ATTACHMENT 2

EMERGENCY FEEDWATER SYSTEM RELIABILITY ANALYSIS
FOR THE
OCONEE NUCLEAR GENERATING STATION

EMERGENCY FEEDWATER SYSTEM
RELIABILITY ANALYSIS
FOR THE
OCONEE NUCLEAR GENERATING STATION
UNIT NO. I, II, III

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EXECUTIVE SUMMARY

The NRC has requested all operating plants with Babcock & Wilcox (B&W) designed reactors to consider means for upgrading the reliability of their Emergency Feedwater Systems (EFWS). As a part of the response to this request, Duke Power Company and the other B&W Owners Group utilities have requested B&W to perform a simplified reliability analysis of existing emergency feedwater systems. This draft report presents the results of that reliability study for the EFWS for Oconee Units I, II and III.

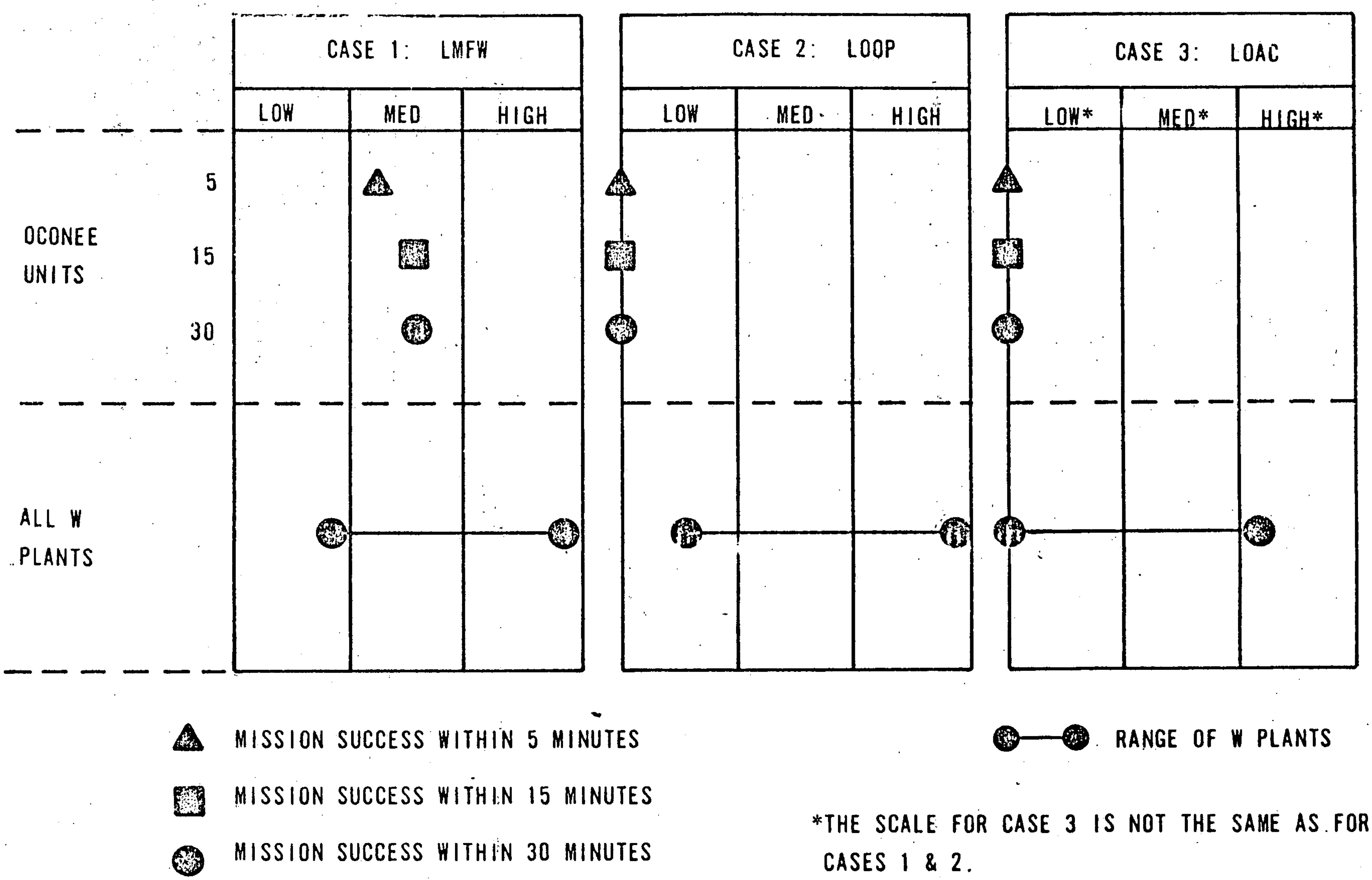
The primary objective of this study was to evaluate EFWS reliability (defined as "point unavailability") using an approach which would produce results comparable to those obtained by NRC Staff analyses for Westinghouse and Combustion Engineering Plants. Another objective was to identify dominant failure contributors affecting system reliability.

EFWS reliability was assessed for three cases: Loss of Main Feedwater (LMFW) with reactor trip, LMFW with Loss of Offsite Power (LMFW/LOOP) and LMFW with Loss of all AC Power (LMFW/LOAC). System reliability was assessed by the construction and analysis of fault trees.

The results of the study are on the following page. These results indicate that EFWS reliability for the Oconee Units, based on reliabilities obtained by the NRC for Westinghouse plants, is low to medium for LMFW and is low for LMFW/LOOP and LMFW/LOAC. These results reflect several significant AC dependencies of the EFWS.

Some of the dominant failure contributors which were identified in this study were 1) EFW turbine failure because of inadequate lubricating oil cooling; 2) turbine pump failure because of inadequate bearing cooling water flow and 3) inadequate suction for the EFW turbine pump. The likelihood of these failures is increased by the fact that certain critical components affecting these failures are automatically shed from their normal power source on loss of offsite power.

A similar study is being performed for each Owners Group utility and additional plant specific draft reports will be prepared. At the conclusion of the program, information contained in the plant specific reports will be collected and used to generate a generic reliability report comparing all B&W operating plants.



COMPARISON OF OCONEE UNITS EFWS RELIABILITY WITH NRC RESULTS FOR W PLANTS

1.0 INTRODUCTION

1.1 Background

This report presents the results of a reliability study for the Emergency Feedwater System (EFWS) for Oconee I, II and III. The NRC is conducting similar analyses for Westinghouse and Combustion Engineering plants. Preliminary results of the NRC study are available (Reference 1) and have been included in this report for comparison with the Oconee EFWS reliability. The approach employed in this study has been developed in close coordination with the NRC and is, therefore, expected to yield comparable results.

1.2 Objectives

The objectives of this study are:

- To perform a simplified analysis to assess the relative reliability of the EFWS for Oconee I, II and III. It is intended that the results of this analysis be directly comparable to those obtained by the NRC for Westinghouse and Combustion Engineering Plants. This is assured by the use of the same evaluative technique, event scenarios, assumptions and reliability data used by the NRC.
- To identify, through the development of reliability-based insight, dominant failure contributors to EFWS unreliability.

1.3 Scope

The EFWS was analyzed as it will exist by October 15, 1979. Three event scenarios were analyzed:

- Case 1 - Loss of Main Feedwater with Reactor Trip (LMFW)
- Case 2 - LMFW coincident with Loss of Offsite Power (LMFW/LOOP)
- Case 3 - LMFW coincident with Loss of all AC Power (LMFW/LOAC).

These event scenarios were taken as given; that is, postulated causes for these scenarios and the associated probabilities of their occurrence were not considered. Additionally, external common mode events (earthquakes, fires, etc.) and their effects were excluded from consideration.

For each of the three cases, system reliability as a function of time was evaluated.

1.4 Analysis Technique

The evaluation of reliability for the EFWS was based primarily on the construction and analysis of fault trees. This technique encourages the development of insights which permit identification of the primary contributors to system unreliability. Application of this technique is described in detail in Section 3.1.

1.5 Assumptions and Criteria

Assumptions and criteria were made in consultation with the NRC staff and were selected to assure that the Oconee reliability evaluation results will be comparable to those obtained by the NRC for the Westinghouse and Combustion Engineering analyses.

1) Criterion for Mission Success - In order to evaluate the overall reliability contribution of system components, it is necessary to establish whether or not failure of those components will prevent successful accomplishment of the EFWS mission. Thus, it is necessary to explicitly define the criterion for mission success. The criterion adopted for this study was the attainment of flow from the turbine-driven pump to at least one steam generator or from both motor-driven pumps to both steam generators. (Discharge cross-connections between the motor-driven pumps were considered unavailable because they contain locked-closed valves.)

   System reliability was calculated at times of 5, 15, and 30 minutes to allow for a range of operator action. These times were specifically chosen because NRC-supplied operator reliability data for these times was available; however, these times are reasonable and consistent with LMFW mitigation for B&W plants. In their study, the NRC staff has used steam generator dryout time as a criterion for successful EFWS initiation, and the 5-minute case represents a comparable result for B&W plants since emergency feedwater delivery within 5 minutes will prevent steam generator dryout. However, steam generator dryout itself does not imply serious consequences; a more appropriate criteria is the maintenance of adequate core cooling. Recent ECCS analyses (Reference 2) have shown that adequate core cooling can be maintained for times in excess of 20 minutes without EFWS operation, providing that at least one High Pressure Injection Pump is operated.

In general, the loss of flow, resulting from random component failures which occur after EFWS initiation, was not a consideration within the scope of this study. However, system characteristics or component limitations which were known to potentially restrict the duration of system operation were considered in accordance with NRC guidance. Such limitations were included by assuming that they resulted in instantaneous unavailability of affected components unless the underlying causes were correctable within 5, 15 or 30 minutes.

2) Power Availability - The following assumptions were made regarding power availability;

LMFW - All AC and DC power was assumed available with a probability of 1.0.

LMFW/LOOP - All AC and DC power was assumed available with a probability of 1.0 with the following exception: All components which are load-shed on LOOP are considered unavailable for the duration of the event (5, 15, and 30 minutes).

LMFW/LOAC - DC and battery backed AC were assumed available with a probability of 1.0.

For LOOP and LOAC, it was assumed that no power was available from the other Oconee Units.

3) Suction Source Availability - Technical Specifications require that 72,000 gallons of water be held in reserve for EFWS use. This water is held in a combination of sources: The condensor hotwell, the upper surge tank and the condensate storage tank. For this study, it was assumed that, for Case 1, sufficient water is available to meet this requirement from either the condensor hotwell (100,000 gal.) or from the upper surge tanks (80,000 gal. combined) with makeup provided from the condensor hotwell by the hotwell pumps. For Cases 2 and 3, in which the hotwell transfer pumps are lost, it was assumed that the upper surge tank would have insufficient water to meet the Technical Specification requirement, requiring condensor hotwell availability to assure mission success.

4) NRC-Supplied Data - NRC supplied unreliability data for hardware, operator actions and preventive maintenance were assumed valid and directly applicable. These data are listed in Appendix B.

5) Coupled Manual Actions - Manual initiation of valves with identical function was considered coupled. Such valves were assumed to be both opened manually or both not opened. The case in which one valve was opened and the other valve was left closed was not considered.

6) Degrade Failure - Degraded failures were not considered; that is, components were assumed to operate properly or were treated as failed.

7) Turbine Driven Pump Flow Diversion - It was assumed that the full flow of the turbine-driven pump is diverted to the upper surge tank in the event that FDW-88 in the test recirculation line is inadvertently left open.

8) Interconnections with Other Units - The EFWS for each unit is interconnected at several locations with the EFW system in the other units. No credit was taken for emergency feedwater supplied by the other units; no penalty was taken for flow diverted to other units.

2.0 SYSTEM DESCRIPTION

2.1 Overall Configuration

A diagram of the Oconee Units Emergency Feedwater System (EFWS) is presented in Figure 1. The system configuration shown is the same for each of the three units. The EFWS is capable of feeding to either or both steam generators under automatic or manual initiation and control. The system consists of separate feed trains supplied by two motor-driven pumps and/or one turbine driven pump, and a combined suction source.

2.1.1 Suction

Two primary reserves of water are continuously available for EFWS use: The condensor hotwell, a 142,000 gallon tank normally containing more than 100,000 gallons; and the two compartments of the upper surge tank, UST "A" and UST "B", two 36,000 gallon tanks which normally contain 25,000 gallons each and which are cross-connected with normally-open motor-operated valves. Upon loss of main feedwater, the upper surge tanks may be automatically replenished from the condensor hotwell. The hotwell pumps are normally running. As shown in Figure 1, detection of low suction flow to the main feedwater pumps causes hotwell pump discharge to be recirculated to the upper surge tank dome.

The turbine-driven pump takes suction from the upper surge tank via an 8-inch line containing normally open valves. This pump can also be connected to the condensor hotwell by opening the normally-closed motor-operated valve C-391. The motor-driven pumps have a common suction header which is supplied from both the condensor hotwell and the upper surge tanks.

2.1.2 Pumps

Emergency feedwater is supplied to the feed trains by either the turbine-driven emergency feedwater pump, rates at 1080 GPM, and/or both motor-driven emergency feedwater pumps, each rated at 500 GPM.

Recirculation for the motor-driven pumps is provided by special check valves (FDW-370 and 380) which operate at low flow conditions to recirculate less than 10 GPM per pump to the upper surge tank. A recirculation flow of 100 GPM (nominal) is provided for the turbine-driven pump by valve FDW-89.

Of importance to system reliability is the 6-inch test line containing valve FDW-88. This line is used to perform periodic tests of the turbine-driven pump and is capable of diverting full flow of the turbine pump to the upper surge tanks.

Support system dependencies for all EFWS pumps are described in detail in Section 2.2.

2.1.3 Discharge Paths

Motor-driven pumps "A" and "B" normally supply feedwater to steam generators A and B, respectively. The turbine-driven pump feeds both generators through a common discharge header. Two paths are available for the flow of emergency feedwater to each steam generator from the discharge of the motor-driven pump feeding that generator.

The primary flow path to each generator contains an air-operated flow control valve, FDW-315 or FDW-316; flow to these valves is supplied via normally-open valves and check valves. A description of the operation of the flow control valves is provided in Section 2.4.1.2.

An alternate path for emergency feedwater flow to each steam generator is available using part of the normal startup feedwater flow path. This discharge path is available to the motor-driven pumps by opening normally-closed motor-operated valves FDW-374 or FDW-384. Flow through this alternate path is controlled by DC motor-operated valves FDW-38 or FDW-47.

Crosstie connections between the motor-driven pump discharges contain locked closed manual valves (FDW 313 and 314); these cross connections were considered unavailable for the purposes of this study.

2.1.4 Steam Supply to the EFWS Turbine

Steam is normally supplied to the EFWS turbine from either steam generator via normally open motor-operated valves MS-82 and MS-84. An alternate source of steam is the startup and auxiliary steam header via valve AS-38. This steam supply is interconnected with other Oconee Units.

Steam availability is controlled by a series of valves. The first in this series is the air-operated steam admission valve, MS-93. On turbine initiation, a solenoid valve is de-energized, venting the air supply to MS-93 and causing it to open. The next valve, MS-94, is a mechanically operated turbine overspeed stop valve. This valve trips automatically on turbine overspeed and must be reset locally. Turbine speed is controlled by the final valve, MS-95, the turbine governor. Exhaust from the turbine is vented directly to the atmosphere.

2.1.5 Valve Operation and Indication

Information on electric- and air-operated EFWS valves, including valves in associated support systems, is contained in Table 1. Table 1A addresses AC motor-operated valves; Table 1B addresses DC motor-operated valves; and Table 1C addresses air-operated valves.

2.2 Supporting Systems

Supporting systems are required for the EFWS motors, turbine, pumps, and air-operated valves.

2.2.1 Lube Oil

Figure 2 shows the support system dependence of the EFWS turbine and pump. As indicated in the figure, the turbine depends on auxiliary systems to circulate and cool oil for bearing lubrication. Primary oil circulation is provided by a turbine shaft-driven oil pump. However, until the turbine reaches a speed sufficient to drive this pump, the oil is circulated by a DC motor-operated auxiliary oil pump. The turbine governor valve is connected to the bearing oil supply and will not admit steam to the turbine until a sufficient bearing oil pressure exists.

Oil cooling is accomplished with an oil cooler through which water is circulated by an AC motor-operated pump. Because of the size of the oil reservoir, it is estimated that the turbine can be operated without adverse consequences for up to 45 minutes in the absence of cooling water flow to the oil cooler.

There are no external lube oil dependencies for the motor-driven pumps and motors.

2.2.2 Cooling Water

Cooling water must be supplied to the cooling jackets of both the turbine-driven and motor-driven EFWS pumps.

Cooling for the turbine-driven pump jacket is shown in Figure 2. Cooling water is supplied from either the Low Pressure Service Water (LPSW) pumps or by gravity flow from the High Pressure Service Water (HPSW) elevated tank. In either case, AC operated valve LPSW-137 (or an associated manual valve) must be opened to permit cooling water flow. It is estimated that the pump can operate only 12 to 15 minutes without cooling water.

Cooling for the motor-driven pump jackets is shown in Figure 3. Cooling water for these pumps is also supplied by the LPSW system. This water flows through normally-open air-operated valves downstream of the pump jackets. If these valves are inadvertently closed, flow would be assured by valve open signals (to de-energized colenoid valves) which accompany motor-driven pump initiation.

The Low Pressure Service Water (LPSW) pumps also supply water to the turbine-driven pump lube oil cooler. One of these pumps is kept running at all times. (NOTE: The only significant difference between the Oconee units involves the number of LPSW pumps: Units 1 and 2 share 3 LPSW pumps; Unit 3 has two dedicated pumps. This difference did not affect the reliability of the EFWS.)

2.2.3 Air

Air supply to air-operated valves within the EFWS and associated support systems is obtained from a common air supply system. In the event of loss of offsite power, this air supply is expected to last for only a few minutes unless manual action is taken to load the air compressors onto emergency AC power. Flow control valves FDW-315 and FDW-316 may be manually valved into a backup nitrogen supply.

2.3 Power Sources

The distribution of AC power (not including battery-backed AC) to components within the EFWS and associated support systems is shown in Figure 4.

During normal operation all affected components received their power from two 4160 VAC busses which are fed from the switchyard.

For Case 2, loss of offsite power, the Keowee Hydro Station generators will be automatically started and will provide power to the 4160 VAC busses. Either of the Keowee generators is capable of carrying the load on both busses. As shown in Figure 4, there are redundant paths between the Keowee Hydro Station and the Oconee Units.

The 4160 VAC busses directly feed the Low Pressure Service Water pump motors, the two EFWS pump motors and the hotwell pump motors. The busses also feed nine 600 VAC load centers; however, four of these load centers are automatically shed during a Case 2 loss of offsite power. These four centers are "3X1", "3X2", "3X3", and "3X4". The hotwell pump motors are also shed during Case 2.

The 600 VAC motor control centers on each load center have the capability to automatically transfer to an alternate (emergency) load center on loss of the normal load center power. However, as shown in Figure 4, this feature has no effect on the EFWS components which are shed because the alternate load centers for these loads are also shed. Affected components include: The EFWS turbine cooling water valve LPSW-137; normally-open suction valves C-152, -153, -156, and -158; normally-closed suction valves C-160 and -391; steam valves MS-82, -84, -17, -26, -24 and -23; and all three hotwell pump motors.

For Case 3, loss of all AC power, none of the components in Figure 4 will be operable. However, the components shown in Figure 5 and all DC operated and 115 VAC inverter-backed components will remain powered.

2.4 Instrumentation and Control

2.4.1 Initiation and Control

A simplified logic diagram showing the means of EFWS initiation and control is provided in Figure 6. The diagram is divided into three sections corresponding to motor-driven pump (MDEFWP) initiation, flow control valve logic and turbine-driven pump (TDEFWP) initiation respectively.

2.4.1.1 Motor-Driven Pump Initiation

The Motor-Driven Emergency Feedwater Pump (MDEFWP) for each train is initiated by low Main Feedwater (MFW) discharge pressure from both MFW pumps or pump trip signals from both pumps. The motor controller for each EFWS motor-driven pump is connected to sets of normally closed contacts for each of the MFW pumps. If the initiating conditions exist, these contacts open, de-energizing a 125 VDC relay causing the EFWS motor to run if its control switch is in automatic.

The same initiating signal opens a valve to supply cooling water to the cooling jacket and a motor-operated discharge valve. However, both of these valves are normally kept open, so that the initiation signal to these valves should be unnecessary.

2.4.1.2 Flow Control Valves

The source of control for the flow control valves FDW-315 and FDW-316 is determined by a selector switch with positions for manual or automatic control. In the manual control mode, the valves are controlled from manual air pressure controllers (which normally send a 0% open signal to the valves). In the automatic control mode, control of the valves remains in manual unless a signal for EFWS initiation is received. In this event, valve control is transferred from the manual controller to automatic steam generator level control. As shown in Figure 6, during automatic level control, either of two control trains (called train "A" and "B") may provide level control for each steam generator. Steam generator level control is provided by level control instrumentation and analog circuits which are on battery-backed power and which are separate and independent from the Integrated Control System (ICS).

2.4.1.3 Turbine-Driven Pump Initiation

The same initiating conditions that start the EFWS motors also initiate the EFWS pump turbine using redundant sets of contacts. The contacts cause a battery-backed AC solenoid valve to de-energize opening the steam admission valve MS-93. Limit switches on MS-93 change state, allowing the auxiliary lube oil pump to start; when sufficient oil pressure is attained, the turbine governor valve will open starting the turbine.

As shown in Figure 6, other functional relationships include an oil pressure switch which permits starting of the lube oil cooling water motor and the steam admission valve limit switch which permits valve LPSW-137 to open allowing cooling water to flow through the pump cooling jacket.

Initiation of automatic level control for the flow control valves is not duplicated for the turbine initiation logic. In Case 3, when the EFWS motors are unavailable, initiation of automatic control for the flow control valves still depends on the DC powered portion of the logic associated with those motors.

2.4.2 Instrumentation

Battery-backed instrumentation is available throughout the EFWS and associated support systems. This instrumentation includes:

- EFWS Flow - measured for both discharge paths for both feed trains.
- Discharge Pressures - for all EFW pumps.
- Cooling Water Flow - to the motor-driven pumps cooling jackets.

2.5 Operator Actions

In the absence of hardware failures and with proper system configuration, the following operator actions are required:

Case 1

No operator actions are required to assure mission success.

Case 2

Flow from all three EFWS pumps will be initiated but operator action is required within 15 minutes to open valve LPSW-137 to avoid damage to the turbine-driven pump from lack of cooling. This action would involve manual opening of the valve or manual loading of load center "3X1" onto a 4160 VAC bus. Also, for the upper surge tanks to be replenished from the condensor hotwell, manual action would be needed to load a hotwell pump onto a 4160 VAC bus.

If use of the flow control valves is to be retained, it will be necessary for the operator to valve the nitrogen supply to the valves or re-energize the load centers supplying power to the air compressor.

Case 3

Flow from the turbine-driven pump will be initiated, but again manual opening of valve LPSW-137 is required within 15 minutes in order to continue EFWS flow. The hotwell pumps will be unavailable for replenishing the upper surge tanks. Because the upper surge tanks contain less than 72,000 gallons, manual opening of valve C-391 would be required to take suction from the condensor hotwell. Again manual action to valve nitrogen to the flow control valves would be required to retain control of these valves.

It is assumed that the EFWS turbine will not operate indefinitely because of the absence of lube oil cooling.

2.6 Testing

Full flow tests for the turbine-driven pump are performed monthly using the 6-inch line to recirculate pump discharge to the upper surge tank. During this test, operators are stationed at valves FDW-309 and 310 (closed) and valve FDW-88 (open). In the event emergency feedwater is required during performance of this test, these operators can rapidly return the system to a functional configuration.

Monthly tests of the motor-driven pumps are performed using the mini-flow recirculation line. This test indicates the pump(s) capability to start and reach the desired discharge pressure.

2.7 Technical Specification Limitations

Technical Specifications currently being prepared will permit one EFWS pump to be out of service for up to 72 hours. After this time limit has expired, the unit affected must be brought to hot shutdown within 12 hours.

Existing Technical Specifications also require that a total of 72,000 gallons of water be reserved for EFWS use. This water must be available for the combination of EFWS water reserves including the surge tanks, condensor hotwell.

Existing Technical Specifications permit one Keowee generator to be out of service for 72 hours providing that periodic testing shows the other generator to be operable. For planned outages, both Keowee generators may be out of service for up to 72 hours providing that off-site grid availability has been considered and the offsite dedicated gas-turbine generator (Lee Unit) is available. For unplanned outages, both Keowee generators may be out of service for 24 hours providing the off-site gas turbine is available.

3.0 Reliability Evaluation

3.1 Fault Tree Technique

The Oconee EFWS reliability was evaluated by constructing and analyzing a fault tree. The fault tree developed during this study is contained in Appendix A. The top level event in this tree is failure to achieve mission success; from this point, the tree branches downward to a level of detail corresponding to NRC-supplied data. This level is generally indicated by basic event circles.

As indicated on page A-1, system failure can result from preventive maintenance related failures or component failures. Component failures consist of failure of the turbine-driven pump train coupled with a failure of one of the motor-driven pump trains. The combinations of failures which can defect the pump trains are addressed in the following pages of the appendix.

The techniques used in fault-tree construction and the symbols shown in Appendix A are consistent with those used in WASH-1400 (Reference 3). Following completion of the tree, hand calculations were performed to obtain system unavailability for 5, 15 and 30 minutes for each of the three event scenario cases.

3.2 Comparative Reliability Results

The results of the analysis are presented in Figure 7. Indicated in this figure are the system reliability results for each of the three cases and for each time 5, 15 and 30 minutes. The basic format for this figure, including the characterization of Low, Medium, and High reliability, was adopted from information presented by the NRC in Reference 1. Because the NRC-supplied input data were often unverified estimates of component and human reliability, absolute values of calculated system reliability must be de-emphasized; results have significance only when used on a relative basis for purposes of comparison. Accordingly, the intent of Figure 7 is to show the relative reliability standing of the Oconee EFWS for each of the three cases and also to compare these results to the NRC results for Westinghouse plants. The Westinghouse results and numerical values permitting construction of Figure 7 were all obtained

from Reference 1. It should be noted that there is a scale change for the Case 3 results; reliability results for Case 3 cannot be cross-compared with Cases 1 and 2.

As shown in Figure 7, relative to Westinghouse, Oconee has low to medium reliability for Case 1 and low reliability for Cases 2 and 3. The underlying causes for these reliability results are described below.

3.3 Dominant Failure Contributors

This analysis indicated the existence of several significant AC dependencies within the EFWS. In general, these dependencies were time dependent; that is, while they may not defeat emergency feedwater initiation, they do restrict the duration of operation of major EFWS components. Examples of these dependencies include the availability of cooling water to the EFWS turbine lube oil cooler, bearing cooling water to the turbine-driven pump, and capacities of the suction water sources.

Under guidance from the NRC, this study accounted for these time-related dependencies by factoring them into the system reliabilities calculated for 5, 15 and 30 minutes. Typically, this was done by assuming instantaneous unavailability of affected components, unless the underlying causes could be corrected within the 5, 15 and 30 minutes available for operator action. Additionally, for turbine-related dependencies, it was assumed that the turbine was initiated at time zero, so that maximum emphasis is placed on correction of the time-limiting failures.

It must be emphasized that the methods used for accounting for these AC dependencies results in a very conservative analysis. The analysis does not take credit for successful EFWS operation until failure, nor does it take into account the very strong probability that AC power will be restored prior to failure, nor does it take credit for measures which could be used to extend the time until failure (e.g., cycling the turbine on and off).

3.3.1 Case 1 - LMFW

Dominant failure contributors for Case 1 for the EFWS turbine and turbine-driven pump include:

1. Insufficient lube oil circulation or lube oil cooling for the turbine caused by pump failures (auxiliary oil pump or cooling water pump).
2. Insufficient cooling water to the turbine-driven pump bearings caused in part by valve LPSW-137 not opening when required.
3. Loss of suction water caused by a failure to replenish the upper surge tanks from the condenser hotwell, or failure to open valve C-391 to the condenser hotwell.
4. Flow diversion via the test recirculation line in the event that valve FDW-88 has been inadvertently left open following test or maintenance or was mistakenly opened during operations on adjacent valves.

Other important failure contributors for Case 1 include motor-driven pump failures (mechanical and control circuits) and preventive maintenance-related failures.

3.3.2 Case 2 - LMFW/LOOP

Turbine and turbine-driven pump failures are the same as in Case 1. However, the probabilities of some failures are significantly worsened by the loss of offsite power. In particular, LPSW-137 is load shed during a Case 2 incident; coupled with loss of valve position indication and a lack of flow indication, this circumstance results in a high probability of failure for the operator to recognize and correct the lack of cooling water to the turbine-driven pump bearings. This action requires local opening of the valve.

Another failure contributor for the turbine-driven pump which is made worse in Case 2 is loss of suction for the pump. Because the condenser hotwell pumps are unavailable for replenishing the surge tanks, it is probable that the condensor hotwell suction will ultimately have to be made available to the turbine pump. This, however, requires

the opening of valve C-391 which has also been load shed, requiring an operator to open the valve locally.

Another potentially significant failure for Case 2 is inadequate steam supply to the turbine caused by steam relief valve MS-92 sticking open. This may occur as MS-92 relieves high pressure caused by pressure control valves MS-87 and MS-129 failing open on loss of plant air.

The turbine-related failure contributors described above tend to force overall system reliability to that obtainable by reliance on both motor-driven pump trains. This result is reflected in the reliability for Case 2 shown in Figure 7.

Motor-driven pump and preventive maintenance-related failures are the same as for Case 1.

3.3.3 Case 3 - LMFW/LOAC

Because of assumptions regarding the incorporation of time dependent failure mechanisms, the reliability analysis for Case 3 indicates that the EFWS will be unavailable for each of the times 5, 15 and 30 minutes.

This result stems from the ultimate loss of the turbine because of a lack of cooling water to the lube oil cooler. No manual actions are available to mitigate this event.

REFERENCES

1. "Auxiliary Feedwater Reliability Study," an NRC staff presentation to the ACRS at the ACRS Meeting of July 26, 1979, 1717 "H" Street, Room 1046, Washington, D.C.

2. "Evaluation of Transient Behavior and Small Reactor Coolant System Breaks in the 177 Fuel Assembly Plant," May 7, 1979.

3. WASH-1400 (NUREG-75/014), "Reactor Safety Study (Appendix II)", USNRC, October 1975.

TABLE I - VALVE INFORMATION

(PART A - AC MOTOR OPERATED VALVES)

VALVE NUMBER	NORMAL POSITION	VALVE OPERATOR POWER SOURCE (VOLT/MC)	VALVE OPERATOR SHED ON LOSS OF OFFSITE POWER
C-124	C	208/3XGA	Yes
C-153	O	208/3XGA	Yes
C-152	O	208/3XGA	Yes
C-158	O	208/3XGA	Yes
C-156	O	208/3XGA	Yes
C-160	C	208/3XC	Yes
C-391	C	208/3XC	Yes
FDW-368	O	600/3XJ	No
FDW-369	O	600/3XI	No
FDW-372	O	600/3XI	No
FDW-382	O	600/3XJ	No
FDW-374	C	600/3XI	No
FDW-384	C	600/3XJ	No
MS-17	O	208/3XGB	Yes
MS-24	O	208/3XGB	Yes
MS-26	O	208/3XGB	Yes
MS-33	O	208/3XGB	Yes
MS-82	O	208/3XA	Yes
MS-84	O	208/3XA	Yes
LPSW-137	C	208/3XA	Yes
(PART B - DC MOTOR OPERATED VALVES)			
FDW-38	C	250/3DP	
FDW-47	C	250/3DP	

NOTES:

(1) All valves are controllable and position indicated in the control room.

(2) All valves fail "As-Is" on Loss of Power.

(3) Power for position indication and control for all valves is derived from the power source for the valve operator.

(4) Legend:
C = Closed, O = Open
T = Throttled,
SV = Solenoid Valve,
PCV = Pressure Control Valve,
LS = Limit Switch

TABLE I - (CONT'D)
(PART C - AIR OPERATED VALVES)

VALVE NUMBER	NORMAL POSITION	EFWS ACTUATION POSITION	CONTROL SOURCE & POWER	SOURCE & POWER OF CONTROL ROOM POSITION INDICATION	FAIL POSITION ON LOSS OF CONTROL SIGNAL	FAIL POSITION ON LOSS OF AIR
FDW-315	C	T	SV-200/DC	Solenoid	T	O
FDW-316	C	T	SV-201/DC	Solenoid	T	O
FDW-35	O	O	PCV	LS/AC	NA	As Is
FDW-44	O	O	PCV	LS/AC	NA	As Is
MS-93	C	O	SV-74/AC	LS/DC	O	O
MS-87	T	T	PCV	----	NA	O
MS-22	C	O	SV-179/AC	LS/AC	C	C
MS-19	C	O	SV-178/AC	LS/AC	C	C
MS-31	C	O	SV-181/AC	LS/AC	C	C
MS-28	C	O	SV-180/AC	LS/AC	C	C
MS-126	O	O	PCV	----	NA	C
HPSW-191	O	O	PCV	----	NA	O
LPSW-516	O	O	SV-202/AC	----	O	O
LPSW-525	O	O	SV-203/AC	----	O	O
C-128	C	O	FCV	----	C	C
MS-129	O	O	PCV	----	NA	O

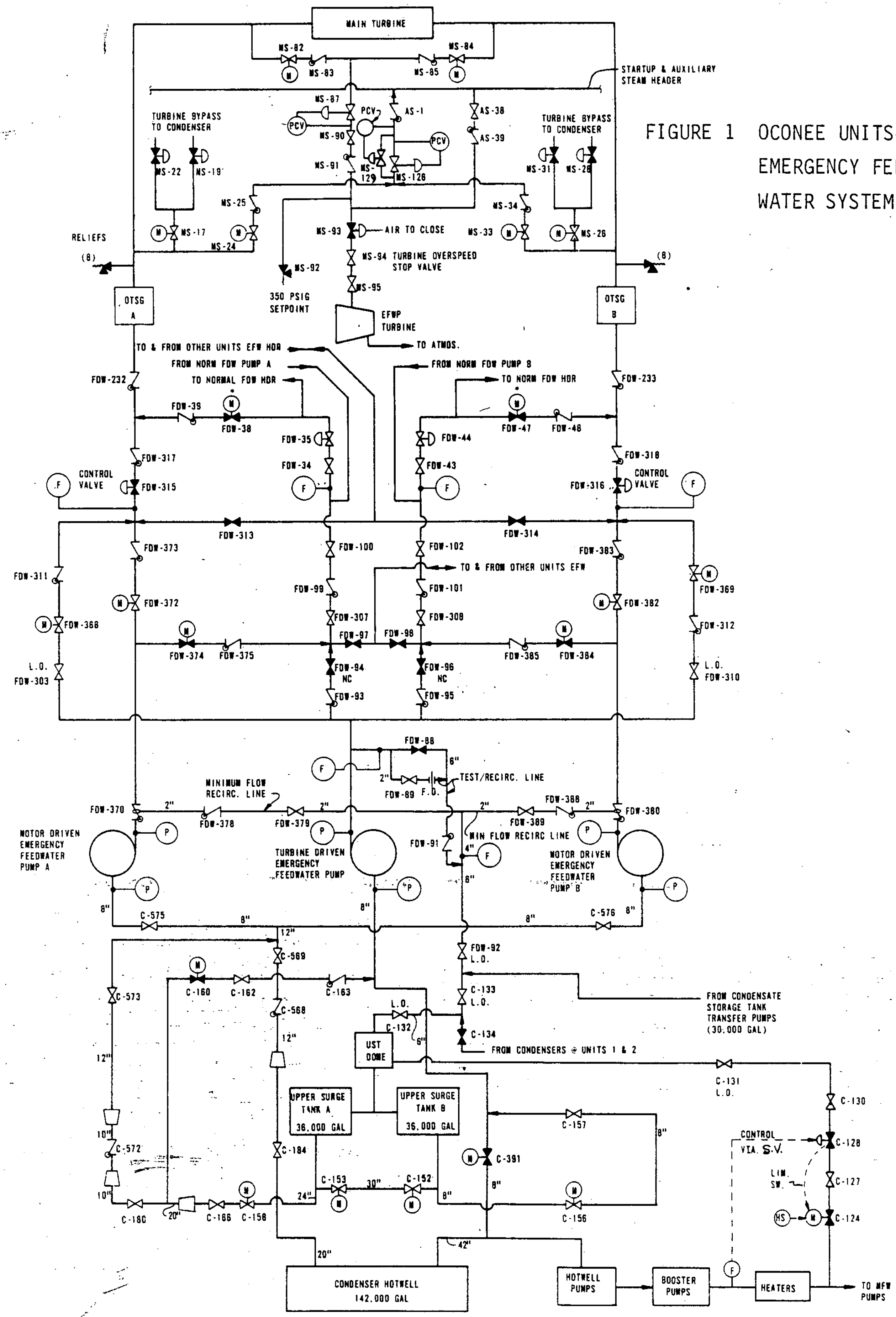


FIGURE 1 OCONEE UNITS-EMERGENCY FEEDWATER SYSTEM

Figure 2 OCONEE UNIT-EFW TURBINE AND PUMP SUPPORT SYSTEMS

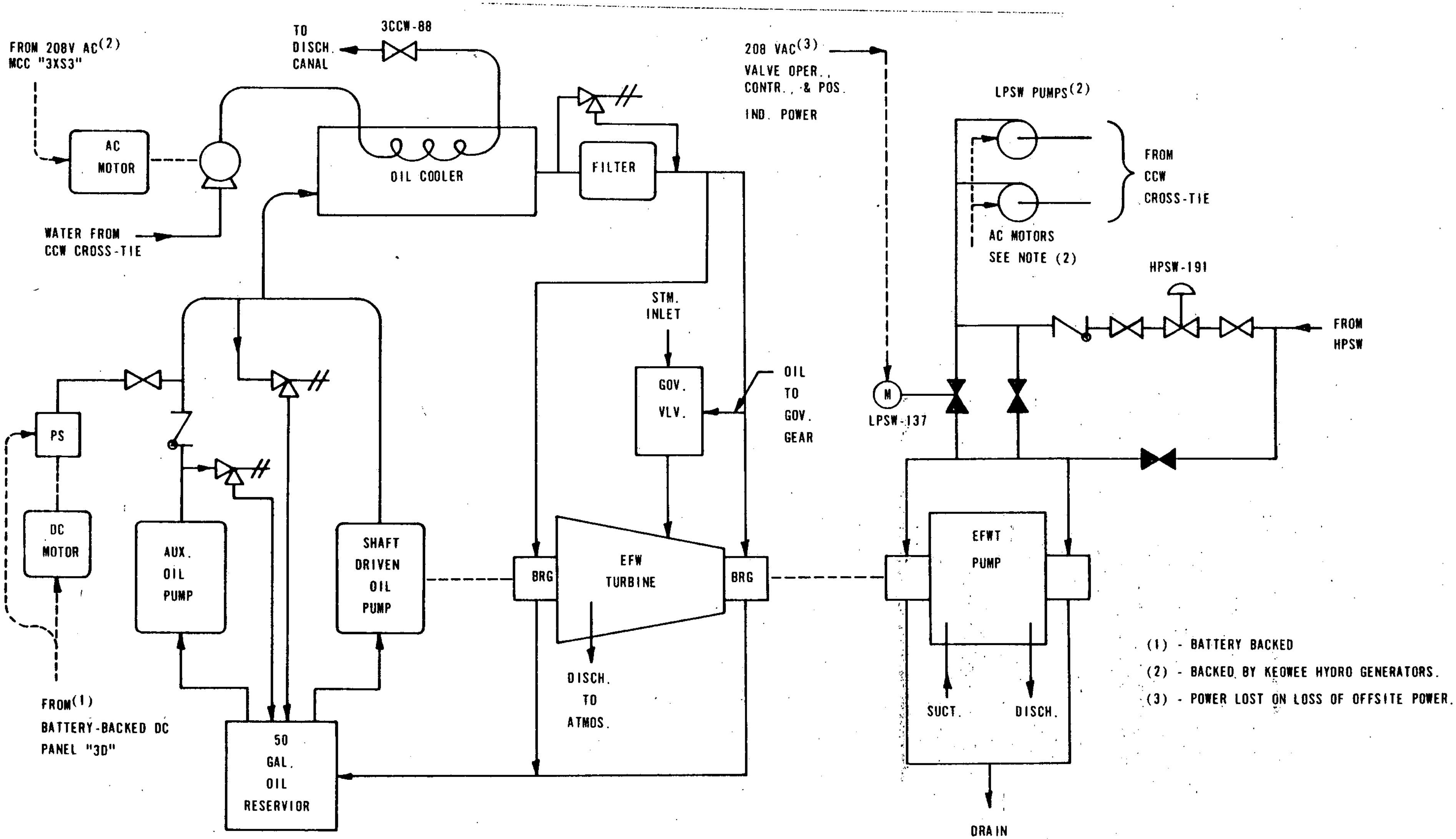
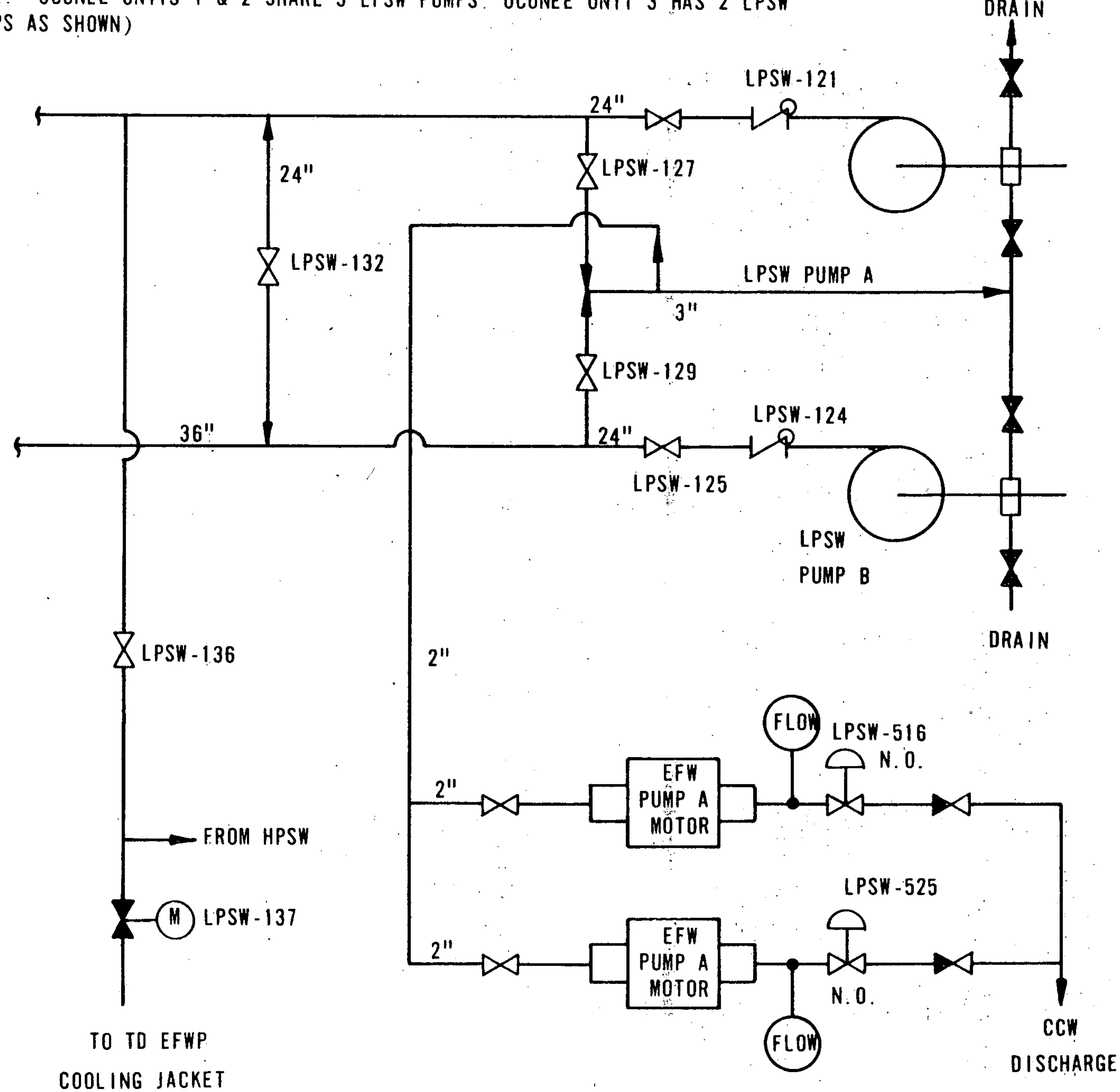


Figure 3 OCONEE UNITS-MOTOR-DRIVEN EMERGENCY FEEDWATER PUMP MOTOR COOLING WATER (NOTE: OCONEE UNITS 1 & 2 SHARE 3 LPSW PUMPS. OCONEE UNIT 3 HAS 2 LPSW PUMPS AS SHOWN)



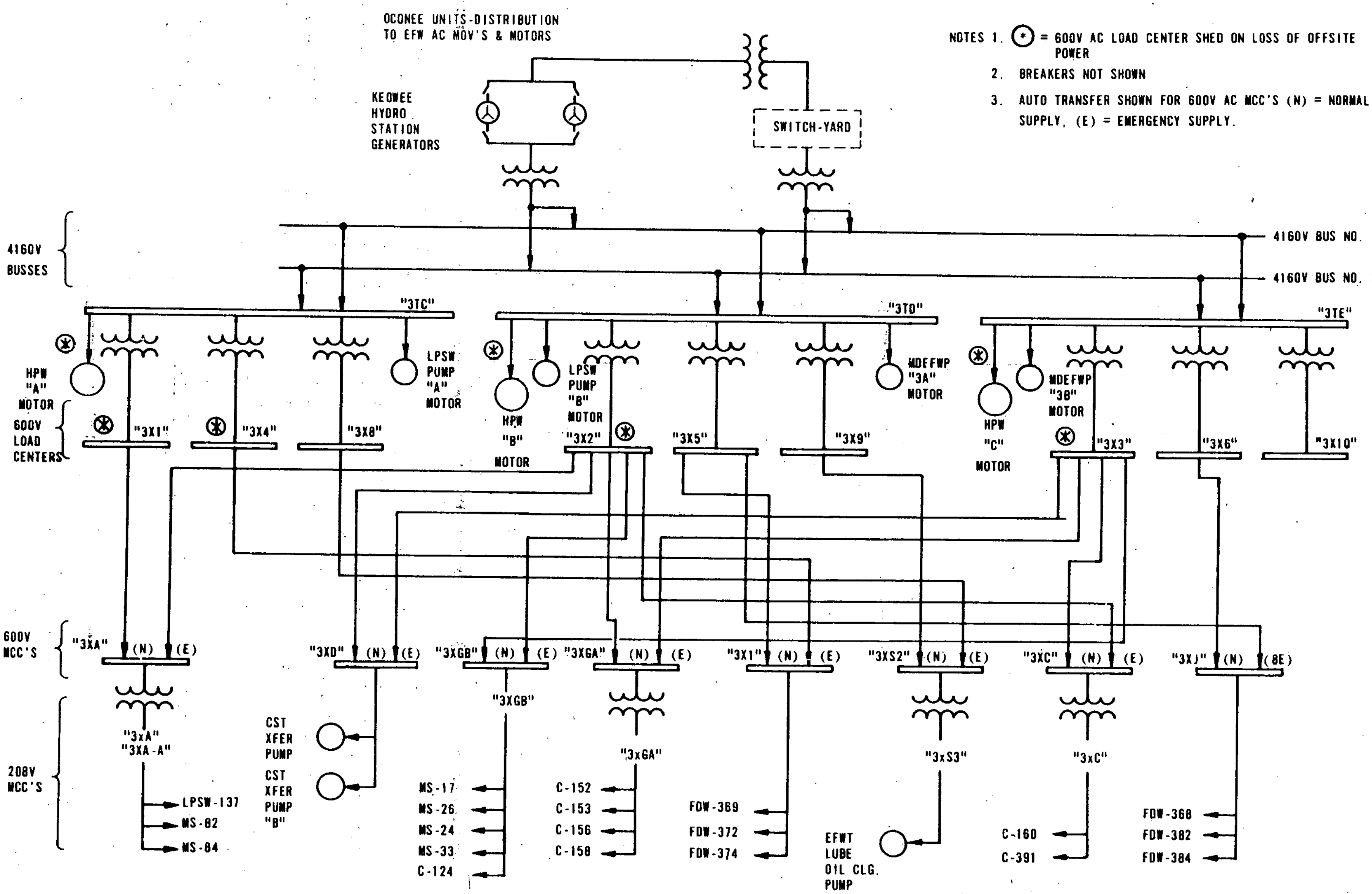


FIGURE 4 OCONEE UNITS-DISTRIBUTION TO EFW AC MOV'S & MOTORS

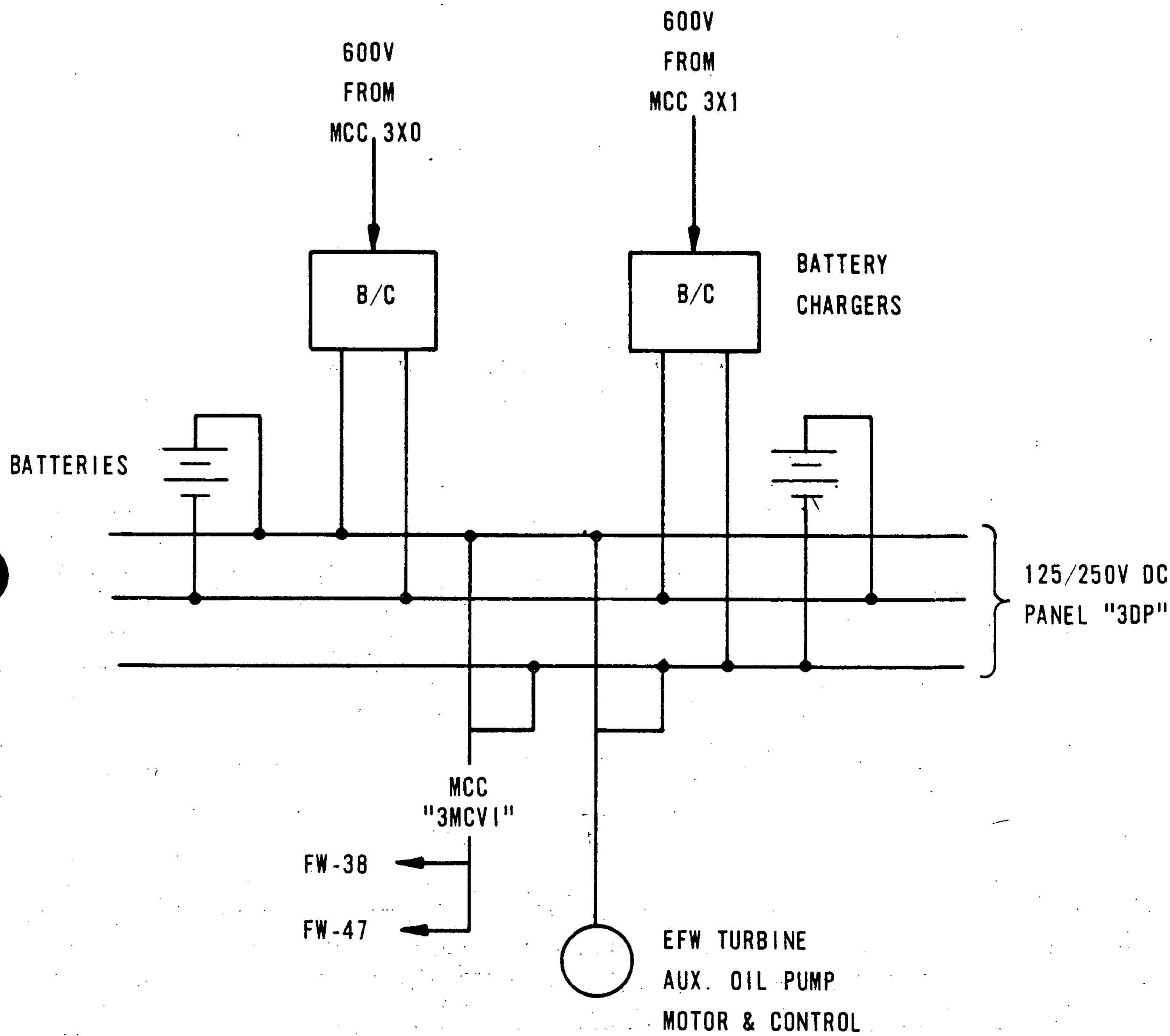
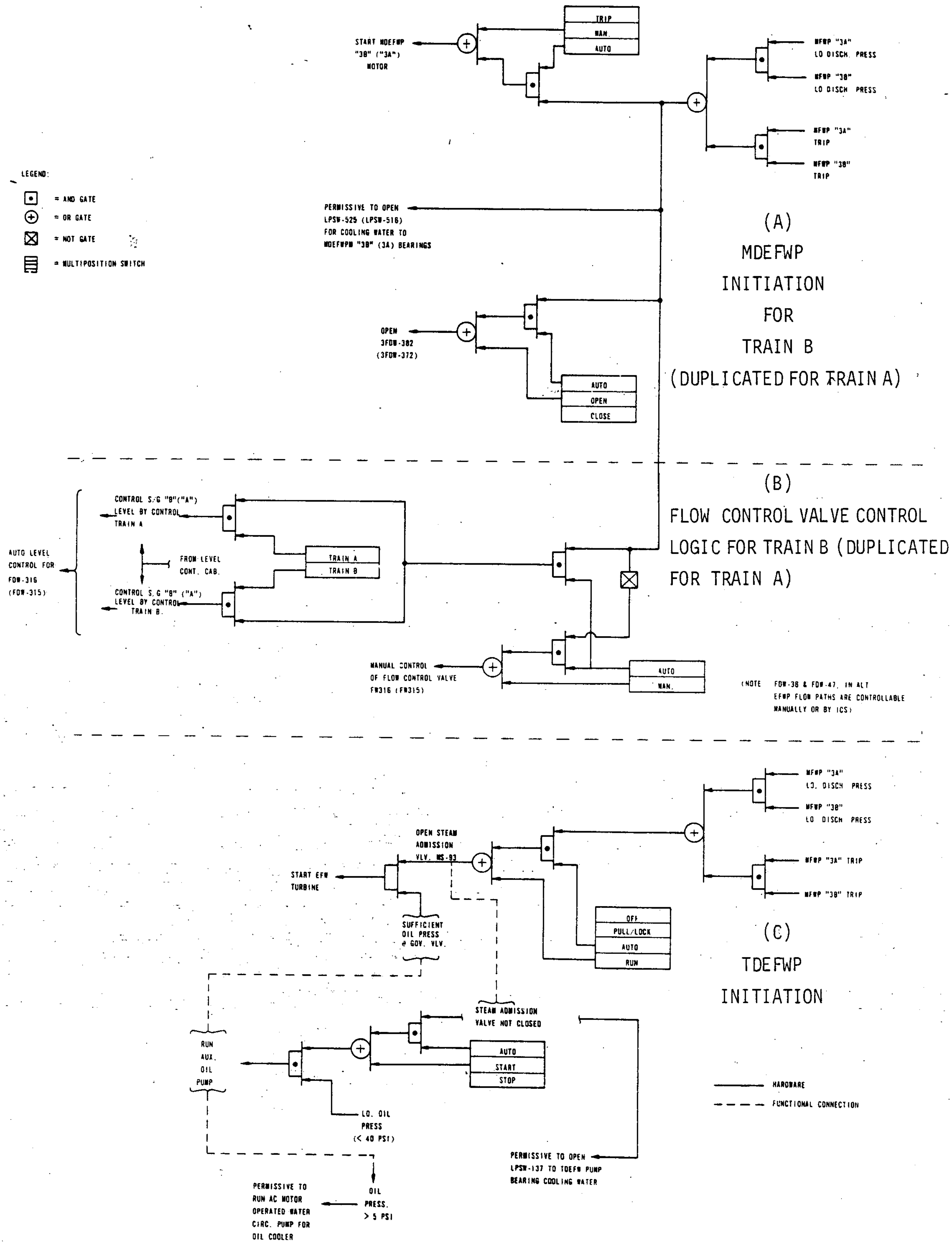


Figure 5 OCONEE UNITS DC POWER FOR EFWS COMPONENTS (EXCLUDING INSTRUMENTATION, CONTROLS & VALVE POSITION INDICATORS)

FIGURE 6 OCONEE UNITS EFWS INITIATION & CONTROL LOGIC-SIMPLIFIED



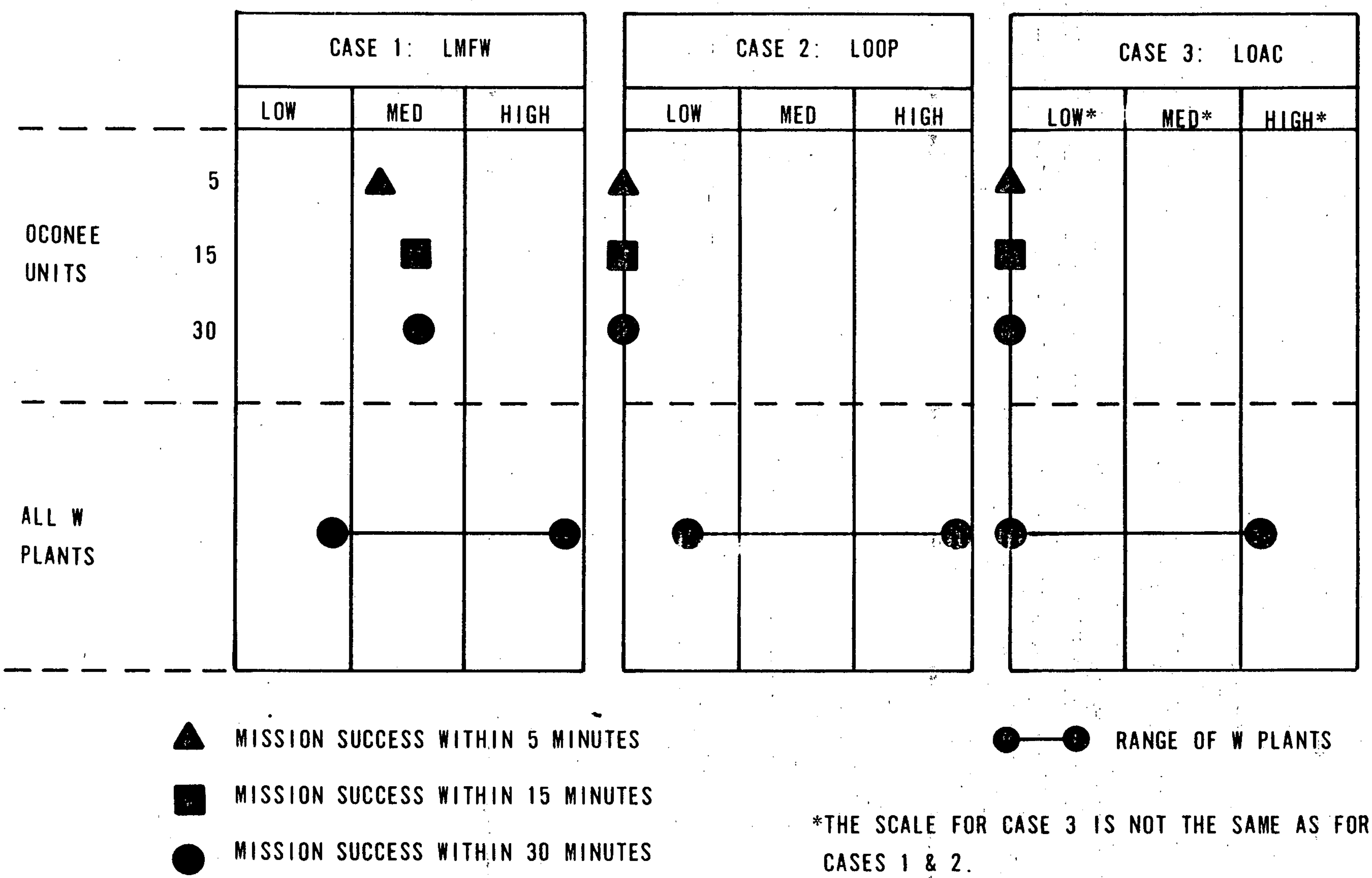
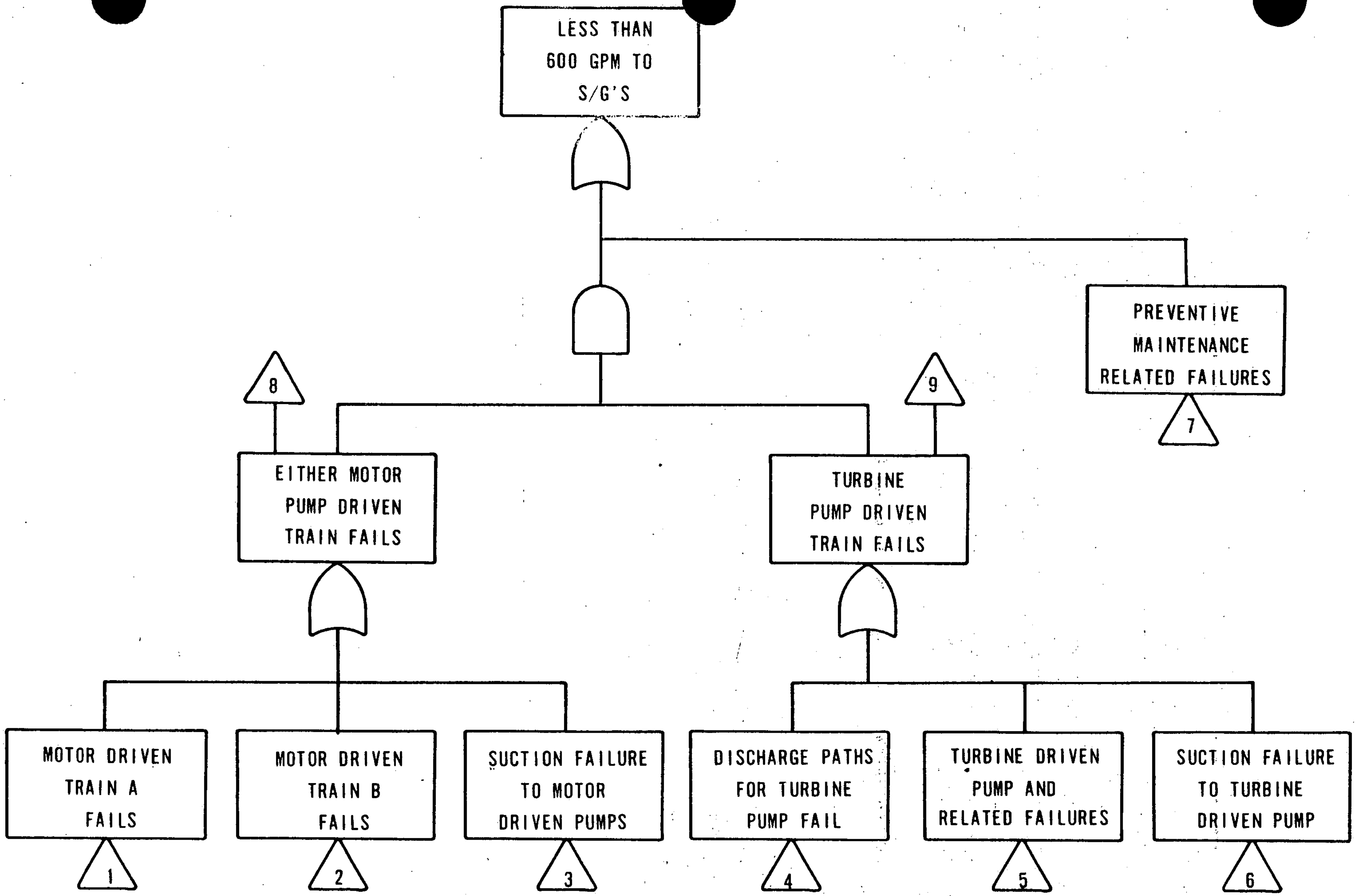
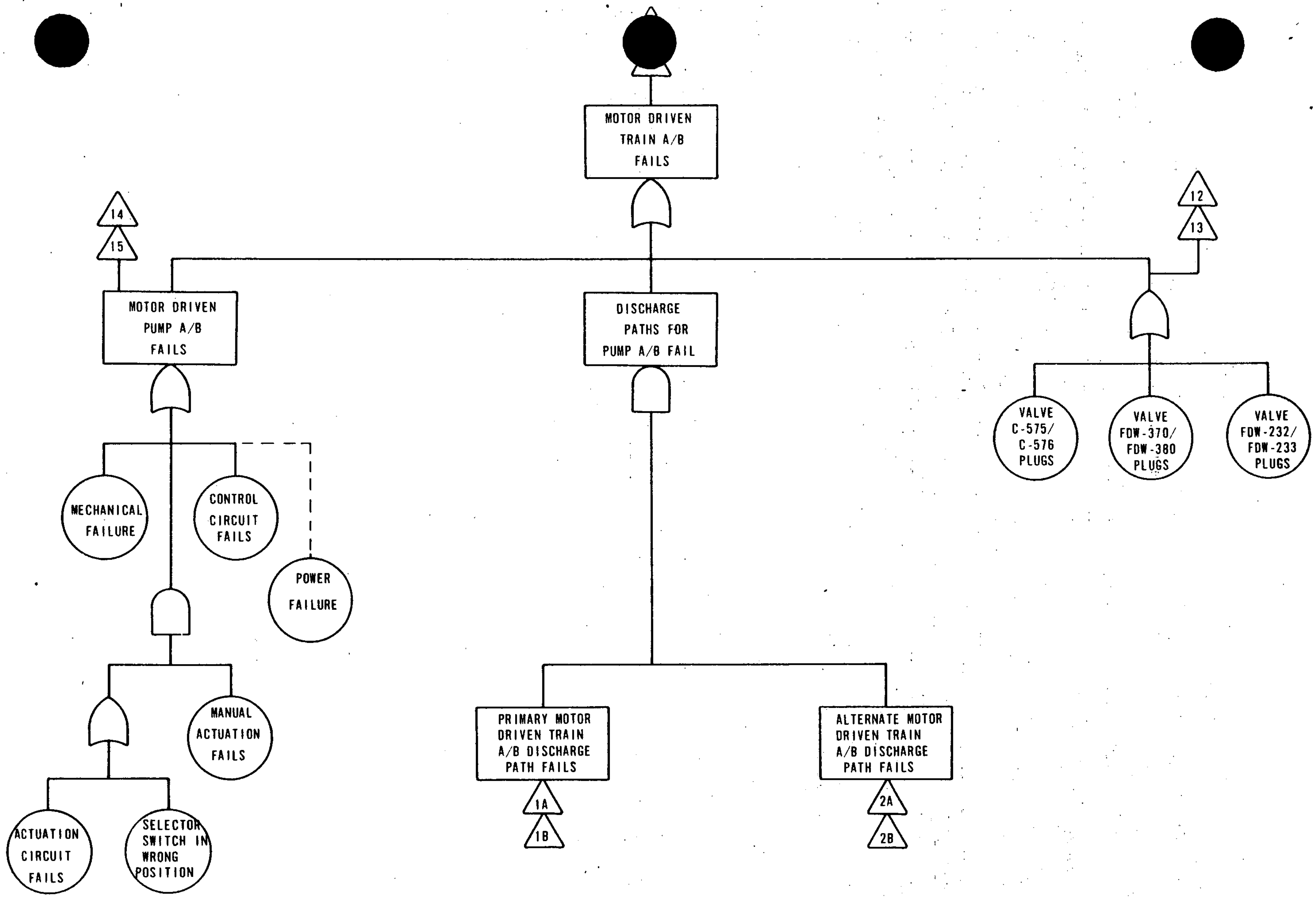


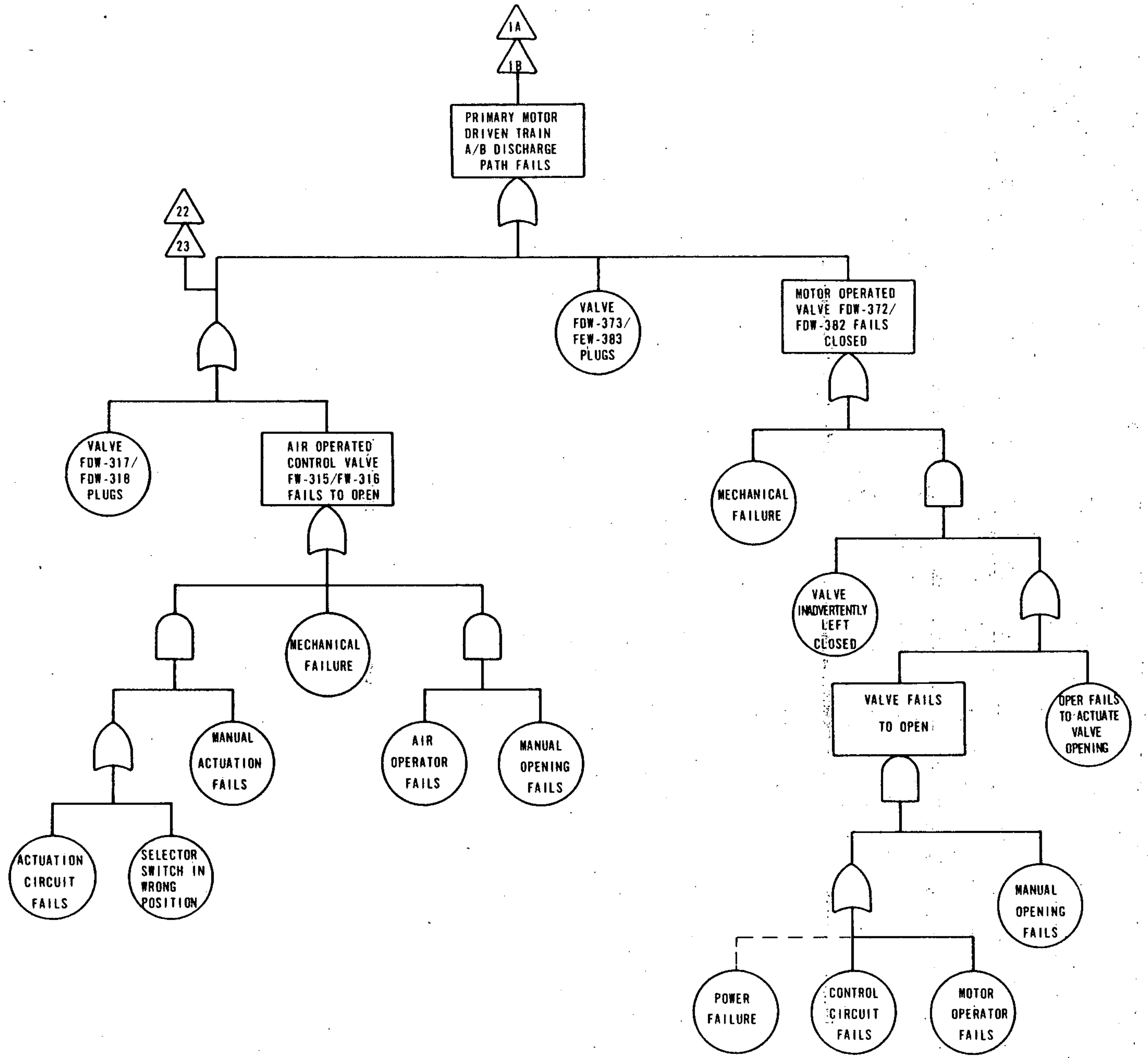
Fig. 7

COMPARISON OF OCONEE UNITS EFWS RELIABILITY WITH NRC RESULTS FOR W PLANTS

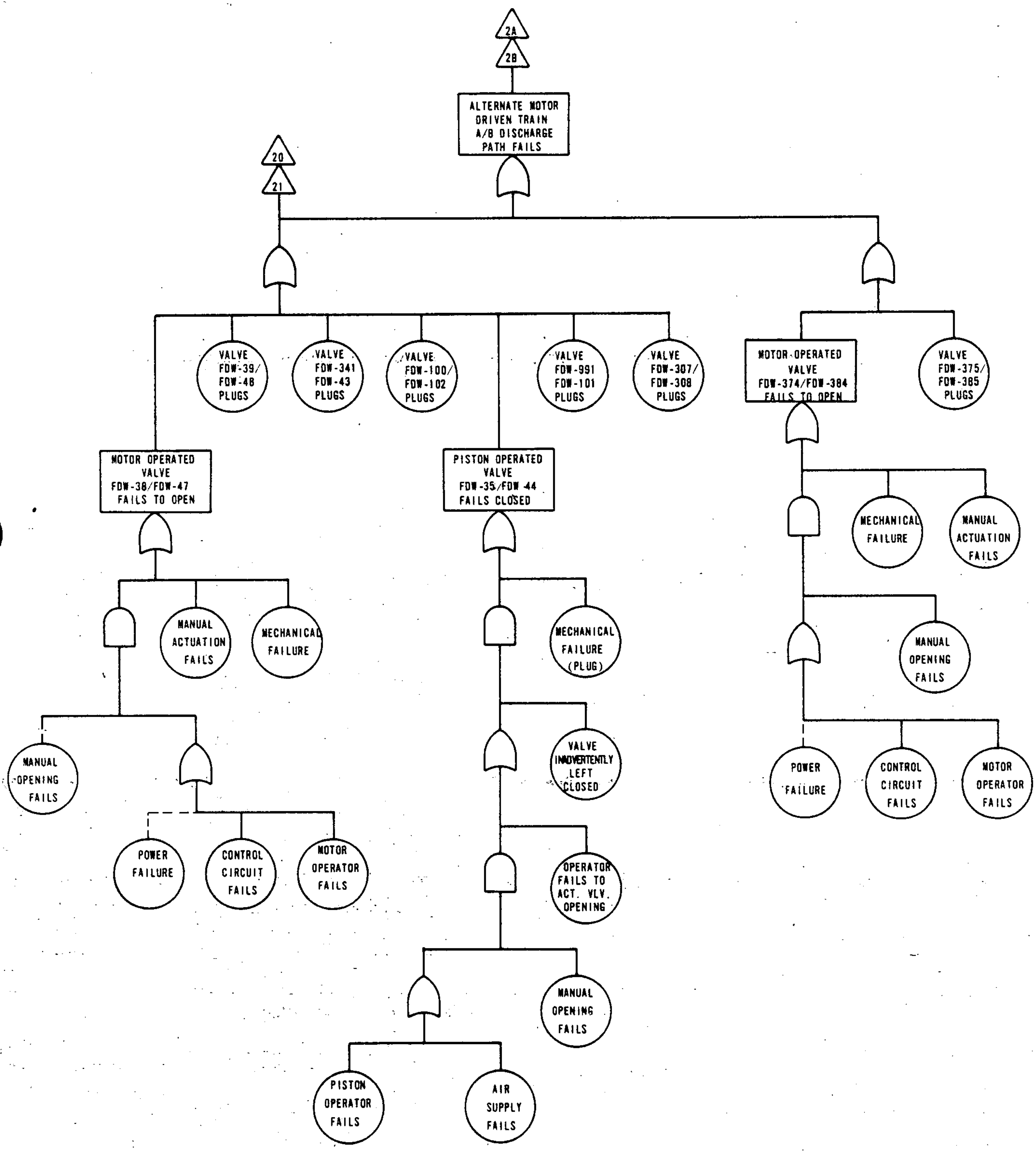


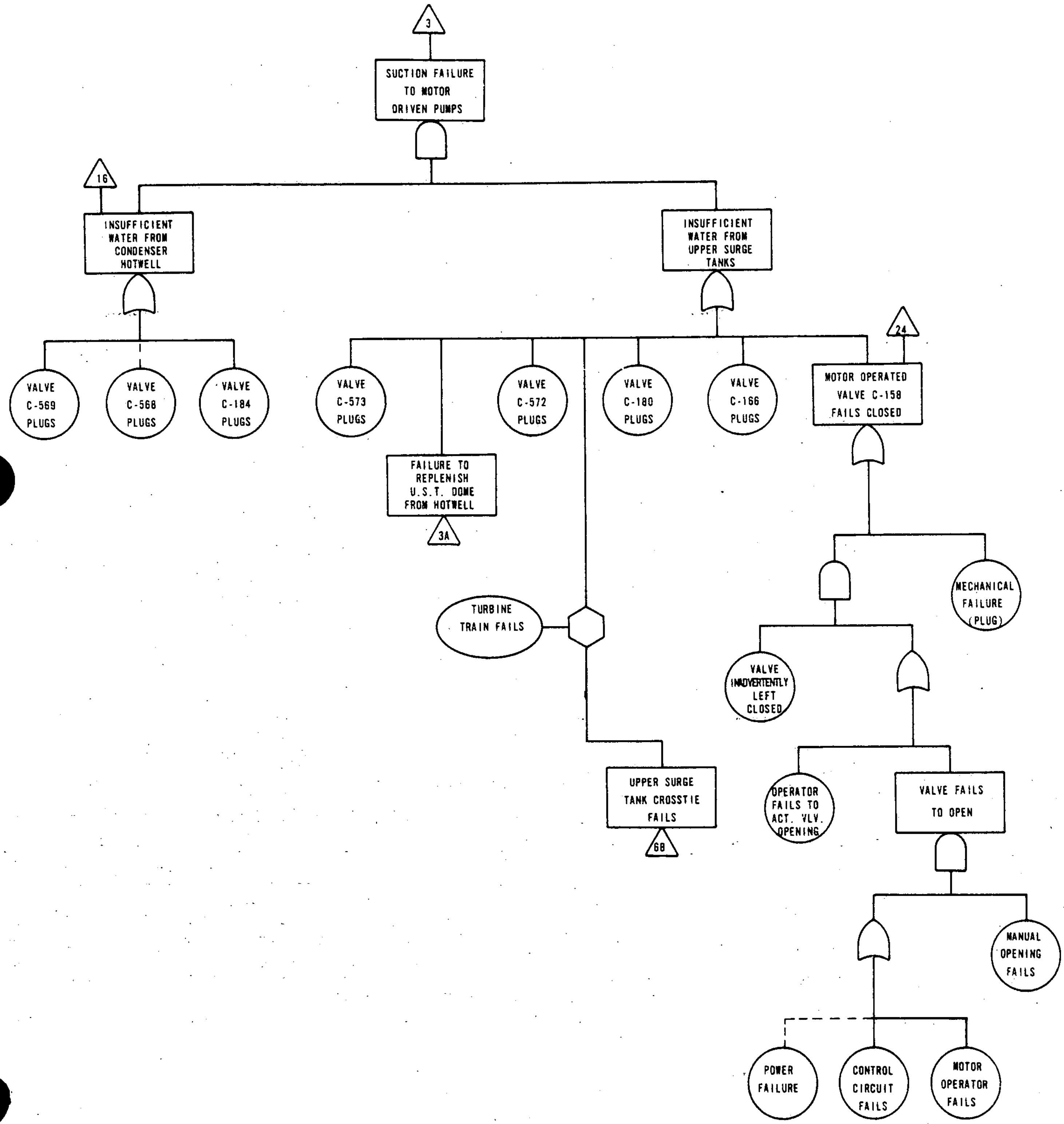
APPENDIX A-FAULT TREE


MOTOR DRIVEN TRAIN A/B FAILS
14
15
MOTOR DRIVEN PUMP A/B FAILS
DISCHARGE PATHS FOR PUMP A/B FAIL
12
13
VALVE C-575/ C-576 PLUGS
VALVE FDW-370/ FDW-380 PLUGS
VALVE FDW-232/ FDW-233 PLUGS
MECHANICAL FAILURE
CONTROL CIRCUIT FAILS
POWER FAILURE
MANUAL ACTUATION FAILS
ACTUATION CIRCUIT FAILS
SELECTOR SWITCH IN WRONG POSITION
PRIMARY MOTOR DRIVEN TRAIN A/B DISCHARGE PATH FAILS
1A
1B
ALTERNATE MOTOR DRIVEN TRAIN A/B DISCHARGE PATH FAILS
2A
2B

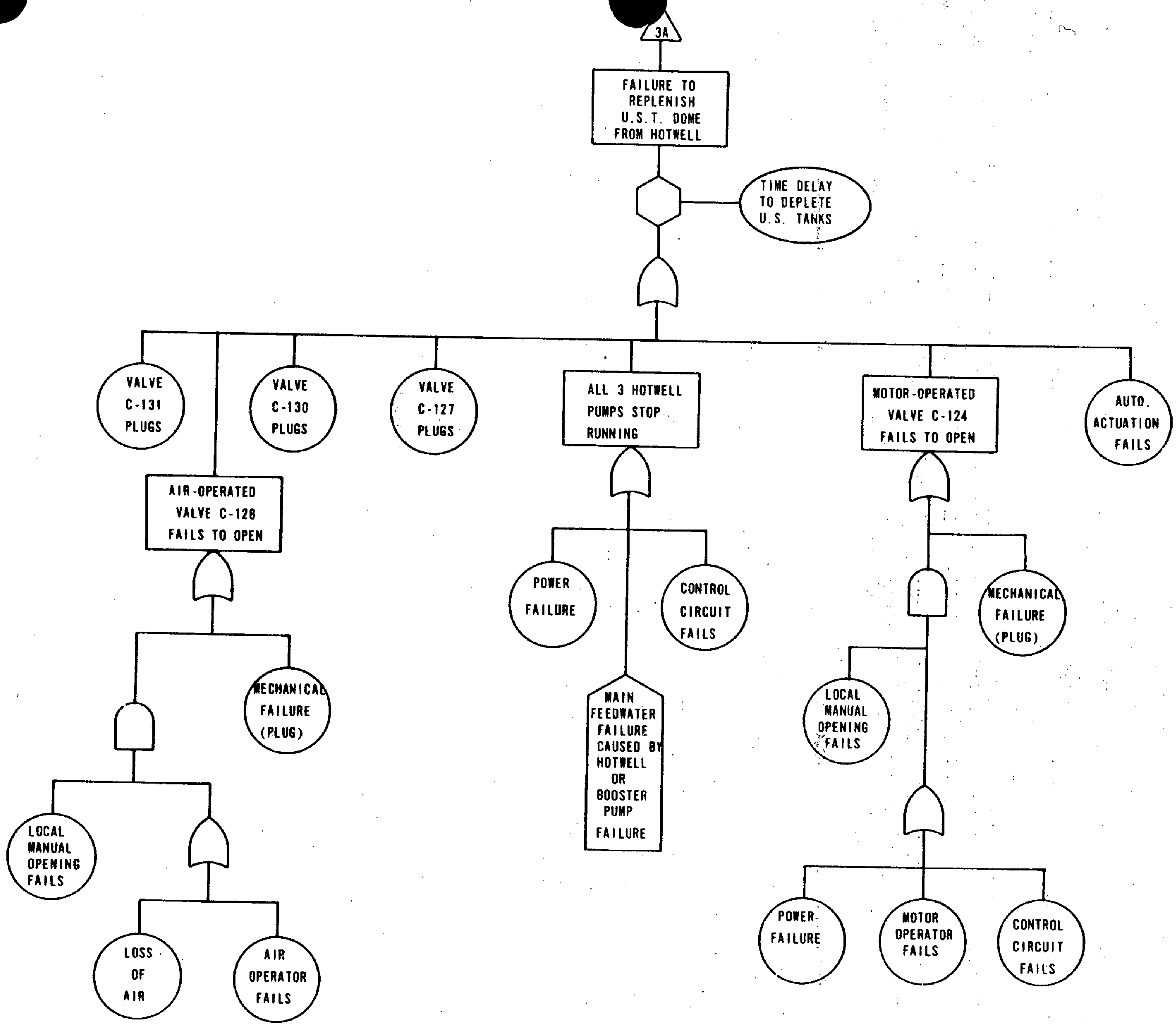


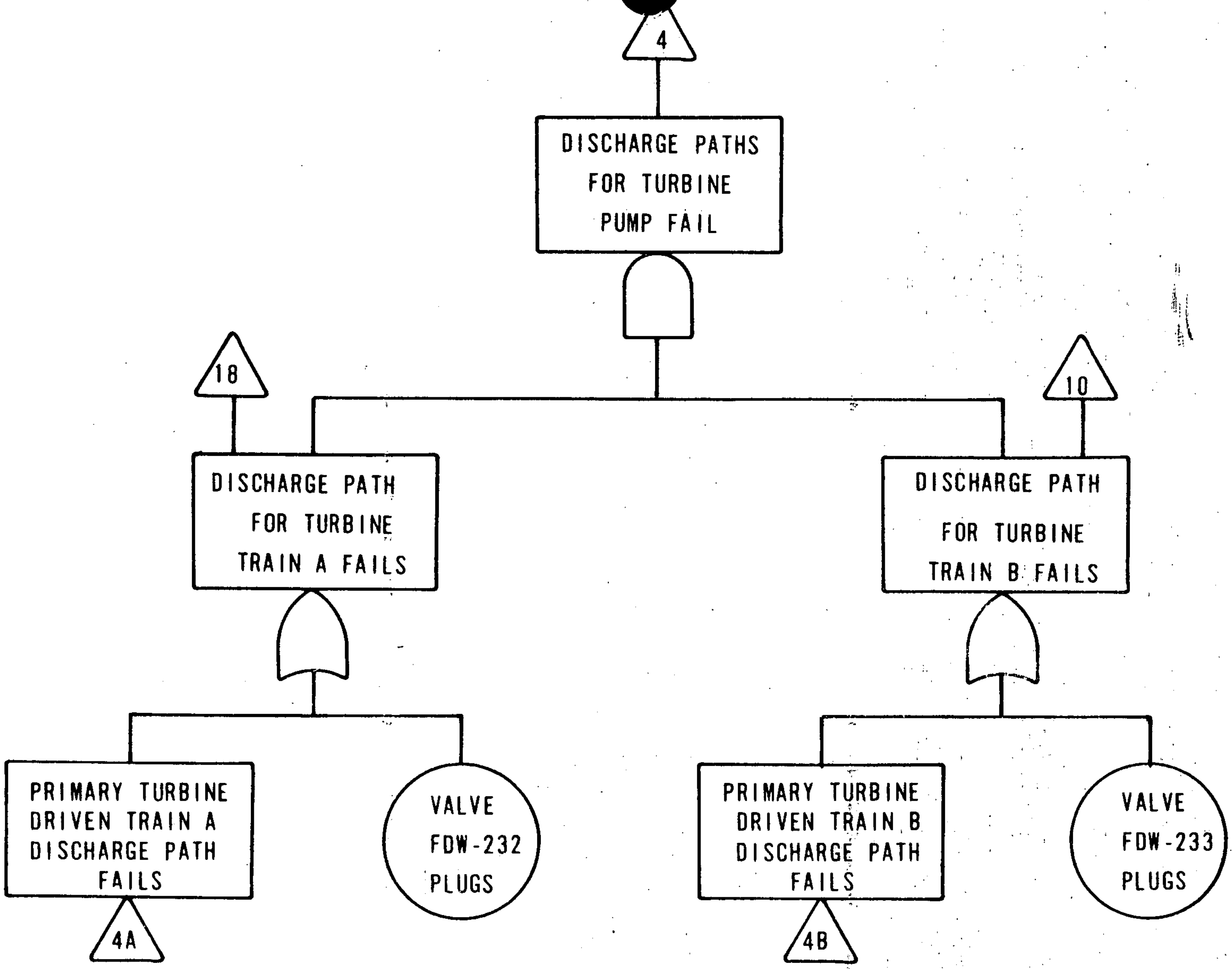
1A
1B
PRIMARY MOTOR DRIVEN TRAIN A/B DISCHARGE PATH FAILS
22
23
VALVE FDW-373/ FEW-383 PLUGS
MOTOR OPERATED VALVE FDW-372/ FDW-382 FAILS CLOSED
VALVE FDW-317/ FDW-318 PLUGS
AIR OPERATED CONTROL VALVE FW-315/FW-316 FAILS TO OPEN
MECHANICAL FAILURE
MECHANICAL FAILURE
MANUAL ACTUATION FAILS
AIR OPERATOR FAILS
MANUAL OPENING FAILS
ACTUATION CIRCUIT FAILS
SELECTOR SWITCH IN WRONG POSITION
VALVE INADVERTENTLY LEFT CLOSED
VALVE FAILS TO OPEN
OPER FAILS TO ACTUATE VALVE OPENING
MANUAL OPENING FAILS
POWER FAILURE
CONTROL CIRCUIT FAILS
MOTOR OPERATOR FAILS

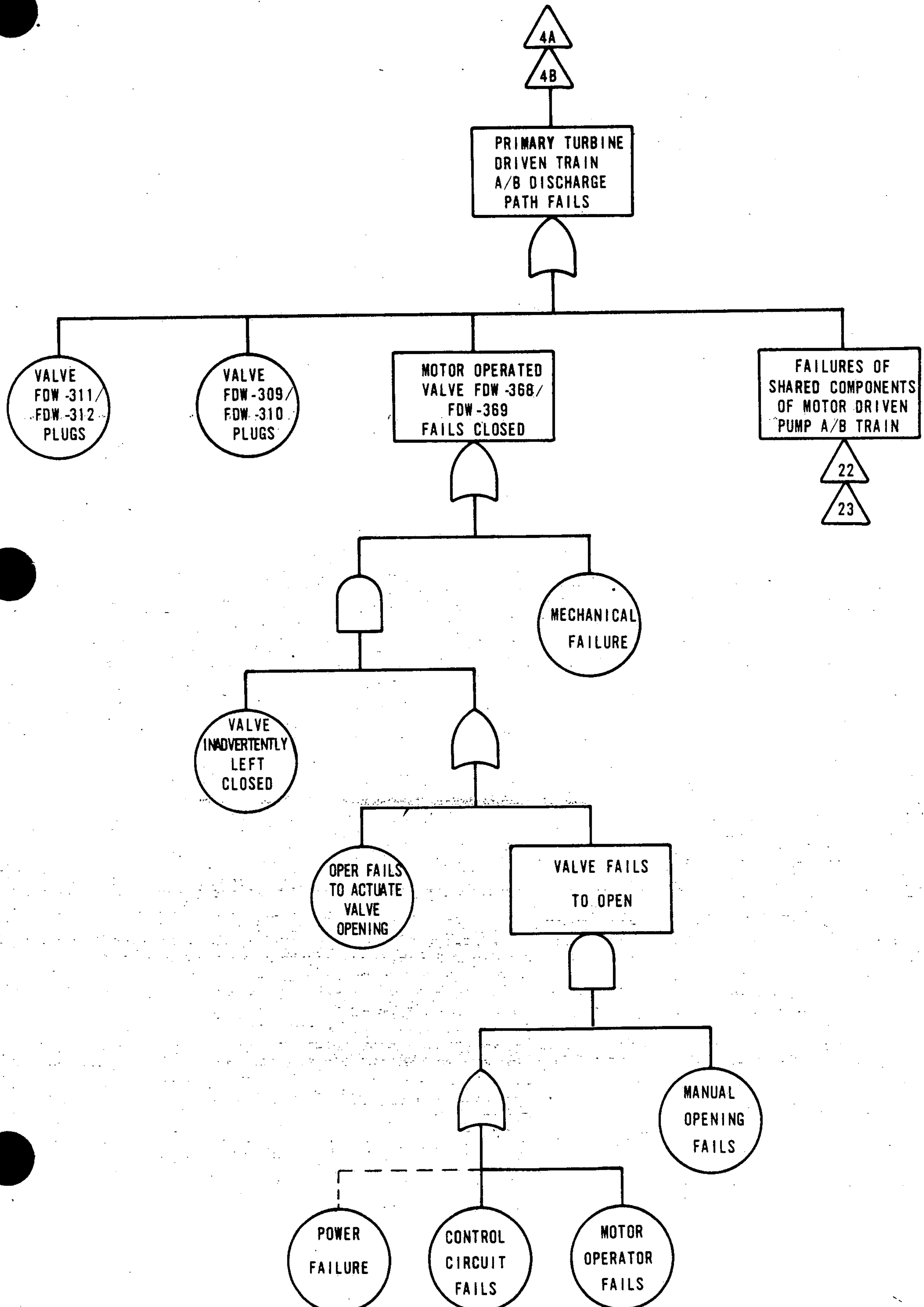

2A
2B
ALTERNATE MOTOR DRIVEN TRAIN A/B DISCHARGE PATH FAILS
20
21
VALVE FDW-39/ FDW-48 PLUGS
VALVE FDW-341 FDW-43 PLUGS
VALVE FDW-100/ FDW-102 PLUGS
VALVE FDW-991 FDW-101 PLUGS
VALVE FDW-307/ FDW-308 PLUGS
MOTOR-OPERATED VALVE FDW-374/FDW-384 FAILS TO OPEN
VALVE FDW-375/ FDW-385 PLUGS
MOTOR OPERATED VALVE FDW-38/FDW-47 FAILS TO OPEN
PISTON OPERATED VALVE FDW-35/FDW 44 FAILS CLOSED
MECHANICAL FAILURE
MANUAL ACTUATION FAILS
MANUAL ACTUATION FAILS
MECHANICAL FAILURE
MECHANICAL FAILURE (PLUG)
MANUAL OPENING FAILS
MANUAL OPENING FAILS
VALVE INADVERTENTLY LEFT CLOSED
POWER FAILURE
CONTROL CIRCUIT FAILS
MOTOR OPERATOR FAILS
POWER FAILURE
CONTROL CIRCUIT FAILS
MOTOR OPERATOR FAILS
OPERATOR FAILS TO ACT. VLV. OPENING
MANUAL OPENING FAILS
PISTON OPERATOR FAILS
AIR SUPPLY FAILS

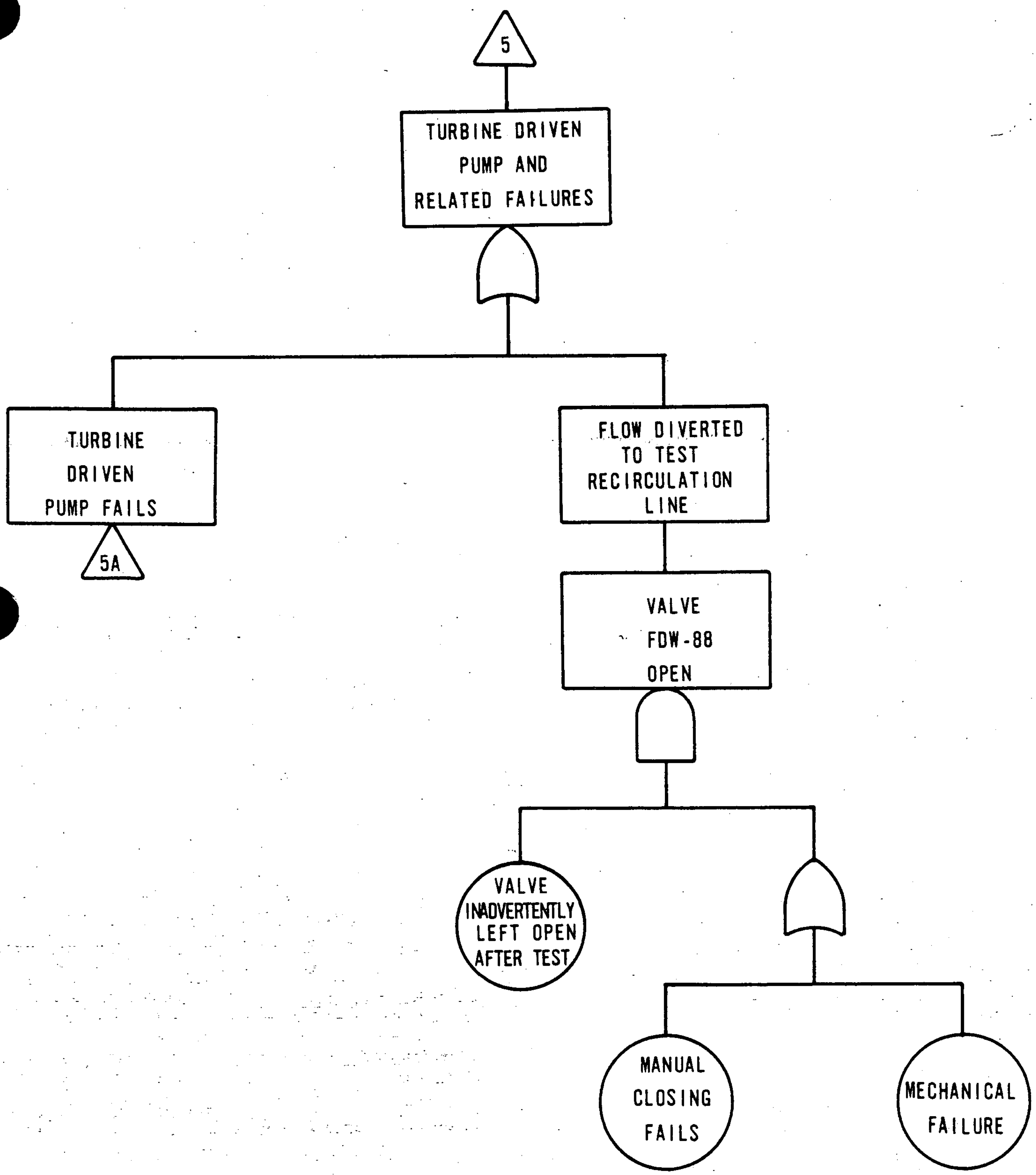


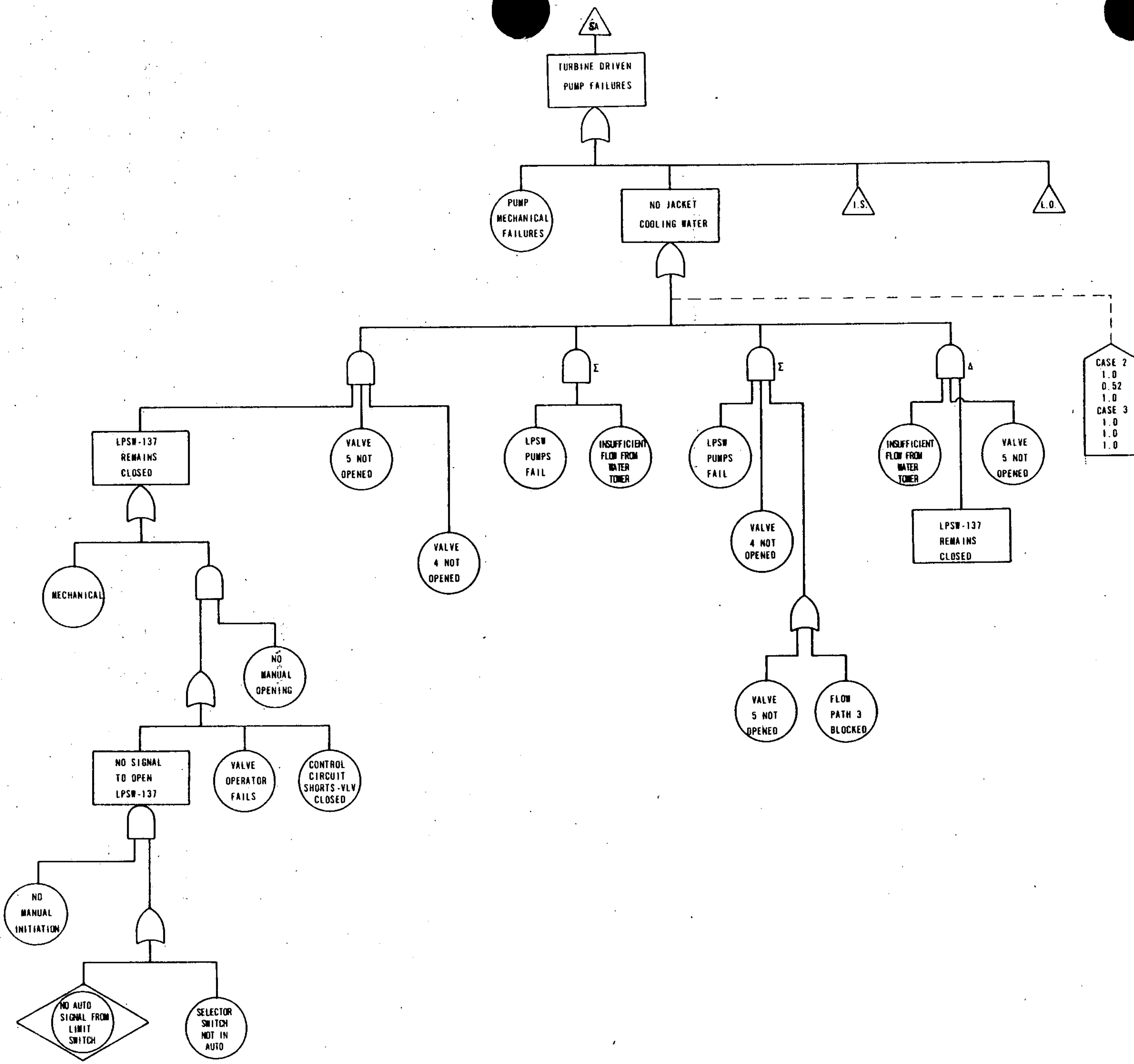
3
SUCTION FAILURE TO MOTOR DRIVEN PUMPS
16
INSUFFICIENT WATER FROM CONDENSER HOTWELL
INSUFFICIENT WATER FROM UPPER SURGE TANKS
24
VALVE C-569 PLUGS
VALVE C-568 PLUGS
VALVE C-184 PLUGS
VALVE C-573 PLUGS
VALVE C-572 PLUGS
VALVE C-180 PLUGS
VALVE C-166 PLUGS
MOTOR OPERATED VALVE C-158 FAILS CLOSED
FAILURE TO REPLENISH U.S.T. DOME FROM HOTWELL
3A
TURBINE TRAIN FAILS
MECHANICAL FAILURE (PLUG)
VALVE INADVERTENTLY LEFT CLOSED
UPPER SURGE TANK CROSSTIE FAILS
6B
OPERATOR FAILS TO ACT. VLV. OPENING
VALVE FAILS TO OPEN
MANUAL OPENING FAILS
POWER FAILURE
CONTROL CIRCUIT FAILS
MOTOR OPERATOR FAILS


3A
FAILURE TO REPLENISH U.S.T. DOME FROM HOTWELL
TIME DELAY TO DEPLETE U.S. TANKS
VALVE C-131 PLUGS
VALVE C-130 PLUGS
VALVE C-127 PLUGS
ALL 3 HOTWELL PUMPS STOP RUNNING
MOTOR-OPERATED VALVE C-124 FAILS TO OPEN
AUTO. ACTUATION FAILS
AIR-OPERATED VALVE C-128 FAILS TO OPEN
POWER FAILURE
CONTROL CIRCUIT FAILS
MECHANICAL FAILURE (PLUG)
MECHANICAL FAILURE (PLUG)
MAIN FEEDWATER FAILURE CAUSED BY HOTWELL OR BOOSTER PUMP FAILURE
LOCAL MANUAL OPENING FAILS
LOCAL MANUAL OPENING FAILS
LOSS OF AIR
AIR OPERATOR FAILS
POWER FAILURE
MOTOR OPERATOR FAILS
CONTROL CIRCUIT FAILS

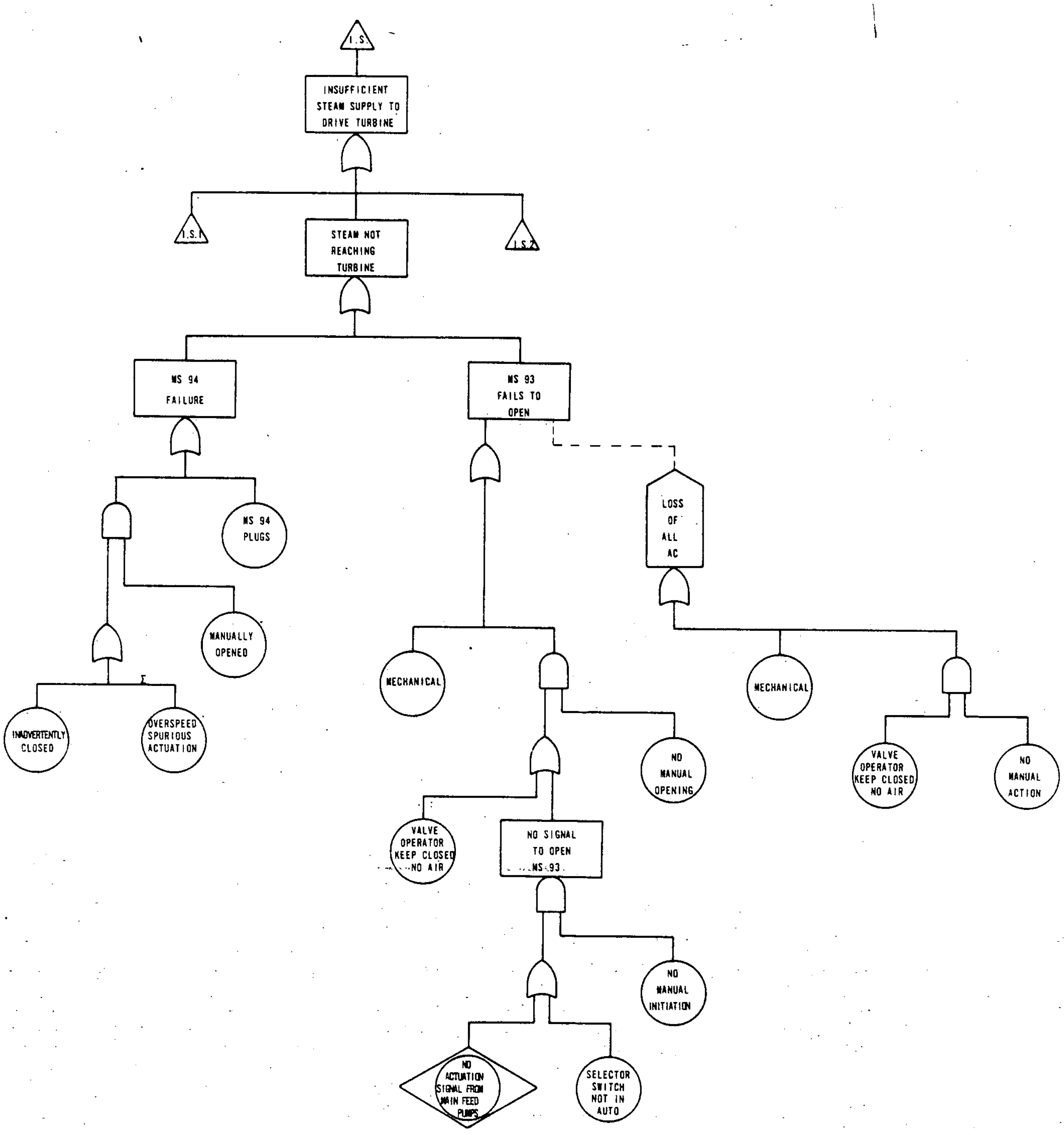

4
DISCHARGE PATHS FOR TURBINE PUMP FAIL
18
DISCHARGE PATH FOR TURBINE TRAIN A FAILS
10
DISCHARGE PATH FOR TURBINE TRAIN B FAILS
PRIMARY TURBINE DRIVEN TRAIN A DISCHARGE PATH FAILS
4A
VALVE FDW-232 PLUGS
PRIMARY TURBINE DRIVEN TRAIN B DISCHARGE PATH FAILS
4B
VALVE FDW-233 PLUGS

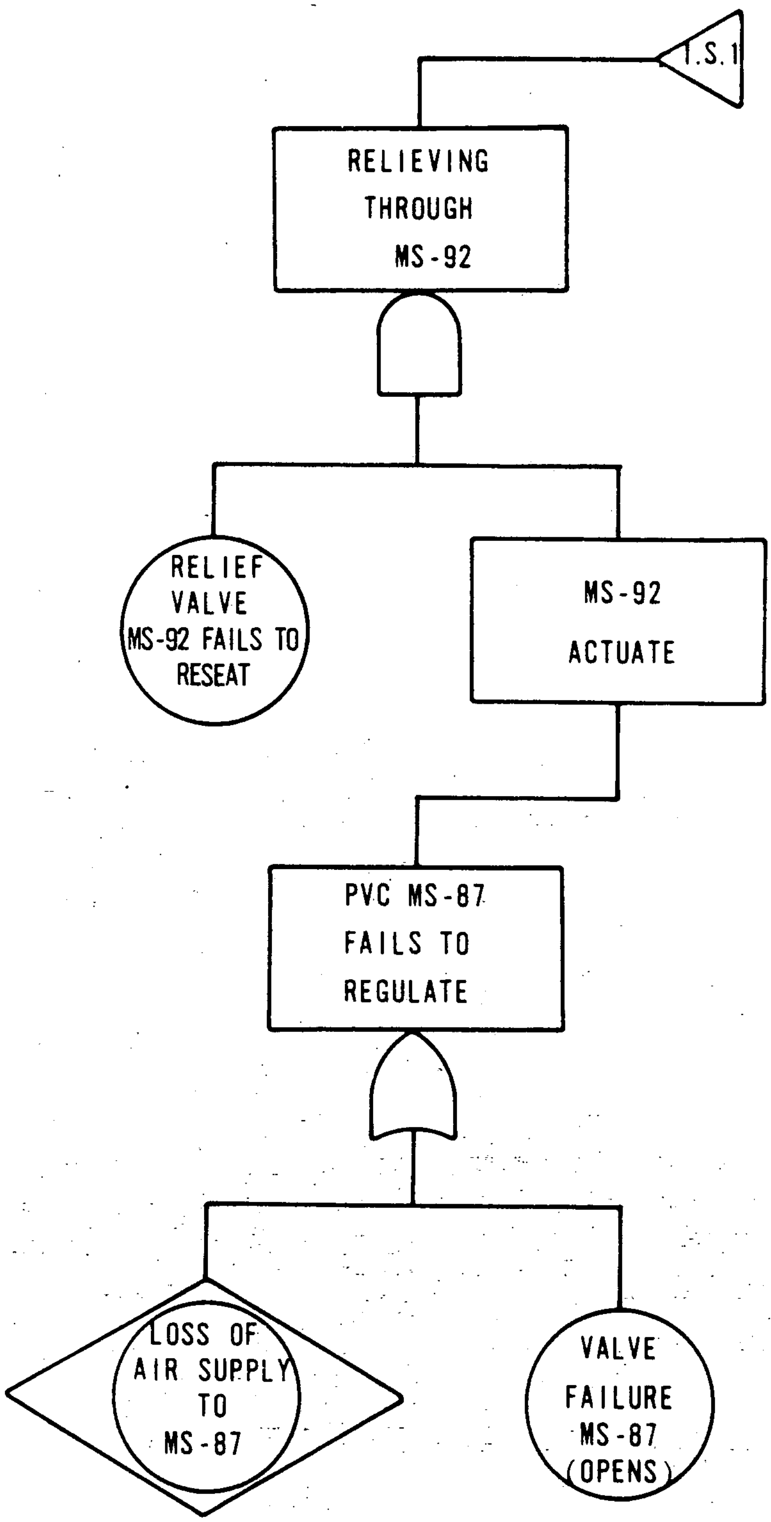

4A
4B
PRIMARY TURBINE DRIVEN TRAIN A/B DISCHARGE PATH FAILS
VALVE FDW-311/ FDW-312 PLUGS
VALVE FDW-309/ FDW-310 PLUGS
MOTOR OPERATED VALVE FDW-368/ FDW-369 FAILS CLOSED
FAILURES OF SHARED COMPONENTS OF MOTOR DRIVEN PUMP A/B TRAIN
22
23
MECHANICAL FAILURE
VALVE INADVERTENTLY LEFT CLOSED
OPER FAILS TO ACTUATE VALVE OPENING
VALVE FAILS TO OPEN
MANUAL OPENING FAILS
POWER FAILURE
CONTROL CIRCUIT FAILS
MOTOR OPERATOR FAILS


5
TURBINE DRIVEN PUMP AND RELATED FAILURES
TURBINE DRIVEN PUMP FAILS
5A
FLOW DIVERTED TO TEST RECIRCULATION LINE
VALVE FDW-88 OPEN
VALVE INADVERTENTLY LEFT OPEN AFTER TEST
MANUAL CLOSING FAILS
MECHANICAL FAILURE

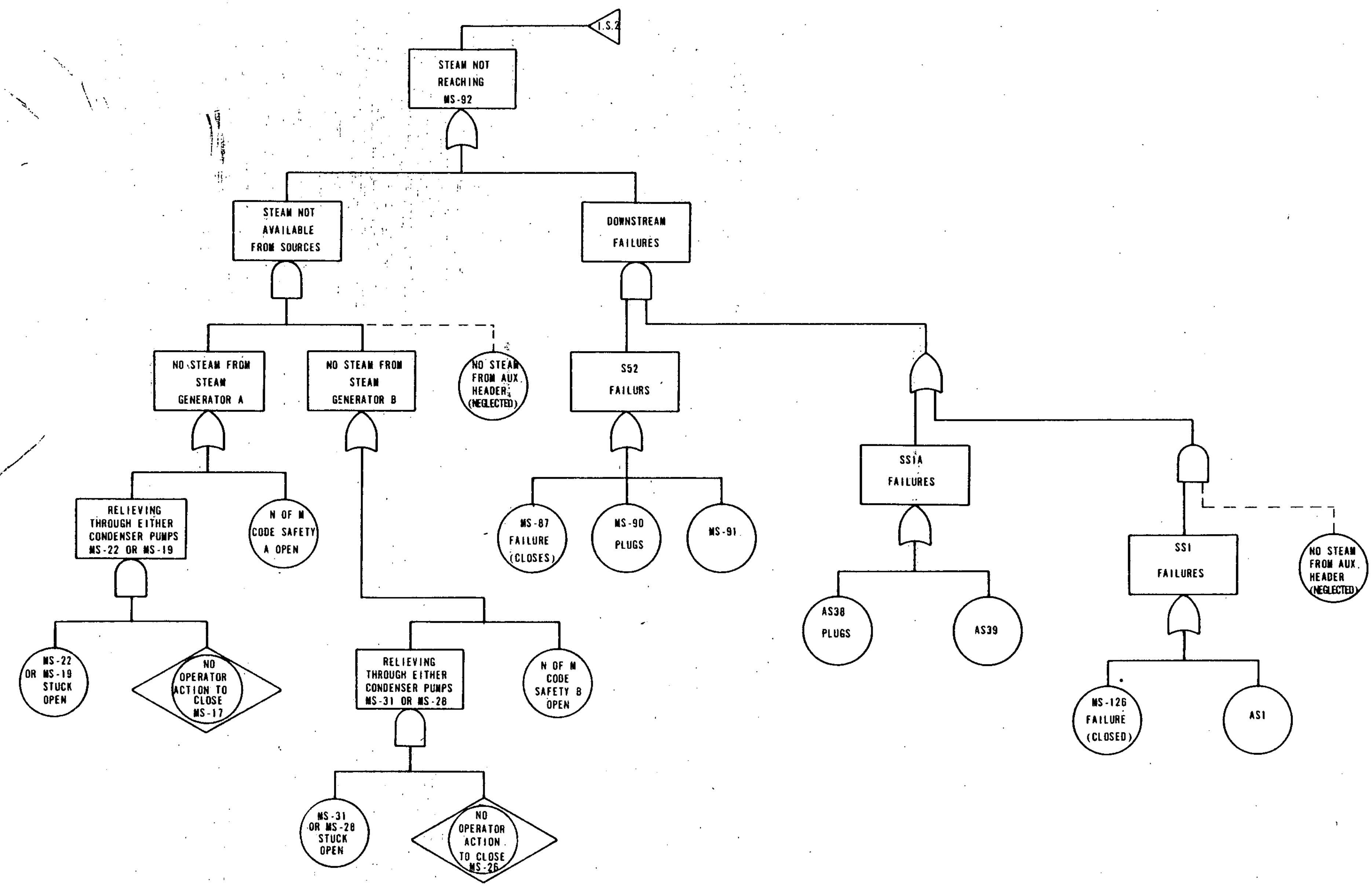


5A
TURBINE DRIVEN PUMP FAILURES
PUMP MECHANICAL FAILURES
NO JACKET COOLING WATER
I.S.
L.O.
CASE 2
1.0
0.52
1.0
CASE 3
1.0
1.0
1.0
Σ
Σ
Δ
LPSW-137 REMAINS CLOSED
VALVE 5 NOT OPENED
VALVE 4 NOT OPENED
LPSW PUMPS FAIL
INSUFFICIENT FLOW FROM WATER TOWER
LPSW PUMPS FAIL
VALVE 4 NOT OPENED
VALVE 5 NOT OPENED
FLOW PATH 3 BLOCKED
INSUFFICIENT FLOW FROM WATER TOWER
VALVE 5 NOT OPENED
LPSW-137 REMAINS CLOSED
MECHANICAL
NO MANUAL OPENING
NO SIGNAL TO OPEN LPSW-137
VALVE OPERATOR FAILS
CONTROL CIRCUIT SHORTS-VLV CLOSED
NO MANUAL INITIATION
NO AUTO SIGNAL FROM LIMIT SWITCH
SELECTOR SWITCH NOT IN AUTO

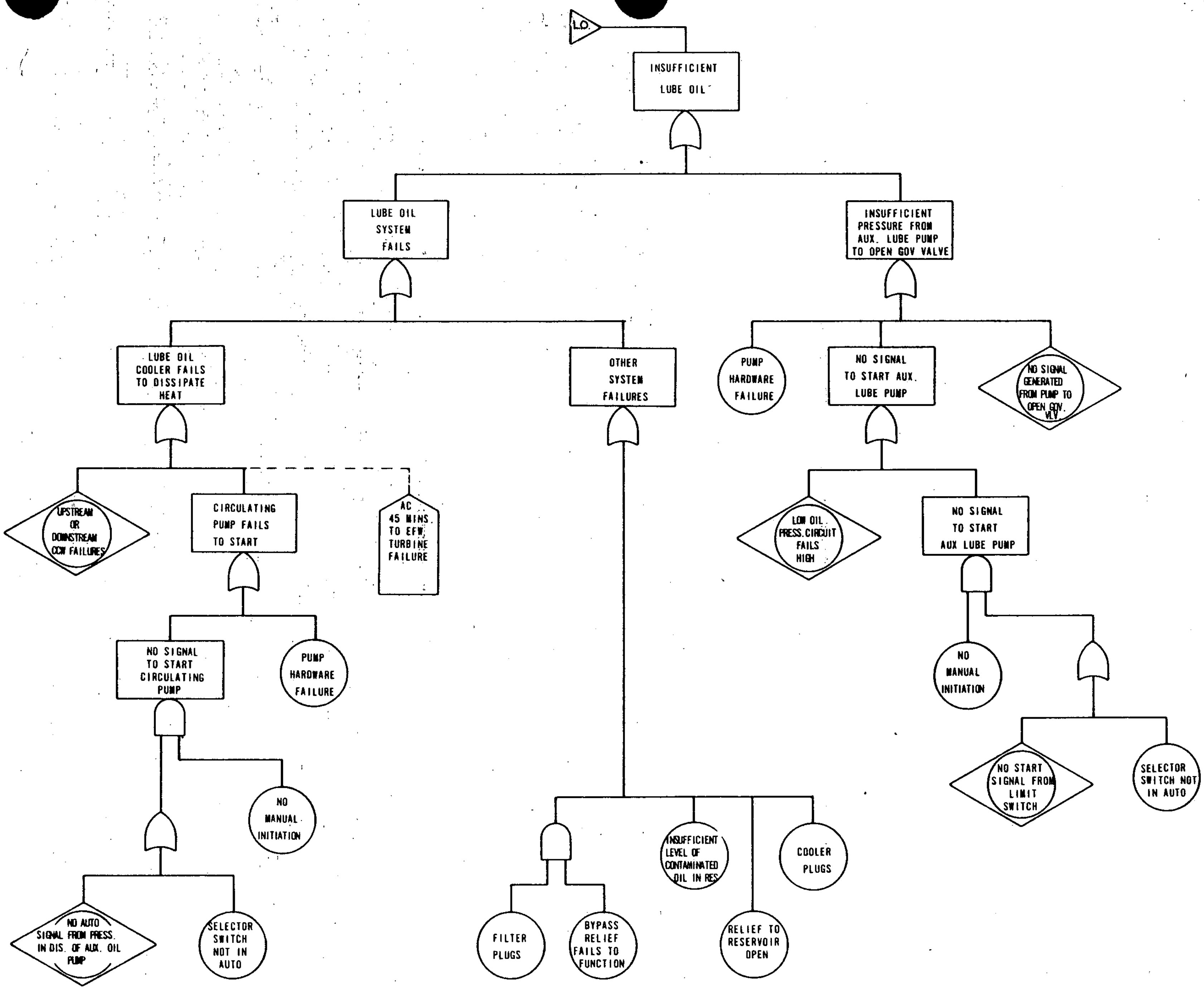

I.S.
INSUFFICIENT STEAM SUPPLY TO DRIVE TURBINE
I.S.1
STEAM NOT REACHING TURBINE
I.S.2
MS 94 FAILURE
MS 93 FAILS TO OPEN
LOSS OF ALL AC
MS 94 PLUGS
MANUALLY OPENED
INADVERTENTLY CLOSED
OVERSPEED SPURIOUS ACTUATION
MECHANICAL
NO MANUAL OPENING
VALVE OPERATOR KEEP CLOSED NO AIR
NO SIGNAL TO OPEN MS 93
NO MANUAL INITIATION
NO ACTUATION SIGNAL FROM MAIN FEED PUMPS
SELECTOR SWITCH NOT IN AUTO
MECHANICAL
VALVE OPERATOR KEEP CLOSED NO AIR
NO MANUAL ACTION

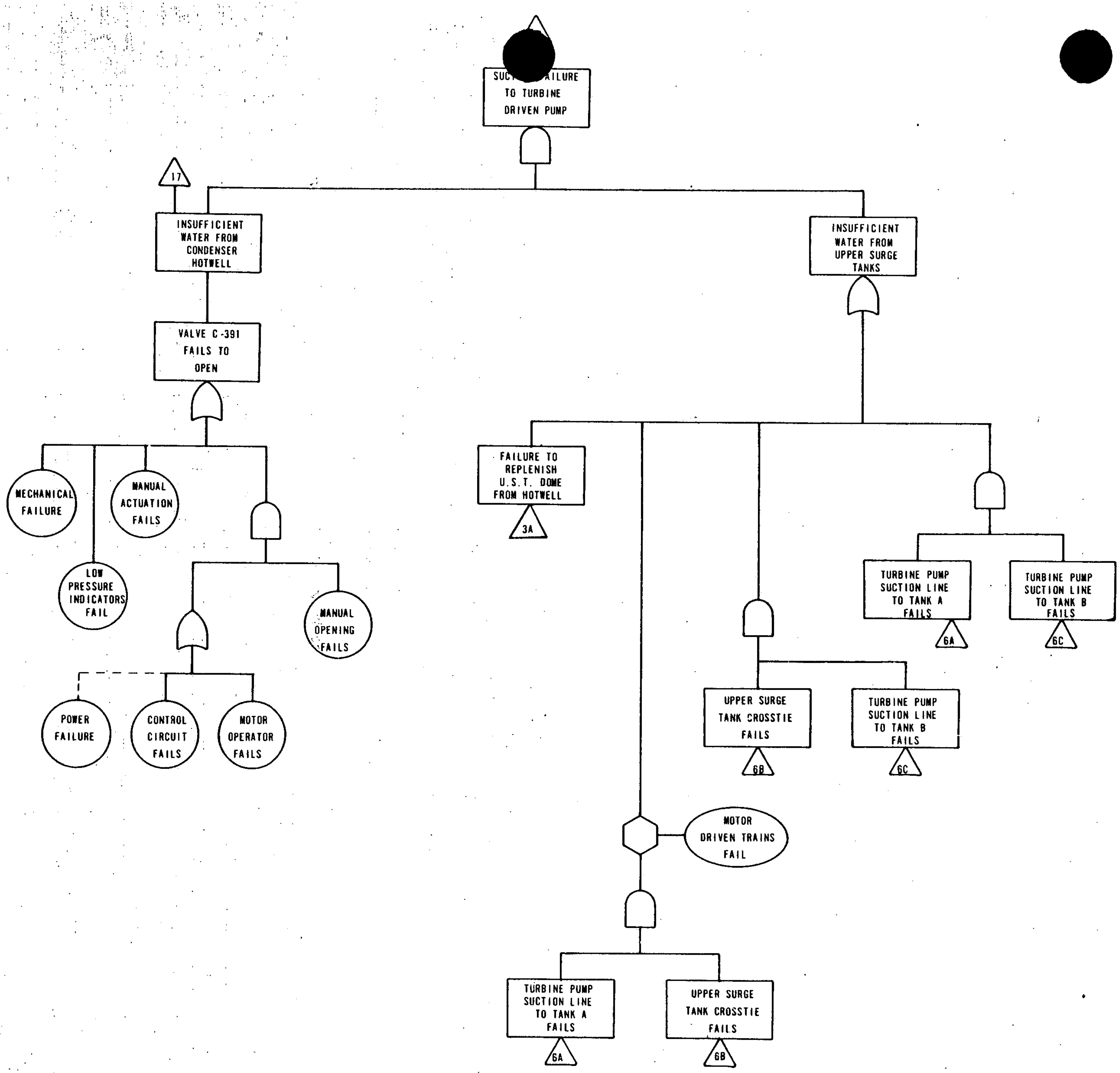


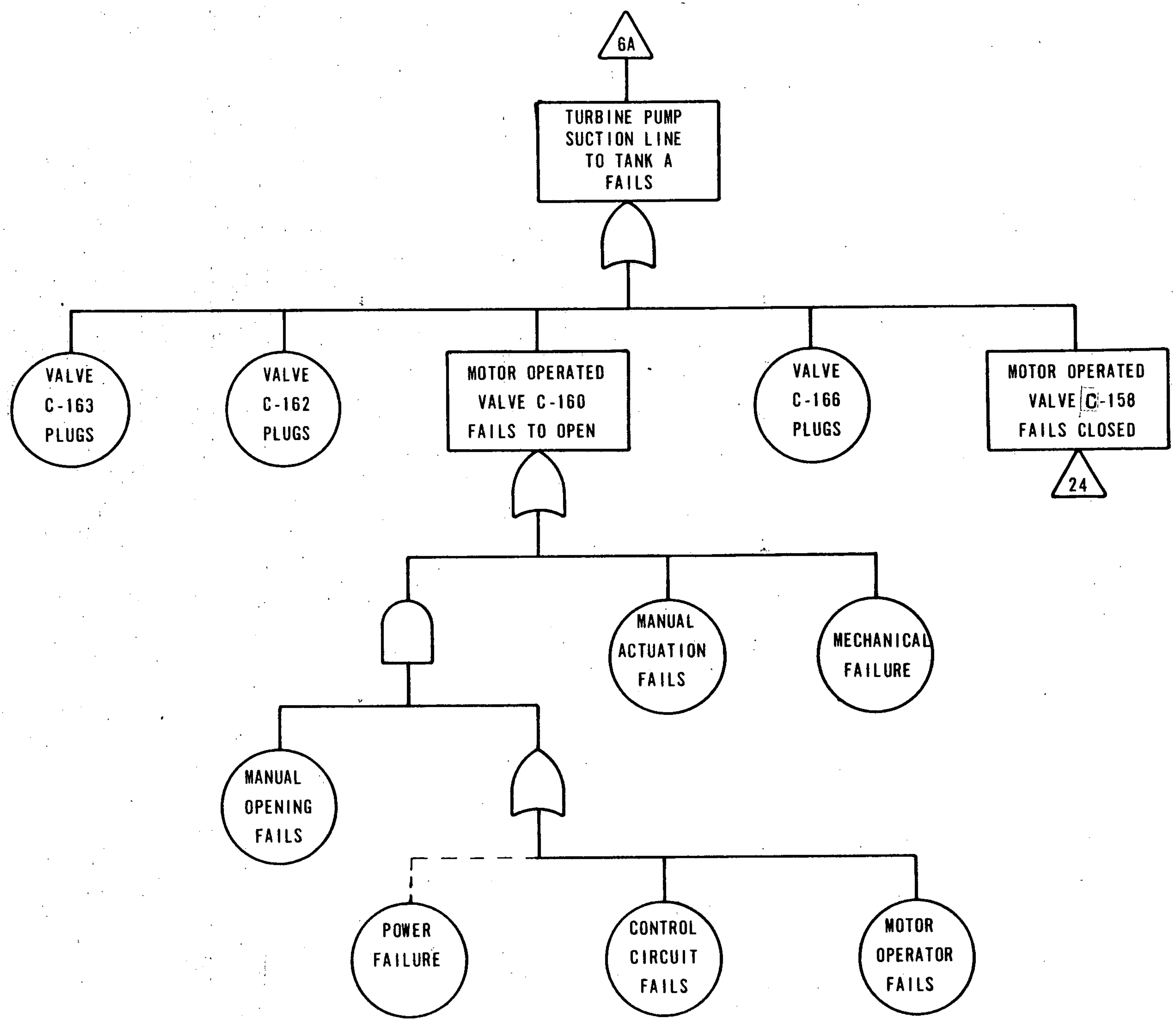
T.S.1
RELIEVING THROUGH MS-92
RELIEF VALVE MS-92 FAILS TO RESEAT
MS-92 ACTUATE
PVC MS-87 FAILS TO REGULATE
LOSS OF AIR SUPPLY TO MS-87
VALVE FAILURE MS-87 (OPENS)

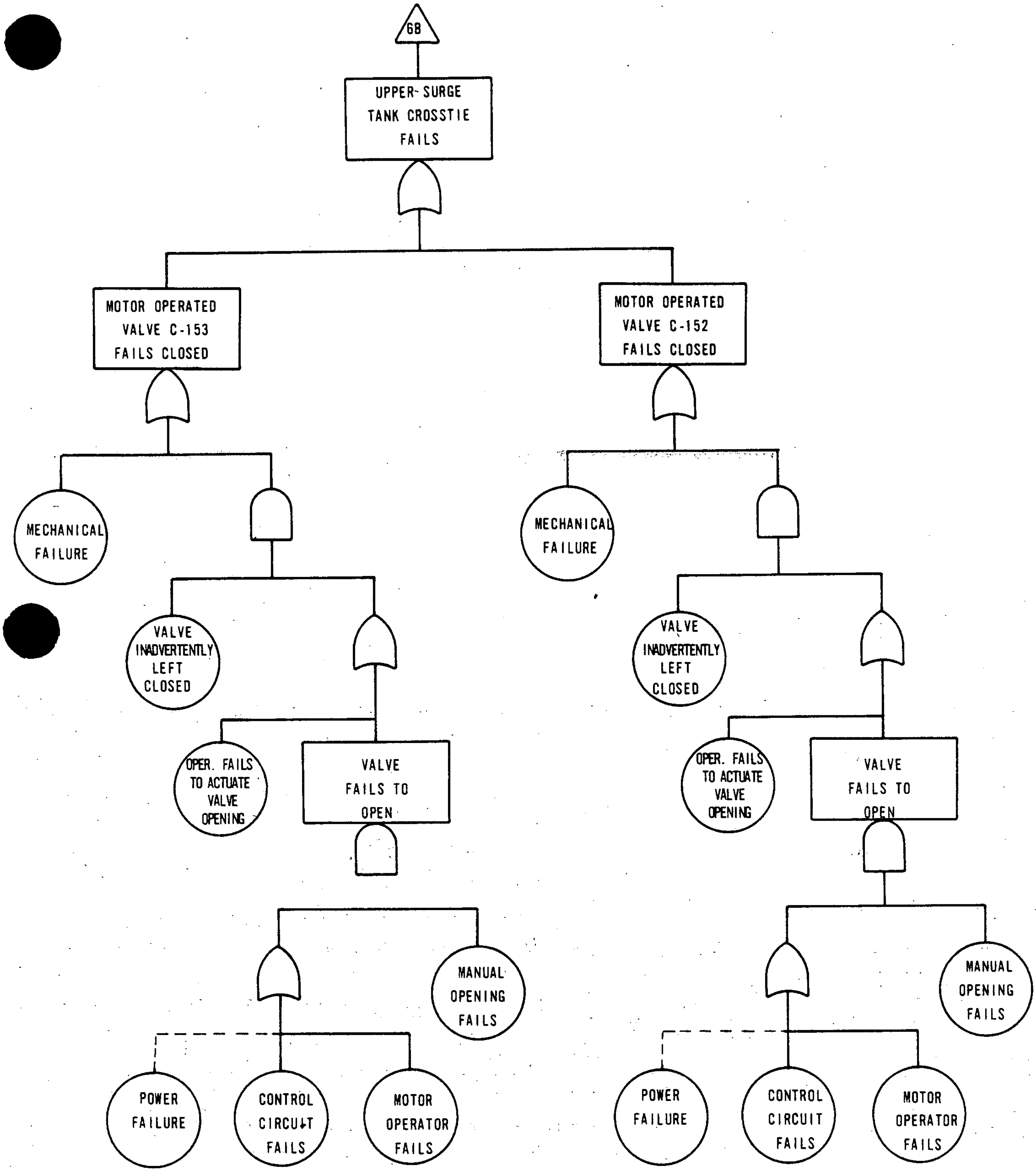


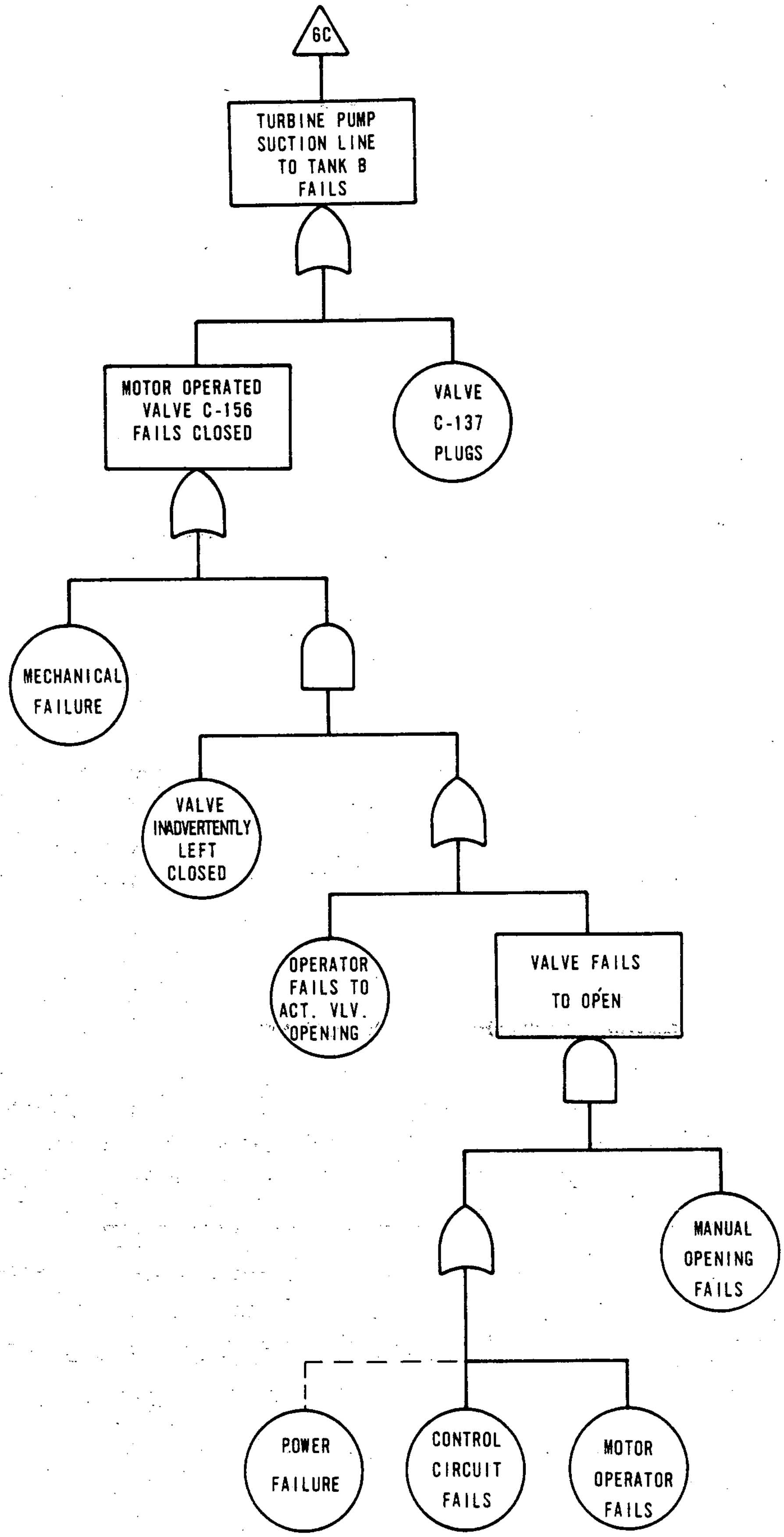
I.S.2
STEAM NOT REACHING MS-92
STEAM NOT AVAILABLE FROM SOURCES
DOWNSTREAM FAILURES
NO STEAM FROM STEAM GENERATOR A
NO STEAM FROM STEAM GENERATOR B
NO STEAM FROM AUX HEADER (NEGLECTED)
S52 FAILURS
RELIEVING THROUGH EITHER CONDENSER PUMPS MS-22 OR MS-19
N OF M CODE SAFETY A OPEN
MS-22 OR MS-19 STUCK OPEN
NO OPERATOR ACTION TO CLOSE MS-17
RELIEVING THROUGH EITHER CONDENSER PUMPS MS-31 OR MS-28
N OF M CODE SAFETY B OPEN
MS-31 OR MS-28 STUCK OPEN
NO OPERATOR ACTION TO CLOSE MS-26
MS-87 FAILURE (CLOSES)
MS-90 PLUGS
MS-91
SS1A FAILURES
AS38 PLUGS
AS39
SS1 FAILURES
NO STEAM FROM AUX. HEADER (NEGLECTED)
MS-126 FAILURE (CLOSED)
AS1

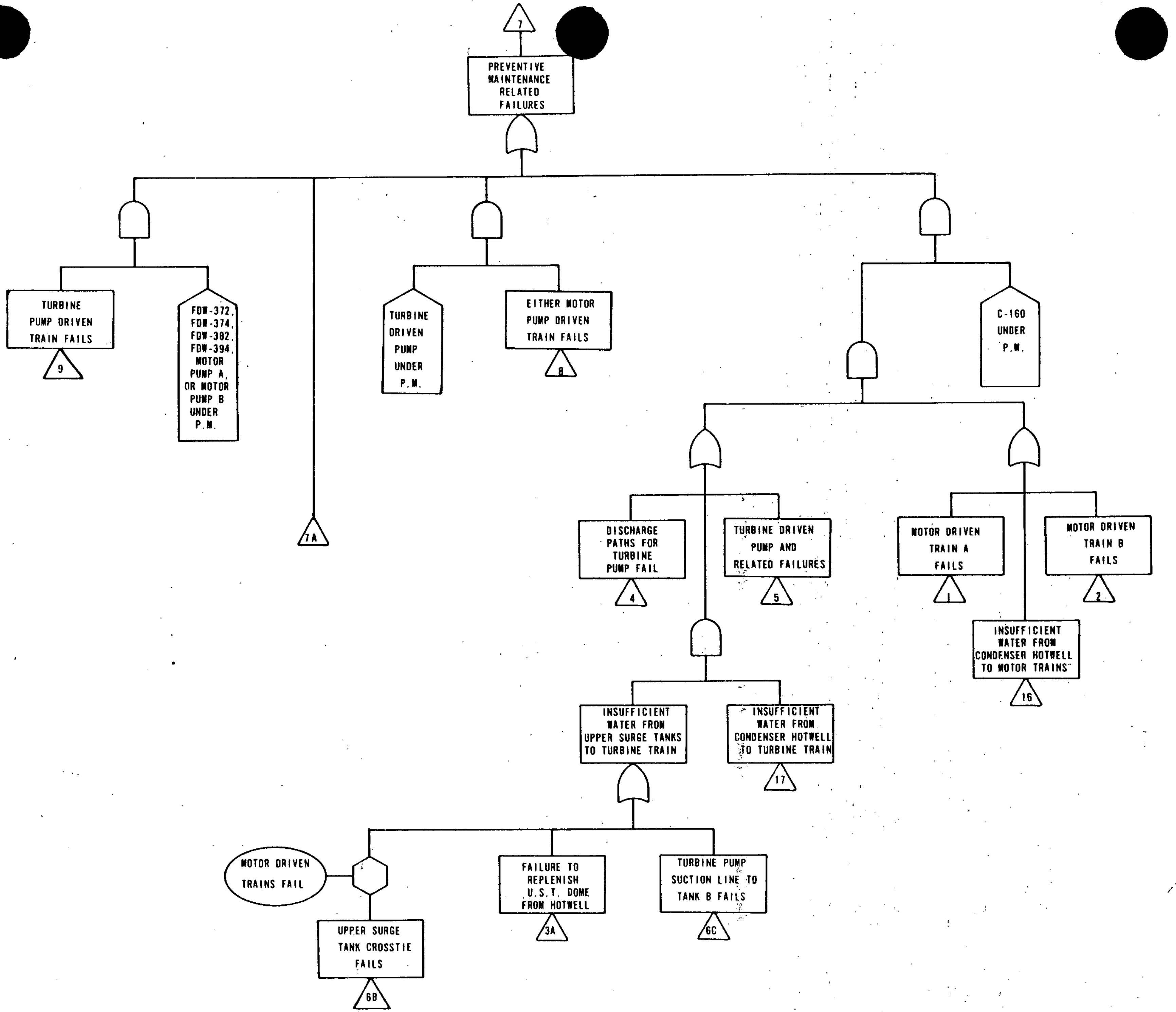

L.O.
INSUFFICIENT LUBE OIL
LUBE OIL SYSTEM FAILS
INSUFFICIENT PRESSURE FROM AUX. LUBE PUMP TO OPEN GOV VALVE
LUBE OIL COOLER FAILS TO DISSIPATE HEAT
OTHER SYSTEM FAILURES
PUMP HARDWARE FAILURE
NO SIGNAL TO START AUX. LUBE PUMP
NO SIGNAL GENERATED FROM PUMP TO OPEN GOV. VLV.
UPSTREAM OR DOWNSTREAM CCW FAILURES
CIRCULATING PUMP FAILS TO START
AC 45 MINS. TO EFW, TURBINE FAILURE
LOW OIL PRESS. CIRCUIT FAILS HIGH
NO SIGNAL TO START AUX LUBE PUMP
NO SIGNAL TO START CIRCULATING PUMP
PUMP HARDWARE FAILURE
NO MANUAL INITIATION
NO MANUAL INITIATION
NO START SIGNAL FROM LIMIT SWITCH
SELECTOR SWITCH NOT IN AUTO
INSUFFICIENT LEVEL OF CONTAMINATED OIL IN RES
COOLER PLUGS
NO AUTO SIGNAL FROM PRESS. IN DIS. OF AUX. OIL PUMP
SELECTOR SWITCH NOT IN AUTO
FILTER PLUGS
BYPASS RELIEF FAILS TO FUNCTION
RELIEF TO RESERVOIR OPEN

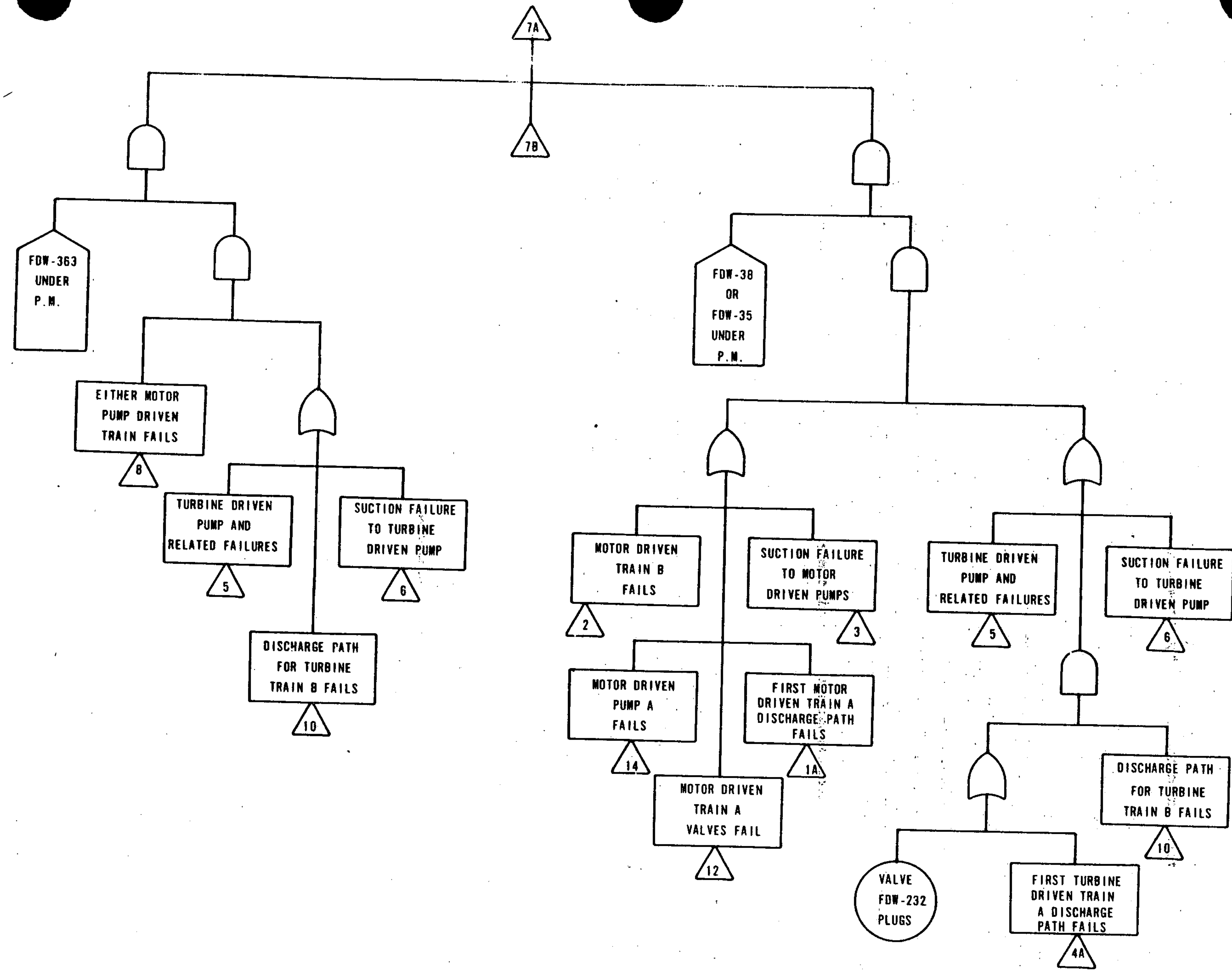

SUC… AILURE
TO TURBINE
DRIVEN PUMP
17
INSUFFICIENT WATER FROM CONDENSER HOTWELL
INSUFFICIENT WATER FROM UPPER SURGE TANKS
VALVE C-391 FAILS TO OPEN
MECHANICAL FAILURE
LOW PRESSURE INDICATORS FAIL
MANUAL ACTUATION FAILS
MANUAL OPENING FAILS
POWER FAILURE
CONTROL CIRCUIT FAILS
MOTOR OPERATOR FAILS
FAILURE TO REPLENISH U.S.T. DOME FROM HOTWELL
3A
TURBINE PUMP SUCTION LINE TO TANK A FAILS
6A
TURBINE PUMP SUCTION LINE TO TANK B FAILS
6C
UPPER SURGE TANK CROSSTIE FAILS
6B
TURBINE PUMP SUCTION LINE TO TANK B FAILS
6C
MOTOR DRIVEN TRAINS FAIL
TURBINE PUMP SUCTION LINE TO TANK A FAILS
6A
UPPER SURGE TANK CROSSTIE FAILS
6B

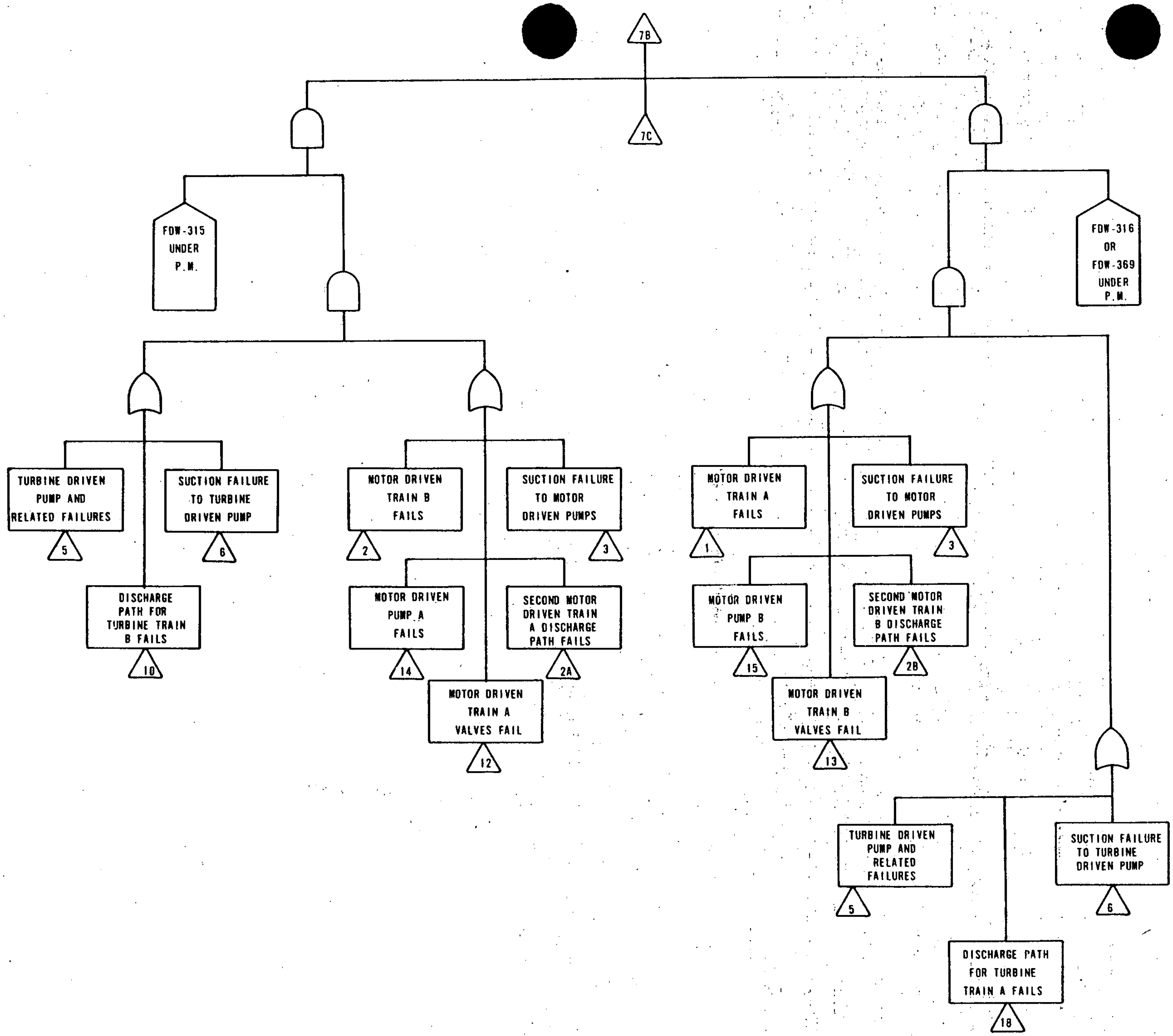

6A
TURBINE PUMP SUCTION LINE TO TANK A FAILS
VALVE C-163 PLUGS
VALVE C-162 PLUGS
MOTOR OPERATED VALVE C-160 FAILS TO OPEN
VALVE C-166 PLUGS
MOTOR OPERATED VALVE C-158 FAILS CLOSED
24
MANUAL ACTUATION FAILS
MECHANICAL FAILURE
MANUAL OPENING FAILS
POWER FAILURE
CONTROL CIRCUIT FAILS
MOTOR OPERATOR FAILS

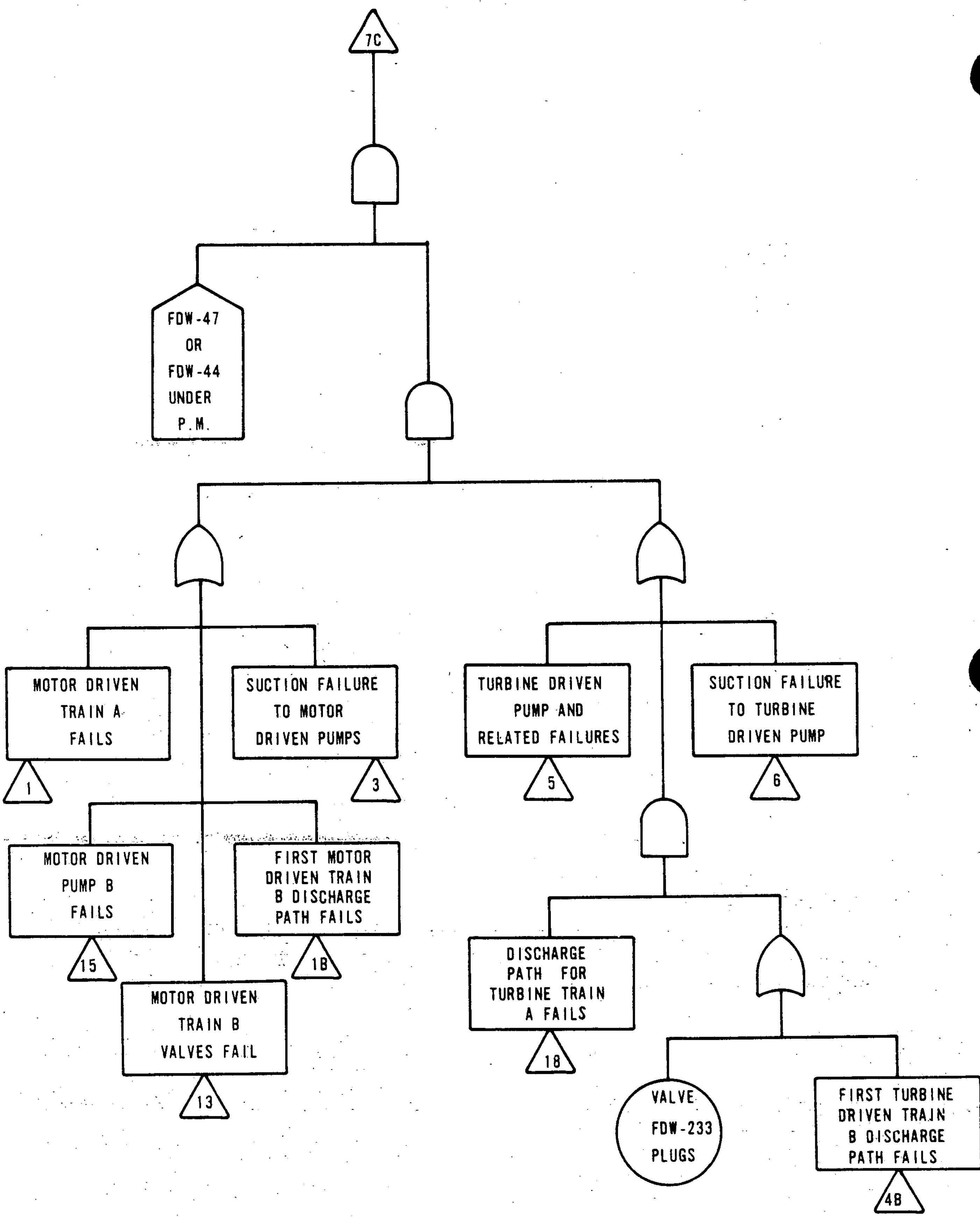

6B
UPPER-SURGE TANK CROSSTIE FAILS
MOTOR OPERATED VALVE C-153 FAILS CLOSED
MOTOR OPERATED VALVE C-152 FAILS CLOSED
MECHANICAL FAILURE
VALVE INADVERTENTLY LEFT CLOSED
OPER. FAILS TO ACTUATE VALVE OPENING
VALVE FAILS TO OPEN
MANUAL OPENING FAILS
POWER FAILURE
CONTROL CIRCUIT FAILS
MOTOR OPERATOR FAILS
MECHANICAL FAILURE
VALVE INADVERTENTLY LEFT CLOSED
OPER. FAILS TO ACTUATE VALVE OPENING
VALVE FAILS TO OPEN
MANUAL OPENING FAILS
POWER FAILURE
CONTROL CIRCUIT FAILS
MOTOR OPERATOR FAILS


6C
TURBINE PUMP SUCTION LINE TO TANK B FAILS
MOTOR OPERATED VALVE C-156 FAILS CLOSED
VALVE C-137 PLUGS
MECHANICAL FAILURE
VALVE INADVERTENTLY LEFT CLOSED
OPERATOR FAILS TO ACT. VLV. OPENING
VALVE FAILS TO OPEN
MANUAL OPENING FAILS
POWER FAILURE
CONTROL CIRCUIT FAILS
MOTOR OPERATOR FAILS


7
PREVENTIVE MAINTENANCE RELATED FAILURES
TURBINE PUMP DRIVEN TRAIN FAILS
9
FDW-372, FDW-374, FDW-382, FDW-394, MOTOR PUMP A, OR MOTOR PUMP B UNDER P.M.
7A
TURBINE DRIVEN PUMP UNDER P.M.
EITHER MOTOR PUMP DRIVEN TRAIN FAILS
8
C-160 UNDER P.M.
DISCHARGE PATHS FOR TURBINE PUMP FAIL
4
TURBINE DRIVEN PUMP AND RELATED FAILURES
5
MOTOR DRIVEN TRAIN A FAILS
1
MOTOR DRIVEN TRAIN B FAILS
2
INSUFFICIENT WATER FROM CONDENSER HOTWELL TO MOTOR TRAINS
16
INSUFFICIENT WATER FROM UPPER SURGE TANKS TO TURBINE TRAIN
INSUFFICIENT WATER FROM CONDENSER HOTWELL TO TURBINE TRAIN
17
MOTOR DRIVEN TRAINS FAIL
UPPER SURGE TANK CROSSTIE FAILS
6B
FAILURE TO REPLENISH U.S.T. DOME FROM HOTWELL
3A
TURBINE PUMP SUCTION LINE TO TANK B FAILS
6C


7A
7B
FDW-363 UNDER P.M.
EITHER MOTOR PUMP DRIVEN TRAIN FAILS
8
TURBINE DRIVEN PUMP AND RELATED FAILURES
5
SUCTION FAILURE TO TURBINE DRIVEN PUMP
6
DISCHARGE PATH FOR TURBINE TRAIN B FAILS
10
FDW-38 OR FDW-35 UNDER P.M.
MOTOR DRIVEN TRAIN B FAILS
2
SUCTION FAILURE TO MOTOR DRIVEN PUMPS
3
MOTOR DRIVEN PUMP A FAILS
14
FIRST MOTOR DRIVEN TRAIN A DISCHARGE PATH FAILS
1A
MOTOR DRIVEN TRAIN A VALVES FAIL
12
TURBINE DRIVEN PUMP AND RELATED FAILURES
5
SUCTION FAILURE TO TURBINE DRIVEN PUMP
6
DISCHARGE PATH FOR TURBINE TRAIN B FAILS
10
VALVE FDW-232 PLUGS
FIRST TURBINE DRIVEN TRAIN A DISCHARGE PATH FAILS
4A


7B
7C
FDW-315 UNDER P.M.
FDW-316 OR FDW-369 UNDER P.M.
TURBINE DRIVEN PUMP AND RELATED FAILURES
5
SUCTION FAILURE TO TURBINE DRIVEN PUMP
6
DISCHARGE PATH FOR TURBINE TRAIN B FAILS
10
MOTOR DRIVEN TRAIN B FAILS
2
SUCTION FAILURE TO MOTOR DRIVEN PUMPS
3
MOTOR DRIVEN PUMP A FAILS
14
SECOND MOTOR DRIVEN TRAIN A DISCHARGE PATH FAILS
2A
MOTOR DRIVEN TRAIN A VALVES FAIL
12
MOTOR DRIVEN TRAIN A FAILS
1
SUCTION FAILURE TO MOTOR DRIVEN PUMPS
3
MOTOR DRIVEN PUMP B FAILS
15
SECOND MOTOR DRIVEN TRAIN B DISCHARGE PATH FAILS
2B
MOTOR DRIVEN TRAIN B VALVES FAIL
13
TURBINE DRIVEN PUMP AND RELATED FAILURES
5
SUCTION FAILURE TO TURBINE DRIVEN PUMP
6
DISCHARGE PATH FOR TURBINE TRAIN A FAILS
18



7C
FDW-47 OR FDW-44 UNDER P.M.
MOTOR DRIVEN TRAIN A FAILS
1
SUCTION FAILURE TO MOTOR DRIVEN PUMPS
3
TURBINE DRIVEN PUMP AND RELATED FAILURES
5
SUCTION FAILURE TO TURBINE DRIVEN PUMP
6
MOTOR DRIVEN PUMP B FAILS
15
FIRST MOTOR DRIVEN TRAIN B DISCHARGE PATH FAILS
1B
MOTOR DRIVEN TRAIN B VALVES FAIL
13
DISCHARGE PATH FOR TURBINE TRAIN A FAILS
18
VALVE FDW-233 PLUGS
FIRST TURBINE DRIVEN TRAIN B DISCHARGE PATH FAILS
4B

APPENDIX B

NRC-SUPPLIED DATA USED FOR PURPOSES OF CONDUCTING A COMPARATIVE ASSESSMENT OF EXISTING AFWS DESIGNS & THEIR POTENTIAL RELIABILITIES

	Point Value Estimate of Probability of* Failure on Demand
I. Component (Hardware) Failure Data	
a. Valves:	
Manual Valves (Plugged)	$\sim 1 \times 10^{-4}$
Check Valves	$\sim 1 \times 10^{-4}$
Motor Operated Valves	
• Mechanical Components	$\sim 1 \times 10^{-3}$
• Plugging Contribution	$\sim 1 \times 10^{-4}$
• Control Circuit (Local to Valve)	
w/Quarterly Tests	$\sim 6 \times 10^{-3}$
w/Monthly Tests	$\sim 2 \times 10^{-3}$
b. Pumps: (1 Pump)	
Mechanical Components	$\sim 1 \times 10^{-3}$
Control Circuit	
• w/Quarterly Tests	$\sim 7 \times 10^{-3}$
• w/Monthly Tests	$\sim 4 \times 10^{-3}$
c. Actuation Logic	$\sim 7 \times 10^{-3}$

*Error factors of 3-10 (up and down) about such values are not unexpected for basic data uncertainties.

II. [illegible]n Acts & Errors - Failure Data:

← Estimated Human Error/Failure Probabilities →
← Modifying Factors & Situations →

	With Valve Position Indication in Control Room		With Local Walk-Around & Double Check Procedures		w/o Either	
	Point Value Estimate	Est on Error Factor	Point Value Estimate	Est on Error Factor	Point Value Estimate	Est on Error Factor
A) Acts & Errors of a Pre-Accident Nature						
1. Valves mispositioned during test/maintenance.						
a) Specific single valve wrongly selected out of a population of valves during conduct of a test or maintenance act ("X" no. of valves in population at choice).	$\frac{1}{20} \times 10^{-2} \times \frac{1}{X}$	20	$\frac{1}{20} \times 10^{-2} \times \frac{1}{X}$	10	$10^{-2} \times \frac{1}{X}$	10
b) Inadvertently leaves correct valve in wrong position.	$\sim 5 \times 10^{-4}$	20	$\sim 5 \times 10^{-3}$	10	$\sim 10^{-2}$	10
2. More than one valve is affected (coupled errors).	$\sim 1 \times 10^{-4}$	20	$\sim 1 \times 10^{-3}$	10	$\sim 3 \times 10^{-3}$	10

II. Human Acts & Errors - Failure Data (Cont'd):

← Estimated Human Error/Failure Probabilities →

	Time Actuation Needed	Estimated Failure Prob. for Primary Operator to Actuate AFWS Components
B) Acts & Errors of a Post-Accident Nature		
1. Manual actuation of AFWS from Control Room. Considering "non-dedicated" operator to actuate AFWS and possible backup actuation of AFWS.	∿5 min. ∿15 min. ∿30 min.	$\sim 5 \times 10^{-2}$ $\sim 1 \times 10^{-2}$ $\sim 5 \times 10^{-3}$

III. Maintenance Outage Contribution

Maintenance outage for pumps and EMOVS:

$$Q_{Maintenance} \approx \frac{0.22\ (\#hours/maintenance\ act)}{720}$$