILABLE (VALUE=1)
XHOSMAN
4
OPERATOR FAILS TO RECOGNIZE NEED OF DEPRESSURIZATION
XXX-XHE-FO-DEPRESS
1.61E-01
OP. FAILS TO RECOG. NEED FOR LOW PRESS. MAKEUP (LOCA)
XXX-XHE-FO-LPMAKEUP
2
1.61E-01
OPERATOR FAILS TO ACTUATE U43 IN LPCI MODE
U43-XHE-FO-LPCI
1.61E-03
Page 1
SIGNAL FROM C.R. FAILS
GU43-0006-_1
RMU 001 FROM C.R. FAILS
GU43-0008-_1
Page 10
RMU 002 FROM C.R. FAILS
GU43-0009-_1
Page 11
1
2
3
4

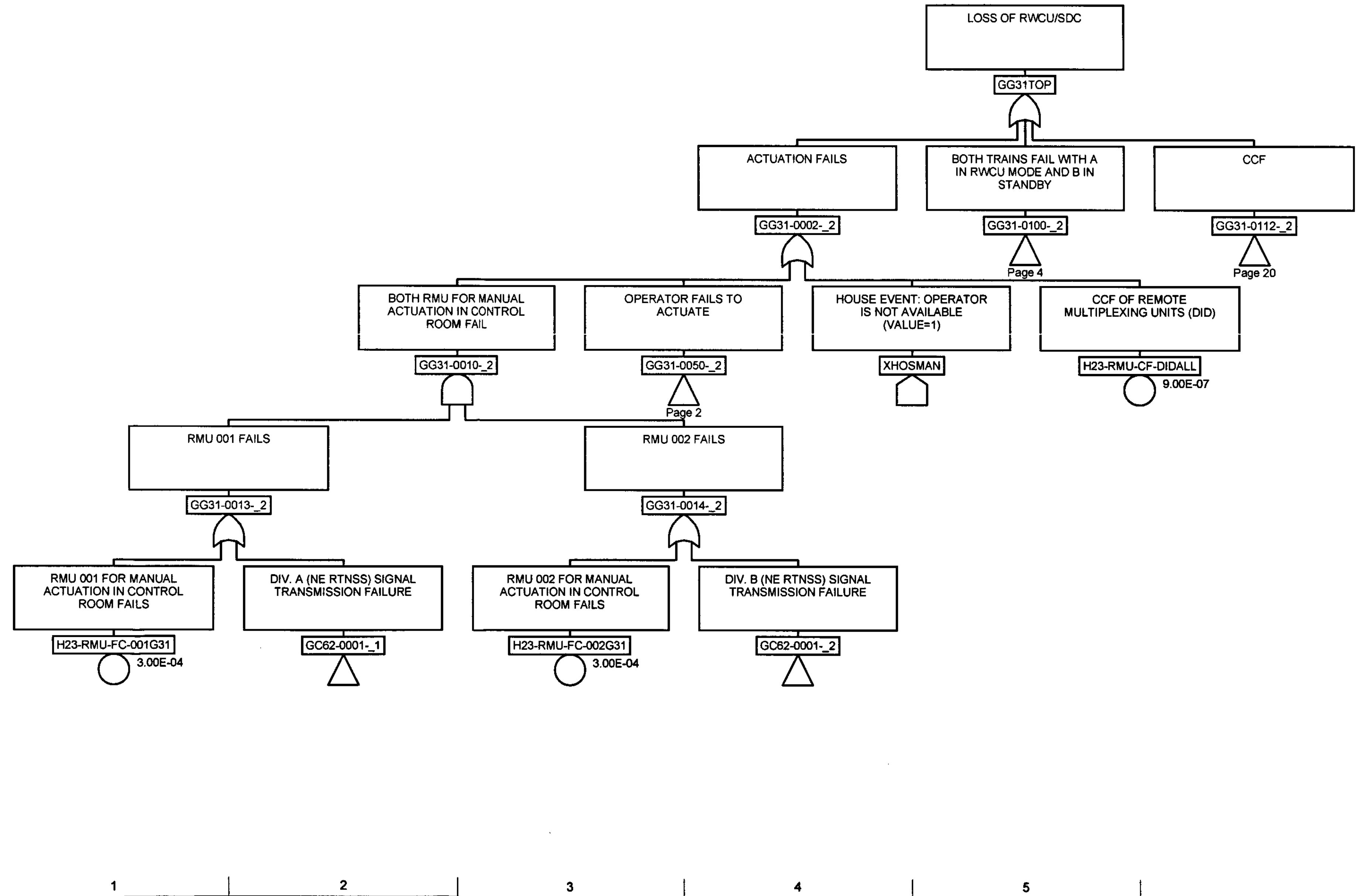

FLOW DISCHARGE LINEINTO THE RPV HARDW.FAILURES
GU43-0007-_1
Page 2
AOV F332 FAILS TO OPERATE TO NOT DEENERG.POS.
G21-ACV-CC-F332
2.00E-03
CHECK VALVE F331 FAILS TO CLOSE
G21-UV_-OC-F331
2.16E-04
CHECK VALVE F333 FAILS TO OPEN
G21-UV_-CC-F333
1.60E-03
1
2

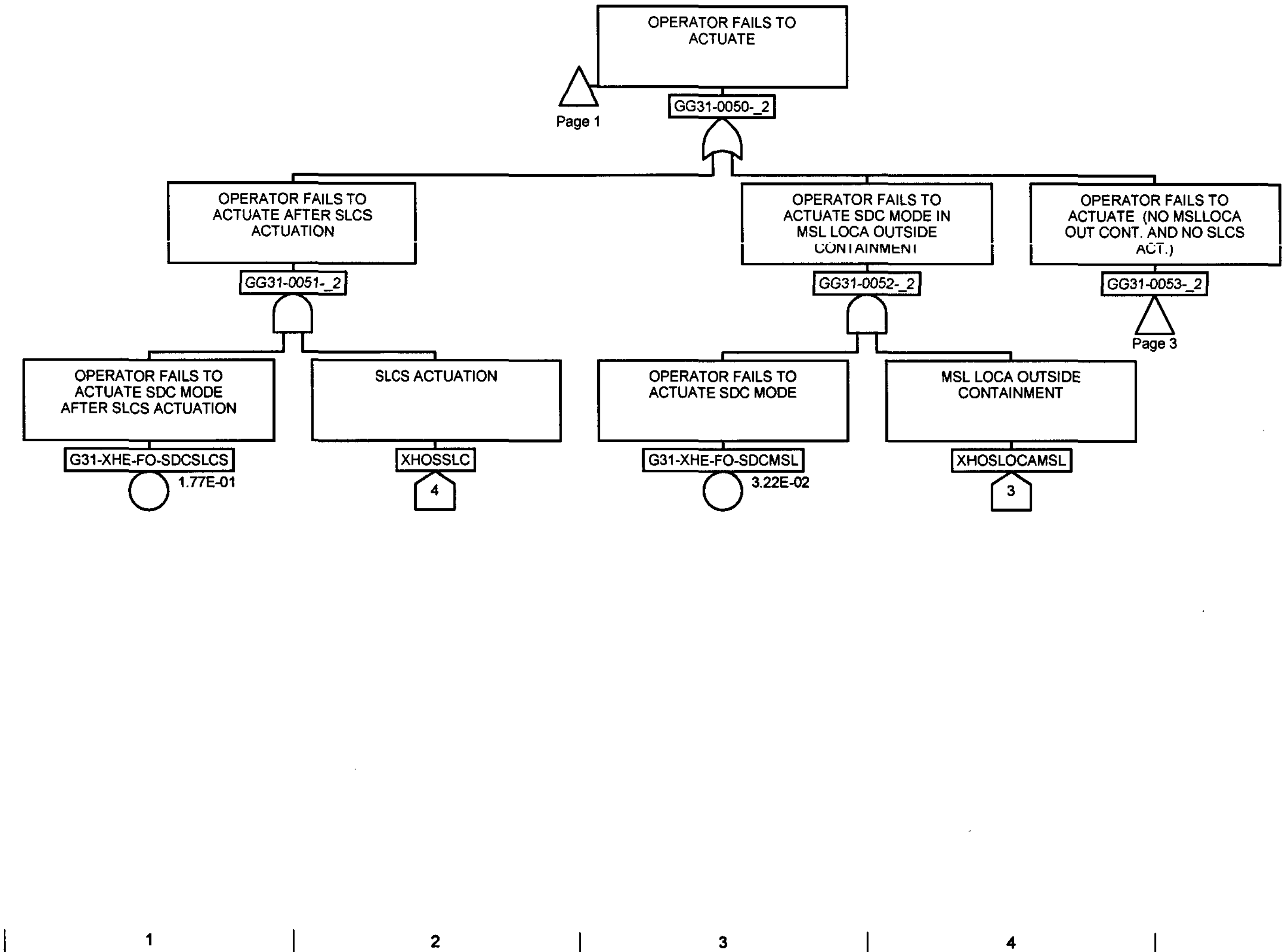

RMU 001 FROM C.R. FAILS
Page 8
GU43-0008-_1
DIV. A (NE RTNSS) SIGNAL TRANSMISSION FAILURE
GC62-0001-_1
2
RMU 001 FOR U43 C.R. MANUAL ACTUAT. FAILS TO OPERATE
H23-RMU-FC-1U43LPCI
3.00E-04
1
2

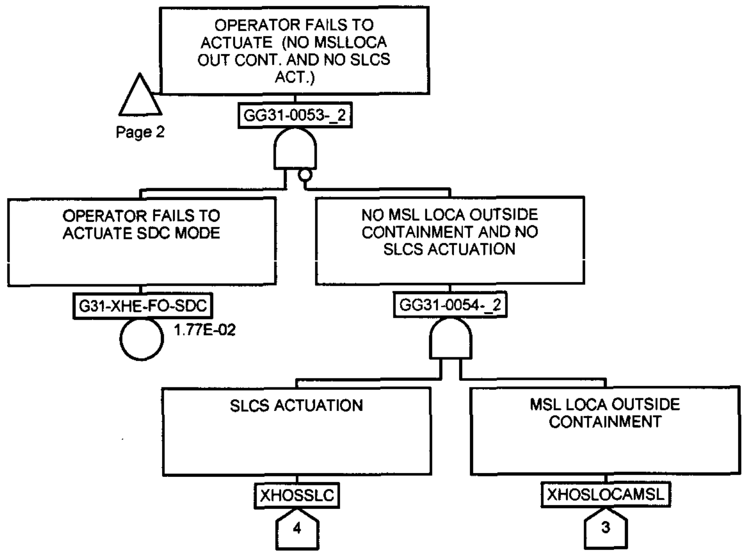

RMU 002 FROM C.R. FAILS
Page 8
GU43-0009-_1
DIV. B (NE RTNSS) SIGNAL TRANSMISSION FAILURE
GC62-0001-_2
2
RMU 002 FOR U43 C.R. MANUAL ACTUAT. FAILS TO OPERATE
H23-RMU-FC-2U43LPCI
3.00E-04
1
2

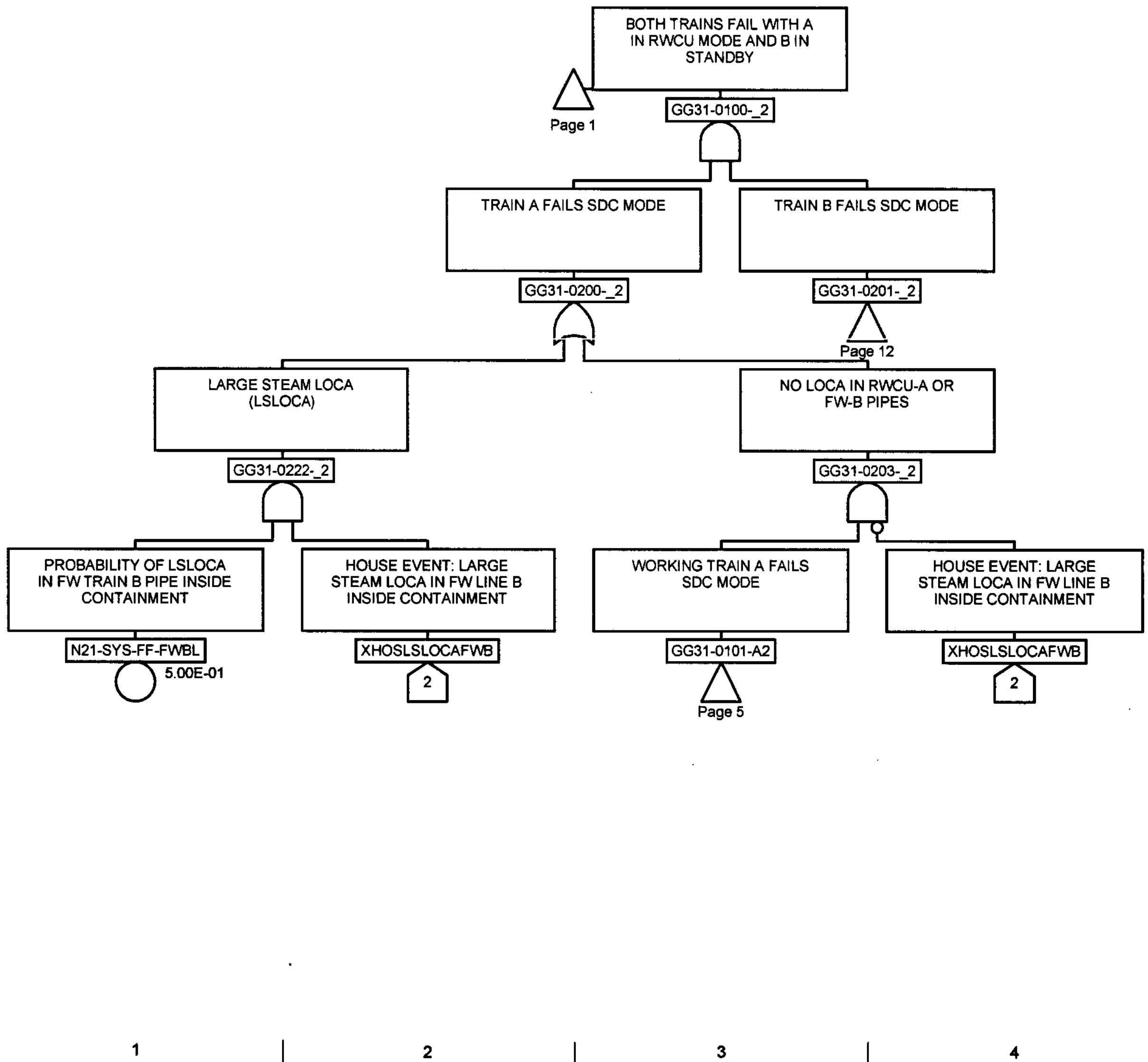
Name	Page	Zone
B21-UV -CC-F102A	2	1
B21-UV -CC-F103A	2	1
G21-ACV-CC-F332	9	1
G21-ACV-CC-U43	6	1
G21-UV -CC-F333	9	2
G21-UV -CC-U43	6	2
G21-UV -OC-F331	9	2
G21-UV -TM-F332/333	2	2
G21-XHE-MH-F334	2	2
GC62-0001- 1	5	2
GC62-0001- 1	10	1
GC62-0001- 2	4	2
GC62-0001- 2	11	1
GG21-0007- 6	2	2
GR13-0001- 20	5	1
GR13-0001- 24	4	1
GR13-0003- 19	6	2
GU43-0001- 1	8	2
GU43-0001- 2	3	3
GU43-0001- 3	1	2
GU43-0002- 1	1	1
GU43-0002- 1	2	2
GU43-0002- 1	8	1
GU43-0002- 2	3	2
GU43-0002- 3	1	2
GU43-0003- 1	8	3
GU43-0003- 2	3	3
GU43-0003- 2	7	2
GU43-0004- 1	8	3
GU43-0004- 2	3	3
GU43-0004- 3	1	2
GU43-0005- 1	8	3
GU43-0005- 2	3	4
GU43-0005- 2	6	2
GU43-0005- 3	1	2
GU43-0006- 1	1	2
GU43-0006- 1	8	4
GU43-0006- 2	3	2
GU43-0007- 1	2	1
GU43-0007- 1	9	2
GU43-0007- 2	3	3
GU43-0008- 1	8	4
GU43-0008- 1	10	2
GU43-0008- 2	3	3
GU43-0008- 2	5	2
GU43-0009- 1	8	5
GU43-0009- 1	11	2
GU43-0009- 2	3	4
GU43-0009- 2	4	2
GU43-0010- 2	7	2
H23-RMU-FC-1MAKEUP	5	2
H23-RMU-FC-1U43LPCI	10	2
H23-RMU-FC-2MAKEUP	4	2
H23-RMU-FC-2U43LPCI	11	2
U43-SYS-FF-LPCI	1	3
U43-SYS-FF-LPCI	3	1
U43-SYS-FF-LPCI	8	4
U43-SYS-FF-YARD	7	3
U43-XHE-FO-LPCI	8	3
U43-XHE-FO-LPCIADS	1	2
U43-XHE-FO-MAKEUP	3	1
U43-XHE-FO-YARD	7	2
XHOSMAN	1	3
XHOSMAN	3	3
XHOSMAN	7	2
XHOSMAN	8	4
XXX-XHE-FO-DEPRESS	8	1
XXX-XHE-FO-ICPCCS	3	2
XXX-XHE-FO-ICPCCS	7	1
XXX-XHE-FO-LPMAKEUP	1	1
XXX-XHE-FO-LPMAKEUP	8	2

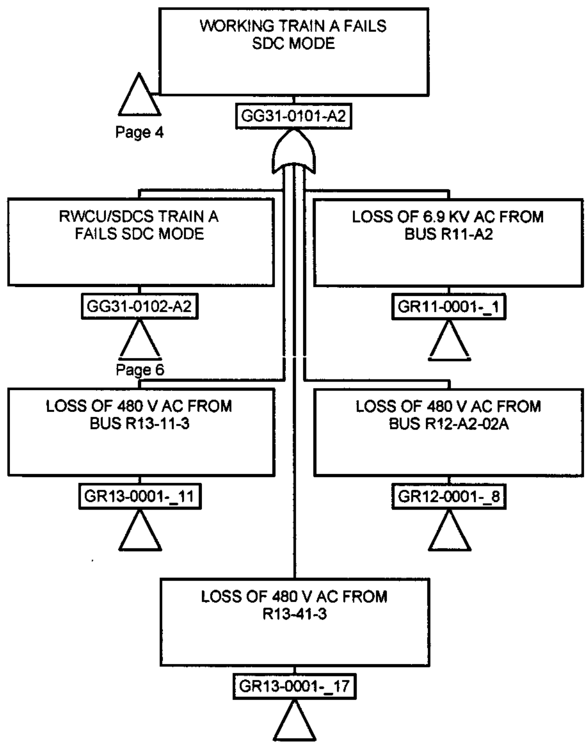
Appendix B.4.8
Reactor Water Cleanup/Shutdown Cooling System
Fault Tree

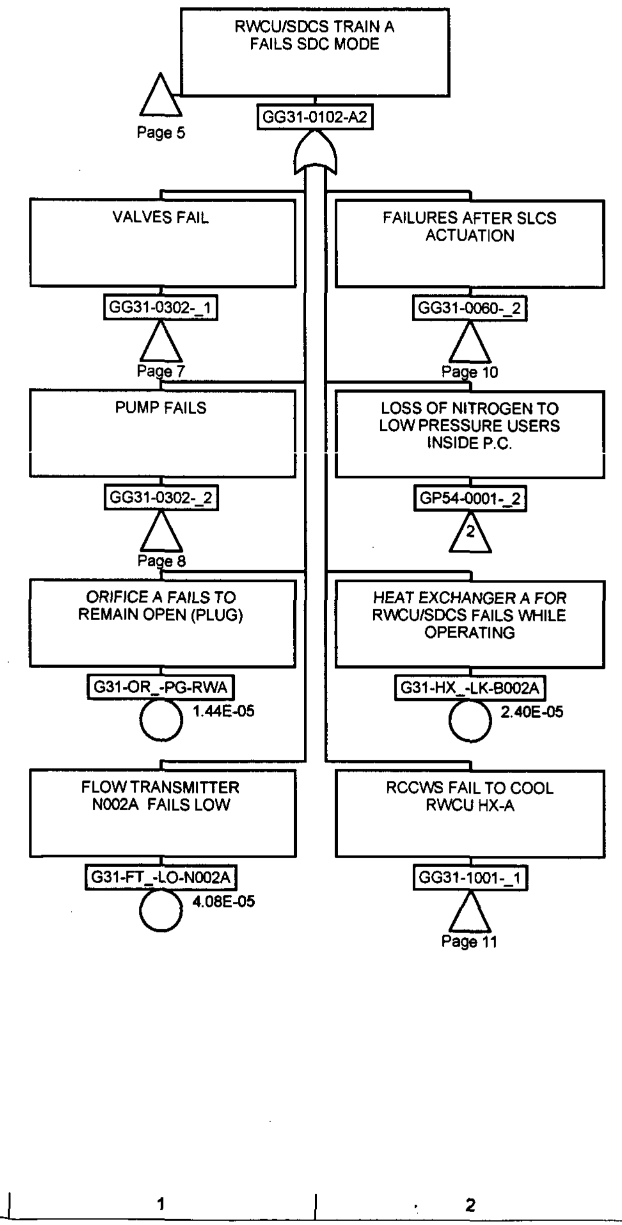

LOSS OF RWCU/SDC
GG31TOP
ACTUATION FAILS
GG31-0002-_2
BOTH TRAINS FAIL WITH A IN RWCU MODE AND B IN STANDBY
GG31-0100-_2
Page 4
CCF
GG31-0112-_2
Page 20
BOTH RMU FOR MANUAL ACTUATION IN CONTROL ROOM FAIL
GG31-0010-_2
OPERATOR FAILS TO ACTUATE
GG31-0050-_2
Page 2
HOUSE EVENT: OPERATOR IS NOT AVAILABLE (VALUE=1)
XHOSMAN
CCF OF REMOTE MULTIPLEXING UNITS (DID)
H23-RMU-CF-DIDALL
9.00E-07
RMU 001 FAILS
GG31-0013-_2
RMU 002 FAILS
GG31-0014-_2
RMU 001 FOR MANUAL ACTUATION IN CONTROL ROOM FAILS
H23-RMU-FC-001G31
3.00E-04
DIV. A (NE RTNSS) SIGNAL TRANSMISSION FAILURE
GC62-0001-_1
RMU 002 FOR MANUAL ACTUATION IN CONTROL ROOM FAILS
H23-RMU-FC-002G31
3.00E-04
DIV. B (NE RTNSS) SIGNAL TRANSMISSION FAILURE
GC62-0001-_2
1
2
3
4
5

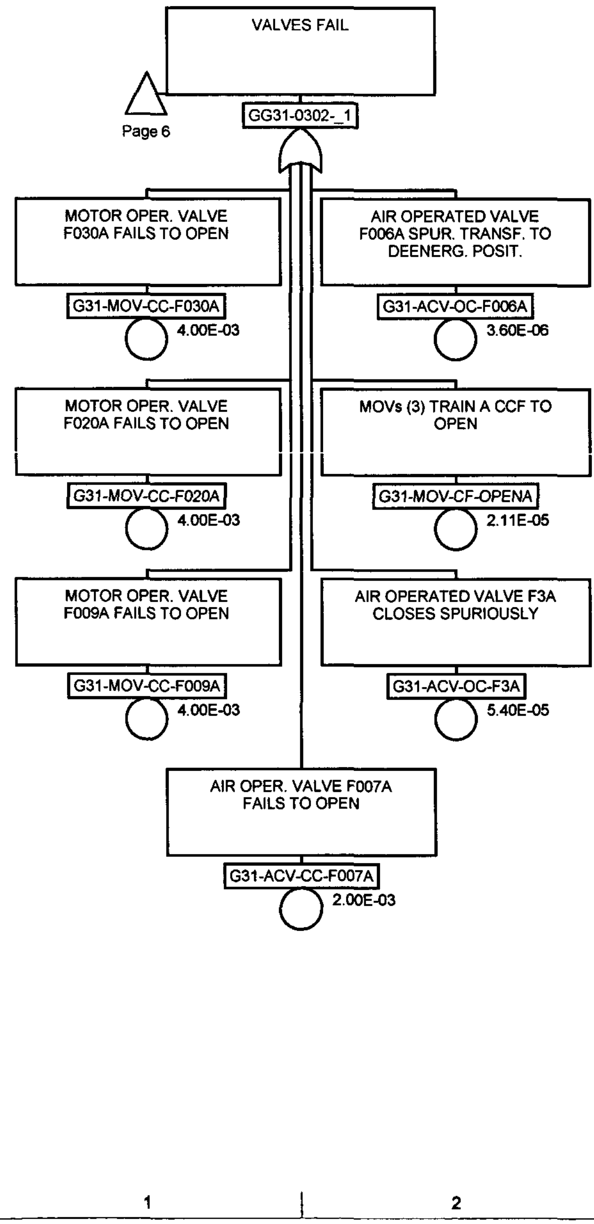

OPERATOR FAILS TO ACTUATE
GG31-0050-_2
Page 1
OPERATOR FAILS TO ACTUATE AFTER SLCS ACTUATION
GG31-0051-_2
OPERATOR FAILS TO ACTUATE SDC MODE IN MSL LOCA OUTSIDE CONTAINMENT
GG31-0052-_2
OPERATOR FAILS TO ACTUATE (NO MSLLOCA OUT CONT. AND NO SLCS ACT.)
GG31-0053-_2
Page 3
OPERATOR FAILS TO ACTUATE SDC MODE AFTER SLCS ACTUATION
G31-XHE-FO-SDCSLCS
1.77E-01
SLCS ACTUATION
XHOSSLC
4
OPERATOR FAILS TO ACTUATE SDC MODE
G31-XHE-FO-SDCMSL
3.22E-02
MSL LOCA OUTSIDE CONTAINMENT
XHOSLOCAMSL
3
1
2
3
4

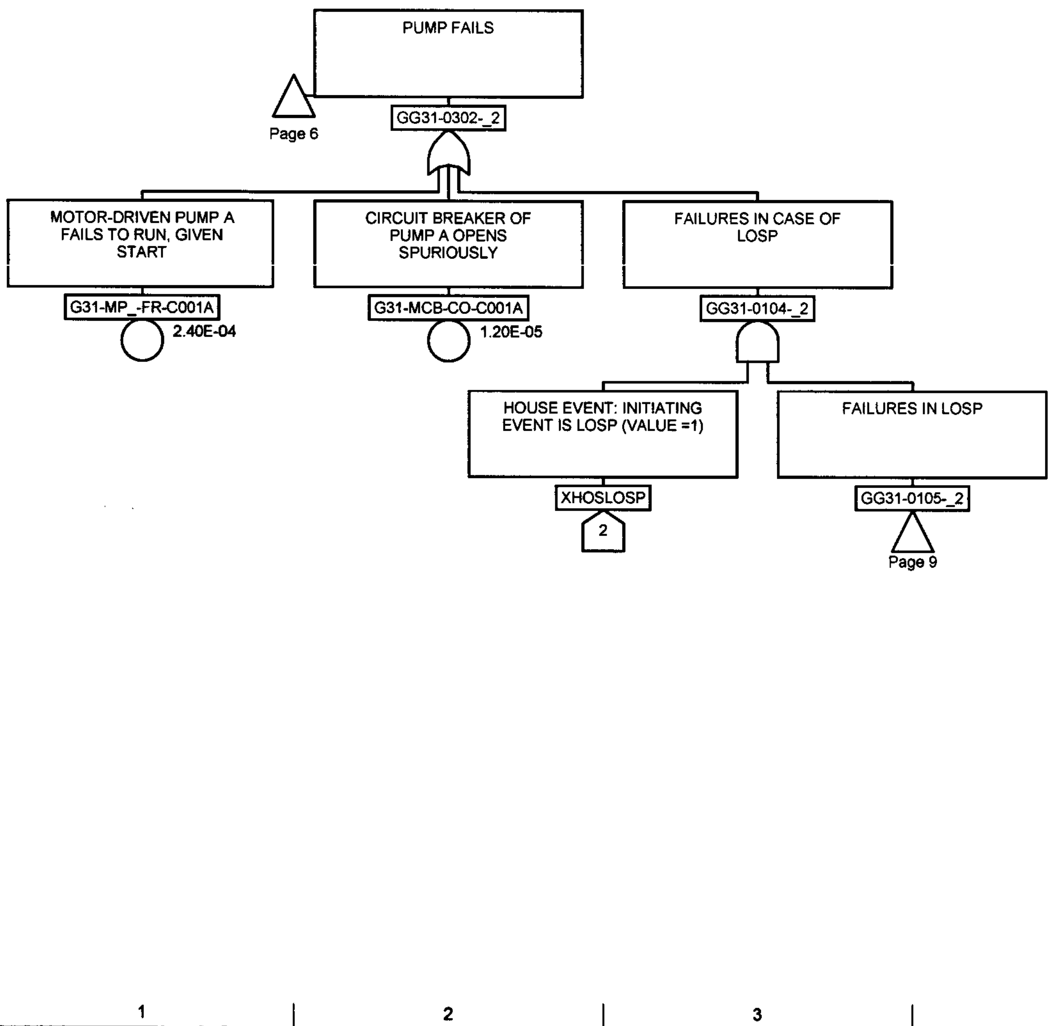

OPERATOR FAILS TO ACTUATE (NO MSLLOCA OUT CONT. AND NO SLCS ACT.)
GG31-0053-_2
Page 2
OPERATOR FAILS TO ACTUATE SDC MODE
G31-XHE-FO-SDC
1.77E-02
NO MSL LOCA OUTSIDE CONTAINMENT AND NO SLCS ACTUATION
GG31-0054-_2
SLCS ACTUATION
XHOSSLC
4
MSL LOCA OUTSIDE CONTAINMENT
XHOSLOCAMSL
3

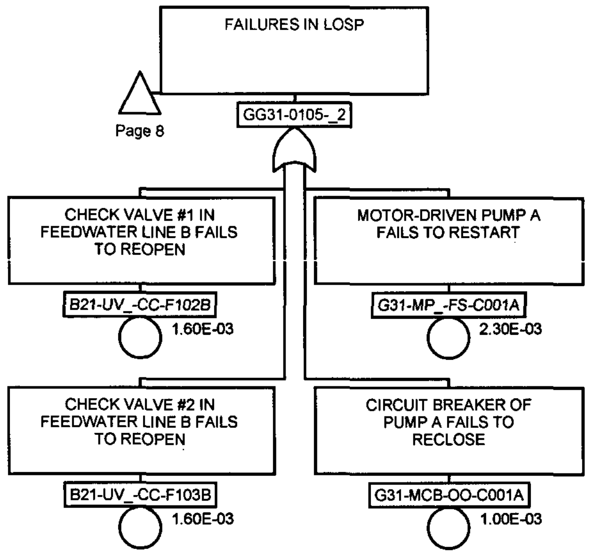

BOTH TRAINS FAIL WITH A IN RWCU MODE AND B IN STANDBY
GG31-0100-_2
Page 1
TRAIN A FAILS SDC MODE
GG31-0200-_2
TRAIN B FAILS SDC MODE
GG31-0201-_2
Page 12
LARGE STEAM LOCA (LSLOCA)
GG31-0222-_2
NO LOCA IN RWCU-A OR FW-B PIPES
GG31-0203-_2
PROBABILITY OF LSLOCA IN FW TRAIN B PIPE INSIDE CONTAINMENT
N21-SYS-FF-FWBL
5.00E-01
HOUSE EVENT: LARGE STEAM LOCA IN FW LINE B INSIDE CONTAINMENT
XHOSLSLOCAFWB
2
WORKING TRAIN A FAILS SDC MODE
GG31-0101-A2
Page 5
HOUSE EVENT: LARGE STEAM LOCA IN FW LINE B INSIDE CONTAINMENT
XHOSLSLOCAFWB
2
1
2
3
4


WORKING TRAIN A FAILS SDC MODE
GG31-0101-A2
Page 4
RWCU/SDCS TRAIN A FAILS SDC MODE
GG31-0102-A2
Page 6
LOSS OF 6.9 KV AC FROM BUS R11-A2
GR11-0001-_1
LOSS OF 480 V AC FROM BUS R13-11-3
GR13-0001-_11
LOSS OF 480 V AC FROM BUS R12-A2-02A
GR12-0001-_8
LOSS OF 480 V AC FROM R13-41-3
GR13-0001-_17
1
2

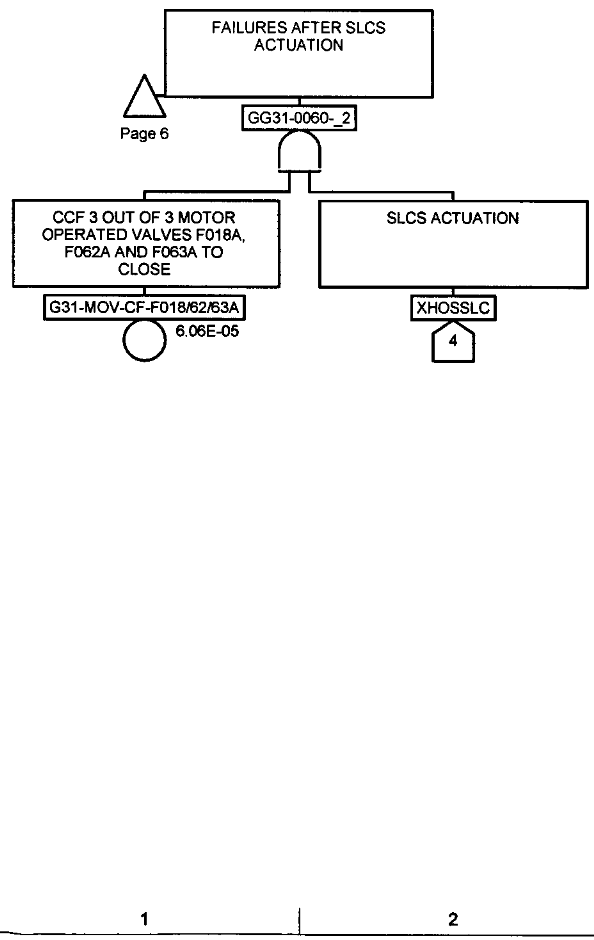

RWCU/SDCS TRAIN A FAILS SDC MODE
Page 5
GG31-0102-A2
VALVES FAIL
GG31-0302-_1
Page 7
FAILURES AFTER SLCS ACTUATION
GG31-0060-_2
Page 10
PUMP FAILS
GG31-0302-_2
Page 8
LOSS OF NITROGEN TO LOW PRESSURE USERS INSIDE P.C.
GP54-0001-_2
2
ORIFICE A FAILS TO REMAIN OPEN (PLUG)
G31-OR_-PG-RWA
1.44E-05
HEAT EXCHANGER A FOR RWCU/SDCS FAILS WHILE OPERATING
G31-HX_-LK-B002A
2.40E-05
FLOW TRANSMITTER N002A FAILS LOW
G31-FT_-LO-N002A
4.08E-05
RCCWS FAIL TO COOL RWCU HX-A
GG31-1001-_1
Page 11
1
2

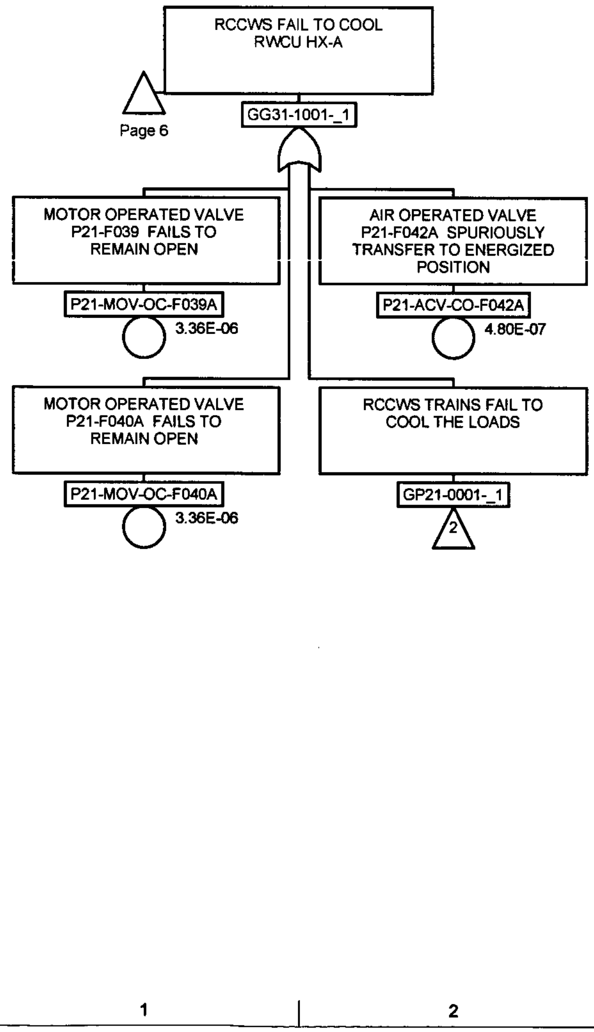

VALVES FAIL
GG31-0302-_1
Page 6
MOTOR OPER. VALVE F030A FAILS TO OPEN
G31-MOV-CC-F030A
4.00E-03
AIR OPERATED VALVE F006A SPUR. TRANSF. TO DEENERG. POSIT.
G31-ACV-OC-F006A
3.60E-06
MOTOR OPER. VALVE F020A FAILS TO OPEN
G31-MOV-CC-F020A
4.00E-03
MOVs (3) TRAIN A CCF TO OPEN
G31-MOV-CF-OPENA
2.11E-05
MOTOR OPER. VALVE F009A FAILS TO OPEN
G31-MOV-CC-F009A
4.00E-03
AIR OPERATED VALVE F3A CLOSES SPURIOUSLY
G31-ACV-OC-F3A
5.40E-05
AIR OPER. VALVE F007A FAILS TO OPEN
G31-ACV-CC-F007A
2.00E-03
1
2

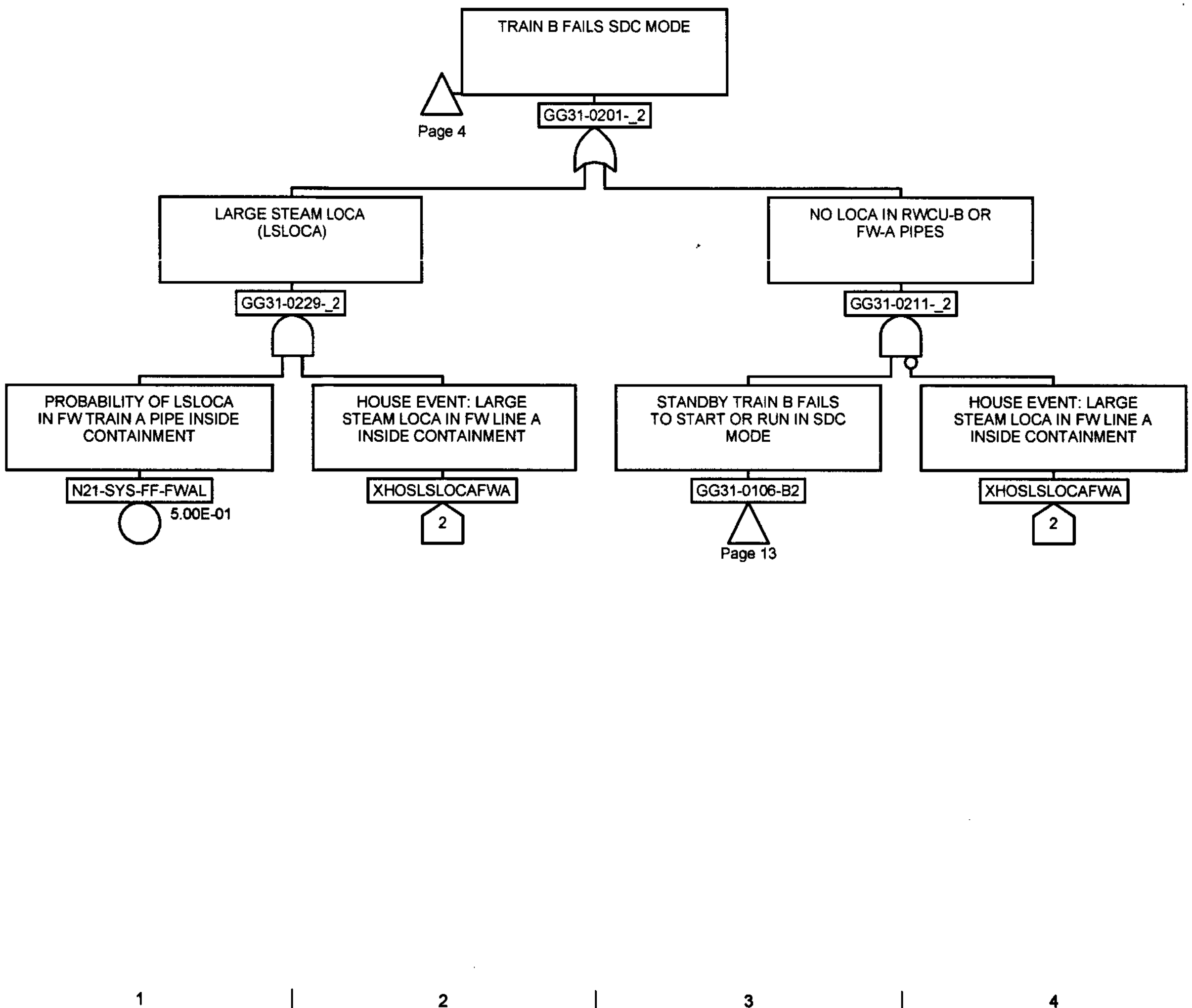

PUMP FAILS
GG31-0302-_2
Page 6
MOTOR-DRIVEN PUMP A FAILS TO RUN, GIVEN START
G31-MP_-FR-C001A
2.40E-04
CIRCUIT BREAKER OF PUMP A OPENS SPURIOUSLY
G31-MCB-CO-C001A
1.20E-05
FAILURES IN CASE OF LOSP
GG31-0104-_2
HOUSE EVENT: INITIATING EVENT IS LOSP (VALUE =1)
XHOSLOSP
2
FAILURES IN LOSP
GG31-0105-_2
Page 9
1
2
3

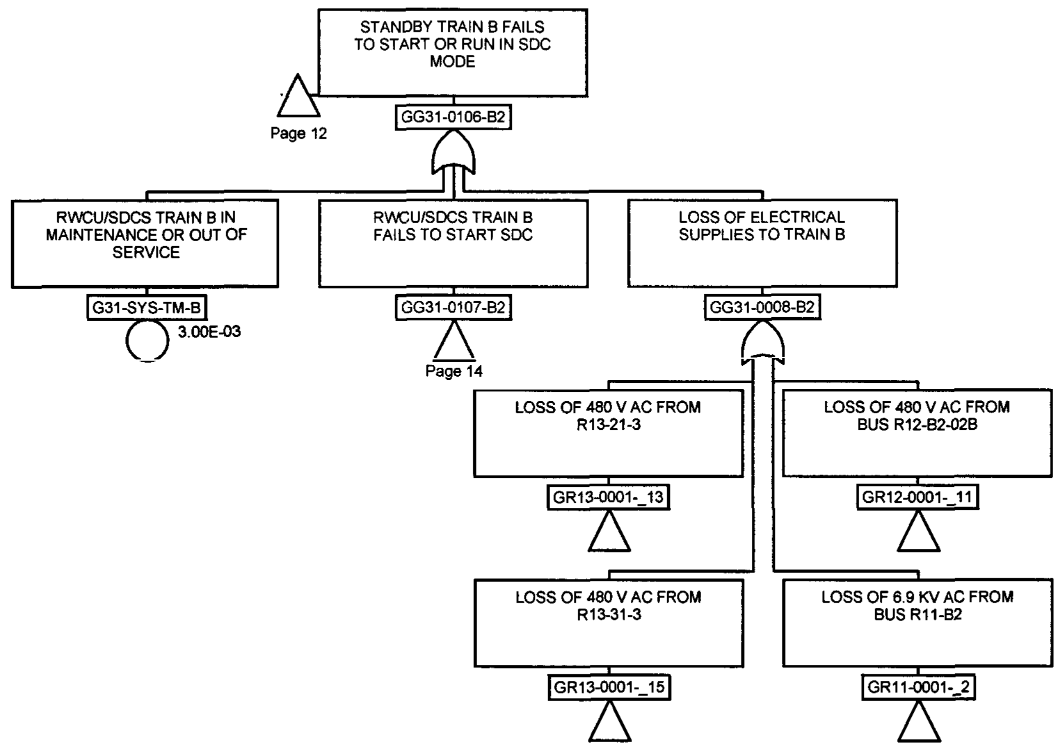

FAILURES IN LOSP
GG31-0105-_2
Page 8
CHECK VALVE #1 IN FEEDWATER LINE B FAILS TO REOPEN
B21-UV_-CC-F102B
1.60E-03
MOTOR-DRIVEN PUMP A FAILS TO RESTART
G31-MP_-FS-C001A
2.30E-03
CHECK VALVE #2 IN FEEDWATER LINE B FAILS TO REOPEN
B21-UV_-CC-F103B
1.60E-03
CIRCUIT BREAKER OF PUMP A FAILS TO RECLOSE
G31-MCB-OO-C001A
1.00E-03

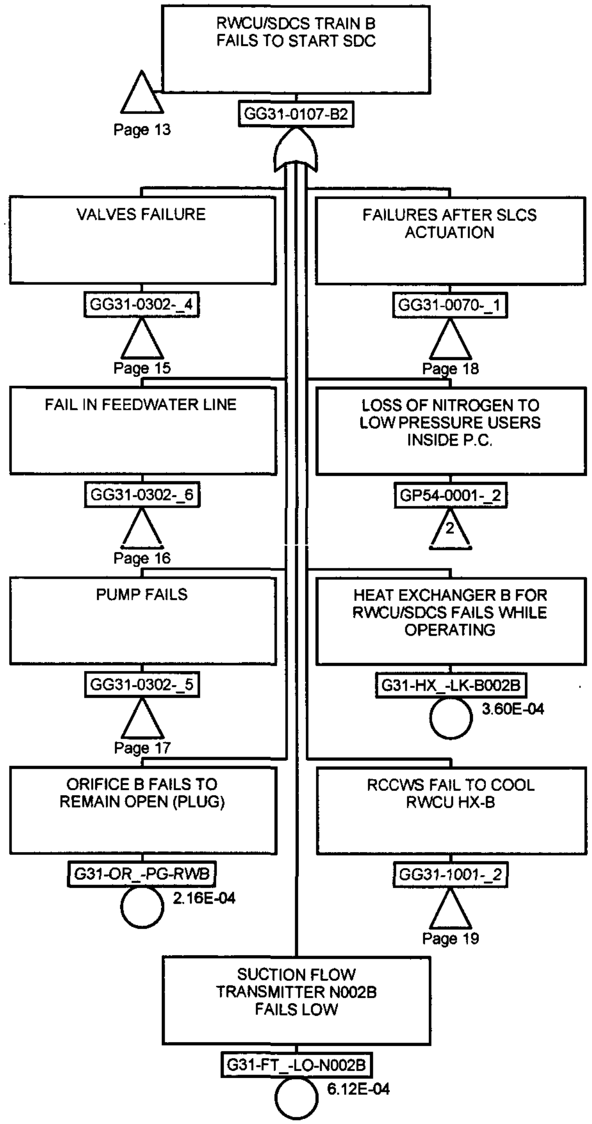
1 2


FAILURES AFTER SLCS ACTUATION
Page 6
GG31-0060-_2
CCF 3 OUT OF 3 MOTOR OPERATED VALVES F018A, F062A AND F063A TO CLOSE
G31-MOV-CF-F018/62/63A
6.06E-05
SLCS ACTUATION
XHOSSLC
4
1
2

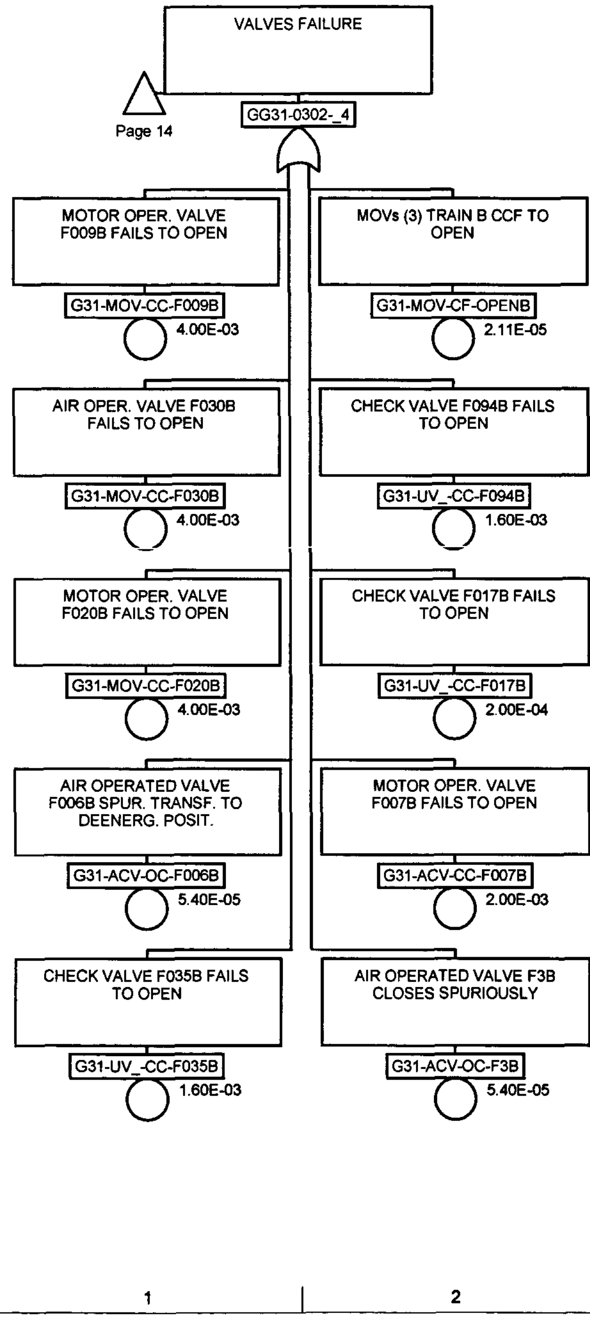

RCCWS FAIL TO COOL RWCU HX-A
Page 6
GG31-1001-_1
MOTOR OPERATED VALVE P21-F039 FAILS TO REMAIN OPEN
P21-MOV-OC-F039A
3.36E-06
AIR OPERATED VALVE P21-F042A SPURIOUSLY TRANSFER TO ENERGIZED POSITION
P21-ACV-CO-F042A
4.80E-07
MOTOR OPERATED VALVE P21-F040A FAILS TO REMAIN OPEN
P21-MOV-OC-F040A
3.36E-06
RCCWS TRAINS FAIL TO COOL THE LOADS
GP21-0001-_1
2
1
2

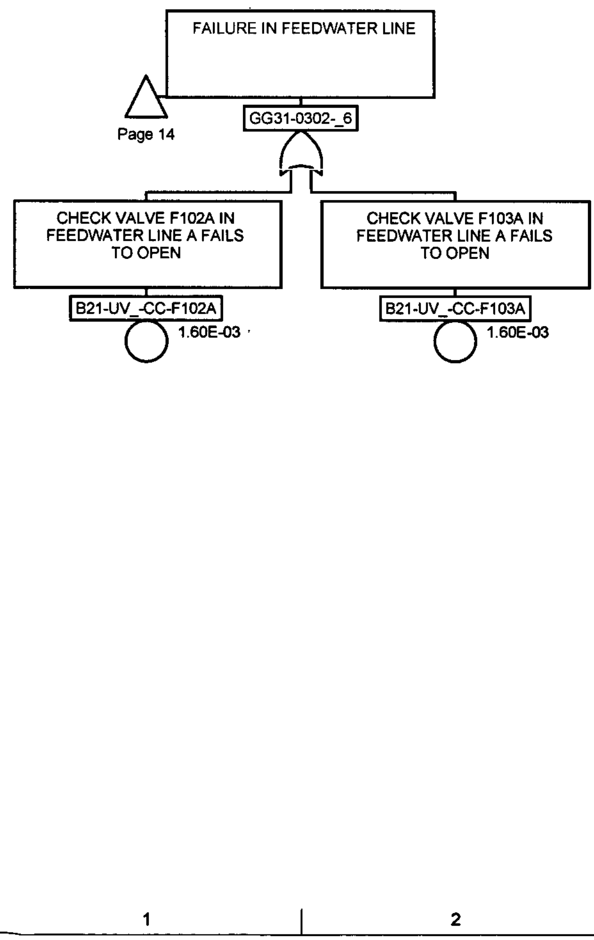

TRAIN B FAILS SDC MODE
GG31-0201-_2
Page 4
LARGE STEAM LOCA (LSLOCA)
GG31-0229-_2
NO LOCA IN RWCU-B OR FW-A PIPES
GG31-0211-_2
PROBABILITY OF LSLOCA IN FW TRAIN A PIPE INSIDE CONTAINMENT
N21-SYS-FF-FWAL
5.00E-01
HOUSE EVENT: LARGE STEAM LOCA IN FW LINE A INSIDE CONTAINMENT
XHOSLSLOCAFWA
2
STANDBY TRAIN B FAILS TO START OR RUN IN SDC MODE
GG31-0106-B2
Page 13
HOUSE EVENT: LARGE STEAM LOCA IN FW LINE A INSIDE CONTAINMENT
XHOSLSLOCAFWA
2
1
2
3
4

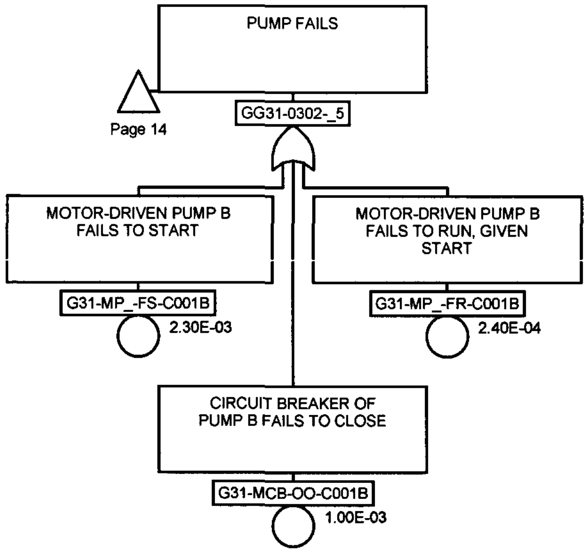

STANDBY TRAIN B FAILS TO START OR RUN IN SDC MODE
GG31-0106-B2
Page 12
RWCU/SDCS TRAIN B IN MAINTENANCE OR OUT OF SERVICE
G31-SYS-TM-B
3.00E-03
RWCU/SDCS TRAIN B FAILS TO START SDC
GG31-0107-B2
Page 14
LOSS OF ELECTRICAL SUPPLIES TO TRAIN B
GG31-0008-B2
LOSS OF 480 V AC FROM R13-21-3
GR13-0001-_13
LOSS OF 480 V AC FROM BUS R12-B2-02B
GR12-0001-_11
LOSS OF 480 V AC FROM R13-31-3
GR13-0001-_15
LOSS OF 6.9 KV AC FROM BUS R11-B2
GR11-0001-_2
1
2
3

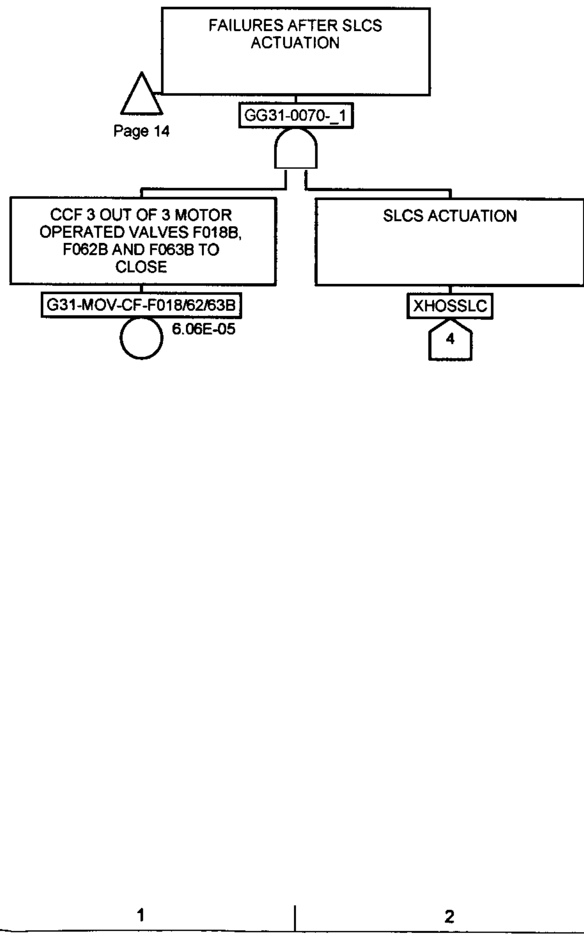


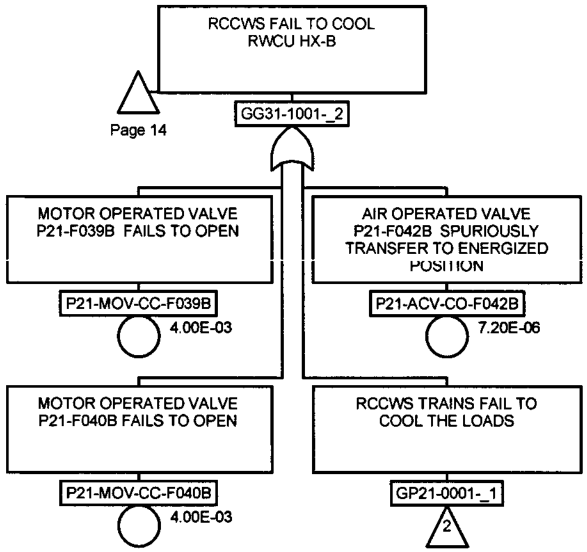
RWCU/SDCS TRAIN B FAILS TO START SDC
GG31-0107-B2
Page 13
VALVES FAILURE
GG31-0302-_4
Page 15
FAILURES AFTER SLCS ACTUATION
GG31-0070-_1
Page 18
FAIL IN FEEDWATER LINE
GG31-0302-_6
Page 16
LOSS OF NITROGEN TO LOW PRESSURE USERS INSIDE P.C.
GP54-0001-_2
2
PUMP FAILS
GG31-0302-_5
Page 17
HEAT EXCHANGER B FOR RWCU/SDCS FAILS WHILE OPERATING
G31-HX_-LK-B002B
3.60E-04
ORIFICE B FAILS TO REMAIN OPEN (PLUG)
G31-OR_-PG-RWB
2.16E-04
RCCWS FAIL TO COOL RWCU HX-B
GG31-1001-_2
Page 19
SUCTION FLOW TRANSMITTER N002B FAILS LOW
G31-FT_-LO-N002B
6.12E-04


VALVES FAILURE
Page 14
GG31-0302-_4
MOTOR OPER. VALVE F009B FAILS TO OPEN
G31-MOV-CC-F009B
4.00E-03
MOVs (3) TRAIN B CCF TO OPEN
G31-MOV-CF-OPENB
2.11E-05
AIR OPER. VALVE F030B FAILS TO OPEN
G31-MOV-CC-F030B
4.00E-03
CHECK VALVE F094B FAILS TO OPEN
G31-UV_-CC-F094B
1.60E-03
MOTOR OPER. VALVE F020B FAILS TO OPEN
G31-MOV-CC-F020B
4.00E-03
CHECK VALVE F017B FAILS TO OPEN
G31-UV_-CC-F017B
2.00E-04
AIR OPERATED VALVE F006B SPUR. TRANSF. TO DEENERG. POSIT.
G31-ACV-OC-F006B
5.40E-05
MOTOR OPER. VALVE F007B FAILS TO OPEN
G31-ACV-CC-F007B
2.00E-03
CHECK VALVE F035B FAILS TO OPEN
G31-UV_-CC-F035B
1.60E-03
AIR OPERATED VALVE F3B CLOSES SPURIOUSLY
G31-ACV-OC-F3B
5.40E-05
1
2

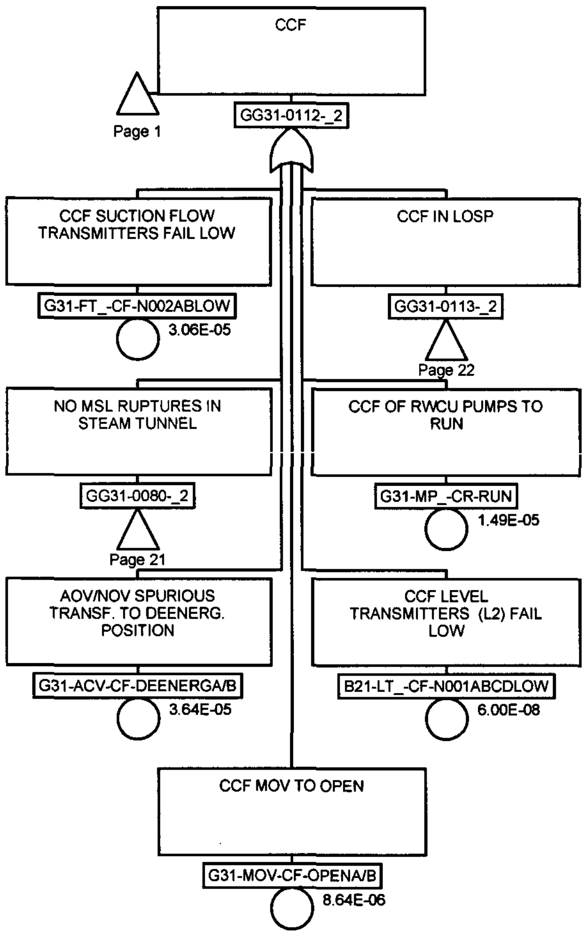

FAILURE IN FEEDWATER LINE
Page 14
GG31-0302-_6
CHECK VALVE F102A IN FEEDWATER LINE A FAILS TO OPEN
B21-UV_-CC-F102A
1.60E-03
CHECK VALVE F103A IN FEEDWATER LINE A FAILS TO OPEN
B21-UV_-CC-F103A
1.60E-03
1
2

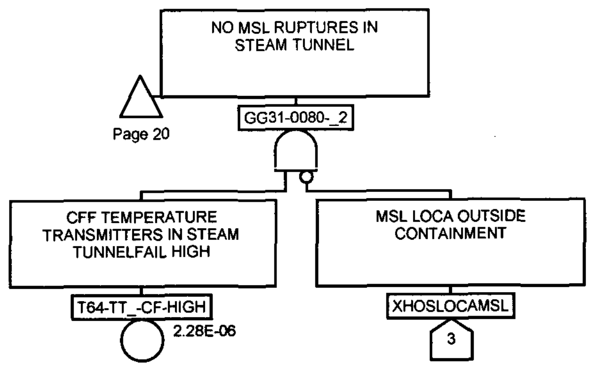

PUMP FAILS
Page 14
GG31-0302-_5
MOTOR-DRIVEN PUMP B FAILS TO START
G31-MP_-FS-C001B
2.30E-03
MOTOR-DRIVEN PUMP B FAILS TO RUN, GIVEN START
G31-MP_-FR-C001B
2.40E-04
CIRCUIT BREAKER OF PUMP B FAILS TO CLOSE
G31-MCB-OO-C001B
1.00E-03
1
2


FAILURES AFTER SLCS ACTUATION
GG31-0070-_1
Page 14
CCF 3 OUT OF 3 MOTOR OPERATED VALVES F018B, F062B AND F063B TO CLOSE
G31-MOV-CF-F018/62/63B
6.06E-05
SLCS ACTUATION
XHOSSLC
4
1
2

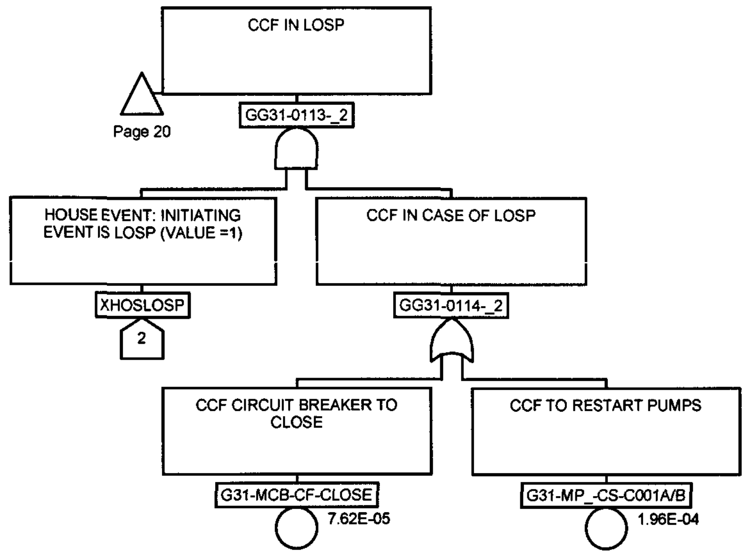

RCCWS FAIL TO COOL RWCU HX-B
GG31-1001-_2
Page 14
MOTOR OPERATED VALVE P21-F039B FAILS TO OPEN
P21-MOV-CC-F039B
4.00E-03
AIR OPERATED VALVE P21-F042B SPURIOUSLY TRANSFER TO ENERGIZED POSITION
P21-ACV-CO-F042B
7.20E-06
MOTOR OPERATED VALVE P21-F040B FAILS TO OPEN
P21-MOV-CC-F040B
4.00E-03
RCCWS TRAINS FAIL TO COOL THE LOADS
GP21-0001-_1
2

1 2


CCF
Page 1
GG31-0112-_2
CCF SUCTION FLOW TRANSMITTERS FAIL LOW
G31-FT_-CF-N002ABLOW
3.06E-05
CCF IN LOSP
GG31-0113-_2
Page 22
NO MSL RUPTURES IN STEAM TUNNEL
GG31-0080-_2
Page 21
CCF OF RWCU PUMPS TO RUN
G31-MP_-CR-RUN
1.49E-05
AOV/NOV SPURIOUS TRANSF. TO DEENERG. POSITION
G31-ACV-CF-DEENERGA/B
3.64E-05
CCF LEVEL TRANSMITTERS (L2) FAIL LOW
B21-LT_-CF-N001ABCDLOW
6.00E-08
CCF MOV TO OPEN
G31-MOV-CF-OPENA/B
8.64E-06
1
2



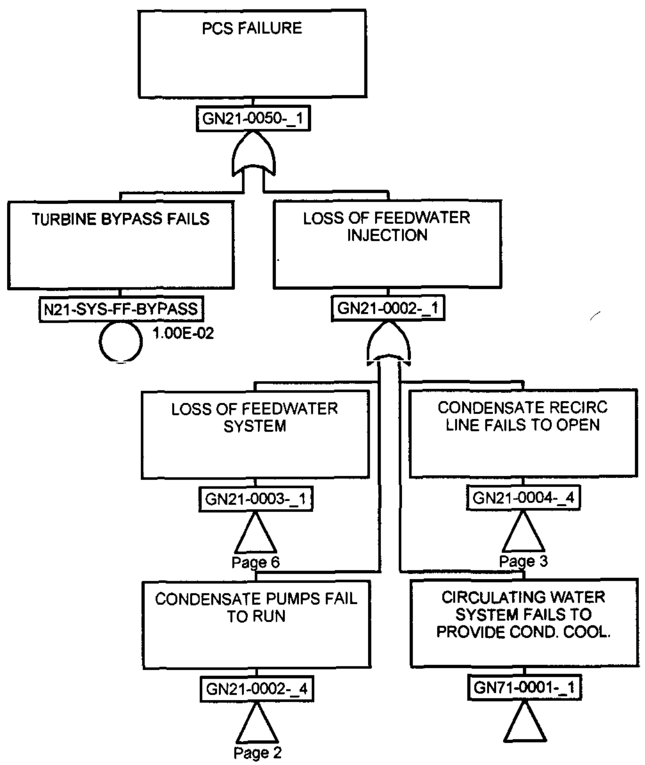
NO MSL RUPTURES IN STEAM TUNNEL
Page 20
GG31-0080-_2
CFF TEMPERATURE TRANSMITTERS IN STEAM TUNNELFAIL HIGH
T64-TT_-CF-HIGH
2.28E-06
MSL LOCA OUTSIDE CONTAINMENT
XHOSLOCAMSL
3

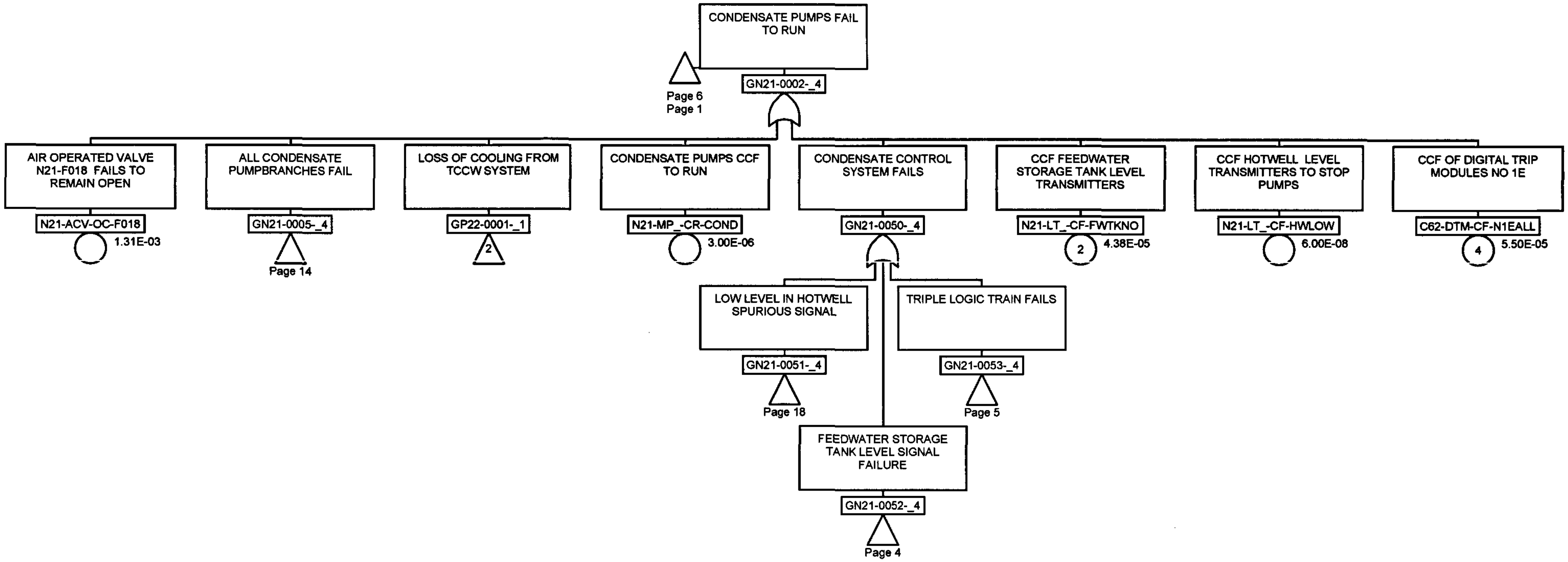

CCF IN LOSP
GG31-0113-_2
Page 20
HOUSE EVENT: INITIATING EVENT IS LOSP (VALUE =1)
XHOSLOSP
2
CCF IN CASE OF LOSP
GG31-0114-_2
CCF CIRCUIT BREAKER TO CLOSE
G31-MCB-CF-CLOSE
7.62E-05
CCF TO RESTART PUMPS
G31-MP_-CS-C001A/B
1.96E-04
1
2

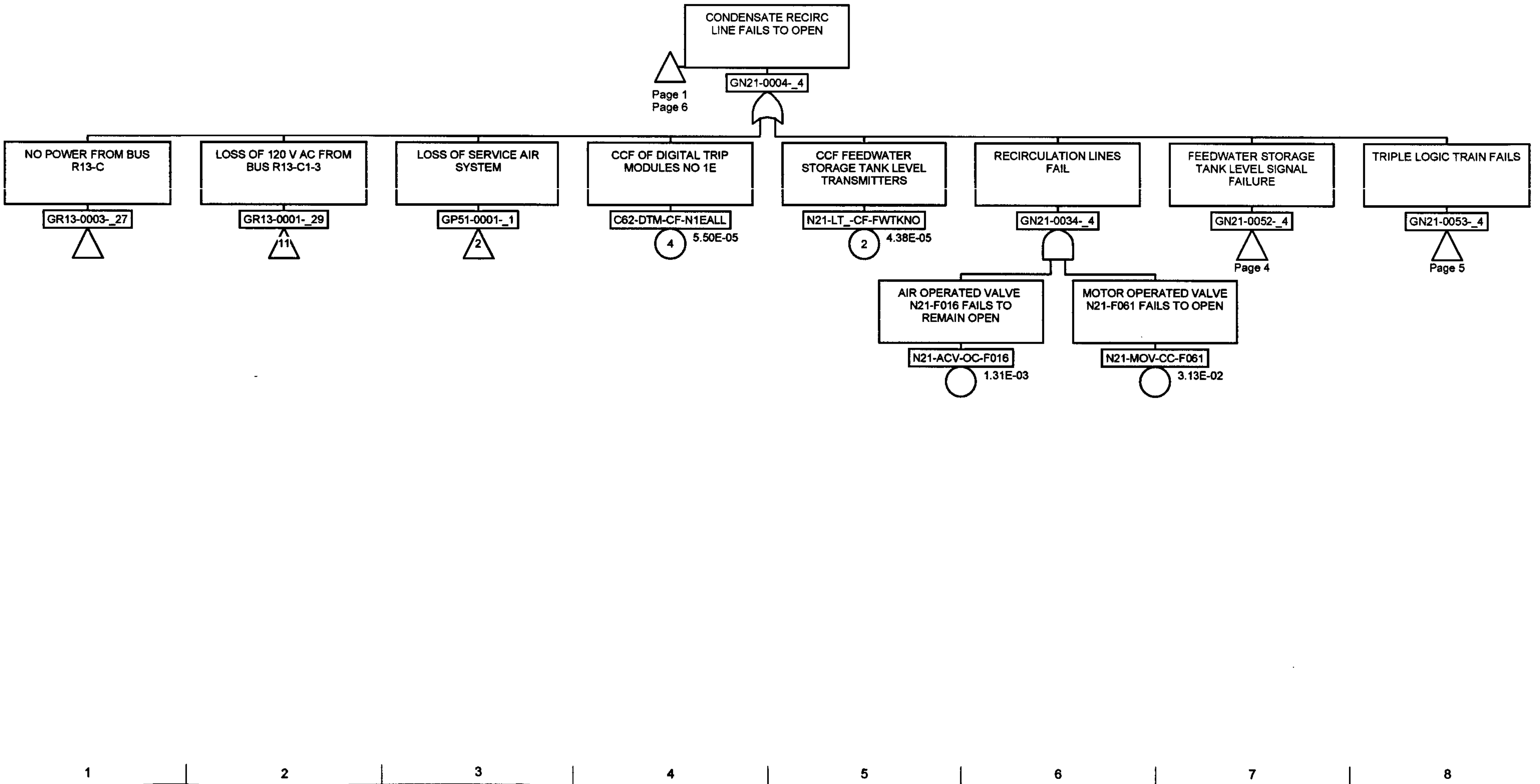
Name	Page	Zone	Name	Page	Zone	Name	Page	Zone
B21-LT -CF-N001ABCDLOW	20	2	GG31-0050- 2	1	3	GP21-0001- 1	19	2
B21-UV -CC-F102A	16	1	GG31-0050- 2	2	3	GP54-0001- 2	6	2
B21-UV -CC-F102B	9	1	GG31-0051- 2	2	2	GP54-0001- 2	14	2
B21-UV -CC-F103A	16	2	GG31-0052- 2	2	4	GR11-0001- 1	5	2
B21-UV -CC-F103B	9	1	GG31-0053- 2	2	5	GR11-0001- 2	13	4
G31-ACV-CC-F007A	7	2	GG31-0053- 2	3	2	GR12-0001- 11	13	4
G31-ACV-CC-F007B	15	2	GG31-0054- 2	3	2	GR12-0001- 8	5	2
G31-ACV-CF-DEENERGA/B	20	1	GG31-0060- 2	6	2	GR13-0001- 11	5	1
G31-ACV-OC-F006A	7	2	GG31-0060- 2	10	2	GR13-0001- 13	13	3
G31-ACV-OC-F006B	15	1	GG31-0070- 1	14	2	GR13-0001- 15	13	3
G31-ACV-OC-F3A	7	2	GG31-0070- 1	18	2	GR13-0001- 17	5	2
G31-ACV-OC-F3B	15	2	GG31-0080- 2	20	1	H23-RMU-CF-DIDALL	1	5
G31-FT -CF-N002ABLOW	20	1	GG31-0080- 2	21	2	H23-RMU-FC-001G31	1	1
G31-FT -LO-N002A	6	1	GG31-0100- 2	1	5	H23-RMU-FC-002G31	1	3
G31-FT -LO-N002B	14	2	GG31-0100- 2	4	3	N21-SYS-FF-FWAL	12	1
G31-HX -LK-B002A	6	2	GG31-0101-A2	4	3	N21-SYS-FF-FWBL	4	1
G31-HX -LK-B002B	14	2	GG31-0101-A2	5	2	P21-ACV-CO-F042A	11	2
G31-MCB-CF-CLOSE	22	2	GG31-0102-A2	5	1	P21-ACV-CO-F042B	19	2
G31-MCB-CO-C001A	8	2	GG31-0102-A2	6	2	P21-MOV-CC-F039B	19	1
G31-MCB-OO-C001A	9	2	GG31-0104- 2	8	3	P21-MOV-CC-F040B	19	1
G31-MCB-OO-C001B	17	2	GG31-0105- 2	8	4	P21-MOV-OC-F039A	11	1
G31-MOV-CC-F009A	7	1	GG31-0105- 2	9	2	P21-MOV-OC-F040A	11	1
G31-MOV-CC-F009B	15	1	GG31-0106-B2	12	3	T64-TT -CF-HIGH	21	1
G31-MOV-CC-F020A	7	1	GG31-0106-B2	13	2	XHOSLOCAMSL	2	4
G31-MOV-CC-F020B	15	1	GG31-0107-B2	13	2	XHOSLOCAMSL	3	3
G31-MOV-CC-F030A	7	1	GG31-0107-B2	14	2	XHOSLOCAMSL	21	2
G31-MOV-CC-F030B	15	1	GG31-0112- 2	1	6	XHOSLOSP	8	3
G31-MOV-CF-F018/62/63A	10	1	GG31-0112- 2	20	2	XHOSLOSP	22	1
G31-MOV-CF-F018/62/63B	18	1	GG31-0113- 2	20	2	XHOSLSLOCAFWA	12	2
G31-MOV-CF-OPENA	7	2	GG31-0113- 2	22	2	XHOSLSLOCAFWA	12	4
G31-MOV-CF-OPENA/B	20	2	GG31-0114- 2	22	2	XHOSLSLOCAFWB	4	2
G31-MOV-CF-OPENB	15	2	GG31-0200- 2	4	2	XHOSLSLOCAFWB	4	4
G31-MP -CR-RUN	20	2	GG31-0201- 2	4	3	XHOSMAN	1	4
G31-MP -CS-C001A/B	22	3	GG31-0201- 2	12	2	XHOSSLC	2	2
G31-MP -FR-C001A	8	1	GG31-0203- 2	4	4	XHOSSLC	3	2
G31-MP -FR-C001B	17	2	GG31-0211- 2	12	4	XHOSSLC	10	2
G31-MP -FS-C001A	9	2	GG31-0222- 2	4	2	XHOSSLC	18	2
G31-MP -FS-C001B	17	1	GG31-0229- 2	12	2			
G31-OR -PG-RWA	6	1	GG31-0302- 1	6	1			
G31-OR -PG-RWB	14	1	GG31-0302- 1	7	2			
G31-SYS-TM-B	13	1	GG31-0302- 2	6	1			
G31-UV -CC-F017B	15	2	GG31-0302- 2	8	2			
G31-UV -CC-F035B	15	1	GG31-0302- 4	14	1			
G31-UV -CC-F094B	15	2	GG31-0302- 4	15	2			
G31-XHE-FO-SDC	3	1	GG31-0302- 5	14	1			
G31-XHE-FO-SDCMSL	2	3	GG31-0302- 5	17	2			
G31-XHE-FO-SDCSLCS	2	1	GG31-0302- 6	14	1			
GC62-0001- 1	1	2	GG31-0302- 6	16	2			
GC62-0001- 2	1	4	GG31-1001- 1	6	2			
GG31-0002- 2	1	4	GG31-1001- 1	11	2			
GG31-0008-B2	13	3	GG31-1001- 2	14	2			
GG31-0010- 2	1	2	GG31-1001-_2	19	2			
GG31-0013- 2	1	2	GG31TOP	1	5			
GG31-0014-_2	1	4	GP21-0001-_1	11	2			

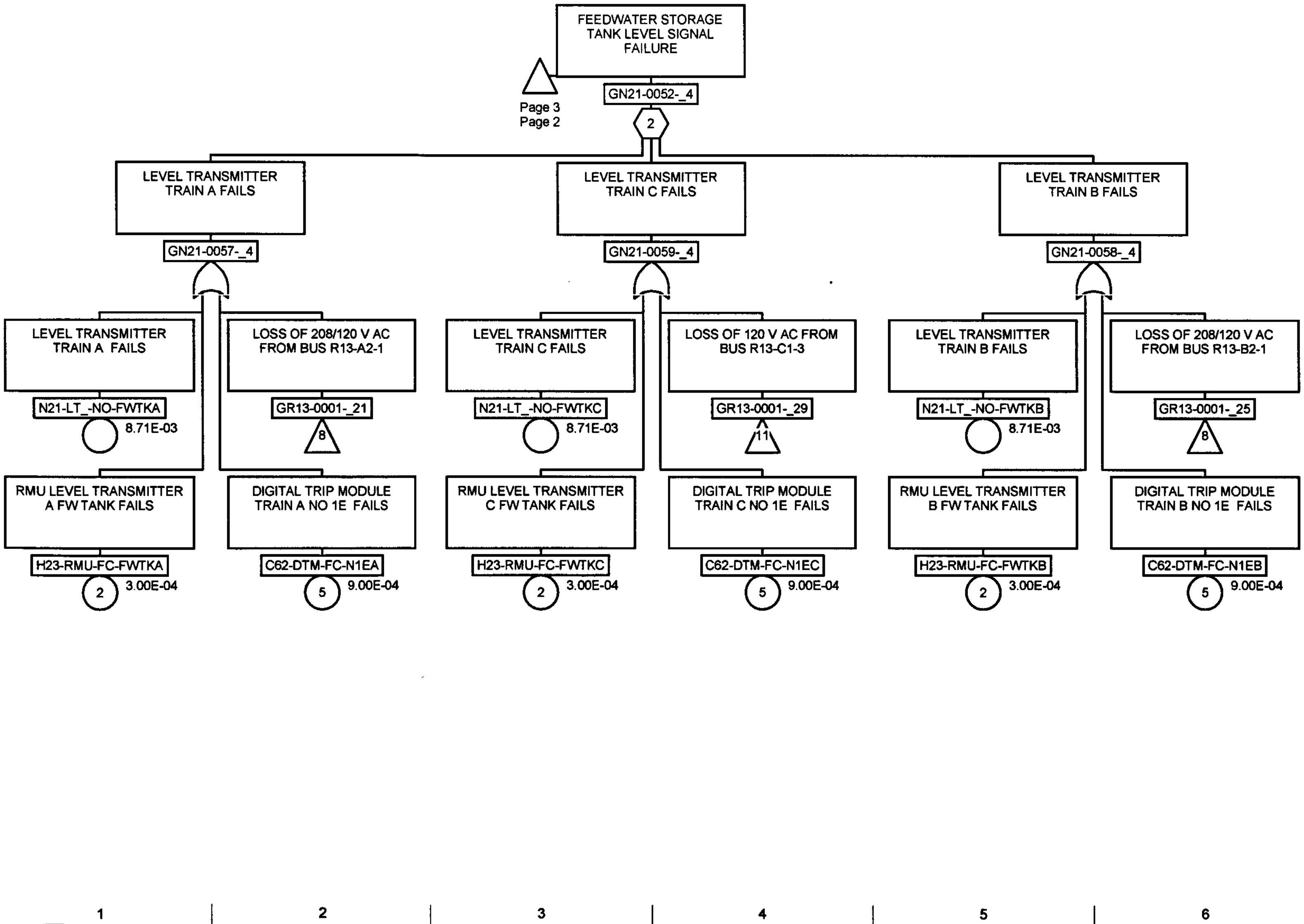
Appendix B.4.9-1

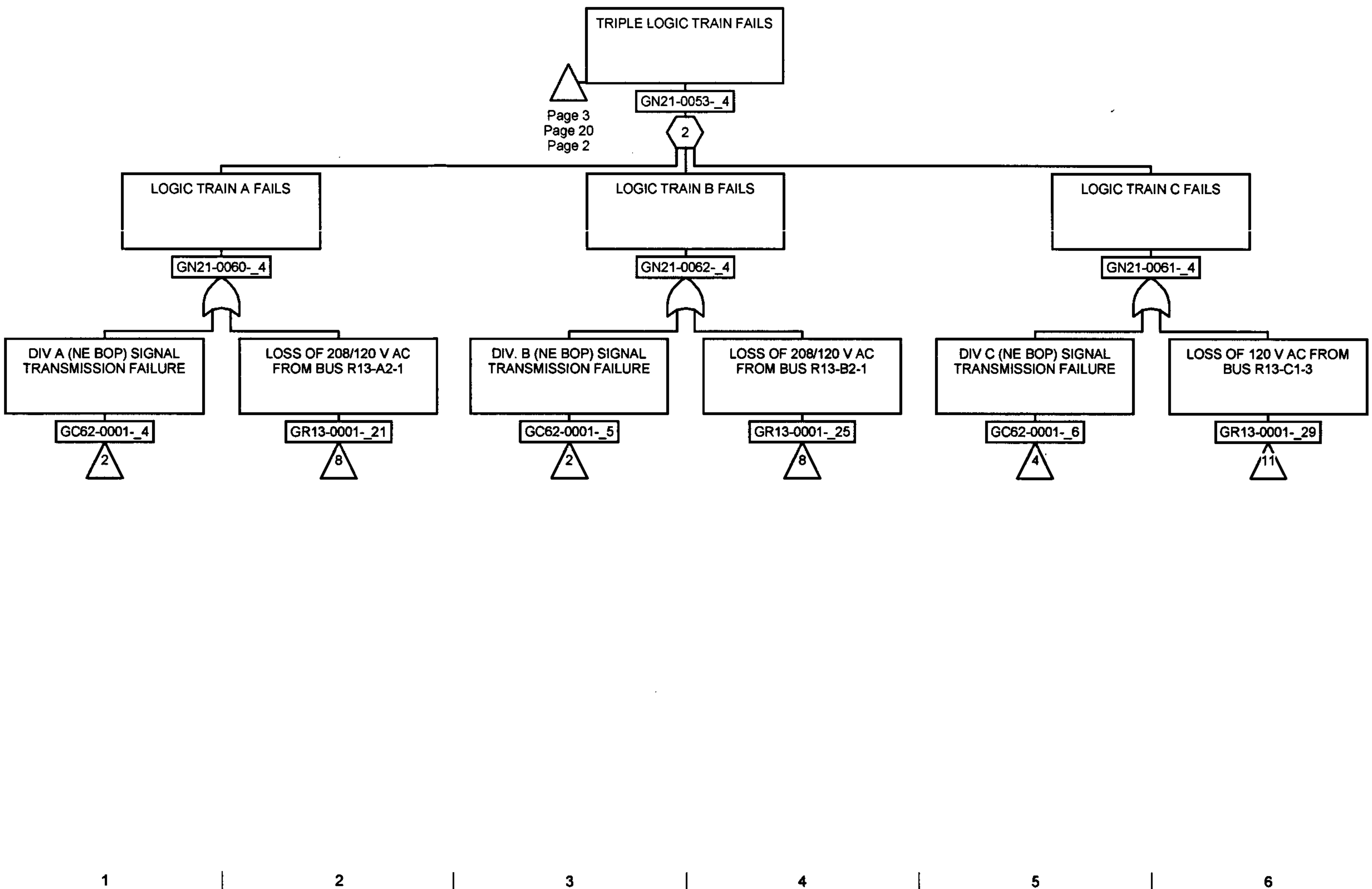
Feedwater/Condensate and TCCW Fault Tree

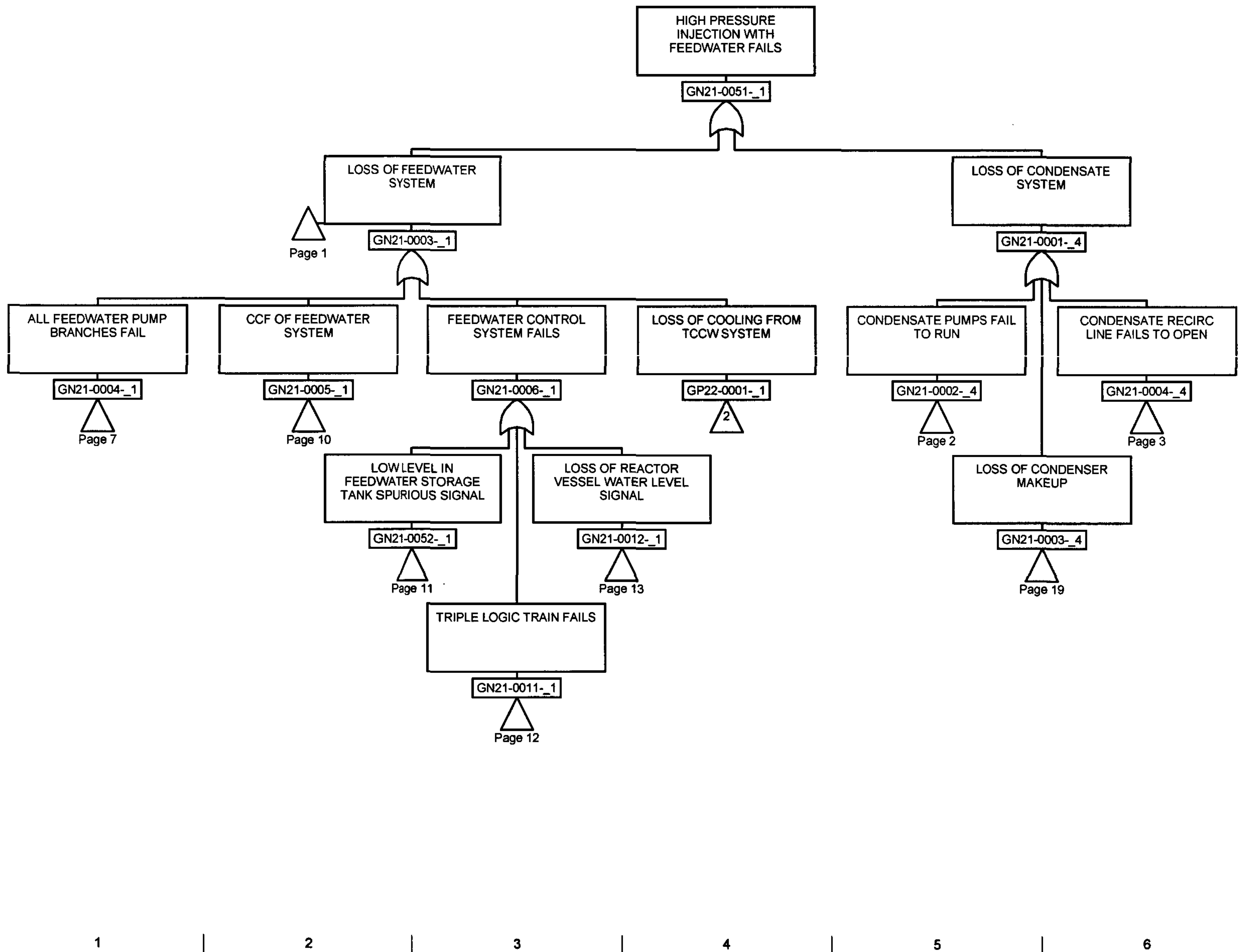

PCS FAILURE
GN21-0050-_1
TURBINE BYPASS FAILS
N21-SYS-FF-BYPASS
1.00E-02
LOSS OF FEEDWATER INJECTION
GN21-0002-_1
LOSS OF FEEDWATER SYSTEM
GN21-0003-_1
Page 6
CONDENSATE RECIRC LINE FAILS TO OPEN
GN21-0004-_4
Page 3
CONDENSATE PUMPS FAIL TO RUN
GN21-0002-_4
Page 2
CIRCULATING WATER SYSTEM FAILS TO PROVIDE COND. COOL.
GN71-0001-_1
1
2

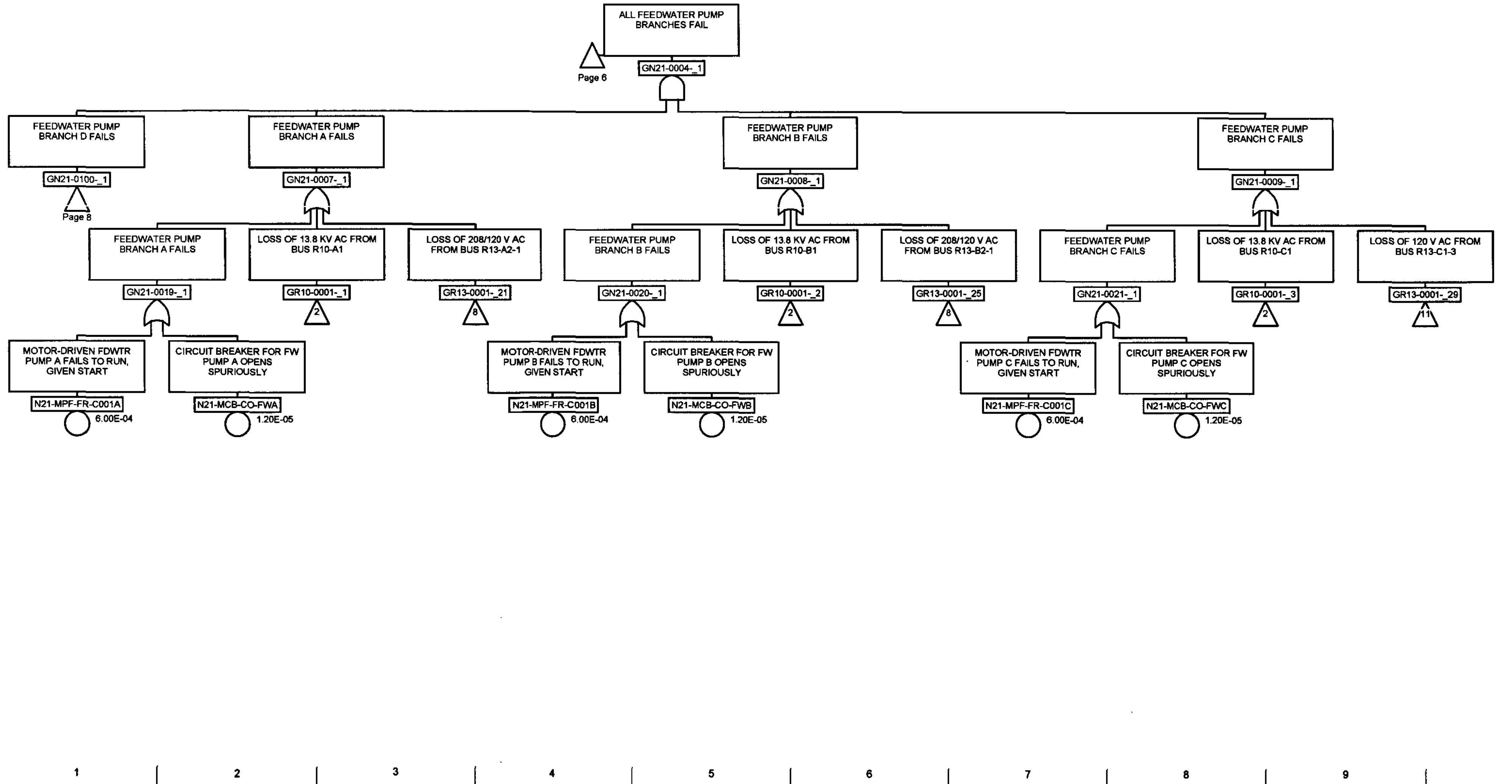

CONDENSATE PUMPS FAIL TO RUN
GN21-0002-_4
Page 6
Page 1
AIR OPERATED VALVE N21-F018 FAILS TO REMAIN OPEN
N21-ACV-OC-F018
1.31E-03
ALL CONDENSATE PUMPBRANCHES FAIL
GN21-0005-_4
Page 14
LOSS OF COOLING FROM TCCW SYSTEM
GP22-0001-_1
2
CONDENSATE PUMPS CCF TO RUN
N21-MP_-CR-COND
3.00E-06
CONDENSATE CONTROL SYSTEM FAILS
GN21-0050-_4
CCF FEEDWATER STORAGE TANK LEVEL TRANSMITTERS
N21-LT_-CF-FWTKNO
2
4.38E-05
CCF HOTWELL LEVEL TRANSMITTERS TO STOP PUMPS
N21-LT_-CF-HWLOW
6.00E-08
CCF OF DIGITAL TRIP MODULES NO 1E
C62-DTM-CF-N1EALL
4
5.50E-05
LOW LEVEL IN HOTWELL SPURIOUS SIGNAL
GN21-0051-_4
Page 18
TRIPLE LOGIC TRAIN FAILS
GN21-0053-_4
Page 5
FEEDWATER STORAGE TANK LEVEL SIGNAL FAILURE
GN21-0052-_4
Page 4

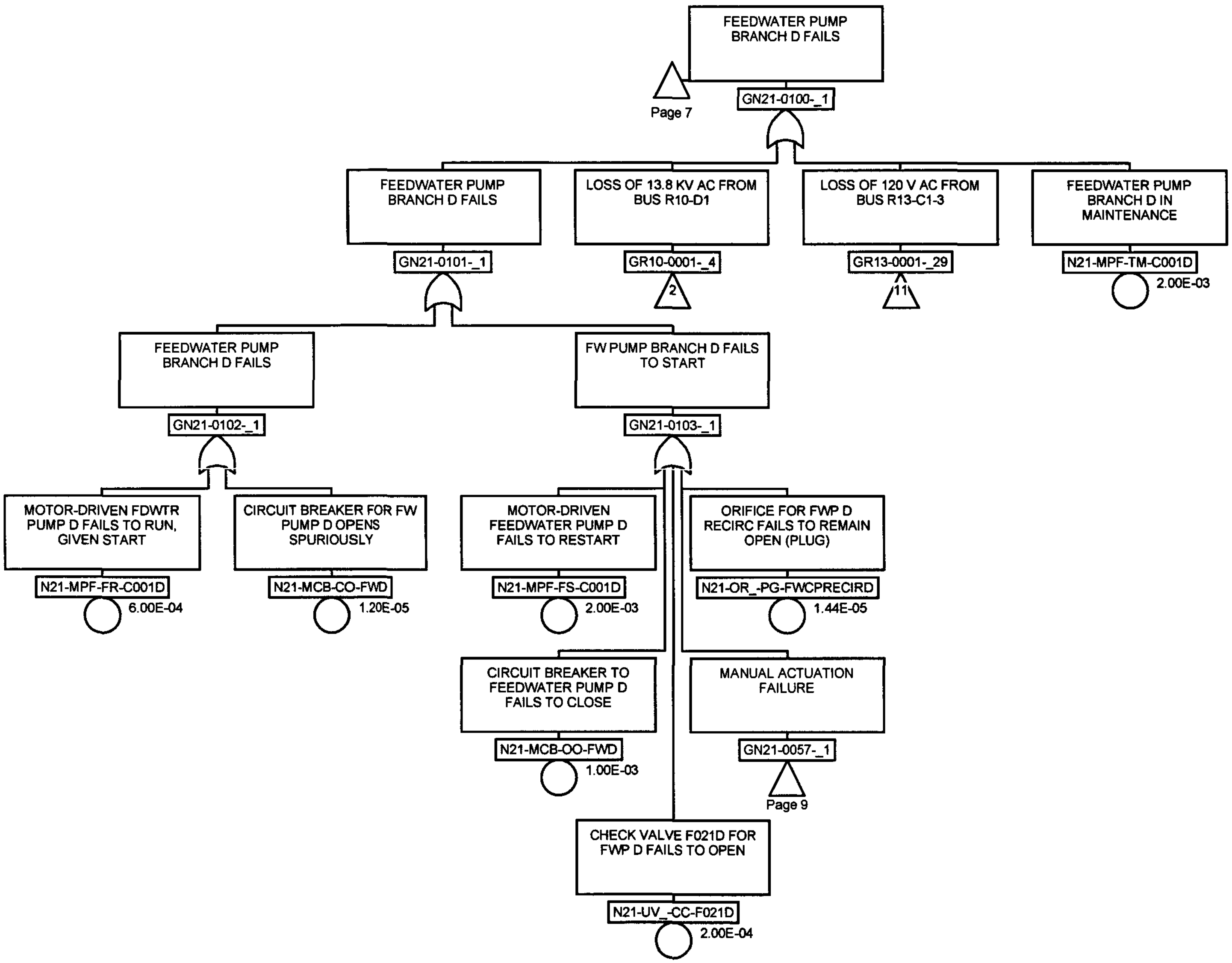

CONDENSATE RECIRC LINE FAILS TO OPEN
GN21-0004-_4
Page 1
Page 6
NO POWER FROM BUS R13-C
GR13-0003-_27
LOSS OF 120 V AC FROM BUS R13-C1-3
GR13-0001-_29
11
LOSS OF SERVICE AIR SYSTEM
GP51-0001-_1
2
CCF OF DIGITAL TRIP MODULES NO 1E
C62-DTM-CF-N1EALL
4
5.50E-05
CCF FEEDWATER STORAGE TANK LEVEL TRANSMITTERS
N21-LT_-CF-FWTKNO
2
4.38E-05
RECIRCULATION LINES FAIL
GN21-0034-_4
FEEDWATER STORAGE TANK LEVEL SIGNAL FAILURE
GN21-0052-_4
Page 4
TRIPLE LOGIC TRAIN FAILS
GN21-0053-_4
Page 5
AIR OPERATED VALVE N21-F016 FAILS TO REMAIN OPEN
N21-ACV-OC-F016
1.31E-03
MOTOR OPERATED VALVE N21-F061 FAILS TO OPEN
N21-MOV-CC-F061
3.13E-02
1
2
3
4
5
6
7
8

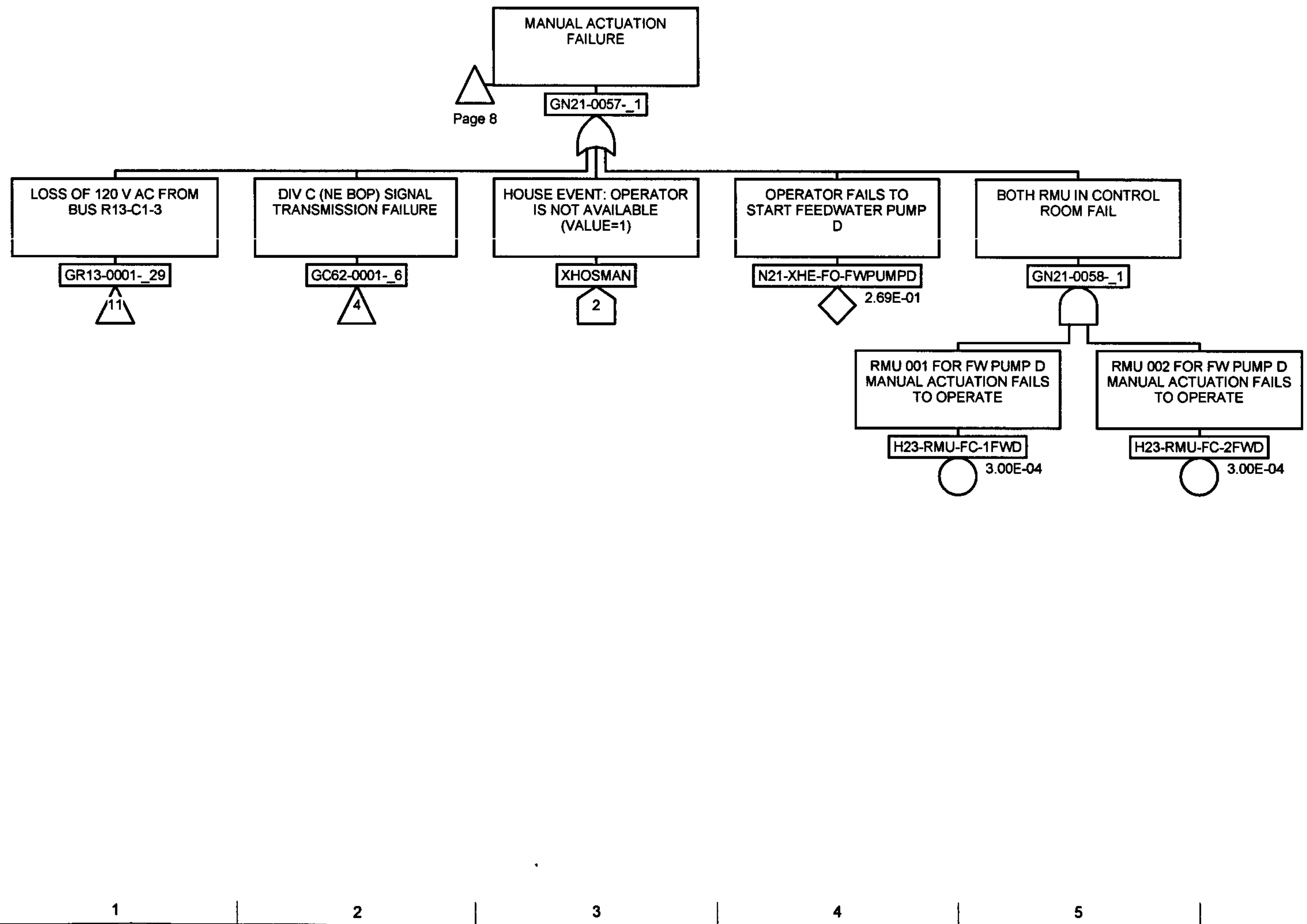

FEEDWATER STORAGE TANK LEVEL SIGNAL FAILURE
GN21-0052-_4
Page 3
Page 2
2
LEVEL TRANSMITTER TRAIN A FAILS
GN21-0057-_4
LEVEL TRANSMITTER TRAIN C FAILS
GN21-0059-_4
LEVEL TRANSMITTER TRAIN B FAILS
GN21-0058-_4
LEVEL TRANSMITTER TRAIN A FAILS
N21-LT_-NO-FWTKA
8.71E-03
LOSS OF 208/120 V AC FROM BUS R13-A2-1
GR13-0001-_21
8
LEVEL TRANSMITTER TRAIN C FAILS
N21-LT_-NO-FWTKC
8.71E-03
LOSS OF 120 V AC FROM BUS R13-C1-3
GR13-0001-_29
11
LEVEL TRANSMITTER TRAIN B FAILS
N21-LT_-NO-FWTKB
8.71E-03
LOSS OF 208/120 V AC FROM BUS R13-B2-1
GR13-0001-_25
8
RMU LEVEL TRANSMITTER A FW TANK FAILS
H23-RMU-FC-FWTKA
2
3.00E-04
DIGITAL TRIP MODULE TRAIN A NO 1E FAILS
C62-DTM-FC-N1EA
5
9.00E-04
RMU LEVEL TRANSMITTER C FW TANK FAILS
H23-RMU-FC-FWTKC
2
3.00E-04
DIGITAL TRIP MODULE TRAIN C NO 1E FAILS
C62-DTM-FC-N1EC
5
9.00E-04
RMU LEVEL TRANSMITTER B FW TANK FAILS
H23-RMU-FC-FWTKB
2
3.00E-04
DIGITAL TRIP MODULE TRAIN B NO 1E FAILS
C62-DTM-FC-N1EB
5
9.00E-04
1
2
3
4
5
6

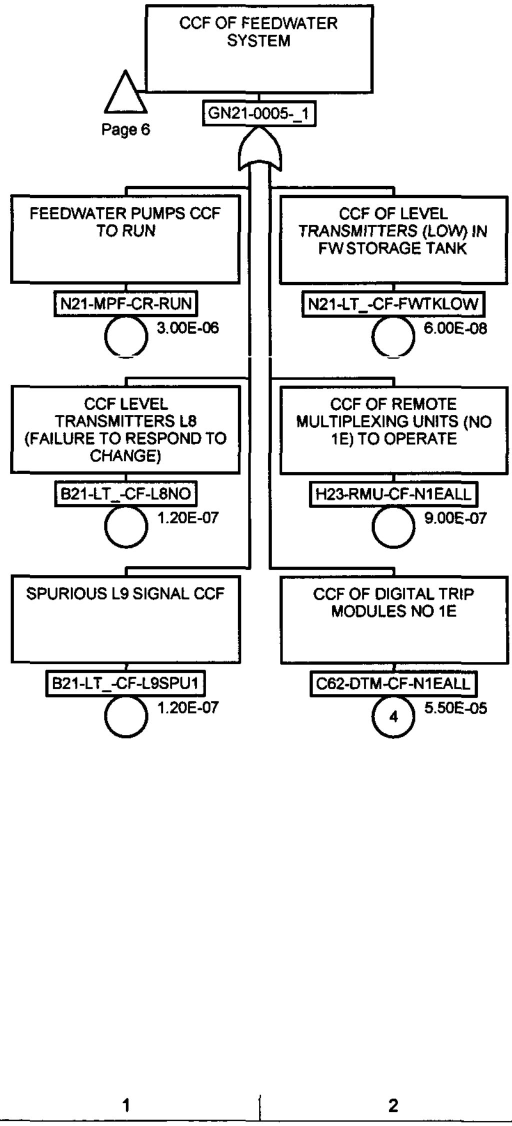

TRIPLE LOGIC TRAIN FAILS
GN21-0053-_4
Page 3
Page 20
Page 2
2
LOGIC TRAIN A FAILS
GN21-0060-_4
LOGIC TRAIN B FAILS
GN21-0062-_4
LOGIC TRAIN C FAILS
GN21-0061-_4
DIV A (NE BOP) SIGNAL TRANSMISSION FAILURE
GC62-0001-_4
2
LOSS OF 208/120 V AC FROM BUS R13-A2-1
GR13-0001-_21
8
DIV. B (NE BOP) SIGNAL TRANSMISSION FAILURE
GC62-0001-_5
2
LOSS OF 208/120 V AC FROM BUS R13-B2-1
GR13-0001-_25
8
DIV C (NE BOP) SIGNAL TRANSMISSION FAILURE
GC62-0001-_6
4
LOSS OF 120 V AC FROM BUS R13-C1-3
GR13-0001-_29
11
1
2
3
4
5
6

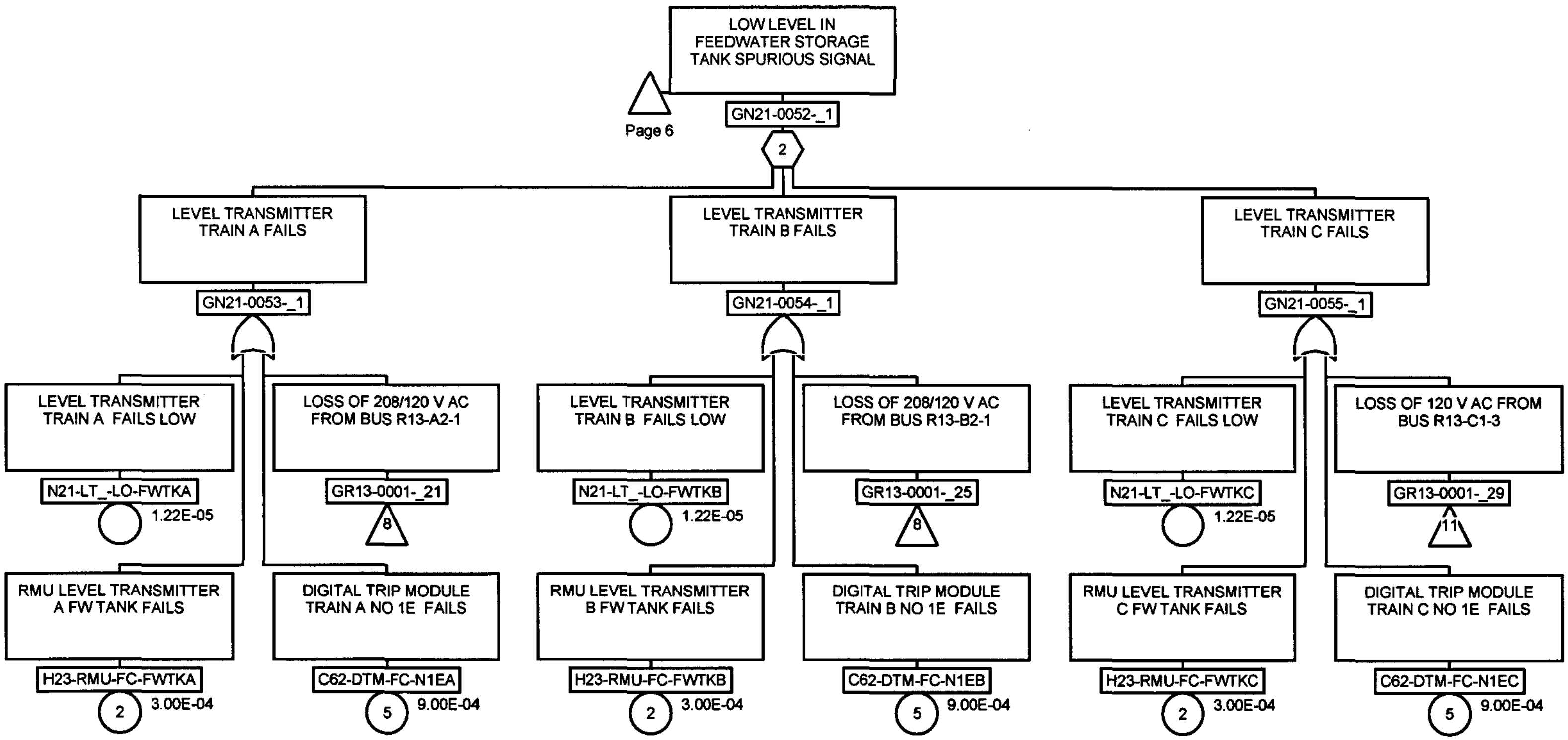

HIGH PRESSURE INJECTION WITH FEEDWATER FAILS
GN21-0051-_1
LOSS OF FEEDWATER SYSTEM
Page 1
GN21-0003-_1
LOSS OF CONDENSATE SYSTEM
GN21-0001-_4
ALL FEEDWATER PUMP BRANCHES FAIL
GN21-0004-_1
Page 7
CCF OF FEEDWATER SYSTEM
GN21-0005-_1
Page 10
FEEDWATER CONTROL SYSTEM FAILS
GN21-0006-_1
LOSS OF COOLING FROM TCCW SYSTEM
GP22-0001-_1
2
CONDENSATE PUMPS FAIL TO RUN
GN21-0002-_4
Page 2
CONDENSATE RECIRC LINE FAILS TO OPEN
GN21-0004-_4
Page 3
LOW LEVEL IN FEEDWATER STORAGE TANK SPURIOUS SIGNAL
GN21-0052-_1
Page 11
LOSS OF REACTOR VESSEL WATER LEVEL SIGNAL
GN21-0012-_1
Page 13
LOSS OF CONDENSER MAKEUP
GN21-0003-_4
Page 19
TRIPLE LOGIC TRAIN FAILS
GN21-0011-_1
Page 12
1
2
3
4
5
6


ALL FEEDWATER PUMP BRANCHES FAIL
GN21-0004-_1
Page 6
FEEDWATER PUMP BRANCH D FAILS
GN21-0100-_1
Page 8
FEEDWATER PUMP BRANCH A FAILS
GN21-0007-_1
FEEDWATER PUMP BRANCH B FAILS
GN21-0008-_1
FEEDWATER PUMP BRANCH C FAILS
GN21-0009-_1
FEEDWATER PUMP BRANCH A FAILS
GN21-0019-_1
LOSS OF 13.8 KV AC FROM BUS R10-A1
GR10-0001-_1
2
LOSS OF 208/120 V AC FROM BUS R13-A2-1
GR13-0001-_21
8
FEEDWATER PUMP BRANCH B FAILS
GN21-0020-_1
LOSS OF 13.8 KV AC FROM BUS R10-B1
GR10-0001-_2
2
LOSS OF 208/120 V AC FROM BUS R13-B2-1
GR13-0001-_25
8
FEEDWATER PUMP BRANCH C FAILS
GN21-0021-_1
LOSS OF 13.8 KV AC FROM BUS R10-C1
GR10-0001-_3
2
LOSS OF 120 V AC FROM BUS R13-C1-3
GR13-0001-_29
11
MOTOR-DRIVEN FDWTR PUMP A FAILS TO RUN, GIVEN START
N21-MPF-FR-C001A
6.00E-04
CIRCUIT BREAKER FOR FW PUMP A OPENS SPURIOUSLY
N21-MCB-CO-FWA
1.20E-05
MOTOR-DRIVEN FDWTR PUMP B FAILS TO RUN, GIVEN START
N21-MPF-FR-C001B
6.00E-04
CIRCUIT BREAKER FOR FW PUMP B OPENS SPURIOUSLY
N21-MCB-CO-FWB
1.20E-05
MOTOR-DRIVEN FDWTR PUMP C FAILS TO RUN, GIVEN START
N21-MPF-FR-C001C
6.00E-04
CIRCUIT BREAKER FOR FW PUMP C OPENS SPURIOUSLY
N21-MCB-CO-FWC
1.20E-05
1
2
3
4
5
6
7
8
9


FEEDWATER PUMP BRANCH D FAILS
GN21-0100-_1
Page 7
FEEDWATER PUMP BRANCH D FAILS
GN21-0101-_1
LOSS OF 13.8 KV AC FROM BUS R10-D1
GR10-0001-_4
2
LOSS OF 120 V AC FROM BUS R13-C1-3
GR13-0001-_29
11
FEEDWATER PUMP BRANCH D IN MAINTENANCE
N21-MPF-TM-C001D
2.00E-03
FEEDWATER PUMP BRANCH D FAILS
GN21-0102-_1
FW PUMP BRANCH D FAILS TO START
GN21-0103-_1
MOTOR-DRIVEN FDWTR PUMP D FAILS TO RUN, GIVEN START
N21-MPF-FR-C001D
6.00E-04
CIRCUIT BREAKER FOR FW PUMP D OPENS SPURIOUSLY
N21-MCB-CO-FWD
1.20E-05
MOTOR-DRIVEN FEEDWATER PUMP D FAILS TO RESTART
N21-MPF-FS-C001D
2.00E-03
ORIFICE FOR FWP D RECIRC FAILS TO REMAIN OPEN (PLUG)
N21-OR_-PG-FWCPRECIRD
1.44E-05
CIRCUIT BREAKER TO FEEDWATER PUMP D FAILS TO CLOSE
N21-MCB-OO-FWD
1.00E-03
MANUAL ACTUATION FAILURE
GN21-0057-_1
Page 9
CHECK VALVE F021D FOR FWP D FAILS TO OPEN
N21-UV_-CC-F021D
2.00E-04
1
2
3
4
5

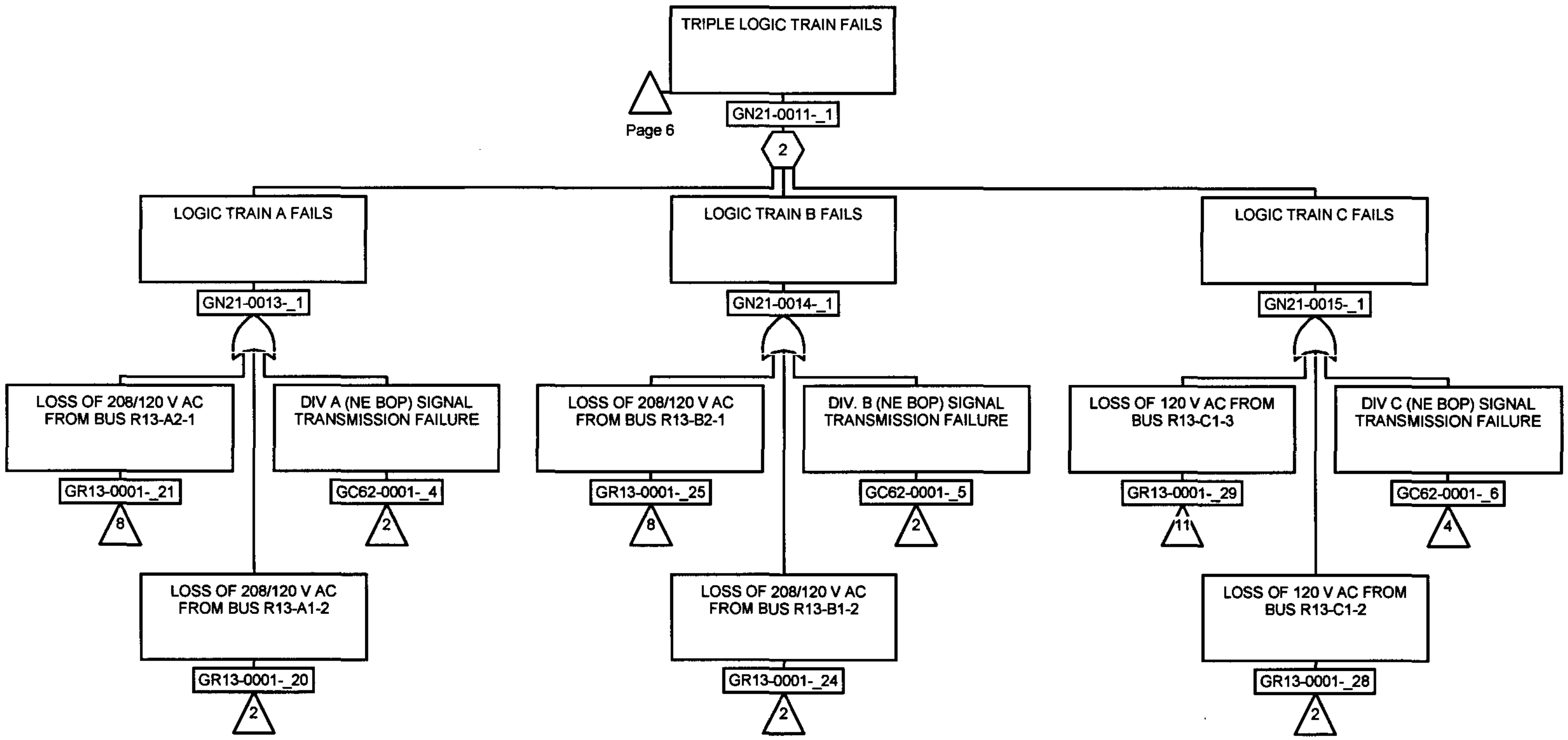

MANUAL ACTUATION FAILURE
GN21-0057-_1
Page 8
LOSS OF 120 V AC FROM BUS R13-C1-3
GR13-0001-_29
11
DIV C (NE BOP) SIGNAL TRANSMISSION FAILURE
GC62-0001-_6
4
HOUSE EVENT: OPERATOR IS NOT AVAILABLE (VALUE=1)
XHOSMAN
2
OPERATOR FAILS TO START FEEDWATER PUMP D
N21-XHE-FO-FWPUMPD
2.69E-01
BOTH RMU IN CONTROL ROOM FAIL
GN21-0058-_1
RMU 001 FOR FW PUMP D MANUAL ACTUATION FAILS TO OPERATE
H23-RMU-FC-1FWD
3.00E-04
RMU 002 FOR FW PUMP D MANUAL ACTUATION FAILS TO OPERATE
H23-RMU-FC-2FWD
3.00E-04
1
2
3
4
5

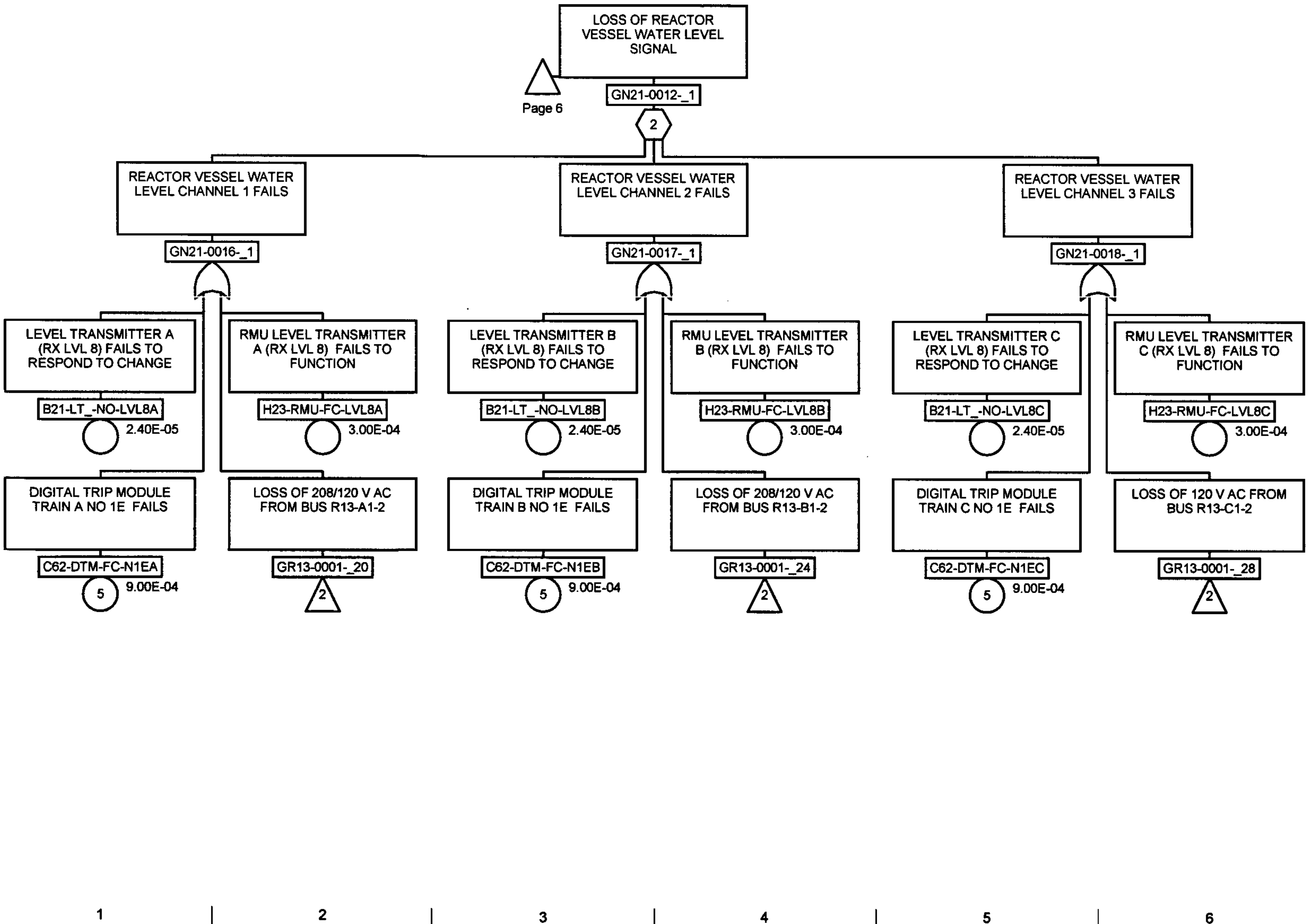

CCF OF FEEDWATER SYSTEM
GN21-0005-_1
Page 6
FEEDWATER PUMPS CCF TO RUN
N21-MPF-CR-RUN
3.00E-06
CCF OF LEVEL TRANSMITTERS (LOW) IN FW STORAGE TANK
N21-LT_-CF-FWTKLOW
6.00E-08
CCF LEVEL TRANSMITTERS L8 (FAILURE TO RESPOND TO CHANGE)
B21-LT_-CF-L8NO
1.20E-07
CCF OF REMOTE MULTIPLEXING UNITS (NO 1E) TO OPERATE
H23-RMU-CF-N1EALL
9.00E-07
SPURIOUS L9 SIGNAL CCF
B21-LT_-CF-L9SPU1
1.20E-07
CCF OF DIGITAL TRIP MODULES NO 1E
C62-DTM-CF-N1EALL
4
5.50E-05
1
2

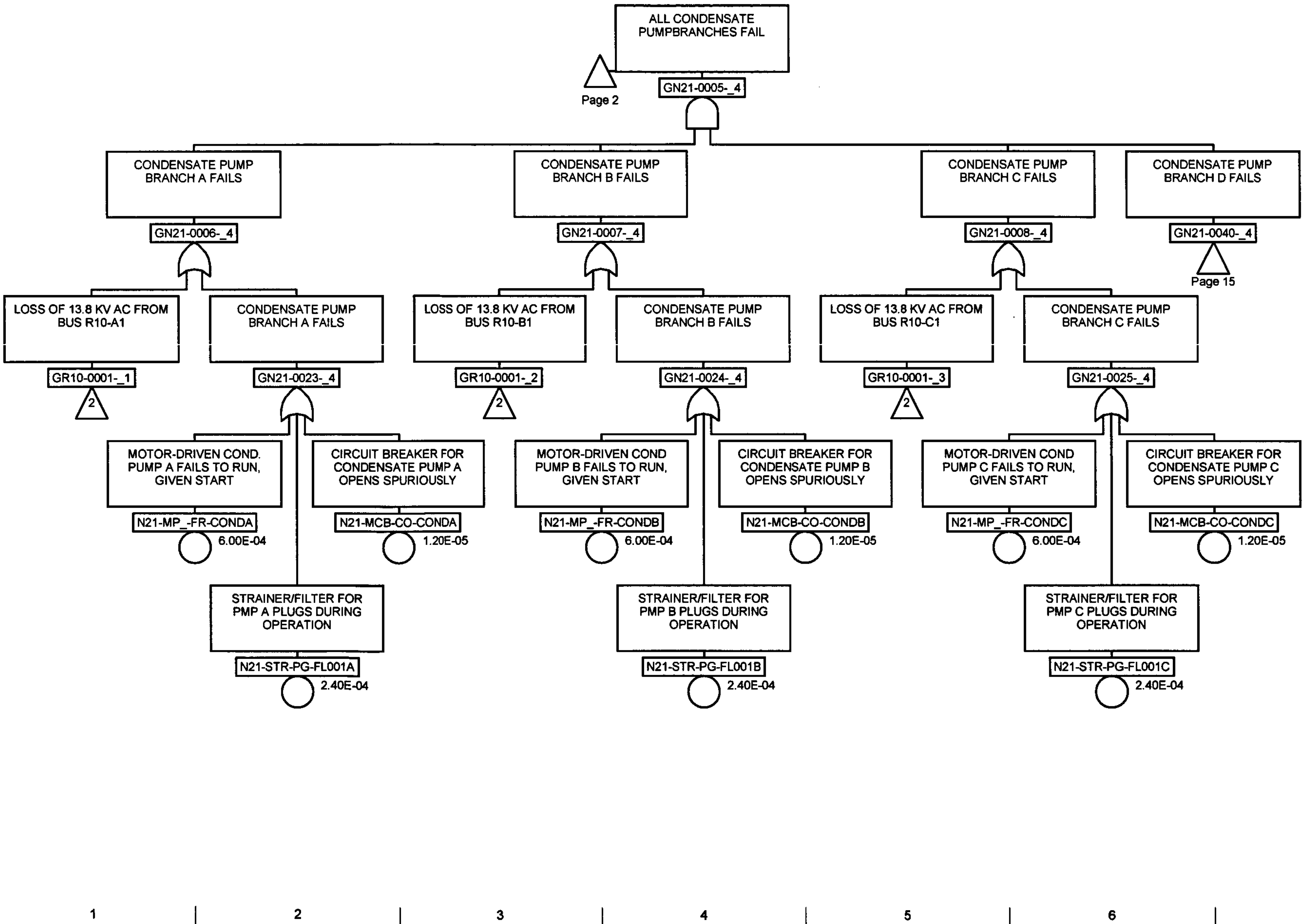


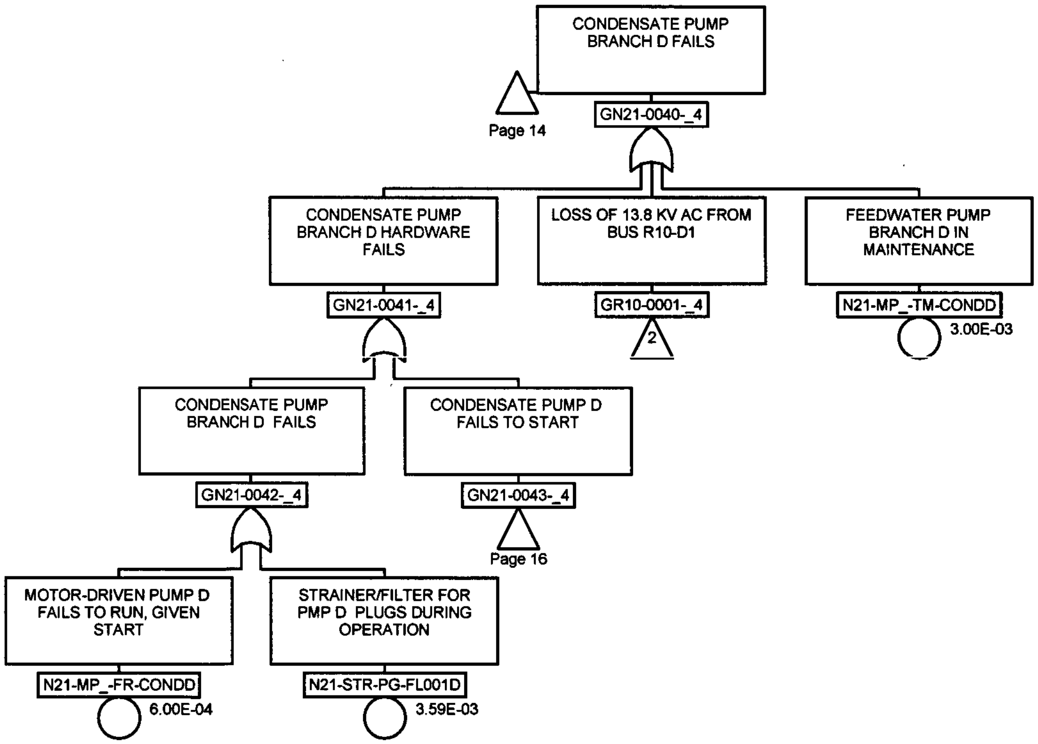
LOW LEVEL IN FEEDWATER STORAGE TANK SPURIOUS SIGNAL
GN21-0052-_1
Page 6
2
LEVEL TRANSMITTER TRAIN A FAILS
GN21-0053-_1
LEVEL TRANSMITTER TRAIN B FAILS
GN21-0054-_1
LEVEL TRANSMITTER TRAIN C FAILS
GN21-0055-_1
LEVEL TRANSMITTER TRAIN A FAILS LOW
N21-LT_-LO-FWTKA
1.22E-05
LOSS OF 208/120 V AC FROM BUS R13-A2-1
GR13-0001-_21
8
RMU LEVEL TRANSMITTER A FW TANK FAILS
H23-RMU-FC-FWTKA
2
3.00E-04
DIGITAL TRIP MODULE TRAIN A NO 1E FAILS
C62-DTM-FC-N1EA
5
9.00E-04
LEVEL TRANSMITTER TRAIN B FAILS LOW
N21-LT_-LO-FWTKB
1.22E-05
LOSS OF 208/120 V AC FROM BUS R13-B2-1
GR13-0001-_25
8
RMU LEVEL TRANSMITTER B FW TANK FAILS
H23-RMU-FC-FWTKB
2
3.00E-04
DIGITAL TRIP MODULE TRAIN B NO 1E FAILS
C62-DTM-FC-N1EB
5
9.00E-04
LEVEL TRANSMITTER TRAIN C FAILS LOW
N21-LT_-LO-FWTKC
1.22E-05
LOSS OF 120 V AC FROM BUS R13-C1-3
GR13-0001-_29
11
RMU LEVEL TRANSMITTER C FW TANK FAILS
H23-RMU-FC-FWTKC
2
3.00E-04
DIGITAL TRIP MODULE TRAIN C NO 1E FAILS
C62-DTM-FC-N1EC
5
9.00E-04

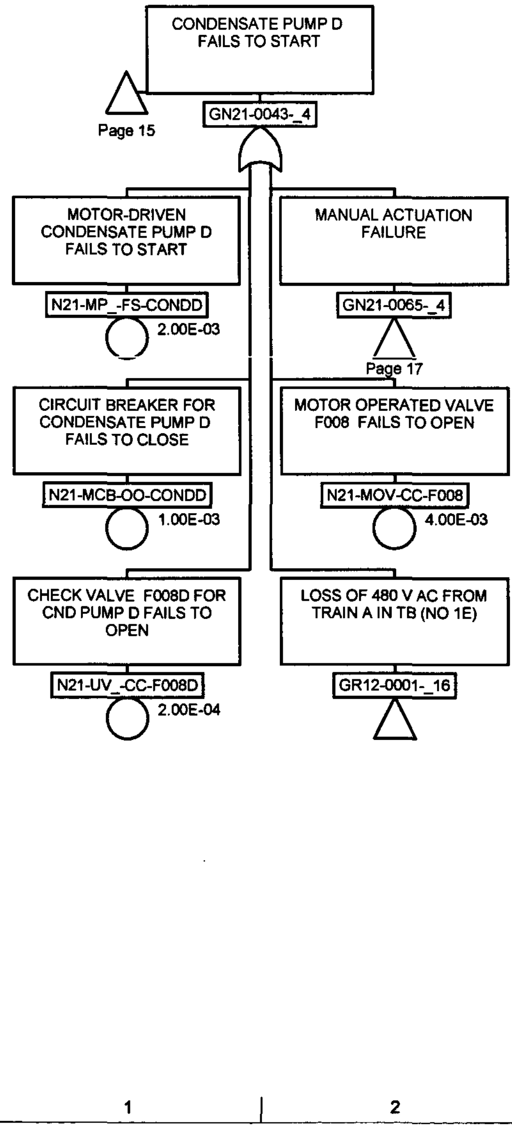
1 2 3 4 5 6

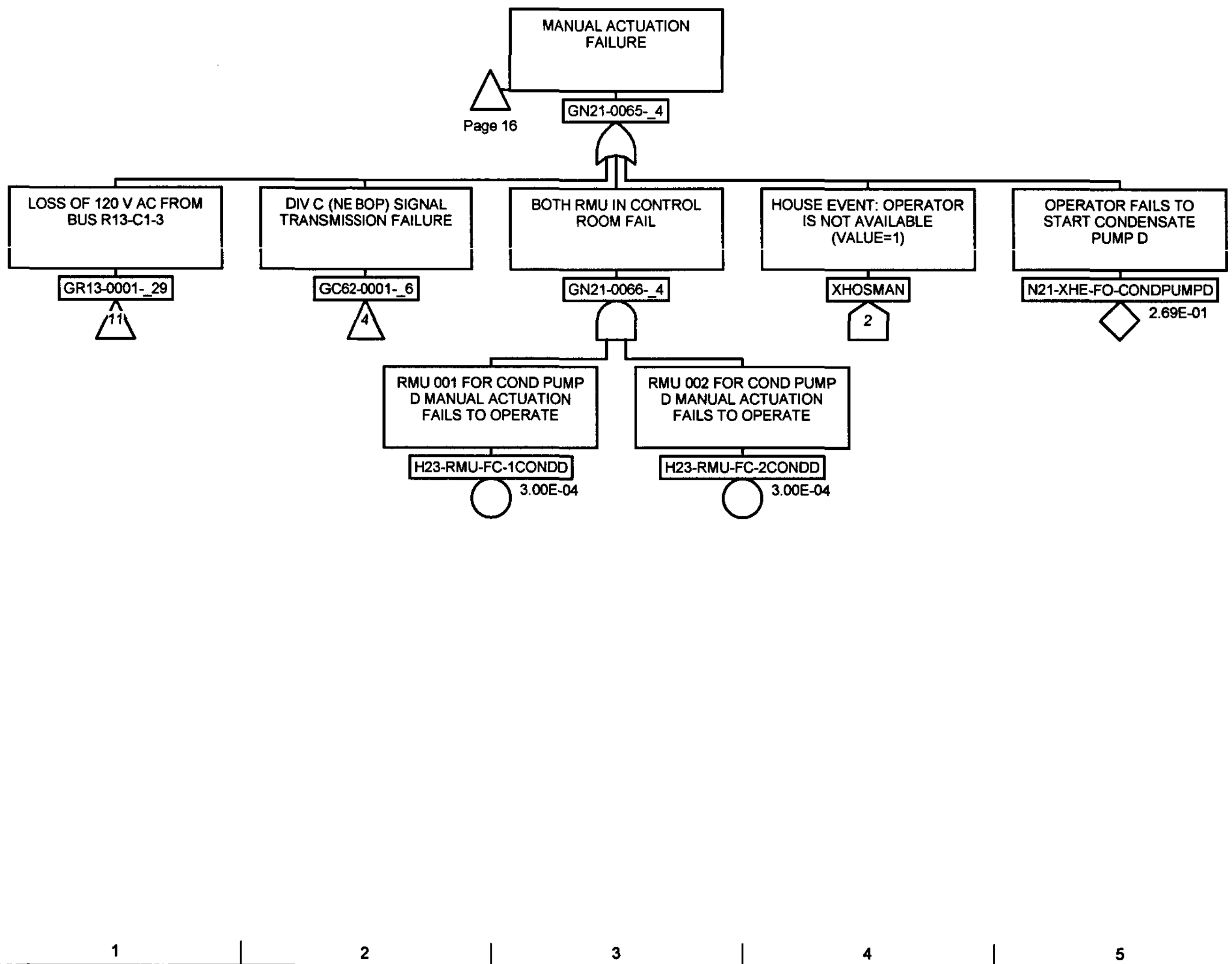

TRIPLE LOGIC TRAIN FAILS
GN21-0011-_1
Page 6
2
LOGIC TRAIN A FAILS
GN21-0013-_1
LOGIC TRAIN B FAILS
GN21-0014-_1
LOGIC TRAIN C FAILS
GN21-0015-_1
LOSS OF 208/120 V AC FROM BUS R13-A2-1
GR13-0001-_21
8
DIV A (NE BOP) SIGNAL TRANSMISSION FAILURE
GC62-0001-_4
2
LOSS OF 208/120 V AC FROM BUS R13-A1-2
GR13-0001-_20
2
LOSS OF 208/120 V AC FROM BUS R13-B2-1
GR13-0001-_25
8
DIV. B (NE BOP) SIGNAL TRANSMISSION FAILURE
GC62-0001-_5
2
LOSS OF 208/120 V AC FROM BUS R13-B1-2
GR13-0001-_24
2
LOSS OF 120 V AC FROM BUS R13-C1-3
GR13-0001-_29
11
DIV C (NE BOP) SIGNAL TRANSMISSION FAILURE
GC62-0001-_6
4
LOSS OF 120 V AC FROM BUS R13-C1-2
GR13-0001-_28
2

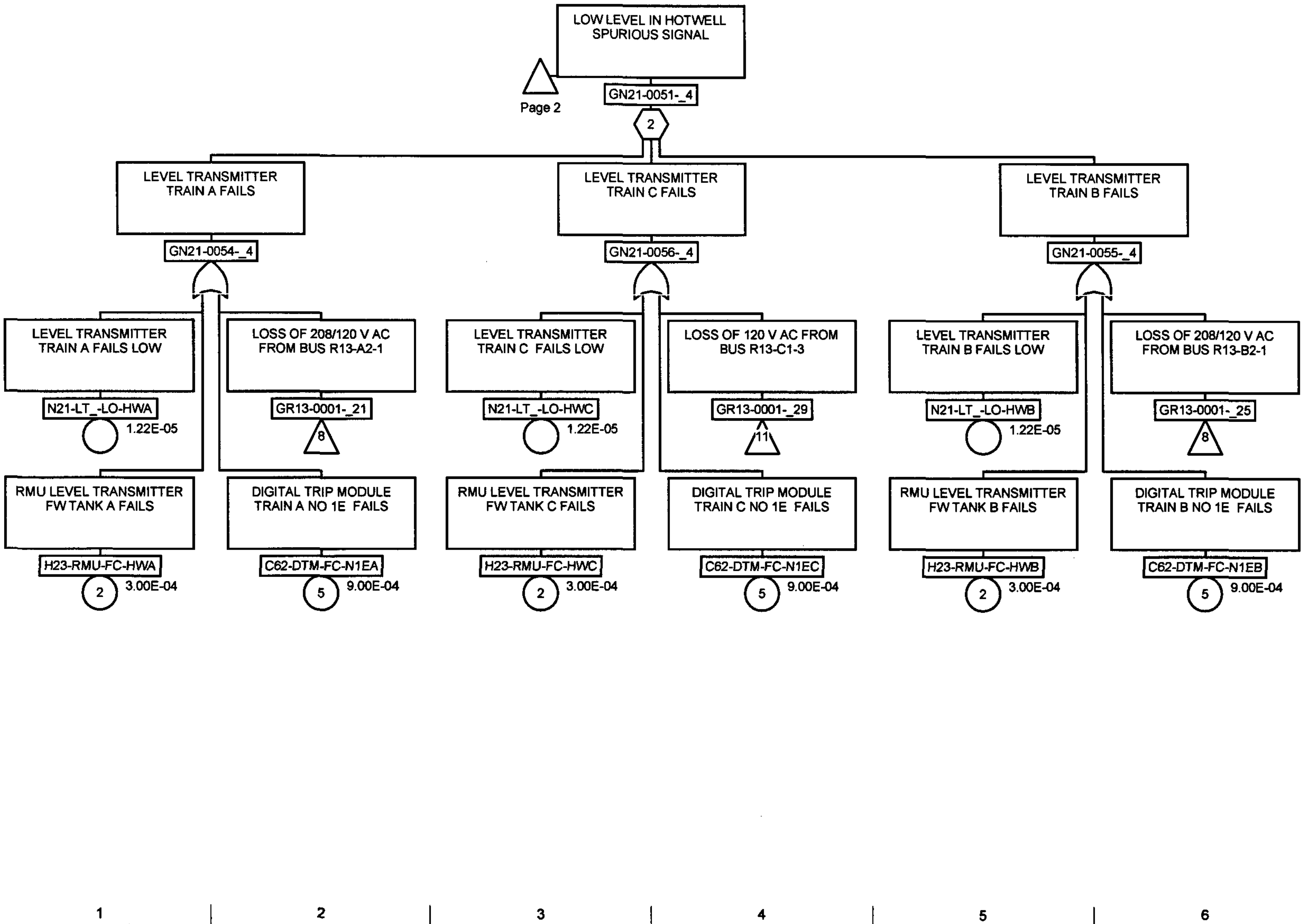

LOSS OF REACTOR VESSEL WATER LEVEL SIGNAL
Page 6
GN21-0012-_1
2
REACTOR VESSEL WATER LEVEL CHANNEL 1 FAILS
GN21-0016-_1
REACTOR VESSEL WATER LEVEL CHANNEL 2 FAILS
GN21-0017-_1
REACTOR VESSEL WATER LEVEL CHANNEL 3 FAILS
GN21-0018-_1
LEVEL TRANSMITTER A (RX LVL 8) FAILS TO RESPOND TO CHANGE
B21-LT_-NO-LVL8A
2.40E-05
RMU LEVEL TRANSMITTER A (RX LVL 8) FAILS TO FUNCTION
H23-RMU-FC-LVL8A
3.00E-04
LEVEL TRANSMITTER B (RX LVL 8) FAILS TO RESPOND TO CHANGE
B21-LT_-NO-LVL8B
2.40E-05
RMU LEVEL TRANSMITTER B (RX LVL 8) FAILS TO FUNCTION
H23-RMU-FC-LVL8B
3.00E-04
LEVEL TRANSMITTER C (RX LVL 8) FAILS TO RESPOND TO CHANGE
B21-LT_-NO-LVL8C
2.40E-05
RMU LEVEL TRANSMITTER C (RX LVL 8) FAILS TO FUNCTION
H23-RMU-FC-LVL8C
3.00E-04
DIGITAL TRIP MODULE TRAIN A NO 1E FAILS
C62-DTM-FC-N1EA
5
9.00E-04
LOSS OF 208/120 V AC FROM BUS R13-A1-2
GR13-0001-_20
2
DIGITAL TRIP MODULE TRAIN B NO 1E FAILS
C62-DTM-FC-N1EB
5
9.00E-04
LOSS OF 208/120 V AC FROM BUS R13-B1-2
GR13-0001-_24
2
DIGITAL TRIP MODULE TRAIN C NO 1E FAILS
C62-DTM-FC-N1EC
5
9.00E-04
LOSS OF 120 V AC FROM BUS R13-C1-2
GR13-0001-_28
2
1
2
3
4
5
6

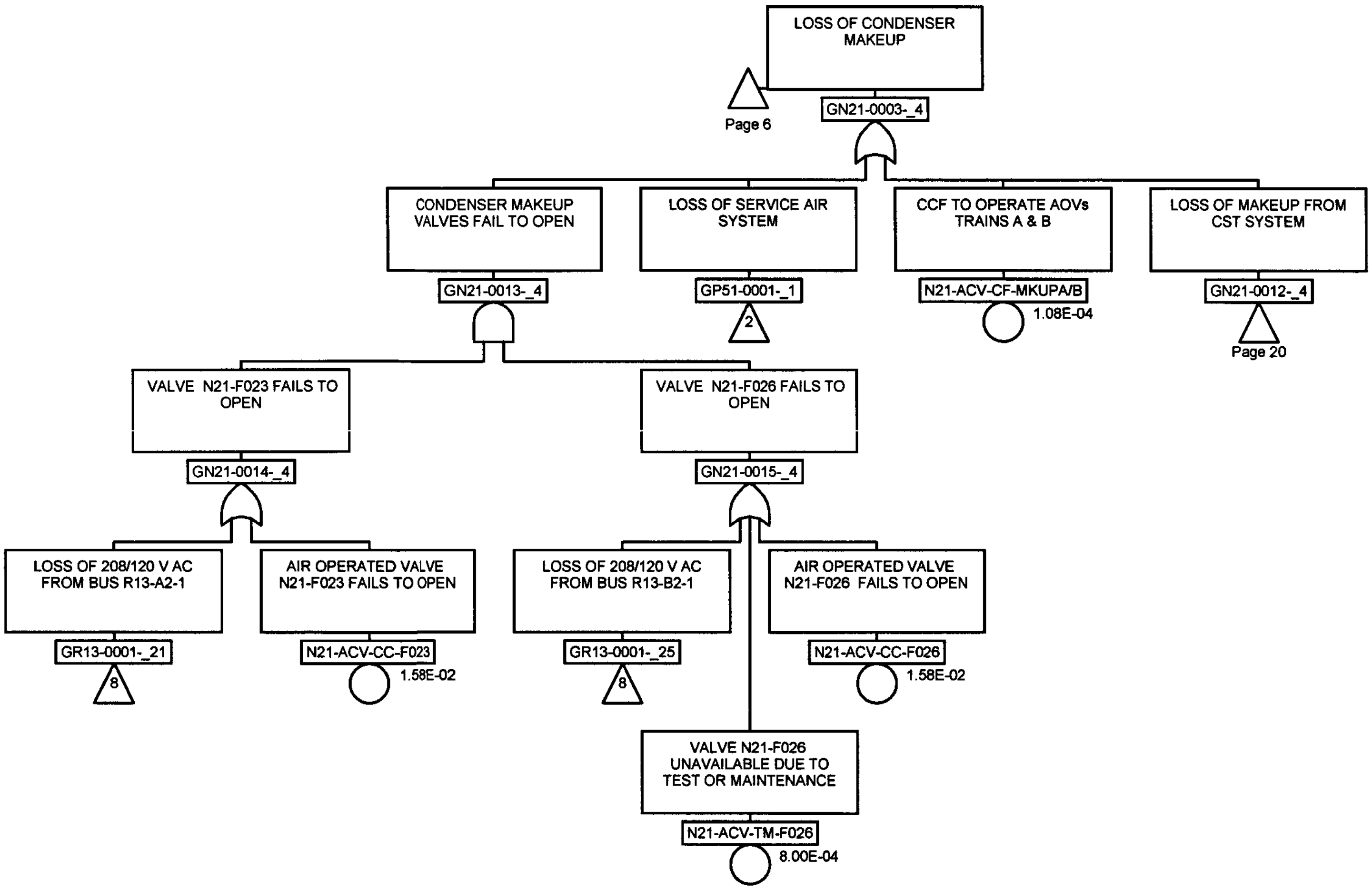

ALL CONDENSATE PUMPBRANCHES FAIL
GN21-0005-_4
Page 2
CONDENSATE PUMP BRANCH A FAILS
GN21-0006-_4
CONDENSATE PUMP BRANCH B FAILS
GN21-0007-_4
CONDENSATE PUMP BRANCH C FAILS
GN21-0008-_4
CONDENSATE PUMP BRANCH D FAILS
GN21-0040-_4
Page 15
LOSS OF 13.8 KV AC FROM BUS R10-A1
GR10-0001-_1
2
CONDENSATE PUMP BRANCH A FAILS
GN21-0023-_4
LOSS OF 13.8 KV AC FROM BUS R10-B1
GR10-0001-_2
2
CONDENSATE PUMP BRANCH B FAILS
GN21-0024-_4
LOSS OF 13.8 KV AC FROM BUS R10-C1
GR10-0001-_3
2
CONDENSATE PUMP BRANCH C FAILS
GN21-0025-_4
MOTOR-DRIVEN COND. PUMP A FAILS TO RUN, GIVEN START
N21-MP_-FR-CONDA
6.00E-04
CIRCUIT BREAKER FOR CONDENSATE PUMP A OPENS SPURIOUSLY
N21-MCB-CO-CONDA
1.20E-05
MOTOR-DRIVEN COND PUMP B FAILS TO RUN, GIVEN START
N21-MP_-FR-CONDB
6.00E-04
CIRCUIT BREAKER FOR CONDENSATE PUMP B OPENS SPURIOUSLY
N21-MCB-CO-CONDB
1.20E-05
MOTOR-DRIVEN COND PUMP C FAILS TO RUN, GIVEN START
N21-MP_-FR-CONDC
6.00E-04
CIRCUIT BREAKER FOR CONDENSATE PUMP C OPENS SPURIOUSLY
N21-MCB-CO-CONDC
1.20E-05
STRAINER/FILTER FOR PMP A PLUGS DURING OPERATION
N21-STR-PG-FL001A
2.40E-04
STRAINER/FILTER FOR PMP B PLUGS DURING OPERATION
N21-STR-PG-FL001B
2.40E-04
STRAINER/FILTER FOR PMP C PLUGS DURING OPERATION
N21-STR-PG-FL001C
2.40E-04
1
2
3
4
5
6


CONDENSATE PUMP BRANCH D FAILS
GN21-0040-_4
Page 14
CONDENSATE PUMP BRANCH D HARDWARE FAILS
GN21-0041-_4
LOSS OF 13.8 KV AC FROM BUS R10-D1
GR10-0001-_4
2
FEEDWATER PUMP BRANCH D IN MAINTENANCE
N21-MP_-TM-CONDD
3.00E-03
CONDENSATE PUMP BRANCH D FAILS
GN21-0042-_4
CONDENSATE PUMP D FAILS TO START
GN21-0043-_4
Page 16
MOTOR-DRIVEN PUMP D FAILS TO RUN, GIVEN START
N21-MP_-FR-CONDD
6.00E-04
STRAINER/FILTER FOR PMP D PLUGS DURING OPERATION
N21-STR-PG-FL001D
3.59E-03
1
2
3


CONDENSATE PUMP D FAILS TO START
GN21-0043-_4
Page 15
MOTOR-DRIVEN CONDENSATE PUMP D FAILS TO START
N21-MP_-FS-CONDD
2.00E-03
MANUAL ACTUATION FAILURE
GN21-0065-_4
Page 17
CIRCUIT BREAKER FOR CONDENSATE PUMP D FAILS TO CLOSE
N21-MCB-OO-CONDD
1.00E-03
MOTOR OPERATED VALVE F008 FAILS TO OPEN
N21-MOV-CC-F008
4.00E-03
CHECK VALVE F008D FOR CND PUMP D FAILS TO OPEN
N21-UV_-CC-F008D
2.00E-04
LOSS OF 480 V AC FROM TRAIN A IN TB (NO 1E)
GR12-0001-_16
1
2


MANUAL ACTUATION FAILURE
Page 16
GN21-0065-_4
LOSS OF 120 V AC FROM BUS R13-C1-3
GR13-0001-_29
11
DIV C (NE BOP) SIGNAL TRANSMISSION FAILURE
GC62-0001-_6
4
BOTH RMU IN CONTROL ROOM FAIL
GN21-0066-_4
HOUSE EVENT: OPERATOR IS NOT AVAILABLE (VALUE=1)
XHOSMAN
2
OPERATOR FAILS TO START CONDENSATE PUMP D
N21-XHE-FO-CONDPUMPD
2.69E-01
RMU 001 FOR COND PUMP D MANUAL ACTUATION FAILS TO OPERATE
H23-RMU-FC-1CONDD
3.00E-04
RMU 002 FOR COND PUMP D MANUAL ACTUATION FAILS TO OPERATE
H23-RMU-FC-2CONDD
3.00E-04
1
2
3
4
5


LOW LEVEL IN HOTWELL SPURIOUS SIGNAL
Page 2
GN21-0051-_4
2
LEVEL TRANSMITTER TRAIN A FAILS
GN21-0054-_4
LEVEL TRANSMITTER TRAIN C FAILS
GN21-0056-_4
LEVEL TRANSMITTER TRAIN B FAILS
GN21-0055-_4
LEVEL TRANSMITTER TRAIN A FAILS LOW
N21-LT_-LO-HWA
1.22E-05
LOSS OF 208/120 V AC FROM BUS R13-A2-1
GR13-0001-_21
8
LEVEL TRANSMITTER TRAIN C FAILS LOW
N21-LT_-LO-HWC
1.22E-05
LOSS OF 120 V AC FROM BUS R13-C1-3
GR13-0001-_29
11
LEVEL TRANSMITTER TRAIN B FAILS LOW
N21-LT_-LO-HWB
1.22E-05
LOSS OF 208/120 V AC FROM BUS R13-B2-1
GR13-0001-_25
8
RMU LEVEL TRANSMITTER FW TANK A FAILS
H23-RMU-FC-HWA
2
3.00E-04
DIGITAL TRIP MODULE TRAIN A NO 1E FAILS
C62-DTM-FC-N1EA
5
9.00E-04
RMU LEVEL TRANSMITTER FW TANK C FAILS
H23-RMU-FC-HWC
2
3.00E-04
DIGITAL TRIP MODULE TRAIN C NO 1E FAILS
C62-DTM-FC-N1EC
5
9.00E-04
RMU LEVEL TRANSMITTER FW TANK B FAILS
H23-RMU-FC-HWB
2
3.00E-04
DIGITAL TRIP MODULE TRAIN B NO 1E FAILS
C62-DTM-FC-N1EB
5
9.00E-04
1
2
3
4
5
6



LOSS OF CONDENSER MAKEUP
GN21-0003-_4
Page 6
CONDENSER MAKEUP VALVES FAIL TO OPEN
GN21-0013-_4
LOSS OF SERVICE AIR SYSTEM
GP51-0001-_1
2
CCF TO OPERATE AOVs TRAINS A & B
N21-ACV-CF-MKUPA/B
1.08E-04
LOSS OF MAKEUP FROM CST SYSTEM
GN21-0012-_4
Page 20
VALVE N21-F023 FAILS TO OPEN
GN21-0014-_4
VALVE N21-F026 FAILS TO OPEN
GN21-0015-_4
LOSS OF 208/120 V AC FROM BUS R13-A2-1
GR13-0001-_21
8
AIR OPERATED VALVE N21-F023 FAILS TO OPEN
N21-ACV-CC-F023
1.58E-02
LOSS OF 208/120 V AC FROM BUS R13-B2-1
GR13-0001-_25
8
AIR OPERATED VALVE N21-F026 FAILS TO OPEN
N21-ACV-CC-F026
1.58E-02
VALVE N21-F026 UNAVAILABLE DUE TO TEST OR MAINTENANCE
N21-ACV-TM-F026
8.00E-04
1
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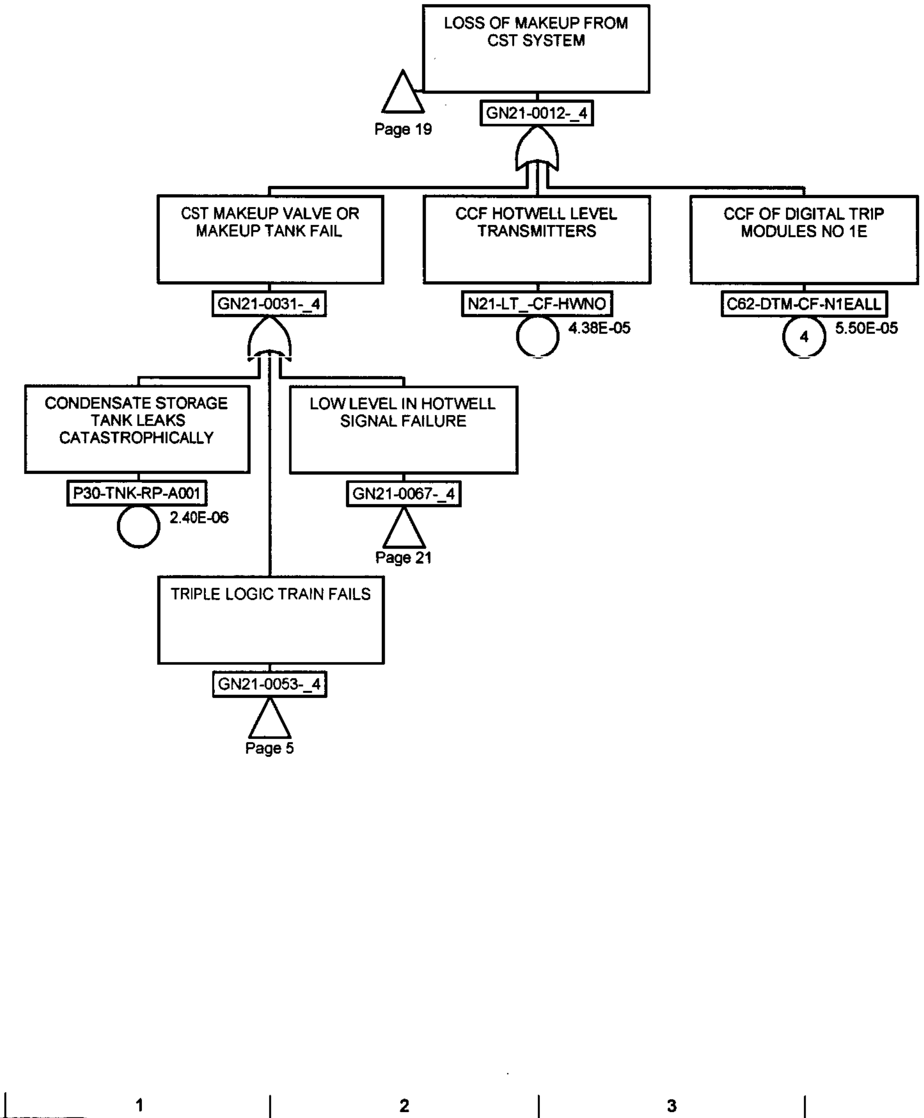
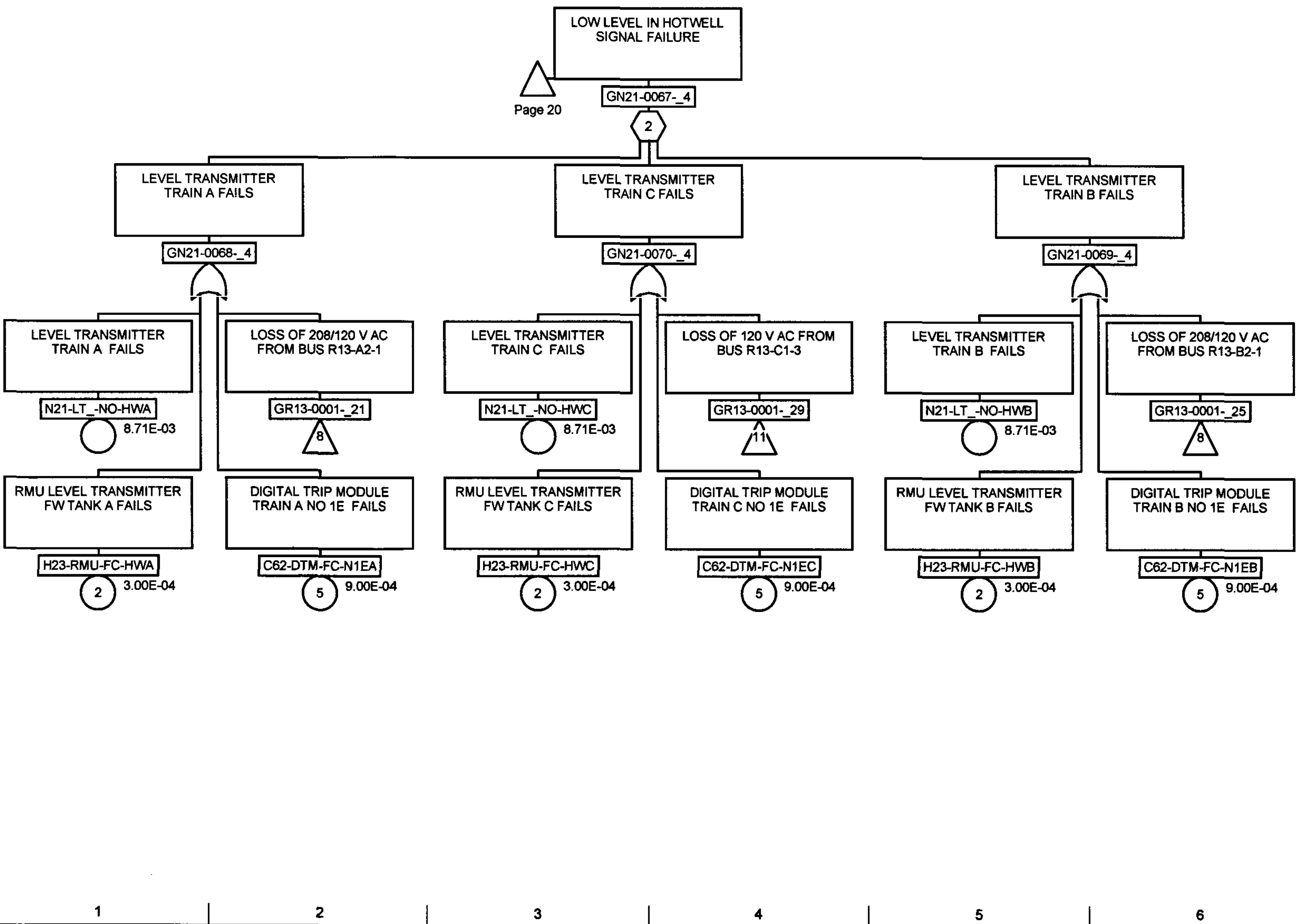
5


LOSS OF MAKEUP FROM CST SYSTEM
GN21-0012-_4
Page 19
CST MAKEUP VALVE OR MAKEUP TANK FAIL
GN21-0031-_4
CCF HOTWELL LEVEL TRANSMITTERS
N21-LT_-CF-HWNO
4.38E-05
CCF OF DIGITAL TRIP MODULES NO 1E
C62-DTM-CF-N1EALL
4
5.50E-05
CONDENSATE STORAGE TANK LEAKS CATASTROPHICALLY
P30-TNK-RP-A001
2.40E-06
LOW LEVEL IN HOTWELL SIGNAL FAILURE
GN21-0067-_4
Page 21
TRIPLE LOGIC TRAIN FAILS
GN21-0053-_4
Page 5
1
2
3


LOW LEVEL IN HOTWELL SIGNAL FAILURE
Page 20
GN21-0067-_4
2
LEVEL TRANSMITTER TRAIN A FAILS
GN21-0068-_4
LEVEL TRANSMITTER TRAIN C FAILS
GN21-0070-_4
LEVEL TRANSMITTER TRAIN B FAILS
GN21-0069-_4
LEVEL TRANSMITTER TRAIN A FAILS
N21-LT_-NO-HWA
8.71E-03
LOSS OF 208/120 V AC FROM BUS R13-A2-1
GR13-0001-_21
8
LEVEL TRANSMITTER TRAIN C FAILS
N21-LT_-NO-HWC
8.71E-03
LOSS OF 120 V AC FROM BUS R13-C1-3
GR13-0001-_29
11
LEVEL TRANSMITTER TRAIN B FAILS
N21-LT_-NO-HWB
8.71E-03
LOSS OF 208/120 V AC FROM BUS R13-B2-1
GR13-0001-_25
8
RMU LEVEL TRANSMITTER FW TANK A FAILS
H23-RMU-FC-HWA
2
3.00E-04
DIGITAL TRIP MODULE TRAIN A NO 1E FAILS
C62-DTM-FC-N1EA
5
9.00E-04
RMU LEVEL TRANSMITTER FW TANK C FAILS
H23-RMU-FC-HWC
2
3.00E-04
DIGITAL TRIP MODULE TRAIN C NO 1E FAILS
C62-DTM-FC-N1EC
5
9.00E-04
RMU LEVEL TRANSMITTER FW TANK B FAILS
H23-RMU-FC-HWB
2
3.00E-04
DIGITAL TRIP MODULE TRAIN B NO 1E FAILS
C62-DTM-FC-N1EB
5
9.00E-04
1
2
3
4
5
6

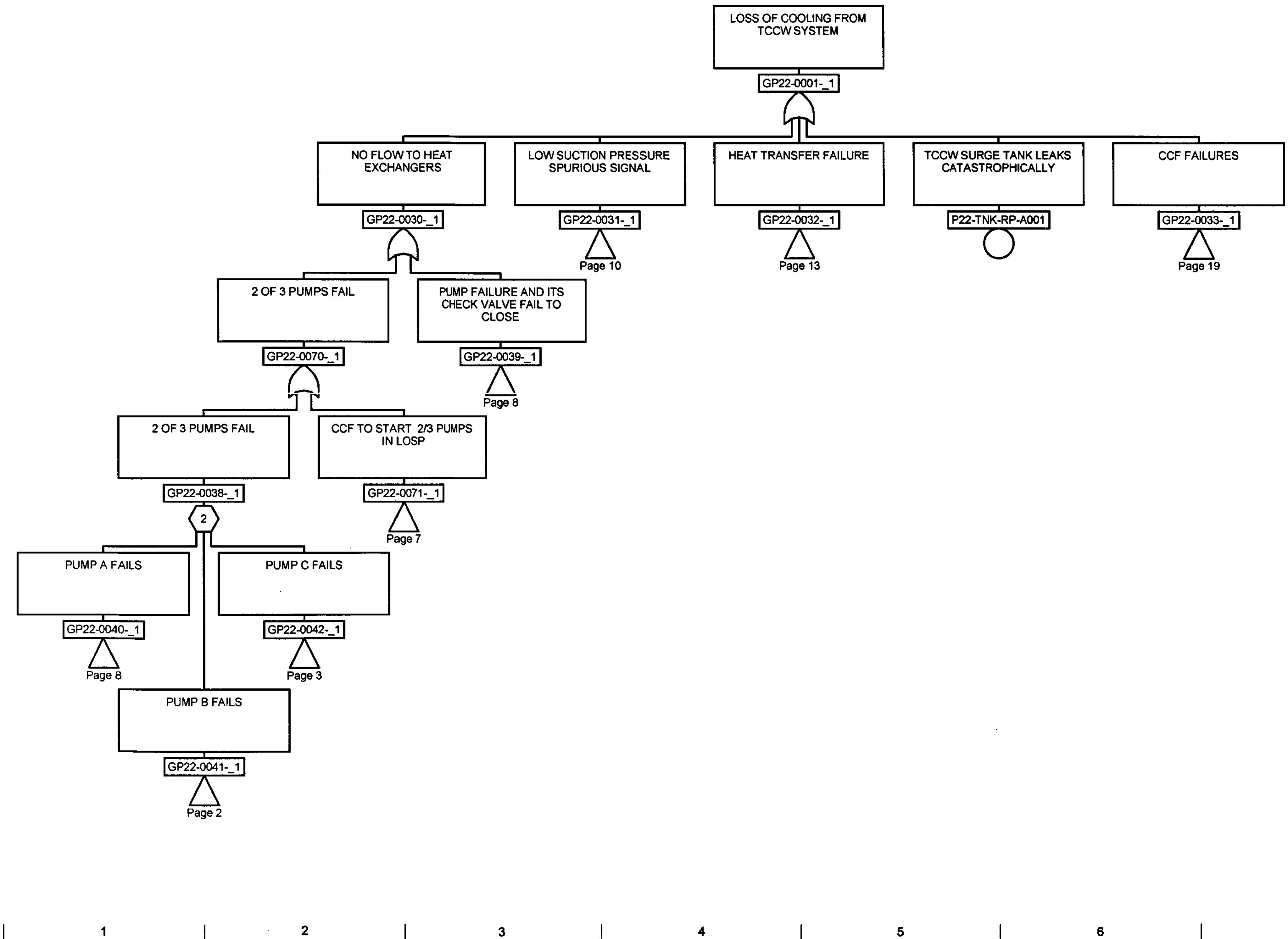
Name	Page	Zone	Name	Page	Zone	Name	Page	Zone
B21-LT -CF-L8NO	10	1	GN21-0008- 1	7	5	GN21-0057- 4	4	2
B21-LT -CF-L9SPU1	10	1	GN21-0008- 4	14	6	GN21-0058- 1	9	5
B21-LT -NO-LVL8A	13	1	GN21-0009- 1	7	8	GN21-0058- 4	4	6
B21-LT -NO-LVL8B	13	3	GN21-0011- 1	6	3	GN21-0059- 4	4	4
B21-LT -NO-LVL8C	13	5	GN21-0011- 1	12	3	GN21-0060- 4	5	2
C62-DTM-CF-N1EALL	2	8	GN21-0012- 1	6	4	GN21-0061- 4	5	6
C62-DTM-CF-N1EALL	3	4	GN21-0012- 1	13	3	GN21-0062- 4	5	4
C62-DTM-CF-N1EALL	10	2	GN21-0012- 4	19	5	GN21-0065- 4	16	2
C62-DTM-CF-N1EALL	20	4	GN21-0012- 4	20	2	GN21-0065- 4	17	3
C62-DTM-FC-N1EA	4	2	GN21-0013- 1	12	2	GN21-0066- 4	17	3
C62-DTM-FC-N1EA	11	2	GN21-0013- 4	19	2	GN21-0067- 4	20	2
C62-DTM-FC-N1EA	13	1	GN21-0014- 1	12	4	GN21-0067- 4	21	3
C62-DTM-FC-N1EA	18	2	GN21-0014- 4	19	2	GN21-0068- 4	21	2
C62-DTM-FC-N1EA	21	2	GN21-0015- 1	12	6	GN21-0069- 4	21	6
C62-DTM-FC-N1EB	4	6	GN21-0015- 4	19	4	GN21-0070- 4	21	4
C62-DTM-FC-N1EB	11	4	GN21-0016- 1	13	2	GN21-0100- 1	7	1
C62-DTM-FC-N1EB	13	3	GN21-0017- 1	13	4	GN21-0100- 1	8	4
C62-DTM-FC-N1EB	18	6	GN21-0018- 1	13	6	GN21-0101- 1	8	2
C62-DTM-FC-N1EB	21	6	GN21-0019- 1	7	2	GN21-0102- 1	8	2
C62-DTM-FC-N1EC	4	4	GN21-0020- 1	7	5	GN21-0103- 1	8	4
C62-DTM-FC-N1EC	11	6	GN21-0021- 1	7	8	GN71-0001- 1	1	3
C62-DTM-FC-N1EC	13	5	GN21-0023- 4	14	2	GP22-0001- 1	2	3
C62-DTM-FC-N1EC	18	4	GN21-0024- 4	14	4	GP22-0001- 1	6	4
C62-DTM-FC-N1EC	21	4	GN21-0025- 4	14	6	GP51-0001- 1	3	3
GC62-0001- 4	5	1	GN21-0031- 4	20	2	GP51-0001- 1	19	3
GC62-0001- 4	12	2	GN21-0034- 4	3	6	GR10-0001- 1	7	3
GC62-0001- 5	5	3	GN21-0040- 4	14	7	GR10-0001- 1	14	1
GC62-0001- 5	12	4	GN21-0040- 4	15	3	GR10-0001- 2	7	6
GC62-0001- 6	5	5	GN21-0041- 4	15	2	GR10-0001- 2	14	3
GC62-0001- 6	9	2	GN21-0042- 4	15	2	GR10-0001- 3	7	9
GC62-0001- 6	12	6	GN21-0043- 4	15	3	GR10-0001- 3	14	5
GC62-0001- 6	17	2	GN21-0043- 4	16	2	GR10-0001- 4	8	3
GN21-0001- 4	6	6	GN21-0050- 1	1	2	GR10-0001- 4	15	3
GN21-0002- 1	1	2	GN21-0050- 4	2	5	GR12-0001- 16	16	2
GN21-0002- 4	1	2	GN21-0051- 1	6	4	GR13-0001- 20	12	2
GN21-0002- 4	2	5	GN21-0051- 4	2	5	GR13-0001- 20	13	2
GN21-0002- 4	6	5	GN21-0051- 4	18	3	GR13-0001- 21	4	2
GN21-0003- 1	1	2	GN21-0052- 1	6	3	GR13-0001- 21	5	2
GN21-0003- 1	6	3	GN21-0052- 1	11	3	GR13-0001- 21	7	4
GN21-0003- 4	6	6	GN21-0052- 4	2	5	GR13-0001- 21	11	2
GN21-0003- 4	19	4	GN21-0052- 4	3	7	GR13-0001- 21	12	1
GN21-0004- 1	6	1	GN21-0052- 4	4	3	GR13-0001- 21	18	2
GN21-0004- 1	7	5	GN21-0053- 1	11	2	GR13-0001- 21	19	1
GN21-0004- 4	1	3	GN21-0053- 4	2	6	GR13-0001- 21	21	2
GN21-0004- 4	3	5	GN21-0053- 4	3	8	GR13-0001- 24	12	4
GN21-0004- 4	6	6	GN21-0053- 4	5	3	GR13-0001- 24	13	4
GN21-0005- 1	6	2	GN21-0053- 4	20	2	GR13-0001- 25	4	6
GN21-0005- 1	10	2	GN21-0054- 1	11	4	GR13-0001- 25	5	4
GN21-0005- 4	2	2	GN21-0054- 4	18	2	GR13-0001- 25	7	7
GN21-0005- 4	14	4	GN21-0055- 1	11	6	GR13-0001- 25	11	4
GN21-0006- 1	6	3	GN21-0055- 4	18	6	GR13-0001- 25	12	3
GN21-0006- 4	14	2	GN21-0056- 4	18	4	GR13-0001- 25	18	6
GN21-0007- 1	7	2	GN21-0057- 1	8	4	GR13-0001- 25	19	3
GN21-0007- 4	14	4	GN21-0057- 1	9	3	GR13-0001- 25	21	6

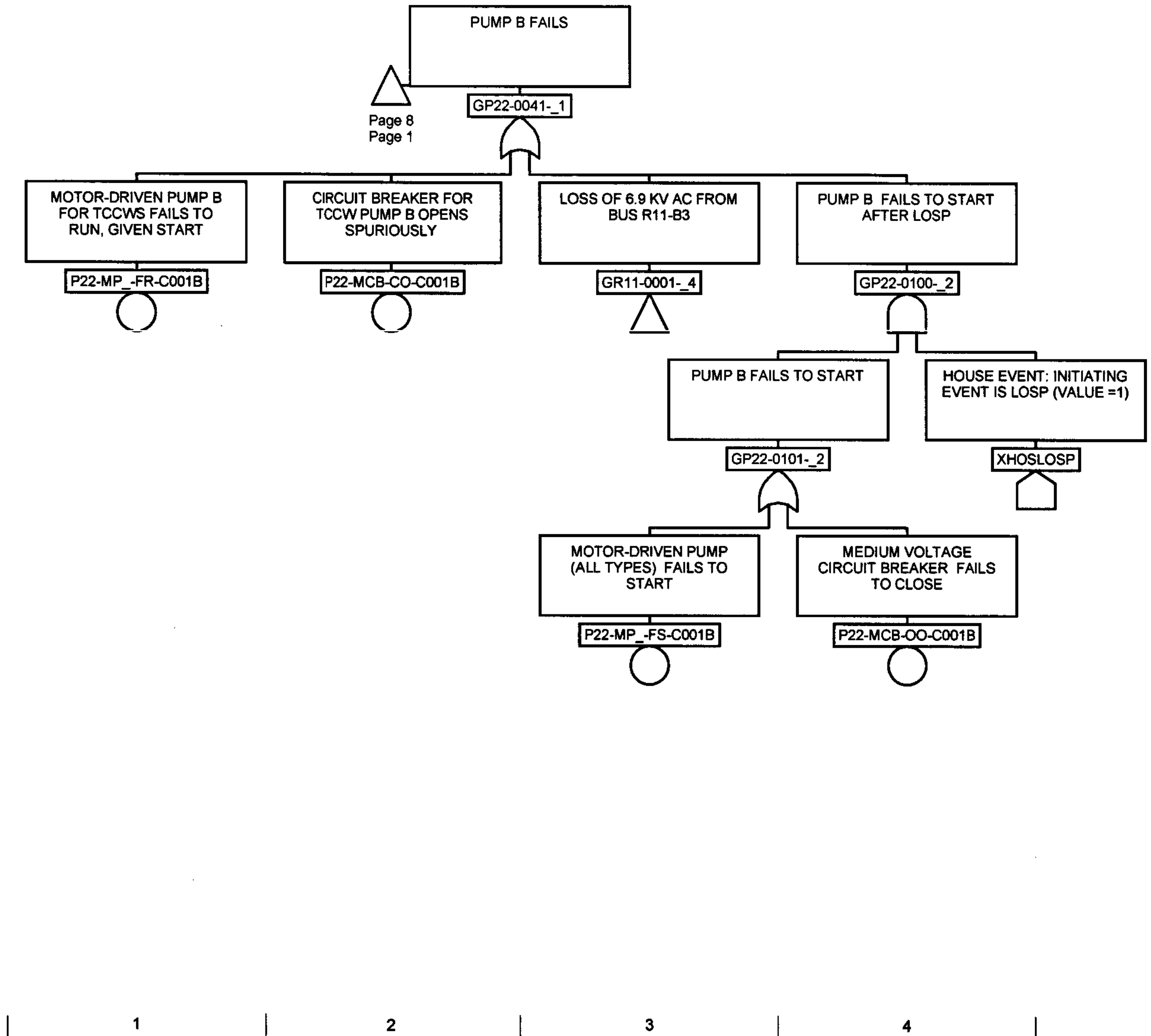
Name	Page	Zone
GR13-0001- 28	12	6
GR13-0001- 28	13	6
GR13-0001- 29	3	2
GR13-0001- 29	4	4
GR13-0001- 29	5	6
GR13-0001- 29	7	10
GR13-0001- 29	8	4
GR13-0001- 29	9	1
GR13-0001- 29	11	6
GR13-0001- 29	12	5
GR13-0001- 29	17	1
GR13-0001- 29	18	4
GR13-0001- 29	21	4
GR13-0003- 27	3	1
H23-RMU-CF-N1EALL	10	2
H23-RMU-FC-1CONDD	17	3
H23-RMU-FC-1FWD	9	5
H23-RMU-FC-2CONDD	17	4
H23-RMU-FC-2FWD	9	6
H23-RMU-FC-FWTKA	4	1
H23-RMU-FC-FWTKA	11	1
H23-RMU-FC-FWTKB	4	5
H23-RMU-FC-FWTKB	11	3
H23-RMU-FC-FWTKC	4	3
H23-RMU-FC-FWTKC	11	5
H23-RMU-FC-HWA	18	1
H23-RMU-FC-HWA	21	1
H23-RMU-FC-HWB	18	5
H23-RMU-FC-HWB	21	5
H23-RMU-FC-HWC	18	3
H23-RMU-FC-HWC	21	3
H23-RMU-FC-LVL8A	13	2
H23-RMU-FC-LVL8B	13	4
H23-RMU-FC-LVL8C	13	6
N21-ACV-CC-F023	19	2
N21-ACV-CC-F026	19	4
N21-ACV-CF-MKUPA/B	19	4
N21-ACV-OC-F016	3	6
N21-ACV-OC-F018	2	1
N21-ACV-TM-F026	19	4
N21-LT -CF-FWTKLOW	10	2
N21-LT -CF-FWTKNO	2	6
N21-LT -CF-FWTKNO	3	5
N21-LT -CF-HWLOW	2	7
N21-LT -CF-HWNO	20	3
N21-LT -LO-FWTKA	11	1
N21-LT -LO-FWTKB	11	3
N21-LT -LO-FWTKC	11	5
N21-LT -LO-HWA	18	1
N21-LT -LO-HWB	18	5
N21-LT -LO-HWC	18	3
N21-LT -NO-FWTKA	4	1
N21-LT -NO-FWTKB	4	5
N21-LT_-NO-FWTKC	4	3
N21-LT -NO-HWA	21	1
N21-LT -NO-HWB	21	5
N21-LT -NO-HWC	21	3
N21-MCB-CO-CONDA	14	3
N21-MCB-CO-CONDB	14	5
N21-MCB-CO-CONDC	14	7
N21-MCB-CO-FWA	7	2
N21-MCB-CO-FWB	7	5
N21-MCB-CO-FWC	7	8
N21-MCB-CO-FWD	8	2
N21-MCB-OO-CONDD	16	1
N21-MCB-OO-FWD	8	3
N21-MOV-CC-F008	16	2
N21-MOV-CC-F061	3	7
N21-MPF-CR-RUN	10	1
N21-MPF-FR-C001A	7	1
N21-MPF-FR-C001B	7	4
N21-MPF-FR-C001C	7	7
N21-MPF-FR-C001D	8	1
N21-MPF-FS-C001D	8	3
N21-MPF-TM-C001D	8	5
N21-MP -CR-COND	2	4
N21-MP -FR-CONDA	14	2
N21-MP -FR-CONDB	14	4
N21-MP -FR-CONDC	14	6
N21-MP -FR-CONDD	15	1
N21-MP -FS-CONDD	16	1
N21-MP -TM-CONDD	15	4
N21-OR -PG-FWCPRECIRD	8	4
N21-STR-PG-FL001A	14	2
N21-STR-PG-FL001B	14	4
N21-STR-PG-FL001C	14	6
N21-STR-PG-FL001D	15	2
N21-SYS-FF-BYPASS	1	1
N21-UV -CC-F008D	16	1
N21-UV -CC-F021D	8	4
N21-XHE-FO-CONDPUMPD	17	5
N21-XHE-FO-FWPUMPD	9	4
P30-TNK-RP-A001	20	1
XHOSMAN	9	3
XHOSMAN	17	4

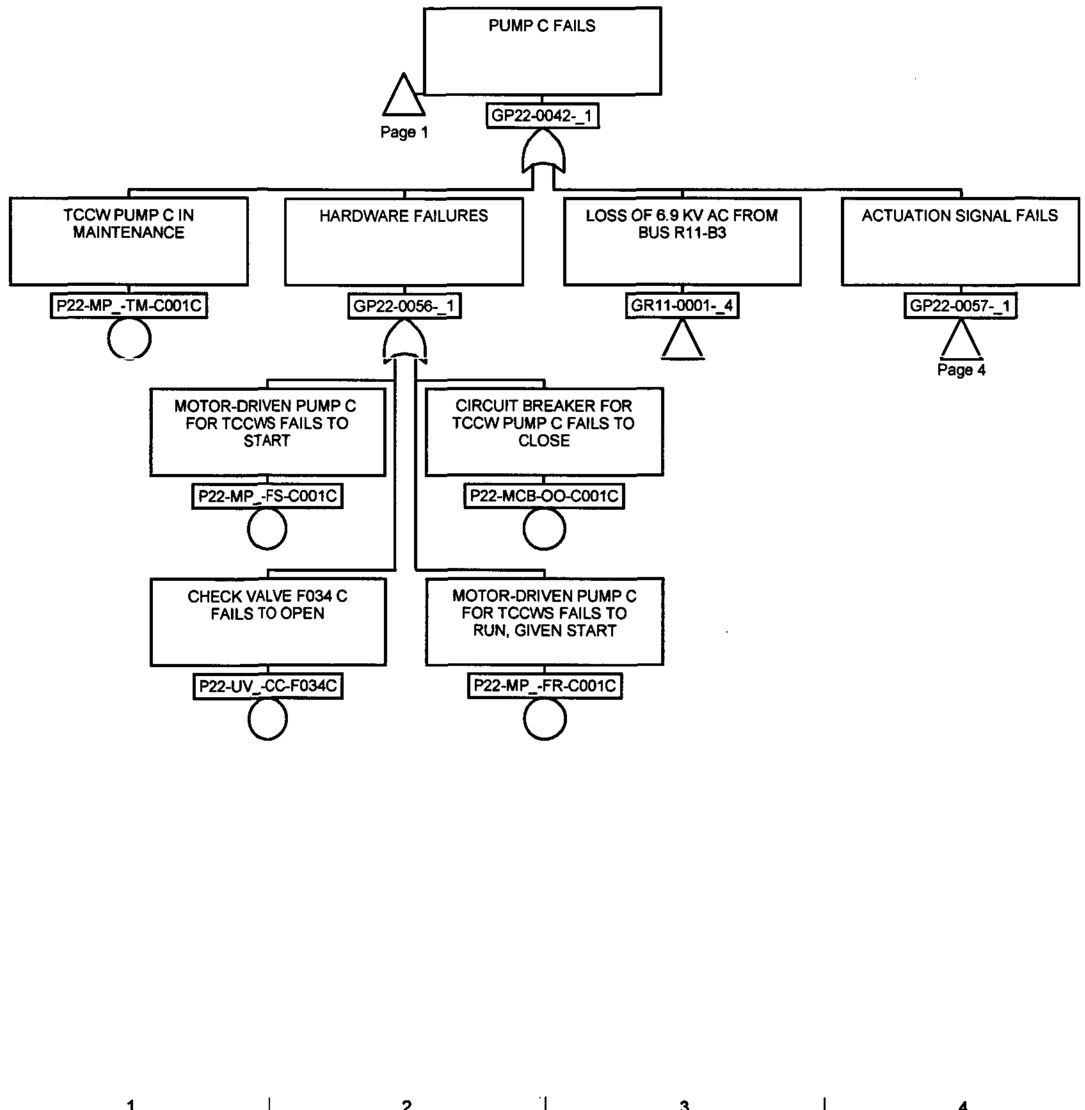
Appendix B.4.9-2

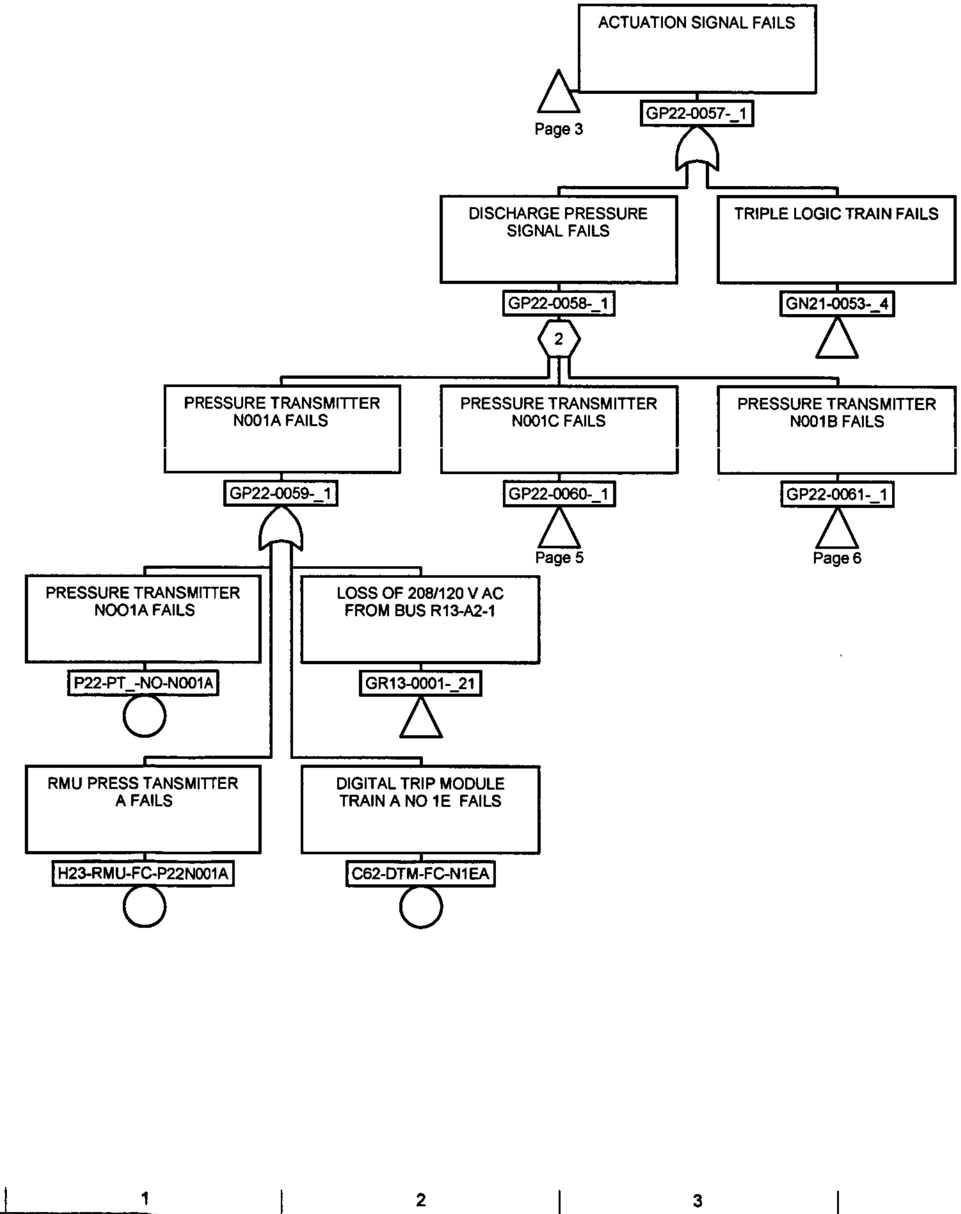
Feedwater/Condensate and TCCW

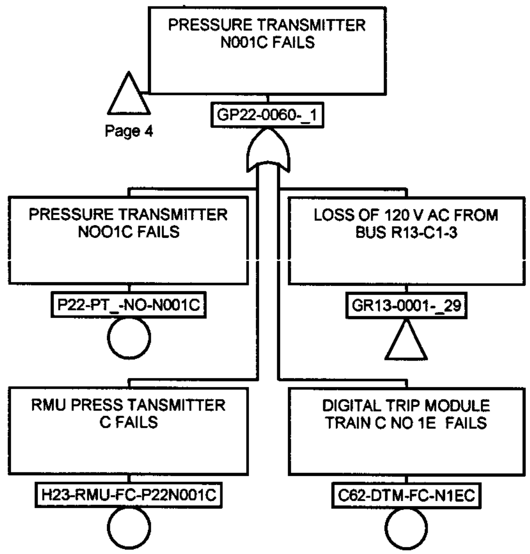
Fault Tree

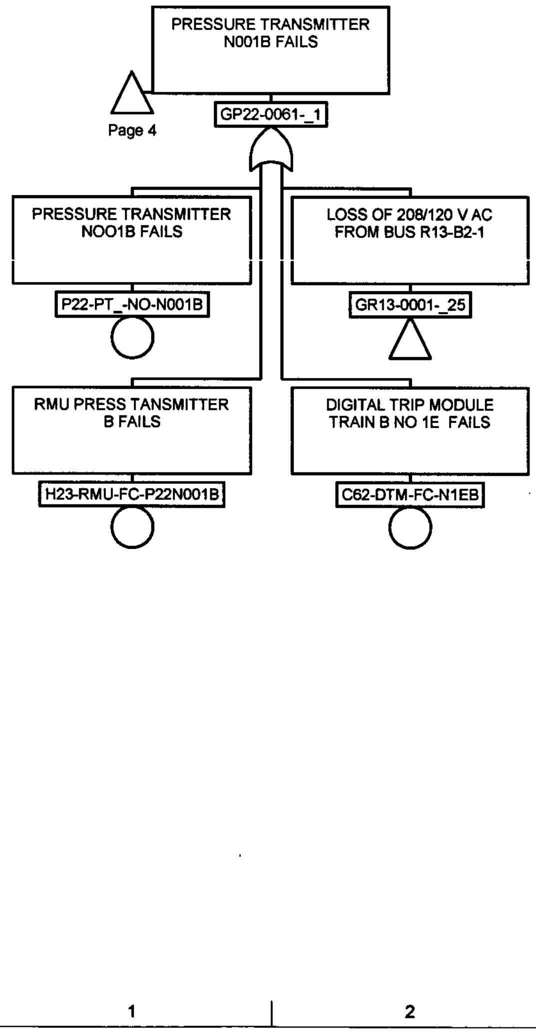

LOSS OF COOLING FROM TCCW SYSTEM
GP22-0001-_1
NO FLOW TO HEAT EXCHANGERS
GP22-0030-_1
LOW SUCTION PRESSURE SPURIOUS SIGNAL
GP22-0031-_1
Page 10
HEAT TRANSFER FAILURE
GP22-0032-_1
Page 13
TCCW SURGE TANK LEAKS CATASTROPHICALLY
P22-TNK-RP-A001
CCF FAILURES
GP22-0033-_1
Page 19
2 OF 3 PUMPS FAIL
GP22-0070-_1
PUMP FAILURE AND ITS CHECK VALVE FAIL TO CLOSE
GP22-0039-_1
Page 8
2 OF 3 PUMPS FAIL
GP22-0038-_1
2
CCF TO START 2/3 PUMPS IN LOSP
GP22-0071-_1
Page 7
PUMP A FAILS
GP22-0040-_1
Page 8
PUMP C FAILS
GP22-0042-_1
Page 3
PUMP B FAILS
GP22-0041-_1
Page 2
1
2
3
4
5
6

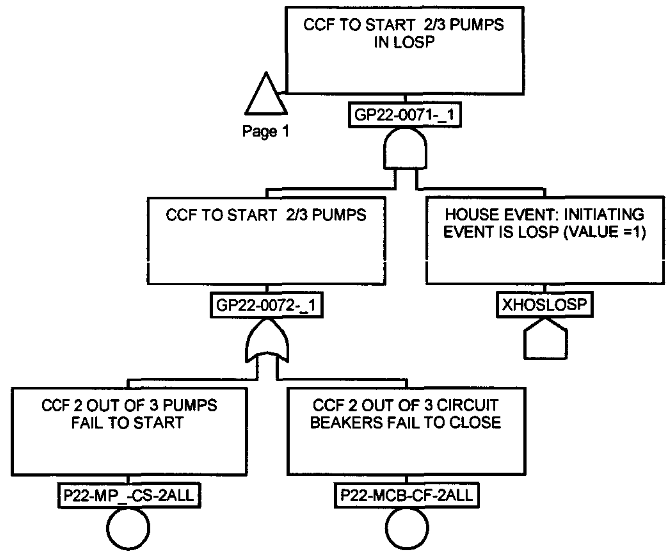

PUMP B FAILS
GP22-0041-_1
Page 8
Page 1
MOTOR-DRIVEN PUMP B FOR TCCWS FAILS TO RUN, GIVEN START
P22-MP_-FR-C001B
CIRCUIT BREAKER FOR TCCW PUMP B OPENS SPURIOUSLY
P22-MCB-CO-C001B
LOSS OF 6.9 KV AC FROM BUS R11-B3
GR11-0001-_4
PUMP B FAILS TO START AFTER LOSP
GP22-0100-_2
PUMP B FAILS TO START
GP22-0101-_2
HOUSE EVENT: INITIATING EVENT IS LOSP (VALUE =1)
XHOSLOSP
MOTOR-DRIVEN PUMP (ALL TYPES) FAILS TO START
P22-MP_-FS-C001B
MEDIUM VOLTAGE CIRCUIT BREAKER FAILS TO CLOSE
P22-MCB-OO-C001B
1
2
3
4

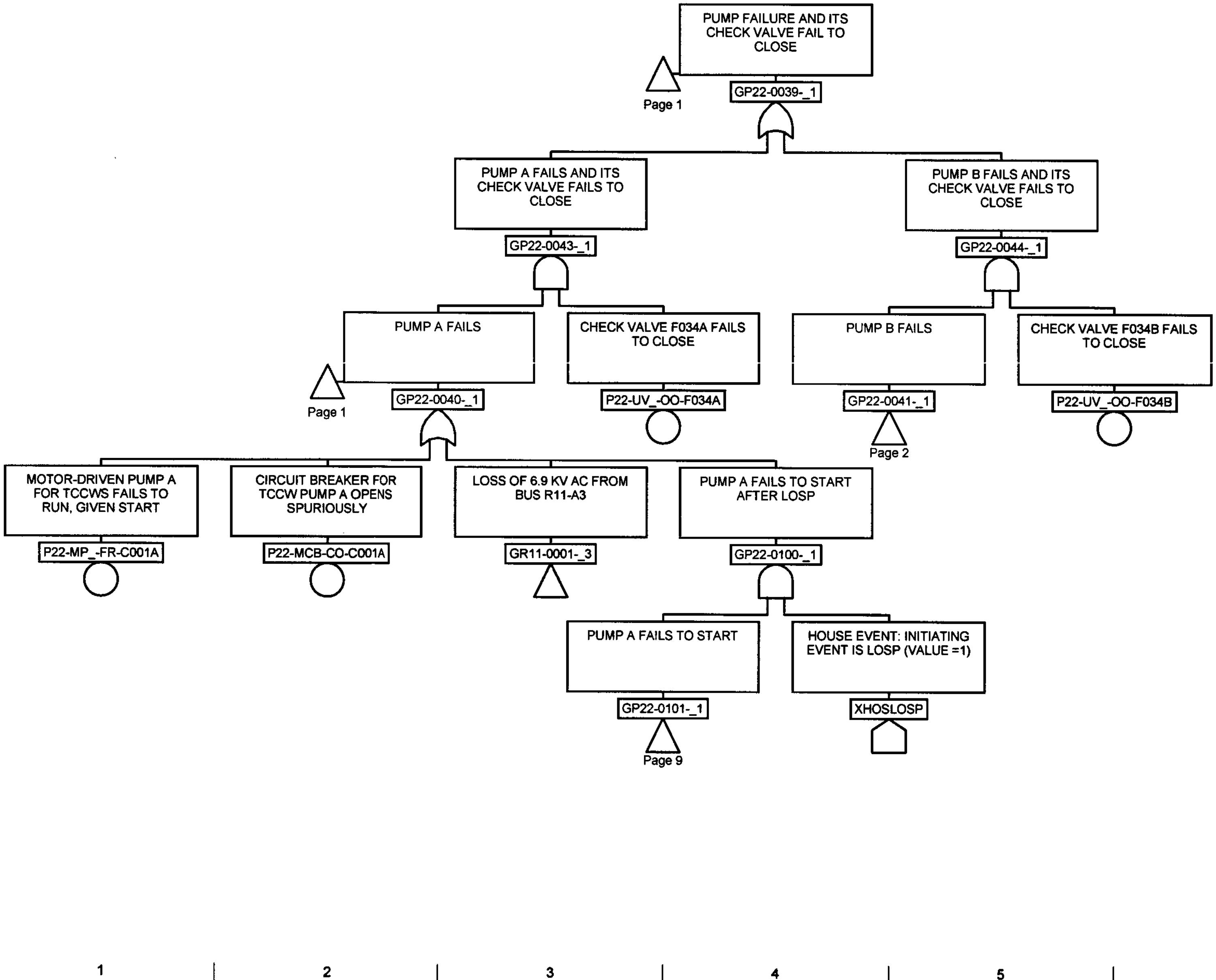

PUMP C FAILS
Page 1
GP22-0042-_1
TCCW PUMP C IN MAINTENANCE
P22-MP_-TM-C001C
HARDWARE FAILURES
GP22-0056-_1
LOSS OF 6.9 KV AC FROM BUS R11-B3
GR11-0001-_4
ACTUATION SIGNAL FAILS
GP22-0057-_1
Page 4
MOTOR-DRIVEN PUMP C FOR TCCWS FAILS TO START
P22-MP_-FS-C001C
CIRCUIT BREAKER FOR TCCW PUMP C FAILS TO CLOSE
P22-MCB-OO-C001C
CHECK VALVE F034 C FAILS TO OPEN
P22-UV_-CC-F034C
MOTOR-DRIVEN PUMP C FOR TCCWS FAILS TO RUN, GIVEN START
P22-MP_-FR-C001C
1
2
3
4

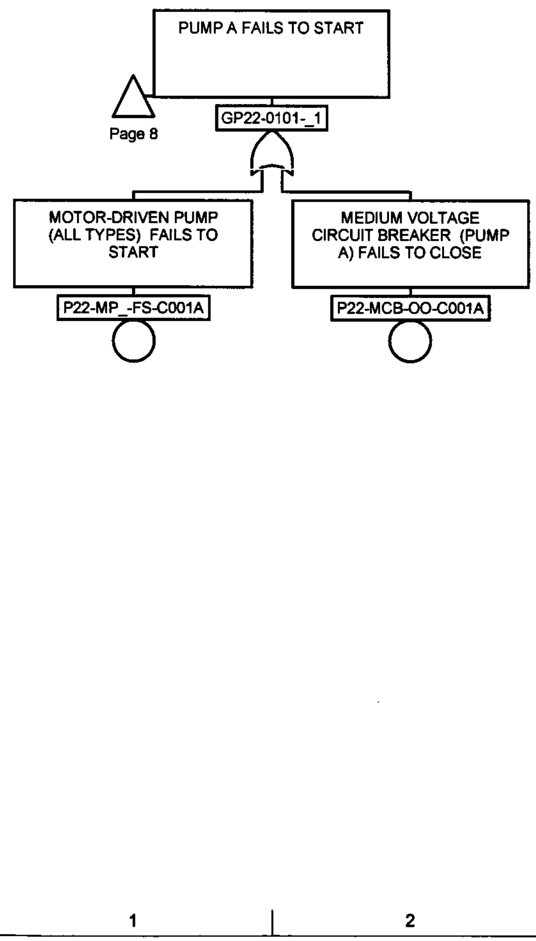

ACTUATION SIGNAL FAILS
GP22-0057-_1
Page 3
DISCHARGE PRESSURE SIGNAL FAILS
GP22-0058-_1
2
TRIPLE LOGIC TRAIN FAILS
GN21-0053-_4
PRESSURE TRANSMITTER N001A FAILS
GP22-0059-_1
PRESSURE TRANSMITTER N001C FAILS
GP22-0060-_1
Page 5
PRESSURE TRANSMITTER N001B FAILS
GP22-0061-_1
Page 6
PRESSURE TRANSMITTER NOO1A FAILS
P22-PT_-NO-N001A
LOSS OF 208/120 V AC FROM BUS R13-A2-1
GR13-0001-_21
RMU PRESS TANSMITTER A FAILS
H23-RMU-FC-P22N001A
DIGITAL TRIP MODULE TRAIN A NO 1E FAILS
C62-DTM-FC-N1EA
1
2
3

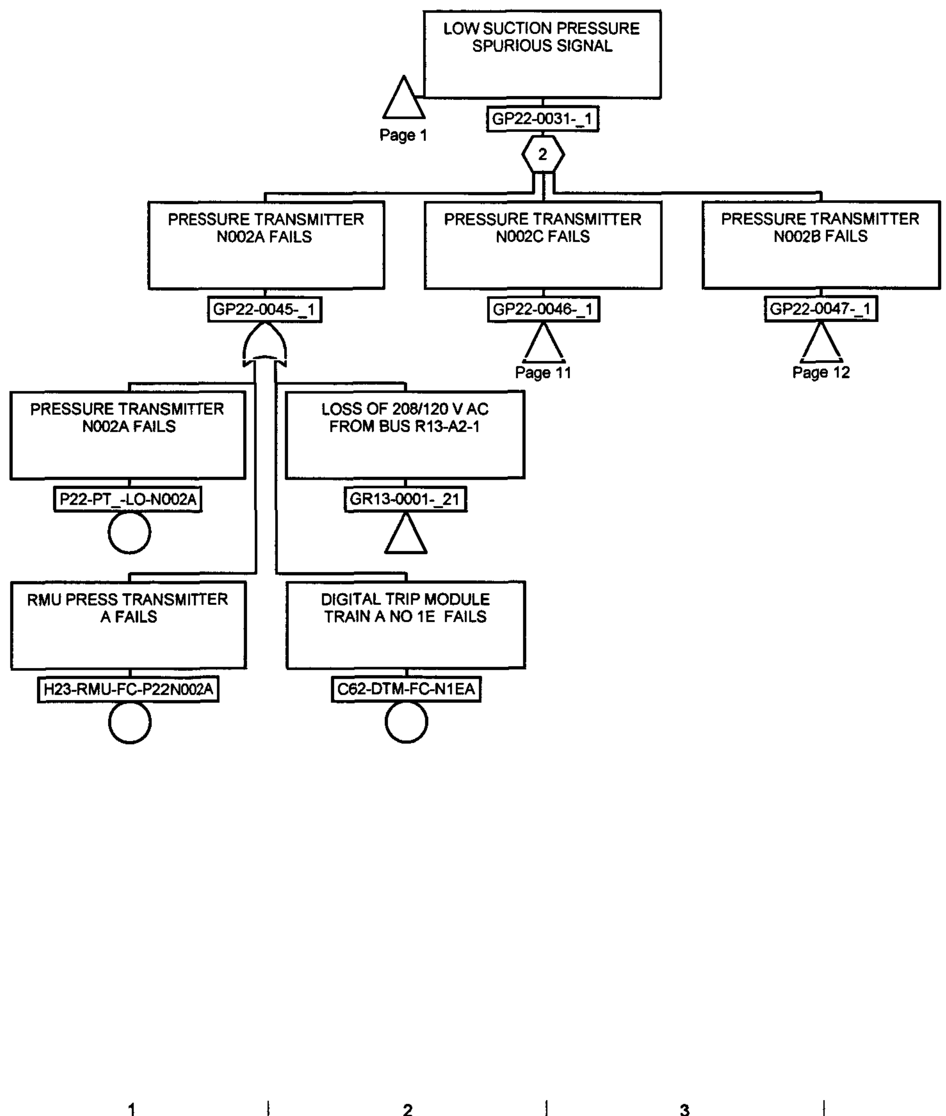

PRESSURE TRANSMITTER N001C FAILS
GP22-0060-_1
Page 4
PRESSURE TRANSMITTER NOO1C FAILS
P22-PT_-NO-N001C
LOSS OF 120 V AC FROM BUS R13-C1-3
GR13-0001-_29
RMU PRESS TANSMITTER C FAILS
H23-RMU-FC-P22N001C
DIGITAL TRIP MODULE TRAIN C NO 1E FAILS
C62-DTM-FC-N1EC
1
2


PRESSURE TRANSMITTER
N001B FAILS
GP22-0061-_1
Page 4
PRESSURE TRANSMITTER
NOO1B FAILS
P22-PT_-NO-N001B
LOSS OF 208/120 V AC
FROM BUS R13-B2-1
GR13-0001-_25
RMU PRESS TANSMITTER
B FAILS
H23-RMU-FC-P22N001B
DIGITAL TRIP MODULE
TRAIN B NO 1E FAILS
C62-DTM-FC-N1EB
1
2

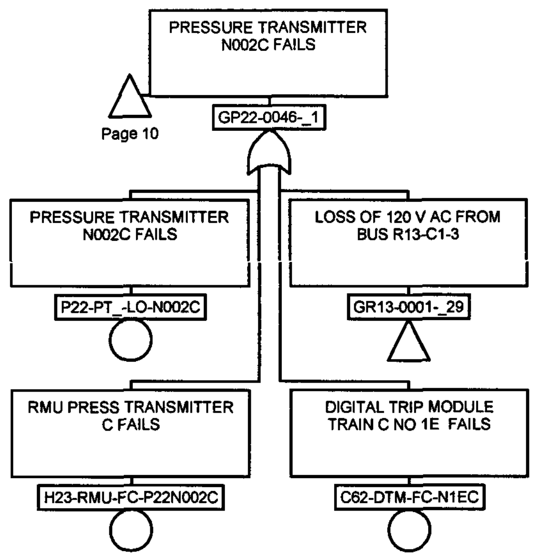

CCF TO START 2/3 PUMPS IN LOSP
GP22-0071-_1
Page 1
CCF TO START 2/3 PUMPS
GP22-0072-_1
HOUSE EVENT: INITIATING EVENT IS LOSP (VALUE =1)
XHOSLOSP
CCF 2 OUT OF 3 PUMPS FAIL TO START
P22-MP_-CS-2ALL
CCF 2 OUT OF 3 CIRCUIT BEAKERS FAIL TO CLOSE
P22-MCB-CF-2ALL
1
2

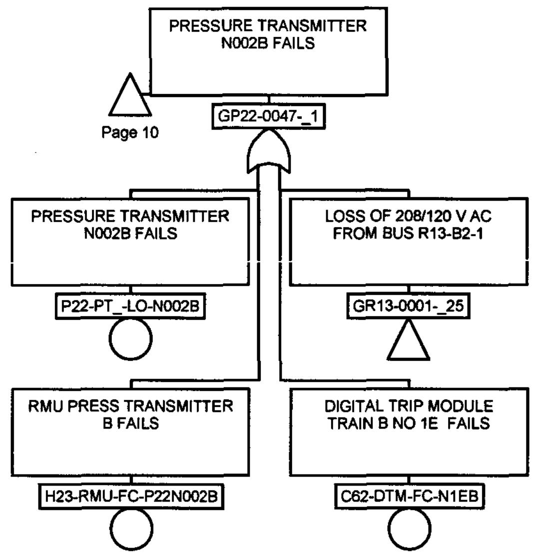

PUMP FAILURE AND ITS CHECK VALVE FAIL TO CLOSE
GP22-0039-_1
Page 1
PUMP A FAILS AND ITS CHECK VALVE FAILS TO CLOSE
GP22-0043-_1
PUMP B FAILS AND ITS CHECK VALVE FAILS TO CLOSE
GP22-0044-_1
PUMP A FAILS
GP22-0040-_1
Page 1
CHECK VALVE F034A FAILS TO CLOSE
P22-UV_-OO-F034A
PUMP B FAILS
GP22-0041-_1
Page 2
CHECK VALVE F034B FAILS TO CLOSE
P22-UV_-OO-F034B
MOTOR-DRIVEN PUMP A FOR TCCWS FAILS TO RUN, GIVEN START
P22-MP_-FR-C001A
CIRCUIT BREAKER FOR TCCW PUMP A OPENS SPURIOUSLY
P22-MCB-CO-C001A
LOSS OF 6.9 KV AC FROM BUS R11-A3
GR11-0001-_3
PUMP A FAILS TO START AFTER LOSP
GP22-0100-_1
PUMP A FAILS TO START
GP22-0101-_1
Page 9
HOUSE EVENT: INITIATING EVENT IS LOSP (VALUE =1)
XHOSLOSP
1
2
3
4
5

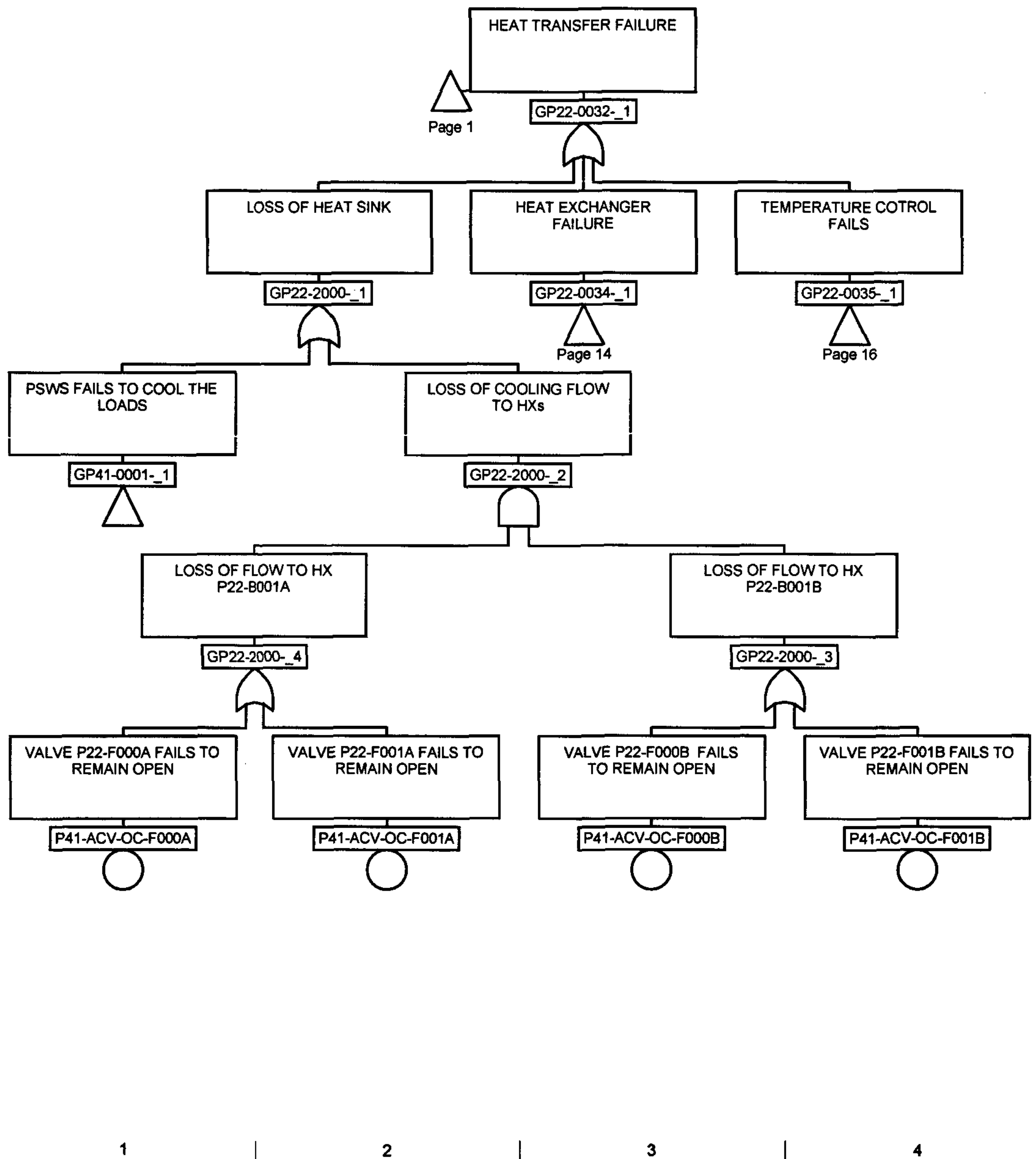

PUMP A FAILS TO START
Page 8
GP22-0101-_1
MOTOR-DRIVEN PUMP (ALL TYPES) FAILS TO START
P22-MP_-FS-C001A
MEDIUM VOLTAGE CIRCUIT BREAKER (PUMP A) FAILS TO CLOSE
P22-MCB-OO-C001A
1
2

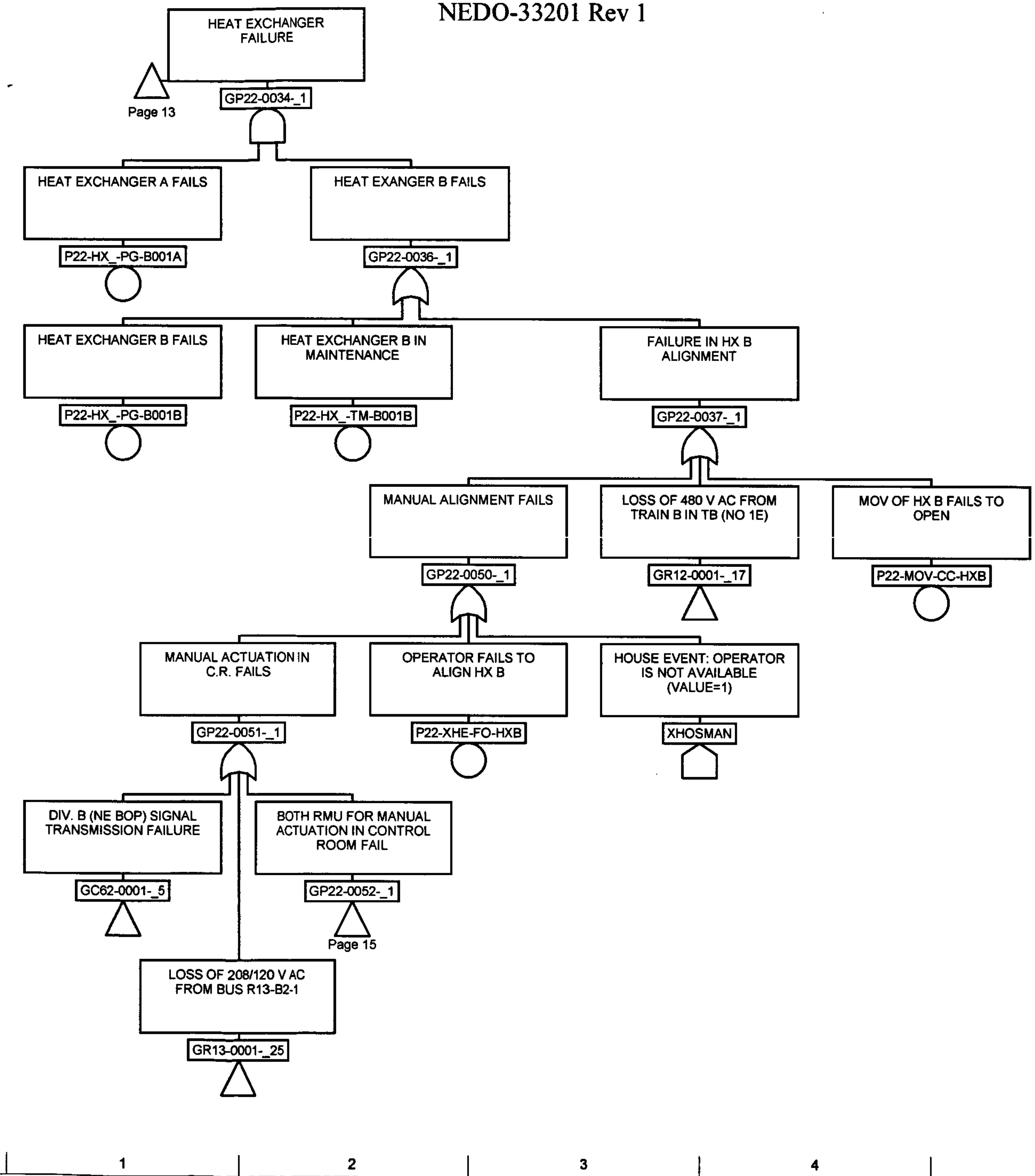


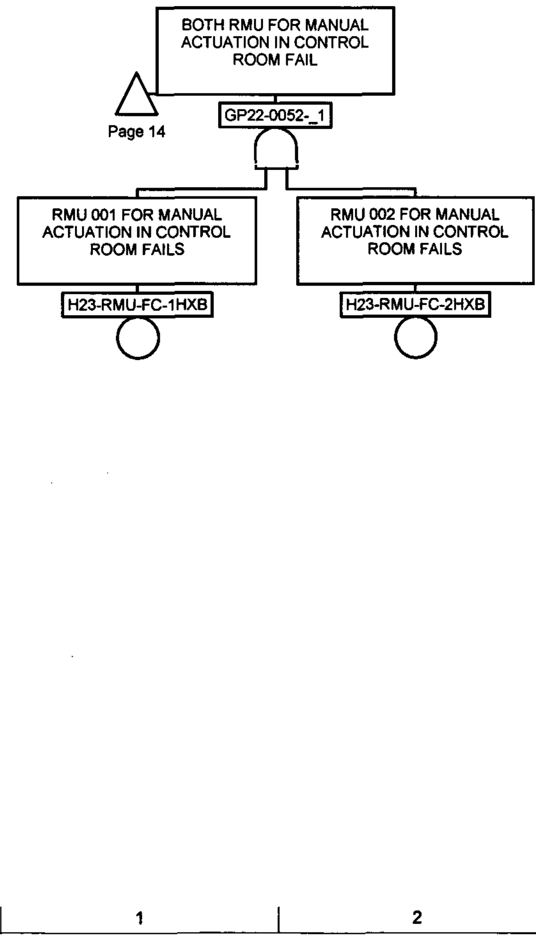
LOW SUCTION PRESSURE SPURIOUS SIGNAL
GP22-0031-_1
Page 1
2
PRESSURE TRANSMITTER N002A FAILS
GP22-0045-_1
PRESSURE TRANSMITTER N002C FAILS
GP22-0046-_1
Page 11
PRESSURE TRANSMITTER N002B FAILS
GP22-0047-_1
Page 12
PRESSURE TRANSMITTER N002A FAILS
P22-PT_-LO-N002A
LOSS OF 208/120 V AC FROM BUS R13-A2-1
GR13-0001-_21
RMU PRESS TRANSMITTER A FAILS
H23-RMU-FC-P22N002A
DIGITAL TRIP MODULE TRAIN A NO 1E FAILS
C62-DTM-FC-N1EA
1
2
3

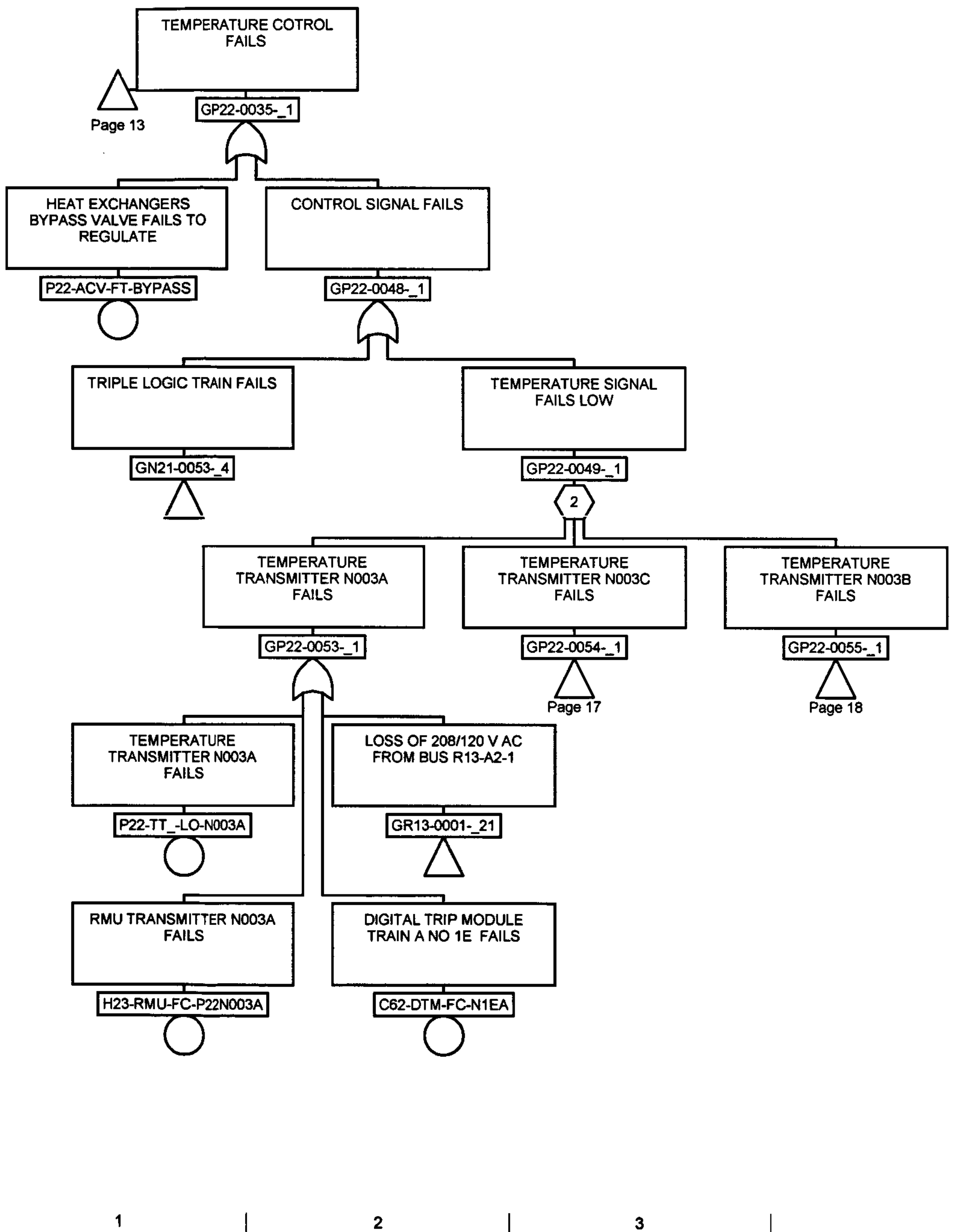

PRESSURE TRANSMITTER N002C FAILS
GP22-0046-_1
Page 10
PRESSURE TRANSMITTER N002C FAILS
P22-PT_-LO-N002C
LOSS OF 120 V AC FROM BUS R13-C1-3
GR13-0001-_29
RMU PRESS TRANSMITTER C FAILS
H23-RMU-FC-P22N002C
DIGITAL TRIP MODULE TRAIN C NO 1E FAILS
C62-DTM-FC-N1EC

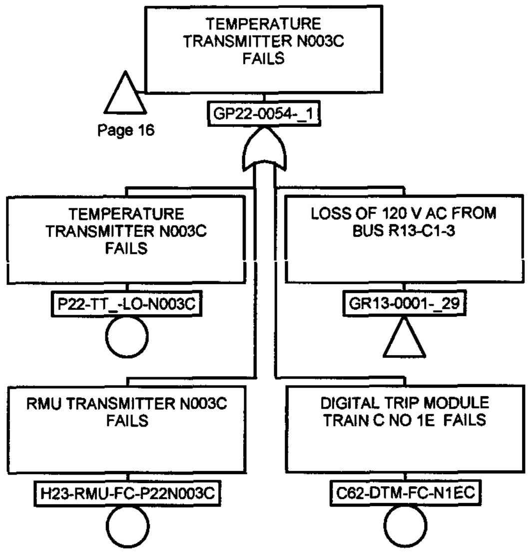

PRESSURE TRANSMITTER
N002B FAILS
GP22-0047-_1
Page 10
PRESSURE TRANSMITTER
N002B FAILS
P22-PT_-LO-N002B
LOSS OF 208/120 V AC
FROM BUS R13-B2-1
GR13-0001-_25
RMU PRESS TRANSMITTER
B FAILS
H23-RMU-FC-P22N002B
DIGITAL TRIP MODULE
TRAIN B NO 1E FAILS
C62-DTM-FC-N1EB
1
2

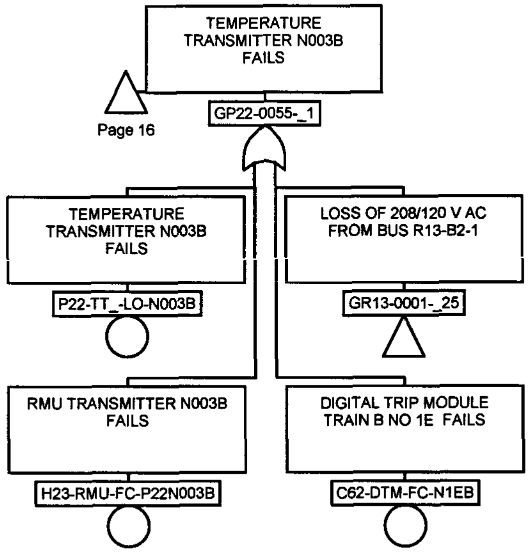

HEAT TRANSFER FAILURE
GP22-0032-_1
Page 1
LOSS OF HEAT SINK
GP22-2000-_1
HEAT EXCHANGER FAILURE
GP22-0034-_1
Page 14
TEMPERATURE COTROL FAILS
GP22-0035-_1
Page 16
PSWS FAILS TO COOL THE LOADS
GP41-0001-_1
LOSS OF COOLING FLOW TO HXs
GP22-2000-_2
LOSS OF FLOW TO HX P22-B001A
GP22-2000-_4
LOSS OF FLOW TO HX P22-B001B
GP22-2000-_3
VALVE P22-F000A FAILS TO REMAIN OPEN
P41-ACV-OC-F000A
VALVE P22-F001A FAILS TO REMAIN OPEN
P41-ACV-OC-F001A
VALVE P22-F000B FAILS TO REMAIN OPEN
P41-ACV-OC-F000B
VALVE P22-F001B FAILS TO REMAIN OPEN
P41-ACV-OC-F001B
1
2
3
4

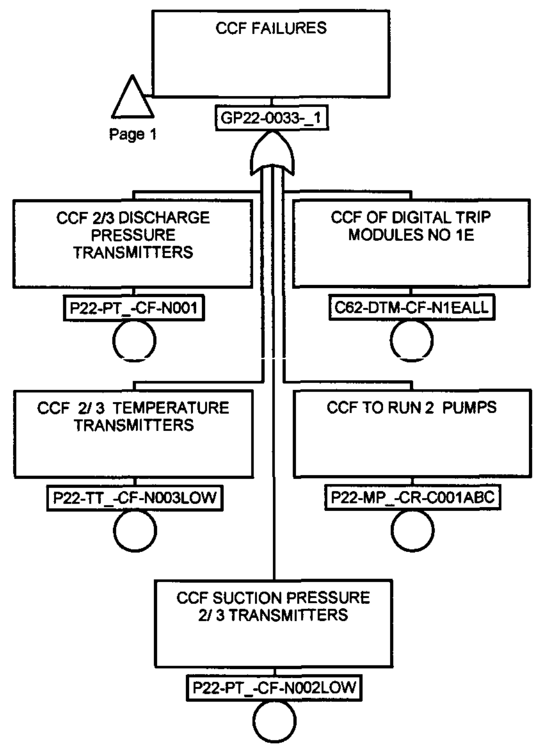

HEAT EXCHANGER FAILURE
Page 13
GP22-0034-_1
HEAT EXCHANGER A FAILS
P22-HX_-PG-B001A
HEAT EXANGER B FAILS
GP22-0036-_1
HEAT EXCHANGER B FAILS
P22-HX_-PG-B001B
HEAT EXCHANGER B IN MAINTENANCE
P22-HX_-TM-B001B
FAILURE IN HX B ALIGNMENT
GP22-0037-_1
MANUAL ALIGNMENT FAILS
GP22-0050-_1
LOSS OF 480 V AC FROM TRAIN B IN TB (NO 1E)
GR12-0001-_17
MOV OF HX B FAILS TO OPEN
P22-MOV-CC-HXB
MANUAL ACTUATION IN C.R. FAILS
GP22-0051-_1
OPERATOR FAILS TO ALIGN HX B
P22-XHE-FO-HXB
HOUSE EVENT: OPERATOR IS NOT AVAILABLE (VALUE=1)
XHOSMAN
DIV. B (NE BOP) SIGNAL TRANSMISSION FAILURE
GC62-0001-_5
BOTH RMU FOR MANUAL ACTUATION IN CONTROL ROOM FAIL
GP22-0052-_1
Page 15
LOSS OF 208/120 V AC FROM BUS R13-B2-1
GR13-0001-_25
1
2
3
4


BOTH RMU FOR MANUAL ACTUATION IN CONTROL ROOM FAIL
GP22-0052-_1
Page 14
RMU 001 FOR MANUAL ACTUATION IN CONTROL ROOM FAILS
H23-RMU-FC-1HXB
RMU 002 FOR MANUAL ACTUATION IN CONTROL ROOM FAILS
H23-RMU-FC-2HXB
1
2


TEMPERATURE COTROL FAILS
GP22-0035-_1
Page 13
HEAT EXCHANGERS BYPASS VALVE FAILS TO REGULATE
P22-ACV-FT-BYPASS
CONTROL SIGNAL FAILS
GP22-0048-_1
TRIPLE LOGIC TRAIN FAILS
GN21-0053-_4
TEMPERATURE SIGNAL FAILS LOW
GP22-0049-_1
2
TEMPERATURE TRANSMITTER N003A FAILS
GP22-0053-_1
TEMPERATURE TRANSMITTER N003C FAILS
GP22-0054-_1
Page 17
TEMPERATURE TRANSMITTER N003B FAILS
GP22-0055-_1
Page 18
TEMPERATURE TRANSMITTER N003A FAILS
P22-TT_-LO-N003A
LOSS OF 208/120 V AC FROM BUS R13-A2-1
GR13-0001-_21
RMU TRANSMITTER N003A FAILS
H23-RMU-FC-P22N003A
DIGITAL TRIP MODULE TRAIN A NO 1E FAILS
C62-DTM-FC-N1EA
1
2
3


TEMPERATURE TRANSMITTER N003C FAILS
GP22-0054-_1
Page 16
TEMPERATURE TRANSMITTER N003C FAILS
P22-TT_-LO-N003C
LOSS OF 120 V AC FROM BUS R13-C1-3
GR13-0001-_29
RMU TRANSMITTER N003C FAILS
H23-RMU-FC-P22N003C
DIGITAL TRIP MODULE TRAIN C NO 1E FAILS
C62-DTM-FC-N1EC
1
2


TEMPERATURE TRANSMITTER N003B FAILS
GP22-0055-_1
Page 16
TEMPERATURE TRANSMITTER N003B FAILS
P22-TT_-LO-N003B
LOSS OF 208/120 V AC FROM BUS R13-B2-1
GR13-0001-_25
RMU TRANSMITTER N003B FAILS
H23-RMU-FC-P22N003B
DIGITAL TRIP MODULE TRAIN B NO 1E FAILS
C62-DTM-FC-N1EB
1
2


CCF FAILURES
Page 1
GP22-0033-_1
CCF 2/3 DISCHARGE PRESSURE TRANSMITTERS
P22-PT_-CF-N001
CCF OF DIGITAL TRIP MODULES NO 1E
C62-DTM-CF-N1EALL
CCF 2/ 3 TEMPERATURE TRANSMITTERS
P22-TT_-CF-N003LOW
CCF TO RUN 2 PUMPS
P22-MP_-CR-C001ABC
CCF SUCTION PRESSURE 2/ 3 TRANSMITTERS
P22-PT_-CF-N002LOW

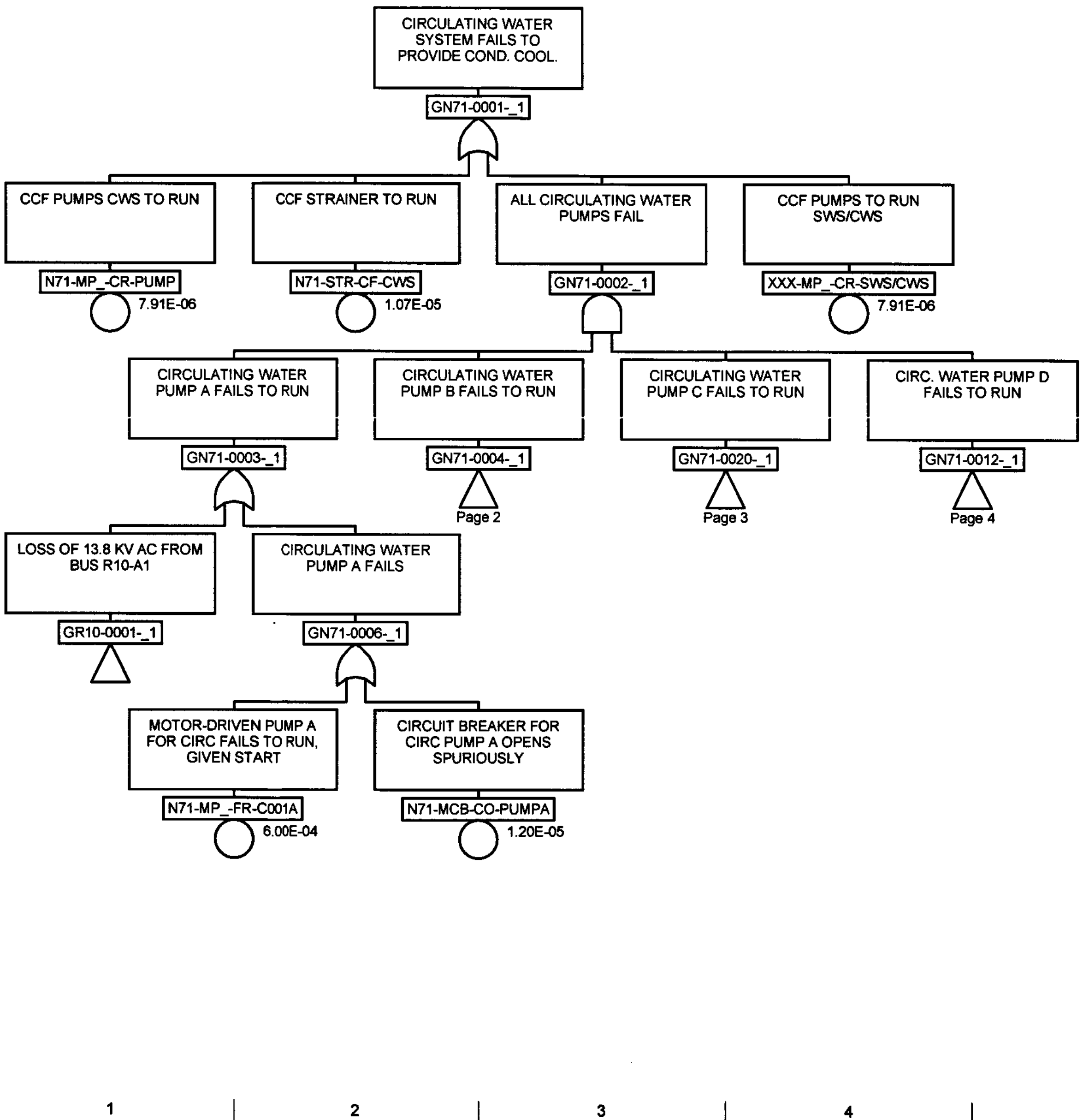
Name	Page	Zone
C62-DTM-CF-N1EALL	19	2
C62-DTM-FC-N1EA	4	2
C62-DTM-FC-N1EA	10	2
C62-DTM-FC-N1EA	16	2
C62-DTM-FC-N1EB	6	2
C62-DTM-FC-N1EB	12	2
C62-DTM-FC-N1EB	18	2
C62-DTM-FC-N1EC	5	2
C62-DTM-FC-N1EC	11	2
C62-DTM-FC-N1EC	17	2
GC62-0001- 5	14	1
GN21-0053- 4	4	4
GN21-0053- 4	16	1
GP22-0001- 1	1	4
GP22-0030- 1	1	2
GP22-0031- 1	1	3
GP22-0031- 1	10	3
GP22-0032- 1	1	4
GP22-0032- 1	13	3
GP22-0033- 1	1	6
GP22-0033- 1	19	2
GP22-0034- 1	13	3
GP22-0034- 1	14	2
GP22-0035- 1	13	4
GP22-0035- 1	16	2
GP22-0036- 1	14	2
GP22-0037- 1	14	3
GP22-0038- 1	1	2
GP22-0039- 1	1	3
GP22-0039- 1	8	4
GP22-0040- 1	1	1
GP22-0040- 1	8	3
GP22-0041- 1	1	2
GP22-0041- 1	2	3
GP22-0041- 1	8	5
GP22-0042- 1	1	2
GP22-0042- 1	3	3
GP22-0043- 1	8	3
GP22-0044- 1	8	5
GP22-0045- 1	10	2
GP22-0046- 1	10	3
GP22-0046- 1	11	2
GP22-0047- 1	10	4
GP22-0047- 1	12	2
GP22-0048- 1	16	2
GP22-0049- 1	16	3
GP22-0050- 1	14	3
GP22-0051- 1	14	2
GP22-0052- 1	14	2
GP22-0052- 1	15	2
GP22-0053- 1	16	2
GP22-0054- 1	16	3
GP22-0054- 1	17	2
GP22-0055- 1	16	4
GP22-0055- 1	18	2
GP22-0056- 1	3	2
GP22-0057- 1	3	4
GP22-0057- 1	4	3
GP22-0058- 1	4	3
GP22-0059- 1	4	2
GP22-0060- 1	4	3
GP22-0060- 1	5	2
GP22-0061- 1	4	4
GP22-0061- 1	6	2
GP22-0070- 1	1	2
GP22-0071- 1	1	3
GP22-0071- 1	7	2
GP22-0072- 1	7	2
GP22-0100- 1	8	4
GP22-0100- 2	2	4
GP22-0101- 1	8	4
GP22-0101- 1	9	2
GP22-0101- 2	2	4
GP22-2000- 1	13	2
GP22-2000- 2	13	3
GP22-2000- 3	13	4
GP22-2000- 4	13	2
GP41-0001- 1	13	1
GR11-0001- 3	8	3
GR11-0001- 4	2	3
GR11-0001- 4	3	3
GR12-0001- 17	14	4
GR13-0001- 21	4	2
GR13-0001- 21	10	2
GR13-0001- 21	16	2
GR13-0001- 25	6	2
GR13-0001- 25	12	2
GR13-0001- 25	14	2
GR13-0001- 25	18	2
GR13-0001- 29	5	2
GR13-0001- 29	11	2
GR13-0001- 29	17	2
H23-RMU-FC-1HXB	15	1
H23-RMU-FC-2HXB	15	2
H23-RMU-FC-P22N001A	4	1
H23-RMU-FC-P22N001B	6	1
H23-RMU-FC-P22N001C	5	1
H23-RMU-FC-P22N002A	10	1
H23-RMU-FC-P22N002B	12	1
H23-RMU-FC-P22N002C	11	1
H23-RMU-FC-P22N003A	16	1
H23-RMU-FC-P22N003B	18	1
H23-RMU-FC-P22N003C	17	1
P22-ACV-FT-BYPASS	16	1
P22-HX -PG-B001A	14	1
P22-HX -PG-B001B	14	1
P22-HX -TM-B001B	14	2
P22-MCB-CF-2ALL	7	2

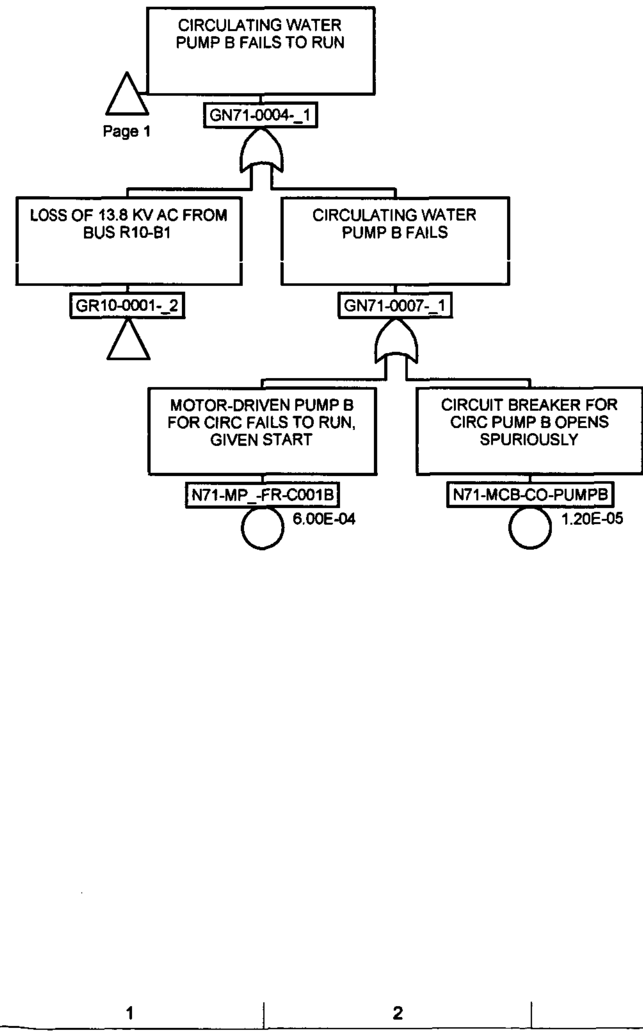
Name	Page	Zone	Name	Page	Zone
P22-MCB-CO-C001A	8	2			
P22-MCB-CO-C001B	2	2			
P22-MCB-OO-C001A	9	2			
P22-MCB-OO-C001B	2	4			
P22-MCB-OO-C001C	3	3			
P22-MOV-CC-HXB	14	5			
P22-MP -CR-C001ABC	19	2			
P22-MP -CS-2ALL	7	1			
P22-MP -FR-C001A	8	1			
P22-MP -FR-C001B	2	1			
P22-MP -FR-C001C	3	3			
P22-MP -FS-C001A	9	1			
P22-MP -FS-C001B	2	3			
P22-MP -FS-C001C	3	2			
P22-MP -TM-C001C	3	1			
P22-PT -CF-N001	19	1			
P22-PT -CF-N002LOW	19	2			
P22-PT -LO-N002A	10	1			
P22-PT -LO-N002B	12	1			
P22-PT -LO-N002C	11	1			
P22-PT -NO-N001A	4	1			
P22-PT -NO-N001B	6	1			
P22-PT -NO-N001C	5	1			
P22-TNK-RP-A001	1	5			
P22-TT -CF-N003LOW	19	1			
P22-TT -LO-N003A	16	1			
P22-TT -LO-N003B	18	1			
P22-TT -LO-N003C	17	1			
P22-UV -CC-F034C	3	2			
P22-UV -OO-F034A	8	4			
P22-UV -OO-F034B	8	6			
P22-XHE-FO-HXB	14	3			
P41-ACV-OC-F000A	13	1			
P41-ACV-OC-F000B	13	3			
P41-ACV-OC-F001A	13	2			
P41-ACV-OC-F001B	13	4			
XHOSLOSP	2	5			
XHOSLOSP	7	3			
XHOSLOSP	8	5			
XHOSMAN	14	4			

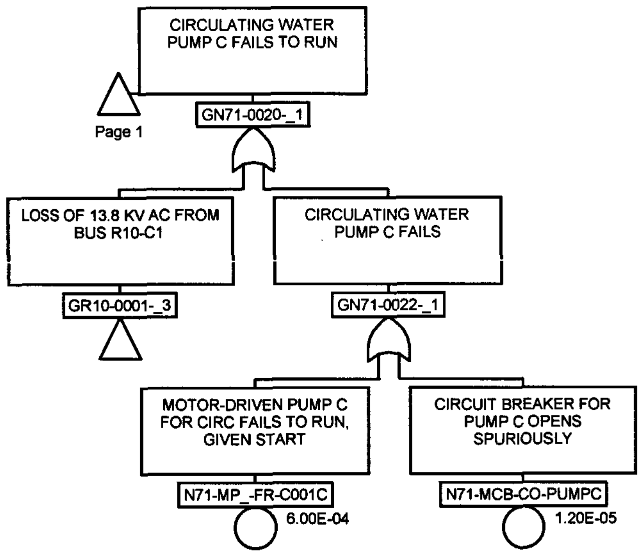
Appendix B.4.9-3

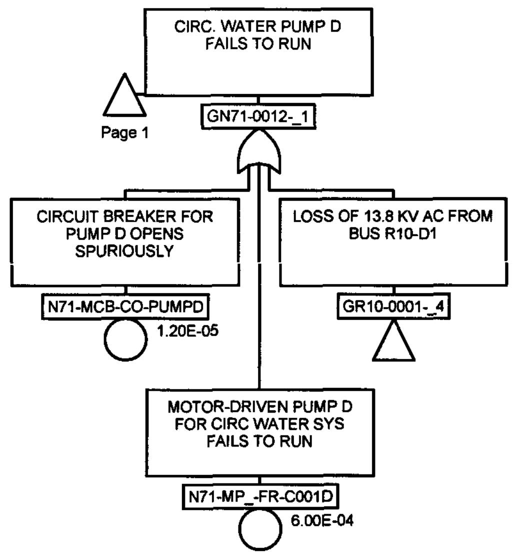
Feedwater/Condensate and TCCW

Fault Tree


CIRCULATING WATER SYSTEM FAILS TO PROVIDE COND. COOL.
GN71-0001-_1
CCF PUMPS CWS TO RUN
N71-MP_-CR-PUMP
7.91E-06
CCF STRAINER TO RUN
N71-STR-CF-CWS
1.07E-05
ALL CIRCULATING WATER PUMPS FAIL
GN71-0002-_1
CCF PUMPS TO RUN SWS/CWS
XXX-MP_-CR-SWS/CWS
7.91E-06
CIRCULATING WATER PUMP A FAILS TO RUN
GN71-0003-_1
CIRCULATING WATER PUMP B FAILS TO RUN
GN71-0004-_1
Page 2
CIRCULATING WATER PUMP C FAILS TO RUN
GN71-0020-_1
Page 3
CIRC. WATER PUMP D FAILS TO RUN
GN71-0012-_1
Page 4
LOSS OF 13.8 KV AC FROM BUS R10-A1
GR10-0001-_1
CIRCULATING WATER PUMP A FAILS
GN71-0006-_1
MOTOR-DRIVEN PUMP A FOR CIRC FAILS TO RUN, GIVEN START
N71-MP_-FR-C001A
6.00E-04
CIRCUIT BREAKER FOR CIRC PUMP A OPENS SPURIOUSLY
N71-MCB-CO-PUMPA
1.20E-05
1
2
3
4


CIRCULATING WATER PUMP B FAILS TO RUN
Page 1
GN71-0004-_1
LOSS OF 13.8 KV AC FROM BUS R10-B1
GR10-0001-_2
CIRCULATING WATER PUMP B FAILS
GN71-0007-_1
MOTOR-DRIVEN PUMP B FOR CIRC FAILS TO RUN, GIVEN START
N71-MP_-FR-C001B
6.00E-04
CIRCUIT BREAKER FOR CIRC PUMP B OPENS SPURIOUSLY
N71-MCB-CO-PUMPB
1.20E-05
1
2

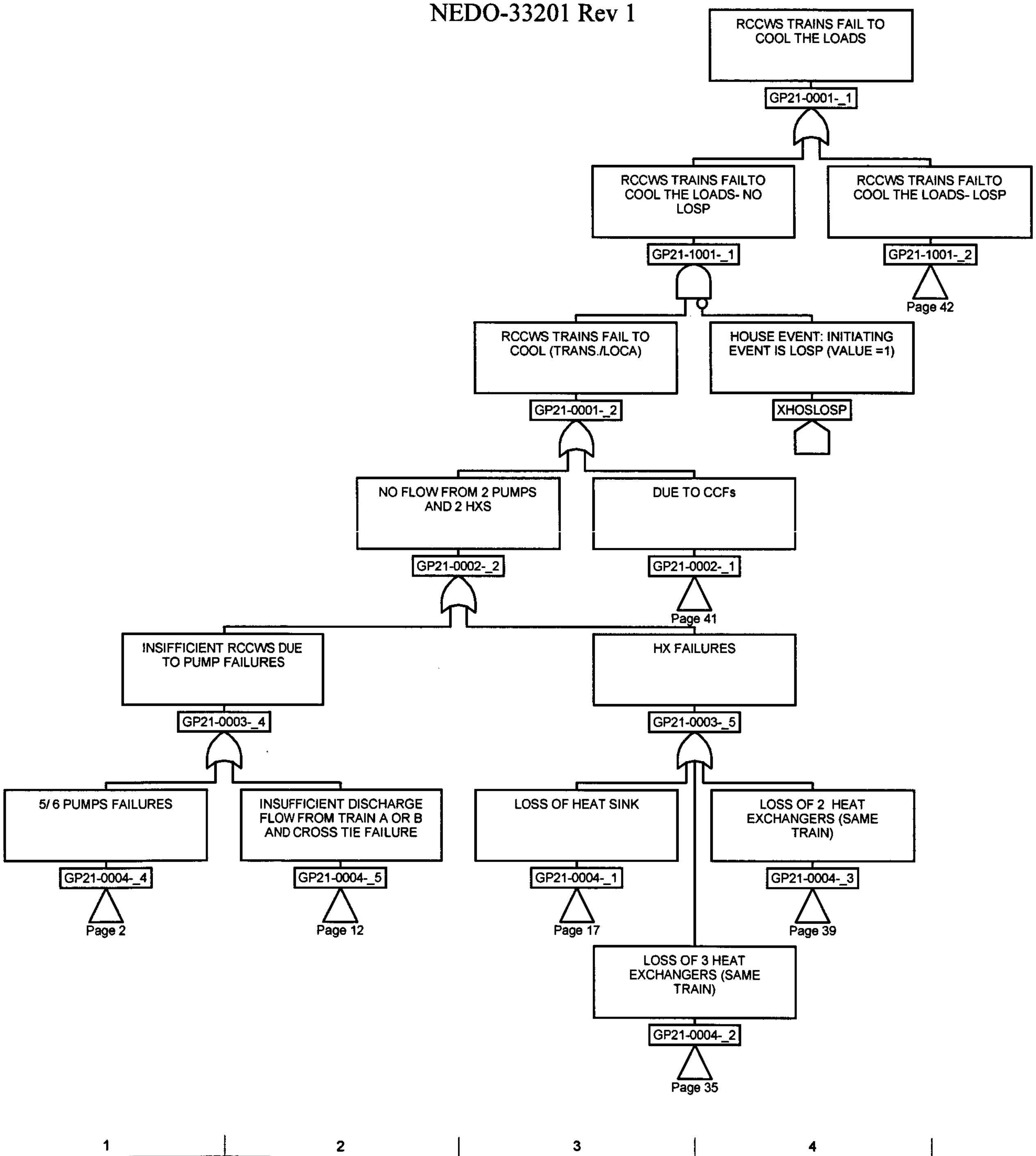

CIRCULATING WATER PUMP C FAILS TO RUN
GN71-0020-_1
Page 1
LOSS OF 13.8 KV AC FROM BUS R10-C1
GR10-0001-_3
CIRCULATING WATER PUMP C FAILS
GN71-0022-_1
MOTOR-DRIVEN PUMP C FOR CIRC FAILS TO RUN, GIVEN START
N71-MP_-FR-C001C
6.00E-04
CIRCUIT BREAKER FOR PUMP C OPENS SPURIOUSLY
N71-MCB-CO-PUMPC
1.20E-05

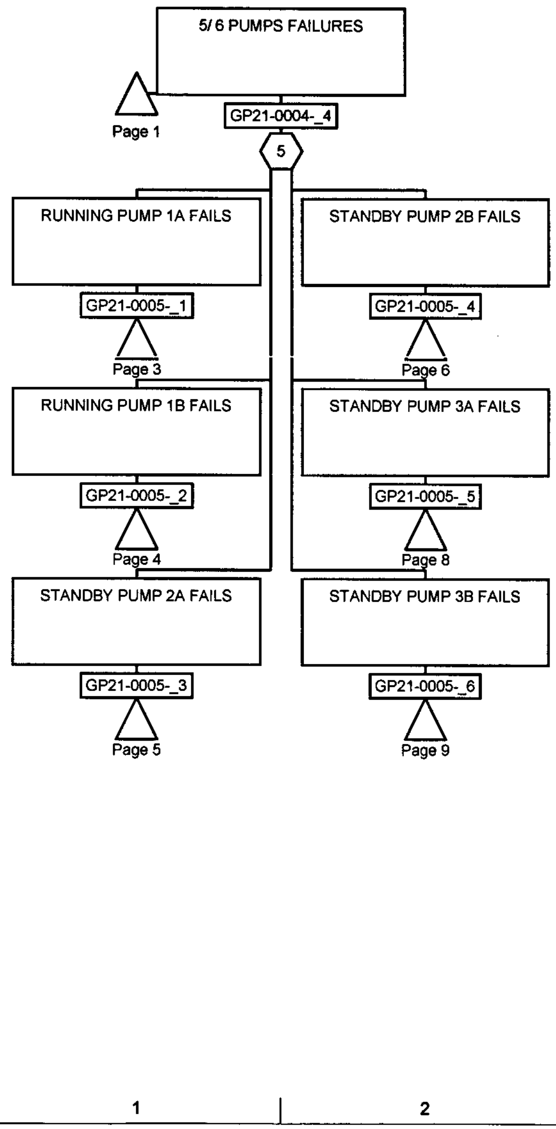

CIRC. WATER PUMP D FAILS TO RUN
GN71-0012-_1
Page 1
CIRCUIT BREAKER FOR PUMP D OPENS SPURIOUSLY
N71-MCB-CO-PUMPD
1.20E-05
LOSS OF 13.8 KV AC FROM BUS R10-D1
GR10-0001-_4
MOTOR-DRIVEN PUMP D FOR CIRC WATER SYS FAILS TO RUN
N71-MP_-FR-C001D
6.00E-04

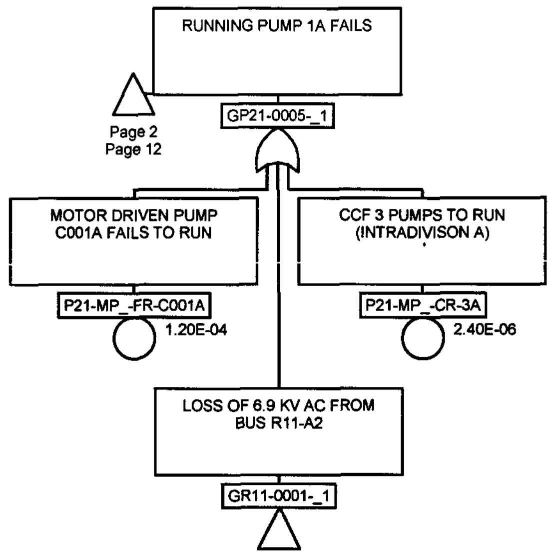
1 2

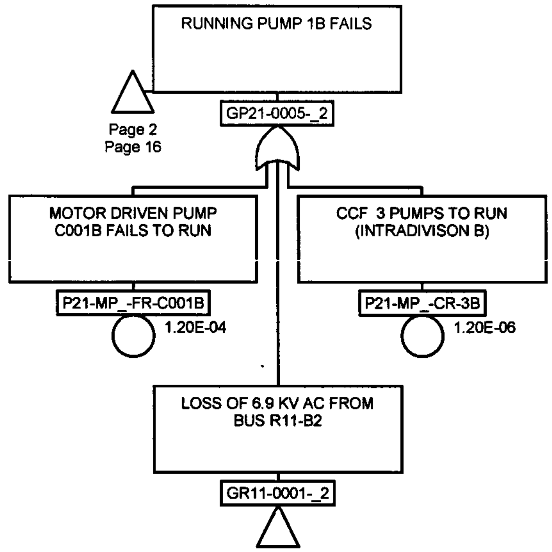
Name	Page	Zone	Name	Page	Zone	Name	Page	Zone
GN71-0001- 1	1	3						
GN71-0002- 1	1	3						
GN71-0003- 1	1	2						
GN71-0004- 1	1	3						
GN71-0004- 1	2	2						
GN71-0006- 1	1	2						
GN71-0007- 1	2	2						
GN71-0012- 1	1	5						
GN71-0012- 1	4	2						
GN71-0020- 1	1	4						
GN71-0020- 1	3	2						
GN71-0022- 1	3	2						
GR10-0001- 1	1	1						
GR10-0001- 2	2	1						
GR10-0001- 3	3	1						
GR10-0001- 4	4	2						
N71-MCB-CO-PUMPA	1	3						
N71-MCB-CO-PUMPB	2	3						
N71-MCB-CO-PUMPC	3	3						
N71-MCB-CO-PUMPD	4	1						
N71-MP -CR-PUMP	1	1						
N71-MP -FR-C001A	1	2						
N71-MP -FR-C001B	2	2						
N71-MP -FR-C001C	3	2						
N71-MP -FR-C001D	4	2						
N71-STR-CF-CWS	1	2						
XXX-MP_-CR-SWS/CWS	1	4						

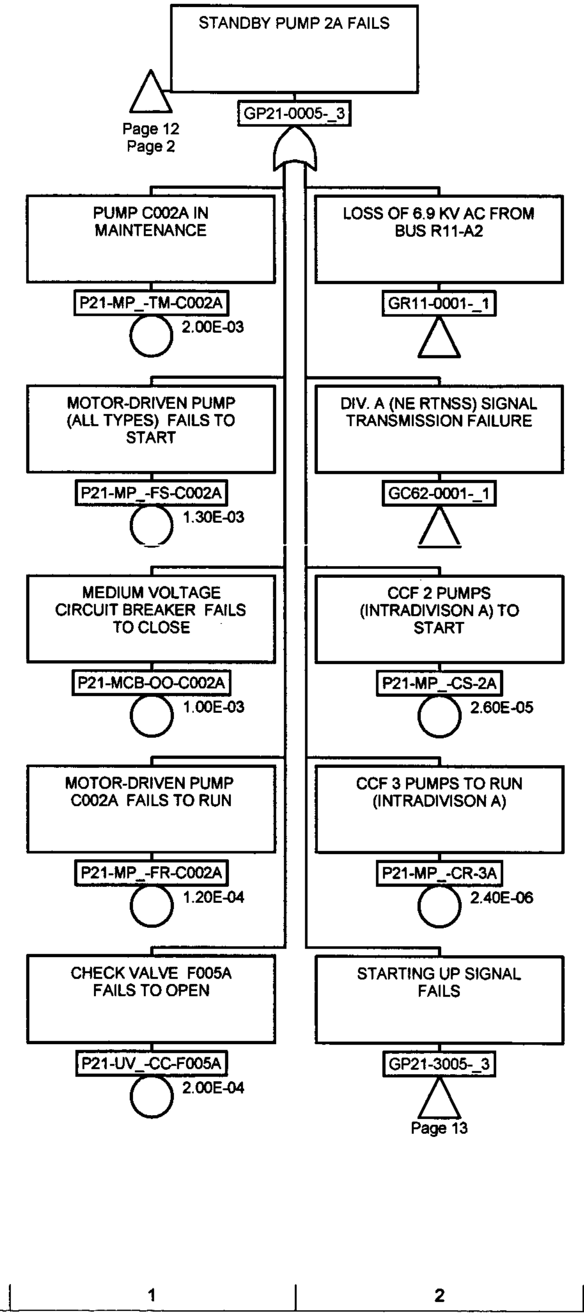
Appendix B.4.10 Reactor Component Cooling Water System Fault Tree

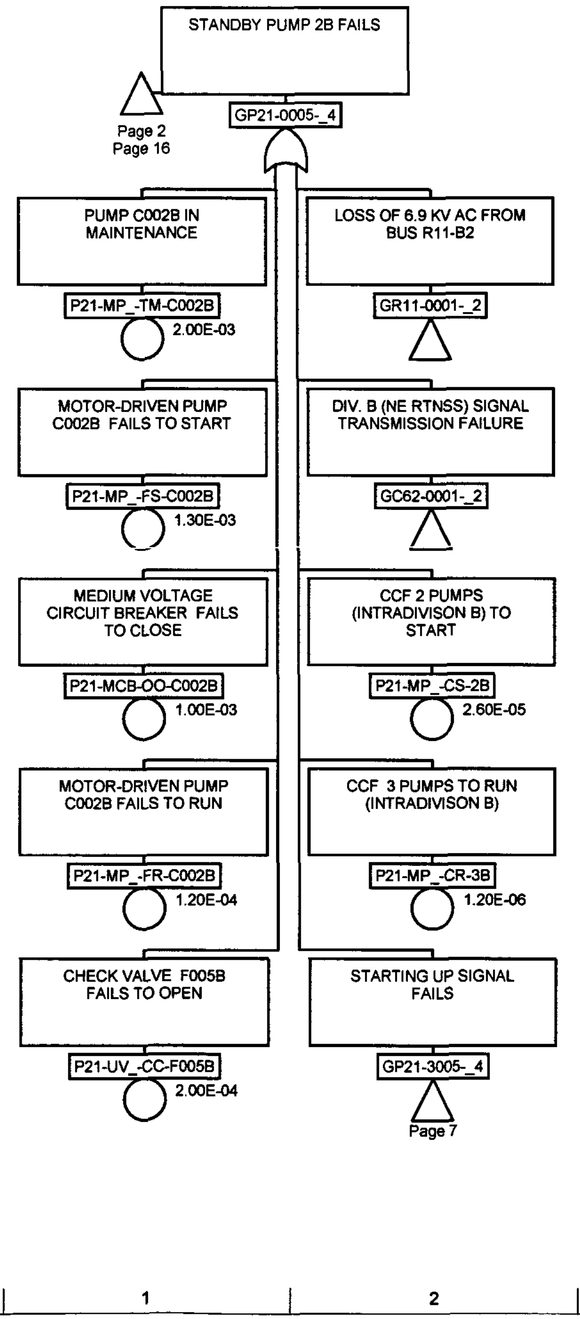

RCCWS TRAINS FAIL TO COOL THE LOADS
GP21-0001-_1
RCCWS TRAINS FAILTO COOL THE LOADS- NO LOSP
GP21-1001-_1
RCCWS TRAINS FAILTO COOL THE LOADS- LOSP
GP21-1001-_2
Page 42
RCCWS TRAINS FAIL TO COOL (TRANS./LOCA)
GP21-0001-_2
HOUSE EVENT: INITIATING EVENT IS LOSP (VALUE =1)
XHOSLOSP
NO FLOW FROM 2 PUMPS AND 2 HXS
GP21-0002-_2
DUE TO CCFs
GP21-0002-_1
Page 41
INSIFFICIENT RCCWS DUE TO PUMP FAILURES
GP21-0003-_4
HX FAILURES
GP21-0003-_5
5/ 6 PUMPS FAILURES
GP21-0004-_4
Page 2
INSUFFICIENT DISCHARGE FLOW FROM TRAIN A OR B AND CROSS TIE FAILURE
GP21-0004-_5
Page 12
LOSS OF HEAT SINK
GP21-0004-_1
Page 17
LOSS OF 2 HEAT EXCHANGERS (SAME TRAIN)
GP21-0004-_3
Page 39
LOSS OF 3 HEAT EXCHANGERS (SAME TRAIN)
GP21-0004-_2
Page 35
1
2
3
4

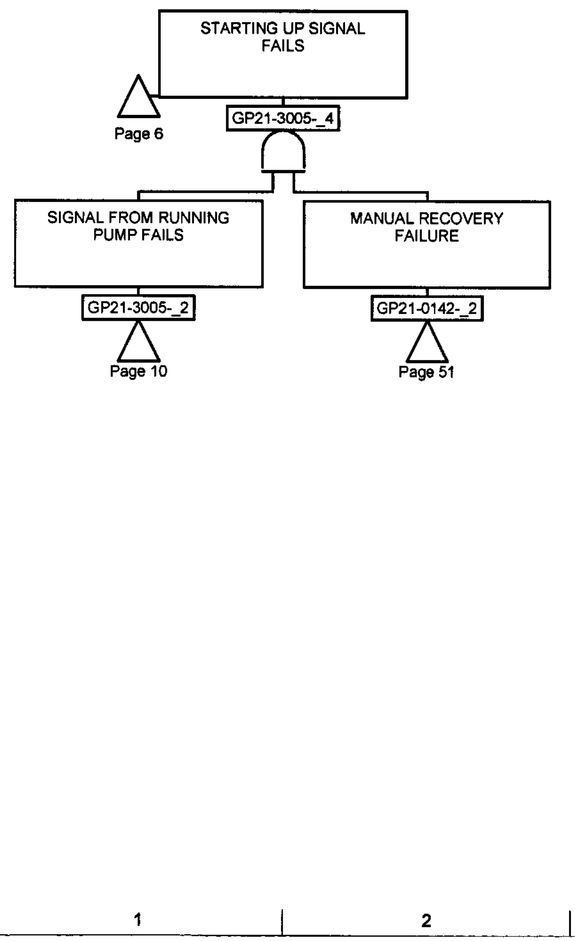

5/ 6 PUMPS FAILURES
Page 1
GP21-0004-_4
5
RUNNING PUMP 1A FAILS
GP21-0005-_1
Page 3
STANDBY PUMP 2B FAILS
GP21-0005-_4
Page 6
RUNNING PUMP 1B FAILS
GP21-0005-_2
Page 4
STANDBY PUMP 3A FAILS
GP21-0005-_5
Page 8
STANDBY PUMP 2A FAILS
GP21-0005-_3
Page 5
STANDBY PUMP 3B FAILS
GP21-0005-_6
Page 9
1
2

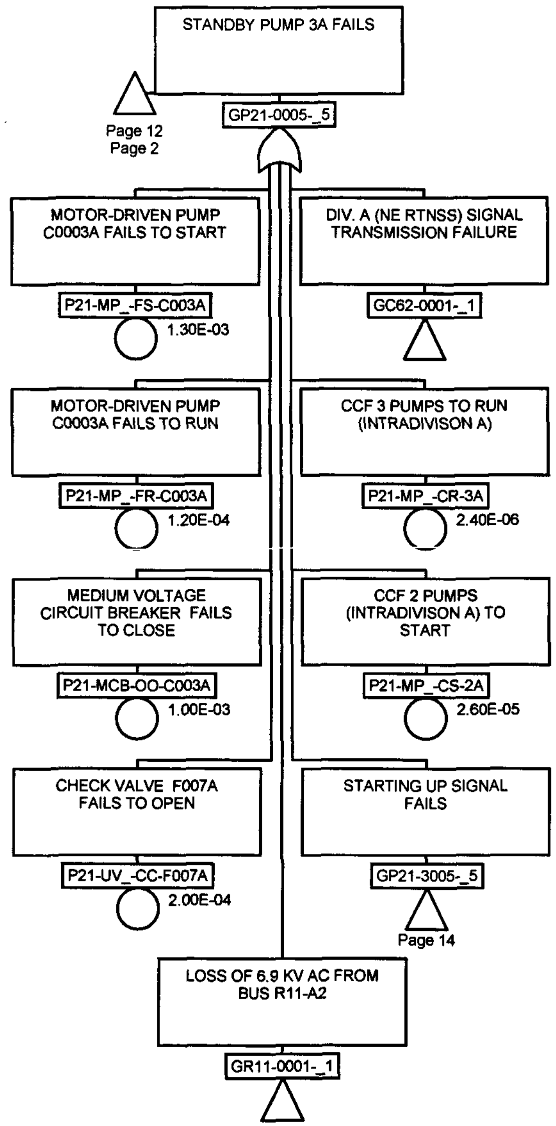

RUNNING PUMP 1A FAILS
GP21-0005-_1
Page 2
Page 12
MOTOR DRIVEN PUMP C001A FAILS TO RUN
P21-MP_-FR-C001A
1.20E-04
CCF 3 PUMPS TO RUN (INTRADIVISON A)
P21-MP_-CR-3A
2.40E-06
LOSS OF 6.9 KV AC FROM BUS R11-A2
GR11-0001-_1

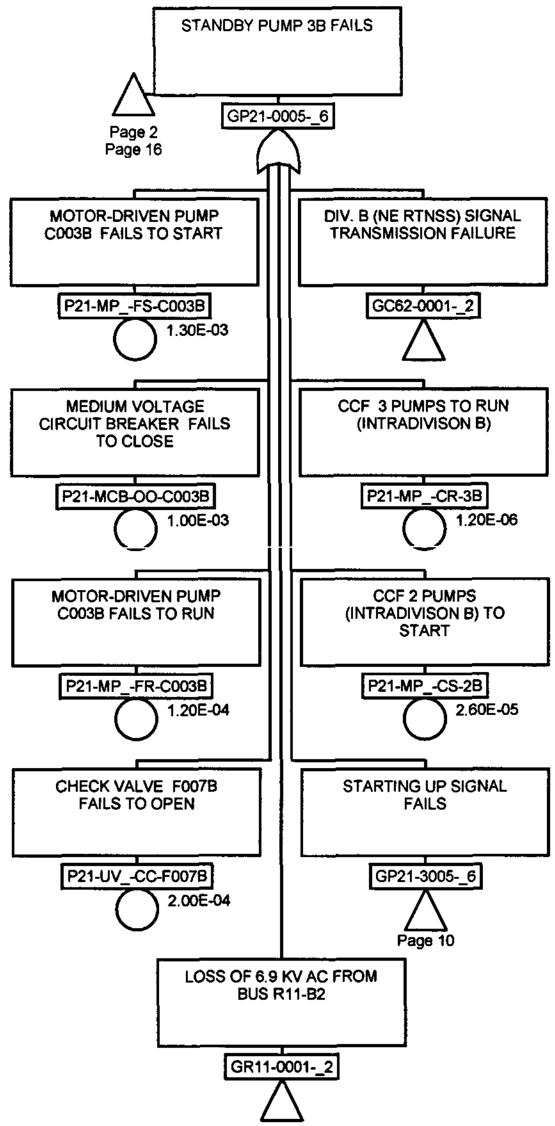

RUNNING PUMP 1B FAILS
GP21-0005-_2
Page 2
Page 16
MOTOR DRIVEN PUMP C001B FAILS TO RUN
P21-MP_-FR-C001B
1.20E-04
CCF 3 PUMPS TO RUN (INTRADIVISON B)
P21-MP_-CR-3B
1.20E-06
LOSS OF 6.9 KV AC FROM BUS R11-B2
GR11-0001-_2
1
2

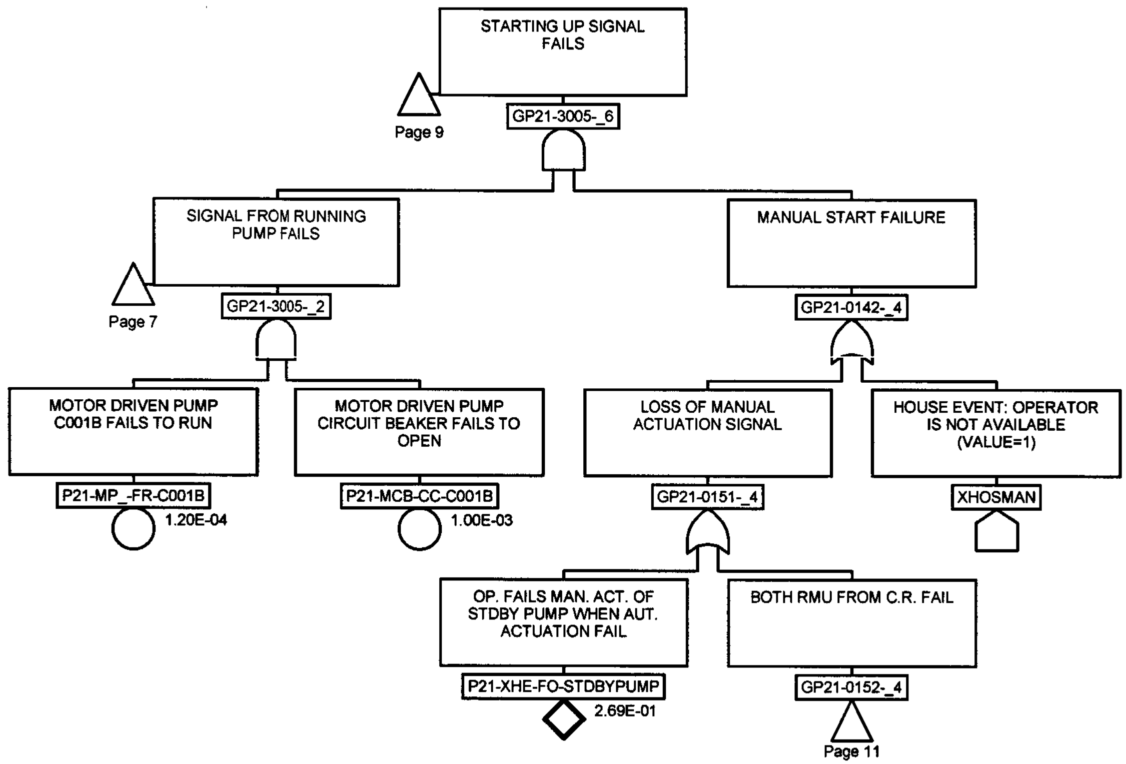

STANDBY PUMP 2A FAILS
GP21-0005-_3
Page 12
Page 2
PUMP C002A IN MAINTENANCE
P21-MP_-TM-C002A
2.00E-03
LOSS OF 6.9 KV AC FROM BUS R11-A2
GR11-0001-_1
MOTOR-DRIVEN PUMP (ALL TYPES) FAILS TO START
P21-MP_-FS-C002A
1.30E-03
DIV. A (NE RTNSS) SIGNAL TRANSMISSION FAILURE
GC62-0001-_1
MEDIUM VOLTAGE CIRCUIT BREAKER FAILS TO CLOSE
P21-MCB-OO-C002A
1.00E-03
CCF 2 PUMPS (INTRADIVISON A) TO START
P21-MP_-CS-2A
2.60E-05
MOTOR-DRIVEN PUMP C002A FAILS TO RUN
P21-MP_-FR-C002A
1.20E-04
CCF 3 PUMPS TO RUN (INTRADIVISON A)
P21-MP_-CR-3A
2.40E-06
CHECK VALVE F005A FAILS TO OPEN
P21-UV_-CC-F005A
2.00E-04
STARTING UP SIGNAL FAILS
GP21-3005-_3
Page 13
1
2

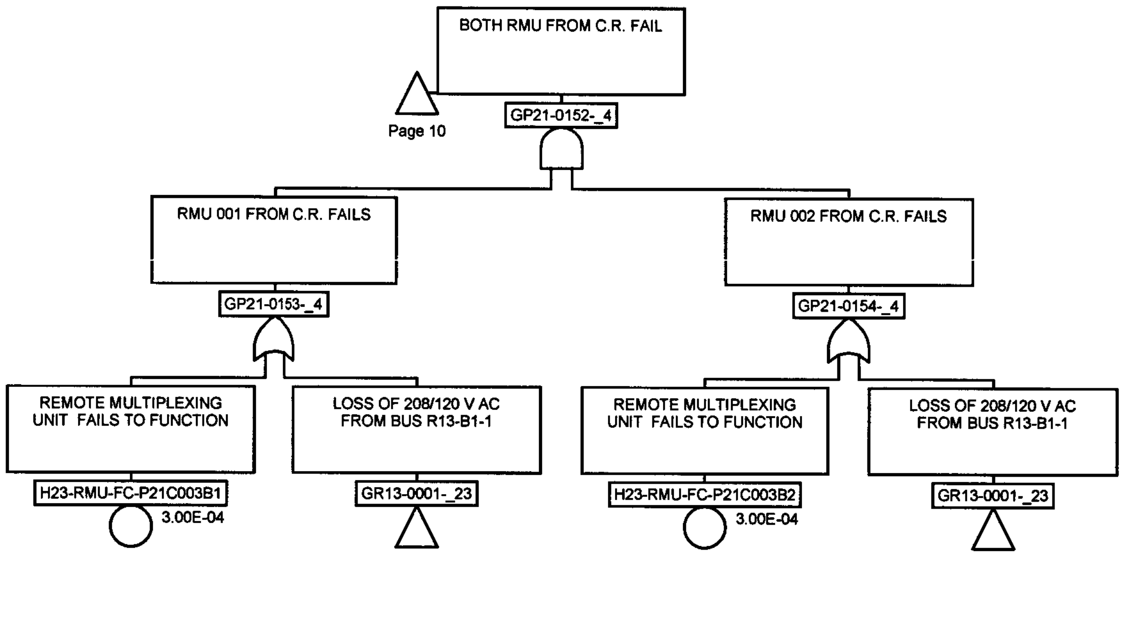

STANDBY PUMP 2B FAILS
Page 2
Page 16
GP21-0005-_4
PUMP C002B IN MAINTENANCE
P21-MP_-TM-C002B
2.00E-03
LOSS OF 6.9 KV AC FROM BUS R11-B2
GR11-0001-_2
MOTOR-DRIVEN PUMP C002B FAILS TO START
P21-MP_-FS-C002B
1.30E-03
DIV. B (NE RTNSS) SIGNAL TRANSMISSION FAILURE
GC62-0001-_2
MEDIUM VOLTAGE CIRCUIT BREAKER FAILS TO CLOSE
P21-MCB-OO-C002B
1.00E-03
CCF 2 PUMPS (INTRADIVISON B) TO START
P21-MP_-CS-2B
2.60E-05
MOTOR-DRIVEN PUMP C002B FAILS TO RUN
P21-MP_-FR-C002B
1.20E-04
CCF 3 PUMPS TO RUN (INTRADIVISON B)
P21-MP_-CR-3B
1.20E-06
CHECK VALVE F005B FAILS TO OPEN
P21-UV_-CC-F005B
2.00E-04
STARTING UP SIGNAL FAILS
GP21-3005-_4
Page 7
1
2


STARTING UP SIGNAL FAILS
GP21-3005-_4
Page 6
SIGNAL FROM RUNNING PUMP FAILS
GP21-3005-_2
Page 10
MANUAL RECOVERY FAILURE
GP21-0142-_2
Page 51
1
2


STANDBY PUMP 3A FAILS
GP21-0005-_5
Page 12
Page 2
MOTOR-DRIVEN PUMP C0003A FAILS TO START
P21-MP_-FS-C003A
1.30E-03
DIV. A (NE RTNSS) SIGNAL TRANSMISSION FAILURE
GC62-0001-_1
MOTOR-DRIVEN PUMP C0003A FAILS TO RUN
P21-MP_-FR-C003A
1.20E-04
CCF 3 PUMPS TO RUN (INTRADIVISON A)
P21-MP_-CR-3A
2.40E-06
MEDIUM VOLTAGE CIRCUIT BREAKER FAILS TO CLOSE
P21-MCB-OO-C003A
1.00E-03
CCF 2 PUMPS (INTRADIVISON A) TO START
P21-MP_-CS-2A
2.60E-05
CHECK VALVE F007A FAILS TO OPEN
P21-UV_-CC-F007A
2.00E-04
STARTING UP SIGNAL FAILS
GP21-3005-_5
Page 14
LOSS OF 6.9 KV AC FROM BUS R11-A2
GR11-0001-_1
1
2


STANDBY PUMP 3B FAILS
GP21-0005-_6
Page 2
Page 16
MOTOR-DRIVEN PUMP C003B FAILS TO START
P21-MP_-FS-C003B
1.30E-03
DIV. B (NE RTNSS) SIGNAL TRANSMISSION FAILURE
GC62-0001-_2
MEDIUM VOLTAGE CIRCUIT BREAKER FAILS TO CLOSE
P21-MCB-OO-C003B
1.00E-03
CCF 3 PUMPS TO RUN (INTRADIVISON B)
P21-MP_-CR-3B
1.20E-06
MOTOR-DRIVEN PUMP C003B FAILS TO RUN
P21-MP_-FR-C003B
1.20E-04
CCF 2 PUMPS (INTRADIVISON B) TO START
P21-MP_-CS-2B
2.60E-05
CHECK VALVE F007B FAILS TO OPEN
P21-UV_-CC-F007B
2.00E-04
STARTING UP SIGNAL FAILS
GP21-3005-_6
Page 10
LOSS OF 6.9 KV AC FROM BUS R11-B2
GR11-0001-_2
1
2


STARTING UP SIGNAL FAILS
GP21-3005-_6
Page 9
SIGNAL FROM RUNNING PUMP FAILS
GP21-3005-_2
Page 7
MANUAL START FAILURE
GP21-0142-_4
MOTOR DRIVEN PUMP C001B FAILS TO RUN
P21-MP_-FR-C001B
1.20E-04
MOTOR DRIVEN PUMP CIRCUIT BEAKER FAILS TO OPEN
P21-MCB-CC-C001B
1.00E-03
LOSS OF MANUAL ACTUATION SIGNAL
GP21-0151-_4
HOUSE EVENT: OPERATOR IS NOT AVAILABLE (VALUE=1)
XHOSMAN
OP. FAILS MAN. ACT. OF STDBY PUMP WHEN AUT. ACTUATION FAIL
P21-XHE-FO-STDBYPUMP
2.69E-01
BOTH RMU FROM C.R. FAIL
GP21-0152-_4
Page 11
1
2
3
4


BOTH RMU FROM C.R. FAIL
Page 10
GP21-0152-_4
RMU 001 FROM C.R. FAILS
GP21-0153-_4
RMU 002 FROM C.R. FAILS
GP21-0154-_4
REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION
H23-RMU-FC-P21C003B1
3.00E-04
LOSS OF 208/120 V AC FROM BUS R13-B1-1
GR13-0001-_23
REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION
H23-RMU-FC-P21C003B2
3.00E-04
LOSS OF 208/120 V AC FROM BUS R13-B1-1
GR13-0001-_23
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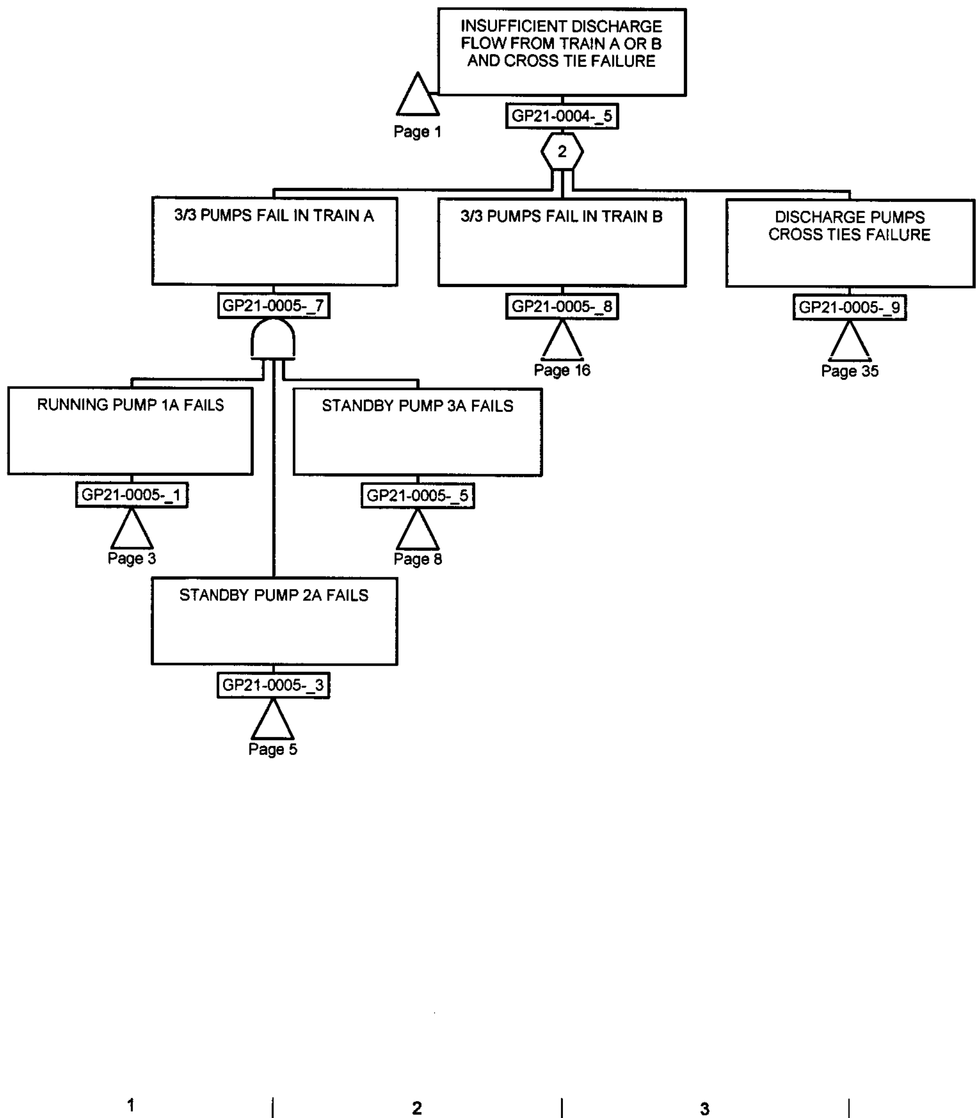
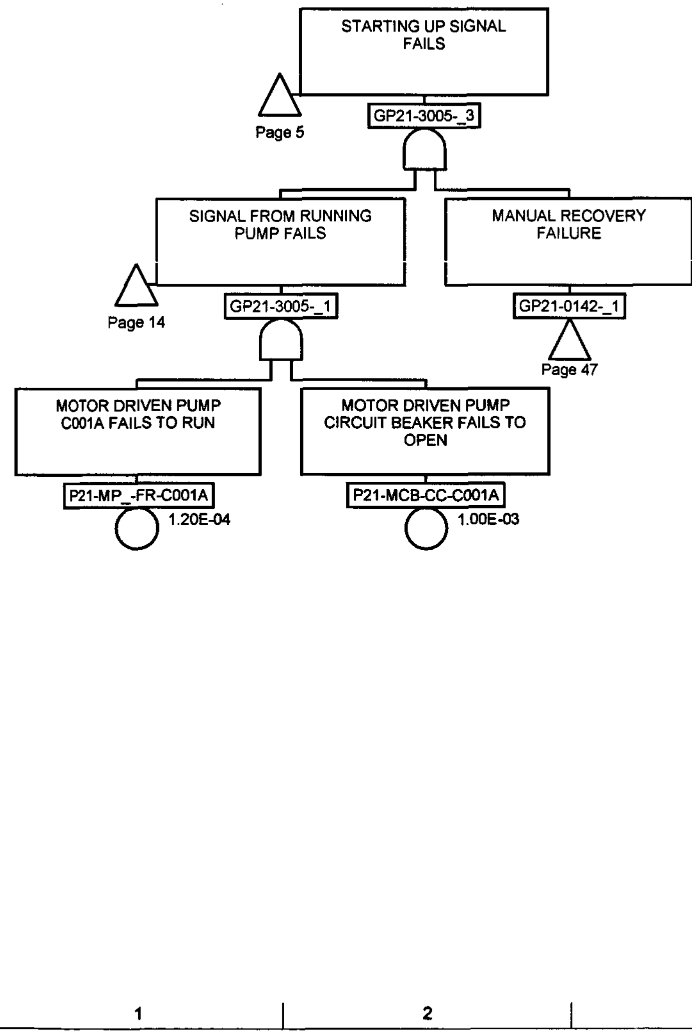

INSUFFICIENT DISCHARGE FLOW FROM TRAIN A OR B AND CROSS TIE FAILURE
GP21-0004-_5
Page 1
2
3/3 PUMPS FAIL IN TRAIN A
GP21-0005-_7
3/3 PUMPS FAIL IN TRAIN B
GP21-0005-_8
Page 16
DISCHARGE PUMPS CROSS TIES FAILURE
GP21-0005-_9
Page 35
RUNNING PUMP 1A FAILS
GP21-0005-_1
Page 3
STANDBY PUMP 3A FAILS
GP21-0005-_5
Page 8
STANDBY PUMP 2A FAILS
GP21-0005-_3
Page 5
1
2
3


STARTING UP SIGNAL FAILS
GP21-3005-_3
Page 5
SIGNAL FROM RUNNING PUMP FAILS
GP21-3005-_1
Page 14
MANUAL RECOVERY FAILURE
GP21-0142-_1
Page 47
MOTOR DRIVEN PUMP C001A FAILS TO RUN
P21-MP_-FR-C001A
1.20E-04
MOTOR DRIVEN PUMP CIRCUIT BEAKER FAILS TO OPEN
P21-MCB-CC-C001A
1.00E-03
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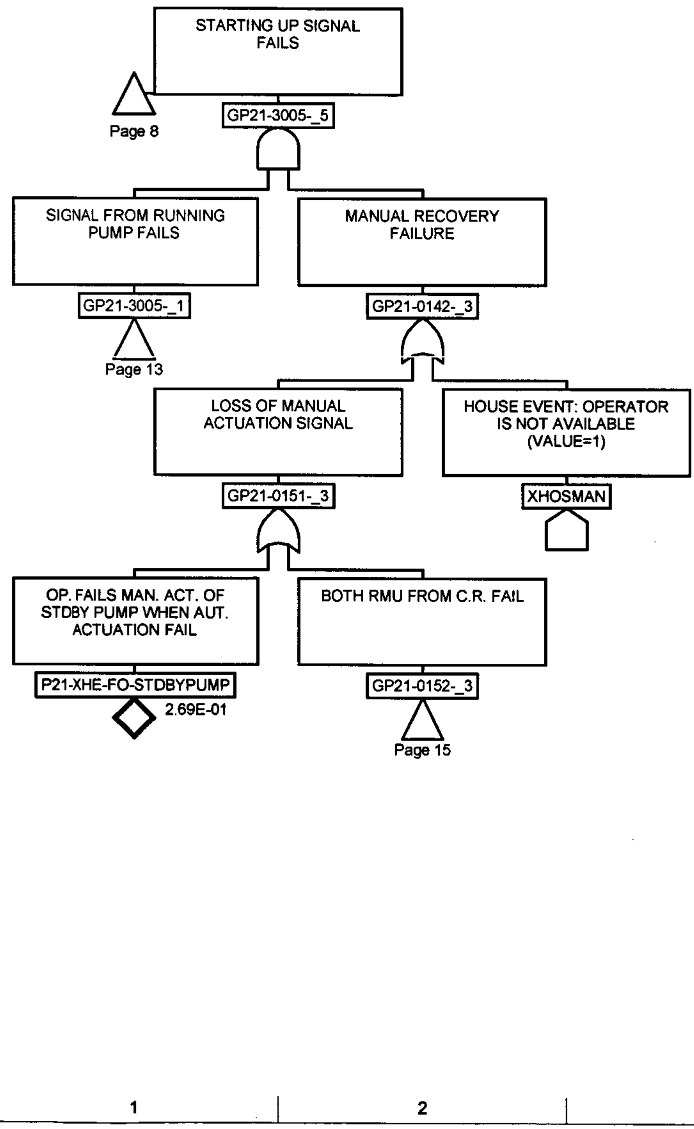
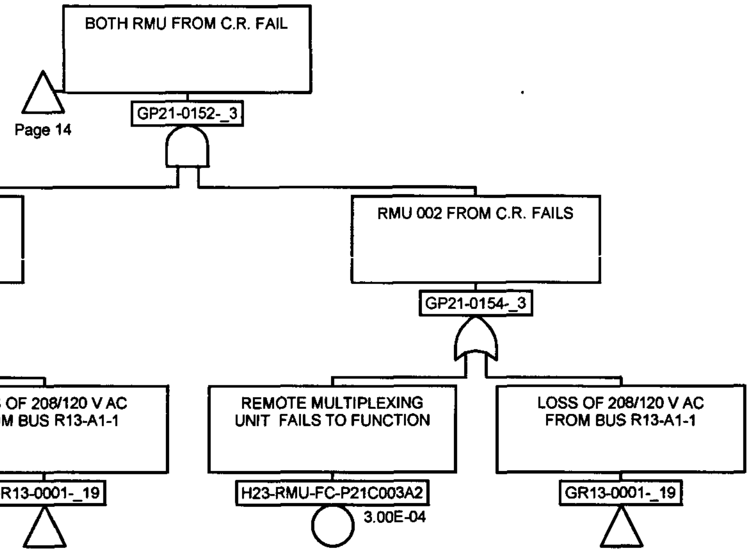

STARTING UP SIGNAL FAILS
GP21-3005-_5
Page 8
SIGNAL FROM RUNNING PUMP FAILS
GP21-3005-_1
Page 13
MANUAL RECOVERY FAILURE
GP21-0142-_3
LOSS OF MANUAL ACTUATION SIGNAL
GP21-0151-_3
HOUSE EVENT: OPERATOR IS NOT AVAILABLE (VALUE=1)
XHOSMAN
OP. FAILS MAN. ACT. OF STDBY PUMP WHEN AUT. ACTUATION FAIL
P21-XHE-FO-STDBYPUMP
2.69E-01
BOTH RMU FROM C.R. FAIL
GP21-0152-_3
Page 15
1
2


BOTH RMU FROM C.R. FAIL
Page 14
GP21-0152-_3
RMU 001 FROM C.R. FAILS
GP21-0153-_3
RMU 002 FROM C.R. FAILS
GP21-0154-_3
REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION
H23-RMU-FC-P21C003A1
3.00E-04
LOSS OF 208/120 V AC FROM BUS R13-A1-1
GR13-0001-_19
REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION
H23-RMU-FC-P21C003A2
3.00E-04
LOSS OF 208/120 V AC FROM BUS R13-A1-1
GR13-0001-_19
1
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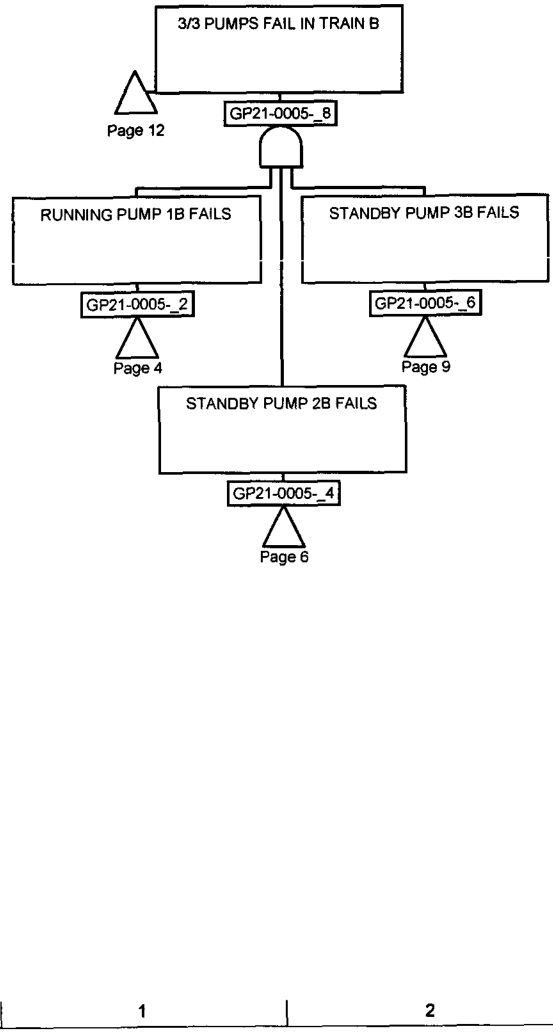
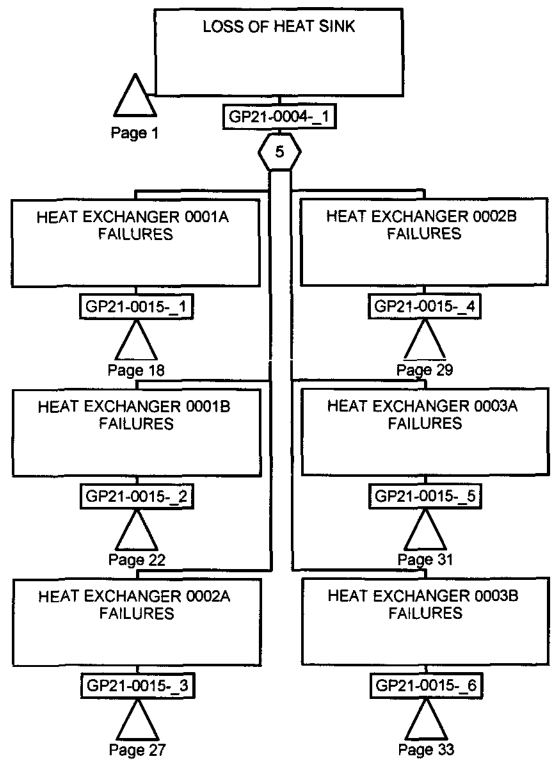
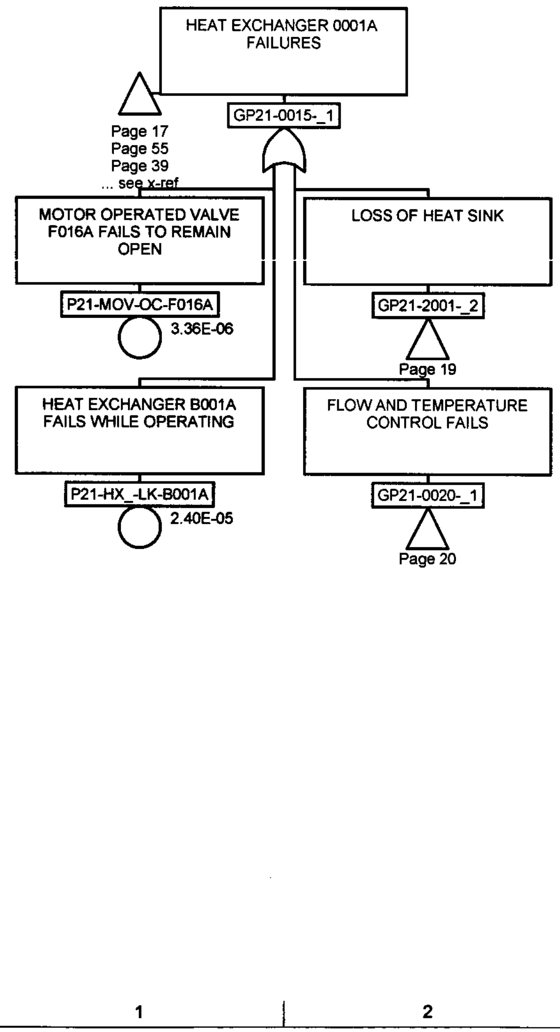
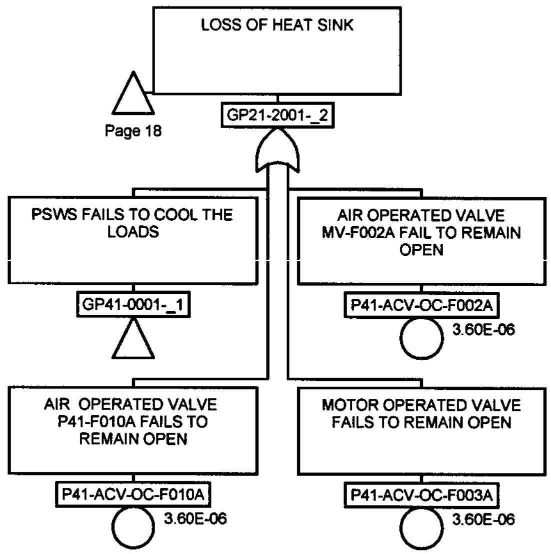
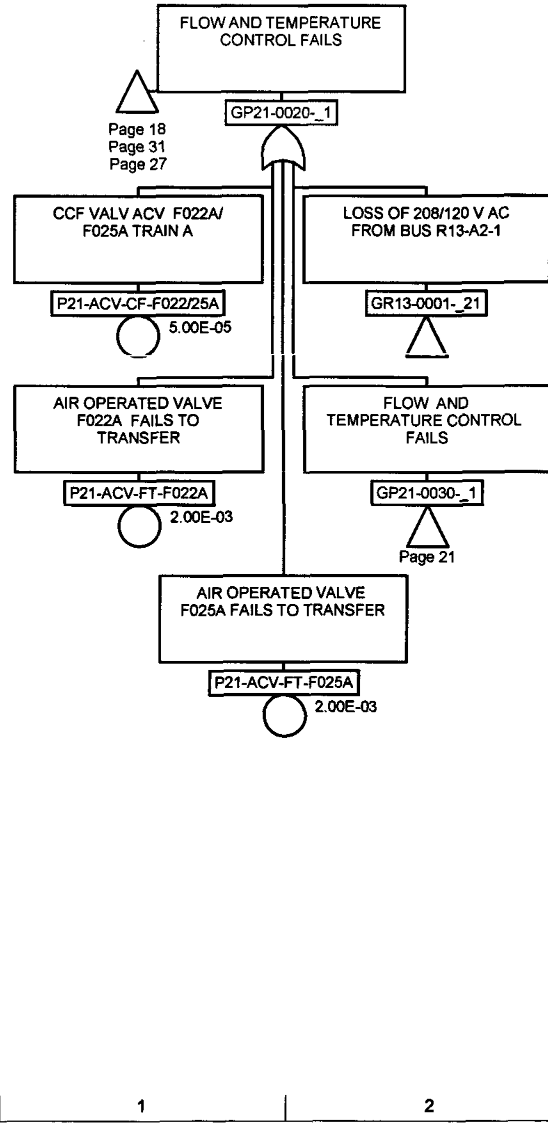
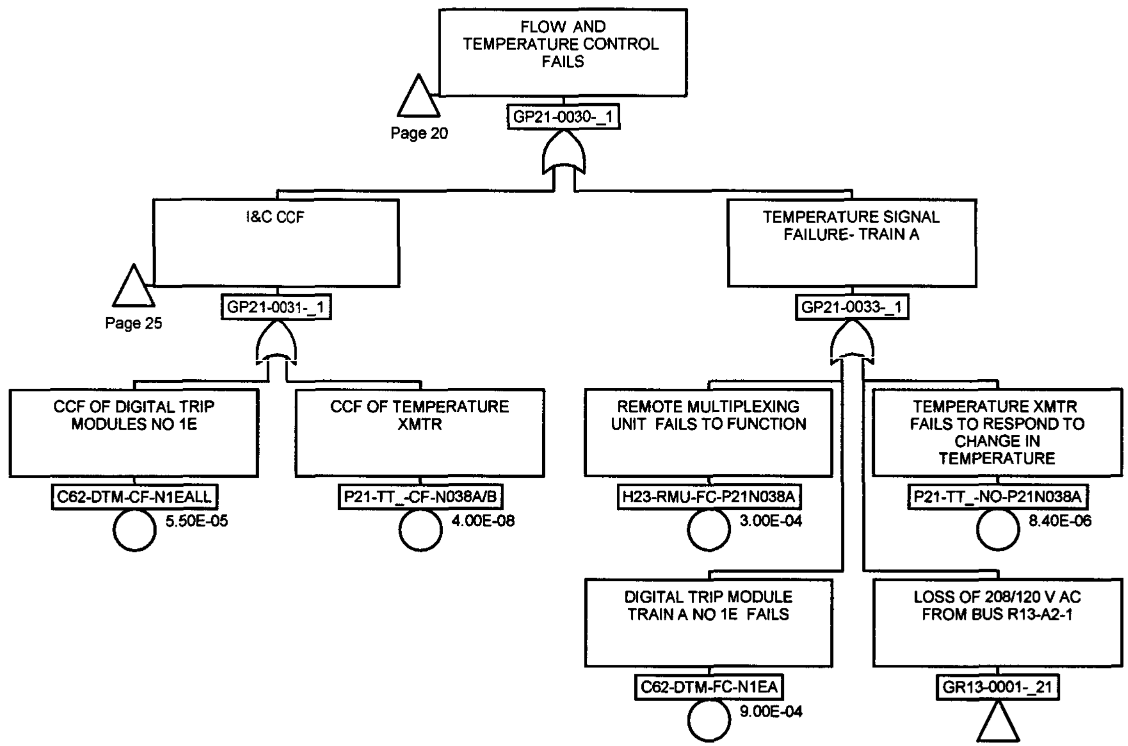

3/3 PUMPS FAIL IN TRAIN B
GP21-0005-_8
Page 12
RUNNING PUMP 1B FAILS
GP21-0005-_2
Page 4
STANDBY PUMP 3B FAILS
GP21-0005-_6
Page 9
STANDBY PUMP 2B FAILS
GP21-0005-_4
Page 6
1
2

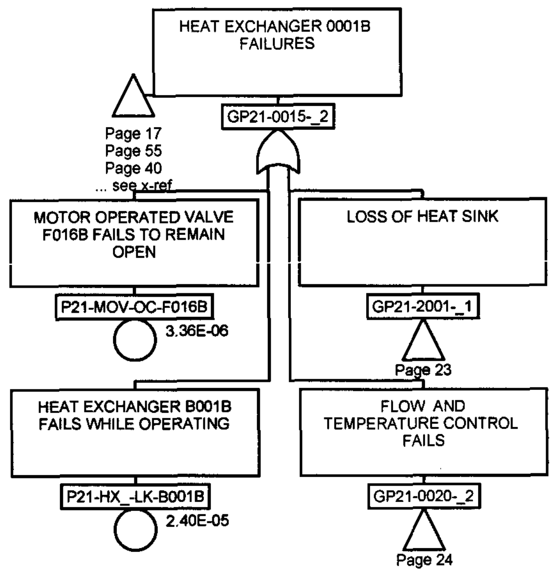

LOSS OF HEAT SINK
Page 1
GP21-0004-_1
5
HEAT EXCHANGER 0001A FAILURES
GP21-0015-_1
Page 18
HEAT EXCHANGER 0002B FAILURES
GP21-0015-_4
Page 29
HEAT EXCHANGER 0001B FAILURES
GP21-0015-_2
Page 22
HEAT EXCHANGER 0003A FAILURES
GP21-0015-_5
Page 31
HEAT EXCHANGER 0002A FAILURES
GP21-0015-_3
Page 27
HEAT EXCHANGER 0003B FAILURES
GP21-0015-_6
Page 33
1
2

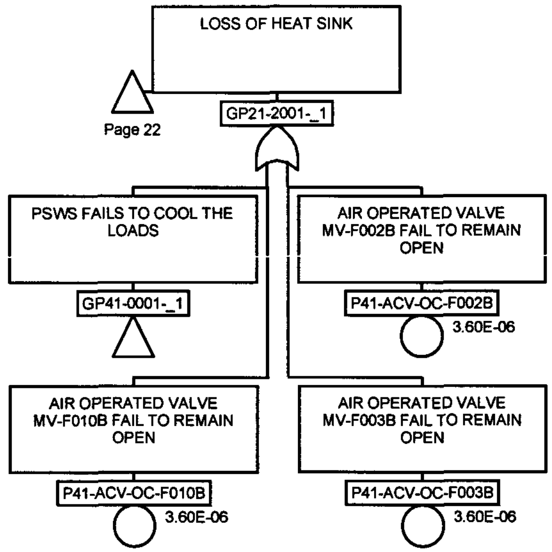

HEAT EXCHANGER 0001A FAILURES
GP21-0015-_1
Page 17
Page 55
Page 39
... see x-ref
MOTOR OPERATED VALVE F016A FAILS TO REMAIN OPEN
P21-MOV-OC-F016A
3.36E-06
LOSS OF HEAT SINK
GP21-2001-_2
Page 19
HEAT EXCHANGER B001A FAILS WHILE OPERATING
P21-HX_-LK-B001A
2.40E-05
FLOW AND TEMPERATURE CONTROL FAILS
GP21-0020-_1
Page 20
1
2


LOSS OF HEAT SINK
Page 18
GP21-2001-_2
PSWS FAILS TO COOL THE LOADS
GP41-0001-_1
AIR OPERATED VALVE MV-F002A FAIL TO REMAIN OPEN
P41-ACV-OC-F002A
3.60E-06
AIR OPERATED VALVE P41-F010A FAILS TO REMAIN OPEN
P41-ACV-OC-F010A
3.60E-06
MOTOR OPERATED VALVE FAILS TO REMAIN OPEN
P41-ACV-OC-F003A
3.60E-06
1
2


FLOW AND TEMPERATURE CONTROL FAILS
GP21-0020-_1
Page 18
Page 31
Page 27
CCF VALV ACV F022A/ F025A TRAIN A
P21-ACV-CF-F022/25A
5.00E-05
LOSS OF 208/120 V AC FROM BUS R13-A2-1
GR13-0001-_21
AIR OPERATED VALVE F022A FAILS TO TRANSFER
P21-ACV-FT-F022A
2.00E-03
FLOW AND TEMPERATURE CONTROL FAILS
GP21-0030-_1
Page 21
AIR OPERATED VALVE F025A FAILS TO TRANSFER
P21-ACV-FT-F025A
2.00E-03
1
2


FLOW AND TEMPERATURE CONTROL FAILS
GP21-0030-_1
Page 20
I&C CCF
GP21-0031-_1
Page 25
TEMPERATURE SIGNAL FAILURE- TRAIN A
GP21-0033-_1
CCF OF DIGITAL TRIP MODULES NO 1E
C62-DTM-CF-N1EALL
5.50E-05
CCF OF TEMPERATURE XMTR
P21-TT_-CF-N038A/B
4.00E-08
REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION
H23-RMU-FC-P21N038A
3.00E-04
TEMPERATURE XMTR FAILS TO RESPOND TO CHANGE IN TEMPERATURE
P21-TT_-NO-P21N038A
8.40E-06
DIGITAL TRIP MODULE TRAIN A NO 1E FAILS
C62-DTM-FC-N1EA
9.00E-04
LOSS OF 208/120 V AC FROM BUS R13-A2-1
GR13-0001-_21


HEAT EXCHANGER 0001B FAILURES
GP21-0015-_2
Page 17
Page 55
Page 40
... see x-ref
MOTOR OPERATED VALVE F016B FAILS TO REMAIN OPEN
P21-MOV-OC-F016B
3.36E-06
LOSS OF HEAT SINK
GP21-2001-_1
Page 23
HEAT EXCHANGER B001B FAILS WHILE OPERATING
P21-HX_-LK-B001B
2.40E-05
FLOW AND TEMPERATURE CONTROL FAILS
GP21-0020-_2
Page 24


LOSS OF HEAT SINK
GP21-2001-_1
Page 22
PSWS FAILS TO COOL THE LOADS
GP41-0001-_1
AIR OPERATED VALVE MV-F002B FAIL TO REMAIN OPEN
P41-ACV-OC-F002B
3.60E-06
AIR OPERATED VALVE MV-F010B FAIL TO REMAIN OPEN
P41-ACV-OC-F010B
3.60E-06
AIR OPERATED VALVE MV-F003B FAIL TO REMAIN OPEN
P41-ACV-OC-F003B
3.60E-06
1
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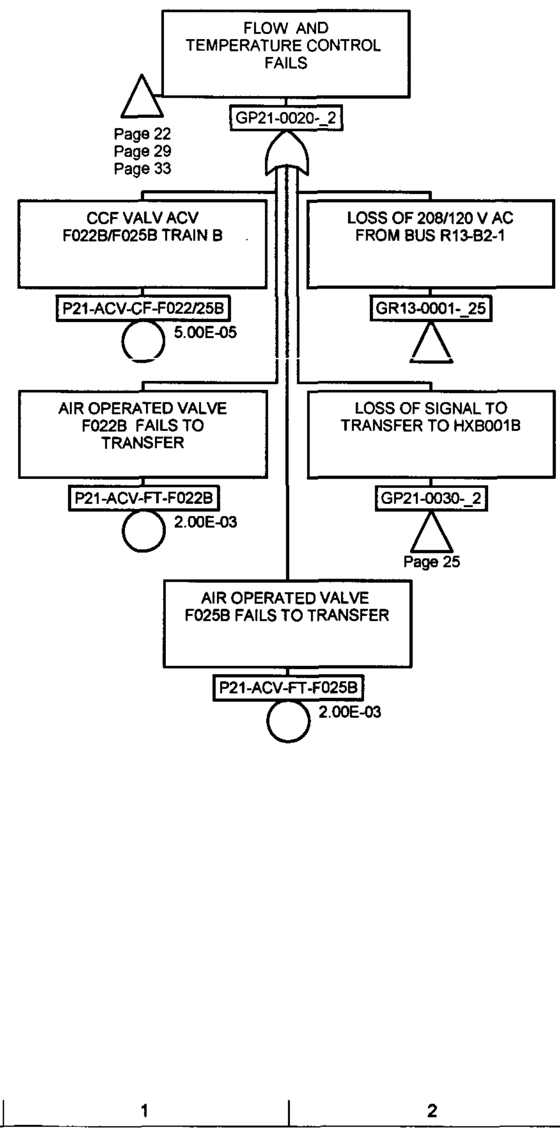
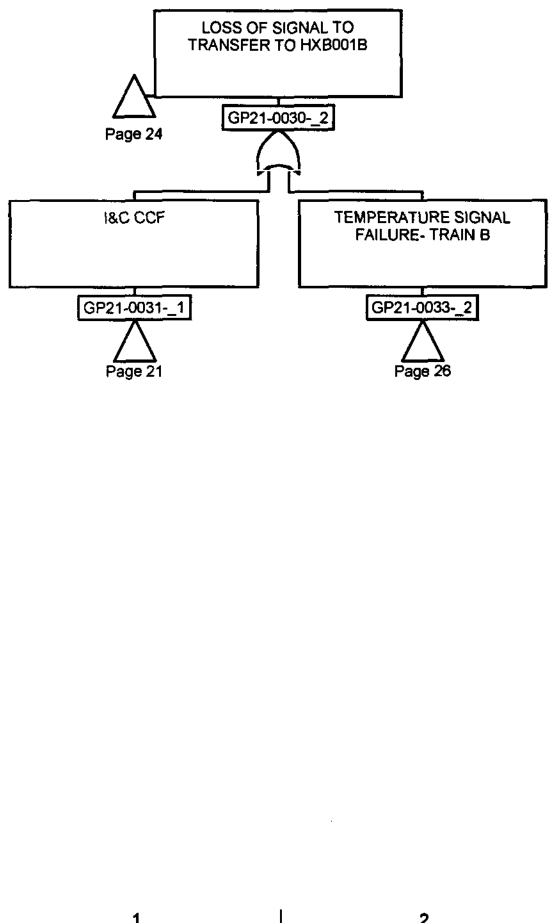
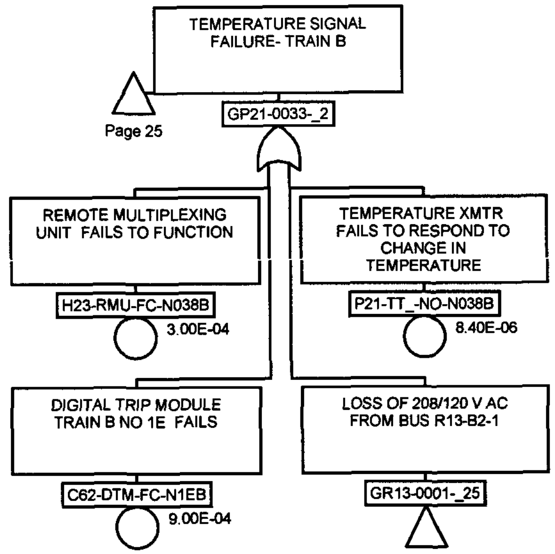

FLOW AND TEMPERATURE CONTROL FAILS
GP21-0020-_2
Page 22
Page 29
Page 33
CCF VALV ACV F022B/F025B TRAIN B
P21-ACV-CF-F022/25B
5.00E-05
LOSS OF 208/120 V AC FROM BUS R13-B2-1
GR13-0001-_25
AIR OPERATED VALVE F022B FAILS TO TRANSFER
P21-ACV-FT-F022B
2.00E-03
LOSS OF SIGNAL TO TRANSFER TO HXB001B
GP21-0030-_2
Page 25
AIR OPERATED VALVE F025B FAILS TO TRANSFER
P21-ACV-FT-F025B
2.00E-03
1
2


LOSS OF SIGNAL TO TRANSFER TO HXB001B
Page 24
GP21-0030-_2
I&C CCF
GP21-0031-_1
Page 21
TEMPERATURE SIGNAL FAILURE- TRAIN B
GP21-0033-_2
Page 26
1
2


TEMPERATURE SIGNAL FAILURE- TRAIN B
Page 25
GP21-0033-_2
REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION
H23-RMU-FC-N038B
3.00E-04
TEMPERATURE XMTR FAILS TO RESPOND TO CHANGE IN TEMPERATURE
P21-TT_-NO-N038B
8.40E-06
DIGITAL TRIP MODULE TRAIN B NO 1E FAILS
C62-DTM-FC-N1EB
9.00E-04
LOSS OF 208/120 V AC FROM BUS R13-B2-1
GR13-0001-_25

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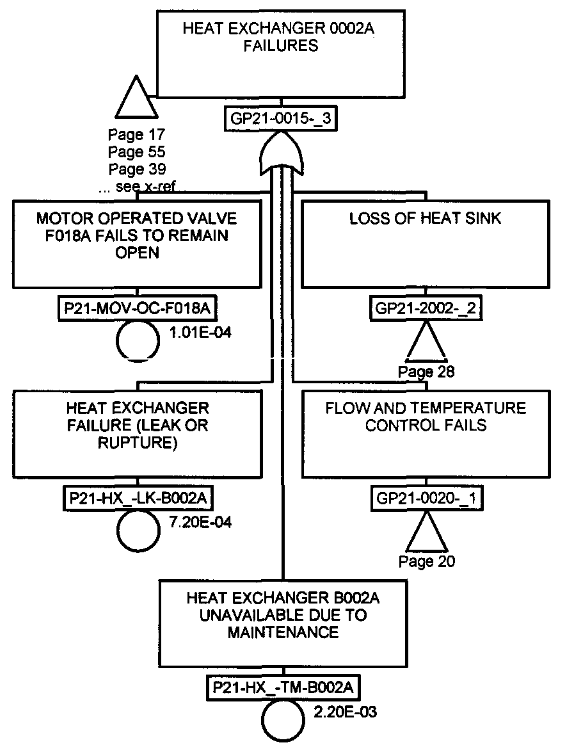
HEAT EXCHANGER 0002A FAILURES
GP21-0015-_3
Page 17
Page 55
Page 39
... see x-ref
MOTOR OPERATED VALVE F018A FAILS TO REMAIN OPEN
P21-MOV-OC-F018A
1.01E-04
LOSS OF HEAT SINK
GP21-2002-_2
Page 28
HEAT EXCHANGER FAILURE (LEAK OR RUPTURE)
P21-HX_-LK-B002A
7.20E-04
FLOW AND TEMPERATURE CONTROL FAILS
GP21-0020-_1
Page 20
HEAT EXCHANGER B002A UNAVAILABLE DUE TO MAINTENANCE
P21-HX_-TM-B002A
2.20E-03
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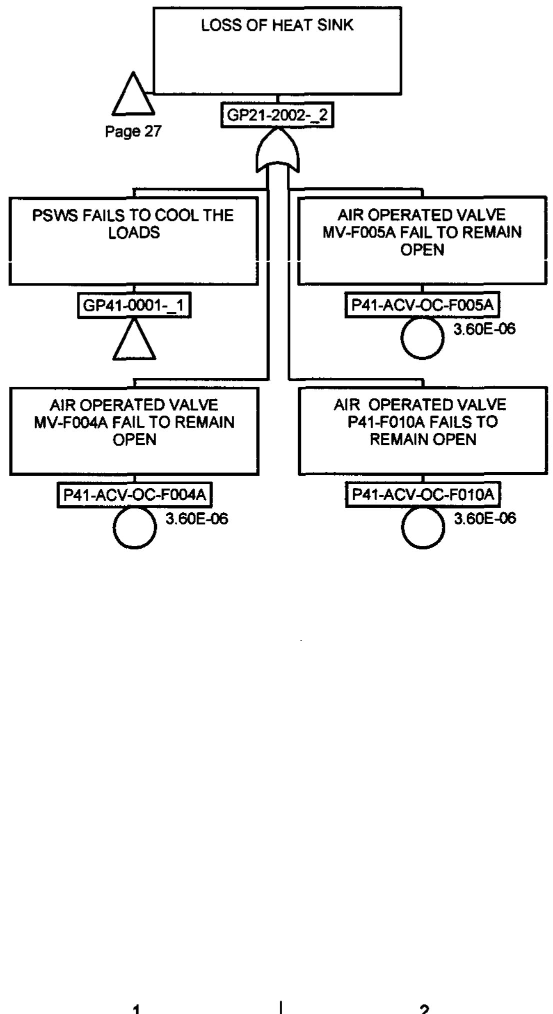
2



LOSS OF HEAT SINK
Page 27
GP21-2002-_2
PSWS FAILS TO COOL THE LOADS
GP41-0001-_1
AIR OPERATED VALVE MV-F005A FAIL TO REMAIN OPEN
P41-ACV-OC-F005A
3.60E-06
AIR OPERATED VALVE MV-F004A FAIL TO REMAIN OPEN
P41-ACV-OC-F004A
3.60E-06
AIR OPERATED VALVE P41-F010A FAILS TO REMAIN OPEN
P41-ACV-OC-F010A
3.60E-06
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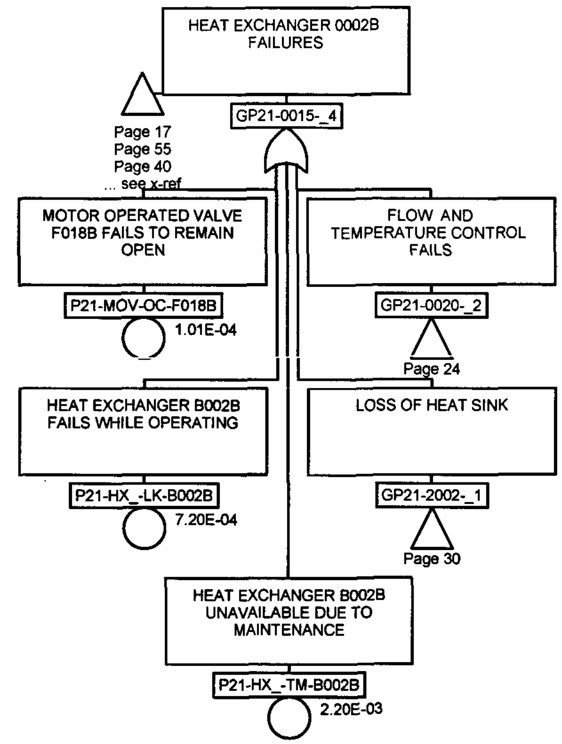
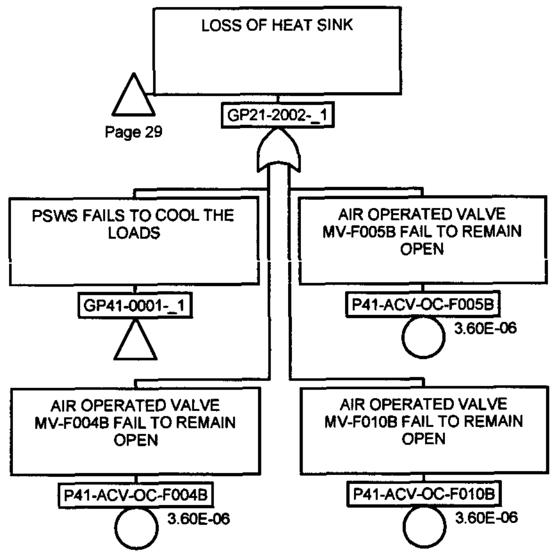
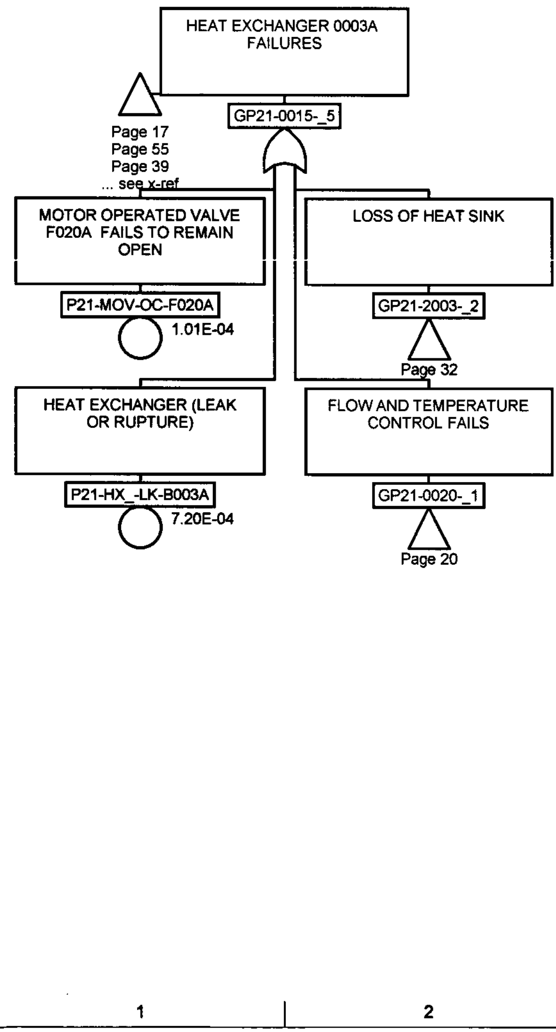
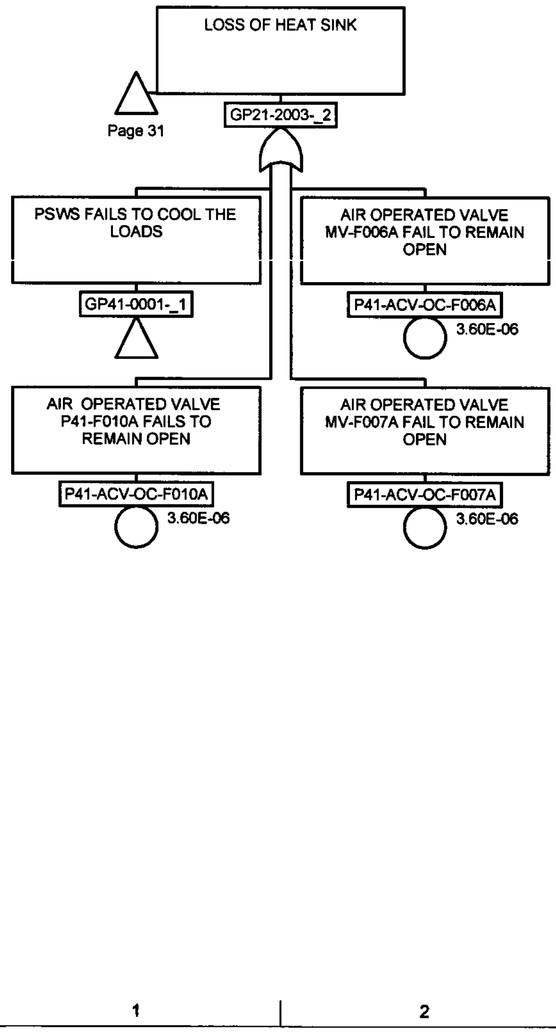

HEAT EXCHANGER 0002B FAILURES
GP21-0015-_4
Page 17
Page 55
Page 40
... see x-ref
MOTOR OPERATED VALVE F018B FAILS TO REMAIN OPEN
P21-MOV-OC-F018B
1.01E-04
FLOW AND TEMPERATURE CONTROL FAILS
GP21-0020-_2
Page 24
HEAT EXCHANGER B002B FAILS WHILE OPERATING
P21-HX_-LK-B002B
7.20E-04
LOSS OF HEAT SINK
GP21-2002-_1
Page 30
HEAT EXCHANGER B002B UNAVAILABLE DUE TO MAINTENANCE
P21-HX_-TM-B002B
2.20E-03
1
2



LOSS OF HEAT SINK
GP21-2002-_1
Page 29
PSWS FAILS TO COOL THE LOADS
GP41-0001-_1
AIR OPERATED VALVE MV-F005B FAIL TO REMAIN OPEN
P41-ACV-OC-F005B
3.60E-06
AIR OPERATED VALVE MV-F004B FAIL TO REMAIN OPEN
P41-ACV-OC-F004B
3.60E-06
AIR OPERATED VALVE MV-F010B FAIL TO REMAIN OPEN
P41-ACV-OC-F010B
3.60E-06


HEAT EXCHANGER 0003A FAILURES
GP21-0015-_5
Page 17
Page 55
Page 39
... see x-ref
MOTOR OPERATED VALVE F020A FAILS TO REMAIN OPEN
P21-MOV-OC-F020A
1.01E-04
LOSS OF HEAT SINK
GP21-2003-_2
Page 32
HEAT EXCHANGER (LEAK OR RUPTURE)
P21-HX_-LK-B003A
7.20E-04
FLOW AND TEMPERATURE CONTROL FAILS
GP21-0020-_1
Page 20
1
2


LOSS OF HEAT SINK
Page 31
GP21-2003-_2
PSWS FAILS TO COOL THE LOADS
GP41-0001-_1
AIR OPERATED VALVE MV-F006A FAIL TO REMAIN OPEN
P41-ACV-OC-F006A
3.60E-06
AIR OPERATED VALVE P41-F010A FAILS TO REMAIN OPEN
P41-ACV-OC-F010A
3.60E-06
AIR OPERATED VALVE MV-F007A FAIL TO REMAIN OPEN
P41-ACV-OC-F007A
3.60E-06
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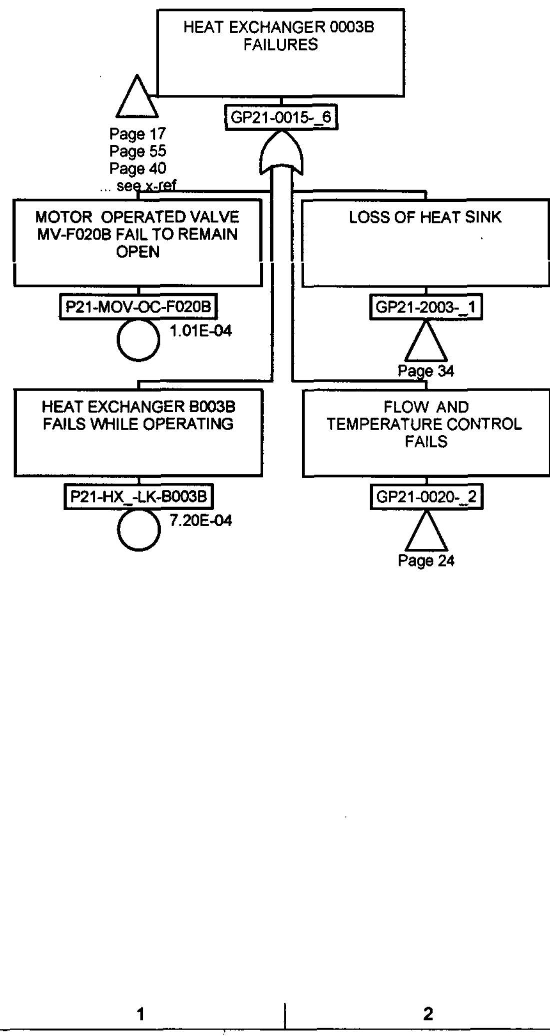
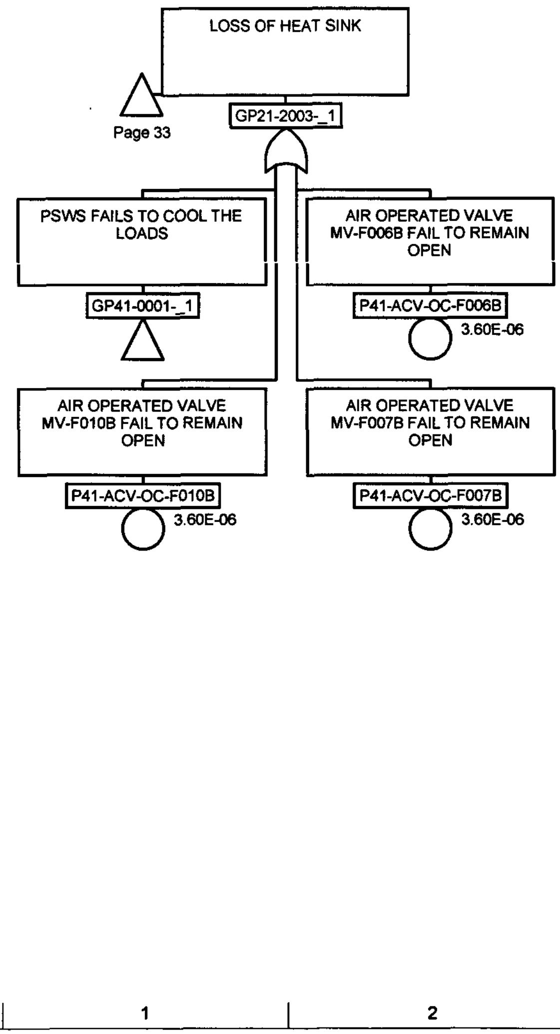

HEAT EXCHANGER 0003B FAILURES
GP21-0015-_6
Page 17
Page 55
Page 40
... see x-ref
MOTOR OPERATED VALVE MV-F020B FAIL TO REMAIN OPEN
P21-MOV-OC-F020B
1.01E-04
LOSS OF HEAT SINK
GP21-2003-_1
Page 34
HEAT EXCHANGER B003B FAILS WHILE OPERATING
P21-HX_-LK-B003B
7.20E-04
FLOW AND TEMPERATURE CONTROL FAILS
GP21-0020-_2
Page 24
1
2


LOSS OF HEAT SINK
Page 33
GP21-2003-_1
PSWS FAILS TO COOL THE LOADS
GP41-0001-_1
AIR OPERATED VALVE MV-F006B FAIL TO REMAIN OPEN
P41-ACV-OC-F006B
3.60E-06
AIR OPERATED VALVE MV-F010B FAIL TO REMAIN OPEN
P41-ACV-OC-F010B
3.60E-06
AIR OPERATED VALVE MV-F007B FAIL TO REMAIN OPEN
P41-ACV-OC-F007B
3.60E-06
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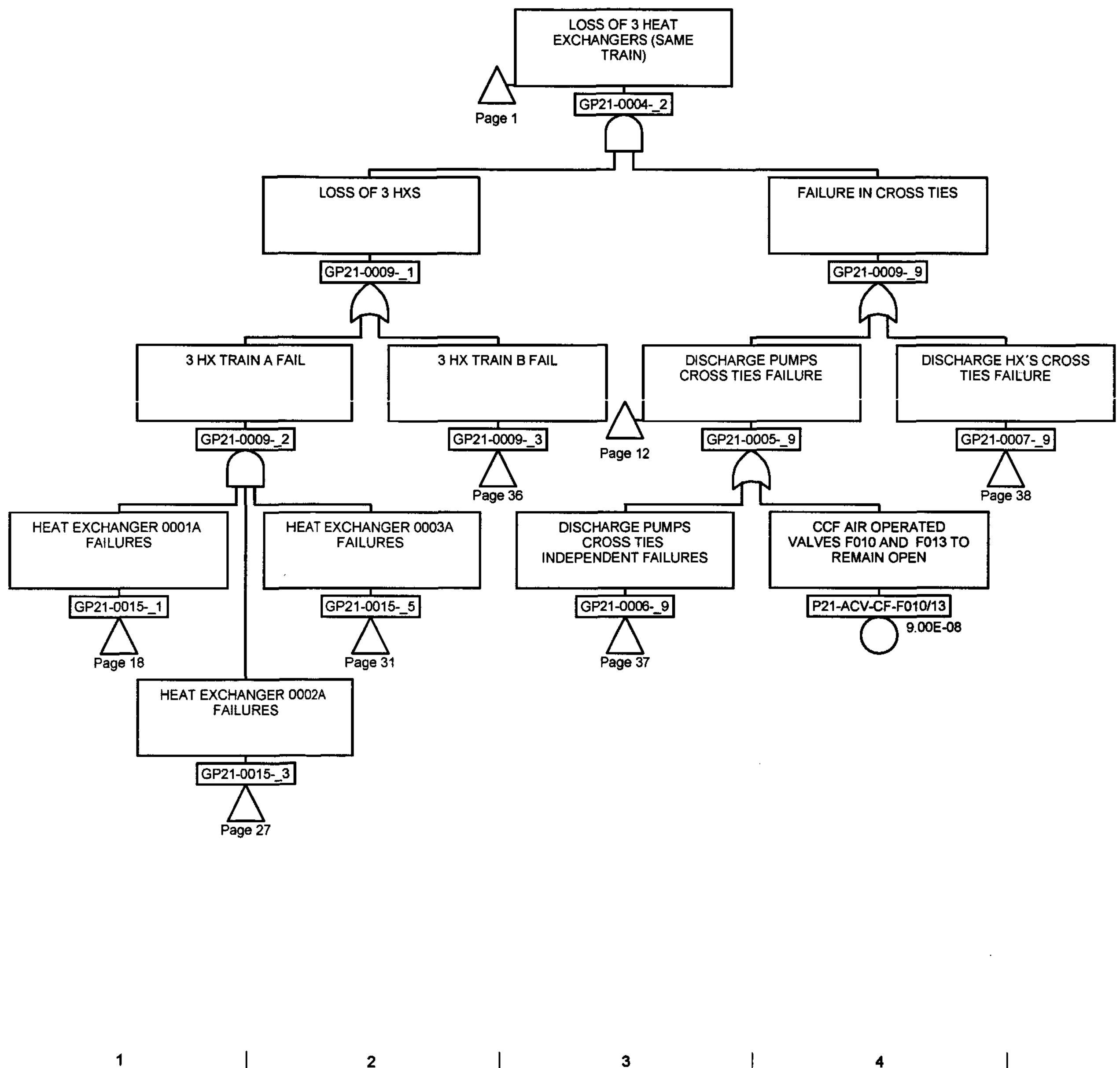
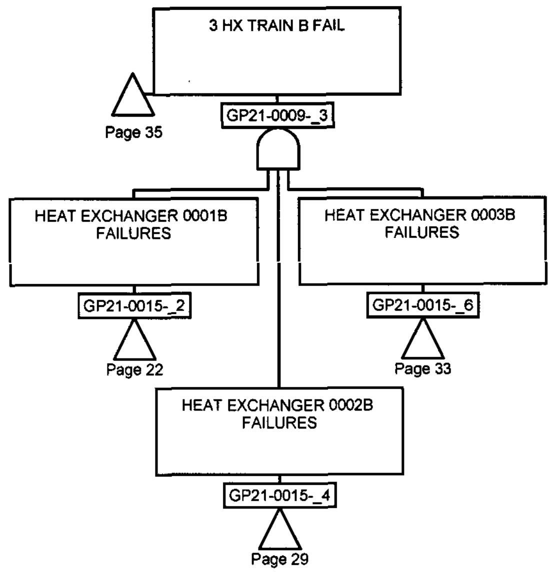
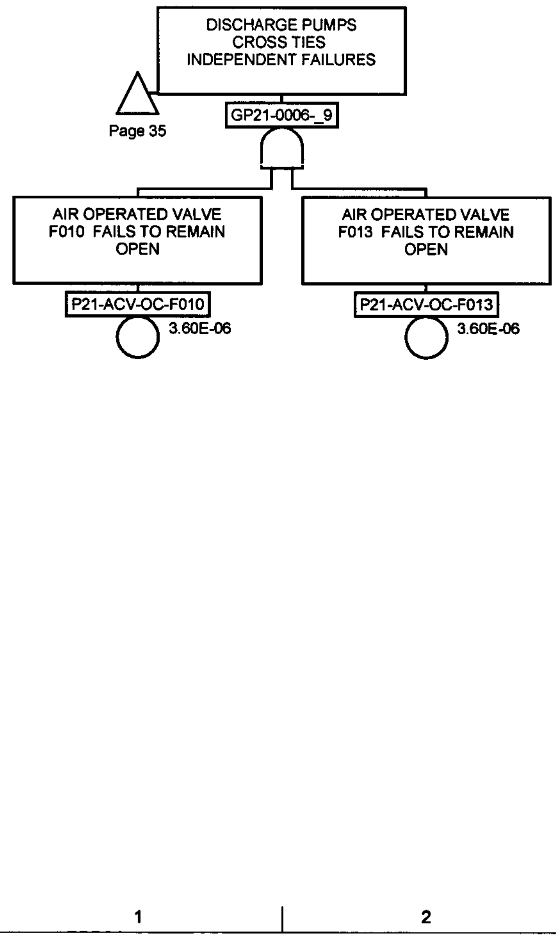
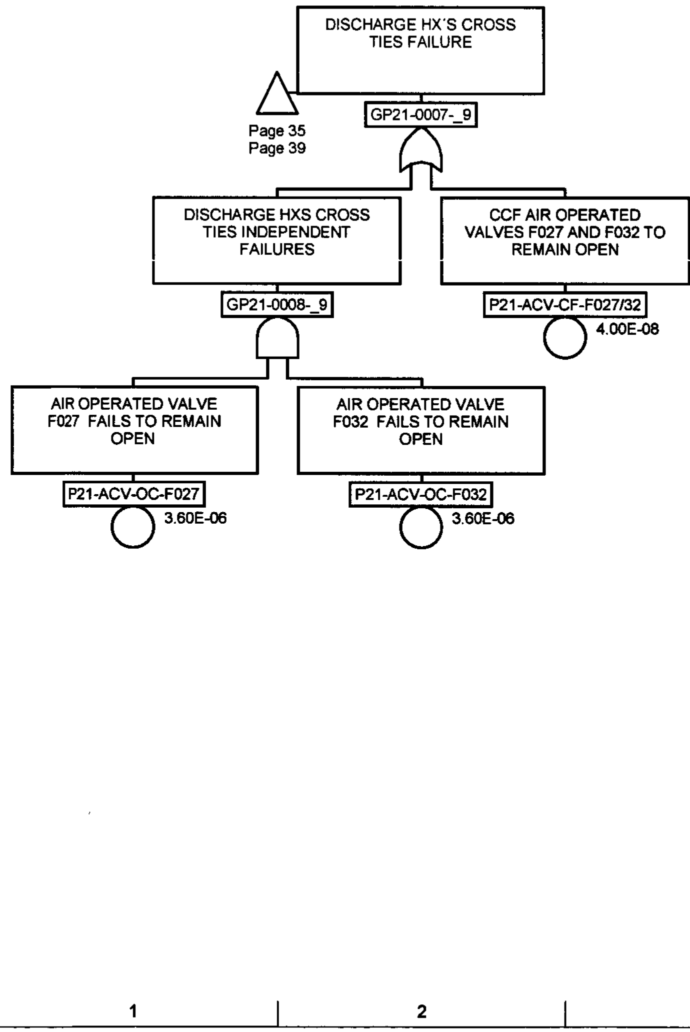
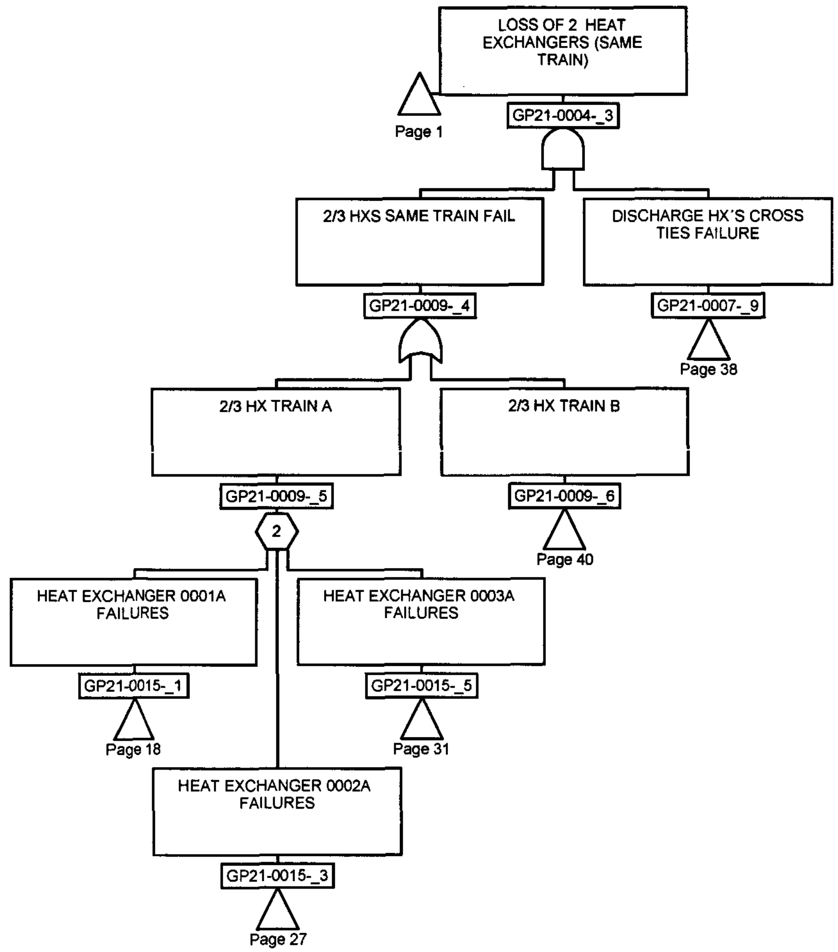
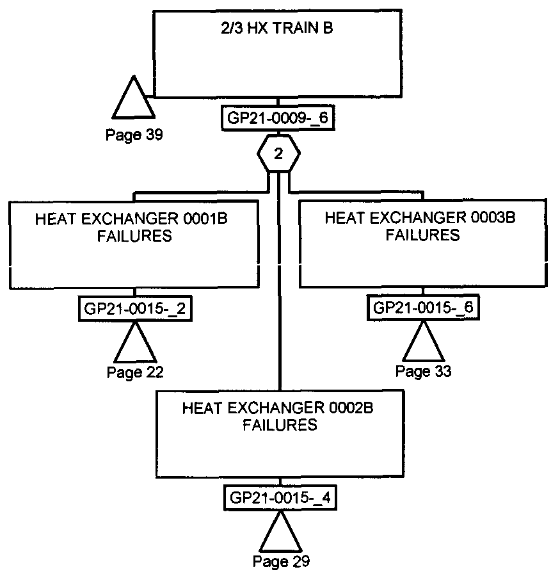

LOSS OF 3 HEAT EXCHANGERS (SAME TRAIN)
GP21-0004-_2
Page 1
LOSS OF 3 HXS
GP21-0009-_1
FAILURE IN CROSS TIES
GP21-0009-_9
3 HX TRAIN A FAIL
GP21-0009-_2
3 HX TRAIN B FAIL
GP21-0009-_3
Page 36
DISCHARGE PUMPS CROSS TIES FAILURE
GP21-0005-_9
Page 12
DISCHARGE HX'S CROSS TIES FAILURE
GP21-0007-_9
Page 38
HEAT EXCHANGER 0001A FAILURES
GP21-0015-_1
Page 18
HEAT EXCHANGER 0003A FAILURES
GP21-0015-_5
Page 31
DISCHARGE PUMPS CROSS TIES INDEPENDENT FAILURES
GP21-0006-_9
Page 37
CCF AIR OPERATED VALVES F010 AND F013 TO REMAIN OPEN
P21-ACV-CF-F010/13
9.00E-08
HEAT EXCHANGER 0002A FAILURES
GP21-0015-_3
Page 27
1
2
3
4

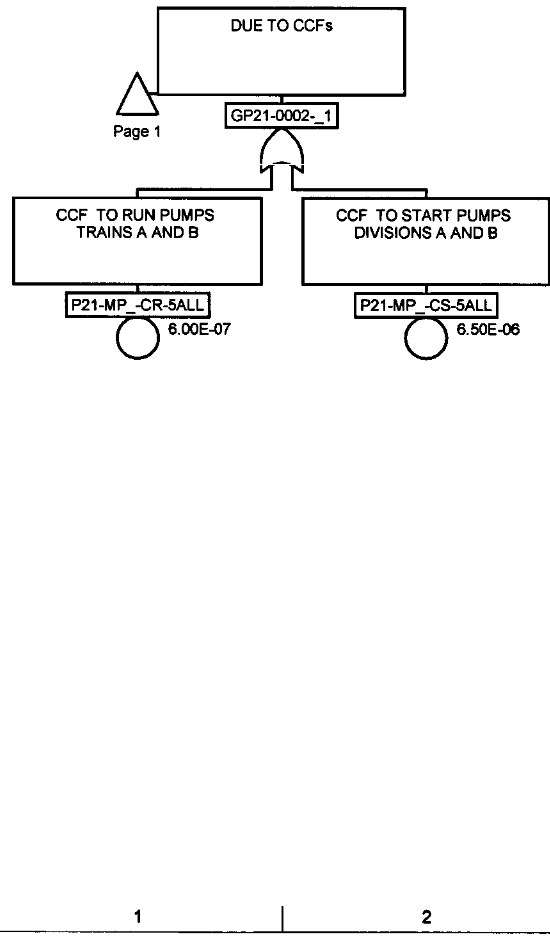

3 HX TRAIN B FAIL
GP21-0009-_3
Page 35
HEAT EXCHANGER 0001B FAILURES
GP21-0015-_2
Page 22
HEAT EXCHANGER 0003B FAILURES
GP21-0015-_6
Page 33
HEAT EXCHANGER 0002B FAILURES
GP21-0015-_4
Page 29

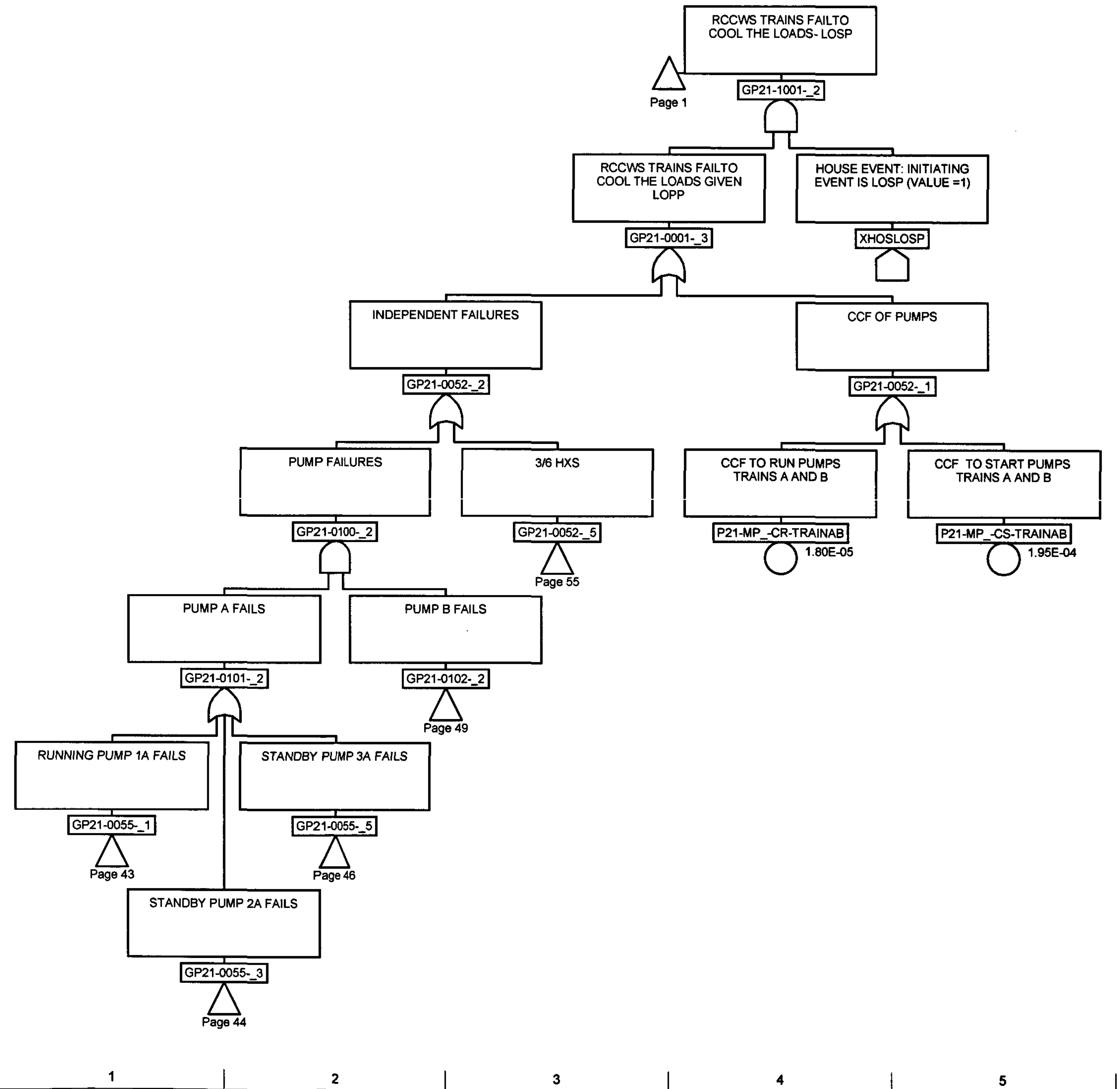

DISCHARGE PUMPS CROSS TIES INDEPENDENT FAILURES
GP21-0006-_9
Page 35
AIR OPERATED VALVE F010 FAILS TO REMAIN OPEN
P21-ACV-OC-F010
3.60E-06
AIR OPERATED VALVE F013 FAILS TO REMAIN OPEN
P21-ACV-OC-F013
3.60E-06
1
2

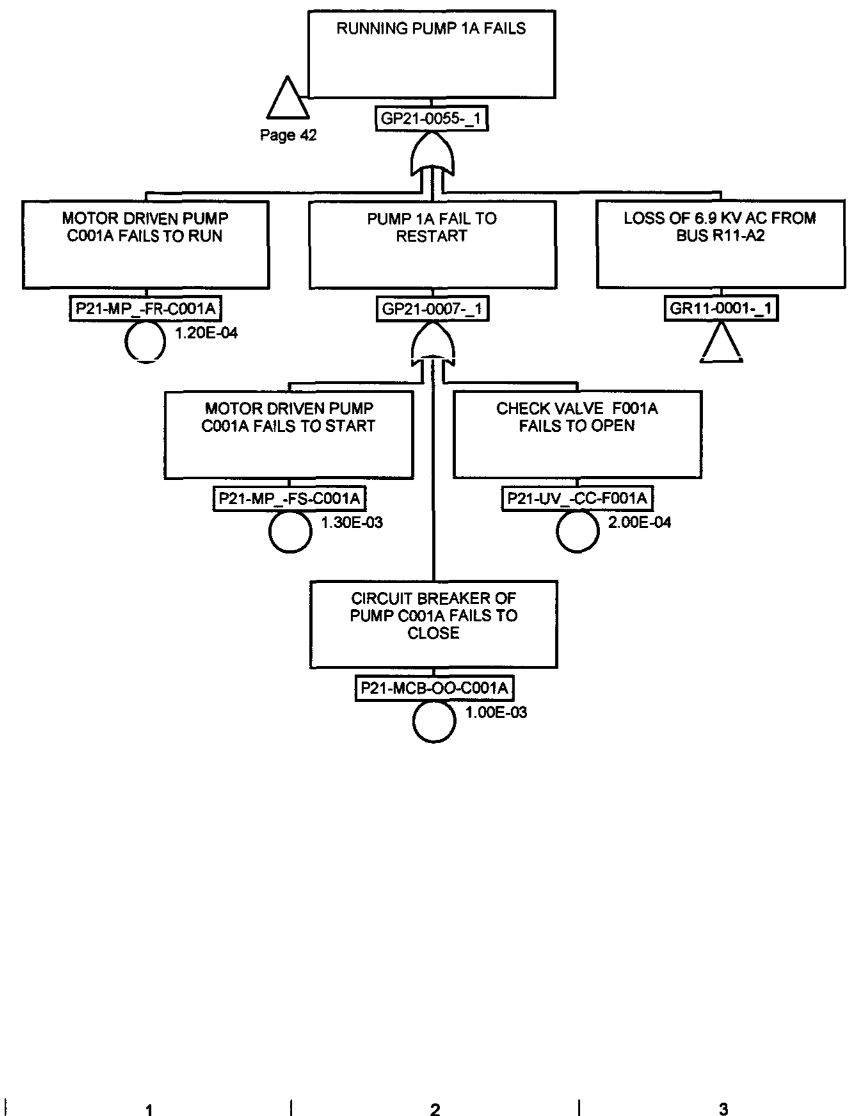

DISCHARGE HX'S CROSS TIES FAILURE
GP21-0007-_9
Page 35
Page 39
DISCHARGE HXS CROSS TIES INDEPENDENT FAILURES
GP21-0008-_9
CCF AIR OPERATED VALVES F027 AND F032 TO REMAIN OPEN
P21-ACV-CF-F027/32
4.00E-08
AIR OPERATED VALVE F027 FAILS TO REMAIN OPEN
P21-ACV-OC-F027
3.60E-06
AIR OPERATED VALVE F032 FAILS TO REMAIN OPEN
P21-ACV-OC-F032
3.60E-06
1
2


LOSS OF 2 HEAT EXCHANGERS (SAME TRAIN)
Page 1
GP21-0004-_3
2/3 HXS SAME TRAIN FAIL
GP21-0009-_4
DISCHARGE HX'S CROSS TIES FAILURE
GP21-0007-_9
Page 38
2/3 HX TRAIN A
GP21-0009-_5
2
2/3 HX TRAIN B
GP21-0009-_6
Page 40
HEAT EXCHANGER 0001A FAILURES
GP21-0015-_1
Page 18
HEAT EXCHANGER 0003A FAILURES
GP21-0015-_5
Page 31
HEAT EXCHANGER 0002A FAILURES
GP21-0015-_3
Page 27


2/3 HX TRAIN B
Page 39
GP21-0009-_6
2
HEAT EXCHANGER 0001B FAILURES
GP21-0015-_2
Page 22
HEAT EXCHANGER 0003B FAILURES
GP21-0015-_6
Page 33
HEAT EXCHANGER 0002B FAILURES
GP21-0015-_4
Page 29


DUE TO CCFs
GP21-0002-_1
Page 1
CCF TO RUN PUMPS TRAINS A AND B
P21-MP_-CR-5ALL
6.00E-07
CCF TO START PUMPS DIVISIONS A AND B
P21-MP_-CS-5ALL
6.50E-06
1
2


RCCWS TRAINS FAILTO COOL THE LOADS- LOSP
Page 1
GP21-1001-_2
RCCWS TRAINS FAILTO COOL THE LOADS GIVEN LOPP
GP21-0001-_3
HOUSE EVENT: INITIATING EVENT IS LOSP (VALUE =1)
XHOSLOSP
INDEPENDENT FAILURES
GP21-0052-_2
CCF OF PUMPS
GP21-0052-_1
PUMP FAILURES
GP21-0100-_2
3/6 HXS
GP21-0052-_5
Page 55
CCF TO RUN PUMPS TRAINS A AND B
P21-MP_-CR-TRAINAB
1.80E-05
CCF TO START PUMPS TRAINS A AND B
P21-MP_-CS-TRAINAB
1.95E-04
PUMP A FAILS
GP21-0101-_2
PUMP B FAILS
GP21-0102-_2
Page 49
RUNNING PUMP 1A FAILS
GP21-0055-_1
Page 43
STANDBY PUMP 3A FAILS
GP21-0055-_5
Page 46
STANDBY PUMP 2A FAILS
GP21-0055-_3
Page 44
1
2
3
4
5


RUNNING PUMP 1A FAILS
GP21-0055-_1
Page 42
MOTOR DRIVEN PUMP C001A FAILS TO RUN
P21-MP_-FR-C001A
1.20E-04
PUMP 1A FAIL TO RESTART
GP21-0007-_1
LOSS OF 6.9 KV AC FROM BUS R11-A2
GR11-0001-_1
MOTOR DRIVEN PUMP C001A FAILS TO START
P21-MP_-FS-C001A
1.30E-03
CHECK VALVE F001A FAILS TO OPEN
P21-UV_-CC-F001A
2.00E-04
CIRCUIT BREAKER OF PUMP C001A FAILS TO CLOSE
P21-MCB-OO-C001A
1.00E-03
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2
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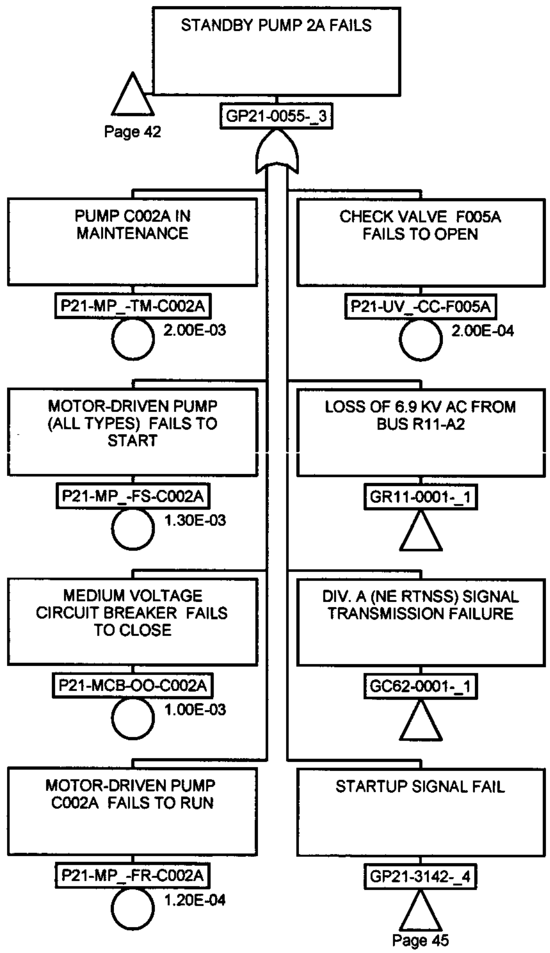
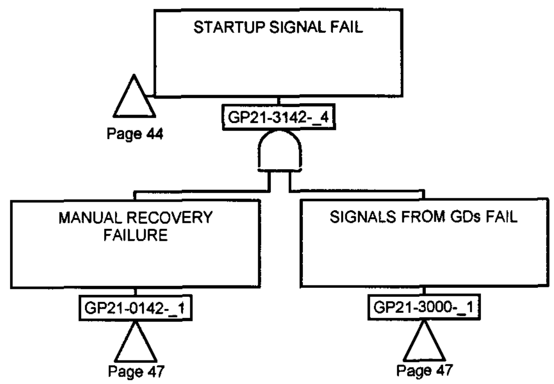
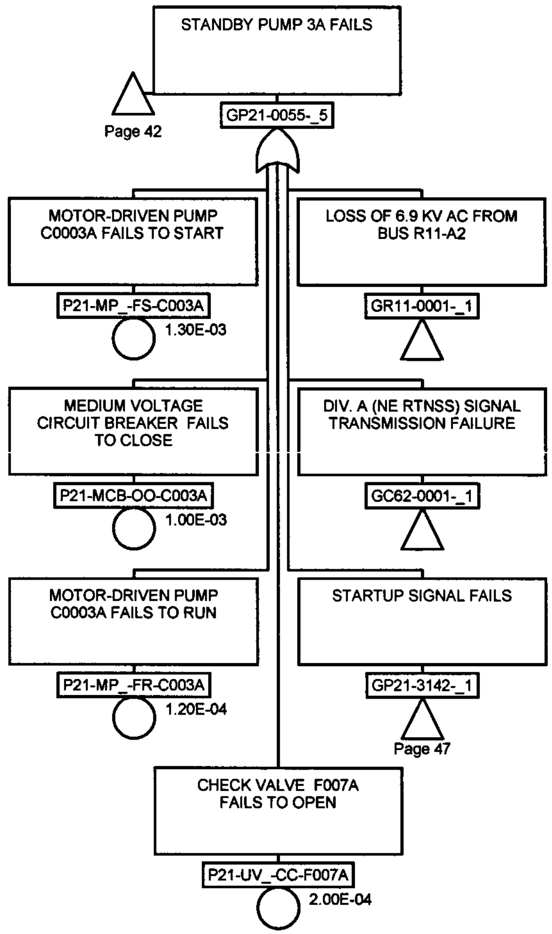
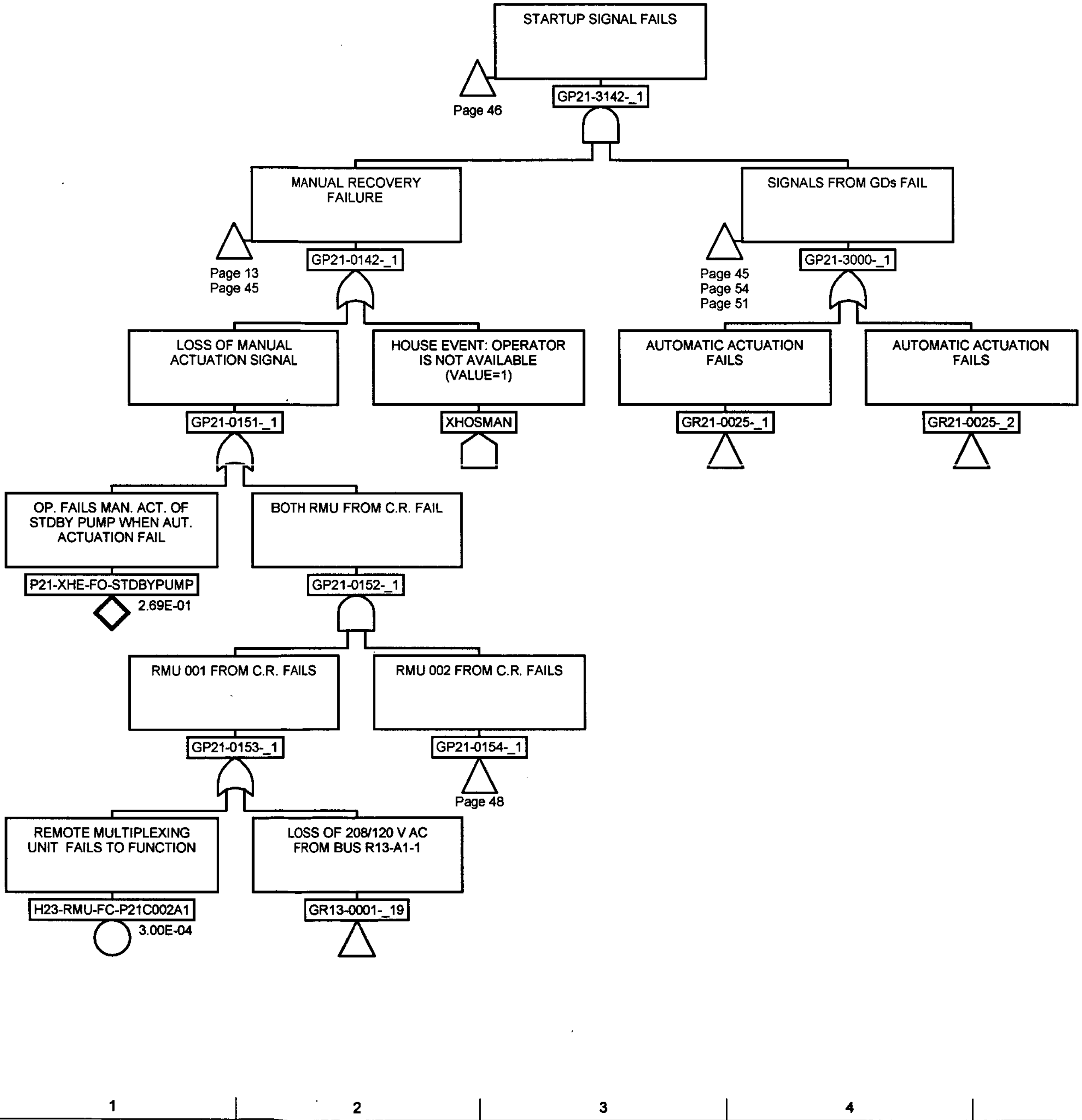
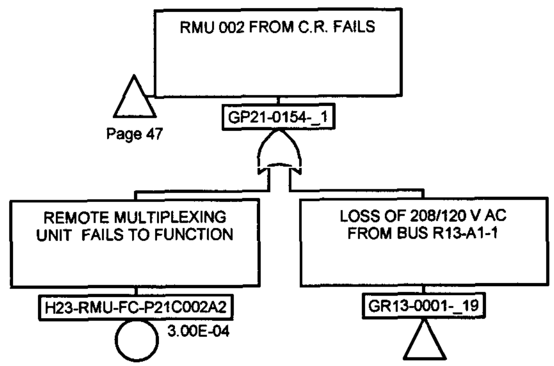
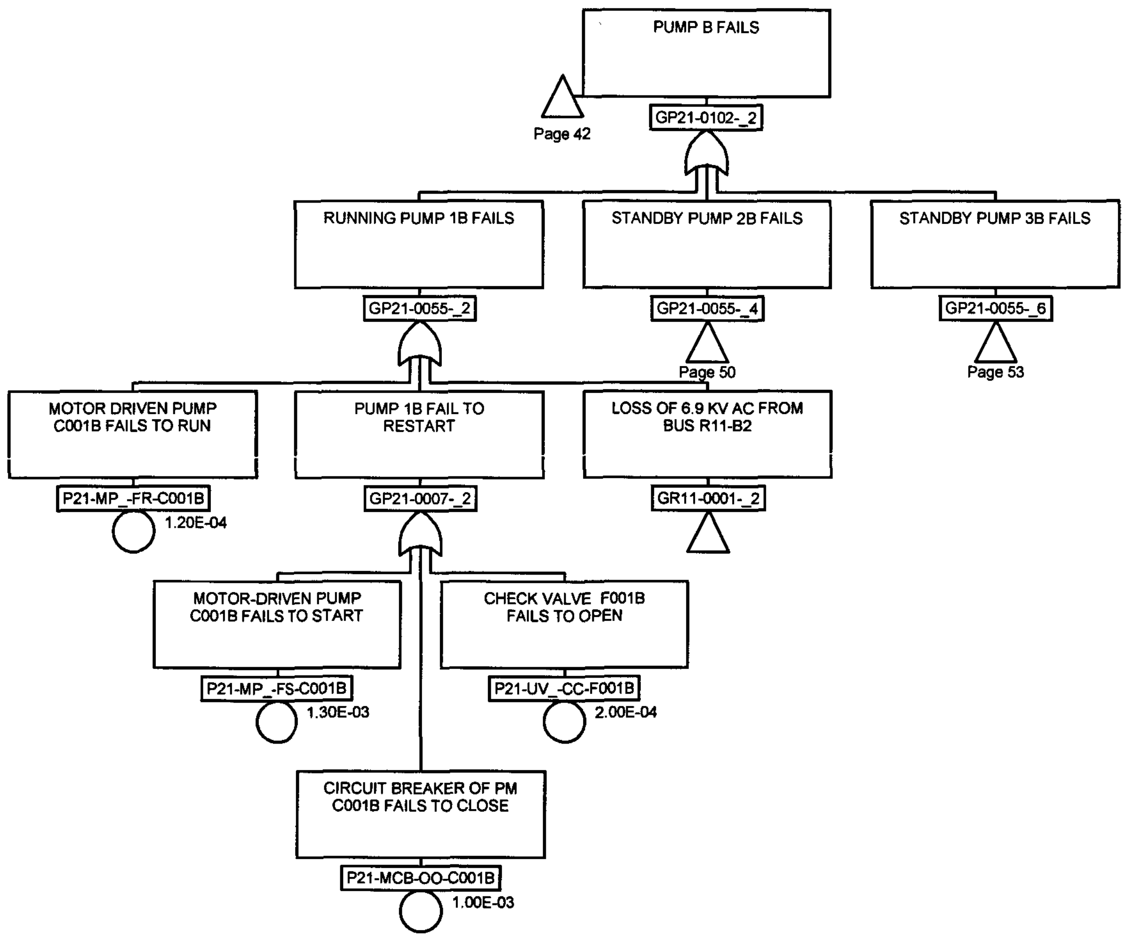

STANDBY PUMP 2A FAILS
GP21-0055-_3
Page 42
PUMP C002A IN MAINTENANCE
P21-MP_-TM-C002A
2.00E-03
CHECK VALVE F005A FAILS TO OPEN
P21-UV_-CC-F005A
2.00E-04
MOTOR-DRIVEN PUMP (ALL TYPES) FAILS TO START
P21-MP_-FS-C002A
1.30E-03
LOSS OF 6.9 KV AC FROM BUS R11-A2
GR11-0001-_1
MEDIUM VOLTAGE CIRCUIT BREAKER FAILS TO CLOSE
P21-MCB-OO-C002A
1.00E-03
DIV. A (NE RTNSS) SIGNAL TRANSMISSION FAILURE
GC62-0001-_1
MOTOR-DRIVEN PUMP C002A FAILS TO RUN
P21-MP_-FR-C002A
1.20E-04
STARTUP SIGNAL FAIL
GP21-3142-_4
Page 45
1
2

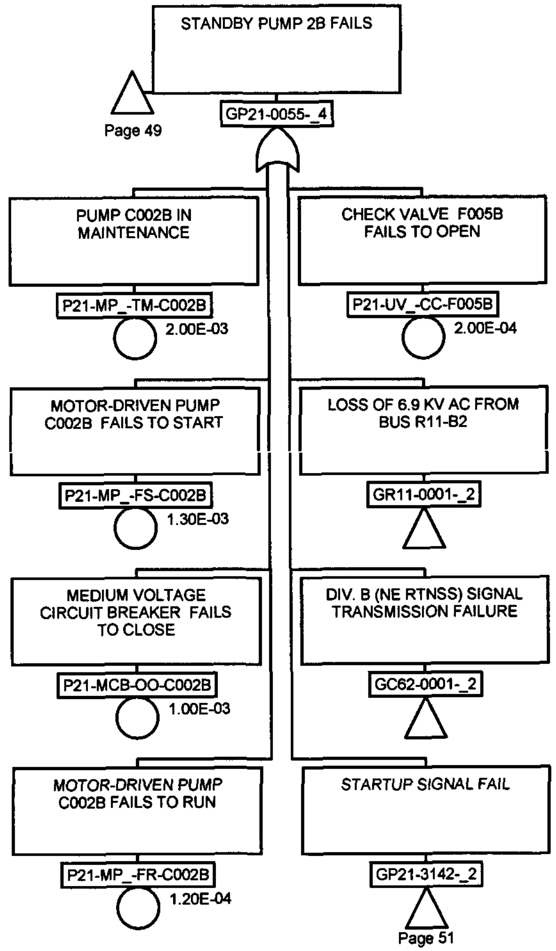

STARTUP SIGNAL FAIL
Page 44
GP21-3142-_4
MANUAL RECOVERY FAILURE
SIGNALS FROM GDs FAIL
GP21-0142-_1
GP21-3000-_1
Page 47
Page 47

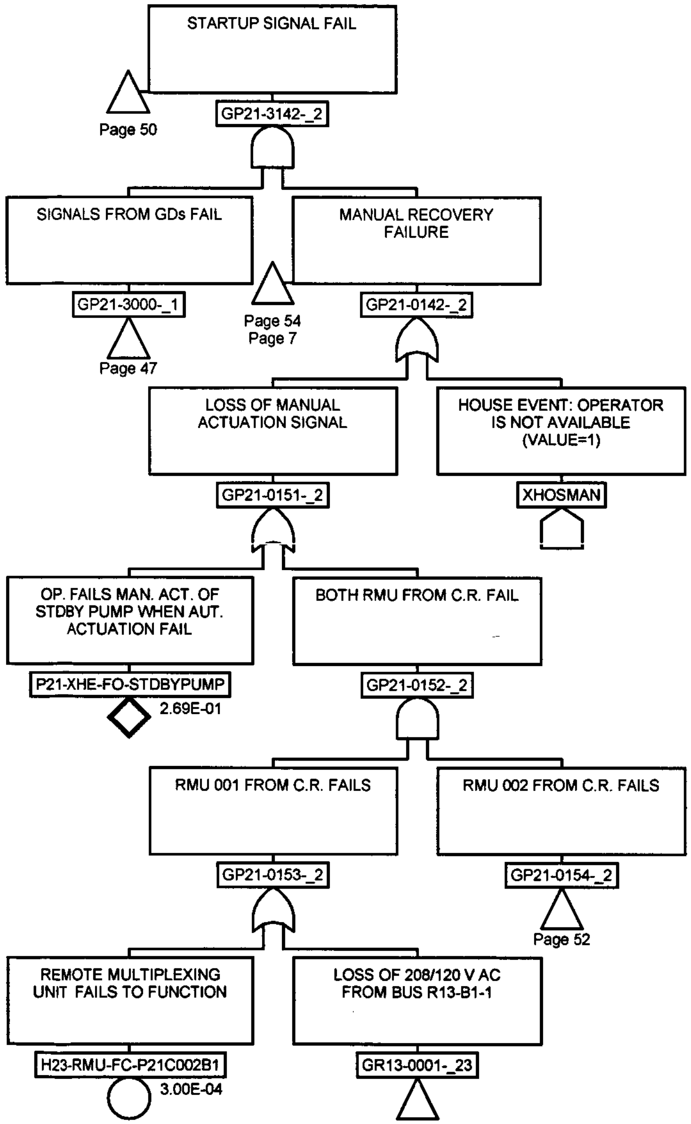

STANDBY PUMP 3A FAILS
Page 42
GP21-0055-_5
MOTOR-DRIVEN PUMP C0003A FAILS TO START
P21-MP_-FS-C003A
1.30E-03
LOSS OF 6.9 KV AC FROM BUS R11-A2
GR11-0001-_1
MEDIUM VOLTAGE CIRCUIT BREAKER FAILS TO CLOSE
P21-MCB-OO-C003A
1.00E-03
DIV. A (NE RTNSS) SIGNAL TRANSMISSION FAILURE
GC62-0001-_1
MOTOR-DRIVEN PUMP C0003A FAILS TO RUN
P21-MP_-FR-C003A
1.20E-04
STARTUP SIGNAL FAILS
GP21-3142-_1
Page 47
CHECK VALVE F007A FAILS TO OPEN
P21-UV_-CC-F007A
2.00E-04


STARTUP SIGNAL FAILS
Page 46
GP21-3142-_1
MANUAL RECOVERY FAILURE
Page 13
Page 45
GP21-0142-_1
SIGNALS FROM GDs FAIL
Page 45
Page 54
Page 51
GP21-3000-_1
LOSS OF MANUAL ACTUATION SIGNAL
GP21-0151-_1
HOUSE EVENT: OPERATOR IS NOT AVAILABLE (VALUE=1)
XHOSMAN
AUTOMATIC ACTUATION FAILS
GR21-0025-_1
AUTOMATIC ACTUATION FAILS
GR21-0025-_2
OP. FAILS MAN. ACT. OF STDBY PUMP WHEN AUT. ACTUATION FAIL
P21-XHE-FO-STDBYPUMP
2.69E-01
BOTH RMU FROM C.R. FAIL
GP21-0152-_1
RMU 001 FROM C.R. FAILS
GP21-0153-_1
RMU 002 FROM C.R. FAILS
GP21-0154-_1
Page 48
REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION
H23-RMU-FC-P21C002A1
3.00E-04
LOSS OF 208/120 V AC FROM BUS R13-A1-1
GR13-0001-_19
1
2
3
4


RMU 002 FROM C.R. FAILS
GP21-0154-_1
Page 47
REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION
H23-RMU-FC-P21C002A2
3.00E-04
LOSS OF 208/120 V AC FROM BUS R13-A1-1
GR13-0001-_19


PUMP B FAILS
GP21-0102-_2
Page 42
RUNNING PUMP 1B FAILS
GP21-0055-_2
STANDBY PUMP 2B FAILS
GP21-0055-_4
Page 50
STANDBY PUMP 3B FAILS
GP21-0055-_6
Page 53
MOTOR DRIVEN PUMP C001B FAILS TO RUN
P21-MP_-FR-C001B
1.20E-04
PUMP 1B FAIL TO RESTART
GP21-0007-_2
LOSS OF 6.9 KV AC FROM BUS R11-B2
GR11-0001-_2
MOTOR-DRIVEN PUMP C001B FAILS TO START
P21-MP_-FS-C001B
1.30E-03
CHECK VALVE F001B FAILS TO OPEN
P21-UV_-CC-F001B
2.00E-04
CIRCUIT BREAKER OF PM C001B FAILS TO CLOSE
P21-MCB-OO-C001B
1.00E-03


STANDBY PUMP 2B FAILS
GP21-0055-_4
Page 49
PUMP C002B IN MAINTENANCE
P21-MP_-TM-C002B
2.00E-03
CHECK VALVE F005B FAILS TO OPEN
P21-UV_-CC-F005B
2.00E-04
MOTOR-DRIVEN PUMP C002B FAILS TO START
P21-MP_-FS-C002B
1.30E-03
LOSS OF 6.9 KV AC FROM BUS R11-B2
GR11-0001-_2
MEDIUM VOLTAGE CIRCUIT BREAKER FAILS TO CLOSE
P21-MCB-OO-C002B
1.00E-03
DIV. B (NE RTNSS) SIGNAL TRANSMISSION FAILURE
GC62-0001-_2
MOTOR-DRIVEN PUMP C002B FAILS TO RUN
P21-MP_-FR-C002B
1.20E-04
STARTUP SIGNAL FAIL
GP21-3142-_2
Page 51
1
2


STARTUP SIGNAL FAIL
Page 50
GP21-3142-_2
SIGNALS FROM GDs FAIL
MANUAL RECOVERY FAILURE
GP21-3000-_1
Page 47
Page 54
Page 7
GP21-0142-_2
LOSS OF MANUAL ACTUATION SIGNAL
HOUSE EVENT: OPERATOR IS NOT AVAILABLE (VALUE=1)
GP21-0151-_2
XHOSMAN
OP. FAILS MAN. ACT. OF STDBY PUMP WHEN AUT. ACTUATION FAIL
BOTH RMU FROM C.R. FAIL
P21-XHE-FO-STDBYPUMP
2.69E-01
GP21-0152-_2
RMU 001 FROM C.R. FAILS
RMU 002 FROM C.R. FAILS
GP21-0153-_2
GP21-0154-_2
Page 52
REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION
LOSS OF 208/120 V AC FROM BUS R13-B1-1
H23-RMU-FC-P21C002B1
3.00E-04
GR13-0001-_23
1
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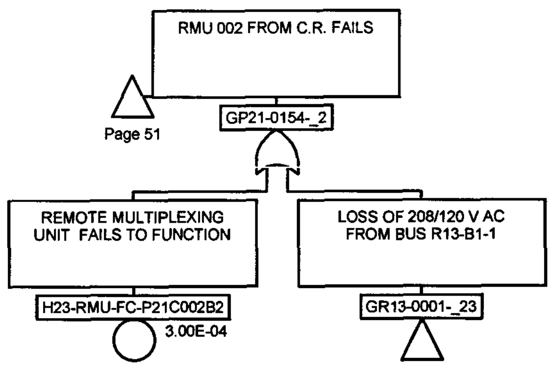
RMU 002 FROM C.R. FAILS
Page 51
GP21-0154-_2
REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION
H23-RMU-FC-P21C002B2
3.00E-04
LOSS OF 208/120 V AC FROM BUS R13-B1-1
GR13-0001-_23
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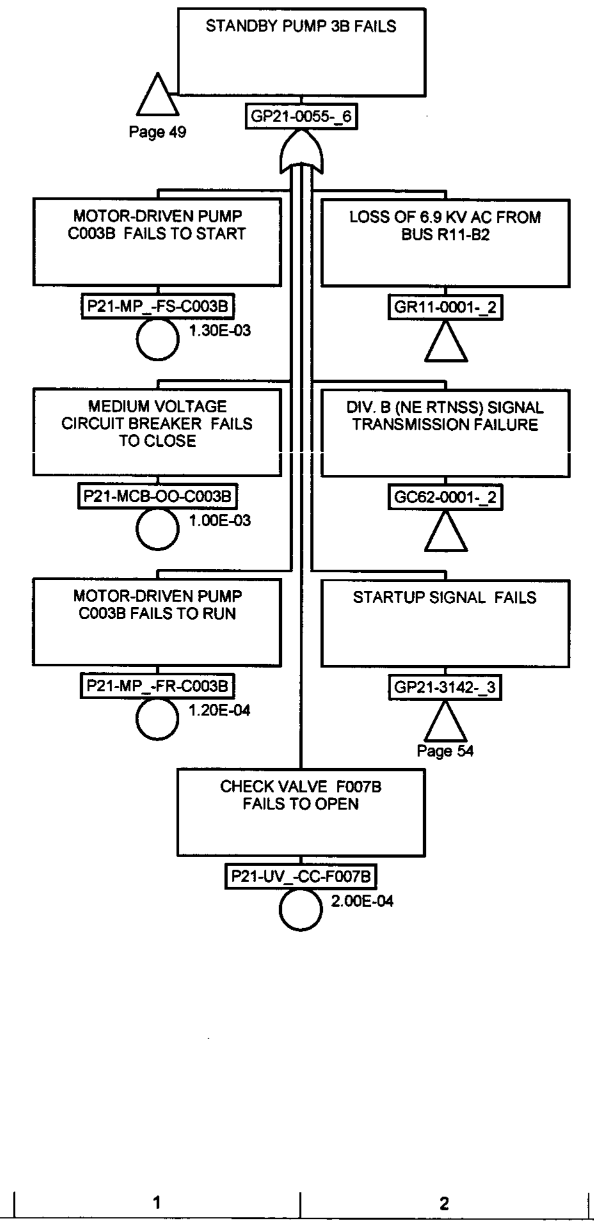
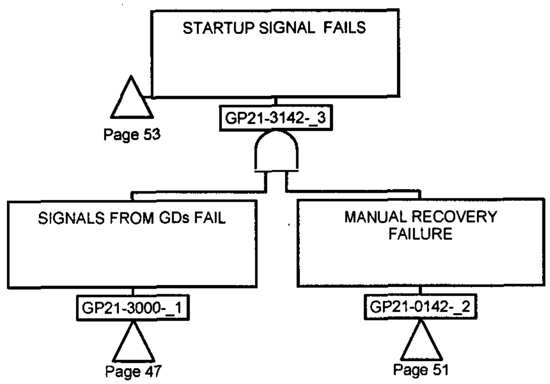
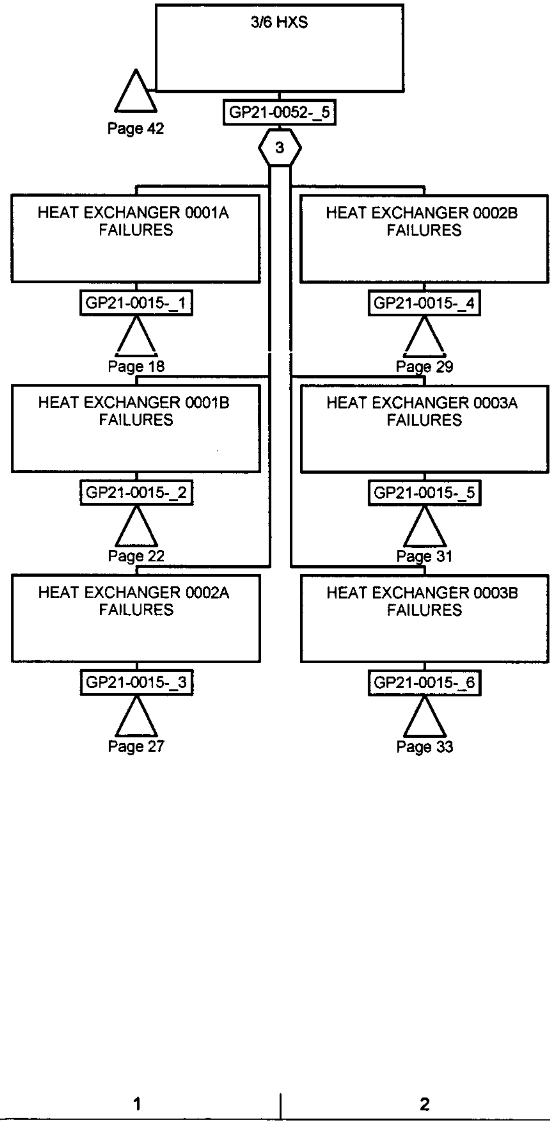
2


STANDBY PUMP 3B FAILS
GP21-0055-_6
Page 49
MOTOR-DRIVEN PUMP C003B FAILS TO START
P21-MP_-FS-C003B
1.30E-03
LOSS OF 6.9 KV AC FROM BUS R11-B2
GR11-0001-_2
MEDIUM VOLTAGE CIRCUIT BREAKER FAILS TO CLOSE
P21-MCB-OO-C003B
1.00E-03
DIV. B (NE RTNSS) SIGNAL TRANSMISSION FAILURE
GC62-0001-_2
MOTOR-DRIVEN PUMP C003B FAILS TO RUN
P21-MP_-FR-C003B
1.20E-04
STARTUP SIGNAL FAILS
GP21-3142-_3
Page 54
CHECK VALVE F007B FAILS TO OPEN
P21-UV_-CC-F007B
2.00E-04
1
2


STARTUP SIGNAL FAILS
Page 53
GP21-3142-_3
SIGNALS FROM GDs FAIL
MANUAL RECOVERY FAILURE
GP21-3000-_1
GP21-0142-_2
Page 47
Page 51



3/6 HXS
GP21-0052-_5
Page 42
3
HEAT EXCHANGER 0001A FAILURES
GP21-0015-_1
Page 18
HEAT EXCHANGER 0002B FAILURES
GP21-0015-_4
Page 29
HEAT EXCHANGER 0001B FAILURES
GP21-0015-_2
Page 22
HEAT EXCHANGER 0003A FAILURES
GP21-0015-_5
Page 31
HEAT EXCHANGER 0002A FAILURES
GP21-0015-_3
Page 27
HEAT EXCHANGER 0003B FAILURES
GP21-0015-_6
Page 33
1
2

Name	Page	Zone	Name	Page	Zone	Name	Page	Zone
C62-DTM-CF-N1EALL	21	1	GP21-0007- 1	43	2	GP21-0030- 1	21	3
C62-DTM-FC-N1EA	21	3	GP21-0007- 2	49	2	GP21-0030- 2	24	2
C62-DTM-FC-N1EB	26	1	GP21-0007- 9	35	5	GP21-0030- 2	25	2
GC62-0001- 1	5	2	GP21-0007- 9	38	2	GP21-0031- 1	21	2
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GC62-0001- 1	44	2	GP21-0008- 9	38	2	GP21-0033- 1	21	4
GC62-0001- 1	46	2	GP21-0009- 1	35	2	GP21-0033- 2	25	2
GC62-0001- 2	6	2	GP21-0009- 2	35	2	GP21-0033- 2	26	2
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GC62-0001- 2	50	2	GP21-0009- 3	36	2	GP21-0052- 2	42	3
GC62-0001- 2	53	2	GP21-0009- 4	39	2	GP21-0052- 5	42	3
GP21-0001- 1	1	4	GP21-0009- 5	39	2	GP21-0052- 5	55	2
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GP21-0002- 1	1	4	GP21-0009- 9	35	4	GP21-0055- 2	49	2
GP21-0002- 1	41	2	GP21-0015- 1	17	1	GP21-0055- 3	42	2
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GP21-0006- 9	35	3	GP21-0020- 2	33	2	GP21-0154- 2	52	2
GP21-0006- 9	37	2	GP21-0030- 1	20	2	GP21-0154- 3	15	4

Name	Page	Zone
GP21-0154- 4	11	4
GP21-1001- 1	1	4
GP21-1001- 2	1	5
GP21-1001- 2	42	4
GP21-2001- 1	22	2
GP21-2001- 1	23	2
GP21-2001- 2	18	2
GP21-2001- 2	19	2
GP21-2002- 1	29	2
GP21-2002- 1	30	2
GP21-2002- 2	27	2
GP21-2002- 2	28	2
GP21-2003- 1	33	2
GP21-2003- 1	34	2
GP21-2003- 2	31	2
GP21-2003- 2	32	2
GP21-3000- 1	45	2
GP21-3000- 1	47	4
GP21-3000- 1	51	1
GP21-3000- 1	54	1
GP21-3005- 1	13	2
GP21-3005- 1	14	1
GP21-3005- 2	7	1
GP21-3005- 2	10	2
GP21-3005- 3	5	2
GP21-3005- 3	13	2
GP21-3005- 4	6	2
GP21-3005- 4	7	2
GP21-3005- 5	8	2
GP21-3005- 5	14	2
GP21-3005- 6	9	2
GP21-3005- 6	10	3
GP21-3142- 1	46	2
GP21-3142- 1	47	3
GP21-3142- 2	50	2
GP21-3142- 2	51	2
GP21-3142- 3	53	2
GP21-3142- 3	54	2
GP21-3142- 4	44	2
GP21-3142- 4	45	2
GP41-0001- 1	19	1
GP41-0001- 1	23	1
GP41-0001- 1	28	1
GP41-0001- 1	30	1
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GR13-0001- 21	21	4
GR13-0001- 23	11	2
GR13-0001- 23	11	4
GR13-0001- 23	51	2
GR13-0001- 23	52	2
GR13-0001- 25	24	2
GR13-0001- 25	26	2
GR21-0025- 1	47	4
GR21-0025- 2	47	5
H23-RMU-FC-N038B	26	1
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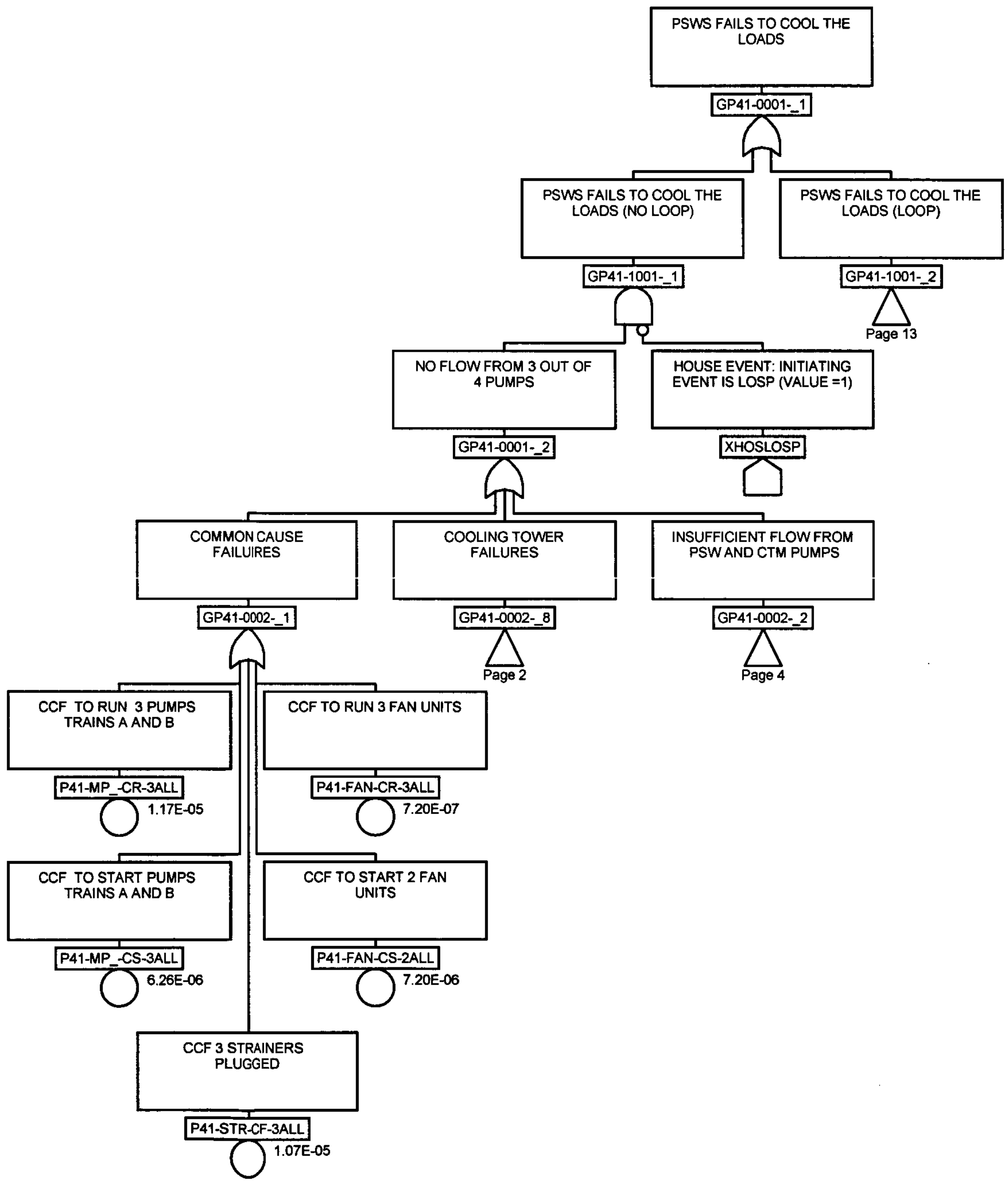
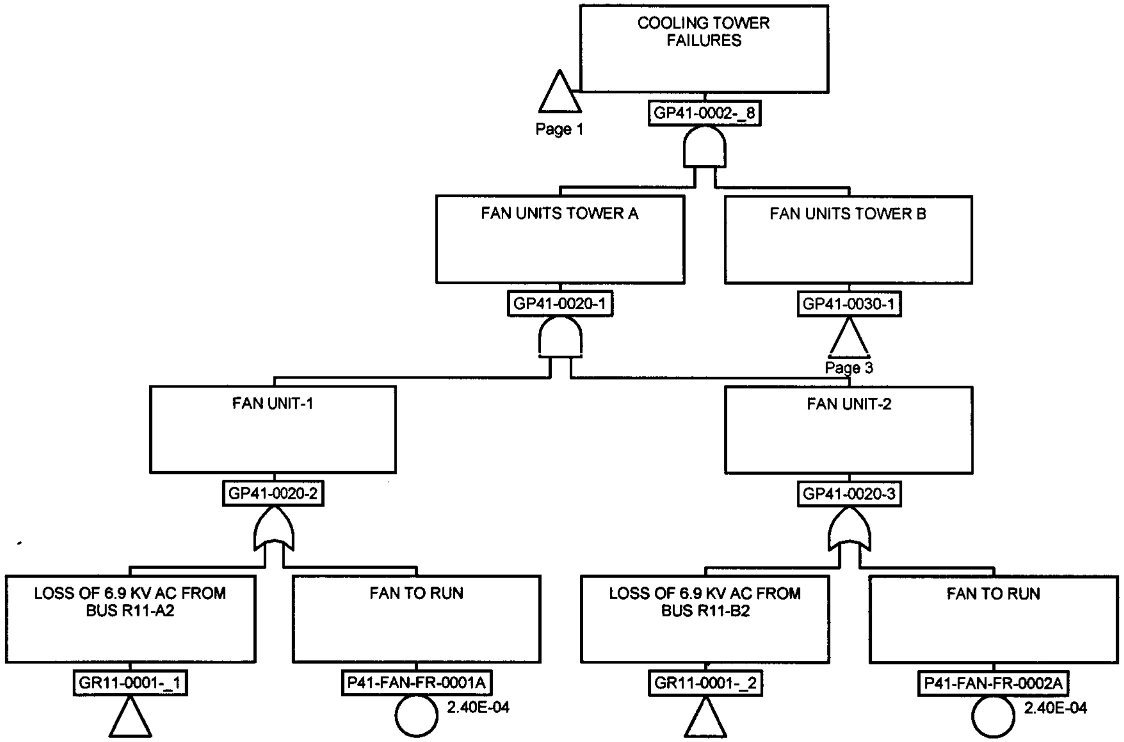
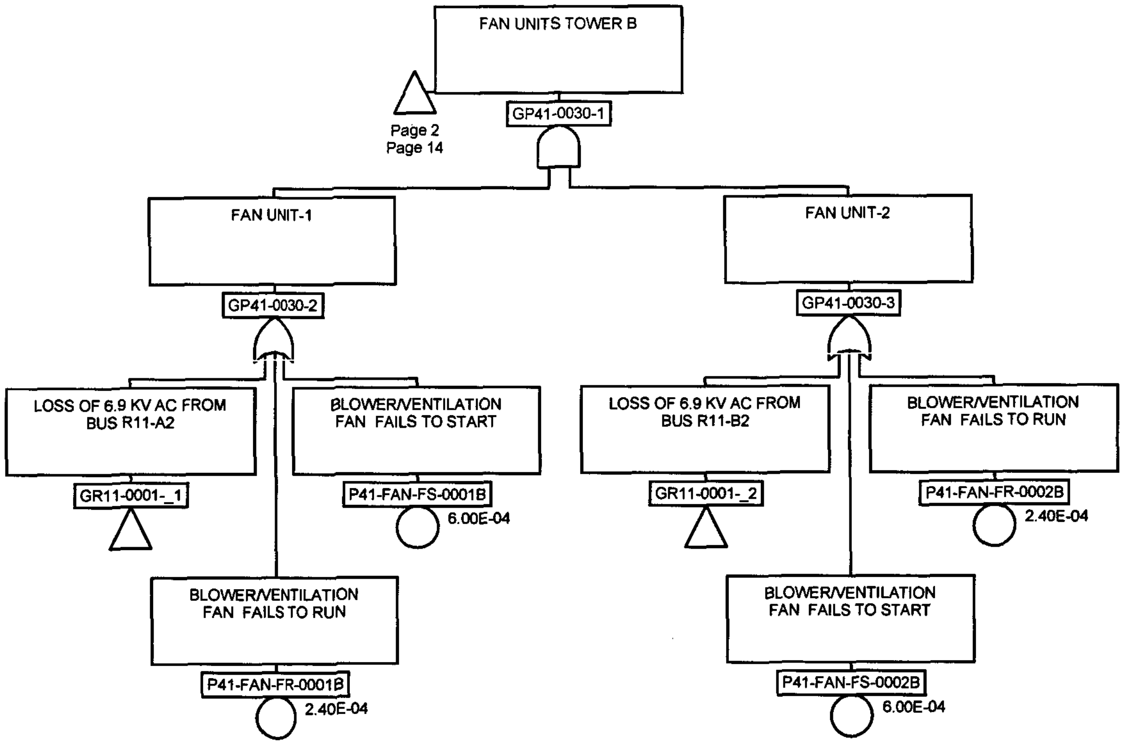
H23-RMU-FC-P21C002A2	48	1
H23-RMU-FC-P21C002B1	51	1
H23-RMU-FC-P21C002B2	52	1
H23-RMU-FC-P21C003A1	15	1
H23-RMU-FC-P21C003A2	15	3
H23-RMU-FC-P21C003B1	11	1
H23-RMU-FC-P21C003B2	11	3
H23-RMU-FC-P21N038A	21	3
P21-ACV-CF-F010/13	35	4
P21-ACV-CF-F022/25A	20	1
P21-ACV-CF-F022/25B	24	1
P21-ACV-CF-F027/32	38	3
P21-ACV-FT-F022A	20	1
P21-ACV-FT-F022B	24	1
P21-ACV-FT-F025A	20	2
P21-ACV-FT-F025B	24	2
P21-ACV-OC-F010	37	1
P21-ACV-OC-F013	37	2
P21-ACV-OC-F027	38	1
P21-ACV-OC-F032	38	2
P21-HX -LK-B001A	18	1
P21-HX -LK-B001B	22	1
P21-HX -LK-B002A	27	1
P21-HX -LK-B002B	29	1
P21-HX -LK-B003A	31	1
P21-HX -LK-B003B	33	1
P21-HX -TM-B002A	27	2
P21-HX -TM-B002B	29	2
P21-MCB-CC-C001A	13	2
P21-MCB-CC-C001B	10	2
P21-MCB-OO-C001A	43	2
P21-MCB-OO-C001B	49	2
P21-MCB-OO-C002A	5	1
P21-MCB-OO-C002A	44	1
P21-MCB-OO-C002B	6	1
P21-MCB-OO-C002B	50	1
P21-MCB-OO-C003A	8	1
P21-MCB-OO-C003A	46	1
P21-MCB-OO-C003B	9	1
P21-MCB-OO-C003B	53	1
P21-MOV-OC-F016A	18	1
P21-MOV-OC-F016B	22	1
P21-MOV-OC-F018A	27	1
P21-MOV-OC-F018B	29	1
P21-MOV-OC-F020A	31	1
P21-MOV-OC-F020B	33	1
P21-MP -CR-3A	3	2
P21-MP -CR-3A	5	2
P21-MP -CR-3A	8	2
P21-MP -CR-3B	4	2
P21-MP -CR-3B	6	2
P21-MP -CR-3B	9	2
P21-MP -CR-5ALL	41	1
P21-MP -CR-TRAINAB	42	4
P21-MP -CS-2A	5	2
P21-MP -CS-2A	8	2
P21-MP -CS-2B	6	2
P21-MP -CS-2B	9	2
P21-MP -CS-5ALL	41	2
P21-MP -CS-TRAINAB	42	5
P21-MP -FR-C001A	3	1
P21-MP -FR-C001A	13	1
P21-MP -FR-C001A	43	1
P21-MP -FR-C001B	4	1
P21-MP -FR-C001B	10	1
P21-MP -FR-C001B	49	1
P21-MP -FR-C002A	5	1
P21-MP -FR-C002A	44	1
P21-MP -FR-C002B	6	1
P21-MP -FR-C002B	50	1
P21-MP -FR-C003A	8	1
P21-MP -FR-C003A	46	1
P21-MP -FR-C003B	9	1
P21-MP -FR-C003B	53	1
P21-MP -FS-C001A	43	2
P21-MP -FS-C001B	49	2
P21-MP -FS-C002A	5	1
P21-MP -FS-C002A	44	1
P21-MP -FS-C002B	6	1
P21-MP -FS-C002B	50	1
P21-MP -FS-C003A	8	1
P21-MP -FS-C003A	46	1
P21-MP -FS-C003B	9	1
P21-MP -FS-C003B	53	1
P21-MP -TM-C002A	5	1
P21-MP -TM-C002A	44	1
P21-MP -TM-C002B	6	1
P21-MP -TM-C002B	50	1

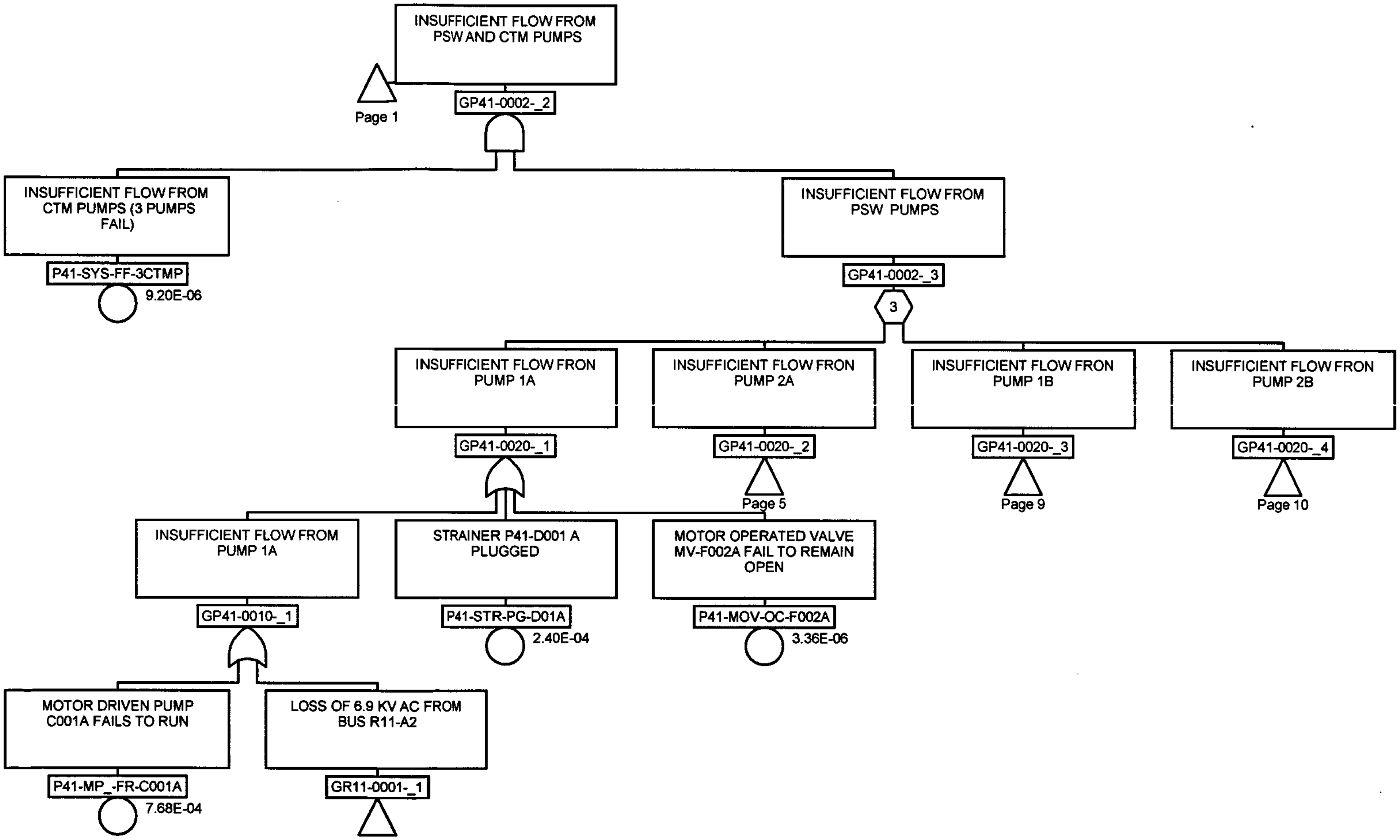
Name	Page	Zone	Name	Page	Zone	Name	Page	Zone
P21-TT -CF-N038A/B	21	2						
P21-TT -NO-N038B	26	2						
P21-TT -NO-P21N038A	21	4						
P21-UV -CC-F001A	43	3						
P21-UV -CC-F001B	49	3						
P21-UV -CC-F005A	5	1						
P21-UV -CC-F005A	44	2						
P21-UV -CC-F005B	6	1						
P21-UV -CC-F005B	50	2						
P21-UV -CC-F007A	8	1						
P21-UV -CC-F007A	46	2						
P21-UV -CC-F007B	9	1						
P21-UV -CC-F007B	53	2						
P21-XHE-FO-STDBYPUMP	10	3						
P21-XHE-FO-STDBYPUMP	14	1						
P21-XHE-FO-STDBYPUMP	47	1						
P21-XHE-FO-STDBYPUMP	51	1						
P41-ACV-OC-F002A	19	2						
P41-ACV-OC-F002B	23	2						
P41-ACV-OC-F003A	19	2						
P41-ACV-OC-F003B	23	2						
P41-ACV-OC-F004A	28	1						
P41-ACV-OC-F004B	30	1						
P41-ACV-OC-F005A	28	2						
P41-ACV-OC-F005B	30	2						
P41-ACV-OC-F006A	32	2						
P41-ACV-OC-F006B	34	2						
P41-ACV-OC-F007A	32	2						
P41-ACV-OC-F007B	34	2						
P41-ACV-OC-F010A	19	1						
P41-ACV-OC-F010A	28	2						
P41-ACV-OC-F010A	32	1						
P41-ACV-OC-F010B	23	1						
P41-ACV-OC-F010B	30	2						
P41-ACV-OC-F010B	34	1						
XHOSLOSP	1	4						
XHOSLOSP	42	5						
XHOSMAN	10	4						
XHOSMAN	14	3						
XHOSMAN	47	3						
XHOSMAN	51	3						

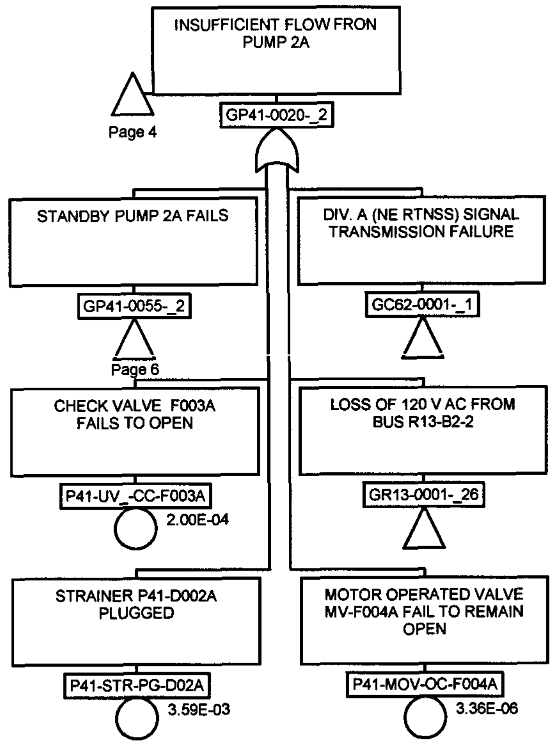
Appendix B.4.11 Plant Service Water System Fault Tree

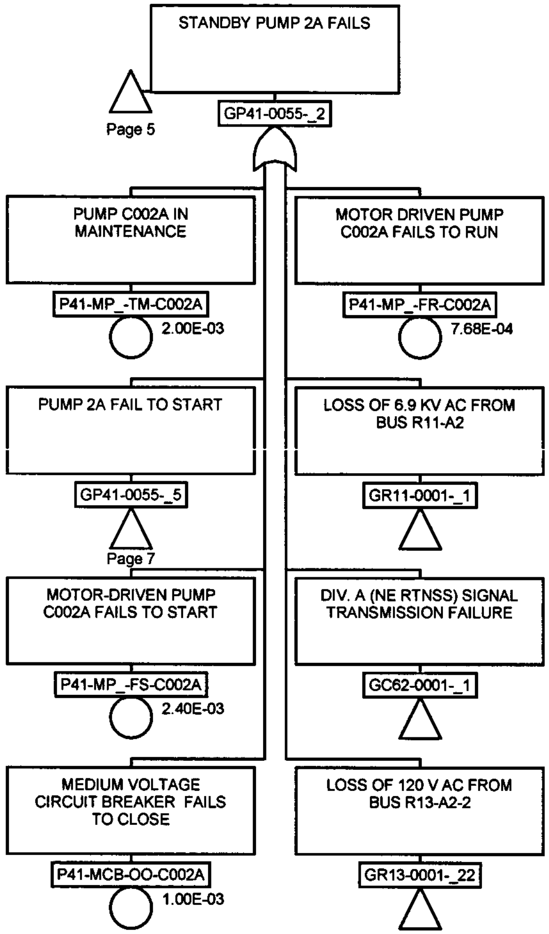

PSWS FAILS TO COOL THE LOADS
GP41-0001-_1
PSWS FAILS TO COOL THE LOADS (NO LOOP)
GP41-1001-_1
PSWS FAILS TO COOL THE LOADS (LOOP)
GP41-1001-_2
Page 13
NO FLOW FROM 3 OUT OF 4 PUMPS
GP41-0001-_2
HOUSE EVENT: INITIATING EVENT IS LOSP (VALUE =1)
XHOSLOSP
COMMON CAUSE FAILUIRES
GP41-0002-_1
COOLING TOWER FAILURES
GP41-0002-_8
Page 2
INSUFFICIENT FLOW FROM PSW AND CTM PUMPS
GP41-0002-_2
Page 4
CCF TO RUN 3 PUMPS TRAINS A AND B
P41-MP_-CR-3ALL
1.17E-05
CCF TO RUN 3 FAN UNITS
P41-FAN-CR-3ALL
7.20E-07
CCF TO START PUMPS TRAINS A AND B
P41-MP_-CS-3ALL
6.26E-06
CCF TO START 2 FAN UNITS
P41-FAN-CS-2ALL
7.20E-06
CCF 3 STRAINERS PLUGGED
P41-STR-CF-3ALL
1.07E-05

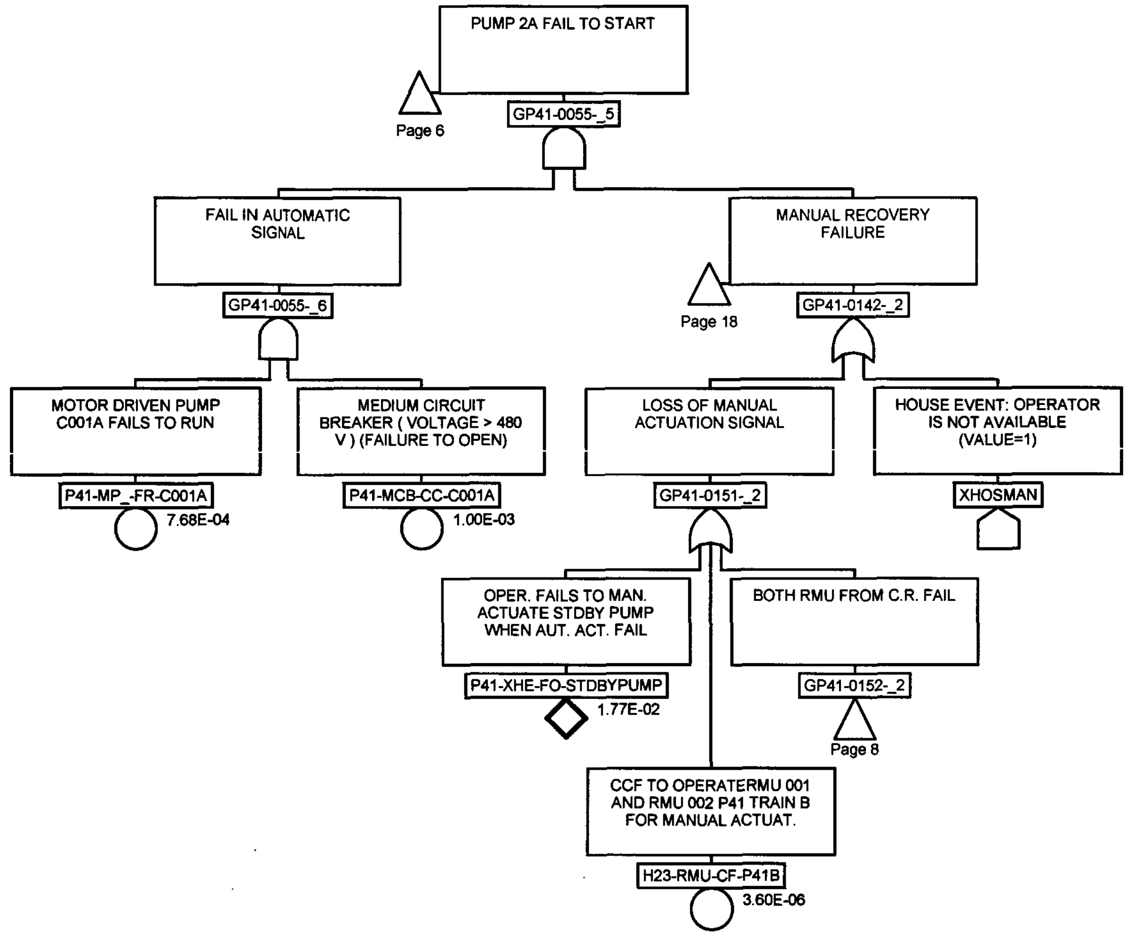

COOLING TOWER FAILURES
GP41-0002-_8
Page 1
FAN UNITS TOWER A
GP41-0020-1
FAN UNITS TOWER B
GP41-0030-1
Page 3
FAN UNIT-1
GP41-0020-2
FAN UNIT-2
GP41-0020-3
LOSS OF 6.9 KV AC FROM BUS R11-A2
GR11-0001-_1
FAN TO RUN
P41-FAN-FR-0001A
2.40E-04
LOSS OF 6.9 KV AC FROM BUS R11-B2
GR11-0001-_2
FAN TO RUN
P41-FAN-FR-0002A
2.40E-04

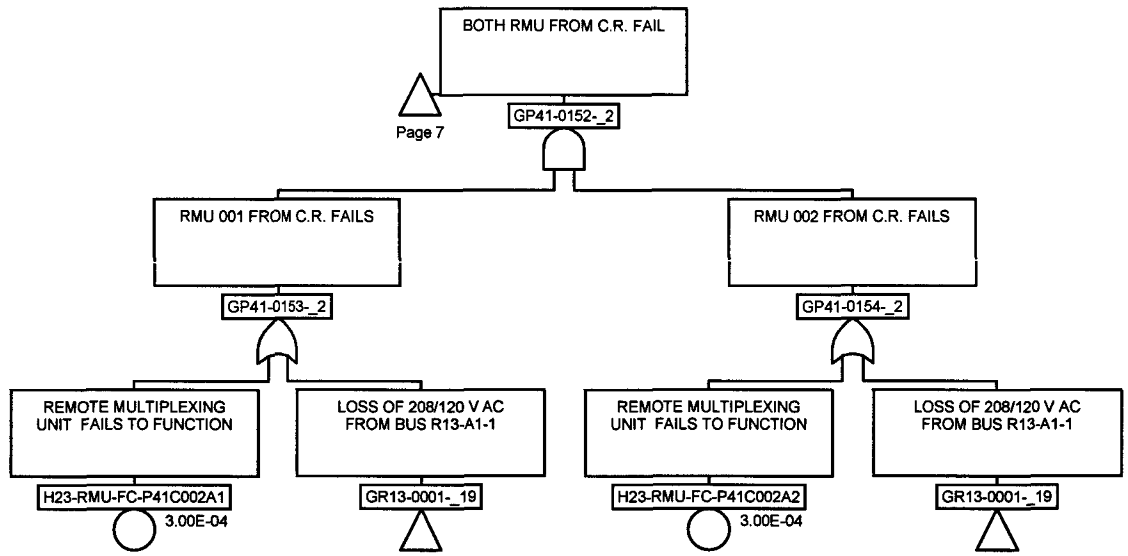

FAN UNITS TOWER B
GP41-0030-1
Page 2
Page 14
FAN UNIT-1
GP41-0030-2
FAN UNIT-2
GP41-0030-3
LOSS OF 6.9 KV AC FROM BUS R11-A2
GR11-0001-_1
BLOWER/VENTILATION FAN FAILS TO START
P41-FAN-FS-0001B
6.00E-04
BLOWER/VENTILATION FAN FAILS TO RUN
P41-FAN-FR-0001B
2.40E-04
LOSS OF 6.9 KV AC FROM BUS R11-B2
GR11-0001-_2
BLOWER/VENTILATION FAN FAILS TO RUN
P41-FAN-FR-0002B
2.40E-04
BLOWER/VENTILATION FAN FAILS TO START
P41-FAN-FS-0002B
6.00E-04

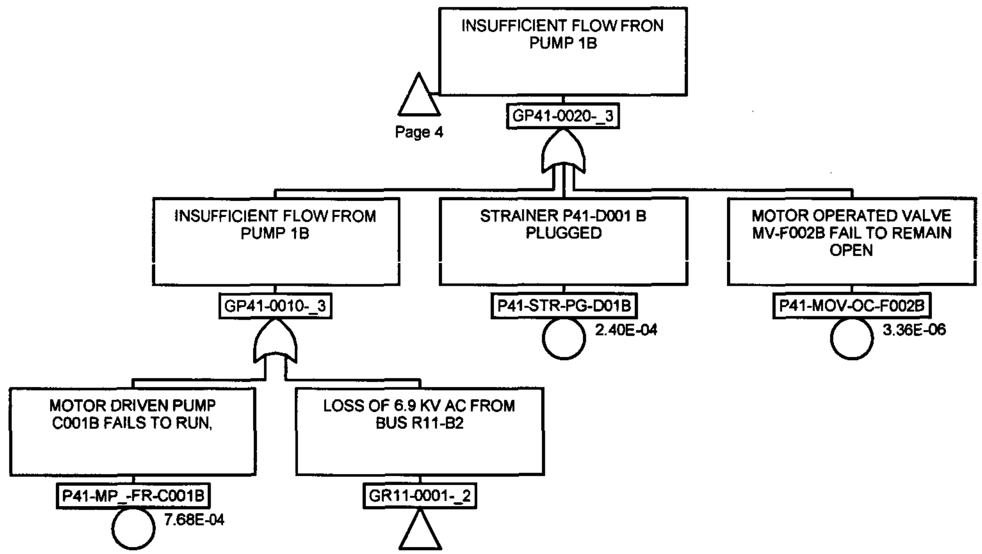

INSUFFICIENT FLOW FROM PSW AND CTM PUMPS
Page 1
GP41-0002-_2
INSUFFICIENT FLOW FROM CTM PUMPS (3 PUMPS FAIL)
P41-SYS-FF-3CTMP
9.20E-06
INSUFFICIENT FLOW FROM PSW PUMPS
GP41-0002-_3
3
INSUFFICIENT FLOW FRON PUMP 1A
GP41-0020-_1
INSUFFICIENT FLOW FRON PUMP 2A
GP41-0020-_2
Page 5
INSUFFICIENT FLOW FRON PUMP 1B
GP41-0020-_3
Page 9
INSUFFICIENT FLOW FRON PUMP 2B
GP41-0020-_4
Page 10
INSUFFICIENT FLOW FROM PUMP 1A
GP41-0010-_1
STRAINER P41-D001 A PLUGGED
P41-STR-PG-D01A
2.40E-04
MOTOR OPERATED VALVE MV-F002A FAIL TO REMAIN OPEN
P41-MOV-OC-F002A
3.36E-06
MOTOR DRIVEN PUMP C001A FAILS TO RUN
P41-MP_-FR-C001A
7.68E-04
LOSS OF 6.9 KV AC FROM BUS R11-A2
GR11-0001-_1

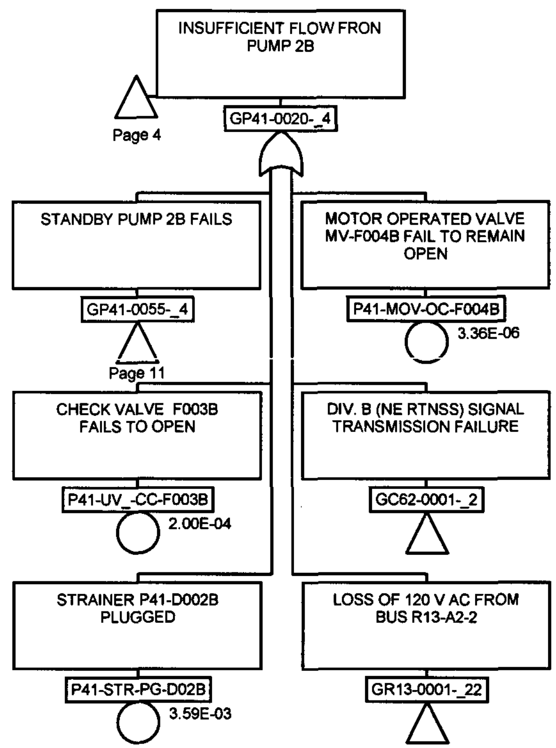

INSUFFICIENT FLOW FRON PUMP 2A
GP41-0020-_2
Page 4
STANDBY PUMP 2A FAILS
GP41-0055-_2
Page 6
DIV. A (NE RTNSS) SIGNAL TRANSMISSION FAILURE
GC62-0001-_1
CHECK VALVE F003A FAILS TO OPEN
P41-UV_-CC-F003A
2.00E-04
LOSS OF 120 V AC FROM BUS R13-B2-2
GR13-0001-_26
STRAINER P41-D002A PLUGGED
P41-STR-PG-D02A
3.59E-03
MOTOR OPERATED VALVE MV-F004A FAIL TO REMAIN OPEN
P41-MOV-OC-F004A
3.36E-06

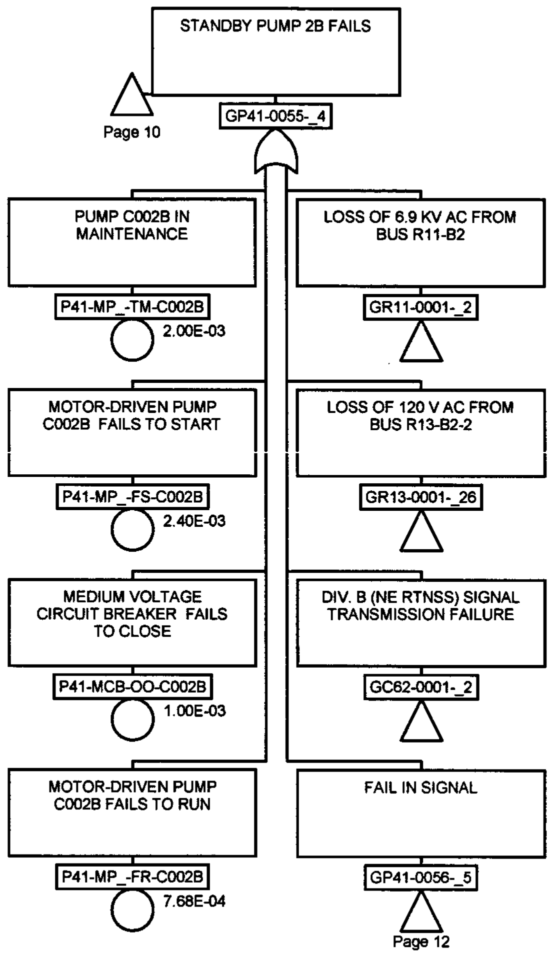

STANDBY PUMP 2A FAILS
GP41-0055-_2
Page 5
PUMP C002A IN MAINTENANCE
P41-MP_-TM-C002A
2.00E-03
MOTOR DRIVEN PUMP C002A FAILS TO RUN
P41-MP_-FR-C002A
7.68E-04
PUMP 2A FAIL TO START
GP41-0055-_5
Page 7
LOSS OF 6.9 KV AC FROM BUS R11-A2
GR11-0001-_1
MOTOR-DRIVEN PUMP C002A FAILS TO START
P41-MP_-FS-C002A
2.40E-03
DIV. A (NE RTNSS) SIGNAL TRANSMISSION FAILURE
GC62-0001-_1
MEDIUM VOLTAGE CIRCUIT BREAKER FAILS TO CLOSE
P41-MCB-OO-C002A
1.00E-03
LOSS OF 120 V AC FROM BUS R13-A2-2
GR13-0001-_22

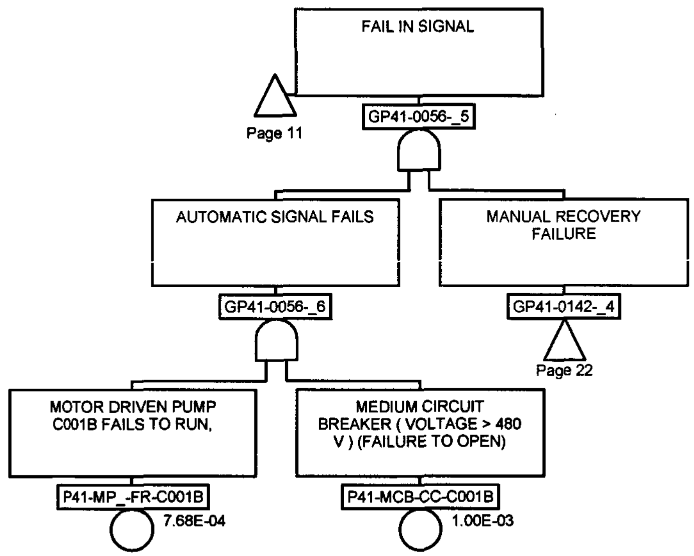

PUMP 2A FAIL TO START
Page 6
GP41-0055-_5
FAIL IN AUTOMATIC SIGNAL
GP41-0055-_6
MANUAL RECOVERY FAILURE
Page 18
GP41-0142-_2
MOTOR DRIVEN PUMP C001A FAILS TO RUN
P41-MP_-FR-C001A
7.68E-04
MEDIUM CIRCUIT BREAKER (VOLTAGE > 480 V) (FAILURE TO OPEN)
P41-MCB-CC-C001A
1.00E-03
LOSS OF MANUAL ACTUATION SIGNAL
GP41-0151-_2
HOUSE EVENT: OPERATOR IS NOT AVAILABLE (VALUE=1)
XHOSMAN
OPER. FAILS TO MAN. ACTUATE STDBY PUMP WHEN AUT. ACT. FAIL
P41-XHE-FO-STDBYPUMP
1.77E-02
BOTH RMU FROM C.R. FAIL
GP41-0152-_2
Page 8
CCF TO OPERATERMU 001 AND RMU 002 P41 TRAIN B FOR MANUAL ACTUAT.
H23-RMU-CF-P41B
3.60E-06

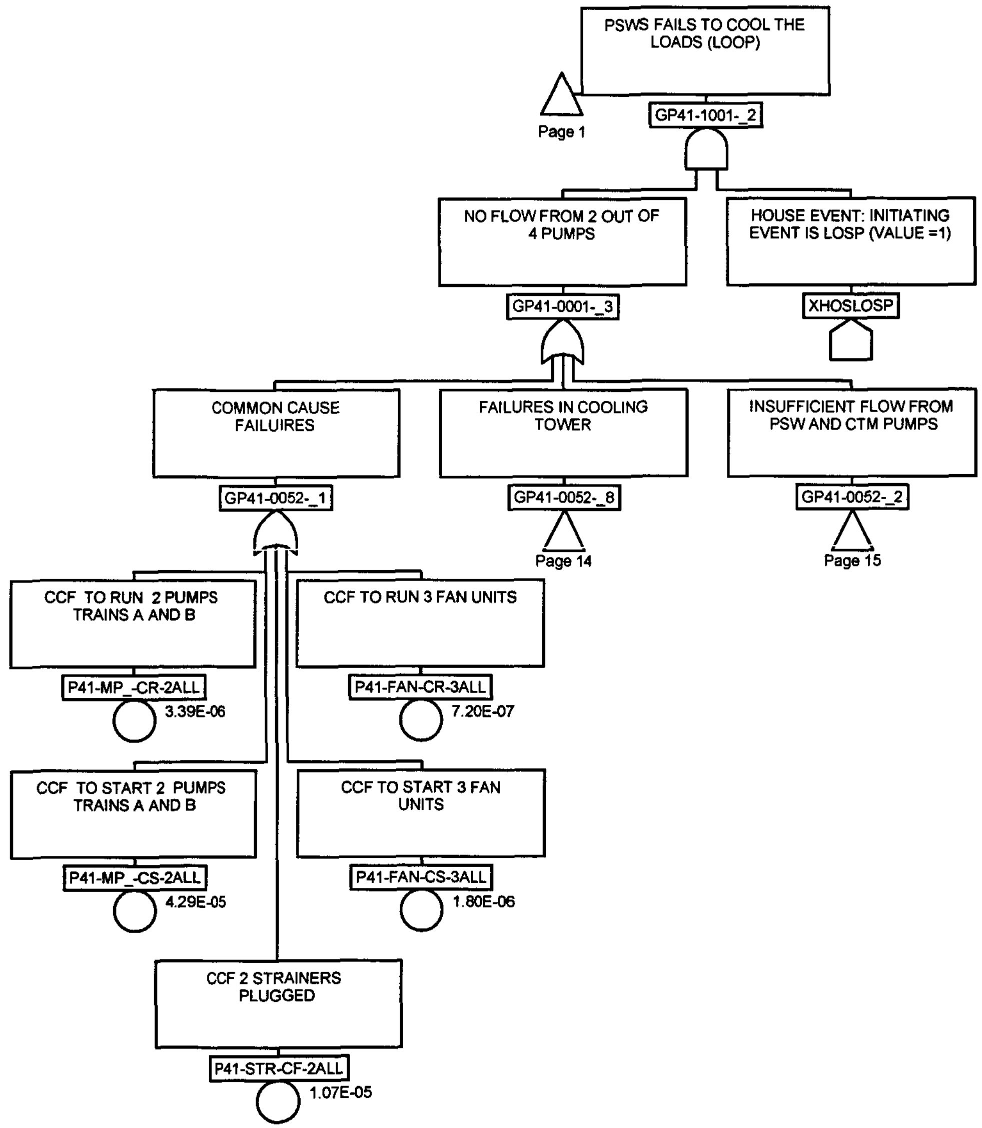

BOTH RMU FROM C.R. FAIL
Page 7
GP41-0152-_2
RMU 001 FROM C.R. FAILS
GP41-0153-_2
RMU 002 FROM C.R. FAILS
GP41-0154-_2
REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION
H23-RMU-FC-P41C002A1
3.00E-04
LOSS OF 208/120 V AC FROM BUS R13-A1-1
GR13-0001-_19
REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION
H23-RMU-FC-P41C002A2
3.00E-04
LOSS OF 208/120 V AC FROM BUS R13-A1-1
GR13-0001-_19

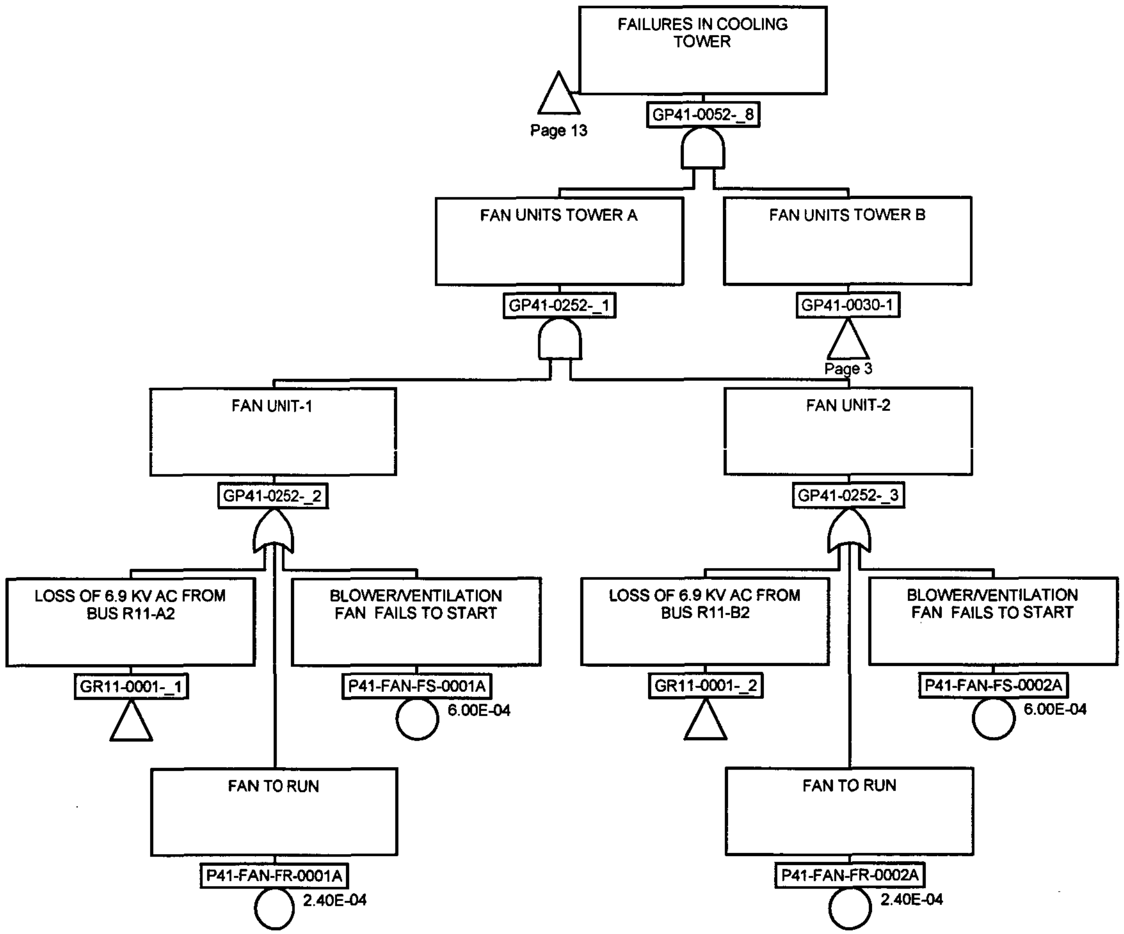

INSUFFICIENT FLOW FRON PUMP 1B
Page 4
GP41-0020-_3
INSUFFICIENT FLOW FROM PUMP 1B
GP41-0010-_3
STRAINER P41-D001 B PLUGGED
P41-STR-PG-D01B
2.40E-04
MOTOR OPERATED VALVE MV-F002B FAIL TO REMAIN OPEN
P41-MOV-OC-F002B
3.36E-06
MOTOR DRIVEN PUMP C001B FAILS TO RUN,
P41-MP_-FR-C001B
7.68E-04
LOSS OF 6.9 KV AC FROM BUS R11-B2
GR11-0001-_2

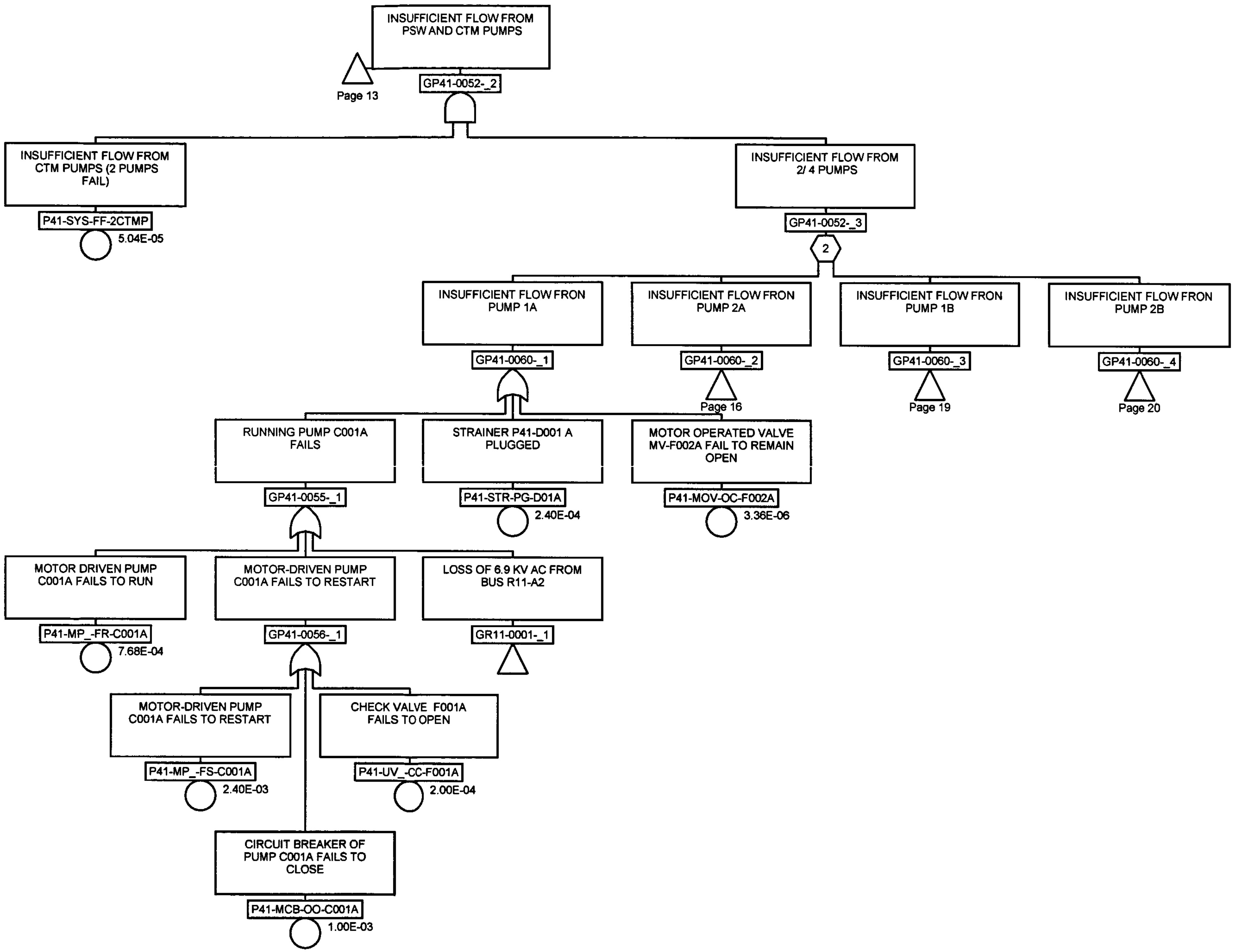

INSUFFICIENT FLOW FRON PUMP 2B
GP41-0020-_4
Page 4
STANDBY PUMP 2B FAILS
GP41-0055-_4
Page 11
MOTOR OPERATED VALVE MV-F004B FAIL TO REMAIN OPEN
P41-MOV-OC-F004B
3.36E-06
CHECK VALVE F003B FAILS TO OPEN
P41-UV_-CC-F003B
2.00E-04
DIV. B (NE RTNSS) SIGNAL TRANSMISSION FAILURE
GC62-0001-_2
STRAINER P41-D002B PLUGGED
P41-STR-PG-D02B
3.59E-03
LOSS OF 120 V AC FROM BUS R13-A2-2
GR13-0001-_22

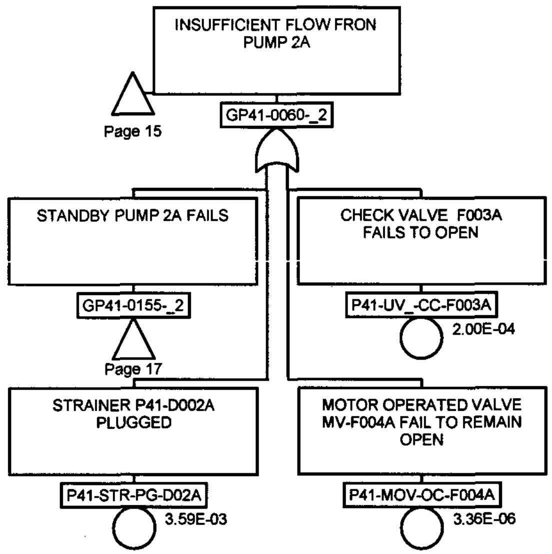

STANDBY PUMP 2B FAILS
GP41-0055-_4
Page 10
PUMP C002B IN MAINTENANCE
P41-MP_-TM-C002B
2.00E-03
LOSS OF 6.9 KV AC FROM BUS R11-B2
GR11-0001-_2
MOTOR-DRIVEN PUMP C002B FAILS TO START
P41-MP_-FS-C002B
2.40E-03
LOSS OF 120 V AC FROM BUS R13-B2-2
GR13-0001-_26
MEDIUM VOLTAGE CIRCUIT BREAKER FAILS TO CLOSE
P41-MCB-OO-C002B
1.00E-03
DIV. B (NE RTNSS) SIGNAL TRANSMISSION FAILURE
GC62-0001-_2
MOTOR-DRIVEN PUMP C002B FAILS TO RUN
P41-MP_-FR-C002B
7.68E-04
FAIL IN SIGNAL
GP41-0056-_5
Page 12

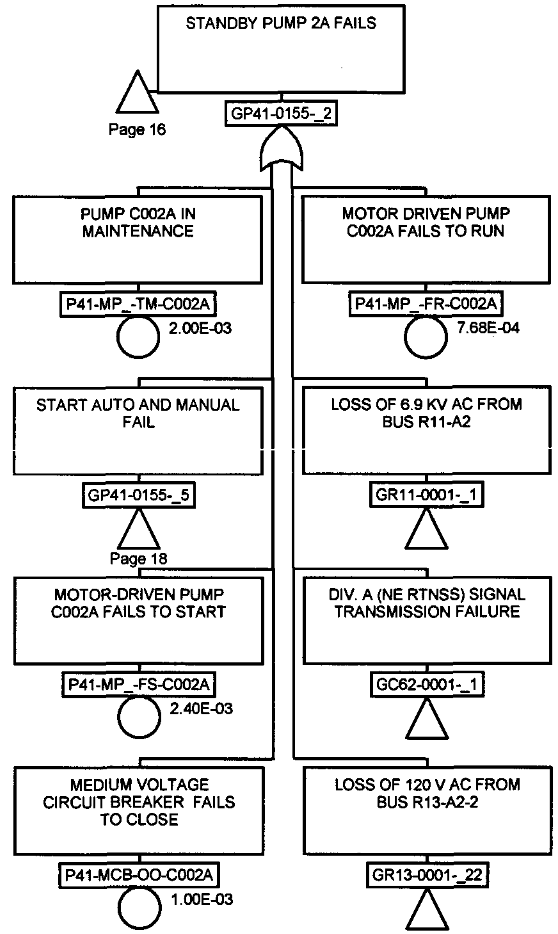

FAIL IN SIGNAL
GP41-0056-_5
Page 11
AUTOMATIC SIGNAL FAILS
GP41-0056-_6
MANUAL RECOVERY FAILURE
GP41-0142-_4
Page 22
MOTOR DRIVEN PUMP C001B FAILS TO RUN,
P41-MP_-FR-C001B
7.68E-04
MEDIUM CIRCUIT BREAKER (VOLTAGE > 480 V) (FAILURE TO OPEN)
P41-MCB-CC-C001B
1.00E-03


PSWS FAILS TO COOL THE LOADS (LOOP)
GP41-1001-_2
Page 1
NO FLOW FROM 2 OUT OF 4 PUMPS
GP41-0001-_3
HOUSE EVENT: INITIATING EVENT IS LOSP (VALUE =1)
XHOSLOSP
COMMON CAUSE FAILUIRES
GP41-0052-_1
FAILURES IN COOLING TOWER
GP41-0052-_8
Page 14
INSUFFICIENT FLOW FROM PSW AND CTM PUMPS
GP41-0052-_2
Page 15
CCF TO RUN 2 PUMPS TRAINS A AND B
P41-MP_-CR-2ALL
3.39E-06
CCF TO RUN 3 FAN UNITS
P41-FAN-CR-3ALL
7.20E-07
CCF TO START 2 PUMPS TRAINS A AND B
P41-MP_-CS-2ALL
4.29E-05
CCF TO START 3 FAN UNITS
P41-FAN-CS-3ALL
1.80E-06
CCF 2 STRAINERS PLUGGED
P41-STR-CF-2ALL
1.07E-05

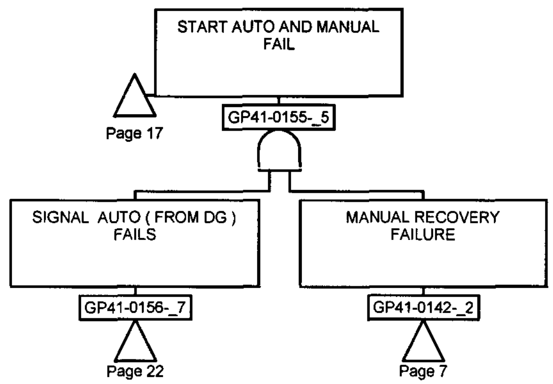

FAILURES IN COOLING TOWER
GP41-0052-_8
Page 13
FAN UNITS TOWER A
GP41-0252-_1
FAN UNITS TOWER B
GP41-0030-1
Page 3
FAN UNIT-1
GP41-0252-_2
FAN UNIT-2
GP41-0252-_3
LOSS OF 6.9 KV AC FROM BUS R11-A2
GR11-0001-_1
BLOWER/VENTILATION FAN FAILS TO START
P41-FAN-FS-0001A
6.00E-04
LOSS OF 6.9 KV AC FROM BUS R11-B2
GR11-0001-_2
BLOWER/VENTILATION FAN FAILS TO START
P41-FAN-FS-0002A
6.00E-04
FAN TO RUN
P41-FAN-FR-0001A
2.40E-04
FAN TO RUN
P41-FAN-FR-0002A
2.40E-04

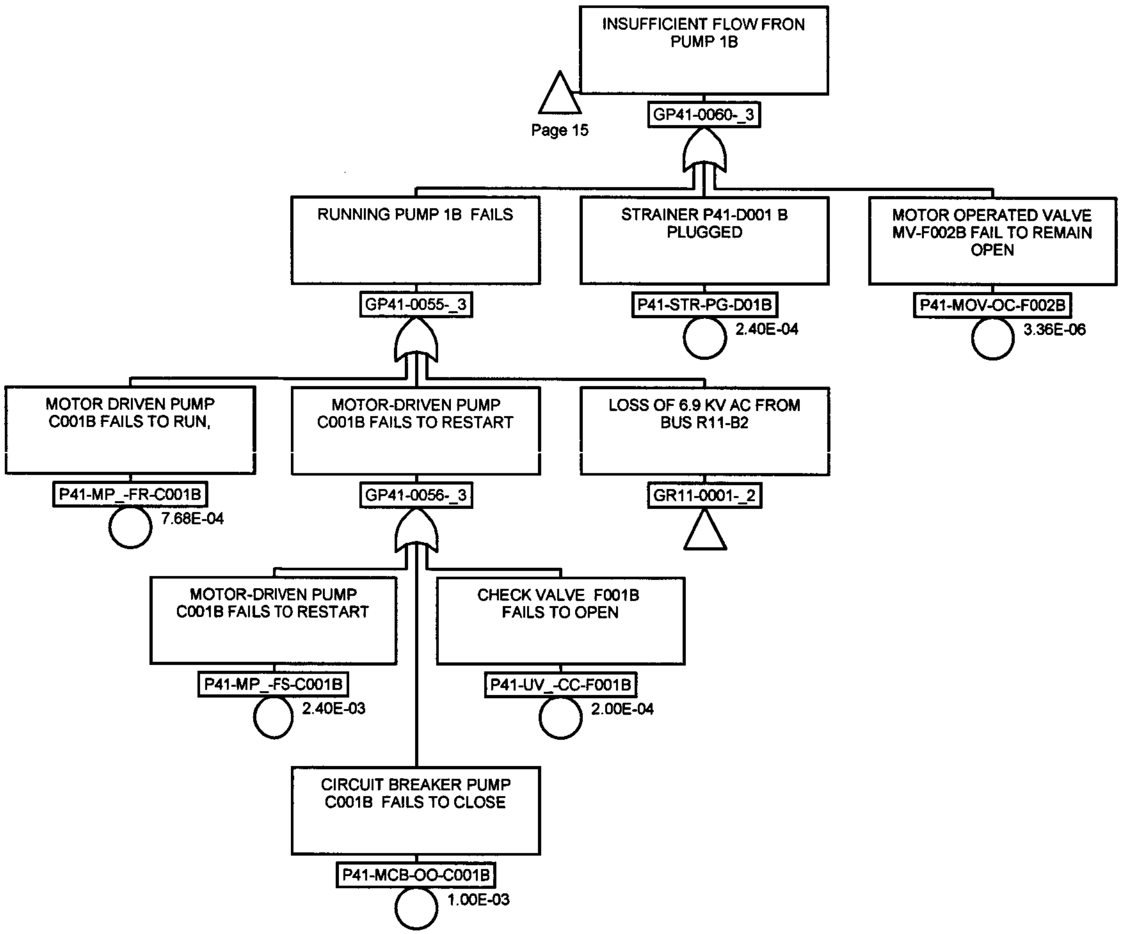

INSUFFICIENT FLOW FROM PSW AND CTM PUMPS
Page 13
GP41-0052-_2
INSUFFICIENT FLOW FROM CTM PUMPS (2 PUMPS FAIL)
P41-SYS-FF-2CTMP
5.04E-05
INSUFFICIENT FLOW FROM 2/ 4 PUMPS
GP41-0052-_3
2
INSUFFICIENT FLOW FRON PUMP 1A
GP41-0060-_1
INSUFFICIENT FLOW FRON PUMP 2A
GP41-0060-_2
Page 16
INSUFFICIENT FLOW FRON PUMP 1B
GP41-0060-_3
Page 19
INSUFFICIENT FLOW FRON PUMP 2B
GP41-0060-_4
Page 20
RUNNING PUMP C001A FAILS
GP41-0055-_1
STRAINER P41-D001 A PLUGGED
P41-STR-PG-D01A
2.40E-04
MOTOR OPERATED VALVE MV-F002A FAIL TO REMAIN OPEN
P41-MOV-OC-F002A
3.36E-06
MOTOR DRIVEN PUMP C001A FAILS TO RUN
P41-MP_-FR-C001A
7.68E-04
MOTOR-DRIVEN PUMP C001A FAILS TO RESTART
GP41-0056-_1
LOSS OF 6.9 KV AC FROM BUS R11-A2
GR11-0001-_1
MOTOR-DRIVEN PUMP C001A FAILS TO RESTART
P41-MP_-FS-C001A
2.40E-03
CHECK VALVE F001A FAILS TO OPEN
P41-UV_-CC-F001A
2.00E-04
CIRCUIT BREAKER OF PUMP C001A FAILS TO CLOSE
P41-MCB-OO-C001A
1.00E-03

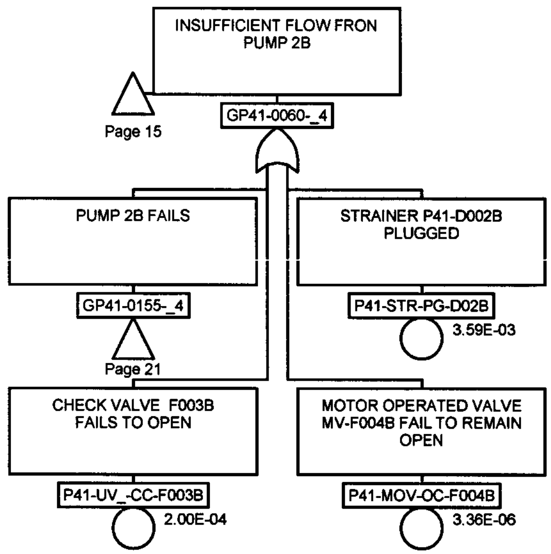

INSUFFICIENT FLOW FRON PUMP 2A
GP41-0060-_2
Page 15
STANDBY PUMP 2A FAILS
GP41-0155-_2
Page 17
CHECK VALVE F003A FAILS TO OPEN
P41-UV_-CC-F003A
2.00E-04
STRAINER P41-D002A PLUGGED
P41-STR-PG-D02A
3.59E-03
MOTOR OPERATED VALVE MV-F004A FAIL TO REMAIN OPEN
P41-MOV-OC-F004A
3.36E-06

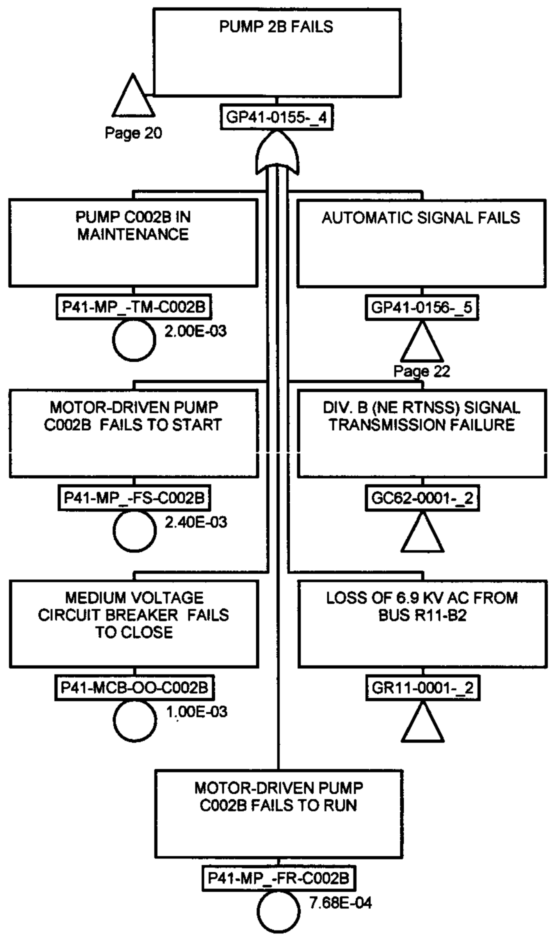


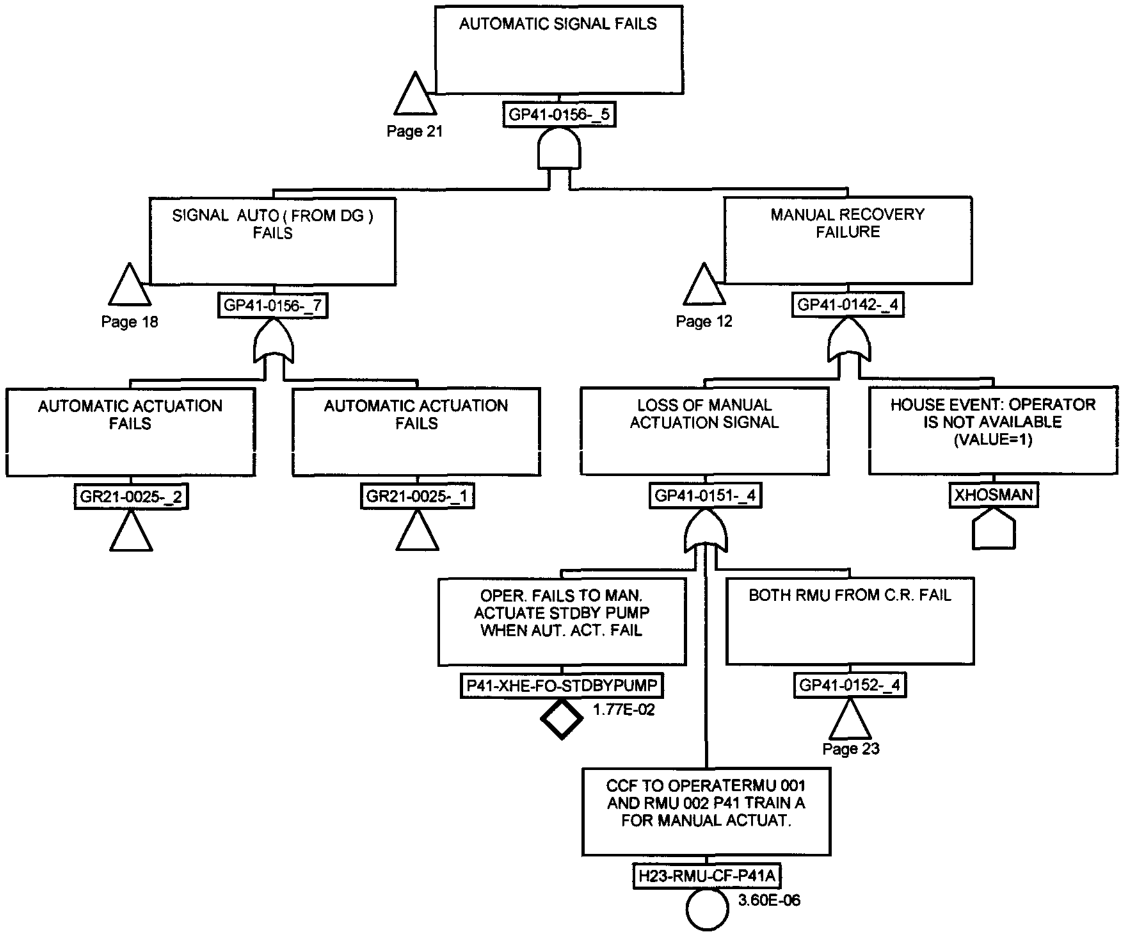
STANDBY PUMP 2A FAILS
GP41-0155-_2
Page 16
PUMP C002A IN MAINTENANCE
P41-MP_-TM-C002A
2.00E-03
MOTOR DRIVEN PUMP C002A FAILS TO RUN
P41-MP_-FR-C002A
7.68E-04
START AUTO AND MANUAL FAIL
GP41-0155-_5
Page 18
LOSS OF 6.9 KV AC FROM BUS R11-A2
GR11-0001-_1
MOTOR-DRIVEN PUMP C002A FAILS TO START
P41-MP_-FS-C002A
2.40E-03
DIV. A (NE RTNSS) SIGNAL TRANSMISSION FAILURE
GC62-0001-_1
MEDIUM VOLTAGE CIRCUIT BREAKER FAILS TO CLOSE
P41-MCB-OO-C002A
1.00E-03
LOSS OF 120 V AC FROM BUS R13-A2-2
GR13-0001-_22

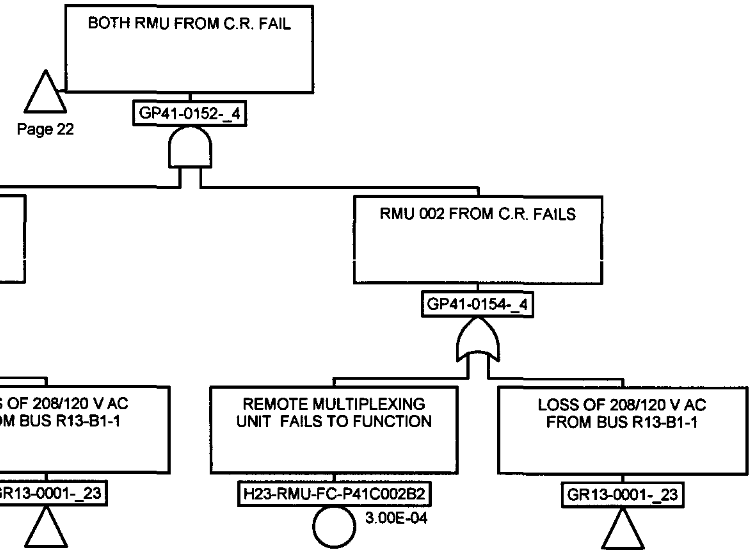

START AUTO AND MANUAL FAIL
GP41-0155-_5
Page 17
SIGNAL AUTO (FROM DG) FAILS
GP41-0156-_7
Page 22
MANUAL RECOVERY FAILURE
GP41-0142-_2
Page 7


INSUFFICIENT FLOW FRON PUMP 1B
GP41-0060-_3
Page 15
RUNNING PUMP 1B FAILS
GP41-0055-_3
STRAINER P41-D001 B PLUGGED
P41-STR-PG-D01B
2.40E-04
MOTOR OPERATED VALVE MV-F002B FAIL TO REMAIN OPEN
P41-MOV-OC-F002B
3.36E-06
MOTOR DRIVEN PUMP C001B FAILS TO RUN,
P41-MP_-FR-C001B
7.68E-04
MOTOR-DRIVEN PUMP C001B FAILS TO RESTART
GP41-0056-_3
LOSS OF 6.9 KV AC FROM BUS R11-B2
GR11-0001-_2
MOTOR-DRIVEN PUMP C001B FAILS TO RESTART
P41-MP_-FS-C001B
2.40E-03
CHECK VALVE F001B FAILS TO OPEN
P41-UV_-CC-F001B
2.00E-04
CIRCUIT BREAKER PUMP C001B FAILS TO CLOSE
P41-MCB-OO-C001B
1.00E-03

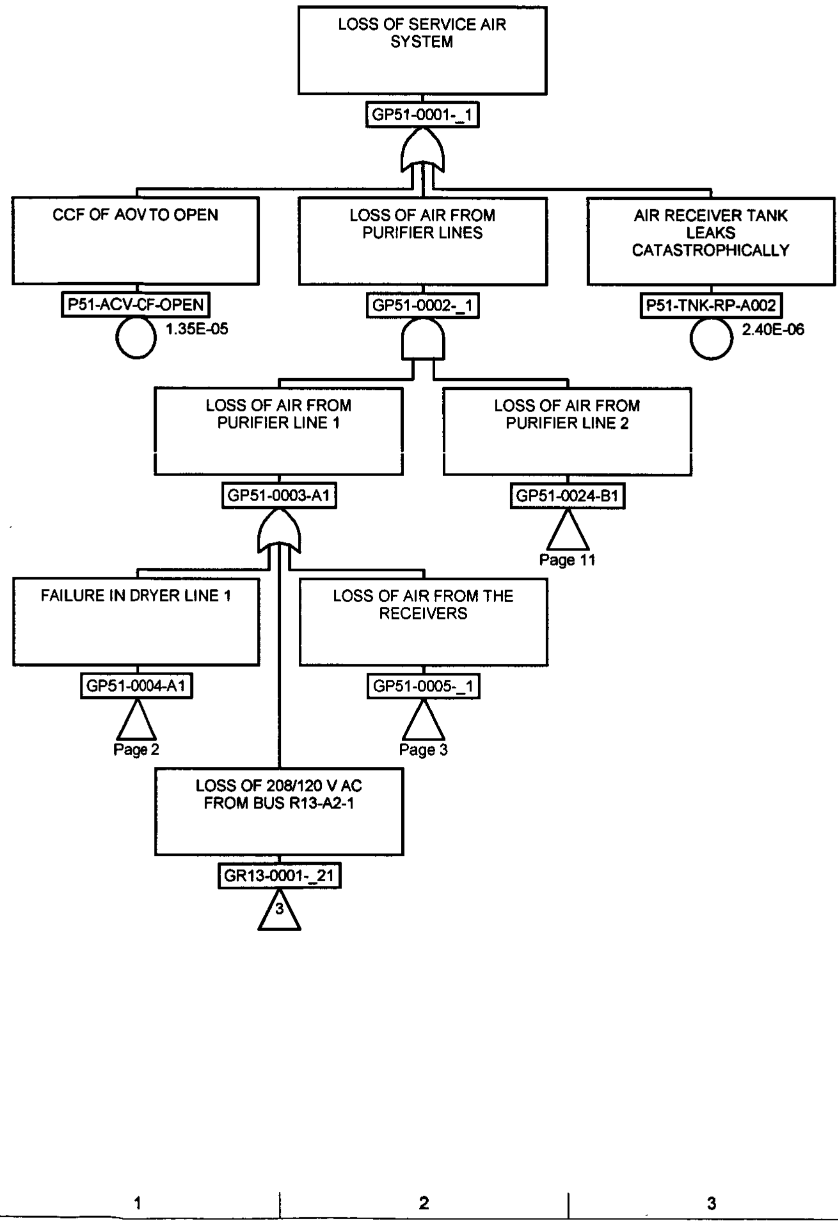

INSUFFICIENT FLOW FRON PUMP 2B
GP41-0060-_4
Page 15
PUMP 2B FAILS
GP41-0155-_4
Page 21
STRAINER P41-D002B PLUGGED
P41-STR-PG-D02B
3.59E-03
CHECK VALVE F003B FAILS TO OPEN
P41-UV_-CC-F003B
2.00E-04
MOTOR OPERATED VALVE MV-F004B FAIL TO REMAIN OPEN
P41-MOV-OC-F004B
3.36E-06

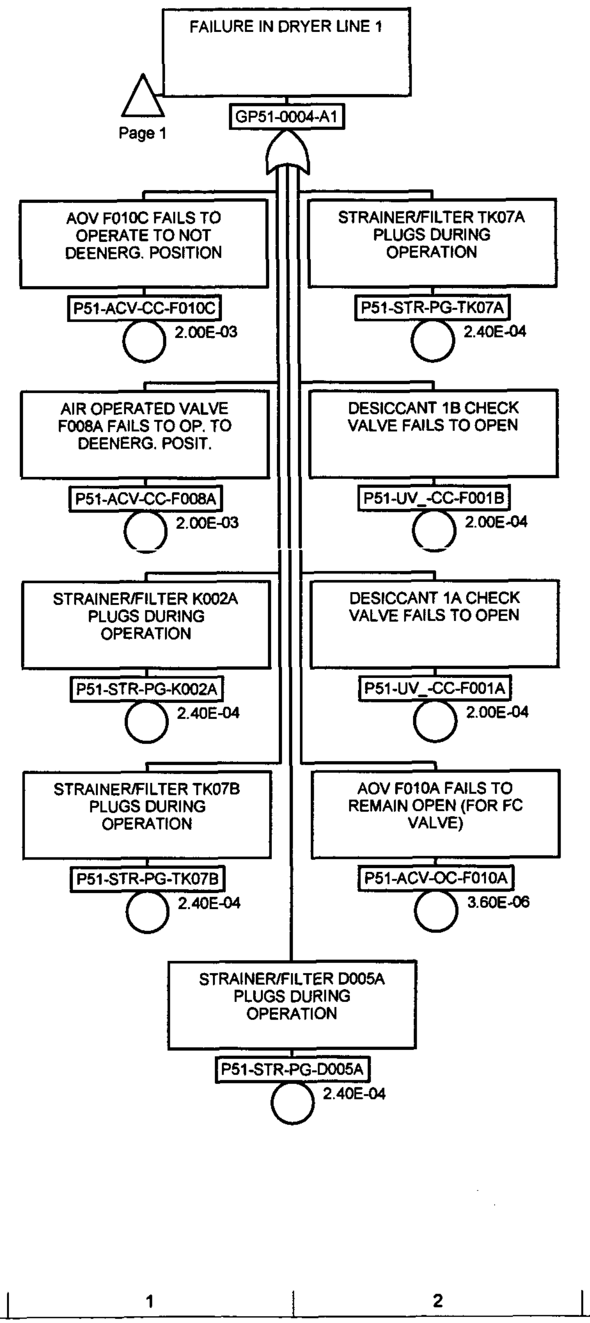

PUMP 2B FAILS
GP41-0155-_4
Page 20
PUMP C002B IN MAINTENANCE
P41-MP_-TM-C002B
2.00E-03
AUTOMATIC SIGNAL FAILS
GP41-0156-_5
Page 22
MOTOR-DRIVEN PUMP C002B FAILS TO START
P41-MP_-FS-C002B
2.40E-03
DIV. B (NE RTNSS) SIGNAL TRANSMISSION FAILURE
GC62-0001-_2
MEDIUM VOLTAGE CIRCUIT BREAKER FAILS TO CLOSE
P41-MCB-OO-C002B
1.00E-03
LOSS OF 6.9 KV AC FROM BUS R11-B2
GR11-0001-_2
MOTOR-DRIVEN PUMP C002B FAILS TO RUN
P41-MP_-FR-C002B
7.68E-04

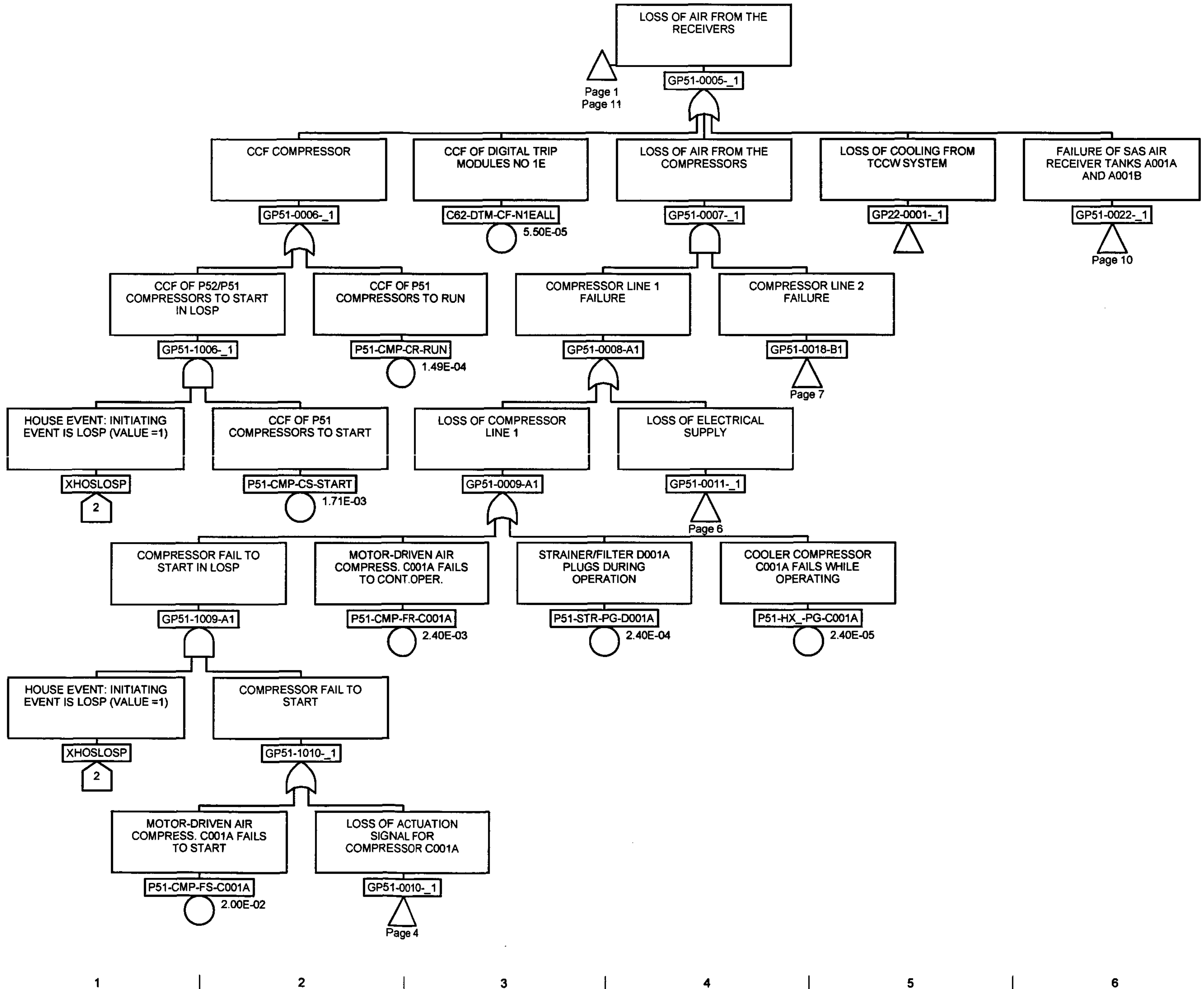

AUTOMATIC SIGNAL FAILS
GP41-0156-_5
Page 21
SIGNAL AUTO (FROM DG) FAILS
GP41-0156-_7
Page 18
MANUAL RECOVERY FAILURE
GP41-0142-_4
Page 12
AUTOMATIC ACTUATION FAILS
GR21-0025-_2
AUTOMATIC ACTUATION FAILS
GR21-0025-_1
LOSS OF MANUAL ACTUATION SIGNAL
GP41-0151-_4
HOUSE EVENT: OPERATOR IS NOT AVAILABLE (VALUE=1)
XHOSMAN
OPER. FAILS TO MAN. ACTUATE STDBY PUMP WHEN AUT. ACT. FAIL
P41-XHE-FO-STDBYPUMP
1.77E-02
BOTH RMU FROM C.R. FAIL
GP41-0152-_4
Page 23
CCF TO OPERATERMU 001 AND RMU 002 P41 TRAIN A FOR MANUAL ACTUAT.
H23-RMU-CF-P41A
3.60E-06

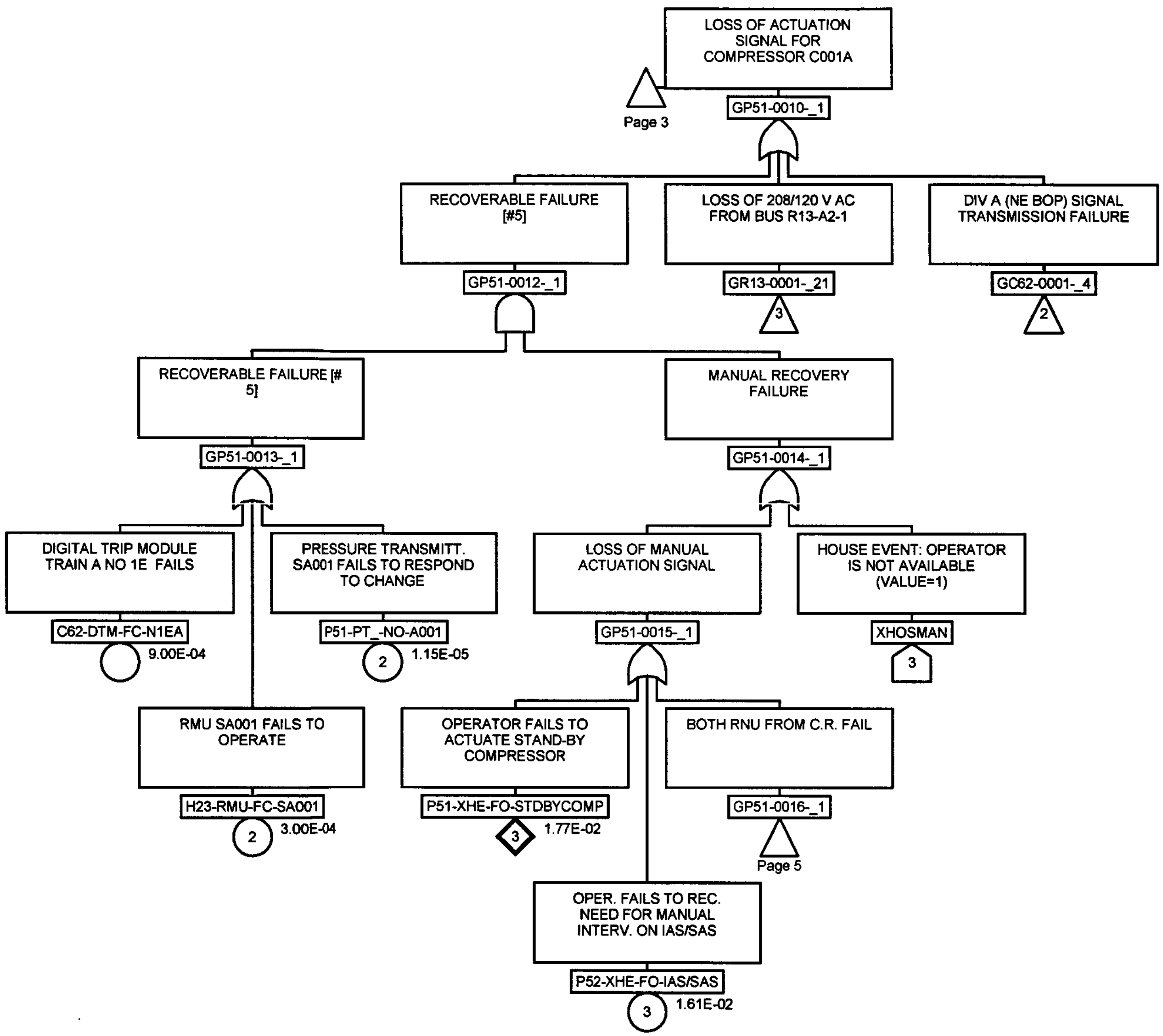

BOTH RMU FROM C.R. FAIL
Page 22
GP41-0152-_4
RMU 001 FROM C.R. FAILS
GP41-0153-_4
RMU 002 FROM C.R. FAILS
GP41-0154-_4
REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION
H23-RMU-FC-P41C002B1
3.00E-04
LOSS OF 208/120 V AC FROM BUS R13-B1-1
GR13-0001-_23
REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION
H23-RMU-FC-P41C002B2
3.00E-04
LOSS OF 208/120 V AC FROM BUS R13-B1-1
GR13-0001-_23

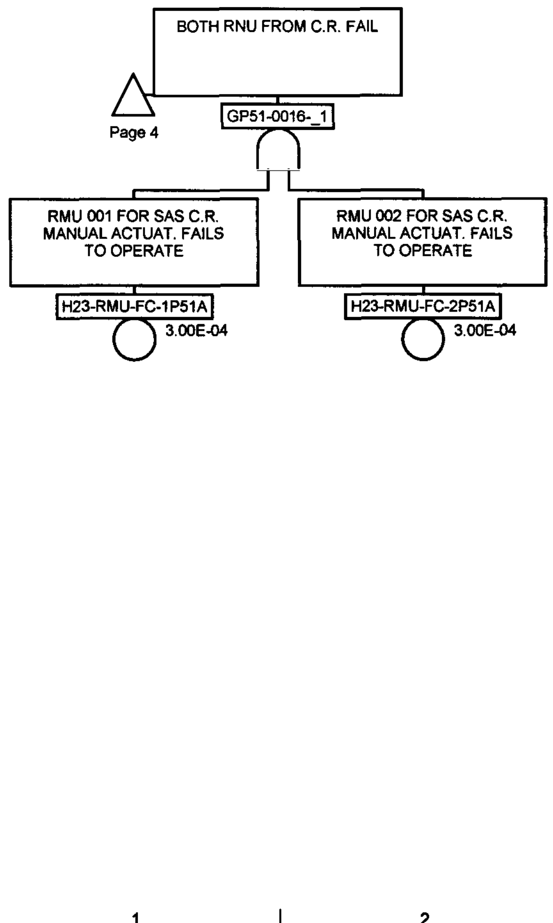
Appendix B.4.12
Instrument Air System and Service Air System Fault Tree

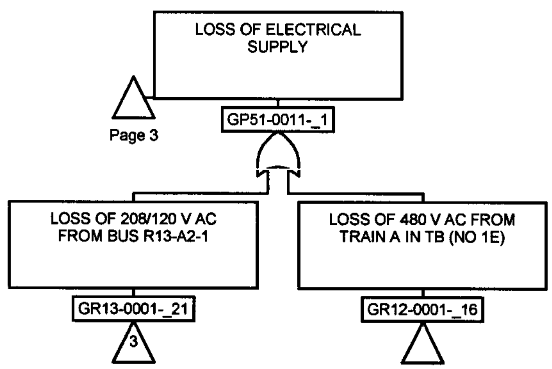

LOSS OF SERVICE AIR SYSTEM
GP51-0001-_1
CCF OF AOV TO OPEN
P51-ACV-CF-OPEN
1.35E-05
LOSS OF AIR FROM PURIFIER LINES
GP51-0002-_1
AIR RECEIVER TANK LEAKS CATASTROPHICALLY
P51-TNK-RP-A002
2.40E-06
LOSS OF AIR FROM PURIFIER LINE 1
GP51-0003-A1
LOSS OF AIR FROM PURIFIER LINE 2
GP51-0024-B1
Page 11
FAILURE IN DRYER LINE 1
GP51-0004-A1
Page 2
LOSS OF AIR FROM THE RECEIVERS
GP51-0005-_1
Page 3
LOSS OF 208/120 V AC FROM BUS R13-A2-1
GR13-0001-_21
3
1
2
3

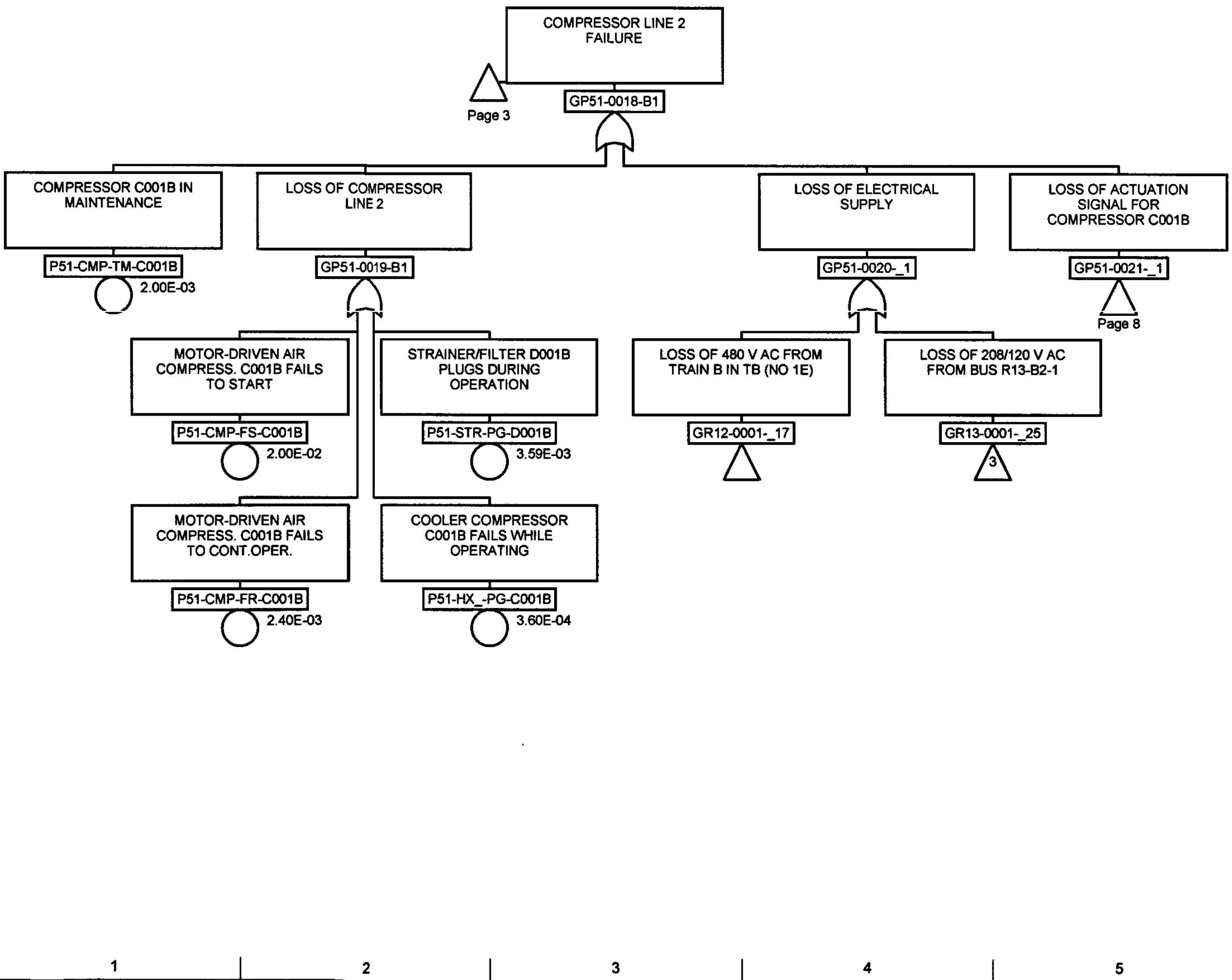

FAILURE IN DRYER LINE 1
GP51-0004-A1
Page 1
AOV F010C FAILS TO OPERATE TO NOT DEENERG. POSITION
P51-ACV-CC-F010C
2.00E-03
STRAINER/FILTER TK07A PLUGS DURING OPERATION
P51-STR-PG-TK07A
2.40E-04
AIR OPERATED VALVE F008A FAILS TO OP. TO DEENERG. POSIT.
P51-ACV-CC-F008A
2.00E-03
DESICCANT 1B CHECK VALVE FAILS TO OPEN
P51-UV_-CC-F001B
2.00E-04
STRAINER/FILTER K002A PLUGS DURING OPERATION
P51-STR-PG-K002A
2.40E-04
DESICCANT 1A CHECK VALVE FAILS TO OPEN
P51-UV_-CC-F001A
2.00E-04
STRAINER/FILTER TK07B PLUGS DURING OPERATION
P51-STR-PG-TK07B
2.40E-04
AOV F010A FAILS TO REMAIN OPEN (FOR FC VALVE)
P51-ACV-OC-F010A
3.60E-06
STRAINER/FILTER D005A PLUGS DURING OPERATION
P51-STR-PG-D005A
2.40E-04
1
2


LOSS OF AIR FROM THE RECEIVERS
GP51-0005-_1
Page 1
Page 11
CCF COMPRESSOR
GP51-0006-_1
CCF OF DIGITAL TRIP MODULES NO 1E
C62-DTM-CF-N1EALL
5.50E-05
LOSS OF AIR FROM THE COMPRESSORS
GP51-0007-_1
LOSS OF COOLING FROM TCCW SYSTEM
GP22-0001-_1
FAILURE OF SAS AIR RECEIVER TANKS A001A AND A001B
GP51-0022-_1
Page 10
CCF OF P52/P51 COMPRESSORS TO START IN LOSP
GP51-1006-_1
CCF OF P51 COMPRESSORS TO RUN
P51-CMP-CR-RUN
1.49E-04
COMPRESSOR LINE 1 FAILURE
GP51-0008-A1
COMPRESSOR LINE 2 FAILURE
GP51-0018-B1
Page 7
HOUSE EVENT: INITIATING EVENT IS LOSP (VALUE =1)
XHOSLOSP
2
CCF OF P51 COMPRESSORS TO START
P51-CMP-CS-START
1.71E-03
LOSS OF COMPRESSOR LINE 1
GP51-0009-A1
LOSS OF ELECTRICAL SUPPLY
GP51-0011-_1
Page 6
COMPRESSOR FAIL TO START IN LOSP
GP51-1009-A1
MOTOR-DRIVEN AIR COMPRESS. C001A FAILS TO CONT.OPER.
P51-CMP-FR-C001A
2.40E-03
STRAINER/FILTER D001A PLUGS DURING OPERATION
P51-STR-PG-D001A
2.40E-04
COOLER COMPRESSOR C001A FAILS WHILE OPERATING
P51-HX_-PG-C001A
2.40E-05
HOUSE EVENT: INITIATING EVENT IS LOSP (VALUE =1)
XHOSLOSP
2
COMPRESSOR FAIL TO START
GP51-1010-_1
MOTOR-DRIVEN AIR COMPRESS. C001A FAILS TO START
P51-CMP-FS-C001A
2.00E-02
LOSS OF ACTUATION SIGNAL FOR COMPRESSOR C001A
GP51-0010-_1
Page 4
1
2
3
4
5
6

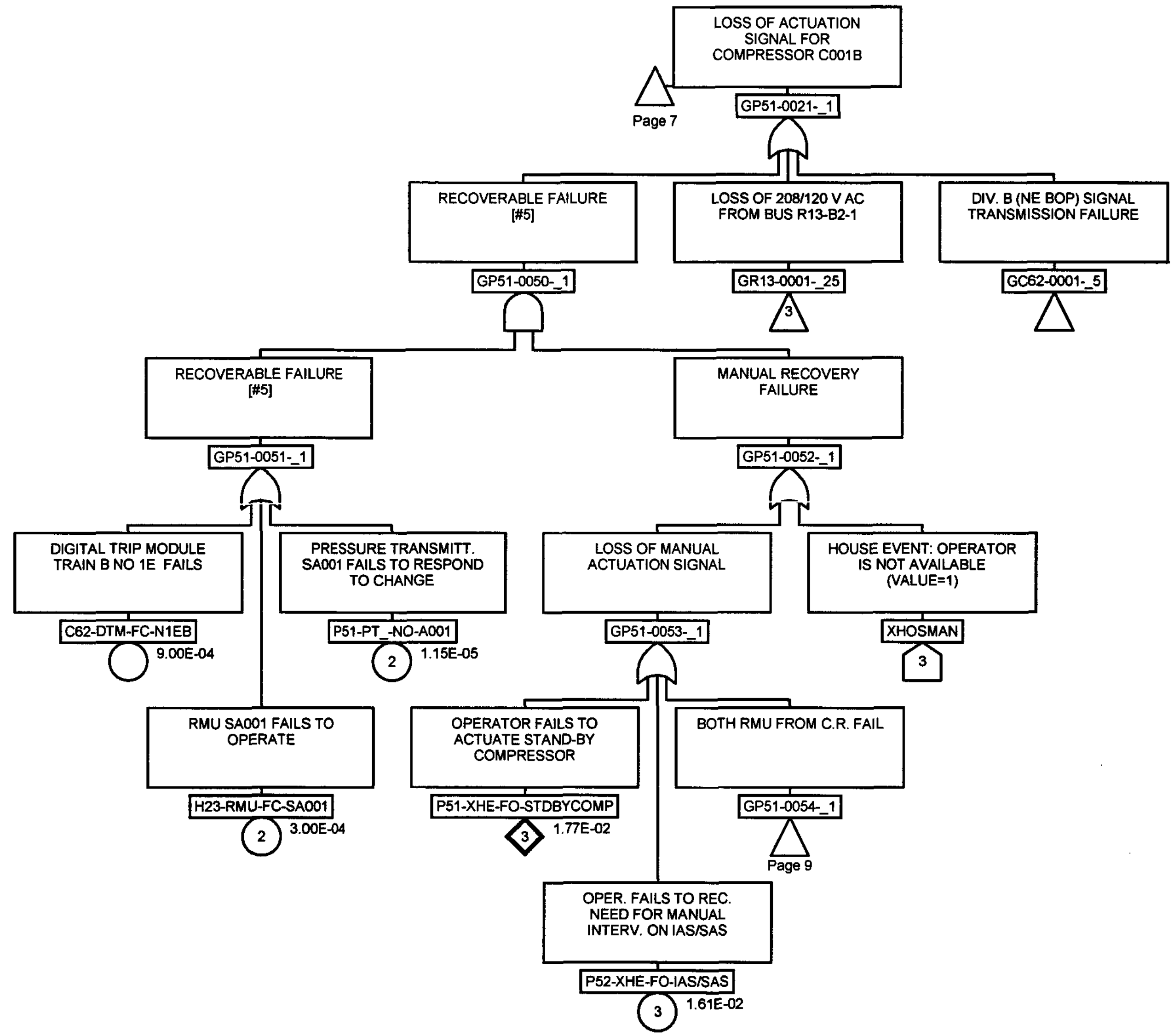

LOSS OF ACTUATION SIGNAL FOR COMPRESSOR C001A
GP51-0010-_1
Page 3
RECOVERABLE FAILURE [#5]
GP51-0012-_1
LOSS OF 208/120 V AC FROM BUS R13-A2-1
GR13-0001-_21
3
DIV A (NE BOP) SIGNAL TRANSMISSION FAILURE
GC62-0001-_4
2
RECOVERABLE FAILURE [# 5]
GP51-0013-_1
MANUAL RECOVERY FAILURE
GP51-0014-_1
DIGITAL TRIP MODULE TRAIN A NO 1E FAILS
C62-DTM-FC-N1EA
9.00E-04
PRESSURE TRANSMITT. SA001 FAILS TO RESPOND TO CHANGE
P51-PT_-NO-A001
2
1.15E-05
LOSS OF MANUAL ACTUATION SIGNAL
GP51-0015-_1
HOUSE EVENT: OPERATOR IS NOT AVAILABLE (VALUE=1)
XHOSMAN
3
RMU SA001 FAILS TO OPERATE
H23-RMU-FC-SA001
2
3.00E-04
OPERATOR FAILS TO ACTUATE STAND-BY COMPRESSOR
P51-XHE-FO-STDBYCOMP
3
1.77E-02
BOTH RNU FROM C.R. FAIL
GP51-0016-_1
Page 5
OPER. FAILS TO REC. NEED FOR MANUAL INTERV. ON IAS/SAS
P52-XHE-FO-IAS/SAS
3
1.61E-02
1
2
3
4

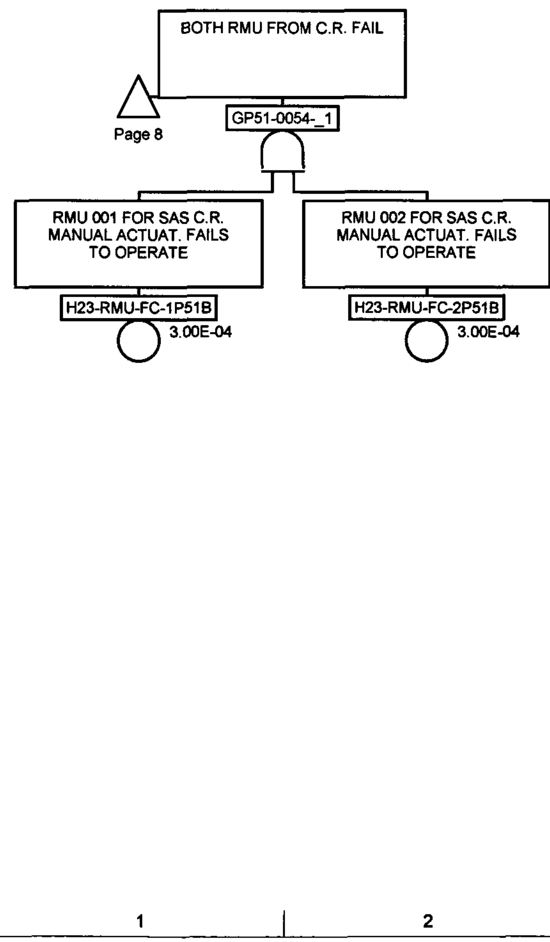

BOTH RNU FROM C.R. FAIL
Page 4
GP51-0016-_1
RMU 001 FOR SAS C.R. MANUAL ACTUAT. FAILS TO OPERATE
H23-RMU-FC-1P51A
3.00E-04
RMU 002 FOR SAS C.R. MANUAL ACTUAT. FAILS TO OPERATE
H23-RMU-FC-2P51A
3.00E-04
1
2

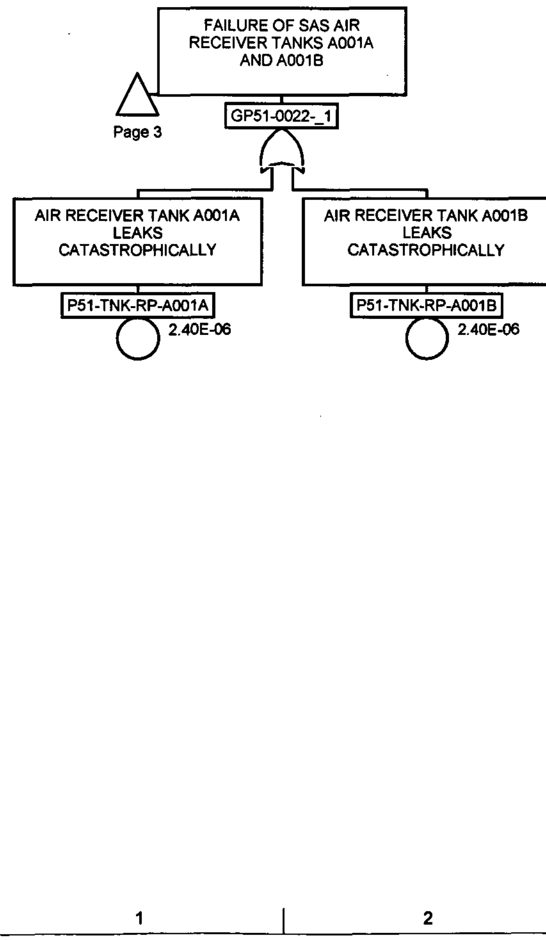

LOSS OF ELECTRICAL SUPPLY
Page 3
GP51-0011-_1
LOSS OF 208/120 V AC FROM BUS R13-A2-1
GR13-0001-_21
3
LOSS OF 480 V AC FROM TRAIN A IN TB (NO 1E)
GR12-0001-_16
1
2

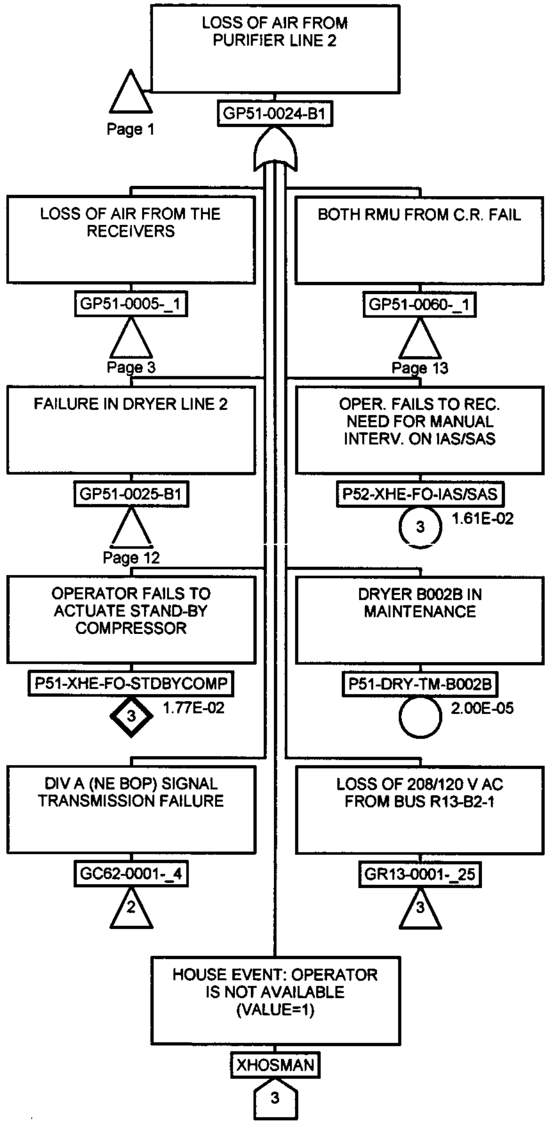


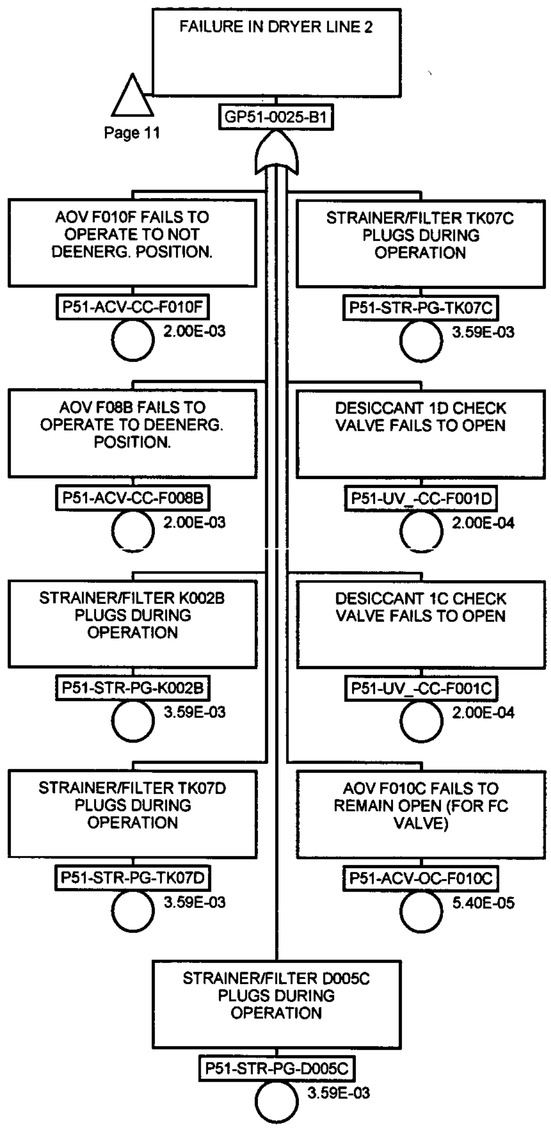
COMPRESSOR LINE 2 FAILURE
GP51-0018-B1
Page 3
COMPRESSOR C001B IN MAINTENANCE
P51-CMP-TM-C001B
2.00E-03
LOSS OF COMPRESSOR LINE 2
GP51-0019-B1
LOSS OF ELECTRICAL SUPPLY
GP51-0020-_1
LOSS OF ACTUATION SIGNAL FOR COMPRESSOR C001B
GP51-0021-_1
Page 8
MOTOR-DRIVEN AIR COMPRESS. C001B FAILS TO START
P51-CMP-FS-C001B
2.00E-02
STRAINER/FILTER D001B PLUGS DURING OPERATION
P51-STR-PG-D001B
3.59E-03
LOSS OF 480 V AC FROM TRAIN B IN TB (NO 1E)
GR12-0001-_17
LOSS OF 208/120 V AC FROM BUS R13-B2-1
GR13-0001-_25
3
MOTOR-DRIVEN AIR COMPRESS. C001B FAILS TO CONT.OPER.
P51-CMP-FR-C001B
2.40E-03
COOLER COMPRESSOR C001B FAILS WHILE OPERATING
P51-HX_-PG-C001B
3.60E-04
1
2
3
4
5

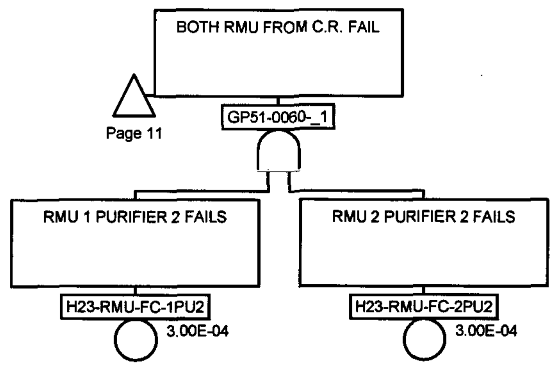

LOSS OF ACTUATION SIGNAL FOR COMPRESSOR C001B
GP51-0021-_1
Page 7
RECOVERABLE FAILURE [#5]
GP51-0050-_1
LOSS OF 208/120 V AC FROM BUS R13-B2-1
GR13-0001-_25
3
DIV. B (NE BOP) SIGNAL TRANSMISSION FAILURE
GC62-0001-_5
RECOVERABLE FAILURE [#5]
GP51-0051-_1
MANUAL RECOVERY FAILURE
GP51-0052-_1
DIGITAL TRIP MODULE TRAIN B NO 1E FAILS
C62-DTM-FC-N1EB
9.00E-04
PRESSURE TRANSMITT. SA001 FAILS TO RESPOND TO CHANGE
P51-PT_-NO-A001
2
1.15E-05
LOSS OF MANUAL ACTUATION SIGNAL
GP51-0053-_1
HOUSE EVENT: OPERATOR IS NOT AVAILABLE (VALUE=1)
XHOSMAN
3
RMU SA001 FAILS TO OPERATE
H23-RMU-FC-SA001
2
3.00E-04
OPERATOR FAILS TO ACTUATE STAND-BY COMPRESSOR
P51-XHE-FO-STDBYCOMP
3
1.77E-02
BOTH RMU FROM C.R. FAIL
GP51-0054-_1
Page 9
OPER. FAILS TO REC. NEED FOR MANUAL INTERV. ON IAS/SAS
P52-XHE-FO-IAS/SAS
3
1.61E-02
1
2
3
4


BOTH RMU FROM C.R. FAIL
GP51-0054-_1
Page 8
RMU 001 FOR SAS C.R. MANUAL ACTUAT. FAILS TO OPERATE
H23-RMU-FC-1P51B
3.00E-04
RMU 002 FOR SAS C.R. MANUAL ACTUAT. FAILS TO OPERATE
H23-RMU-FC-2P51B
3.00E-04
1
2


FAILURE OF SAS AIR RECEIVER TANKS A001A AND A001B
GP51-0022-_1
Page 3
AIR RECEIVER TANK A001A LEAKS CATASTROPHICALLY
P51-TNK-RP-A001A
2.40E-06
AIR RECEIVER TANK A001B LEAKS CATASTROPHICALLY
P51-TNK-RP-A001B
2.40E-06
1
2


LOSS OF AIR FROM PURIFIER LINE 2
GP51-0024-B1
Page 1
LOSS OF AIR FROM THE RECEIVERS
GP51-0005-_1
Page 3
BOTH RMU FROM C.R. FAIL
GP51-0060-_1
Page 13
FAILURE IN DRYER LINE 2
GP51-0025-B1
Page 12
OPER. FAILS TO REC. NEED FOR MANUAL INTERV. ON IAS/SAS
P52-XHE-FO-IAS/SAS
3
1.61E-02
OPERATOR FAILS TO ACTUATE STAND-BY COMPRESSOR
P51-XHE-FO-STDBYCOMP
3
1.77E-02
DRYER B002B IN MAINTENANCE
P51-DRY-TM-B002B
2.00E-05
DIV A (NE BOP) SIGNAL TRANSMISSION FAILURE
GC62-0001-_4
2
LOSS OF 208/120 V AC FROM BUS R13-B2-1
GR13-0001-_25
3
HOUSE EVENT: OPERATOR IS NOT AVAILABLE (VALUE=1)
XHOSMAN
3
1
2


FAILURE IN DRYER LINE 2
Page 11
GP51-0025-B1
AOV F010F FAILS TO OPERATE TO NOT DEENERG. POSITION.
P51-ACV-CC-F010F
2.00E-03
STRAINER/FILTER TK07C PLUGS DURING OPERATION
P51-STR-PG-TK07C
3.59E-03
AOV F08B FAILS TO OPERATE TO DEENERG. POSITION.
P51-ACV-CC-F008B
2.00E-03
DESICCANT 1D CHECK VALVE FAILS TO OPEN
P51-UV_-CC-F001D
2.00E-04
STRAINER/FILTER K002B PLUGS DURING OPERATION
P51-STR-PG-K002B
3.59E-03
DESICCANT 1C CHECK VALVE FAILS TO OPEN
P51-UV_-CC-F001C
2.00E-04
STRAINER/FILTER TK07D PLUGS DURING OPERATION
P51-STR-PG-TK07D
3.59E-03
AOV F010C FAILS TO REMAIN OPEN (FOR FC VALVE)
P51-ACV-OC-F010C
5.40E-05
STRAINER/FILTER D005C PLUGS DURING OPERATION
P51-STR-PG-D005C
3.59E-03
1
2

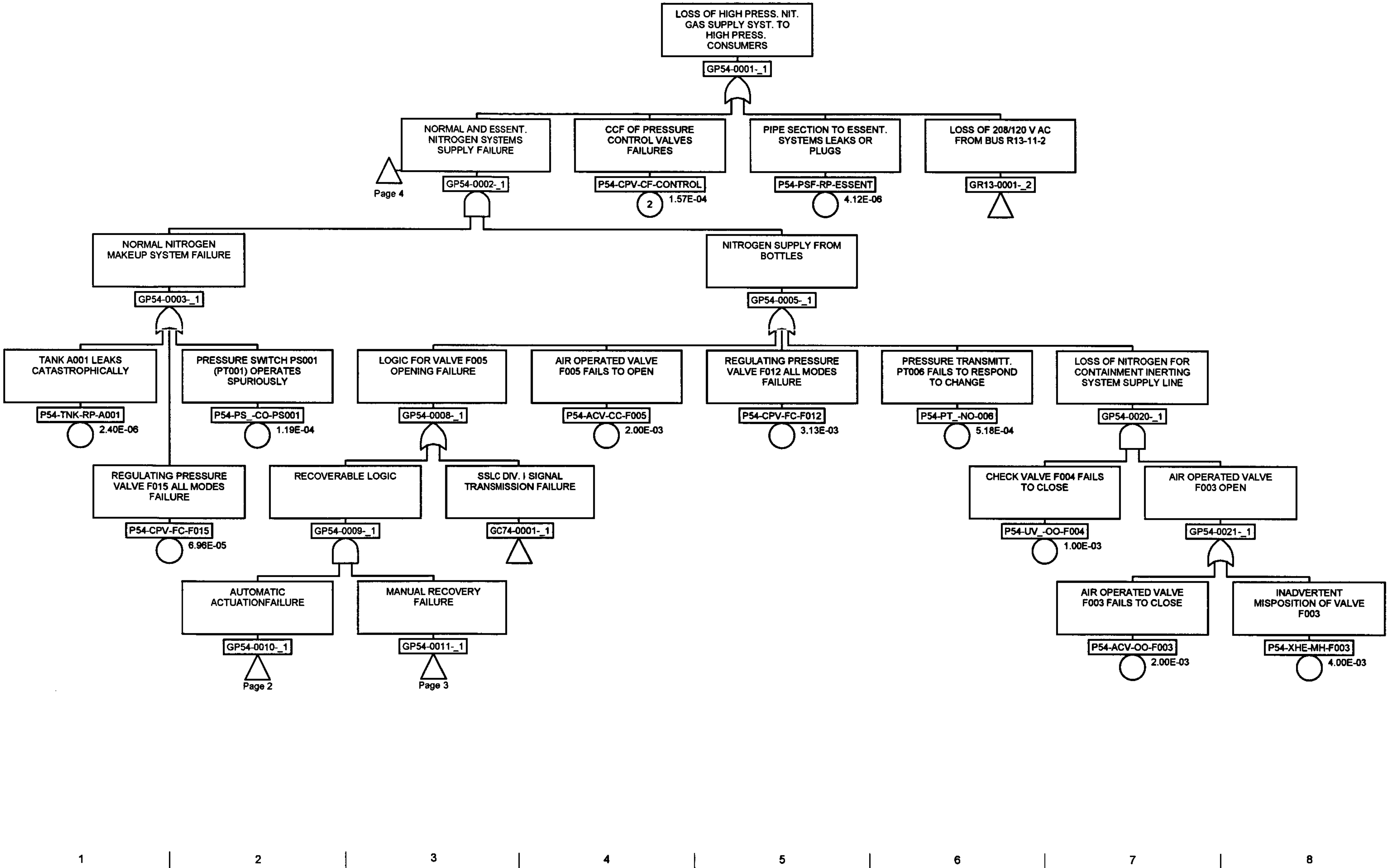

BOTH RMU FROM C.R. FAIL
Page 11
GP51-0060-_1
RMU 1 PURIFIER 2 FAILS
RMU 2 PURIFIER 2 FAILS
H23-RMU-FC-1PU2
3.00E-04
H23-RMU-FC-2PU2
3.00E-04

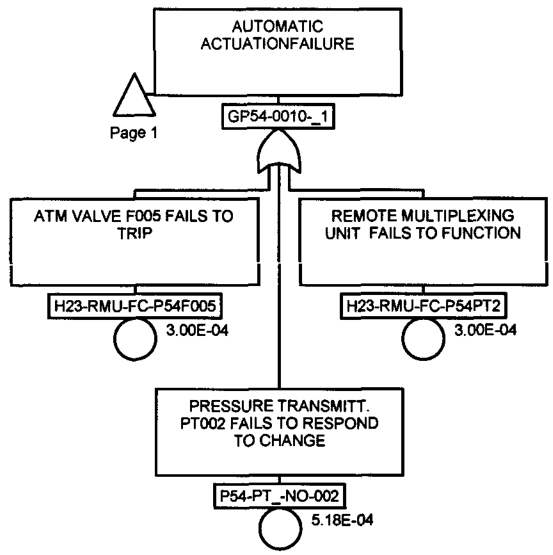
1 | 2

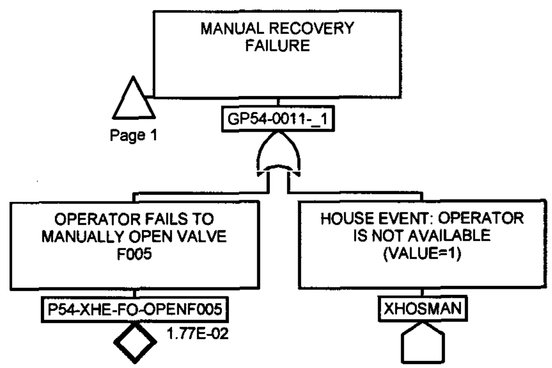
Name	Page	Zone
C62-DTM-CF-N1EALL	3	3
C62-DTM-FC-N1EA	4	1
C62-DTM-FC-N1EB	8	1
GC62-0001- 4	4	5
GC62-0001- 4	11	1
GC62-0001- 5	8	5
GP22-0001- 1	3	5
GP51-0001- 1	1	2
GP51-0002- 1	1	2
GP51-0003-A1	1	2
GP51-0004-A1	1	1
GP51-0004-A1	2	2
GP51-0005- 1	1	2
GP51-0005- 1	3	4
GP51-0005- 1	11	1
GP51-0006- 1	3	2
GP51-0007- 1	3	4
GP51-0008-A1	3	4
GP51-0009-A1	3	3
GP51-0010- 1	3	3
GP51-0010- 1	4	4
GP51-0011- 1	3	4
GP51-0011- 1	6	2
GP51-0012- 1	4	3
GP51-0013- 1	4	2
GP51-0014- 1	4	4
GP51-0015- 1	4	3
GP51-0016- 1	4	4
GP51-0016- 1	5	2
GP51-0018-B1	3	5
GP51-0018-B1	7	3
GP51-0019-B1	7	2
GP51-0020- 1	7	4
GP51-0021- 1	7	5
GP51-0021- 1	8	4
GP51-0022- 1	3	6
GP51-0022- 1	10	2
GP51-0024-B1	1	3
GP51-0024-B1	11	2
GP51-0025-B1	11	1
GP51-0025-B1	12	2
GP51-0050- 1	8	3
GP51-0051- 1	8	2
GP51-0052- 1	8	4
GP51-0053- 1	8	3
GP51-0054- 1	8	4
GP51-0054- 1	9	2
GP51-0060- 1	11	2
GP51-0060- 1	13	2
GP51-1006- 1	3	2
GP51-1009-A1	3	2
GP51-1010- 1	3	2
GR12-0001- 16	6	2
GR12-0001-_17	7	4

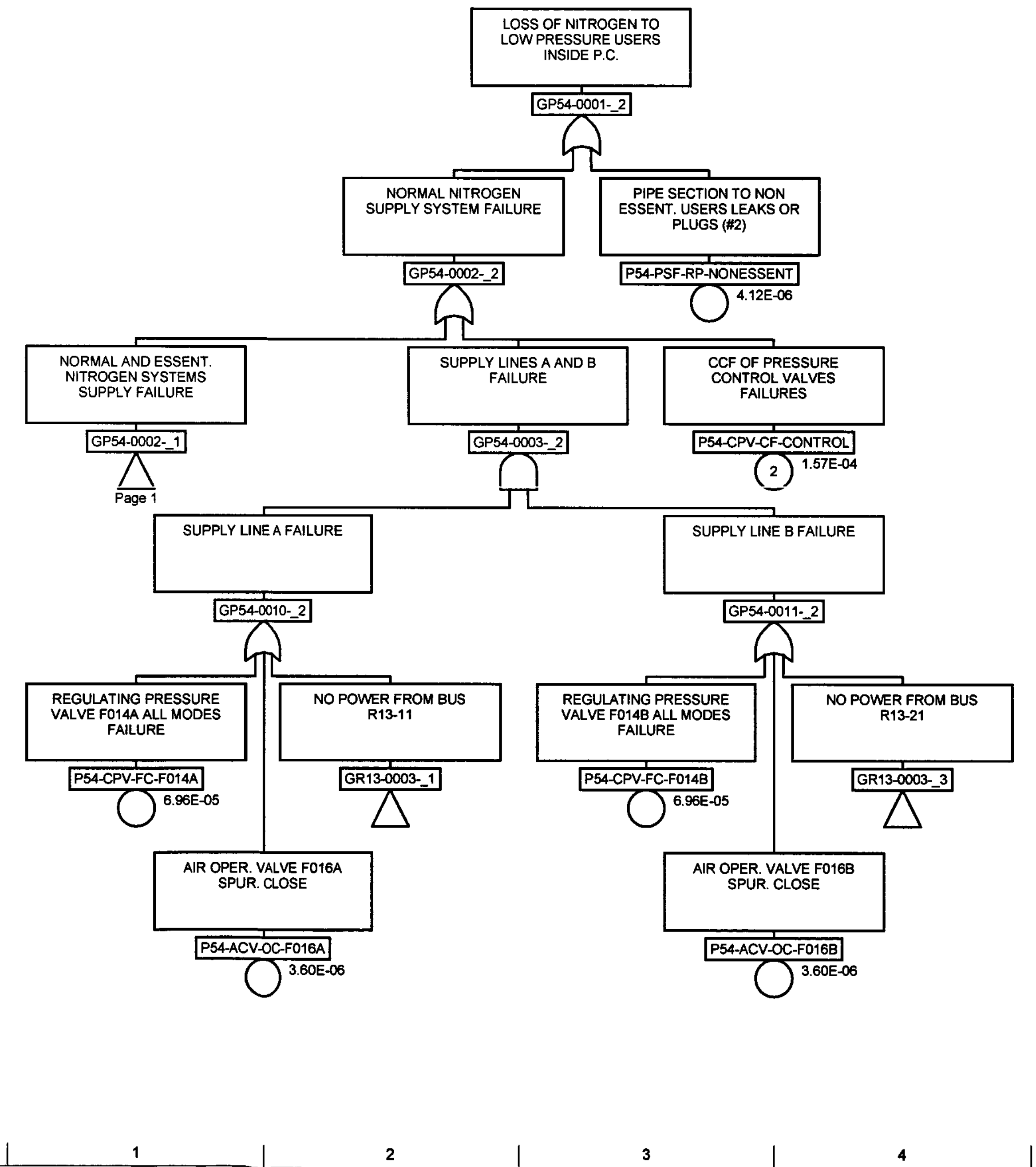
Name	Page	Zone
GR13-0001- 21	1	2
GR13-0001- 21	4	4
GR13-0001- 21	6	1
GR13-0001- 25	7	5
GR13-0001- 25	8	4
GR13-0001- 25	11	2
H23-RMU-FC-1P51A	5	1
H23-RMU-FC-1P51B	9	1
H23-RMU-FC-1PU2	13	1
H23-RMU-FC-2P51A	5	2
H23-RMU-FC-2P51B	9	2
H23-RMU-FC-2PU2	13	2
H23-RMU-FC-SA001	4	2
H23-RMU-FC-SA001	8	2
P51-ACV-CC-F008A	2	1
P51-ACV-CC-F008B	12	1
P51-ACV-CC-F010C	2	1
P51-ACV-CC-F010F	12	1
P51-ACV-CF-OPEN	1	1
P51-ACV-OC-F010A	2	2
P51-ACV-OC-F010C	12	2
P51-CMP-CR-RUN	3	3
P51-CMP-CS-START	3	2
P51-CMP-FR-C001A	3	3
P51-CMP-FR-C001B	7	2
P51-CMP-FS-C001A	3	2
P51-CMP-FS-C001B	7	2
P51-CMP-TM-C001B	7	1
P51-DRY-TM-B002B	11	2
P51-HX -PG-C001A	3	5
P51-HX -PG-C001B	7	3
P51-PT -NO-A001	4	2
P51-PT -NO-A001	8	2
P51-STR-PG-D001A	3	4
P51-STR-PG-D001B	7	3
P51-STR-PG-D005A	2	2
P51-STR-PG-D005C	12	2
P51-STR-PG-K002A	2	1
P51-STR-PG-K002B	12	1
P51-STR-PG-TK07A	2	2
P51-STR-PG-TK07B	2	1
P51-STR-PG-TK07C	12	2
P51-STR-PG-TK07D	12	1
P51-TNK-RP-A001A	10	1
P51-TNK-RP-A001B	10	2
P51-TNK-RP-A002	1	3
P51-UV -CC-F001A	2	2
P51-UV -CC-F001B	2	2
P51-UV -CC-F001C	12	2
P51-UV -CC-F001D	12	2
P51-XHE-FO-STDBYCOMP	4	3
P51-XHE-FO-STDBYCOMP	8	3
P51-XHE-FO-STDBYCOMP	11	1
P52-XHE-FO-IAS/SAS	4	3

Appendix B.4.13 High Pressure Nitrogen Supply System Fault Tree


LOSS OF HIGH PRESS. NIT. GAS SUPPLY SYST. TO HIGH PRESS. CONSUMERS
GP54-0001-_1
NORMAL AND ESSENT. NITROGEN SYSTEMS SUPPLY FAILURE
GP54-0002-_1
Page 4
CCF OF PRESSURE CONTROL VALVES FAILURES
P54-CPV-CF-CONTROL
2
1.57E-04
PIPE SECTION TO ESSENT. SYSTEMS LEAKS OR PLUGS
P54-PSF-RP-ESSENT
4.12E-06
LOSS OF 208/120 V AC FROM BUS R13-11-2
GR13-0001-_2
NORMAL NITROGEN MAKEUP SYSTEM FAILURE
GP54-0003-_1
NITROGEN SUPPLY FROM BOTTLES
GP54-0005-_1
TANK A001 LEAKS CATASTROPHICALLY
P54-TNK-RP-A001
2.40E-06
PRESSURE SWITCH PS001 (PT001) OPERATES SPURIOUSLY
P54-PS_-CO-PS001
1.19E-04
REGULATING PRESSURE VALVE F015 ALL MODES FAILURE
P54-CPV-FC-F015
6.96E-05
LOGIC FOR VALVE F005 OPENING FAILURE
GP54-0008-_1
RECOVERABLE LOGIC
GP54-0009-_1
SSLC DIV. I SIGNAL TRANSMISSION FAILURE
GC74-0001-_1
AUTOMATIC ACTUATIONFAILURE
GP54-0010-_1
Page 2
MANUAL RECOVERY FAILURE
GP54-0011-_1
Page 3
AIR OPERATED VALVE F005 FAILS TO OPEN
P54-ACV-CC-F005
2.00E-03
REGULATING PRESSURE VALVE F012 ALL MODES FAILURE
P54-CPV-FC-F012
3.13E-03
PRESSURE TRANSMITT. PT006 FAILS TO RESPOND TO CHANGE
P54-PT_-NO-006
5.18E-04
LOSS OF NITROGEN FOR CONTAINMENT INERTING SYSTEM SUPPLY LINE
GP54-0020-_1
CHECK VALVE F004 FAILS TO CLOSE
P54-UV_-OO-F004
1.00E-03
AIR OPERATED VALVE F003 OPEN
GP54-0021-_1
AIR OPERATED VALVE F003 FAILS TO CLOSE
P54-ACV-OO-F003
2.00E-03
INADVERTENT MISPOSITION OF VALVE F003
P54-XHE-MH-F003
4.00E-03
1
2
3
4
5
6
7
8

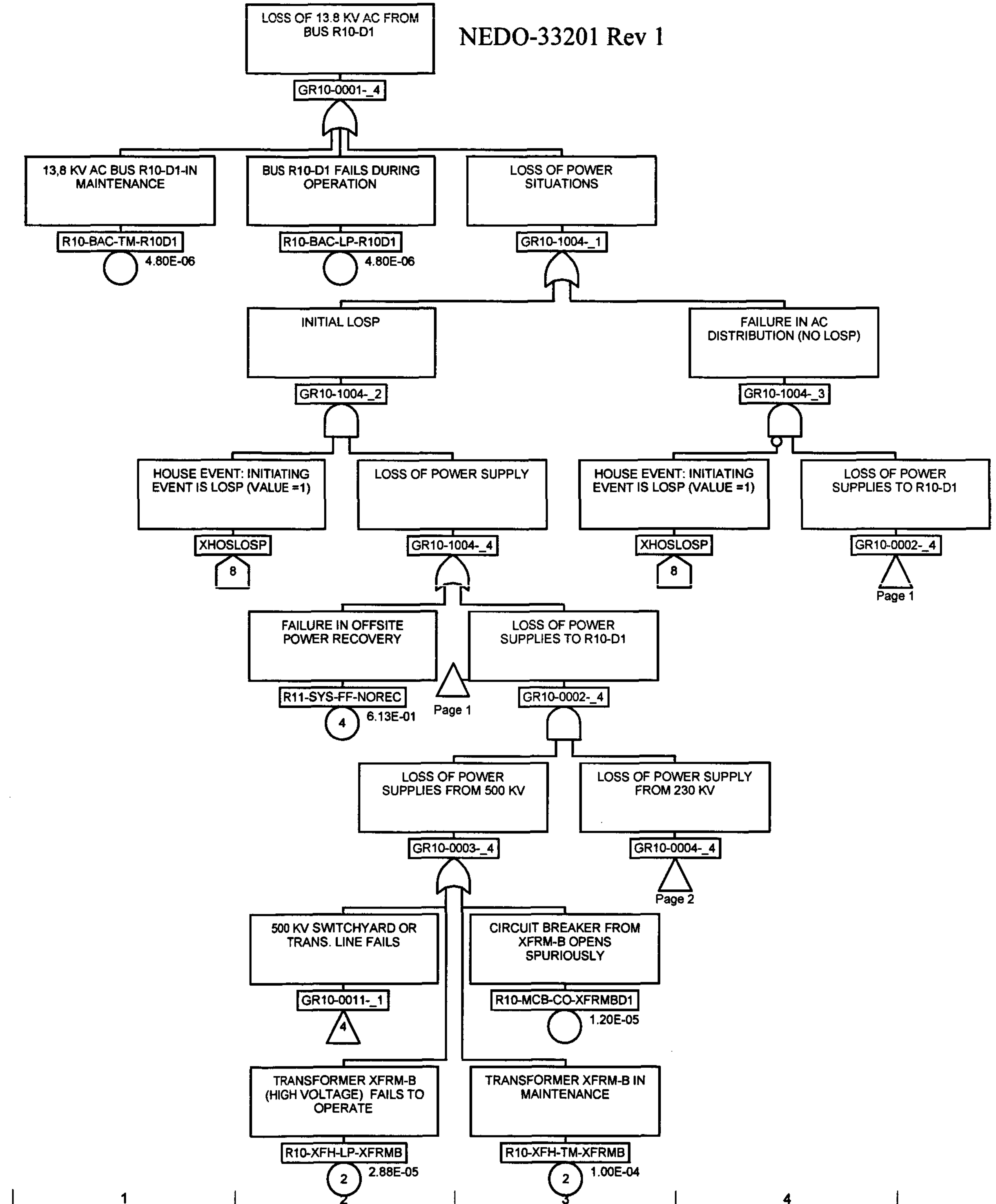

AUTOMATIC
ACTUATIONFAILURE
GP54-0010-_1
Page 1
ATM VALVE F005 FAILS TO
TRIP
H23-RMU-FC-P54F005
3.00E-04
REMOTE MULTIPLEXING
UNIT FAILS TO FUNCTION
H23-RMU-FC-P54PT2
3.00E-04
PRESSURE TRANSMITT.
PT002 FAILS TO RESPOND
TO CHANGE
P54-PT_-NO-002
5.18E-04
1
2


MANUAL RECOVERY FAILURE
Page 1
GP54-0011-_1
OPERATOR FAILS TO MANUALLY OPEN VALVE F005
P54-XHE-FO-OPENF005
1.77E-02
HOUSE EVENT: OPERATOR IS NOT AVAILABLE (VALUE=1)
XHOSMAN

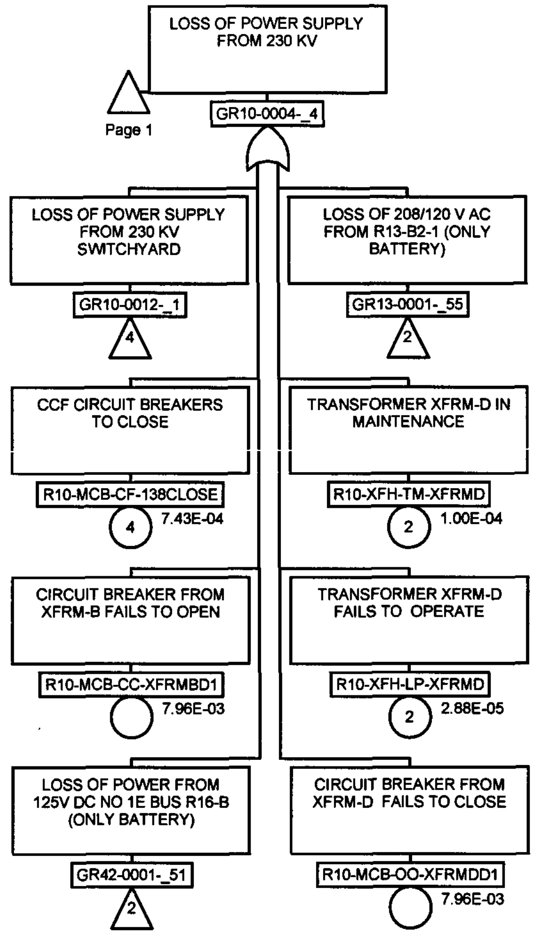

LOSS OF NITROGEN TO LOW PRESSURE USERS INSIDE P.C.
GP54-0001-_2
NORMAL NITROGEN SUPPLY SYSTEM FAILURE
GP54-0002-_2
PIPE SECTION TO NON ESSENT. USERS LEAKS OR PLUGS (#2)
P54-PSF-RP-NONESSENT
4.12E-06
NORMAL AND ESSENT. NITROGEN SYSTEMS SUPPLY FAILURE
GP54-0002-_1
Page 1
SUPPLY LINES A AND B FAILURE
GP54-0003-_2
CCF OF PRESSURE CONTROL VALVES FAILURES
P54-CPV-CF-CONTROL
2
1.57E-04
SUPPLY LINE A FAILURE
GP54-0010-_2
SUPPLY LINE B FAILURE
GP54-0011-_2
REGULATING PRESSURE VALVE F014A ALL MODES FAILURE
P54-CPV-FC-F014A
6.96E-05
NO POWER FROM BUS R13-11
GR13-0003-_1
REGULATING PRESSURE VALVE F014B ALL MODES FAILURE
P54-CPV-FC-F014B
6.96E-05
NO POWER FROM BUS R13-21
GR13-0003-_3
AIR OPER. VALVE F016A SPUR. CLOSE
P54-ACV-OC-F016A
3.60E-06
AIR OPER. VALVE F016B SPUR. CLOSE
P54-ACV-OC-F016B
3.60E-06
1
2
3
4

Name	Page	Zone	Name	Page	Zone
GC74-0001- 1	1	4			
GP54-0001- 1	1	5			
GP54-0001- 2	4	3			
GP54-0002- 1	1	3			
GP54-0002- 1	4	1			
GP54-0002- 2	4	2			
GP54-0003- 1	1	2			
GP54-0003- 2	4	3			
GP54-0005- 1	1	5			
GP54-0008- 1	1	3			
GP54-0009- 1	1	3			
GP54-0010- 1	1	2			
GP54-0010- 1	2	2			
GP54-0010- 2	4	2			
GP54-0011- 1	1	3			
GP54-0011- 1	3	2			
GP54-0011- 2	4	4			
GP54-0020- 1	1	7			
GP54-0021- 1	1	8			
GR13-0001- 2	1	6			
GR13-0003- 1	4	2			
GR13-0003- 3	4	4			
H23-RMU-FC-P54F005	2	1			
H23-RMU-FC-P54PT2	2	2			
P54-ACV-CC-F005	1	4			
P54-ACV-OC-F016A	4	2			
P54-ACV-OC-F016B	4	4			
P54-ACV-OO-F003	1	7			
P54-CPV-CF-CONTROL	1	4			
P54-CPV-CF-CONTROL	4	4			
P54-CPV-FC-F012	1	5			
P54-CPV-FC-F014A	4	1			
P54-CPV-FC-F014B	4	3			
P54-CPV-FC-F015	1	2			
P54-PSF-RP-ESSENT	1	5			
P54-PSF-RP-NONESSENT	4	3			
P54-PS -CO-PS001	1	2			
P54-PT -NO-002	2	2			
P54-PT -NO-006	1	6			
P54-TNK-RP-A001	1	1			
P54-UV -OO-F004	1	7			
P54-XHE-FO-OPENF005	3	1			
P54-XHE-MH-F003	1	8			
XHOSMAN	3	2			

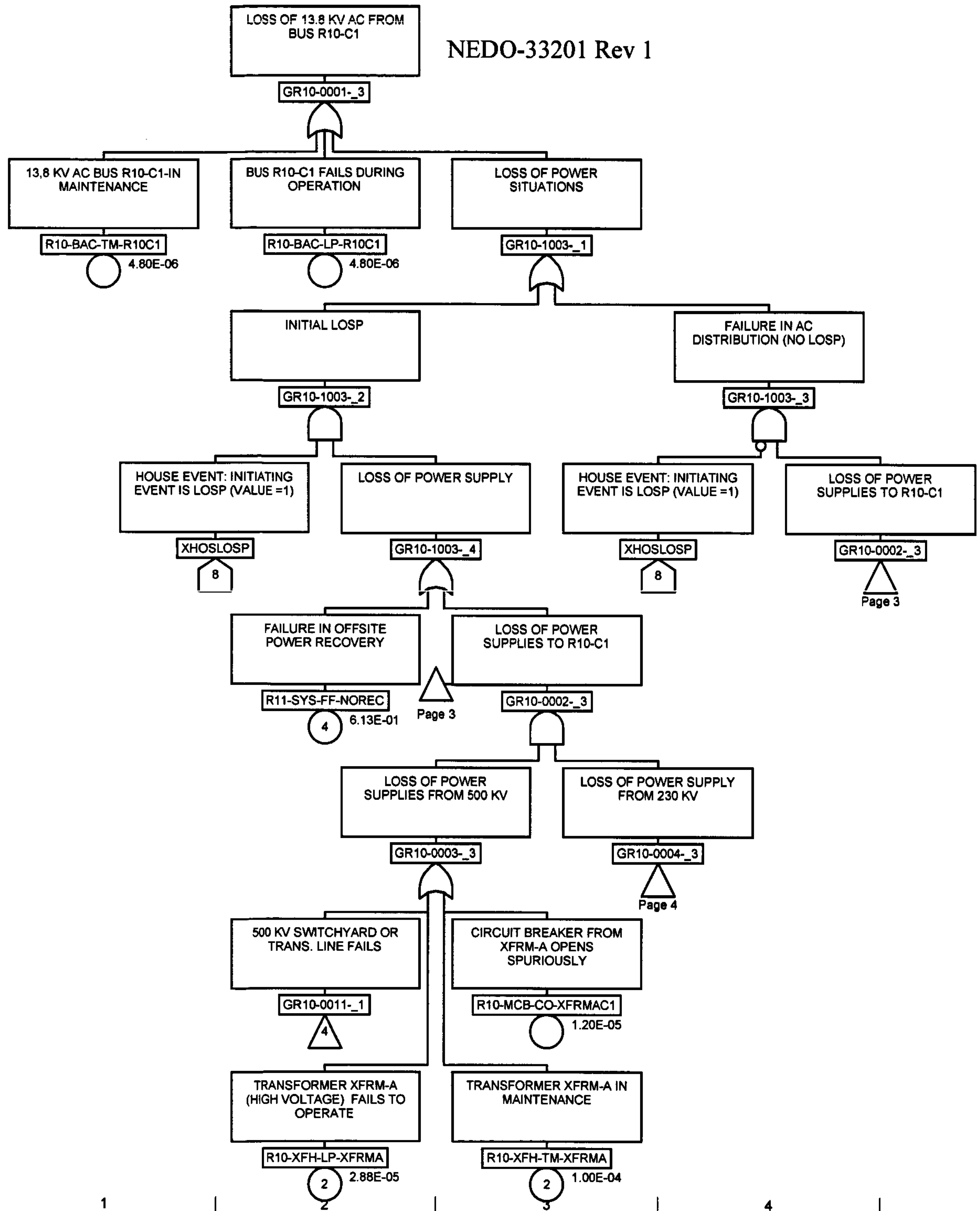
Appendix B.4.14-1 A.C. Electric Power System Fault Tree

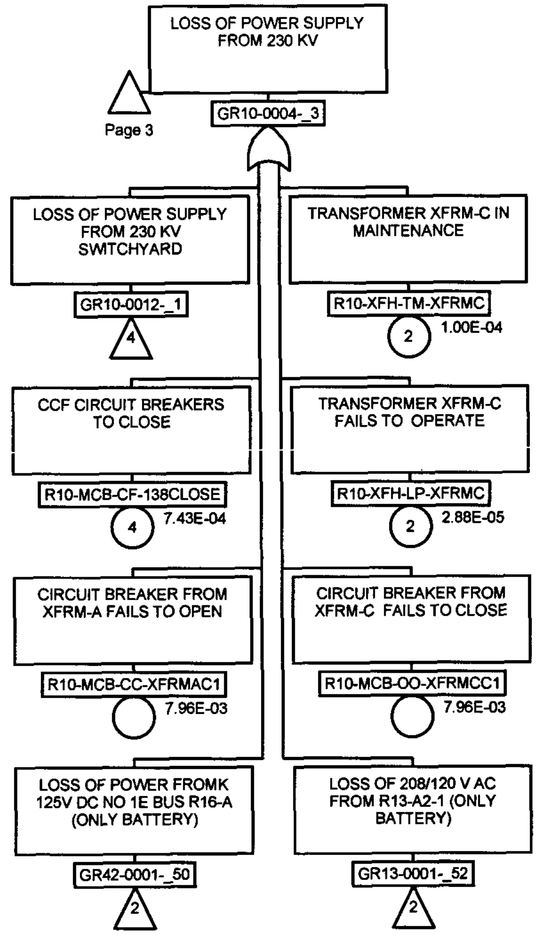


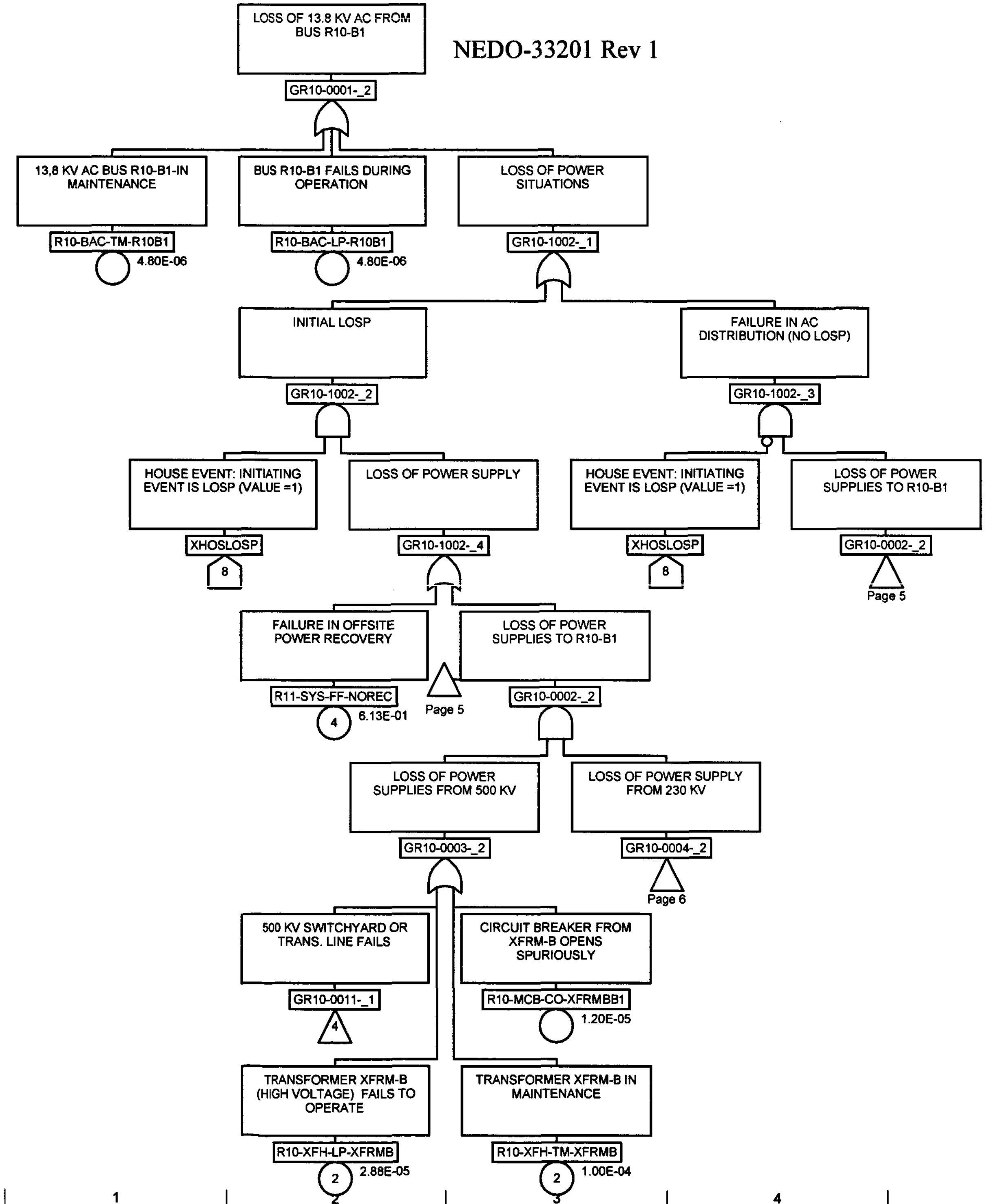
LOSS OF 13.8 KV AC FROM BUS R10-D1
GR10-0001-_4
13,8 KV AC BUS R10-D1-IN MAINTENANCE
R10-BAC-TM-R10D1
4.80E-06
BUS R10-D1 FAILS DURING OPERATION
R10-BAC-LP-R10D1
4.80E-06
LOSS OF POWER SITUATIONS
GR10-1004-_1
INITIAL LOSP
GR10-1004-_2
FAILURE IN AC DISTRIBUTION (NO LOSP)
GR10-1004-_3
HOUSE EVENT: INITIATING EVENT IS LOSP (VALUE =1)
XHOSLOSP
8
LOSS OF POWER SUPPLY
GR10-1004-_4
HOUSE EVENT: INITIATING EVENT IS LOSP (VALUE =1)
XHOSLOSP
8
LOSS OF POWER SUPPLIES TO R10-D1
GR10-0002-_4
Page 1
FAILURE IN OFFSITE POWER RECOVERY
R11-SYS-FF-NOREC
4
6.13E-01
Page 1
LOSS OF POWER SUPPLIES TO R10-D1
GR10-0002-_4
LOSS OF POWER SUPPLIES FROM 500 KV
GR10-0003-_4
LOSS OF POWER SUPPLY FROM 230 KV
GR10-0004-_4
Page 2
500 KV SWITCHYARD OR TRANS. LINE FAILS
GR10-0011-_1
4
CIRCUIT BREAKER FROM XFRM-B OPENS SPURIOUSLY
R10-MCB-CO-XFRMBD1
1.20E-05
TRANSFORMER XFRM-B (HIGH VOLTAGE) FAILS TO OPERATE
R10-XFH-LP-XFRMB
2
2.88E-05
TRANSFORMER XFRM-B IN MAINTENANCE
R10-XFH-TM-XFRMB
2
1.00E-04
1
2
3
4

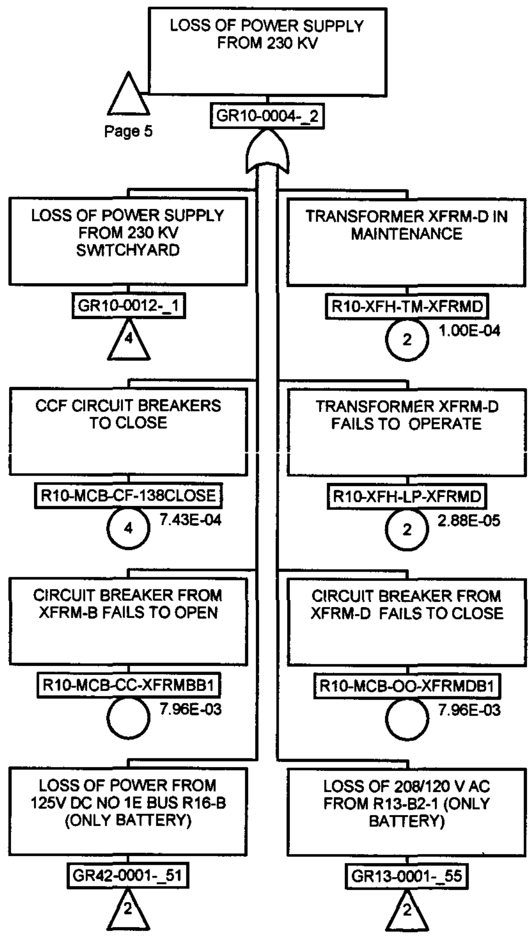


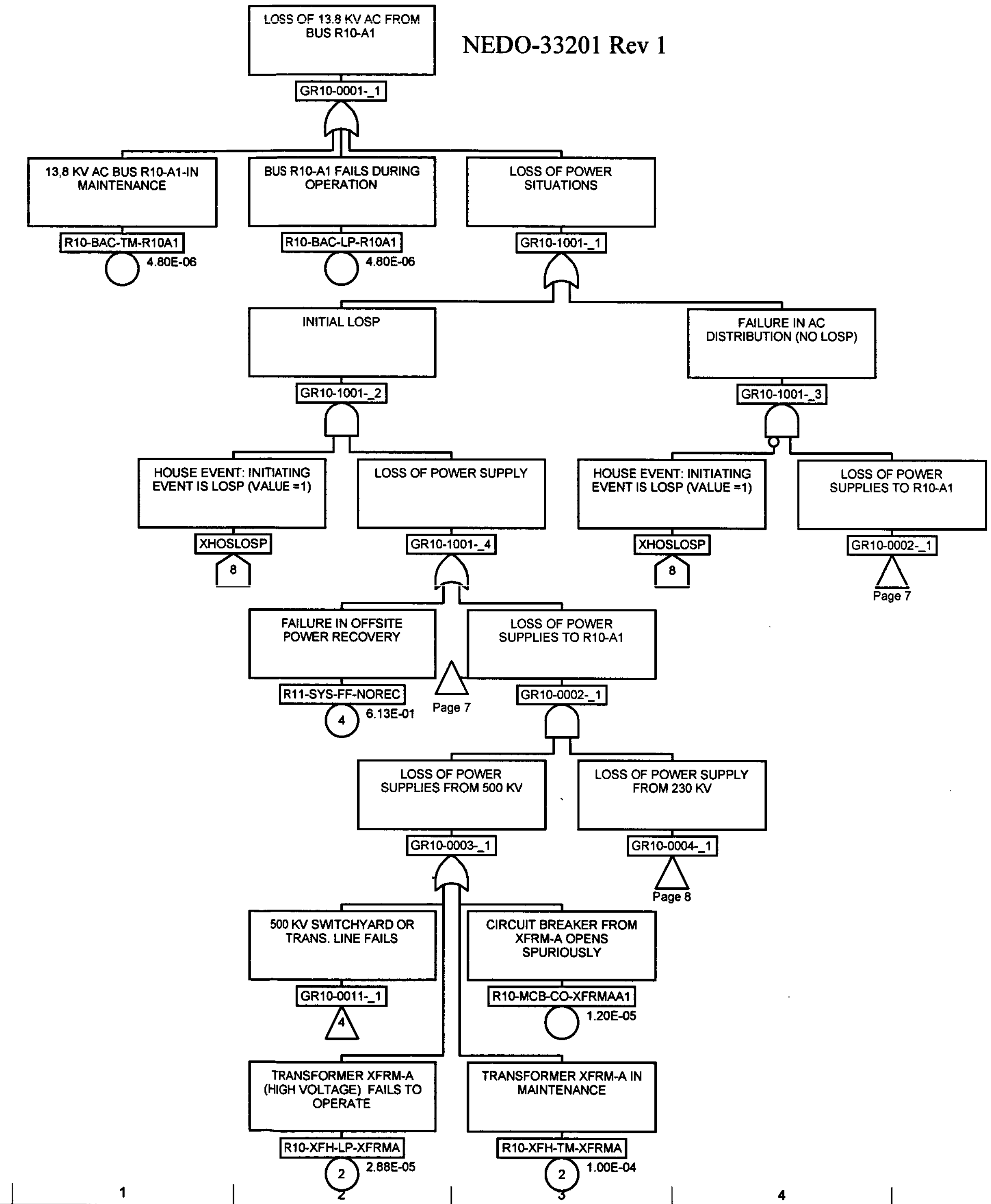
	1	2			
R10			x-R10.caf	Appendix B.4.14-1	Page 2

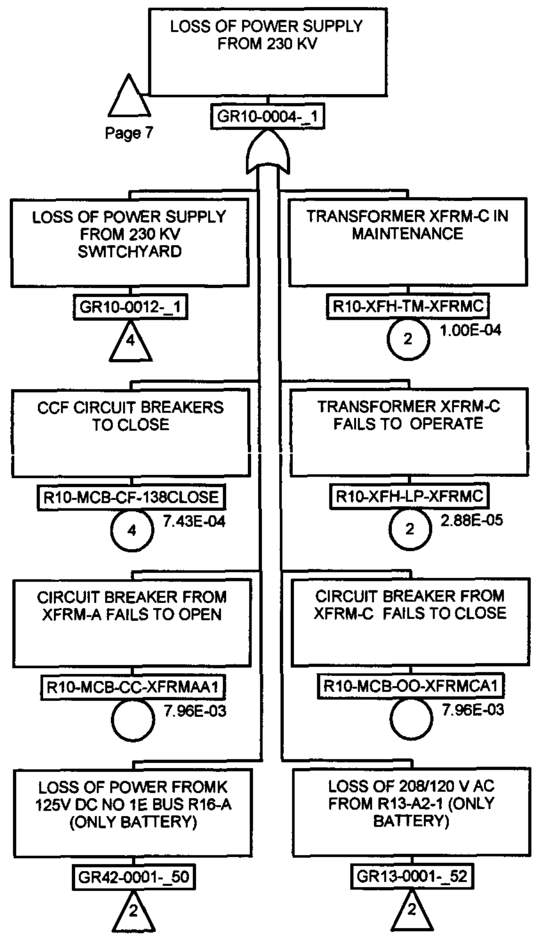

LOSS OF 13.8 KV AC FROM BUS R10-C1
GR10-0001-_3
13,8 KV AC BUS R10-C1-IN MAINTENANCE
R10-BAC-TM-R10C1
4.80E-06
BUS R10-C1 FAILS DURING OPERATION
R10-BAC-LP-R10C1
4.80E-06
LOSS OF POWER SITUATIONS
GR10-1003-_1
INITIAL LOSP
GR10-1003-_2
FAILURE IN AC DISTRIBUTION (NO LOSP)
GR10-1003-_3
HOUSE EVENT: INITIATING EVENT IS LOSP (VALUE =1)
XHOSLOSP
8
LOSS OF POWER SUPPLY
GR10-1003-_4
HOUSE EVENT: INITIATING EVENT IS LOSP (VALUE =1)
XHOSLOSP
8
LOSS OF POWER SUPPLIES TO R10-C1
GR10-0002-_3
Page 3
FAILURE IN OFFSITE POWER RECOVERY
R11-SYS-FF-NOREC
4
6.13E-01
Page 3
LOSS OF POWER SUPPLIES TO R10-C1
GR10-0002-_3
LOSS OF POWER SUPPLIES FROM 500 KV
GR10-0003-_3
LOSS OF POWER SUPPLY FROM 230 KV
GR10-0004-_3
Page 4
500 KV SWITCHYARD OR TRANS. LINE FAILS
GR10-0011-_1
4
CIRCUIT BREAKER FROM XFRM-A OPENS SPURIOUSLY
R10-MCB-CO-XFRMAC1
1.20E-05
TRANSFORMER XFRM-A (HIGH VOLTAGE) FAILS TO OPERATE
R10-XFH-LP-XFRMA
2
2.88E-05
TRANSFORMER XFRM-A IN MAINTENANCE
R10-XFH-TM-XFRMA
2
1.00E-04
1
2
3
4


LOSS OF POWER SUPPLY FROM 230 KV
GR10-0004-_3
Page 3
LOSS OF POWER SUPPLY FROM 230 KV SWITCHYARD
GR10-0012-_1
4
TRANSFORMER XFRM-C IN MAINTENANCE
R10-XFH-TM-XFRMC
2
1.00E-04
CCF CIRCUIT BREAKERS TO CLOSE
R10-MCB-CF-138CLOSE
4
7.43E-04
TRANSFORMER XFRM-C FAILS TO OPERATE
R10-XFH-LP-XFRMC
2
2.88E-05
CIRCUIT BREAKER FROM XFRM-A FAILS TO OPEN
R10-MCB-CC-XFRMAC1
7.96E-03
CIRCUIT BREAKER FROM XFRM-C FAILS TO CLOSE
R10-MCB-OO-XFRMCC1
7.96E-03
LOSS OF POWER FROMK 125V DC NO 1E BUS R16-A (ONLY BATTERY)
GR42-0001-_50
2
LOSS OF 208/120 V AC FROM R13-A2-1 (ONLY BATTERY)
GR13-0001-_52
2


LOSS OF 13.8 KV AC FROM BUS R10-B1
GR10-0001-_2
13,8 KV AC BUS R10-B1-IN MAINTENANCE
R10-BAC-TM-R10B1
4.80E-06
BUS R10-B1 FAILS DURING OPERATION
R10-BAC-LP-R10B1
4.80E-06
LOSS OF POWER SITUATIONS
GR10-1002-_1
INITIAL LOSP
GR10-1002-_2
FAILURE IN AC DISTRIBUTION (NO LOSP)
GR10-1002-_3
HOUSE EVENT: INITIATING EVENT IS LOSP (VALUE =1)
XHOSLOSP
8
LOSS OF POWER SUPPLY
GR10-1002-_4
HOUSE EVENT: INITIATING EVENT IS LOSP (VALUE =1)
XHOSLOSP
8
LOSS OF POWER SUPPLIES TO R10-B1
GR10-0002-_2
Page 5
FAILURE IN OFFSITE POWER RECOVERY
R11-SYS-FF-NOREC
4
6.13E-01
Page 5
LOSS OF POWER SUPPLIES TO R10-B1
GR10-0002-_2
LOSS OF POWER SUPPLIES FROM 500 KV
GR10-0003-_2
LOSS OF POWER SUPPLY FROM 230 KV
GR10-0004-_2
Page 6
500 KV SWITCHYARD OR TRANS. LINE FAILS
GR10-0011-_1
4
CIRCUIT BREAKER FROM XFRM-B OPENS SPURIOUSLY
R10-MCB-CO-XFRMBB1
1.20E-05
TRANSFORMER XFRM-B (HIGH VOLTAGE) FAILS TO OPERATE
R10-XFH-LP-XFRMB
2
2.88E-05
TRANSFORMER XFRM-B IN MAINTENANCE
R10-XFH-TM-XFRMB
2
1.00E-04
1
2
3
4


LOSS OF POWER SUPPLY FROM 230 KV
GR10-0004-_2
Page 5
LOSS OF POWER SUPPLY FROM 230 KV SWITCHYARD
GR10-0012-_1
4
TRANSFORMER XFRM-D IN MAINTENANCE
R10-XFH-TM-XFRMD
2
1.00E-04
CCF CIRCUIT BREAKERS TO CLOSE
R10-MCB-CF-138CLOSE
4
7.43E-04
TRANSFORMER XFRM-D FAILS TO OPERATE
R10-XFH-LP-XFRMD
2
2.88E-05
CIRCUIT BREAKER FROM XFRM-B FAILS TO OPEN
R10-MCB-CC-XFRMBB1
7.96E-03
CIRCUIT BREAKER FROM XFRM-D FAILS TO CLOSE
R10-MCB-OO-XFRMDB1
7.96E-03
LOSS OF POWER FROM 125V DC NO 1E BUS R16-B (ONLY BATTERY)
GR42-0001-_51
2
LOSS OF 208/120 V AC FROM R13-B2-1 (ONLY BATTERY)
GR13-0001-_55
2
1
2


LOSS OF 13.8 KV AC FROM BUS R10-A1
GR10-0001-_1
13,8 KV AC BUS R10-A1-IN MAINTENANCE
R10-BAC-TM-R10A1
4.80E-06
BUS R10-A1 FAILS DURING OPERATION
R10-BAC-LP-R10A1
4.80E-06
LOSS OF POWER SITUATIONS
GR10-1001-_1
INITIAL LOSP
GR10-1001-_2
FAILURE IN AC DISTRIBUTION (NO LOSP)
GR10-1001-_3
HOUSE EVENT: INITIATING EVENT IS LOSP (VALUE =1)
XHOSLOSP
8
LOSS OF POWER SUPPLY
GR10-1001-_4
HOUSE EVENT: INITIATING EVENT IS LOSP (VALUE =1)
XHOSLOSP
8
LOSS OF POWER SUPPLIES TO R10-A1
GR10-0002-_1
Page 7
FAILURE IN OFFSITE POWER RECOVERY
R11-SYS-FF-NOREC
4
6.13E-01
Page 7
LOSS OF POWER SUPPLIES TO R10-A1
GR10-0002-_1
LOSS OF POWER SUPPLIES FROM 500 KV
GR10-0003-_1
LOSS OF POWER SUPPLY FROM 230 KV
GR10-0004-_1
Page 8
500 KV SWITCHYARD OR TRANS. LINE FAILS
GR10-0011-_1
4
CIRCUIT BREAKER FROM XFRM-A OPENS SPURIOUSLY
R10-MCB-CO-XFRMAA1
1.20E-05
TRANSFORMER XFRM-A (HIGH VOLTAGE) FAILS TO OPERATE
R10-XFH-LP-XFRMA
2
2.88E-05
TRANSFORMER XFRM-A IN MAINTENANCE
R10-XFH-TM-XFRMA
2
1.00E-04
1
2
3
4

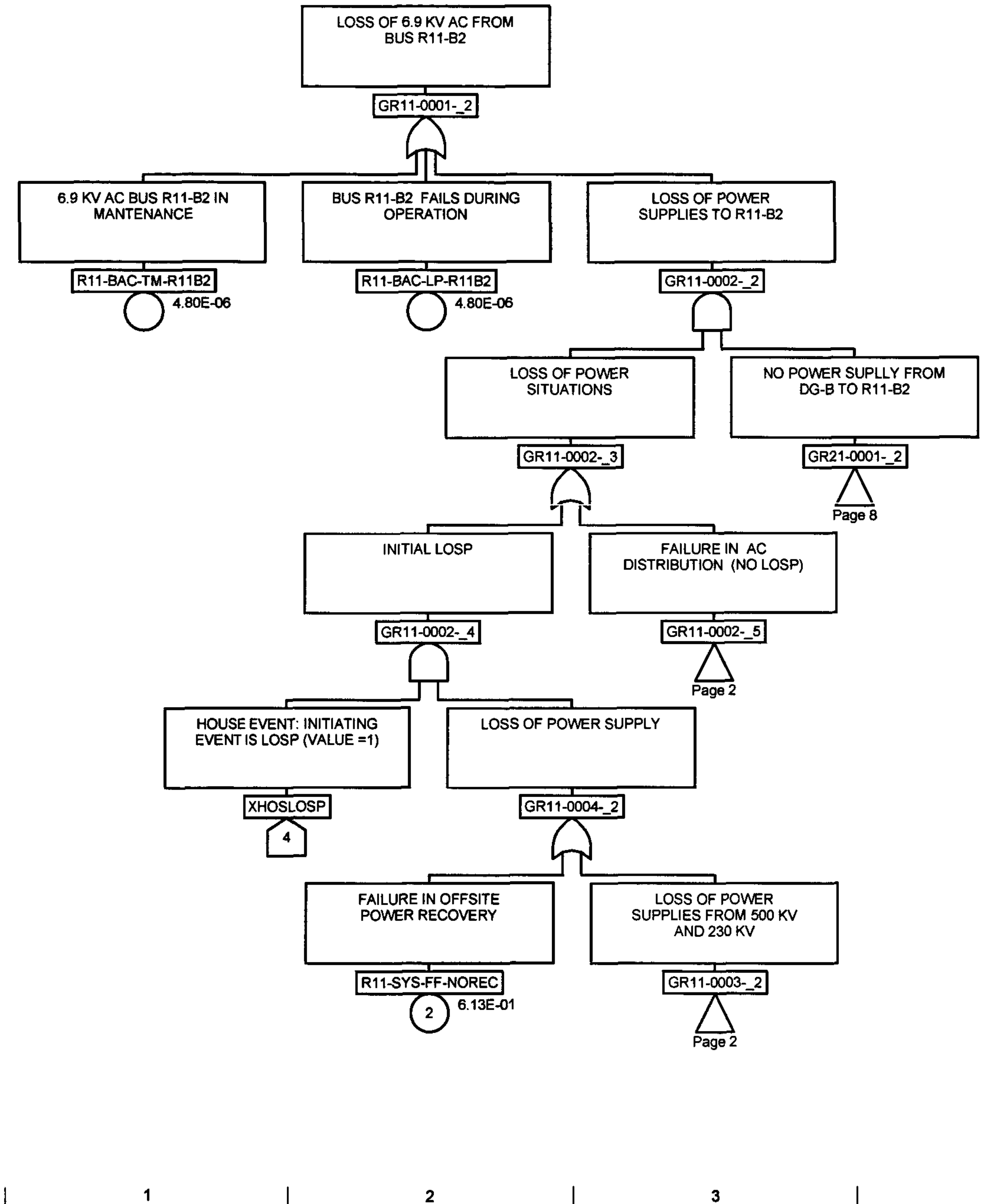

LOSS OF POWER SUPPLY FROM 230 KV
Page 7
GR10-0004-_1
LOSS OF POWER SUPPLY FROM 230 KV SWITCHYARD
GR10-0012-_1
4
TRANSFORMER XFRM-C IN MAINTENANCE
R10-XFH-TM-XFRMC
2
1.00E-04
CCF CIRCUIT BREAKERS TO CLOSE
R10-MCB-CF-138CLOSE
4
7.43E-04
TRANSFORMER XFRM-C FAILS TO OPERATE
R10-XFH-LP-XFRMC
2
2.88E-05
CIRCUIT BREAKER FROM XFRM-A FAILS TO OPEN
R10-MCB-CC-XFRMAA1
7.96E-03
CIRCUIT BREAKER FROM XFRM-C FAILS TO CLOSE
R10-MCB-OO-XFRMCA1
7.96E-03
LOSS OF POWER FROMK 125V DC NO 1E BUS R16-A (ONLY BATTERY)
GR42-0001-_50
2
LOSS OF 208/120 V AC FROM R13-A2-1 (ONLY BATTERY)
GR13-0001-_52
2

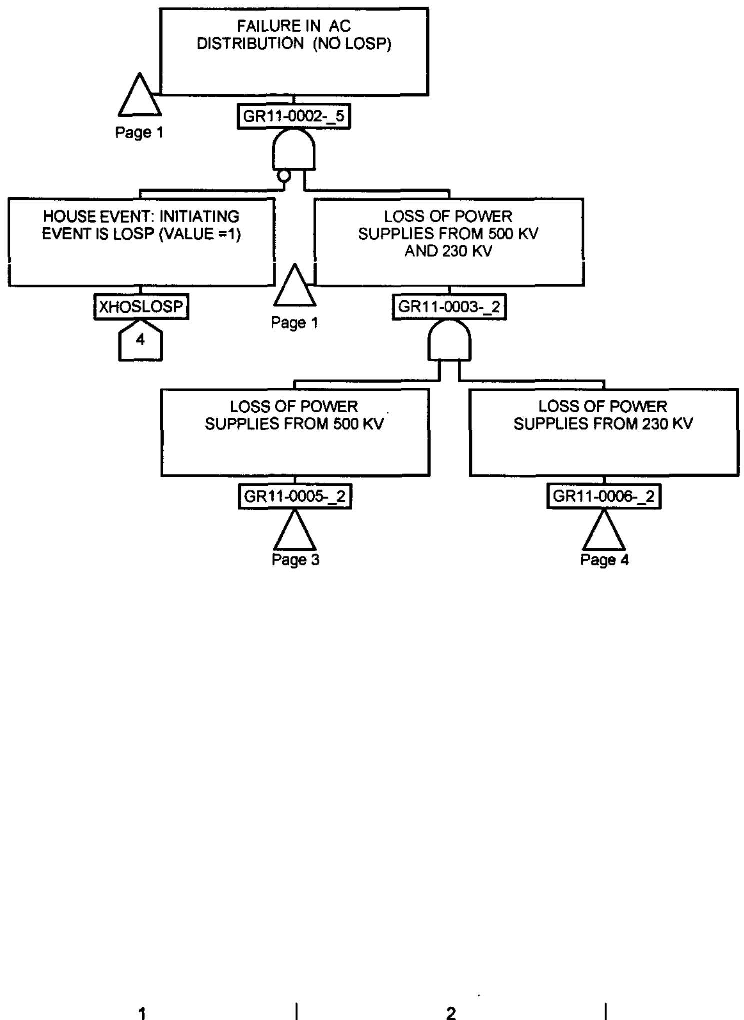
Name	Page	Zone	Name	Page	Zone	Name	Page	Zone
GR10-0001- 1	7	2	GR42-0001- 51	2	1			
GR10-0001- 2	5	2	GR42-0001- 51	6	1			
GR10-0001- 3	3	2	R10-BAC-LP-R10A1	7	2			
GR10-0001- 4	1	2	R10-BAC-LP-R10B1	5	2			
GR10-0002- 1	7	3	R10-BAC-LP-R10C1	3	2			
GR10-0002- 1	7	5	R10-BAC-LP-R10D1	1	2			
GR10-0002- 2	5	3	R10-BAC-TM-R10A1	7	1			
GR10-0002- 2	5	5	R10-BAC-TM-R10B1	5	1			
GR10-0002- 3	3	3	R10-BAC-TM-R10C1	3	1			
GR10-0002- 3	3	5	R10-BAC-TM-R10D1	1	1			
GR10-0002- 4	1	3	R10-MCB-CC-XFRMAA1	8	1			
GR10-0002- 4	1	5	R10-MCB-CC-XFRMAC1	4	1			
GR10-0003- 1	7	3	R10-MCB-CC-XFRMBB1	6	1			
GR10-0003- 2	5	3	R10-MCB-CC-XFRMBD1	2	1			
GR10-0003- 3	3	3	R10-MCB-CF-138CLOSE	2	1			
GR10-0003- 4	1	3	R10-MCB-CF-138CLOSE	4	1			
GR10-0004- 1	7	4	R10-MCB-CF-138CLOSE	6	1			
GR10-0004- 1	8	2	R10-MCB-CF-138CLOSE	8	1			
GR10-0004- 2	5	4	R10-MCB-CO-XFRMAA1	7	3			
GR10-0004- 2	6	2	R10-MCB-CO-XFRMAC1	3	3			
GR10-0004- 3	3	4	R10-MCB-CO-XFRMBB1	5	3			
GR10-0004- 3	4	2	R10-MCB-CO-XFRMBD1	1	3			
GR10-0004- 4	1	4	R10-MCB-OO-XFRMCA1	8	2			
GR10-0004- 4	2	2	R10-MCB-OO-XFRMCC1	4	2			
GR10-0011- 1	1	2	R10-MCB-OO-XFRMDB1	6	2			
GR10-0011- 1	3	2	R10-MCB-OO-XFRMDD1	2	2			
GR10-0011- 1	5	2	R10-XFH-LP-XFRMA	3	2			
GR10-0011- 1	7	2	R10-XFH-LP-XFRMA	7	2			
GR10-0012- 1	2	1	R10-XFH-LP-XFRMB	1	2			
GR10-0012- 1	4	1	R10-XFH-LP-XFRMB	5	2			
GR10-0012- 1	6	1	R10-XFH-LP-XFRMC	4	2			
GR10-0012- 1	8	1	R10-XFH-LP-XFRMC	8	2			
GR10-1001- 1	7	3	R10-XFH-LP-XFRMD	2	2			
GR10-1001- 2	7	2	R10-XFH-LP-XFRMD	6	2			
GR10-1001- 3	7	4	R10-XFH-TM-XFRMA	3	3			
GR10-1001- 4	7	3	R10-XFH-TM-XFRMA	7	3			
GR10-1002- 1	5	3	R10-XFH-TM-XFRMB	1	3			
GR10-1002- 2	5	2	R10-XFH-TM-XFRMB	5	3			
GR10-1002- 3	5	4	R10-XFH-TM-XFRMC	4	2			
GR10-1002- 4	5	3	R10-XFH-TM-XFRMC	8	2			
GR10-1003- 1	3	3	R10-XFH-TM-XFRMD	2	2			
GR10-1003- 2	3	2	R10-XFH-TM-XFRMD	6	2			
GR10-1003- 3	3	4	R11-SYS-FF-NOREC	1	2			
GR10-1003- 4	3	3	R11-SYS-FF-NOREC	3	2			
GR10-1004- 1	1	3	R11-SYS-FF-NOREC	5	2			
GR10-1004- 2	1	2	R11-SYS-FF-NOREC	7	2			
GR10-1004- 3	1	4	XHOSLOSP	1	2			
GR10-1004- 4	1	3	XHOSLOSP	1	4			
GR13-0001- 52	4	2	XHOSLOSP	3	2			
GR13-0001- 52	8	2	XHOSLOSP	3	4			
GR13-0001- 55	2	2	XHOSLOSP	5	2			
GR13-0001- 55	6	2	XHOSLOSP	5	4			
GR42-0001- 50	4	1	XHOSLOSP	7	2			
GR42-0001- 50	8	1	XHOSLOSP	7	4			

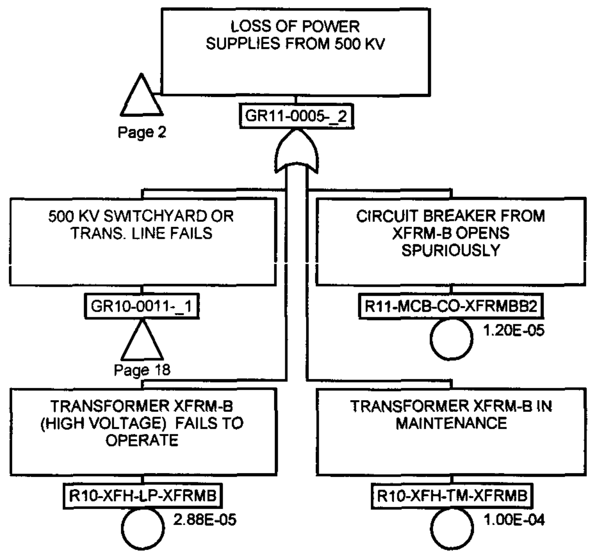
Appendix B.4.14-2

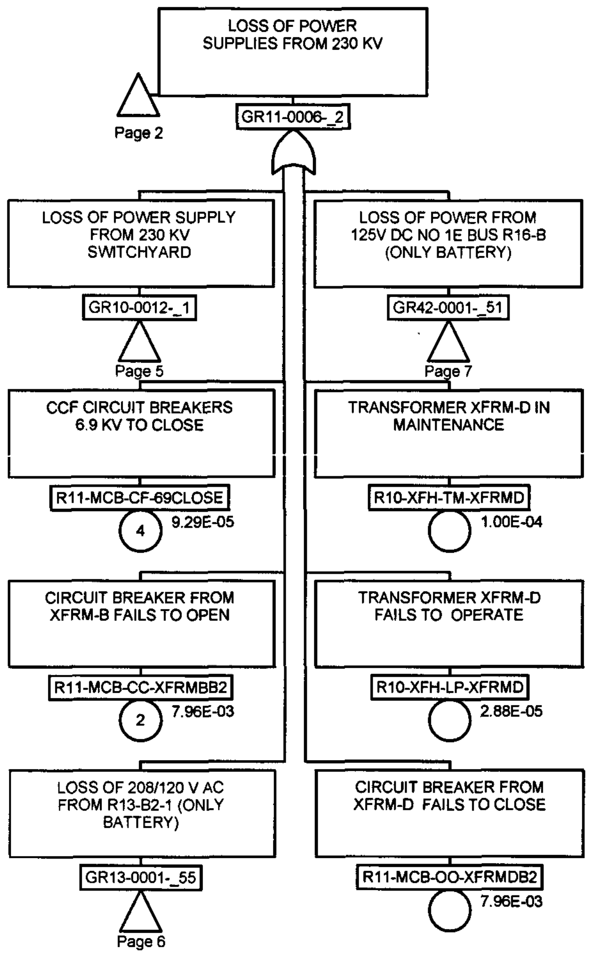
A.C. Electric Power System

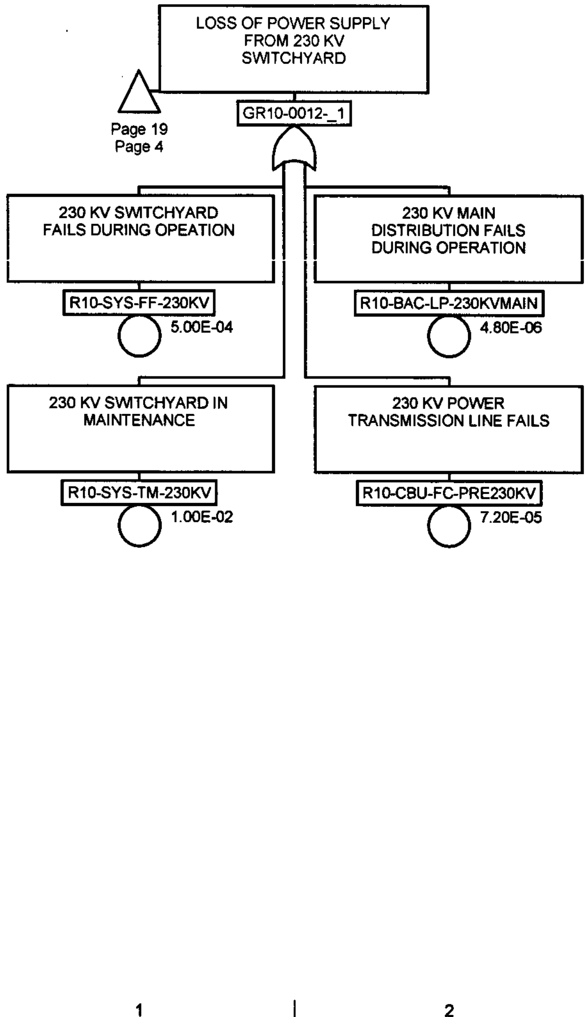
Fault Tree

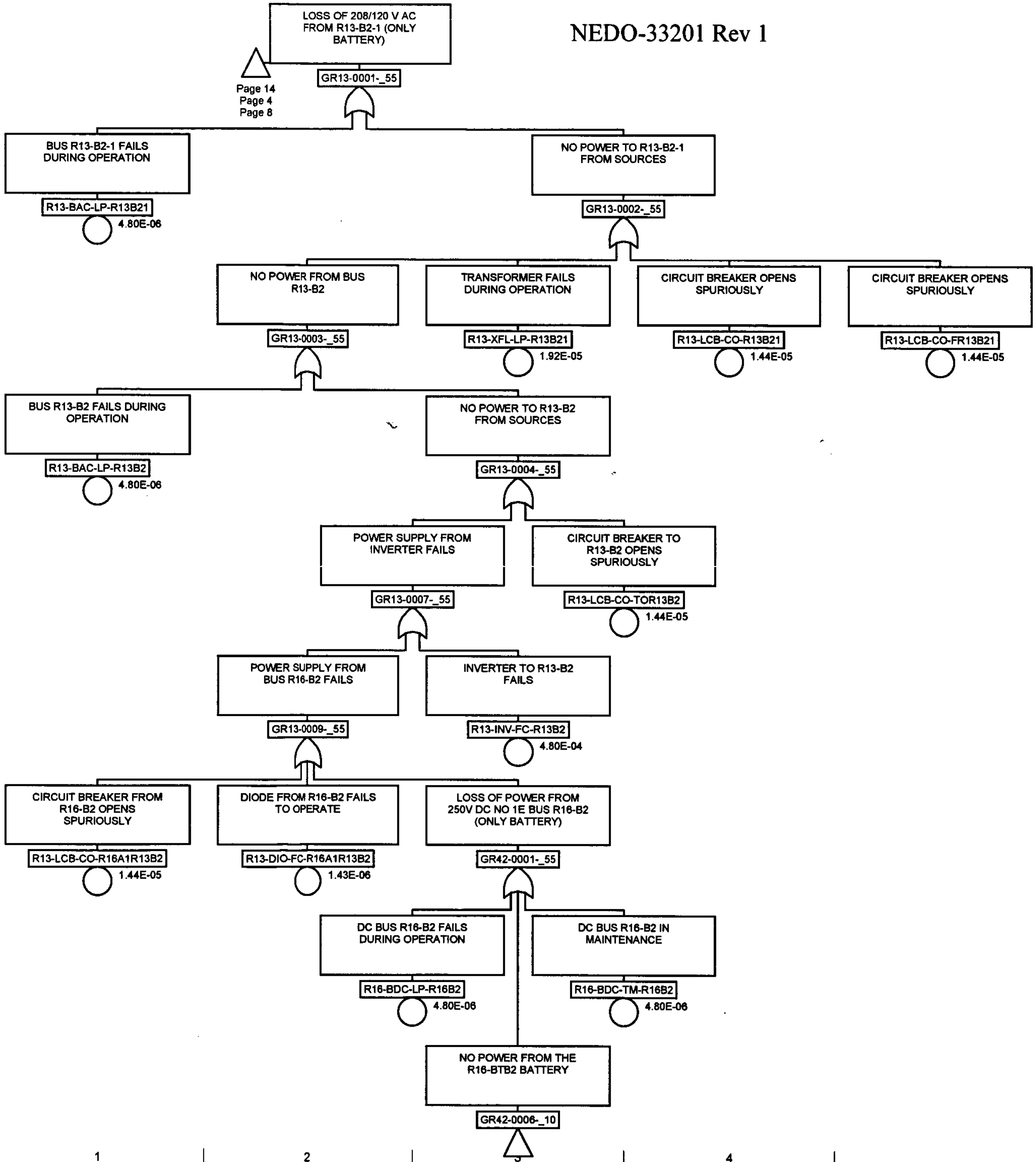

LOSS OF 6.9 KV AC FROM BUS R11-B2
GR11-0001-_2
6.9 KV AC BUS R11-B2 IN MANTENANCE
R11-BAC-TM-R11B2
4.80E-06
BUS R11-B2 FAILS DURING OPERATION
R11-BAC-LP-R11B2
4.80E-06
LOSS OF POWER SUPPLIES TO R11-B2
GR11-0002-_2
LOSS OF POWER SITUATIONS
GR11-0002-_3
NO POWER SUPLLY FROM DG-B TO R11-B2
GR21-0001-_2
Page 8
INITIAL LOSP
GR11-0002-_4
FAILURE IN AC DISTRIBUTION (NO LOSP)
GR11-0002-_5
Page 2
HOUSE EVENT: INITIATING EVENT IS LOSP (VALUE =1)
XHOSLOSP
4
LOSS OF POWER SUPPLY
GR11-0004-_2
FAILURE IN OFFSITE POWER RECOVERY
R11-SYS-FF-NOREC
2
6.13E-01
LOSS OF POWER SUPPLIES FROM 500 KV AND 230 KV
GR11-0003-_2
Page 2
1
2
3

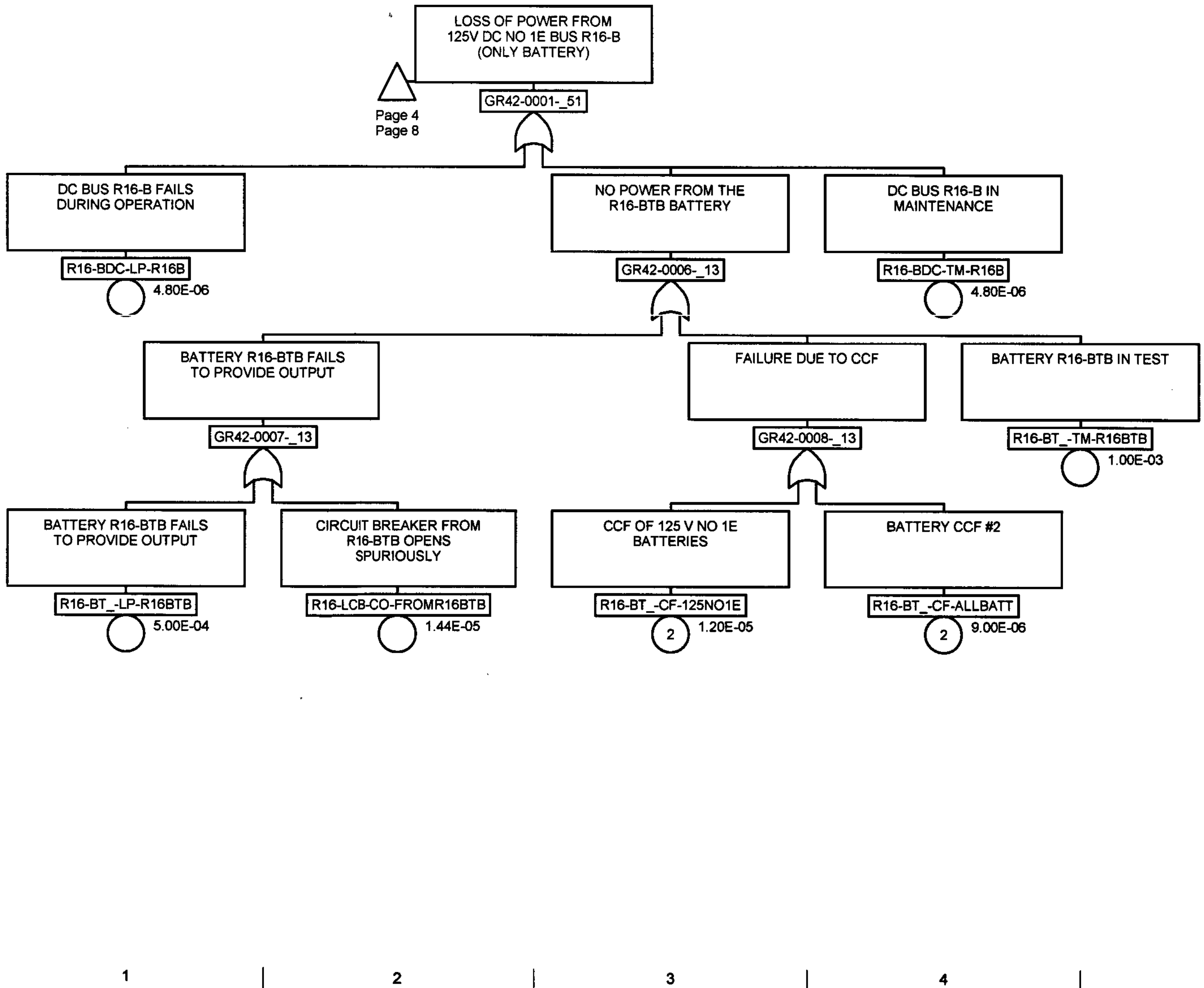

FAILURE IN AC DISTRIBUTION (NO LOSP)
Page 1
GR11-0002-_5
HOUSE EVENT: INITIATING EVENT IS LOSP (VALUE =1)
LOSS OF POWER SUPPLIES FROM 500 KV AND 230 KV
XHOSLOSP
4
Page 1
GR11-0003-_2
LOSS OF POWER SUPPLIES FROM 500 KV
LOSS OF POWER SUPPLIES FROM 230 KV
GR11-0005-_2
GR11-0006-_2
Page 3
Page 4
1
2

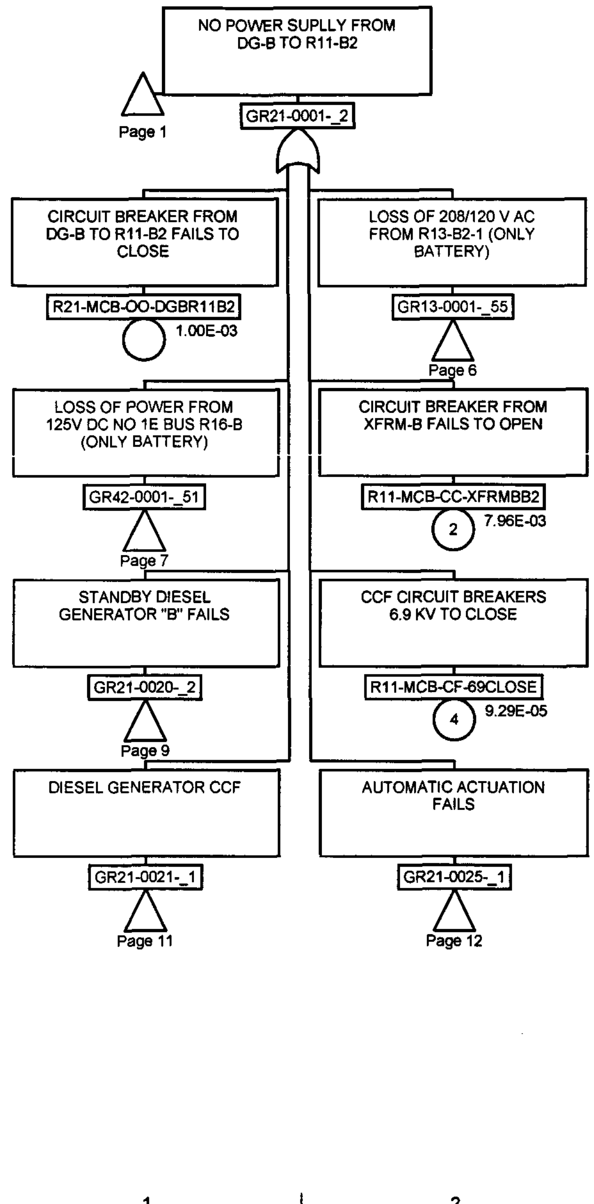

LOSS OF POWER SUPPLIES FROM 500 KV
GR11-0005-_2
Page 2
500 KV SWITCHYARD OR TRANS. LINE FAILS
GR10-0011-_1
Page 18
CIRCUIT BREAKER FROM XFRM-B OPENS SPURIOUSLY
R11-MCB-CO-XFRMBB2
1.20E-05
TRANSFORMER XFRM-B (HIGH VOLTAGE) FAILS TO OPERATE
R10-XFH-LP-XFRMB
2.88E-05
TRANSFORMER XFRM-B IN MAINTENANCE
R10-XFH-TM-XFRMB
1.00E-04
1
2

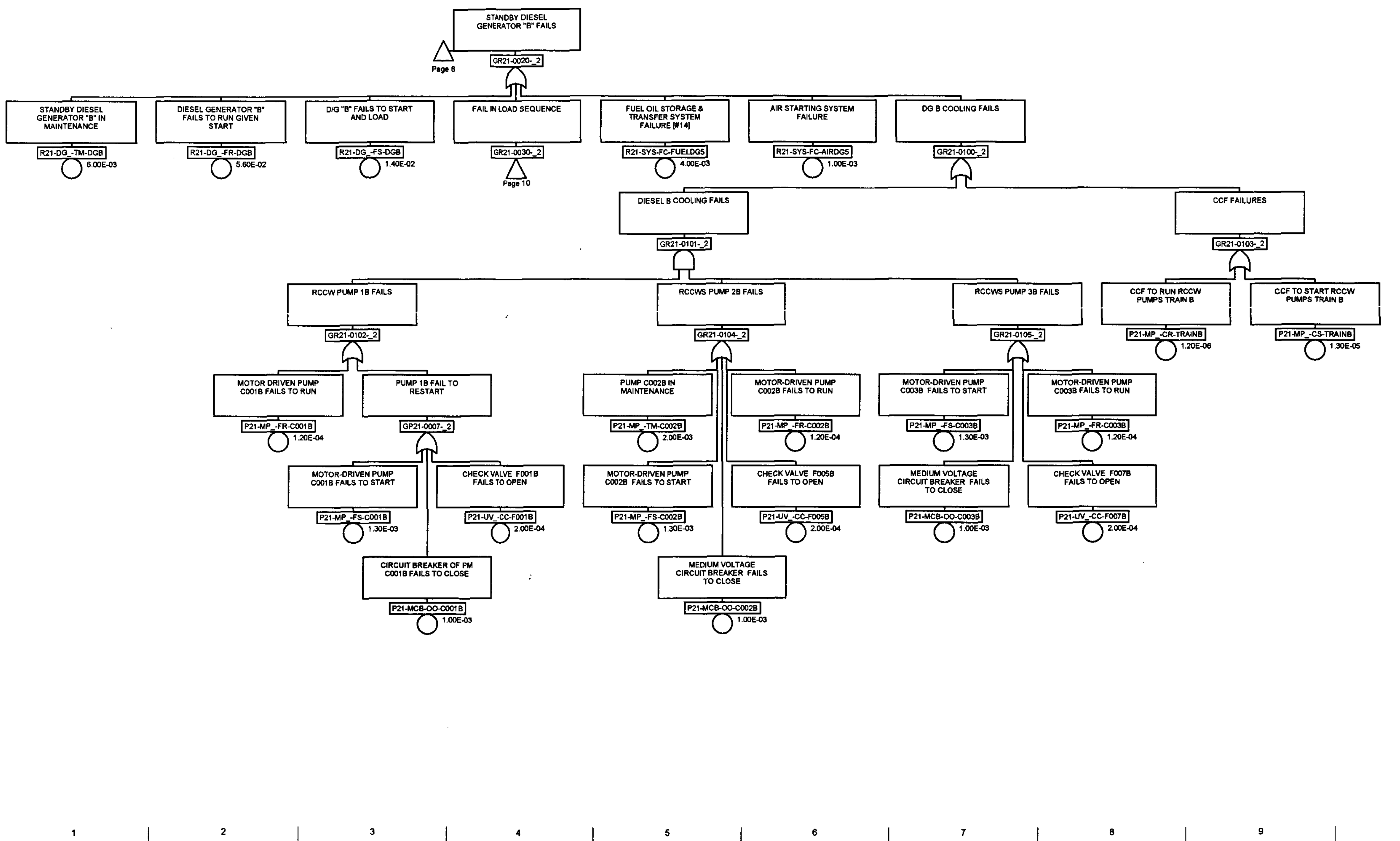

LOSS OF POWER SUPPLIES FROM 230 KV
GR11-0006-_2
Page 2
LOSS OF POWER SUPPLY FROM 230 KV SWITCHYARD
GR10-0012-_1
Page 5
LOSS OF POWER FROM 125V DC NO 1E BUS R16-B (ONLY BATTERY)
GR42-0001-_51
Page 7
CCF CIRCUIT BREAKERS 6.9 KV TO CLOSE
R11-MCB-CF-69CLOSE
4
9.29E-05
TRANSFORMER XFRM-D IN MAINTENANCE
R10-XFH-TM-XFRMD
1.00E-04
CIRCUIT BREAKER FROM XFRM-B FAILS TO OPEN
R11-MCB-CC-XFRMBB2
2
7.96E-03
TRANSFORMER XFRM-D FAILS TO OPERATE
R10-XFH-LP-XFRMD
2.88E-05
LOSS OF 208/120 V AC FROM R13-B2-1 (ONLY BATTERY)
GR13-0001-_55
Page 6
CIRCUIT BREAKER FROM XFRM-D FAILS TO CLOSE
R11-MCB-OO-XFRMDB2
7.96E-03
1
2

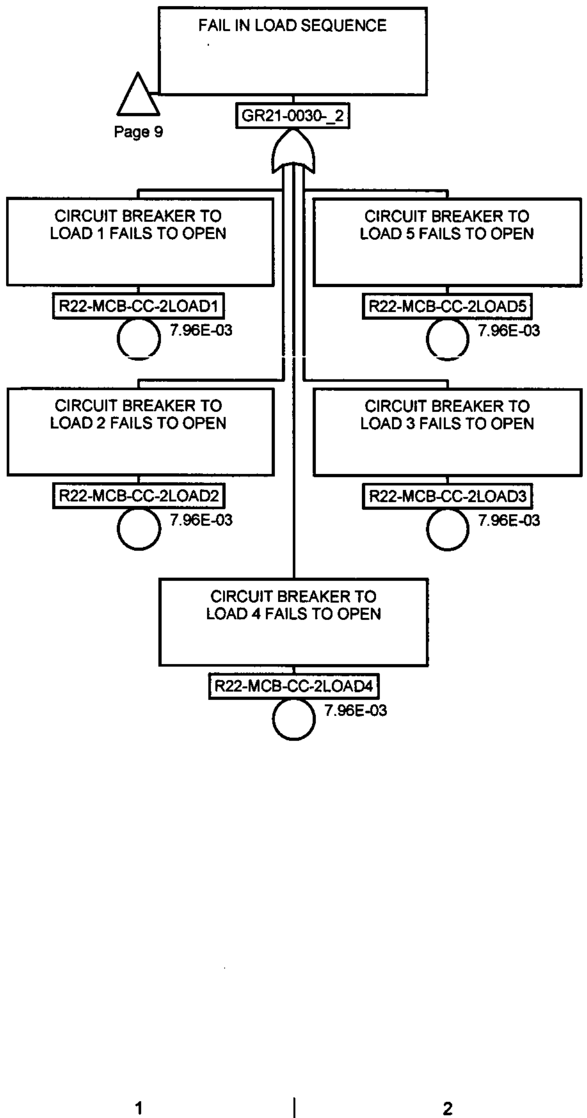

LOSS OF POWER SUPPLY FROM 230 KV SWITCHYARD
GR10-0012-_1
Page 19
Page 4
230 KV SWITCHYARD FAILS DURING OPEATION
R10-SYS-FF-230KV
5.00E-04
230 KV MAIN DISTRIBUTION FAILS DURING OPERATION
R10-BAC-LP-230KVMAIN
4.80E-06
230 KV SWITCHYARD IN MAINTENANCE
R10-SYS-TM-230KV
1.00E-02
230 KV POWER TRANSMISSION LINE FAILS
R10-CBU-FC-PRE230KV
7.20E-05
1
2

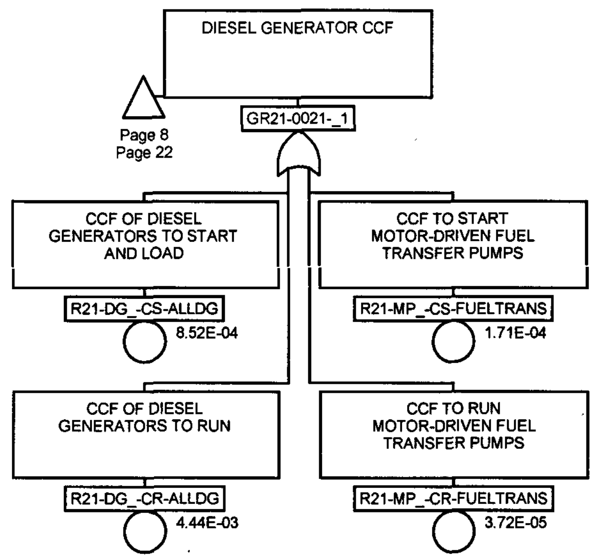

LOSS OF 208/120 V AC FROM R13-B2-1 (ONLY BATTERY)
GR13-0001-_55
Page 14
Page 4
Page 8
BUS R13-B2-1 FAILS DURING OPERATION
R13-BAC-LP-R13B21
4.80E-06
NO POWER TO R13-B2-1 FROM SOURCES
GR13-0002-_55
NO POWER FROM BUS R13-B2
GR13-0003-_55
TRANSFORMER FAILS DURING OPERATION
R13-XFL-LP-R13B21
1.92E-05
CIRCUIT BREAKER OPENS SPURIOUSLY
R13-LCB-CO-R13B21
1.44E-05
CIRCUIT BREAKER OPENS SPURIOUSLY
R13-LCB-CO-FR13B21
1.44E-05
BUS R13-B2 FAILS DURING OPERATION
R13-BAC-LP-R13B2
4.80E-06
NO POWER TO R13-B2 FROM SOURCES
GR13-0004-_55
POWER SUPPLY FROM INVERTER FAILS
GR13-0007-_55
CIRCUIT BREAKER TO R13-B2 OPENS SPURIOUSLY
R13-LCB-CO-TOR13B2
1.44E-05
POWER SUPPLY FROM BUS R16-B2 FAILS
GR13-0009-_55
INVERTER TO R13-B2 FAILS
R13-INV-FC-R13B2
4.80E-04
CIRCUIT BREAKER FROM R16-B2 OPENS SPURIOUSLY
R13-LCB-CO-R16A1R13B2
1.44E-05
DIODE FROM R16-B2 FAILS TO OPERATE
R13-DIO-FC-R16A1R13B2
1.43E-06
LOSS OF POWER FROM 250V DC NO 1E BUS R16-B2 (ONLY BATTERY)
GR42-0001-_55
DC BUS R16-B2 FAILS DURING OPERATION
R16-BDC-LP-R16B2
4.80E-06
DC BUS R16-B2 IN MAINTENANCE
R16-BDC-TM-R16B2
4.80E-06
NO POWER FROM THE R16-BTB2 BATTERY
GR42-0006-_10
1
2
3
4

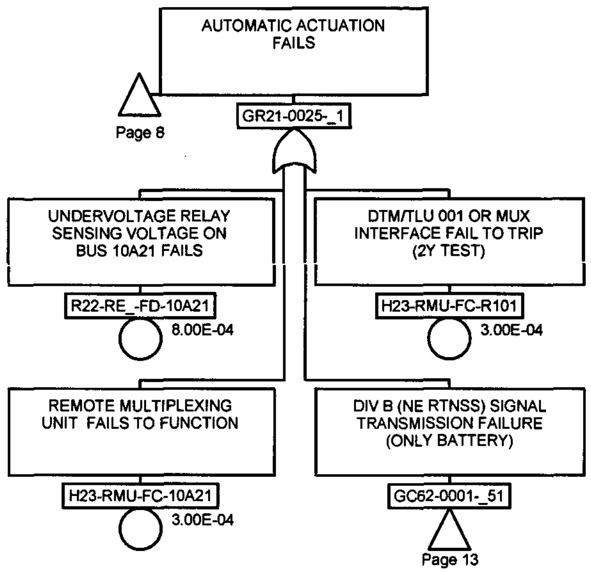

LOSS OF POWER FROM 125V DC NO 1E BUS R16-B (ONLY BATTERY)
GR42-0001-_51
Page 4
Page 8
DC BUS R16-B FAILS DURING OPERATION
R16-BDC-LP-R16B
4.80E-06
NO POWER FROM THE R16-BTB BATTERY
GR42-0006-_13
DC BUS R16-B IN MAINTENANCE
R16-BDC-TM-R16B
4.80E-06
BATTERY R16-BTB FAILS TO PROVIDE OUTPUT
GR42-0007-_13
FAILURE DUE TO CCF
GR42-0008-_13
BATTERY R16-BTB IN TEST
R16-BT_-TM-R16BTB
1.00E-03
BATTERY R16-BTB FAILS TO PROVIDE OUTPUT
R16-BT_-LP-R16BTB
5.00E-04
CIRCUIT BREAKER FROM R16-BTB OPENS SPURIOUSLY
R16-LCB-CO-FROMR16BTB
1.44E-05
CCF OF 125 V NO 1E BATTERIES
R16-BT_-CF-125NO1E
2
1.20E-05
BATTERY CCF #2
R16-BT_-CF-ALLBATT
2
9.00E-06
1
2
3
4

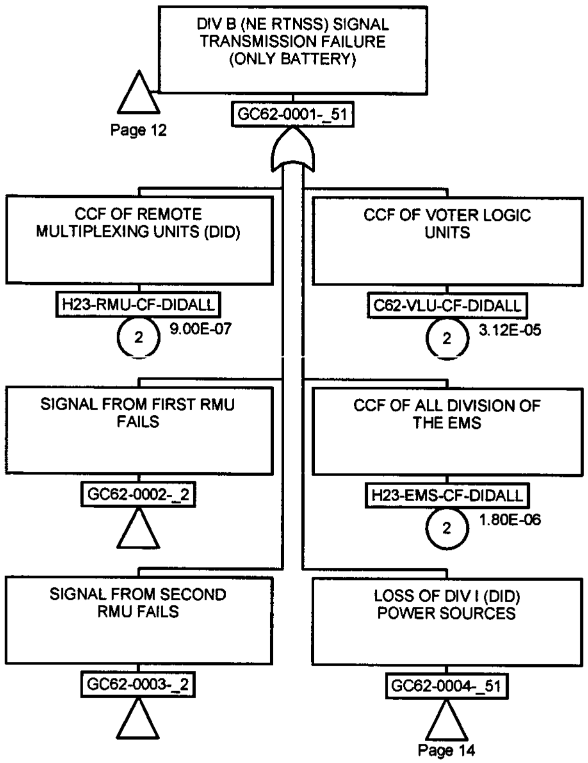

NO POWER SUPLLY FROM DG-B TO R11-B2
GR21-0001-_2
Page 1
CIRCUIT BREAKER FROM DG-B TO R11-B2 FAILS TO CLOSE
R21-MCB-OO-DGBR11B2
1.00E-03
LOSS OF 208/120 V AC FROM R13-B2-1 (ONLY BATTERY)
GR13-0001-_55
Page 6
LOSS OF POWER FROM 125V DC NO 1E BUS R16-B (ONLY BATTERY)
GR42-0001-_51
Page 7
CIRCUIT BREAKER FROM XFRM-B FAILS TO OPEN
R11-MCB-CC-XFRMBB2
2
7.96E-03
STANDBY DIESEL GENERATOR "B" FAILS
GR21-0020-_2
Page 9
CCF CIRCUIT BREAKERS 6.9 KV TO CLOSE
R11-MCB-CF-69CLOSE
4
9.29E-05
DIESEL GENERATOR CCF
GR21-0021-_1
Page 11
AUTOMATIC ACTUATION FAILS
GR21-0025-_1
Page 12
1
2

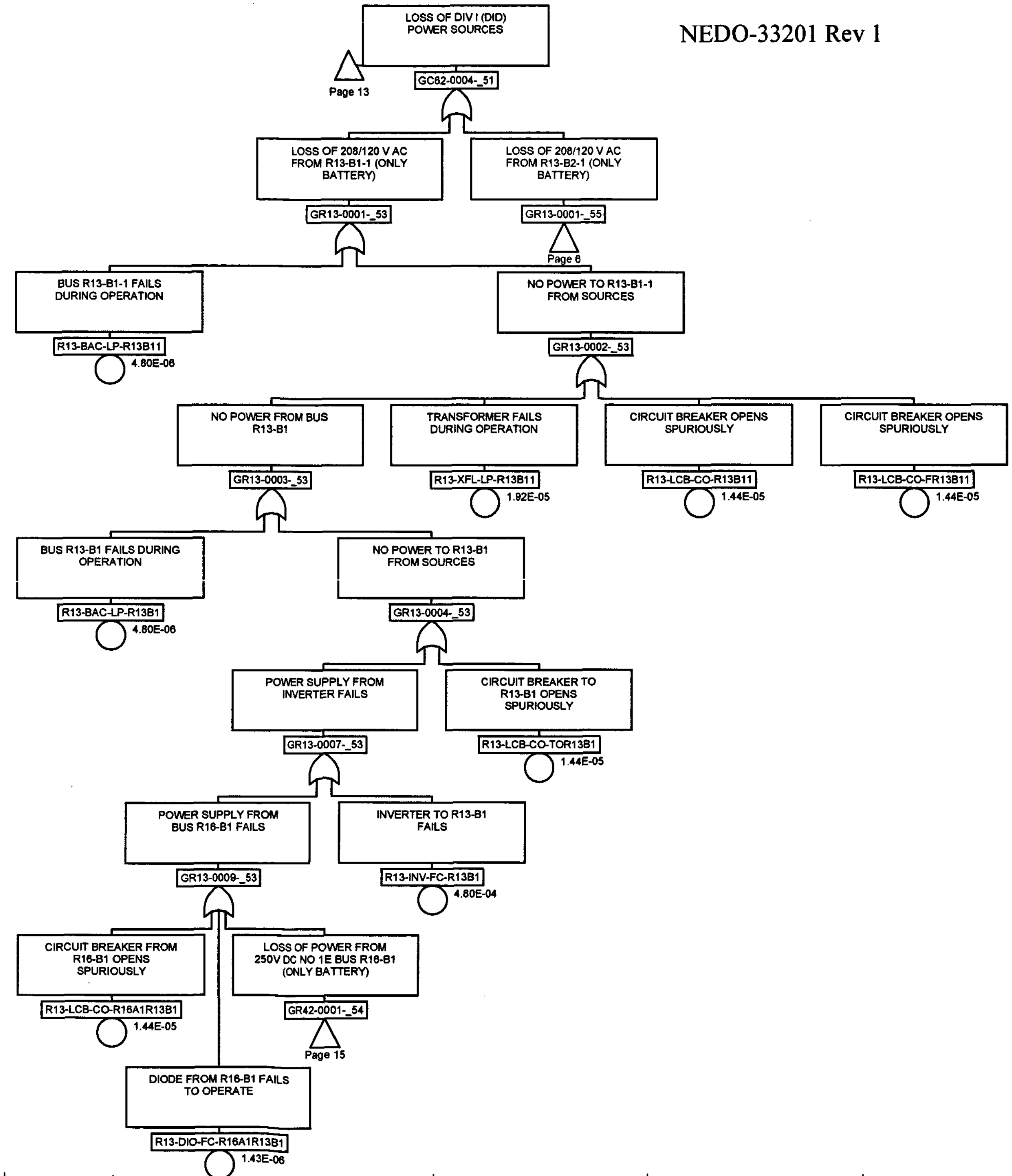

STANDBY DIESEL GENERATOR "B" FAILS
GR21-0020-_2
Page 8
STANDBY DIESEL GENERATOR "B" IN MAINTENANCE
R21-DG_-TM-DGB
6.00E-03
DIESEL GENERATOR "B" FAILS TO RUN GIVEN START
R21-DG_-FR-DGB
5.60E-02
D/G "B" FAILS TO START AND LOAD
R21-DG_-FS-DGB
1.40E-02
FAIL IN LOAD SEQUENCE
GR21-0030-_2
Page 10
FUEL OIL STORAGE & TRANSFER SYSTEM FAILURE [#14]
R21-SYS-FC-FUELDG5
4.00E-03
AIR STARTING SYSTEM FAILURE
R21-SYS-FC-AIRDG5
1.00E-03
DG B COOLING FAILS
GR21-0100-_2
DIESEL B COOLING FAILS
GR21-0101-_2
CCF FAILURES
GR21-0103-_2
RCCW PUMP 1B FAILS
GR21-0102-_2
RCCWS PUMP 2B FAILS
GR21-0104-_2
RCCWS PUMP 3B FAILS
GR21-0105-_2
CCF TO RUN RCCW PUMPS TRAIN B
P21-MP_-CR-TRAINB
1.20E-06
CCF TO START RCCW PUMPS TRAIN B
P21-MP_-CS-TRAINB
1.30E-05
MOTOR DRIVEN PUMP C001B FAILS TO RUN
P21-MP_-FR-C001B
1.20E-04
PUMP 1B FAIL TO RESTART
GP21-0007-_2
MOTOR-DRIVEN PUMP C001B FAILS TO START
P21-MP_-FS-C001B
1.30E-03
CHECK VALVE F001B FAILS TO OPEN
P21-UV_-CC-F001B
2.00E-04
CIRCUIT BREAKER OF PM C001B FAILS TO CLOSE
P21-MCB-OO-C001B
1.00E-03
PUMP C002B IN MAINTENANCE
P21-MP_-TM-C002B
2.00E-03
MOTOR-DRIVEN PUMP C002B FAILS TO RUN
P21-MP_-FR-C002B
1.20E-04
MOTOR-DRIVEN PUMP C002B FAILS TO START
P21-MP_-FS-C002B
1.30E-03
CHECK VALVE F005B FAILS TO OPEN
P21-UV_-CC-F005B
2.00E-04
MEDIUM VOLTAGE CIRCUIT BREAKER FAILS TO CLOSE
P21-MCB-OO-C002B
1.00E-03
MOTOR-DRIVEN PUMP C003B FAILS TO START
P21-MP_-FS-C003B
1.30E-03
MOTOR-DRIVEN PUMP C003B FAILS TO RUN
P21-MP_-FR-C003B
1.20E-04
MEDIUM VOLTAGE CIRCUIT BREAKER FAILS TO CLOSE
P21-MCB-OO-C003B
1.00E-03
CHECK VALVE F007B FAILS TO OPEN
P21-UV_-CC-F007B
2.00E-04
1
2
3
4
5
6
7
8
9


FAIL IN LOAD SEQUENCE
Page 9
GR21-0030-_2
CIRCUIT BREAKER TO LOAD 1 FAILS TO OPEN
R22-MCB-CC-2LOAD1
7.96E-03
CIRCUIT BREAKER TO LOAD 5 FAILS TO OPEN
R22-MCB-CC-2LOAD5
7.96E-03
CIRCUIT BREAKER TO LOAD 2 FAILS TO OPEN
R22-MCB-CC-2LOAD2
7.96E-03
CIRCUIT BREAKER TO LOAD 3 FAILS TO OPEN
R22-MCB-CC-2LOAD3
7.96E-03
CIRCUIT BREAKER TO LOAD 4 FAILS TO OPEN
R22-MCB-CC-2LOAD4
7.96E-03
1
2

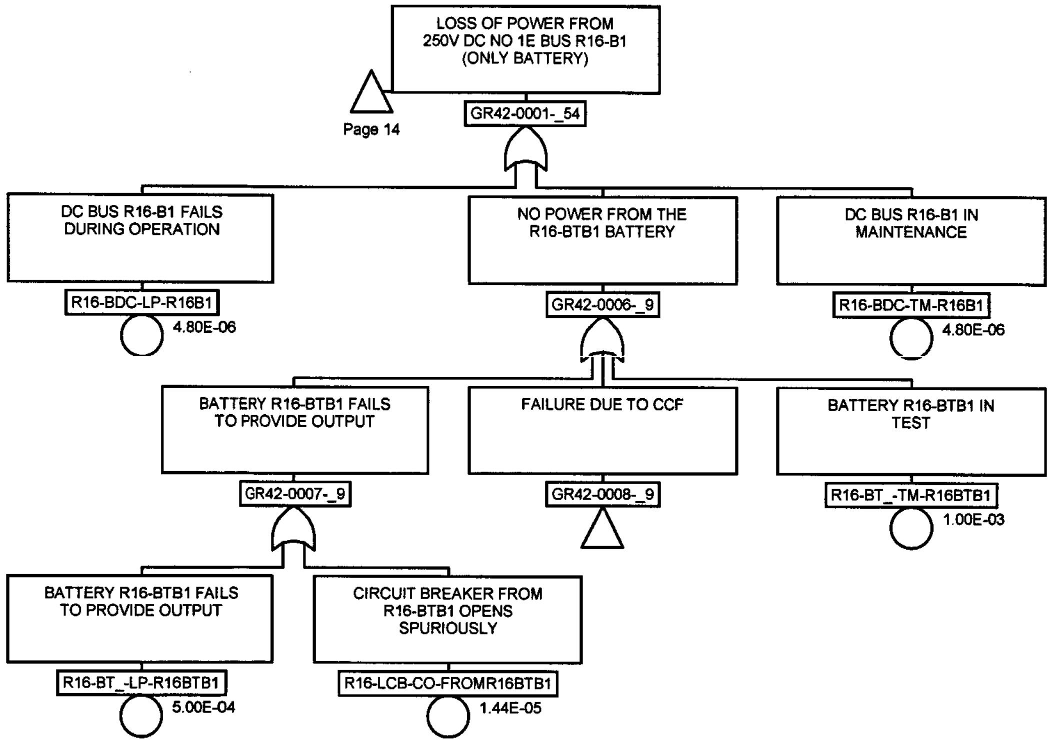

DIESEL GENERATOR CCF
GR21-0021-_1
Page 8
Page 22
CCF OF DIESEL GENERATORS TO START AND LOAD
R21-DG_-CS-ALLDG
8.52E-04
CCF TO START MOTOR-DRIVEN FUEL TRANSFER PUMPS
R21-MP_-CS-FUELTRANS
1.71E-04
CCF OF DIESEL GENERATORS TO RUN
R21-DG_-CR-ALLDG
4.44E-03
CCF TO RUN MOTOR-DRIVEN FUEL TRANSFER PUMPS
R21-MP_-CR-FUELTRANS
3.72E-05
1
2

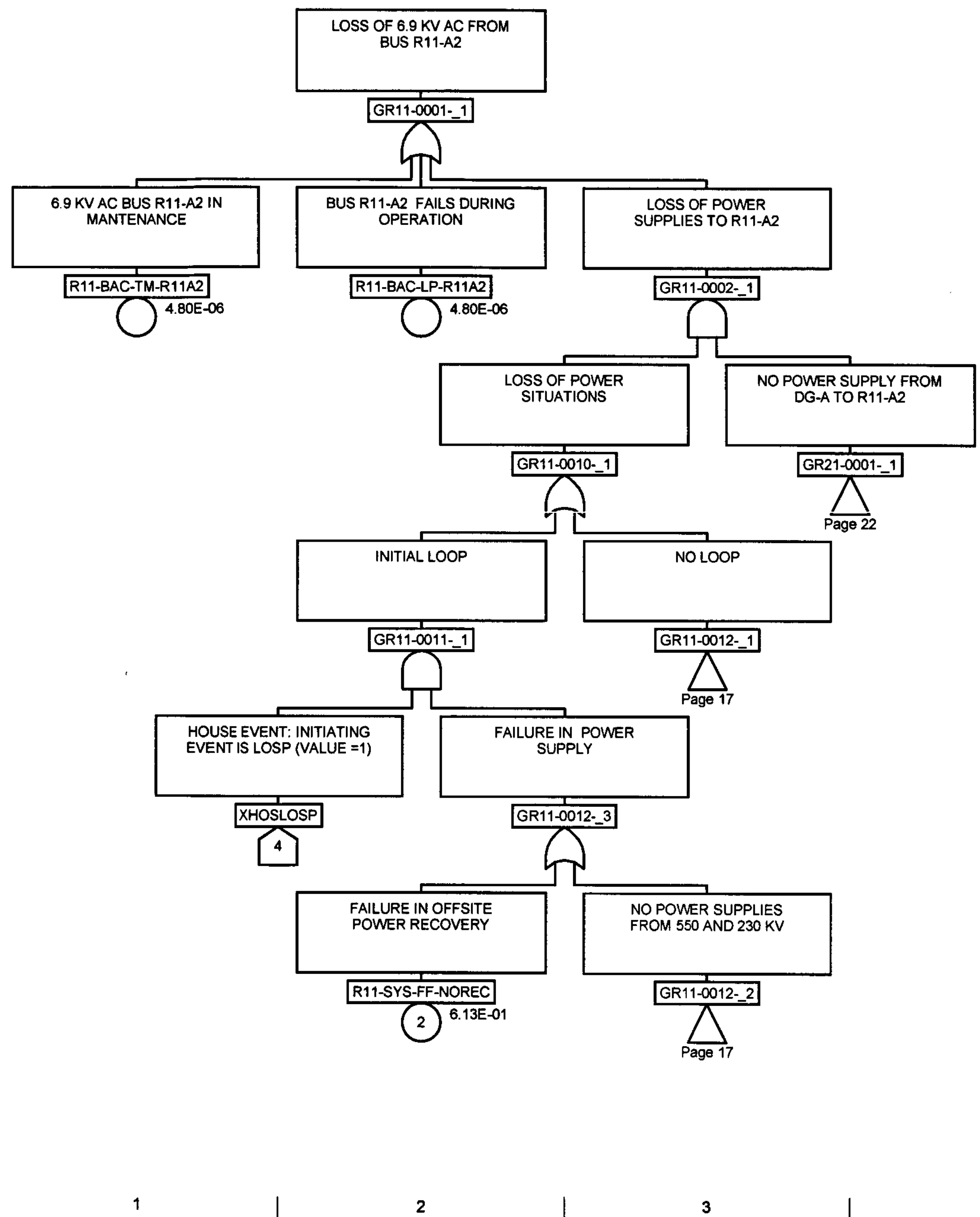

AUTOMATIC ACTUATION FAILS
Page 8
GR21-0025-_1
UNDERVOLTAGE RELAY SENSING VOLTAGE ON BUS 10A21 FAILS
R22-RE_-FD-10A21
8.00E-04
DTM/TLU 001 OR MUX INTERFACE FAIL TO TRIP (2Y TEST)
H23-RMU-FC-R101
3.00E-04
REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION
H23-RMU-FC-10A21
3.00E-04
DIV B (NE RTNSS) SIGNAL TRANSMISSION FAILURE (ONLY BATTERY)
GC62-0001-_51
Page 13
1
2

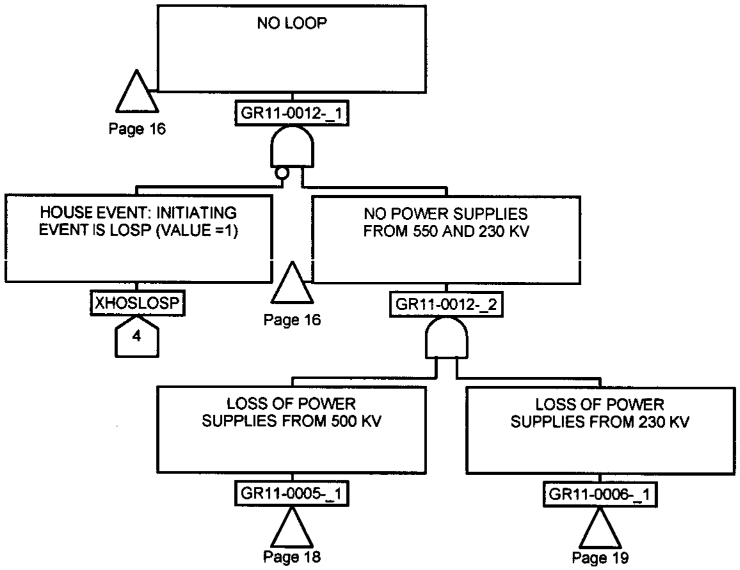

DIV B (NE RTNSS) SIGNAL TRANSMISSION FAILURE (ONLY BATTERY)
GC62-0001-_51
Page 12
CCF OF REMOTE MULTIPLEXING UNITS (DID)
H23-RMU-CF-DIDALL
2
9.00E-07
CCF OF VOTER LOGIC UNITS
C62-VLU-CF-DIDALL
2
3.12E-05
SIGNAL FROM FIRST RMU FAILS
GC62-0002-_2
CCF OF ALL DIVISION OF THE EMS
H23-EMS-CF-DIDALL
2
1.80E-06
SIGNAL FROM SECOND RMU FAILS
GC62-0003-_2
LOSS OF DIV I (DID) POWER SOURCES
GC62-0004-_51
Page 14

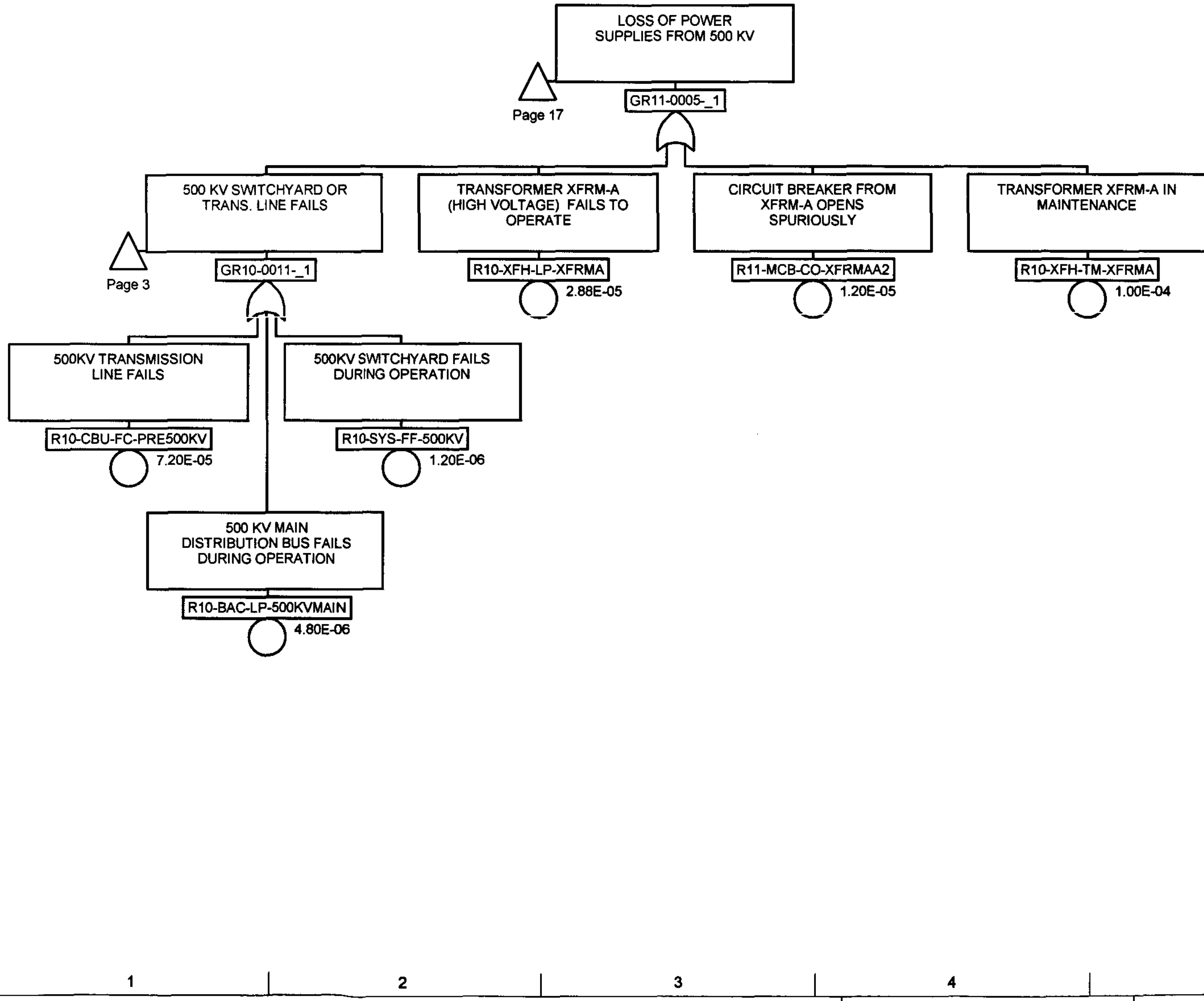


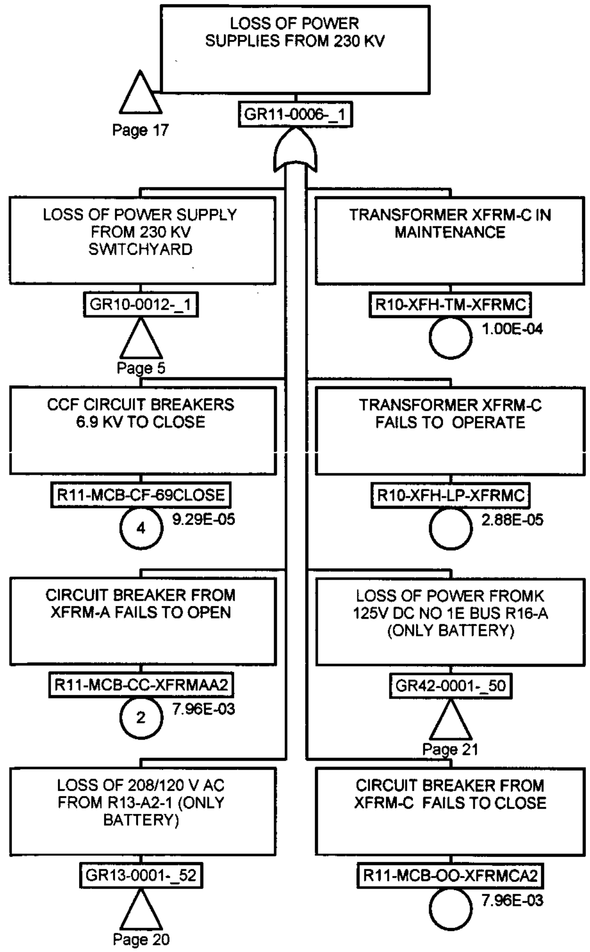
LOSS OF DIV I (DID) POWER SOURCES
GC62-0004-_51
Page 13
LOSS OF 208/120 V AC FROM R13-B1-1 (ONLY BATTERY)
GR13-0001-_53
LOSS OF 208/120 V AC FROM R13-B2-1 (ONLY BATTERY)
GR13-0001-_55
Page 6
BUS R13-B1-1 FAILS DURING OPERATION
R13-BAC-LP-R13B11
4.80E-06
NO POWER TO R13-B1-1 FROM SOURCES
GR13-0002-_53
NO POWER FROM BUS R13-B1
GR13-0003-_53
TRANSFORMER FAILS DURING OPERATION
R13-XFL-LP-R13B11
1.92E-05
CIRCUIT BREAKER OPENS SPURIOUSLY
R13-LCB-CO-R13B11
1.44E-05
CIRCUIT BREAKER OPENS SPURIOUSLY
R13-LCB-CO-FR13B11
1.44E-05
BUS R13-B1 FAILS DURING OPERATION
R13-BAC-LP-R13B1
4.80E-06
NO POWER TO R13-B1 FROM SOURCES
GR13-0004-_53
POWER SUPPLY FROM INVERTER FAILS
GR13-0007-_53
CIRCUIT BREAKER TO R13-B1 OPENS SPURIOUSLY
R13-LCB-CO-TOR13B1
1.44E-05
POWER SUPPLY FROM BUS R16-B1 FAILS
GR13-0009-_53
INVERTER TO R13-B1 FAILS
R13-INV-FC-R13B1
4.80E-04
CIRCUIT BREAKER FROM R16-B1 OPENS SPURIOUSLY
R13-LCB-CO-R16A1R13B1
1.44E-05
LOSS OF POWER FROM 250V DC NO 1E BUS R16-B1 (ONLY BATTERY)
GR42-0001-_54
Page 15
DIODE FROM R16-B1 FAILS TO OPERATE
R13-DIO-FC-R16A1R13B1
1.43E-06
1
2
3
4

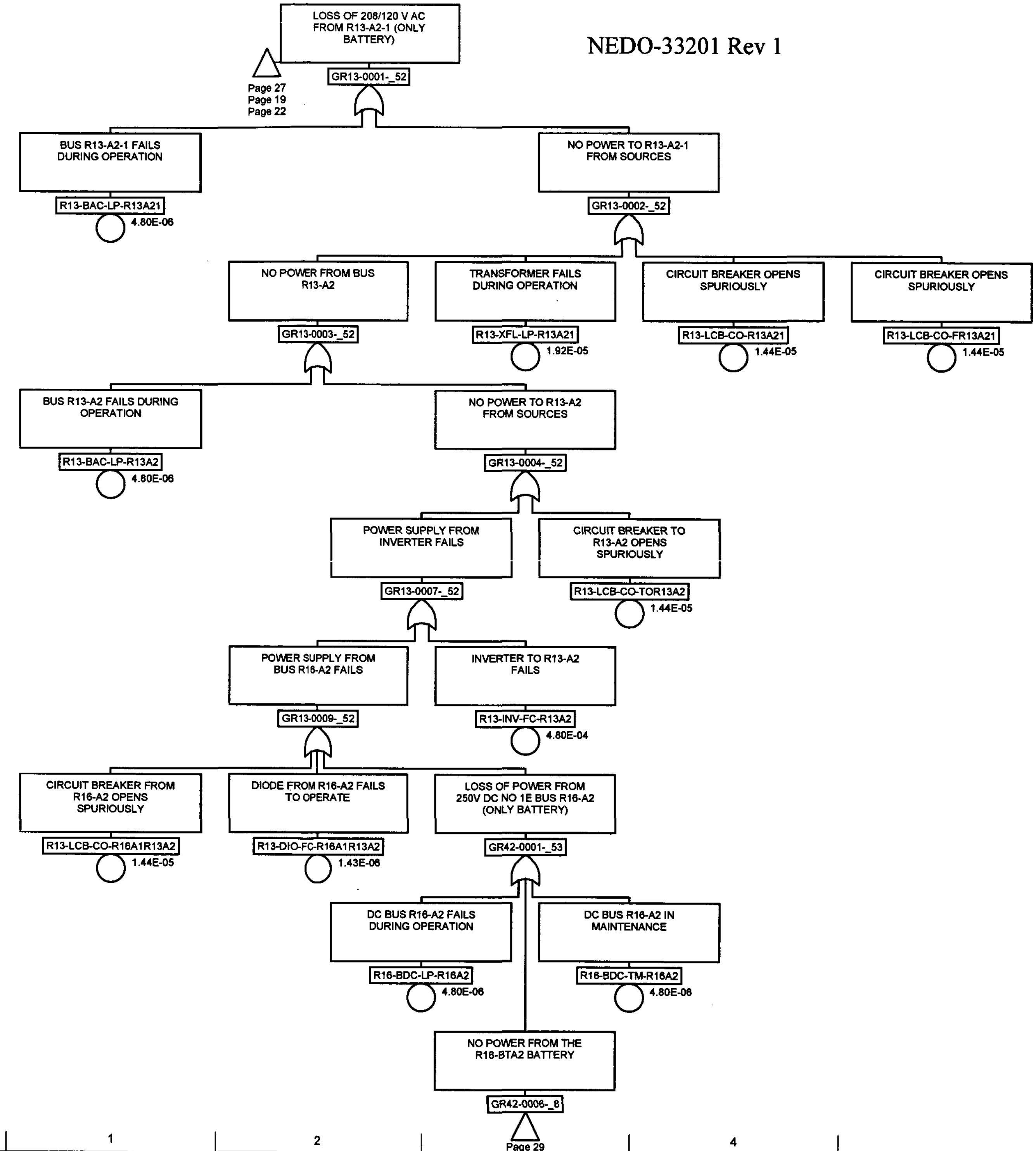

LOSS OF POWER FROM 250V DC NO 1E BUS R16-B1 (ONLY BATTERY)
Page 14
GR42-0001-_54
DC BUS R16-B1 FAILS DURING OPERATION
R16-BDC-LP-R16B1
4.80E-06
NO POWER FROM THE R16-BTB1 BATTERY
GR42-0006-_9
DC BUS R16-B1 IN MAINTENANCE
R16-BDC-TM-R16B1
4.80E-06
BATTERY R16-BTB1 FAILS TO PROVIDE OUTPUT
GR42-0007-_9
FAILURE DUE TO CCF
GR42-0008-_9
BATTERY R16-BTB1 IN TEST
R16-BT_-TM-R16BTB1
1.00E-03
BATTERY R16-BTB1 FAILS TO PROVIDE OUTPUT
R16-BT_-LP-R16BTB1
5.00E-04
CIRCUIT BREAKER FROM R16-BTB1 OPENS SPURIOUSLY
R16-LCB-CO-FROMR16BTB1
1.44E-05
1
2
3

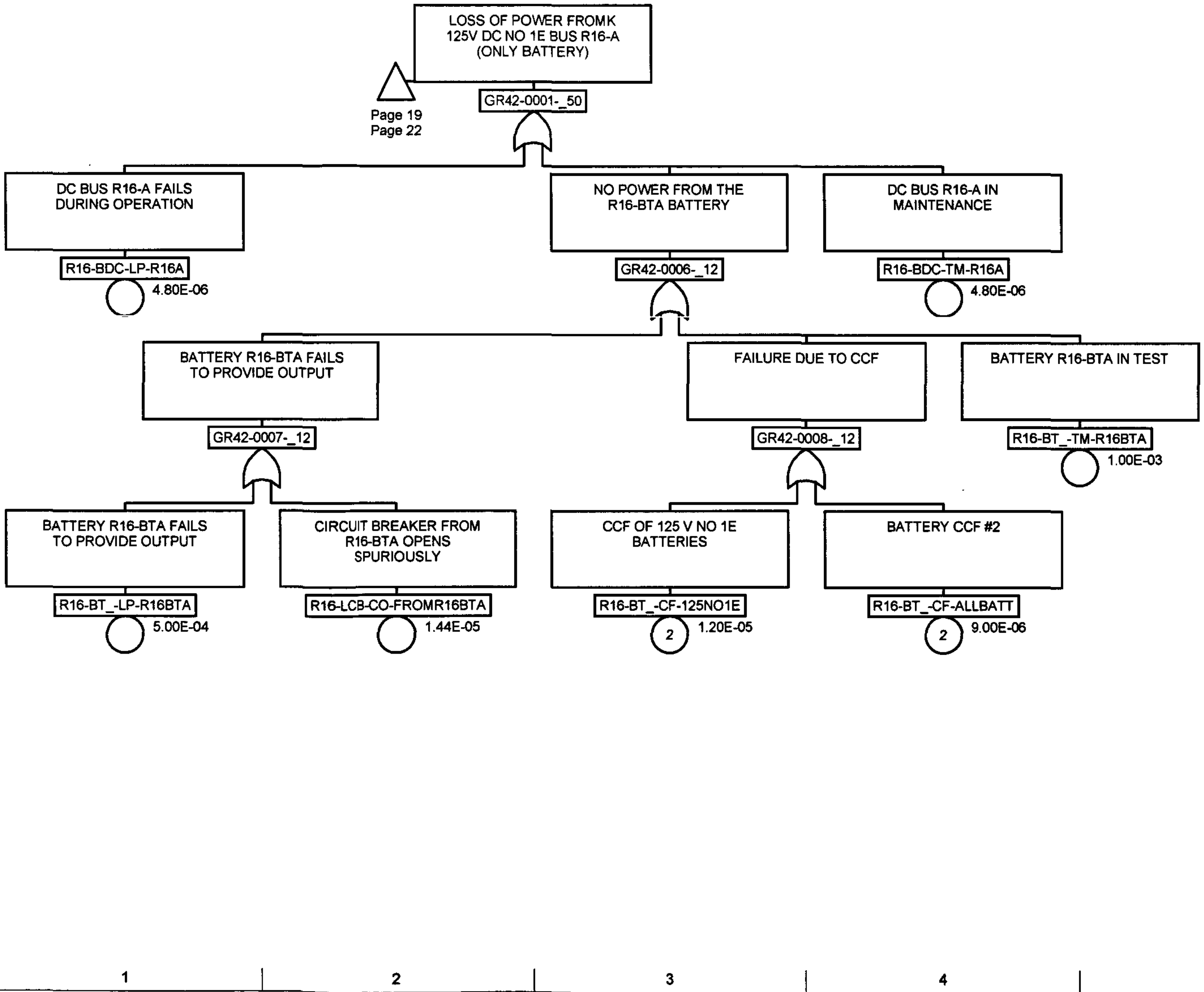

LOSS OF 6.9 KV AC FROM BUS R11-A2
GR11-0001-_1
6.9 KV AC BUS R11-A2 IN MANTENANCE
R11-BAC-TM-R11A2
4.80E-06
BUS R11-A2 FAILS DURING OPERATION
R11-BAC-LP-R11A2
4.80E-06
LOSS OF POWER SUPPLIES TO R11-A2
GR11-0002-_1
LOSS OF POWER SITUATIONS
GR11-0010-_1
NO POWER SUPPLY FROM DG-A TO R11-A2
GR21-0001-_1
Page 22
INITIAL LOOP
GR11-0011-_1
NO LOOP
GR11-0012-_1
Page 17
HOUSE EVENT: INITIATING EVENT IS LOSP (VALUE =1)
XHOSLOSP
4
FAILURE IN POWER SUPPLY
GR11-0012-_3
FAILURE IN OFFSITE POWER RECOVERY
R11-SYS-FF-NOREC
2
6.13E-01
NO POWER SUPPLIES FROM 550 AND 230 KV
GR11-0012-_2
Page 17
1
2
3

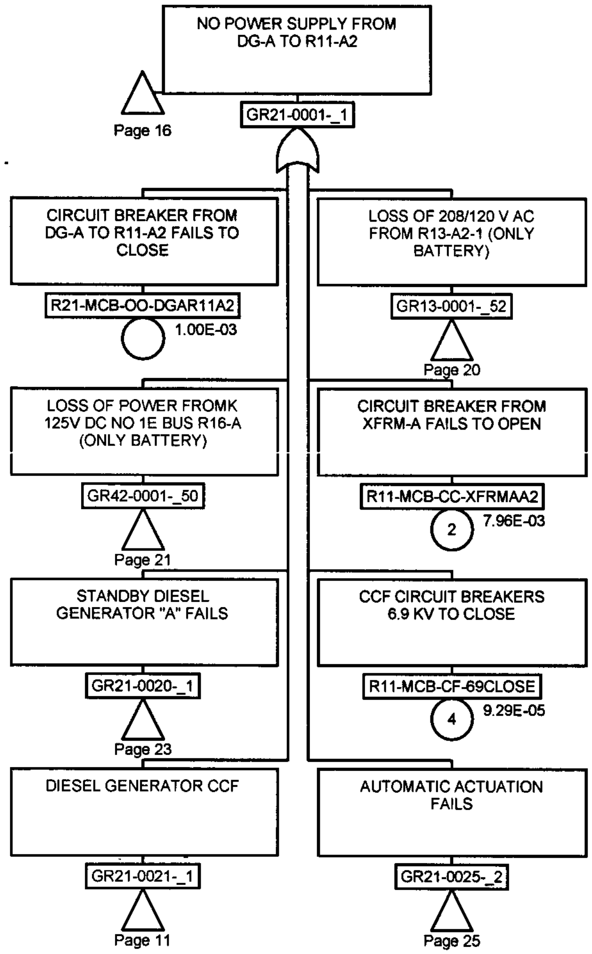

NO LOOP
Page 16
GR11-0012-_1
HOUSE EVENT: INITIATING EVENT IS LOSP (VALUE =1)
NO POWER SUPPLIES FROM 550 AND 230 KV
XHOSLOSP
4
Page 16
GR11-0012-_2
LOSS OF POWER SUPPLIES FROM 500 KV
LOSS OF POWER SUPPLIES FROM 230 KV
GR11-0005-_1
GR11-0006-_1
Page 18
Page 19
1
2

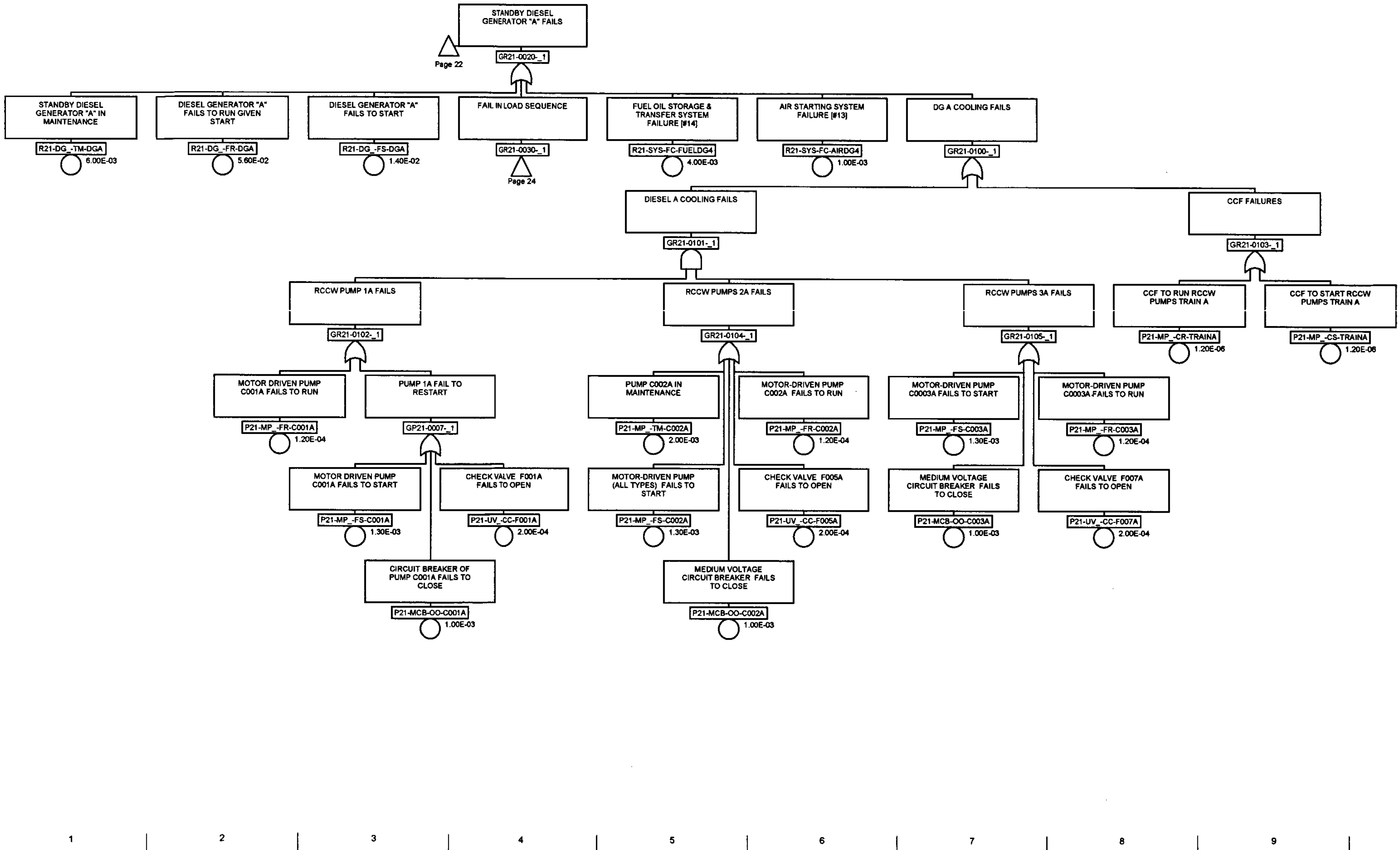

LOSS OF POWER SUPPLIES FROM 500 KV
GR11-0005-_1
Page 17
500 KV SWITCHYARD OR TRANS. LINE FAILS
GR10-0011-_1
Page 3
TRANSFORMER XFRM-A (HIGH VOLTAGE) FAILS TO OPERATE
R10-XFH-LP-XFRMA
2.88E-05
CIRCUIT BREAKER FROM XFRM-A OPENS SPURIOUSLY
R11-MCB-CO-XFRMAA2
1.20E-05
TRANSFORMER XFRM-A IN MAINTENANCE
R10-XFH-TM-XFRMA
1.00E-04
500KV TRANSMISSION LINE FAILS
R10-CBU-FC-PRE500KV
7.20E-05
500KV SWITCHYARD FAILS DURING OPERATION
R10-SYS-FF-500KV
1.20E-06
500 KV MAIN DISTRIBUTION BUS FAILS DURING OPERATION
R10-BAC-LP-500KVMAIN
4.80E-06
1
2
3
4


LOSS OF POWER SUPPLIES FROM 230 KV
GR11-0006-_1
Page 17
LOSS OF POWER SUPPLY FROM 230 KV SWITCHYARD
GR10-0012-_1
Page 5
TRANSFORMER XFRM-C IN MAINTENANCE
R10-XFH-TM-XFRMC
1.00E-04
CCF CIRCUIT BREAKERS 6.9 KV TO CLOSE
R11-MCB-CF-69CLOSE
4
9.29E-05
TRANSFORMER XFRM-C FAILS TO OPERATE
R10-XFH-LP-XFRMC
2.88E-05
CIRCUIT BREAKER FROM XFRM-A FAILS TO OPEN
R11-MCB-CC-XFRMAA2
2
7.96E-03
LOSS OF POWER FROMK 125V DC NO 1E BUS R16-A (ONLY BATTERY)
GR42-0001-_50
Page 21
LOSS OF 208/120 V AC FROM R13-A2-1 (ONLY BATTERY)
GR13-0001-_52
Page 20
CIRCUIT BREAKER FROM XFRM-C FAILS TO CLOSE
R11-MCB-OO-XFRMCA2
7.96E-03
1
2


LOSS OF 208/120 V AC FROM R13-A2-1 (ONLY BATTERY)
GR13-0001-_52
Page 27
Page 19
Page 22
BUS R13-A2-1 FAILS DURING OPERATION
R13-BAC-LP-R13A21
4.80E-06
NO POWER TO R13-A2-1 FROM SOURCES
GR13-0002-_52
NO POWER FROM BUS R13-A2
GR13-0003-_52
TRANSFORMER FAILS DURING OPERATION
R13-XFL-LP-R13A21
1.92E-05
CIRCUIT BREAKER OPENS SPURIOUSLY
R13-LCB-CO-R13A21
1.44E-05
CIRCUIT BREAKER OPENS SPURIOUSLY
R13-LCB-CO-FR13A21
1.44E-05
BUS R13-A2 FAILS DURING OPERATION
R13-BAC-LP-R13A2
4.80E-06
NO POWER TO R13-A2 FROM SOURCES
GR13-0004-_52
POWER SUPPLY FROM INVERTER FAILS
GR13-0007-_52
CIRCUIT BREAKER TO R13-A2 OPENS SPURIOUSLY
R13-LCB-CO-TOR13A2
1.44E-05
POWER SUPPLY FROM BUS R16-A2 FAILS
GR13-0009-_52
INVERTER TO R13-A2 FAILS
R13-INV-FC-R13A2
4.80E-04
CIRCUIT BREAKER FROM R16-A2 OPENS SPURIOUSLY
R13-LCB-CO-R16A1R13A2
1.44E-05
DIODE FROM R16-A2 FAILS TO OPERATE
R13-DIO-FC-R16A1R13A2
1.43E-06
LOSS OF POWER FROM 250V DC NO 1E BUS R16-A2 (ONLY BATTERY)
GR42-0001-_53
DC BUS R16-A2 FAILS DURING OPERATION
R16-BDC-LP-R16A2
4.80E-06
DC BUS R16-A2 IN MAINTENANCE
R16-BDC-TM-R16A2
4.80E-06
NO POWER FROM THE R16-BTA2 BATTERY
GR42-0006-_8
Page 29
1
2
4


LOSS OF POWER FROMK 125V DC NO 1E BUS R16-A (ONLY BATTERY)
GR42-0001-_50
Page 19
Page 22
DC BUS R16-A FAILS DURING OPERATION
R16-BDC-LP-R16A
4.80E-06
NO POWER FROM THE R16-BTA BATTERY
GR42-0006-_12
DC BUS R16-A IN MAINTENANCE
R16-BDC-TM-R16A
4.80E-06
BATTERY R16-BTA FAILS TO PROVIDE OUTPUT
GR42-0007-_12
FAILURE DUE TO CCF
GR42-0008-_12
BATTERY R16-BTA IN TEST
R16-BT_-TM-R16BTA
1.00E-03
BATTERY R16-BTA FAILS TO PROVIDE OUTPUT
R16-BT_-LP-R16BTA
5.00E-04
CIRCUIT BREAKER FROM R16-BTA OPENS SPURIOUSLY
R16-LCB-CO-FROMR16BTA
1.44E-05
CCF OF 125 V NO 1E BATTERIES
R16-BT_-CF-125NO1E
2
1.20E-05
BATTERY CCF #2
R16-BT_-CF-ALLBATT
2
9.00E-06
1
2
3
4


NO POWER SUPPLY FROM DG-A TO R11-A2
GR21-0001-_1
Page 16
CIRCUIT BREAKER FROM DG-A TO R11-A2 FAILS TO CLOSE
R21-MCB-OO-DGAR11A2
1.00E-03
LOSS OF 208/120 V AC FROM R13-A2-1 (ONLY BATTERY)
GR13-0001-_52
Page 20
LOSS OF POWER FROMK 125V DC NO 1E BUS R16-A (ONLY BATTERY)
GR42-0001-_50
Page 21
CIRCUIT BREAKER FROM XFRM-A FAILS TO OPEN
R11-MCB-CC-XFRMAA2
2
7.96E-03
STANDBY DIESEL GENERATOR "A" FAILS
GR21-0020-_1
Page 23
CCF CIRCUIT BREAKERS 6.9 KV TO CLOSE
R11-MCB-CF-69CLOSE
4
9.29E-05
DIESEL GENERATOR CCF
GR21-0021-_1
Page 11
AUTOMATIC ACTUATION FAILS
GR21-0025-_2
Page 25
1
2


STANDBY DIESEL GENERATOR "A" FAILS
GR21-0020-_1
Page 22
STANDBY DIESEL GENERATOR "A" IN MAINTENANCE
R21-DG_-TM-DGA
6.00E-03
DIESEL GENERATOR "A" FAILS TO RUN GIVEN START
R21-DG_-FR-DGA
5.60E-02
DIESEL GENERATOR "A" FAILS TO START
R21-DG_-FS-DGA
1.40E-02
FAIL IN LOAD SEQUENCE
GR21-0030-_1
Page 24
FUEL OIL STORAGE & TRANSFER SYSTEM FAILURE [#14]
R21-SYS-FC-FUELDG4
4.00E-03
AIR STARTING SYSTEM FAILURE [#13]
R21-SYS-FC-AIRDG4
1.00E-03
DG A COOLING FAILS
GR21-0100-_1
DIESEL A COOLING FAILS
GR21-0101-_1
CCF FAILURES
GR21-0103-_1
RCCW PUMP 1A FAILS
GR21-0102-_1
RCCW PUMPS 2A FAILS
GR21-0104-_1
RCCW PUMPS 3A FAILS
GR21-0105-_1
CCF TO RUN RCCW PUMPS TRAIN A
P21-MP_-CR-TRAINA
1.20E-06
CCF TO START RCCW PUMPS TRAIN A
P21-MP_-CS-TRAINA
1.20E-06
MOTOR DRIVEN PUMP C001A FAILS TO RUN
P21-MP_-FR-C001A
1.20E-04
PUMP 1A FAIL TO RESTART
GP21-0007-_1
MOTOR DRIVEN PUMP C001A FAILS TO START
P21-MP_-FS-C001A
1.30E-03
CHECK VALVE F001A FAILS TO OPEN
P21-UV_-CC-F001A
2.00E-04
CIRCUIT BREAKER OF PUMP C001A FAILS TO CLOSE
P21-MCB-OO-C001A
1.00E-03
PUMP C002A IN MAINTENANCE
P21-MP_-TM-C002A
2.00E-03
MOTOR-DRIVEN PUMP C002A FAILS TO RUN
P21-MP_-FR-C002A
1.20E-04
MOTOR-DRIVEN PUMP (ALL TYPES) FAILS TO START
P21-MP_-FS-C002A
1.30E-03
CHECK VALVE F005A FAILS TO OPEN
P21-UV_-CC-F005A
2.00E-04
MEDIUM VOLTAGE CIRCUIT BREAKER FAILS TO CLOSE
P21-MCB-OO-C002A
1.00E-03
MOTOR-DRIVEN PUMP C0003A FAILS TO START
P21-MP_-FS-C003A
1.30E-03
MOTOR-DRIVEN PUMP C0003A FAILS TO RUN
P21-MP_-FR-C003A
1.20E-04
MEDIUM VOLTAGE CIRCUIT BREAKER FAILS TO CLOSE
P21-MCB-OO-C003A
1.00E-03
CHECK VALVE F007A FAILS TO OPEN
P21-UV_-CC-F007A
2.00E-04
1
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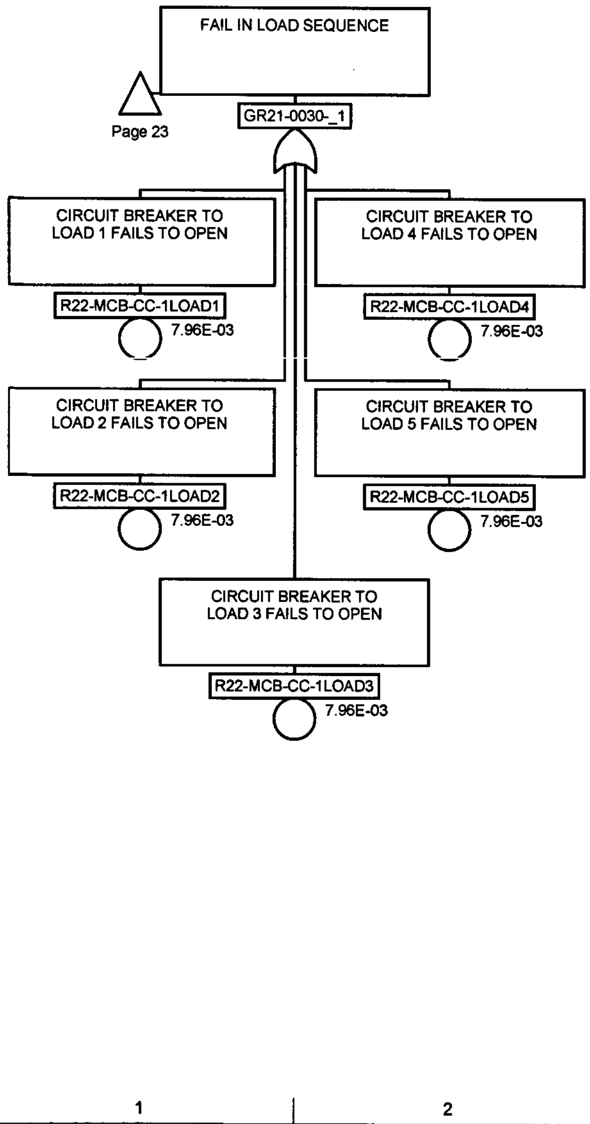
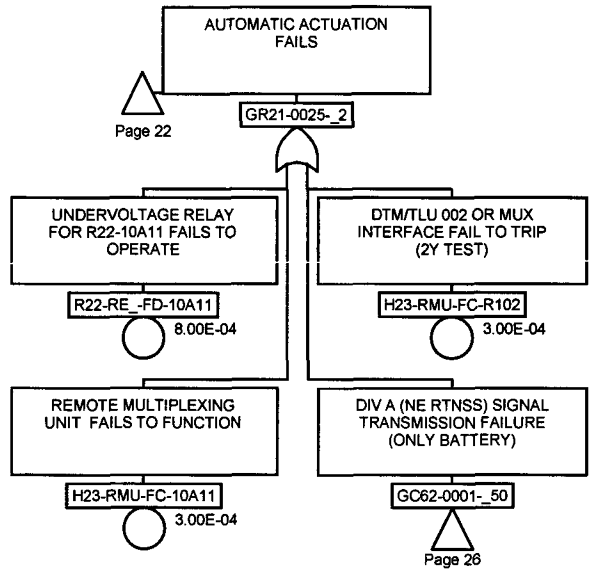
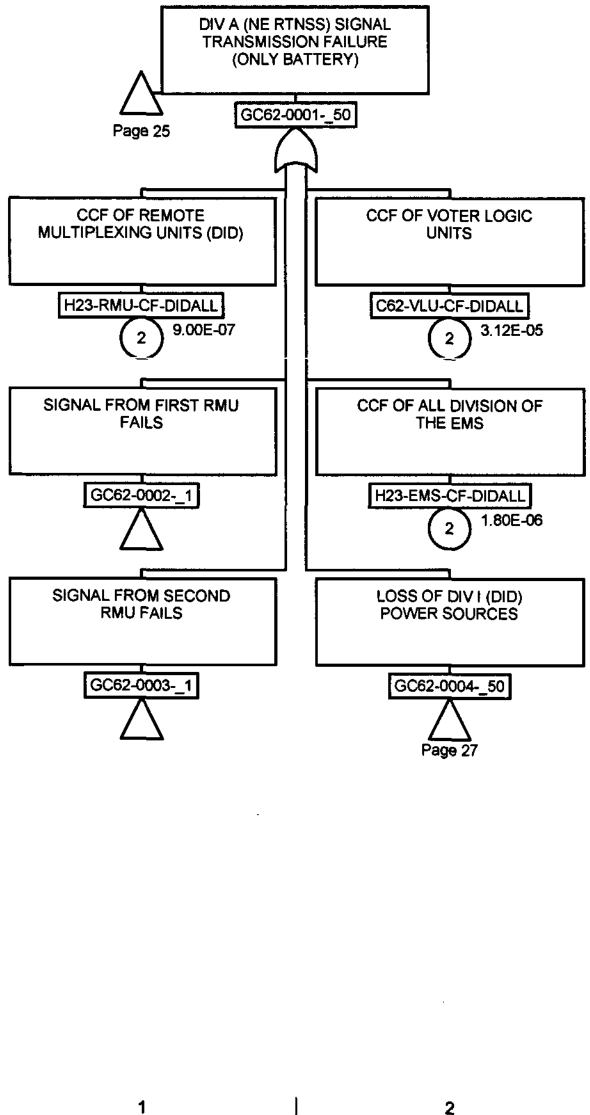
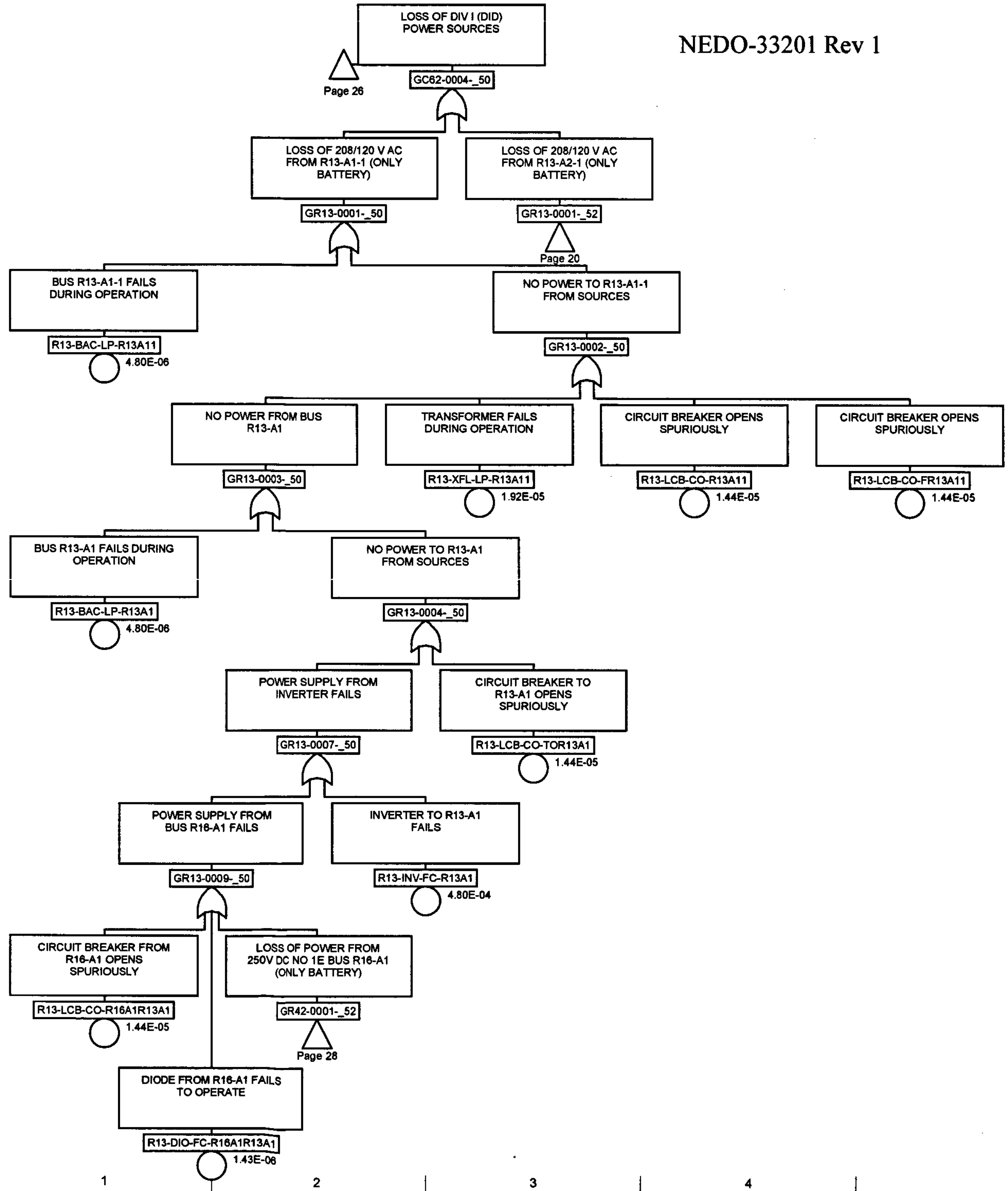
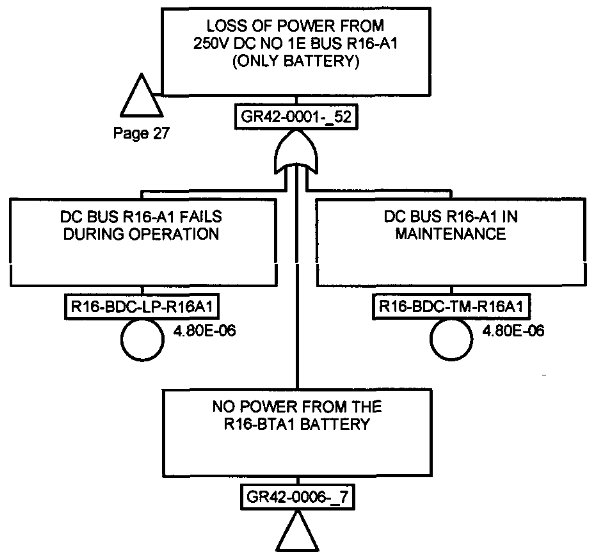
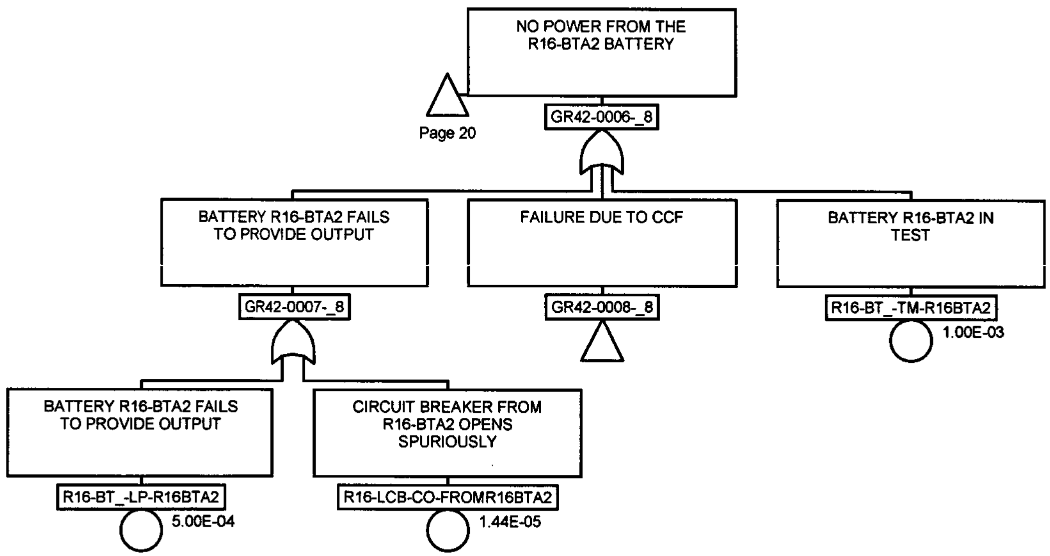

FAIL IN LOAD SEQUENCE
Page 23
GR21-0030-_1
CIRCUIT BREAKER TO LOAD 1 FAILS TO OPEN
R22-MCB-CC-1LOAD1
7.96E-03
CIRCUIT BREAKER TO LOAD 4 FAILS TO OPEN
R22-MCB-CC-1LOAD4
7.96E-03
CIRCUIT BREAKER TO LOAD 2 FAILS TO OPEN
R22-MCB-CC-1LOAD2
7.96E-03
CIRCUIT BREAKER TO LOAD 5 FAILS TO OPEN
R22-MCB-CC-1LOAD5
7.96E-03
CIRCUIT BREAKER TO LOAD 3 FAILS TO OPEN
R22-MCB-CC-1LOAD3
7.96E-03
1
2


AUTOMATIC ACTUATION FAILS
GR21-0025-_2
Page 22
UNDERVOLTAGE RELAY FOR R22-10A11 FAILS TO OPERATE
R22-RE_-FD-10A11
8.00E-04
DTM/TLU 002 OR MUX INTERFACE FAIL TO TRIP (2Y TEST)
H23-RMU-FC-R102
3.00E-04
REMOTE MULTIPLEXING UNIT FAILS TO FUNCTION
H23-RMU-FC-10A11
3.00E-04
DIV A (NE RTNSS) SIGNAL TRANSMISSION FAILURE (ONLY BATTERY)
GC62-0001-_50
Page 26
1
2


DIV A (NE RTNSS) SIGNAL TRANSMISSION FAILURE (ONLY BATTERY)
GC62-0001-_50
Page 25
CCF OF REMOTE MULTIPLEXING UNITS (DID)
H23-RMU-CF-DIDALL
2
9.00E-07
CCF OF VOTER LOGIC UNITS
C62-VLU-CF-DIDALL
2
3.12E-05
SIGNAL FROM FIRST RMU FAILS
GC62-0002-_1
CCF OF ALL DIVISION OF THE EMS
H23-EMS-CF-DIDALL
2
1.80E-06
SIGNAL FROM SECOND RMU FAILS
GC62-0003-_1
LOSS OF DIV I (DID) POWER SOURCES
GC62-0004-_50
Page 27
1
2


LOSS OF DIV I (DID) POWER SOURCES
Page 26
GC62-0004-_50
LOSS OF 208/120 V AC FROM R13-A1-1 (ONLY BATTERY)
GR13-0001-_50
LOSS OF 208/120 V AC FROM R13-A2-1 (ONLY BATTERY)
GR13-0001-_52
Page 20
BUS R13-A1-1 FAILS DURING OPERATION
R13-BAC-LP-R13A11
4.80E-06
NO POWER TO R13-A1-1 FROM SOURCES
GR13-0002-_50
NO POWER FROM BUS R13-A1
GR13-0003-_50
TRANSFORMER FAILS DURING OPERATION
R13-XFL-LP-R13A11
1.92E-05
CIRCUIT BREAKER OPENS SPURIOUSLY
R13-LCB-CO-R13A11
1.44E-05
CIRCUIT BREAKER OPENS SPURIOUSLY
R13-LCB-CO-FR13A11
1.44E-05
BUS R13-A1 FAILS DURING OPERATION
R13-BAC-LP-R13A1
4.80E-06
NO POWER TO R13-A1 FROM SOURCES
GR13-0004-_50
POWER SUPPLY FROM INVERTER FAILS
GR13-0007-_50
CIRCUIT BREAKER TO R13-A1 OPENS SPURIOUSLY
R13-LCB-CO-TOR13A1
1.44E-05
POWER SUPPLY FROM BUS R16-A1 FAILS
GR13-0009-_50
INVERTER TO R13-A1 FAILS
R13-INV-FC-R13A1
4.80E-04
CIRCUIT BREAKER FROM R16-A1 OPENS SPURIOUSLY
R13-LCB-CO-R16A1R13A1
1.44E-05
LOSS OF POWER FROM 250V DC NO 1E BUS R16-A1 (ONLY BATTERY)
GR42-0001-_52
Page 28
DIODE FROM R16-A1 FAILS TO OPERATE
R13-DIO-FC-R16A1R13A1
1.43E-06
1
2
3
4


LOSS OF POWER FROM
250V DC NO 1E BUS R16-A1
(ONLY BATTERY)
GR42-0001-_52
Page 27
DC BUS R16-A1 FAILS
DURING OPERATION
R16-BDC-LP-R16A1
4.80E-06
DC BUS R16-A1 IN
MAINTENANCE
R16-BDC-TM-R16A1
4.80E-06
NO POWER FROM THE
R16-BTA1 BATTERY
GR42-0006-_7


NO POWER FROM THE R16-BTA2 BATTERY
GR42-0006-_8
Page 20
BATTERY R16-BTA2 FAILS TO PROVIDE OUTPUT
GR42-0007-_8
FAILURE DUE TO CCF
GR42-0008-_8
BATTERY R16-BTA2 IN TEST
R16-BT_-TM-R16BTA2
1.00E-03
BATTERY R16-BTA2 FAILS TO PROVIDE OUTPUT
R16-BT_-LP-R16BTA2
5.00E-04
CIRCUIT BREAKER FROM R16-BTA2 OPENS SPURIOUSLY
R16-LCB-CO-FROMR16BTA2
1.44E-05
1
2
3

Name	Page	Zone	Name	Page	Zone
C62-VLU-CF-DIDALL	13	2	GR13-0001- 55	6	2
C62-VLU-CF-DIDALL	26	2	GR13-0001- 55	8	2
GC62-0001- 50	25	2	GR13-0001- 55	14	3
GC62-0001- 50	26	2	GR13-0002- 50	27	3
GC62-0001- 51	12	2	GR13-0002- 52	20	3
GC62-0001- 51	13	2	GR13-0002- 53	14	3
GC62-0002- 1	26	1	GR13-0002- 55	6	3
GC62-0002- 2	13	1	GR13-0003- 50	27	2
GC62-0003- 1	26	1	GR13-0003- 52	20	2
GC62-0003- 2	13	1	GR13-0003- 53	14	2
GC62-0004- 50	26	2	GR13-0003- 55	6	2
GC62-0004- 50	27	3	GR13-0004- 50	27	2
GC62-0004- 51	13	2	GR13-0004- 52	20	3
GC62-0004- 51	14	3	GR13-0004- 53	14	2
GP21-0007- 1	23	3	GR13-0004- 55	6	3
GP21-0007- 2	9	3	GR13-0007- 50	27	2
GR10-0011- 1	3	1	GR13-0007- 52	20	3
GR10-0011- 1	18	2	GR13-0007- 53	14	2
GR10-0012- 1	4	1	GR13-0007- 55	6	3
GR10-0012- 1	5	2	GR13-0009- 50	27	2
GR10-0012- 1	19	1	GR13-0009- 52	20	2
GR11-0001- 1	16	2	GR13-0009- 53	14	2
GR11-0001- 2	1	2	GR13-0009- 55	6	2
GR11-0002- 1	16	3	GR21-0001- 1	16	4
GR11-0002- 2	1	3	GR21-0001- 1	22	2
GR11-0002- 3	1	3	GR21-0001- 2	1	4
GR11-0002- 4	1	2	GR21-0001- 2	8	2
GR11-0002- 5	1	3	GR21-0020- 1	22	1
GR11-0002- 5	2	2	GR21-0020- 1	23	4
GR11-0003- 2	1	3	GR21-0020- 2	8	1
GR11-0003- 2	2	2	GR21-0020- 2	9	4
GR11-0004- 2	1	3	GR21-0021- 1	8	1
GR11-0005- 1	17	2	GR21-0021- 1	11	2
GR11-0005- 1	18	3	GR21-0021- 1	22	1
GR11-0005- 2	2	2	GR21-0025- 1	8	2
GR11-0005- 2	3	2	GR21-0025- 1	12	2
GR11-0006- 1	17	3	GR21-0025- 2	22	2
GR11-0006- 1	19	2	GR21-0025- 2	25	2
GR11-0006- 2	2	3	GR21-0030- 1	23	4
GR11-0006- 2	4	2	GR21-0030- 1	24	2
GR11-0010- 1	16	3	GR21-0030- 2	9	4
GR11-0011- 1	16	2	GR21-0030- 2	10	2
GR11-0012- 1	16	3	GR21-0100- 1	23	7
GR11-0012- 1	17	2	GR21-0100- 2	9	7
GR11-0012- 2	16	3	GR21-0101- 1	23	5
GR11-0012- 2	17	2	GR21-0101- 2	9	5
GR11-0012- 3	16	3	GR21-0102- 1	23	3
GR13-0001- 50	27	2	GR21-0102- 2	9	3
GR13-0001- 52	19	1	GR21-0103- 1	23	9
GR13-0001- 52	20	2	GR21-0103- 2	9	9
GR13-0001- 52	22	2	GR21-0104- 1	23	5
GR13-0001- 52	27	3	GR21-0104- 2	9	5
GR13-0001- 53	14	2	GR21-0105- 1	23	7
GR13-0001-_55	4	1	GR21-0105-_2	9	7

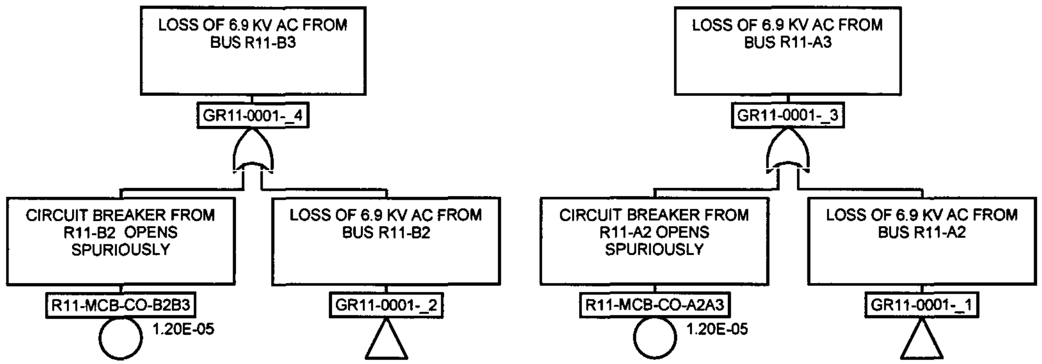
Name	Page	Zone	Name	Page	Zone
GR42-0001- 50	19	2	P21-MP -FS-C002B	9	5
GR42-0001- 50	21	2	P21-MP -FS-C003A	23	7
GR42-0001- 50	22	1	P21-MP -FS-C003B	9	7
GR42-0001- 51	4	2	P21-MP -TM-C002A	23	5
GR42-0001- 51	7	2	P21-MP -TM-C002B	9	5
GR42-0001- 51	8	1	P21-UV -CC-F001A	23	4
GR42-0001- 52	27	2	P21-UV -CC-F001B	9	4
GR42-0001- 52	28	2	P21-UV -CC-F005A	23	6
GR42-0001- 53	20	3	P21-UV -CC-F005B	9	6
GR42-0001- 54	14	2	P21-UV -CC-F007A	23	8
GR42-0001- 54	15	2	P21-UV -CC-F007B	9	8
GR42-0001- 55	6	3	R10-BAC-LP-230KVMAIN	5	2
GR42-0006- 10	6	3	R10-BAC-LP-500KVMAIN	18	2
GR42-0006- 12	21	3	R10-CBU-FC-PRE230KV	5	2
GR42-0006- 13	7	3	R10-CBU-FC-PRE500KV	18	1
GR42-0006- 7	28	2	R10-SYS-FF-230KV	5	1
GR42-0006- 8	20	3	R10-SYS-FF-500KV	18	2
GR42-0006- 8	29	2	R10-SYS-TM-230KV	5	1
GR42-0006- 9	15	2	R10-XFH-LP-XFRMA	18	3
GR42-0007- 12	21	2	R10-XFH-LP-XFRMB	3	1
GR42-0007- 13	7	2	R10-XFH-LP-XFRMC	19	2
GR42-0007- 8	29	2	R10-XFH-LP-XFRMD	4	2
GR42-0007- 9	15	2	R10-XFH-TM-XFRMA	18	5
GR42-0008- 12	21	4	R10-XFH-TM-XFRMB	3	2
GR42-0008- 13	7	4	R10-XFH-TM-XFRMC	19	2
GR42-0008- 8	29	3	R10-XFH-TM-XFRMD	4	2
GR42-0008- 9	15	3	R11-BAC-LP-R11A2	16	2
H23-EMS-CF-DIDALL	13	2	R11-BAC-LP-R11B2	1	2
H23-EMS-CF-DIDALL	26	2	R11-BAC-TM-R11A2	16	1
H23-RMU-CF-DIDALL	13	1	R11-BAC-TM-R11B2	1	1
H23-RMU-CF-DIDALL	26	1	R11-MCB-CC-XFRMAA2	19	1
H23-RMU-FC-10A11	25	1	R11-MCB-CC-XFRMAA2	22	2
H23-RMU-FC-10A21	12	1	R11-MCB-CC-XFRMBB2	4	1
H23-RMU-FC-R101	12	2	R11-MCB-CC-XFRMBB2	8	2
H23-RMU-FC-R102	25	2	R11-MCB-CF-69CLOSE	4	1
P21-MCB-OO-C001A	23	3	R11-MCB-CF-69CLOSE	8	2
P21-MCB-OO-C001B	9	3	R11-MCB-CF-69CLOSE	19	1
P21-MCB-OO-C002A	23	5	R11-MCB-CF-69CLOSE	22	2
P21-MCB-OO-C002B	9	5	R11-MCB-CO-XFRMAA2	18	4
P21-MCB-OO-C003A	23	7	R11-MCB-CO-XFRMBB2	3	2
P21-MCB-OO-C003B	9	7	R11-MCB-OO-XFRMCA2	19	2
P21-MP -CR-TRAINA	23	8	R11-MCB-OO-XFRMDB2	4	2
P21-MP -CR-TRAINB	9	8	R11-SYS-FF-NOREC	1	2
P21-MP -CS-TRAINA	23	9	R11-SYS-FF-NOREC	16	2
P21-MP -CS-TRAINB	9	9	R13-BAC-LP-R13A1	27	1
P21-MP -FR-C001A	23	2	R13-BAC-LP-R13A11	27	1
P21-MP -FR-C001B	9	2	R13-BAC-LP-R13A2	20	1
P21-MP -FR-C002A	23	6	R13-BAC-LP-R13A21	20	1
P21-MP -FR-C002B	9	6	R13-BAC-LP-R13B1	14	1
P21-MP -FR-C003A	23	8	R13-BAC-LP-R13B11	14	1
P21-MP -FR-C003B	9	8	R13-BAC-LP-R13B2	6	1
P21-MP -FS-C001A	23	3	R13-BAC-LP-R13B21	6	1
P21-MP -FS-C001B	9	3	R13-DIO-FC-R16A1R13A1	27	2
P21-MP_-FS-C002A	23	5	R13-DIO-FC-R16A1R13A2	20	2

Name	Page	Zone	Name	Page	Zone
R13-DIO-FC-R16A1R13B1	14	2	R21-DG -CR-ALLDG	11	1
R13-DIO-FC-R16A1R13B2	6	2	R21-DG -CS-ALLDG	11	1
R13-INV-FC-R13A1	27	3	R21-DG -FR-DGA	23	2
R13-INV-FC-R13A2	20	3	R21-DG -FR-DGB	9	2
R13-INV-FC-R13B1	14	3	R21-DG -FS-DGA	23	3
R13-INV-FC-R13B2	6	3	R21-DG -FS-DGB	9	3
R13-LCB-CO-FR13A11	27	5	R21-DG -TM-DGA	23	1
R13-LCB-CO-FR13A21	20	5	R21-DG -TM-DGB	9	1
R13-LCB-CO-FR13B11	14	5	R21-MCB-OO-DGAR11A2	22	1
R13-LCB-CO-FR13B21	6	5	R21-MCB-OO-DGBR11B2	8	1
R13-LCB-CO-R13A11	27	4	R21-MP -CR-FUELTRANS	11	2
R13-LCB-CO-R13A21	20	4	R21-MP -CS-FUELTRANS	11	2
R13-LCB-CO-R13B11	14	4	R21-SYS-FC-AIRDG4	23	6
R13-LCB-CO-R13B21	6	4	R21-SYS-FC-AIRDG5	9	6
R13-LCB-CO-R16A1R13A1	27	1	R21-SYS-FC-FUELDG4	23	5
R13-LCB-CO-R16A1R13A2	20	1	R21-SYS-FC-FUELDG5	9	5
R13-LCB-CO-R16A1R13B1	14	1	R22-MCB-CC-1LOAD1	24	1
R13-LCB-CO-R16A1R13B2	6	1	R22-MCB-CC-1LOAD2	24	1
R13-LCB-CO-TOR13A1	27	3	R22-MCB-CC-1LOAD3	24	2
R13-LCB-CO-TOR13A2	20	4	R22-MCB-CC-1LOAD4	24	2
R13-LCB-CO-TOR13B1	14	3	R22-MCB-CC-1LOAD5	24	2
R13-LCB-CO-TOR13B2	6	4	R22-MCB-CC-2LOAD1	10	1
R13-XFL-LP-R13A11	27	3	R22-MCB-CC-2LOAD2	10	1
R13-XFL-LP-R13A21	20	3	R22-MCB-CC-2LOAD3	10	2
R13-XFL-LP-R13B11	14	3	R22-MCB-CC-2LOAD4	10	2
R13-XFL-LP-R13B21	6	3	R22-MCB-CC-2LOAD5	10	2
R16-BDC-LP-R16A	21	1	R22-RE -FD-10A11	25	1
R16-BDC-LP-R16A1	28	1	R22-RE -FD-10A21	12	1
R16-BDC-LP-R16A2	20	3	XHOSLOSP	1	2
R16-BDC-LP-R16B	7	1	XHOSLOSP	2	1
R16-BDC-LP-R16B1	15	1	XHOSLOSP	16	2
R16-BDC-LP-R16B2	6	3	XHOSLOSP	17	1
R16-BDC-TM-R16A	21	4			
R16-BDC-TM-R16A1	28	2			
R16-BDC-TM-R16A2	20	4			
R16-BDC-TM-R16B	7	4			
R16-BDC-TM-R16B1	15	3			
R16-BDC-TM-R16B2	6	4			
R16-BT -CF-125NO1E	7	3			
R16-BT -CF-125NO1E	21	3			
R16-BT -CF-ALLBATT	7	4			
R16-BT -CF-ALLBATT	21	4			
R16-BT -LP-R16BTA	21	1			
R16-BT -LP-R16BTA2	29	1			
R16-BT -LP-R16BTB	7	1			
R16-BT -LP-R16BTB1	15	1			
R16-BT -TM-R16BTA	21	5			
R16-BT -TM-R16BTA2	29	4			
R16-BT -TM-R16BTB	7	5			
R16-BT -TM-R16BTB1	15	4			
R16-LCB-CO-FROMR16BTA	21	2			
R16-LCB-CO-FROMR16BTA2	29	2			
R16-LCB-CO-FROMR16BTB	7	2			
R16-LCB-CO-FROMR16BTB1	15	2			

Appendix B.4.14-3

A.C. Electric Power System

Fault Tree


LOSS OF 6.9 KV AC FROM BUS R11-B3
GR11-0001-_4
CIRCUIT BREAKER FROM R11-B2 OPENS SPURIOUSLY
R11-MCB-CO-B2B3
1.20E-05
LOSS OF 6.9 KV AC FROM BUS R11-B2
GR11-0001-_2
LOSS OF 6.9 KV AC FROM BUS R11-A3
GR11-0001-_3
CIRCUIT BREAKER FROM R11-A2 OPENS SPURIOUSLY
R11-MCB-CO-A2A3
1.20E-05
LOSS OF 6.9 KV AC FROM BUS R11-A2
GR11-0001-_1

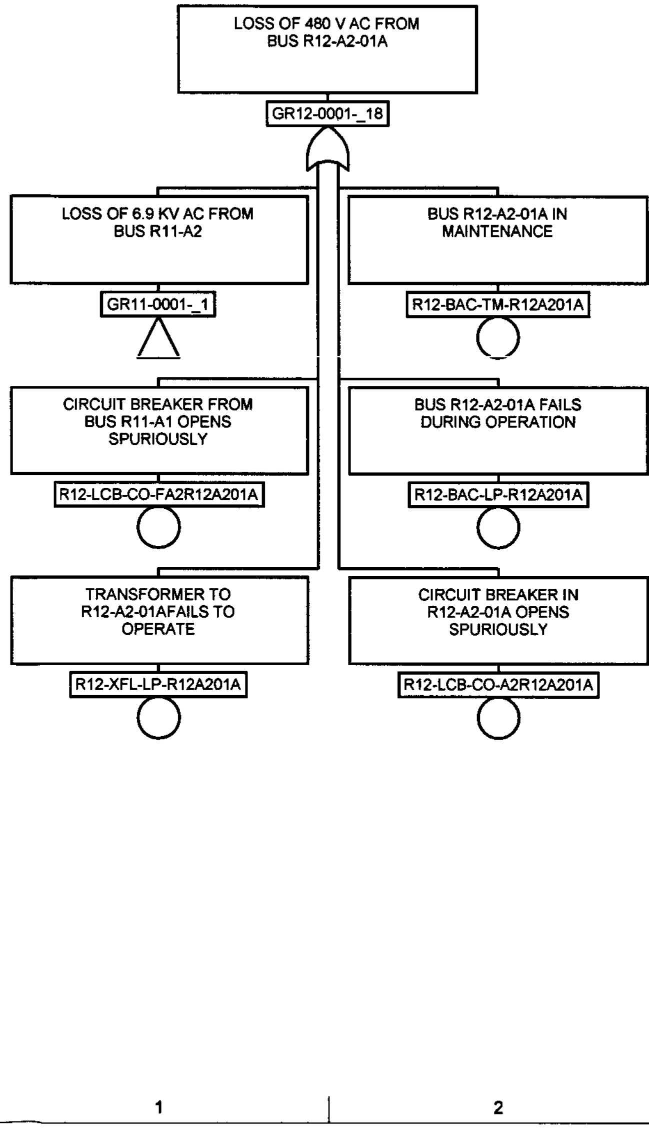
1	2	3	4

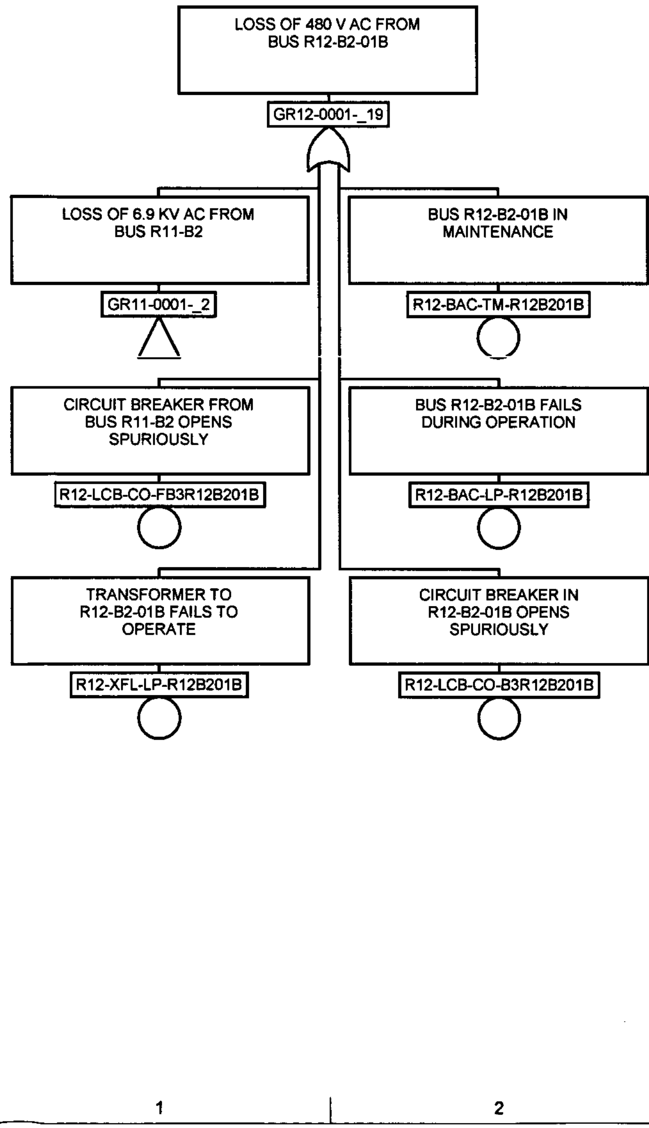
Name	Page	Zone	Name	Page	Zone
GR11-0001- 1	1	4			
GR11-0001- 2	1	2			
GR11-0001- 3	1	4			
GR11-0001- 4	1	2			
R11-MCB-CO-A2A3	1	3			
R11-MCB-CO-B2B3	1	1			

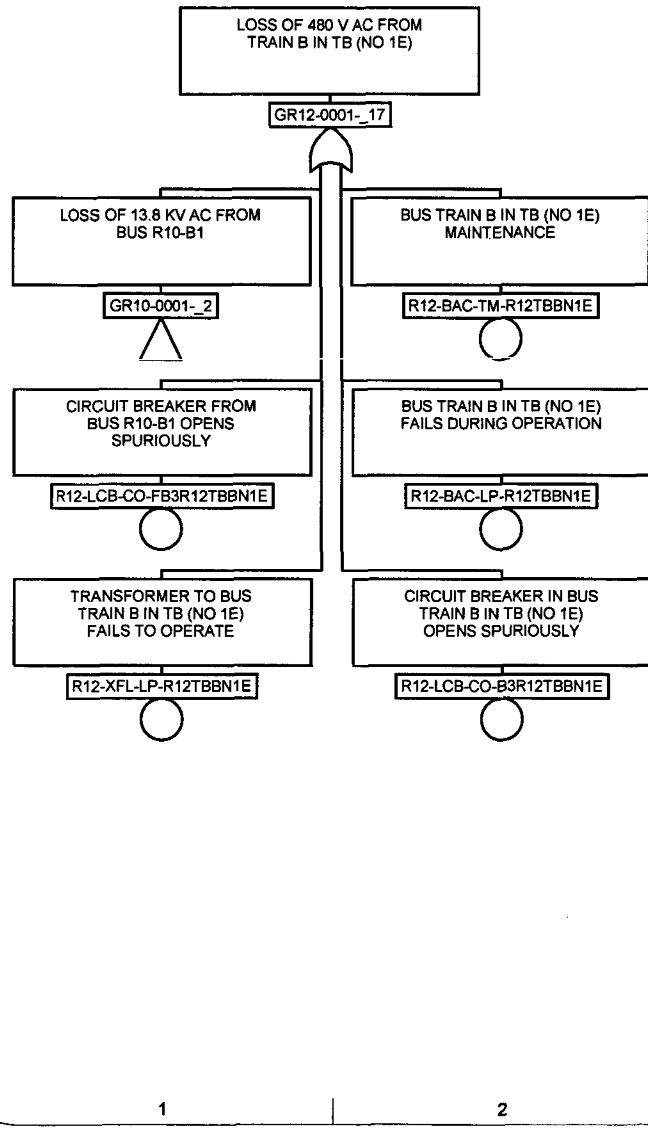
Appendix B.4.14-4

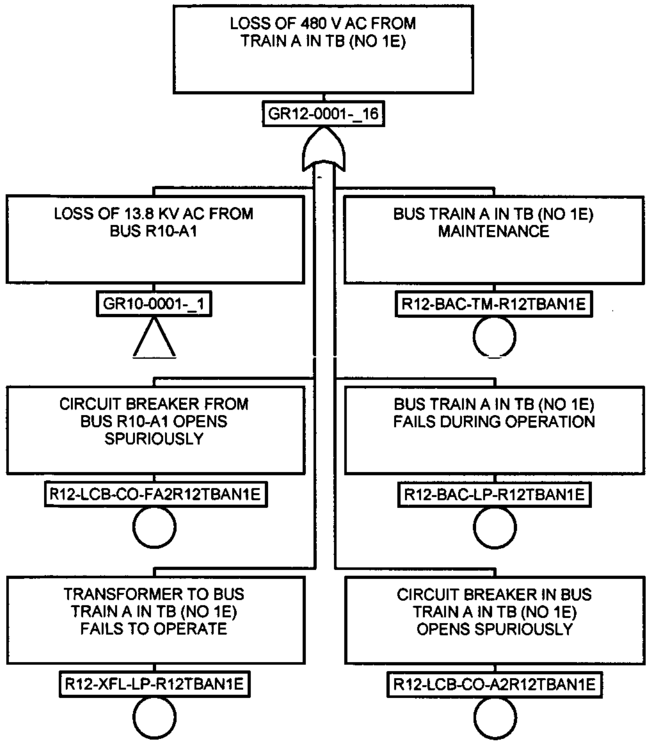
A.C. Electric Power System

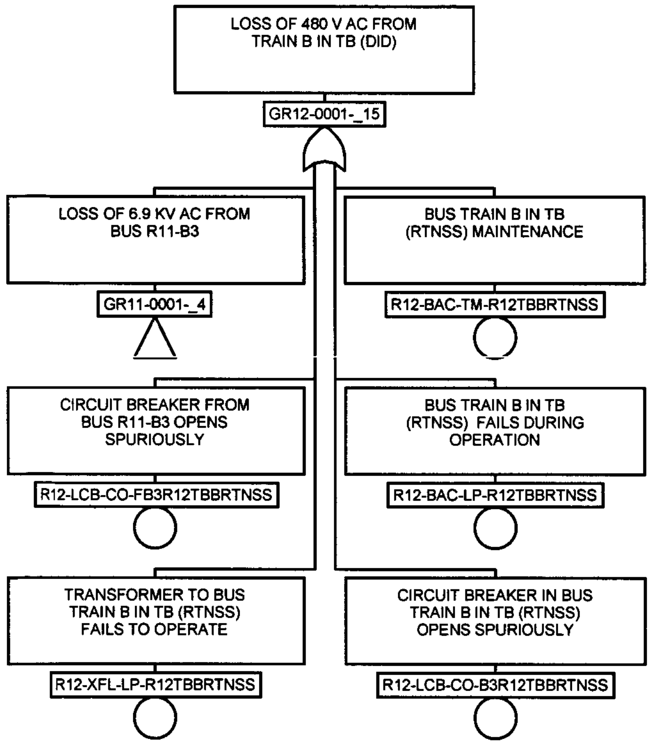
Fault Tree

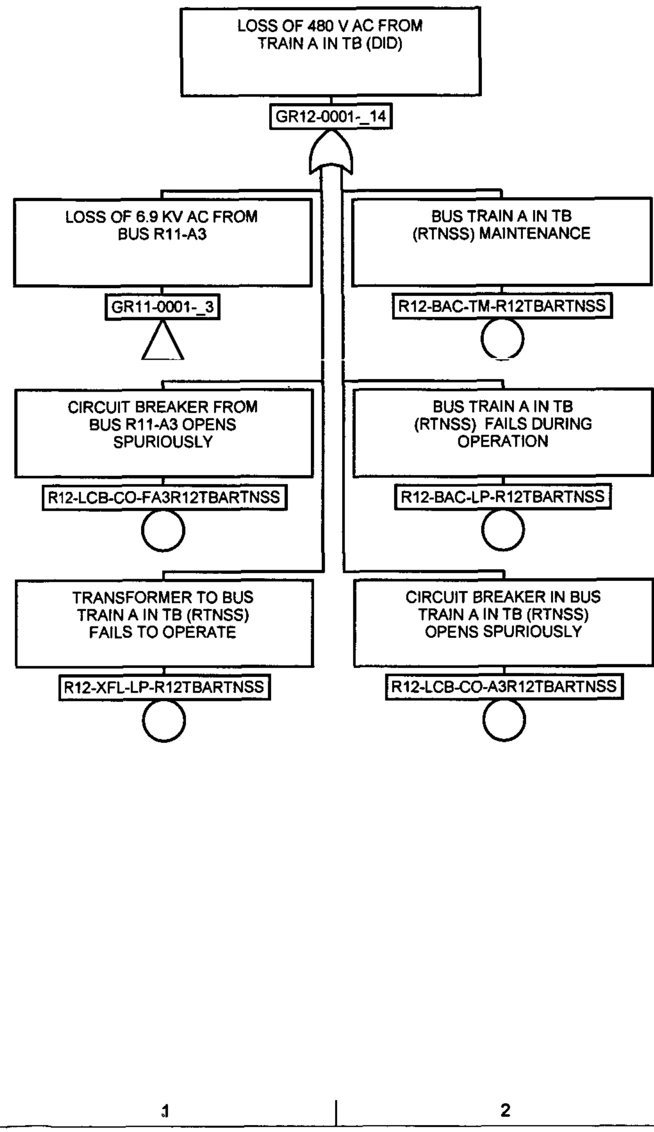

LOSS OF 480 V AC FROM BUS R12-A2-01A
GR12-0001-_18
LOSS OF 6.9 KV AC FROM BUS R11-A2
GR11-0001-_1
BUS R12-A2-01A IN MAINTENANCE
R12-BAC-TM-R12A201A
CIRCUIT BREAKER FROM BUS R11-A1 OPENS SPURIOUSLY
R12-LCB-CO-FA2R12A201A
BUS R12-A2-01A FAILS DURING OPERATION
R12-BAC-LP-R12A201A
TRANSFORMER TO R12-A2-01AFAILS TO OPERATE
R12-XFL-LP-R12A201A
CIRCUIT BREAKER IN R12-A2-01A OPENS SPURIOUSLY
R12-LCB-CO-A2R12A201A
1
2

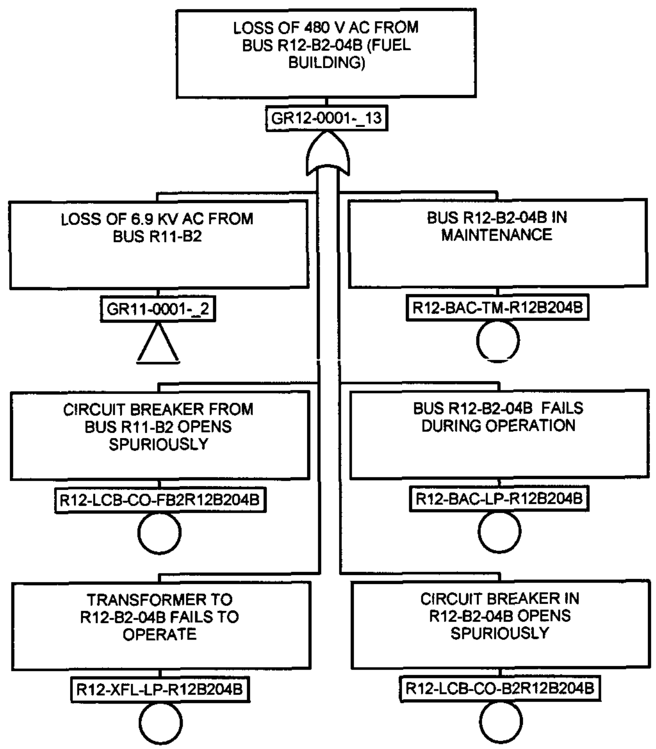

LOSS OF 480 V AC FROM BUS R12-B2-01B
GR12-0001-_19
LOSS OF 6.9 KV AC FROM BUS R11-B2
GR11-0001-_2
BUS R12-B2-01B IN MAINTENANCE
R12-BAC-TM-R12B201B
CIRCUIT BREAKER FROM BUS R11-B2 OPENS SPURIOUSLY
R12-LCB-CO-FB3R12B201B
BUS R12-B2-01B FAILS DURING OPERATION
R12-BAC-LP-R12B201B
TRANSFORMER TO R12-B2-01B FAILS TO OPERATE
R12-XFL-LP-R12B201B
CIRCUIT BREAKER IN R12-B2-01B OPENS SPURIOUSLY
R12-LCB-CO-B3R12B201B
1
2

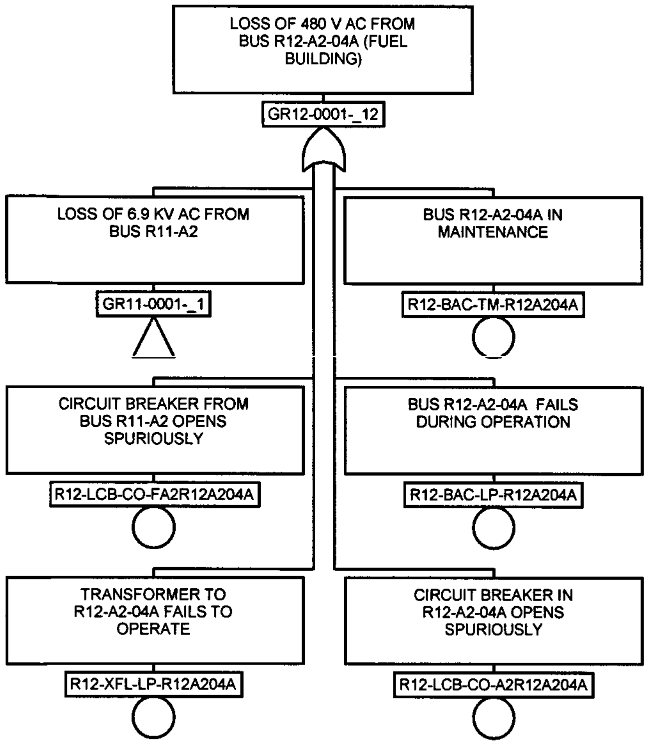

LOSS OF 480 V AC FROM TRAIN B IN TB (NO 1E)
GR12-0001-_17
LOSS OF 13.8 KV AC FROM BUS R10-B1
GR10-0001-_2
BUS TRAIN B IN TB (NO 1E) MAINTENANCE
R12-BAC-TM-R12TBBN1E
CIRCUIT BREAKER FROM BUS R10-B1 OPENS SPURIOUSLY
R12-LCB-CO-FB3R12TBBN1E
BUS TRAIN B IN TB (NO 1E) FAILS DURING OPERATION
R12-BAC-LP-R12TBBN1E
TRANSFORMER TO BUS TRAIN B IN TB (NO 1E) FAILS TO OPERATE
R12-XFL-LP-R12TBBN1E
CIRCUIT BREAKER IN BUS TRAIN B IN TB (NO 1E) OPENS SPURIOUSLY
R12-LCB-CO-B3R12TBBN1E
1
2

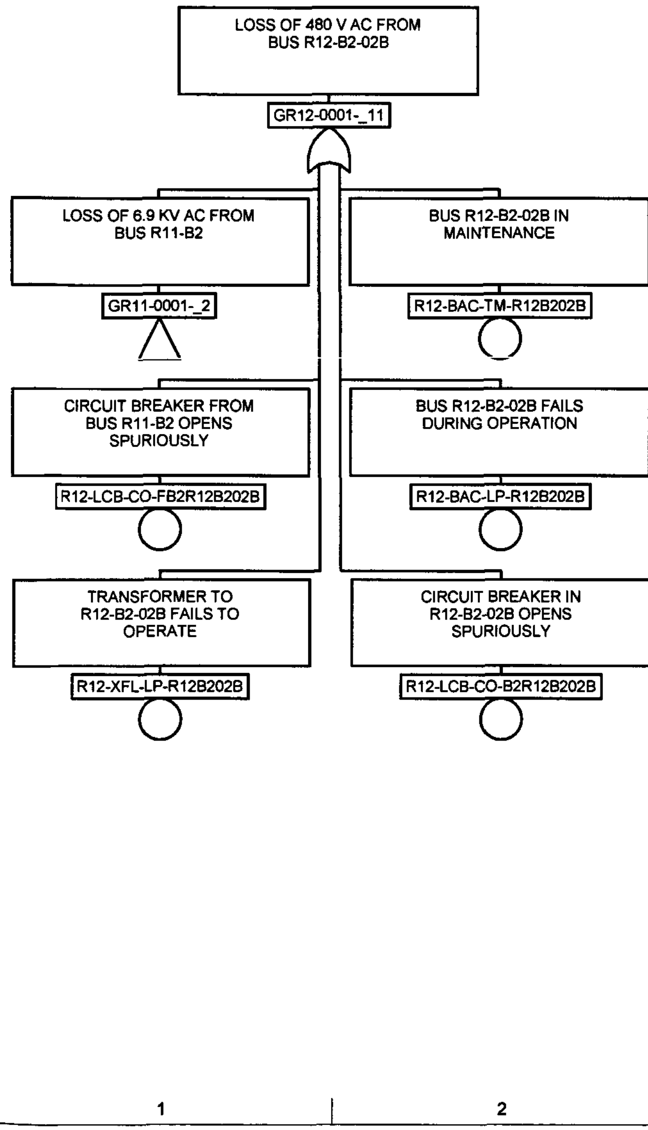

LOSS OF 480 V AC FROM TRAIN A IN TB (NO 1E)
GR12-0001-_16
LOSS OF 13.8 KV AC FROM BUS R10-A1
GR10-0001-_1
BUS TRAIN A IN TB (NO 1E) MAINTENANCE
R12-BAC-TM-R12TBAN1E
CIRCUIT BREAKER FROM BUS R10-A1 OPENS SPURIOUSLY
R12-LCB-CO-FA2R12TBAN1E
BUS TRAIN A IN TB (NO 1E) FAILS DURING OPERATION
R12-BAC-LP-R12TBAN1E
TRANSFORMER TO BUS TRAIN A IN TB (NO 1E) FAILS TO OPERATE
R12-XFL-LP-R12TBAN1E
CIRCUIT BREAKER IN BUS TRAIN A IN TB (NO 1E) OPENS SPURIOUSLY
R12-LCB-CO-A2R12TBAN1E
1
2


LOSS OF 480 V AC FROM TRAIN B IN TB (DID)
GR12-0001-_15
LOSS OF 6.9 KV AC FROM BUS R11-B3
GR11-0001-_4
BUS TRAIN B IN TB (RTNSS) MAINTENANCE
R12-BAC-TM-R12TBBRTNSS
CIRCUIT BREAKER FROM BUS R11-B3 OPENS SPURIOUSLY
R12-LCB-CO-FB3R12TBBRTNSS
BUS TRAIN B IN TB (RTNSS) FAILS DURING OPERATION
R12-BAC-LP-R12TBBRTNSS
TRANSFORMER TO BUS TRAIN B IN TB (RTNSS) FAILS TO OPERATE
R12-XFL-LP-R12TBBRTNSS
CIRCUIT BREAKER IN BUS TRAIN B IN TB (RTNSS) OPENS SPURIOUSLY
R12-LCB-CO-B3R12TBBRTNSS
1
2

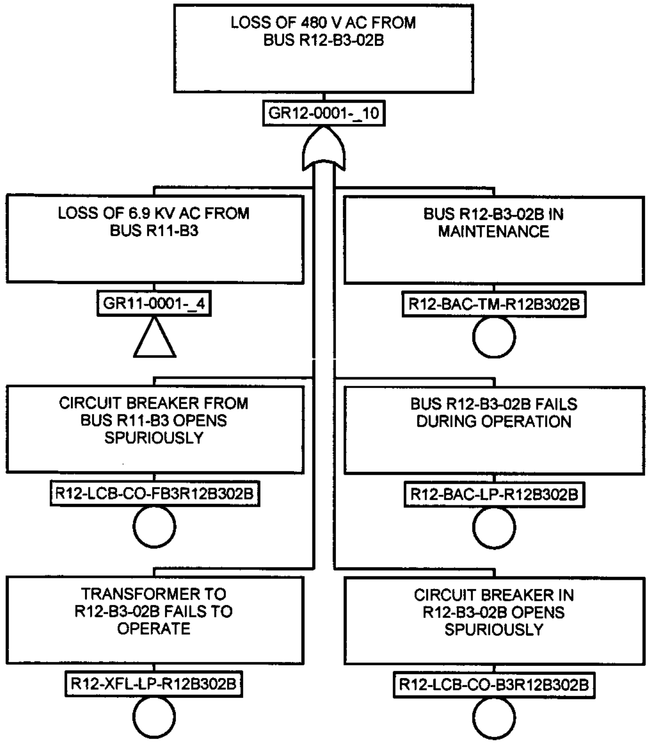

LOSS OF 480 V AC FROM TRAIN A IN TB (DID)
GR12-0001-_14
LOSS OF 6.9 KV AC FROM BUS R11-A3
GR11-0001-_3
BUS TRAIN A IN TB (RTNSS) MAINTENANCE
R12-BAC-TM-R12TBARTNSS
CIRCUIT BREAKER FROM BUS R11-A3 OPENS SPURIOUSLY
R12-LCB-CO-FA3R12TBARTNSS
BUS TRAIN A IN TB (RTNSS) FAILS DURING OPERATION
R12-BAC-LP-R12TBARTNSS
TRANSFORMER TO BUS TRAIN A IN TB (RTNSS) FAILS TO OPERATE
R12-XFL-LP-R12TBARTNSS
CIRCUIT BREAKER IN BUS TRAIN A IN TB (RTNSS) OPENS SPURIOUSLY
R12-LCB-CO-A3R12TBARTNSS
1
2

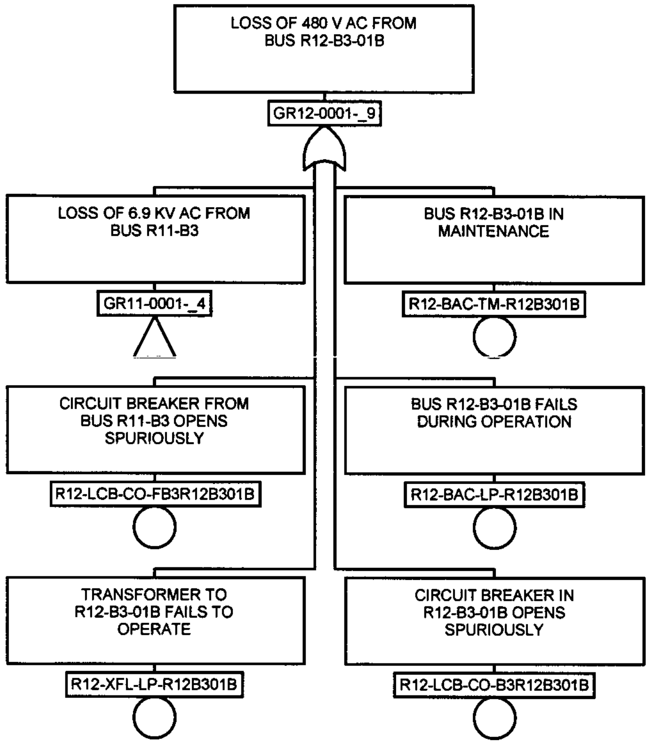

LOSS OF 480 V AC FROM BUS R12-B2-04B (FUEL BUILDING)
GR12-0001-_13
LOSS OF 6.9 KV AC FROM BUS R11-B2
GR11-0001-_2
BUS R12-B2-04B IN MAINTENANCE
R12-BAC-TM-R12B204B
CIRCUIT BREAKER FROM BUS R11-B2 OPENS SPURIOUSLY
R12-LCB-CO-FB2R12B204B
BUS R12-B2-04B FAILS DURING OPERATION
R12-BAC-LP-R12B204B
TRANSFORMER TO R12-B2-04B FAILS TO OPERATE
R12-XFL-LP-R12B204B
CIRCUIT BREAKER IN R12-B2-04B OPENS SPURIOUSLY
R12-LCB-CO-B2R12B204B
1
2

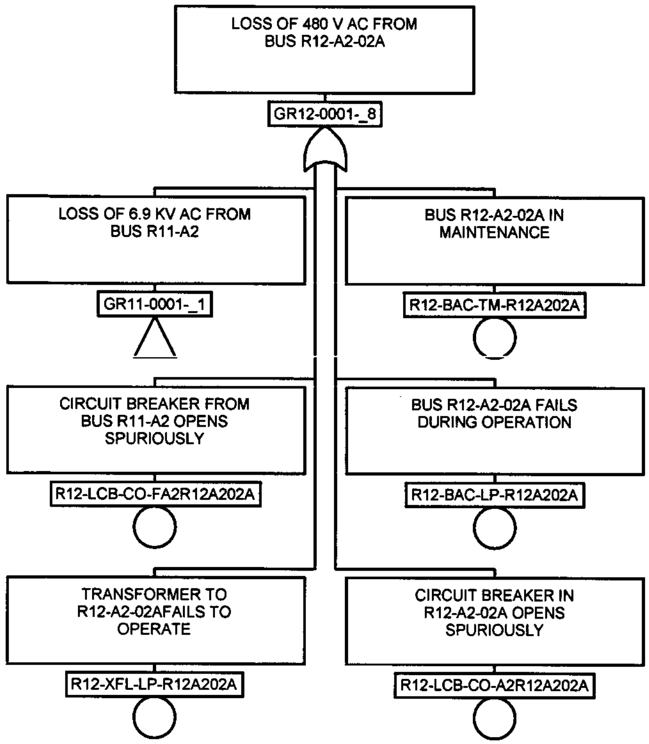

LOSS OF 480 V AC FROM BUS R12-A2-04A (FUEL BUILDING)
GR12-0001-_12
LOSS OF 6.9 KV AC FROM BUS R11-A2
GR11-0001-_1
BUS R12-A2-04A IN MAINTENANCE
R12-BAC-TM-R12A204A
CIRCUIT BREAKER FROM BUS R11-A2 OPENS SPURIOUSLY
R12-LCB-CO-FA2R12A204A
BUS R12-A2-04A FAILS DURING OPERATION
R12-BAC-LP-R12A204A
TRANSFORMER TO R12-A2-04A FAILS TO OPERATE
R12-XFL-LP-R12A204A
CIRCUIT BREAKER IN R12-A2-04A OPENS SPURIOUSLY
R12-LCB-CO-A2R12A204A
1
2

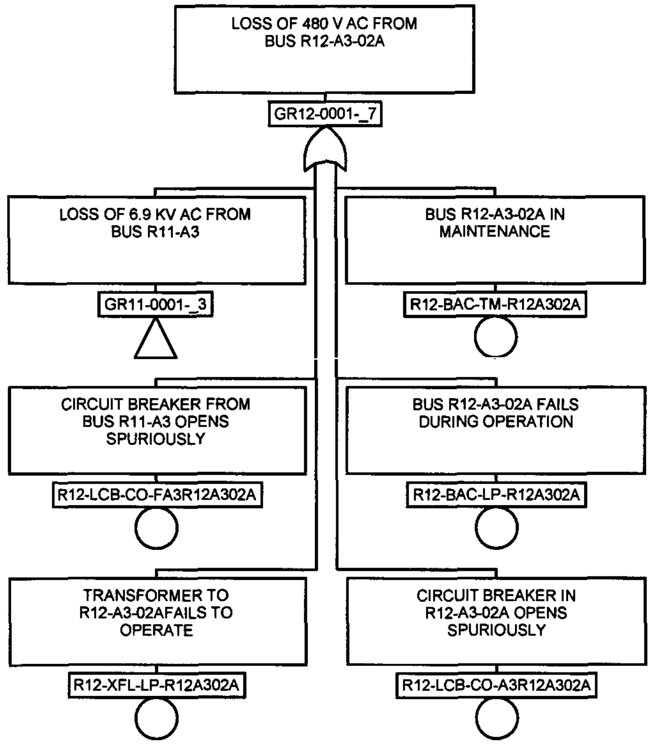


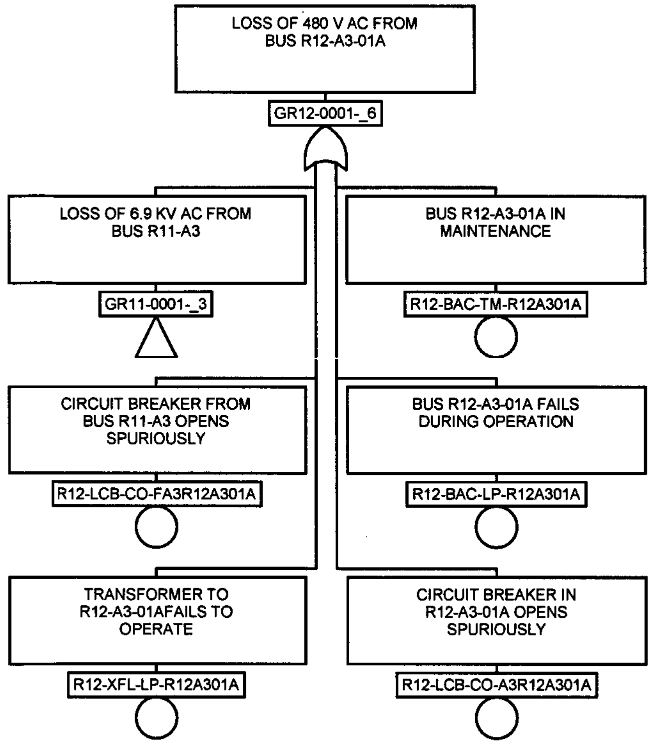
LOSS OF 480 V AC FROM BUS R12-B2-02B
GR12-0001-_11
LOSS OF 6.9 KV AC FROM BUS R11-B2
GR11-0001-_2
BUS R12-B2-02B IN MAINTENANCE
R12-BAC-TM-R12B202B
CIRCUIT BREAKER FROM BUS R11-B2 OPENS SPURIOUSLY
R12-LCB-CO-FB2R12B202B
BUS R12-B2-02B FAILS DURING OPERATION
R12-BAC-LP-R12B202B
TRANSFORMER TO R12-B2-02B FAILS TO OPERATE
R12-XFL-LP-R12B202B
CIRCUIT BREAKER IN R12-B2-02B OPENS SPURIOUSLY
R12-LCB-CO-B2R12B202B
1
2

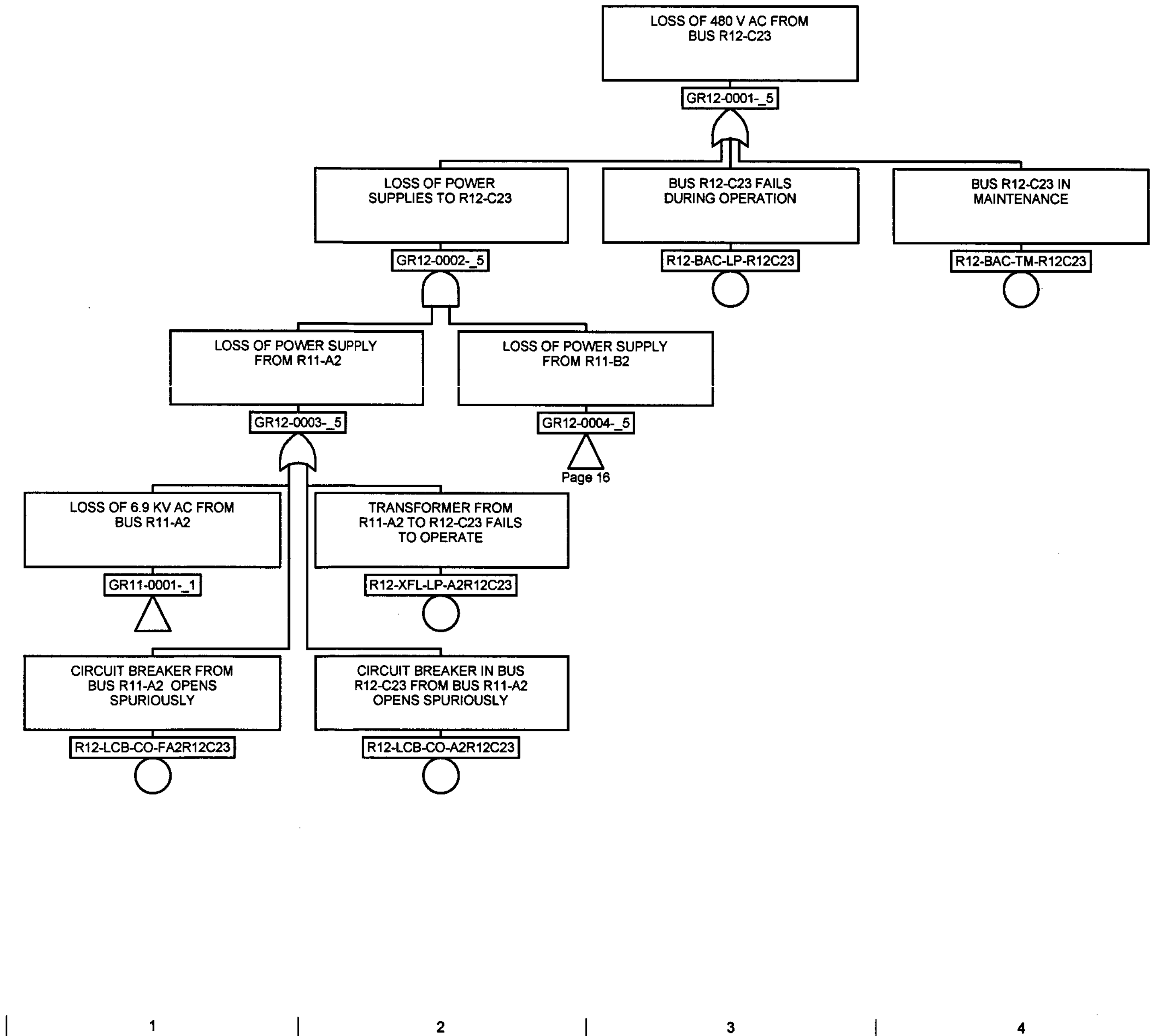

LOSS OF 480 V AC FROM BUS R12-B3-02B
GR12-0001-_10
LOSS OF 6.9 KV AC FROM BUS R11-B3
GR11-0001-_4
BUS R12-B3-02B IN MAINTENANCE
R12-BAC-TM-R12B302B
CIRCUIT BREAKER FROM BUS R11-B3 OPENS SPURIOUSLY
R12-LCB-CO-FB3R12B302B
BUS R12-B3-02B FAILS DURING OPERATION
R12-BAC-LP-R12B302B
TRANSFORMER TO R12-B3-02B FAILS TO OPERATE
R12-XFL-LP-R12B302B
CIRCUIT BREAKER IN R12-B3-02B OPENS SPURIOUSLY
R12-LCB-CO-B3R12B302B
1
2

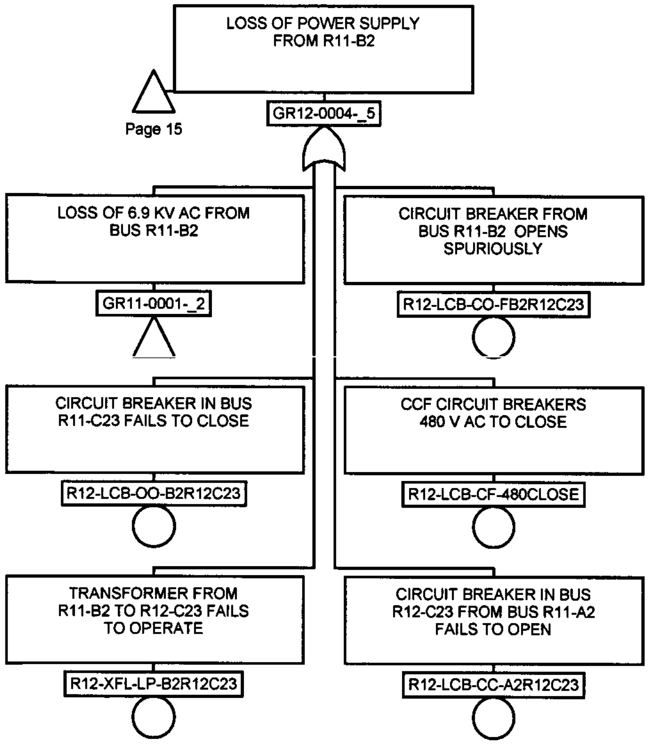

LOSS OF 480 V AC FROM BUS R12-B3-01B
GR12-0001-_9
LOSS OF 6.9 KV AC FROM BUS R11-B3
GR11-0001-_4
BUS R12-B3-01B IN MAINTENANCE
R12-BAC-TM-R12B301B
CIRCUIT BREAKER FROM BUS R11-B3 OPENS SPURIOUSLY
R12-LCB-CO-FB3R12B301B
BUS R12-B3-01B FAILS DURING OPERATION
R12-BAC-LP-R12B301B
TRANSFORMER TO R12-B3-01B FAILS TO OPERATE
R12-XFL-LP-R12B301B
CIRCUIT BREAKER IN R12-B3-01B OPENS SPURIOUSLY
R12-LCB-CO-B3R12B301B
1
2

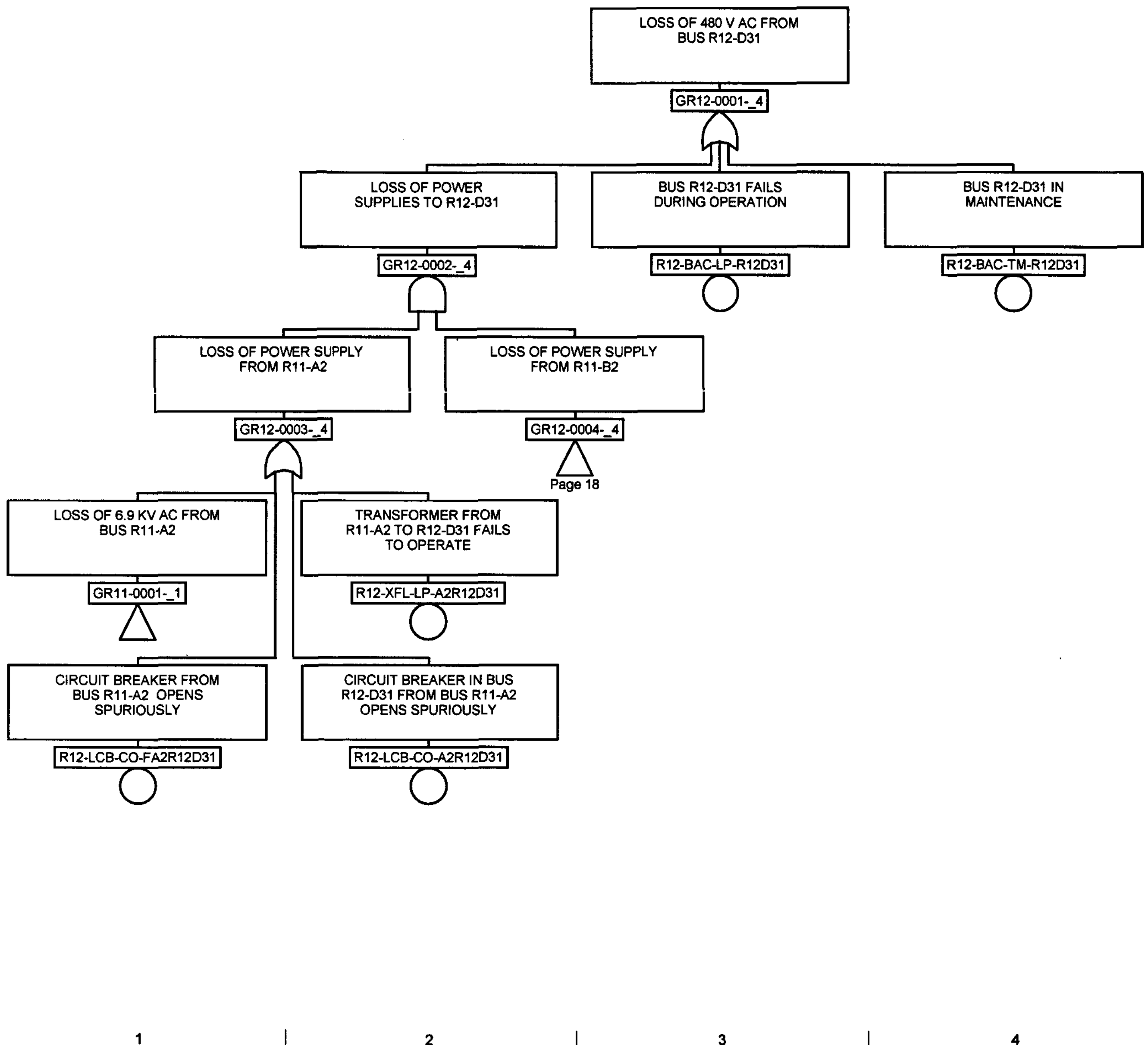

LOSS OF 480 V AC FROM BUS R12-A2-02A
GR12-0001-_8
LOSS OF 6.9 KV AC FROM BUS R11-A2
GR11-0001-_1
BUS R12-A2-02A IN MAINTENANCE
R12-BAC-TM-R12A202A
CIRCUIT BREAKER FROM BUS R11-A2 OPENS SPURIOUSLY
R12-LCB-CO-FA2R12A202A
BUS R12-A2-02A FAILS DURING OPERATION
R12-BAC-LP-R12A202A
TRANSFORMER TO R12-A2-02AFAILS TO OPERATE
R12-XFL-LP-R12A202A
CIRCUIT BREAKER IN R12-A2-02A OPENS SPURIOUSLY
R12-LCB-CO-A2R12A202A
1
2

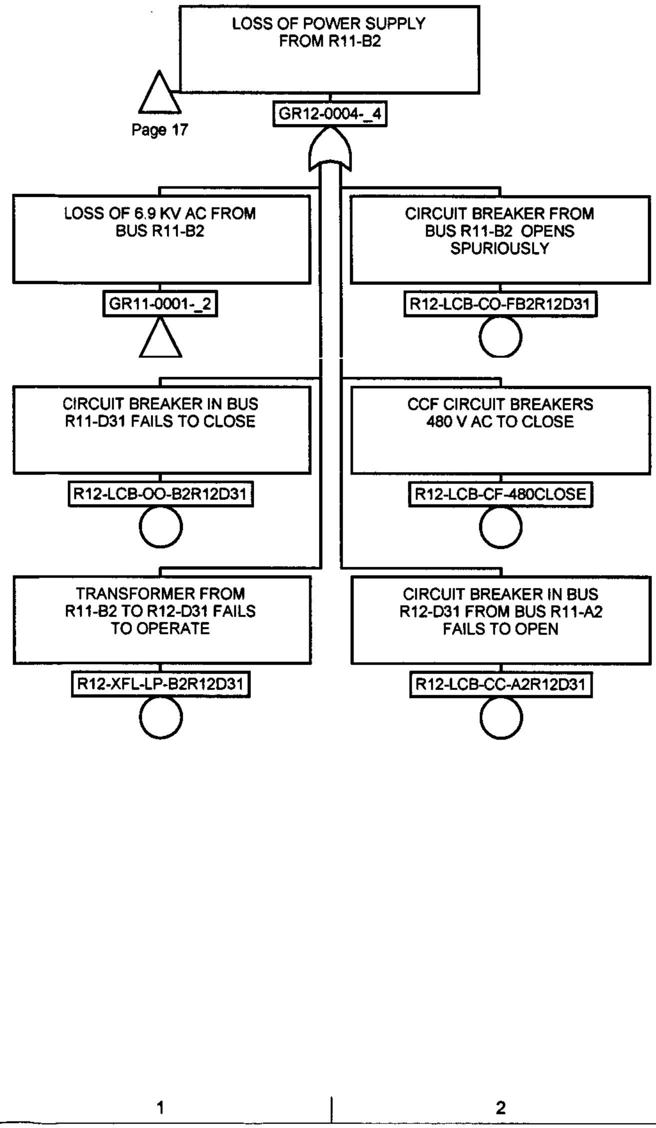

LOSS OF 480 V AC FROM BUS R12-A3-02A
GR12-0001-_7
LOSS OF 6.9 KV AC FROM BUS R11-A3
GR11-0001-_3
BUS R12-A3-02A IN MAINTENANCE
R12-BAC-TM-R12A302A
CIRCUIT BREAKER FROM BUS R11-A3 OPENS SPURIOUSLY
R12-LCB-CO-FA3R12A302A
BUS R12-A3-02A FAILS DURING OPERATION
R12-BAC-LP-R12A302A
TRANSFORMER TO R12-A3-02AFAILS TO OPERATE
R12-XFL-LP-R12A302A
CIRCUIT BREAKER IN R12-A3-02A OPENS SPURIOUSLY
R12-LCB-CO-A3R12A302A
1
2

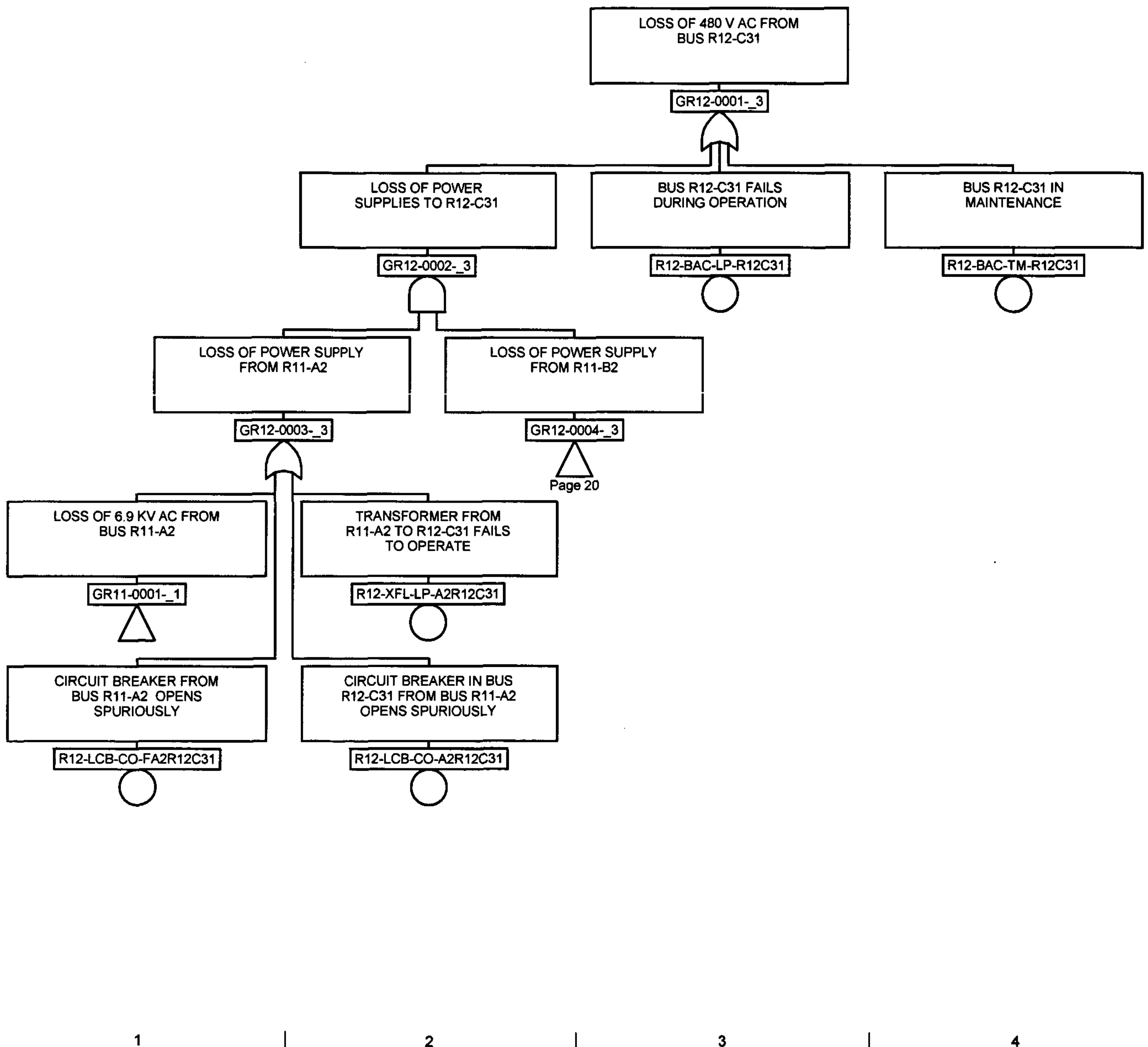

LOSS OF 480 V AC FROM BUS R12-A3-01A
GR12-0001-_6
LOSS OF 6.9 KV AC FROM BUS R11-A3
GR11-0001-_3
BUS R12-A3-01A IN MAINTENANCE
R12-BAC-TM-R12A301A
CIRCUIT BREAKER FROM BUS R11-A3 OPENS SPURIOUSLY
R12-LCB-CO-FA3R12A301A
BUS R12-A3-01A FAILS DURING OPERATION
R12-BAC-LP-R12A301A
TRANSFORMER TO R12-A3-01AFAILS TO OPERATE
R12-XFL-LP-R12A301A
CIRCUIT BREAKER IN R12-A3-01A OPENS SPURIOUSLY
R12-LCB-CO-A3R12A301A
1
2

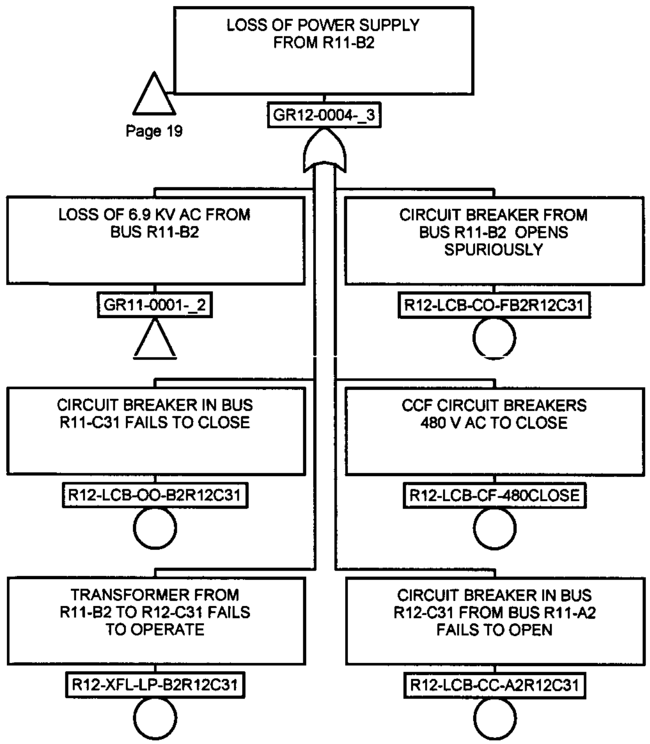

LOSS OF 480 V AC FROM BUS R12-C23
GR12-0001-_5
LOSS OF POWER SUPPLIES TO R12-C23
GR12-0002-_5
BUS R12-C23 FAILS DURING OPERATION
R12-BAC-LP-R12C23
BUS R12-C23 IN MAINTENANCE
R12-BAC-TM-R12C23
LOSS OF POWER SUPPLY FROM R11-A2
GR12-0003-_5
LOSS OF POWER SUPPLY FROM R11-B2
GR12-0004-_5
Page 16
LOSS OF 6.9 KV AC FROM BUS R11-A2
GR11-0001-_1
TRANSFORMER FROM R11-A2 TO R12-C23 FAILS TO OPERATE
R12-XFL-LP-A2R12C23
CIRCUIT BREAKER FROM BUS R11-A2 OPENS SPURIOUSLY
R12-LCB-CO-FA2R12C23
CIRCUIT BREAKER IN BUS R12-C23 FROM BUS R11-A2 OPENS SPURIOUSLY
R12-LCB-CO-A2R12C23
1
2
3
4

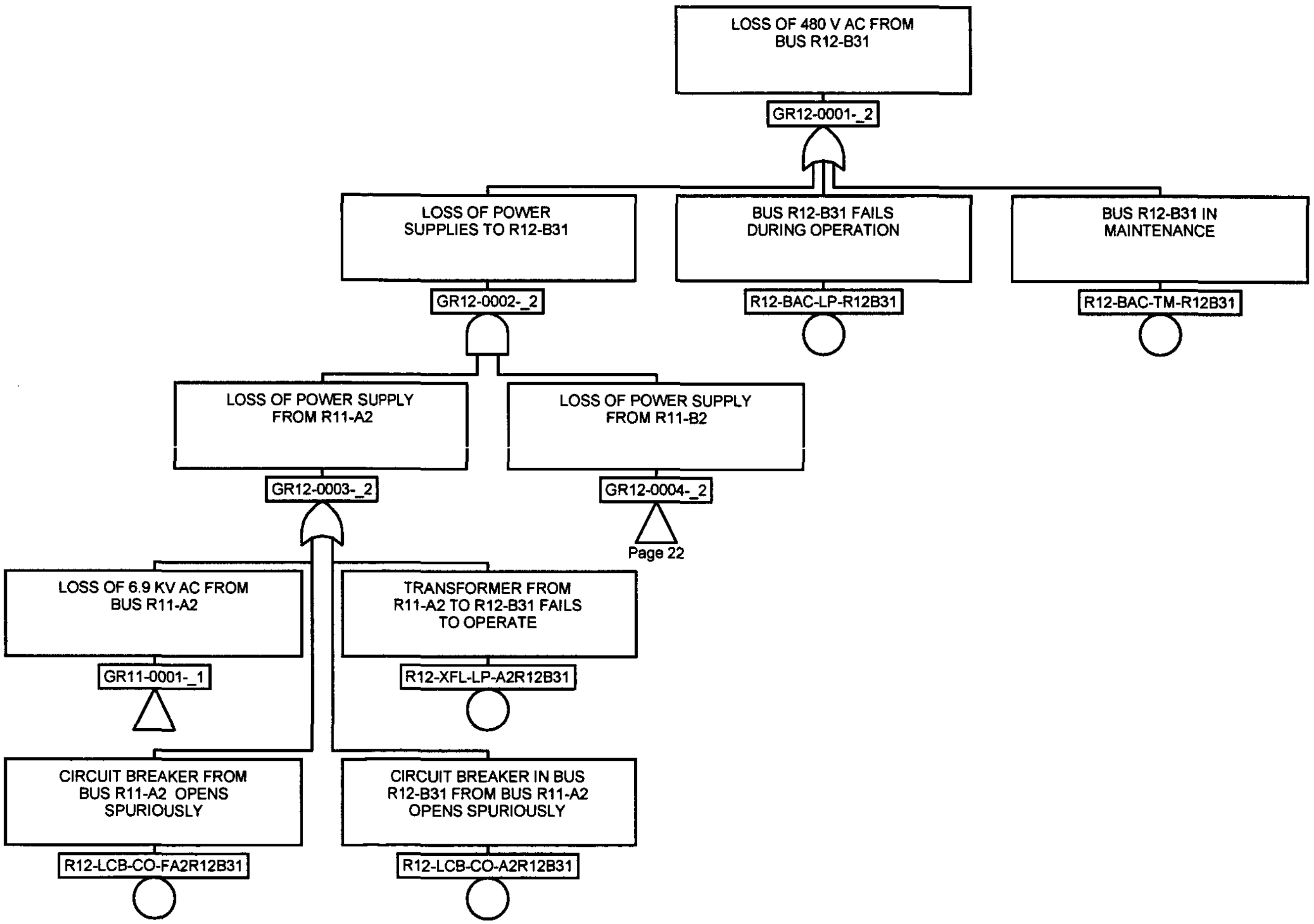

LOSS OF POWER SUPPLY FROM R11-B2
GR12-0004-_5
Page 15
LOSS OF 6.9 KV AC FROM BUS R11-B2
GR11-0001-_2
CIRCUIT BREAKER FROM BUS R11-B2 OPENS SPURIOUSLY
R12-LCB-CO-FB2R12C23
CIRCUIT BREAKER IN BUS R11-C23 FAILS TO CLOSE
R12-LCB-OO-B2R12C23
CCF CIRCUIT BREAKERS 480 V AC TO CLOSE
R12-LCB-CF-480CLOSE
TRANSFORMER FROM R11-B2 TO R12-C23 FAILS TO OPERATE
R12-XFL-LP-B2R12C23
CIRCUIT BREAKER IN BUS R12-C23 FROM BUS R11-A2 FAILS TO OPEN
R12-LCB-CC-A2R12C23
1
2

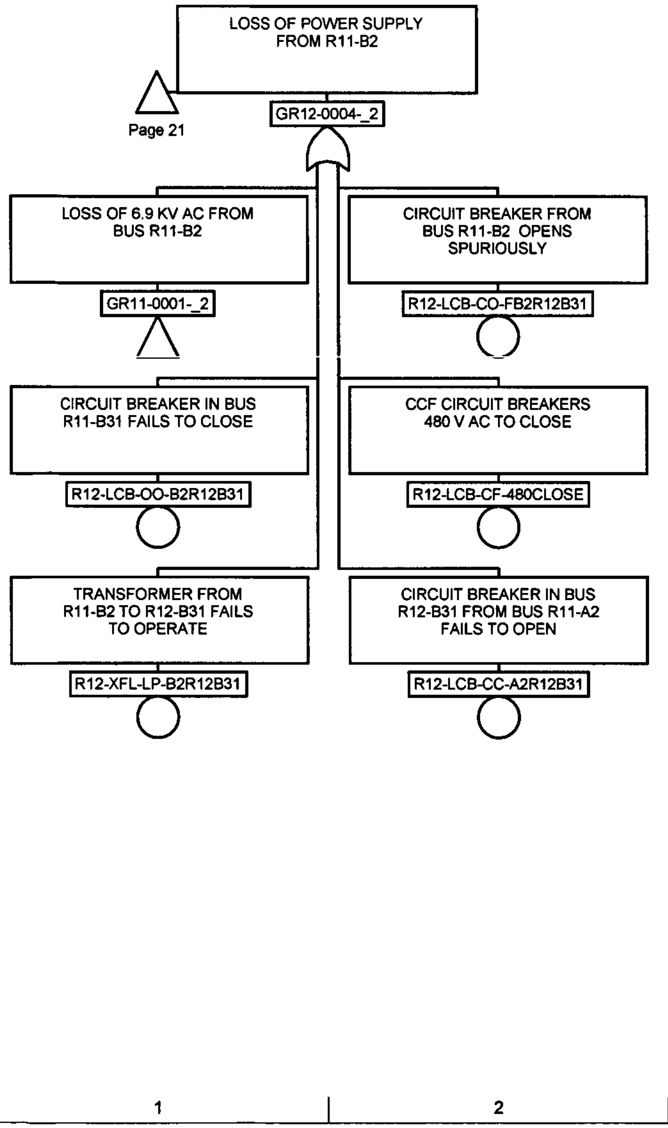

LOSS OF 480 V AC FROM BUS R12-D31
GR12-0001-_4
LOSS OF POWER SUPPLIES TO R12-D31
GR12-0002-_4
BUS R12-D31 FAILS DURING OPERATION
R12-BAC-LP-R12D31
BUS R12-D31 IN MAINTENANCE
R12-BAC-TM-R12D31
LOSS OF POWER SUPPLY FROM R11-A2
GR12-0003-_4
LOSS OF POWER SUPPLY FROM R11-B2
GR12-0004-_4
Page 18
LOSS OF 6.9 KV AC FROM BUS R11-A2
GR11-0001-_1
TRANSFORMER FROM R11-A2 TO R12-D31 FAILS TO OPERATE
R12-XFL-LP-A2R12D31
CIRCUIT BREAKER FROM BUS R11-A2 OPENS SPURIOUSLY
R12-LCB-CO-FA2R12D31
CIRCUIT BREAKER IN BUS R12-D31 FROM BUS R11-A2 OPENS SPURIOUSLY
R12-LCB-CO-A2R12D31
1
2
3
4

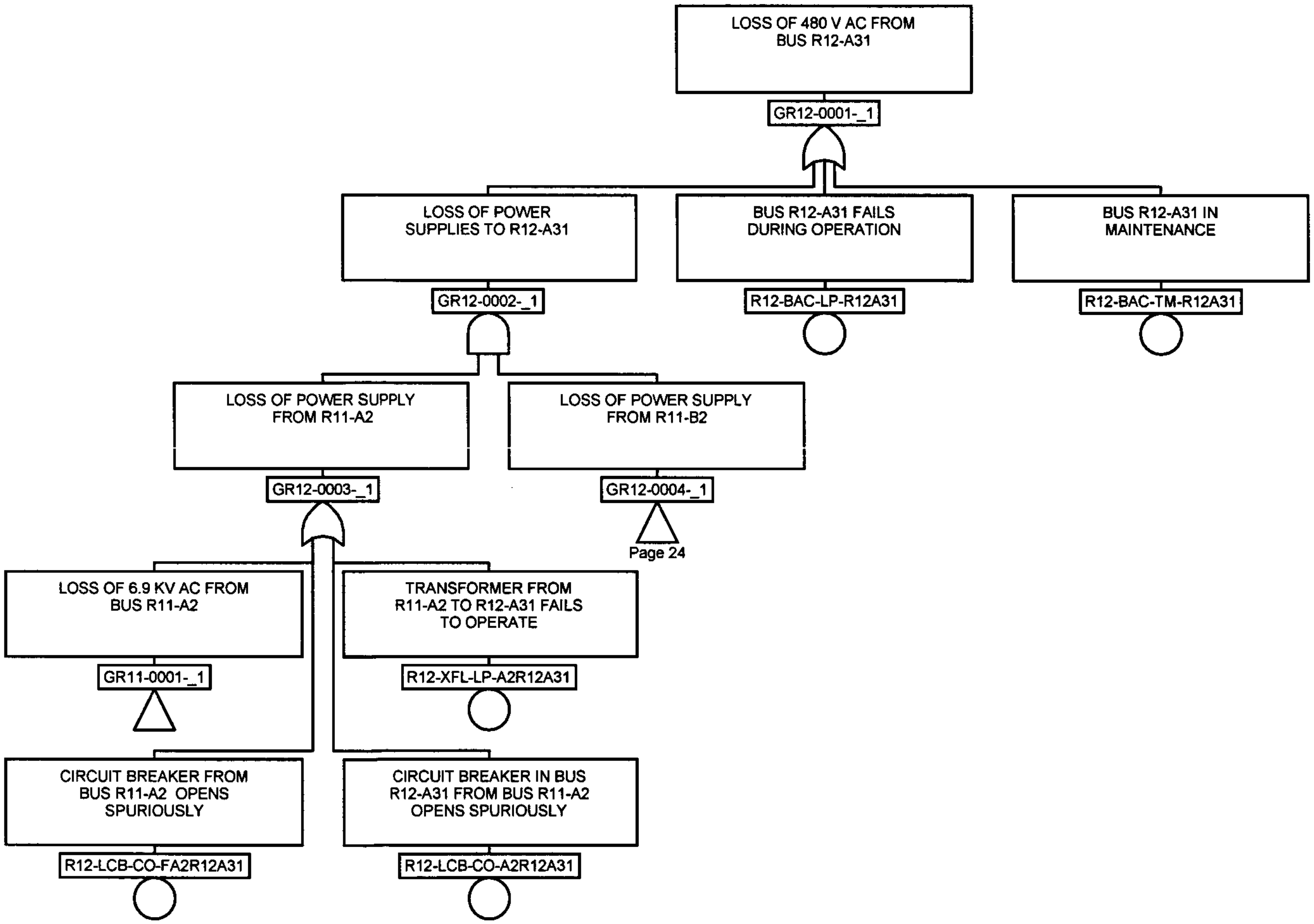

LOSS OF POWER SUPPLY FROM R11-B2
GR12-0004-_4
Page 17
LOSS OF 6.9 KV AC FROM BUS R11-B2
GR11-0001-_2
CIRCUIT BREAKER FROM BUS R11-B2 OPENS SPURIOUSLY
R12-LCB-CO-FB2R12D31
CIRCUIT BREAKER IN BUS R11-D31 FAILS TO CLOSE
R12-LCB-OO-B2R12D31
CCF CIRCUIT BREAKERS 480 V AC TO CLOSE
R12-LCB-CF-480CLOSE
TRANSFORMER FROM R11-B2 TO R12-D31 FAILS TO OPERATE
R12-XFL-LP-B2R12D31
CIRCUIT BREAKER IN BUS R12-D31 FROM BUS R11-A2 FAILS TO OPEN
R12-LCB-CC-A2R12D31
1
2

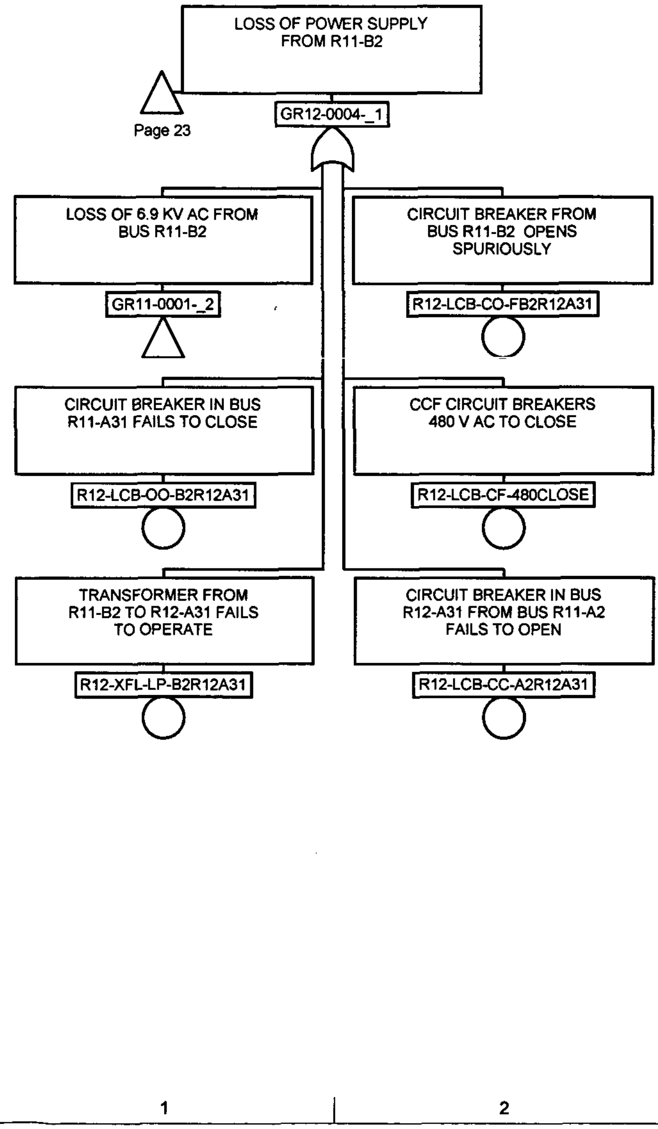

LOSS OF 480 V AC FROM BUS R12-C31
GR12-0001-_3
LOSS OF POWER SUPPLIES TO R12-C31
BUS R12-C31 FAILS DURING OPERATION
BUS R12-C31 IN MAINTENANCE
GR12-0002-_3
R12-BAC-LP-R12C31
R12-BAC-TM-R12C31
LOSS OF POWER SUPPLY FROM R11-A2
LOSS OF POWER SUPPLY FROM R11-B2
GR12-0003-_3
GR12-0004-_3
Page 20
LOSS OF 6.9 KV AC FROM BUS R11-A2
TRANSFORMER FROM R11-A2 TO R12-C31 FAILS TO OPERATE
GR11-0001-_1
R12-XFL-LP-A2R12C31
CIRCUIT BREAKER FROM BUS R11-A2 OPENS SPURIOUSLY
CIRCUIT BREAKER IN BUS R12-C31 FROM BUS R11-A2 OPENS SPURIOUSLY
R12-LCB-CO-FA2R12C31
R12-LCB-CO-A2R12C31
1
2
3
4


LOSS OF POWER SUPPLY FROM R11-B2
GR12-0004-_3
Page 19
LOSS OF 6.9 KV AC FROM BUS R11-B2
GR11-0001-_2
CIRCUIT BREAKER FROM BUS R11-B2 OPENS SPURIOUSLY
R12-LCB-CO-FB2R12C31
CIRCUIT BREAKER IN BUS R11-C31 FAILS TO CLOSE
R12-LCB-OO-B2R12C31
CCF CIRCUIT BREAKERS 480 V AC TO CLOSE
R12-LCB-CF-480CLOSE
TRANSFORMER FROM R11-B2 TO R12-C31 FAILS TO OPERATE
R12-XFL-LP-B2R12C31
CIRCUIT BREAKER IN BUS R12-C31 FROM BUS R11-A2 FAILS TO OPEN
R12-LCB-CC-A2R12C31
1
2


LOSS OF 480 V AC FROM BUS R12-B31
GR12-0001-_2
LOSS OF POWER SUPPLIES TO R12-B31
GR12-0002-_2
BUS R12-B31 FAILS DURING OPERATION
R12-BAC-LP-R12B31
BUS R12-B31 IN MAINTENANCE
R12-BAC-TM-R12B31
LOSS OF POWER SUPPLY FROM R11-A2
GR12-0003-_2
LOSS OF POWER SUPPLY FROM R11-B2
GR12-0004-_2
Page 22
LOSS OF 6.9 KV AC FROM BUS R11-A2
GR11-0001-_1
TRANSFORMER FROM R11-A2 TO R12-B31 FAILS TO OPERATE
R12-XFL-LP-A2R12B31
CIRCUIT BREAKER FROM BUS R11-A2 OPENS SPURIOUSLY
R12-LCB-CO-FA2R12B31
CIRCUIT BREAKER IN BUS R12-B31 FROM BUS R11-A2 OPENS SPURIOUSLY
R12-LCB-CO-A2R12B31
1
2
3
4


LOSS OF POWER SUPPLY FROM R11-B2
GR12-0004-_2
Page 21
LOSS OF 6.9 KV AC FROM BUS R11-B2
GR11-0001-_2
CIRCUIT BREAKER FROM BUS R11-B2 OPENS SPURIOUSLY
R12-LCB-CO-FB2R12B31
CIRCUIT BREAKER IN BUS R11-B31 FAILS TO CLOSE
R12-LCB-OO-B2R12B31
CCF CIRCUIT BREAKERS 480 V AC TO CLOSE
R12-LCB-CF-480CLOSE
TRANSFORMER FROM R11-B2 TO R12-B31 FAILS TO OPERATE
R12-XFL-LP-B2R12B31
CIRCUIT BREAKER IN BUS R12-B31 FROM BUS R11-A2 FAILS TO OPEN
R12-LCB-CC-A2R12B31
1
2


LOSS OF 480 V AC FROM BUS R12-A31
GR12-0001-_1
LOSS OF POWER SUPPLIES TO R12-A31
GR12-0002-_1
BUS R12-A31 FAILS DURING OPERATION
R12-BAC-LP-R12A31
BUS R12-A31 IN MAINTENANCE
R12-BAC-TM-R12A31
LOSS OF POWER SUPPLY FROM R11-A2
GR12-0003-_1
LOSS OF POWER SUPPLY FROM R11-B2
GR12-0004-_1
Page 24
LOSS OF 6.9 KV AC FROM BUS R11-A2
GR11-0001-_1
TRANSFORMER FROM R11-A2 TO R12-A31 FAILS TO OPERATE
R12-XFL-LP-A2R12A31
CIRCUIT BREAKER FROM BUS R11-A2 OPENS SPURIOUSLY
R12-LCB-CO-FA2R12A31
CIRCUIT BREAKER IN BUS R12-A31 FROM BUS R11-A2 OPENS SPURIOUSLY
R12-LCB-CO-A2R12A31


LOSS OF POWER SUPPLY FROM R11-B2
GR12-0004-_1
Page 23
LOSS OF 6.9 KV AC FROM BUS R11-B2
GR11-0001-_2
CIRCUIT BREAKER FROM BUS R11-B2 OPENS SPURIOUSLY
R12-LCB-CO-FB2R12A31
CIRCUIT BREAKER IN BUS R11-A31 FAILS TO CLOSE
R12-LCB-OO-B2R12A31
CCF CIRCUIT BREAKERS 480 V AC TO CLOSE
R12-LCB-CF-480CLOSE
TRANSFORMER FROM R11-B2 TO R12-A31 FAILS TO OPERATE
R12-XFL-LP-B2R12A31
CIRCUIT BREAKER IN BUS R12-A31 FROM BUS R11-A2 FAILS TO OPEN
R12-LCB-CC-A2R12A31
1
2

Name	Page	Zone	Name	Page	Zone
GR10-0001- 1	4	1	GR12-0004- 1	24	2
GR10-0001- 2	3	1	GR12-0004- 2	21	3
GR11-0001- 1	1	1	GR12-0004- 2	22	2
GR11-0001- 1	8	1	GR12-0004- 3	19	3
GR11-0001- 1	12	1	GR12-0004- 3	20	2
GR11-0001- 1	15	1	GR12-0004- 4	17	3
GR11-0001- 1	17	1	GR12-0004- 4	18	2
GR11-0001- 1	19	1	GR12-0004- 5	15	3
GR11-0001- 1	21	1	GR12-0004- 5	16	2
GR11-0001- 1	23	1	R12-BAC-LP-R12A201A	1	2
GR11-0001- 2	2	1	R12-BAC-LP-R12A202A	12	2
GR11-0001- 2	7	1	R12-BAC-LP-R12A204A	8	2
GR11-0001- 2	9	1	R12-BAC-LP-R12A301A	14	2
GR11-0001- 2	16	1	R12-BAC-LP-R12A302A	13	2
GR11-0001- 2	18	1	R12-BAC-LP-R12A31	23	3
GR11-0001- 2	20	1	R12-BAC-LP-R12B201B	2	2
GR11-0001- 2	22	1	R12-BAC-LP-R12B202B	9	2
GR11-0001- 2	24	1	R12-BAC-LP-R12B204B	7	2
GR11-0001- 3	6	1	R12-BAC-LP-R12B301B	11	2
GR11-0001- 3	13	1	R12-BAC-LP-R12B302B	10	2
GR11-0001- 3	14	1	R12-BAC-LP-R12B31	21	3
GR11-0001- 4	5	1	R12-BAC-LP-R12C23	15	3
GR11-0001- 4	10	1	R12-BAC-LP-R12C31	19	3
GR11-0001- 4	11	1	R12-BAC-LP-R12D31	17	3
GR12-0001- 1	23	3	R12-BAC-LP-R12TBAN1E	4	2
GR12-0001- 10	10	2	R12-BAC-LP-R12TBARTNSS	6	2
GR12-0001- 11	9	2	R12-BAC-LP-R12TBBN1E	3	2
GR12-0001- 12	8	2	R12-BAC-LP-R12TBBRTNSS	5	2
GR12-0001- 13	7	2	R12-BAC-TM-R12A201A	1	2
GR12-0001- 14	6	2	R12-BAC-TM-R12A202A	12	2
GR12-0001- 15	5	2	R12-BAC-TM-R12A204A	8	2
GR12-0001- 16	4	2	R12-BAC-TM-R12A301A	14	2
GR12-0001- 17	3	2	R12-BAC-TM-R12A302A	13	2
GR12-0001- 18	1	2	R12-BAC-TM-R12A31	23	4
GR12-0001- 19	2	2	R12-BAC-TM-R12B201B	2	2
GR12-0001- 2	21	3	R12-BAC-TM-R12B202B	9	2
GR12-0001- 3	19	3	R12-BAC-TM-R12B204B	7	2
GR12-0001- 4	17	3	R12-BAC-TM-R12B301B	11	2
GR12-0001- 5	15	3	R12-BAC-TM-R12B302B	10	2
GR12-0001- 6	14	2	R12-BAC-TM-R12B31	21	4
GR12-0001- 7	13	2	R12-BAC-TM-R12C23	15	4
GR12-0001- 8	12	2	R12-BAC-TM-R12C31	19	4
GR12-0001- 9	11	2	R12-BAC-TM-R12D31	17	4
GR12-0002- 1	23	2	R12-BAC-TM-R12TBAN1E	4	2
GR12-0002- 2	21	2	R12-BAC-TM-R12TBARTNSS	6	2
GR12-0002- 3	19	2	R12-BAC-TM-R12TBBN1E	3	2
GR12-0002- 4	17	2	R12-BAC-TM-R12TBBRTNSS	5	2
GR12-0002- 5	15	2	R12-LCB-CC-A2R12A31	24	2
GR12-0003- 1	23	2	R12-LCB-CC-A2R12B31	22	2
GR12-0003- 2	21	2	R12-LCB-CC-A2R12C23	16	2
GR12-0003- 3	19	2	R12-LCB-CC-A2R12C31	20	2
GR12-0003- 4	17	2	R12-LCB-CC-A2R12D31	18	2
GR12-0003- 5	15	2	R12-LCB-CF-480CLOSE	16	2
GR12-0004- 1	23	3	R12-LCB-CF-480CLOSE	18	2

Name	Page	Zone
R12-LCB-CF-480CLOSE	20	2
R12-LCB-CF-480CLOSE	22	2
R12-LCB-CF-480CLOSE	24	2
R12-LCB-CO-A2R12A201A	1	2
R12-LCB-CO-A2R12A202A	12	2
R12-LCB-CO-A2R12A204A	8	2
R12-LCB-CO-A2R12A31	23	2
R12-LCB-CO-A2R12B31	21	2
R12-LCB-CO-A2R12C23	15	2
R12-LCB-CO-A2R12C31	19	2
R12-LCB-CO-A2R12D31	17	2
R12-LCB-CO-A2R12TBAN1E	4	2
R12-LCB-CO-A3R12A301A	14	2
R12-LCB-CO-A3R12A302A	13	2
R12-LCB-CO-A3R12TBARTNSS	6	2
R12-LCB-CO-B2R12B202B	9	2
R12-LCB-CO-B2R12B204B	7	2
R12-LCB-CO-B3R12B201B	2	2
R12-LCB-CO-B3R12B301B	11	2
R12-LCB-CO-B3R12B302B	10	2
R12-LCB-CO-B3R12TBBN1E	3	2
R12-LCB-CO-B3R12TBBRTNSS	5	2
R12-LCB-CO-FA2R12A201A	1	1
R12-LCB-CO-FA2R12A202A	12	1
R12-LCB-CO-FA2R12A204A	8	1
R12-LCB-CO-FA2R12A31	23	1
R12-LCB-CO-FA2R12B31	21	1
R12-LCB-CO-FA2R12C23	15	1
R12-LCB-CO-FA2R12C31	19	1
R12-LCB-CO-FA2R12D31	17	1
R12-LCB-CO-FA2R12TBAN1E	4	1
R12-LCB-CO-FA3R12A301A	14	1
R12-LCB-CO-FA3R12A302A	13	1
R12-LCB-CO-FA3R12TBARTNSS	6	1
R12-LCB-CO-FB2R12A31	24	2
R12-LCB-CO-FB2R12B202B	9	1
R12-LCB-CO-FB2R12B204B	7	1
R12-LCB-CO-FB2R12B31	22	2
R12-LCB-CO-FB2R12C23	16	2
R12-LCB-CO-FB2R12C31	20	2
R12-LCB-CO-FB2R12D31	18	2
R12-LCB-CO-FB3R12B201B	2	1
R12-LCB-CO-FB3R12B301B	11	1
R12-LCB-CO-FB3R12B302B	10	1
R12-LCB-CO-FB3R12TBBN1E	3	1
R12-LCB-CO-FB3R12TBBRTNSS	5	1
R12-LCB-OO-B2R12A31	24	1
R12-LCB-OO-B2R12B31	22	1
R12-LCB-OO-B2R12C23	16	1
R12-LCB-OO-B2R12C31	20	1
R12-LCB-OO-B2R12D31	18	1
R12-XFL-LP-A2R12A31	23	2
R12-XFL-LP-A2R12B31	21	2
R12-XFL-LP-A2R12C23	15	2
R12-XFL-LP-A2R12C31	19	2
R12-XFL-LP-A2R12D31	17	2
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R12-XFL-LP-B2R12C31	20	1
R12-XFL-LP-B2R12D31	18	1
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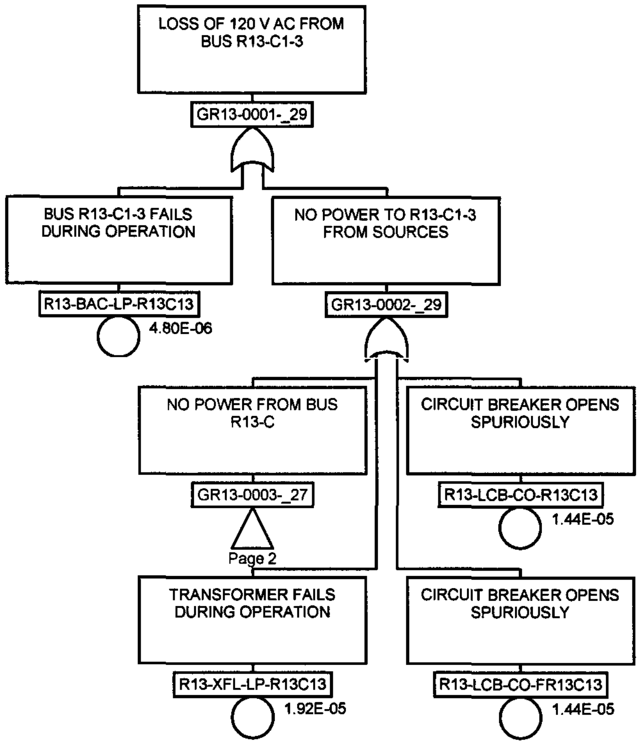
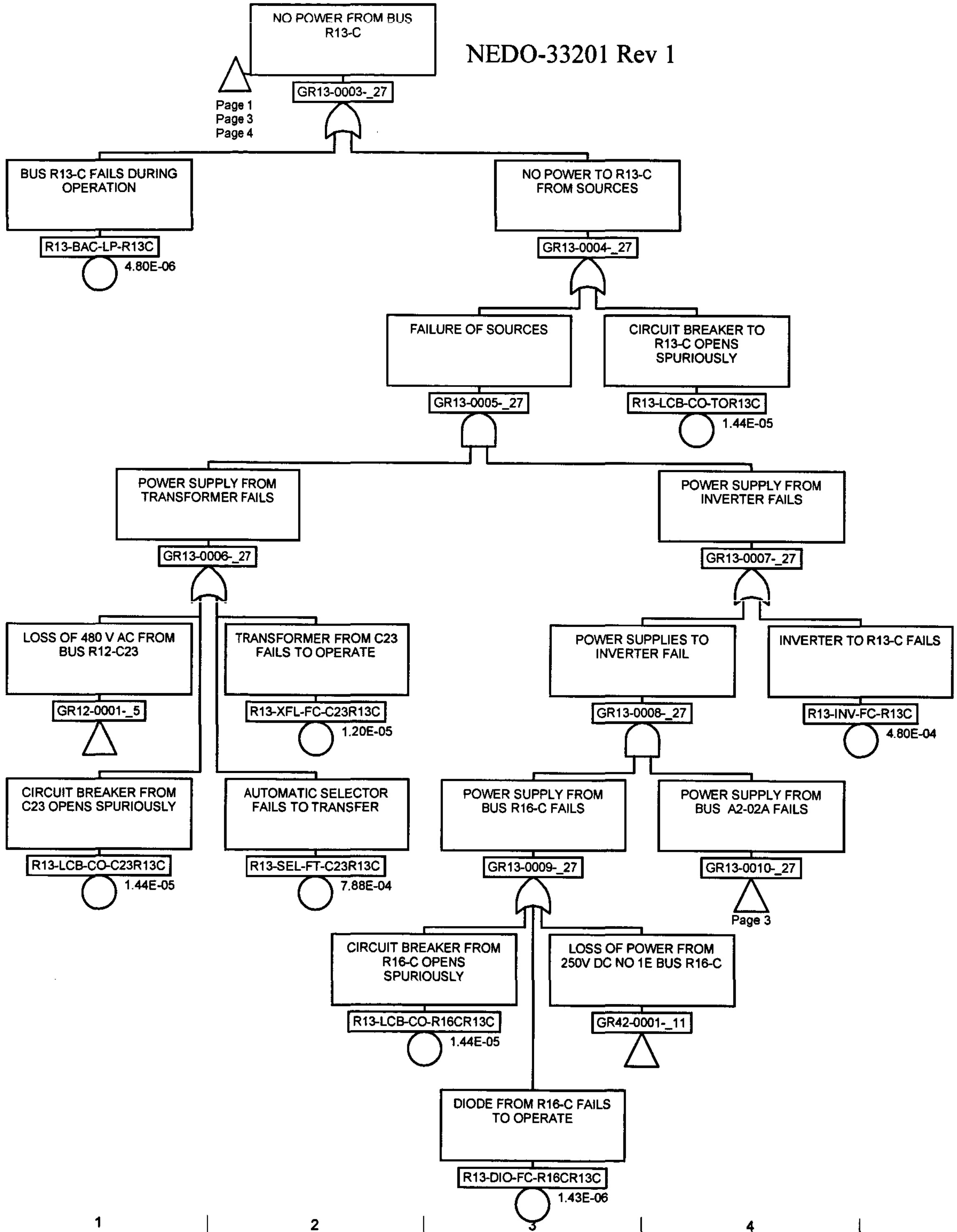
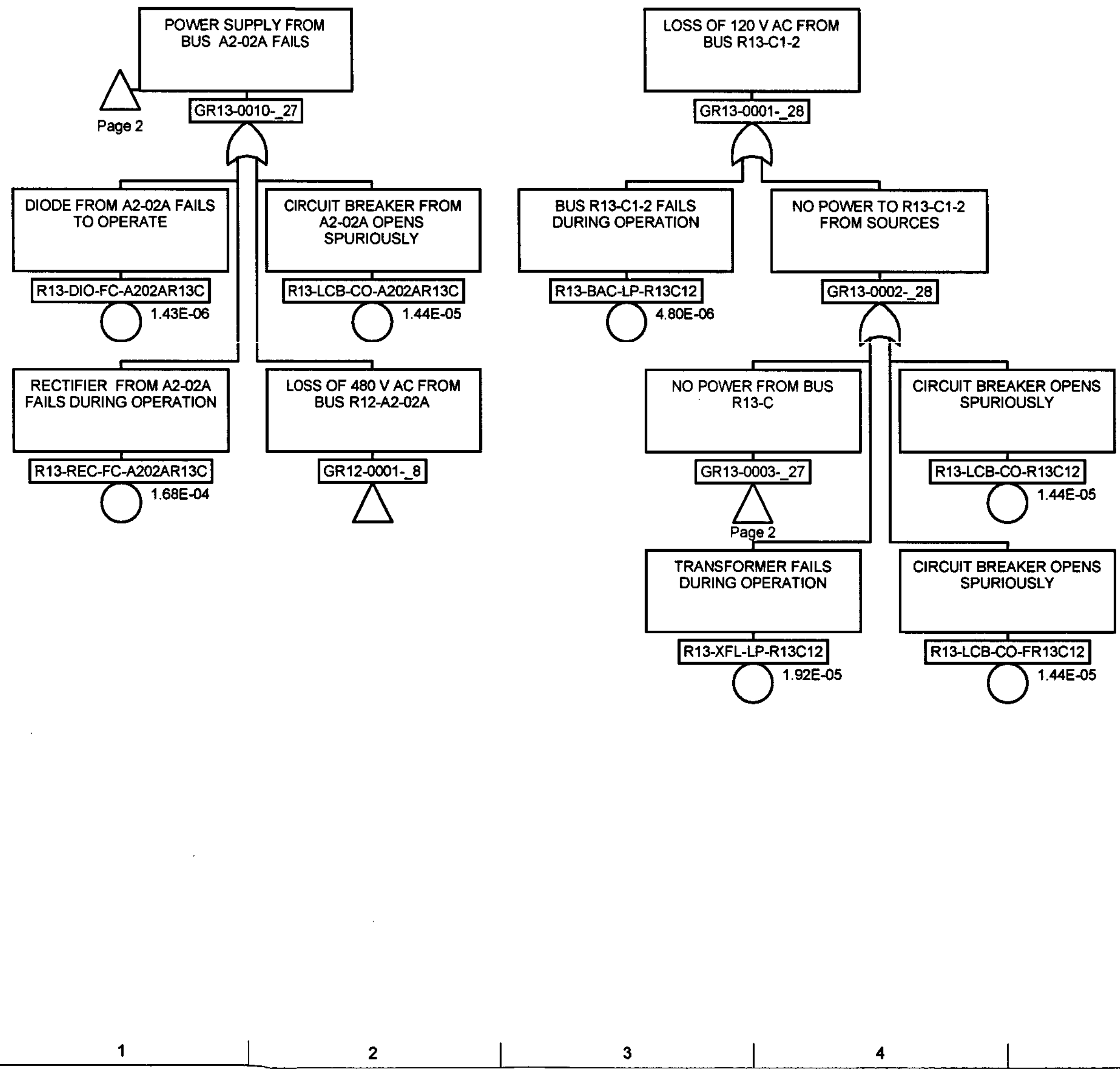
R12-XFL-LP-R12A302A	13	1
R12-XFL-LP-R12B201B	2	1
R12-XFL-LP-R12B202B	9	1
R12-XFL-LP-R12B204B	7	1
R12-XFL-LP-R12B301B	11	1
R12-XFL-LP-R12B302B	10	1
R12-XFL-LP-R12TBAN1E	4	1
R12-XFL-LP-R12TBARTNSS	6	1
R12-XFL-LP-R12TBBN1E	3	1
R12-XFL-LP-R12TBBRTNSS	5	1

Appendix B.4.15 Uninterruptible A.C. Power Supply System Fault Tree


LOSS OF 120 V AC FROM BUS R13-C1-3
GR13-0001-_29
BUS R13-C1-3 FAILS DURING OPERATION
R13-BAC-LP-R13C13
4.80E-06
NO POWER TO R13-C1-3 FROM SOURCES
GR13-0002-_29
NO POWER FROM BUS R13-C
GR13-0003-_27
Page 2
CIRCUIT BREAKER OPENS SPURIOUSLY
R13-LCB-CO-R13C13
1.44E-05
TRANSFORMER FAILS DURING OPERATION
R13-XFL-LP-R13C13
1.92E-05
CIRCUIT BREAKER OPENS SPURIOUSLY
R13-LCB-CO-FR13C13
1.44E-05
1
2


NO POWER FROM BUS R13-C
GR13-0003-_27
Page 1
Page 3
Page 4
BUS R13-C FAILS DURING OPERATION
R13-BAC-LP-R13C
4.80E-06
NO POWER TO R13-C FROM SOURCES
GR13-0004-_27
FAILURE OF SOURCES
GR13-0005-_27
CIRCUIT BREAKER TO R13-C OPENS SPURIOUSLY
R13-LCB-CO-TOR13C
1.44E-05
POWER SUPPLY FROM TRANSFORMER FAILS
GR13-0006-_27
POWER SUPPLY FROM INVERTER FAILS
GR13-0007-_27
LOSS OF 480 V AC FROM BUS R12-C23
GR12-0001-_5
TRANSFORMER FROM C23 FAILS TO OPERATE
R13-XFL-FC-C23R13C
1.20E-05
POWER SUPPLIES TO INVERTER FAIL
GR13-0008-_27
INVERTER TO R13-C FAILS
R13-INV-FC-R13C
4.80E-04
CIRCUIT BREAKER FROM C23 OPENS SPURIOUSLY
R13-LCB-CO-C23R13C
1.44E-05
AUTOMATIC SELECTOR FAILS TO TRANSFER
R13-SEL-FT-C23R13C
7.88E-04
POWER SUPPLY FROM BUS R16-C FAILS
GR13-0009-_27
POWER SUPPLY FROM BUS A2-02A FAILS
GR13-0010-_27
Page 3
CIRCUIT BREAKER FROM R16-C OPENS SPURIOUSLY
R13-LCB-CO-R16CR13C
1.44E-05
LOSS OF POWER FROM 250V DC NO 1E BUS R16-C
GR42-0001-_11
DIODE FROM R16-C FAILS TO OPERATE
R13-DIO-FC-R16CR13C
1.43E-06
1
2
3
4


POWER SUPPLY FROM BUS A2-02A FAILS
Page 2
GR13-0010-_27
DIODE FROM A2-02A FAILS TO OPERATE
R13-DIO-FC-A202AR13C
1.43E-06
CIRCUIT BREAKER FROM A2-02A OPENS SPURIOUSLY
R13-LCB-CO-A202AR13C
1.44E-05
RECTIFIER FROM A2-02A FAILS DURING OPERATION
R13-REC-FC-A202AR13C
1.68E-04
LOSS OF 480 V AC FROM BUS R12-A2-02A
GR12-0001-_8
LOSS OF 120 V AC FROM BUS R13-C1-2
GR13-0001-_28
BUS R13-C1-2 FAILS DURING OPERATION
R13-BAC-LP-R13C12
4.80E-06
NO POWER TO R13-C1-2 FROM SOURCES
GR13-0002-_28
NO POWER FROM BUS R13-C
GR13-0003-_27
Page 2
CIRCUIT BREAKER OPENS SPURIOUSLY
R13-LCB-CO-R13C12
1.44E-05
TRANSFORMER FAILS DURING OPERATION
R13-XFL-LP-R13C12
1.92E-05
CIRCUIT BREAKER OPENS SPURIOUSLY
R13-LCB-CO-FR13C12
1.44E-05
1
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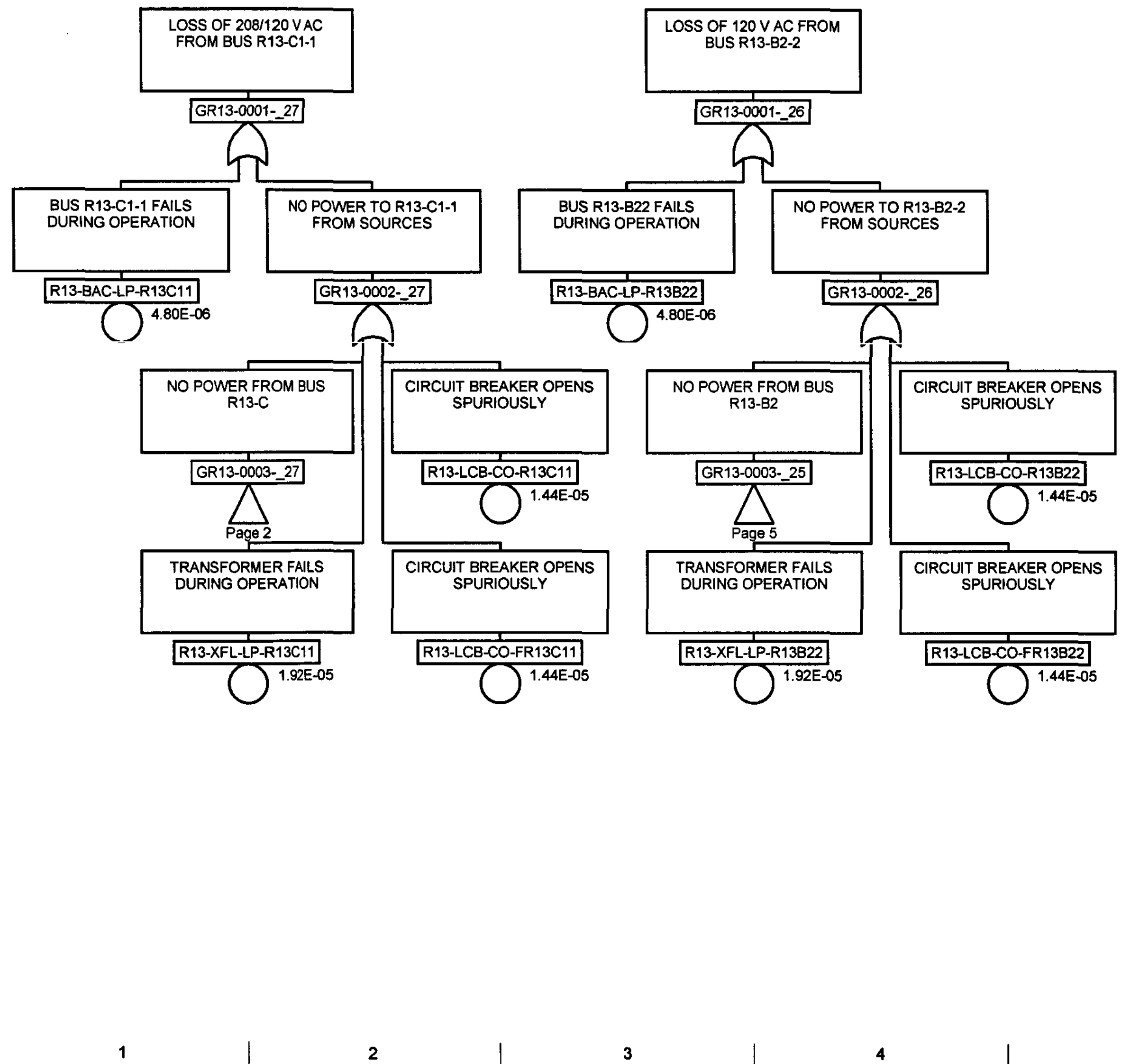
4


LOSS OF 208/120 V AC FROM BUS R13-C1-1
GR13-0001-_27
BUS R13-C1-1 FAILS DURING OPERATION
R13-BAC-LP-R13C11
4.80E-06
NO POWER TO R13-C1-1 FROM SOURCES
GR13-0002-_27
NO POWER FROM BUS R13-C
GR13-0003-_27
Page 2
CIRCUIT BREAKER OPENS SPURIOUSLY
R13-LCB-CO-R13C11
1.44E-05
TRANSFORMER FAILS DURING OPERATION
R13-XFL-LP-R13C11
1.92E-05
CIRCUIT BREAKER OPENS SPURIOUSLY
R13-LCB-CO-FR13C11
1.44E-05
LOSS OF 120 V AC FROM BUS R13-B2-2
GR13-0001-_26
BUS R13-B22 FAILS DURING OPERATION
R13-BAC-LP-R13B22
4.80E-06
NO POWER TO R13-B2-2 FROM SOURCES
GR13-0002-_26
NO POWER FROM BUS R13-B2
GR13-0003-_25
Page 5
CIRCUIT BREAKER OPENS SPURIOUSLY
R13-LCB-CO-R13B22
1.44E-05
TRANSFORMER FAILS DURING OPERATION
R13-XFL-LP-R13B22
1.92E-05
CIRCUIT BREAKER OPENS SPURIOUSLY
R13-LCB-CO-FR13B22
1.44E-05
1
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3
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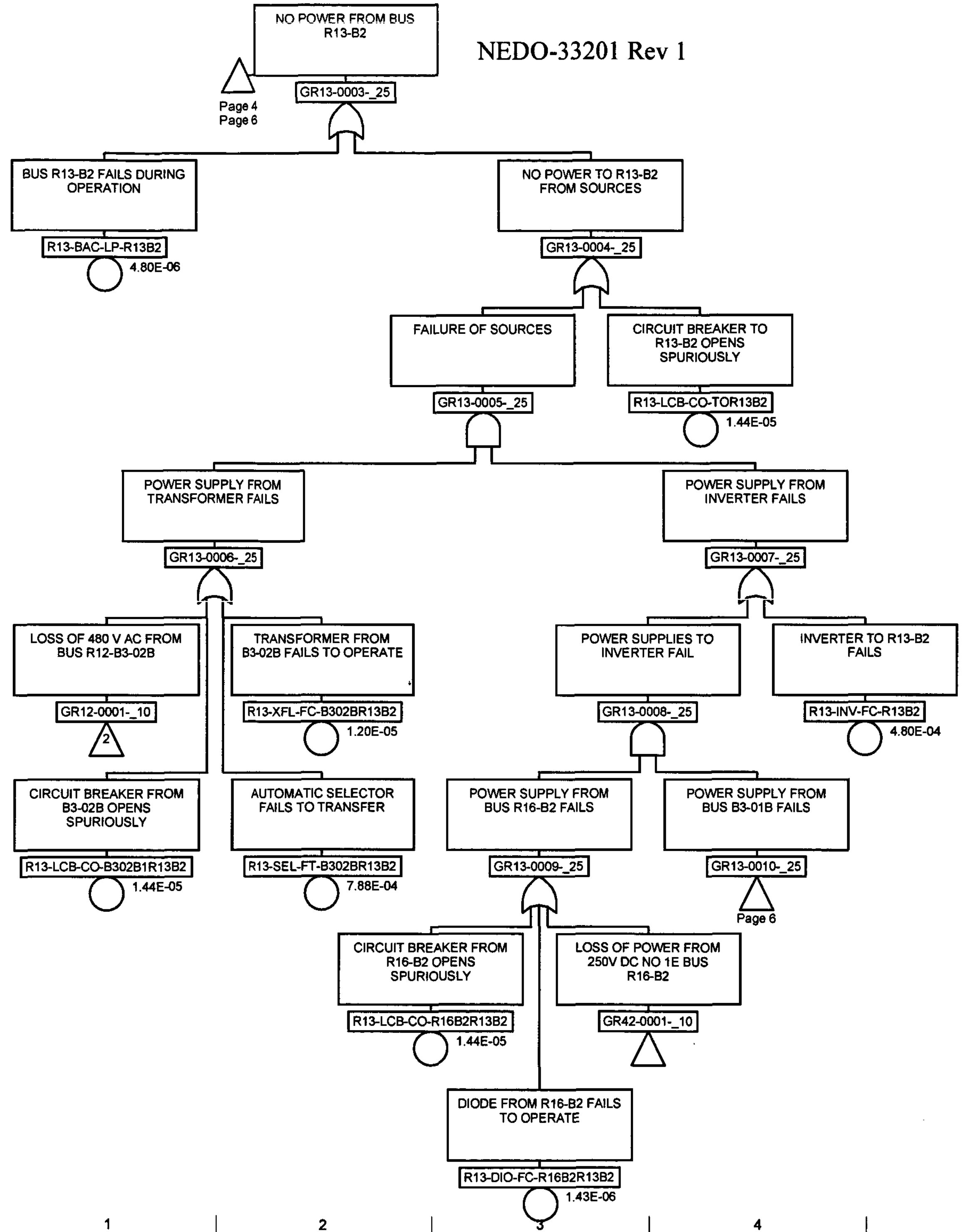
NO POWER FROM BUS R13-B2
GR13-0003-_25
Page 4
Page 6
BUS R13-B2 FAILS DURING OPERATION
R13-BAC-LP-R13B2
4.80E-06
NO POWER TO R13-B2 FROM SOURCES
GR13-0004-_25
FAILURE OF SOURCES
GR13-0005-_25
CIRCUIT BREAKER TO R13-B2 OPENS SPURIOUSLY
R13-LCB-CO-TOR13B2
1.44E-05
POWER SUPPLY FROM TRANSFORMER FAILS
GR13-0006-_25
POWER SUPPLY FROM INVERTER FAILS
GR13-0007-_25
LOSS OF 480 V AC FROM BUS R12-B3-02B
GR12-0001-_10
2
TRANSFORMER FROM B3-02B FAILS TO OPERATE
R13-XFL-FC-B302BR13B2
1.20E-05
POWER SUPPLIES TO INVERTER FAIL
GR13-0008-_25
INVERTER TO R13-B2 FAILS
R13-INV-FC-R13B2
4.80E-04
CIRCUIT BREAKER FROM B3-02B OPENS SPURIOUSLY
R13-LCB-CO-B302B1R13B2
1.44E-05
AUTOMATIC SELECTOR FAILS TO TRANSFER
R13-SEL-FT-B302BR13B2
7.88E-04
POWER SUPPLY FROM BUS R16-B2 FAILS
GR13-0009-_25
POWER SUPPLY FROM BUS B3-01B FAILS
GR13-0010-_25
Page 6
CIRCUIT BREAKER FROM R16-B2 OPENS SPURIOUSLY
R13-LCB-CO-R16B2R13B2
1.44E-05
LOSS OF POWER FROM 250V DC NO 1E BUS R16-B2
GR42-0001-_10
DIODE FROM R16-B2 FAILS TO OPERATE
R13-DIO-FC-R16B2R13B2
1.43E-06
1
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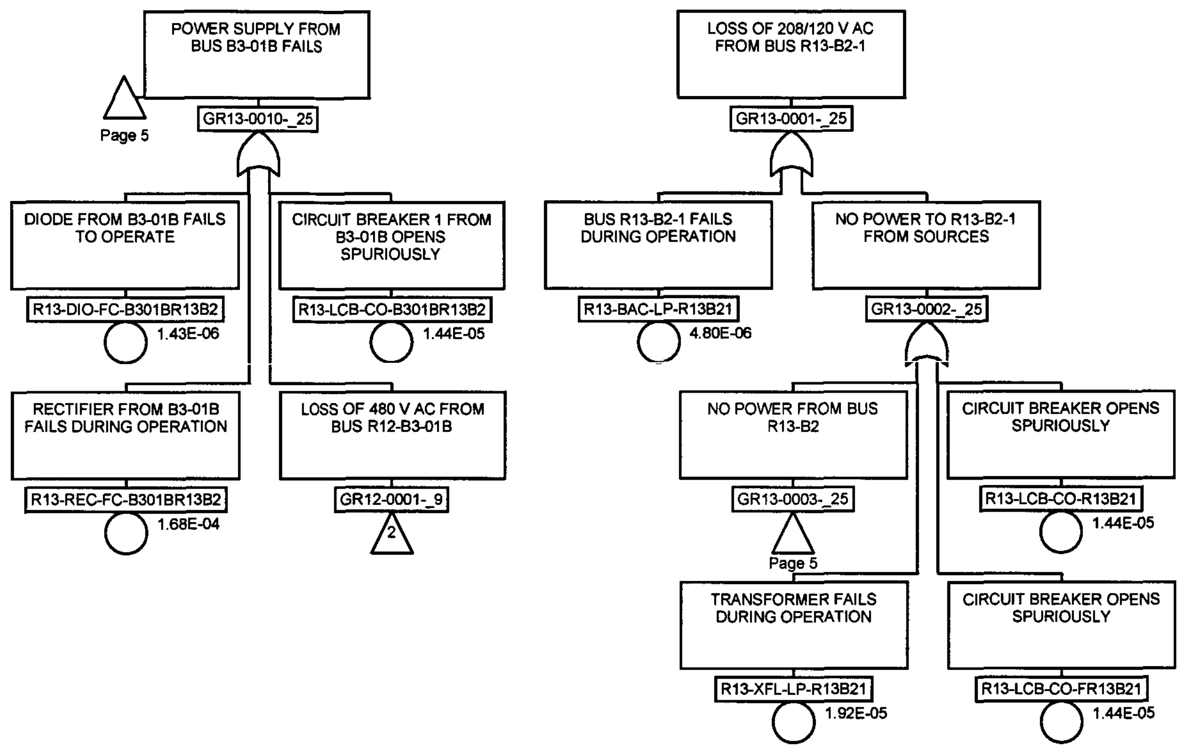
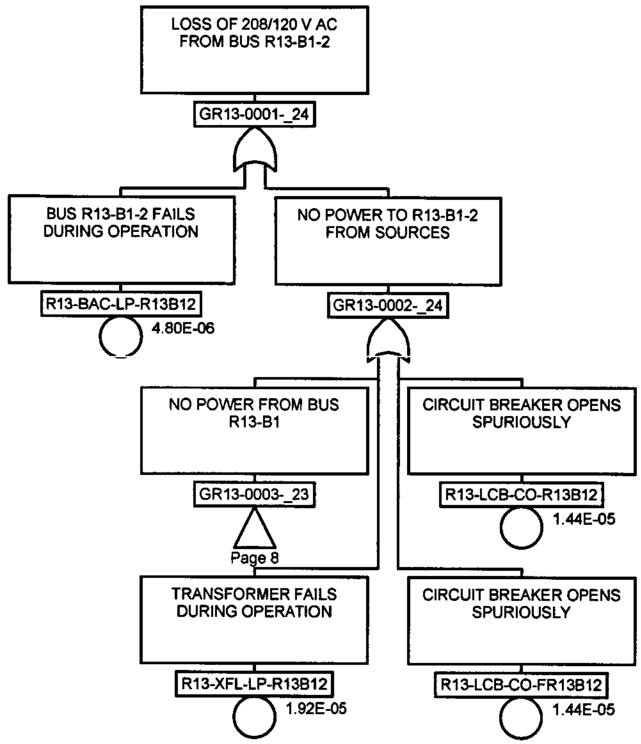
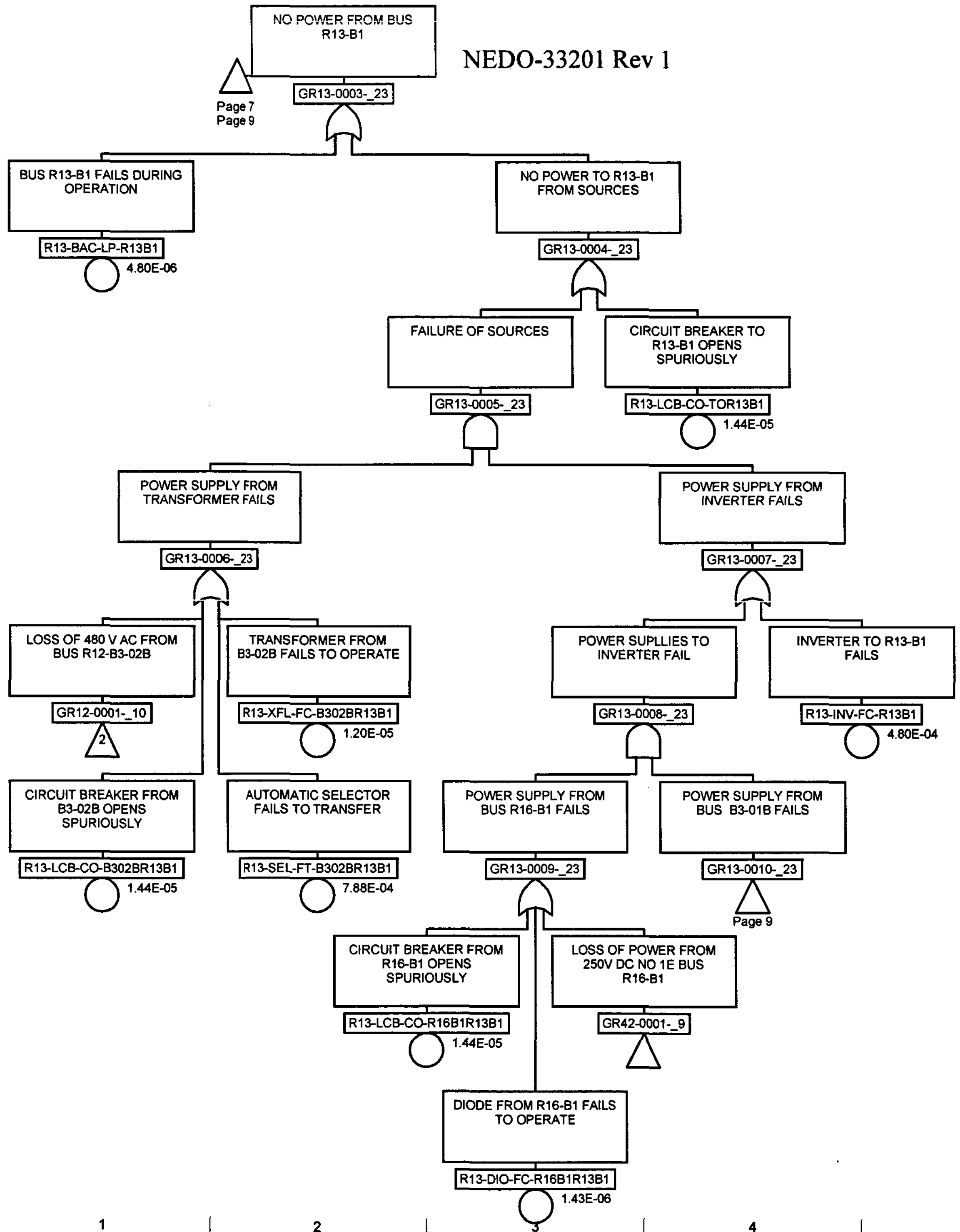

POWER SUPPLY FROM BUS B3-01B FAILS
GR13-0010-_25
Page 5
DIODE FROM B3-01B FAILS TO OPERATE
R13-DIO-FC-B301BR13B2
1.43E-06
CIRCUIT BREAKER 1 FROM B3-01B OPENS SPURIOUSLY
R13-LCB-CO-B301BR13B2
1.44E-05
RECTIFIER FROM B3-01B FAILS DURING OPERATION
R13-REC-FC-B301BR13B2
1.68E-04
LOSS OF 480 V AC FROM BUS R12-B3-01B
GR12-0001-_9
2
LOSS OF 208/120 V AC FROM BUS R13-B2-1
GR13-0001-_25
BUS R13-B2-1 FAILS DURING OPERATION
R13-BAC-LP-R13B21
4.80E-06
NO POWER TO R13-B2-1 FROM SOURCES
GR13-0002-_25
NO POWER FROM BUS R13-B2
GR13-0003-_25
Page 5
CIRCUIT BREAKER OPENS SPURIOUSLY
R13-LCB-CO-R13B21
1.44E-05
TRANSFORMER FAILS DURING OPERATION
R13-XFL-LP-R13B21
1.92E-05
CIRCUIT BREAKER OPENS SPURIOUSLY
R13-LCB-CO-FR13B21
1.44E-05


LOSS OF 208/120 V AC FROM BUS R13-B1-2
GR13-0001-_24
BUS R13-B1-2 FAILS DURING OPERATION
R13-BAC-LP-R13B12
4.80E-06
NO POWER TO R13-B1-2 FROM SOURCES
GR13-0002-_24
NO POWER FROM BUS R13-B1
GR13-0003-_23
Page 8
CIRCUIT BREAKER OPENS SPURIOUSLY
R13-LCB-CO-R13B12
1.44E-05
TRANSFORMER FAILS DURING OPERATION
R13-XFL-LP-R13B12
1.92E-05
CIRCUIT BREAKER OPENS SPURIOUSLY
R13-LCB-CO-FR13B12
1.44E-05
1
2


NO POWER FROM BUS R13-B1
GR13-0003-_23
Page 7
Page 9
BUS R13-B1 FAILS DURING OPERATION
R13-BAC-LP-R13B1
4.80E-06
NO POWER TO R13-B1 FROM SOURCES
GR13-0004-_23
FAILURE OF SOURCES
GR13-0005-_23
CIRCUIT BREAKER TO R13-B1 OPENS SPURIOUSLY
R13-LCB-CO-TOR13B1
1.44E-05
POWER SUPPLY FROM TRANSFORMER FAILS
GR13-0006-_23
POWER SUPPLY FROM INVERTER FAILS
GR13-0007-_23
LOSS OF 480 V AC FROM BUS R12-B3-02B
GR12-0001-_10
2
TRANSFORMER FROM B3-02B FAILS TO OPERATE
R13-XFL-FC-B302BR13B1
1.20E-05
POWER SUPLLIES TO INVERTER FAIL
GR13-0008-_23
INVERTER TO R13-B1 FAILS
R13-INV-FC-R13B1
4.80E-04
CIRCUIT BREAKER FROM B3-02B OPENS SPURIOUSLY
R13-LCB-CO-B302BR13B1
1.44E-05
AUTOMATIC SELECTOR FAILS TO TRANSFER
R13-SEL-FT-B302BR13B1
7.88E-04
POWER SUPPLY FROM BUS R16-B1 FAILS
GR13-0009-_23
POWER SUPPLY FROM BUS B3-01B FAILS
GR13-0010-_23
Page 9
CIRCUIT BREAKER FROM R16-B1 OPENS SPURIOUSLY
R13-LCB-CO-R16B1R13B1
1.44E-05
LOSS OF POWER FROM 250V DC NO 1E BUS R16-B1
GR42-0001-_9
DIODE FROM R16-B1 FAILS TO OPERATE
R13-DIO-FC-R16B1R13B1
1.43E-06
1
2
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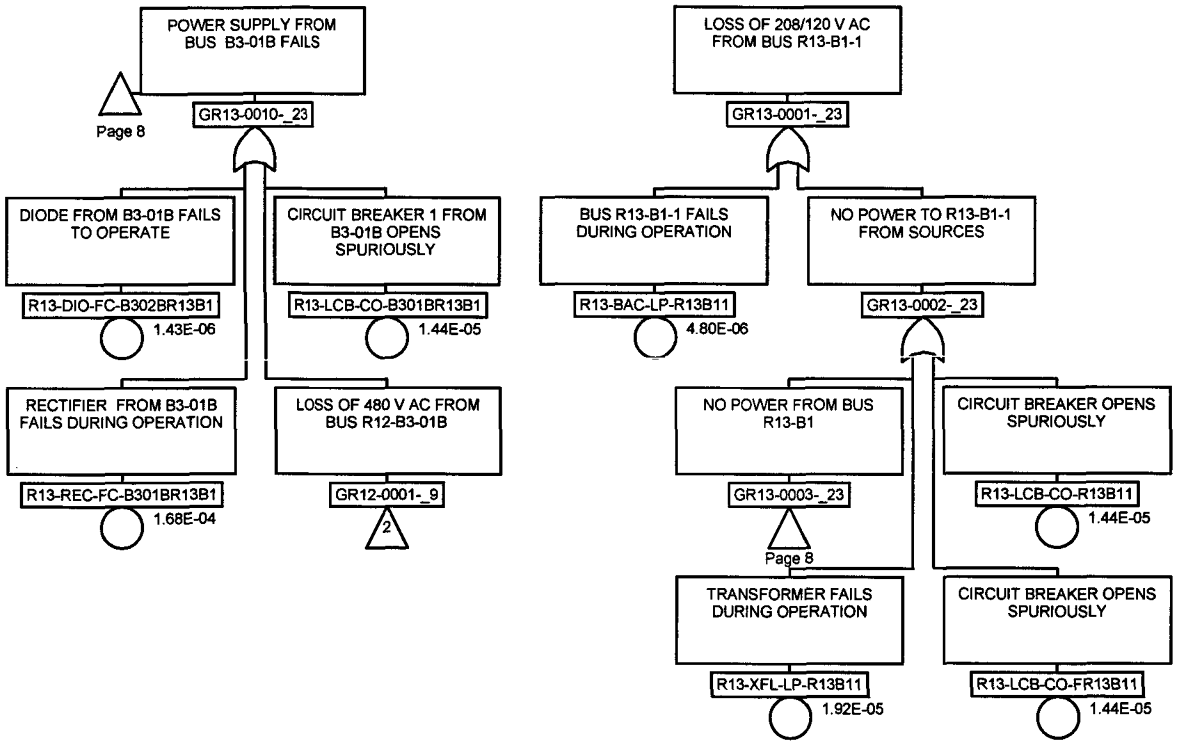
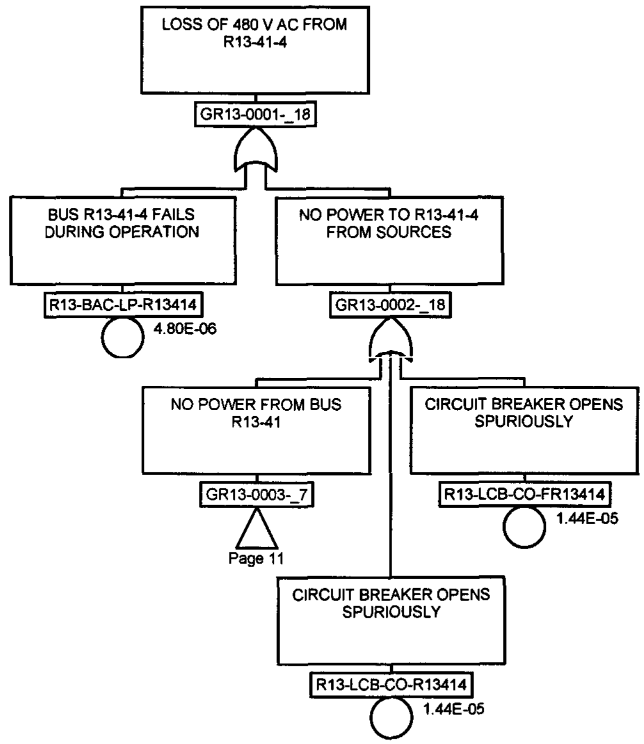
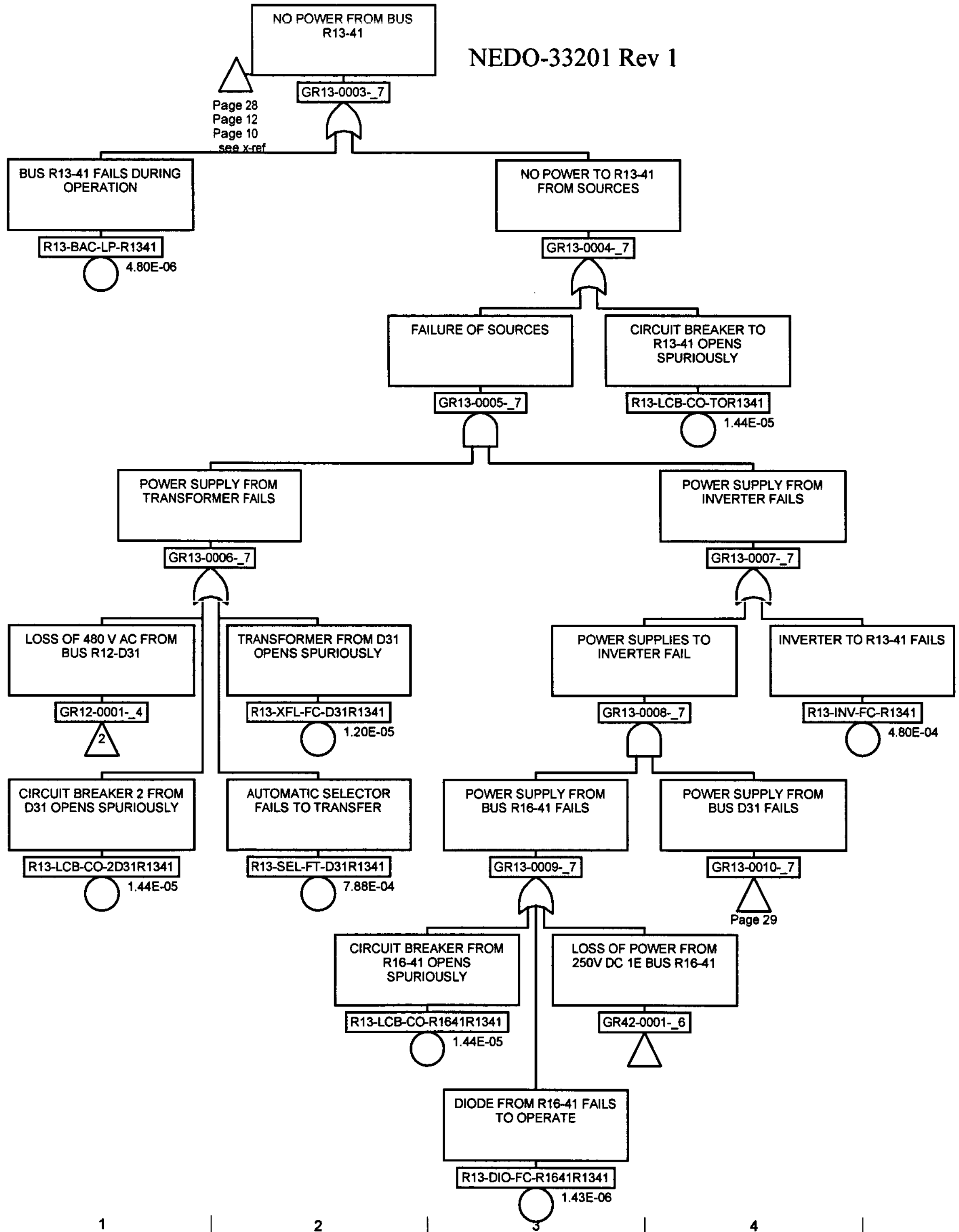


POWER SUPPLY FROM BUS B3-01B FAILS
GR13-0010-_23
Page 8
DIODE FROM B3-01B FAILS TO OPERATE
R13-DIO-FC-B302BR13B1
1.43E-06
CIRCUIT BREAKER 1 FROM B3-01B OPENS SPURIOUSLY
R13-LCB-CO-B301BR13B1
1.44E-05
RECTIFIER FROM B3-01B FAILS DURING OPERATION
R13-REC-FC-B301BR13B1
1.68E-04
LOSS OF 480 V AC FROM BUS R12-B3-01B
GR12-0001-_9
2
LOSS OF 208/120 V AC FROM BUS R13-B1-1
GR13-0001-_23
BUS R13-B1-1 FAILS DURING OPERATION
R13-BAC-LP-R13B11
4.80E-06
NO POWER TO R13-B1-1 FROM SOURCES
GR13-0002-_23
NO POWER FROM BUS R13-B1
GR13-0003-_23
Page 8
CIRCUIT BREAKER OPENS SPURIOUSLY
R13-LCB-CO-R13B11
1.44E-05
TRANSFORMER FAILS DURING OPERATION
R13-XFL-LP-R13B11
1.92E-05
CIRCUIT BREAKER OPENS SPURIOUSLY
R13-LCB-CO-FR13B11
1.44E-05



LOSS OF 480 V AC FROM R13-41-4
GR13-0001-_18
BUS R13-41-4 FAILS DURING OPERATION
R13-BAC-LP-R13414
4.80E-06
NO POWER TO R13-41-4 FROM SOURCES
GR13-0002-_18
NO POWER FROM BUS R13-41
GR13-0003-_7
Page 11
CIRCUIT BREAKER OPENS SPURIOUSLY
R13-LCB-CO-FR13414
1.44E-05
CIRCUIT BREAKER OPENS SPURIOUSLY
R13-LCB-CO-R13414
1.44E-05

1 2


NO POWER FROM BUS R13-41
GR13-0003-_7
Page 28
Page 12
Page 10
see x-ref
BUS R13-41 FAILS DURING OPERATION
R13-BAC-LP-R1341
4.80E-06
NO POWER TO R13-41 FROM SOURCES
GR13-0004-_7
FAILURE OF SOURCES
GR13-0005-_7
CIRCUIT BREAKER TO R13-41 OPENS SPURIOUSLY
R13-LCB-CO-TOR1341
1.44E-05
POWER SUPPLY FROM TRANSFORMER FAILS
GR13-0006-_7
POWER SUPPLY FROM INVERTER FAILS
GR13-0007-_7
LOSS OF 480 V AC FROM BUS R12-D31
GR12-0001-_4
2
TRANSFORMER FROM D31 OPENS SPURIOUSLY
R13-XFL-FC-D31R1341
1.20E-05
POWER SUPPLIES TO INVERTER FAIL
GR13-0008-_7
INVERTER TO R13-41 FAILS
R13-INV-FC-R1341
4.80E-04
CIRCUIT BREAKER 2 FROM D31 OPENS SPURIOUSLY
R13-LCB-CO-2D31R1341
1.44E-05
AUTOMATIC SELECTOR FAILS TO TRANSFER
R13-SEL-FT-D31R1341
7.88E-04
POWER SUPPLY FROM BUS R16-41 FAILS
GR13-0009-_7
POWER SUPPLY FROM BUS D31 FAILS
GR13-0010-_7
Page 29
CIRCUIT BREAKER FROM R16-41 OPENS SPURIOUSLY
R13-LCB-CO-R1641R1341
1.44E-05
LOSS OF POWER FROM 250V DC 1E BUS R16-41
GR42-0001-_6
DIODE FROM R16-41 FAILS TO OPERATE
R13-DIO-FC-R1641R1341
1.43E-06
1
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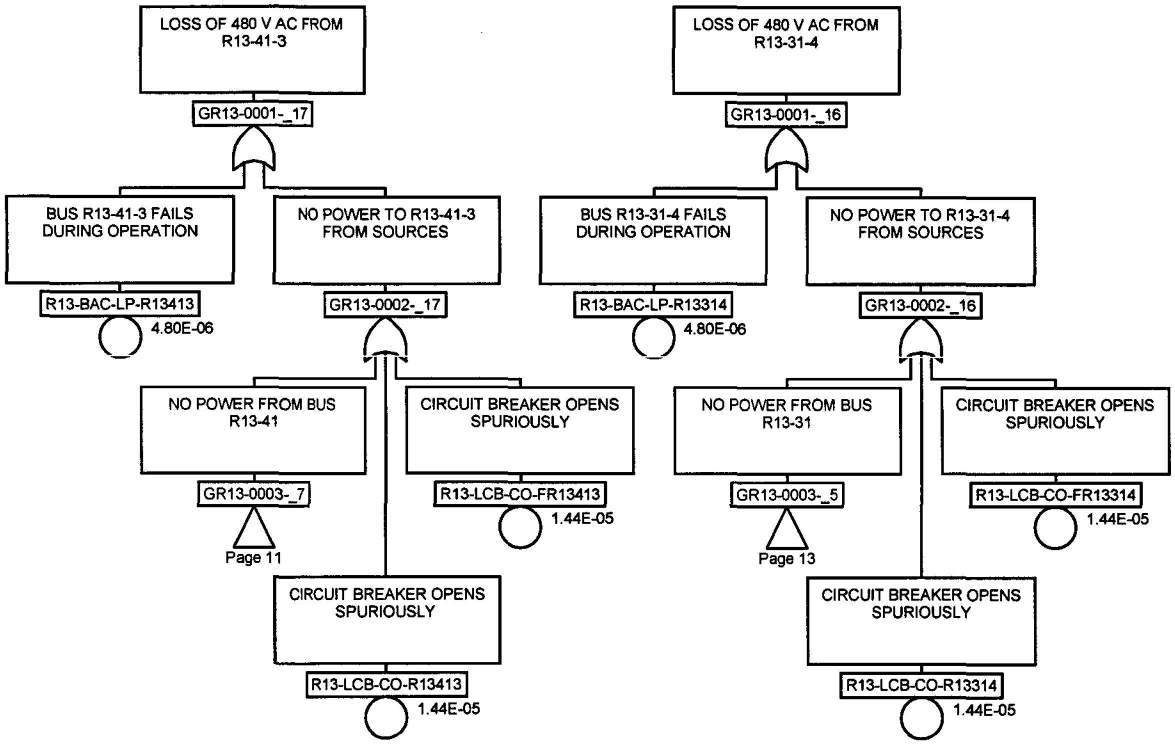

LOSS OF 480 V AC FROM R13-41-3
GR13-0001-_17
BUS R13-41-3 FAILS DURING OPERATION
R13-BAC-LP-R13413
4.80E-06
NO POWER TO R13-41-3 FROM SOURCES
GR13-0002-_17
NO POWER FROM BUS R13-41
GR13-0003-_7
Page 11
CIRCUIT BREAKER OPENS SPURIOUSLY
R13-LCB-CO-FR13413
1.44E-05
CIRCUIT BREAKER OPENS SPURIOUSLY
R13-LCB-CO-R13413
1.44E-05
LOSS OF 480 V AC FROM R13-31-4
GR13-0001-_16
BUS R13-31-4 FAILS DURING OPERATION
R13-BAC-LP-R13314
4.80E-06
NO POWER TO R13-31-4 FROM SOURCES
GR13-0002-_16
NO POWER FROM BUS R13-31
GR13-0003-_5
Page 13
CIRCUIT BREAKER OPENS SPURIOUSLY
R13-LCB-CO-FR13314
1.44E-05
CIRCUIT BREAKER OPENS SPURIOUSLY
R13-LCB-CO-R13314
1.44E-05
1
2
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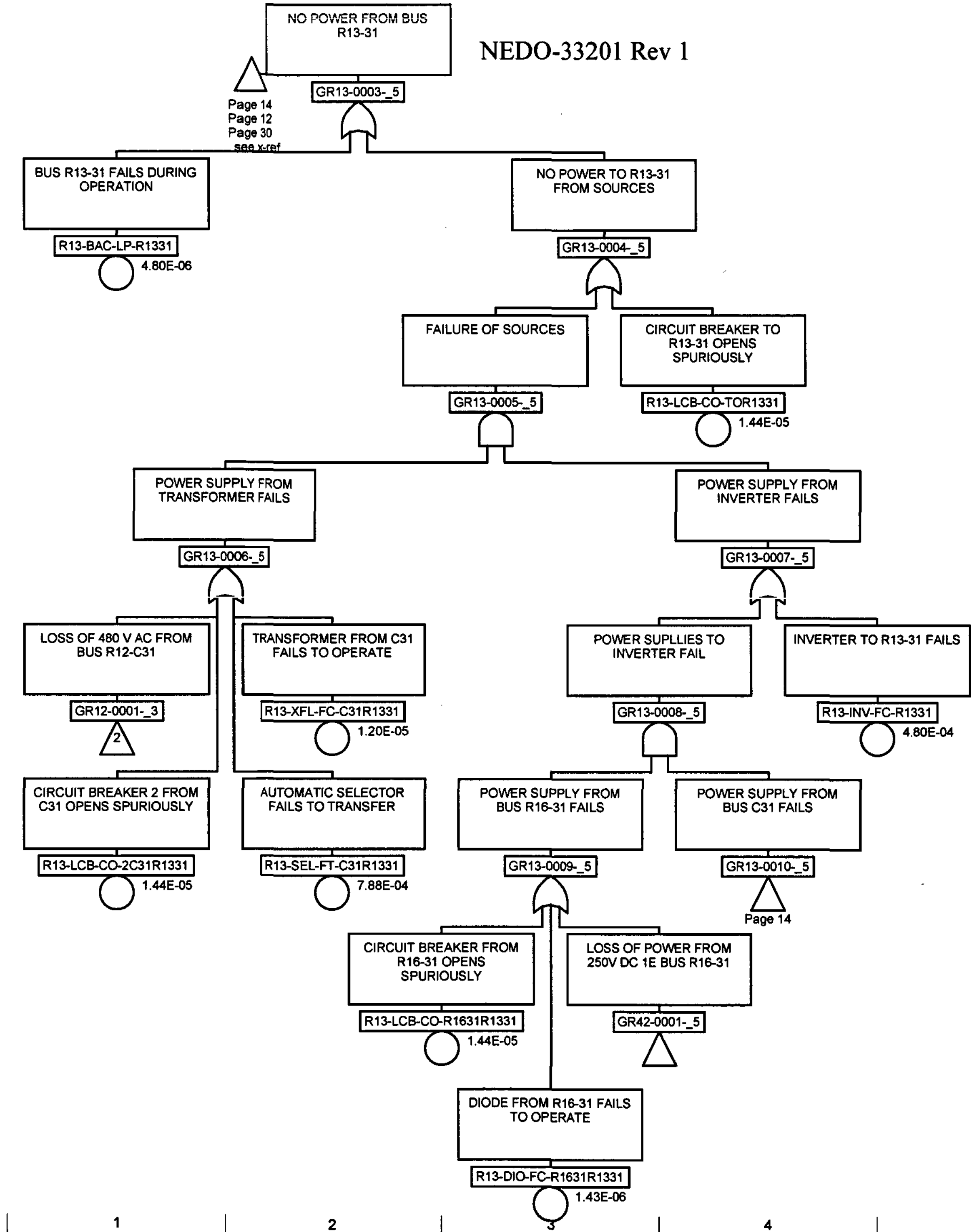
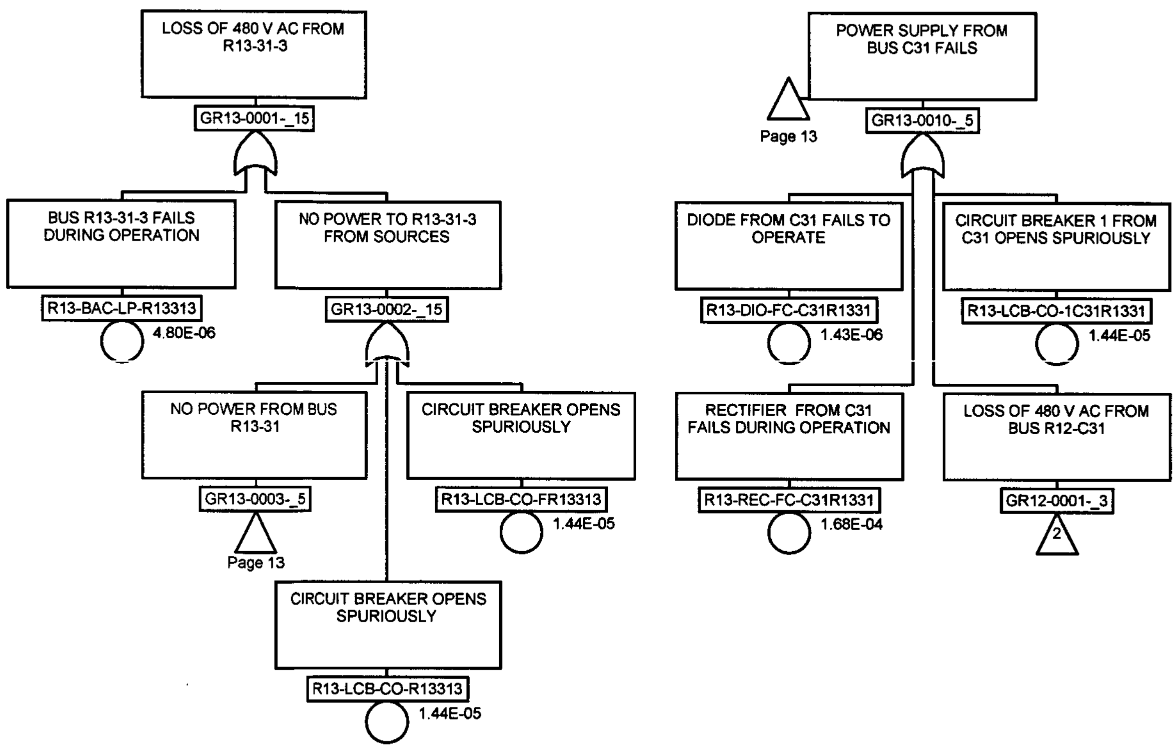
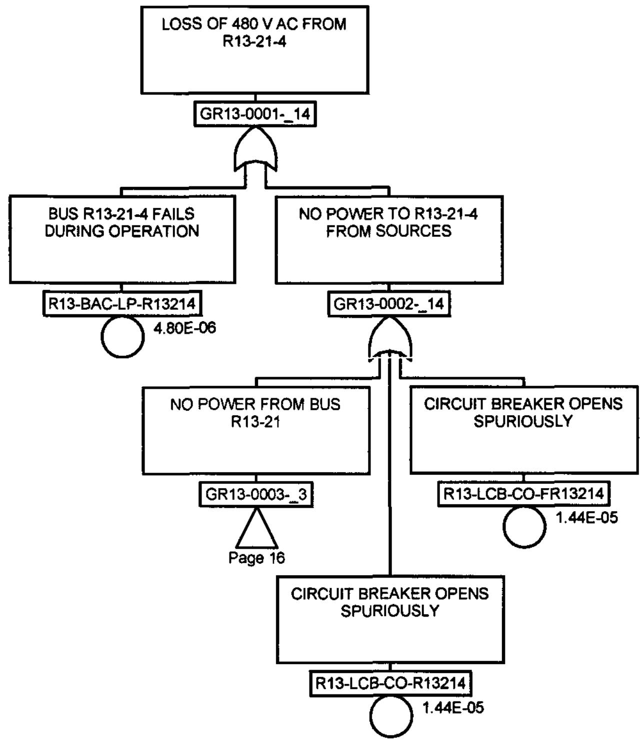
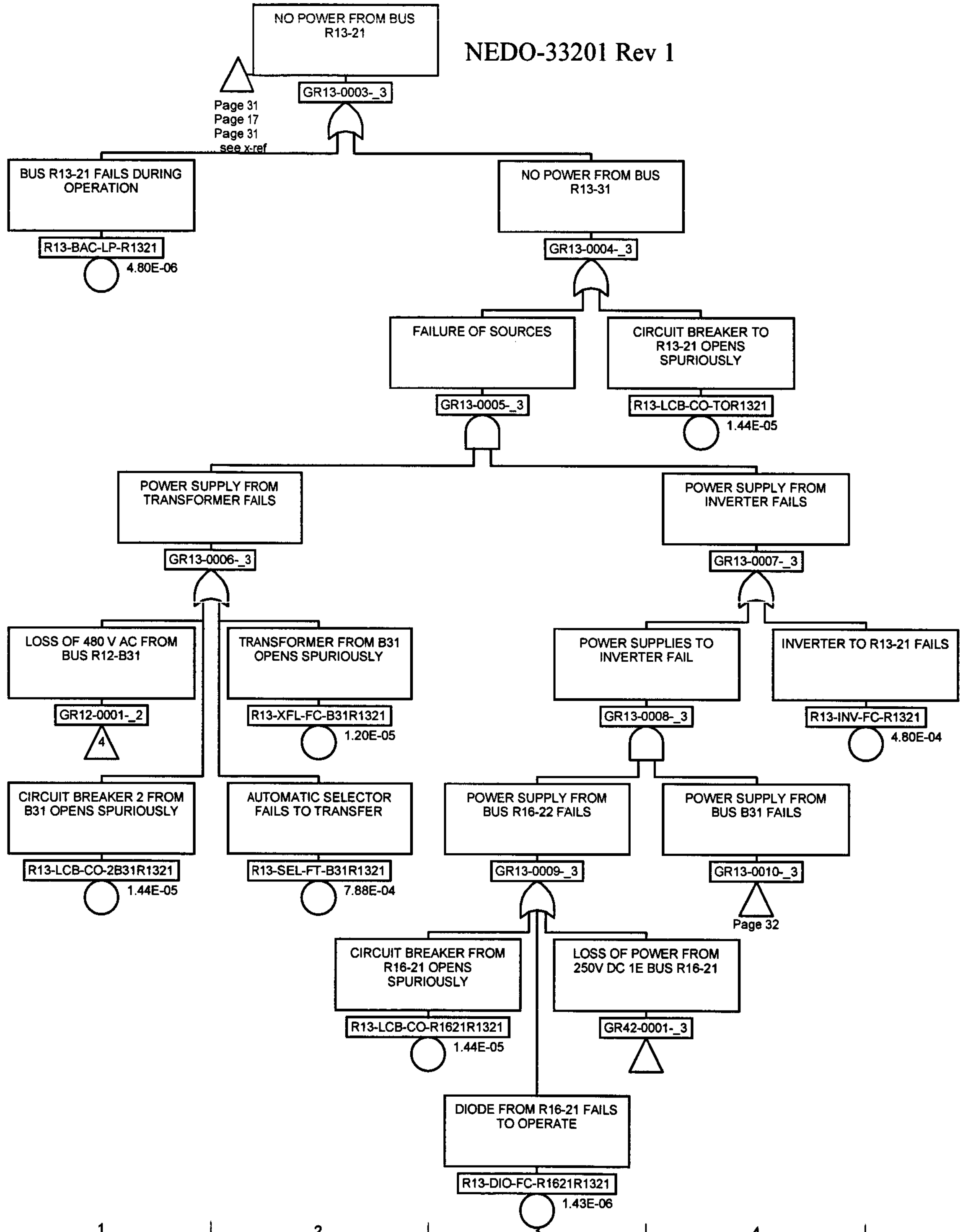
4


NO POWER FROM BUS R13-31
GR13-0003-_5
Page 14
Page 12
Page 30
see x-ref
BUS R13-31 FAILS DURING OPERATION
R13-BAC-LP-R1331
4.80E-06
NO POWER TO R13-31 FROM SOURCES
GR13-0004-_5
FAILURE OF SOURCES
GR13-0005-_5
CIRCUIT BREAKER TO R13-31 OPENS SPURIOUSLY
R13-LCB-CO-TOR1331
1.44E-05
POWER SUPPLY FROM TRANSFORMER FAILS
GR13-0006-_5
POWER SUPPLY FROM INVERTER FAILS
GR13-0007-_5
LOSS OF 480 V AC FROM BUS R12-C31
GR12-0001-_3
2
TRANSFORMER FROM C31 FAILS TO OPERATE
R13-XFL-FC-C31R1331
1.20E-05
CIRCUIT BREAKER 2 FROM C31 OPENS SPURIOUSLY
R13-LCB-CO-2C31R1331
1.44E-05
AUTOMATIC SELECTOR FAILS TO TRANSFER
R13-SEL-FT-C31R1331
7.88E-04
POWER SUPLLIES TO INVERTER FAIL
GR13-0008-_5
INVERTER TO R13-31 FAILS
R13-INV-FC-R1331
4.80E-04
POWER SUPPLY FROM BUS R16-31 FAILS
GR13-0009-_5
POWER SUPPLY FROM BUS C31 FAILS
GR13-0010-_5
Page 14
CIRCUIT BREAKER FROM R16-31 OPENS SPURIOUSLY
R13-LCB-CO-R1631R1331
1.44E-05
LOSS OF POWER FROM 250V DC 1E BUS R16-31
GR42-0001-_5
DIODE FROM R16-31 FAILS TO OPERATE
R13-DIO-FC-R1631R1331
1.43E-06
1
2
3
4


LOSS OF 480 V AC FROM R13-31-3
GR13-0001-_15
BUS R13-31-3 FAILS DURING OPERATION
R13-BAC-LP-R13313
4.80E-06
NO POWER TO R13-31-3 FROM SOURCES
GR13-0002-_15
NO POWER FROM BUS R13-31
GR13-0003-_5
Page 13
CIRCUIT BREAKER OPENS SPURIOUSLY
R13-LCB-CO-FR13313
1.44E-05
CIRCUIT BREAKER OPENS SPURIOUSLY
R13-LCB-CO-R13313
1.44E-05
POWER SUPPLY FROM BUS C31 FAILS
Page 13
GR13-0010-_5
DIODE FROM C31 FAILS TO OPERATE
R13-DIO-FC-C31R1331
1.43E-06
CIRCUIT BREAKER 1 FROM C31 OPENS SPURIOUSLY
R13-LCB-CO-1C31R1331
1.44E-05
RECTIFIER FROM C31 FAILS DURING OPERATION
R13-REC-FC-C31R1331
1.68E-04
LOSS OF 480 V AC FROM BUS R12-C31
GR12-0001-_3
2
1
2
3
4


LOSS OF 480 V AC FROM R13-21-4
GR13-0001-_14
BUS R13-21-4 FAILS DURING OPERATION
R13-BAC-LP-R13214
4.80E-06
NO POWER TO R13-21-4 FROM SOURCES
GR13-0002-_14
NO POWER FROM BUS R13-21
GR13-0003-_3
Page 16
CIRCUIT BREAKER OPENS SPURIOUSLY
R13-LCB-CO-FR13214
1.44E-05
CIRCUIT BREAKER OPENS SPURIOUSLY
R13-LCB-CO-R13214
1.44E-05
1
2


NO POWER FROM BUS R13-21
GR13-0003-_3
Page 31
Page 17
Page 31
see x-ref
BUS R13-21 FAILS DURING OPERATION
R13-BAC-LP-R1321
4.80E-06
NO POWER FROM BUS R13-31
GR13-0004-_3
FAILURE OF SOURCES
GR13-0005-_3
CIRCUIT BREAKER TO R13-21 OPENS SPURIOUSLY
R13-LCB-CO-TOR1321
1.44E-05
POWER SUPPLY FROM TRANSFORMER FAILS
GR13-0006-_3
POWER SUPPLY FROM INVERTER FAILS
GR13-0007-_3
LOSS OF 480 V AC FROM BUS R12-B31
GR12-0001-_2
4
TRANSFORMER FROM B31 OPENS SPURIOUSLY
R13-XFL-FC-B31R1321
1.20E-05
POWER SUPPLIES TO INVERTER FAIL
GR13-0008-_3
INVERTER TO R13-21 FAILS
R13-INV-FC-R1321
4.80E-04
CIRCUIT BREAKER 2 FROM B31 OPENS SPURIOUSLY
R13-LCB-CO-2B31R1321
1.44E-05
AUTOMATIC SELECTOR FAILS TO TRANSFER
R13-SEL-FT-B31R1321
7.88E-04
POWER SUPPLY FROM BUS R16-22 FAILS
GR13-0009-_3
POWER SUPPLY FROM BUS B31 FAILS
GR13-0010-_3
Page 32
CIRCUIT BREAKER FROM R16-21 OPENS SPURIOUSLY
R13-LCB-CO-R1621R1321
1.44E-05
LOSS OF POWER FROM 250V DC 1E BUS R16-21
GR42-0001-_3
DIODE FROM R16-21 FAILS TO OPERATE
R13-DIO-FC-R1621R1321
1.43E-06
1
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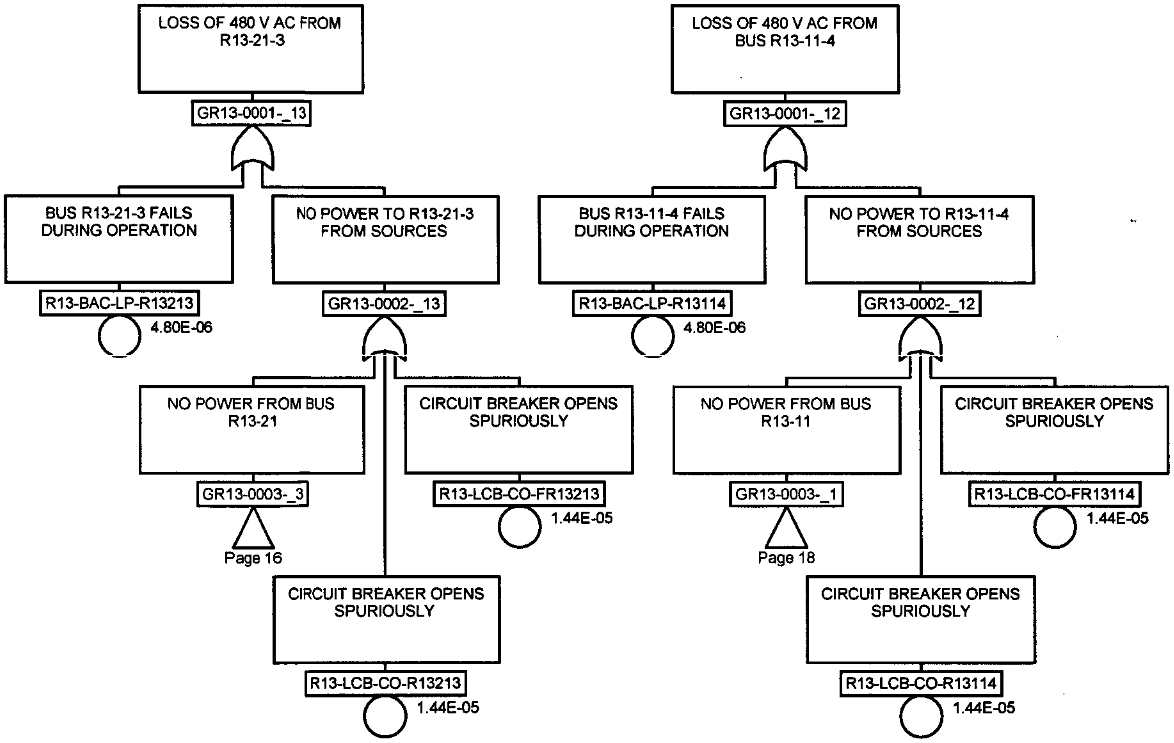
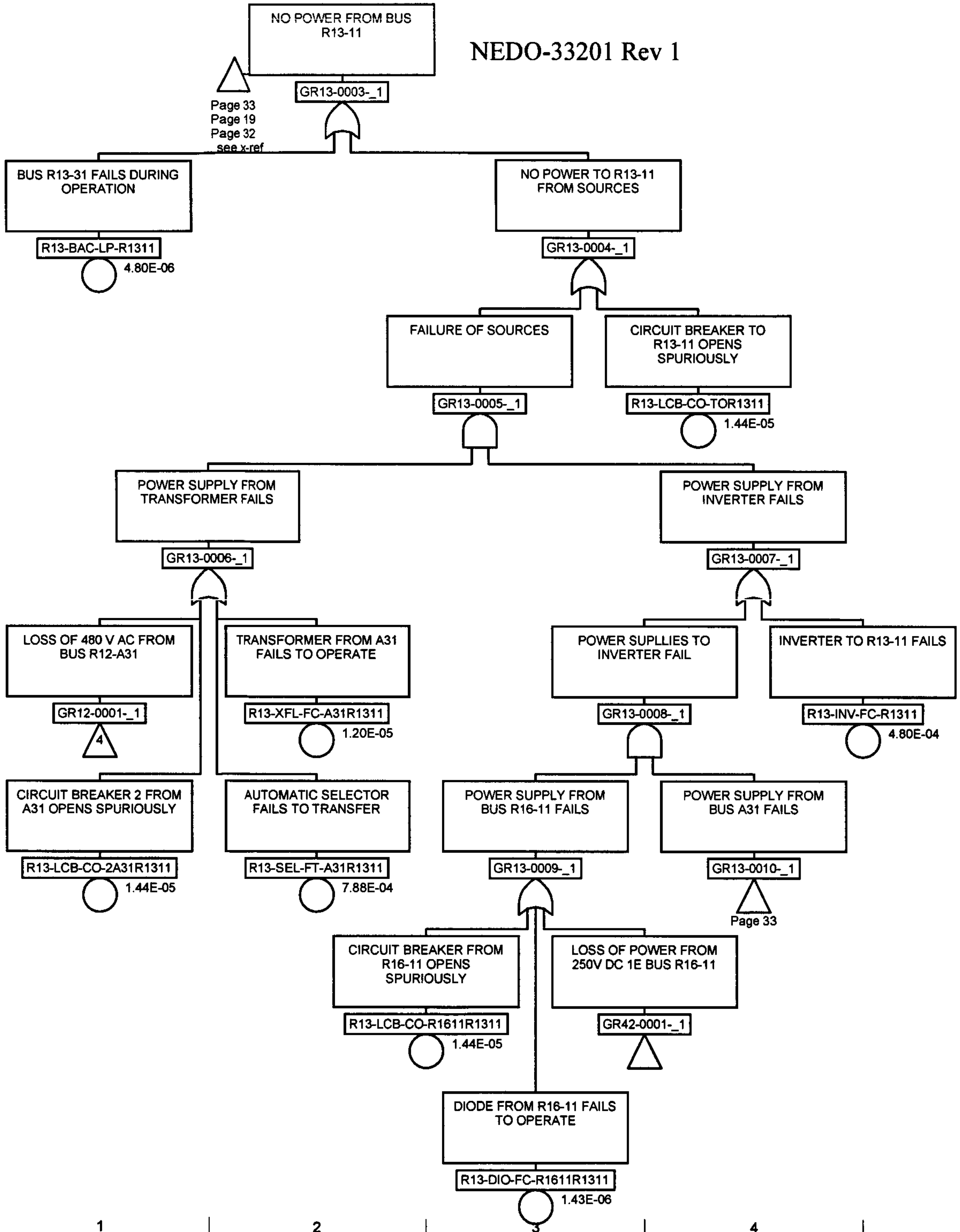
3
4


LOSS OF 480 V AC FROM R13-21-3
GR13-0001-_13
BUS R13-21-3 FAILS DURING OPERATION
R13-BAC-LP-R13213
4.80E-06
NO POWER TO R13-21-3 FROM SOURCES
GR13-0002-_13
NO POWER FROM BUS R13-21
GR13-0003-_3
Page 16
CIRCUIT BREAKER OPENS SPURIOUSLY
R13-LCB-CO-FR13213
1.44E-05
CIRCUIT BREAKER OPENS SPURIOUSLY
R13-LCB-CO-R13213
1.44E-05
LOSS OF 480 V AC FROM BUS R13-11-4
GR13-0001-_12
BUS R13-11-4 FAILS DURING OPERATION
R13-BAC-LP-R13114
4.80E-06
NO POWER TO R13-11-4 FROM SOURCES
GR13-0002-_12
NO POWER FROM BUS R13-11
GR13-0003-_1
Page 18
CIRCUIT BREAKER OPENS SPURIOUSLY
R13-LCB-CO-FR13114
1.44E-05
CIRCUIT BREAKER OPENS SPURIOUSLY
R13-LCB-CO-R13114
1.44E-05


NO POWER FROM BUS R13-11
GR13-0003-_1
Page 33
Page 19
Page 32
see x-ref
BUS R13-31 FAILS DURING OPERATION
R13-BAC-LP-R1311
4.80E-06
NO POWER TO R13-11 FROM SOURCES
GR13-0004-_1
FAILURE OF SOURCES
GR13-0005-_1
CIRCUIT BREAKER TO R13-11 OPENS SPURIOUSLY
R13-LCB-CO-TOR1311
1.44E-05
POWER SUPPLY FROM TRANSFORMER FAILS
GR13-0006-_1
POWER SUPPLY FROM INVERTER FAILS
GR13-0007-_1
LOSS OF 480 V AC FROM BUS R12-A31
GR12-0001-_1
4
TRANSFORMER FROM A31 FAILS TO OPERATE
R13-XFL-FC-A31R1311
1.20E-05
POWER SUPLLIES TO INVERTER FAIL
GR13-0008-_1
INVERTER TO R13-11 FAILS
R13-INV-FC-R1311
4.80E-04
CIRCUIT BREAKER 2 FROM A31 OPENS SPURIOUSLY
R13-LCB-CO-2A31R1311
1.44E-05
AUTOMATIC SELECTOR FAILS TO TRANSFER
R13-SEL-FT-A31R1311
7.88E-04
POWER SUPPLY FROM BUS R16-11 FAILS
GR13-0009-_1
POWER SUPPLY FROM BUS A31 FAILS
GR13-0010-_1
Page 33
CIRCUIT BREAKER FROM R16-11 OPENS SPURIOUSLY
R13-LCB-CO-R1611R1311
1.44E-05
LOSS OF POWER FROM 250V DC 1E BUS R16-11
GR42-0001-_1
DIODE FROM R16-11 FAILS TO OPERATE
R13-DIO-FC-R1611R1311
1.43E-06
1
2
3
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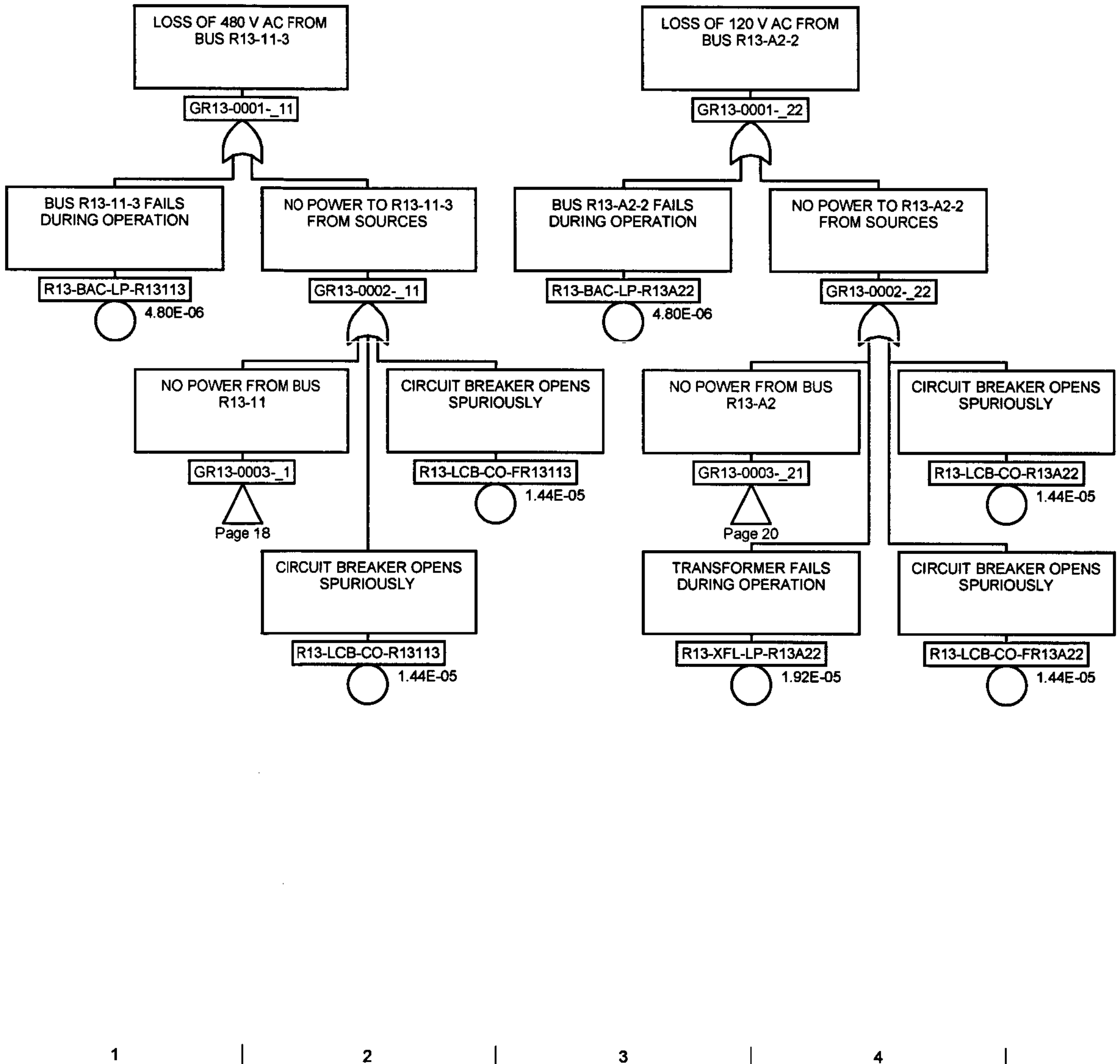
LOSS OF 480 V AC FROM BUS R13-11-3
GR13-0001-_11
BUS R13-11-3 FAILS DURING OPERATION
R13-BAC-LP-R13113
4.80E-06
NO POWER TO R13-11-3 FROM SOURCES
GR13-0002-_11
NO POWER FROM BUS R13-11
GR13-0003-_1
Page 18
CIRCUIT BREAKER OPENS SPURIOUSLY
R13-LCB-CO-FR13113
1.44E-05
CIRCUIT BREAKER OPENS SPURIOUSLY
R13-LCB-CO-R13113
1.44E-05
LOSS OF 120 V AC FROM BUS R13-A2-2
GR13-0001-_22
BUS R13-A2-2 FAILS DURING OPERATION
R13-BAC-LP-R13A22
4.80E-06
NO POWER TO R13-A2-2 FROM SOURCES
GR13-0002-_22
NO POWER FROM BUS R13-A2
GR13-0003-_21
Page 20
CIRCUIT BREAKER OPENS SPURIOUSLY
R13-LCB-CO-R13A22
1.44E-05
TRANSFORMER FAILS DURING OPERATION
R13-XFL-LP-R13A22
1.92E-05
CIRCUIT BREAKER OPENS SPURIOUSLY
R13-LCB-CO-FR13A22
1.44E-05
1
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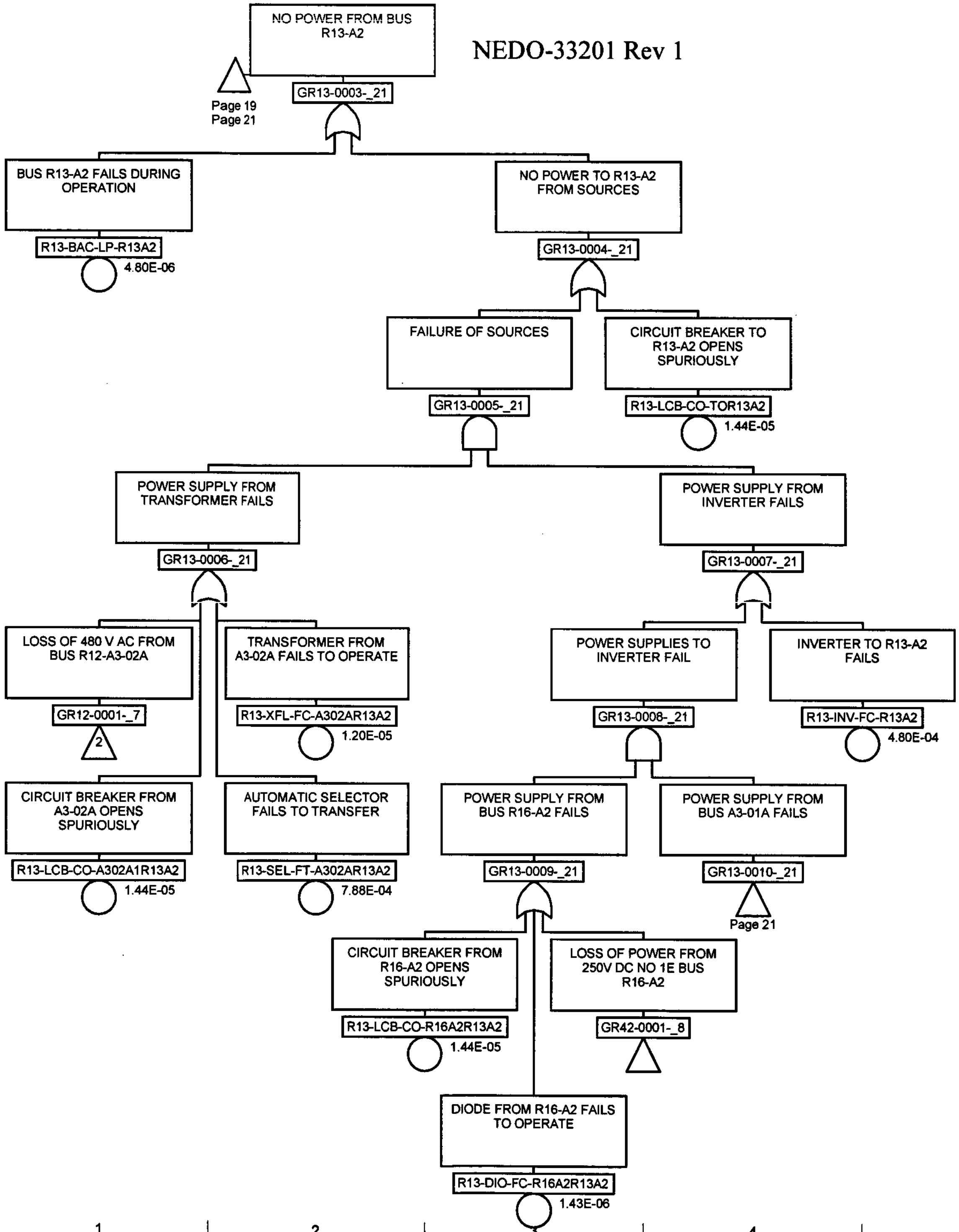
NO POWER FROM BUS R13-A2
GR13-0003-_21
Page 19
Page 21
BUS R13-A2 FAILS DURING OPERATION
R13-BAC-LP-R13A2
4.80E-06
NO POWER TO R13-A2 FROM SOURCES
GR13-0004-_21
FAILURE OF SOURCES
GR13-0005-_21
CIRCUIT BREAKER TO R13-A2 OPENS SPURIOUSLY
R13-LCB-CO-TOR13A2
1.44E-05
POWER SUPPLY FROM TRANSFORMER FAILS
GR13-0006-_21
POWER SUPPLY FROM INVERTER FAILS
GR13-0007-_21
LOSS OF 480 V AC FROM BUS R12-A3-02A
GR12-0001-_7
2
TRANSFORMER FROM A3-02A FAILS TO OPERATE
R13-XFL-FC-A302AR13A2
1.20E-05
POWER SUPPLIES TO INVERTER FAIL
GR13-0008-_21
INVERTER TO R13-A2 FAILS
R13-INV-FC-R13A2
4.80E-04
CIRCUIT BREAKER FROM A3-02A OPENS SPURIOUSLY
R13-LCB-CO-A302A1R13A2
1.44E-05
AUTOMATIC SELECTOR FAILS TO TRANSFER
R13-SEL-FT-A302AR13A2
7.88E-04
POWER SUPPLY FROM BUS R16-A2 FAILS
GR13-0009-_21
POWER SUPPLY FROM BUS A3-01A FAILS
GR13-0010-_21
Page 21
CIRCUIT BREAKER FROM R16-A2 OPENS SPURIOUSLY
R13-LCB-CO-R16A2R13A2
1.44E-05
LOSS OF POWER FROM 250V DC NO 1E BUS R16-A2
GR42-0001-_8
DIODE FROM R16-A2 FAILS TO OPERATE
R13-DIO-FC-R16A2R13A2
1.43E-06
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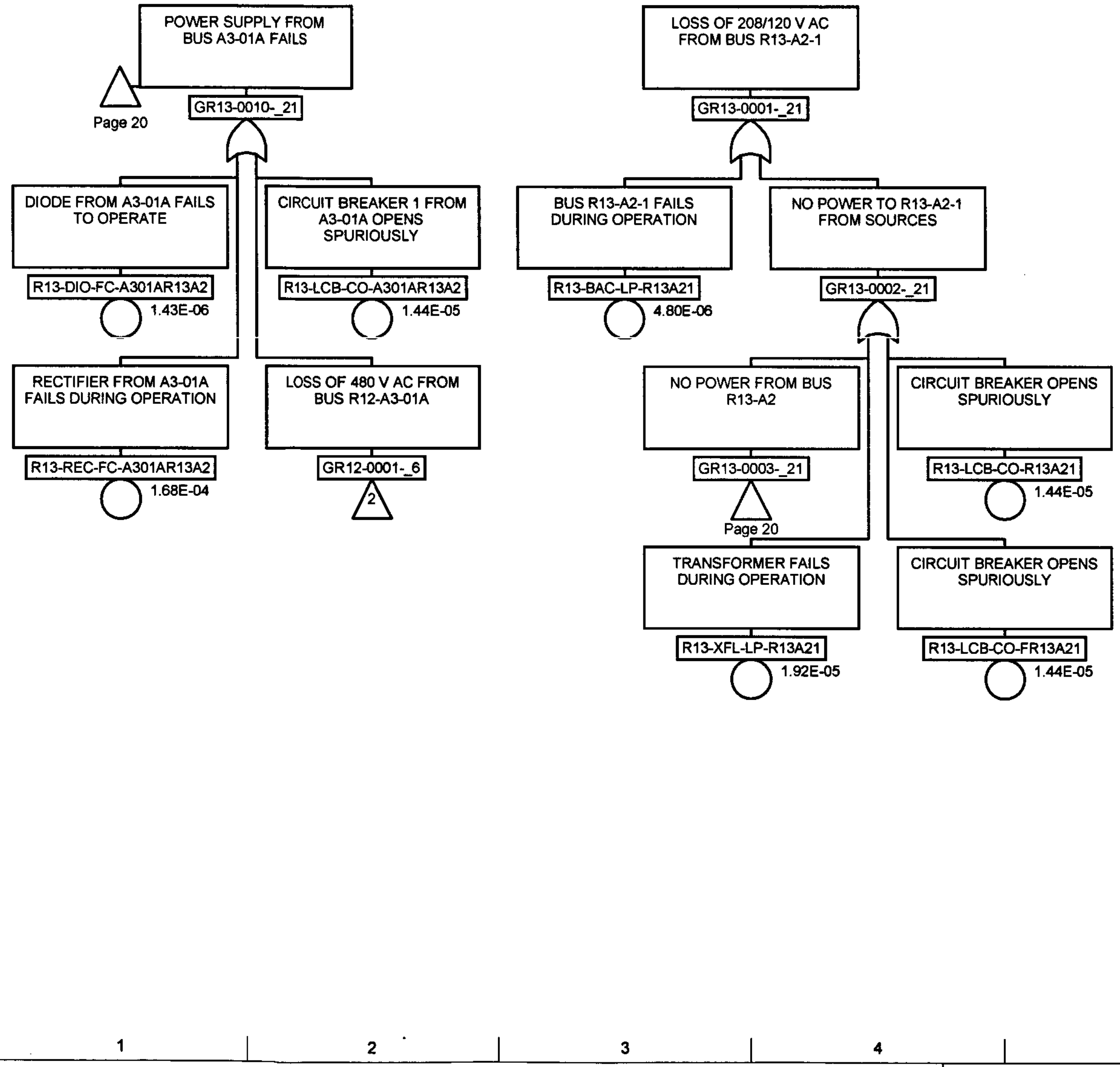
POWER SUPPLY FROM BUS A3-01A FAILS
GR13-0010-_21
Page 20
DIODE FROM A3-01A FAILS TO OPERATE
R13-DIO-FC-A301AR13A2
1.43E-06
CIRCUIT BREAKER 1 FROM A3-01A OPENS SPURIOUSLY
R13-LCB-CO-A301AR13A2
1.44E-05
RECTIFIER FROM A3-01A FAILS DURING OPERATION
R13-REC-FC-A301AR13A2
1.68E-04
LOSS OF 480 V AC FROM BUS R12-A3-01A
GR12-0001-_6
2
LOSS OF 208/120 V AC FROM BUS R13-A2-1
GR13-0001-_21
BUS R13-A2-1 FAILS DURING OPERATION
R13-BAC-LP-R13A21
4.80E-06
NO POWER TO R13-A2-1 FROM SOURCES
GR13-0002-_21
NO POWER FROM BUS R13-A2
GR13-0003-_21
Page 20
CIRCUIT BREAKER OPENS SPURIOUSLY
R13-LCB-CO-R13A21
1.44E-05
TRANSFORMER FAILS DURING OPERATION
R13-XFL-LP-R13A21
1.92E-05
CIRCUIT BREAKER OPENS SPURIOUSLY
R13-LCB-CO-FR13A21
1.44E-05
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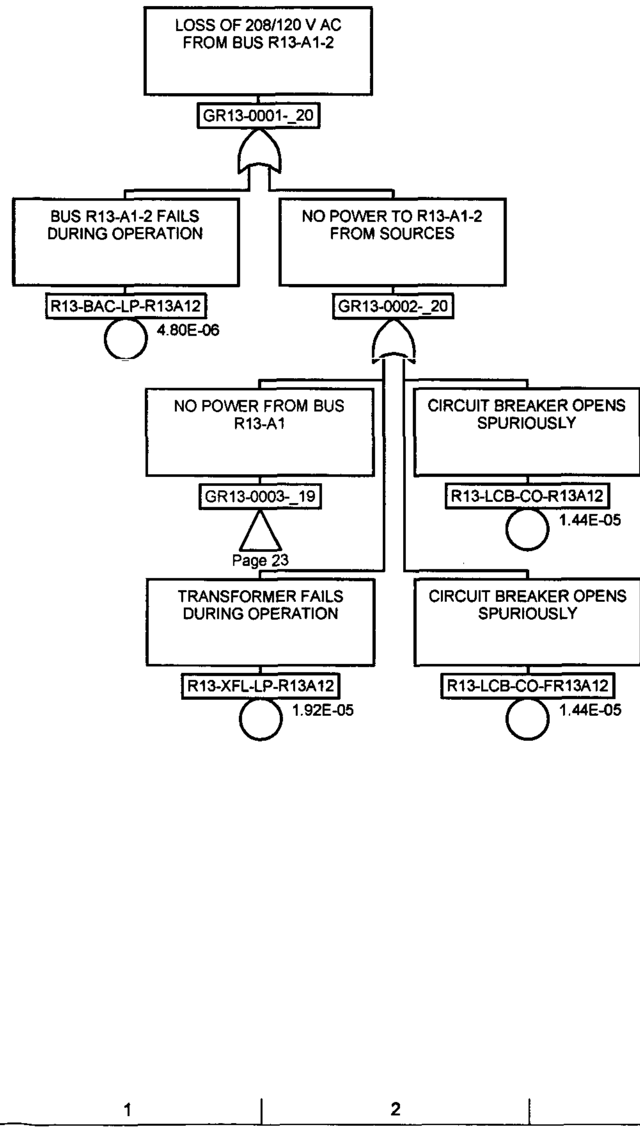
LOSS OF 208/120 V AC
FROM BUS R13-A1-2
GR13-0001-_20
BUS R13-A1-2 FAILS
DURING OPERATION
R13-BAC-LP-R13A12
4.80E-06
NO POWER TO R13-A1-2
FROM SOURCES
GR13-0002-_20
NO POWER FROM BUS
R13-A1
GR13-0003-_19
Page 23
CIRCUIT BREAKER OPENS
SPURIOUSLY
R13-LCB-CO-R13A12
1.44E-05
TRANSFORMER FAILS
DURING OPERATION
R13-XFL-LP-R13A12
1.92E-05
CIRCUIT BREAKER OPENS
SPURIOUSLY
R13-LCB-CO-FR13A12
1.44E-05
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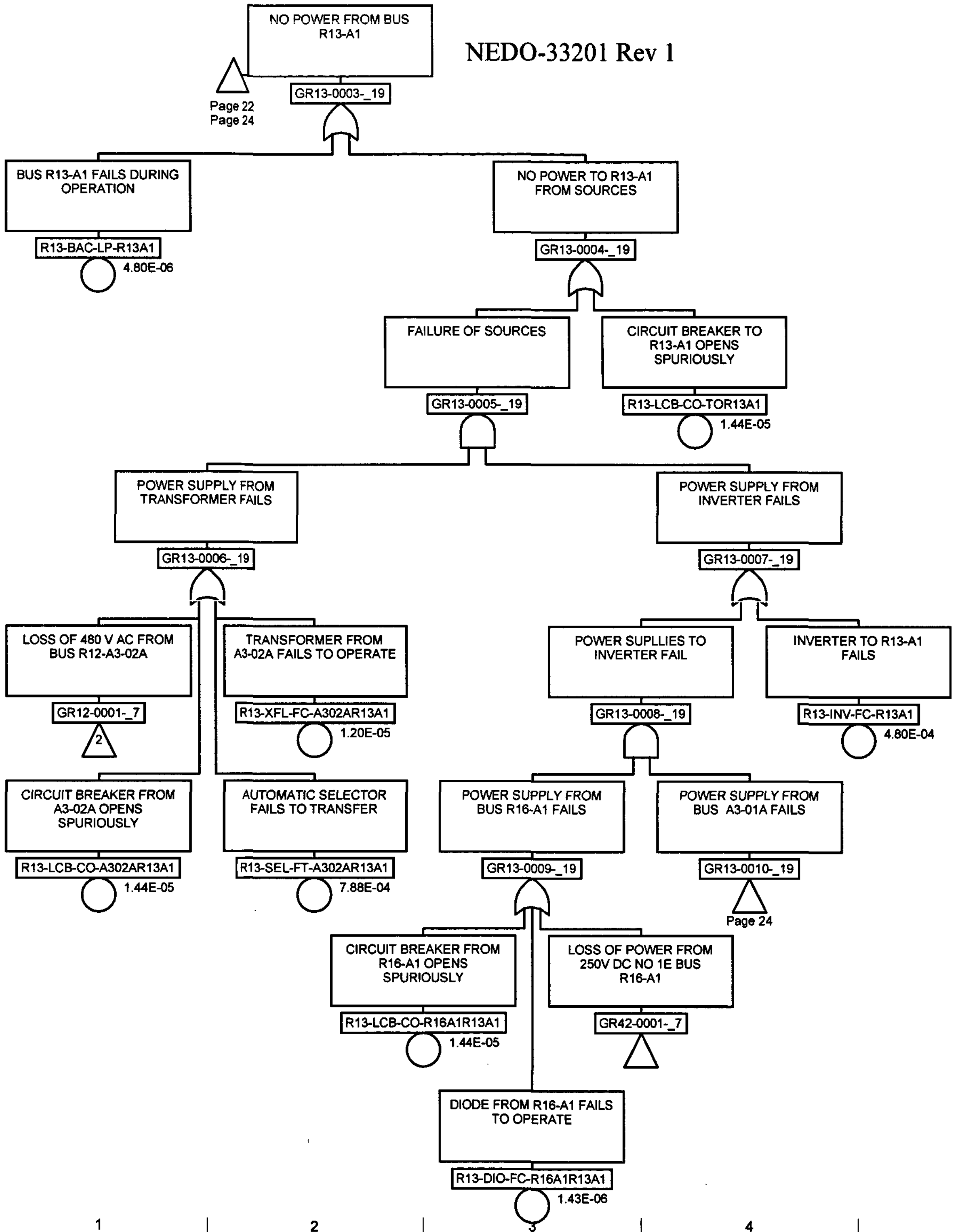
NO POWER FROM BUS R13-A1
GR13-0003-_19
Page 22
Page 24
BUS R13-A1 FAILS DURING OPERATION
R13-BAC-LP-R13A1
4.80E-06
NO POWER TO R13-A1 FROM SOURCES
GR13-0004-_19
FAILURE OF SOURCES
GR13-0005-_19
CIRCUIT BREAKER TO R13-A1 OPENS SPURIOUSLY
R13-LCB-CO-TOR13A1
1.44E-05
POWER SUPPLY FROM TRANSFORMER FAILS
GR13-0006-_19
POWER SUPPLY FROM INVERTER FAILS
GR13-0007-_19
LOSS OF 480 V AC FROM BUS R12-A3-02A
GR12-0001-_7
2
TRANSFORMER FROM A3-02A FAILS TO OPERATE
R13-XFL-FC-A302AR13A1
1.20E-05
POWER SUPLLIES TO INVERTER FAIL
GR13-0008-_19
INVERTER TO R13-A1 FAILS
R13-INV-FC-R13A1
4.80E-04
CIRCUIT BREAKER FROM A3-02A OPENS SPURIOUSLY
R13-LCB-CO-A302AR13A1
1.44E-05
AUTOMATIC SELECTOR FAILS TO TRANSFER
R13-SEL-FT-A302AR13A1
7.88E-04
POWER SUPPLY FROM BUS R16-A1 FAILS
GR13-0009-_19
POWER SUPPLY FROM BUS A3-01A FAILS
GR13-0010-_19
Page 24
CIRCUIT BREAKER FROM R16-A1 OPENS SPURIOUSLY
R13-LCB-CO-R16A1R13A1
1.44E-05
LOSS OF POWER FROM 250V DC NO 1E BUS R16-A1
GR42-0001-_7
DIODE FROM R16-A1 FAILS TO OPERATE
R13-DIO-FC-R16A1R13A1
1.43E-06
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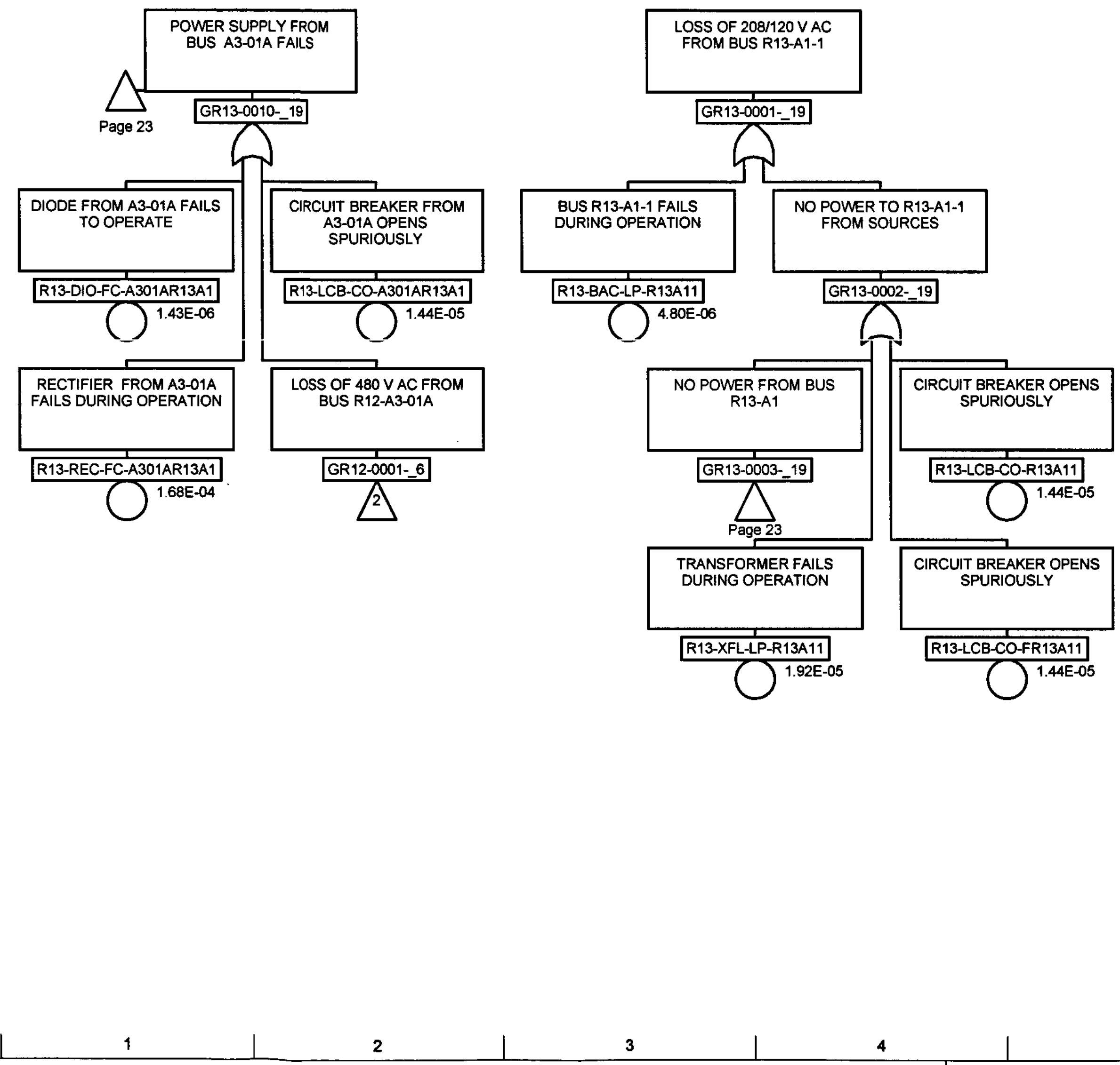
POWER SUPPLY FROM BUS A3-01A FAILS
GR13-0010-_19
Page 23
DIODE FROM A3-01A FAILS TO OPERATE
R13-DIO-FC-A301AR13A1
1.43E-06
CIRCUIT BREAKER FROM A3-01A OPENS SPURIOUSLY
R13-LCB-CO-A301AR13A1
1.44E-05
RECTIFIER FROM A3-01A FAILS DURING OPERATION
R13-REC-FC-A301AR13A1
1.68E-04
LOSS OF 480 V AC FROM BUS R12-A3-01A
GR12-0001-_6
2
LOSS OF 208/120 V AC FROM BUS R13-A1-1
GR13-0001-_19
BUS R13-A1-1 FAILS DURING OPERATION
R13-BAC-LP-R13A11
4.80E-06
NO POWER TO R13-A1-1 FROM SOURCES
GR13-0002-_19
NO POWER FROM BUS R13-A1
GR13-0003-_19
Page 23
CIRCUIT BREAKER OPENS SPURIOUSLY
R13-LCB-CO-R13A11
1.44E-05
TRANSFORMER FAILS DURING OPERATION
R13-XFL-LP-R13A11
1.92E-05
CIRCUIT BREAKER OPENS SPURIOUSLY
R13-LCB-CO-FR13A11
1.44E-05
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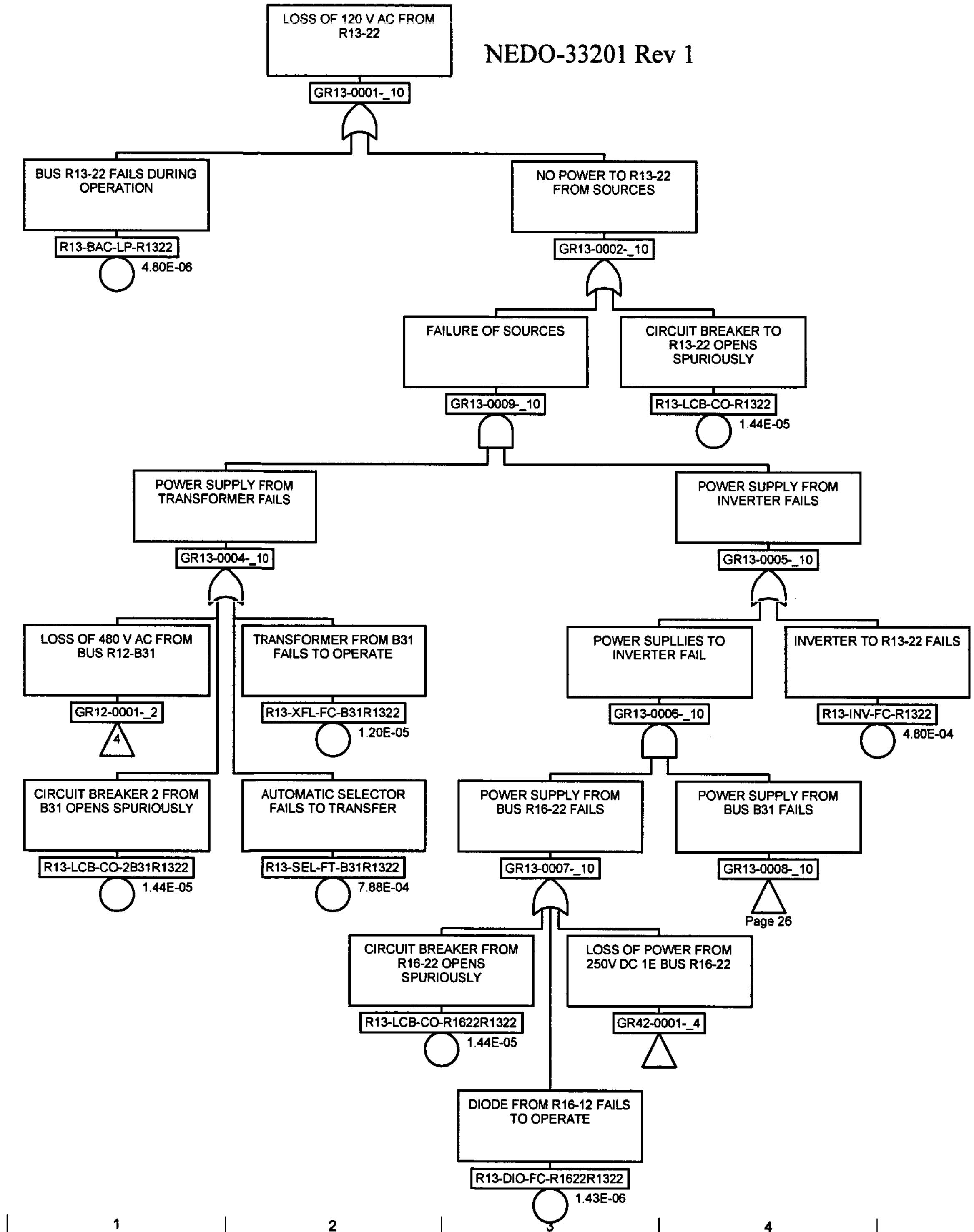
LOSS OF 120 V AC FROM R13-22
GR13-0001-_10
BUS R13-22 FAILS DURING OPERATION
R13-BAC-LP-R1322
4.80E-06
NO POWER TO R13-22 FROM SOURCES
GR13-0002-_10
FAILURE OF SOURCES
GR13-0009-_10
CIRCUIT BREAKER TO R13-22 OPENS SPURIOUSLY
R13-LCB-CO-R1322
1.44E-05
POWER SUPPLY FROM TRANSFORMER FAILS
GR13-0004-_10
POWER SUPPLY FROM INVERTER FAILS
GR13-0005-_10
LOSS OF 480 V AC FROM BUS R12-B31
GR12-0001-_2
4
TRANSFORMER FROM B31 FAILS TO OPERATE
R13-XFL-FC-B31R1322
1.20E-05
CIRCUIT BREAKER 2 FROM B31 OPENS SPURIOUSLY
R13-LCB-CO-2B31R1322
1.44E-05
AUTOMATIC SELECTOR FAILS TO TRANSFER
R13-SEL-FT-B31R1322
7.88E-04
POWER SUPLLIES TO INVERTER FAIL
GR13-0006-_10
INVERTER TO R13-22 FAILS
R13-INV-FC-R1322
4.80E-04
POWER SUPPLY FROM BUS R16-22 FAILS
GR13-0007-_10
POWER SUPPLY FROM BUS B31 FAILS
GR13-0008-_10
Page 26
CIRCUIT BREAKER FROM R16-22 OPENS SPURIOUSLY
R13-LCB-CO-R1622R1322
1.44E-05
LOSS OF POWER FROM 250V DC 1E BUS R16-22
GR42-0001-_4
DIODE FROM R16-12 FAILS TO OPERATE
R13-DIO-FC-R1622R1322
1.43E-06
1
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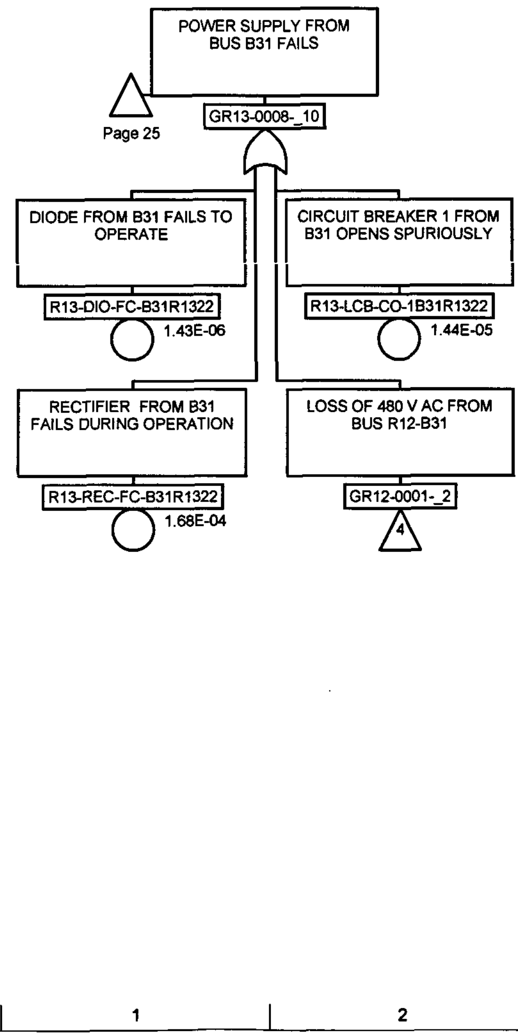
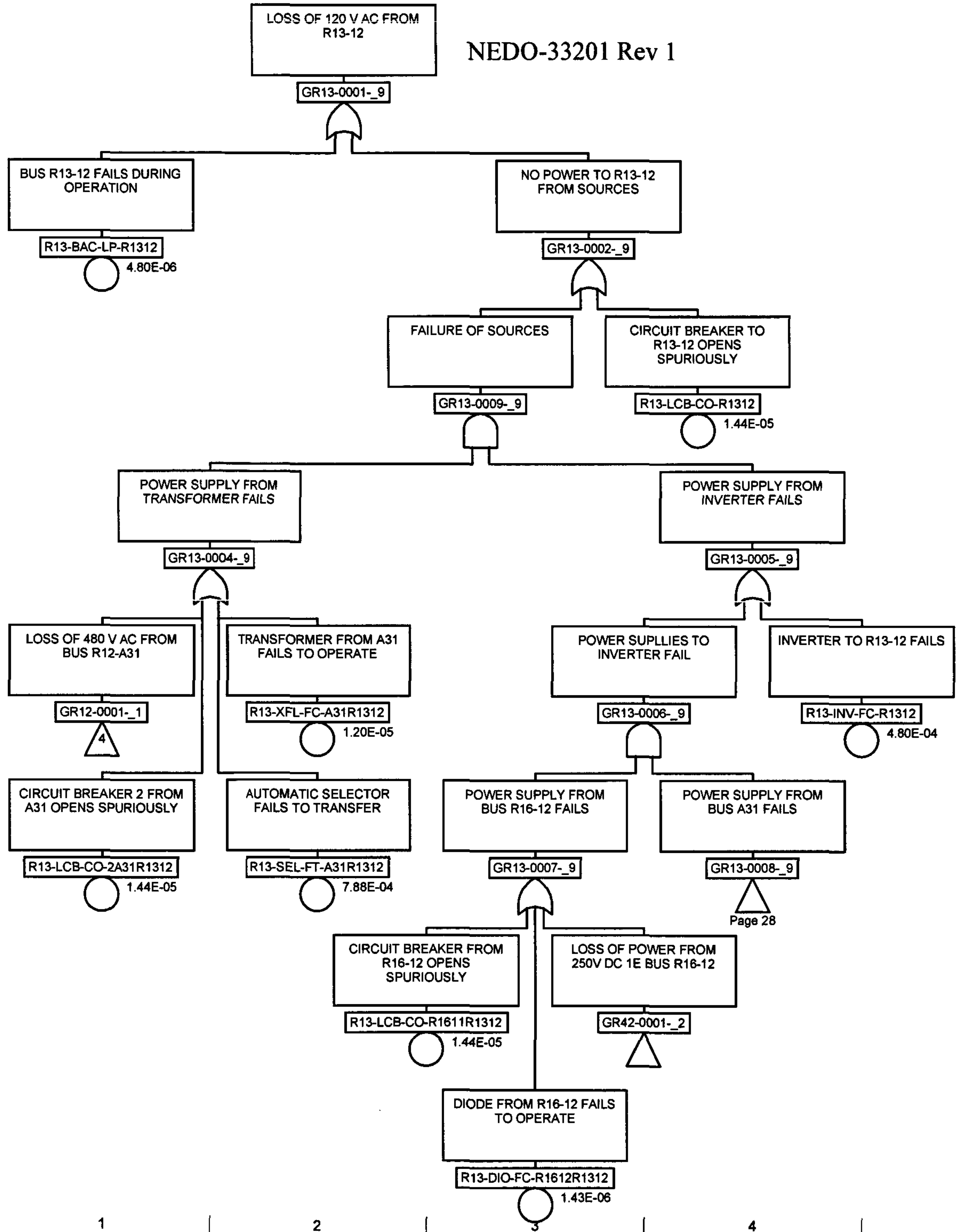

POWER SUPPLY FROM BUS B31 FAILS
GR13-0008-_10
Page 25
DIODE FROM B31 FAILS TO OPERATE
R13-DIO-FC-B31R1322
1.43E-06
CIRCUIT BREAKER 1 FROM B31 OPENS SPURIOUSLY
R13-LCB-CO-1B31R1322
1.44E-05
RECTIFIER FROM B31 FAILS DURING OPERATION
R13-REC-FC-B31R1322
1.68E-04
LOSS OF 480 V AC FROM BUS R12-B31
GR12-0001-_2
4
1
2


LOSS OF 120 V AC FROM R13-12
GR13-0001-_9
BUS R13-12 FAILS DURING OPERATION
R13-BAC-LP-R1312
4.80E-06
NO POWER TO R13-12 FROM SOURCES
GR13-0002-_9
FAILURE OF SOURCES
GR13-0009-_9
CIRCUIT BREAKER TO R13-12 OPENS SPURIOUSLY
R13-LCB-CO-R1312
1.44E-05
POWER SUPPLY FROM TRANSFORMER FAILS
GR13-0004-_9
POWER SUPPLY FROM INVERTER FAILS
GR13-0005-_9
LOSS OF 480 V AC FROM BUS R12-A31
GR12-0001-_1
4
TRANSFORMER FROM A31 FAILS TO OPERATE
R13-XFL-FC-A31R1312
1.20E-05
POWER SUPLLIES TO INVERTER FAIL
GR13-0006-_9
INVERTER TO R13-12 FAILS
R13-INV-FC-R1312
4.80E-04
CIRCUIT BREAKER 2 FROM A31 OPENS SPURIOUSLY
R13-LCB-CO-2A31R1312
1.44E-05
AUTOMATIC SELECTOR FAILS TO TRANSFER
R13-SEL-FT-A31R1312
7.88E-04
POWER SUPPLY FROM BUS R16-12 FAILS
GR13-0007-_9
POWER SUPPLY FROM BUS A31 FAILS
GR13-0008-_9
Page 28
CIRCUIT BREAKER FROM R16-12 OPENS SPURIOUSLY
R13-LCB-CO-R1611R1312
1.44E-05
LOSS OF POWER FROM 250V DC 1E BUS R16-12
GR42-0001-_2
DIODE FROM R16-12 FAILS TO OPERATE
R13-DIO-FC-R1612R1312
1.43E-06
1
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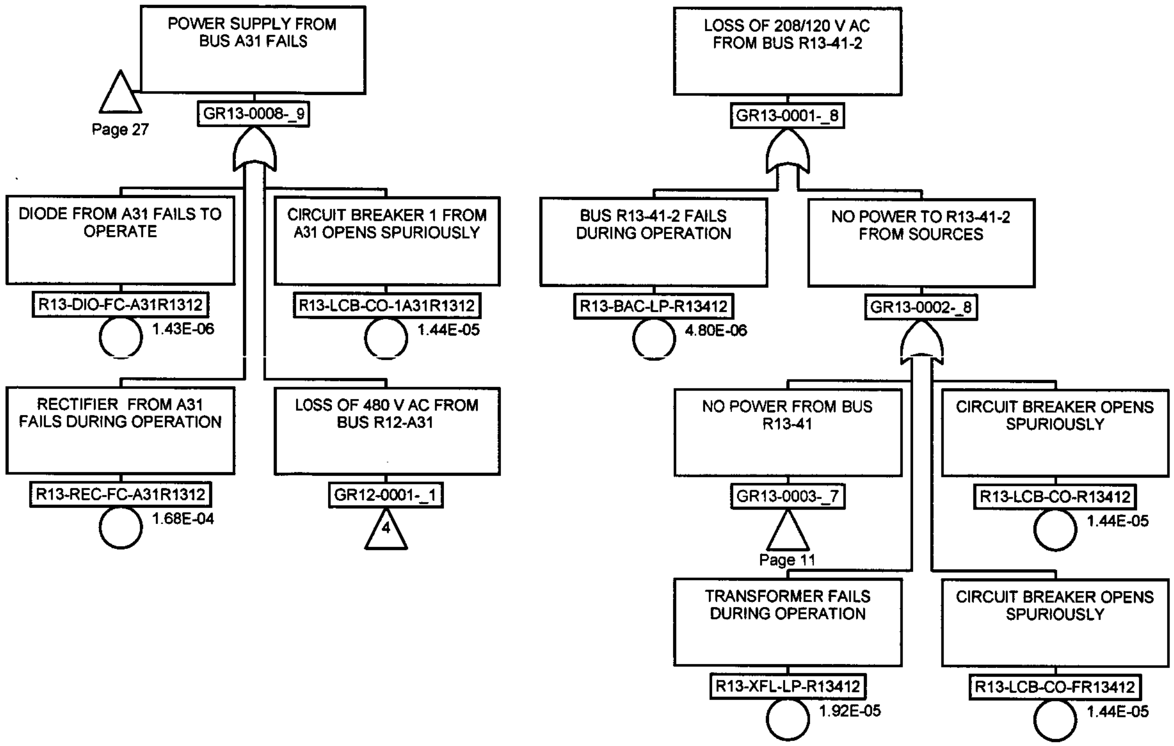
POWER SUPPLY FROM BUS A31 FAILS
GR13-0008-_9
Page 27
DIODE FROM A31 FAILS TO OPERATE
R13-DIO-FC-A31R1312
1.43E-06
CIRCUIT BREAKER 1 FROM A31 OPENS SPURIOUSLY
R13-LCB-CO-1A31R1312
1.44E-05
RECTIFIER FROM A31 FAILS DURING OPERATION
R13-REC-FC-A31R1312
1.68E-04
LOSS OF 480 V AC FROM BUS R12-A31
GR12-0001-_1
4
LOSS OF 208/120 V AC FROM BUS R13-41-2
GR13-0001-_8
BUS R13-41-2 FAILS DURING OPERATION
R13-BAC-LP-R13412
4.80E-06
NO POWER TO R13-41-2 FROM SOURCES
GR13-0002-_8
NO POWER FROM BUS R13-41
GR13-0003-_7
Page 11
CIRCUIT BREAKER OPENS SPURIOUSLY
R13-LCB-CO-R13412
1.44E-05
TRANSFORMER FAILS DURING OPERATION
R13-XFL-LP-R13412
1.92E-05
CIRCUIT BREAKER OPENS SPURIOUSLY
R13-LCB-CO-FR13412
1.44E-05
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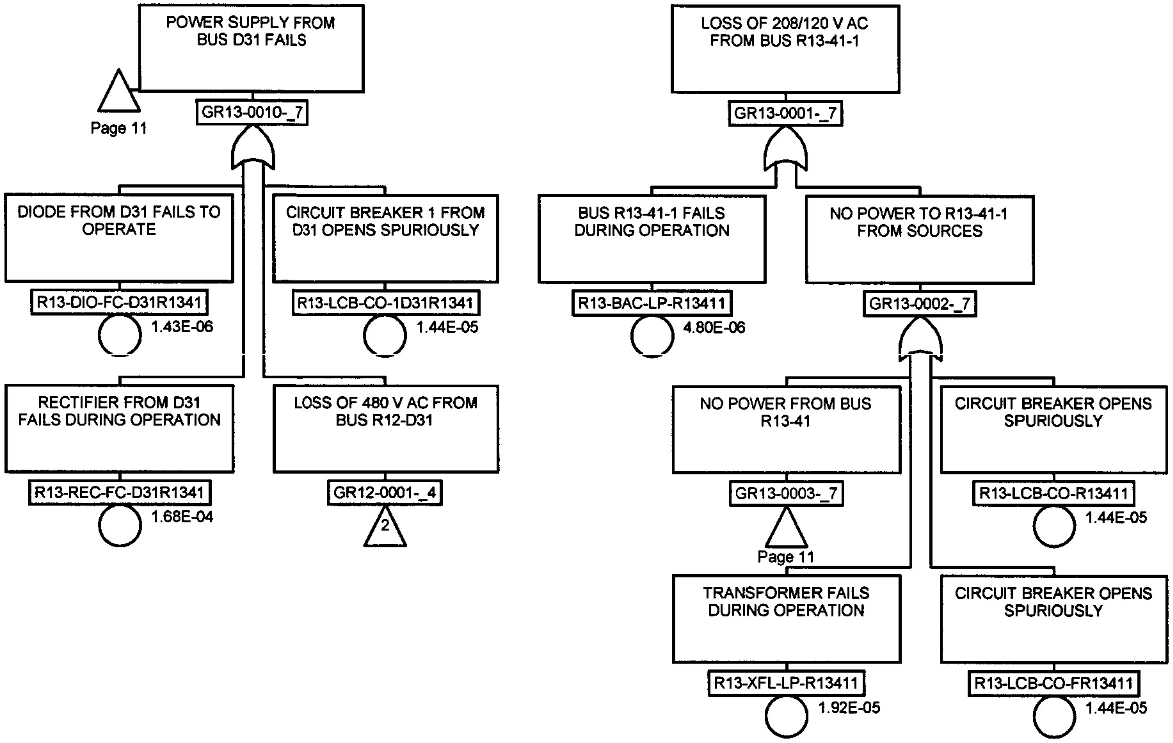
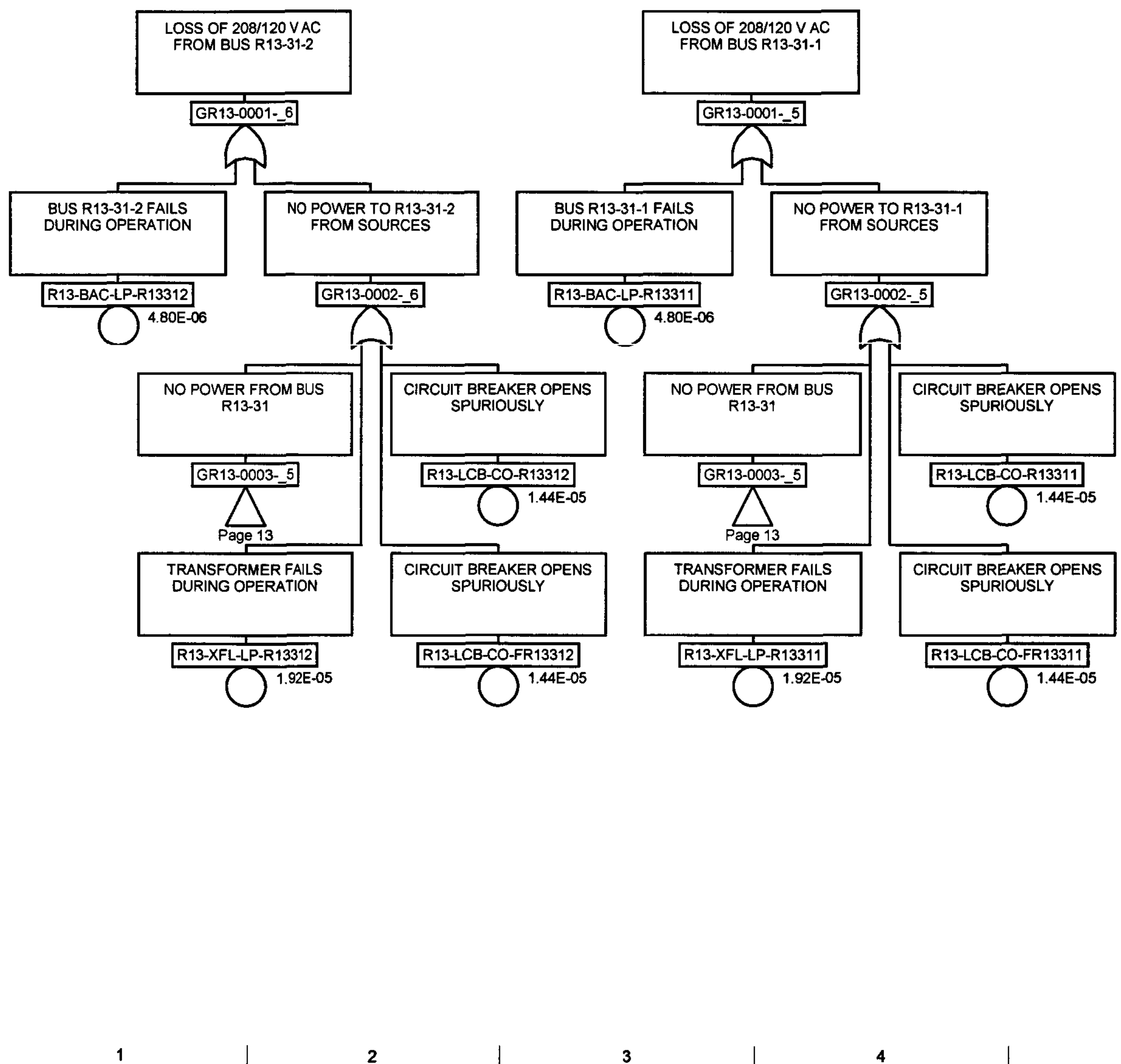

POWER SUPPLY FROM BUS D31 FAILS
GR13-0010-_7
Page 11
DIODE FROM D31 FAILS TO OPERATE
R13-DIO-FC-D31R1341
1.43E-06
CIRCUIT BREAKER 1 FROM D31 OPENS SPURIOUSLY
R13-LCB-CO-1D31R1341
1.44E-05
RECTIFIER FROM D31 FAILS DURING OPERATION
R13-REC-FC-D31R1341
1.68E-04
LOSS OF 480 V AC FROM BUS R12-D31
GR12-0001-_4
2
LOSS OF 208/120 V AC FROM BUS R13-41-1
GR13-0001-_7
BUS R13-41-1 FAILS DURING OPERATION
R13-BAC-LP-R13411
4.80E-06
NO POWER TO R13-41-1 FROM SOURCES
GR13-0002-_7
NO POWER FROM BUS R13-41
GR13-0003-_7
Page 11
CIRCUIT BREAKER OPENS SPURIOUSLY
R13-LCB-CO-R13411
1.44E-05
TRANSFORMER FAILS DURING OPERATION
R13-XFL-LP-R13411
1.92E-05
CIRCUIT BREAKER OPENS SPURIOUSLY
R13-LCB-CO-FR13411
1.44E-05


LOSS OF 208/120 V AC FROM BUS R13-31-2
GR13-0001-_6
BUS R13-31-2 FAILS DURING OPERATION
R13-BAC-LP-R13312
4.80E-06
NO POWER TO R13-31-2 FROM SOURCES
GR13-0002-_6
NO POWER FROM BUS R13-31
GR13-0003-_5
Page 13
CIRCUIT BREAKER OPENS SPURIOUSLY
R13-LCB-CO-R13312
1.44E-05
TRANSFORMER FAILS DURING OPERATION
R13-XFL-LP-R13312
1.92E-05
CIRCUIT BREAKER OPENS SPURIOUSLY
R13-LCB-CO-FR13312
1.44E-05
LOSS OF 208/120 V AC FROM BUS R13-31-1
GR13-0001-_5
BUS R13-31-1 FAILS DURING OPERATION
R13-BAC-LP-R13311
4.80E-06
NO POWER TO R13-31-1 FROM SOURCES
GR13-0002-_5
NO POWER FROM BUS R13-31
GR13-0003-_5
Page 13
CIRCUIT BREAKER OPENS SPURIOUSLY
R13-LCB-CO-R13311
1.44E-05
TRANSFORMER FAILS DURING OPERATION
R13-XFL-LP-R13311
1.92E-05
CIRCUIT BREAKER OPENS SPURIOUSLY
R13-LCB-CO-FR13311
1.44E-05
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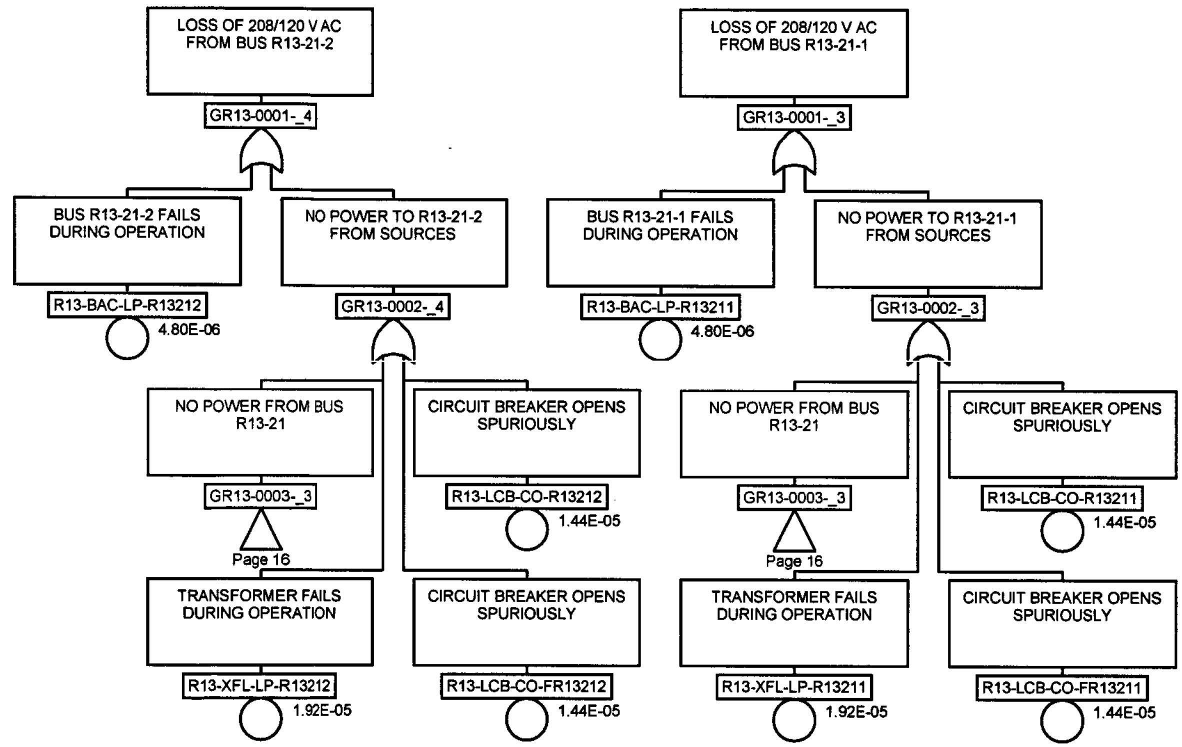
LOSS OF 208/120 V AC FROM BUS R13-21-2
GR13-0001-_4
BUS R13-21-2 FAILS DURING OPERATION
R13-BAC-LP-R13212
4.80E-06
NO POWER TO R13-21-2 FROM SOURCES
GR13-0002-_4
NO POWER FROM BUS R13-21
GR13-0003-_3
Page 16
CIRCUIT BREAKER OPENS SPURIOUSLY
R13-LCB-CO-R13212
1.44E-05
TRANSFORMER FAILS DURING OPERATION
R13-XFL-LP-R13212
1.92E-05
CIRCUIT BREAKER OPENS SPURIOUSLY
R13-LCB-CO-FR13212
1.44E-05
LOSS OF 208/120 V AC FROM BUS R13-21-1
GR13-0001-_3
BUS R13-21-1 FAILS DURING OPERATION
R13-BAC-LP-R13211
4.80E-06
NO POWER TO R13-21-1 FROM SOURCES
GR13-0002-_3
NO POWER FROM BUS R13-21
GR13-0003-_3
Page 16
CIRCUIT BREAKER OPENS SPURIOUSLY
R13-LCB-CO-R13211
1.44E-05
TRANSFORMER FAILS DURING OPERATION
R13-XFL-LP-R13211
1.92E-05
CIRCUIT BREAKER OPENS SPURIOUSLY
R13-LCB-CO-FR13211
1.44E-05
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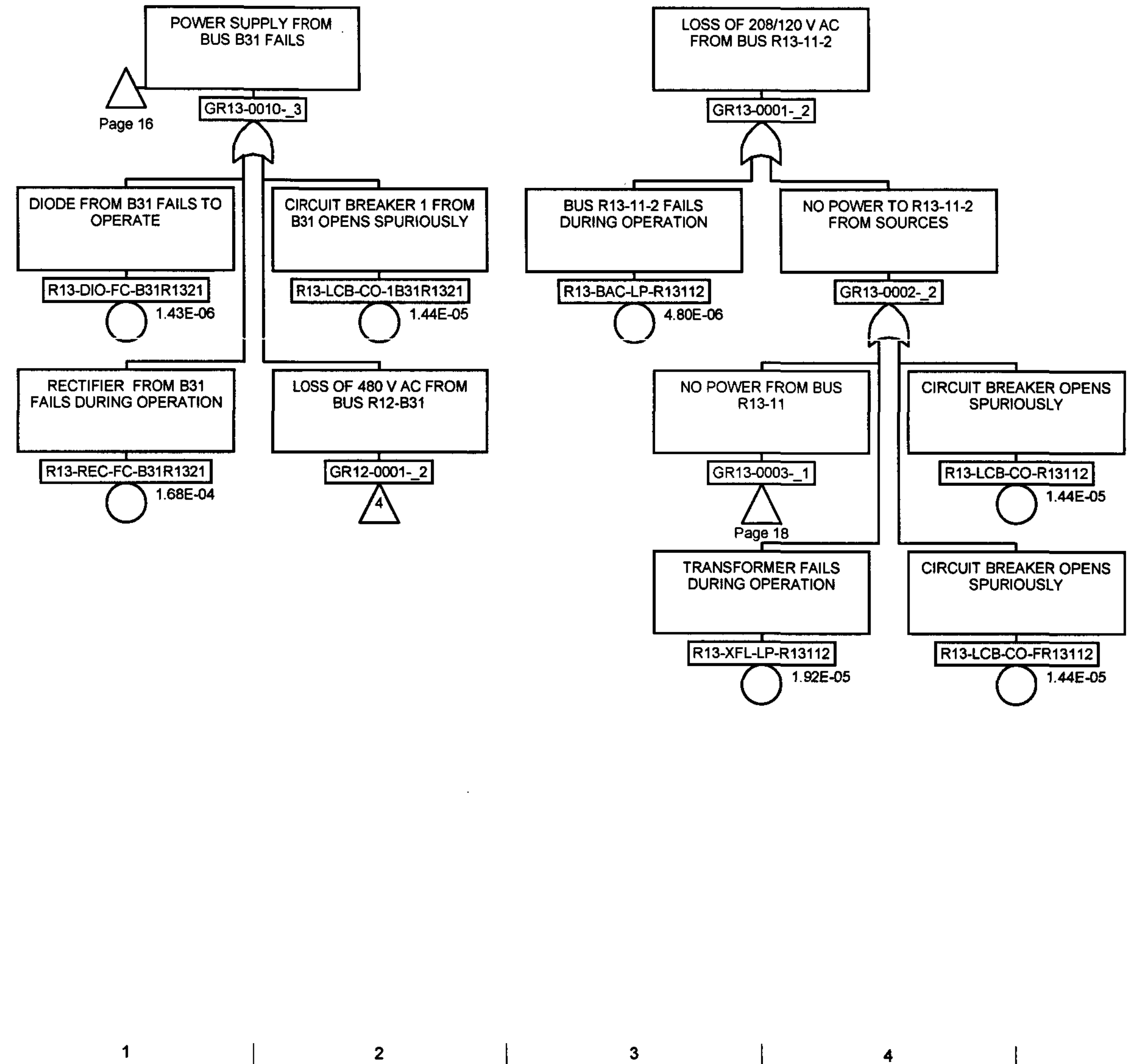
POWER SUPPLY FROM BUS B31 FAILS
Page 16
GR13-0010-_3
DIODE FROM B31 FAILS TO OPERATE
R13-DIO-FC-B31R1321
1.43E-06
CIRCUIT BREAKER 1 FROM B31 OPENS SPURIOUSLY
R13-LCB-CO-1B31R1321
1.44E-05
RECTIFIER FROM B31 FAILS DURING OPERATION
R13-REC-FC-B31R1321
1.68E-04
LOSS OF 480 V AC FROM BUS R12-B31
GR12-0001-_2
4
LOSS OF 208/120 V AC FROM BUS R13-11-2
GR13-0001-_2
BUS R13-11-2 FAILS DURING OPERATION
R13-BAC-LP-R13112
4.80E-06
NO POWER TO R13-11-2 FROM SOURCES
GR13-0002-_2
NO POWER FROM BUS R13-11
GR13-0003-_1
Page 18
CIRCUIT BREAKER OPENS SPURIOUSLY
R13-LCB-CO-R13112
1.44E-05
TRANSFORMER FAILS DURING OPERATION
R13-XFL-LP-R13112
1.92E-05
CIRCUIT BREAKER OPENS SPURIOUSLY
R13-LCB-CO-FR13112
1.44E-05
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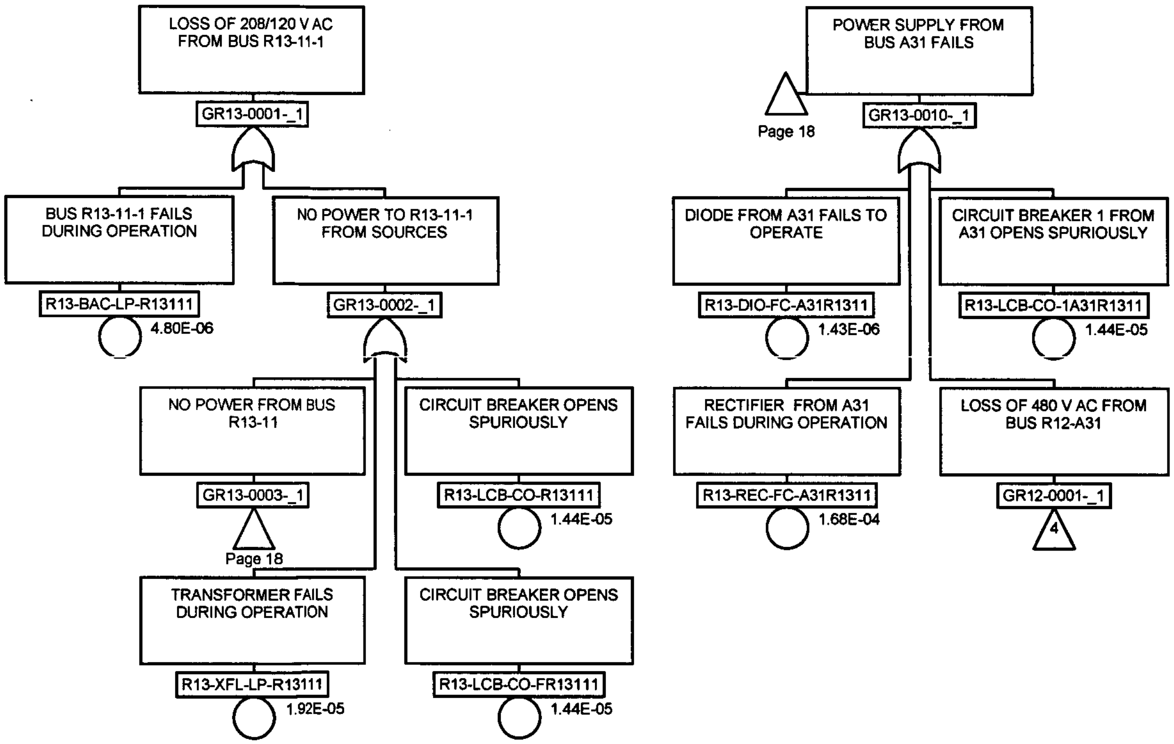

LOSS OF 208/120 V AC FROM BUS R13-11-1
GR13-0001-_1
BUS R13-11-1 FAILS DURING OPERATION
R13-BAC-LP-R13111
4.80E-06
NO POWER TO R13-11-1 FROM SOURCES
GR13-0002-_1
NO POWER FROM BUS R13-11
GR13-0003-_1
Page 18
CIRCUIT BREAKER OPENS SPURIOUSLY
R13-LCB-CO-R13111
1.44E-05
TRANSFORMER FAILS DURING OPERATION
R13-XFL-LP-R13111
1.92E-05
CIRCUIT BREAKER OPENS SPURIOUSLY
R13-LCB-CO-FR13111
1.44E-05
POWER SUPPLY FROM BUS A31 FAILS
Page 18
GR13-0010-_1
DIODE FROM A31 FAILS TO OPERATE
R13-DIO-FC-A31R1311
1.43E-06
CIRCUIT BREAKER 1 FROM A31 OPENS SPURIOUSLY
R13-LCB-CO-1A31R1311
1.44E-05
RECTIFIER FROM A31 FAILS DURING OPERATION
R13-REC-FC-A31R1311
1.68E-04
LOSS OF 480 V AC FROM BUS R12-A31
GR12-0001-_1
4

Name	Page	Zone	Name	Page	Zone	Name	Page	Zone
GR12-0001- 1	18	1	GR13-0002- 12	17	4	GR13-0003- 5	14	2
GR12-0001- 1	27	1	GR13-0002- 13	17	2	GR13-0003- 5	30	2
GR12-0001- 1	28	2	GR13-0002- 14	15	2	GR13-0003- 5	30	4
GR12-0001- 1	33	5	GR13-0002- 15	14	2	GR13-0003- 7	10	2
GR12-0001- 10	5	1	GR13-0002- 16	12	4	GR13-0003- 7	11	2
GR12-0001- 10	8	1	GR13-0002- 17	12	2	GR13-0003- 7	12	2
GR12-0001- 2	16	1	GR13-0002- 18	10	2	GR13-0003- 7	28	4
GR12-0001- 2	25	1	GR13-0002- 19	24	4	GR13-0003- 7	29	4
GR12-0001- 2	26	2	GR13-0002- 2	32	4	GR13-0004- 1	18	3
GR12-0001- 2	32	2	GR13-0002- 20	22	2	GR13-0004- 10	25	2
GR12-0001- 3	13	1	GR13-0002- 21	21	4	GR13-0004- 19	23	3
GR12-0001- 3	14	5	GR13-0002- 22	19	4	GR13-0004- 21	20	3
GR12-0001- 4	11	1	GR13-0002- 23	9	4	GR13-0004- 23	8	3
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GR12-0001- 6	24	2	GR13-0002- 27	4	2	GR13-0004- 5	13	3
GR12-0001- 7	20	1	GR13-0002- 28	3	4	GR13-0004- 7	11	3
GR12-0001- 7	23	1	GR13-0002- 29	1	2	GR13-0004- 9	27	2
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GR13-0001- 8	28	4	GR13-0003- 3	17	2	GR13-0007- 5	13	4
GR13-0001- 9	27	2	GR13-0003- 3	31	2	GR13-0007- 7	11	4
GR13-0002- 1	33	2	GR13-0003- 3	31	4	GR13-0007- 9	27	3
GR13-0002- 10	25	3	GR13-0003- 5	12	4	GR13-0008- 1	18	4
GR13-0002-_11	19	2	GR13-0003-_5	13	2	GR13-0008-_10	25	4

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GR13-0008- 19	23	4	R13-BAC-LP-R13114	17	3	R13-DIO-FC-R16B2R13B2	5	3
GR13-0008- 21	20	4	R13-BAC-LP-R1312	27	1	R13-DIO-FC-R16CR13C	2	3
GR13-0008- 23	8	4	R13-BAC-LP-R1321	16	1	R13-INV-FC-R1311	18	5
GR13-0008- 25	5	4	R13-BAC-LP-R13211	31	3	R13-INV-FC-R1312	27	5
GR13-0008- 27	2	4	R13-BAC-LP-R13212	31	1	R13-INV-FC-R1321	16	5
GR13-0008- 3	16	4	R13-BAC-LP-R13213	17	1	R13-INV-FC-R1322	25	5
GR13-0008- 5	13	4	R13-BAC-LP-R13214	15	1	R13-INV-FC-R1331	13	5
GR13-0008- 7	11	4	R13-BAC-LP-R1322	25	1	R13-INV-FC-R1341	11	5
GR13-0008- 9	27	4	R13-BAC-LP-R1331	13	1	R13-INV-FC-R13A1	23	5
GR13-0008- 9	28	2	R13-BAC-LP-R13311	30	3	R13-INV-FC-R13A2	20	5
GR13-0009- 1	18	3	R13-BAC-LP-R13312	30	1	R13-INV-FC-R13B1	8	5
GR13-0009- 10	25	3	R13-BAC-LP-R13313	14	1	R13-INV-FC-R13B2	5	5
GR13-0009- 19	23	3	R13-BAC-LP-R13314	12	3	R13-INV-FC-R13C	2	5
GR13-0009- 21	20	3	R13-BAC-LP-R1341	11	1	R13-LCB-CO-1A31R1311	33	4
GR13-0009- 23	8	3	R13-BAC-LP-R13411	29	3	R13-LCB-CO-1A31R1312	28	2
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GR13-0009- 3	16	3	R13-BAC-LP-R13414	10	1	R13-LCB-CO-1C31R1331	14	4
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GR13-0010- 21	21	2	R13-BAC-LP-R13B12	7	1	R13-LCB-CO-A301AR13A1	24	2
GR13-0010- 23	8	4	R13-BAC-LP-R13B2	5	1	R13-LCB-CO-A301AR13A2	21	2
GR13-0010- 23	9	2	R13-BAC-LP-R13B21	6	3	R13-LCB-CO-A302A1R13A2	20	1
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GR13-0010- 25	6	2	R13-BAC-LP-R13C	2	1	R13-LCB-CO-B301BR13B1	9	2
GR13-0010- 27	2	4	R13-BAC-LP-R13C11	4	1	R13-LCB-CO-B301BR13B2	6	2
GR13-0010- 27	3	2	R13-BAC-LP-R13C12	3	3	R13-LCB-CO-B302B1R13B2	5	1
GR13-0010- 3	16	4	R13-BAC-LP-R13C13	1	1	R13-LCB-CO-B302BR13B1	8	1
GR13-0010- 3	32	2	R13-DIO-FC-A202AR13C	3	1	R13-LCB-CO-C23R13C	2	1
GR13-0010- 5	13	4	R13-DIO-FC-A301AR13A1	24	1	R13-LCB-CO-FR13111	33	3
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GR13-0010- 7	29	2	R13-DIO-FC-A31R1312	28	1	R13-LCB-CO-FR13114	17	5
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GR42-0001- 10	5	4	R13-DIO-FC-B302BR13B1	9	1	R13-LCB-CO-FR13212	31	3
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GR42-0001- 6	11	4	R13-DIO-FC-R1612R1312	27	3	R13-LCB-CO-FR13314	12	5
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R13-BAC-LP-R13111	33	1	R13-DIO-FC-R16A1R13A1	23	3	R13-LCB-CO-FR13A11	24	5
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Name	Page	Zone	Name	Page	Zone	Name	Page	Zone
R13-LCB-CO-FR13A21	21	5	R13-LCB-CO-TOR13A2	20	4	R13-XFL-LP-R13C12	3	4
R13-LCB-CO-FR13A22	19	5	R13-LCB-CO-TOR13B1	8	4	R13-XFL-LP-R13C13	1	2
R13-LCB-CO-FR13B11	9	5	R13-LCB-CO-TOR13B2	5	4			
R13-LCB-CO-FR13B12	7	3	R13-LCB-CO-TOR13C	2	4			
R13-LCB-CO-FR13B21	6	5	R13-REC-FC-A202AR13C	3	1			
R13-LCB-CO-FR13B22	4	5	R13-REC-FC-A301AR13A1	24	1			
R13-LCB-CO-FR13C11	4	3	R13-REC-FC-A301AR13A2	21	1			
R13-LCB-CO-FR13C12	3	5	R13-REC-FC-A31R1311	33	4			
R13-LCB-CO-FR13C13	1	3	R13-REC-FC-A31R1312	28	1			
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R13-LCB-CO-R13112	32	5	R13-REC-FC-B301BR13B2	6	1			
R13-LCB-CO-R13113	19	2	R13-REC-FC-B31R1321	32	1			
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R13-LCB-CO-R13211	31	5	R13-REC-FC-D31R1341	29	1			
R13-LCB-CO-R13212	31	3	R13-SEL-FT-A302AR13A1	23	2			
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R13-LCB-CO-R13214	15	2	R13-SEL-FT-A31R1311	18	2			
R13-LCB-CO-R1322	25	4	R13-SEL-FT-A31R1312	27	2			
R13-LCB-CO-R13311	30	5	R13-SEL-FT-B302BR13B1	8	2			
R13-LCB-CO-R13312	30	3	R13-SEL-FT-B302BR13B2	5	2			
R13-LCB-CO-R13313	14	2	R13-SEL-FT-B31R1321	16	2			
R13-LCB-CO-R13314	12	4	R13-SEL-FT-B31R1322	25	2			
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R13-LCB-CO-R13412	28	5	R13-SEL-FT-C31R1331	13	2			
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R13-LCB-CO-R13414	10	2	R13-XFL-FC-A302AR13A1	23	2			
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R13-LCB-CO-R13A12	22	3	R13-XFL-FC-A31R1311	18	2			
R13-LCB-CO-R13A21	21	5	R13-XFL-FC-A31R1312	27	2			
R13-LCB-CO-R13A22	19	5	R13-XFL-FC-B302BR13B1	8	2			
R13-LCB-CO-R13B11	9	5	R13-XFL-FC-B302BR13B2	5	2			
R13-LCB-CO-R13B12	7	3	R13-XFL-FC-B31R1321	16	2			
R13-LCB-CO-R13B21	6	5	R13-XFL-FC-B31R1322	25	2			
R13-LCB-CO-R13B22	4	5	R13-XFL-FC-C23R13C	2	2			
R13-LCB-CO-R13C11	4	3	R13-XFL-FC-C31R1331	13	2			
R13-LCB-CO-R13C12	3	5	R13-XFL-FC-D31R1341	11	2			
R13-LCB-CO-R13C13	1	3	R13-XFL-LP-R13111	33	2			
R13-LCB-CO-R1611R1311	18	3	R13-XFL-LP-R13112	32	4			
R13-LCB-CO-R1611R1312	27	3	R13-XFL-LP-R13211	31	4			
R13-LCB-CO-R1621R1321	16	3	R13-XFL-LP-R13212	31	2			
R13-LCB-CO-R1622R1322	25	3	R13-XFL-LP-R13311	30	4			
R13-LCB-CO-R1631R1331	13	3	R13-XFL-LP-R13312	30	2			
R13-LCB-CO-R1641R1341	11	3	R13-XFL-LP-R13411	29	4			
R13-LCB-CO-R16A1R13A1	23	3	R13-XFL-LP-R13412	28	4			
R13-LCB-CO-R16A2R13A2	20	3	R13-XFL-LP-R13A11	24	4			
R13-LCB-CO-R16B1R13B1	8	3	R13-XFL-LP-R13A12	22	2			
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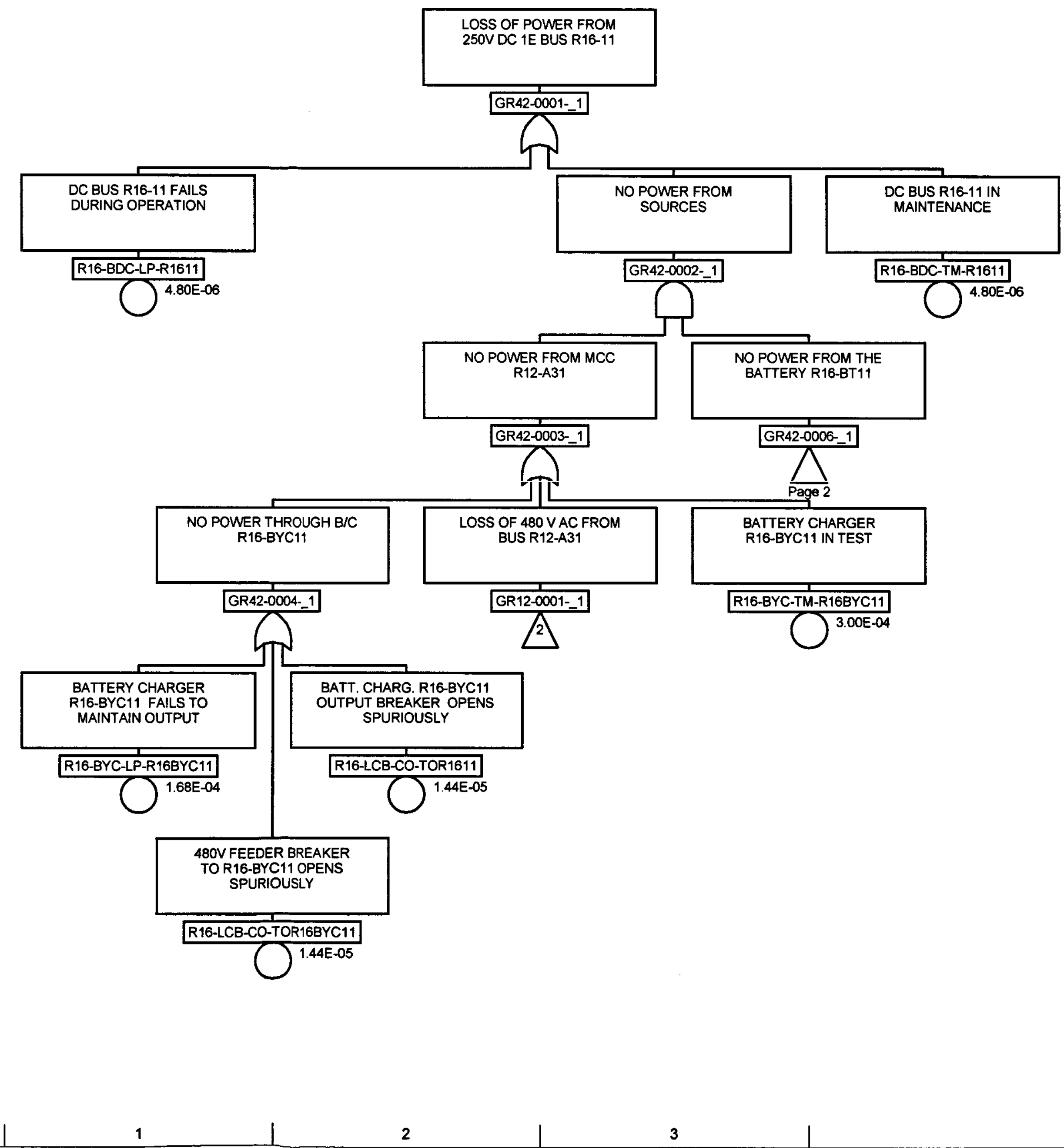
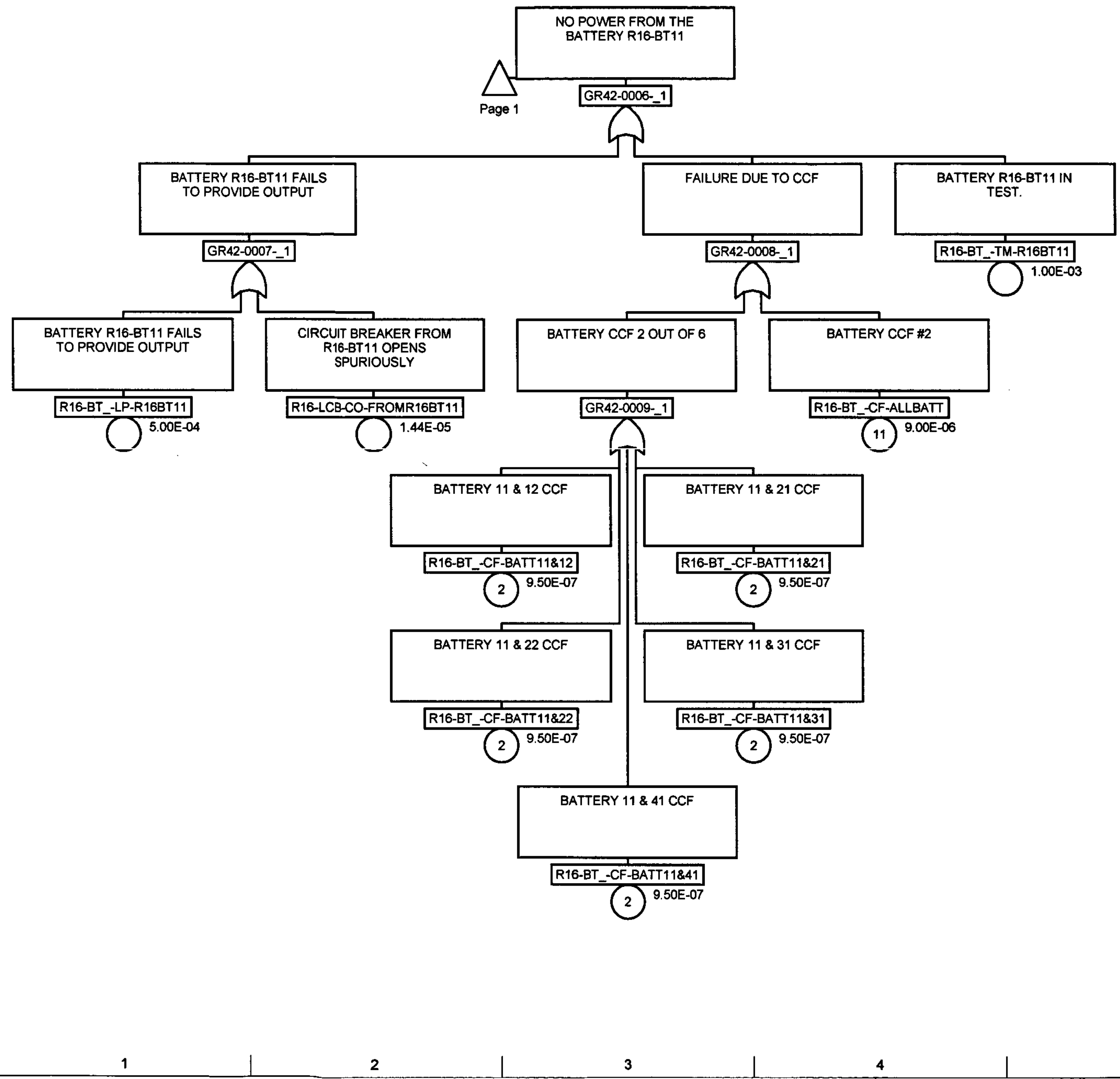
R13-LCB-CO-R16CR13C	2	3	R13-XFL-LP-R13A22	19	4			
R13-LCB-CO-TOR1311	18	4	R13-XFL-LP-R13B11	9	4			
R13-LCB-CO-TOR1321	16	4	R13-XFL-LP-R13B12	7	2			
R13-LCB-CO-TOR1331	13	4	R13-XFL-LP-R13B21	6	4			
R13-LCB-CO-TOR1341	11	4	R13-XFL-LP-R13B22	4	4			
R13-LCB-CO-TOR13A1	23	4	R13-XFL-LP-R13C11	4	2			

Appendix B.4.17 DC Power Supply System Fault Tree


LOSS OF POWER FROM 250V DC 1E BUS R16-11
GR42-0001-_1
DC BUS R16-11 FAILS DURING OPERATION
R16-BDC-LP-R1611
4.80E-06
NO POWER FROM SOURCES
GR42-0002-_1
DC BUS R16-11 IN MAINTENANCE
R16-BDC-TM-R1611
4.80E-06
NO POWER FROM MCC R12-A31
GR42-0003-_1
NO POWER FROM THE BATTERY R16-BT11
GR42-0006-_1
Page 2
NO POWER THROUGH B/C R16-BYC11
GR42-0004-_1
LOSS OF 480 V AC FROM BUS R12-A31
GR12-0001-_1
2
BATTERY CHARGER R16-BYC11 IN TEST
R16-BYC-TM-R16BYC11
3.00E-04
BATTERY CHARGER R16-BYC11 FAILS TO MAINTAIN OUTPUT
R16-BYC-LP-R16BYC11
1.68E-04
BATT. CHARG. R16-BYC11 OUTPUT BREAKER OPENS SPURIOUSLY
R16-LCB-CO-TOR1611
1.44E-05
480V FEEDER BREAKER TO R16-BYC11 OPENS SPURIOUSLY
R16-LCB-CO-TOR16BYC11
1.44E-05
1
2
3


NO POWER FROM THE BATTERY R16-BT11
Page 1
GR42-0006-_1
BATTERY R16-BT11 FAILS TO PROVIDE OUTPUT
GR42-0007-_1
FAILURE DUE TO CCF
GR42-0008-_1
BATTERY R16-BT11 IN TEST.
R16-BT_-TM-R16BT11
1.00E-03
BATTERY R16-BT11 FAILS TO PROVIDE OUTPUT
R16-BT_-LP-R16BT11
5.00E-04
CIRCUIT BREAKER FROM R16-BT11 OPENS SPURIOUSLY
R16-LCB-CO-FROMR16BT11
1.44E-05
BATTERY CCF 2 OUT OF 6
GR42-0009-_1
BATTERY CCF #2
R16-BT_-CF-ALLBATT
11
9.00E-06
BATTERY 11 & 12 CCF
R16-BT_-CF-BATT11&12
2
9.50E-07
BATTERY 11 & 21 CCF
R16-BT_-CF-BATT11&21
2
9.50E-07
BATTERY 11 & 22 CCF
R16-BT_-CF-BATT11&22
2
9.50E-07
BATTERY 11 & 31 CCF
R16-BT_-CF-BATT11&31
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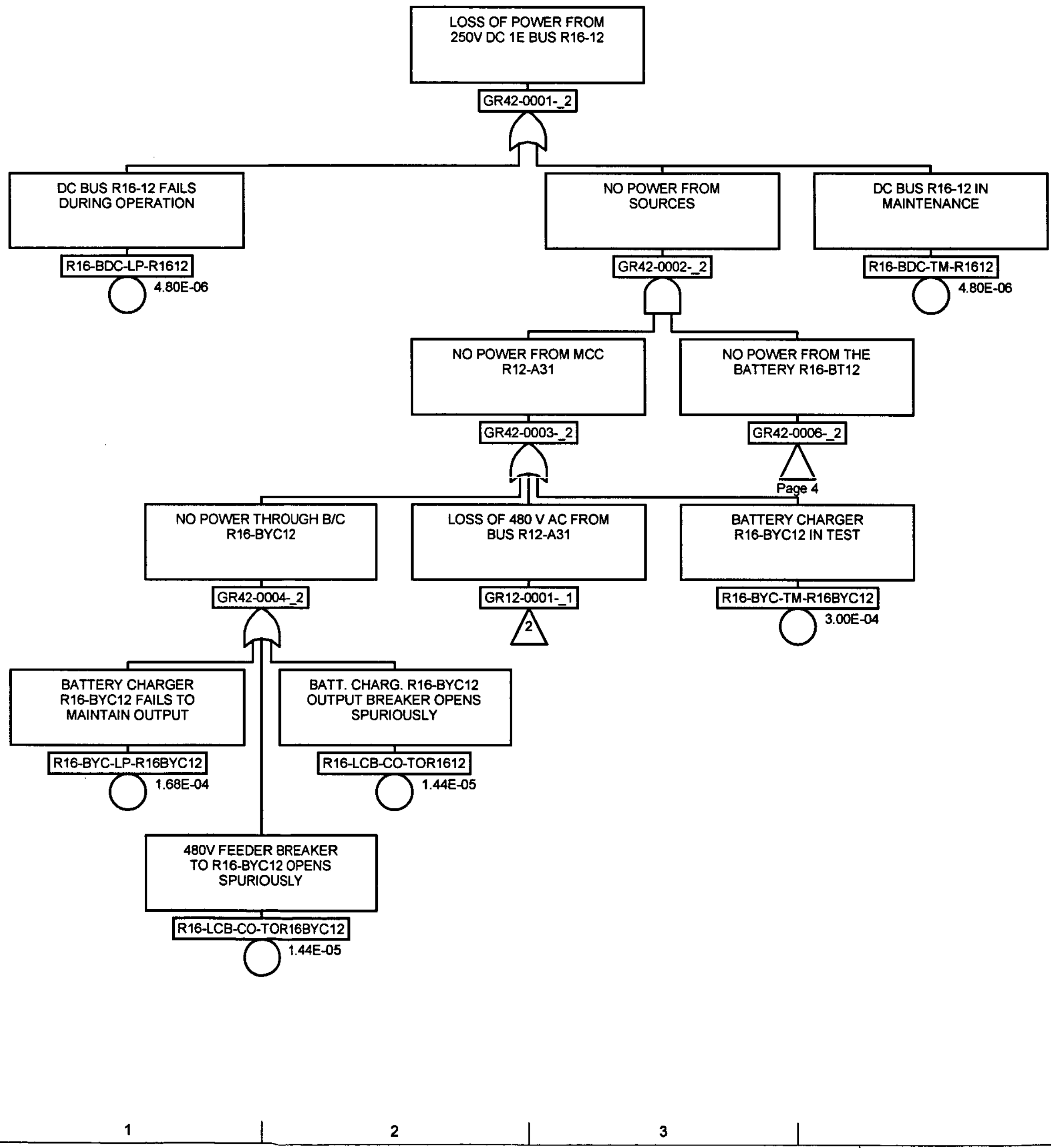
2
3
4


LOSS OF POWER FROM 250V DC 1E BUS R16-12
GR42-0001-_2
DC BUS R16-12 FAILS DURING OPERATION
R16-BDC-LP-R1612
4.80E-06
NO POWER FROM SOURCES
GR42-0002-_2
DC BUS R16-12 IN MAINTENANCE
R16-BDC-TM-R1612
4.80E-06
NO POWER FROM MCC R12-A31
GR42-0003-_2
NO POWER FROM THE BATTERY R16-BT12
GR42-0006-_2
Page 4
NO POWER THROUGH B/C R16-BYC12
GR42-0004-_2
LOSS OF 480 V AC FROM BUS R12-A31
GR12-0001-_1
2
BATTERY CHARGER R16-BYC12 IN TEST
R16-BYC-TM-R16BYC12
3.00E-04
BATTERY CHARGER R16-BYC12 FAILS TO MAINTAIN OUTPUT
R16-BYC-LP-R16BYC12
1.68E-04
BATT. CHARG. R16-BYC12 OUTPUT BREAKER OPENS SPURIOUSLY
R16-LCB-CO-TOR1612
1.44E-05
480V FEEDER BREAKER TO R16-BYC12 OPENS SPURIOUSLY
R16-LCB-CO-TOR16BYC12
1.44E-05
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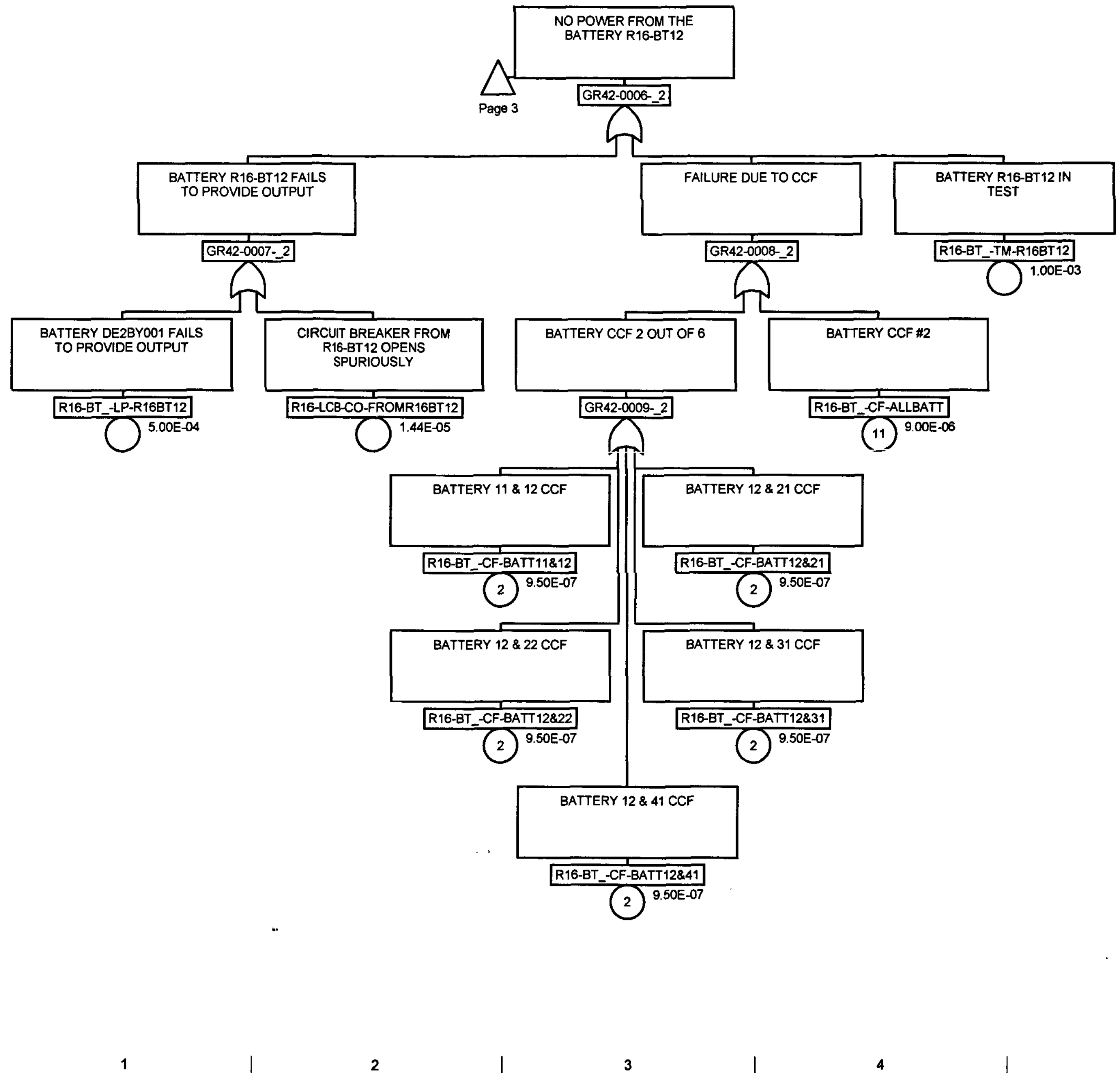
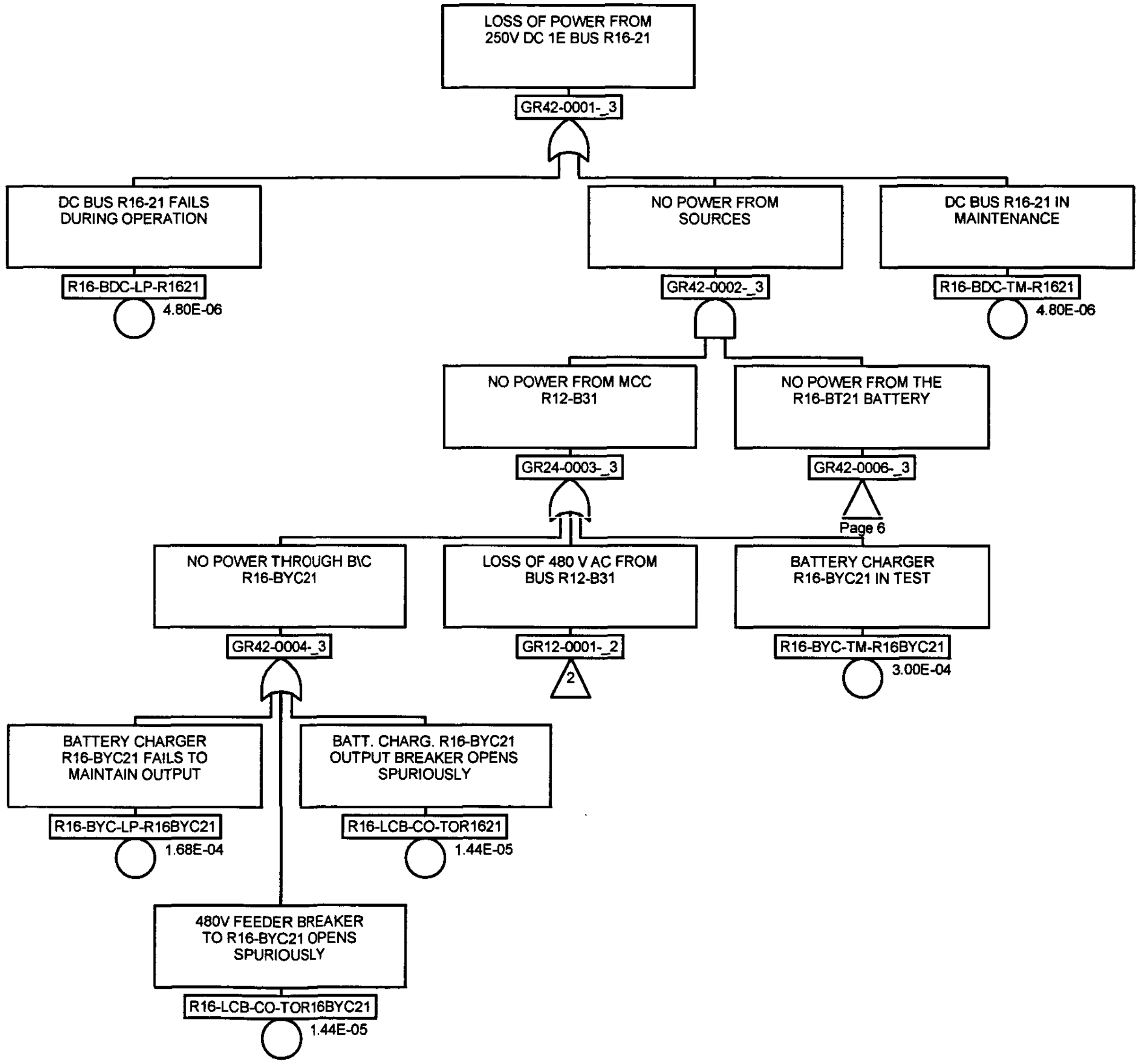
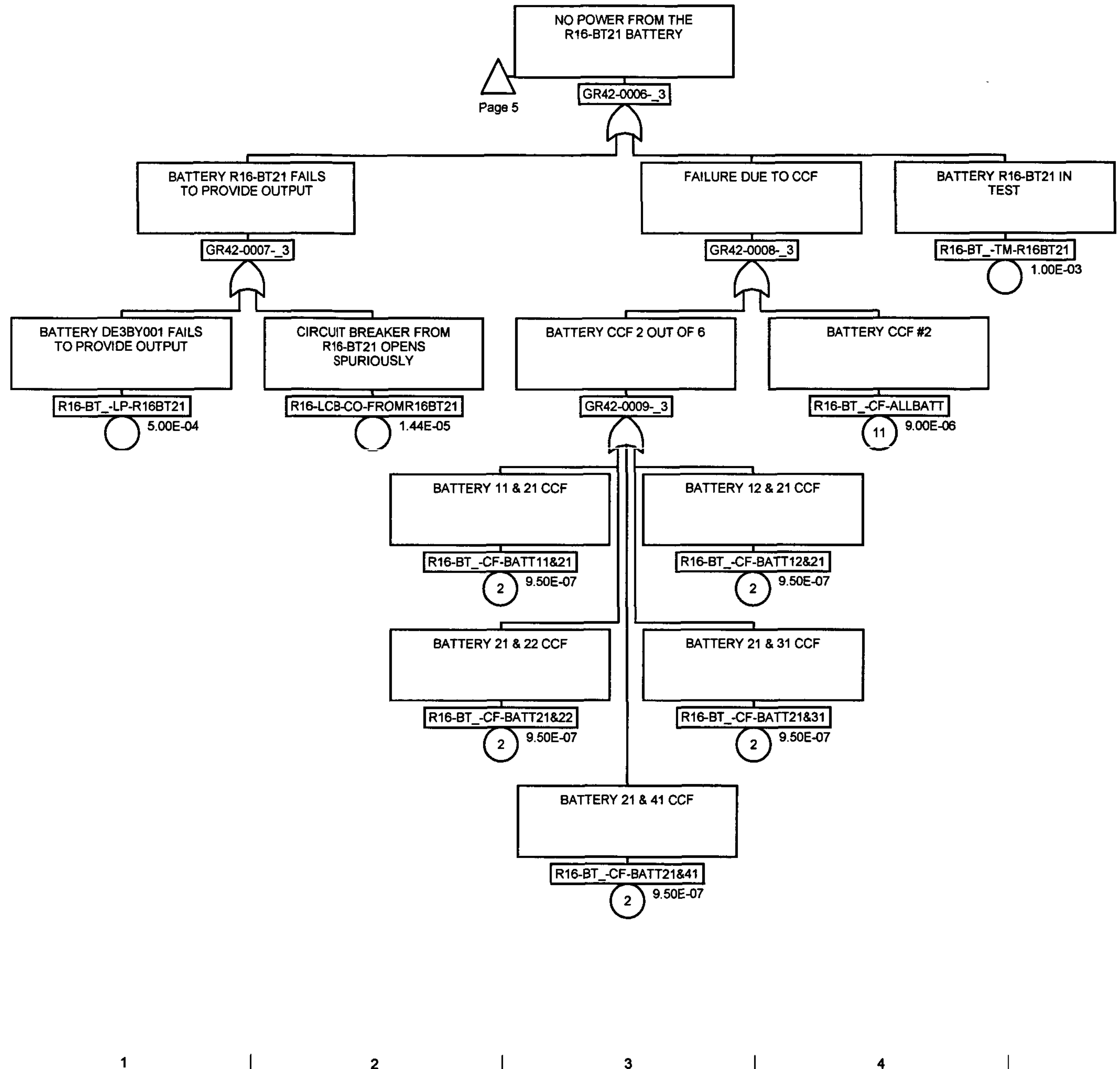
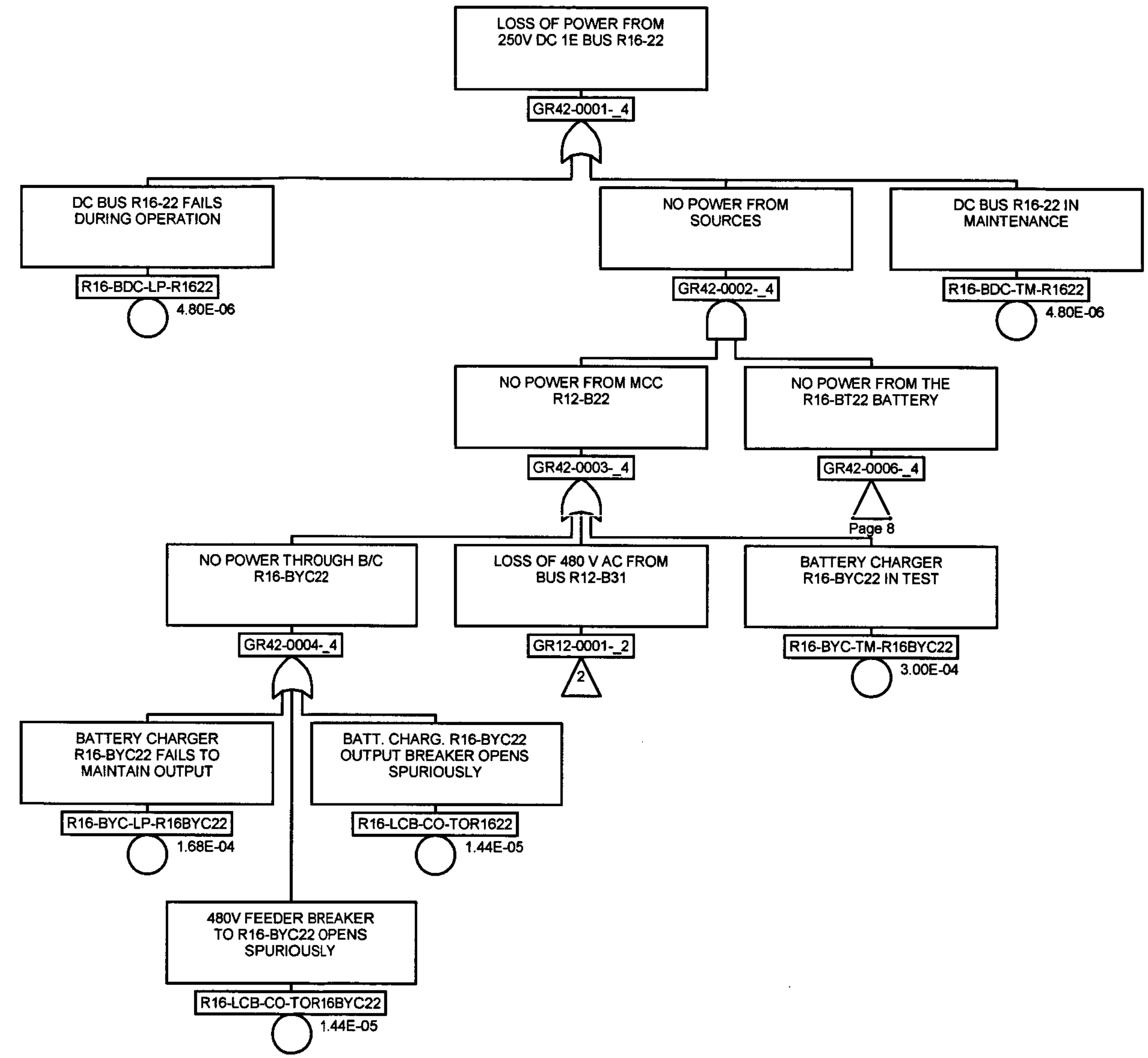
2
3

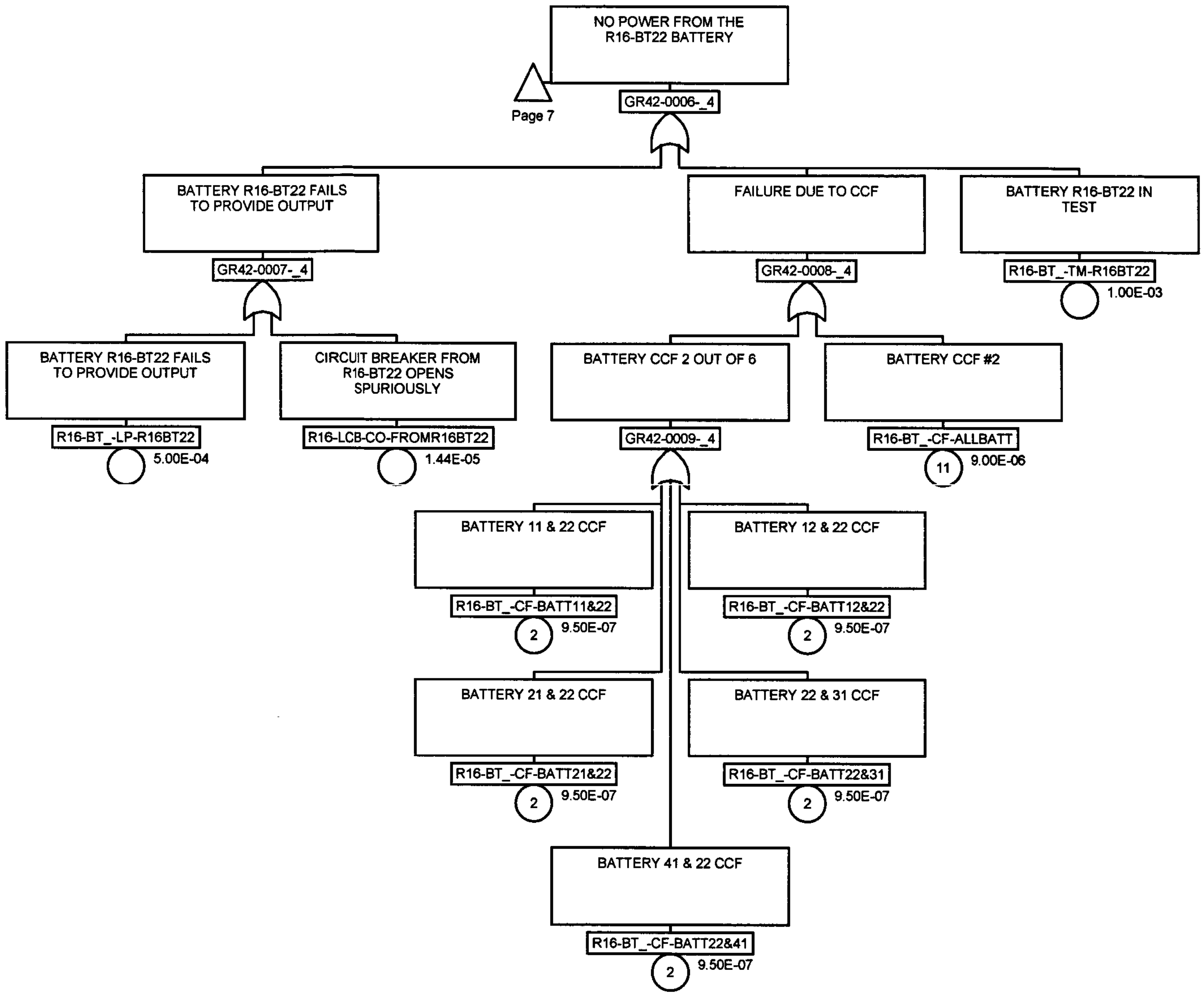

NO POWER FROM THE BATTERY R16-BT12
Page 3
GR42-0006-_2
BATTERY R16-BT12 FAILS TO PROVIDE OUTPUT
GR42-0007-_2
FAILURE DUE TO CCF
GR42-0008-_2
BATTERY R16-BT12 IN TEST
R16-BT_-TM-R16BT12
1.00E-03
BATTERY DE2BY001 FAILS TO PROVIDE OUTPUT
R16-BT_-LP-R16BT12
5.00E-04
CIRCUIT BREAKER FROM R16-BT12 OPENS SPURIOUSLY
R16-LCB-CO-FROMR16BT12
1.44E-05
BATTERY CCF 2 OUT OF 6
GR42-0009-_2
BATTERY CCF #2
R16-BT_-CF-ALLBATT
11
9.00E-06
BATTERY 11 & 12 CCF
R16-BT_-CF-BATT11&12
2
9.50E-07
BATTERY 12 & 21 CCF
R16-BT_-CF-BATT12&21
2
9.50E-07
BATTERY 12 & 22 CCF
R16-BT_-CF-BATT12&22
2
9.50E-07
BATTERY 12 & 31 CCF
R16-BT_-CF-BATT12&31
2
9.50E-07
BATTERY 12 & 41 CCF
R16-BT_-CF-BATT12&41
2
9.50E-07
1
2
3
4

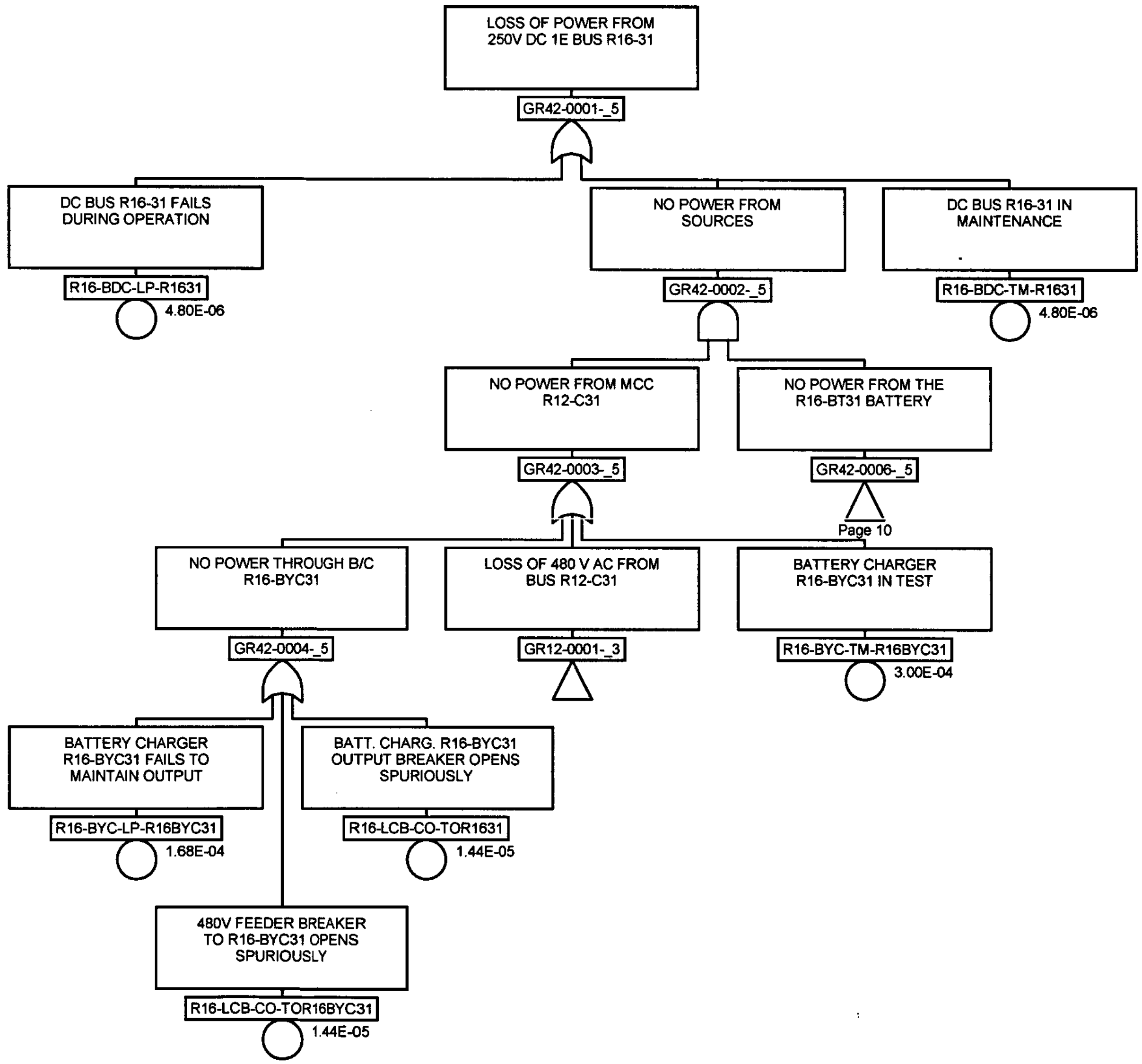

LOSS OF POWER FROM 250V DC 1E BUS R16-21
GR42-0001-_3
DC BUS R16-21 FAILS DURING OPERATION
R16-BDC-LP-R1621
4.80E-06
NO POWER FROM SOURCES
GR42-0002-_3
DC BUS R16-21 IN MAINTENANCE
R16-BDC-TM-R1621
4.80E-06
NO POWER FROM MCC R12-B31
GR24-0003-_3
NO POWER FROM THE R16-BT21 BATTERY
GR42-0006-_3
Page 6
NO POWER THROUGH B\C R16-BYC21
GR42-0004-_3
LOSS OF 480 V AC FROM BUS R12-B31
GR12-0001-_2
2
BATTERY CHARGER R16-BYC21 IN TEST
R16-BYC-TM-R16BYC21
3.00E-04
BATTERY CHARGER R16-BYC21 FAILS TO MAINTAIN OUTPUT
R16-BYC-LP-R16BYC21
1.68E-04
BATT. CHARG. R16-BYC21 OUTPUT BREAKER OPENS SPURIOUSLY
R16-LCB-CO-TOR1621
1.44E-05
480V FEEDER BREAKER TO R16-BYC21 OPENS SPURIOUSLY
R16-LCB-CO-TOR16BYC21
1.44E-05

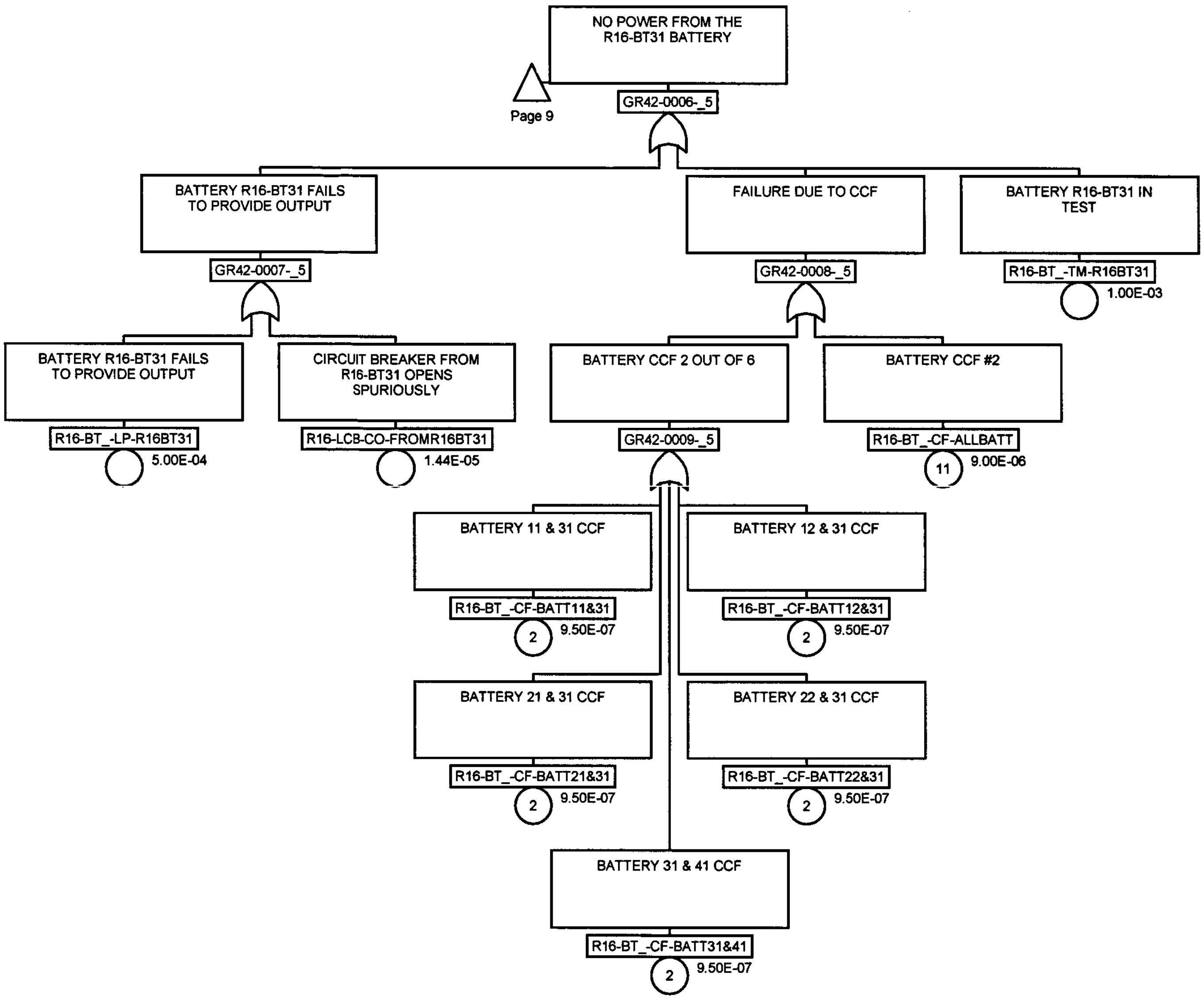
1	2	3

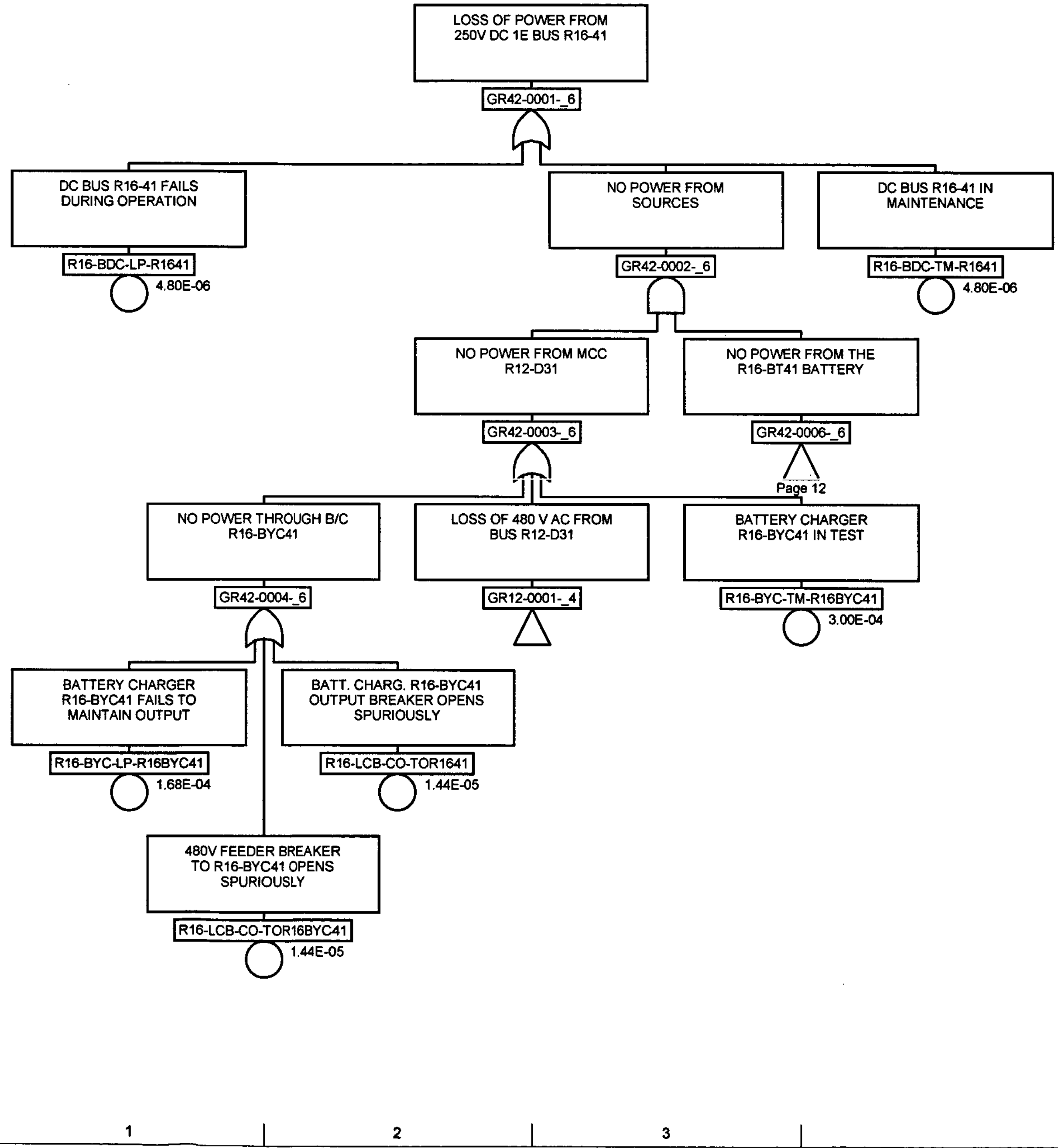

NO POWER FROM THE R16-BT21 BATTERY
GR42-0006-_3
Page 5
BATTERY R16-BT21 FAILS TO PROVIDE OUTPUT
GR42-0007-_3
FAILURE DUE TO CCF
GR42-0008-_3
BATTERY R16-BT21 IN TEST
R16-BT_-TM-R16BT21
1.00E-03
BATTERY DE3BY001 FAILS TO PROVIDE OUTPUT
R16-BT_-LP-R16BT21
5.00E-04
CIRCUIT BREAKER FROM R16-BT21 OPENS SPURIOUSLY
R16-LCB-CO-FROMR16BT21
1.44E-05
BATTERY CCF 2 OUT OF 6
GR42-0009-_3
BATTERY CCF #2
R16-BT_-CF-ALLBATT
11
9.00E-06
BATTERY 11 & 21 CCF
R16-BT_-CF-BATT11&21
2
9.50E-07
BATTERY 12 & 21 CCF
R16-BT_-CF-BATT12&21
2
9.50E-07
BATTERY 21 & 22 CCF
R16-BT_-CF-BATT21&22
2
9.50E-07
BATTERY 21 & 31 CCF
R16-BT_-CF-BATT21&31
2
9.50E-07
BATTERY 21 & 41 CCF
R16-BT_-CF-BATT21&41
2
9.50E-07
1
2
3
4

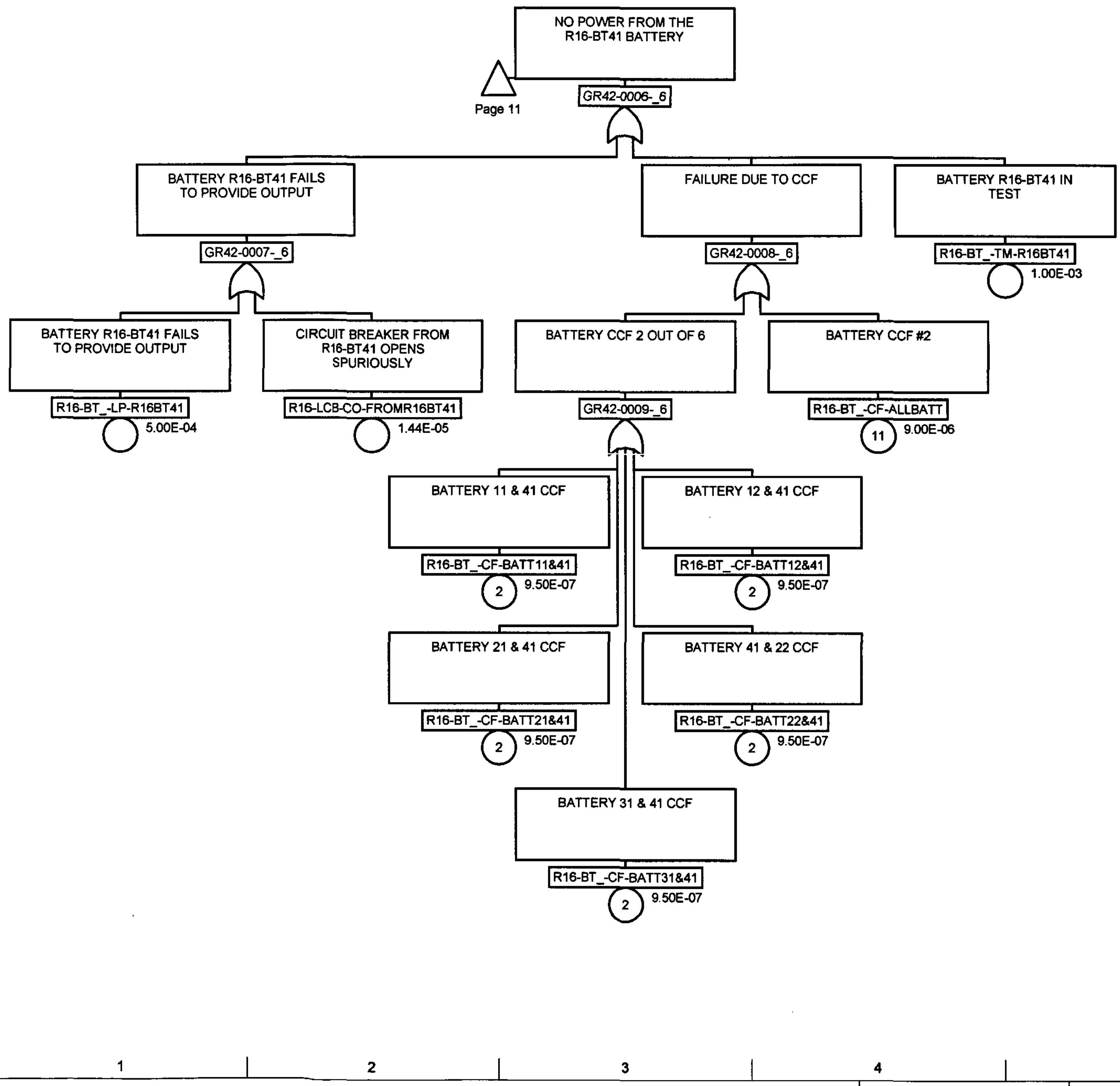

LOSS OF POWER FROM 250V DC 1E BUS R16-22
GR42-0001-_4
DC BUS R16-22 FAILS DURING OPERATION
R16-BDC-LP-R1622
4.80E-06
NO POWER FROM SOURCES
GR42-0002-_4
DC BUS R16-22 IN MAINTENANCE
R16-BDC-TM-R1622
4.80E-06
NO POWER FROM MCC R12-B22
GR42-0003-_4
NO POWER FROM THE R16-BT22 BATTERY
GR42-0006-_4
Page 8
NO POWER THROUGH B/C R16-BYC22
GR42-0004-_4
LOSS OF 480 V AC FROM BUS R12-B31
GR12-0001-_2
2
BATTERY CHARGER R16-BYC22 IN TEST
R16-BYC-TM-R16BYC22
3.00E-04
BATTERY CHARGER R16-BYC22 FAILS TO MAINTAIN OUTPUT
R16-BYC-LP-R16BYC22
1.68E-04
BATT. CHARG. R16-BYC22 OUTPUT BREAKER OPENS SPURIOUSLY
R16-LCB-CO-TOR1622
1.44E-05
480V FEEDER BREAKER TO R16-BYC22 OPENS SPURIOUSLY
R16-LCB-CO-TOR16BYC22
1.44E-05
1
2
3

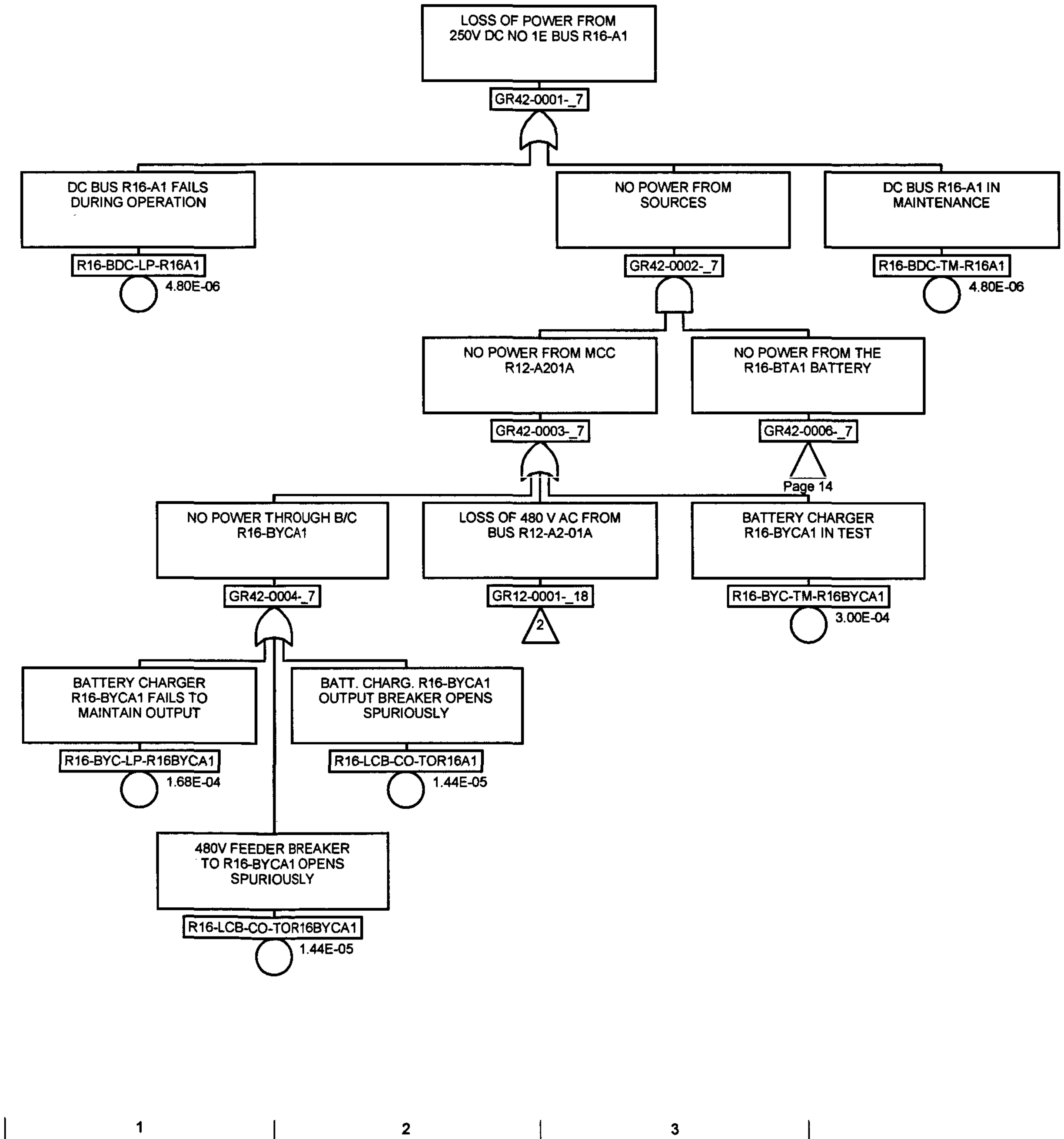

NO POWER FROM THE R16-BT22 BATTERY
Page 7
GR42-0006-_4
BATTERY R16-BT22 FAILS TO PROVIDE OUTPUT
GR42-0007-_4
FAILURE DUE TO CCF
GR42-0008-_4
BATTERY R16-BT22 IN TEST
R16-BT_-TM-R16BT22
1.00E-03
BATTERY R16-BT22 FAILS TO PROVIDE OUTPUT
R16-BT_-LP-R16BT22
5.00E-04
CIRCUIT BREAKER FROM R16-BT22 OPENS SPURIOUSLY
R16-LCB-CO-FROMR16BT22
1.44E-05
BATTERY CCF 2 OUT OF 6
GR42-0009-_4
BATTERY CCF #2
R16-BT_-CF-ALLBATT
11
9.00E-06
BATTERY 11 & 22 CCF
R16-BT_-CF-BATT11&22
2
9.50E-07
BATTERY 12 & 22 CCF
R16-BT_-CF-BATT12&22
2
9.50E-07
BATTERY 21 & 22 CCF
R16-BT_-CF-BATT21&22
2
9.50E-07
BATTERY 22 & 31 CCF
R16-BT_-CF-BATT22&31
2
9.50E-07
BATTERY 41 & 22 CCF
R16-BT_-CF-BATT22&41
2
9.50E-07
1
2
3
4

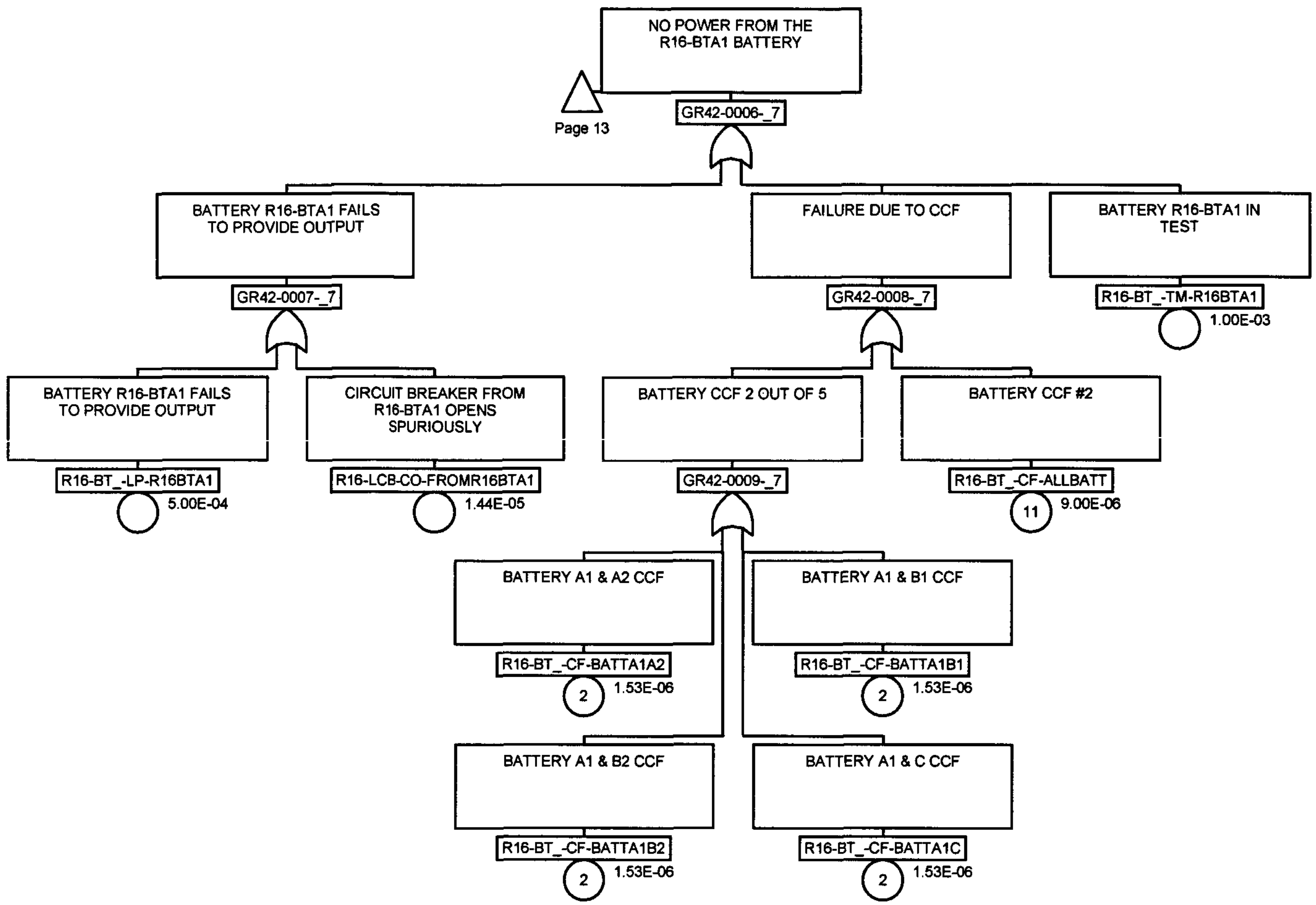

LOSS OF POWER FROM 250V DC 1E BUS R16-31
GR42-0001-_5
DC BUS R16-31 FAILS DURING OPERATION
R16-BDC-LP-R1631
4.80E-06
NO POWER FROM SOURCES
GR42-0002-_5
DC BUS R16-31 IN MAINTENANCE
R16-BDC-TM-R1631
4.80E-06
NO POWER FROM MCC R12-C31
GR42-0003-_5
NO POWER FROM THE R16-BT31 BATTERY
GR42-0006-_5
Page 10
NO POWER THROUGH B/C R16-BYC31
GR42-0004-_5
LOSS OF 480 V AC FROM BUS R12-C31
GR12-0001-_3
BATTERY CHARGER R16-BYC31 IN TEST
R16-BYC-TM-R16BYC31
3.00E-04
BATTERY CHARGER R16-BYC31 FAILS TO MAINTAIN OUTPUT
R16-BYC-LP-R16BYC31
1.68E-04
BATT. CHARG. R16-BYC31 OUTPUT BREAKER OPENS SPURIOUSLY
R16-LCB-CO-TOR1631
1.44E-05
480V FEEDER BREAKER TO R16-BYC31 OPENS SPURIOUSLY
R16-LCB-CO-TOR16BYC31
1.44E-05
1
2
3

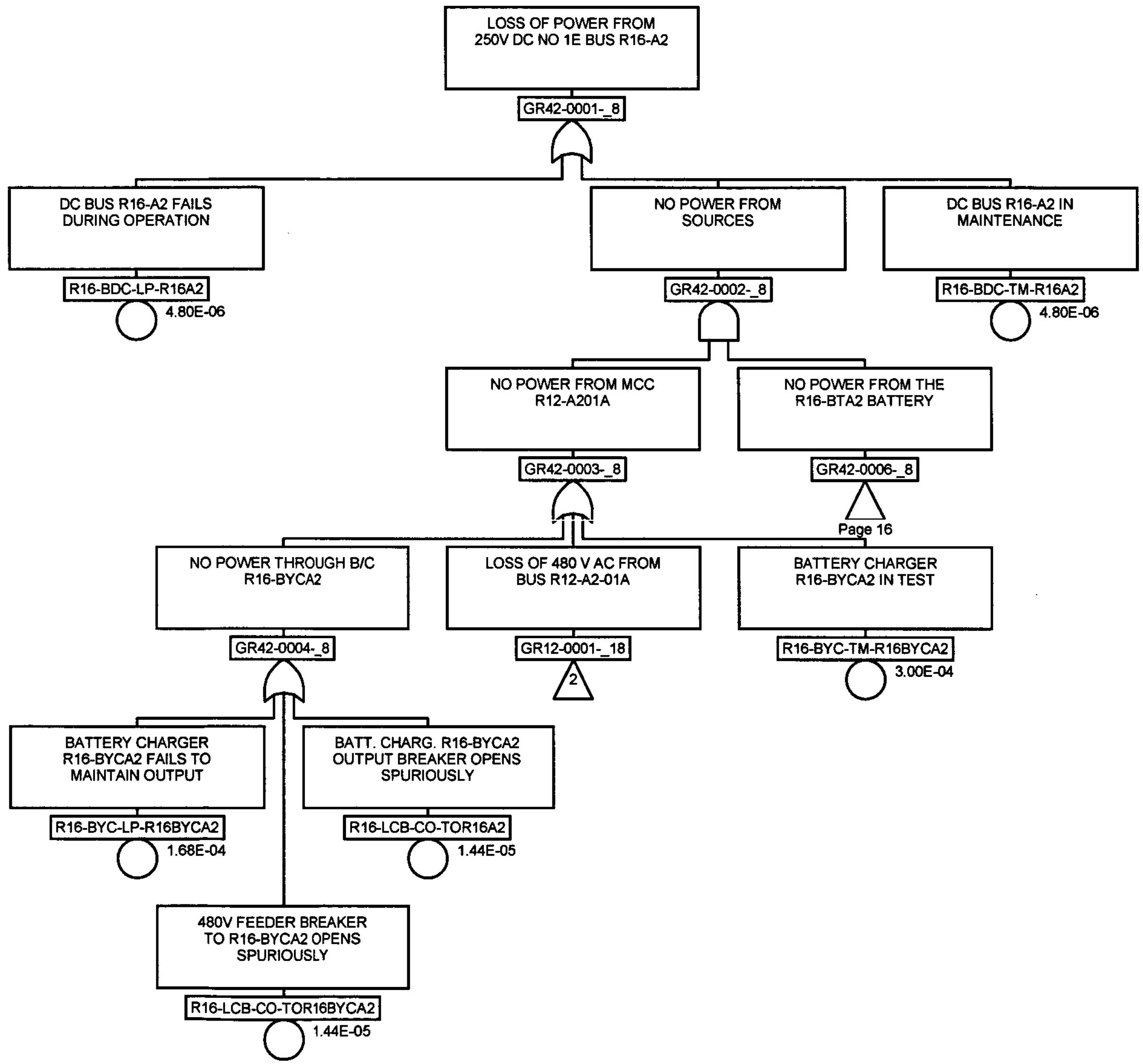

NO POWER FROM THE R16-BT31 BATTERY
GR42-0006-_5
Page 9
BATTERY R16-BT31 FAILS TO PROVIDE OUTPUT
GR42-0007-_5
FAILURE DUE TO CCF
GR42-0008-_5
BATTERY R16-BT31 IN TEST
R16-BT_-TM-R16BT31
1.00E-03
BATTERY R16-BT31 FAILS TO PROVIDE OUTPUT
R16-BT_-LP-R16BT31
5.00E-04
CIRCUIT BREAKER FROM R16-BT31 OPENS SPURIOUSLY
R16-LCB-CO-FROMR16BT31
1.44E-05
BATTERY CCF 2 OUT OF 6
GR42-0009-_5
BATTERY CCF #2
R16-BT_-CF-ALLBATT
11
9.00E-06
BATTERY 11 & 31 CCF
R16-BT_-CF-BATT11&31
2
9.50E-07
BATTERY 12 & 31 CCF
R16-BT_-CF-BATT12&31
2
9.50E-07
BATTERY 21 & 31 CCF
R16-BT_-CF-BATT21&31
2
9.50E-07
BATTERY 22 & 31 CCF
R16-BT_-CF-BATT22&31
2
9.50E-07
BATTERY 31 & 41 CCF
R16-BT_-CF-BATT31&41
2
9.50E-07
1
2
3
4

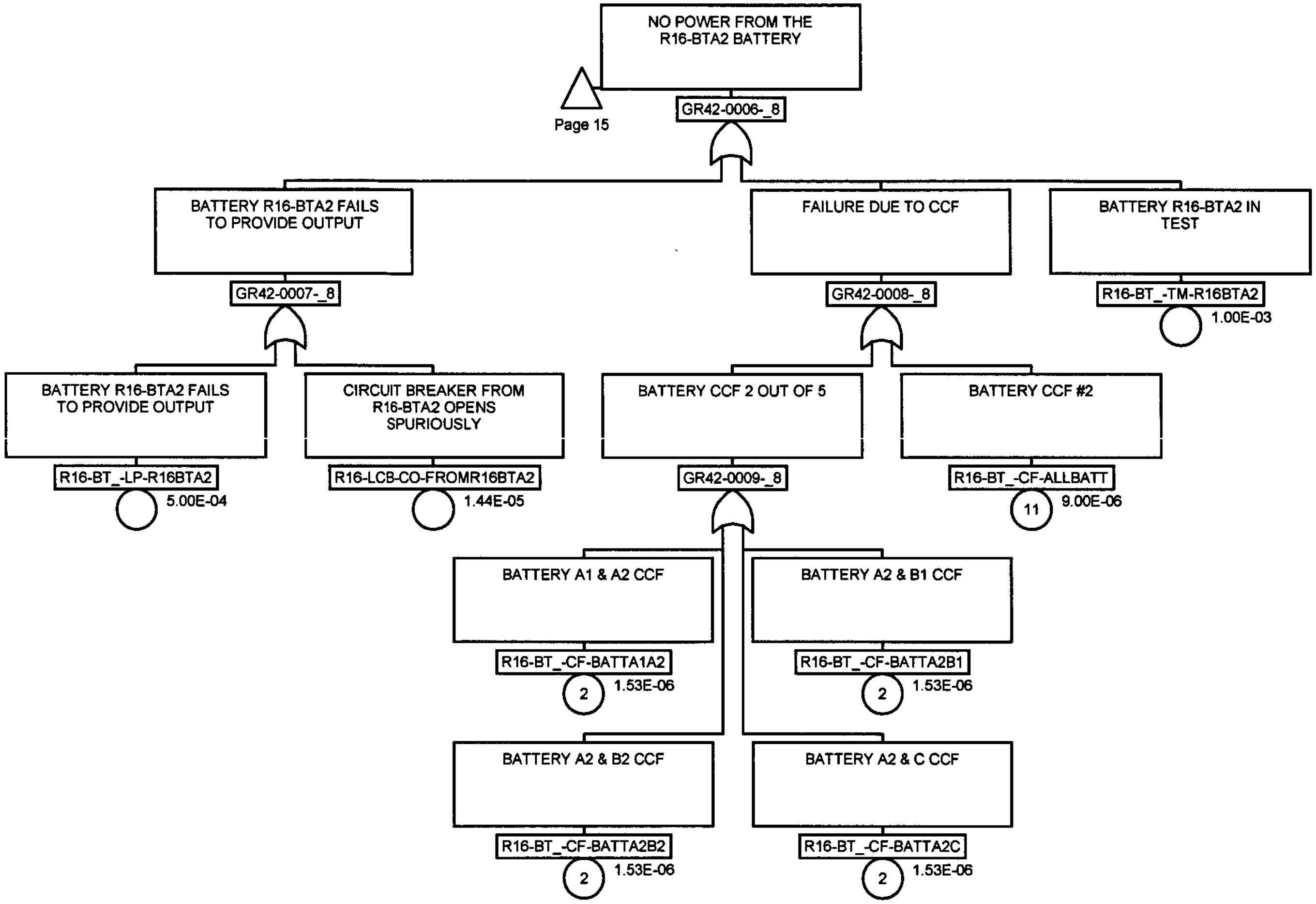

LOSS OF POWER FROM 250V DC 1E BUS R16-41
GR42-0001-_6
DC BUS R16-41 FAILS DURING OPERATION
R16-BDC-LP-R1641
4.80E-06
NO POWER FROM SOURCES
GR42-0002-_6
DC BUS R16-41 IN MAINTENANCE
R16-BDC-TM-R1641
4.80E-06
NO POWER FROM MCC R12-D31
GR42-0003-_6
NO POWER FROM THE R16-BT41 BATTERY
GR42-0006-_6
Page 12
NO POWER THROUGH B/C R16-BYC41
GR42-0004-_6
LOSS OF 480 V AC FROM BUS R12-D31
GR12-0001-_4
BATTERY CHARGER R16-BYC41 IN TEST
R16-BYC-TM-R16BYC41
3.00E-04
BATTERY CHARGER R16-BYC41 FAILS TO MAINTAIN OUTPUT
R16-BYC-LP-R16BYC41
1.68E-04
BATT. CHARG. R16-BYC41 OUTPUT BREAKER OPENS SPURIOUSLY
R16-LCB-CO-TOR1641
1.44E-05
480V FEEDER BREAKER TO R16-BYC41 OPENS SPURIOUSLY
R16-LCB-CO-TOR16BYC41
1.44E-05
1
2
3


NO POWER FROM THE R16-BT41 BATTERY
Page 11
GR42-0006-_6
BATTERY R16-BT41 FAILS TO PROVIDE OUTPUT
GR42-0007-_6
FAILURE DUE TO CCF
GR42-0008-_6
BATTERY R16-BT41 IN TEST
R16-BT_-TM-R16BT41
1.00E-03
BATTERY R16-BT41 FAILS TO PROVIDE OUTPUT
R16-BT_-LP-R16BT41
5.00E-04
CIRCUIT BREAKER FROM R16-BT41 OPENS SPURIOUSLY
R16-LCB-CO-FROMR16BT41
1.44E-05
BATTERY CCF 2 OUT OF 6
GR42-0009-_6
BATTERY CCF #2
R16-BT_-CF-ALLBATT
11
9.00E-06
BATTERY 11 & 41 CCF
R16-BT_-CF-BATT11&41
2
9.50E-07
BATTERY 12 & 41 CCF
R16-BT_-CF-BATT12&41
2
9.50E-07
BATTERY 21 & 41 CCF
R16-BT_-CF-BATT21&41
2
9.50E-07
BATTERY 41 & 22 CCF
R16-BT_-CF-BATT22&41
2
9.50E-07
BATTERY 31 & 41 CCF
R16-BT_-CF-BATT31&41
2
9.50E-07
1
2
3
4

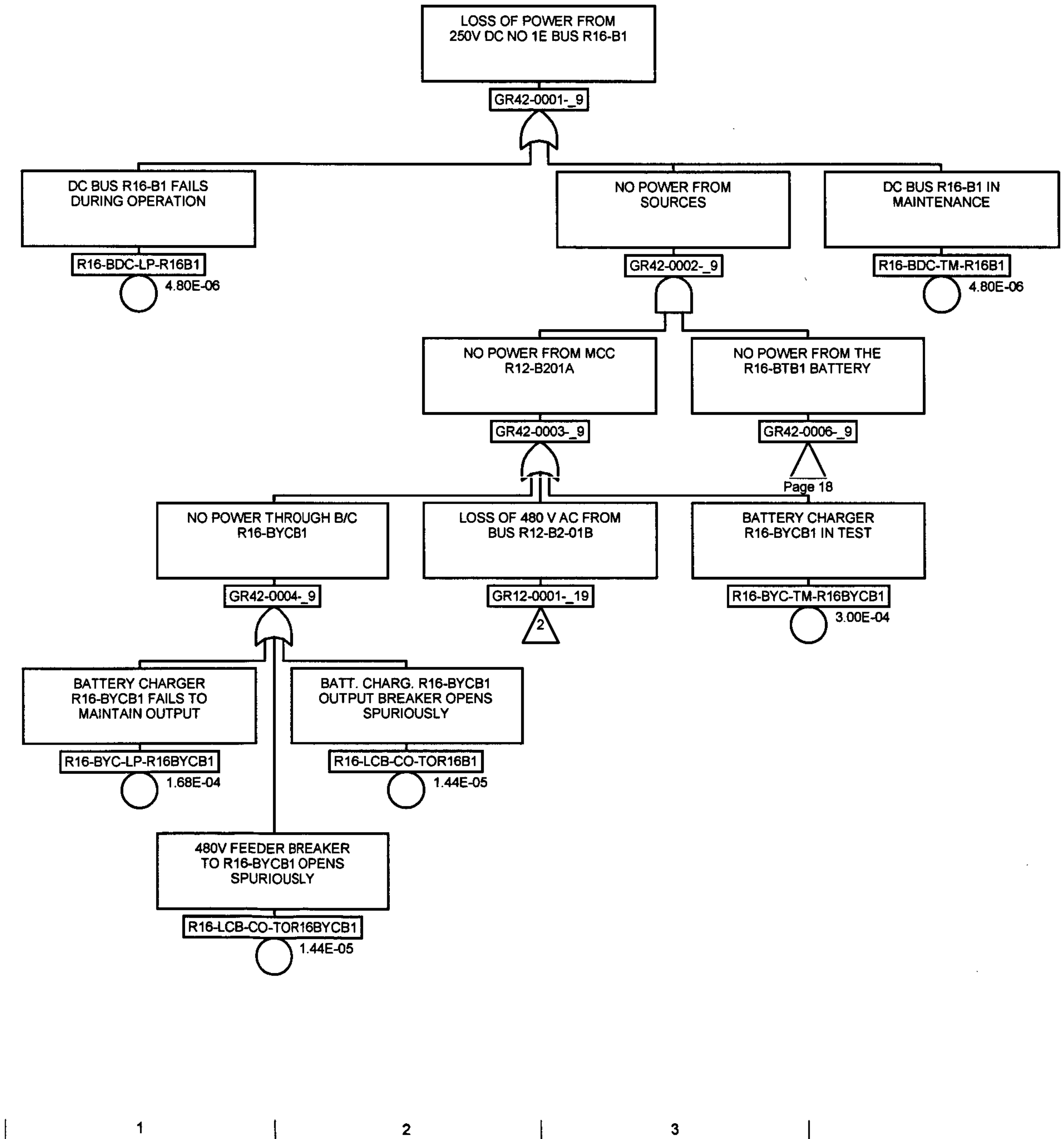

LOSS OF POWER FROM 250V DC NO 1E BUS R16-A1
GR42-0001-_7
DC BUS R16-A1 FAILS DURING OPERATION
R16-BDC-LP-R16A1
4.80E-06
NO POWER FROM SOURCES
GR42-0002-_7
DC BUS R16-A1 IN MAINTENANCE
R16-BDC-TM-R16A1
4.80E-06
NO POWER FROM MCC R12-A201A
GR42-0003-_7
NO POWER FROM THE R16-BTA1 BATTERY
GR42-0006-_7
Page 14
NO POWER THROUGH B/C R16-BYCA1
GR42-0004-_7
LOSS OF 480 V AC FROM BUS R12-A2-01A
GR12-0001-_18
2
BATTERY CHARGER R16-BYCA1 IN TEST
R16-BYC-TM-R16BYCA1
3.00E-04
BATTERY CHARGER R16-BYCA1 FAILS TO MAINTAIN OUTPUT
R16-BYC-LP-R16BYCA1
1.68E-04
BATT. CHARG. R16-BYCA1 OUTPUT BREAKER OPENS SPURIOUSLY
R16-LCB-CO-TOR16A1
1.44E-05
480V FEEDER BREAKER TO R16-BYCA1 OPENS SPURIOUSLY
R16-LCB-CO-TOR16BYCA1
1.44E-05
1
2
3

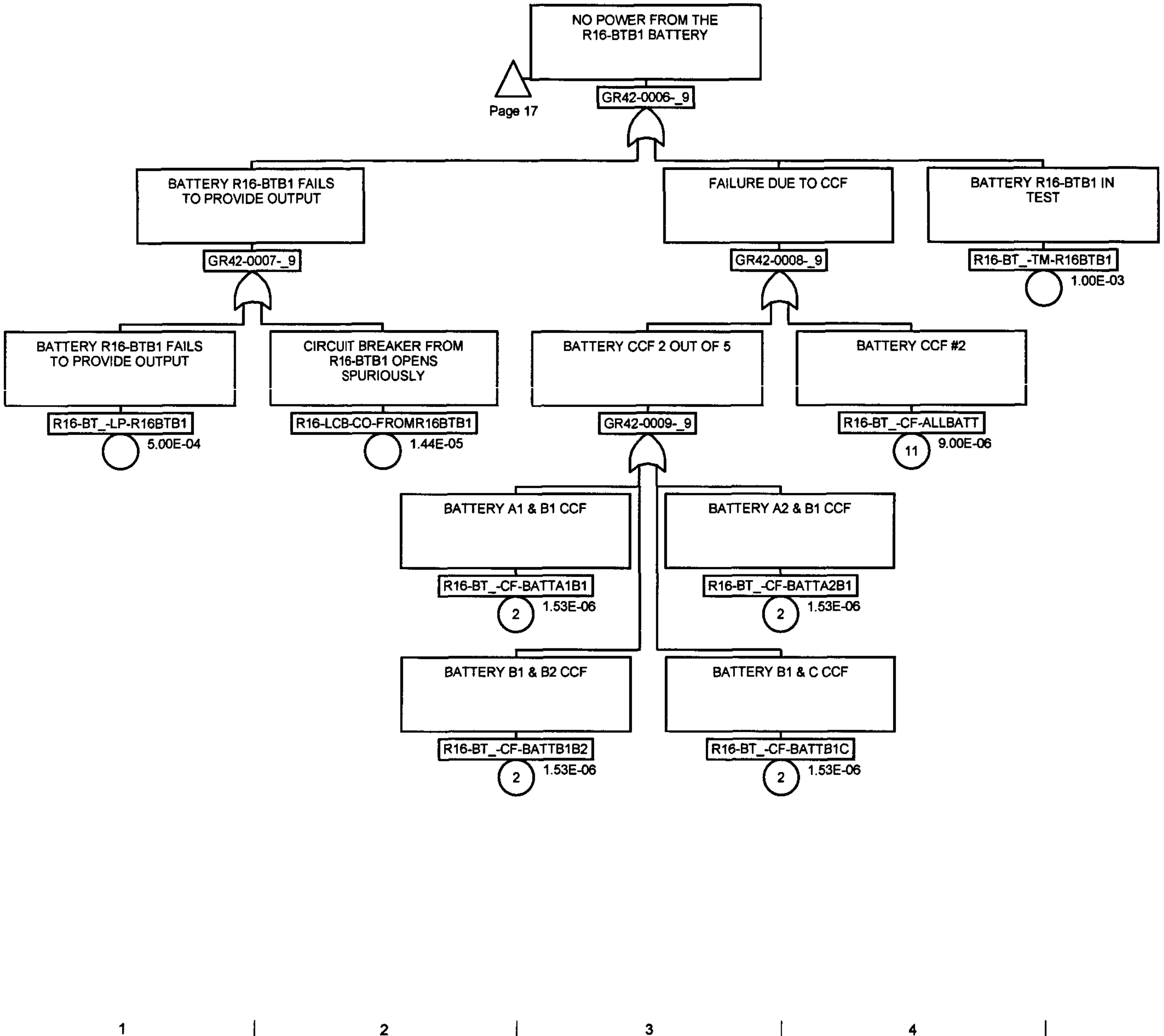

NO POWER FROM THE R16-BTA1 BATTERY
GR42-0006-_7
Page 13
BATTERY R16-BTA1 FAILS TO PROVIDE OUTPUT
GR42-0007-_7
FAILURE DUE TO CCF
GR42-0008-_7
BATTERY R16-BTA1 IN TEST
R16-BT_-TM-R16BTA1
1.00E-03
BATTERY R16-BTA1 FAILS TO PROVIDE OUTPUT
R16-BT_-LP-R16BTA1
5.00E-04
CIRCUIT BREAKER FROM R16-BTA1 OPENS SPURIOUSLY
R16-LCB-CO-FROMR16BTA1
1.44E-05
BATTERY CCF 2 OUT OF 5
GR42-0009-_7
BATTERY CCF #2
R16-BT_-CF-ALLBATT
11
9.00E-06
BATTERY A1 & A2 CCF
R16-BT_-CF-BATTA1A2
2
1.53E-06
BATTERY A1 & B1 CCF
R16-BT_-CF-BATTA1B1
2
1.53E-06
BATTERY A1 & B2 CCF
R16-BT_-CF-BATTA1B2
2
1.53E-06
BATTERY A1 & C CCF
R16-BT_-CF-BATTA1C
2
1.53E-06
1
2
3
4

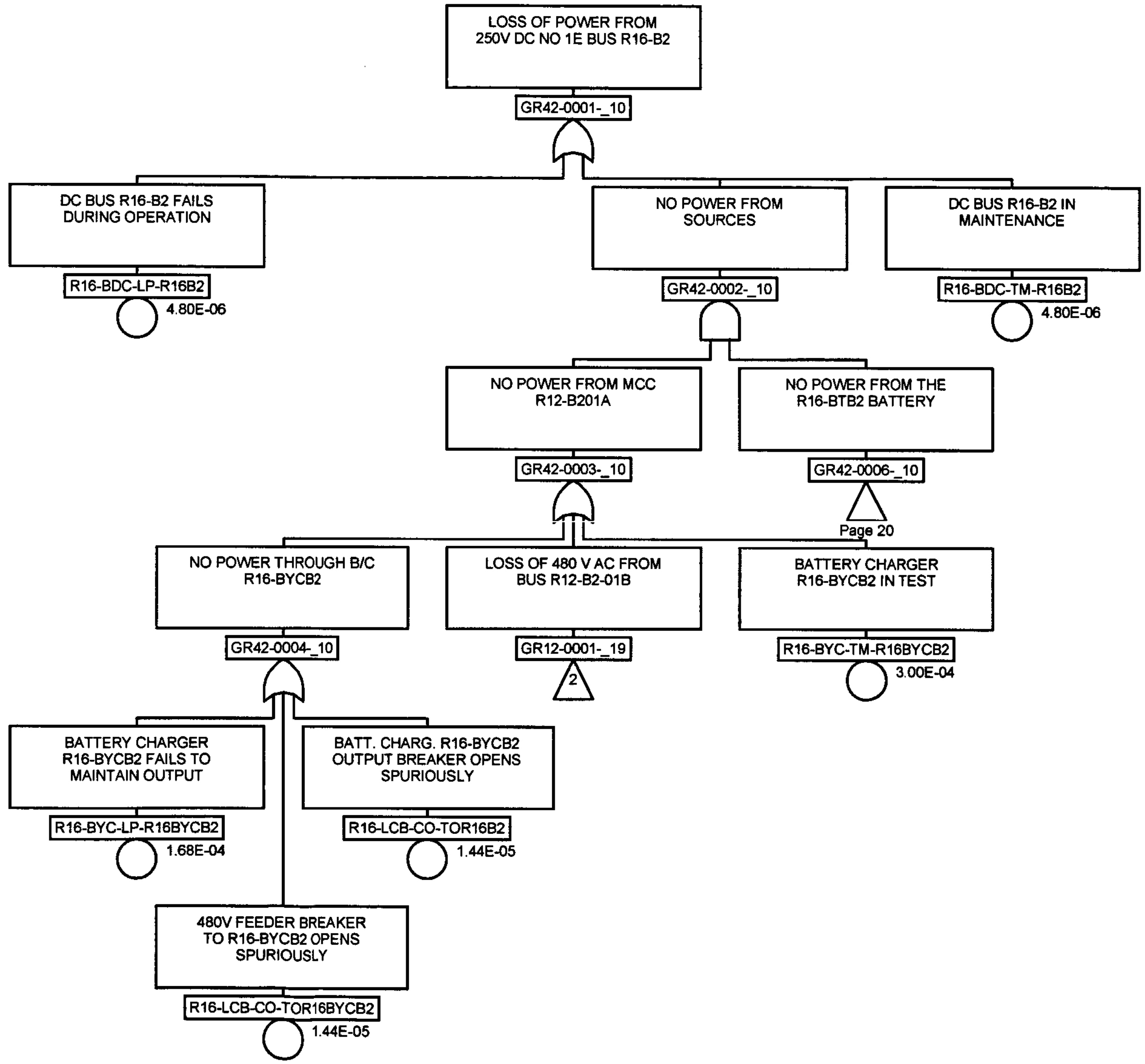

LOSS OF POWER FROM 250V DC NO 1E BUS R16-A2
GR42-0001-_8
DC BUS R16-A2 FAILS DURING OPERATION
R16-BDC-LP-R16A2
4.80E-06
NO POWER FROM SOURCES
GR42-0002-_8
DC BUS R16-A2 IN MAINTENANCE
R16-BDC-TM-R16A2
4.80E-06
NO POWER FROM MCC R12-A201A
GR42-0003-_8
NO POWER FROM THE R16-BTA2 BATTERY
GR42-0006-_8
Page 16
NO POWER THROUGH B/C R16-BYCA2
GR42-0004-_8
LOSS OF 480 V AC FROM BUS R12-A2-01A
GR12-0001-_18
2
BATTERY CHARGER R16-BYCA2 IN TEST
R16-BYC-TM-R16BYCA2
3.00E-04
BATTERY CHARGER R16-BYCA2 FAILS TO MAINTAIN OUTPUT
R16-BYC-LP-R16BYCA2
1.68E-04
BATT. CHARG. R16-BYCA2 OUTPUT BREAKER OPENS SPURIOUSLY
R16-LCB-CO-TOR16A2
1.44E-05
480V FEEDER BREAKER TO R16-BYCA2 OPENS SPURIOUSLY
R16-LCB-CO-TOR16BYCA2
1.44E-05
1
2
3

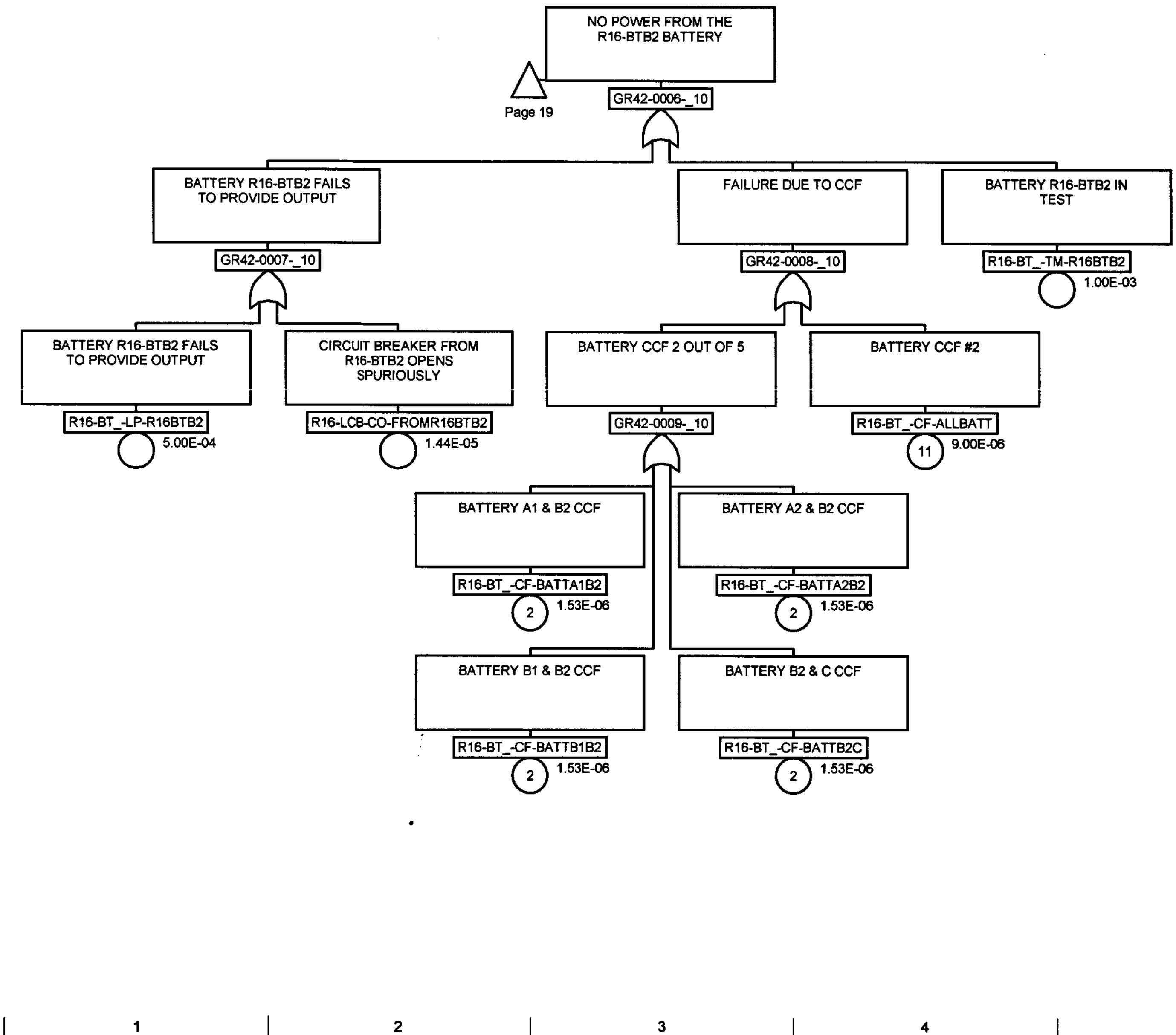


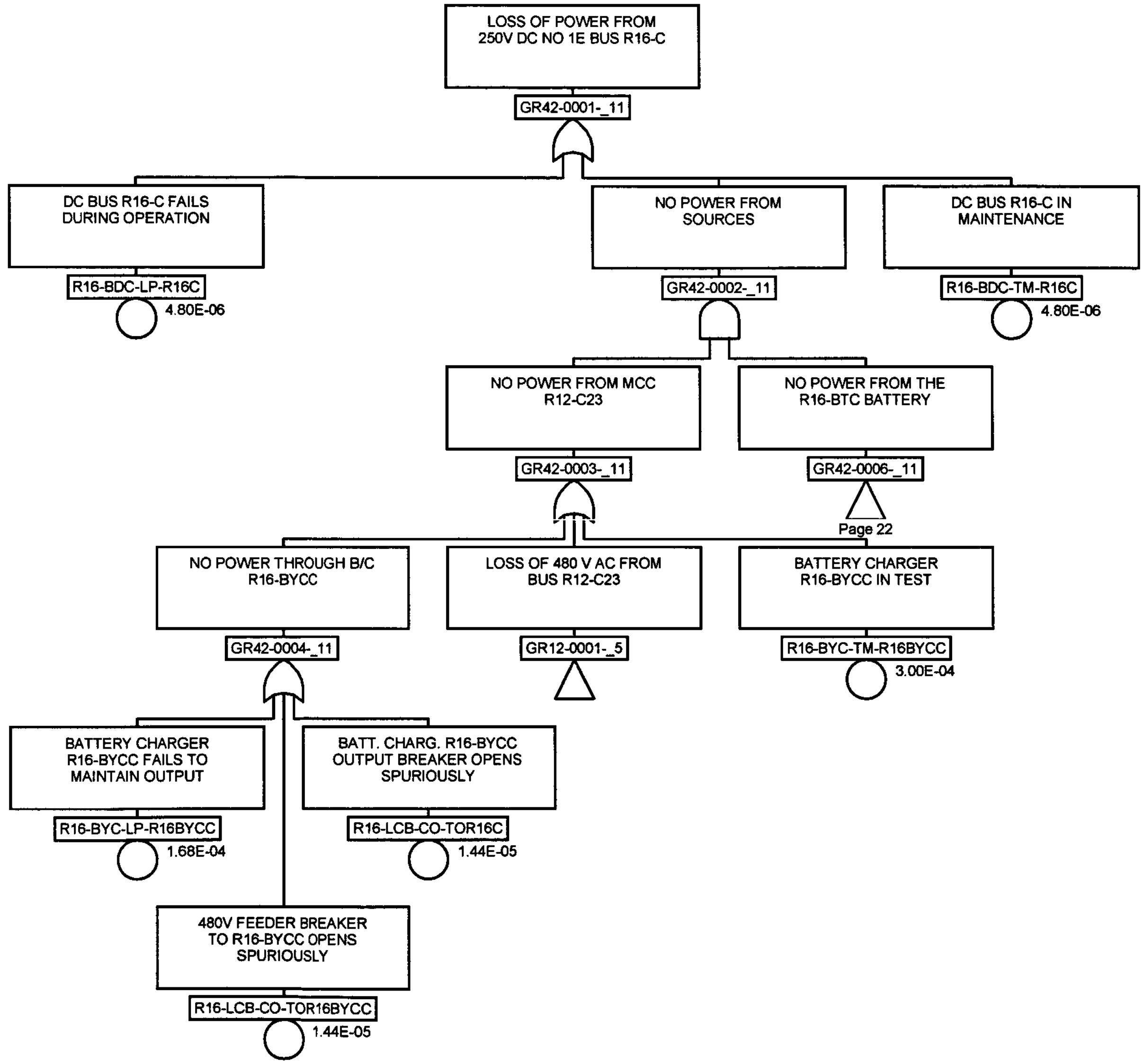
NO POWER FROM THE R16-BTA2 BATTERY
GR42-0006-_8
Page 15
BATTERY R16-BTA2 FAILS TO PROVIDE OUTPUT
GR42-0007-_8
FAILURE DUE TO CCF
GR42-0008-_8
BATTERY R16-BTA2 IN TEST
R16-BT_-TM-R16BTA2
1.00E-03
BATTERY R16-BTA2 FAILS TO PROVIDE OUTPUT
R16-BT_-LP-R16BTA2
5.00E-04
CIRCUIT BREAKER FROM R16-BTA2 OPENS SPURIOUSLY
R16-LCB-CO-FROMR16BTA2
1.44E-05
BATTERY CCF 2 OUT OF 5
GR42-0009-_8
BATTERY CCF #2
R16-BT_-CF-ALLBATT
11
9.00E-06
BATTERY A1 & A2 CCF
R16-BT_-CF-BATTA1A2
2
1.53E-06
BATTERY A2 & B1 CCF
R16-BT_-CF-BATTA2B1
2
1.53E-06
BATTERY A2 & B2 CCF
R16-BT_-CF-BATTA2B2
2
1.53E-06
BATTERY A2 & C CCF
R16-BT_-CF-BATTA2C
2
1.53E-06


LOSS OF POWER FROM 250V DC NO 1E BUS R16-B1
GR42-0001-_9
DC BUS R16-B1 FAILS DURING OPERATION
R16-BDC-LP-R16B1
4.80E-06
NO POWER FROM SOURCES
GR42-0002-_9
DC BUS R16-B1 IN MAINTENANCE
R16-BDC-TM-R16B1
4.80E-06
NO POWER FROM MCC R12-B201A
GR42-0003-_9
NO POWER FROM THE R16-BTB1 BATTERY
GR42-0006-_9
Page 18
NO POWER THROUGH B/C R16-BYCB1
GR42-0004-_9
LOSS OF 480 V AC FROM BUS R12-B2-01B
GR12-0001-_19
2
BATTERY CHARGER R16-BYCB1 IN TEST
R16-BYC-TM-R16BYCB1
3.00E-04
BATTERY CHARGER R16-BYCB1 FAILS TO MAINTAIN OUTPUT
R16-BYC-LP-R16BYCB1
1.68E-04
BATT. CHARG. R16-BYCB1 OUTPUT BREAKER OPENS SPURIOUSLY
R16-LCB-CO-TOR16B1
1.44E-05
480V FEEDER BREAKER TO R16-BYCB1 OPENS SPURIOUSLY
R16-LCB-CO-TOR16BYCB1
1.44E-05
1
2
3

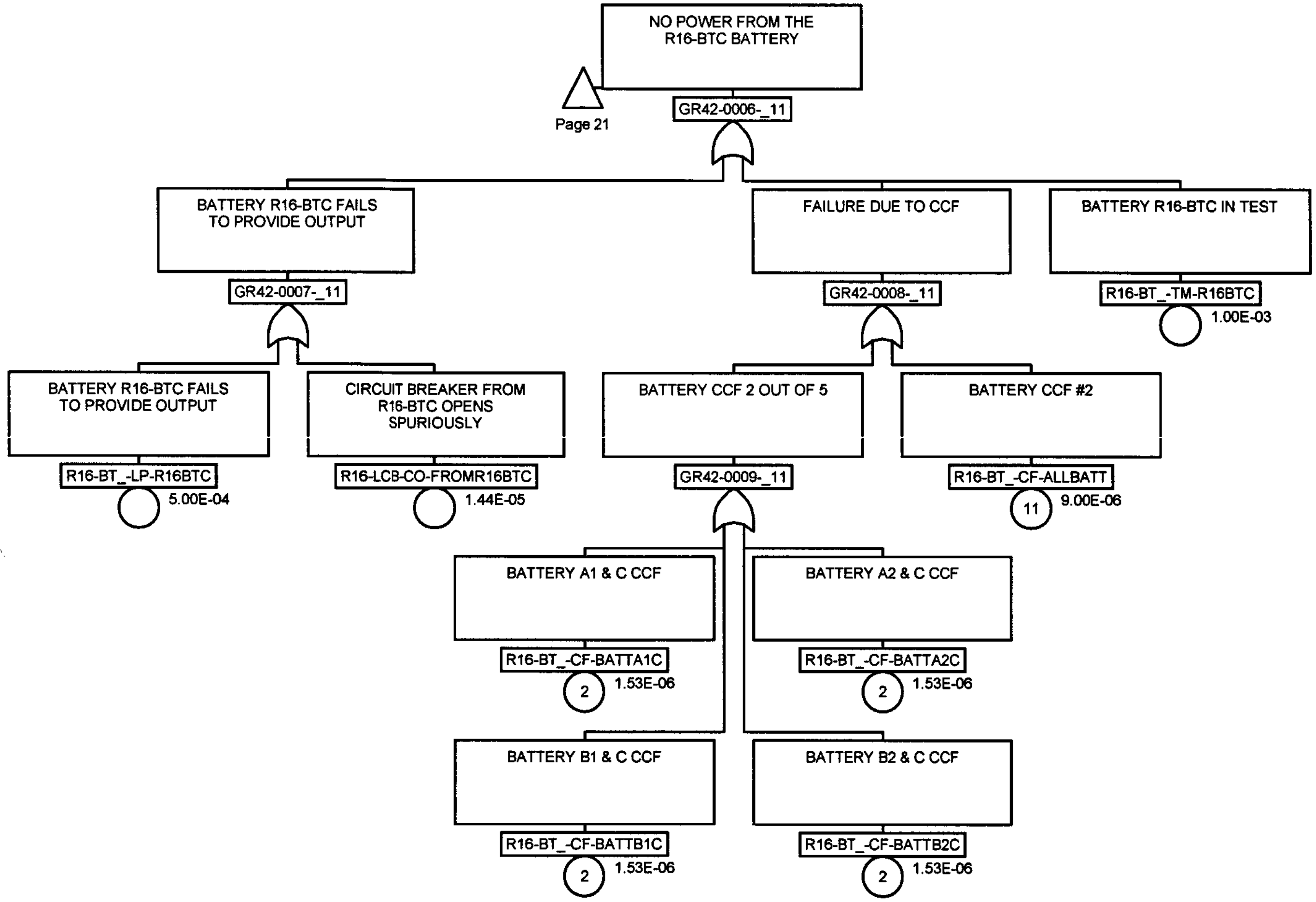

NO POWER FROM THE R16-BTB1 BATTERY
Page 17
GR42-0006-_9
BATTERY R16-BTB1 FAILS TO PROVIDE OUTPUT
GR42-0007-_9
FAILURE DUE TO CCF
GR42-0008-_9
BATTERY R16-BTB1 IN TEST
R16-BT_-TM-R16BTB1
1.00E-03
BATTERY R16-BTB1 FAILS TO PROVIDE OUTPUT
R16-BT_-LP-R16BTB1
5.00E-04
CIRCUIT BREAKER FROM R16-BTB1 OPENS SPURIOUSLY
R16-LCB-CO-FROMR16BTB1
1.44E-05
BATTERY CCF 2 OUT OF 5
GR42-0009-_9
BATTERY CCF #2
R16-BT_-CF-ALLBATT
11
9.00E-06
BATTERY A1 & B1 CCF
R16-BT_-CF-BATTA1B1
2
1.53E-06
BATTERY A2 & B1 CCF
R16-BT_-CF-BATTA2B1
2
1.53E-06
BATTERY B1 & B2 CCF
R16-BT_-CF-BATTB1B2
2
1.53E-06
BATTERY B1 & C CCF
R16-BT_-CF-BATTB1C
2
1.53E-06
1
2
3
4


LOSS OF POWER FROM 250V DC NO 1E BUS R16-B2
GR42-0001-_10
DC BUS R16-B2 FAILS DURING OPERATION
R16-BDC-LP-R16B2
4.80E-06
NO POWER FROM SOURCES
GR42-0002-_10
DC BUS R16-B2 IN MAINTENANCE
R16-BDC-TM-R16B2
4.80E-06
NO POWER FROM MCC R12-B201A
GR42-0003-_10
NO POWER FROM THE R16-BTB2 BATTERY
GR42-0006-_10
Page 20
NO POWER THROUGH B/C R16-BYCB2
GR42-0004-_10
LOSS OF 480 V AC FROM BUS R12-B2-01B
GR12-0001-_19
2
BATTERY CHARGER R16-BYCB2 IN TEST
R16-BYC-TM-R16BYCB2
3.00E-04
BATTERY CHARGER R16-BYCB2 FAILS TO MAINTAIN OUTPUT
R16-BYC-LP-R16BYCB2
1.68E-04
BATT. CHARG. R16-BYCB2 OUTPUT BREAKER OPENS SPURIOUSLY
R16-LCB-CO-TOR16B2
1.44E-05
480V FEEDER BREAKER TO R16-BYCB2 OPENS SPURIOUSLY
R16-LCB-CO-TOR16BYCB2
1.44E-05


NO POWER FROM THE R16-BTB2 BATTERY
GR42-0006-_10
Page 19
BATTERY R16-BTB2 FAILS TO PROVIDE OUTPUT
GR42-0007-_10
FAILURE DUE TO CCF
GR42-0008-_10
BATTERY R16-BTB2 IN TEST
R16-BT_-TM-R16BTB2
1.00E-03
BATTERY R16-BTB2 FAILS TO PROVIDE OUTPUT
R16-BT_-LP-R16BTB2
5.00E-04
CIRCUIT BREAKER FROM R16-BTB2 OPENS SPURIOUSLY
R16-LCB-CO-FROMR16BTB2
1.44E-05
BATTERY CCF 2 OUT OF 5
GR42-0009-_10
BATTERY CCF #2
R16-BT_-CF-ALLBATT
11
9.00E-06
BATTERY A1 & B2 CCF
R16-BT_-CF-BATTA1B2
2
1.53E-06
BATTERY A2 & B2 CCF
R16-BT_-CF-BATTA2B2
2
1.53E-06
BATTERY B1 & B2 CCF
R16-BT_-CF-BATTB1B2
2
1.53E-06
BATTERY B2 & C CCF
R16-BT_-CF-BATTB2C
2
1.53E-06
1
2
3
4



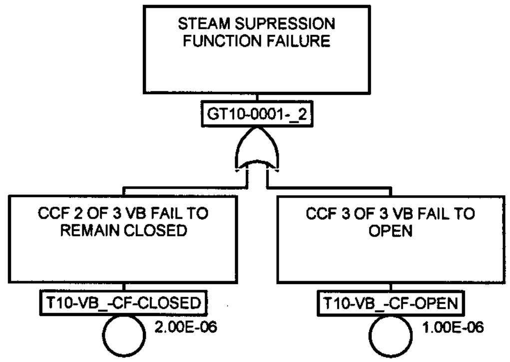
LOSS OF POWER FROM 250V DC NO 1E BUS R16-C
GR42-0001-_11
DC BUS R16-C FAILS DURING OPERATION
R16-BDC-LP-R16C
4.80E-06
NO POWER FROM SOURCES
GR42-0002-_11
DC BUS R16-C IN MAINTENANCE
R16-BDC-TM-R16C
4.80E-06
NO POWER FROM MCC R12-C23
GR42-0003-_11
NO POWER FROM THE R16-BTC BATTERY
GR42-0006-_11
Page 22
NO POWER THROUGH B/C R16-BYCC
GR42-0004-_11
LOSS OF 480 V AC FROM BUS R12-C23
GR12-0001-_5
BATTERY CHARGER R16-BYCC IN TEST
R16-BYC-TM-R16BYCC
3.00E-04
BATTERY CHARGER R16-BYCC FAILS TO MAINTAIN OUTPUT
R16-BYC-LP-R16BYCC
1.68E-04
BATT. CHARG. R16-BYCC OUTPUT BREAKER OPENS SPURIOUSLY
R16-LCB-CO-TOR16C
1.44E-05
480V FEEDER BREAKER TO R16-BYCC OPENS SPURIOUSLY
R16-LCB-CO-TOR16BYCC
1.44E-05
1
2
3


NO POWER FROM THE R16-BTC BATTERY
GR42-0006-_11
Page 21
BATTERY R16-BTC FAILS TO PROVIDE OUTPUT
GR42-0007-_11
FAILURE DUE TO CCF
GR42-0008-_11
BATTERY R16-BTC IN TEST
R16-BT_-TM-R16BTC
1.00E-03
BATTERY R16-BTC FAILS TO PROVIDE OUTPUT
R16-BT_-LP-R16BTC
5.00E-04
CIRCUIT BREAKER FROM R16-BTC OPENS SPURIOUSLY
R16-LCB-CO-FROMR16BTC
1.44E-05
BATTERY CCF 2 OUT OF 5
GR42-0009-_11
BATTERY CCF #2
R16-BT_-CF-ALLBATT
11
9.00E-06
BATTERY A1 & C CCF
R16-BT_-CF-BATTA1C
2
1.53E-06
BATTERY A2 & C CCF
R16-BT_-CF-BATTA2C
2
1.53E-06
BATTERY B1 & C CCF
R16-BT_-CF-BATTB1C
2
1.53E-06
BATTERY B2 & C CCF
R16-BT_-CF-BATTB2C
2
1.53E-06
1
2
3
4

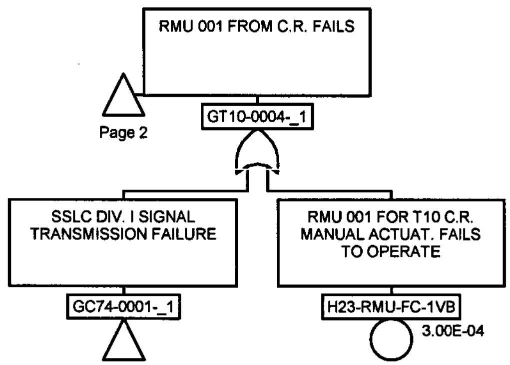
Name	Page	Zone	Name	Page	Zone
GR12-0001- 1	1	3	GR42-0004- 9	17	2
GR12-0001- 1	3	3	GR42-0006- 1	1	3
GR12-0001- 18	13	3	GR42-0006- 1	2	3
GR12-0001- 18	15	3	GR42-0006- 10	19	3
GR12-0001- 19	17	3	GR42-0006- 10	20	3
GR12-0001- 19	19	3	GR42-0006- 11	21	3
GR12-0001- 2	5	3	GR42-0006- 11	22	3
GR12-0001- 2	7	3	GR42-0006- 2	3	3
GR12-0001- 3	9	3	GR42-0006- 2	4	3
GR12-0001- 4	11	3	GR42-0006- 3	5	3
GR12-0001- 5	21	3	GR42-0006- 3	6	3
GR24-0003- 3	5	2	GR42-0006- 4	7	3
GR42-0001- 1	1	2	GR42-0006- 4	8	3
GR42-0001- 10	19	2	GR42-0006- 5	9	3
GR42-0001- 11	21	2	GR42-0006- 5	10	3
GR42-0001- 2	3	2	GR42-0006- 6	11	3
GR42-0001- 3	5	2	GR42-0006- 6	12	3
GR42-0001- 4	7	2	GR42-0006- 7	13	3
GR42-0001- 5	9	2	GR42-0006- 7	14	3
GR42-0001- 6	11	2	GR42-0006- 8	15	3
GR42-0001- 7	13	2	GR42-0006- 8	16	3
GR42-0001- 8	15	2	GR42-0006- 9	17	3
GR42-0001- 9	17	2	GR42-0006- 9	18	3
GR42-0002- 1	1	3	GR42-0007- 1	2	2
GR42-0002- 10	19	3	GR42-0007- 10	20	2
GR42-0002- 11	21	3	GR42-0007- 11	22	2
GR42-0002- 2	3	3	GR42-0007- 2	4	2
GR42-0002- 3	5	3	GR42-0007- 3	6	2
GR42-0002- 4	7	3	GR42-0007- 4	8	2
GR42-0002- 5	9	3	GR42-0007- 5	10	2
GR42-0002- 6	11	3	GR42-0007- 6	12	2
GR42-0002- 7	13	3	GR42-0007- 7	14	2
GR42-0002- 8	15	3	GR42-0007- 8	16	2
GR42-0002- 9	17	3	GR42-0007- 9	18	2
GR42-0003- 1	1	2	GR42-0008- 1	2	4
GR42-0003- 10	19	2	GR42-0008- 10	20	4
GR42-0003- 11	21	2	GR42-0008- 11	22	4
GR42-0003- 2	3	2	GR42-0008- 2	4	4
GR42-0003- 4	7	2	GR42-0008- 3	6	4
GR42-0003- 5	9	2	GR42-0008- 4	8	4
GR42-0003- 6	11	2	GR42-0008- 5	10	4
GR42-0003- 7	13	2	GR42-0008- 6	12	4
GR42-0003- 8	15	2	GR42-0008- 7	14	4
GR42-0003- 9	17	2	GR42-0008- 8	16	4
GR42-0004- 1	1	2	GR42-0008- 9	18	4
GR42-0004- 10	19	2	GR42-0009- 1	2	3
GR42-0004- 11	21	2	GR42-0009- 10	20	3
GR42-0004- 2	3	2	GR42-0009- 11	22	3
GR42-0004- 3	5	2	GR42-0009- 2	4	3
GR42-0004- 4	7	2	GR42-0009- 3	6	3
GR42-0004- 5	9	2	GR42-0009- 4	8	3
GR42-0004- 6	11	2	GR42-0009- 5	10	3
GR42-0004- 7	13	2	GR42-0009- 6	12	3
GR42-0004- 8	15	2	GR42-0009- 7	14	3

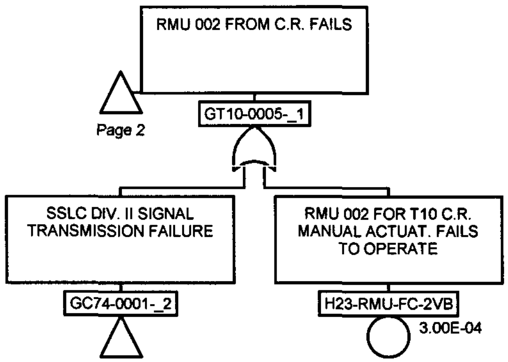
Name	Page	Zone	Name	Page	Zone
GR42-0009- 8	16	3	R16-BT -CF-BATT21&22	8	3
GR42-0009- 9	18	3	R16-BT -CF-BATT21&31	6	4
R16-BDC-LP-R1611	1	1	R16-BT -CF-BATT21&31	10	3
R16-BDC-LP-R1612	3	1	R16-BT -CF-BATT21&41	6	3
R16-BDC-LP-R1621	5	1	R16-BT -CF-BATT21&41	12	3
R16-BDC-LP-R1622	7	1	R16-BT -CF-BATT22&31	8	4
R16-BDC-LP-R1631	9	1	R16-BT -CF-BATT22&31	10	4
R16-BDC-LP-R1641	11	1	R16-BT -CF-BATT22&41	8	3
R16-BDC-LP-R16A1	13	1	R16-BT -CF-BATT22&41	12	4
R16-BDC-LP-R16A2	15	1	R16-BT -CF-BATT31&41	10	3
R16-BDC-LP-R16B1	17	1	R16-BT -CF-BATT31&41	12	3
R16-BDC-LP-R16B2	19	1	R16-BT -CF-BATTA1A2	14	3
R16-BDC-LP-R16C	21	1	R16-BT -CF-BATTA1A2	16	3
R16-BDC-TM-R1611	1	4	R16-BT -CF-BATTA1B1	14	4
R16-BDC-TM-R1612	3	4	R16-BT -CF-BATTA1B1	18	3
R16-BDC-TM-R1621	5	4	R16-BT -CF-BATTA1B2	14	3
R16-BDC-TM-R1622	7	4	R16-BT -CF-BATTA1B2	20	3
R16-BDC-TM-R1631	9	4	R16-BT -CF-BATTA1C	14	4
R16-BDC-TM-R1641	11	4	R16-BT -CF-BATTA1C	22	3
R16-BDC-TM-R16A1	13	4	R16-BT -CF-BATTA2B1	16	4
R16-BDC-TM-R16A2	15	4	R16-BT -CF-BATTA2B1	18	4
R16-BDC-TM-R16B1	17	4	R16-BT -CF-BATTA2B2	16	3
R16-BDC-TM-R16B2	19	4	R16-BT -CF-BATTA2B2	20	4
R16-BDC-TM-R16C	21	4	R16-BT -CF-BATTA2C	16	4
R16-BT -CF-ALLBATT	2	4	R16-BT -CF-BATTA2C	22	4
R16-BT -CF-ALLBATT	4	4	R16-BT -CF-BATTB1B2	18	3
R16-BT -CF-ALLBATT	6	4	R16-BT -CF-BATTB1B2	20	3
R16-BT -CF-ALLBATT	8	4	R16-BT -CF-BATTB1C	18	4
R16-BT -CF-ALLBATT	10	4	R16-BT -CF-BATTB1C	22	3
R16-BT -CF-ALLBATT	12	4	R16-BT -CF-BATTB2C	20	4
R16-BT -CF-ALLBATT	14	4	R16-BT -CF-BATTB2C	22	4
R16-BT -CF-ALLBATT	16	4	R16-BT -LP-R16BT11	2	1
R16-BT -CF-ALLBATT	18	4	R16-BT -LP-R16BT12	4	1
R16-BT -CF-ALLBATT	20	4	R16-BT -LP-R16BT21	6	1
R16-BT -CF-ALLBATT	22	4	R16-BT -LP-R16BT22	8	1
R16-BT -CF-BATT11&12	2	3	R16-BT -LP-R16BT31	10	1
R16-BT -CF-BATT11&12	4	3	R16-BT -LP-R16BT41	12	1
R16-BT -CF-BATT11&21	2	4	R16-BT -LP-R16BTA1	14	1
R16-BT -CF-BATT11&21	6	3	R16-BT -LP-R16BTA2	16	1
R16-BT -CF-BATT11&22	2	3	R16-BT -LP-R16BTB1	18	1
R16-BT -CF-BATT11&22	8	3	R16-BT -LP-R16BTB2	20	1
R16-BT -CF-BATT11&31	2	4	R16-BT -LP-R16BTC	22	1
R16-BT -CF-BATT11&31	10	3	R16-BT -TM-R16BT11	2	5
R16-BT -CF-BATT11&41	2	3	R16-BT -TM-R16BT12	4	5
R16-BT -CF-BATT11&41	12	3	R16-BT -TM-R16BT21	6	5
R16-BT -CF-BATT12&21	4	4	R16-BT -TM-R16BT22	8	5
R16-BT -CF-BATT12&21	6	4	R16-BT -TM-R16BT31	10	5
R16-BT -CF-BATT12&22	4	3	R16-BT -TM-R16BT41	12	5
R16-BT -CF-BATT12&22	8	4	R16-BT -TM-R16BTA1	14	5
R16-BT -CF-BATT12&31	4	4	R16-BT -TM-R16BTA2	16	5
R16-BT -CF-BATT12&31	10	4	R16-BT -TM-R16BTB1	18	5
R16-BT -CF-BATT12&41	4	3	R16-BT -TM-R16BTB2	20	5
R16-BT -CF-BATT12&41	12	4	R16-BT -TM-R16BTC	22	5
R16-BT_-CF-BATT21&22	6	3	R16-BYC-LP-R16BYC11	1	1

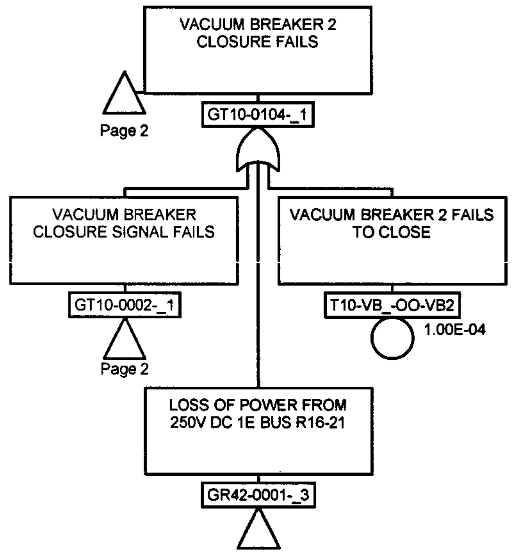
Appendix B.4.18-1 Containment Systems Fault Trees

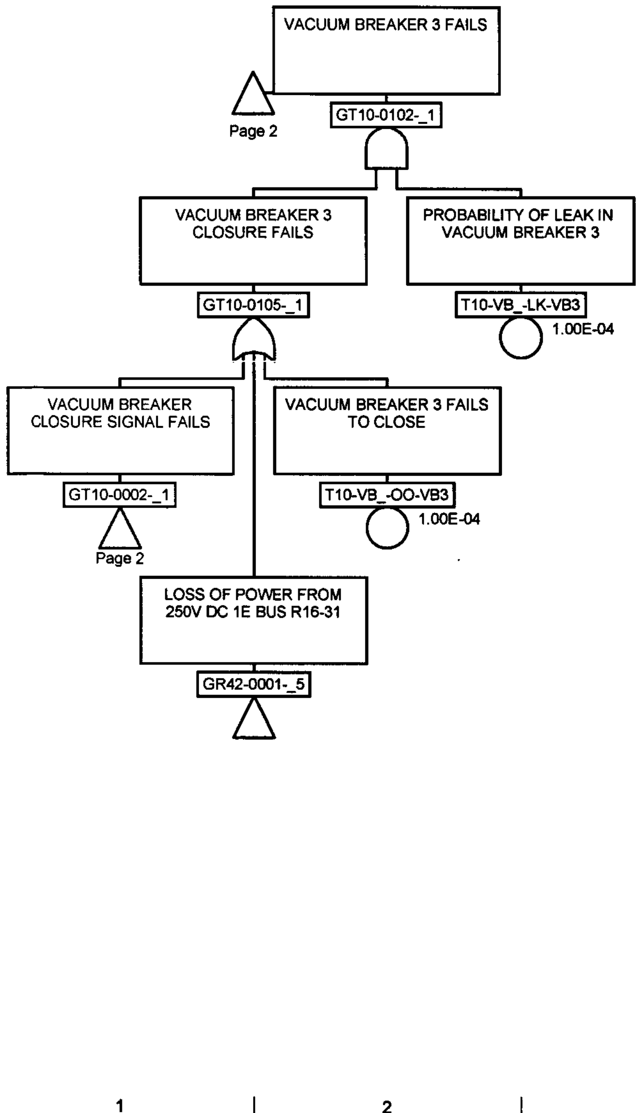

STEAM SUPRESSION FUNCTION FAILURE
GT10-0001-_2
CCF 2 OF 3 VB FAIL TO REMAIN CLOSED
T10-VB_-CF-CLOSED
2.00E-06
CCF 3 OF 3 VB FAIL TO OPEN
T10-VB_-CF-OPEN
1.00E-06
1
2


ISOLATION OF VB LEAKS FAILS
GT10-0001-_1
VACUUM BREAKER 1 FAILS
GT10-0100-_1
VACUUM BREAKER 2 FAILS
GT10-0101-_1
VACUUM BREAKER 3 FAILS
GT10-0102-_1
Page 6
VACUUM BREAKER 1 CLOSURE FAILS
GT10-0103-_1
PROBABILITY OF LEAK IN VACUUM BREAKER 1
T10-VB_-LK-VB1
1.00E-04
VACUUM BREAKER 2 CLOSURE FAILS
GT10-0104-_1
Page 5
PROBABILITY OF LEAK IN VACUUM BREAKER 2
T10-VB_-LK-VB2
1.00E-04
VACUUM BREAKER CLOSURE SIGNAL FAILS
GT10-0002-_1
Page 5
Page 6
LOSS OF POWER FROM 250V DC 1E BUS R16-11
GR42-0001-_1
VACUUM BREAKER 1 FAILS TO CLOSE
T10-VB_-OO-VB1
1.00E-04
OPERATOR FAILS TO CLOSE VACUUM BREAKER
T10-XHE-FO-CLOSE
1.77E-02
HOUSE EVENT: OPERATOR IS NOT AVAILABLE (VALUE=1)
XHOSMAN
SIGNAL FROM C.R. FAILS
GT10-0003-_1
RMU 001 FROM C.R. FAILS
GT10-0004-_1
Page 3
RMU 002 FROM C.R. FAILS
GT10-0005-_1
Page 4
1
2
3
4
5
6


RMU 001 FROM C.R. FAILS
Page 2
GT10-0004-_1
SSLC DIV. I SIGNAL TRANSMISSION FAILURE
GC74-0001-_1
RMU 001 FOR T10 C.R. MANUAL ACTUAT. FAILS TO OPERATE
H23-RMU-FC-1VB
3.00E-04
1
2


RMU 002 FROM C.R. FAILS
Page 2
GT10-0005-_1
SSLC DIV. II SIGNAL TRANSMISSION FAILURE
GC74-0001-_2
RMU 002 FOR T10 C.R. MANUAL ACTUAT. FAILS TO OPERATE
H23-RMU-FC-2VB
3.00E-04

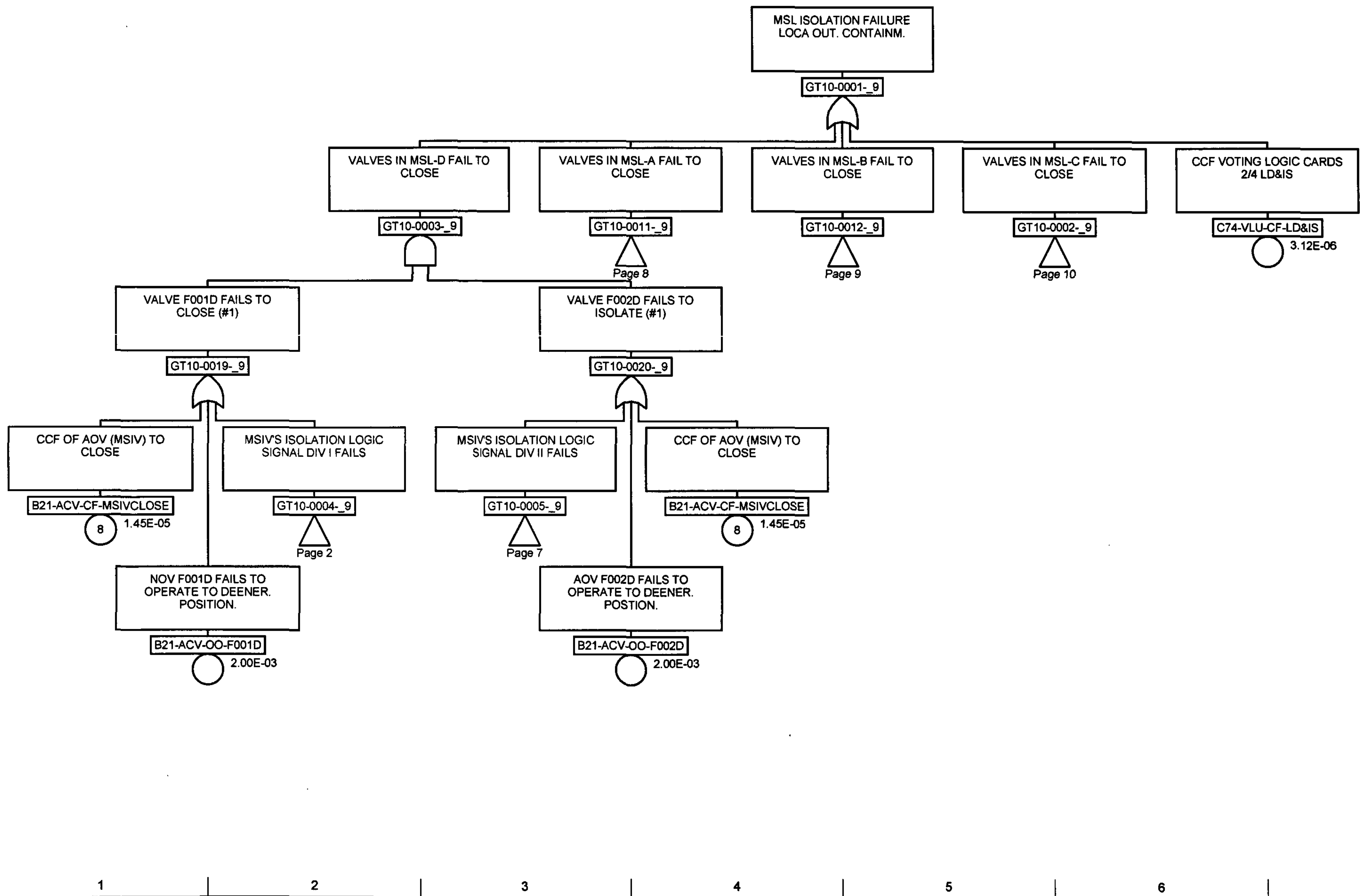

VACUUM BREAKER 2 CLOSURE FAILS
GT10-0104-_1
Page 2
VACUUM BREAKER CLOSURE SIGNAL FAILS
GT10-0002-_1
Page 2
VACUUM BREAKER 2 FAILS TO CLOSE
T10-VB_-OO-VB2
1.00E-04
LOSS OF POWER FROM 250V DC 1E BUS R16-21
GR42-0001-_3

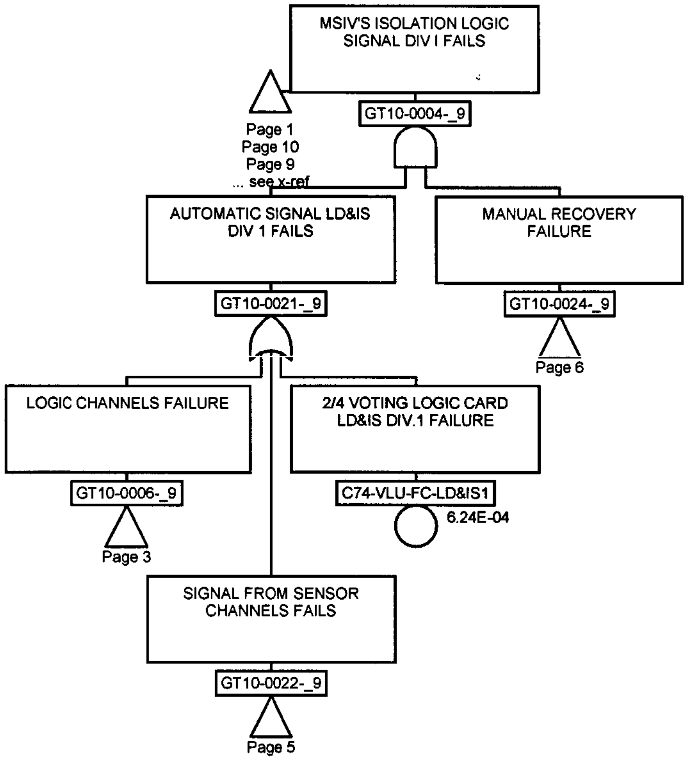

VACUUM BREAKER 3 FAILS
Page 2
GT10-0102-_1
VACUUM BREAKER 3 CLOSURE FAILS
GT10-0105-_1
PROBABILITY OF LEAK IN VACUUM BREAKER 3
T10-VB_-LK-VB3
1.00E-04
VACUUM BREAKER CLOSURE SIGNAL FAILS
GT10-0002-_1
Page 2
VACUUM BREAKER 3 FAILS TO CLOSE
T10-VB_-OO-VB3
1.00E-04
LOSS OF POWER FROM 250V DC 1E BUS R16-31
GR42-0001-_5
1
2

Appendix B.4.18-2

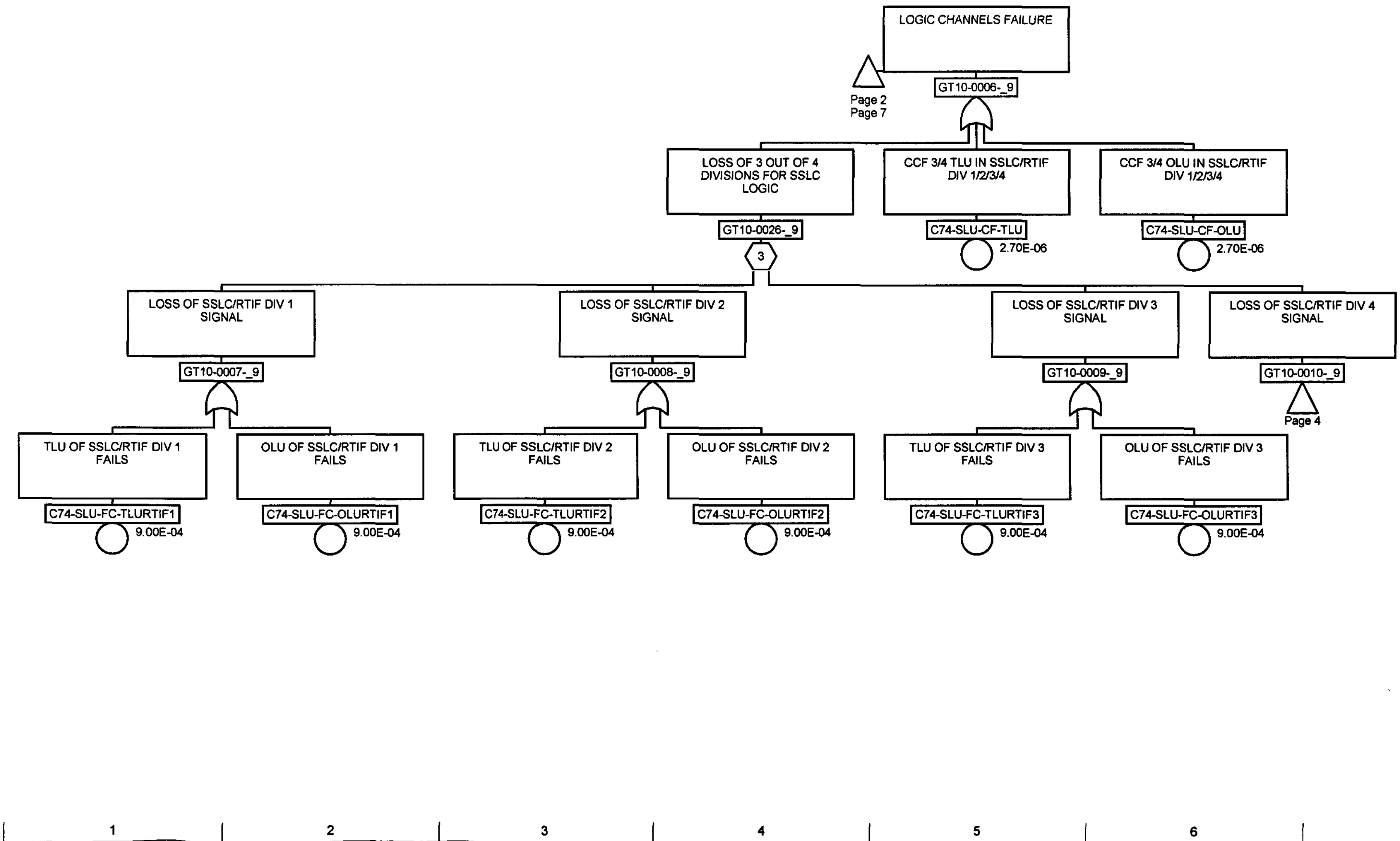
Containment Systems

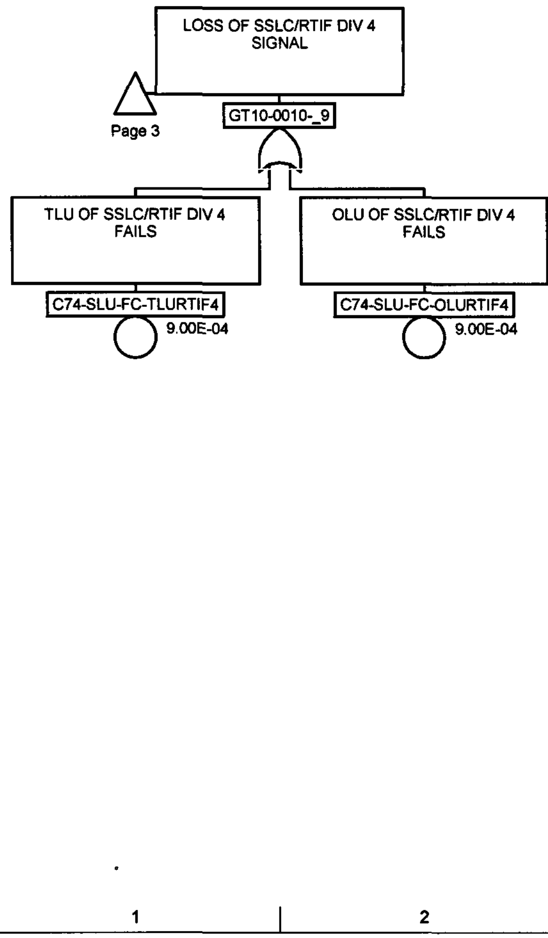
Fault Trees

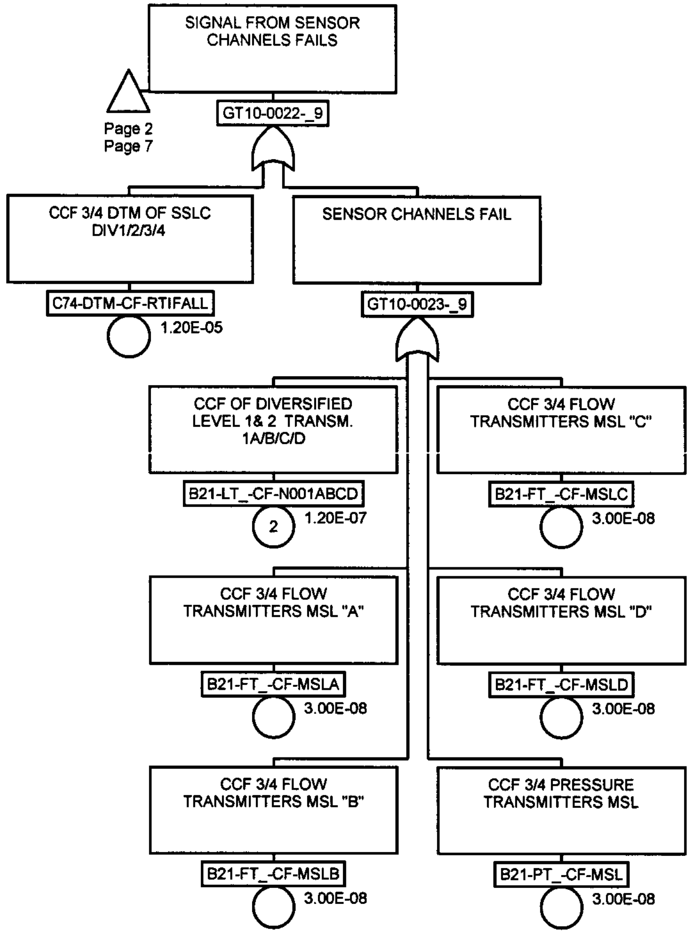

MSL ISOLATION FAILURE LOCA OUT. CONTAINM.
GT10-0001-_9
VALVES IN MSL-D FAIL TO CLOSE
GT10-0003-_9
VALVES IN MSL-A FAIL TO CLOSE
GT10-0011-_9
Page 8
VALVES IN MSL-B FAIL TO CLOSE
GT10-0012-_9
Page 9
VALVES IN MSL-C FAIL TO CLOSE
GT10-0002-_9
Page 10
CCF VOTING LOGIC CARDS 2/4 LD&IS
C74-VLU-CF-LD&IS
3.12E-06
VALVE F001D FAILS TO CLOSE (#1)
GT10-0019-_9
VALVE F002D FAILS TO ISOLATE (#1)
GT10-0020-_9
CCF OF AOV (MSIV) TO CLOSE
B21-ACV-CF-MSIVCLOSE
8
1.45E-05
MSIV'S ISOLATION LOGIC SIGNAL DIV I FAILS
GT10-0004-_9
Page 2
MSIV'S ISOLATION LOGIC SIGNAL DIV II FAILS
GT10-0005-_9
Page 7
CCF OF AOV (MSIV) TO CLOSE
B21-ACV-CF-MSIVCLOSE
8
1.45E-05
NOV F001D FAILS TO OPERATE TO DEENER. POSITION.
B21-ACV-OO-F001D
2.00E-03
AOV F002D FAILS TO OPERATE TO DEENER. POSTION.
B21-ACV-OO-F002D
2.00E-03
1
2
3
4
5
6

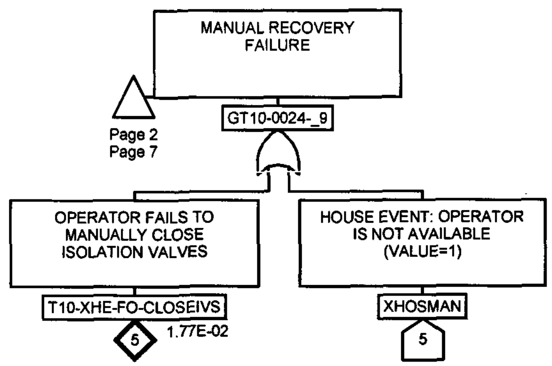


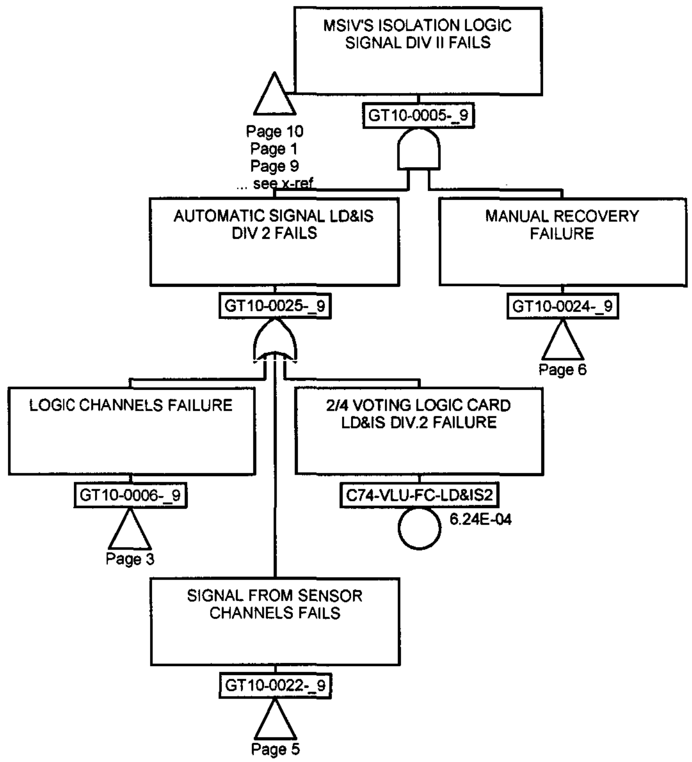
MSIV'S ISOLATION LOGIC SIGNAL DIV I FAILS
GT10-0004-_9
Page 1
Page 10
Page 9
... see x-ref
AUTOMATIC SIGNAL LD&IS DIV 1 FAILS
GT10-0021-_9
MANUAL RECOVERY FAILURE
GT10-0024-_9
Page 6
LOGIC CHANNELS FAILURE
GT10-0006-_9
Page 3
2/4 VOTING LOGIC CARD LD&IS DIV.1 FAILURE
C74-VLU-FC-LD&IS1
6.24E-04
SIGNAL FROM SENSOR CHANNELS FAILS
GT10-0022-_9
Page 5
1
2

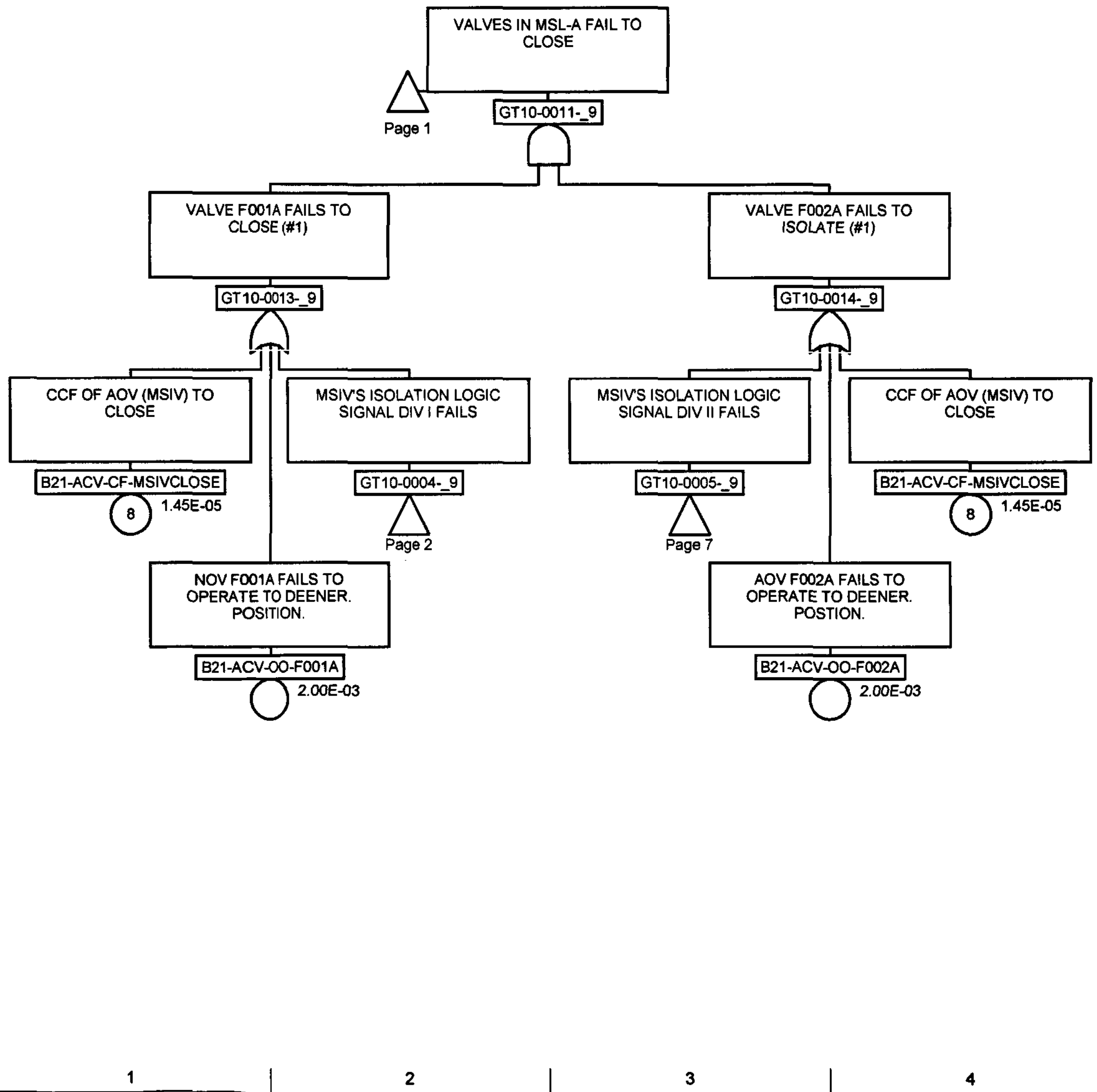

LOGIC CHANNELS FAILURE
GT10-0006-_9
Page 2
Page 7
LOSS OF 3 OUT OF 4 DIVISIONS FOR SSLC LOGIC
GT10-0026-_9
3
CCF 3/4 TLU IN SSLC/RTIF DIV 1/2/3/4
C74-SLU-CF-TLU
2.70E-06
CCF 3/4 OLU IN SSLC/RTIF DIV 1/2/3/4
C74-SLU-CF-OLU
2.70E-06
LOSS OF SSLC/RTIF DIV 1 SIGNAL
GT10-0007-_9
LOSS OF SSLC/RTIF DIV 2 SIGNAL
GT10-0008-_9
LOSS OF SSLC/RTIF DIV 3 SIGNAL
GT10-0009-_9
LOSS OF SSLC/RTIF DIV 4 SIGNAL
GT10-0010-_9
Page 4
TLU OF SSLC/RTIF DIV 1 FAILS
C74-SLU-FC-TLURTIF1
9.00E-04
OLU OF SSLC/RTIF DIV 1 FAILS
C74-SLU-FC-OLURTIF1
9.00E-04
TLU OF SSLC/RTIF DIV 2 FAILS
C74-SLU-FC-TLURTIF2
9.00E-04
OLU OF SSLC/RTIF DIV 2 FAILS
C74-SLU-FC-OLURTIF2
9.00E-04
TLU OF SSLC/RTIF DIV 3 FAILS
C74-SLU-FC-TLURTIF3
9.00E-04
OLU OF SSLC/RTIF DIV 3 FAILS
C74-SLU-FC-OLURTIF3
9.00E-04
1
2
3
4
5
6

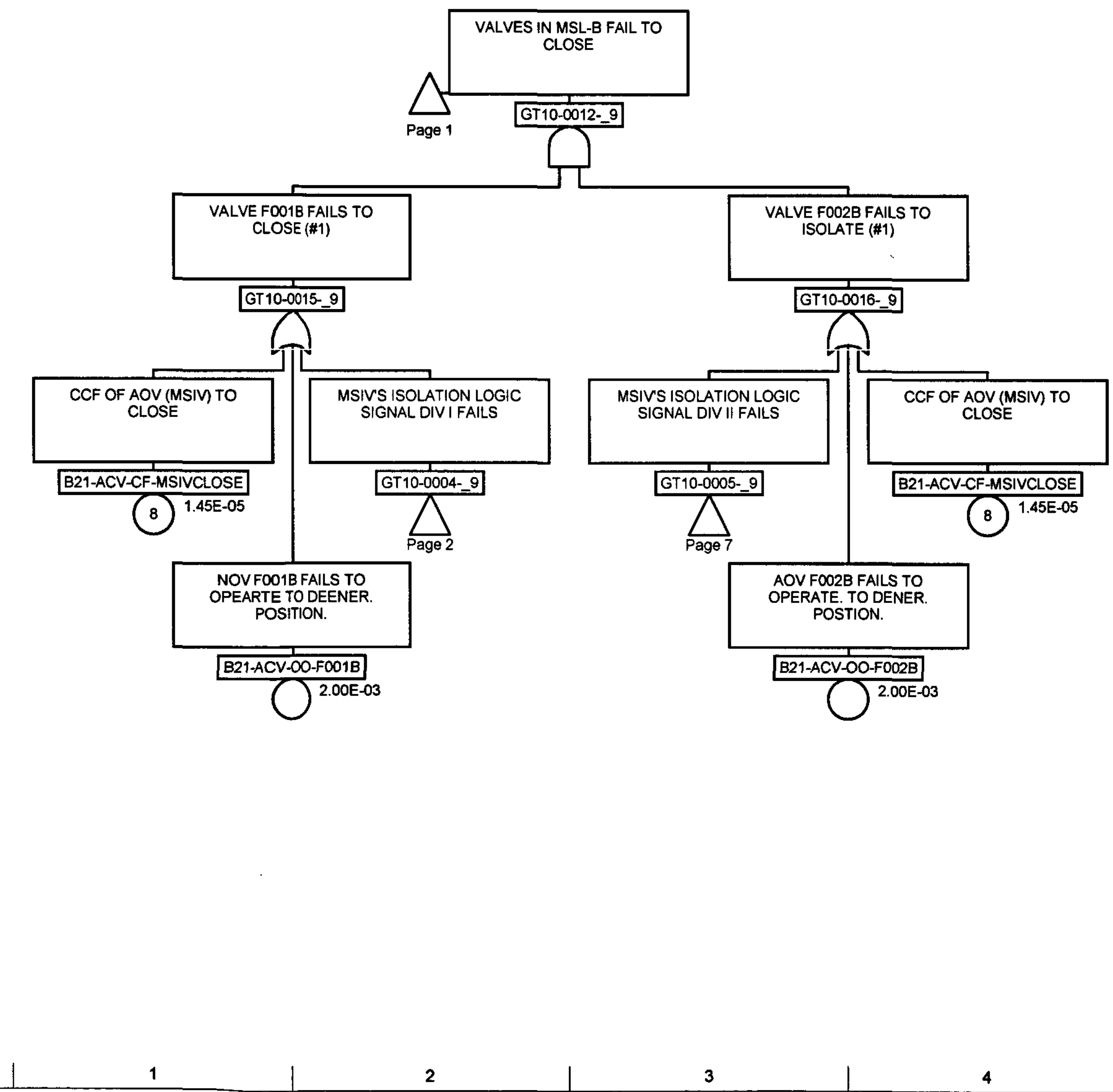

LOSS OF SSLC/RTIF DIV 4 SIGNAL
GT10-0010-_9
Page 3
TLU OF SSLC/RTIF DIV 4 FAILS
C74-SLU-FC-TLURTIF4
9.00E-04
OLU OF SSLC/RTIF DIV 4 FAILS
C74-SLU-FC-OLURTIF4
9.00E-04
1
2

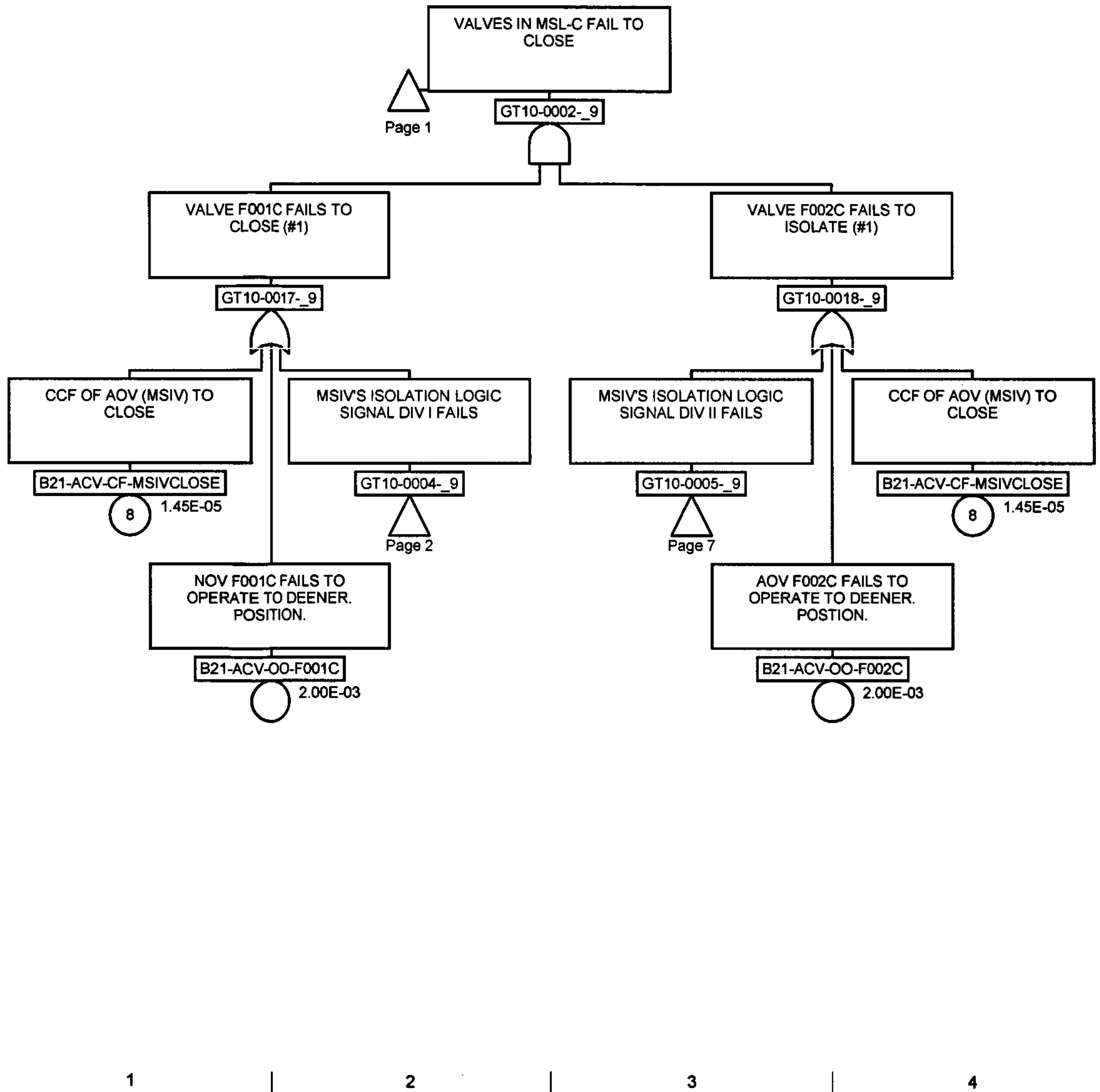

SIGNAL FROM SENSOR CHANNELS FAILS
GT10-0022-_9
Page 2
Page 7
CCF 3/4 DTM OF SSLC DIV1/2/3/4
C74-DTM-CF-RTIFALL
1.20E-05
SENSOR CHANNELS FAIL
GT10-0023-_9
CCF OF DIVERSIFIED LEVEL 1& 2 TRANSM. 1A/B/C/D
B21-LT_-CF-N001ABCD
2
1.20E-07
CCF 3/4 FLOW TRANSMITTERS MSL "C"
B21-FT_-CF-MSLC
3.00E-08
CCF 3/4 FLOW TRANSMITTERS MSL "A"
B21-FT_-CF-MSLA
3.00E-08
CCF 3/4 FLOW TRANSMITTERS MSL "D"
B21-FT_-CF-MSLD
3.00E-08
CCF 3/4 FLOW TRANSMITTERS MSL "B"
B21-FT_-CF-MSLB
3.00E-08
CCF 3/4 PRESSURE TRANSMITTERS MSL
B21-PT_-CF-MSL
3.00E-08
1
2

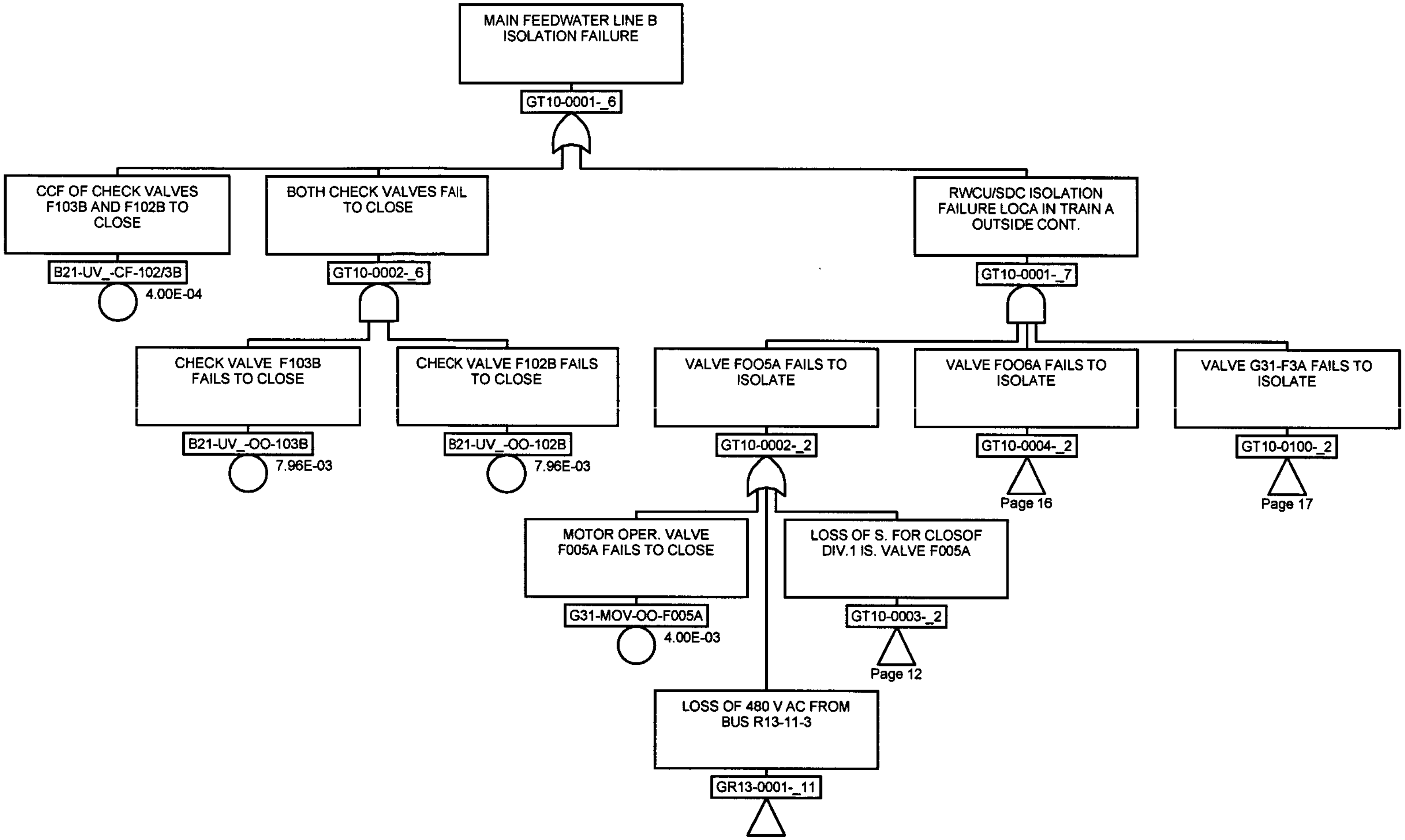

MANUAL RECOVERY FAILURE
GT10-0024-_9
Page 2
Page 7
OPERATOR FAILS TO MANUALLY CLOSE ISOLATION VALVES
T10-XHE-FO-CLOSEIVS
5
1.77E-02
HOUSE EVENT: OPERATOR IS NOT AVAILABLE (VALUE=1)
XHOSMAN
5
1
2

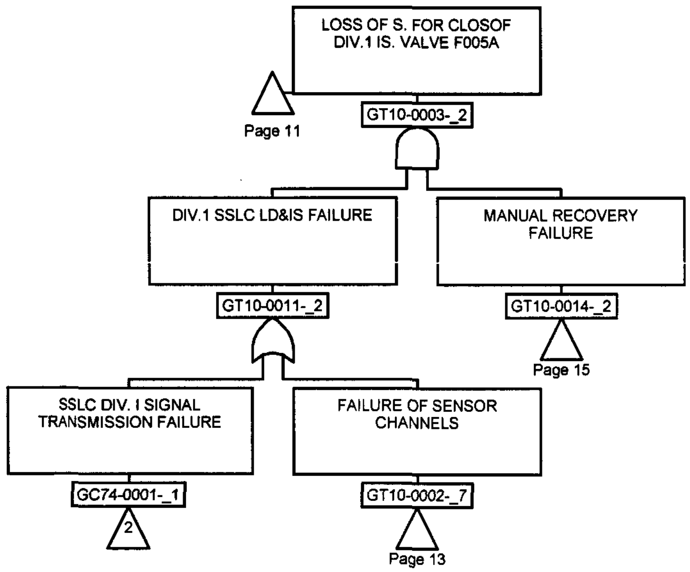

MSIV'S ISOLATION LOGIC SIGNAL DIV II FAILS
GT10-0005-_9
Page 10
Page 1
Page 9
... see x-ref
AUTOMATIC SIGNAL LD&IS DIV 2 FAILS
GT10-0025-_9
MANUAL RECOVERY FAILURE
GT10-0024-_9
Page 6
LOGIC CHANNELS FAILURE
GT10-0006-_9
Page 3
2/4 VOTING LOGIC CARD LD&IS DIV.2 FAILURE
C74-VLU-FC-LD&IS2
6.24E-04
SIGNAL FROM SENSOR CHANNELS FAILS
GT10-0022-_9
Page 5

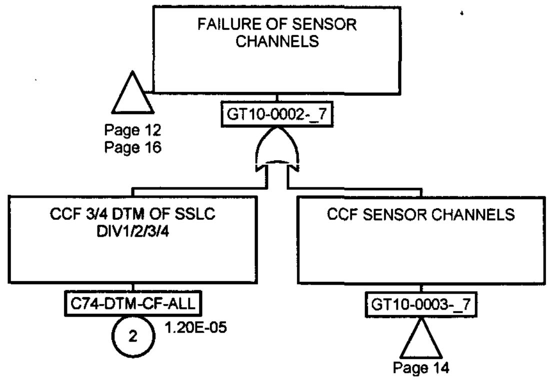

VALVES IN MSL-A FAIL TO CLOSE
GT10-0011-_9
Page 1
VALVE F001A FAILS TO CLOSE (#1)
GT10-0013-_9
VALVE F002A FAILS TO ISOLATE (#1)
GT10-0014-_9
CCF OF AOV (MSIV) TO CLOSE
B21-ACV-CF-MSIVCLOSE
8
1.45E-05
MSIV'S ISOLATION LOGIC SIGNAL DIV I FAILS
GT10-0004-_9
Page 2
MSIV'S ISOLATION LOGIC SIGNAL DIV II FAILS
GT10-0005-_9
Page 7
CCF OF AOV (MSIV) TO CLOSE
B21-ACV-CF-MSIVCLOSE
8
1.45E-05
NOV F001A FAILS TO OPERATE TO DEENER. POSITION.
B21-ACV-OO-F001A
2.00E-03
AOV F002A FAILS TO OPERATE TO DEENER. POSTION.
B21-ACV-OO-F002A
2.00E-03
1
2
3
4

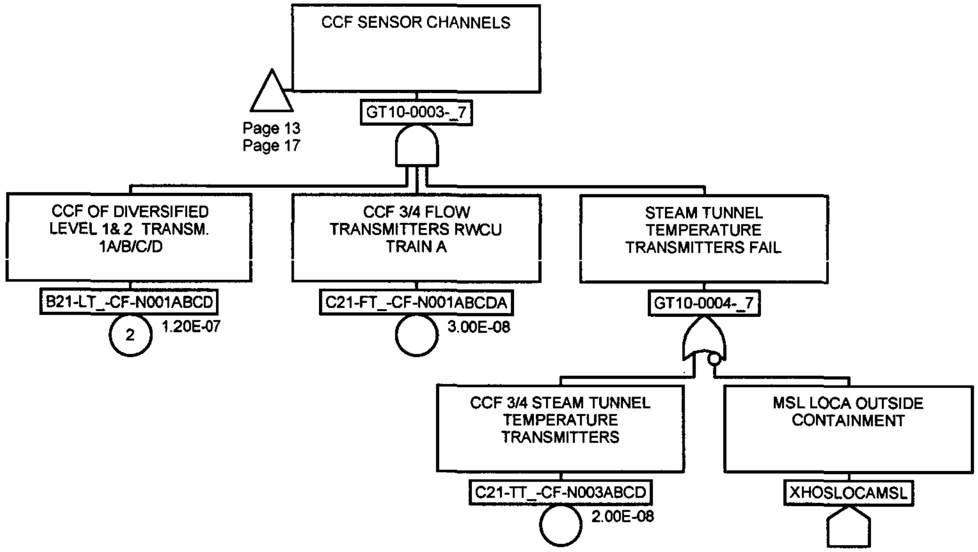

VALVES IN MSL-B FAIL TO CLOSE
Page 1
GT10-0012-_9
VALVE F001B FAILS TO CLOSE (#1)
GT10-0015-_9
VALVE F002B FAILS TO ISOLATE (#1)
GT10-0016-_9
CCF OF AOV (MSIV) TO CLOSE
B21-ACV-CF-MSIVCLOSE
8
1.45E-05
MSIV'S ISOLATION LOGIC SIGNAL DIV I FAILS
GT10-0004-_9
Page 2
MSIV'S ISOLATION LOGIC SIGNAL DIV II FAILS
GT10-0005-_9
Page 7
CCF OF AOV (MSIV) TO CLOSE
B21-ACV-CF-MSIVCLOSE
8
1.45E-05
NOV F001B FAILS TO OPEARTE TO DEENER. POSITION.
B21-ACV-OO-F001B
2.00E-03
AOV F002B FAILS TO OPERATE. TO DENER. POSTION.
B21-ACV-OO-F002B
2.00E-03
1
2
3
4

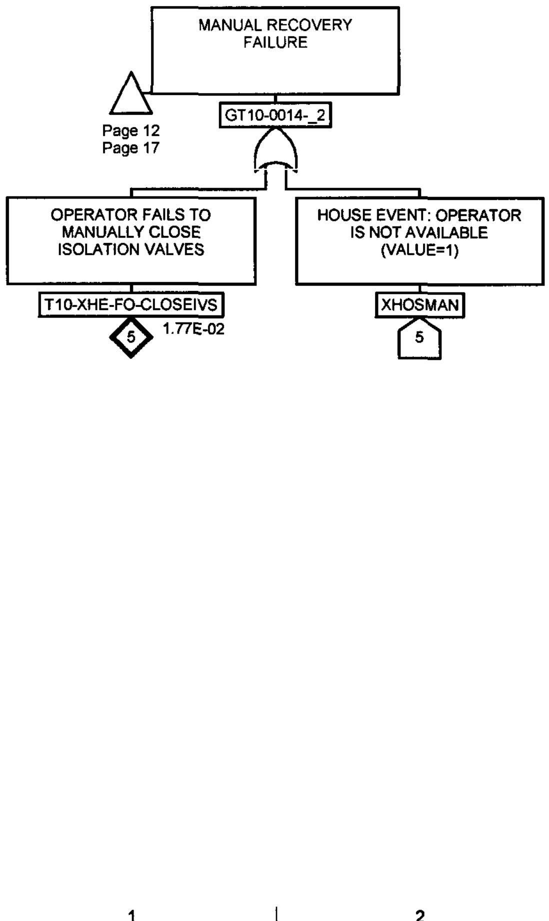

VALVES IN MSL-C FAIL TO CLOSE
GT10-0002-_9
Page 1
VALVE F001C FAILS TO CLOSE (#1)
GT10-0017-_9
VALVE F002C FAILS TO ISOLATE (#1)
GT10-0018-_9
CCF OF AOV (MSIV) TO CLOSE
B21-ACV-CF-MSIVCLOSE
8
1.45E-05
MSIV'S ISOLATION LOGIC SIGNAL DIV I FAILS
GT10-0004-_9
Page 2
MSIV'S ISOLATION LOGIC SIGNAL DIV II FAILS
GT10-0005-_9
Page 7
CCF OF AOV (MSIV) TO CLOSE
B21-ACV-CF-MSIVCLOSE
8
1.45E-05
NOV F001C FAILS TO OPERATE TO DEENER. POSITION.
B21-ACV-OO-F001C
2.00E-03
AOV F002C FAILS TO OPERATE TO DEENER. POSTION.
B21-ACV-OO-F002C
2.00E-03
1
2
3
4

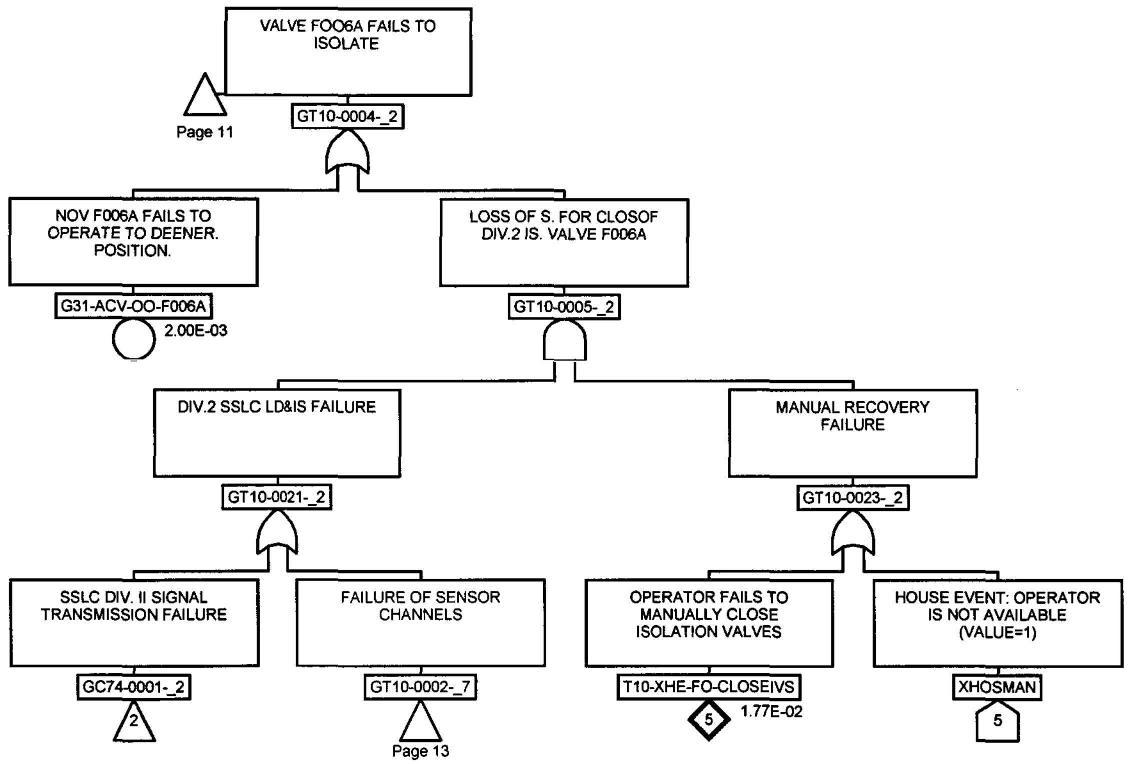

MAIN FEEDWATER LINE B ISOLATION FAILURE
GT10-0001-_6
CCF OF CHECK VALVES F103B AND F102B TO CLOSE
B21-UV_-CF-102/3B
4.00E-04
BOTH CHECK VALVES FAIL TO CLOSE
GT10-0002-_6
RWCU/SDC ISOLATION FAILURE LOCA IN TRAIN A OUTSIDE CONT.
GT10-0001-_7
CHECK VALVE F103B FAILS TO CLOSE
B21-UV_-OO-103B
7.96E-03
CHECK VALVE F102B FAILS TO CLOSE
B21-UV_-OO-102B
7.96E-03
VALVE FOO5A FAILS TO ISOLATE
GT10-0002-_2
VALVE FOO6A FAILS TO ISOLATE
GT10-0004-_2
Page 16
VALVE G31-F3A FAILS TO ISOLATE
GT10-0100-_2
Page 17
MOTOR OPER. VALVE F005A FAILS TO CLOSE
G31-MOV-OO-F005A
4.00E-03
LOSS OF S. FOR CLOSOF DIV.1 IS. VALVE F005A
GT10-0003-_2
Page 12
LOSS OF 480 V AC FROM BUS R13-11-3
GR13-0001-_11

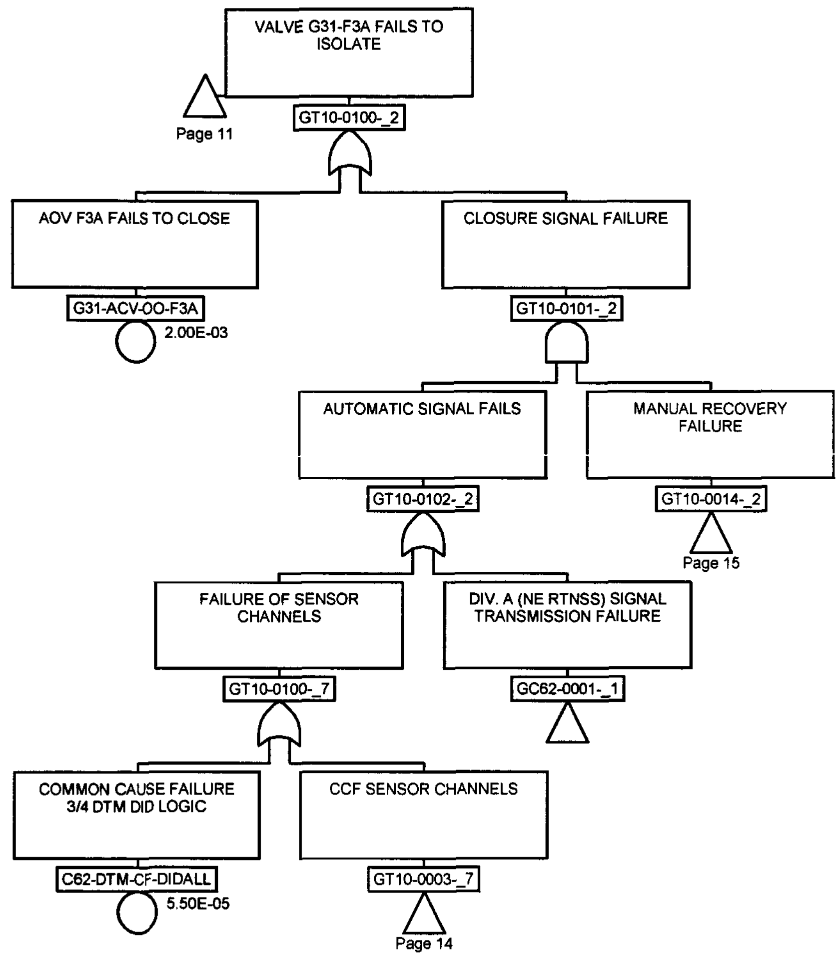

LOSS OF S. FOR CLOSOF DIV.1 IS. VALVE F005A
Page 11
GT10-0003-_2
DIV.1 SSLC LD&IS FAILURE
MANUAL RECOVERY FAILURE
GT10-0011-_2
GT10-0014-_2
Page 15
SSLC DIV. I SIGNAL TRANSMISSION FAILURE
FAILURE OF SENSOR CHANNELS
GC74-0001-_1
2
GT10-0002-_7
Page 13
1
2


FAILURE OF SENSOR CHANNELS
GT10-0002-_7
Page 12
Page 16
CCF 3/4 DTM OF SSLC DIV1/2/3/4
C74-DTM-CF-ALL
2
1.20E-05
CCF SENSOR CHANNELS
GT10-0003-_7
Page 14

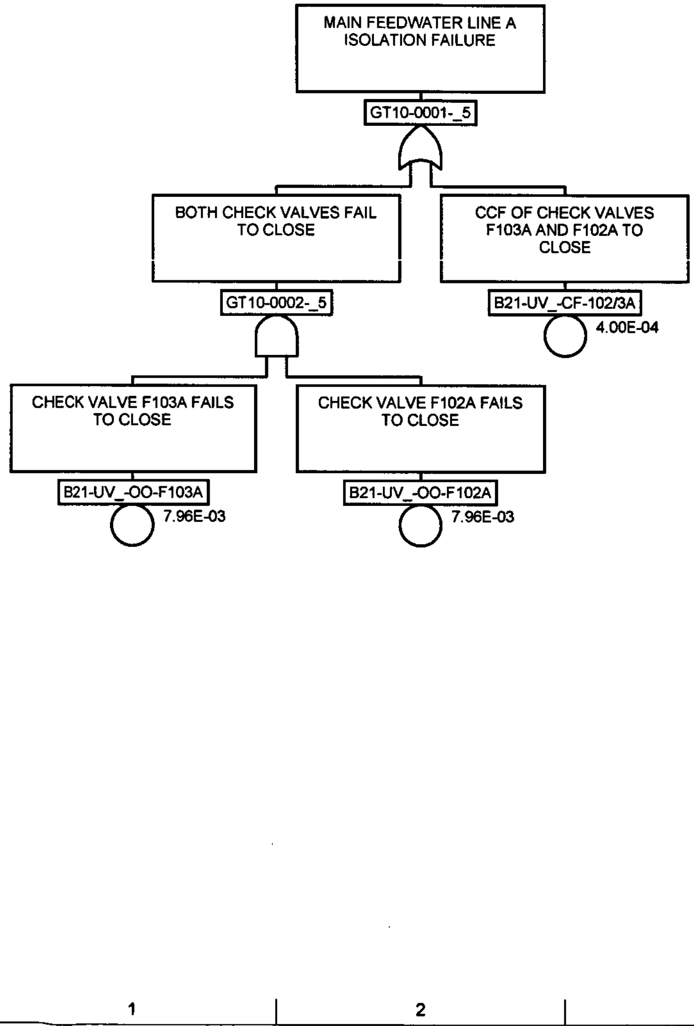

CCF SENSOR CHANNELS
GT10-0003-_7
Page 13
Page 17
CCF OF DIVERSIFIED LEVEL 1& 2 TRANSM. 1A/B/C/D
B21-LT_-CF-N001ABCD
2
1.20E-07
CCF 3/4 FLOW TRANSMITTERS RWCU TRAIN A
C21-FT_-CF-N001ABCDA
3.00E-08
STEAM TUNNEL TEMPERATURE TRANSMITTERS FAIL
GT10-0004-_7
CCF 3/4 STEAM TUNNEL TEMPERATURE TRANSMITTERS
C21-TT_-CF-N003ABCD
2.00E-08
MSL LOCA OUTSIDE CONTAINMENT
XHOSLOCAMSL
1
2
3

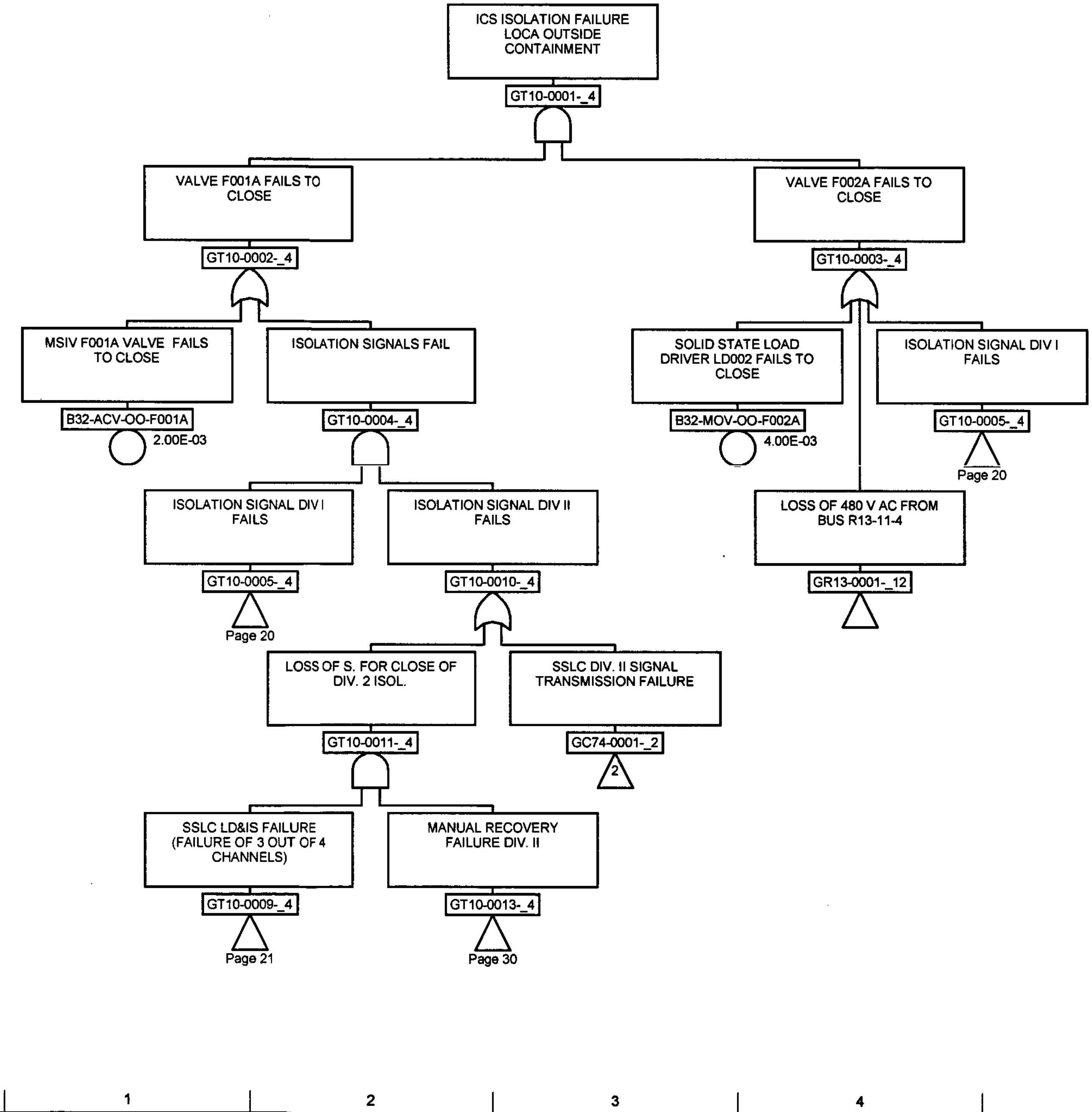

MANUAL RECOVERY FAILURE
GT10-0014-_2
Page 12
Page 17
OPERATOR FAILS TO MANUALLY CLOSE ISOLATION VALVES
T10-XHE-FO-CLOSEIVS
5
1.77E-02
HOUSE EVENT: OPERATOR IS NOT AVAILABLE (VALUE=1)
XHOSMAN
5
1
2


VALVE FOO6A FAILS TO ISOLATE
Page 11
GT10-0004-_2
NOV F006A FAILS TO OPERATE TO DEENER. POSITION.
G31-ACV-OO-F006A
2.00E-03
LOSS OF S. FOR CLOSOF DIV.2 IS. VALVE F006A
GT10-0005-_2
DIV.2 SSLC LD&IS FAILURE
GT10-0021-_2
MANUAL RECOVERY FAILURE
GT10-0023-_2
SSLC DIV. II SIGNAL TRANSMISSION FAILURE
GC74-0001-_2
2
FAILURE OF SENSOR CHANNELS
GT10-0002-_7
Page 13
OPERATOR FAILS TO MANUALLY CLOSE ISOLATION VALVES
T10-XHE-FO-CLOSEIVS
5
1.77E-02
HOUSE EVENT: OPERATOR IS NOT AVAILABLE (VALUE=1)
XHOSMAN
5
1
2
3
4

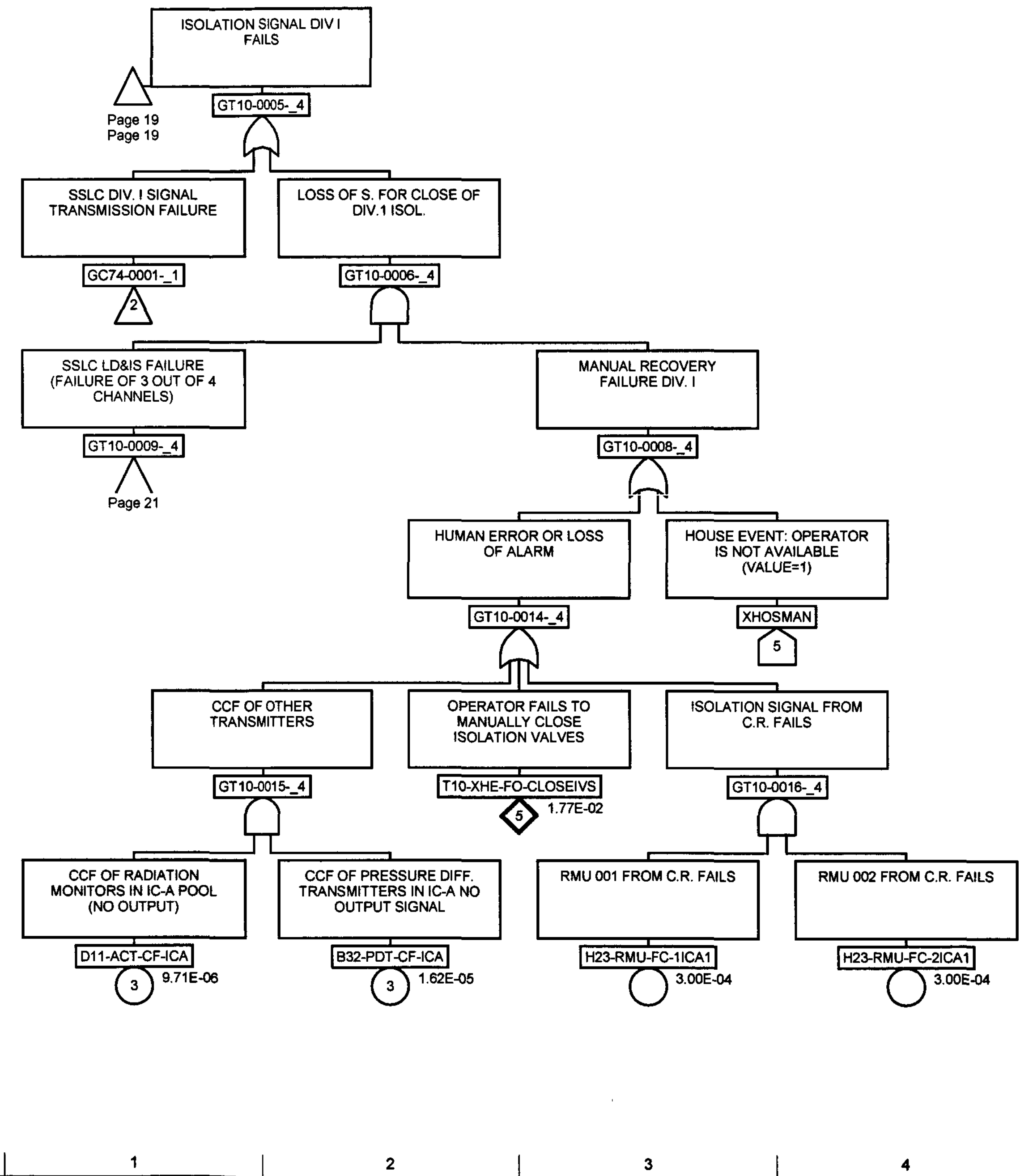


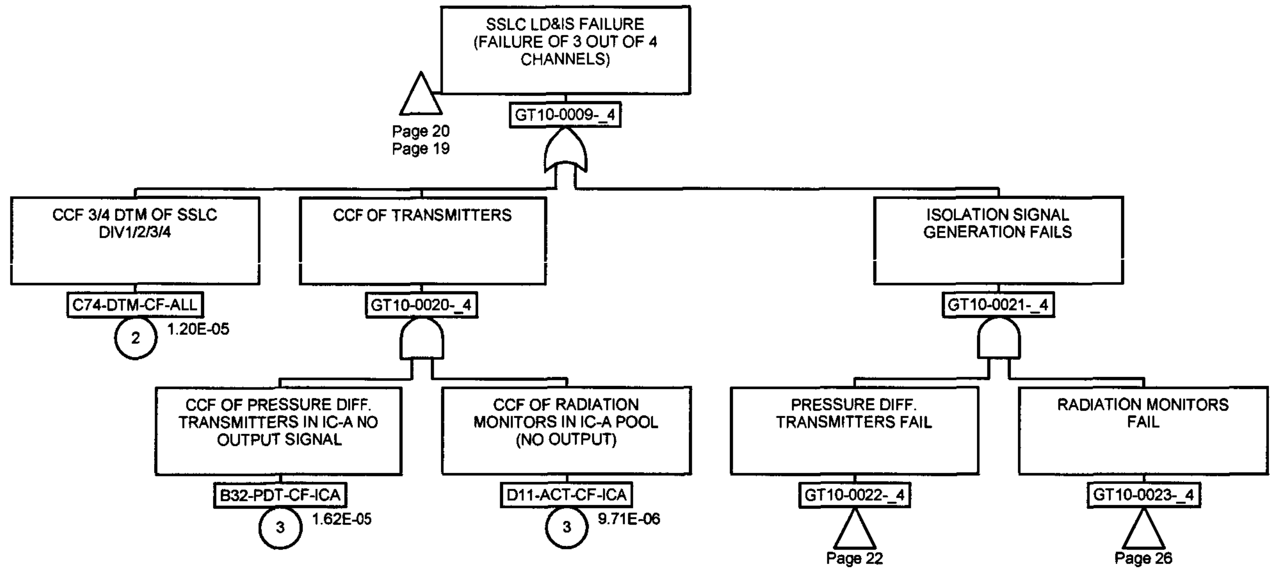
1	2	3			
Containment Isolation			Cont Isolation.caf	Appendix B.4.18-2	Page 17

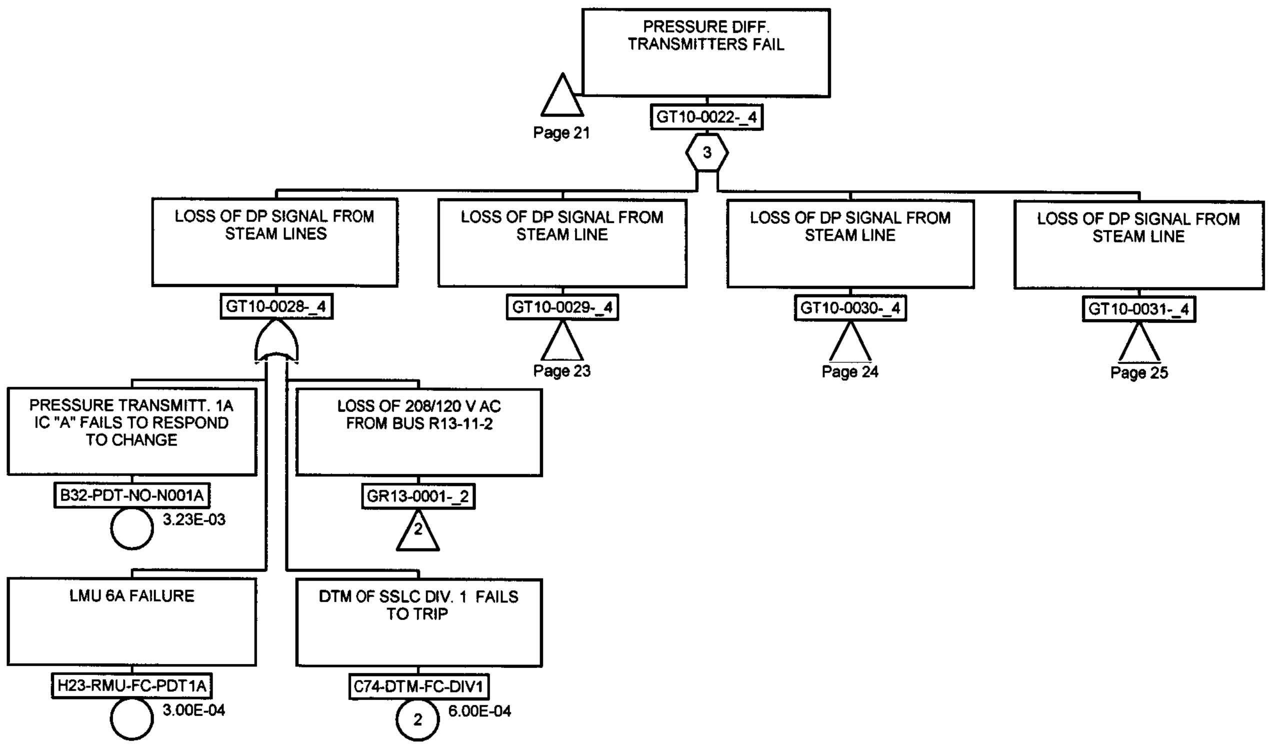

MAIN FEEDWATER LINE A ISOLATION FAILURE
GT10-0001-_5
BOTH CHECK VALVES FAIL TO CLOSE
GT10-0002-_5
CCF OF CHECK VALVES F103A AND F102A TO CLOSE
B21-UV_-CF-102/3A
4.00E-04
CHECK VALVE F103A FAILS TO CLOSE
B21-UV_-OO-F103A
7.96E-03
CHECK VALVE F102A FAILS TO CLOSE
B21-UV_-OO-F102A
7.96E-03
1
2

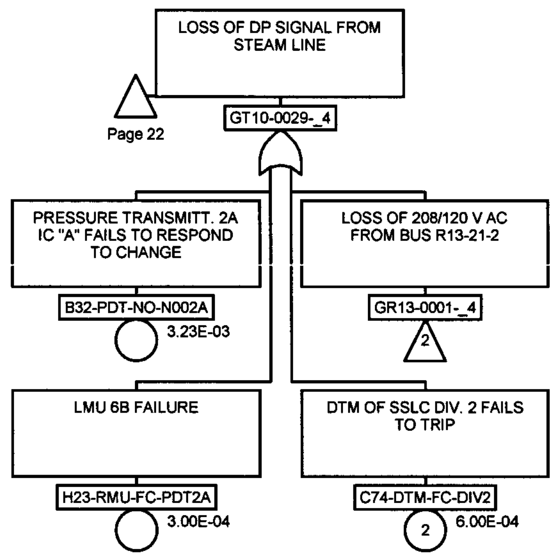


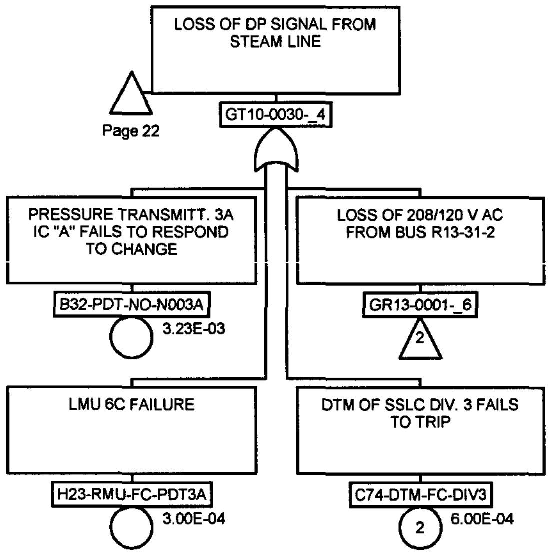
ICS ISOLATION FAILURE LOCA OUTSIDE CONTAINMENT
GT10-0001-_4
VALVE F001A FAILS TO CLOSE
GT10-0002-_4
VALVE F002A FAILS TO CLOSE
GT10-0003-_4
MSIV F001A VALVE FAILS TO CLOSE
B32-ACV-OO-F001A
2.00E-03
ISOLATION SIGNALS FAIL
GT10-0004-_4
SOLID STATE LOAD DRIVER LD002 FAILS TO CLOSE
B32-MOV-OO-F002A
4.00E-03
ISOLATION SIGNAL DIV I FAILS
GT10-0005-_4
Page 20
ISOLATION SIGNAL DIV I FAILS
GT10-0005-_4
Page 20
ISOLATION SIGNAL DIV II FAILS
GT10-0010-_4
LOSS OF 480 V AC FROM BUS R13-11-4
GR13-0001-_12
LOSS OF S. FOR CLOSE OF DIV. 2 ISOL.
GT10-0011-_4
SSLC DIV. II SIGNAL TRANSMISSION FAILURE
GC74-0001-_2
2
SSLC LD&IS FAILURE (FAILURE OF 3 OUT OF 4 CHANNELS)
GT10-0009-_4
Page 21
MANUAL RECOVERY FAILURE DIV. II
GT10-0013-_4
Page 30
1
2
3
4

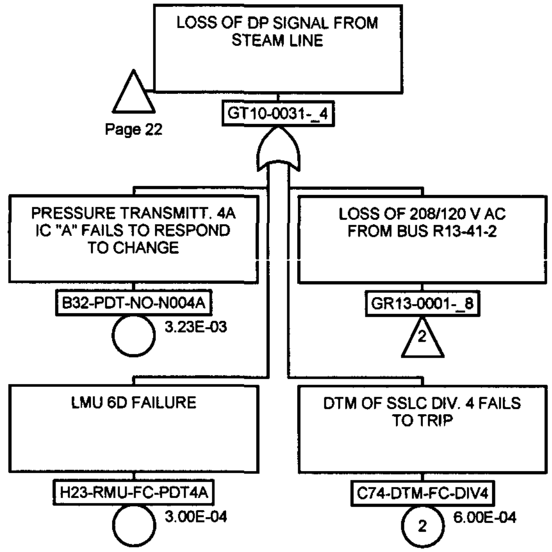

ISOLATION SIGNAL DIV I FAILS
GT10-0005-_4
Page 19
Page 19
SSLC DIV. I SIGNAL TRANSMISSION FAILURE
GC74-0001-_1
2
LOSS OF S. FOR CLOSE OF DIV.1 ISOL.
GT10-0006-_4
SSLC LD&IS FAILURE (FAILURE OF 3 OUT OF 4 CHANNELS)
GT10-0009-_4
Page 21
MANUAL RECOVERY FAILURE DIV. I
GT10-0008-_4
HUMAN ERROR OR LOSS OF ALARM
GT10-0014-_4
HOUSE EVENT: OPERATOR IS NOT AVAILABLE (VALUE=1)
XHOSMAN
5
CCF OF OTHER TRANSMITTERS
GT10-0015-_4
OPERATOR FAILS TO MANUALLY CLOSE ISOLATION VALVES
T10-XHE-FO-CLOSEIVS
5
1.77E-02
ISOLATION SIGNAL FROM C.R. FAILS
GT10-0016-_4
CCF OF RADIATION MONITORS IN IC-A POOL (NO OUTPUT)
D11-ACT-CF-ICA
3
9.71E-06
CCF OF PRESSURE DIFF. TRANSMITTERS IN IC-A NO OUTPUT SIGNAL
B32-PDT-CF-ICA
3
1.62E-05
RMU 001 FROM C.R. FAILS
H23-RMU-FC-1ICA1
3.00E-04
RMU 002 FROM C.R. FAILS
H23-RMU-FC-2ICA1
3.00E-04
1
2
3
4

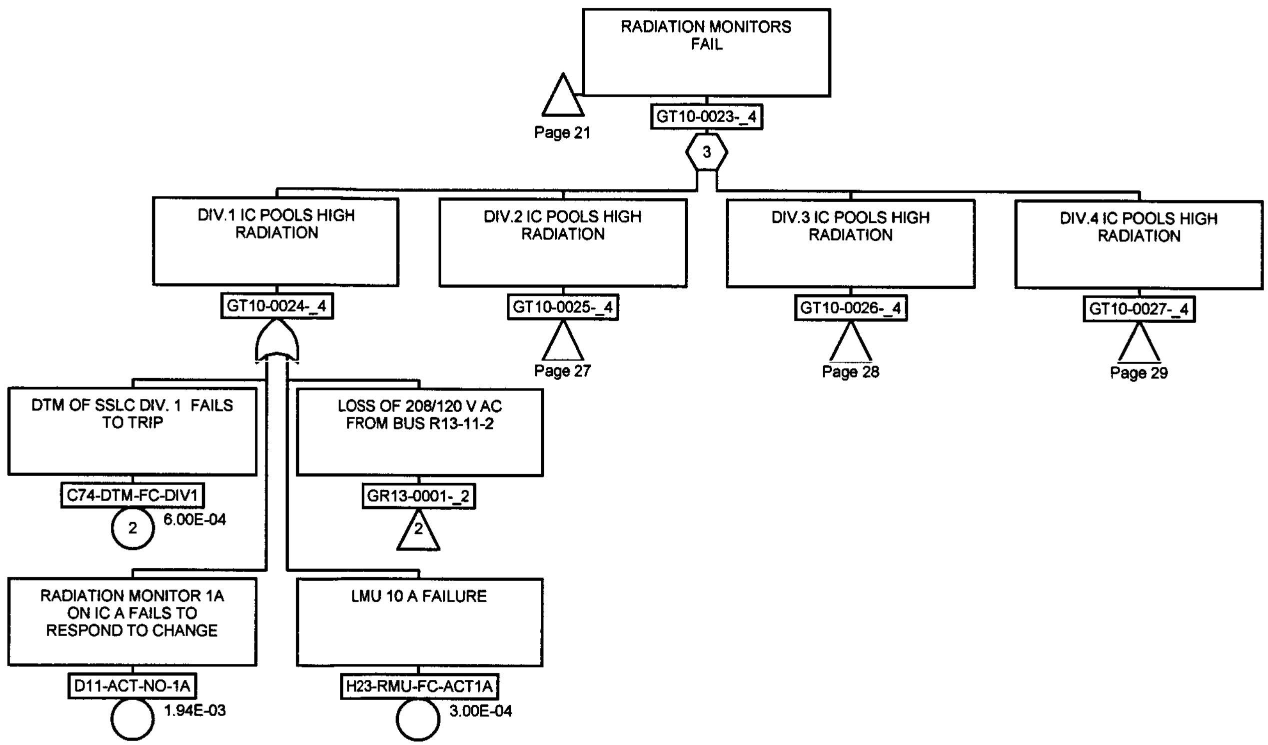

SSLC LD&IS FAILURE (FAILURE OF 3 OUT OF 4 CHANNELS)
GT10-0009-_4
Page 20
Page 19
CCF 3/4 DTM OF SSLC DIV1/2/3/4
C74-DTM-CF-ALL
2
1.20E-05
CCF OF TRANSMITTERS
GT10-0020-_4
ISOLATION SIGNAL GENERATION FAILS
GT10-0021-_4
CCF OF PRESSURE DIFF. TRANSMITTERS IN IC-A NO OUTPUT SIGNAL
B32-PDT-CF-ICA
3
1.62E-05
CCF OF RADIATION MONITORS IN IC-A POOL (NO OUTPUT)
D11-ACT-CF-ICA
3
9.71E-06
PRESSURE DIFF. TRANSMITTERS FAIL
GT10-0022-_4
Page 22
RADIATION MONITORS FAIL
GT10-0023-_4
Page 26

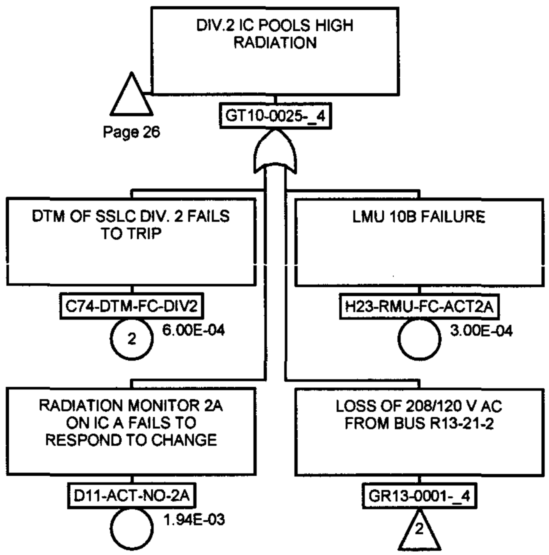

PRESSURE DIFF. TRANSMITTERS FAIL
GT10-0022-_4
Page 21
3
LOSS OF DP SIGNAL FROM STEAM LINES
GT10-0028-_4
LOSS OF DP SIGNAL FROM STEAM LINE
GT10-0029-_4
Page 23
LOSS OF DP SIGNAL FROM STEAM LINE
GT10-0030-_4
Page 24
LOSS OF DP SIGNAL FROM STEAM LINE
GT10-0031-_4
Page 25
PRESSURE TRANSMITT. 1A IC "A" FAILS TO RESPOND TO CHANGE
B32-PDT-NO-N001A
3.23E-03
LOSS OF 208/120 V AC FROM BUS R13-11-2
GR13-0001-_2
2
LMU 6A FAILURE
H23-RMU-FC-PDT1A
3.00E-04
DTM OF SSLC DIV. 1 FAILS TO TRIP
C74-DTM-FC-DIV1
2
6.00E-04
1
2
3
4

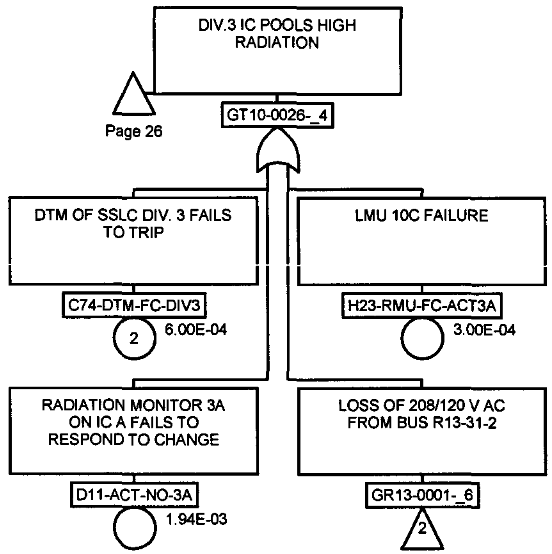

LOSS OF DP SIGNAL FROM STEAM LINE
GT10-0029-_4
Page 22
PRESSURE TRANSMITT. 2A IC "A" FAILS TO RESPOND TO CHANGE
B32-PDT-NO-N002A
3.23E-03
LOSS OF 208/120 V AC FROM BUS R13-21-2
GR13-0001-_4
2
LMU 6B FAILURE
H23-RMU-FC-PDT2A
3.00E-04
DTM OF SSLC DIV. 2 FAILS TO TRIP
C74-DTM-FC-DIV2
2
6.00E-04

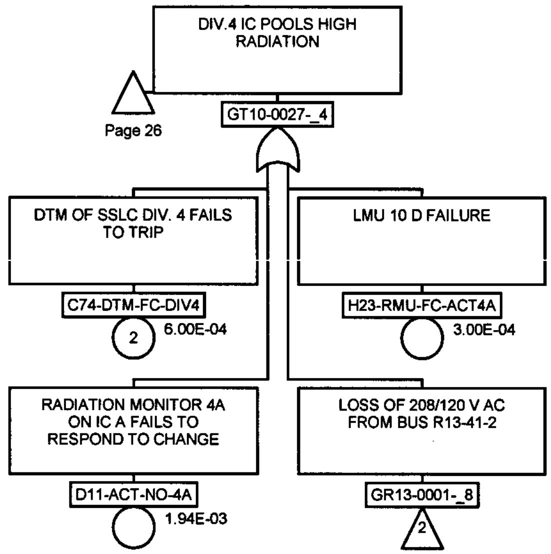

LOSS OF DP SIGNAL FROM STEAM LINE
Page 22
GT10-0030-_4
PRESSURE TRANSMITT. 3A IC "A" FAILS TO RESPOND TO CHANGE
B32-PDT-NO-N003A
3.23E-03
LOSS OF 208/120 V AC FROM BUS R13-31-2
GR13-0001-_6
2
LMU 6C FAILURE
H23-RMU-FC-PDT3A
3.00E-04
DTM OF SSLC DIV. 3 FAILS TO TRIP
C74-DTM-FC-DIV3
2
6.00E-04
1
2

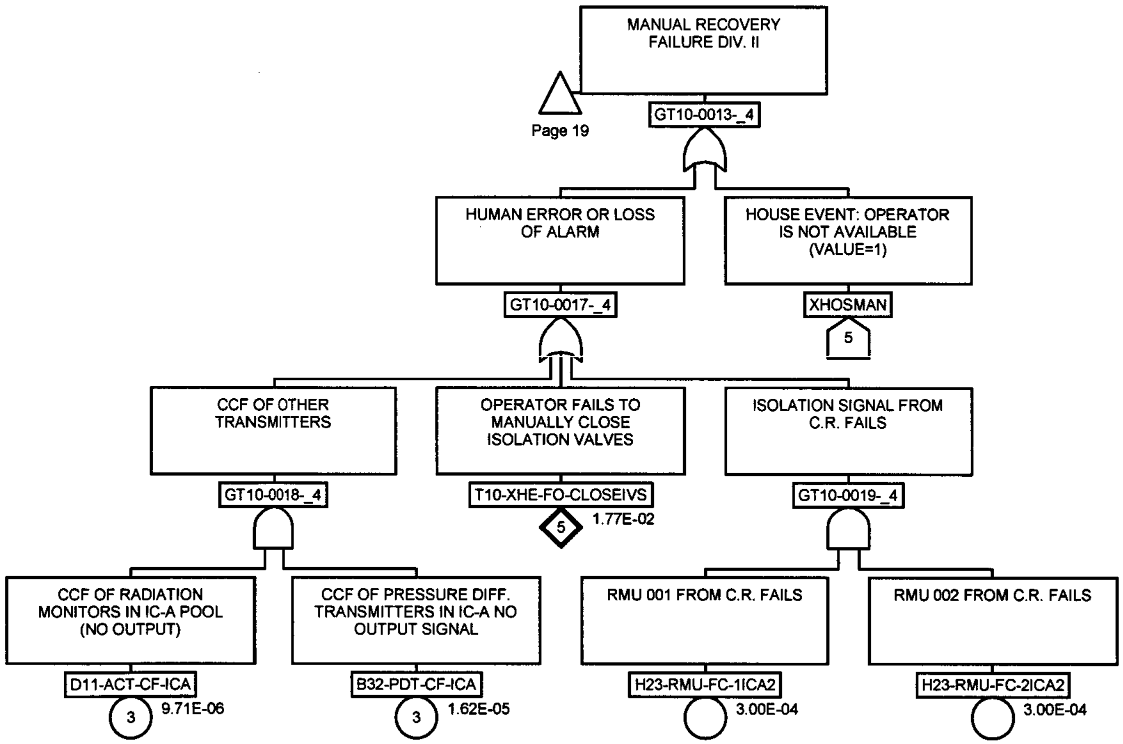

LOSS OF DP SIGNAL FROM STEAM LINE
GT10-0031-_4
Page 22
PRESSURE TRANSMITT. 4A IC "A" FAILS TO RESPOND TO CHANGE
B32-PDT-NO-N004A
3.23E-03
LOSS OF 208/120 V AC FROM BUS R13-41-2
GR13-0001-_8
2
LMU 6D FAILURE
H23-RMU-FC-PDT4A
3.00E-04
DTM OF SSLC DIV. 4 FAILS TO TRIP
C74-DTM-FC-DIV4
2
6.00E-04


RADIATION MONITORS FAIL
GT10-0023-_4
Page 21
3
DIV.1 IC POOLS HIGH RADIATION
GT10-0024-_4
DIV.2 IC POOLS HIGH RADIATION
GT10-0025-_4
Page 27
DIV.3 IC POOLS HIGH RADIATION
GT10-0026-_4
Page 28
DIV.4 IC POOLS HIGH RADIATION
GT10-0027-_4
Page 29
DTM OF SSLC DIV. 1 FAILS TO TRIP
C74-DTM-FC-DIV1
2
6.00E-04
LOSS OF 208/120 V AC FROM BUS R13-11-2
GR13-0001-_2
2
RADIATION MONITOR 1A ON IC A FAILS TO RESPOND TO CHANGE
D11-ACT-NO-1A
1.94E-03
LMU 10 A FAILURE
H23-RMU-FC-ACT1A
3.00E-04


DIV.2 IC POOLS HIGH RADIATION
GT10-0025-_4
Page 26
DTM OF SSLC DIV. 2 FAILS TO TRIP
C74-DTM-FC-DIV2
2
6.00E-04
LMU 10B FAILURE
H23-RMU-FC-ACT2A
3.00E-04
RADIATION MONITOR 2A ON IC A FAILS TO RESPOND TO CHANGE
D11-ACT-NO-2A
1.94E-03
LOSS OF 208/120 V AC FROM BUS R13-21-2
GR13-0001-_4
2
1
2

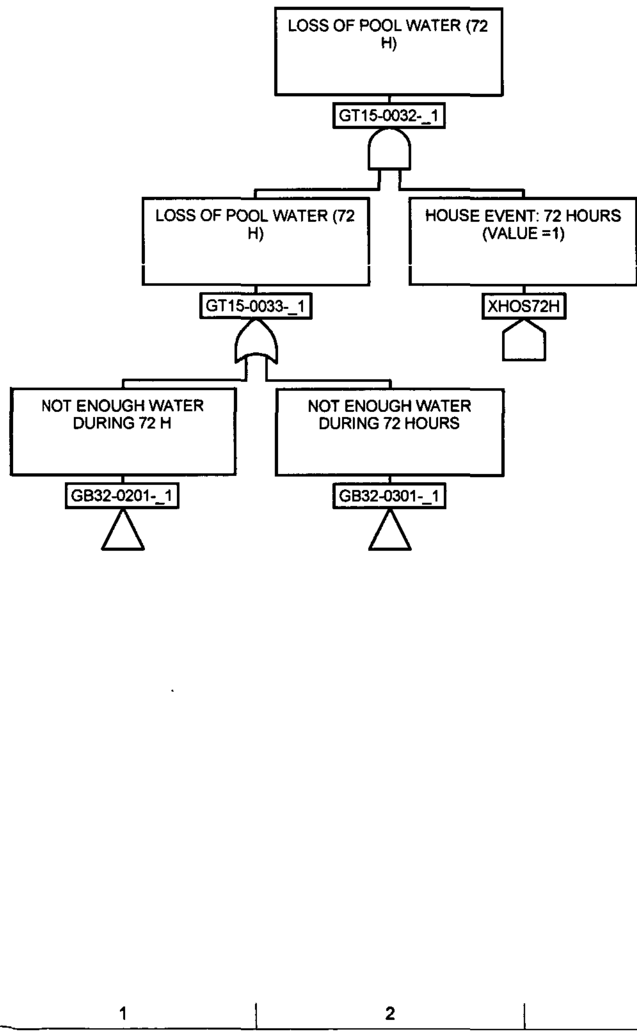

DIV.3 IC POOLS HIGH RADIATION
Page 26
GT10-0026-_4
DTM OF SSLC DIV. 3 FAILS TO TRIP
C74-DTM-FC-DIV3
2
6.00E-04
LMU 10C FAILURE
H23-RMU-FC-ACT3A
3.00E-04
RADIATION MONITOR 3A ON IC A FAILS TO RESPOND TO CHANGE
D11-ACT-NO-3A
1.94E-03
LOSS OF 208/120 V AC FROM BUS R13-31-2
GR13-0001-_6
2
1
2

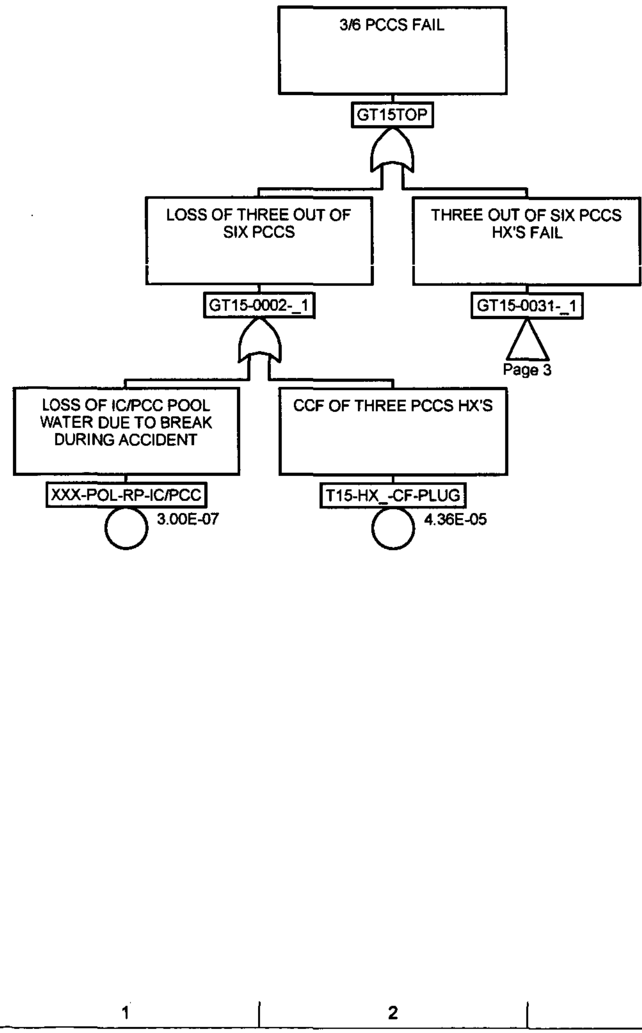

DIV.4 IC POOLS HIGH RADIATION
GT10-0027-_4
Page 26
DTM OF SSLC DIV. 4 FAILS TO TRIP
C74-DTM-FC-DIV4
2
6.00E-04
LMU 10 D FAILURE
H23-RMU-FC-ACT4A
3.00E-04
RADIATION MONITOR 4A ON IC A FAILS TO RESPOND TO CHANGE
D11-ACT-NO-4A
1.94E-03
LOSS OF 208/120 V AC FROM BUS R13-41-2
GR13-0001-_8
2
1
2

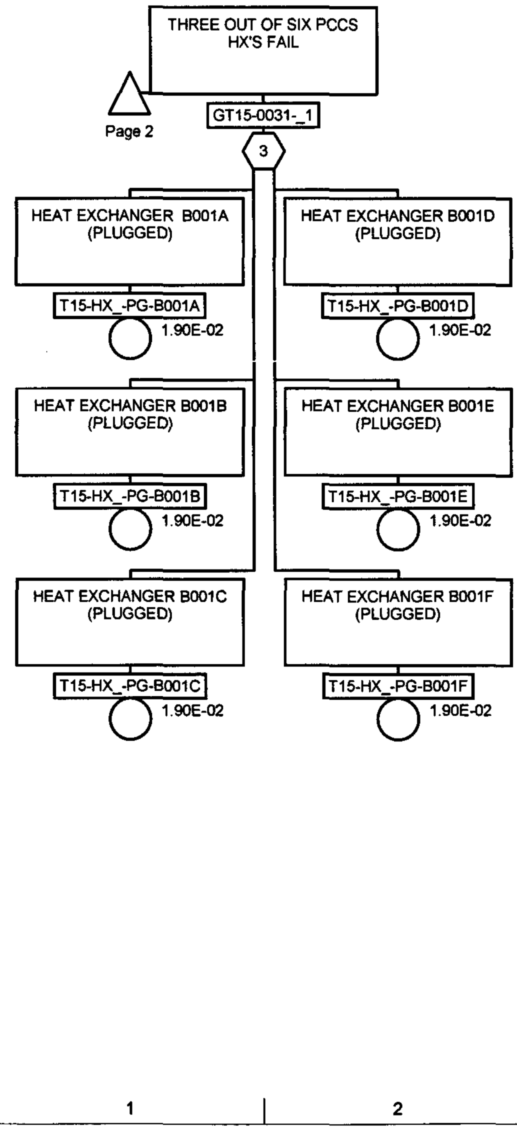

MANUAL RECOVERY FAILURE DIV. II
Page 19
GT10-0013-_4
HUMAN ERROR OR LOSS OF ALARM
GT10-0017-_4
HOUSE EVENT: OPERATOR IS NOT AVAILABLE (VALUE=1)
XHOSMAN
5
CCF OF OTHER TRANSMITTERS
GT10-0018-_4
OPERATOR FAILS TO MANUALLY CLOSE ISOLATION VALVES
T10-XHE-FO-CLOSEIVS
5
1.77E-02
ISOLATION SIGNAL FROM C.R. FAILS
GT10-0019-_4
CCF OF RADIATION MONITORS IN IC-A POOL (NO OUTPUT)
D11-ACT-CF-ICA
3
9.71E-06
CCF OF PRESSURE DIFF. TRANSMITTERS IN IC-A NO OUTPUT SIGNAL
B32-PDT-CF-ICA
3
1.62E-05
RMU 001 FROM C.R. FAILS
H23-RMU-FC-1ICA2
3.00E-04
RMU 002 FROM C.R. FAILS
H23-RMU-FC-2ICA2
3.00E-04

Name	Page	Zone	Name	Page	Zone	Name	Page	Zone
B21-ACV-CF-MSIVCLOSE	1	1	C74-SLU-FC-OLURTIF1	3	2	GT10-0003- 7	14	2
B21-ACV-CF-MSIVCLOSE	1	4	C74-SLU-FC-OLURTIF2	3	4	GT10-0003- 7	17	2
B21-ACV-CF-MSIVCLOSE	8	1	C74-SLU-FC-OLURTIF3	3	6	GT10-0003- 9	1	3
B21-ACV-CF-MSIVCLOSE	8	4	C74-SLU-FC-OLURTIF4	4	2	GT10-0004- 2	11	5
B21-ACV-CF-MSIVCLOSE	9	1	C74-SLU-FC-TLURTIF1	3	1	GT10-0004- 2	16	2
B21-ACV-CF-MSIVCLOSE	9	4	C74-SLU-FC-TLURTIF2	3	3	GT10-0004- 4	19	2
B21-ACV-CF-MSIVCLOSE	10	1	C74-SLU-FC-TLURTIF3	3	5	GT10-0004- 7	14	3
B21-ACV-CF-MSIVCLOSE	10	4	C74-SLU-FC-TLURTIF4	4	1	GT10-0004- 9	1	2
B21-ACV-OO-F001A	8	2	C74-VLU-CF-LD&IS	1	7	GT10-0004- 9	2	2
B21-ACV-OO-F001B	9	2	C74-VLU-FC-LD&IS1	2	2	GT10-0004- 9	8	2
B21-ACV-OO-F001C	10	2	C74-VLU-FC-LD&IS2	7	2	GT10-0004- 9	9	2
B21-ACV-OO-F001D	1	2	D11-ACT-CF-ICA	20	1	GT10-0004- 9	10	2
B21-ACV-OO-F002A	8	4	D11-ACT-CF-ICA	21	3	GT10-0005- 2	16	3
B21-ACV-OO-F002B	9	4	D11-ACT-CF-ICA	30	1	GT10-0005- 4	19	2
B21-ACV-OO-F002C	10	4	D11-ACT-NO-1A	26	1	GT10-0005- 4	19	5
B21-ACV-OO-F002D	1	4	D11-ACT-NO-2A	27	1	GT10-0005- 4	20	2
B21-FT -CF-MSLA	5	2	D11-ACT-NO-3A	28	1	GT10-0005- 9	1	3
B21-FT -CF-MSLB	5	2	D11-ACT-NO-4A	29	1	GT10-0005- 9	7	2
B21-FT -CF-MSLC	5	3	G31-ACV-OO-F006A	16	1	GT10-0005- 9	8	3
B21-FT -CF-MSLD	5	3	G31-ACV-OO-F3A	17	1	GT10-0005- 9	9	3
B21-LT -CF-N001ABCD	5	2	G31-MOV-OO-F005A	11	3	GT10-0005- 9	10	3
B21-LT -CF-N001ABCD	14	1	GC62-0001- 1	17	3	GT10-0006- 4	20	2
B21-PT -CF-MSL	5	3	GC74-0001- 1	12	1	GT10-0006- 9	2	1
B21-UV -CF-102/3A	18	3	GC74-0001- 1	20	1	GT10-0006- 9	3	5
B21-UV -CF-102/3B	11	1	GC74-0001- 2	16	1	GT10-0006- 9	7	1
B21-UV -OO-102B	11	3	GC74-0001- 2	19	3	GT10-0007- 9	3	2
B21-UV -OO-103B	11	2	GR13-0001- 11	11	4	GT10-0008- 4	20	3
B21-UV -OO-F102A	18	2	GR13-0001- 12	19	4	GT10-0008- 9	3	4
B21-UV -OO-F103A	18	1	GR13-0001- 2	22	2	GT10-0009- 4	19	2
B32-ACV-OO-F001A	19	1	GR13-0001- 2	26	2	GT10-0009- 4	20	1
B32-MOV-OO-F002A	19	4	GR13-0001- 4	23	2	GT10-0009- 4	21	3
B32-PDT-CF-ICA	20	2	GR13-0001- 4	27	2	GT10-0009- 9	3	6
B32-PDT-CF-ICA	21	2	GR13-0001- 6	24	2	GT10-0010- 4	19	3
B32-PDT-CF-ICA	30	2	GR13-0001- 6	28	2	GT10-0010- 9	3	7
B32-PDT-NO-N001A	22	1	GR13-0001- 8	25	2	GT10-0010- 9	4	2
B32-PDT-NO-N002A	23	1	GR13-0001- 8	29	2	GT10-0011- 2	12	2
B32-PDT-NO-N003A	24	1	GT10-0001- 4	19	3	GT10-0011- 4	19	2
B32-PDT-NO-N004A	25	1	GT10-0001- 5	18	2	GT10-0011- 9	1	4
C21-FT -CF-N001ABCDA	14	2	GT10-0001- 6	11	3	GT10-0011- 9	8	3
C21-TT -CF-N003ABCD	14	3	GT10-0001- 7	11	5	GT10-0012- 9	1	5
C62-DTM-CF-DIDALL	17	1	GT10-0001- 9	1	5	GT10-0012- 9	9	3
C74-DTM-CF-ALL	13	1	GT10-0002- 2	11	4	GT10-0013- 4	19	3
C74-DTM-CF-ALL	21	1	GT10-0002- 4	19	2	GT10-0013- 4	30	3
C74-DTM-CF-RTIFALL	5	1	GT10-0002- 5	18	2	GT10-0013- 9	8	2
C74-DTM-FC-DIV1	22	2	GT10-0002- 6	11	2	GT10-0014- 2	12	3
C74-DTM-FC-DIV1	26	1	GT10-0002- 7	12	2	GT10-0014- 2	15	2
C74-DTM-FC-DIV2	23	2	GT10-0002- 7	13	2	GT10-0014- 2	17	3
C74-DTM-FC-DIV2	27	1	GT10-0002- 7	16	2	GT10-0014- 4	20	3
C74-DTM-FC-DIV3	24	2	GT10-0002- 9	1	6	GT10-0014- 9	8	4
C74-DTM-FC-DIV3	28	1	GT10-0002- 9	10	3	GT10-0015- 4	20	2
C74-DTM-FC-DIV4	25	2	GT10-0003- 2	11	4	GT10-0015- 9	9	2
C74-DTM-FC-DIV4	29	1	GT10-0003- 2	12	2	GT10-0016- 4	20	4
C74-SLU-CF-OLU	3	6	GT10-0003- 4	19	4	GT10-0016- 9	9	4
C74-SLU-CF-TLU	3	5	GT10-0003-_7	13	2	GT10-0017-_4	30	3

Appendix B.4.19 Passive Containment Cooling System Fault Tree


LOSS OF POOL WATER (72 H)
GT15-0032-_1
LOSS OF POOL WATER (72 H)
GT15-0033-_1
HOUSE EVENT: 72 HOURS (VALUE =1)
XHOS72H
NOT ENOUGH WATER DURING 72 H
GB32-0201-_1
NOT ENOUGH WATER DURING 72 HOURS
GB32-0301-_1
1
2


3/6 PCCS FAIL
GT15TOP
LOSS OF THREE OUT OF SIX PCCS
GT15-0002-_1
THREE OUT OF SIX PCCS HX'S FAIL
GT15-0031-_1
Page 3
LOSS OF IC/PCC POOL WATER DUE TO BREAK DURING ACCIDENT
XXX-POL-RP-IC/PCC
3.00E-07
CCF OF THREE PCCS HX'S
T15-HX_-CF-PLUG
4.36E-05
1
2


THREE OUT OF SIX PCCS HX'S FAIL
Page 2
GT15-0031-_1
3
HEAT EXCHANGER B001A (PLUGGED)
T15-HX_-PG-B001A
1.90E-02
HEAT EXCHANGER B001D (PLUGGED)
T15-HX_-PG-B001D
1.90E-02
HEAT EXCHANGER B001B (PLUGGED)
T15-HX_-PG-B001B
1.90E-02
HEAT EXCHANGER B001E (PLUGGED)
T15-HX_-PG-B001E
1.90E-02
HEAT EXCHANGER B001C (PLUGGED)
T15-HX_-PG-B001C
1.90E-02
HEAT EXCHANGER B001F (PLUGGED)
T15-HX_-PG-B001F
1.90E-02
1
2

Name	Page	Zone	Name	Page	Zone	Name	Page	Zone
GB32-0201- 1	1	1						
GB32-0301- 1	1	2						
GT15-0002- 1	2	2						
GT15-0031- 1	2	3						
GT15-0031- 1	3	2						
GT15-0032- 1	1	2						
GT15-0033-_1	1	2						
GT15TOP	2	2						
T15-HX -CF-PLUG	2	2						
T15-HX -PG-B001A	3	1						
T15-HX -PG-B001B	3	1						
T15-HX -PG-B001C	3	1						
T15-HX -PG-B001D	3	2						
T15-HX -PG-B001E	3	2						
T15-HX -PG-B001F	3	2						
XHOS72H	1	3						
XXX-POL-RP-IC/PCC	2	1						

5 DATA ANALYSIS

Contents

List of Tables

5 DATA ANALYSIS

5.1 INTRODUCTION AND SCOPE

This section is an overview of the reliability data used in the ESBWR PRA.

Generic reliability data are based on ALWR URD (Reference 5-1), which is complemented with, ABWR PRA (Reference 5-2) Database, or other database sources, as necessary, following this order of preference.

The use of data from the references is justified by the fact that these data are representative of components used in previous BWRs. Applicability of the data to the ESBWR components in their specific environments is analyzed and adjustments of the values are performed as necessary.

The data and the methodology for Maintenance and Test Unavailability are based on the use of bounding generic values. In particular, the maintenance unavailability for the diesel-generator ($6.0 \cdot 10^{-3}$) is derived from Appendix A of ALWR URD (Reference 5-1). More details about generic unavailability due to Maintenance and Test is included in the ESBWR PRA Report.

Common Cause Failure (CCF) Data derived are used where available. Examples are diesel-generators, batteries, motor-operated valves, and pumps. The sources used for the estimation of the CCF parameters are NUREG/CR-5497 (Reference 5-7), EPRI TR-100382 (Reference 5-6), and NUREG/CR-5801 (Reference 5-8), in this order of preference.

The methodology described in NUREG/CR-4780 (Reference 5-9) is applied. There are several models to estimate the CCF probabilities and failure rates. The beta factor method is often used because of its simplicity; however, the results are conservative, especially for redundancy numbers higher than two (e.g., three or four). The multiple Greek letter method explicitly considers the contributions of subgroups failures, but its correct estimation is complex according to the explanation given in NUREG/CR-4780 (Reference 5-9). The alpha parameter method is considered the most appropriate for this application, because it considers the contributions of subgroups failures and is easily estimated from the system failure information.

5.2 COMPONENT RELIABILITY DATABASE

The data used for random component failure probabilities are included in Table 5 .2-1.

Generic reliability data are based on ALWR URD (Reference 5-1). This source is complemented with ABWR PRA Database (Reference 5-2) and other database sources, as necessary. The order of reference for the data is as listed above.

GE data are used for microprocessor based components and discrete logic components; a detailed evaluation of the data for these components is given in Reference 5-2.

The use of generic data for most of the electrical and mechanical components is justified by the following facts:

- In this phase, the specific types of components that will be purchased are not defined.
- These generic data are representative of components used in previous BWR plants.

Applicability of these generic data to the components operating in the specific ESBWR environment is analyzed and an adjustment of the value is made for a few cases.

The component boundaries considered for the case of the 6.9 kV/13.8 kV pumps exclude the breaker. For the diesel generators, associated auxiliary systems such as the startup air system, internal cooling circuit, etc, are included in the quantified diesel generator failure rates.

Rates for "failure to operate" are provided on a per-hour basis. Rates for "failure to start" are provided on a per-demand basis. The analyst chooses which model to apply for a particular case:

- According to the philosophy of NUREG/CR-2728 (Reference 5-4), for components whose test period (TP) is up to six months (TP ≤ 6m), the demand failure probability (P) is considered adequate and should be used as stated in the database (Table5.2-1).

  Unavailability of the failure basic event = P

- For components whose test period is from six months up to one year (6M < TP ≤ 1 year), it is suggested that the upper bound on demand failure probability be used as the computational median. In a lognormal distribution, the new mean is the generic mean multiplied by the error factor (EF). (Reference 5-4)

  Unavailability of the failure basic event = P x EF

- For test periods higher than one year (TP > 1 year), a standby failure rate is obtained by the following expression (Reference 5-4):

  $\lambda = 2 \times P/TP_g$

  where TP_g is a generic test period considered as 3 months, assuming that test practices of ESBWR design are similar to components of the generic source.

  Assuming a standby model:

  Unavailability of the failure basic event = $1 - [1-\exp(-\lambda \times TP)]/(\lambda \times TP)$.

Table 5.2-1 also includes a column containing Error Factor. The values for those Error Factors are derived from the appropriate database source when available and otherwise from the following sources:

- NUREG/CR-4550 (Reference 5-3), or
- IREP (Reference 5-4), or
- If data are not available, an engineering assessment.

A lognormal distribution is assumed for all data. For component outages for Test/Maintenance, an error factor of 10 is used as suggested in NUREG/CR-4550 (Reference 5-3).

Table 5.2-1

Database

Component and Failure Mode	Mean	Base [1]	Error Factor	Code	References
1. PUMPS/FANS					
1.1 Pumps					
1.1.1 Diesel-Driven, Standby					
1.1.1.1 Failure to start	$2.0 \cdot 10^{-2}$	d	10	EDP-FS	ALWR
1.1.1.2 Failure to run, given start	$1.0 \cdot 10^{-3}$	hr	10	EDP-FR	ALWR
1.1.2 Motor-Driven, Feedwater					
1.1.2.1 Failure to start	$2.0 \cdot 10^{-3}$	d	10	MPF-FS	ALWR (all types)
1.1.2.2 Failure to run, given start	$2.5 \cdot 10^{-3}$	hr	10	MPF-FR	ALWR (all types)
1.1.2.3 In test or maintenance	$2.0 \cdot 10^{-3}$	d	10	MPF-TM	NUREG/CR-4550
1.1.3 Motor-Driven CRD					
1.1.3.1 Failure to start	$2.4 \cdot 10^{-3}$	d	10	MPC-FS	ALWR
1.1.3.2 Failure to run, given start	$2.4 \cdot 10^{-6}$	hr	10	MPC-FR	ALWR
1.1.4 Aux. Oil Pump					
1.1.4.1 Failure to start	$2.0 \cdot 10^{-3}$	d	10	MP_-FS	ALWR (all types)
1.1.4.2 In test or maintenance	$2.0 \cdot 10^{-3}$	d	10	MP_-TM	NUREG/CR-4550
1.1.5 Condensate/CIRC Pump					
1.1.5.1 Failure to start	$2.0 \cdot 10^{-3}$	d	10	MP_-FS	ALWR (all types)
1.1.5.2 Failure to run, given start	$2.5 \cdot 10^{-5}$	hr	10	MP_-FR	ALWR (all types)
1.1.5.3 In test or maintenance	$3.0 \cdot 10^{-3}$	d	10	MP_-TM	ALWR
1.1.5.4 Circuit breaker fails to close	$8.0 \cdot 10^{-4}$	d	10	MP_-FS	NUREG-1816 (10)
1.1.6 FAPCS/LPCI Pump					
1.1.6.1 Failure to start	$3.0 \cdot 10^{-3}$	d	10	MP_-FS	ALWR
1.1.6.2 Failure to run	$1.5 \cdot 10^{-4}$	hr	10	MP_-FR	ALWR
1.1.7 RWCU/SDC Pump					
1.1.7.1 Failure to start	$2.3 \cdot 10^{-3}$	d	10	MP_-FS	ALWR
1.1.7.2 Failure to run	$1.0 \cdot 10^{-5}$	hr	10	MP_-FR	ALWR
1.1.8 PSWS Pump					
1.1.8.1 Failure to start	$2.4 \cdot 10^{-3}$	d	10	MP_-FS	ALWR
1.1.8.2 Failure to run	$3.2 \cdot 10^{-5}$	hr	10	MP_-FR	ALWR
1.1.8.3 In test or maintenance	$2.0 \cdot 10^{-3}$	d	10	MP_-TM	NUREG/CR-4550
1.1.9 RCCWS, TCCWS Pump					
1.1.9.2 Failure to start	$1.3 \cdot 10^{-3}$	d	10	MP_-FS	ALWR
1.1.9.2 Failure to run	$5.0 \cdot 10^{-6}$	hr	10	MP_-FR	ALWR
1.1.9.3 In test or maintenance	$2.0 \cdot 10^{-3}$	d	10	MP_-TM	NUREG/CR-4550
1.2. Fans					
1.2.1 Motor-Driven-Fan					
1.2.1.1 Failure to start	$6.0 \cdot 10^{-4}$	d	3	FAN-FS	ALWR
1.2.1.2 Failure to run, given start	$1.0 \cdot 10^{-5}$	hr	3	FAN-FR	ALWR
1.3 Instrument and Air Service Compressor					

Table 5.2-1

Database

Component and Failure Mode	Mean	Base [1]	Error Factor	Code	References
1.3.1 Failure to start	$2.0 \cdot 10^{-2}$	d	3	CMP-FS	ALWR
1.3.2 Failure to run, given start	$1.0 \cdot 10^{-4}$	hr	10	CMP-FR	ALWR
1.3.3 In maintenance	$2.0 \cdot 10^{-3}$	d	3	CMP-TM	NUREG/CR-4550
2. VALVES/DAMPERS					
2.1 Valves					
2.1.1 Air operated					
2.1.1.1 Failure to open	$2.0 \cdot 10^{-3}$	d	3	ACV-CC	ALWR
2.1.1.2 Failure to close	$2.0 \cdot 10^{-3}$	d	3	ACV-OO	ALWR
2.1.1.3 Spuriously transfer to deenergized position	$1.5 \cdot 10^{-7}$	hr	10	ACV-OC	ALWR
2.1.1.4 Spuriously transfer to energized position	$2.0 \cdot 10^{-8}$	hr	30	ACV-CO	IEEE-Std-500 (4)
2.1.1.5 Failure to regulate/transfer	$2.0 \cdot 10^{-3}$	d	3	ACV-FT	NUREG/CR-4550
2.1.1.6 In test or maintenance	$8.0 \cdot 10^{-4}$	d	10	ACV-TM	NUREG/CR-4550
2.1.2 Check					
2.1.2.1 Failure to open	$2.0 \cdot 10^{-4}$	d	3	UV_-CC	ALWR
2.1.2.2 Failure to close	$1.0 \cdot 10^{-3}$	d	3	UV_-OO	ALWR
2.1.2.3 Fails to remain open or plugs	$2.0 \cdot 10^{-7}$	hr	30	UV_-OC	ALWR
2.1.2.4 In test maintenance	$8.0 \cdot 10^{-4}$	d	10	UV_-TM	NUREG/CR-4550
2.1.3 Motor-Operated					
2.1.3.1 Failure to open	$4.0 \cdot 10^{-3}$	d	10	MOV-CC	ALWR
2.1.3.2 Failure to close	$4.0 \cdot 10^{-3}$	d	10	MOV-OO	ALWR
2.1.3.3 Failure to remain open	$1.4 \cdot 10^{-7}$	hr	3	MOV-OC	ALWR
2.1.3.4 Failure to remain closed	$5.0 \cdot 10^{-7}$	hr	10	MOV-CO	NUREG/CR-4550
2.1.3.5 In maintenance, test or unavailable	$8.0 \cdot 10^{-4}$	d	10	MOV-TM	NUREG/CR-4550
2.1.3.6 Flow control failure	$2.9 \cdot 10^{-6}$	hr	10	MOV-FC	IEEE-Std-500
2.1.4 Safety/Relief					
2.1.4.1 Failure to open	$6.0 \cdot 10^{-3}$	d	3	SRV-CC	ALWR
2.1.4.2 Failure to open (safety mode)	$2.0 \cdot 10^{-5}$	d	3	SRV-CC	ALWR (5)
2.1.5 Solenoid					
2.1.5.1 Failure to operate (energized.)	$1.0 \cdot 10^{-3}$	d	3	SOV-FE	NUREG/CR-2728
2.1.5.2 Failure to operate (de-energized.)	$1.0 \cdot 10^{-3}$	d	3	SOV-FD	NUREG/CR-2728
2.1.6 Squib					
2.1.6.1 Fails to operate [2]	$3.0 \cdot 10^{-3}$	d	3	SQV-CC	ALWR
2.1.6.2 Opens spuriously	$4.0 \cdot 10^{-7}$	hr	30	SQV-CO	ALWR
2.1.6.3 Fails to operate in extreme environmental conditions (equalizing lines) [2]	$6.0 \cdot 10^{-3}$	d	30	SQV-CC	NUREG/CR-2728 (6)
2.1.7 Vacuum Breaker					
2.1.7.1 Leakage of the vacuum breaker	$1.0 \cdot 10^{-4}$	d	3	VB_-LK	NUREG/CR-2728 (7)

Table 5.2-1

Database

Component and Failure Mode	Mean	Base [1]	Error Factor	Code	References
2.1.7.2 Vacuum breaker fails to close	$1.0 \cdot 10^{-4}$	d	3	VB_-OO	NUREG/CR-2728 (7)
2.1.8 Pressure control					
2.1.8.1 All modes of failure	$2.9 \cdot 10^{-6}$	hr	10	CPV-FC	IEEE-Std-500
2.1.9 Manual valve					
2.1.9.1 Fails to remain closed	$1.0 \cdot 10^{-4}$	d	3	BV_-CO	NUREG/CR-4550
2.1.9.2 Fails to remain open	$1.0 \cdot 10^{-4}$	d	3	BV_-OC	NUREG/CR-4550
2.1.9.3 Fails to close	$3.0\ 10^{-8}$	hr	3	BV_-OO	ALWR
3. SWITCHES					
3.1 Pressure Switch					
3.1.1 Failure to operate	$2.5 \cdot 10^{-4}$	d	3	PS_-CC	ALWR
3.1.2 Operates spuriously	$1.1 \cdot 10^{-7}$	hr	3	PS_-CO	ALWR
4. OTHER MECHANICAL COMPONENTS					
4.1 Orifices					
4.1.1 Failure to remain open (plug)	$6.0 \cdot 10^{-7}$	hr	3	OR_-PG	NUREG/CR-2815 (8)
4.2 Heat exchangers (general use)					
4.2.1 Fails while operating (leaks, plugs)	$1.0 \cdot 10^{-6}$	hr	10	HX_-LK	ALWR
4.2.2 Heater Pressurizer all failures	$2.2 \cdot 10^{-6}$	hr	10	HX_-PG	IEEE-Std-500
4.2.3 In maintenance	$2.2 \cdot 10^{-3}$	d	10	HX_-TM	NUREG/CR-4550
4.2.4 Compressor Cooler fails during operation	$1.0 \cdot 10^{-6}$	hr	10	HX_-PG	ALWR
4.3 Heat exchangers (Isolation Condenser/PCCS)					
4.3.1 Leaks while pressurized	$1.0 \cdot 10^{-7}$	hr	10	HX_-LK	WASH- 1400 (9)
4.4 Strainer/filter					
4.4.1 Plugs during operation	$1.0 \cdot 10^{-5}$	hr	10	STR-PG	ALWR
4.5 Tanks					
4.5.1 Leaks catastrophically	$1.0 \cdot 10^{-7}$	hr	30	TNK-RP	ALWR
4.6 Pool					
4.6.1 Leaks catastrophically	$3.0 \cdot 10^{-7}$	d	10	POL-RP	Engineering Judgment
4.7 Pipe to Essent. Systems [3]					
4.7.1 Leaks or plugs	$1.7 \cdot 10^{-7}$	hr	10	PSF-RP	(9)
4.8 Dryer					
4.8.1 In maintenance	$2.0 \cdot 10^{-5}$	d	10	DRY-TM	IEEE-Std-500
5. ELECTRICAL COMPONENTS					
5.1 Circuit breakers					
5.1.1 Circuit breaker (>6 KV)					
5.1.1.1 Failure to close	$8.0 \cdot 10^{-4}$	d	10	LCB-OO	NUREG-1816 (10)
5.1.1.2 Failure to open	$8.0 \cdot 10^{-4}$	d	10	LCB-CC	NUREG-1816 (10)

Table 5.2-1

Database

Component and Failure Mode	Mean	Base (1)	Error Factor	Code	References
5.1.1.3 Opens spuriously	$6.0 \cdot 10^{-7}$	hr	10	LCB-CO	ALWR
5.1.2 Circuit breakers (≤600V)					
5.1.2.1 Failure to close	$8.0 \cdot 10^{-4}$	d	10	MCB-OO	NUREG-1816 (10)
5.1.2.2 Failure to open	$8.0 \cdot 10^{-4}$	d	10	MCB-CC	NUREG-1816 (10)
5.1.2.3 Opens spuriously	$5.0 \cdot 10^{-7}$	hr	10	MCB-CO	ALWR
5.2 Electrical buswork					
5.2.1 AC					
5.2.1.1 Fails during operation	$2.0 \cdot 10^{-7}$	hr	5	BAC-LP	ALWR
5.2.1.2 In test or maintenance	$8 \cdot 10^{-6}$	d	10	BAC-TM	NUREG/CR-4550
5.2.2 DC					
5.2.2.1 Fails during operation	$2.0 \cdot 10^{-7}$	hr	5	BDC-LP	ALWR
5.2.2.2 In test or maintenance	$8 \cdot 10^{-6}$	d	10	BDC-TM	NUREG/CR-4550
5.3 Transformer					
5.3.1 High voltage					
5.3.1.1 Fails to continue operating	$1.2 \cdot 10^{-6}$	hr	3	XFH-LP	ALWR
5.3.1.2 In test or maintenance	$1.0 \cdot 10^{-4}$	d	10	XFH-TM	IEEE-Std-500
5.3.2 Medium voltage (6.9 KV to 480 V)					
5.3.2.1 Fails to continue operating	$7.0 \cdot 10^{-7}$	hr	3	XFM-LP	ALWR
5.3.3 Low voltage (480 V and lower)					
5.3.3.1 Fails to continue operating	$8.0 \cdot 10^{-7}$	hr	3	XFL-LP	ALWR
5.4 Fuse					
5.4.1 Opens spuriously	$5.0 \cdot 10^{-7}$	hr	10	XFL-FC	ALWR
5.5 Inverter					
5.5.1 Failure during operation	$2.0 \cdot 10^{-5}$	hr	3	INV-FC	ALWR
5.6 Pressure transmitter					
5.6.1 Fails to respond to change	$4.8 \cdot 10^{-7}$	hr	10	PT_-NO	ALWR
5.6.2 Fails high	$3.3 \cdot 10^{-7}$	hr	10	PT_-HI	ALWR
5.6.3 Fails low	$3.3 \cdot 10^{-7}$	hr	10	PT_-LO	ALWR
5.7 Temperature transmitter					
5.7.1 Fails to respond to change	$3.5 \cdot 10^{-7}$	hr	10	TT_-NO	ALWR
5.7.2 Fails high	$1.9 \cdot 10^{-6}$	hr	10	TT_-HI	ALWR
5.7.3 Fails low	$1.9 \cdot 10^{-6}$	hr	10	TT_-LO	ALWR
5.8 Flow transmitter					
5.8.1 Fails to respond to change	$4.6 \cdot 10^{-7}$	hr	10	FT_-NO	ALWR
5.8.2 Fails high	$1.7 \cdot 10^{-6}$	hr	10	FT_-HI	ALWR
5.8.3 Fails low	$1.7 \cdot 10^{-6}$	hr	10	FT_-LO	ALWR
5.9 Level transmitter					
5.9.1 Fails to respond to change	$1.0 \cdot 10^{-6}$	hr	10	LT_-NO	ALWR
5.9.2 Fails high	$5.1 \cdot 10^{-7}$	hr	10	LT_-HI	ALWR
5.9.3 Fails low	$5.1 \cdot 10^{-7}$	hr	10	LT_-LO	ALWR

Table 5.2-1

Database

Component and Failure Mode	Mean	Base (1)	Error Factor	Code	References
5.10 Radiation Monitors					
5.10.1 Fails to respond to change	$1.8 \cdot 10^{-6}$	hr	10	ACT-NO	IEEE-Std-500
5.10.2 Fails high	$2.2 \cdot 10^{-6}$	hr	10	ACT-HI	IEEE-Std-500
5.10.3 Fails low	$2.2 \cdot 10^{-6}$	hr	10	ACT-LO	IEEE-Std-500
5.10.4 APRM Channel fails	$6.8 \cdot 10^{-6}$	hr	10	ACT-FC	NUREG/CR-1740
5.11 Differential Pressure Transmitter					
5.11.1 Fails to respond to change	$3.0 \cdot 10^{-6}$	hr	10	PDT-NO	NEDE-22056
5.11.2 Fails high	$3.0 \cdot 10^{-6}$	hr	10	PDT-HI	NEDE-22056
5.11.3 Fails low	$3.0 \cdot 10^{-6}$	hr	10	PDT-LO	NEDE-22056
5.12 Transmission Line fails (per circuit)	$3.0 \cdot 10^{-6}$	hr	10	CBU-FC	NUREG/CR-2728
5.13 Diesel Generator					
5.13.1 Fails to start	$1.4 \cdot 10^{-2}$	d	3	DG_-FS	ALWR
5.13.2 Fails to run given start	$2.4 \cdot 10^{-3}$	hr	3	DG_-FR	ALWR
5.13.3 In test or maintenance	$6.0 \cdot 10^{-3}$	d	10	DG_-TM	ALWR
5.14 Battery Power System					
5.14.1 Fails to provide output on demand	$5.0 \cdot 10^{-4}$	d	3	BT_-LP	ALWR
5.14.2 In test or maintenance	$1.0 \cdot 10^{-3}$	d	10	BT_-TM	NUREG/CR-4550
5.15 Battery Charger					
5.15.1 Failure to maintain output	$7.0 \cdot 10^{-6}$	hr	3	BYC-LP	ALWR
5.15.2 In test or maintenance	$3.0 \cdot 10^{-4}$	d	10	BYC-TM	NUREG/CR-4550
5.16 Diode					
5.16.1 Fails to operate	$1.4 \cdot 10^{-6}$	d	10	DIO-FC	IEEE-Std-500
5.17 Rectifier					
5.17.1 Fails during operation	$7.0 \cdot 10^{-6}$	hr	3	REC-FC	ALWR
5.17.2 In test or maintenance	$3.0 \cdot 10^{-4}$	d	10	REC-TM	NUREG/CR-4550
5.18 Automatic Selector					
5.18.1 Fails to transfer	$7.3 \cdot 10^{-7}$	hr	10	SEL-FT	NEDC-30851P-A
5.19 Bypass Unit					
5.19.1 Fails to function	$5.0 \cdot 10^{-6}$	hr	10	BYP-FC	(13)
6. SOLID STATE COMPONENTS					
6.1 Microprocessor Based Components					
6.1.1 TLU and TLU Bypass Control Card (Safety Systems)					
6.1.1.1 TLU fails to trip or TLU Bypass Logic Card fails to transfer	$9.0 \cdot 10^{-4}$		10	SLU-FC	(11)
6.1.2 DTM (Safety Systems)					
6.1.2.2 Fails to trip	$6.0 \cdot 10^{-4}$	d	10	DTM-FC	(11)
6.1.3 DTM/TLU and MUX Interface Unit (Non-Safety Systems)					

Table 5.2-1

Database

Component and Failure Mode	Mean	Base (1)	Error Factor	Code	References
6.1.3.1 Fails to trip	$9.0 \cdot 10^{-4}$	d	10	DTM-FC	(11)
6.1.4 RMU					
6.1.4.1 Fails to operate	$5.0 \cdot 10^{-6}$	hr	10	RMU-FC	NUMAC Field Data, B. Simon
6.1.5 EMS					
6.1.5.1 Fails to function	$1.0 \cdot 10^{-5}$	hr	10	EMS-FC	(11)
6.2 Discrete Logic Components					
6.2.1 2/4 Voting Logic Card					
6.2.1.1 All modes failure	$7.8 \cdot 10^{-5}$	d	10	VLU-FC	(11)
6.2.2 1/N Logic Card					
6.2.2.1 All modes failure	$3.0 \cdot 10^{-4}$	d	10	LOG-FC	(11)
6.3 Relay (electromechanical)					
6.3.1 Fails to operate	$1.0 \cdot 10^{-4}$	d	10	RE_-FD	ALWR

Notes: (1) Base, d = demand, hr = hour

(2) For these components, periods between demands are usually irregular and long. The failure rates therefore adequately reflect standby failures, and an hourly rate is not estimated.

(3) A piping section is defined as a section of pipe between major discontinuities (i.e., pumps, valves, elbows, bends...) up to 3 m (10 ft) in length. The fraction of this rate corresponding to leakage severe enough to constitute a rupture should be taken as 5 %. The 5 % value is consistent with WASH-1400. Of this 5 %, 10 % should be taken to be essentially a complete break; 30 % should be taken to be a large rupture; and the remaining 60 % a small rupture. This is the breakdown used in the Oconee PRA, which NRC reviewers found to be acceptable.

(4) For spurious transfer to the energized position, the value for manual valves is recommended.

(5) Data for Safety-Relief Valves (other than PWR Primary nor BWR, actuation mode).

(6) To account for those extreme environmental conditions a failure probability double that for other squib valves is used.

(7) The failure data, obtained from NUREG/CR-2728 for a generic test interval, is 1.25E-5/d; considering a PRA correction criteria, the failure probability assumed is 1.0E-4.

(8) For continuously flushed lines.

(9) Considering a failure rate of 8.5E-9/h, obtained from WASH-1400 for a pipe with a diameter less or equal to 3", and 248 pipes per IC, and taking into account that the 5% of those failures can cause problems (according to the WASH-1400), the failure rate estimated is 1E-7/h.

(10) NUREG-1816, Table C.2, recommends 8E-4/d for failure to open/close of circuit breakers.

(11) a. Two types of failure rates are used: (1) 5E-6/h for component consisting of one or more circuit boards, like DTMs, RMUs, OLUs, VLUs, SLUs, TLUs, etc., based on a required MTBF of 200,000 hours, and (2) 1E-5/h for the overall multiplexing system (EMS), based on a required MTBF of 100,000 hours.

b. For obtaining the failure probability on demand, it is assumed that 95% of the component failures will be detected by self-testing; the LMU, DTM, and TLU cards are self-tested every 30 minutes (Tself-test). The remaining 5% will be detected only during surveillance tests performed quarterly (Ttest = 2190 hr). In both cases, it is assuming a MTTR of five hours. The expression used is:

$P = \lambda \times [0.95 \times ((T_{self\text{-}test}/2 + MTTR) + 0.05 \times (T_{test}/2 + MTTR)]$, where: λ is the failure rate

Table 5.2-1

Database

Component and Failure Mode	Mean	Base (1)	Error Factor	Code	References
(12) The Failure rate used is 1.3 E-06/hr obtained from the document "Printed circuit Card Failure Analysis Report No. 9 GE Nuclear Energy, December 16, 1988", and the estimation of the probability is based on the part b of Note (11) above. (13) Joint Study Report of SSLC Reliability Analysis, No. IF-R-389 and MIL-HDBK-217C					

5.3 COMMON CAUSE FAILURE ANALYSIS

This section contains the results of the analysis performed on the potential common cause failures (CCF) within the systems of the ESBWR plant. The analysis is performed to identify potential CCFs within each system and quantify their probabilities.

5.3.1 Scope

The scope of this section is to consider the component failure types which are within the event trees of each system and represent groups of main components with a redundant function.

Common cause failures are not postulated among components of different systems. Therefore, common cause failures are considered among equal active equipment and with similar functions to provide redundancy.

The types of components where common cause failures have been analyzed are:

- Diesel Generators (DG_)
- Pumps (MP_, MPC, MPF)
- Explosive Valves (SQV)
- Motor Operated Valves (MOV)
- Solenoid Operated Valves (SOV)
- Air Operated Valves (ACV)
- Safety/Relief Valves (SRV)
- Pressure Control Valves (CPV)
- Check Valves (UV_)
- Vacuum Breakers (VB_)
- Batteries (BT_)
- Bypass Units (BYP)
- Compressors (CMP)
- Fans (FAN)
- Heat exchangers (HX_)
- Strainers (STR)
- Circuit Breakers (LCB, MCB)
- Temperature, pressure, level, differential pressure, flow, radiation transmitters (TT_, PT_, LT_, PDT_, FT_, ACT)
- Digital Trip Modules (DTM)
- Essential Multiplexing Systems (EMS)
- Discrete Logic Cards (LOG)

- Remote Multiplexing Units (RMU)
- Safety System Logic Unit (SLU)
- Voting Logic Unit (VLU)
- Orifices (OR_)

The systems where common cause failures are postulated are the following:

- B21 Reactor Depressurization System
- B32 Isolation Condenser System
- C12 Control Rod Drive System
- C41 Standby Liquid Control System
- C62 Instrument and Control System
- C74 Safety Logic and Control System
- E50 Gravity Driven Cooling System
- G21 Fuel and Auxiliary Pool Cooling System
- G31 Reactor Water Cleanup System
- N21 Feedwater and Condensate System
- N71 Circulating Water System
- P21 Reactor Component Cooling Water System
- P41 Plant Service Water System
- P51 Service Air System
- P52 Instrument Air System
- P54 High Pressure Nitrogen Supply System
- R10 13.8 kV AC Power Distribution System
- R11 6.9 kV AC Power Distribution System
- R12 480 V AC Power Distribution System
- R16 250 V DC Power Distribution System
- T15 Passive Containment Cooling System
- U43 Fire Protection System

5.3.2 METHODOLOGY

The systematic method described in NUREG/CR-4780 (Reference 5-9) is used. The common cause failure databases from NUREG/CR-5497 (Reference 5-7), EPRI TR-100382 (Reference 5-6), and from NUREG/CR-5801 (Reference 5-8) are used to create a database that provides the common cause factors for use in this analysis.

There are several models for estimating CCF probabilities and failures rates. The beta factor method is often used because of its simplicity; however, the results are conservative, especially for redundancy numbers higher than two (e.g., three or four). The multiple Greek letter method explicitly considers the contributions of subgroup failures, but its correct estimation is complex according to the explanation given in NUREG/CR-4780 (Reference 5-9). The alpha factor method is considered the most appropriate for this application, because it considers the contributions of subgroup failures and is easily estimated from system failure information, as described below.

5.3.3 ALPHA FACTOR METHOD

The following probabilities are defined considering a common cause group of m components.

Q_k = probability or failure rate, depending on the model being in demand or based on time respectively, of specific **k** components due to a common cause event where $1 \leq k \leq m$.

Q_t = probability or total failure rate of a specific component which is obtained from the Q_k values by the following expression:

$$Q_t = \sum_{k=1}^{m} \binom{m-1}{k-1} Q_K$$

where the binomial term:

$$\binom{m-1}{k-1} = \frac{(m-1)!}{(m-k)!\,(k-1)!}$$

represents the number of different combinations in which a specific component can fail together with other (k-1) components in a group of similar (m) components.

This model, which uses Q_k parameters in the way defined above to calculate probabilities or system failure rates, is called the basic parameter model. Given that, in general, the necessary information to estimate the Q_k directly is not available, therefore, other models have been developed that require additional hypotheses. These other models simplify the estimation of parameters from historical information.

The first hypothesis made is one of symmetry, which postulates that the probability of CCF in any k number of components belonging to a group of m components only depends on the k number and not on which components fail.

The alpha factor model is multiparametric and the parameters are calculated directly from system failure information. The fraction of the total frequency of the failure events, which take place in the system affecting any of the k components in a group of m components, is defined as $\alpha_k(m)$. In terms of probabilities of basic events, the parameters are defined as:

$$\alpha_k^{(m)} = \frac{\binom{m}{k} Q_k^{(m)}}{\sum_{k=1}^{m} \binom{m}{k} Q_k^{(m)}}$$

Using this last equation and the one previously written for Q_t, the probabilities or failure rates of basic events can be expressed based on Q_t and the alpha factors.

$$Q_k^{(m)} = \frac{k\ \alpha_k^{(m)}}{\binom{m-1}{k-1}\ \alpha_t^{(m)}}\ Q_t = \frac{m}{\binom{m}{k}}\ \frac{\alpha_k^{(m)}}{\alpha_t^{(m)}}\ Q_t \qquad (1)$$

where

$$\alpha_t^{(m)} = \sum_{k=1}^{m} K\ \alpha_k^{(m)}$$

To calculate Q_k not only is α_k necessary, but also all the alphas are necessary, from k=1 to k=m, according to the $\alpha_t(m)$ definition.

The CCF common cause factors for non-staggered and staggered tests respectively are the following:

$$Q_k^{(m)} = \frac{k\ \alpha_k^{(m)}}{\binom{m-1}{k-1}\alpha_t^{(m)}}\ Q_t = f_{cc}\ Q_t \qquad Q_k^{(m)} = \frac{\alpha_k^{(m)}}{\binom{m-1}{k-1}}\ Q_t = f_{cc}\ Q_t$$

Non- staggered tests Staggered tests

5.3.4 GENERIC SOURCES

Generic data sources provide alpha factors for most basic events. Generic alpha factors are used for basic events for which no information is found.

The sources used are:

(1) NUREG/CR-5497 (Reference 5-7).

The α factors are taken directly from this source. If information is not available here, the data sources listed below are used.

(1) This expression applies to a "non-staggered" case.

(2) EPRI TR-100382 (Reference 5-6).

An update of the 1985 EPRI database of common cause failures, published as EPRI NP-3967. This database is specifically common cause failures and the most complete regarding analyzed information. This study includes failure events that have taken place in commercial nuclear power plants in the USA.

This document dedicates one section to each type of component, where it describes, firstly, the physical limits of the component, e.g. identifying which subcomponents would be included in the consideration and which would be left out.

EPRI then presents the data sheets, which summarize the common cause events that have occurred.

(3) NUREG/CR-5801 (Reference 5-8).

When information in the EPRI database is not available and it is not possible to assimilate a component within those defined in the previous sources (NUREG/CR-5497 or EPRI TR-100382), NUREG/CR-5801 (Reference 5-8) is used, because it advises the use of generic alpha parameters for cases where information is not available in the databases (see Section 5.5.2, Reference 5-8).

NUREG/CR-5801 (Reference 5-8) recommends that the α_2, α_3 and α_4 factors above are divided by two when the rate of common cause faults in operation is determined.

These values are slightly higher, apart from some cases, which are of the same order as those obtained by the alpha parameter method based on the analysis of the EPRI and NUREG/CR-5497 databases. Because it is not usually practical to obtain information for redundancies higher than four, in these situations, values corresponding to four redundant components are used. This may be conservative.

5.3.5 CCF ESTIMATIONS

In Table 5.3-1 the CCF basic events are identified with a description, their probabilities and failure rates (Q_k), CCF factor (fcc), and total probability (Q_t). Refer to Table 5.2-1 for the data source.

For squib valves, periods between demands are unusually irregular and long. Therefore, the demand failure probabilities are adequate for use, and an hourly rate is not estimated, (i.e., Q_t = 3.00E-3).

For a software failure, a common cause fault is assumed in the microprocessor programming of an added value of 1.00E-05 in the various common cause faults that affect the DTM: C62-DTM-CF-DIDALL, C62-DTM-CF-N1EALL, C74-DTM-CF-ALL, C74-DTM-CF-ATWSALL, and C74-DTM-CF-RTIFALL.

Table 5.3-1
Common Cause Failure Probabilities

Event	Description	CCF Factor (f_{cc})	Ptotal (Q_t)	Prob (Q_k)
B21-ACV-CF-MSIVCLOSE	CCF OF AOV (MSIV) TO CLOSE	7.26E-03	2.00E-03	1.45E-05
B21-FT_-CF-MSLA	CCF 3/4 FLOW TRANSMITTERS MSL "A"	3.00E-03	1.10E-05	3.31E-08
B21-FT_-CF-MSLB	CCF 3/4 FLOW TRANSMITTERS MSL "B"	3.00E-03	1.10E-05	3.31E-08
B21-FT_-CF-MSLC	CCF 3/4 FLOW TRANSMITTERS MSL "C"	3.00E-03	1.10E-05	3.31E-08
B21-FT_-CF-MSLD	CCF 3/4 FLOW TRANSMITTERS MSL "D"	3.00E-03	1.10E-05	3.31E-08
B21-LT_-CF-ATWS	CCF OF DIVERSIFIED LEVEL 1& 2 TRANSM. 1A/B/C/D	5.00E-03	2.40E-05	1.20E-07
B21-LT_-CF-DPSWR	CCF OF DPS WR LEVEL TRANSMITTERS	5.00E-03	2.40E-05	1.20E-07
B21-LT_-CF-L8NO	CCF LEVEL TRANSMITTERS L8 (FAILURE TO RESPOND TO CHANGE)	5.00E-03	2.40E-05	1.20E-07
B21-LT_-CF-L9SPU	SPURIOUS L9 SIGNAL CCF	5.00E-03	2.40E-05	1.20E-07
B21-LT_-CF-L9SPU1	SPURIOUS L9 SIGNAL CCF	5.00E-03	2.40E-05	1.20E-07
B21-LT_-CF-N001A/B/C/D	CCF OF DIVERSIFIED LEVEL 1 & 2 TRANSM. 10A/B/C/D	5.00E-03	2.40E-05	1.20E-07
B21-LT_-CF-N001ABCD	CCF OF DIVERSIFIED LEVEL 1& 2 TRANSM. 1A/B/C/D	5.00E-03	2.40E-05	1.20E-07
B21-LT_-CF-N001ABCDLOW	CCF LEVEL TRANSMITTERS (L2) FAIL LOW	5.00E-03	1.22E-05	6.12E-08
B21-LT_-CF-N010ABCD	CCF OF DIVERSIFIED LEVEL 1 & 2 TRANSM. 10A/B/C/D	5.00E-03	2.40E-05	1.20E-07
B21-LT_-CF-N012ABCD	CCF 3/4 LEVEL TRANSMITTERS N012A/B/C/D	3.00E-03	2.40E-05	7.20E-08
B21-OR_-CF-N012ABCD	CCF 3/4 ORIFICES LINES 12 A/B/C/D (PLUG)	3.00E-03	1.44E-05	4.32E-08
B21-PT_-CF-02ALL	CCF 3 OUT OF 4 RPV PRESSURE TRANSMITTERS	3.00E-03	1.15E-05	3.46E-08
B21-PT_-CF-02ALLNO	CCF OF RPV PRESSURE TRANSMITTERS	3.00E-03	1.15E-05	3.46E-08
B21-PT_-CF-02HIGH	CCF OF PRESSURE RPV TRANSMITTERS HIGH	5.00E-03	7.92E-06	3.96E-08
B21-PT_-CF-ATWS	CCF 3 OUT OF 4 RPV PRESSURE TRANSMITTERS	3.00E-03	1.15E-05	3.46E-08
B21-PT_-CF-MSL	CCF 3/4 PRESSURE TRANSMITTERS MSL	3.00E-03	1.15E-05	3.46E-08
B21-SQV-CF-DPVOPEN	CCF OF DPV'S TO OPEN	5.00E-03	3.00E-03	1.50E-05
B21-SQV-CF-F004AB	CCF OF DPV A AND B TO OPEN	1.20E-02	3.00E-03	3.60E-05
B21-SQV-CF-F004ABC	CCF OF DPV A,B & C TO OPEN	3.00E-03	3.00E-03	9.00E-06
B21-SQV-CF-F004ABD	CCF OF DPV A,B & D TO OPEN	3.00E-03	3.00E-03	9.00E-06
B21-SQV-CF-F004ABE	CCF OF DPV A,B & E TO OPEN	3.00E-03	3.00E-03	9.00E-06
B21-SQV-CF-F004ABF	CCF OF DPV A,B & F TO OPEN	3.00E-03	3.00E-03	9.00E-06
B21-SQV-CF-F004ABG	CCF OF DPV A,B & G TO OPEN	3.00E-03	3.00E-03	9.00E-06
B21-SQV-CF-F004ABH	CCF OF DPV A,B & H TO OPEN	3.00E-03	3.00E-03	9.00E-06
B21-SQV-CF-F004AC	CCF OF DPV A AND C TO OPEN	1.20E-02	3.00E-03	3.60E-05
B21-SQV-CF-F004ACD	CCF OF DPV A,C & D TO OPEN	3.00E-03	3.00E-03	9.00E-06
B21-SQV-CF-F004ACE	CCF OF DPV A,C & E TO OPEN	3.00E-03	3.00E-03	9.00E-06
B21-SQV-CF-F004ACF	CCF OF DPV A,C & F TO OPEN	3.00E-03	3.00E-03	9.00E-06

Table 5.3-1

Common Cause Failure Probabilities

Event	Description	CCF Factor (f_{cc})	Ptotal (Q_t)	Prob (Q_k)
B21-SQV-CF-F004ACG	CCF OF DPV A,C & G TO OPEN	3.00E-03	3.00E-03	9.00E-06
B21-SQV-CF-F004ACH	CCF OF DPV A,C & H TO OPEN	3.00E-03	3.00E-03	9.00E-06
B21-SQV-CF-F004AD	CCF OF DPV A AND D TO OPEN	1.20E-02	3.00E-03	3.60E-05
B21-SQV-CF-F004ADE	CCF OF DPV A,D & E TO OPEN	3.00E-03	3.00E-03	9.00E-06
B21-SQV-CF-F004ADF	CCF OF DPV A,D & F TO OPEN	3.00E-03	3.00E-03	9.00E-06
B21-SQV-CF-F004ADG	CCF OF DPV A,D & G TO OPEN	3.00E-03	3.00E-03	9.00E-06
B21-SQV-CF-F004ADH	CCF OF DPV A,D & H TO OPEN	3.00E-03	3.00E-03	9.00E-06
B21-SQV-CF-F004AE	CCF OF DPV A AND E TO OPEN	1.20E-02	3.00E-03	3.60E-05
B21-SQV-CF-F004AEF	CCF OF DPV A,E & F TO OPEN	3.00E-03	3.00E-03	9.00E-06
B21-SQV-CF-F004AEG	CCF OF DPV A,E & G TO OPEN	3.00E-03	3.00E-03	9.00E-06
B21-SQV-CF-F004AEH	CCF OF DPV A,E & H TO OPEN	3.00E-03	3.00E-03	9.00E-06
B21-SQV-CF-F004AF	CCF OF DPV A AND F TO OPEN	1.20E-02	3.00E-03	3.60E-05
B21-SQV-CF-F004AFG	CCF OF DPV A,F & G TO OPEN	3.00E-03	3.00E-03	9.00E-06
B21-SQV-CF-F004AFH	CCF OF DPV A,F & H TO OPEN	3.00E-03	3.00E-03	9.00E-06
B21-SQV-CF-F004AG	CCF OF DPV A AND G TO OPEN	1.20E-02	3.00E-03	3.60E-05
B21-SQV-CF-F004AGH	CCF OF DPV A,G & H TO OPEN	3.00E-03	3.00E-03	9.00E-06
B21-SQV-CF-F004AH	CCF OF DPV A AND H TO OPEN	1.20E-02	3.00E-03	3.60E-05
B21-SQV-CF-F004BC	CCF OF DPV B AND C TO OPEN	1.20E-02	3.00E-03	3.60E-05
B21-SQV-CF-F004BCD	CCF OF DPV B,C & D TO OPEN	3.00E-03	3.00E-03	9.00E-06
B21-SQV-CF-F004BCE	CCF OF DPV B,C & E TO OPEN	3.00E-03	3.00E-03	9.00E-06
B21-SQV-CF-F004BCF	CCF OF DPV B,C & F TO OPEN	3.00E-03	3.00E-03	9.00E-06
B21-SQV-CF-F004BCG	CCF OF DPV B,C & G TO OPEN	3.00E-03	3.00E-03	9.00E-06
B21-SQV-CF-F004BCH	CCF OF DPV B,C & H TO OPEN	3.00E-03	3.00E-03	9.00E-06
B21-SQV-CF-F004BD	CCF OF DPV B AND D TO OPEN	1.20E-02	3.00E-03	3.60E-05
B21-SQV-CF-F004BDE	CCF OF DPV B,D & E TO OPEN	3.00E-03	3.00E-03	9.00E-06
B21-SQV-CF-F004BDF	CCF OF DPV B,D & F TO OPEN	3.00E-03	3.00E-03	9.00E-06
B21-SQV-CF-F004BDG	CCF OF DPV B,D & G TO OPEN	3.00E-03	3.00E-03	9.00E-06
B21-SQV-CF-F004BDH	CCF OF DPV B,D & H TO OPEN	3.00E-03	3.00E-03	9.00E-06
B21-SQV-CF-F004BE	CCF OF DPV B AND E TO OPEN	1.20E-02	3.00E-03	3.60E-05
B21-SQV-CF-F004BEF	CCF OF DPV B,E & F TO OPEN	3.00E-03	3.00E-03	9.00E-06
B21-SQV-CF-F004BEG	CCF OF DPV B,E & G TO OPEN	3.00E-03	3.00E-03	9.00E-06
B21-SQV-CF-F004BEH	CCF OF DPV B,E & H TO OPEN	3.00E-03	3.00E-03	9.00E-06
B21-SQV-CF-F004BF	CCF OF DPV B AND F TO OPEN	1.20E-02	3.00E-03	3.60E-05
B21-SQV-CF-F004BFG	CCF OF DPV B,F & G TO OPEN	3.00E-03	3.00E-03	9.00E-06
B21-SQV-CF-F004BFH	CCF OF DPV B,F & H TO OPEN	3.00E-03	3.00E-03	9.00E-06
B21-SQV-CF-F004BG	CCF OF DPV B AND G TO OPEN	1.20E-02	3.00E-03	3.60E-05
B21-SQV-CF-F004BGH	CCF OF DPV B,G & H TO OPEN	3.00E-03	3.00E-03	9.00E-06
B21-SQV-CF-F004BH	CCF OF DPV B AND H TO OPEN	1.20E-02	3.00E-03	3.60E-05
B21-SQV-CF-F004CD	CCF OF DPV C AND D TO OPEN	1.20E-02	3.00E-03	3.60E-05
B21-SQV-CF-F004CDE	CCF OF DPV C,D & E TO OPEN	3.00E-03	3.00E-03	9.00E-06
B21-SQV-CF-F004CDF	CCF OF DPV C,D & F TO OPEN	3.00E-03	3.00E-03	9.00E-06
B21-SQV-CF-F004CDG	CCF OF DPV C,D & G TO OPEN	3.00E-03	3.00E-03	9.00E-06
B21-SQV-CF-F004CDH	CCF OF DPV C,D & H TO OPEN	3.00E-03	3.00E-03	9.00E-06
B21-SQV-CF-F004CE	CCF OF DPV C AND E TO OPEN	1,20E-02	3.00E-03	3.60E-05

Table 5.3-1

Common Cause Failure Probabilities

Event	Description	CCF Factor (f_{cc})	Ptotal (Q_t)	Prob (Q_k)
B21-SQV-CF-F004CEF	CCF OF DPV C,E & F TO OPEN	3.00E-03	3.00E-03	9.00E-06
B21-SQV-CF-F004CEG	CCF OF DPV C,E & G TO OPEN	3.00E-03	3.00E-03	9.00E-06
B21-SQV-CF-F004CEH	CCF OF DPV C,E & H TO OPEN	3.00E-03	3.00E-03	9.00E-06
B21-SQV-CF-F004CF	CCF OF DPV C AND F TO OPEN	1.20E-02	3.00E-03	3.60E-05
B21-SQV-CF-F004CFG	CCF OF DPV C,F & G TO OPEN	3.00E-03	3.00E-03	9.00E-06
B21-SQV-CF-F004CFH	CCF OF DPV C,F & H TO OPEN	3.00E-03	3.00E-03	9.00E-06
B21-SQV-CF-F004CG	CCF OF DPV C AND G TO OPEN	1.20E-02	3.00E-03	3.60E-05
B21-SQV-CF-F004CGH	CCF OF DPV C,G & H TO OPEN	3.00E-03	3.00E-03	9.00E-06
B21-SQV-CF-F004CH	CCF OF DPV C AND H TO OPEN	1.20E-02	3.00E-03	3.60E-05
B21-SQV-CF-F004DE	CCF OF DPV D AND E TO OPEN	1.20E-02	3.00E-03	3.60E-05
B21-SQV-CF-F004DEF	CCF OF DPV D,E & F TO OPEN	3.00E-03	3.00E-03	9.00E-06
B21-SQV-CF-F004DEG	CCF OF DPV D,E & G TO OPEN	3.00E-03	3.00E-03	9.00E-06
B21-SQV-CF-F004DEH	CCF OF DPV D,E & H TO OPEN	3.00E-03	3.00E-03	9.00E-06
B21-SQV-CF-F004DF	CCF OF DPV D AND F TO OPEN	1.20E-02	3.00E-03	3.60E-05
B21-SQV-CF-F004DFG	CCF OF DPV D,F & G TO OPEN	3.00E-03	3.00E-03	9.00E-06
B21-SQV-CF-F004DFH	CCF OF DPV D,F & H TO OPEN	3.00E-03	3.00E-03	9.00E-06
B21-SQV-CF-F004DG	CCF OF DPV D AND G TO OPEN	1.20E-02	3.00E-03	3.60E-05
B21-SQV-CF-F004DGH	CCF OF DPV D,G & H TO OPEN	3.00E-03	3.00E-03	9.00E-06
B21-SQV-CF-F004DH	CCF OF DPV D AND H TO OPEN	1.20E-02	3.00E-03	3.60E-05
B21-SQV-CF-F004EF	CCF OF DPV E AND F TO OPEN	1.20E-02	3.00E-03	3.60E-05
B21-SQV-CF-F004EFG	CCF OF DPV E,F & G TO OPEN	3.00E-03	3.00E-03	9.00E-06
B21-SQV-CF-F004EFH	CCF OF DPV E,F & H TO OPEN	3.00E-03	3.00E-03	9.00E-06
B21-SQV-CF-F004EG	CCF OF DPV E AND G TO OPEN	1.20E-02	3.00E-03	3.60E-05
B21-SQV-CF-F004EGH	CCF OF DPV E,G & H TO OPEN	3.00E-03	3.00E-03	9.00E-06
B21-SQV-CF-F004EH	CCF OF DPV E AND H TO OPEN	1.20E-02	3.00E-03	3.60E-05
B21-SQV-CF-F004FG	CCF OF DPV F AND G TO OPEN	1.20E-02	3.00E-03	3.60E-05
B21-SQV-CF-F004FGH	CCF OF DPV F,G & H TO OPEN	3.00E-03	3.00E-03	9.00E-06
B21-SQV-CF-F004FH	CCF OF DPV F AND H TO OPEN	1.20E-02	3.00E-03	3.60E-05
B21-SQV-CF-F004GH	CCF OF DPV G AND H TO OPEN	1.20E-02	3.00E-03	3.60E-05
B21-SRV-CF-9OPEN	CCF TO OPEN 9 SRVs	5.28E-03	3.60E-02	1.90E-04
B21-UV_-CF-102/3A	CCF OF CHECK VALVES F103A AND F102A TO CLOSE	5.00E-02	8.00E-03	4.00E-04
B21-UV_-CF-102/3B	CCF OF CHECK VALVES F103B AND F102B TO CLOSE	5.00E-02	8.00E-03	4.00E-04
B32-ACV-CF-2ICABCD	CCF TO OPEN 2/4 ACV VALVES TRAINS A,B,C,D	7.74E-03	2.00E-03	1.55E-05
B32-LT_-CF-LT72HA	CCF 3 OUT OF FOUR A LEVEL TRANSMITTERS	3.00E-03	2.40E-05	7.20E-08
B32-LT_-CF-LT72HB	CCF 3 OUT OF FOUR B LEVEL TRANSMITTERS	3.00E-03	2.40E-05	7.20E-08
B32-MOV-CF-2ICABCD	CCF TO OPEN 2/4 MOV VALVES TRAINS A,B,C,D	2.02E-03	4.00E-03	8.08E-06
B32-MOV-CF-F005A/B	CCF TO OPERATE BETWEEN F005 A & B	3.60E-03	4.00E-03	1.44E-05
B32-MOV-CF-F005A/C	CCF TO OPERATE BETWEEN F005 A & C	3.60E-03	4.00E-03	1.44E-05
B32-MOV-CF-F005A/D	CCF TO OPERATE BETWEEN F005 A & D	3.60E-03	4.00E-03	1.44E-05

Table 5.3-1

Common Cause Failure Probabilities

Event	Description	CCF Factor (f_{cc})	Ptotal (Q_t)	Prob (Q_k)
B32-MOV-CF-F005B/C	CCF TO OPERATE BETWEEN F005 B & C	3.60E-03	4.00E-03	1.44E-05
B32-MOV-CF-F005B/D	CCF TO OPERATE BETWEEN F005 B & D	3.60E-03	4.00E-03	1.44E-05
B32-MOV-CF-F005C/D	CCF TO OPERATE BETWEEN F005 C & D	3.60E-03	4.00E-03	1.44E-05
B32-MOV-CF-F72HADOPEN	CCF VALVES F72HA AND D TO OPEN	5.00E-02	4.00E-03	2.00E-04
B32-MOV-CF-F72HBCOPEN	CCF VALVES F72HB AND C TO OPEN	5.00E-02	4.00E-03	2.00E-04
B32-PDT-CF-3ICAHIGH	CCF 3/4 PDT'S ISOLATION CONDENSER A SPURIOUS ACTUATION	3.00E-03	3.24E-03	9.72E-06
B32-PDT-CF-3ICBHIGH	CCF 3/4 PDT'S ISOLATION CONDENSER B SPURIOUS ACTUATION	3.00E-03	3.24E-03	9.72E-06
B32-PDT-CF-3ICCHIGH	CCF 3/4 PDT'S ISOLATION CONDENSER C SPURIOUS ACTUATION	3.00E-03	3.24E-03	9.72E-06
B32-PDT-CF-3ICDHIGH	CCF 3/4 PDT'S ISOLATION CONDENSER D SPURIOUS ACTUATION	3.00E-03	3.24E-03	9.72E-06
B32-PDT-CF-ICA	CCF OF PRESSURE DIFF. TRANSMITTERS IN IC-A NO OUTPUT SIGNAL	5.00E-03	3.24E-03	1.62E-05
C12-MCB-CF-CLOSE	CIRCUIT BREAKER CCF TO CLOSE	9.29E-02	1.00E-03	9.29E-05
C12-MOV-CF-OPEN	CCF MOV TO OPEN	4.44E-02	4.00E-03	1.78E-04
C12-MP_-CS-C001A/BOIL	CCF AUX. OIL PUMPS TO START	8.54E-02	2.40E-03	2.05E-04
C12-MPC-CR-C001AB	CCF OF CRD PUMPS TO RUN	6.21E-02	5.76E-05	3.57E-06
C12-MPC-CS-C001A/B	CCF PUMPS TO START	8.54E-02	2.40E-03	2.05E-04
C12-PT_-CF-N001A/BLOW	CCF PRESSURE TRANSMITTERS IN SUCTION LINES FAIL LOW	5.00E-03	7.92E-06	3.96E-08
C21-FT_-CF-N001ABCDA	CCF 3/4 FLOW TRANSMITTERS RWCU TRAIN A	3.00E-03	1.10E-05	3.31E-08
C21-TT_-CF-N003ABCD	CCF 3/4 STEAM TUNNEL TEMPERATURE TRANSMITTERS	3.00E-03	8.40E-06	2.52E-08
C41-LT_-CF-N001TALOW	CCF 2 OUT OF 3 OF LEVEL TRANSMITTERS LOW	2.00E-02	1.22E-05	2.45E-07
C41-LT_-CF-N001TBLOW	CCF 2 OUT OF 3 LEVEL TRANSMITTERS LOW	2.00E-02	1.22E-05	2.45E-07
C41-SQV-CF-F003AC	CCF TO OPERATE OF SQUIB VALVES ON SLCS-A	5.00E-02	3.00E-03	1.50E-04
C41-SQV-CF-F003BD	CCF TO OPERATE OF SQUIB VALVES ON SLCS-B	5.00E-02	3.00E-03	1.50E-04
C51-ACT-CF-1PRM	CCF APRM NEUTRON CHANNELS	5.00E-03	5.96E-02	2.98E-04
C51-ACT-CF-APRMSTUCK	CCF APRM DETECTORS STUCK AT POWER LEVEL	5.00E-03	4.32E-05	2.16E-07
C51-ACT-CF-SRNM	CCF OF SRNM CORE FLUX CHANNELS	5.00E-03	5.96E-02	2.98E-04
C51-VLU-CF-1PRM	PRNM DIV I 2/4 MODULES FAILS	1.20E-02	7.80E-05	9.36E-07
C51-VLU-CF-2PRM	PRNM DIV II 2/4 MODULES FAILS	1.20E-02	7.80E-05	9.36E-07
C51-VLU-CF-APRM	CCF 2/4 MODULES APRM	1.20E-02	7.80E-05	9.36E-07
C51-VLU-CF-SRNM	CCF 3/4 OF SRNM 2/4 VLU	1.20E-02	6.24E-04	7.49E-06
C62-BYP-CF-N1EALL	CCF OF BYPASS UNITS (N1E)	5.00E-02	3.00E-04	1.50E-05
C62-DTM-CF-DIDALL	COMMON CAUSE FAILURE 3/4 DTM DID LOGIC	5.00E-02	9.00E-04	5.50E-05

Table 5.3-1

Common Cause Failure Probabilities

Event	Description	CCF Factor (f_{cc})	Ptotal (Q_t)	Prob (Q_k)
C62-DTM-CF-N1EALL	CCF OF DIGITAL TRIP MODULES NO 1E	5.00E-02	9.00E-04	5.50E-05
C62-VLU-CF-DIDALL	CCF OF VOTER LOGIC UNITS	5.00E-02	6.24E-04	3.12E-05
C62-VLU-CF-N1EALL	CCF OF VOTER LOGIC UNITS	5.00E-02	6.24E-04	3.12E-05
C72-BYP-CF-DPSALL	CCF OF BYPASS UNITS	5.00E-03	3.00E-04	1.50E-06
C72-DTM-CF-DPSALL	CCF 3/4 DTM OF DPS DIV 1/2/3/4	3.00E-03	6.00E-04	1.20E-06
C72-VLU-CF-DPSALL	CCF OF VOTER LOGIC UNITS	5.00E-03	6.24E-04	3.12E-06
C74-BYP-CF-ALL	CCF OF BYPASS UNITS	5.00E-03	3.00E-04	1.50E-06
C74-BYP-CF-DIDALL	CCF OF BYPASS UNITS (DID)	3.00E-03	3.00E-04	9.00E-07
C74-DTM-CF-ALL	CCF OF ¾ DTM OF SSLC DIV 1/2/3/4	3.00E-03	6.00E-04	1.20E-05
C74-DTM-CF-ATWSALL	CCF 3 OUT OF 4 DIGITAL TRIP MODULES	5.00E-03	6.00E-04	1.30E-05
C74-DTM-CF-RTIFALL	CCF 3/4 DTM OF SSLC DIV1/2/3/4	3.00E-03	6.00E-04	1.80E-06
C74-SLU-CF-DLTD	CCF's TO OPERATE OF DISCRETE LOGIC TIME DELAYS	1.20E-02	9.00E-04	1.08E-05
C74-SLU-CF-OLU	CCF 3/4 OLU IN SSLC/RTIF DIV 1/2/3/4	3.00E-03	9.00E-04	2.70E-06
C74-SLU-CF-TLU	CCF 3/4 TLU IN SSLC/RTIF DIV 1/2/3/4	3.00E-03	9.00E-04	2.70E-06
C74-VLU-CF-ALL	CCF OF VOTER LOGIC UNITS	5.00E-03	6.24E-04	3.12E-06
C74-VLU-CF-ATWS	CCF 3/4 VOTING LOGIC UNIT ATWS DIVISSIONS	5.00E-03	6.24E-04	3.12E-06
C74-VLU-CF-LD&IS	CCF VOTING LOGIC CARDS 2/4 LD&IS	5.00E-03	6.24E-04	3.12E-06
C74-VLU-CF-SLCS	CCF 2/2 VOTING CARD SLCS LOGIC	1.20E-02	6.24E-04	7.49E-06
D11-ACT-CF-3ICAHIGH	CCF 3/4 RADIATION MONITORS IC-A SPURIOUS ACTUATION	3.00E-03	5.28E-05	1.58E-07
D11-ACT-CF-3ICBHIGH	CCF 3/4 RADIATION MONITORS IC-B SPURIOUS ACTUATION	3.00E-03	5.28E-05	1.58E-07
D11-ACT-CF-3ICCHIGH	CCF 3/4 RADIATION MONITORS IC-C SPURIOUS ACTUATION	3.00E-03	5.28E-05	1.58E-07
D11-ACT-CF-3ICDHIGH	CCF 3/4 RADIATION MONITORS IC-D SPURIOUS ACTUATION	3.00E-03	5.28E-05	1.58E-07
D11-ACT-CF-ICA	CCF OF RADIATION MONITORS IN IC-A POOL (NO OUTPUT)	5.00E-03	1.94E-03	9.72E-06
E50-LT_-CF-N005ABCLOW	CCF 2/3 LEVEL TRANSMITTERS E50-N005A/B/C LOW	2.00E-02	1.22E-05	2.45E-07
E50-OR_-CF-4EQUA	CCF OF 4 ORIFICES EQUALIZING LINES (PLUG)	3.00E-03	1.44E-05	4.32E-08
E50-OR_-CF-4PLUG	CCF OF 4 OR MORE ORIFICES TO PLUG	5.00E-03	1.44E-05	7.20E-08
E50-OR_-CF-7PLUG	CCF OF 7 ORIFICES TO PLUG	5.00E-03	1.44E-05	7.20E-08
E50-OR_-CF-D001AE	CCF 2/2 ORIFICES LINES A AND E (PLUG)	5.00E-02	1.44E-05	7.20E-07
E50-OR_-CF-D001BCFG	CCF 4/4 ORIFICES LINES B. C. F AND G (PLUG)	5.00E-03	1.44E-05	7.20E-08
E50-OR_-CF-D001DH	CCF 2/2 ORIFICES LINES D AND H (PLUG)	5.00E-02	1.44E-05	7.20E-07
E50-OR_-CF-PLUGALL	CCF OF ALL ORIFICES TO PLUG	5.00E-03	1.44E-05	7.20E-08
E50-SQV-CF-4OPEN	CCF OF 4 OR MORE SQUIB VALVES TO OPEN	5.00E-03	3.00E-03	1.50E-05
E50-SQV-CF-EQALLOPEN	CCF OF ALL 4 SQUIB VALVES TO	5.00E-03	6.00E-03	3.00E-05

Table 5.3-1

Common Cause Failure Probabilities

Event	Description	CCF Factor (f_{cc})	Ptotal (Q_t)	Prob (Q_k)
	OPEN			
E50-SQV-CF-F002A/2E	CCF OF SQUIB VALVES F002A/ F002E	1.20E-02	3.00E-03	3.60E-05
E50-SQV-CF-F002B/2C/2F/2G	CCF OF SQUIB VALVES F002B/ F002C/ F002F/ F002G	5.00E-03	3.00E-03	1.50E-05
E50-SQV-CF-F002D/2H	CCF OF SQUIB VALVES F002D/ F002H	1.20E-02	3.00E-03	3.60E-05
E50-SQV-CF-GDCS7OPEN	CCF OF 7 SQUIB VALVES IN GDCS LINES TO OPEN	5.00E-03	3.00E-03	1.50E-05
E50-SQV-CF-OPENALL	CCF OF ALL SQUIB VALVES TO OPEN	5.00E-03	3.00E-03	1.50E-05
E50-STR-CF-SPPLUG	CCF FILTER/STRAINER IN PSP TO PLUG	3.48E-02	1.08E-02	3.75E-04
G21-ACV-CF-SUCTION	CCF OPEN ACV SUCTION PUMPS LINE	6.66E-03	2.00E-03	1.33E-05
G21-FT_-CF-N014A/BLOW	CCF DISCHARGE FLOW TRANSMITTERS	5.00E-03	1.66E-04	8.28E-07
G21-HX_-CF-PLUG/LEAK	CCF H/Xs TO PLUG/LEAK	4.98E-02	2.40E-05	1.19E-06
G21-MCB-CF-C001A/BCLOSE	CCF CIRCUIT BREAKERS TO CLOSE	9.29E-02	1.00E-03	9.29E-05
G21-MOV-CF-CLOSEA	CCF TO CLOSE MOV TRAIN A	1.51E-02	4.00E-03	6.06E-05
G21-MOV-CF-OPENA/B	CCF TO OPEN MOV TRAINS A AND B	2.16E-03	4.00E-03	8.65E-06
G21-MP_-CR-C001A/B	CCF PUMPS TO RUN	6.21E-02	3.60E-03	2.23E-04
G21-MP_-CS-C001A/B	CCF PUMPS TO START	8.54E-02	3.00E-03	2.56E-04
G21-PT_-CF-N002A/BLOW	CCF SUCTION PRESSURE TRANSMITTERS	5.00E-02	1.19E-04	5.94E-06
G21-STR-CF-SPPLUG	CCF FILTER/STRAINER IN PSP TO PLUG	9.34E-02	1.08E-02	1.01E-03
G31-ACV-CF-DEENERGA/B	AOV/NOV SPURIOUS TRANSF. TO DEENERG. POSITION	2.25E-01	1.62E-04	3.64E-05
G31-FT_-CF-N002ABLOW	CCF SUCTION FLOW TRANSMITTERS FAIL LOW	5.00E-02	6.12E-04	3.06E-05
G31-MCB-CF-CLOSE	CCF CIRCUIT BREAKER TO CLOSE	7.62E-02	1.00E-03	7.62E-05
G31-MOV-CF-F018/62/63A	CCF 3 OUT OF 3 MOTOR OPERATED VALVES F018A, F062A AND F063A TO CLOSE	1.51E-02	4.00E-03	6.06E-05
G31-MOV-CF-F018/62/63B	CCF 3 OUT OF 3 MOTOR OPERATED VALVES F018B, F062B AND F063B TO CLOSE	1.51E-02	4.00E-03	6.06E-05
G31-MOV-CF-OPENA	MOVs (3) TRAIN A CCF TO OPEN	5.28E-03	4.00E-03	2.11E-05
G31-MOV-CF-OPENA/B	CCF MOV TO OPEN	2.16E-03	4.00E-03	8.65E-06
G31-MOV-CF-OPENB	MOVs (3) TRAIN B CCF TO OPEN	5.28E-03	4.00E-03	2.11E-05
G31-MP_-CR-RUN	CCF OF RWCU PUMPS TO RUN	6.21E-02	2.40E-04	1.49E-05
G31-MP_-CS-C001A/B	CCF TO RESTART PUMPS	8.54E-02	2.30E-03	1.96E-04
H23-EMS-CF-ALL	CCF OF ESSENTIAL MULTIPLEXING SYSTEM DIV 1/2/3/4	3.00E-03	6.00E-04	1.80E-06
H23-EMS-CF-ATWSALL	CCF OF ESSENTIAL MULTIPLEXING SYSTEM DIV 1/2/3/4	3.00E-03	6.00E-04	1.80E-06
H23-EMS-CF-DIDALL	CCF OF ALL DIVISION OF THE EMS	3.00E-03	6.00E-04	1.80E-06
H23-EMS-CF-DPSALL	CCF OF ESSENTIAL MULTIPLEXING SYSTEM DIV 1/2/3/4	3.00E-03	6.00E-04	1.80E-06
H23-EMS-CF-N1EALL	CCF OF ALL DIVISION OF THE EMS	3.00E-03	6.00E-04	1.80E-06

Table 5.3-1

Common Cause Failure Probabilities

Event	Description	CCF Factor (f_{cc})	Ptotal (Q_t)	Prob (Q_k)
H23-RMU-CF-ALL	CCF OF REMOTE MULTIPLEXING UNITS TO OPERATE	3.00E-03	3.00E-04	9.00E-07
H23-RMU-CF-ATWSALL	CCF OF REMOTE MULTIPLEXING UNITS TO OPERATE	3.00E-03	3.00E-04	9.00E-07
H23-RMU-CF-DIDALL	CCF OF REMOTE MULTIPLEXING UNITS (DID)	3.00E-03	3.00E-04	9.00E-07
H23-RMU-CF-DPSALL	CCF OF REMOTE MULTIPLEXING UNITS TO OPERATE	3.00E-03	3.00E-04	9.00E-07
H23-RMU-CF-N1EALL	CCF OF REMOTE MULTIPLEXING UNITS (NO 1E) TO OPERATE	3.00E-03	3.00E-04	9.00E-07
H23-RMU-CF-P41A	CCF TO OPERATOR MU 001 AND RMU 002 P41 TRAIN A FOR MANUAL ACTUAT.	1.20E-02	3.00E-04	3.60E-06
H23-RMU-CF-P41B	CCF TO OPERATOR MU 001 AND RMU 002 P41 TRAIN B FOR MANUAL ACTUAT.	1.20E-02	3.00E-04	3.60E-06
N21-ACV-CF-MKUPA/B	CCF TO OPERATE AOVs TRAINS A & B	6.75E-03	1.60E-02	1.08E-04
N21-LT_-CF-FWTKLOW	CCF OF LEVEL TRANSMITTERS (LOW) IN FW STORAGE TANK	5.00E-03	1.22E-05	6.12E-08
N21-LT_-CF-FWTKNO	CCF FEEDWATER STORAGE TANK LEVEL TRANSMITTERS	5.00E-03	8.76E-03	4.38E-05
N21-LT_-CF-HWLOW	CCF HOTWELL LEVEL TRANSMITTERS TO STOP PUMPS	5.00E-03	1.22E-05	6.12E-08
N21-LT_-CF-HWNO	CCF HOTWELL LEVEL TRANSMITTERS	5.00E-03	8.76E-03	4.38E-05
N21-MP_-CR-COND	CONDENSATE PUMPS CCF TO RUN	5.00E-03	6.00E-04	3.00E-06
N71-MP_-CR-PUMP	CCF PUMPS CWS TO RUN	1.32E-02	6.00E-04	7.92E-06
N71-STR-CF-CWS	CCF STRAINER TO RUN	4.44E-02	2.40E-04	1.07E-05
P21-ACV-CF-F010/13	CCF AIR OPERATED VALVES F010 AND F013 TO REMAIN OPEN	2.50E-02	3.60E-06	9.00E-08
P21-ACV-CF-F022/25A	CCF VALV ACV F022A/ F025A TRAIN A	2.50E-02	2.00E-03	5.00E-05
P21-ACV-CF-F022/25B	CCF VALV ACV F022B/F025B TRAIN B	2.50E-02	2.00E-03	5.00E-05
P21-ACV-CF-F027/32	CCF AIR OPERATED VALVES F027 AND F032 TO REMAIN OPEN	2.50E-02	1.82E-06	4.56E-08
P21-MP_-CR-3[a]	CCF 3 PUMPS TO RUN (INTRADIVISON A)	2.00E-02	1.20E-04	2.40E-06
P21-MP_-CR-3B	CCF 3 PUMPS TO RUN (INTRADIVISON B)	1.00E-02	1.20E-04	1.20E-06
P21-MP_-CR-5[a]LL	CCF TO RUN PUMPS TRAINS A AND B	5.00E-03	1.20E-04	6.00E-07
P21-MP_-CR-TRAINA	CCF TO RUN RCCW PUMPS TRAIN A	1.00E-02	1.20E-04	1.20E-06
P21-MP_-CR-TRAINAB	CCF TO RUN PUMPS TRAINS A AND B	5.00E-02	1.20E-04	6.00E-06
P21-MP_-CR-TRAINB	CCF TO RUN RCCW PUMPS TRAIN B	1.00E-02	1.20E-04	1.20E-06
P21-MP_-CS-2[a]	CCF 2 PUMPS (INTRADIVISON A) TO START	2.00E-02	1.30E-03	2.60E-05
P21-MP_-CS-2B	CCF 2 PUMPS (INTRADIVISON B) TO START	2.00E-02	1.30E-03	2.60E-05
P21-MP_-CS-5[a]LL	CCF TO START PUMPS DIVISIONS A AND B	5.00E-03	1.30E-03	6.50E-06

Table 5.3-1

Common Cause Failure Probabilities

Event	Description	CCF Factor (f_{cc})	Ptotal (Q_t)	Prob (Q_k)
P21-MP_-CS-TRAINA	CCF TO START RCCW PUMPS TRAIN A	1.00E-02	1.30E-03	1.30E-05
P21-MP_-CS-TRAINAB	CCF TO START PUMPS TRAINS A AND B	5.00E-02	1.30E-03	6.50E-05
P21-MP_-CS-TRAINB	CCF TO START RCCW PUMPS TRAIN B	1.00E-02	1.30E-03	1.30E-05
P21-TT_-CF-N038A/B	CCF OF TEMPERATURE XMTR	5.00E-03	8.40E-06	4.20E-08
P22-MCB-CF-2ªLL	CCF 2 OUT OF 3 CIRCUIT BREAKERS FAIL TO CLOSE	9.29E-02	1.00E-03	9.29E-05
P22-MP_-CR-C001ABC	CCF TO RUN 2 PUMPS	2.00E-02	1.20E-04	2.40E-06
P22-MP_-CS-2ªLL	CCF 2 OUT OF 3 PUMPS FAIL TO START	2.00E-02	1.30E-03	2.60E-05
P22-PT_-CF-N002LOW	CCF SUCTION PRESSURE 2/ 3 TRANSMITTERS	5.00E-03	7.92E-06	3.96E-08
P22-TT_-CF-N003LOW	CCF 2/ 3 TEMPERATURE TRANSMITTERS	5.00E-03	4.56E-05	2.28E-07
P41-FAN-CR-3ALL	CCF TO RUN 3 FAN UNITS	3.00E-03	2.40E-04	7.20E-07
P41-FAN-CS-2ALL	CCF TO START 2 FAN UNITS	1.20E-02	6.00E-04	7.20E-06
P41-FAN-CS-3ALL	CCF TO START 3 FAN UNITS	3.00E-03	6.00E-04	1.80E-06
P41-MP_-CR-2ALL	CCF TO RUN 2 PUMPS TRAINS A AND B	4.42E-03	7.68E-04	3.40E-06
P41-MP_-CR-3ALL	CCF TO RUN 3 PUMPS TRAINS A AND B	1.53E-02	7.68E-04	1.17E-05
P41-MP_-CS-2ALL	CCF TO START 2 PUMPS TRAINS A AND B	1.79E-02	2.40E-03	4.29E-05
P41-STR-CF-2ALL	CCF 2 STRAINERS PLUGGED	4.44E-02	2.40E-04	1.07E-05
P41-STR-CF-3ALL	CCF 3 STRAINERS PLUGGED	4.44E-02	2.40E-04	1.07E-05
P51-ACV-CF-OPEN	CCF OF AOV TO OPEN	6.75E-03	2.00E-03	1.35E-05
P51-CMP-CR-RUN	CCF OF P51 COMPRESSORS TO RUN	6.21E-02	2.40E-03	1.49E-04
P51-CMP-CS-START	CCF OF P51 COMPRESSORS TO START	8.54E-02	2.00E-02	1.71E-03
P52-ACV-CF-DEENERG	CCF OF AOVs TO OPERATE TO OTHER THEN DEENERG. POS.	1.10E-02	2.00E-03	2.20E-05
P52-ACV-CF-OPEN	CCF OF AOV TO OPEN	6.75E-03	2.00E-03	1.35E-05
P52-CMP-CR-C001AB	CCF TO RUN COMPRESSORS LINES 1 & 2	6.21E-02	2.40E-03	1.49E-04
P52-CMP-CR-P52/P51	CCF OF P52/P51 COMPRESSORS TO RUN	5.00E-03	2.40E-03	1.20E-05
P52-CMP-CS-C001AB	CCF TO START COMPRESSORS LINES 1 & 2	8.54E-02	2.00E-02	1.71E-03
P52-CMP-CS-P52/P51	CCF OF P52/P51 COMPRESSORS TO START	5.00E-03	2.00E-02	1.00E-04
P52-PT_-CF-P51/P52	CCF OF PRESSURE TRANSMITTERS	5.00E-03	5.18E-04	2.59E-06
P54-CPV-CF-CONTROL	CCF OF PRESSURE CONTROL VALVES FAILURES	5.00E-02	3.13E-03	1.57E-04
R10-MCB-CF-138CLOSE	CCF CIRCUIT BREAKERS TO CLOSE	9.29E-02	8.00E-03	7.43E-04
R11-MCB-CF-69CLOSE	CCF CIRCUIT BREAKERS 6.9 KV TO CLOSE	9.29E-02	1.00E-03	9.29E-05
R12-LCB-CF-480CLOSE	CCF CIRCUIT BREAKERS 480 V AC TO CLOSE	9.29E-02	3.00E-04	2.79E-05
R12-LCB-CF-480OPEN	CCF CIRCUIT BREAKERS 480 V AC TO OPEN	9.50E-02	5.00E-04	4.75E-05

Table 5.3-1

Common Cause Failure Probabilities

Event	Description	CCF Factor (f_{cc})	Ptotal (Q_t)	Prob (Q_k)
R16-BT_-CF-125NO1E	CCF OF 125 V NO 1E BATTERIES	2.39E-02	5.00E-04	1.20E-05
R16-BT_-CF-ALLBATT	BATTERY CCF #2	1.80E-02	5.00E-04	9.01E-06
R16-BT_-CF-BATT11&12	BATTERY 11 & 12 CCF	1.91E-03	5.00E-04	9.56E-07
R16-BT_-CF-BATT11&21	BATTERY 11 & 21 CCF	1.91E-03	5.00E-04	9.56E-07
R16-BT_-CF-BATT11&22	BATTERY 11 & 22 CCF	1.91E-03	5.00E-04	9.56E-07
R16-BT_-CF-BATT11&31	BATTERY 11 & 31 CCF	1.91E-03	5.00E-04	9.56E-07
R16-BT_-CF-BATT11&41	BATTERY 11 & 41 CCF	1.91E-03	5.00E-04	9.56E-07
R16-BT_-CF-BATT12&21	BATTERY 12 & 21 CCF	1.91E-03	5.00E-04	9.56E-07
R16-BT_-CF-BATT12&22	BATTERY 12 & 22 CCF	1.91E-03	5.00E-04	9.56E-07
R16-BT_-CF-BATT12&31	BATTERY 12 & 31 CCF	1.91E-03	5.00E-04	9.56E-07
R16-BT_-CF-BATT12&41	BATTERY 12 & 41 CCF	1.91E-03	5.00E-04	9.56E-07
R16-BT_-CF-BATT21&22	BATTERY 21 & 22 CCF	1.91E-03	5.00E-04	9.56E-07
R16-BT_-CF-BATT21&31	BATTERY 21 & 31 CCF	1.91E-03	5.00E-04	9.56E-07
R16-BT_-CF-BATT21&41	BATTERY 21 & 41 CCF	1.91E-03	5.00E-04	9.56E-07
R16-BT_-CF-BATT22&31	BATTERY 22 & 31 CCF	1.91E-03	5.00E-04	9.56E-07
R16-BT_-CF-BATT22&41	BATTERY 41 & 22 CCF	1.91E-03	5.00E-04	9.56E-07
R16-BT_-CF-BATT31&41	BATTERY 31 & 41 CCF	1.91E-03	5.00E-04	9.56E-07
R16-BT_-CF-BATTA1A2	BATTERY A1 & A2 CCF	3.08E-03	5.00E-04	1.54E-06
R16-BT_-CF-BATTA1B1	BATTERY A1 & B1 CCF	3.08E-03	5.00E-04	1.54E-06
R16-BT_-CF-BATTA1B2	BATTERY A1 & B2 CCF	3.08E-03	5.00E-04	1.54E-06
R16-BT_-CF-BATTA1C	BATTERY A1 & C CCF	3.08E-03	5.00E-04	1.54E-06
R16-BT_-CF-BATTA2B1	BATTERY A2 & B1 CCF	3.08E-03	5.00E-04	1.54E-06
R16-BT_-CF-BATTA2B2	BATTERY A2 & B2 CCF	3.08E-03	5.00E-04	1.54E-06
R16-BT_-CF-BATTA2C	BATTERY A2 & C CCF	3.08E-03	5.00E-04	1.54E-06
R16-BT_-CF-BATTB1B2	BATTERY B1 & B2 CCF	3.08E-03	5.00E-04	1.54E-06
R16-BT_-CF-BATTB1C	BATTERY B1 & C CCF	3.08E-03	5.00E-04	1.54E-06
R16-BT_-CF-BATTB2C	BATTERY B2 & C CCF	3.08E-03	5.00E-04	1.54E-06
R21-DG_-CR-ALLDG	CCF OF DIESEL GENERATORS TO RUN	7.73E-02	5.75E-02	4.44E-03
R21-DG_-CS-ALLDG	CCF OF DIESEL GENERATORS TO START AND LOAD	6.09E-02	1.40E-02	8.52E-04
R21-MP_-CR-FUELTRANS	CCF TO RUN MOTOR-DRIVEN FUEL TRANSFER PUMPS	6.21E-02	6.00E-04	3.72E-05
R21-MP_-CS-FUELTRANS	CCF TO START MOTOR-DRIVEN FUEL TRANSFER PUMPS	8.54E-02	2.00E-03	1.71E-04
T10-VB_-CF-CLOSED	CCF 2 OF 3 VB FAIL TO REMAIN CLOSED	2.00E-02	1.00E-04	2.00E-06
T10-VB_-CF-OPEN	CCF 3 OF 3 VB FAIL TO OPEN	1.00E-02	1.00E-04	1.00E-06
T15-HX_-CF-PLUG	CCF OF THREE PCCS HX'S	4.98E-02	8.76E-04	4.36E-05
T62-TT_-CF-SPALL	CCF OF SUPPRESSION POOL TEMP. TRANSMITTERS	5.00E-03	8.40E-06	4.20E-08
T64-TT_-CF-HIGH	CFF TEMPERATURE TRANSMITTERS IN STEAM TUNNELFAIL HIGH	5.00E-02	4.56E-05	2.28E-06
XXX-MP_-CR-SWS/CWS	CCF PUMPS TO RUN SWS/CWS	1.32E-02	6.00E-04	7.92E-06

Table 5.3-1

Common Cause Failure Probabilities

Event	Description	CCF Factor (f_{cc})	Ptotal (Q_t)	Prob (Q_k)
(1) Per hour event failure rates are multiplied by 24 hours to obtain the value given in the (Q_t) column of Table 5.3-1.				

5.4 SPECIAL EVENTS

During the development of the PRA, in the Systems Analysis as well as the Accident Sequence Analysis, certain basic events are identified that do not correspond to any of the following categories, which are called special events:

a. Probabilities or rates of individual failure of components.

b. Unavailability for testing and maintenance.

c. Probabilities of human error.

d. Probabilities or rates of common cause failure.

Each case of these special events is treated differently. Some special events represent the maintenance policy of the plant, for example, the case of redundant trains. Other special events need to be treated like the events calculated from situations produced in the plant, for example, loss and recuperation of the electric power supply.

Table 5.4-1 includes all the events considered as special in the models, the probabilities, descriptions, and data source references.

Table 5.4-1

Special Events

Special Event	Prob	Description	References
B21-SYS-FF-1/9OPEN	5.85E-02	1 OUT OF 9 SRV FAIL TO CLOSE AFTER OPENING	ALWR
B21-SYS-FF-10/18SRV	7.87E-08	10 OUT OF 18 SRV FAIL TO OPEN IN SAFETY MODE	ALWR
B21-SYS-FF-18/18SRV	7.87E-08	18 OUT OF 18 SRV FAIL TO OPEN IN SAFETY MODE	ALWR
B32-SYS-TM-ICA	4.16E-02	IC "A" UNAVAILABLE	NUREG/CR-4550
C12-SYS-TM-TRAINB	3.00E-03	TRAIN B IN MAINTENANCE	ALWR
C41-SYS-FF-MAKEUP	1.00E-01	INVENTORY MAKE-UP BORATION FAILURE	Bounding Value Engineering Judgment
C71-SYS-FF-SCRAM	1.00E-08	SCRAM FAILURE	(2)
E50-SYS-FF-MLLOCA	3.79E-01	PROBABILITY OF MEDIUM LIQUID LOCA IN GDCS LINES	Initiating Events, section 2
E50-SYS-FF-SLLOCA	0.00E+00	PROBABILITY OF SLLOCA IN GDCS LINES	Initiating Events, section 2
G21-SYS-TM-TRAINB	3.00E-03	TRAIN B IN MAINTENANCE	ALWR
G31-SYS-TM-B	3.00E-03	RWCU/SDCS TRAIN B IN MAINTENANCE OR OUT OF SERVICE	ALWR
N21-SYS-FF-BYPASS	1.00E-02	TURBINE BYPASS FAILS	Bounding Value, Engineering Judgment
N21-SYS-FF-FWAL	5.00E-01	PROBABILITY OF LSLOCA IN FW TRAIN A PIPE INSIDE CONTAINMENT	
N21-SYS-FF-FWBL	5.00E-01	PROBABILITY OF LSLOCA IN FW TRAIN B PIPE INSIDE CONTAINMENT	
P41-SYS-FF-2CTMP	5.04E-05	INSUFFICIENT FLOW FROM CTM PUMPS (2 PUMPS FAIL)	ALWR
P41-SYS-FF-3CTMP	9.20E-06	INSUFFICIENT FLOW FROM CTM PUMPS (3 PUMPS FAIL)	ALWR
R10-SYS-FF-230KV	5.00E-04	230 KV SWITCHYARD FAILS DURING OPERATION	ALWR
R10-SYS-FF-500KV	1.20E-06	500KV SWITCHYARD FAILS DURING OPERATION	ALWR
R10-SYS-TM-230KV	1.00E-02	230 KV SWITCHYARD IN MAINTENANCE	ALWR
R11-SYS-FF-NOREC	6.13E-01	FAILURE IN OFFSITE POWER RECOVERY	NUREG/CR-5496,NUREG/CR-6823
R21-SYS-FC-AIRDG4	1.00E-03	AIR STARTING SYSTEM FAILURE [#13]	NUREG/CR-2728
R21-SYS-FC-AIRDG5	1.00E-03	AIR STARTING SYSTEM FAILURE	NUREG/CR-2728
R21-SYS-FC-FUELDG4	4.00E-03	FUEL OIL STORAGE & TRANSFER SYSTEM FAILURE[#14]	ALWR
R21-SYS-FC-FUELDG5	4.00E-03	FUEL OIL STORAGE & TRANSFER SYSTEM FAILURE[#14]	ALWR
T11-SYS-FF-OPEN	5.69E-02	ALL OVERPRESSURE PROTECTION VALVES FAIL TO OPEN	Bounding Value, Engineering Judgment
U43-SYS-FF-LPCI	2.40E-02	U43 HARDWARE FAILURES	ALWR
U43-SYS-FF-YARD	2.00E-03	HARDWARE FAILURES IN YARD AREA	ALWR
XXX-SYS-FF-	7.80E-05	LOSS OF SCRAM FOLLOW SIGNAL. (2/4	(1)

Table 5.4-1

Special Events

Special Event	Prob	Description	References
SCRAMFOLLOW		RELAY LOGIC FAILURE)	

(1). This value corresponds to the probability of the 2/4 Voting Logic Card "all modes failure".
(2). This value was derived for the ABWR using a fault tree model of the Control Rods, including the FMCRD. Because the system is identical to the ESBWR design and it is independent of other systems in the ESBWR, the point estimate from the ABWR analysis was deemed appropriate.

5.5 REFERENCES

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5-3. NUREG/CR-4550, Vol. 1. Analysis of Core Damage Frequency: Internal Events Methodology, Rev. 1, January 1990.

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5-5. IEEE-Std-500, Reliability Data, Std. 500-1984, December 1984.

5-6. EPRI-TR-100382, A Database of Common-Cause Events for Risk and Reliability Applications, June 1992.

5-7. NUREG/CR-5497, Common-Cause Failure Parameter Estimations, October 1998.

5-8. NUREG/CR-5801, Procedure for Analysis of Common-Cause Failures in Probabilistic Safety Analysis, April 1993.

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5-10. NUREG/CR-5500, Reliability Study. General Electric Reactor Protection System, 1984-1995. Vol. 3, May 1999.

5-11. NUREG/CR-5496, Evaluation of Loss of Offsite Power Events at Nuclear Power Plants, 1980-1996, November, 1998.

5-12. NUREG/CR-6823, Handbook of Parameter Estimation for Probabilistic Risk Assessment, September 2003.

5-13. NUREG/CR-2232, Nuclear Plant Reliability Data System 1980 Annual Reports of Cumulative System and Component Reliability, September 1981.

5-14 NUREG-1816, Independent Verification of the Mitigating Systems Performance Index (MSPI) Results for Pilot Plants, February 2005.

6 HUMAN RELIABILITY ANALYSIS

Contents

List of Tables

List of Figures

6 HUMAN RELIABILITY ANALYSIS

6.1 INTRODUCTION AND SCOPE

The purpose of this section is to document the Human Reliability Analysis performed as part of the ESBWR PRA.

Three types of human actions are described in this chapter: actions that take place prior to the initiating event, actions that cause an initiating event, and actions that are taken to mitigate an initiating event. The evaluation is done using bounding Human Error Probabilities (HEP) in order to demonstrate that the ESBWR does not overly rely on human actions to maintain a low Core Damage Frequency (CDF).

Section 6.2 describes the methods used in the analysis. Section 6.3 describes the specific calculations for the HEPs used in the ESBWR PRA and how dependencies are treated. Section 6.4 outlines COL action items related to refinement of HEPs.

6.2 METHODOLOGY

This section describes the methodology applied in evaluating the human interactions (HIs) with the plant systems both during normal operation and during accidents. HIs during normal plant operation are those causing an initiating event and those which fail to restore equipment to their normal condition following a test and/or maintenance action.

The methodology used in the present study is in agreement with the Systematic Human Action Reliability Procedure (SHARP) (Reference 6-1).

In the design phase of ESBWR , generic screening values of human reliability are used. These generic HEPs are obtained from EPRI NP-3583 (Reference 6-1), NUREG/CR-1278 (Reference 6-2), and NUREG/CR-4772 (Reference 6-3).

Human interactions analyzed in the ESBWR PRA are categorized in the following types:

- Type A: Pre-Initiating Event HIs

  Before an initiating event, plant personnel can affect availability of standby systems by inadvertently disabling equipment during the performance of operational activities in the plant.

  These HIs are associated with testing, instrument calibration, preventive maintenance, corrective maintenance, replacement of components and realignment of systems. These activities are assumed to take place prior to the initiating event.

- Type B: Initiating Event-Related HIs

  Plant personnel can initiate an event through various interactions with plant equipment. These would typically occur due to a misposition or maloperation of equipment that inadvertently trips equipment or inserts false control signals.

  This type of human action is implicitly included in the ESBWR model as part of the frequency of the initiating events. The design PRA uses generic initiating event frequencies that include the contribution of operator-initiated events. Therefore, Type B HIs are not explicitly modeled in the ESBWR design PRA.

- Type C: Post Initiating Event HIs

  The nature of the passive ESBWR is such that post initiator operator actions are not as strong of a contributor to the risk profile as in current LWRs. As such, a conservative assessment of HEPs is judged to be acceptable during the design phase. Probabilities used in the PRA are based on generic values based on the time frame for the operators to successfully diagnose situations and perform the necessary actions prior to core damage.

  Two major subsets are identified as follows:

  (1) CP – These are actions that are specifically directed by plant operating and emergency procedures. By following procedures during the course of an accident, plant personnel can operate standby equipment that will terminate the accident.

  (2) CR – These are actions that have traditionally been called recovery actions. In the ESBWR, only actions to recover equipment from misalignment (Type A actions) are included. These require diagnosis and realignment of plant equipment in order

to perform procedure directed actions. Plant personnel can recover and operate initially unavailable equipment to terminate an accident.

Errors of commission have not been included in the ESBWR design PRA.

To analyze these types of HIs, the Systematic Human Action Reliability Procedure (SHARP) has been adopted (Reference 6-9).

6.3 QUANTIFICATION OF HUMAN ERROR PROBABILITIES

A conservative assessment of the HEPs is used for the ESBWR design PRA. Generic screening probabilities are estimated from References 6-1, 6-2, and 6-3. A more detailed analysis of the values could be performed, however this would tend to further reduce the calculated probabilities. In this phase of the design, screening values are appropriate. The values taken from the references are median values. The ESBWR PRA model requires mean values. These were calculated by combining the median values with the associated error factors, assuming a lognormal distribution.

6.3.1 Type A Human Actions

The systems modeled in the PRA are reviewed to determine likely test and maintenance activities. Because procedures for these activities are not available at the design phase, likely configurations for these activities are assumed. Failure to restore from these configurations is identified as potential Type A actions.

For all the components for which there is an alarm or an indication that is checked at least once every day, it is not necessary to consider the probability of an incorrect positioning. In addition, for all the components for which there are a total check (such as a flow test) after manipulation, it is not necessary to consider the probability of an incorrect position or state before postulated accidents. The potential for misalignment of each system is described within each system description in Section 4.

For the screening analysis of human reliability, generic values are used as reported in Table 6.3-1. These HEPs are extracted from documents EPRI NP-3583 (Reference 6-1), NUREG/CR-1278 (Reference 6-2), and NUREG/CR-4772 (Reference 6-3). The detection interval in Table 6.3-1 corresponds to the frequency of the maintenance activity anticipated for the system.

There are three different levels of Type A actions modeled as follows:

- Skill Based

  Skill based actions include the manipulation of equipment that is performed on a routine basis (i.e. every shift) during the operation of the plant. Personnel are trained and well practiced in these manipulations.

  An example is the closure of the associated discharge valve during the maintenance of a pump.

- Rule Based

  Rule based actions include the manipulation of equipment that is performed occasionally. Personnel perform the manipulations under the direction of procedures and following training on those tasks.

  An example is the restoration of isolations following the mixing of a batch of sodium pentaborate SLCS solution.

- Knowledge Based

  Knowledge based actions include the manipulation of equipment that is performed during unique situations.

An example is the immediate reconfiguration of a system following a failure of an operating pump.

Table 6-3 presents the final Type A human error probabilities used in the PRA model.

6.3.2 Type B Human Actions

Due to the way that the initiating event frequencies were developed in the ESBWR design PRA; no Type B actions are included as basic events in the models. The generic initiating events includes operator actions that have historically caused plant transients and accidents. The ESBWR design does not include any features that are not covered by the analysis presented in Section 2.

6.3.3 Type C Human Actions

The systems modeled in the PRA were reviewed to determine the need for human interactions. These would be necessary to provide backup actuations for automatic systems, manual alignment of systems that do not automatically start, and to recover from the misalignments identified in the Type A analysis. Actuations of systems are modeled as "CP" sub-type HEPs and recovery are modeled as "CR" sub-type HEPs. These sub-types are defined in Section 6.2.

There are four time frames considered in the ESBWR design PRA, and the Type C HEPs are based on these time frames. The screening probabilities are assigned, in part, according to these time frames. No credit is taken for actions that must be completed very quickly (i.e., within a few minutes of the cue).

HEPs are estimated in two parts, the cognitive part (or diagnosis phase) and the manual part (or action phase). The total HEP for an action is the sum of these two parts. The HEPs for the cognitive parts are assigned based on the following criteria:

- Skill Based

  The skill based actions are those, which are routine and frequently practiced. An example would be for the operators to insert a backup scram signal following an initiating event.

- Rule Based

  The rule based actions are those, which are performed in response to a specific set of procedures. An example would be to start FAPCS in SPC mode when the suppression pool water temperature reaches a preset limit.

- Knowledge Based

  The knowledge based actions are those where the operators need to deduce the proper course of action based on indirect indications or a complex combination of individual indications. An example would be injection SLCS via the boron mixing system following a failure of a SLCS division.

The HEPs for the manual part (action) are assigned based on the following criteria:

- Skill Based

The skill based actions are those, which are routine, frequently practiced, and require a few simple actions. An example would be for the operators to manual initiate depressurization from the control room.

- Rule Based

  The rule based actions are those which are more complex and involve specific sequences of manipulations, however procedures and training are readily available. An example would be starting FAPCS in suppression pool cooling mode (non-automated).

- Knowledge Based

  The knowledge based actions are those that are complex and not routine. Procedures are available, but training and drills are infrequent. An example would be controlling a system from outside the control room.

For the screening analysis of human reliability, generic values are taken from documents EPRI NP-3583 (Reference 6-1), NUREG/CR-1278 (Reference 6-2), and NUREG/CR-4772 (Reference 6-3). These are presented in Table 6.3-1 and the final HEPs are presented in Table 6.3-4.

6.3.4 HEP Dependencies

The screening analysis accounts for the dependencies among HIs in the following manner:

Type A human errors associated with improper realignments following tests or maintenance typically do not have strong dependence between multiple actions. Dependencies of this kind usually arise from incorrect procedures or poorly trained maintenance personnel. It is anticipated that the COL holder will institute programmatic activities to minimize this type of dependence. Because of this, it is not considered part of the design PRA.

Type A human errors associated with miscalibration are not important in ESBWR. The design of the DCIS incorporates self detection of miscalibrated channels. Therefore, as long as the calibration of the redundant channels is performed on a staggered schedule, this type of human error will not be important and will not be susceptible to dependence.

For Type C human errors that affect various systems, the logic model includes separate basic events representing the cognitive part of the action, and various basic events representing the manipulation of the systems involved. If more than one human action shares a cognitive or manual part, the basic event representing the dependent part is included in both locations in the fault tree model. For the purposes of the design PRA, even partially dependent actions are modeled as fully dependent.

Figure 6-1 shows an example of this modeling. Depressurization using the SRVs is modeled using separate cognitive and manual basic events. This is because initiating low pressure injection using FAPCS is dependent on depressurization and must occur in the same time frame as the depressurization action. As is seen in the figure, the decision to depressurize the plant is modeled under both logic sub-sections.

After quantification, all the human actions that appear combined in the same minimal cutsets whose accumulated frequencies are, at the most, 99% of the core damage frequency, were reviewed. Based on this review, it is considered unnecessary to model any special new dependencies. This is because either no dependence is identified or the dependencies are already

explicitly taken into consideration in the models. For those cases where a degree of dependence is considered possible, it is determined that the values of the probabilities of the human actions combined in the same minimal cutsets at this stage are sufficiently conservative that the impact of the possible dependency is considered to be adequately.

Table 6.3-1

Generic Error Probability Values for Type A Actions

Human Action	Detection Interval	Behavior Type [1]		
		Skill	Rule	Knowledge
Type A [2]	720 h	5×10^{-4} (EF=5)	2.5×10^{-3} (EF=5)	1.25×10^{-2} (EF=5)
	2190 h	1.5×10^{-3} (EF=5)	7.5×10^{-3} (EF=5)	3.75×10^{-2} (EF=5)
	6380 h	3×10^{-3} (EF=5)	1.5×10^{-2} (EF=5)	7.5×10^{-2} (EF=5)
	8640 h	6×10^{-3} (EF=5)	3×10^{-2} (EF=5)	1.5×10^{-1} (EF=3)
Notes:	(1) Values given are the Median HEP and the associated Error Factor (2) Source: EPRI NP-3583, NUREG/CR-1278, NUREG/CR 4772			

Table 6.3-2

Type A Human Action Probabilities

Identification	Description	Type	Behavior Type	Actuation Interval (hr)	Value	Mean Value
P54-XHE-MH-F003	Misalignment of valve F003	A	Rule	720	2.50E-03	4.02E-03
C12-XHE-MH-F013A	Misalignment of valve F013A	A	Rule	8640	3.00E-02	4.83E-02
C12-XHE-MH-F013B	Misalignment of valve F013B	A	Rule	8640	3.00E-02	4.83E-02
C12-XHE-MH-F015A	Misalignment of valve F015A	A	Rule	8640	3.00E-02	4.83E-02
C12-XHE-MH-F015B	Misalignment of valve F015B	A	Rule	8640	3.00E-02	4.83E-02
C12-XHE-MH-F003B	Misalignment of valve F003B	A	Rule	2190	7.50E-03	1.20E-02
C12-XHE-MH-F018A	Misalignment of valve F018A	A	Rule	2190	7.50E-03	1.20E-02
C12-XHE-MH-F018B	Misalignment of valve F018B	A	Rule	2190	7.50E-03	1.20E-02
C12-XHE-MH-F021A	Misalignment of valve F021A	A	Rule	2190	7.50E-03	1.20E-02
C12-XHE-MH-F021B	Misalignment of valve F021B	A	Rule	2190	7.50E-03	1.20E-02
P21-XHE-MH-F022B	Misalignment of valve F022B	A	Rule	2190	7.50E-03	1.20E-02
P21-XHE-MH-F023B	Misalignment of valve F023B	A	Rule	2190	7.50E-03	1.20E-02
P30-XHE-MH-F015	Misalignment of valve F01T	A	Rule	8640	3.00E-02	4.83E-02
G21-XHE-MH-F308	Misalignment of valve F308	A	Rule	8640	3.00E-02	4.83E-02
G21-XHE-MH-F320	Misalignment of valve F320	A	Rule	8640	3.00E-02	4.83E-02
G21-XHE-MH-F334	Misalignment of valve F334	A	Rule	8640	3.00E-02	4.83E-02
C41-XHE-MH-F002A	Misalignment of valve F002A	A	Rule	720	2.50E-03	4.03E-03
C41-XHE-MH-F002B	Misalignment of valve F002B	A	Rule	720	2.50E-03	4.03E-03

Table 6.3-3

Generic Error Probability Values for Type C Actions

Human Action	Cognitive HEP (Time)	Behavior Type (1)		
		Skill	Rule	Knowledge
Type CP (2)	30 minutes	10^{-2} (EF=5)	10^{-1} (EF=5)	1
	60 minutes	10^{-3} (EF=5)	10^{-2} (EF=5)	10^{-1} (EF=5)
	24 hours	10^{-4}(EF=5)	10^{-3} (EF=5)	10^{-2} (EF=5)
	Manipulation HEP	10^{-3} (EF=5)	10^{-2} (EF=5)	10^{-1} (EF=5)
	72 hours	10^{-5} (EF=10)	10^{-4} (EF=10)	10^{-3} (EF=10)
	Manipulation HEP	10^{-4} (EF=5)	10^{-3} (EF=5)	10^{-2} (EF=5)
Type CR (2)	30 minutes	10^{-2} (EF=10)	10^{-1} (EF=10)	1
	24 hours	10^{-3} (EF=10)	10^{-2} (EF=10)	10^{-1} (EF=10)
	Manipulation HEP	10^{-3} (EF=10)	10^{-2} (EF=10)	10^{-1} (EF=10)
	72 hours	10^{-4} (EF=10)	10^{-3} (EF=10)	10^{-2} (EF=10)
	Manipulation HEP	10^{-4} (EF=10)	10^{-3} (EF=10)	10^{-3} (EF=10)
Notes:	(1) Values given are the Median HEP and the associated Error Factor (2) Source: EPRI NP-3583, NUREG/CR-1278, NUREG/CR-4772			

Table 6.3-4

Type C Human Action Probabilities

Identification	Description	Type	Cognitive	Time	Value	Manipula-tion	Value	Mean Value
B21-XHE-FO-9OPEN	Operator fails to manually open 9/10 SRV	CP	XXX-XHE-FO-DESPRESS	N/A		Skill	1.00E-03	1.61E-03
B21-XHE-FO-ADS	Operator fails to back up the ADS actuation	CP	Skill	30 minutes	1.00E-02	Skill	1.00E-03	1.77E-02
B32-XHE-FO-F72HA	Operator fails to manually back-up F72HA valve opening	CP	XXX-XHE-FO-ICPCCS	N/A		Skill	1.00E-03	1.61E-03
B32-XHE-FO-F72HB	Operator fails to manually back-up F72HB valve opening	CP	XXX-XHE-FO-ICPCCS	N/A		Skill	1.00E-03	1.61E-03
C12-XHE-FO-LEVEL2	Operator fails to back-up CRD actuation	CP	Skill	30 minutes	1.00E-02	Rule	1.00E-02	3.22E-02
C41-XHE-FO-INI	Operator fails to back up SLCS initiation	CP	Skill	30 minutes	1.00E-02	Skill	1.00E-03	1.77E-02
C41-XHE-FO-INISLCS	Operator fails to initiate SLCS alternative	CP	Rule	30 minutes	1.00E-01	Rule	1.00E-02	1.77E-01
C41-XHE-FO-OPENF002A	Operator fails to recover the opening of valve F002A	CR	Rule	30 minutes	1.00E-01	Skill	1.00E-03	2.69E-01
C41-XHE-FO-OPENF002B	Operator fails to recover the opening of valve F003A	CR	Rule	30 minutes	1.00E-01	Skill	1.00E-03	2.69E-01
E50-XHE-FO-EQU	Operator fails to manually back up Equalizing lines actuation	CP	XXX-XHE-FO-RPVLDE	N/A		Skill	1.00E-03	1.61E-03
E50-XHE-FO-GDCS	Operator fails to manually back up GDCS actuation	CP	XXX-XHE-FO-RPVLDE	N/A		Skill	1.00E-03	1.61E-03
G21-XHE-FO-LPCI	Operator fails to manually align and actuate FAPCS in LPCI mode	CP	XXX-XHE-FO-DESPRESS	N/A		Skill	1.00E-03	1.61E-03

Table 6.3-4

Type C Human Action Probabilities

Identification	Description	Type	Cognitive	Time	Value	Manipula-tion	Value	Mean Value
G21-XHE-FO-LPCIADS	Operator fails to manually align and actuate FAPCS in LPCI mode	CP	XXX-XHE-FO-LPMAKEUP	N/A		Rule	1.00E-02	1.61E-02
G21-XHE-FO-SPC	Operator fails to manually initiate FAPCS in SPC mode.	CP	N/A	N/A		Skill	1.00E-03	1.61E-03
G21-XHE-FO-SPCADS	Operator fails to manually initiate FAPCS in SPC mode after MDS	CP	N/A	N/A		Rule	1.00E-02	1.61E-02
G31-XHE-FO-SDC	Operator fails to actuate RWCU/SDC mode	CP	Rule	24 hours	1.00E-03	Rule	1.00E-02	1.77E-02
G31-XHE-FO-SDCSLCS	Operator fails to actuate RWCU/SDC mode in ATWS	CP	Knowledge	24 hours	1.00E-02	Knowledge	1.00E-01	1.77E-01
G31-XHE-FO-MIBOC	Operator fails to manually isolate a RWCU/SDC broken line	CR	Skill	72 hours	1.00E-04	Skill	1.00E-04	5.32E-04
G31-XHE-FO-SDCMSL	Operator fails to actuate RWCU/SDC mode in MSL	CP	Knowledge	24 hours	1.00E-02	Rule	1.00E-02	3.22E-02
N21-XHE-FO-CONDPUMPD	Operator fails to start condensate pump D.	CP	Rule	30 minutes	1.00E-01	Skill	1.00E-03	2.69E-01
N21-XHE-FO-FWPUMPD	Operator fails to start feedwater pump D	CP	Rule	30 minutes	1.00E-01	Skill	1.00E-03	2.69E-01
P21-XHE-FO-AIRVALVES	Operator fails in manual opening	CP	Rule	30 minutes	1.00E-01	Skill	1.00E-03	2.69E-01
P21-XHE-FO-STDBYPUMP	Operator fails to back up the start of the standby pump	CP	Rule	30 minutes	1.00E-01	Skill	1.00E-03	2.69E-01
P22-XHE-FO-HXB	Operator fails to align HXB	CP	Rule	30 minutes	1.00E-01	Skill	1.00E-03	2.69E-01

Table 6.3-4

Type C Human Action Probabilities

Identification	Description	Type	Cognitive	Time	Value	Manipula-tion	Value	Mean Value
P41-XHE-FO-STDBYPUMP	Operator fails to back up the start of the standby pump	CP	Skill	30 minutes	1.00E-02	Skill	1.00E-03	1.77E-02
P51-XHE-FO-STDBYCOMP	Operator fails to back-up standby compressor SAS	CP	Rule	60 minutes	1.00E-02	Skill	1.00E-03	1.77E-02
P52-XHE-FO-ALIGNDRYER2	Operator fails to manually actuate valve F015B to failing Dryer 2	CP	P52-XHE-FO-IAS/SAS	N/A		Skill	1.00E-03	1.61E-03
P52-XHE-FO-ALIGNSAS	Operator fails to manual actuation SAS for IAS use	CP	P52-XHE-FO-IAS/SAS	N/A		Skill	1.00E-03	1.61E-03
P52-XHE-FO-IAS/SAS	Operator fails to recognize back-up IAS	CP	Rule	60 minutes	1.00E-02	N/A		1.61E-02
P52-XHE-FO-STDBYCOMP	Operator fails to manually actuate standby compressor IAS	CP	P52-XHE-FO-IAS/SAS	N/A		Skill	1.00E-03	1.61E-03
P54-XHE-FO-OPENF005	Operator fails to back-up F005 valve opening	CP	Rule	60 minutes	1.00E-02	Skill	1.00E-03	1.77E-02
T10-XHE-FO-CLOSE	Operator fails to close vacuum breakers	CP	Rule	60 minutes	1.00E-02	Skill	1.00E-03	1.77E-02
T10-XHE-FO-CLOSEIVS	Operator fails to back up closed isolation valves	CP	Skill	30 minutes	1.00E-02	Skill	1.00E-03	1.77E-02
U43-XHE-FO-LPCI	Operator fails to manually align and actuate FPS in LPCI mode	CP	XXX-XHE-FO-DESPRESS	N/A		Skill	1.00E-03	1.61E-03
U43-XHE-FO-LPCIADS	Operator fails to manually align and actuate FPS in LPCI mode	CP	XXX-XHE-FO-LPMAKEUP	N/A		Rule	1.00E-02	1.61E-02
U43-XHE-FO-MAKEUP	Operator fails to manually actuate U43 for back-up PCCS	CP	XXX-XHE-FO-ICPCCS	N/A	0.00E+00	Rule	1.00E-02	1.61E-02

Table 6.3-4

Type C Human Action Probabilities

Identification	Description	Type	Cognitive	Time	Value	Manipulation	Value	Mean Value
U43-XHE-FO-YARD	Operator fails to supply PCCS from yard area	CP	Rule	72 hours	1.00E-04	Rule	1.00E-03	1.77E-03
XXX-XHE-FO-DEPRESS	Operator fails to recognize the need for SRVs for depressurization	CP	Rule	30 minutes	1.00E-01	N/A		1.61E-01
XXX-XHE-FO-ICPCCS	Operator fails to recognize back-up F72HA/B opening	CP	Rule	24 hours	1.00E-03	N/A		1.61E-03
XXX-XHE-FO-LPMAKEUP	Operator fails to recognize the need for low-pressure makeup with RPV depressurized	CP	Rule	30 minutes	1.00E-01	N/A		1.61E-01
XXX-XHE-FO-RPVLDE	Operator fails to recognize back-up Passive System	CP	Skill	30 minutes	1.00E-02	N/A		1.61E-02
XXX-XHE-FO-SPC	Operator fails to recognize the need for SPC	CP	Rule	60 minutes	1.00E-02	N/A		1.61E-02

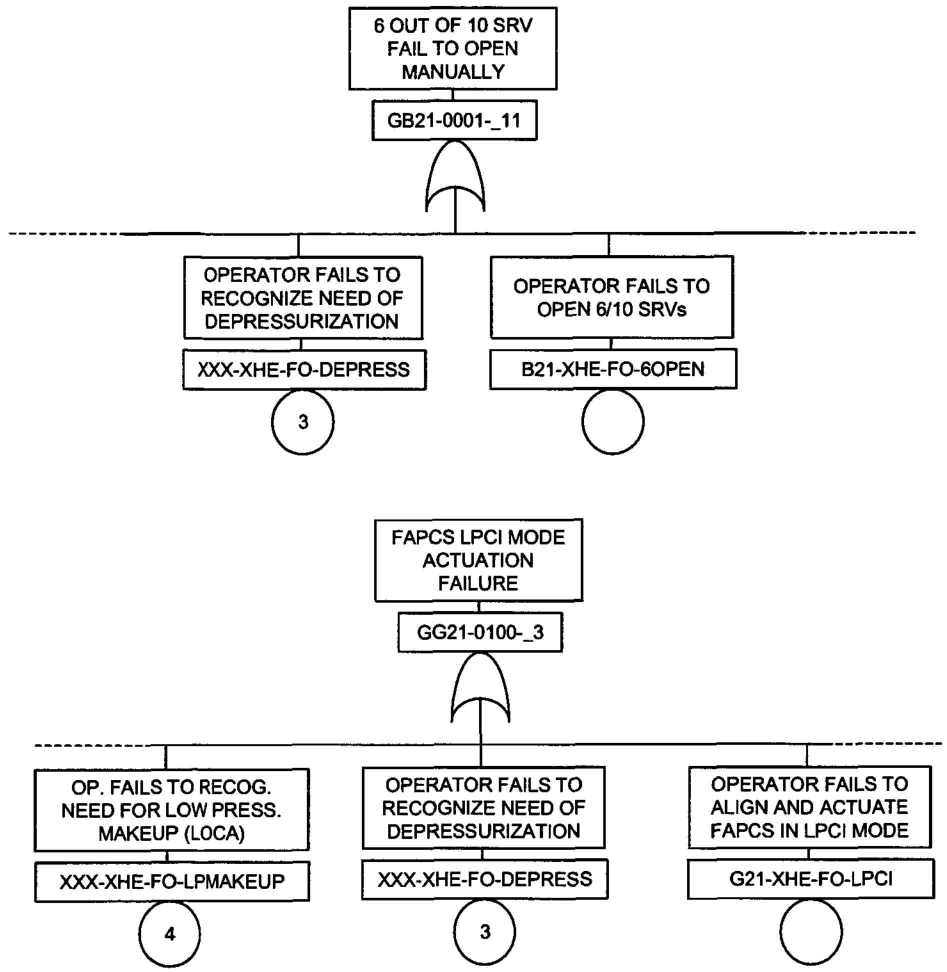

Figure 6.3-1
Human Action Dependence Example

6.4 REFINEMENT OF HUMAN ERROR PROBABILITIES

In order to reduce the conservative contribution of human actions in the ESBWR PRA, human actions that prove to be important can be analyzed in detail.

The criteria for selecting the human actions for detailed analyses are the following:

- Any Type A human action which could potentially cause a failure of more than one redundant/train/division of one or more systems
- Any single Type C human action of an operator which could directly cause damage to the core

The purpose of the detailed analysis is to remove unnecessary conservatism from the PRA results. Because of the way the screening values were chosen, more detailed analysis will reduce the HEPs. As a consequence, detailed analysis is not considered necessary in the DCD phase.

In order to perform a detailed analysis of the human actions modeled in NEDO-33201 Section 6.4, several procedures and data are required. The development and availability of most of these items are expected in the COL phase.

The type of procedures and information necessary to develop detailed analysis are listed below:

Type A human actions

Tagging procedures

Test and calibration procedures

Periodic Operational equipment realignment procedures

Equipment position checking procedures

Walk around inspection procedures

Type C human actions

- Emergency Operating Procedures
- Abnormal Operating Procedures
- Integrated Operating Procedures
- Annunciator Response Procedures
- System operation procedures
- Plant staff organization procedures
- Any other Plant special or auxiliary procedures

Finally, to fully assess the final HEPs, it is necessary to evaluate other performance shaping factors (PSF) that could influence steps in each important human action basic events (e.g., training, man-machine interface, operator experience, etc.). Much of this information will not be available prior to the final construction phase of the plant. Therefore, during the detailed design and COL phase, PSFs will be estimated based on data from existing BWR PRA models.

6.5 REFERENCES

6-1 EPRI: Systematic Human Action Reliability Procedure (SHARP), NP-3583, June 1984.

6-2 NUREG/CR-1278 "Handbook of Human Reliability Analysis with Emphasis on Nuclear Power Plant Applications Final Report", August 1983.

6-3 NUREG/CR-4772 "Accident Sequence Evaluation Program – Human Reliability Analysis Procedure", February 1987.

6-4 EPRI Project RP2170-3 (NUS Report 4531) "Human Cognitive Reliability Model for PRA Analysis" December 1984.