NUREG/CR-3531
BNL-NUREG-51723

Review of the Seabrook Units 1 and 2 Auxiliary Feedwater System Reliability Analysis

Prepared by A. Fresco, R. Youngblood, I. A. Papazoglou

Brookhaven National Laboratory

**Prepared for
U.S. Nuclear Regulatory
Commission**

The views expressed in this report are necessarily those of the U.S. Nuclear Regulatory Commission.

Availability of Reference Materials Cited in NRC Publications

Most documents cited in NRC publications will be available from one of the following sources:

1. The NRC Public Document Room, 1717 H Street, N.W. Washington, DC 20555
2. The NRC/GPO Sales Program, U.S. Nuclear Regulatory Commission, Washington, DC 20555
3. The National Technical Information Service, Springfield, VA 22161

Although the listing that follows represents the majority of documents cited in NRC publications, it is not intended to be exhaustive.

Referenced documents available for inspection and copying for a fee from the NRC Public Document Room include NRC correspondence and internal NRC memoranda; NRC Office of Inspection and Enforcement bulletins, circulars, information notices, inspection and investigation notices; Licensee Event Reports; vendor reports and correspondence; Commission papers; and applicant and licensee documents and correspondence.

The following documents in the NUREG series are available for purchase from the NRC/GPO Sales Program: formal NRC staff and contractor reports, NRC-sponsored conference proceedings, and NRC booklets and brochures. Also available are Regulatory Guides, NRC regulations in the *Code of Federal Regulations*, and *Nuclear Regulatory Commission Issuances*.

Documents available from the National Technical Information Service include NUREG series reports and technical reports prepared by other federal agencies and reports prepared by the Atomic Energy Commission, forerunner agency to the Nuclear Regulatory Commission.

Documents available from public and special technical libraries include all open literature items, such as books, journal and periodical articles, and transactions. *Federal Register* notices, federal and state legislation, and congressional reports can usually be obtained from these libraries.

Documents such as theses, dissertations, foreign reports and translations, and non-NRC conference proceedings are available for purchase from the organization sponsoring the publication cited.

Single copies of NRC draft reports are available free upon written request to the Division of Technical Information and Document Control, U.S. Nuclear Regulatory Commission, Washington, DC 20555.

Copies of industry codes and standards used in a substantive manner in the NRC regulatory process are maintained at the NRC Library, 7920 Norfolk Avenue, Bethesda, Maryland, and are available there for reference use by the public. Codes and standards are usually copyrighted and may be purchased from the originating organization or, if they are American National Standards, from the American National Standards Institute, 1430 Broadway, New York, NY 10018.

GPO Printed copy price: $6.00

NUREG/CR-3531
BNL-NUREG-51723

Review of the Seabrook Units 1 and 2 Auxiliary Feedwater System Reliability Analysis

Manuscript Completed: October 1983
Date Published: February 1984

Prepared by
A. Fresco, R. Youngblood, I. A. Papazoglou

Brookhaven National Laboratory
Upton, NY 11973

Prepared for
Division of Safety Technology
Office of Nuclear Reactor Regulation
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555
NRC FIN A3393

ABSTRACT

This report presents the results of a review of the Emergency Feedwater System Reliability Analysis for Seabrook Nuclear Station Units 1 and 2. The objective of this report is to estimate the probability that the Emergency Feedwater System will fail to perform its mission for each of three different initiators: (1) loss of main feedwater with offsite power available, (2) loss of offsite power, (3) loss of all AC power except vital instrumentation and control 125 VDC/120 VAC power. The scope, methodology, and failure data are prescribed by NUREG-0611, Appendix III. The results are compared with those obtained in NUREG-0611 for other Westinghouse plants.

TABLE OF CONTENTS

TABLE OF CONTENTS (Cont'd)

LIST OF FIGURES

LIST OF TABLES

LIST OF TABLES (Cont'd)

SUMMARY AND CONCLUSIONS

After the accident at Three Mile Island, a study was performed of the reliability of the auxiliary feedwater system (AFWS) of each then-operating plant with NSSS designed by Westinghouse. The results of that study were presented in NUREG-0611.[1] At the request of the NRC,[2] the Yankee Atomic Electric Company and the Public Service Company of New Hampshire, operating license applicants, have provided the NRC with a study of the Seabrook Units 1 and 2 AFWS,[3] performed using NUREG-0611 as a guideline. BNL has reviewed this study. The BNL conclusions are as follows ("High", "Medium" and "Low" refer to the NUREG-0611 reliability scale).

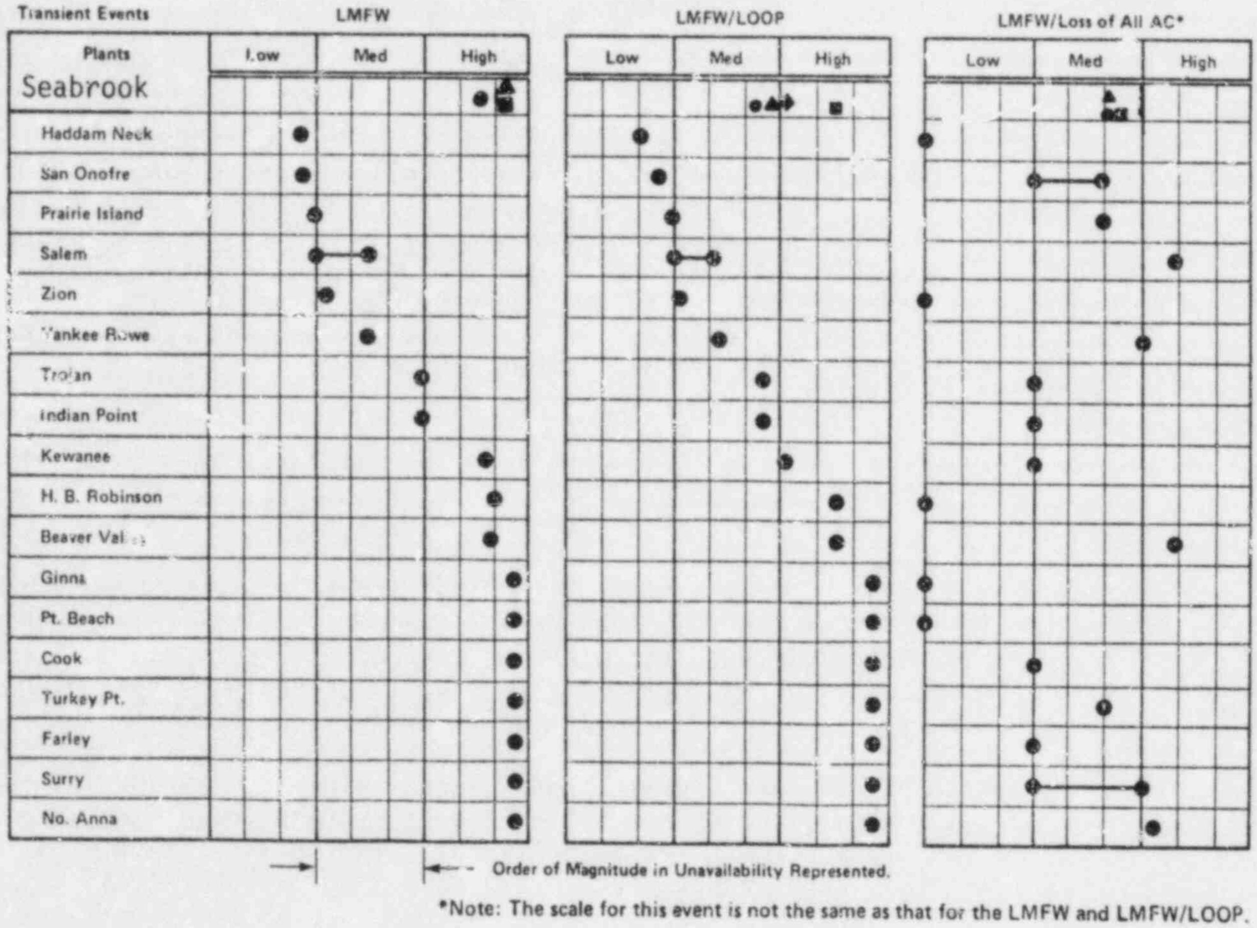
1. For an accident resulting in a loss of main feedwater (LMFW) with offsite power available: The reliability of AFWS is in the High range. (Unavailability = 1.95×10^{-5}/demand.)

2. For a loss of offsite power (LOOP) resulting in a concurrent loss of main feedwater (LMFW): The reliability of the AFWS is in the High range, provided that system design changes as described in the Supplement of this report are implemented. (Unavailability = 8.6×10^{-5}/demand.)

3. For a loss of all AC power (LOAC), except for the 125 VDC/120 VAC vital instrumentation and control power systems, resulting in a concurrent loss of main feedwater (LMFW): The reliability of the AFWS is in the Medium range. (Unavailability = 2.3×10^{-2}/demand.)

The results are summarized in Table 1. Two separate calculations were performed by BNL. The first was based on the Emergency Feedwater system design as it was reported in REF.3. The second was based on modifications proposed by the applicant and contained in a September 7, 1982 letter which appears in Appendix D. Additional modifications were proposed on November 17, 1982 and resulted in a third calculation for the unavailability of the system for LOOP conditions only. The results of the two calculations, as well as the third partial one, are given in Table 1 along with the results of the applicant's analysis. A comparison of the Seabrook AFWS reliability to other AFWS designs in plants using the Westinghouse NSSS is shown in Figure 1.

The design modifications mentioned above are quite significant and are described in Appendix D and the Supplement to this report. In all of the calculations, it was assumed that the Start-Up Feed Pump will be subjected to the same or more stringent Technical Specification outage limitations as the Emergency Feedwater Pumps. If not, the BNL assessed unavailabilities quoted in this report will be subject to substantial increase.



BNL Assessment - NUREG-0611 Scope

● Reference 3 Design

▲ Proposed Design

◆ Supplement Design (Nov. 17, 1982)

Applicant s Results

■ Reference 3 Design

Figure 1: Comparison of Reliability of Seabrook AFWS to Other AFWS Designs in Plants Using the Westinghouse NSSS.

Table 1 Unavailabilities of Seabrook AFWS
Comparison of Applicant's Results
to BNL Assessment

Transient	APPLICANT'S* RESULTS	BNL ASSESSMENT**		
	REF.3 Design	REF.3 Design	Proposed Design	Suppl.Design
1. LMFW	2.1×10^{-5}	4.5×10^{-5}	1.35×10^{-5}	-----
2. LOOP	5.2×10^{-5}	1.8×10^{-4}	1.15×10^{-4}	8.6×10^{-5}
3. LOAC	2.1×10^{-2}	2.3×10^{-2}	2.3×10^{-2}	----

*Using Applicant's Data
**Using NUREG-0611 Data

Note: The Proposed Design refers to the design revisions described in the applicant's letter of September 7, 1982 which appears in Appendix D. After the draft version of this report was transmitted to the NRC, the applicant proposed further changes on November 17, 1982. Those changes and their effect on system unavailability for LOOP are described in the Supplement.

1.0 INTRODUCTION

This report is a review by Brookhaven National Laboratory (BNL) of WLA-1-R-82-02, "Reliability Analysis of the Emergency Feedwater System at the Seabrook Nuclear Power Station", which was prepared by Wood-Leaver and Associates for Yankee Atomic Electric Company and the Public Service Company of New Hampshire.

After the accident at Three Mile Island, a study was performed of the Auxiliary Feedwater Systems (AFWS) of all then-operating plants. The results obtained for operating Westinghouse-designed plants were presented in NUREG-0611.[1] At that time, the objective was to compare AFWS designs; accordingly, generic failure probabilities were used in the analysis, rather than plant-specific data. Some of these generic data were presented in NUREG-0611. The probability that the AFWS would fail to perform its mission on demand was estimated for three initiating events:

(a) loss of main feedwater (LMFW) without loss of offsite power;

(b) loss of main feedwater associated with loss of offsite power (LOOP);

(c) loss of main feedwater associated with loss of offsite and onsite AC (LOAC).

Since then, each applicant for an operating license has been required[2] to submit a reliability analysis of the plant's AFWS, carried out in a manner similar to that employed in the NUREG-0611 study. A quantitative criterion for AFWS reliability has been defined by the NRC in the current Standard Review Plan (SRP) for Auxiliary Feedwater Systems[4]:

> "...An acceptable AFWS should have an unreliability in the range of 10^{-4} to 10^{-5} per demand based on an analysis using methods and data presented in NUREG-0611 and NUREG-0635. Compensating factors such as other methods of accomplishing the safety functions of the AFWS or other reliable methods for cooling the reactor core during abnormal conditions may be considered to justify a larger unavailability of the AFWS."

It should be noted that because of the differences between the applicant's system and the AFWS at most other plants, the applicant has chosen to call his system the Emergency Feedwater System.

2.0 SCOPE OF BNL REVIEW

The BNL review has been conducted in accordance with the methodology, data, and scope of NUREG-0611, Appendix III.(1) It has two major objectives:

(a) To evaluate the applicant's reliability analysis of the AFWS.

(b) To provide an independent assessment, to the extent practical, of the AFWS unavailability.

Unavailability as used in this report has been defined as the "probability that the AFWS will not perform its mission on demand". The term unavailability is used interchangeably with unreliability. Specific goals of this review are then:

(a) To compare the applicant's AFWS to the operating plants studied in NUREG-0611 by following the methodology of the latter as closely as possible.

(b) To evaluate the applicant's AFWS with respect to the reliability goal set forth in SRP 10.4.9, i.e., that the AFWS has unreliability in the range of 10^{-4} to 10^{-5} per demand, using the above methodology.

The NUREG-0611 methodology and the BNL review specifically exclude externally caused common mode failures such as earthquakes, tornados, floods, etc., and internal failures caused by pipe ruptures.

On August 19, 1982, BNL was informed by the NRC that the applicant had proposed certain design changes which are not described in Reference 3. Such changes affect the use of the startup feed pump during loss of offsite power conditions, and also the capability to perform maintenance on valves in the emergency feedwater header and supply lines to the steam generators. Therefore, this report describes and refers to the proposed changes to provide a comparative assessment of both designs. The term "Proposed Design" as used in this report refers to the applicant's proposed changes as described in the August 19, 1982 telephone conversation, and also in the September 7, 1982 letter from the applicant, which appears in Appendix D.

3.0 MISSION SUCCESS CRITERIA

As described in REF.3, for each of the transient conditions analyzed, unreliability was defined as the probability of failure of the combined EFW and startup pump system to start and provide feedwater to at least two of the four steam generators prior to the time that the steam generators would boil dry following a reactor trip from full power. The time required to boil away the water in the steam generators is determined by the initial mass of water contained in them at the time of trip and the amount of decay heat liberated from the core. For the Seabrook Station, this time would generally be in the range of 35 to 60 minutes following a trip from full power operation; therefore, 30 minutes was selected as a conservative mission time for this reliability study.

At the July 15, 1982 plant visit, it was stated that 200,000 gallons of water are required to be available for the design basis shutdown to Hot Shutdown conditions after maintaining the plant at Hot Standby for 2 hours. The hot shutdown conditions are the pressure and temperature of the reactor coolant system at which the residual heat removal system may begin operation.

4.0 SYSTEM DESCRIPTION

4.1 Configuration and Overall Design

The Seabrook Auxiliary Feedwater System, as the term is commonly applied to systems which are used for Startup, Hot Standby and Hot Shutdown, consists of the single pump of the Startup Feed Pump System (SUFPS) and its associated components, all of which are non-safety class. The SUFPS is augmented by the two pumps of the Emergency Feedwater System (EFWS), both of which are safety-class. For the purposes of the analysis, the applicant has defined the combination of the SUFPS and the EFWS as the Auxiliary Feedwater System (AFWS). The AFWS is described in REF.3 as follows:

4.1.1 Startup Feedpump System

The elements of the startup feedpump (SUF) system at Seabrook are shown in Figure 2. The system consists of a single motor-driven pump, P-113, capable of supplying 1500 gpm at 3000 feet of head. The pump takes suction from the Condensate Storage Tank (CST) via the main condensate makeup line. The suction line between the pump and CST is equipped with three normally open manual isolation valves, V-152, V-143 and V-141 (see Figure 5). The discharge headers from the pump attach to six other feedwater system headers, i.e., the main feedwater pump discharge header, the high pressure feedwater heater outlet header, the condensate pump discharge header, the make-up header from the CST, the steam generator recirculation pump discharge header, and the EFW pump discharge header. The pump is also equipped with a recirculation line to the CST for pump protection and testing. Flow through the recirculation line is controlled by a pressure-controlled throttling valve, PCV-4326, that senses pressure at the pump discharge.

With the exception of the main feedwater pump discharge header, the discharge from the startup pump is isolated from all feed system headers by at least one normally closed valve. The supply path to the main feedwater pump discharge header is normally open but is equipped with a manual gear-operated valve, V-100, to allow isolation if necessary. Flow to the EFW pump discharge header is prevented during normal operation by two normally closed manual gear-operated isolation valves, V-163 and V-156.

> BNL Comment: In a conference call on July 26, 1982, the applicant stated that V-156 would be locked closed with the key under administrative control. V-163 would not be locked closed. Thus, under a LOOP condition, the operator would be required to open a locked-closed valve, V-156, if the EFW header is to be used.

During startup, lubrication of the SUF pump is provided by a motor-driven auxiliary lube oil pump, P-161. Operation of the auxiliary lube oil pump is controlled by SUF pump lube oil pressure. When the SUF pump is in the AUTO control mode, startup of the lube oil pump will be followed by start of the SUF pump when sufficient oil pressure is established. Once started, a shaft-driven lube oil pump located on the SUF pump supplies lubrication and the auxiliary

lube oil pump is stopped. Should the shaft-driven pump fail, the auxiliary oil pump will automatically restart.

In its normal operating mode the SUF pump will start automatically on a trip of both main feed pumps (LMFW) unless a safety injection or high-high steam generator level signal also occurs.

BNL Comment: At the July 15, 1982 plant visit, the applicant stated that the basic design philosophy of the SUFPS is that the system is used for all normal plant startups and shutdowns and also for most, if not all, LMFW transients. Therefore, the EFWS would not be automatically activated for a LMFW transient unless a safety injection, a low-low steam generator level, or a loss of offsite power (LOOP) signal also occurs. The applicant considers LMFW to be a part of normal plant operating conditions.

4.1.2 Emergency Feedwater System

The EFWS is a standby system which would not be operated during normal plant operation except in case of a loss of the SUFPS during a startup or a shutdown or after a LMFW. The EFWS is automatically actuated upon an Engineered Safety Feature (ESF) actuation signal, i.e., a loss of offsite power (LOOP), low-low level in any steam generator, or any safety injection signal. The system is described in REF.3 as follows:

A schematic of the EFWS at Seabrook is shown in Figure 3. The system consists of two pumps, each supplied by individual suction lines from the CST. Each pump has a design flow of 710 gpm at a head of 3050 feet and is capable of providing full cooling of the Reactor Coolant System in emergency situations. One pump, P-37B, is driven by an AC motor which is powered by one of the 4160V plant emergency buses. The second pump, P-37A, is steam-turbine driven with steam being supplied from either of two steam generators. Take-off points for the turbine steam supply lines are upstream of the main steam isolation valves, thereby ensuring motive power to the turbine even in the event of steam line isolation. Both pumps are attached to a common return to the CST which is used for pump testing. This return line is isolated during normal operation.

During operation of the EFW system, both pumps discharge into a common header, which in turn supplies four individual supply lines to each of the four steam generator main feed lines. Each emergency feed line joins its associated main feedwater header downstream of the feedwater isolation valve and outside of containment.

The emergency feedwater supply lines are each equipped with two motor-operated flow isolation valves and a flow limiting venturi. The valves are normally open and are designed to fail "as-is" on loss of power. The valve positions are set such that they assure a minimum of 235 gpm to each steam generator during normal operation with both EFW pumps running. The control systems for the valves are designed to isolate an emergency feed supply line if flow in the line exceeds a pre-set high flow value. This feature prevents di-

version of EFW flow following a line break in any steam generator. A single flow orifice located between the isolation valves in each line provides differential pressure information to the control equipment for flow measurement. Two separate flow transmitters are used to provide independent high flow isolation signals to each of the isolation valves. The flow transmitters, control equipment, and motor-operators for the valves upstream of the flow elements are powered by train B emergency electrical buses, while those downstream of the flow elements are powered by train A buses.

Assuming both EFW pumps are running, flow through any EFW line is limited to a maximum of 750 gpm by a flow limiting venturi also located between the isolation valves. This flow limitation provides runout protection for the EFW pumps in the event of depressurization of any steam generator. The venturis provide an added benefit in that a pipe break in any steam generator, along with failure of both isolation valves in the associated EFW line, will not cause a complete loss of cooling water to the remaining steam generators.

Each supply line is also equipped with a non-return valve which prevents the EFW system from being subjected to normal steam generator pressures when the EFW system is not in use.

The pump discharge headers and the common emergency feedwater header are equipped with a total of five isolation valves that are used to segregate various parts of the system for testing and maintenance activities. These valves are all manual, gear-operated valves that are locked open when the system is in its normal readiness state. The pump discharge headers are also equipped with check valves to prevent reverse flow through a pump during operation with the pump out of service. Flow diversion through the pump recirculation lines is prevented during normal operation by normally closed manual valves in each recirculation header. The recirculation lines are also equipped with pressure reducing orifices that will limit flow should the manual valves be left open.

> BNL Comment: At the June 23, 1982 meeting at the NRC offices, the applicant stated that the maximum flow through the recirculation lines is 220 gpm. There is no recirculation during the normal operation of the EFWS. The recirculation lines are used for pump testing. The pump performance at 220 gpm is matched against the manufacturer's performance curve for the TDH at 220 gpm. Any deviations would be noted. There are no provisions for full flow pump testing.

Each pump suction line to the CST contains two manual isolation valves, one in the tank yard (V-154 and V-158), and one in the emergency feed pump building (V-155 and V-159). Both valves are normally open and locked in position.

> BNL Comment: At the July 15, 1982 plant visit, the applicant stated that the CST has a design capacity of 400,000 gallons and that under virtually all plant conditions, the normal level would be this amount. Of the 400,000 gallons, 200,000 gallons is reserved for the EFWS. The connec-

tions for the EFWS are at the base of the CST. The SUFP normally draws water from a connection on the main condensate make-up line which is connected to the CST above the 200,000 gallon level. However, the SUFP can also draw water from the base of the CST through a normally closed, locked valve. This is not shown on Figure 3.

The steam supply lines for the turbine-driven EFW pump are shown in Figure 4. Steam can be supplied to the turbine from either steam generator "A" or "B". Steam from either steam generator is supplied to a common header through air-operated, fail-open valves, V-127 and V-128, that are actuated by an engineered safety feature (ESF) actuation signal. Both valves will open as a result of a loss of offsite power, low-low level in any steam generator, or any safety injection signal, any one of which will also automatically start the motor-driven pump as well.

Each steam supply line is equipped with a check valve, V-94 and V-96, to prevent diversion of steam from the turbine in the event of a pipe break in one of the steam lines. The common supply header to the turbine-driven pump contains a normally open manual isolation valve, V-95, used during turbine maintenance and a spring-loaded mechanical trip valve that closes on turbine overspeed, V-129.

Oil cooling for the turbine-driven EFW pump bearings is provided by an oil cooler supplied directly from the discharge of the turbine-driven pump. The cooling flow is discharged to the common recirculation header.

BNL Comment: See Appendix D for additional design information regarding the air supply for the actuators of V-127 and V-128.

4.2 Component Design Classification

The applicant has not specifically identified the design classification of each component, except to say that all components in the SUFPS are non-safety class up to the normally closed, locked manual valve V-156. The entire EFWS, including the CST, is safety-class. There are no makeup lines to the CST, either safety or non-safety class, which can provide flow at the same rate as one of the EFWS pumps, i.e., 710 gpm.

4.3 Power Sources

As described in REF.3, emergency electrical power for the EFW and SUFP systems is supplied from both 4160V emergency AC buses and both vital DC instrument buses. Power for the motor-driven EFW pump is taken from emergency AC bus E-6 and diesel generator 1B, while the SUF pump, via operator action described in Section 5.2, can be powered from emergency AC bus E-5 and diesel generator 1A. The auxiliary lube oil pump used when starting the SUF pump is also supplied power by bus E-5 through buses E-52 and E-53. Control power for the motor-driven EFW train is taken entirely from vital DC instrument bus 11B. Control power for the steam-turbine admission valves is supplied from both ESF

trains, one valve receiving control power from DC bus 11A in train A, and the other receiving power from DC bus 11B in train B. There are no AC power dependencies in the turbine-driven EFW pump train. Electrical power for the EFW isolation valves also comes from the emergency buses, and train separation criteria are met for each EFW supply line.

> BNL Comment: The SUFPS is normally supplied power from the non-safety station electrical grid. During a LOOP condition, such power is not available and local manual transfer to the emergency sources is required to operate the SUFP.

4.6 Instrumentation and Controls

As described in REF.3, the control room operator at Seabrook has available a variety of instrumentation and controls that allow him to monitor and direct operation of both the emergency feedwater system and the startup feed pump. The important equipment relative to EFW and SUF system operation is listed below:

Instrumentation	Location
o Operating status lights for the motor-driven EFW pump, P-37B	Control room/remote safe shutdown panel
o Position indication lights for both steam admission valves, V-127 and V-128, to the turbine-driven EFW pump, P-37A	Control room/remote safe shutdown panel*
o Suction and discharge pressures for both EFW pumps	Control room/local
o Flow indication for each emergency feedwater supply line	Control room/remote safe shutdown panel
o Three narrow-range and one wide-range level transmitter in each steam generator	Control room/remote safe shutdown panel
o Steam pressure in each steam generator	Control room
o Dual CST level transmitters	Control room

*Position indication is available at the remote shutdown panel only for valve V-127.

BNL Comment: In Appendix D, it is stated that V128 will also have position indication on the remote panel.

Alarms	Location
o Trip alarm for motor-driven EFW pump, P-37B	Control room
o Alarms indicating local operation of either EFW pump	Control room
o Low suction pressure alarms for both EFW pumps	Control room
o Startup feed pump, P-113, trip alarm	Control room
o Startup feed pump pre-lube pump, P-161, running alarm	Control room
o Low and low-low level alarms in each steam generator	Control room
o CST low level alarms	Control room
o SI actuation alarm	Control room
o Pump motor bearing and winding temperature alarms	Control room

BNL Comment: It is not stated whether this applies to the SUFP also.

o Emergency feed pump valves misaligned	Control room

BNL Comment: We assume this applies to V-65, V-67, V-71 and V-73 only.

o SUF pump powered from bus E5	Control room

Controls	Location
o Manual/auto controller for motor-driven EFW pump	Control room/ switchgear room
o Manual/auto controller for turbine-driven EFW pump steam admission valve	Control room/remote safe shutdown panel*
o Manual/auto controller for each EFW flow limiting valve	Control room/remote safe shutdown panel
o Manual/auto controller for startup feed pump	Control room
o Manual/auto controller for startup feed pump prelube pump	Control room

*Only steam-admission valve V127 can be controlled at the remote shutdown panel.

BNL Comment: In Appendix D, it is stated that V128 will also be controllable from the remote panel.

Automatic Actuation Signals	FFW Function
o Safety injection signal	Starts both EFW pumps
o High flow to one S/G	Close both EFW isolation valves in line with high flow
o Low-low level in any steam generator	Starts both EFW pumps
o Loss-of-offsite power signal	Starts both EFW pumps

Automatic Actuation Signals	FFW Function
o Trip of both main feed pumps	Starts SUF pump*
o Low bearing oil pressure at SUF pump	Starts SUF prelube pump

* This signal is prohibited if either a safety injection or steam generator high-high level signal is present.

5.0 EMERGENCY OPERATION

5.1 Loss of Main Feedwater

In the case of LMFW, the SUFP prelube pump receives an automatic signal to start, followed by the SUFP itself upon tripping of both MFW pumps. The SUFP is normally aligned to the main feedwater nozzles upstream of the main feedwater isolation valves (MFWIVs). See Figure 5, which is a simplified sketch showing the normal alignment of the SUFPS to the MFW flowpaths to the steam generators. The sketch was prepared by BNL based on FSAR Figure 10.4-4, Sh-1, "Condensate System, P&I Diagram", and Figure 10.4-5, "Feedwater System, P&I Diagram". There are no manual actions required for the SUFP to supply water to the steam generators unless the suction source line from the CST or the discharge to the MFW nozzles are unavailable. The connection from the SUFP to the EFW header is left closed. The SUFP initiation will be blocked if there is a concurrent safety injection or high-high steam generator level signal.

If the SUFP should fail to operate, the EFWS pumps will be automatically actuated upon low-low level in one or more of the steam generators. The EFWS pumps and header are not normally used for this transient.

5.2 Loss of Offsite Power - REF.3 Design

In the case of LOOP, the EFWS pumps are given an automatic signal to start and no additional actions are required for the pumps to supply water to the EFW header and into the steam generators.

The SUFP cannot supply water through its usual flowpaths to the MFW supply lines to each steam generator because the flowpath connections are upstream of the MFWIVs. The latter are air-operated piston valves which close upon loss of air supply. The footnote on page 29 of REF.3 implies that this will occur as the air compressors lose power from the offsite sources. Also, the normal AC power sources are no longer available to the SUFP. Providing AC power to the SUFP and aligning the pump to the EFW header requires several operator actions which must be taken outside of the Control Room, under the relatively adverse lighting conditions of a loss of offsite power. Such actions are described in REF.3 as follows:

In order to provide power to the SUF pump from an emergency AC bus, an operator must manually "rack out" the SUF pump breaker from bus 4 located in the non-essential switchgear room, move it to the essential switchgear room, and manually "rack in" the breaker to emergency bus E5. He must also change the bus transfer switch to the E5 bus position. The breaker has been equipped with built-in rollers to facilitate moving it from room to room. In addition, the two switchgear rooms are adjacent to each other, minimizing the distance that the breaker must be moved.

Aligning of the SUF pump with the EFW systems also requires an operator (or operators) to change the position of three manual isolation valves. One of the valves (V-109) must be closed to prevent possible flow diversion of the SUF

pump discharge to the condensate tank via the SUFP recirculation line should power be lost to the SUFP recirculation valve (PCV-4326). The remaining two valves (V-156 and V-163) must be opened to connect the SUF pump discharge header to the EFW system header. Valves V-109 and V-163 are located in the turbine hall. Valve V-156 is in the emergency feed pump room, and is locked in the closed position (see Section 4.1.1).

Proposed Design Changes

On page 29 of REF.3, a footnote states that upon loss of offsite power, the MFWIVs automatically close. In the July 26, 1982 conference call, BNL questioned the correctness of this statement, since normally MFWIVs only close upon a steamline or feedwater line break. In this specific case, if the MFWIVs do indeed close, the SUFP can no longer supply water to the steam generators through the main feedwater lines and the EFW header must be used. The entire analysis in REF.3 is based on the assumption that for LOOP, the MFWIVs close and therefore several manual valve operations have to be performed outside the Control Room, as previously described, to align the SUFP to the EFW header.

If the MFWIVs do not close upon LOOP, BNL has assumed in its analysis that the actions required to use the SUFP are the following:

(a) Since the SUFP is already aligned to the MFW supply lines, no valve closures are necessary. This includes V-109 in the recirculation line.

(b) Electrical power must be supplied from Diesel Generator 1A to the SUFP and the prelube pump. Also, the instrument air compressor must be manually loaded on to the diesels to allow operation of the MFW flow control valves which are used to control steam generator level from the SUFP. Such electrical power is not available until after the diesels have completed their automatic sequencing of the essential loads.

The above matter is clarified in the supplement to this report.

5.3 Loss of All AC Power - REF.3 Design

In the case of LOAC, the system is basically reduced to a situation in which the only available pump is P-37A, the turbine-driven pump of the EFWS. Power to P-113, the SUFP, and to P-37B of the EFWS, both motor-driven, will not be available. Since the steam supply valves, V-127 and V-128, are air-operated, fail-open valves that are actuated by a LOOP signal, and also since the air supply is lost upon LOAC, the turbine-driven pump P-37A will automatically start. No further alignment or operator actions are required to start the pump. It is not stated in REF.3 if control of steam generator level could be accomplished under such conditions.

Proposed Design

The proposed design changes do not have a very significant effect on the reliability analysis for the case of LOAC. The only change is in the addition of safety class accumulators for the air operators of the steam supply valves, V-127 and V-128, as per Appendix D.

6.0 TESTING

According to REF.3, the procedure for testing pump P-37A or 37B is to close either manual isolation valve V-65 or V-71 and open manual valve V-67 or V-73 to recirculate emergency feedwater to the condensate storage tank. In the case of the turbine-driven pump, P-37A, only one of the steam supply valves, V-127 or V-128, is used for each test. Therefore, the testing of each valve and its control circuitry is alternated between one test and the next.

The SUFP can be tested in several ways. One method would be through the normally open manual valve V-100 in the line which connects the SUFP discharge to the discharge line of the main feedwater pumps. Another would be to close V-100 and recirculate water to the condensate storage tank through PCV-4326, which will open automatically on high pump discharge pressure. However, if the SUFP is needed, PCV-4326 will automatically close as pump discharge pressure decreases, thereby eliminating possible flow diversion. Neither of these test methods changes the configuration of the SUFP; therefore, no test outage was applied (by the applicant) to the SUFPS.

> BNL Comment: As discussed in Section 5.2, the EFWS pumps are tested at a flow rate of 220 gpm, but not at full flow. The test flow rate for the SUFP has not been specified by the applicant, although it appears that the SUFP can be full flow tested directly into the steam generators by pumping through V-100.

7.0 TECHNICAL SPECIFICATIONS

The proposed Seabrook Technical Specifications[5] for the Emergency Feedwater System are as follows:

LIMITING CONDITION FOR OPERATION

At least two independent steam generator emergency feedwater pumps and associated flow paths shall be OPERABLE with:

a. One motor-driven emergency feedwater pump capable of being powered from an emergency bus, and

b. One steam turbine-driven emergency feedwater pump capable of being powered from an OPERABLE steam supply system.

APPLICABILITY: Power Operation, Startup, Hot Standby

ACTION

a. With one emergency feedwater pump inoperable, restore the required emergency feedwater pumps to OPERABLE status within 72 hours, or be in at least HOT STANDBY within the next 6 hours and in HOT SHUTDOWN within the following 6 hours.

b. With two emergency feedwater pumps inoperable, be in at least HOT STANDBY within 6 hours and in HOT SHUTDOWN within the following 6 hours. Initiate corrective action to restore at least one emergency feedwater pump to OPERABLE status as soon as possible.

SURVEILLANCE REQUIREMENTS

The emergency feedwater system shall be demonstrated OPERABLE:

a. At least once per 31 days by:

1. Verifying that motor driven pump develops a discharge pressure of greater than or equal to * psig at a flow of greater than or equal to * gpm.

2. Verifying that the steam turbine driven pump develops a discharge pressure of greater than or equal to * psig at a flow of greater than or equal to * gpm when the secondary steam supply pressure is greater than * psig. The provisions of Specification 4.0.4** are not applicable for entry into the HOT STANDBY mode.

3. Verifying that each valve (manual, power operated, or automatic) in the flow path that is not locked, sealed, or otherwise secured in position is in its correct position.

*These values were not specified at the writing of this report.
**See Specification 4.0.4 next page.

b. At least once per 18 months during shutdown by:

1. Verifying that each automatic valve in the flow path actuates to its correct position upon receipt of a runout protection test signal.

2. Verifying that each emergency feedwater pump starts as designed automatically upon receipt of an emergency feedwater actuation test signal.

*Specification 4.0.4. Entry into an OPERATIONAL MODE or other specified condition shall not be made unless the Surveillance Requirement(s) associated with the Limiting Condition for Operation have been performed within the stated surveillance interval, or as otherwise specified.

The proposed Seabrook Technical Specifications[5] for the Condensate Storage Tank are as follows:

LIMITING CONDITION FOR OPERATION

The condensate storage tank (CST) shall be OPERABLE with a contained water volume of at least 200,000 gallons of water.

APPLICABILITY: Power Operation, Startup, Hot Standby

ACTION

With the condensate storage tank inoperable, within 4 hours restore the CST to OPERABLE status or be in at least HOT STANDBY within the next 6 hours and in HOT SHUTDOWN within the following 6 hours.

SURVEILLANCE REQUIREMENTS

The condensate storage tank shall be demonstrated OPERABLE at least once per 12 hours by verifying the contained water volume is within its limits when the tank is the supply source for the emergency feedwater pumps.

Surveillance requirements for inservice inspection and testing of ASME Code Class 1, 2 and 3 components of the Emergency Feedwater System, including the Condensate Storage Tank, are detailed in REF.2.

BNL Comment: The applicant's Proposed Technical Specifications comply with Recommendation GS-1 of NUREG-0611 that the outage time for one AFW system flow train and essential instrumentation be limited to 72 hours, and that the subsequent action time by which the plant must be in the HOT SHUTDOWN condition is 12 hours.

It should be remarked that 4.7.1.3.1 implies that the EFW pumps have an alternate water source besides the CST itself. Such an alternate source is not mentioned anywhere in REF.3.

8.0 ASSUMPTIONS

The applicant has made the following assumptions in the pre[illegible] the analysis. BNL comments are provided both here and in Section 9.0 [illegible] necessary:

8.1 General Failure Data

Previous analyses similar to the one presented here that have been conducted by other utilities owning plants designed by Westinghouse have generally had as an objective a comparative evaluation of the reliability of a specific emergency feedwater system with generic reliability analyses reported by the NRC staff in NUREG-0611. However, the October 30, 1981 letter to Seabrook (see Appendix C) specified a quantitative reliability goal for emergency feedwater system performance. For that reason the component failure data presented in NUREG-0611 were considered to be too general to allow an accurate fault tree analysis of system unreliability to be performed. Therefore, it was decided that the best failure information available to date would be incorporated in this study. The following section presents that data and the sources from which they were taken.

Table B.1 (Appendix B) presents a compilation of data for various failure modes of different power plant components, both mechanical and electrical. The data were extracted from the following sources:

a) The Reactor Safety Study (WASH-1400),

b) GE-22A2589, Recommended Component Failure Rates, May 1974,

c) IEEE-Std 500-1977, Nuclear Reliability Data Manual,

and the following reports from the Licensee Event Report (LER) evaluation program:

a) NUREG/CR-1205, Data Summaries of LERs of Pumps

b) NUREG/CR-1362, Data Summaries of LERs of Diesel Generators

c) NUREG/CR-1740, Data Summaries of LERs of Selected Instrumentation and Control Components

d) NUREG/CR-1363, Data Summaries of LERs of Valves

The data values obtained from the above references are presented in Table B.1 for each failure mode for which data from that reference was applicable. To avoid ambiguity where multiple values are presented for a single failure mode, Table B.1 indicates the recommended value that was used in the fault tree analysis. In the cases where multiple data values exist, engineering judgment was used to determine the most appropriate data based on similarity of the plant component, function and environment to the equipment represented by the data.

The unreliabilities calculated exclude any consideration for the causes or probabilities of the specified transient conditions, nor do they consider external common mode failure initiators such as earthquakes, floods, etc.

BNL Comment: These aspects of the data comply with the NUREG-0611 guidelines.

In some instances the data presented in the referenced sources were either too general or the component data were obtained on like components having dissimilar functions. In particular, NUREG/CR-1205 presents component failure data for pumps by generic classification, namely, running, alternating and standby. However, review of the LERs revealed that sufficient data were available to extract specific component data for motor and turbine driven auxiliary feedwater pumps.

Similarly, the generic values presented in NUREG/CR-1363 for safety/relief valve failure rates were calculated using primary side components (i.e., pressurizer relief valves, pump relief valves, etc.) only. The components of interest in the Seabrook fault tree were the steam generator safety/relief valves. A limited amount of data existed in the LERs on secondary safety/relief valve failures. Also, it was noted that licensees do not always report relief valve failures since no credit is taken for them in accident analyses. To compensate for these facts, the values presented in Table B.1 for safety and relief valve premature opening were calculated using the information available in NUREG/CR-1363 and applying a factor of 5 to the safety valve failure rate and a factor of 10 to the relief valve failure rate.

One further point should be mentioned as to the conservative bias built into some of the data. In particular, the failure rates of the diesel generator, as taken from NUREG/CR-1362 for weekly testing, are 1.0×10^{-2}/d for the failure to start mode, and 6.0×10^{-3}/hr for the failure to run mode. These failure rates are calculated assuming that all plant diesel generators are tested weekly. However, this does not account for the many starts of the diesel generators which occur outside of normal testing periods. Therefore, the number of demands on the diesel generators is underestimated while, conversely, the number of failures reflects diesel generator failures which occur during all phases of operations. For those reasons, the failure rates from NUREG/CR-1362 associated with weekly testing were considered to be most representative of the diesel failure frequencies to be expected at the Seabrook station.

BNL Comment: While the applicant's arguments for developing independent data may be very legitimate, the scope of the BNL review is to assess the applicant's design using NUREG-0611 data wherever possible. Therefore, BNL has made no attempt to verify any of the data used by the applicant.

8.2 Treatment of Time Dependent Failures

Failure rates used in the fault tree analysis are either demand dependent or time dependent. Demand dependent failure rates are applied to static com-

ponents which are required to change position or state to perform their required function. Examples are the auxiliary feedwater pumps which are required to start on demand and certain valves, such as the steam turbine inlet valves (V-127 and V-128), which are required to change state upon receipt of the appropriate actuation signal.

Time dependent failures are characterized by the necessity of a component to maintain condition, position or status in order to perform its required function. Examples are the auxiliary feedwater pumps which must continue to run once started, valves which must maintain their position (e.g., remain open), and electrical components which must maintain their status (e.g., pump breakers do not trip) for the entire mission time prescribed for a particular transient. Time dependent failures are also characteristic of components which are in a standby condition and which could fail prior to operation.

The unavailability of a time dependent component is calculated from the hourly failure rate and a mission time for operating components, or a testing interval for standby components. The time interval used is dependent on the testing frequency, the actuation circuitry employed, and the operational requirements of a component for the transient being considered. For example, consider the actuation circuit of the motor-driven emergency feedwater pump (P-37B) shown in Figure 6. This pump can be started automatically on receipt of either a safety injection signal, a loss of offsite power signal, or on a low-low steam generator water level signal. It can also be started manually from the control room by the operator using manual/auto control station CS-4255-1. The Technical Specifications require that the motor-driven EFW pump be tested every month. During these tests the pump will be started manually from the control room using CS-4255-1. This procedure will also test the integrity of the control circuit from CS-4255-1 to the pump. Therefore, for certain failure modes of the control circuits, the proper testing frequency would be calculated from the one month testing interval, i.e.,

$$t = [30 \text{ days} \times 24 \text{ hours/day}]/2 = 360 \text{ hours}.$$

In comparison, the tests of EFW system components to actuate on an automatic signal will be performed only every 18 months. The unavailability of a component due to failure to receive an automatic actuation signal would therefore be calculated on the basis of the following time interval:

$$t = [18 \text{ months} \times 720 \text{ hours/month}]/2 = 6480 \text{ hours}.$$

It is assumed that for the monthly test of the turbine-driven emergency feed pump only one of the two steam admission valves is opened and that these valves are used alternately from one test to the next. Therefore, the control circuitry to the steam inlet valves V-127 and V-128 would each be tested on a bi-monthly interval, and the unavailability of these valves due to failures of the control system are calculated using the following interval:

$$t = [60 \text{ days} \times 24 \text{ hours/day}]/2 = 720 \text{ hours}.$$

The unavailability of components which are required to operate or maintain condition are calculated using the mission time. In the study presented here the mission time is the time in which the steam generators would boil dry given an insufficient supply of water from the emergency feedwater system.

The unavailability of each failure event used in the Seabrook fault tree analysis, defined using the criteria discussed above, is presented in Table B-2 (Appendix B).

> BNL Comment: The applicant has performed a commendable action by extending the scope of the analysis to consider time dependent failures. However, the mission time which has been assumed is only the 30 minutes in which the steam generators would boil dry given an insufficient supply of water from the Emergency (or Auxiliary) Feedwater System. There appears to be no logical basis for assuming the boil dry time to be the proper mission time. The proper mission time should be the time interval from the actuation of the AFWS until the plant has achieved hot shutdown conditions (generally about 8 hours), or until offsite power is restored, typically at least 30 minutes. In any case, running failures were not considered in NUREG-0611 because such failures are usually small when considered within the relatively short mission time of AFWS required operation. One exception is the running failure rate of diesel generator plants given in WASH-1400, 3×10^{-3}/hr. The diesel generators are usually required to operate for only 30 minutes to 1 hour, the average duration of a LOOP incident. For the above reasons, running or time dependent failures have not been considered in the BNL assessment using NUREG-0611 data.

8.3 Test and Maintenance Outages

According to REF.3, the applicant's assumptions regarding test and maintenance outages are as follows:

In addition to a component being unable to accomplish its function due to mechanical or electrical faults, a component may be unable to respond to a system demand because that component is out of service due to maintenance or testing. Technical Specifications limit the time during which some components can be unavailable and the plant still maintained at full power conditions. At Seabrook one such limit applies to the EFW system. In the event that an emergency feedwater pump is disabled, restoration must occur within 72 hours or the plant must be placed in a Hot Standby condition. This 72 hour limit is assumed to apply also to pump discharge isolation valves if they require servicing.

All other components within the emergency feedwater system at Seabrook are assumed to have no time restrictions in relation to plant operation. However, the assumption was made that combinations of components which disable more than one emergency feedwater supply line could not be taken out of service simultaneously. No maintenance requirements were considered for manually operated valves within the emergency feedwater system since these valves are located in

low energy lines, and position changes, other than those required for testing, do not routinely occur between scheduled outages. Unavailabilities of these valves due to maintenance errors during scheduled outages have been considered and will be described in Section 8.4 (Operator Errors).

BNL Comment: Since technically the SUFP and its associated components are not part of the EFWS, the applicant's assumption that there are no time restrictions on all other components within the EFWS does not necessarily apply to the SUFPS. However, to exclude the SUFPS from any maintenance outage time limitation because it is not a safety class system appears to give an unfair advantage to the Seabrook design when compared to plants which have three safety class auxiliary feedwater pumps. Therefore, BNL has assumed that the SUFPS will be subjected to the same time restrictions as the other AFW systems mentioned.

The applicant's assumptions concerning maintenance of manual valves whose positions would normally never change between scheduled outages is reasonable. There are no specific guidelines in NUREG-0611 regarding which types of valves should be assumed to undergo maintenance.

It should also be noted that the applicant is assuming maintenance on the Emergency Feed Flow Isolation Valves as shown in Table 2. In the July 26, 1982 conversation with the applicant, BNL questioned whether maintenance on the motor-operated isolation valves such as V-75, V-87, V-93 and V-81 (see Figure 3) could be performed without also closing one of the EFW header valves such as V-125, V-126 or V-127, as well as one of the EFW pump discharge valves, V-65 or V-71. Simultaneous closure of one of the discharge valves and one of the header valves dramatically increases the system unavailability during maintenance. In particular, if V-75 is to be maintained, both the SUFP and TDP-37A would become unavailable due to the closure of V-65 and V-125, leaving only MDP-37A feeding three steam generators.

In the August 19, 1982 conversation, the NRC indicated that the applicant is now adding a manual isolation valve immediately upstream of V-75, V-87, V-93 and V-81. The manual valves will be designated V-75, V-87, V-93 and V-81, with new numbers assigned to the motor-operated valves. Also, V-125 will be instrumented in accordance with Regulatory Guide 1.97. BNL interprets that as meaning that position indicated in the Control Room will be provided for that valve. The addition of the manual isolation valves was confirmed in the applicant's letter (Appendix D), although the instrumentation of V-125 was not.

Another point to note is that the EFW feed flow isolation valves are only required by the Technical Specifications to be tested at least once every 18 months during shutdown. Therefore, it is not clear how it would be determined that maintenance on those valves is required and whether it may even be reasonable to assume that no maintenance is performed on those valves during power operation. The applicant does assume maintenance on the manual isolation valves at the discharge of each EFW pump, i.e., V-65

and V-71, because those valves are operated every month to perform testing of the pumps. The maintenance is modeled on the fault trees such that no adjacent valves are isolated at the same time. BNL assumes that only maintenance acts of such a nature that isolation of adjacent valves is not required will be performed. In this regard, the function of the EFW header valves V-125, V-126 and V-127 should be clarified to determine if the valves will be closed at any time during operation at Power, Startup, Hot Standby or Hot Shutdown.

In one other situation, BNL has revised the fault trees to indicate that if maintenance on one of the steam supply valves, V-127 or V-128, is to be performed, then the other valve must also be closed (see Figure 4). It was deemed unreasonable to assume that maintenance could be performed on active main steam lines without taking such actions. The net effect is that a maintenance act on one of those valves causes the pump, TDP-37A, to be unavailable.

The discussion on maintenance and test unavailabilities in REF.3 continues as follows:

Maintenance unavailabilities were calculated from data presented in NUREG/CR-1635, Nuclear Plant Reliability Data System 1979 Annual Reports of Cumulative System and Component Reliability. This source presents average restoration times for various components and failure modes. For those components whose outage times are limited by the Technical Specifications, the average restoration time was assumed equal to 72 hours if the average time specified by NUREG/CR-1635 was greater than 72 hours. The maintenance unavailability for a component was then calculated as follows:

$$Q_{maint} = N \times t_{/T}$$

where: N = number of maintenance acts
t = average component restoration time
T = total component calendar hours.

Note that this calculation introduces additional conservatism because it assumes all maintenance acts are performed while the plant is operating at power. A list of maintenance unavailabilities is presented in Table 2.

BNL Comment: As previously noted, BNL has made no effort to verify this data.

Additional unavailabilities can be assigned to emergency feedwater system components due to periodic testing. In particular, the Technical Specifications require that the emergency feedwater pumps be started every month. Referring to Figure 3, the procedure for testing pump P-37A or 37B is to close either manual isolation valve V-65 or V-71 and open manual valve V-67 or V-73 to recirculate emergency feedwater to the condensate storage tank.

The startup feed pump can be tested in several ways (see Figure 2). One method would be through the normally open manual valve V-100 in the line which connects the startup pump discharge to the discharge line of the main feedwater pumps. Another would be to close V-100 and recirculate water to the condensate storae tank through PCV-4326 which will open automatically on high pump discharge pressure. However, if the startup pump is needed, PCV-4326 will automatically close as pump discharge pressure decreases, thereby eliminating possible flow diversion. Neither of these test methods change the configuration of the startup feed pump; therefore, no test outage was applied to the startup feed system. One exception to this assumption is discussed in the section on operator actions (Section 8.4).

BNL Comment: The exception referred to above is the supposed necessity of closing V-109 which isolates the SUFP recirculation line to the Condensate Storage Tank before the SUFP has been aligned to the EFW header. REF.3 states that this local manual operator action is required to prevent diversion of flow from the SUFPS because a LOOP could result in PCV-4326 opening due to loss of air supply. However, in the September 7, 1982 letter (Appendix D), the applicant states that even if the recirculation line to the CST remains open, the maximum recirculation flow rate possible is insufficient to cause a reduction in the SUFP flow capacity to a level at which mission success is jeopardized. Since the SUFP normal flow capacity is 1500 gpm, while each EFW pump has a capacity of 710 gpm and only one of the EFW pumps is required to achieve a flow rate sufficient for mission success, BNL agrees that flow through the SUFP recirculation line cannot cause insufficient flow from the SUFP.

The test frequency for the emergency system is once per month, and the time interval of the test was assumed to be the average test time for pumps of 1.4 hours found in Table III 5-1 of WASH-1400.[6] The unavailability due to testing therefore is:

$$Q_{test} = 1.4/720 = 2 \times 10^{-3}$$

The test unavailabilities and the components to which they apply are shown in Table 2.

BNL Comment: The above test frequency complies with the requirements of NUREG-0611. The applicant assumed, realistically, that all of the pump test unavailability appears only in the EFW pumps' discharge isolation valves V-65 and V-71, since those valves are closed to perform the testing. As such, only item 6(d) in Table 2 has any contribution due to testing shown. Note that the SUFP can be tested by pumping directly into the MFW flow nozzles during power operation so that its test unavailability is assumed to be zero. Also, the diesel generators have been assumed to be available during testing. BNL cannot verify this at this time.

The emergency feed flow isolation valves have been assumed to have a zero test outage time because the Technical Specifications only require that they be tested at least once every 18 months during shutdown. The steam supply valves are normally closed and testing causes them to assume the open position which makes them available. Steam supply valve V-129 is the turbine overspeed protection valve. It can only logically be tested during testing of TD Pump 37-A itself.

8.4 Operator Errors

The following discussion of operator errors appears in REF.3 and refers to the previous SUFPS and EFWS design:

Operator errors can be divided into two basic types: 1) errors of commission, and 2) errors of omission. Errors of commission occur when the operator performs an action which terminates or reverses the normal operation or condition of a component. Examples would be the operator shutting off a running pump or changing the position of a valve.

Errors of omission occur when the operator fails to perform an action which would initiate component operation or place it in its proper operating condition, given that these actions have not occurred automatically. Errors of omission also occur when the operator is the prime mover causing a system to function, such as in the proper alignment of the startup feedwater system to provide backup emergency feedwater flow. This type of error also includes failure to restore valves to their proper position following maintenance test acts.

A description of all operator actions used in the fault tree analysis and their associated unavailabilities are shown in Table 3. The guidelines of NUREG/CR-1278, Handbook of Human Reliability Analysis with Emphasis on Nuclear Power Plant Applications, and NUREG-0611 were used in formulating the unavailabilities.

As a general rule, errors of commission are assigned a probability of 1×10^{-4}, and errors of omission a probability of 1×10^{-3}. These probabilities are adjusted for abnormal circumstances. For instance, a probability of 1×10^{-3} would normally be assigned both to errors of omission by the operator for actions which can be performed from the Control Room, and to maintenance restoration acts. However, if the operation must be performed locally (outside of the Control Room) or under potentially adverse conditions, the failure probability is increased accordingly.

Except for automatic actuation of the lube oil pump (P-161), the startup feedwater system requires manual operation outside of the Control Room for alignment to the emergency feedwater sysem.

BNL Comment: The analysis of REF.3 assumed for conservatism that the SUFP must be aligned to the EFW header for a LMFW transient, although this was never true even under the previous design.

In the event of Loss of Station Power, the operator must manually transfer the startup pump breaker from Bus 4 in the non-essential switchgear room to Bus E5 in the essential switchgear room, change the bus transfer switch to the E5 bus position, open discharge isolation valve V-156 in the emergency feed pump building, open discharge isolation V-163 and close condensate storage tank recirculation line isolation valve V-109 in the turbine hall. This last action (closing V-109) is necessary to prevent a diversion of flow from the startup system because a loss of station power could result in PCV-4326 opening due to loss of air. The operator failure rates for the first three actions are assumed to be 1×10^{-2}/demand because these actions, even though assumed to be covered by emergency procedures, may include multiple steps and must be done at different locations. In contrast, the failure probability assigned to the closing of V-109 is assumed to be only 1×10^{-3}. Since both V-163 and V-109 are located in the same vicinity, it was assumed that a single operator would be assigned the task of changing the position of both valves. Therefore, the failure to complete both actions will be dominated by the failure to perform the first, and the failure probability for the second action is more appropriately represented by the standard failure rate for errors of omission. Thus, the total failure probability for completing both actions is 1.1×10^{-2}.

The loading of the SUFPS on to an emergency bus represents multiple operations (viz., starting the prelube oil pump, moving the pump circuit breaker to the essential switchgear room, starting the SUF pump, etc.). In this case, however, all the controls necessary to start both the SUF prelube pump and the SUF pump are available on the main control board. The only actions required outside the control room are moving of the pump breaker and changing of the bus transfer switch as described earlier. This is likely to be done by one operator following well defined procedures. Therefore, for the purpose of this study, it was judged that a single operator error event could adequately represent failures in the pump loading process.

In addition to using four operator errors that could result in failure of the SUF pump system, special consideration was also given to the failure rates applied to these actions. Even though it is assumed that specific emergency procedures and operator training will be used at Seabrook to ensure proper utilization of the SUF pump during emergencies, the failure rates used in this study for these operator errors is significantly higher (.01/demand) than would normally be expected for situations where well developed procedures are in place and special operator training is provided. Again, use of the higher values was felt to be necessary to reflect the disparity in locations where actions must be performed and because of the short time (30 minutes) available for the actions to be completed.

BNL Comment: As discussed previously, it is not necessary to close V-109, the SUFP recirculation line isolation valve, for either the previous or proposed designs. BNL assumes that more than one operator would be required to perform the valve manipulations because V-156 is located in the EFW pump area, which is a considerable distance from the SUFP, located in

the Turbine Building. In the letter in Appendix D, the applicant states that V-156 will be relocated outside of the EFW pump room area, but not necessarily significantly closer to the SUFP. It is difficult to verify the correctness of the values for human errors assumed in Table 3 on the basis of NUREG-0611 criteria alone. The operator actions required are far more complex and demanding than those described in Table III-2 of NUREG-0611 (Table B-3 of this report).

In the proposed design, which with respect to the use of the SUFP is not really a design change but a correction of the assumptions made in REF.3, it is only necessary to align the SUFP to the EFW header if the MFW flow paths are not available. This will be true for both LMFW and LOOP. For both of these cases, feedwater flow can now be provided through two separate flow paths to each steam generator. This is discussed in more detail in Section 5.0.

9.0 RELIABILITY ANALYSIS

9.1 Qualitative Aspects

9.1.1 Mode of System Initiation

1. LMFW - The SUFPS is automatically initiated upon trip of both MFW pumps, as described in Section 5.1. Should the SUFPS fail to initiate, the EFWS is automatically initiated upon low-low steam generator level. The SUFP and the EFW pumps can also be manually actuated from the Control Room. Therefore, the applicant complies with Recommendation GL-1 of NUREG-0611 that the AFW system flow be automatically initiated using safety grade equipment and that manual start serve as a backup to automatic AFW initiation.

2. LOOP - Only the EFWS pumps are automatically initiated. The SUFPS can only be initiated after completion of the manual actions previously described. However, the applicant still complies with Recommendation GL-1 mentioned above.

3. LOAC - The TD pump 37-A is automatically initiated upon loss of power to its air-operated steam admission valves. Since it is aligned to the CST, it is also capable of providing the required AFW flow for at least two hours independent of any AC power source. Therefore, the applicant complies with Recommendation GL-3 of NUREG-0611.

9.1.2 System Control Following Initiation

1. LMFW - Only the SUFP is normally operating. Steam generator level is maintained by modulating the air-operated flow control valves on the MFW feed lines to the steam generators. REF.3 does not state whether there are provisions for automatic level control, but it is assumed that control can be performed manually from the Control Room.

If, for some reason, the normal water supply to the SUFP, which is above the 200,000 gallon level in the CST, is not available, local manual operator actions can be taken to align the SUFP to the base of the CST by opening locked-closed valve V-142. It can also be manually aligned to the condenser hot well. However, normally there are no manual or automatic actions required to maintain flow from the CST.

2. LOOP - The EFW pumps are automatically initiated so that steam generator level control is now maintained by modulating the redundant AC motor-operated flow control valves on the EFW feed lines to each steam generator. If the SUFP is also operating, it will normally feed through the MFW feed lines. If one of the instrument air compressors can also be connected to the diesel generators, then the air-operated MFW flow control valves could be utilized to control steam generator level. See the supplement to this report for an extended discussion of this subject.

The EFW pumps are aligned only to the base of the CST, and no further manipulations are necessary to maintain the suction source. The SUFP suction source control is the same as described for LMFW above.

3. LOAC - Only the TD pump P-37A will be operating. No EFW flow control is possible because of loss of power to the AC motor-operated flow control valves. As in the LOOP case, the pump is aligned to the base of the CST and no further manipulations are necessary, or possible, nor is AC power required, to maintain the suction source.

According to the listing of Instrumentation and Controls in Section 4.4, the CST has redundant level transmitters and low level alarms which are monitored in the Control Room. Therefore, the applicant appears to comply with Additional Short Term Recommendation I of NUREG-0611 that the licensee should provide redundant level indication and low level alarms in the Control Room for the AFW system primary water supply to allow the operator to anticipate the need to make up water or transfer to an alternate water supply and prevent a low pump suction pressure condition from occurring.

The recommendation also states that the low level alarm should allow at least 20 minutes for operator action, assuming that the largest capacity AFW pump is operating. In the Seabrook design, the CST is a safety class component with sufficient capacity (total 400,000 gallons with 200,000 gallons dedicated to the EFW pumps) to supply water to the SUFP or the EFW pumps to cool the reactor to the Hot Shutdown condition. REF.3 does not state what sources or flow rates are available to the CST, but this subject is discussed in Section 9.1.4.

BNL cannot determine whether any additional operator actions can or should be taken within the 20 minute period. REF.3 also does not state the time available to the operator upon receipt of the low level alarm.

At the July 15, 1982 plant visit, the NRC staff members discussed with the applicant whether the redundant level transmitters and alarms for the CST are safety grade. REF.3 does not state whether there are redundant level transmitters and low level alarms for the upper half of the CST from which the SUFP normally draws suction. The entire subject of the CST instrumentation is currently under review by the NRC staff.

One of the design changes identified in the letter given in Appendix D is the in-stallation of EFW pump minimum recirculation lines. The discharge of one pump will be connected to the suction line of the other pump. This change will minimize the possibility of pump damage if a pump should be actuated with its discharge valve closed. The capacity of the minimum recirculation lines is not stated in Appendix D, but it is assumed that flow to the steam generators cannot be degraded by the recirculation lines.

There appears to be no position indication in the Control Room for any of the suction valves V-154, V-155, V-158 and V-159. According to FSAR Fig. 10.4-4 (Sh. 1) for the Condensate System, V-154 and V-158 which are adjacent to the CST are locked open. However, FSAR Fig. 6.8-1 for the Emergency Feedwater System does not indicate that the valves adjacent to the EFW pumps, V-155 and V-159, are locked open.

9.1.3 Effects of Test and Maintenance Activities

See Section 8.3 for a detailed discussion of this subject.

9.1.4 Availability of Alternate Water Supplies

In the Seabrook design, the EFW pumps are normally aligned to the base of the CST, as discussed in Section 9.1.2. For the reasons mentioned in that section, there are no design basis alternate EFW supplies to the CST. However, a limited make-up flow rate is available from the Demineralized Water System. At the June 23, 1982 meeting at NRC Headquarters, the applicant stated that some other means could be found to supply a limited make-up flow rate to the CST, such as by use of the Fire Protection System. However, no makeup exists that can supply water at the flow rate of one of the EFW pumps.

Since the SUFPS is the applicant's primary means of supplying feedwater to the steam generators in case of LMFW, consideration should be given to its sources of supply. As stated in Section 9.1.2, the SUFPS is normally aligned to the upper half of the 400,000 gallon CST. It can also be aligned to the base of the CST by opening locked-closed valve V-142. If the main condenser is not under vacuum, the SUFP can also take suction from the Condenser Hot Well, according to FSAR Section 10.4.12.2.

Therefore, the applicant should provide further information in the form of emergency procedures governing the transfer to alternate water sources for the SUFPS. On the basis of the information provided in REF.3, the applicant has not provided adequate emergency procedures for transferring to alternate sources of AFW supply, as described in Recommendation GS-4 of NUREG-0611. The procedures should include criteria to inform the operators when, and in what order, the transfer to alternate water sources should take place.

9.1.5 Adequacy and Separation of Power Sources

REF.3 states that a qualitative review of the engineering drawings showed that electrical power sources were found to be sufficiently separated and diverse to prevent dependencies due to power failures. It also states that separation of the SUF and EFW pumps provides protection from electrical train common-cause failures due to localized grounding of power supplies.

See also the discussion in Section 4.3 of this report on Power Sources.

9.1.6 Common Mode Failures

The following discussion has been taken from REF.3:

The cut-set results from the reliability analysis were also used in conjunction with the system engineering drawings to conduct a qualitative review of potential common-cause failure modes of the Seabrook AFW system. During the review, consideration was given to potential dependencies resulting from common location, environment, human interactions, and support equipment for all three

AFW pump trains. As a result of this investigation, two potential susceptibilities were identified.

The first of the common-cause susceptibilities results from a combined location and environmental dependency. Because both emergency feedwater pumps are located in the same pump room, conditions which result in an extreme environment in that room can adversely affect both pumps. An obvious potential source for such an environmental upset are failures associated with the steam turbine-driven pump that cause steam to escape into the pump room. The resultant high temperatures and high humidity might result in consequential failure of the motor-driven pump. Failure of the two EFW pumps alone are not sufficient to fail the AFW system because of the availability of the SUF pump which is located in the turbine building. However, for the SUF pump to be able to supply cooling to the steam generators via the EFW piping requires that manual isolation valve V-156 be opened. This valve is located in the emergency feed pump room and would be inaccessible in the event of extreme environments in the room.

...[I]n many situations it will not be necessary to align the SUF pump with the EFW system in order to use it for plant cooling. Only in circumstances where the normal flow path through the main feedwater lines is unavailable will this be required. Therefore, even should both EFW pumps fail due to a pump room steam leak and valve V-156 also be inaccessible, the ability to cool the plant will still exist in most circumstances.

Most probable causes for steam leaks in the pump room of sufficient severity to cause environmental problems are associated with cracks in the pump turbine casing or breaks in the steam supply lines to the turbine. The most likely cause of the main feedwater lines being unavailable for supplying cooling to the steam generators is a safety injection signal which will cause closure of the main feed isolation valves. The probability of simultaneous occurrence of these events is small compared to the overall system unavailability predicted by the fault tree analyses. Therefore, this common-cause susceptibility has a negligible effect on the system.

A common-cause failure potential often present in systems that incorporate automatic feedwater line isolation features is the possibility of a faulty calibration procedure causing all isolation setpoints to be improperly adjusted. As a result, inadvertent closure of all isolation valves can occur during system startup or following system flow perturbations. The design of the Seabrook system avoids this problem by incorporating control logic to inhibit isolation of more than a single EFW line. Signals denoting the closure of EFW isolation valve in any EFW line will inhibit closure of additional valves in the remaining lines.

No other common-cause susceptibilities were identified which might adversely impact the Seabrook AFW design. Electrical power sources were found to be sufficiently separated and diverse to prevent dependencies due to power failures. With one exception*, all powered valves critical to system operation are of a fail-safe design such that loss of air or loss of power events

*Recirculation valve PCV-4326 on the SUF pump discharge.

do not pose threats to system function. With the exception of the location dependency noted above, separation of the SUF pump from the EFW pumps provides protection from location dependent effects such as vibration, grit, temperature, impact, explosions, etc. Separation of the SUF and EFW pumps also provides protection from electrical train common-cause failures due to localized grounding of power supplies.

BNL Comment: As noted previously in Section 5.2 of this report, if recirculation valve PCV-4326 on the SUFP discharge to the CST should fail open, or if manual valve V-109 is not closed by operator action, the recirculation flow rate to the CST is not large enough to cause insufficient flow from the SUFP. Also, V-156 will be located outside of the EFW Pump Room area. See Appendix D.

9.1.7 Single Point Failures

No single point failures have been found by BNL during the course of review of REF.3 or during the plant visit on July 15, 1982.

9.1.8 Adequacy of Emergency Procedures

Since the Seabrook EFWS is still undergoing design changes at the writing of this report, the applicant was not able to provide adequate emergency procedures. Such procedures should be provided in the future.

9.2 Quantitative Aspects

9.2.1 Applicant's Use of NRC-Suggested Methodology and Data

9.2.1.1 Fault Tree Construction and Evaluation

According to REF.3, the applicant's fault trees were developed in the following manner:

The fault tree model used for this study was developed from an existing fault tree created several years ago as part of a "mini WASH-1400" review of the Seabrook Station. In its original form the tree considered the two-pump emergency feedwater system, but did not include modeling of the startup feed pump. In the initial phases of this study the old fault tree model was reviewed for accuracy and revised as necessary to properly reflect the current EFW system design at Seabrook. In addition, the logic necessary to model the impact of the SUF system on AFW system reliability was incorporated into the trees. As a result, the fault tree now models the entire "three-pump" AFW system as it currently exists in the Seabrook design. In essence, failures of all components shown in Figures 2 through 4 are now considered by the fault tree model. A logic diagram of the complete fault tree is provided in Appendix A.

In addition to component failures, the fault tree also includes logic to consider the effects of failures in interfacing systems on AFW system reliability. Examples are failures of the electrical power sources for the EFW and SUF pump and controls, failures of reactor protection system actuation signals, failures at piping interfaces with the main feedwater/condensate system, failures in the steam generators, and errors by plant personnel while maintaining and operating the system.

BNL Comment: The applicant's fault trees are quite comprehensive and include areas not required by NUREG-0611, e.g., pipe ruptures and running failures. The human errors have been broken down into the following types as shown on Table A.3, Fault Codes:

OA - Operator Fails to Open/De-energize/Disengage

OB - Operator Fails to Close/Energize/Engage

OC - Operator Inadvertently Opens/De-energizes/Disengages/ Leaves Open

OD - Operator Inadvertently Closes/Energizes/Engages/ Leaves Closed

OE - Operator Fails to Start

OG - Operator Fails to Leave Running

Unfortunately, the fault trees were prepared based on the assumption that the SUFP would only be used by aligning it to the EFW header for both LMFW and LOOP. The normal flow path of the SUFP through the MFW feedlines was not modeled into the trees.

In any case, the applicant has exceeded the requirements of NUREG-0611, Figs. III-2 and III-3, concerning the construction and content of the fault trees.

The applicant provides the following additional discussion concerning the fault trees in REF.3:

In a general sense, a loss of main feedwater event is the transient for which the auxiliary feedwater system is intended to provide protection. Therefore, the reliability of the AFW system for the LMFW transient can be viewed as a reference against which reliability calculations for the other transients may be compared. The fault tree described in the previous sections and presented in Appendix A was designed specifically for the LMFW event. Evaluations of the other transients were made by modifying this baseline fault tree as described later.

Before discussing the modifications necessary to model these other events, one point of conservatism regarding LMFW events that has been included into the

fault tree should be reiterated. ...[F]ault tree modeling of the effects of the startup feed pump on AFW system reliability assumed in all cases that the SUF pump was successful only when supplying the emergency feedwater header. As a result, all the operator actions required to achieve this goal must be successful. This includes manually starting the SUF pump and, if necessary, loading it on an emergency bus. It also requires the necessary actions to change the positions of the three valves in the startup pump discharge and cross-tie headers... In many LMFW transients, however, none of these actions will be required. In those transients which result in a trip of the main feed pumps but do not result in either a high steam generator level or a safety injection signal, the SUF pump will be automatically started and will deliver flow to the steam generators by way of the main feed lines. Therefore, no operator actions are necessary to receive the benefit of cooling from the SUF pump. Similarly, if these same transients are accompanied by a loss of the normal SUF pump power source, only the actions to load the SUF pump on the emergency bus and isolate its recirculation line are necessary. Flow can still be provided to the steam generators through the main feedwater lines without additional valve manipulations.* Thus, the fault tree model, by requiring the SUF pump to supply cooling water via the EFW headers in all cases, provides conservative estimates of reliability for these transients where main feedwater flow paths are still available and in which a safety injection or high steam generator level signal is not generated.

The LMFW/LOSP transients impact the EFW system in only one way. They eliminate the redundant electrical power sources for both the motor-driven EFW pump and the motor-driven SUF pump. As a result, the reliability of both pumps is reduced because all single point failures causing loss of the emergency bus supplying the pump will also result in loss of the pump. In the case of the startup pump, the necessity of an operator action to load the pump to the emergency bus is also introduced into the system.

Modeling the loss of offsite power in the fault tree was done by converting gates EP 21 (pg. A-43 of Appendix A) and SUP 21 (Pg. A-38 of Appendix A) to AND gates, converting gates EPE6 (pg. A-43 of Appendix A) and SUP 19 (pg. A-38 of Appendix A), and MOD4 (pg. A-45 to A-48 of Appendix A) to OR gates, and inputting an LOSP frequency of 0. This has the same effect as inputting an LOSP frequency of 1.0 in the reference tree but greatly reduces the computer calculations required to evaluate the tree. All cut-sets and failure probabilities determined for the modified tree will be conditional on the LOSP event even though the code cut-set output will not include specific indication of that fact.

*Note that if the cause of the power loss is a loss of offsite power, the main feedwater lines will not be open because of closure of the main feedwater isolation valves on loss of power.

BNL Comment: This is the footnote which was questioned by BNL and led to the system design clarification concerning the use of the SUFPS.

The total loss of AC power events have a much more drastic effect on AFW system reliability. In essence the system is reduced to a single pump system because both motor-driven pumps become unavailable. Thus, all single point failures disabling the turbine-driven EFW pump result in loss of system function.

For the total loss of AC power events, the fault tree modifications were also more extensive. All tree structures below gates AF127, SUP1, and MOD4 (pgs. A-30, A-41, and A-45 of Appendix A) were eliminated. The net effect is the same as inputting frequency values of 1.0 for both the LOSP event and failure of both diesel generators in that both motor-driven pumps are eliminated from the system. Again code results are conditional on these failures although the conditionality is not reflected specifically in the output.

BNL Comment: The above methods of modeling LOOP and LOAC are functionally correct and acceptable.

9.2.1.2 Failure Data

This subject has been substantially discussed in Section 8.0. In summary, the applicant has developed his own data base resulting in failure probabilities generally lower than those assigned by NUREG-0611. The one case in which the applicant utilized the exact NUREG-0611 specified data is for test outage time of the EFW pumps.

One significant case where the applicant's data is higher than the NUREG-0611 is for random failure of TDP-37A. The NUREG-0611 data specified 3×10^{-3}/demand for Failure to Start of a turbine-driven pump while the applicant has assumed 8.4×10^{-3}/demand.

The applicant's data base is shown in Table B.1.

9.2.2 Applicant's Results

9.2.2.1 System Unavailabilities

The applicant's results as described in REF.3 are as follows:

Computer Codes

All qualitative cut-set analyses and numerical evaluations of unreliability made using the Seabrook AFW system fault tree model were performed by the WAMBAM (7) and WAMCUT (8) computer codes. Versions of these codes were obtained from the Electric Power Research Institute (EPRI) by PSNH and its service organization, Yankee Atomic Electric Co. (YAEC) for the purpose of conducting this study. Some modifications were required to the codes to reduce their memory requirements during execution so that they could be run on the CDC-7600 computer at YAEC; however, the modifications only affected the size of the fault tree that could be analyzed and not the numerical probability calculations or cut-set evaluations performed by the code.

Events Analyzed

Three specific events were analyzed using the Seabrook fault tree. They were:

- o A loss of main feedwater transient with reactor trip (LMFW)
- o A loss of main feedwater transient with coincident loss of offsite power (LMFW/LOSP)
- o A loss of main feedwater transient with coincident loss of offsite power and both onsite emergency diesel-generators (LMFW/LOAC).

In all cases, successful operation of the AFW system required that at least two of the four plant steam generators be supplied with cooling flow from the AFW system.

Numerical Reliability Results

A total of five cases were analyzed with the Seabrook AFW system fault tree model. They were the LMFW, LMFW/LOSP, and LMFW/LOAC events assuming all three pumps are part of the EFW system, and the LMFW and LMFW/LOSP events assuming only the two-train emergency feedwater system is used to provide steam generator cooling. The latter two cases were done to provide a reference for evaluating the effect of the SUF pump on overall system reliability. The results of the five cases are shown in Table 4.

It is clear from these results that the Seabrook AFW system easily meets the NRC specified reliability goals when use of the SUF pump is considered for the LMFW transient. Even with a coincident loss of offsite power, the system exhibits an unreliability of better than 10^{-4}/demand. In terms of the results published by the NRC in NUREG-0611 for other Westinghouse plants, the Seabrook AFW system would fall into the high, high, and medium categories respectively for the LMFW, LMFW/LOSP and LMFW/LOAC transients.

9.2.2.2 Dominant Failure Modes and Conclusions

The applicant's dominant failure modes and conclusions as described in REF.3 are as follows:

Dominant Failures for Three Pump AFW System

Dominant contributors to availability of the AFW system at Seabrook for the three loss of main feedwater/loss of power events are shown in Tables 5, 6 and 7 and Figures 7 to 9. Events are ranked by the magnitude of their contribution to system unavailability. It should be noted that no single point

failures* were found in either the LMFW or LMFW/LOSP events that would disable the entire AFW system, although, as should be expected, a number of single failures will disable the turbine-driven pump train during a LMFW/LOAC event.

Applicant's Conclusions

The results presented in this report lead to the following conclusions:

1. The Seabrook combined auxiliary feedwater system consisting of the two-train emergency feedwater system and the single-train startup feedwater system has an unreliability of 2.1×10^{-5} for a loss of main feedwater event and is well within the range of unreliability specified by the NRC staff in their October 30, 1981 letter to the Public Service Company of New Hampshire (see Appendix C).

2. The unreliability of the Seabrook combined AFW system during combined loss of main feedwater/loss of offsite power events is 5.2×10^{-5}, and for a combined loss of main feedwater/loss of all AC power event is 2.1×10^{-2}. These values compare favorably with analyses done for auxiliary feedwater systems at other plants of Westinghouse design.

3. Major contributors to system unreliability generally relate to failures of pumps and to maintenance errors causing pump trains to be inadvertently disabled.

4. No severe common-cause failure susceptibilities were identified for the Seabrook auxiliary feedwater system.

9.2.3 BNL Assessment

9.2.3.1 Fault Trees

REF.3 Design

The applicant's fault trees were checked for correctness and completeness. As noted previously, a detailed analysis of pipe and valve ruptures, including operator recovery from the effects of the ruptures, has been included on the trees. The trees as constructed do not rule out coincident test or maintenance of more than one pump, either both EFW pumps or the SUFP coincident with one or both EFW pumps. There are also no restrictions incorporated on test or maintenance on any of the valves in the feedlines to each of the steam

*One single failure exists that will disable the AFW system under any circumstance. That is a failure of the condensate storage tank such that no water is available to the suction of any of the pumps. The probability of such a failure was assumed negligible for the purposes of this study.

generators, either in conjunction with pump maintenance or such that 3 out of 4 of the feedlines are isolated due to maintenance. Therefore, the expected contribution within the calculated system unavailabilities due to coincident test or maintenance of components in violation of the Technical Specifications can be expected to be significant. It should be noted that when using the WAMBAM code, the effects of coincident test or maintenance can not be readily identified since the code yields only a numerical result. No listing of specific cutsets is provided as in the WAMCUT code. However, it is only practical to use WAMCUT to identify the coincident test or maintenance contributions at fairly high minimum probability cutoff points. As the cut off point is lowered, the number of cutsets can run into the thousands and the computer time can exponentially increase with diminishing improvement in the final results.

Taking the above factors into account, BNL evaluated the applicant's fault trees using NUREG-0611 data wherever applicable. In addition to the top event, AFW, the following subgates were evaluated:

1. AF91 (pg. A-31) - No Flow to Supply Header From TDP-37A.

2. AF127 (pg. A-32) - No Flow to Supply Header From MDP-37B.

3. SUP1 (pg. A-41) - No Flow to Supply Header From SUPP P-113.

The effects of double and triple maintenance outages and also pipe ruptures and electrical and control wiring faults not included in the NUREG-0611 methodology was estimated by running the WAMBAM code to a cutoff of 10^{-10} for the top event AFW and the subgates listed. The WAMCUT code was also used with a cutoff of 10^{-5}, primarily to obtain a listing of the cutsets for the subgates AF91, AF127 and SUP1 so that a breakdown of the hardware failures versus test or maintenance outages for each of the subgates could be obtained.

A modification was made to the trees to account for the fact that if maintenance is performed on one of the steam admission valves, V-127 or V-128, to TDP-37A, both valves will have to be closed.

Therefore, faults QV1XV12700 and QV1XV12800 were removed from the input of gates AF108 and AF114 (pgs. A-36 and A-37) respectively and combined into a new OR gate designated AF100TM as an input to gate AF100 (pg. A-35) to logically model the fact that TDP-37A will be inoperable.

Proposed Design

After receipt of the August 19, 1982 telephone call from the NRC, BNL determined that no new fault trees were required to obtain an accurate answer for the new design configuration. Fig. 5 is a simplified flow schematic of the

SUFP as it will normally be used for the LMFW and LOOP transients (i.e. the SUFP will be aligned to the MFW flow paths), based upon FSAR Fig. 10.4-4 (Condensate System P&I Diagram) and Fig. 10.4-5 (Feedwater System P&I Diagram). The normal flowpath of the SUFP discharge is to the discharge of Steam Generator Feed Pump P-32B. The Steam Generator Feed Pumps P-32A and P-32B are interconnected by a cross-tie. P-32A normally discharges to Heater E-26A. The heater can be by-passed through valve V8. Similarly P-32B normally discharges to Heater E-26B and the heater can be by-passed through valve V19. The heater discharges are then connected to a common Main Feedwater header. The branch connections from the header to the steam generators each contain a motor-operated isolation valve, V28 for S.G.A., V37 for S.G.B., V46 for S.G.C., and V55 for S.G.D. The branch lines are continued on Fig. 3.

As can be seen from Fig. 2, the SUFP is normally aligned to both of the heaters and then to all four steam generators. When considered together with the EFWS, there now exist two virtually independent systems for admitting AFW to the steam generators, i.e., the SUFPS and its normal MFW connections, and the EFWS and its header and branch connections. In the SUFPS, aside from failures in the SUFP itself or in the valves leading from the CST, all the cutsets which cause insufficient flow from the SUFPS are at least second-order. For example, if V3 and V14, the heater inlet valves, were both inadvertantly closed due to human error or closed due to plugging, this would be a cause of LMFW if neither one of the heater by-pass valves, V8 and V19 were open. Since the plant is assumed to be at power operation prior to the three transients considered in this report, such a fault should be readily detectable by the operators. Only one of the by-pass valves would have to be opened to allow flow from the SUFPS. Similarly, the inadvertent closure or failure of any valve on the MFW branch connections to the steam generators should be readily detectable by the operators since the plant was at power operation prior to the fault. Valve faults would have to occur in at least 3 out of the 4 branch connections in order to cause insufficient flow from the SUFPS. All of the cutsets discussed above are quantitatively insignificant when compared to the quantitative value of subgate SUP1, No Flow to Supply Header From SUFP P-113 so that No Flow to 3 Out of 4 Steam Generators From the SUFPS Through the MFW Flowpaths can be adequately represented by SUP1, if failure to open of V156 and V163 is omitted.

It should be noted that NUREG-0611 has no failure data for MFW heaters, either due to hardware or test or maintenance. Also, Table B.3 has no provisions for human errors in normally operating MFW systems but is oriented rather to the typically standby nature of AFWS. For all of the above reasons, BNL has determined that additional fault trees for the MFW flowpaths are neither necessary nor practical.

9.2.3.2 Failure Data

As noted previously, the NUREG-0611 data has been utilized throughout the BNL assessment, to the extent possible, for both the REF.3 Design and the Proposed Design. Test and maintenance of manual valves was assumed to be zero in accordance with the applicant's contentions described in Section 8.3.

One area which should be discussed is the value assigned to operator error in failing to restore a locked manual valve to its proper position after test or maintenance. According to Table B.3 a value of 5×10^{-3} should be assigned to Operator Inadvertently Leaves Correct Valve in Wrong Position if it has local walk-around and double check procedures associated with it. If it has neither, 1×10^{-2} should be assigned. There is no distinction made between locked and unlocked valves. However, the Technical Specifications require surveillance of manual valves only if they are not locked into position. Therefore, from Table B.3, a value of 1×10^{-2} should be assigned in this case. This obviously seems inconsistent with the intent of the Technical Specifications. According to Table 3, Section 8.4, the applicant has assumed a value of 1×10^{-3} for such valves in the case of the operator failing to restore a valve to its normal position after maintenance. We find 1×10^{-3} to be a reasonable assumption if 30 minutes recovery time is available for operator corrective actions, and have utilized this value in the BNL assessment. In the case where recovery is not feasible, such as a pump starting with a suction valve closed thereby causing damage to the pump, no recovery is assumed, i.e., 5×10^{-3}.

Concerning the operator actions required to manually connect the SUFP to the emergency power sources, the applicant has assumed 1×10^{-2} for MPB1P1610E, Operator Fails to Start the Startup Prelube Pump, P161, as discussed in Section 8.4. The failure to start the SUFP is represented by failure to start the Prelube Pump. We believe that 1×10^{-2} is not realistic given the complexity of the task under a moderately stressful situation with reduced station lighting as occurs in a LOOP. In the BNL assessment, a value of 3×10^{-2} has been assumed for this operator failure and this becomes a very significant contributor to the subgate SUP1 -"No Flow to Supply Header from SUFP."

In the area of pump test outages, we assume that since the EFW pumps or the SUFP are already in operation during the testing and there is a 30 minute mission success time, the operators should be able to restore the pumps to their normal alignment to allow flow into the steam generators, i.e., outages due to testing have been assumed to be negligible.

9.2.3.3 System Unavailabilities

Both the WAMBAM and WAMCUT computer codes have been utilized as previously described in Section 9.2.3.1. The results are given separately for each transient:

1. LMFW

a) REF.3 Design

The BNL assessment for this event is 4.5×10^{-5}. The method of calculation is shown in Table 8.

b) Proposed Design

See Table 9. The BNL assessment for this event is 1.96×10^{-5}.

2. LOOP

a) REF.3 Design

The basic defference between this case and 1(a) is that random failure and maintenance outage of both Emergency Diesel Generators must be considered. The value 3×10^{-2} is added to the hardware failure of gates AF127 and SUP1 for random diesel failure while 6.4×10^{-3} is added to the maintenance failures of those two gates. See Table 10.

The BNL assessment for this case is 1.8×10^{-4}.

b) Proposed Design

This case is a combination of Case 1(b) and 2(a), above. See Table 11.

The BNL assessment for this case is 1.15×10^{-4}.

3. LOAC

a) REF.3 Design

Since this case is essentially a single pump situation, i.e. TDP-37A, the top event can be approximated quite accurately by neglecting failures in the feedlines to the 4 steam generators. The expression for the top event is then:

$$\text{Top Event} = AF91 + \overline{V125}$$

$$= 2.18 \times 10^{-2} + 0.11 \times 10^{-2} = 2.3 \times 10^{-2}$$

where $\overline{V125}$ = 1×10^{-3} Operator Error

1×10^{-4} Plugging

1.1×10^{-3}

b) Proposed Design

This case is exactly the same as 3(a) above:

$$\text{Top Event} = 2.18 \times 10^{-2} + 0.11 \times 10^{-2} = 2.3 \times 10^{-2}$$

The results of all three cases are summarized and compared to the applicant's results in Table 1 (see Summary and Conclusions) and Table 12.

9.2.3.4 Dominant Failure Modes

1. LMFW

a) REF.3 Design

The dominant modes are random or maintenance failures of MDP-37B coupled with maintenance errors causing V125 to be closed. This agrees qualitatively with the applicant's results given in Table 5. The WAMCUT results for this case are shown in Fig. 12, Sh. 1-2. If V125 is closed, flow from both the SUFP and TDP-37A is restricted to Steam Generator A only. Any failure in MDP-37B causes system failure. The SUFP is connected to the offsite power sources and it receives an automatic initiation signal.

b) Proposed Design

In this case, the SUFPS is no longer dependent on the EFW header and the position of V125. The dominant modes are random and maintenance failures of all three pumps. The significance of V125 diminishes greatly. The SUFP is again powered from offsite sources and it receives an automatic initiation signal but its overall failure rate is larger than the failure rate of the safety-class EFW pumps.

2. LOOP

a) REF.3 Design

The dominant modes are similar to Case 1(a) except that in addition to random or maintenance failures of MDP-37B coupled with maintenance errors causing V125 to be closed, random and maintenance failures of Emergency Diesel Generator 1B are present. This agrees qualitatively with the BNL results. The SUFP must be connected to the Emergency Diesel Generator 1A power source and aligned to the EFW header, but it is functionally redundant to TDP-37A so that failures of MDP-37B and V125 still predominate. The results of the WAMCUT output are shown in Fig. 13, Sh. 1-2.

b) Proposed Design

This case is similar to Case 1(b) in that the SUFPS is no longer dependent upon the EFW header and the position of V125. In addition to the random and maintenance failures of all three pumps themselves, random and maintenance failures of Emergency Diesel Generators 1A and 1B become significant contributors as well as failure to connect the SUFPS to electrical power sources. Diesel 1A is used to supply power to the SUFPS.

3. LOAC

In this case, there are no major differences between the REF.3 Design and the Proposed Design which affect the dominant failure modes. The dominant modes are maintenance acts on or random failure of the TDP-37A itself or on one of the steam admission valves V127 or V128.

The position of V125 is also critical in that if it is left closed due to maintenance error, only Steam Generator A can be supplied feedwater, violating the mission success criteria. A listing of the cutsets generated by WAMCUT for subgate AF91 which represents "No Flow to the Supply Header From TDP-37A" is shown in Figs. 10 and 11.

9.2.3.5 General Comparison to Other Plants

The Proposed Design at Seabrook consists of two safety-class EFW pumps and a Startup Feed Pump. The latter is dedicated for use up to 5% of power operation and for the Hot Standby and Hot Shutdown modes. Many plants have two safety-class motor-driven pumps and a third safety-class steam turbine-driven pump. In the Seabrook design, one of the safety-class pumps is steam turbine-driven while the other is motor-driven. A somewhat similar arrangement exists at the Byron/Braidwood plant which has two safety-class AFW pumps and a manually-actuated Startup Pump which is in series with four Booster Pumps and four Condensate Pumps. One of the safety-class pumps is motor-driven while the other is diesel-driven.

The Seabrook SUFP exhibits automatic initiation upon trip of both MFW pumps and draws suction from the CST with a normal reserve of 200,000 gallons. It is independent of any Booster or Condensate Pumps. The CST is a safety-class designed tank with sufficient capacity (400,000 gallons) to supply both the EFW pumps and the SUFP if all three are operating simultaneously. There are no manual actions required, either locally or in the Control Room, to maintain the suction source to the pumps once the pumps have begun operation, except if the SUFP is to be aligned to the base of the CST or to the Condenser Hot Well.

The SUFPS is normally aligned to the MFW headers for both the LMFW and LOOP transients. The Seabrook design limits or stops all feedwater flow to a

steam generator undergoing depressurization without compromising the use of each pump, since any one of the pumps can feed all four steam generators.

With the exception of the need to manually connect the SUFP to Emergency Diesel Generator 1A during LOOP and the higher failure rate of the SUFPS itself, the Seabrook design is comparable in reliability to plants with three safety-class AFW pumps. The use of only the SUFPS for LMFW reduces the number of challenges to the EFWS.

One definite disadvantage in comparison to most other plants is the presence of valves V125, V126 and V127 on the EFW header. In particular, the inadvertent closure of V125 or V127 can limit the flow from one of the EFW pumps to only one steam generator.

9.2.3.6 General Comments

The following aspects of the Seabrook AFWS should be highlighted·

1. Pump Suction Valves

The locked open, manual isolation valves on the suction line to each EFW pump, V154 and V155 for TDP-37A and V158 and V159 for MDP-37B, and to the SUF pump, V141, V143, and V152, do not have Control Room indication or position interlocking with the pumps' start-up circuit. Since they are locked open, they do not require periodic surveillance as per the Technical Specificaitons. If one of the valves is closed and the correpsonding pump is actuated, damage to the pump will probably occur since there are no protective pump trips upon low NPSH.

2. Emergency Feedwater Header Valves

Closure of valve V125 or V126 or V127 on the EFW header reduces the number of steam generators which are supplied from each EFW pump. However, the applicant has indicated in the Supplement to this report that these valves would only be closed in the event of a pipe rupture in the EFW system.

3. SUFPS Technical Specification Limits

Although it is not explicitly stated in the Technical Specifications, BNL's calculated unavailabilities for this EFWS are based on the assumption that the SUF pump will be subjected to Technical Specification limits on allowed outage time. If no such limits are placed on the SUF pump, the system unavailabilities will be substantially increased.

REFERENCES

1. "Generic Evaluation of Feedwater Transients and Small Break Loss-of-Coolant Accidents in Westinghouse Designed Operating Plants", NUREG-0611, U.S. NRC, (January, 1980).

2. Letter from D.F. Ross, Jr., U.S. NRC, to "All Pending Operating License Applicants of Nuclear Steam Supply Systems Designed by Westinghouse and Combustion Engineering", (March 10, 1980).

3. "Reliability Analysis of the Emergency Feedwater System at the Seabrook Nuclear Power Station", B.A. Brogan, R.E. Land, L.E. Peters, Jr., and A.E. Tome, Jr., Wood-Leaver and Associates Report No. WLA-1-R-82-02 (June, 1982).

4. "Auxiliary Feedwater System (PWR)", U.S. NRC Standard Review Plan 10.4.9, Rev.-2, NUREG-0800, (July, 1981).

5. Seabrook Station-Final Safety Analysis Report-Technical Specifications.

6. "Reactor Safety Study: An Assessment of Accident Risks in U.S. Commercial Nuclear Power Plants - Appendix 3 and 4: Failure Data", U.S. Nuclear Regulatory Commission, WASH-1400 (NUREG 75/014), (October, 1975).

7. "User's Guide for the WAMBAM Computer Code", F.L. Leverenz and H. Kirch, EPRI Research Project 217-2-5, Key Phase Report (January, 1976).

8. "WAMCUT, A Computer Code for Fault Tree Evaluation", R.C. Erdmann, F.L. Leverenz and H. Kirch, EPRI Research Project 767-1, NP-803 (June, 1978).

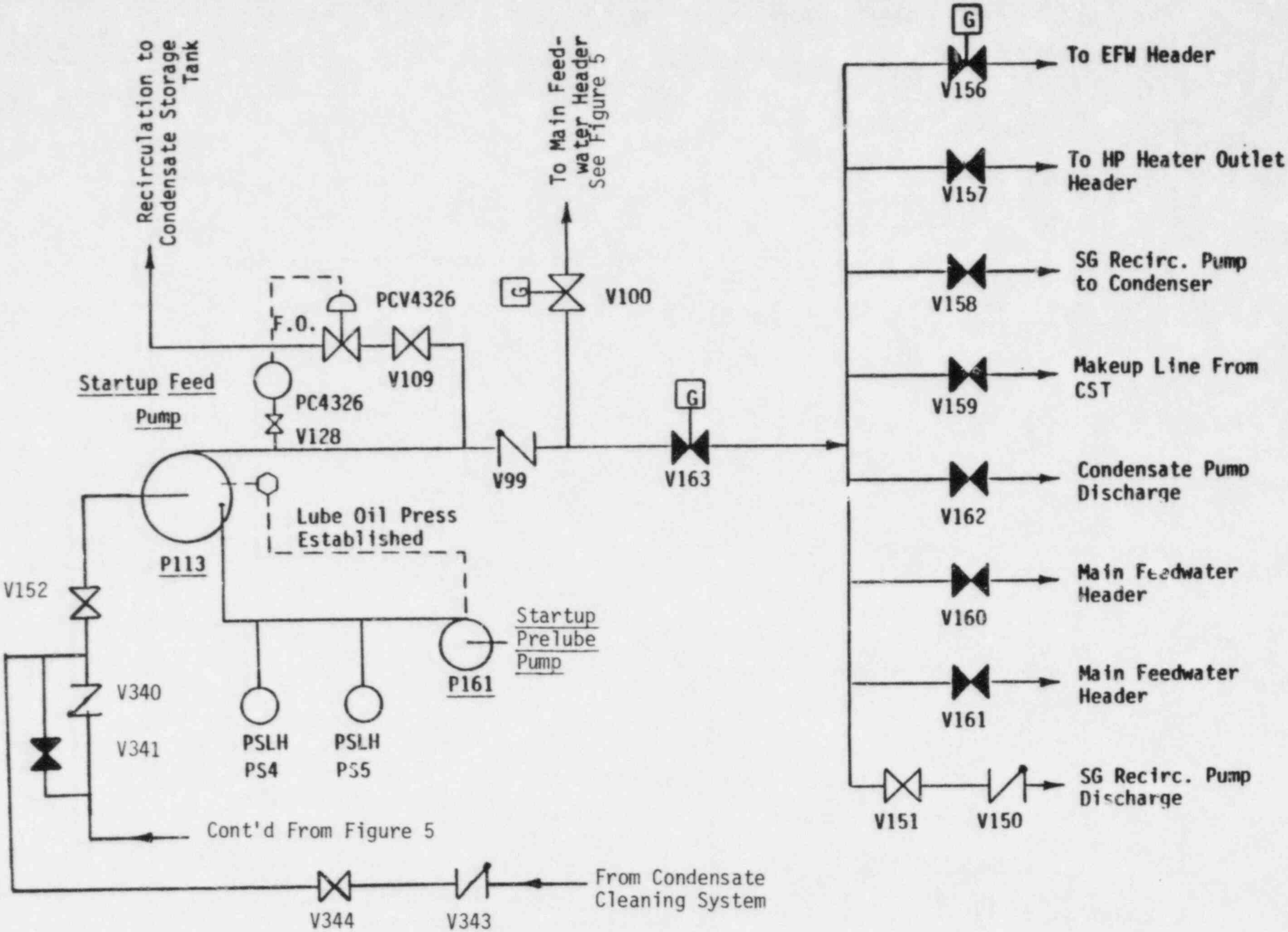


Figure 2: Seabrook Nuclear Station Startup Feed Pump System

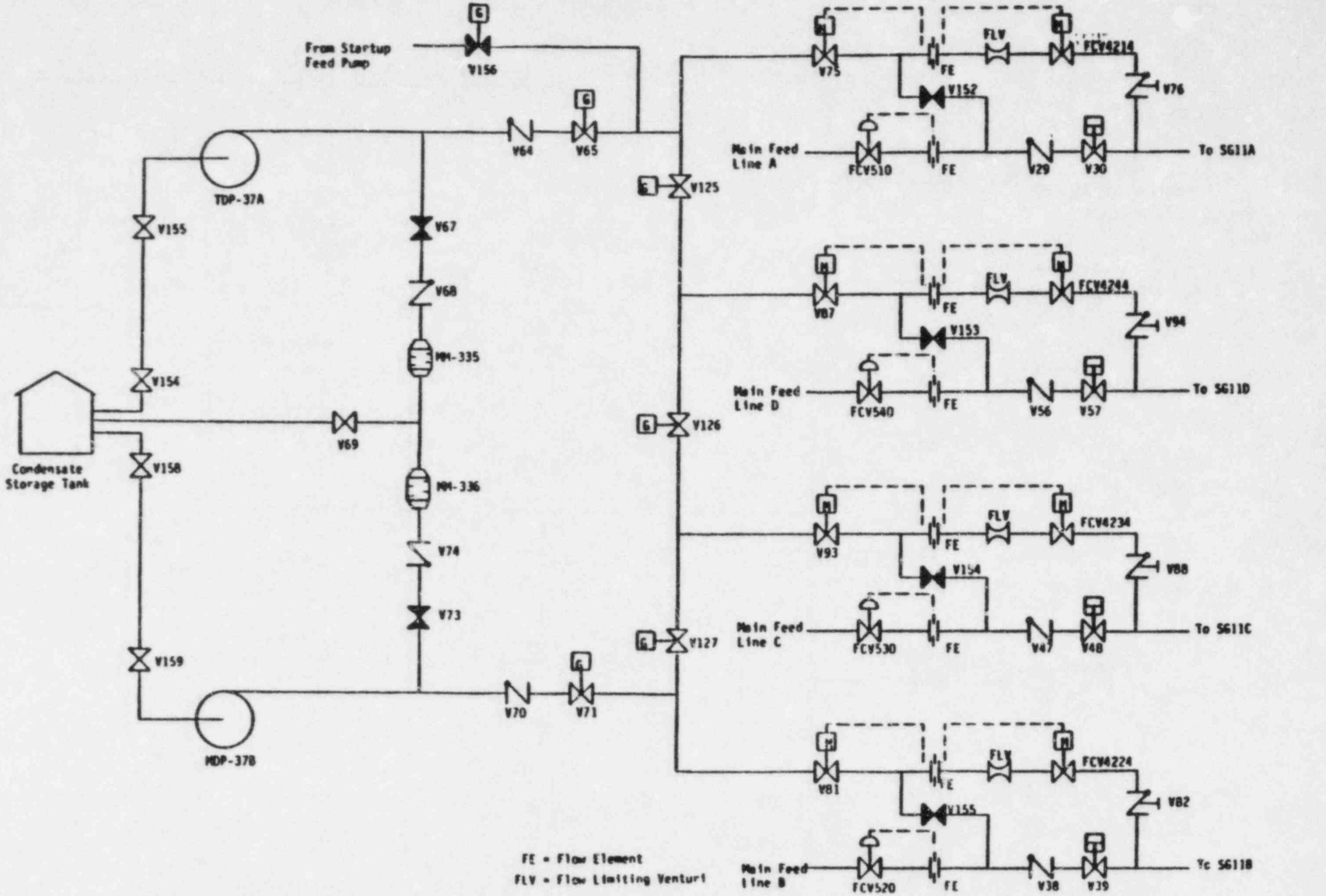


Figure 3: Seabrook Nuclear Station Emergency Feedwater System

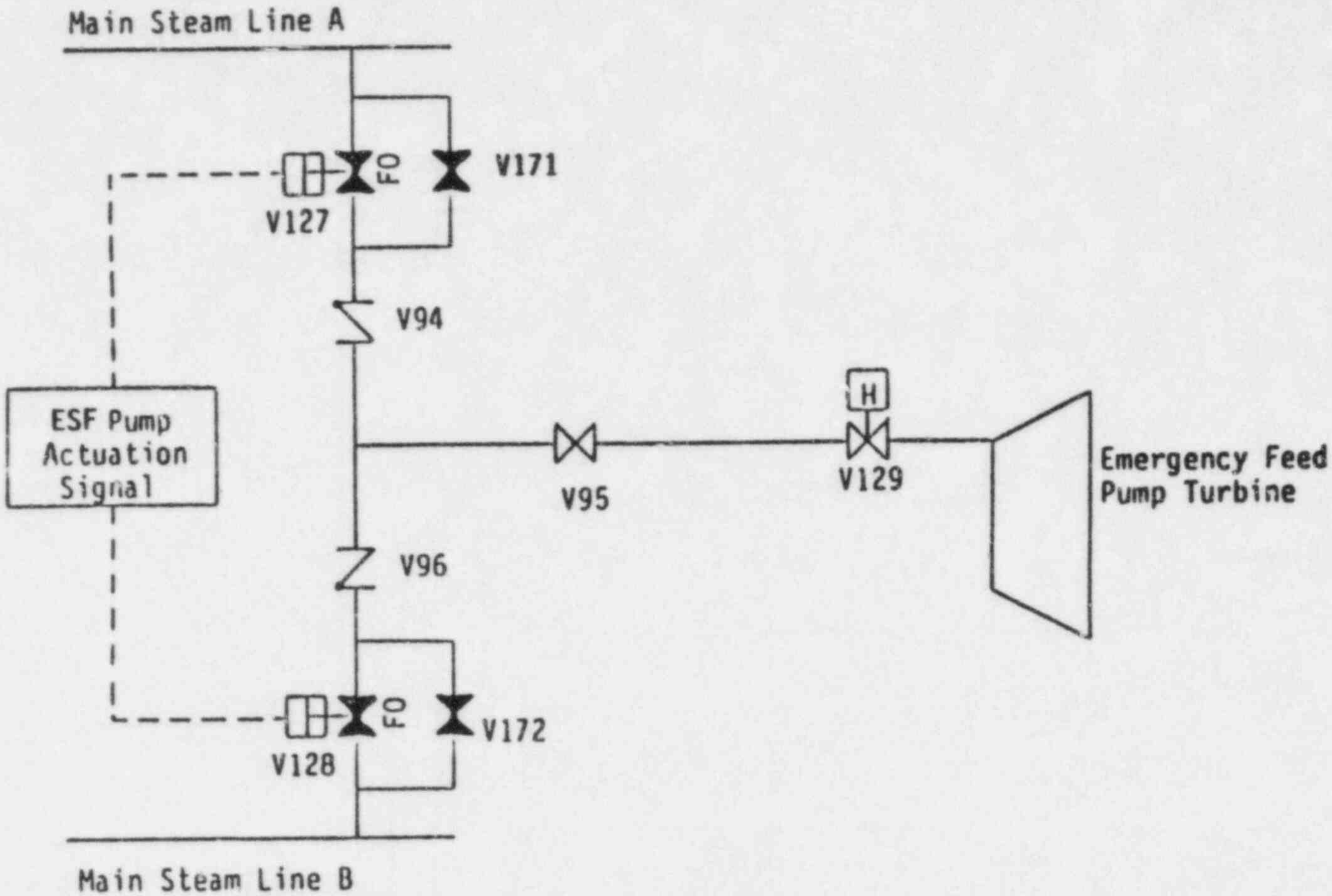


Figure 4: **Steam Supply for Turbine-Driven EFW Pump**

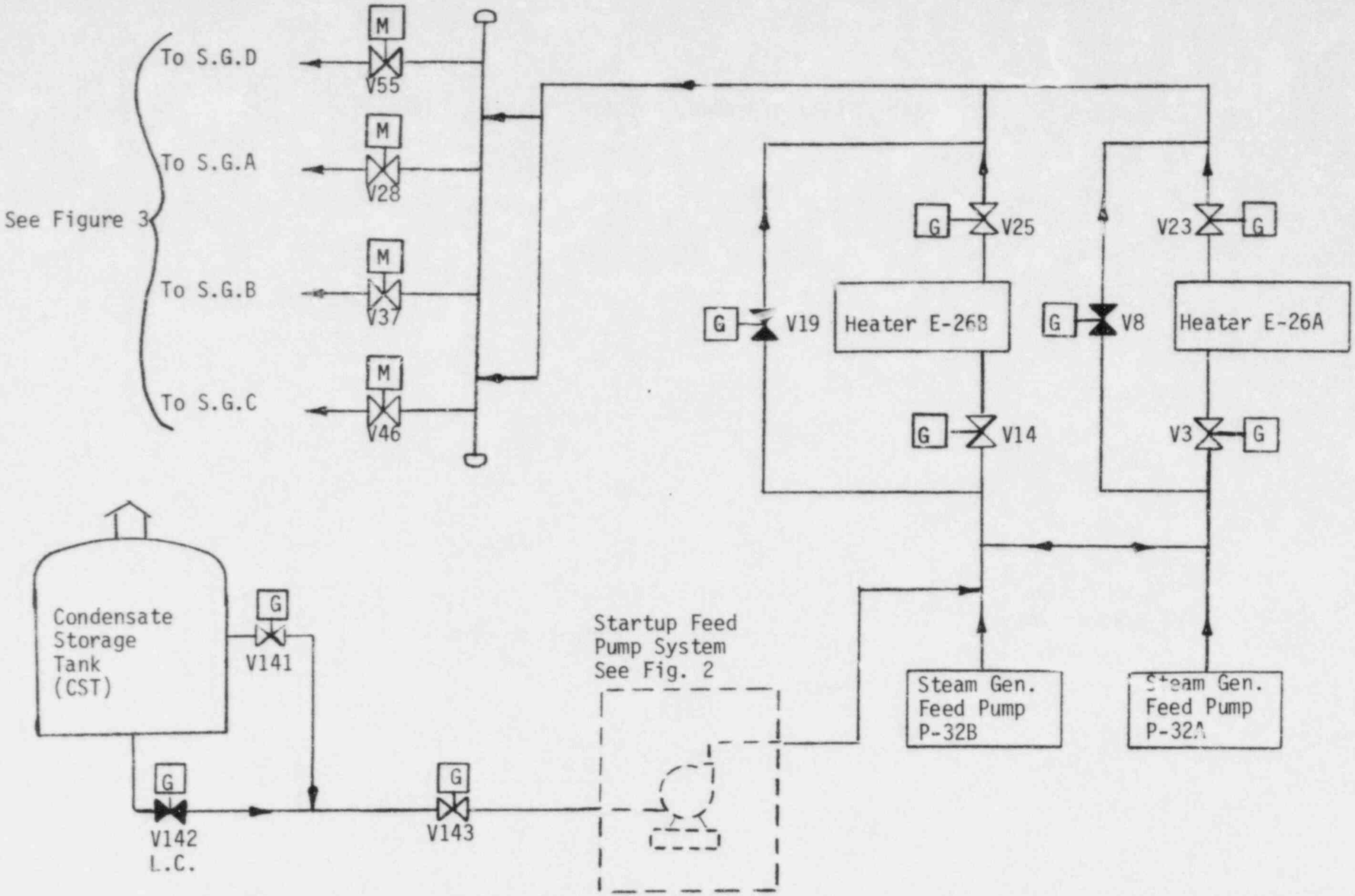


Figure 5: Startup Feed Pump Normal Alignment to the Main Feedwater System (Simplified)

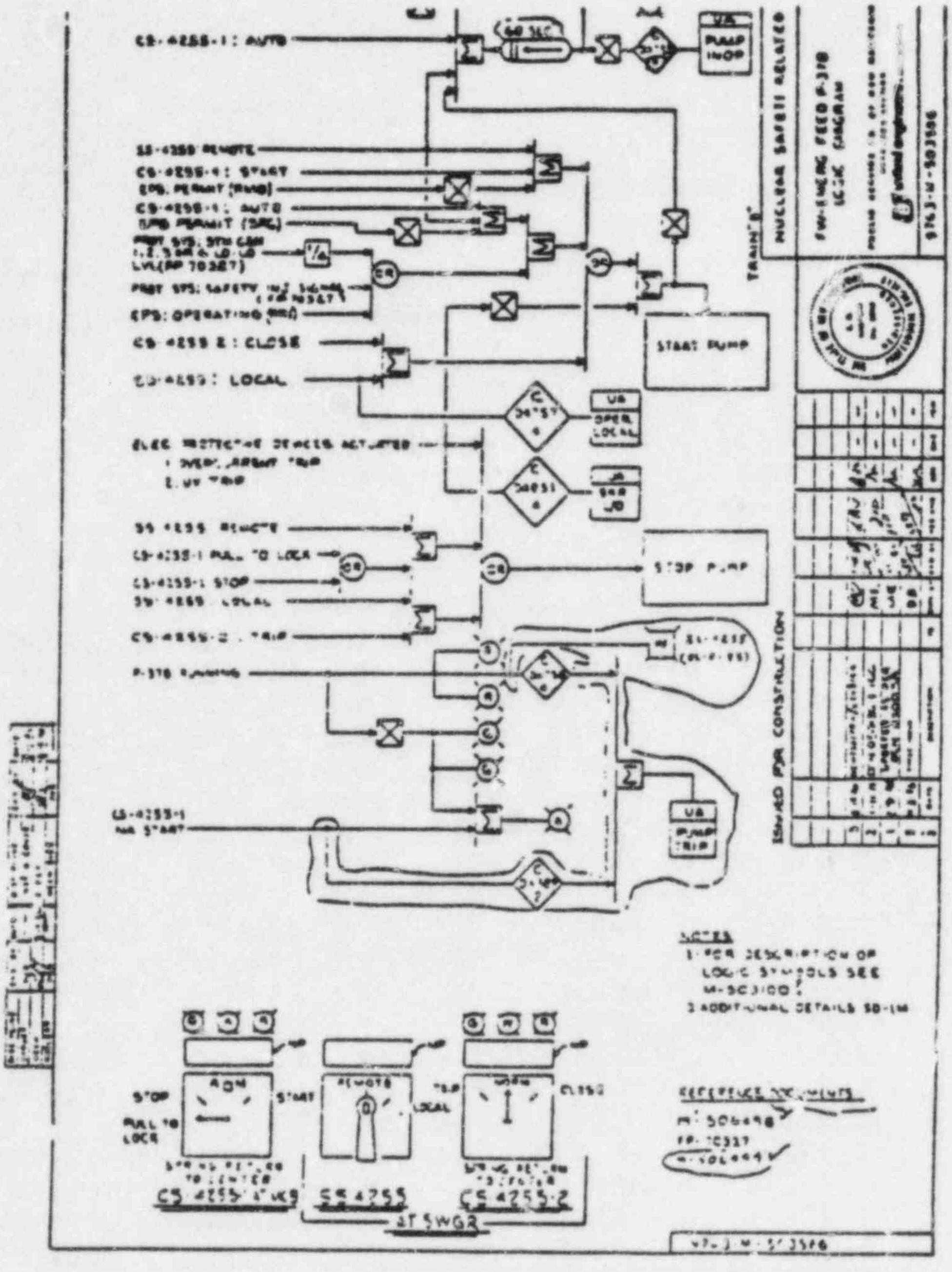


Figure 6: Motor-Driven EFW Pump Control Logic

System Unavailability Calculated by WAMBAM:

1028	AFW	2.06786E-05

Important Cut-sets as Caculated by WAMCUT:

CUT SETS FOR GATE AFW ORDERED BY PROBABILITY

1.	3.40E-06	MPB1D37BMG	MVD1V1250D	
2.	2.40E-06	MPB1D37BME	MVD1V1250D	
3.	2.00E-06	MVD1V71BOO	MVD1V1250D	
4.	1.20E-06	MVD1V1250D	MCD1D37BMK	
5.	1.00E-06	MVD1V1250D	FVM1V1580D	
6.	1.00E-06	MVD1V1250D	FVM1V1590D	
7.	9.40E-07	MPB1D37BOO	MVD1V1250D	
8.	3.40E-07	MPB1D37BMG	MVD1V125MD	
9.	3.14E-07	MPB1D37BMG	MPB1T37AME	MVD1V1630A
10.	2.86E-07	MPB1D37BMG	MPB1T37AME	MVD1V1560A
11.	2.40E-07	MVD1V125MD	MPB1D37BME	
12.	2.22E-07	MPB1T37AME	MPB1D37BME	MVD1V1630A
13.	2.13E-07	MPB1T37AMG	MPB1D37BMG	MVD1V1630A
14.	2.02E-07	MPB1T37AME	MPB1D37BME	MVD1V1560A
15.	2.00E-07	MVA1V70BMA	MVD1V1250D	
16.	2.00E-07	MVD1V125MD	MVD1V71BOO	
17.	1.94E-07	MPB1T37AMG	MPB1D37BMG	MVD1V1560A
18.	1.85E-07	MPB1T37AME	MVD1V71BOO	MVD1V1630A
19.	1.68E-07	MPB1T37AME	MVD1V71BOO	MVD1V1560A
20.	1.66E-07	MPB1D37BMG	MPB1T37AME	6IC1FPSAMN
21.	1.50E-07	MPB1T37AMG	M' B1D37BM	MVD1V1630A
22.	1.37E-07	MPB1T37AMG	MPB1D37BME	MVD1V1560A
23.	1.25E-07	MPB1T37AMG	MVD1V71BOO	MVD1V1630A
24.	1.20E-07	MVD1V125MD	MCD1D37BMK	
25.	1.17E-07	MPB1T37AME	MPB1D37BME	6IC1FPSAMN
26.	1.14E-07	MPB1D37BMG	MPB1T37AME	MPB1P113ME
27.	1.14E-07	MPB1D37BMG	MPB1T37AME	MPB1P161ME
28.	1.14E-07	MPB1T37AMG	MVD1V71BOO	MVD1V1560A
29.	1.12E-07	MPB1T37AMG	MPB1D37BMG	6IC1FPSAMN
30.	1.11E-07	MPB1D37BMG	MPB1T37AME	MRA1P161MK
31.	1.11E-07	MPB1T37AME	MCD1D37BMK	MVD1V1630A
32.	1.01E-07	MPB1T37AME	MCD1D37BMK	MVD1V1560A

Figure 7: Applicant's WAM Results for Loss of Main Feedwater

System Unavailability Calculated by WAMBAM:

1028	AFW	5.21742E-05

Important Cut-sets as Calculated by WAMCUT:

CUT SETS FOR GATE AFW ORDERED BY PROBABILITY

1.	1.00E-05	MVD1V1250D	RGD11B--ME	
2.	3.40E-06	MPB1D37BMG	MVD1V1250D	
3.	3.00E-06	MVD1V1250D	RGD11B--MG	
4.	2.40E-06	MPB1D37BME	MVD1V1250D	
5.	2.00E-06	MVD1V71BOO	MVD1V1250D	
6.	1.20E-06	MVD1V1250D	MCD1D37BMK	
7.	1.00E-06	MVD1V125MD	RGD11B--ME	
8.	1.00E-06	MVD1V1250D	FVM1V158OD	
9.	1.00E-06	MVD1V1250D	FVM1V159CD	
10.	1.00E-06	MVD1V1250D	RCA1A74-MB	
11.	9.40E-07	MPB1D37BOO	MVD1V1250D	
12.	9.24E-07	MPB1T37AME	RGD11B--ME	MVD1V1630A
13.	8.40E-07	MPB1T37AME	RGD11B--ME	RGD1DG1AME
14.	8.40E-07	MPB1T37AME	RGD11B--ME	MVD1V1560A
15.	7.00E-07	MVD1V1250D	RGD11B--OO	
16.	6.27E-07	MPB1T37AMG	RGD11B--ME	MVD1V1630A
17.	5.70E-07	MPB1T37AMG	RGD11B--ME	RGD1DG1AME
18.	5.70E-07	MPB1T37AMG	RGD11B--ME	MVD1V1560A
19.	4.87E-07	MPB1T37AME	RGD11B--ME	6IC1FFSAMN
20.	3.40E-07	MPB1D37BMG	MVD1V125MD	
21.	3.36E-07	MPB1T37AME	RGD11B--ME	MPB1P113ME
22.	3.36E-07	MPB1T37AME	RGD11B--ME	MPB1P161ME
23.	3.31E-07	MPB1T37AMG	RGD11B--ME	6IC1FFSAMN
24.	3.28E-07	MPB1T37AME	RGD11B--ME	MRA1P161MK
25.	3.14E-07	MPB1D37BMG	MPB1T37AME	MVD1V1630A
26.	3.00E-07	MVD1V125MD	RGD11B--MG	
27.	2.86E-07	MPB1D37BMG	MPB1T37AME	RGD1DG1AME
28.	2.86E-07	MPB1D37BMG	MPB1T37AME	MVD1V1560A
29.	2.77E-07	MPB1T37AME	RGD11B--MG	MVD1V1630A
30.	2.52E-07	MPB1T37AME	RGD11B--MG	RGD1DG1AME
31.	2.52E-07	MPB1T37AME	RGD11B--MG	MVD1V1560A
32.	2.52E-07	MPB1T37AME	RGD11B--ME	RGD1DG1AMG
33.	2.40E-07	MVD1V125MD	MPB1D37BME	
34.	2.28E-07	MPB1T37AMG	RGD11B--ME	MPB1P113ME
35.	2.28E-07	MPB1T37AMG	RGD11B--ME	MPB1P161ME
36.	2.22E-07	MPB1T37AMG	RGD11B--ME	MRA1P161MK

Figure 8: Applicant's WAM Results for Loss of Offsite Power (Sheet 1)

Important Cut-sets as Calculated by WAMCUT:

37.	2.22E-07	MPB1T37AME	MPB1D37BME	MVD1V163OA
38.	2.20E-07	MVD1V65AOO	RGD11B--ME	MVD1V163OA
39.	2.13E-07	MPB1T37AMG	MPB1D37BMG	MVD1V163OA
40.	2.02E-07	MPB1T37AME	MPB1D37BME	RGD1DG1AME
41.	2.02E-07	MPB1T37AME	MPB1D37BME	MVD1V156OA
42.	2.00E-07	MVA1V70BMA	MVD1V125OD	
43.	2.00E-07	MVD1V125MD	MVD1V71BOO	
44.	2.00E-07	MVD1V65AOO	RGD11B--ME	RGD1DG1AME
45.	2.00E-07	MVD1V65AOO	RGD11B--ME	MVD1V156OA
46.	1.94E-07	MPB1T37AMG	MPB1D37BMG	RGD1DG1AME
47.	1.94E-07	MPB1T37AMG	MPB1D37BMG	MVD1V156OA
48.	1.88E-07	MPB1T37AMG	RGD11B--MG	MVD1V163OA
49.	1.85E-07	MPB1T37AME	MVD1V71BOO	MVD1V163OA
50.	1.71E-07	MPB1T37AMG	RGD11B--MG	RGD1DG1AME
51.	1.71E-07	MPB1T37AMG	RGD11B--MG	MVD1V156OA
52.	1.71E-07	MPB1T37AMG	RGD11B--ME	RGD1DG1AMG
53.	1.68E-07	MPB1T37AME	MVD1V71BOO	RGD1DG1AME
54.	1.68E-07	MPB1T37AME	MVD1V71BOO	MVD1V156OA
55.	1.66E-07	MPB1D37BMG	MPB1T37AME	6IC1FPSAMN
56.	1.50E-07	MPB1T37AMG	MPB1D37BME	MVD1V163OA
57.	1.46E-07	MPB1T37AME	RGD11B--MG	6IC1FPSAMN
58.	1.37E-07	MPB1T37AMG	MPB1D37BME	RGD1DG1AME
59.	1.37E-07	MPB1T37AMG	MPB1D37BME	MVD1V156OA
60.	1.25E-07	MPB1T37AMG	MVD1V71BOO	MVD1V163OA
61.	1.20E-07	MVD1V125MD	MCD1D37BMK	
62.	1.17E-07	MPB1T37AME	MPB1D37BME	6IC1FPSAMN
63.	1.16E-07	MVD1V65AOO	RGD11B--ME	6IC1FPSAMN
64.	1.14E-07	MPB1D37BMG	MPB1T37AME	MPB1P113ME
65.	1.14E-07	MPB1D37BMG	MPB1T37AME	MPB1P161ME
66.	1.14E-07	MPB1T37AMG	MVD1V71BOO	RGD1DG1AME
67.	1.14E-07	MPB1T37AMG	MVD1V71BOO	MVD1V156OA
68.	1.12E-07	MPB1T37AMG	MPB1D37BMG	6IC1FPSAMN
69.	1.11E-07	MPB1D37BMG	MPB1T37AME	MRA1P161MK
70.	1.11E-07	MPB1T37AME	MCD1D37BMK	MVD1V163OA
71.	1.10E-07	FVM1V154OD	RGD11B--ME	MVD1V163OA
72.	1.10E-07	FVM1V155OD	RGD11B--ME	MVD1V163OA
73.	1.10E-07	QVD1V95AOD	RGD11B--ME	MVD1V163OA
74.	1.01E-07	MPB1T37AME	RGD11B--MG	MPB1P113ME
75.	1.01E-07	MPB1T37AME	RGD11B--MG	MPB1P161ME
76.	1.01E-07	MPB1T37AME	MCD1D37BMK	RGD1DG1AME
77.	1.01E-07	MPB1T37AME	MCD1D37BMK	MVD1V156OA
78.	1.01E-07	MPB1T37AME	RGD11B--ME	MCD1P113MK
79.	1.01E-07	MPB1T37AME	RGD11B--ME	MCD1P161MK

Figure 8 (Continued) (Sheet 2)

System Unavailability Calculated by WAMBAM:

702	AFW	2.13190E-02

Important Cut-sets as Calculated by WAMCUT:

CUT SETS FOR GATE AFW ORDERED BY PROBABILITY

1.	8.40E-03	MPB1T37AME	
2.	5.70E-03	MPB1T37AMG	
3.	2.00E-03	MVD1V65A00	
4.	1.00E-03	MVD1V1250D	
5.	1.00E-03	FVM1V1540D	
6.	1.00E-03	FVM1V1550D	
7.	1.00E-03	QVD1V95A0D	
8.	4.20E-04	MPB1T37A00	
9.	2.00E-04	MVA1V64AMA	
10.	1.00E-04	MVD1V125MD	
11.	1.00E-04	FVM1V154MD	
12.	1.00E-04	FVM1V155MD	
13.	1.00E-04	QVM1V95AMD	
14.	1.00E-04	QVD1V12900	
15.	1.00E-04	MVD1V65A0D	
16.	1.00E-04	MVD1V654MD	
17.	8.50E-05	MVD1421400	MVD1V1260D

Figure 9: Applicant's WAM Results for Total Loss of AC Power

SEABROOK-LMFW: EFWS 2 TRAINS + STARTUP FEEDPUMP - NUREG-0611 SCOPE

CUT SETS FOR GATE AF91 WITH PROBABILITY .GE. 1.00E-05

1	1.00E-04	MVD1V65AMD
2.	5.00E-04	MVD1V65AOD
3.	1.00E-04	QVD1V129MD
4.	1.00E-04	QVM1V95AMD
5.	1.00E-03	QVM1V95AOD
6.	2.50E-03	QVX1V12700
7.	2.50E-03	QVX1V12800
8.	3.00E-03	MPB1T37AME
9.	5.80E-03	MPB1T37AOO
10.	1.00E-04	FVM1V155MD
11.	5.00E-03	FVM1V155OD
12.	1.00E-04	FVM1V154MD
13.	1.00E-03	FVM1V154OD
14.	1.00E-04	MVA1V64AMA

CUT SETS FOR GATE AF91 ORDERED BY PROBABILITY

1.	5.80E-03	MPB1T37AOO
2.	5.00E-03	FVM1V155OD
3.	3.00E-03	MPB1T37AME
4.	2.50E-03	QVX1V12800
5.	2.50E-03	QVX1V12700
6.	1.00E-03	FVM1V154OD
7.	1.00E-03	QVM1V95AOD
8.	5.00E-04	MVD1V65AOD
9.	1.00E-04	MVA1V64AMA
10.	1.00E-04	FVM1V154MD
11.	1.00E-04	FVM1V155MD
12.	1.00E-04	QVM1V95AMD
13.	1.00E-04	QVD1V129MD
14.	1.00E-04	MVD1V65AMD

1ST MOMENT= 2.1785E-02

Figure 10: BNL Cutsets - LMFW
Sheet 1: No Flow from Turbine-Driven Pump P-37A.

SEABROOK-LMFW: EFWS 2 TRAINS + STARTUP FEEDPUMP - NUREG-0611 SCOPE

CUT SETS FOR GATE AF127 WITH PROBABILITY .GE. 1.00E-05

1.	1.00E-04	MVD1V71BMD	
2.	5.00E-04	MVD1V71BOD	
3.	5.00E-03	MPB1D37BME	
4.	5.80E-03	MPB1D37BOO	
5.	1.00E-04	FVM1V159MD	
6.	5.00E-03	FVM1V159OD	
7.	1.00E-04	FVM1V158MD	
8.	1.00E-03	FVM1V158OD	
9.	1.00E-04	MVA1V70BMA	
10.	3.00E-05	LOSP	PGD11B--ME

CUT SETS FOR GATE AF127 ORDERED BY PROBABILITY

1.	5.80E-03	MPB1D37BOO	
2.	5.00E-03	FVM1V159OD	
3.	5.00E-03	MPB1D37BME	
4.	1.00E-03	FVM1V158OD	
5.	5.00E-04	MVD1V71BOD	
6.	1.00E-04	MVA1V70BMA	
7.	1.00E-04	FVM1V158MD	
8.	1.00E-04	FVM1V159MD	
9.	1.00E-04	MVD1V71BMD	
10.	3.00E-05	LOSP	PGD11B--ME

1ST MOMENT= 1.7647E-02

Figure 10 (Continued) BNL Cutsets-LMFW
Sheet 2: No Flow from Motor-Driven Pump P-37B.

SEABROOK-LMFW: EFWS 2 TRAINS + STARTUP FEEDPUMP - NUREG-0611 SCOPE

CUT SETS FOR GATE SUP1 WITH PROBABILITY .GE. 1.00E-05

1.	3.00E-02	MPB1P1610E	
2.	1.00E-02	MVD1V1560A	
3.	1.00E-02	MVD1V1630A	
4.	5.80E-03	MPB1P11300	
5.	5.00E-03	MPB1P113ME	
6.	5.00E-03	MPB1P161ME	
7.	5.00E-03	FVM1V1520D	
8.	2.00E-03	MCE1P113MN	
9.	1.00E-03	FVD1V1410D	
10.	1.00E-03	FVD1V1430D	
11.	1.00E-04	MPB1P1130G	
12.	1.00E-04	RCA150AEMC	
13.	1.00E-04	RCA1AF4-MC	
14.	1.00E-04	RCA1A63-MC	
15.	1.00E-04	FVM1V152MD	
16.	1.00E-04	FVD1V141MD	
17.	1.00E-04	FVD1V143MD	
18.	1.00E-04	MVA1V99-MA	
19.	3.00E-05	LOSP	RGD1DG1AME
20.	3.00E-05	RCA1A42-MB	RGD1DG1AME
21.	1.00E-05	LOSP	RCA1A93-0B
22.	1.00E-05	RCA1A42-MB	RCA1A93-0B

1ST MOMENT= 7.3536E-02

Figure 10 (Continued) BNL Cutsets-LMFW
Sheet 3: No Flow from Start-up Feed Pump P-113.

SEABROOK-LOOP: EFWS 2 TRAINS + STARTUP FEEDPUMP - NUREG-0611 SCOPE

CUT SETS FOR GATE AF91 WITH PROBABILITY .GE. 1.00E-05

1.	1.00E-04	MVD1V65AMD
2.	5.00E-04	MVD1V65AOD
3.	1.00E-04	QVD1V129MD
4.	1.00E-04	QVM1V95AMD
5.	1.00E-03	QVM1V95AOD
6.	2.50E-03	QVX1V12700
7.	2.50E-03	QVX1V12800
8.	3.00E-03	MPB1T37AME
9.	5.80E-03	MPB1T37AOO
10.	1.00E-04	FVM1V155MD
11.	5.00E-03	FVM1V155OD
12.	1.00E-04	FVM1V154MD
13.	1.00E-03	FVM1V154OD
14.	1.00E-04	MVA1V64AMA

CUT SETS FOR GATE AF91 ORDERED BY PROBABILITY

1.	5.80E-03	MPB1T37AOO
2.	5.00E-03	FVM1V155OD
3.	3.00E-03	MPB1T37AME
4.	2.50E-03	QVX1V12800
5.	2.50E-03	QVX1V12700
6.	1.00E-03	FVM1V154OD
7.	1.00E-03	QVM1V95AOD
8.	5.00E-04	MVD1V65AOD
9.	1.00E-04	MVA1V64AMA
10.	1.00E-04	FVM1V154MD
11.	1.00E-04	FVM1V155MD
12.	1.00E-04	QVM1V95AMD
13.	1.00E-04	QVD1V129MD
14.	1.00E-04	MVD1V65AMD

1ST MOMENT= 2.1785E-02

Figure 11: BNL Cutsets - LOOP
Sheet 1: No Flow from Turbine-Driven Pump P-37A.

SEABROOK-LOOP: EFWS 2 TRAINS + STARTUP FEEDPUMP - NUREG-0611 SCOPE

CUT SETS FOR GATE AF127 WITH PROBABILITY .GE. 1.00E-05

1.	1.00E-04	MVD1V71BMD
2.	5.00E-04	MVD1V71BOD
3.	1.00E-03	RCA1A74-MB
4.	3.00E-02	RGD11B--ME
5.	6.40E-03	RGD11B--OO
6.	5.00E-03	MPB1D37BME
7.	5.80E-03	MPB1D37BOO
8.	1.00E-04	FVM1V159MD
9.	5.00E-03	FVM1V159OD
10.	1.00E-04	FVM1V158MD
11.	1.00E-03	FVM1V158OD
12.	1.00E-04	MVA1V70BMA

CUT SETS FOR GATE AF127 ORDERED BY PROBABILITY

1.	3.00E-02	RGD11B--ME
2.	6.40E-03	RGD11B--OO
3.	5.80E-03	MPB1D37BOO
4.	5.00E-03	FVM1V159OD
5.	5.00E-03	MPB1D37BME
6.	1.00E-03	FVM1V158OD
7.	1.00E-03	RCA1A74-MB
8.	5.00E-04	MVD1V71BOD
9.	1.00E-04	MVA1V70BMA
10.	1.00E-04	FVM1V158MD
11.	1.00E-04	FVM1V159MD
12.	1.00E-04	MVD1V71BMD

1ST MOMENT= 5.4175E-02

Figure 11 (Continued) BNL Cutsets-LOOP
Sheet 2: No Flow from Motor-Driven Pump P-37B.

SEABROOK-LOOP: EFWS 2 TRAINS + STARTUP FEEDPUMP - NUREG-0611 SCOPE

CUT SETS FOR GATE SUP1 WITH PROBABILITY .GE. 1.00E-05

1.	3.00E-02	MPB1P1610F
2.	3.00E-02	RGD1DG1AME
3.	1.00E-02	RCA1A93-OB
4.	1.00E-02	MVD1V1560A
5.	1.00E-02	MVD1V1630A
6.	6.40E-03	RGD11A--OO
7.	5.80E-03	MPB1P11300
8.	5.00E-03	MPB1P113ME
9.	5.00E-03	MPB1P161ME
10.	5.00E-03	FVM1V1520D
11.	2.00E-03	MCE1P113MN
12.	1.00E-03	RCA1A93-MB
13.	1.00E-03	RCA1A54-MB
14.	1.00E-03	FVD1V1410D
15.	1.00E-03	FVD1V1430D
16.	1.00E-04	MPB1P1130G
17.	1.00E-04	RCA150AEMC
18.	1.00E-04	RCA1AF4-MC
19.	1.00E-04	RCA1A63-MC
20.	1.00E-04	FVM1V152MD
21.	1.00E-04	FVD1V141MD
22.	1.00E-04	FVD1V143MD
23.	1.00E-04	MVA1V99-MA

1ST MOMENT= 1.1766E-01

Figure 11 (Continued) BNL Cutsets-LOOP
Sheet 3: No Flow from Start-up Feed Pump P-113.

SEABROOK-LMFW: EFWS 2 TRAINS + STARTUP FEEDPUMP - NUREG-0611 SCOPE

CUT SETS FOR GATE AFW WITH PROBABILITY .GE. 1.00E-07

1.	5.80E-06	MPB1D37B00	MVD1V1250D	
2.	5.00E-06	MVD1V1250D	FVM1V1590D	
3.	5.00E-06	MPB1D37BME	MVD1V1250D	
4.	1.01E-06	MPB1T37A00	MPB1D37B00	MPB1P1610E
5.	1.00E-06	MVD1V1250D	FVM1V1580D	
6.	8.70E-07	MPB1T37A00	FVM1V1590D	MPB1P1610E
7.	8.70E-07	MPB1D37B00	FVM1V1550D	MPB1P1610E
8.	8.70E-07	MPB1D37BME	MPB1T37A00	MPB1P1610E
9.	7.50E-07	FVM1V1550D	FVM1V1590D	MPB1P1610E
10.	7.50E-07	MPB1D37BME	FVM1V1550D	MPB1P1610E
11.	5.80E-07	MVD1V125MD	MPB1D37B00	
12.	5.22E-07	MPB1T37AME	MPB1D37B00	MPB1P1610E
13.	5.00E-07	MVD1V1250D	MVD1V7180D	
14.	5.00E-07	MVD1V125MD	FVM1V1590D	
15.	5.00E-07	MVD1V125MD	MPB1D37BME	
16.	4.50E-07	MPB1T37AME	FVM1V1590D	MPB1P1610E
17.	4.50E-07	MPB1T37AME	MPB1D37BME	MPB1P1610E
18.	4.35E-07	MPB1D37B00	QVX1V1280D	MPB1P1610E
19.	4.35E-07	MPB1D37B00	QVX1V1270D	MPB1P1610E
20.	3.75E-07	QVX1V12800	FVM1V1590D	MPB1P1610E
21.	3.75E-07	QVX1V12700	FVM1V1590D	MPB1P1610E
22.	3.75E-07	MPB1D37BME	QVX1V12800	MPB1P1610E
23.	3.75E-07	MPB1D37BME	QVX1V12700	MPB1P1610E
24.	3.36E-07	MPB1T37A00	MPB1D37B00	MVD1V1560A
25.	3.36E-07	MPB1T37A00	MPB1D37B00	MVD1V1630A
26.	2.90E-07	MPB1T37A00	FVM1V1590D	MVD1V1560A
27.	2.90E-07	MPB1T37A00	FVM1V1590D	MVD1V1630A
28.	2.90E-07	MPB1D37B00	FVM1V1550D	MVD1V1560A
29.	2.90E-07	MPB1D37B00	FVM1V1550D	MVD1V1630A
30.	2.90E-07	MPB1D37BME	MPB1T37A00	MVD1V1560A
31.	2.90E-07	MPB1D37BME	MPB1T37A00	MVD1V1630A
32.	2.50E-07	FVM1V1550D	FVM1V1590D	MVD1V1560A
33.	2.50E-07	FVM1V1550D	FVM1V1590D	MVD1V1630A
34.	2.50E-07	MPB1D37BME	FVM1V1550D	MVD1V1560A
35.	2.50E-07	MPB1D37BME	FVM1V1550D	MVD1V1630A
36.	1.95E-07	MPB1T37A00	MPB1D37B00	MPB1P11300
37.	1.74E-07	MPB1T37A00	FVM1V1580D	MPB1P1610E
38.	1.74E-07	MPB1D37B00	FVM1V1540D	MPB1P1610E
39.	1.74E-07	MPB1T37AME	MPB1D37B00	MVD1V1560A
40.	1.74E-07	MPB1T37AME	MPB1D37B00	MVD1V1630A
41.	1.74E-07	MPB1D37B00	QVM1V05A0D	MPB1P1610E
42.	1.74E-07	MPB1T37A00	MVD1V1270D	MPB1P1610E
43.	1.68E-07	MPB1T37A00	FVM1V1590D	MPB1P11300
44.	1.68E-07	MPB1D37B00	FVM1V1550D	MPB1P11300
45.	1.68E-07	MPB1D37BME	MPB1T37A00	MPB1P11300
46.	1.68E-07	MPB1T37A00	MPB1D37B00	MPB1P113ME
47.	1.68E-07	MPB1T37A00	MPB1D37B00	MPB1P161ME
48.	1.68E-07	MPB1T37A00	MPB1D37B00	FVM1V1520D

Figure 12: BNL Cutsets - Top Event No Flow to 3 out of 4 Steam Generators - LMFW Gate AFW (Sheet 1)

49.	1.50E-07	FVM1V1540D	FVM1V1590D	MPB1P1610E
50.	1.50E-07	MPB1T37AME	FVM1V1590D	MVD1V1560A
51.	1.50E-07	MPB1T37AME	FVM1V1590D	MVD1V1630A
52.	1.50E-07	QVM1V95A0D	FVM1V1590D	MPB1P1610E
53.	1.50E-07	MPB1T37AME	MPB1D37BME	MVD1V1560A
54.	1.50E-07	MPB1T37AME	MPB1D37BME	MVD1V1630A
55.	1.50E-07	FVM1V1550D	FVM1V1580D	MPB1P1610E
56.	1.50E-07	MPB1D37BME	FVM1V1540D	MPB1P1610E
57.	1.50E-07	MPB1D37BME	QVM1V95A0D	MPB1P1610E
58.	1.50E-07	FVM1V1550D	MVD1V1270D	MPB1P1610E
59.	1.45E-07	MPB1T37A00	FVM1V1590D	MPB1P113ME
60.	1.45E-07	MPB1T37A00	FVM1V1590D	MPB1P161ME
61.	1.45E-07	MPB1T37A00	FVM1V1590D	FVM1V1520D
62.	1.45E-07	MPB1D37B00	FVM1V1550D	MPB1P113ME
63.	1.45E-07	MPB1D37B00	FVM1V1550D	MPB1P161ME
64.	1.45E-07	MPB1D37B00	FVM1V1550D	FVM1V1520D
65.	1.45E-07	MPB1D37B00	QVX1V12800	MVD1V1560A
66.	1.45E-07	MPB1D37B00	QVX1V12800	MVD1V1630A
67.	1.45E-07	MPB1D37B00	QVX1V12700	MVD1V1560A
68.	1.45E-07	MPB1D37B00	QVX1V12700	MVD1V1630A
69.	1.45E-07	FVM1V1550D	FVM1V1590D	MPB1P11300
70.	1.45E-07	MPB1D37BME	FVM1V1550D	MPB1P11300
71.	1.45E-07	MPB1D37BME	MPB1T37A00	MPB1P113ME
72.	1.45E-07	MPB1D37BME	MPB1T37A00	MPB1P161ME
73.	1.45E-07	MPB1D37BME	MPB1T37A00	FVM1V1520D
74.	1.25E-07	FVM1V1550D	FVM1V1590D	MPB1P113ME
75.	1.25E-07	FVM1V1550D	FVM1V1590D	MPB1P161ME
76.	1.25E-07	FVM1V1550D	FVM1V1590D	FVM1V1520D
77.	1.25E-07	QVX1V12800	FVM1V1590D	MVD1V1560A
78.	1.25E-07	QVX1V12800	FVM1V1590D	MVD1V1630A
79.	1.25E-07	QVX1V12700	FVM1V1590D	MVD1V1560A
80.	1.25E-07	QVX1V12700	FVM1V1590D	MVD1V1630A
81.	1.25E-07	MPB1D37BME	FVM1V1550D	MPB1P113ME
82.	1.25E-07	MPB1D37BME	FVM1V1550D	MPB1P161ME
83.	1.25E-07	MPB1D37BME	FVM1V1550D	FVM1V1520D
84.	1.25E-07	MPB1D37BME	QVX1V12800	MVD1V1560A
85.	1.25E-07	MPB1D37BME	QVX1V12800	MVD1V1630A
86.	1.25E-07	MPB1D37BME	QVX1V12700	MVD1V1560A
87.	1.25E-07	MPB1D37BME	QVX1V12700	MVD1V1630A
88.	1.01E-07	MPB1T37AME	MPB1D37B00	MPB1P11300

1ST MOMENT= 3.8976E-05

CUT TOOK 9.498 SECS

Figure 12 (Continued) (Sheet 2)

SEABROOK-LOOP: EFWS 2 TRAINS + STARTUP FEEDPUMP - NUREG-0611 SCOPE

CUT SETS FOR GATE AFW WITH PROBABILITY .GE. 5.00E-07

1.	3.00E-05	MVD1V1250D	RGD11B--ME	
2.	6.40E-06	MVD1V1250D	RGD11B--00	
3.	5.80E-06	MPB1D37B00	MVD1V1250D	
4.	5.22E-06	MPB1T37A00	RGD11B--ME	MPB1P1610E
5.	5.22E-06	MPB1T37A00	RGD11B--ME	RGD1DG1AME
6.	5.00E-06	MVD1V1250D	FVM1V1590D	
7.	5.00E-06	MPB1D37BME	MVD1V1250D	
8.	4.50E-06	FVM1V1550D	RGD11B--ME	MPB1P1510E
9.	4.50E-06	FVM1V1550D	RGD11B--ME	RGD1DG1AME
10.	3.00E-06	MVD1V125MD	RGD11B--ME	
11.	2.70E-06	MPB1T37AME	RGD11B--ME	MPB1P1610E
12.	2.70E-06	MPB1T37AME	RGD11B--ME	RGD1DG1AME
13.	2.25E-06	QVX1V12800	RGD11B--ME	MPB1P1610E
14.	2.25E-06	QVX1V12800	RGD11B--ME	RGD1DG1AME
15.	2.25E-06	QVX1V12700	RGD11B--ME	MPB1P1610E
16.	2.25E-06	QVX1V12700	RGD11B--ME	RGD1DG1AME
17.	1.74E-06	MPB1T37A00	RGD11B--ME	RCA1A93-0B
18.	1.74E-06	MPB1T37A00	RGD11B--ME	MVD1V1560A
19.	1.74E-06	MPB1T37A00	RGD11B--ME	MVD1V1630A
20.	1.50E-06	FVM1V1550D	RGD11B--ME	RCA1A93-0B
21.	1.50E-06	FVM1V1550D	RGD11B--ME	MVD1V1560A
22.	1.50E-06	FVM1V1550D	RGD11B--ME	MVD1V1630A
23.	1.11E-06	MPB1T37A00	RGD11B--ME	RGD11A--00
24.	1.11E-06	MPB1T37A00	RGD11B--00	MPB1P1610E
25.	1.11E-06	MPB1T37A00	RGD11B--00	RGD1DG1AME
26.	1.01E-06	MPB1T37A00	MPB1D37B00	MPB1P1610E
27.	1.01E-06	MPB1T37A00	MPB1D37B00	RGD1DG1AME
28.	1.01E-06	MPB1T37A00	RGD11B--ME	MPB1P11300
29.	1.00E-06	MVD1V1250D	FVM1V1580D	
30.	1.00E-06	MVD1V1250D	RCA1A74-MB	
31.	9.60E-07	FVM1V1550D	RGD11B--00	MPB1P1610E
32.	9.60E-07	FVM1V1550D	RGD11B--00	RGD1DG1AME
33.	9.60E-07	FVM1V1550D	RGD11B--ME	RGD11A--00
34.	9.00E-07	FVM1V1540D	RGD11B--ME	MPB1P1610E
35.	9.00E-07	FVM1V1540D	RGD11B--ME	RGD1DG1AME
36.	9.00E-07	MPB1T37AME	RGD11B--ME	RCA1A93-0B
37.	9.00E-07	MPB1T37AME	RGD11B--ME	MVD1V1560A
38.	9.00E-07	MPB1T37AME	RGD11B--ME	MVD1V1630A
39.	9.00E-07	QVM1V95A0D	RGD11B--ME	MPB1P1610E
40.	9.00E-07	QVM1V95A0D	RGD11B--ME	RGD1DG1AME
41.	8.70E-07	MPB1T37A00	FVM1V1590D	MPB1P1610E
42.	8.70E-07	MPB1T37A00	FVM1V1590D	RGD1DG1AME
43.	8.70E-07	MPB1D37B00	FVM1V1550D	MPB1P1610E
44.	8.70E-07	MPB1D37B00	FVM1V1550D	RGD1DG1AME
45.	8.70E-07	MPB1D37BME	MPB1T37A00	MPB1P1610E
46.	8.70E-07	MPB1D37BME	MPB1T37A00	RGD1DG1AME
47.	8.70E-07	FVM1V1550D	RGD11B--ME	MPB1P11300
48.	8.70E-07	MPB1T37A00	RGD11B--ME	MPB1P113ME
49.	8.70E-07	MPB1T37A00	RGD11B--ME	MPB1P161ME
50.	8.70E-07	MPB1T37A00	RGD11B--ME	FVM1V1520D

Figure 13. BNL Cutsets - Top Event No Flow to 3 out of 4 Steam Generators - LOOP Gate AFW (Sheet 1)

51.	7.50E-07	FVM1V1550D	RGD11B--ME	MPB1P113ME
52.	7.50E-07	FVM1V1550D	RGD11B--ME	MPB1P161ME
53.	7.50E-07	FVM1V1550D	RGD11B--ME	FVM1V1520D
54.	7.50E-07	QVX1V12800	RGD11B--ME	RCA1A93-0B
55.	7.50E-07	QVX1V12800	RGD11B--ME	MVD1V1560A
56.	7.50E-07	QVX1V12800	RGD11B--ME	MVD1V1630A
57.	7.50E-07	QVX1V12700	RGD11B--ME	RCA1A93-0B
58.	7.50E-07	QVX1V12700	RGD11B--ME	MVD1V1560A
59.	7.50E-07	QVX1V12700	RGD11B--ME	MVD1V1630A
60.	7.50E-07	FVM1V1550D	FVM1V1590D	MPB1P1610E
61.	7.50E-07	FVM1V1550D	FVM1V1590D	RGD1DG1AME
62.	7.50E-07	MPB1D37BME	FVM1V1550D	MPB1P1610E
63.	7.50E-07	MPB1D37BME	FVM1V1550D	RGD1DG1AME
64.	6.40E-07	MVD1V125MD	RGD11B--00	
65.	5.80E-07	MVD1V125MD	MPB1D37B00	
66.	5.76E-07	MPB1T37AME	RGD11B--ME	RGD11A--00
67.	5.76E-07	MPB1T37AME	RGD11B--00	MPB1P1610E
68.	5.76E-07	MPB1T37AME	RGD11B--00	RGD1DG1AME
69.	5.22E-07	MPB1T37AME	MPB1D37B00	MPB1P1610E
70.	5.22E-07	MPB1T37AME	MPB1D37B00	RGD1DG1AME
71.	5.22E-07	MPB1T37AME	RGD11B--ME	MPB1P11300
72.	5.00E-07	MVD1V1250D	MVD1V7180D	
73.	5.00E-07	MVD1V125MD	FVM1V1590D	
74.	5.00E-07	MVD1V125MD	MPB1D37BME	

1ST MOMENT= 1.4077E-04

CUT TOOK 6.391 SECS

Figure 13: (Continued) (Sheet 2)

TABLE 2

APPLICANT'S SUMMARY OF MAINTENANCE AND TEST UNAVAILABILITIES

Components	Maintenance	Test	Total
1) Motor Driven EFP-37B	4.2×10^{-4}	N/A	4.2×10^{-4}
2) Turbine Driven EFP-37A		N/A	9.4×10^{-4}
Pump contribution	4.2×10^{-4}		
Turbine contribution	5.2×10^{-4}		
3) Startup Feed Pump P-113	4.2×10^{-4}	N/A	4.2×10^{-4}
4) Lube Oil Pump P-161	5.0×10^{-4}	N/A	5.0×10^{-4}
5) Diesel Generator	7.0×10^{-4}	N/A	7.0×10^{-4}
6) Valves			
a) Emerg. Feed Flow Isolation Valves (4214,4224,4234, 4244,75,87,93, 81)	8.5×10^{-4}	N/A	8.5×10^{-4}
b) Steam Supply Valves V-127, V-128	8.7×10^{-4}	N/A	8.7×10^{-4}
c) Steam Supply Valve V-129	1.0×10^{-4}	N/A	1.0×10^{-4}
d) Manual Isolation Valve V-65, V-71	9.3×10^{-6}	2.0×10^{-3}	2.0×10^{-3}

TABLE 3

APPLICANT'S SUMMARY OF OPERATOR ACTIONS/FAILURE PROBABILITIES

	Operator Action/Error	Failure Probability
1)	Operator fails to open either Steam Supply Valve V-127 or V-128 given failure to open automatically	5×10^{-3}
2)	Operator fails to close an isolation valve which fails to close automatically	5×10^{-3}
3)	Operator fails to close Emergency Feedwater System manual isolation valve to isolate rupture in header	9×10^{-1}
4)	Operator fails to restore valve to normal position after maintenance	1×10^{-3}
5)	Operator inadvertently blocks actuation signal, turns off running pump, shuts an isolation valve or fails to restore valve given indication of improper positioning	1×10^{-4}
6)	Operator fails to open V-156 in startup feed pump discharge line and align pump to emergency power within 20 minutes	1×10^{-2}
7)	Operator fails to open V-163 in startup feed pump discharge line and close V-109 in recirculation line to the CST	1.1×10^{-2}
8)	Operator fails to start the startup feed pump (P-113) from the control room given no automatic actuation signal and existence of emergency procedure	1×10^{-3}
9)	Operator fails to properly transfer breaker for SUF pump to bus E5	1×10^{-2}
10)	Operator fails to operate transfer switch on Bus E4	?

TABLE 4

APPLICANT'S
AFW SYSTEM UNRELIABILITY RESULTS

TRANSIENT	3-PUMP AFW SYSTEM	2-PUMP EFW SYSTEM
LMFW	2.1×10^{-5}	2.8×10^{-4}
LMFW/LOSP	5.2×10^{-5}	1.4×10^{-3} (5.8×10^{-4})
LMFW/LOAC	2.1×10^{-2}	2.1×10^{-2}

BNL Comment: At the June 23, 1982 meeting at NRC headquarters, the applicant stated that the value of 1.4×10^{-3} for the 2-pump EFW System under the LMFW/LOSP case should be 5.8×10^{-4}.

TABLE 5

APPLICANT'S RESULTS DOMINANT CONTRIBUTORS TO CONDITIONAL UNAVAILABILITY LOSS OF MAIN FEEDWATER EVENT

EVENT	CONTRIBUTION TO UNAVAILABILITY
1. Equipment and maintenance faults: Failures preventing motor-driven EFW pump from functioning coupled with maintenance errors causing isolation valve V125 to be closed.	7.0×10^{-6}
2. Maintenance faults: Maintenance outage of motor-driven EFW pump train coupled with maintenance errors causing isolation valve V125 to be closed.	3.0×10^{-6}
3. Maintenance faults: Maintenance errors causing isolation valve V125 to be closed and the motor-driven EFW train to be inoperable.	2.0×10^{-6}
4. Equipment and operator faults: Equipment failures in both EFW trains coupled with failure of operator to properly align SUF pump with EFW system.	1.9×10^{-6}
5. Equipment faults: Equipment failures disabling motor-driven EFW pump train and isolation valve V125.	9.0×10^{-7}
6. Equipment faults: Equipment failures disable all three pump trains.	7.3×10^{-7}
7. Equipment, maintenance and operator faults: Equipment failure in one EFW train while other EFW train out of service coupled with failure of operator to properly align SUF pump with EFW system.	5.9×10^{-7}
8. Cut-sets with unavailability values less than 1×10^{-7}.	4.4×10^{-6}
Total unavailability (all cut-sets) =	2.1×10^{-5}

TABLE 6

APPLICANT'S RESULTS
DOMINANT CONTRIBUTORS TO CONDITIONAL UNAVAILABILITY
LOSS OF MAIN FEEDWATER/LOSS OF OFFSITE POWER EVENT

EVENT	CONTRIBUTION TO UNAVAILABILITY
1. Equipment and maintenance faults: Failures preventing either diesel generator 1B or motor-driven EFW pump from functioning coupled with maintenance errors causing isolation valve V125 to be closed.	2.1×10^{-5}
2. Equipment and operator faults: Equipment failures disabling both EFW trains coupled with failure of operator to properly align SUF pump with EFW system.	5.8×10^{-6}
3. Maintenance faults: Maintenance outages or errors disabling motor-driven EFW pump train coupled with maintenance errors causing isolation valve V125 to be closed.	5.6×10^{-6}
4. Equipment faults (triples): equipment failures disable all three pump trains.	7.0×10^{-6}
5. Equipment faults (doubles): Equipment failures disabling motor-driven EFW pump train coupled with failure of valve V125 to remain open.	2.0×10^{-6}
6. Maintenance, equipment, and operator faults: Maintenance errors that disable turbine-driven EFW pump train coupled with equipment and operator errors that disable both the remaining EFW pump train and the SUF pumps.	1.8×10^{-6}
7. Maintenance, equipment, and operator faults: Maintenance errors that disable turbine-driven EFW pump train coupled with failures of diesel-generator 1B and failure of operator to properly align SUF pump with EFW system.	3.3×10^{-7}
8. Cut-sets with unavailability values less than 10^{-7}.	8.5×10^{-6}
Total unavailability (all cut-sets) =	5.2×10^{-5}

TABLE 7

APPLICANT'S RESULTS
DOMINANT CONTRIBUTORS TO CONDITIONAL UNAVAILABILITY
LOSS OF MAIN FEEDWATER/LOSS OF ALL AC POWER

EVENT	CONTRIBUTION TO UNAVAILABILITY
1. Equipment faults: Failure of turbine-driven EFW pump to start or continue running once started.	1.4×10^{-2}
2. Maintenance faults: Maintenance errors causing turbine-driven EFW train to be inoperable.	4.1×10^{-3}
3. Maintenance faults: Turbine-driven EFW train out of service for maintenance.	2.5×10^{-3}
4. Equipment faults: Miscellaneous single valve failures.	7.0×10^{-4}
5. Maintenance faults: Miscellaneous multiple maintenance errors causing turbine-driven EFW train to be inoperable.	8.5×10^{-5}
6. Cut-sets with unavailability values less than 10^{-5}.	1.1×10^{-5}
Total unavailability (all cut-sets) =	2.1×10^{-2}

TABLE 8

BNL RESULTS
UNAVAILABILITY OF SEABROOK AFWS
REF. 3 DESIGN USING NUREG-0611 DATA
LMFW TRANSIENT

1. Final answer from the WAMBAM code for the top event, AFW, "Insufficient Auxiliary Feedwater Flow to Steam Generators" which includes double and triple test and/or maintenance outage contributions is:

$$AFW = 5.0 \times 10^{-5} \text{ at a minimum probability cutoff of } 1 \times 10^{-10}.$$

2. Unavailability of the following subgates from the WAMCUT code at a minimum probability cutoff of 1×10^{-5} is (from Fig. 10, Sh. 1 to 3):

AF91: No Flow to supply Header From TDP-37A
$AF91 = 2.18 \times 10^{-2}$

AF127: No Flow to Supply Header from MDP-37B
$AF127 = 1.78 \times 10^{-2}$

SUP1: No Flow to Supply Header From SUFP
$SUP1 = 7.35 \times 10^{-2}$

3. Contributions to unavailability of subgates AF91, AF127 and SUP1 separated into Hardware and Maintenance (or Test) are:

AF91	AF127	SUP1
$H_1 = 1.1 \times 10^{-2}$	$H_2 = 1.2 \times 10^{-2}$	$H_3 = 7.0 \times 10^{-2}$
$M_1 = 1.1 \times 10^{-2}$	$M_2 = 5.8 \times 10^{-3}$	$M_3 = 5.8 \times 10^{-3}$

where H refers to failures due to random equipment failures and human errors and M refers to outages caused by maintenance and test acts.

4. Define a new top event, AFWSH, "No Flow to Supply Header From TDP-37A, TDP-37B, and SUFP":

$$AFWSH = (AF91) \cdot (AF127) \cdot (SUP1)$$

$$= (H_1 + M_1) \cdot (H_2 + M_2) \cdot (H_3 + M_3)$$

TABLE 8 (cont'd)

Let AFWSH' = $H_1H_2H_3 + H_1H_2M_3 + H_1M_2H_3 + M_1H_2H_3$

where double and triple maintenance and/or test contributions have been eliminated.

$$AFWSH' = 9.24 \times 10^{-6} + 0.76 \times 10^{-6} + 4.47 \times 10^{-6} + 9.24 \times 10^{-6}$$

$$AFWSH' = 2.371 \times 10^{-5}$$

5. The unavailability of AFWSH including the double and triple maintenance and/or test contributions is:

$$AFWSH = (AF91) \cdot (AF127) \cdot (SUP1)$$

$$= (2.18 \times 10^{-2})\ (1.78 \times 10^{-2})\ (7.35 \times 10^{-2})$$

$$= 2.85 \times 10^{-5}$$

6. To estimate the contribution of double maintenance and/or test actions, subtract AFWSH' from AFWSH:

$$DMT = AFWSH - AFWSH' = 2.85 \times 10^{-5} - 2.37 \times 10^{-5}$$

$$DMT = 0.48 \times 10^{-5}$$

7. To obtain the final answer for the top event, AFW corrected to eliminate double maintenance and/or test actions, AFW', subtract DMT from AFW:

$$AFW' = AFW - DMT = 5.0 \times 10^{-5} - 0.5 \times 10^{-5}$$

$$AFW' = 4.5 \times 10^{-5}$$

NOTE: The difference between the subgates AF91, AF127 and SUP1 and the sum of their components, e.g., SUP1 < $H_3 + M_3$, is caused by the subtraction of intersection terms in the WAMCUT code.

TABLE 9

BNL RESULTS
UNAVAILABILITY OF SEABROOK AFWS
PROPOSED DESIGN USING NUREG-0611 DATA
LMFW TRANSIENT

1. Refer to Fig. 2, 4 and 6. The SUFP is assumed to be supplying feedwater through the MFW system and the EFW pumps supply feedwater through the EFW header. The top event AFW*, "Insufficient Auxiliary Feedwater Flow to Steam Generators From the SUFPS and the EFWS", is approximated by the following expression:

$$AFW^* = SUP1 \cdot [(AF91 + V125) \cdot (AF127) + (AF91) \cdot (AF127 + V127)]$$

$$= (AF91) \cdot (AF127) \cdot (SUP1) + (AF127) \cdot (SUP1) \cdot (V125) + (AF91) \cdot (SUP1) \cdot (V127)$$

where AF91, AF127, and SUP1 are as defined in Table 8
and V125 = Unavailability of V125,
V127 = Unavailability of V127.

2. V125 and V127 are locked open valves without periodic surveillance. For the reasons discussed in Section 9.2.3.2, they are assigned 1×10^{-3} for the operator inadvertently leaving them in the wrong position. Therefore:

$$\overline{V125} = \overline{V127} = 1 \times 10^{-3} \text{ Operator Error}$$
$$\underline{1 \times 10^{-4} \text{ Plugging}}$$
$$1.1 \times 10^{-3}$$

3. Since it is no longer necessary for the operator to open V163 or V156, the failure rates for the operator failing to open these two valves can be subtracted from H_3 of SUP1 as shown in Fig. 10, Sh. 3 (MVD1V1560A = 1.0E-02 and MVD1V1630A = 1.0E-02). From Table 8, the values of AF91, AF127 and SUP1 are now:

TABLE 9 (cont'd)

AF91	AF127	SUP1
$H_1 = 1.1x10^{-2}$	$H_2 = 1.2x10^{-2}$	$H_3 = 5.0x10^{-2}$
$M_1 = 1.1x10^{-2}$	$M_2 = 5.8x10^{-3}$	$M_3 = 5.8x10^{-3}$

4. Separating AFW* into Hardware Failures and Maintenance (or Test) Failures:

(a) $(AF91) \cdot (AF127) \cdot (SUP1) = H_1H_2H_3 + H_1M_2H_3 +$

(b) $(AF127) \cdot (SUP1) \cdot (V125) = (H_2H_3 + M_2H_3 + H_2M_3) \cdot (V125)$

(c) $(AF91) \cdot (SUP1) \cdot (V127) = (H_1H_3 + H_1M_3 + M_1H_3) \cdot (V127)$

5. Substituting the new value for H_3

(a) $= 6.60 \times 10^{-6} + 3.19 \times 10^{-6} + 0.76 \times 10^{-6} + 6.60 \times 10^{-6}$

$= 1.72 \times 10^{-5}$

(b) $= (6.0 \times 10^{-4} + 2.9 \times 10^{-4} + 0.7 \times 10^{-4}) \cdot (11 \times 10^{-4})$

$= (9.6 \times 10^{-4})(11 \times 10^{-4}) = 1.06 \times 10^{-6}$

(c) $= (5.5 \times 10^{-4} + 0.64 \times 10^{-4} + 5.5 \times 10^{-4}) \cdot (11 \times 10^{-4})$

$= (11.64 \times 10^{-4})\ (11 \times 10^{-4}) = 1.28 \times 10^{-6}$

6. Therefore

AFW* = (a) + (b) + (c) = 1.95×10^{-5}

$$\frac{AFW^*}{LMFW} = 1.95 \times 10^{-5}$$

TABLE 10

BNL RESULTS

UNAVAILABILITY OF SEABROOK AFWS
REF. 3 DESIGN USING NUREG-0611 DATA
LOOP TRANSIENT

1. Final answer from the WAMBAM code for the top event, AFW, "Insufficient Auxiliary Feedwater Flow to Steam Generators" which includes double and triple test and/or maintenance outage contributions is:

$$AFW = 2.01 \times 10^{-4} \text{ at a minimum probability cutoff of } 1 \times 10^{-10}$$

2. Unavailability of the following subgates from the WAMCUT code at a minimum probability cutoff of 1×10^{-5} is (from Fig. 11, Sh. 1 to 3):

AF91: No Flow to Supply Header From TDP-37A
$AF91 = 2.18 \times 10^{-2}$

AF127: No Flow to Supply Header From MDP-37B
$AF127 = 5.52 \times 10^{-2}$

SUP1: No Flow to Supply Header From SUFP
$SUP1 = 1.18 \times 10^{-1}$

3. Contributions to unavailability of subgates AF91, AF127 and SUP1 separated into Hardware and Maintenance (or Test):

AF91	AF127	SUP1
$H_1 = 1.1 \times 10^{-2}$	$H_2 = 4.3 \times 10^{-2}$	$H_3 = 1.12 \times 10^{-1}$
$M_1 = 1.1 \times 10^{-2}$	$M_3 = 1.2 \times 10^{-2}$	$M_3 = 1.2 \times 10^{-2}$

4. Define a new top event, AFWSH, "No Flow to Supply Header From TDP-37A, TDP-37B, and SUFP":

$$AFWSH = (AF91) \cdot (AF127) \cdot (SUP1)$$

$$= (H_1 + M_1) \cdot (H_2 + M_2) \cdot (H_3 + M_3)$$

TABLE 10 (cont'd)

Let AFWSH' = $H_1H_2H_3 + H_1H_2M_3 + H_1M_2H_3 + M_1H_2H_3$

where double and triple maintenance and/or test contributions have been eliminated

$$AFWSH' = 5.30 \times 10^{-5} + 0.568 \times 10^{-5} + 1.478 \times 10^{-5} + 5.30 \times 10^{-5}$$

$$AFWSH' = 12.65 \times 10^{-5}$$

5. The unavailability of AFWSH including the double and triple maintenance and/or test contributions is:

$$AFWSH = (AF91)\cdot(AF127)\cdot(SUP1)$$

$$= (2.18 \times 10^{-2})\ (5.52 \times 10^{-2})\ (1.18 \times 10^{-1})$$

$$AFWSH = 14.20 \times 10^{-5}$$

6. To estimate the contribution of double maintenance and/or test actions, subtract AFWSH' from AFWSH:

$$DMT = AFWSH - AFWSH' = 14.20 \times 10^{-5} - 12.65 \times 10^{-5}$$

$$DMT = 1.55 \times 10^{-5}$$

7. To obtain the final answer for the top event, AFW corrected to eliminate double maintenance and/or test actions, AFW', subtract DMT from AFW:

$$AFW' = AFW - DMT = 20.1 \times 10^{-5} - 1.6 \times 10^{-5}$$

$$AFW'_{LOOP} = 1.8 \times 10^{-4}$$

TABLE 11

BNL RESULTS
UNAVAILABILITY OF SEABROOK AFWS
PROPOSED DESIGN USING NUREG-0611 DATA
LOOP TRANSIENT

1. Refer to Table 8 and 10. Again the expression for AFW* is:

$$AFW^* = (AF91)\cdot(AF127)\cdot(SUP1) + (AF127)\cdot(SUP1)\cdot(V125)$$
$$+ (AF91)\cdot(SUP1)\cdot(V127)$$

2. As in the Proposed Design for the LMFW transient, it is no longer necessary for the operator to open V156 or V163 so that the failure rates for those events can again be subtracted from H_3 of SUP1. The values of AF91, AF127 and SUP1 are now:

AF91	AF127	SUP1
$H_1 = 1.1\times10^{-2}$	$H_2 = 4.3\times10^{-2}$	$H_3 = 9.2\times10^{-2}$
$M_1 = 1.1\times10^{-2}$	$M_2 = 1.2\times10^{-2}$	$M_3 = 1.2\times10^{-2}$

3. Separating AFW* into Hardware Failures and Maintenance (or Test) Failures:

(a) $(AF91)\cdot(AF127)\cdot(SUP1) = H_1H_2H_3 + H_1M_2H_3 + H_1H_2M_3 + M_1H_2H_2$

(b) $(AF127)\cdot(SUP1)\cdot(V125) = (H_2H_3 + M_2H_3 + H_2M_3)\cdot(V125)$

(c) $(AF91)\cdot(SUP1)\cdot(V127) = (H_1H_3 + H_1M_3 + M_1H_3)\cdot(V127)$

4. Substituting the new value for H_3,

(a) $= 43.52 \times 10^{-6} + 12.14 \times 10^{-6} + 5.68 \times 10^{-6} + 43.52 \times 10^{-6}$

$= 104.86 \times 10^{-6}$

TABLE 11 (cont'd)

$$(b) = (39.56 \times 10^{-4} + 11.04 \times 10^{-4} + 5.16 \times 10^{-4})(11 \times 10^{-4})$$

$$= (55.76 \times 10^{-4})(11 \times 10^{-4}) = 6.13 \times 10^{-6}$$

$$(c) = (10.12 \times 10^{-4} + 1.32 \times 10^{-4} + 10.12 \times 10^{-4})(11 \times 10^{-4})$$

$$= (31.68 \times 10^{-4})(11 \times 10^{-4}) = 3.48 \times 10^{-6}$$

$$AFW^{*} = (a) + (b) + (c) = 1.15 \times 10^{-4}$$

$$AFW^{*}_{LOOP} = 1.15 \times 10^{-4}$$

TABLE 12

SUMMARY OF BNL ASSESSMENTS

Description		LMFW REF.3	LMFW Proposed	LOOP REF.3	LOOP Proposed	LOAC REF.3	LOAC Proposed
1. TDP-37A	AF91	$2.18x10^{-2}$	$2.18x10^{-2}$	$2.18x10^{-2}$	$2.18x10^{-2}$	$2.18x10^{-2}$	$2.18x10^{-2}$
	H_1	$1.1x10^{-2}$	$1.1x10^{-2}$	$1.1x10^{-2}$	1.1x10-2	$1.1x10^{-2}$	$1.1x10^{-2}$
	M1	$1.1x10^{-2}$	$1.1x10^{-2}$	$1.1x10^{-2}$	$1.1x10^{-2}$	$1.1x10^{-2}$	$1.1x10^{-2}$
2. MDP-37B	AF127	$1.78x10^{-2}$	$1.78x10^{-2}$	$5.42x10^{-2}$	$5.42x10^{-2}$	-	-
	H_2	$1.2x10^{-2}$	$1.2x10^{-2}$	$4.3x10^{-2}$	$4.3x10^{-2}$	-	-
	M_2	$5.8x10^{-3}$	$5.8x10^{-3}$	$1.2x10^{-2}$	$1.2x10^{-2}$	-	-
3. SUFP	SUP1	$7.35x10^{-2}$	$5.35x10^{-2}$	$1.18x10^{-1}$	$9.8x10^{-2}$	-	-
	H_3	$7.0x10^{-2}$	$5.0x10^{-2}$	$1.12x10^{-1}$	$9.2x10^{-2}$	-	-
	M_3	$5.8x10^{-3}$	$5.8x10^{-3}$	$1.2x10^{-2}$	$1.2x10^{-2}$	-	-
4. HEADER VALVES	V125, V127	$1.1x10^{-3}$	$1.1x10^{3}$	$1.1x10^{-3}$	$1.1x10^{-3}$	$1.1x10^{-3}$	$1.1x10^{-3}$
5. WAMBAM	AFW	$5.0x10^{-5}$	-	$2.0x10^{-4}$	-	-	-
6. TOP EVENT	AFW'	$4.5x10^{-5}$	-	$1.8x10^{-4}$	-	$2.3x10^{-2}$	-
	AFW*	-	$1.95x10^{-5}$	-	$1.15x10^{-4}$	-	$2.3x10^{-2}$

APPENDIX A

SEABROOK AUXILIARY FEEDWATER SYSTEM FAULT TREES

The following is a guideline for interpreting the basic fault identifiers used in the attached Seabrook EFW fault tree and in fault identifier Table B-2.

Each fault identifier consists of 10 alphanumeric characters of the form:

X-XX-1-XXXX-XX

The first character identifies the system to which the component belongs (see Table A.1). The second and third characters identify the component type (Table A.2). The fifth through eighth characters are for component identification and the last two characters identify the fault codes (Table A.3).

TABLE A.1

SYSTEM IDENTIFICATION CODE

C - Condensate System

M - Emergency Feedwater System

Q - Steam Supply System

R - Electrical Distribution System

5 - Condensate Storage System

6 - Control/Protection System

TABLE A.2

COMPONENT TYPES

BA - Batteries

BC - Battery Chargers

CA - Circuit Breaker

CB - Contactor

CC - Controller

CD - Starter

CE - Switch

EC - Electrical Conductors

GD - Diesel Generator

HX - Heat Exchanger

IC - Instrument Controller

ID - Sensor/Detector/Element - Pressure

IE - Sensor/Detector/Element - Temperature

IF - Sensor/Detector/Element - Flow

IG - Sensor/Detector/Element - Level

IH - Sensor/Detector/Element - Radiation

IP - Power Supply

IX - Instrument Error

MA - AC Motor

MD - DC Motor

OA - Piping less than 1 inch in diameter

OB - Piping greater than 1 inch but less than 2 inch

OC - Piping greater than 2 inch but less than 3 inch

OD - Piping greater than 3 inch but less than 4 inch

OE - Piping greater than 4 inch but less than 6 inch

OF - Piping greater than 6 inch but less than 8 inch

OG - Piping greater than 8 inch but less than 10 inch

OH - Piping greater than 10 inch but less than 12 inch

OI - Piping greater than 12 inch but less than 16 inch

OJ - Piping greater than 16 inch but less than 24 inch

OK - Piping greater than 24 inch but less than 36 inch

OL - Piping greater than 36 inch

TABLE A.2 (CONT'D.)

PB - Centrifugal Pump

RA - Control, General Purpose

TR - Transformer

TU - Turbine

VA - Check Valve

VB - Relief Valve

VC - Vacuum Relief

VD - Isolation, Shutoff Valve

VG - Flow Control

TABLE A.3

FAULT CODES

CL - Cooling Failure

LB - Lubrication Failure

MA - Fails to Open/De-energize/Disengage

MB - Fails to Close/Energize/Engage

MC - Fails to Remain Closed/De-energize/Disengaged

MD - Fails to Remain Open/Energized/Engaged

ME - Fail to Start

MG - Fail to Run

MJ - Leak/Rupture/Electrical Short Circuit

MK - Open Circuit

ML - Overload

MM - Underload

MN - No Signal/No Input

MO - Spurious Signal

OA - Operator Fails to Open/De-energize/Disengage

OB - Operator Fails to Close/Energize/Engage

OC - Operator Inadvertently Opens/De-energizes/Disengages/Leaves Open

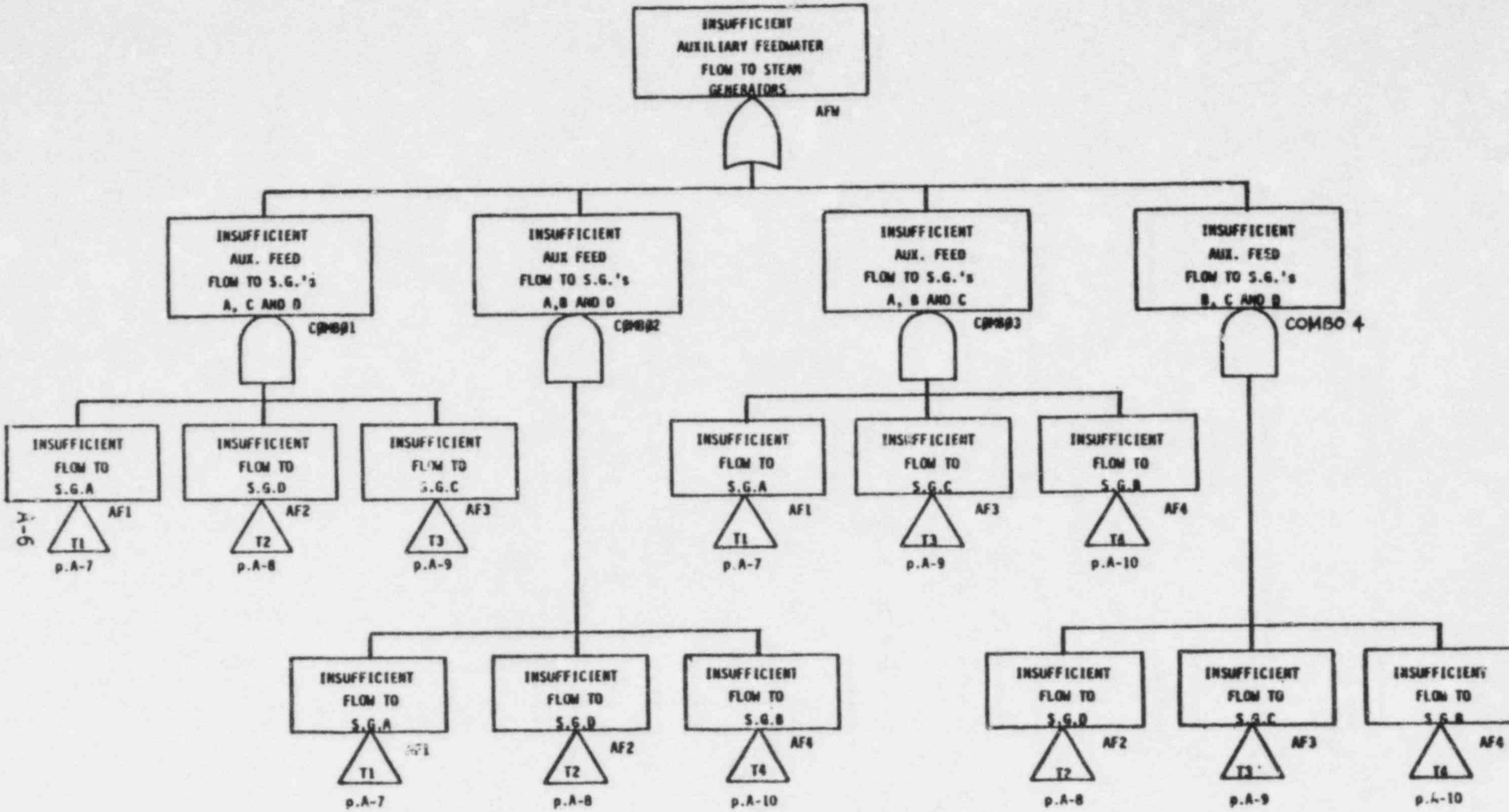
OD - Operator Inadvertently Closes/Energizes/Engages/Leaves Closed

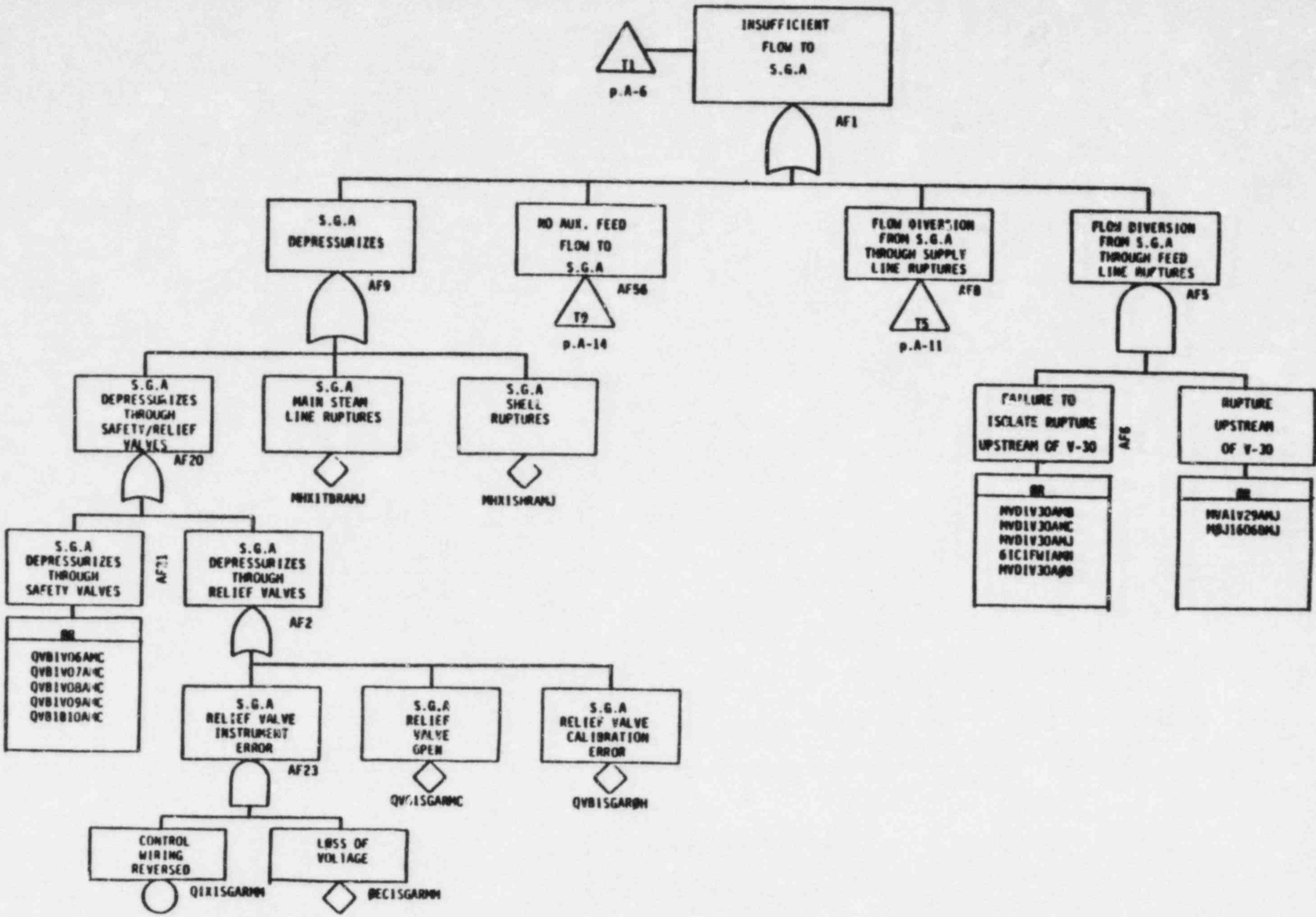
OE - Operator Fails to Start

OG - Operator Fails to Leave Running

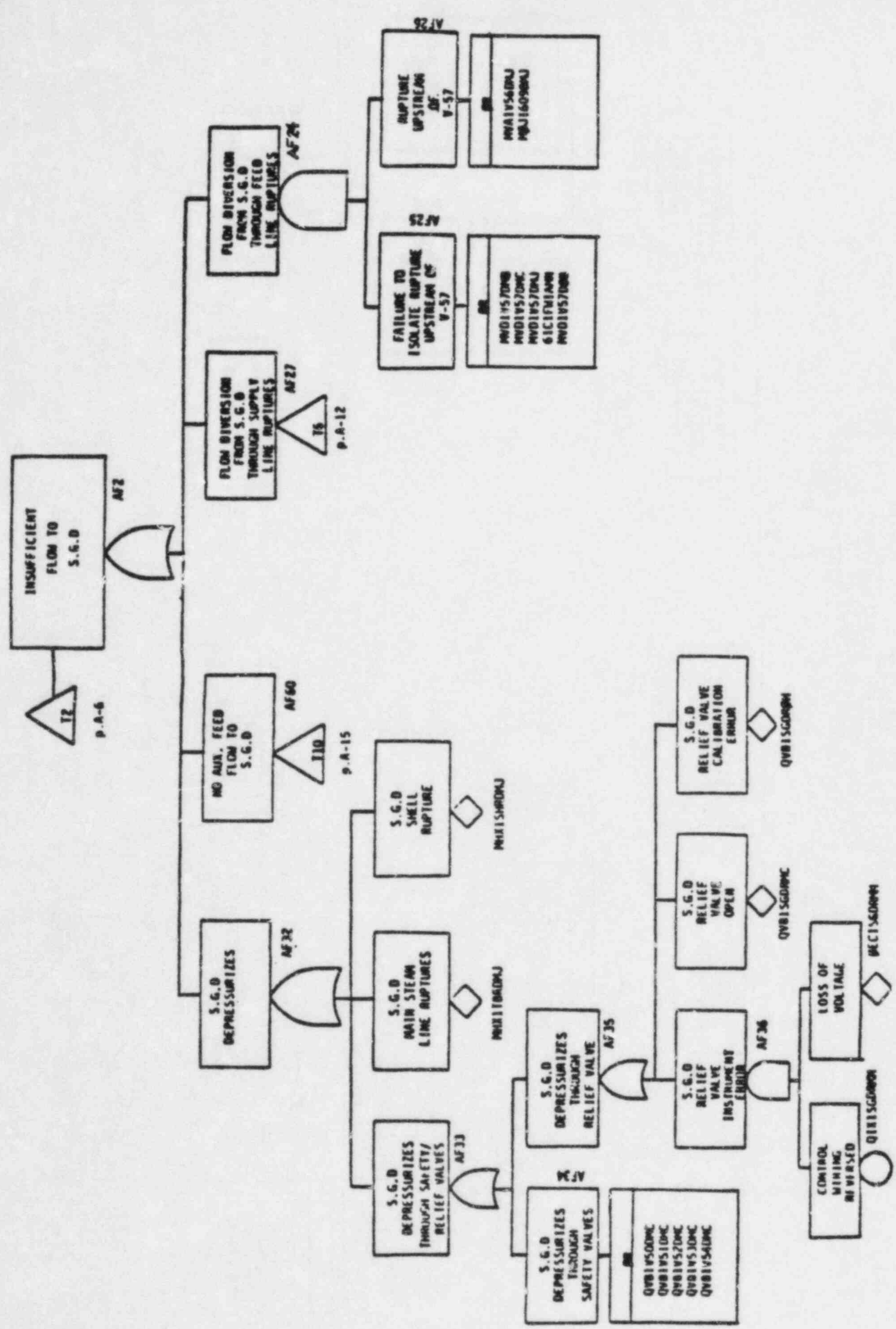
OH - Calibration Error

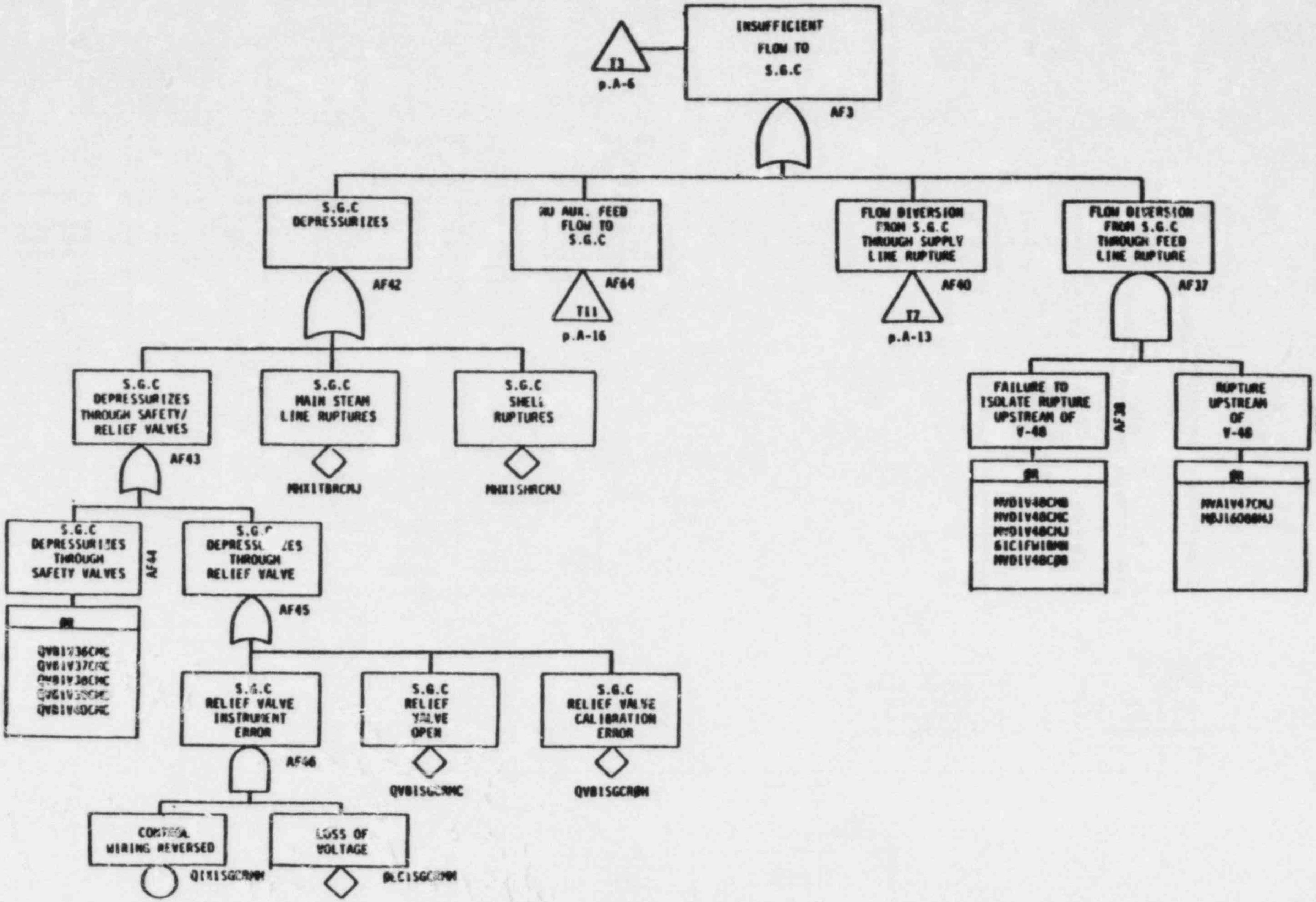
OO - Out of Service

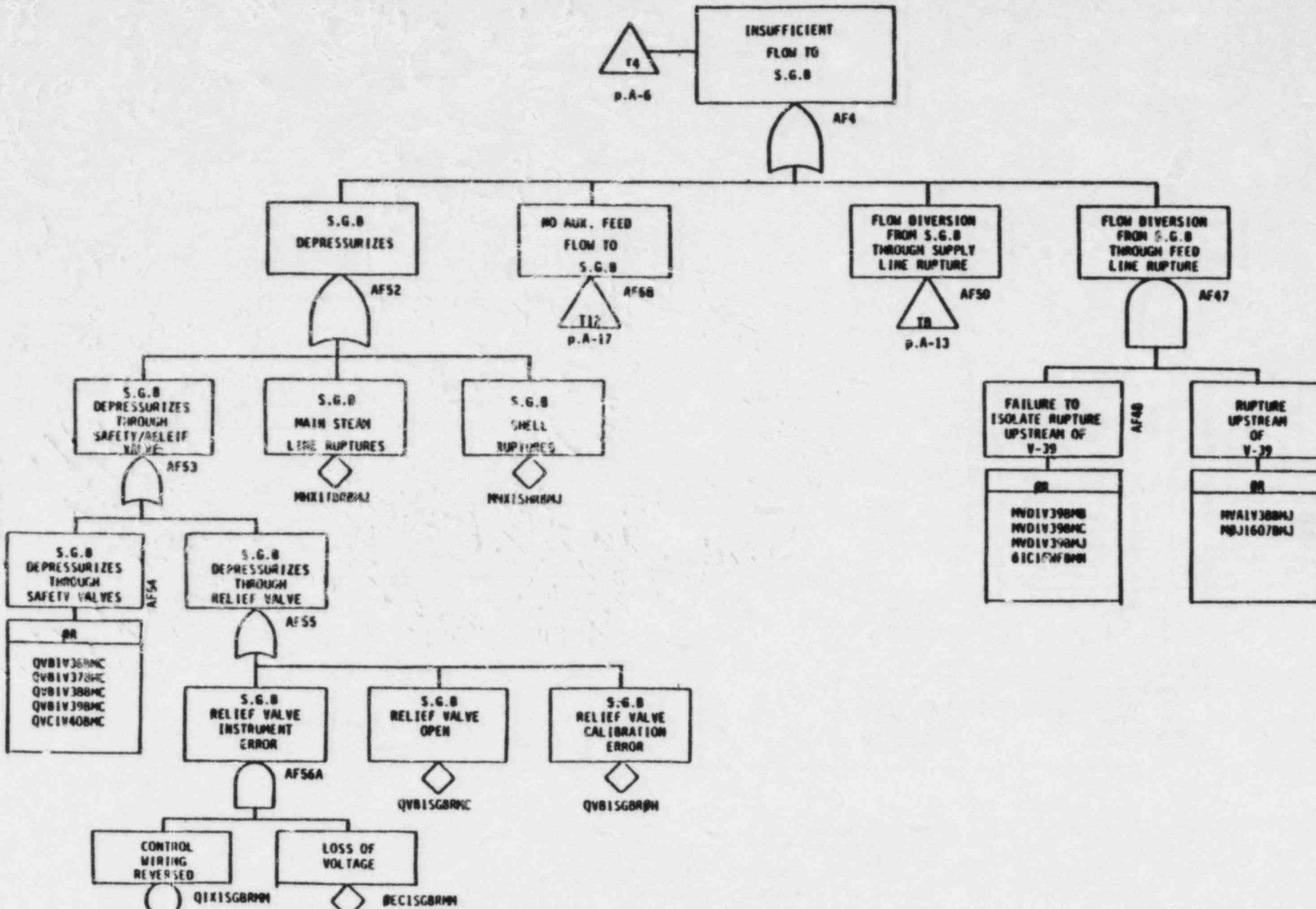

INSUFFICIENT AUXILIARY FEEDWATER FLOW TO STEAM GENERATORS
AFW
INSUFFICIENT AUX. FEED FLOW TO S.G.'s A, C AND D
COMBO1
INSUFFICIENT AUX FEED FLOW TO S.G.'s A,B AND D
COMBO2
INSUFFICIENT AUX. FEED FLOW TO S.G.'s A, B AND C
COMBO3
INSUFFICIENT AUX. FEED FLOW TO S.G.'s B, C AND D
COMBO 4
INSUFFICIENT FLOW TO S.G.A
AF1
T1
p.A-7
INSUFFICIENT FLOW TO S.G.D
AF2
T2
p.A-8
INSUFFICIENT FLOW TO S.G.C
AF3
T3
p.A-9
INSUFFICIENT FLOW TO S.G.B
AF4
T4
p.A-10

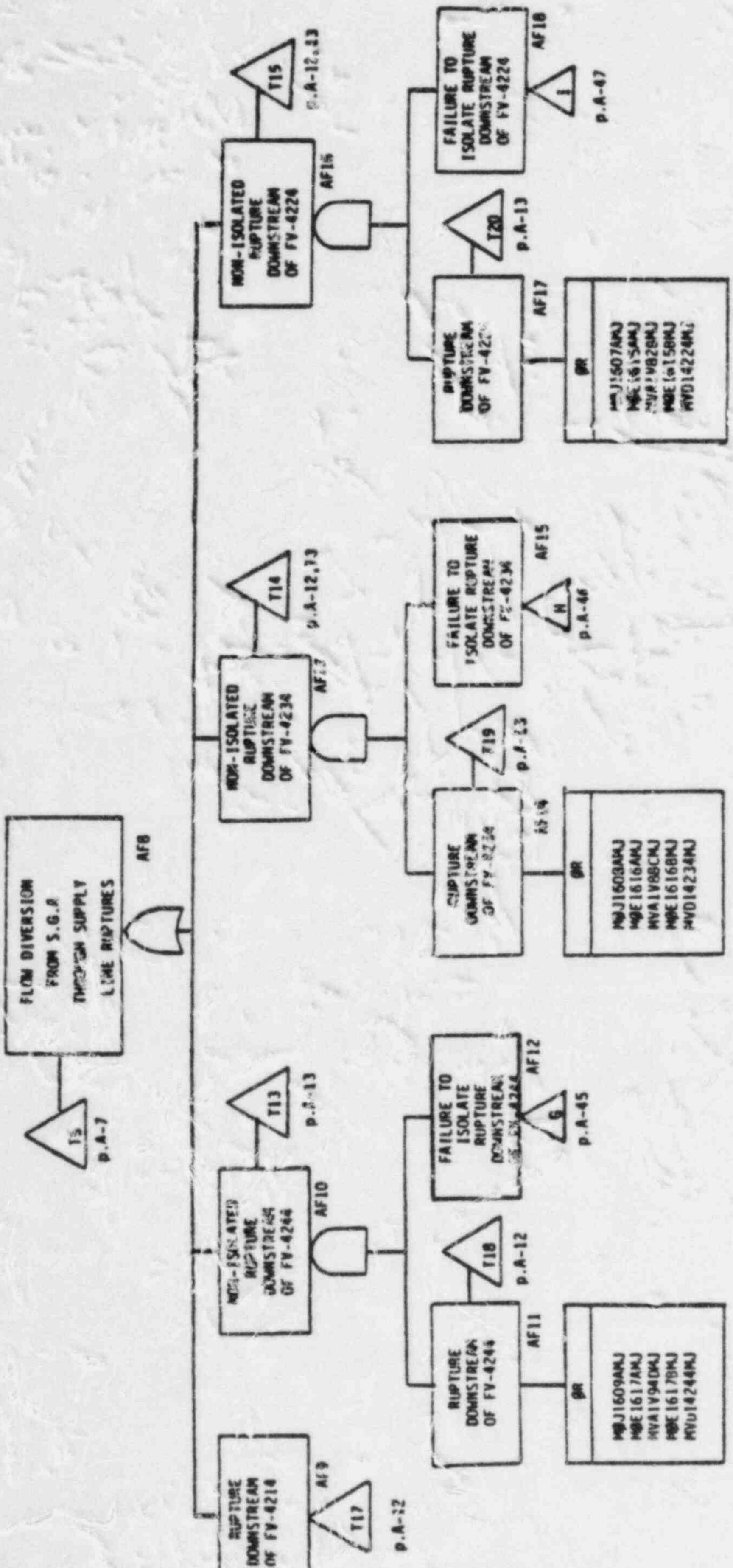


INSUFFICIENT FLOW TO S.G.A
T1
p.A-6
AF1
S.G.A DEPRESSURIZES
AF9
NO AUX. FEED FLOW TO S.G.A
AF56
T9
p.A-14
FLOW DIVERSION FROM S.G.A THROUGH SUPPLY LINE RUPTURES
AF8
T5
p.A-11
FLOW DIVERSION FROM S.G.A THROUGH FEED LINE RUPTURES
AF5
S.G.A DEPRESSURIZES THROUGH SAFETY/RELIEF VALVES
AF20
S.G.A MAIN STEAM LINE RUPTURES
MHXITBRAMJ
S.G.A SHELL RUPTURES
MHXISHRAMJ
FAILURE TO ISOLATE RUPTURE UPSTREAM OF V-30
AF6
OR
MVDIV30AMB
MVDIV30AMC
MVDIV30AMJ
6ICIFWIAMM
MVDIV30AØ8
RUPTURE UPSTREAM OF V-30
AF7
OR
MVAIV29AMJ
MBJ16060MJ
S.G.A DEPRESSURIZES THROUGH SAFETY VALVES
AF21
OR
QVBIV06AMC
QVBIV07AMC
QVBIV08AMC
QVBIV09AMC
QVBIB10AMC
S.G.A DEPRESSURIZES THROUGH RELIEF VALVES
AF2
S.G.A RELIEF VALVE INSTRUMENT ERROR
AF23
S.G.A RELIEF VALVE OPEN
QVIISGARMC
S.G.A RELIEF VALVE CALIBRATION ERROR
QVBISGARØH
CONTROL WIRING REVERSED
QIXISGARMM
LOSS OF VOLTAGE
BECISGARMM

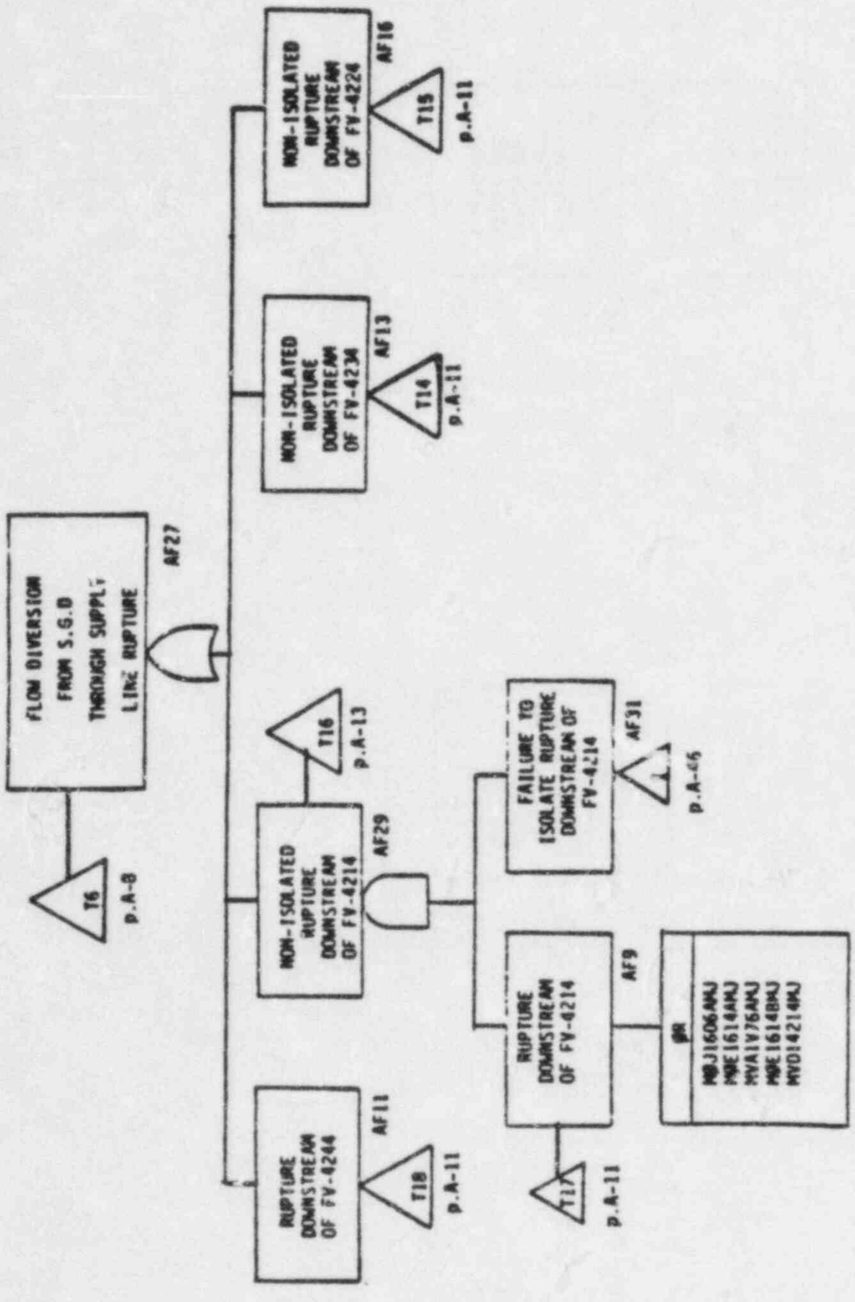

INSUFFICIENT FLOW TO S.G.D
AF2
T2
p.A-6
NO AUX. FEED FLOW TO S.G.D
AF60
T10
p.A-15
FLOW DIVERSION FROM S.G.D THROUGH SUPPLY LINE RUPTURES
AF27
T6
p.A-12
FLOW DIVERSION FROM S.G.D THROUGH FEED LINE RUPTURES
AF24
FAILURE TO ISOLATE RUPTURE UPSTREAM OF V-57
AF25
RUPTURE UPSTREAM OF V-57
AF26
S.G.D DEPRESSURIZES
AF32
S.G.D MAIN STEAM LINE RUPTURES
S.G.D SHELL RUPTURE
S.G.D DEPRESSURIZES THROUGH SAFETY/RELIEF VALVES
AF33
S.G.D DEPRESSURIZES THROUGH SAFETY VALVES
AF34
S.G.D DEPRESSURIZES THROUGH RELIEF VALVE
AF35
S.G.D RELIEF VALVE INSTRUMENT ERROR
AF36
S.G.D RELIEF VALVE OPEN
S.G.D RELIEF VALVE CALIBRATION ERROR
LOSS OF VOLTAGE
CONTROL WIRING REVERSED

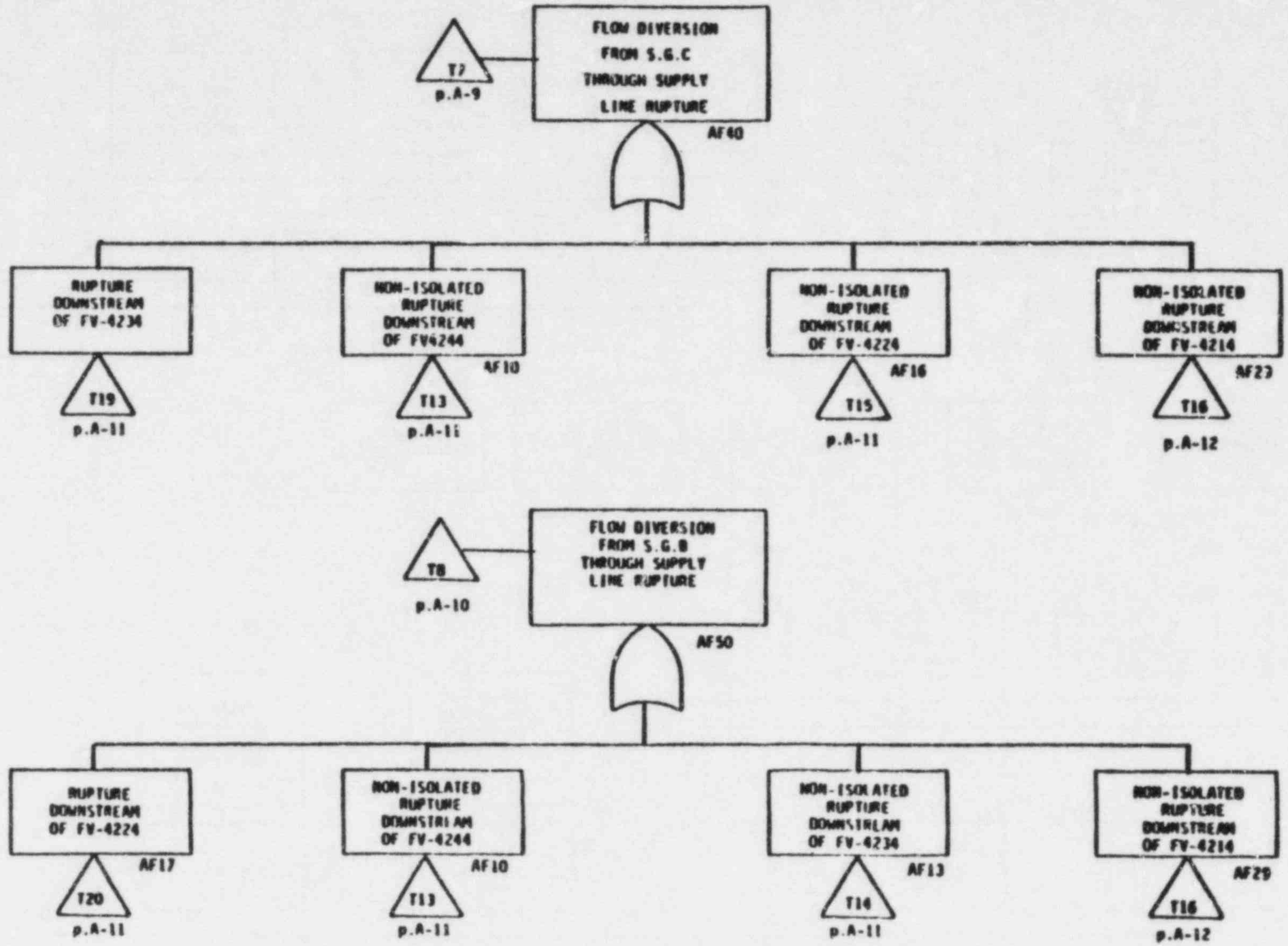

INSUFFICIENT FLOW TO S.G.C
T3
p.A-6
AF3
S.G.C DEPRESSURIZES
AF42
FLOW TO S.G.C
AF64
T11
p.A-16
FLOW DIVERSION FROM S.G.C THROUGH SUPPLY LINE RUPTURE
AF40
T7
p.A-13
FLOW DIVERSION FROM S.G.C THROUGH FEED LINE RUPTURE
AF37
S.G.C DEPRESSURIZES THROUGH SAFETY/ RELIEF VALVES
AF43
S.G.C MAIN STEAM LINE RUPTURES
MHXITBRCMJ
S.G.C SHELL RUPTURES
MHXISHRCMJ
FAILURE TO ISOLATE RUPTURE UPSTREAM OF V-48
AF38
RUPTURE UPSTREAM OF V-48
AF39
OR
MVDIV48CMB
MVDIV48CMC
MVDIV48CMJ
GICIFWIBMM
MVDIV48CØB
OR
MVAIV47CMJ
MBJ1600BMJ
THROUGH SAFETY VALVES
AF44
THROUGH RELIEF VALVE
AF45
OR
QVBIV36CMC
QVBIV37CMC
QVBIV38CMC
QVBIV40CMC
S.G.C RELIEF VALVE INSTRUMENT ERROR
AF46
S.G.C RELIEF OPEN
S.G.C RELIEF VALVE CALIBRATION ERROR
QVBISGCRØM
WIRING REVERSED
LOSS OF VOLTAGE

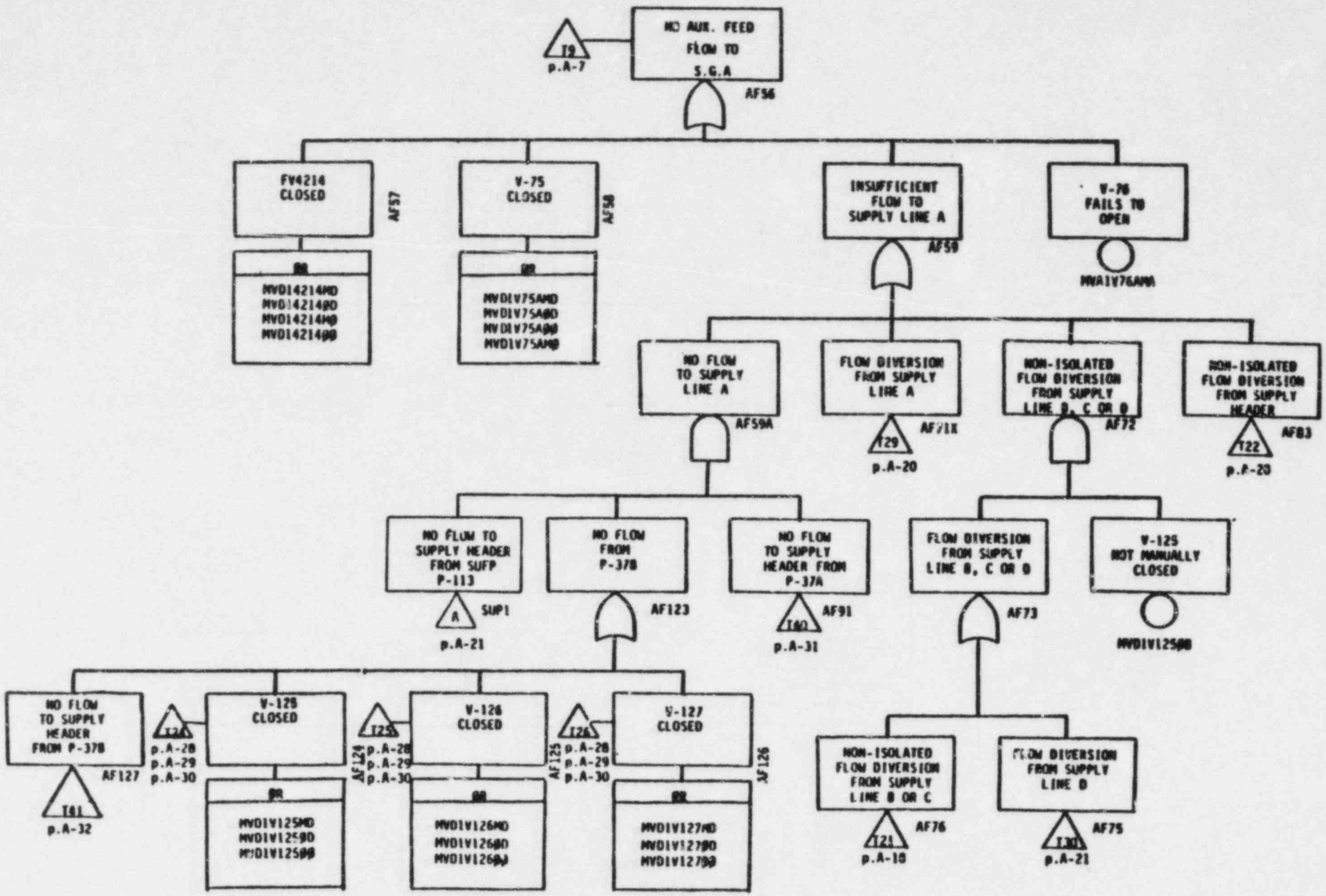

INSUFFICIENT FLOW TO S.G.B
T4
p.A-6
AF4
S.G.B DEPRESSURIZES
AF52
NO AUX. FEED FLOW TO S.G.B
AF68
T12
p.A-17
FLOW DIVERSION FROM S.G.B THROUGH SUPPLY LINE RUPTURE
AF50
T8
p.A-13
FLOW DIVERSION FROM S.G.B THROUGH FEED LINE RUPTURE
AF47
S.G.B DEPRESSURIZES THROUGH SAFETY/RELEIF VALVE
AF53
S.G.B MAIN STEAM LINE RUPTURES
S.G.B SHELL RUPTURES
FAILURE TO ISOLATE RUPTURE UPSTREAM OF V-39
AF48
RUPTURE UPSTREAM OF V-39
AF49
S.G.B DEPRESSURIZES THROUGH SAFETY VALVES
AF54
S.G.B DEPRESSURIZES THROUGH RELIEF VALVE
AF55
OR
QVB1V36BMC
QVB1V37BMC
QVB1V38BMC
QVB1V39BMC
QVC1V40BMC
OR
MVD1V39BMB
MVD1V39BMC
MVD1V39BMJ
OR
MVA1V38BMJ
MBJ1607BMJ
S.G.B RELIEF VALVE INSTRUMENT ERROR
AF56A
S.G.B RELIEF VALVE OPEN
QVB1SGBRMC
S.G.B RELIEF VALVE CALIBRATION ERROR
QVB1SGBRØH
CONTROL WIRING REVERSED
QIX1SGBRMM
LOSS OF VOLTAGE
ØEC1SGBRMM



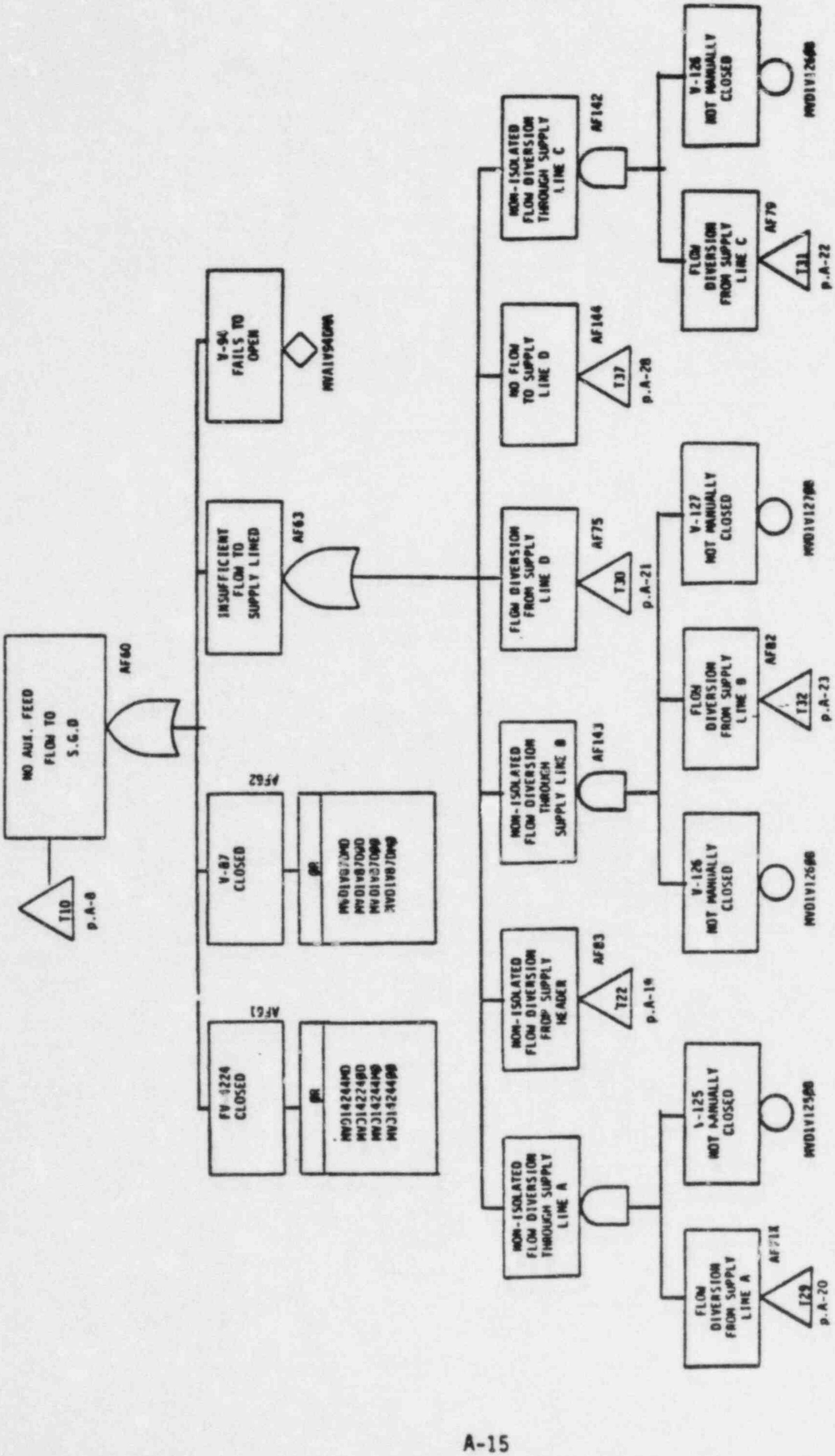
FLOW DIVERSION FROM S.G.A THROUGH SUPPLY LINE RUPTURES
AF8
T5
p.A-7
RUPTURE DOWNSTREAM OF FV-4214
AF9
T17
p.A-12
NON-ISOLATED RUPTURE DOWNSTREAM OF FV-4244
AF10
T13
p.A-13
RUPTURE DOWNSTREAM OF FV-4244
AF11
T18
p.A-12
OR
MBJ1609AHJ
MBE1617AHJ
MVA1V94DHJ
MBE1617BHJ
MVD14244HJ
FAILURE TO ISOLATE RUPTURE DOWNSTREAM
AF12
G
p.A-45
NON-ISOLATED RUPTURE DOWNSTREAM OF FV-4234
T14
p.A-12,13
RUPTURE DOWNSTREAM
T19
OR
MBJ1608AHJ
MBE1616AHJ
MVA1V88CHJ
MBE1616BHJ
MVD14234HJ
FAILURE TO ISOLATE RUPTURE DOWNSTREAM
AF15
H
p.A-46
NON-ISOLATED RUPTURE DOWNSTREAM OF FV-4224
AF16
T15
RUPTURE DOWNSTREAM
AF17
T20
p.A-13
OR
MVD14224HJ
FAILURE TO ISOLATE RUPTURE DOWNSTREAM OF FV-4224
AF18
I
p.A-47

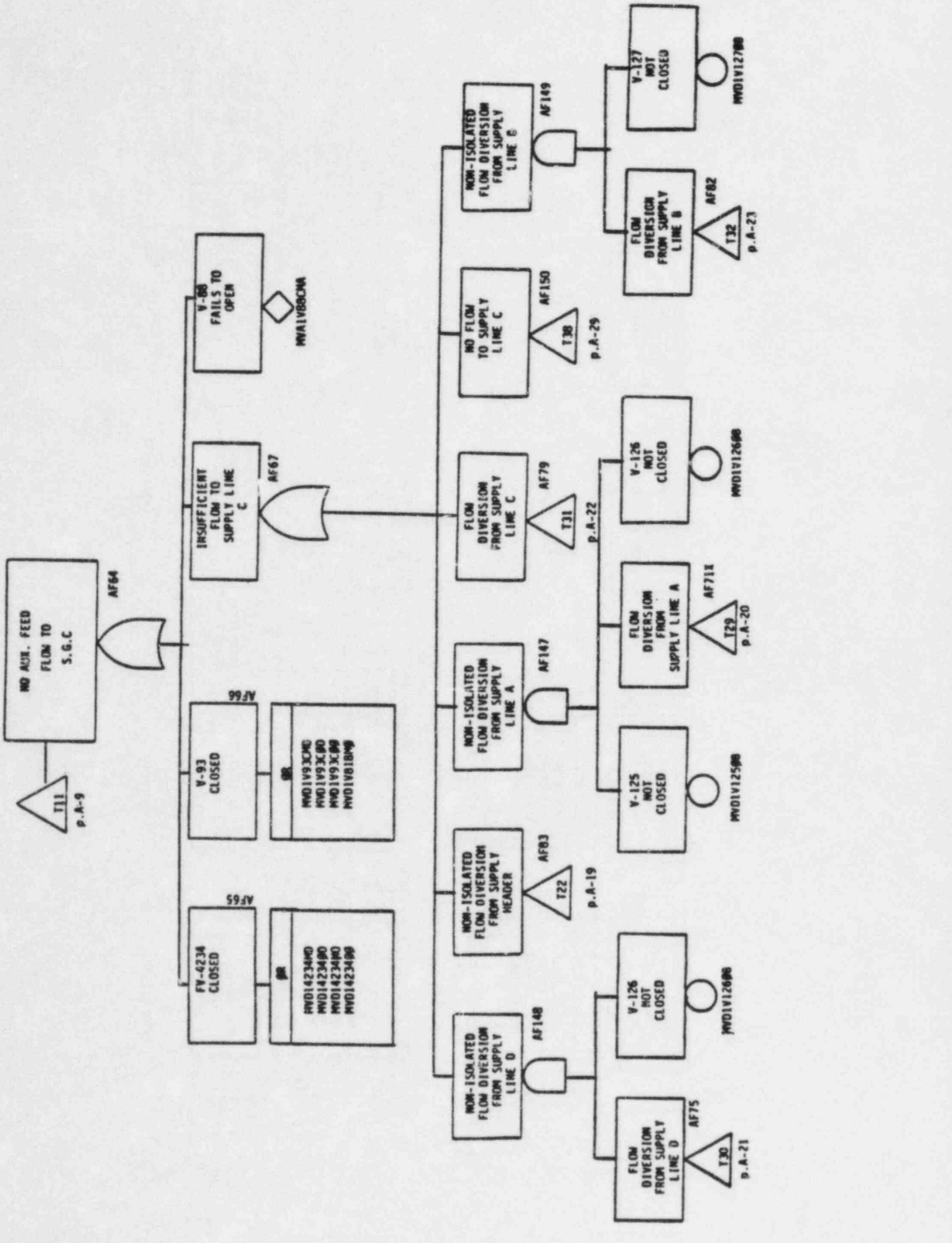

FLOW DIVERSION FROM S.G.D THROUGH SUPPLY LINE RUPTURE
AF27
T6
p.A-8
RUPTURE DOWNSTREAM OF FV-4244
AF11
T18
p.A-11
NON-ISOLATED RUPTURE DOWNSTREAM OF FV-4214
AF29
T16
p.A-13
NON-ISOLATED RUPTURE DOWNSTREAM OF FV-4234
AF13
T14
p.A-11
NON-ISOLATED RUPTURE DOWNSTREAM OF FV-4224
AF16
T15
p.A-11
RUPTURE DOWNSTREAM OF FV-4214
AF9
T17
p.A-11
FAILURE TO ISOLATE RUPTURE DOWNSTREAM OF FV-4214
AF31
OR

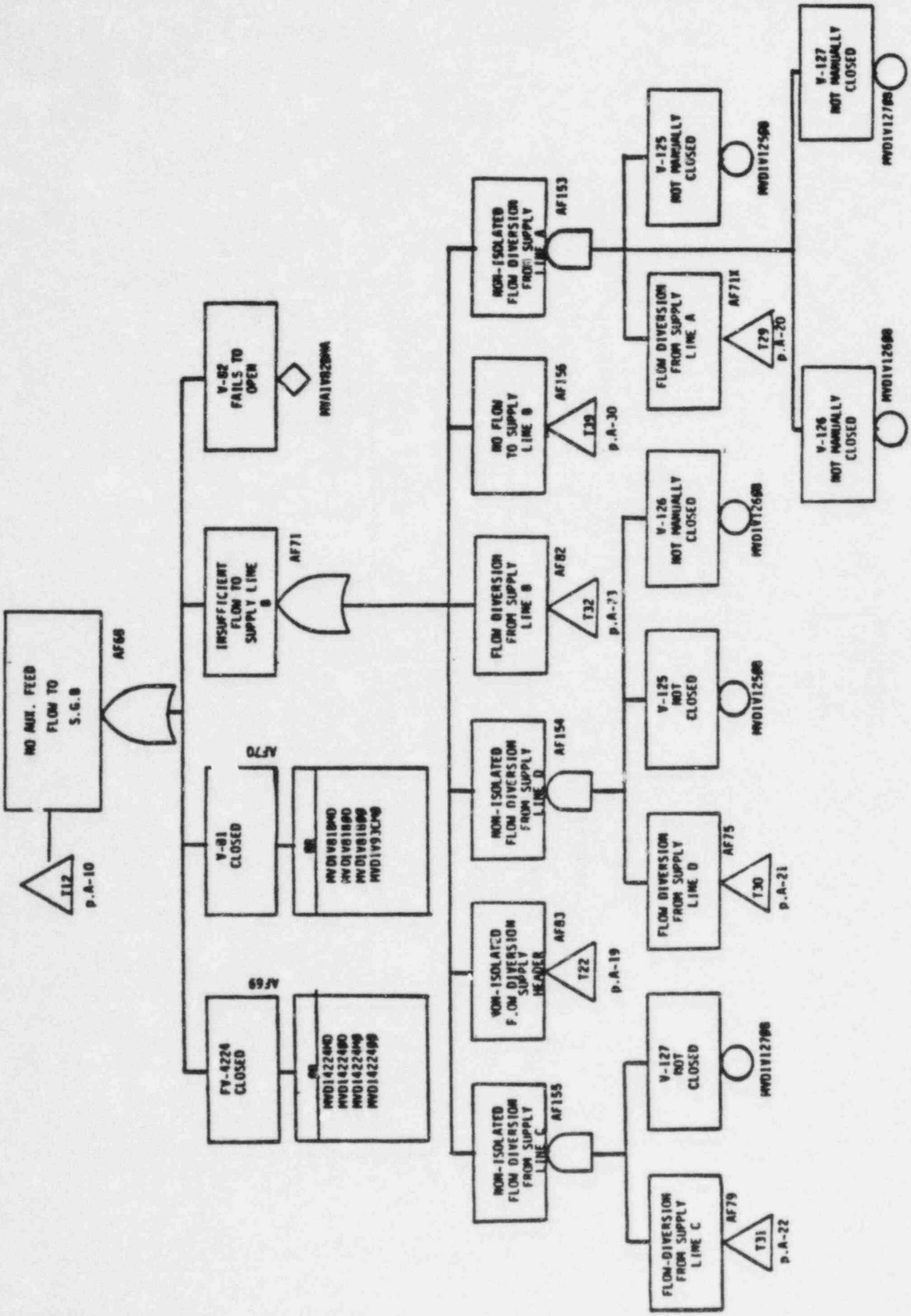

FLOW DIVERSION FROM S.G.C THROUGH SUPPLY LINE RUPTURE
AF40
T7
p.A-9
RUPTURE DOWNSTREAM OF FV-4234
T19
p.A-11
NON-ISOLATED RUPTURE DOWNSTREAM OF FV4244
AF10
T13
p.A-11
NON-ISOLATED RUPTURE DOWNSTREAM OF FV-4224
AF16
T15
p.A-11
NON-ISOLATED RUPTURE DOWNSTREAM OF FV-4214
AF23
T16
p.A-12
FLOW DIVERSION FROM S.G.B THROUGH SUPPLY LINE RUPTURE
AF50
T8
p.A-10
RUPTURE DOWNSTREAM OF FV-4224
AF17
T20
p.A-11
NON-ISOLATED RUPTURE DOWNSTREAM OF FV-4244
AF10
T13
p.A-11
NON-ISOLATED RUPTURE DOWNSTREAM OF FV-4234
AF13
T14
p.A-11
NON-ISOLATED RUPTURE DOWNSTREAM OF FV-4214
AF29
T16
p.A-12



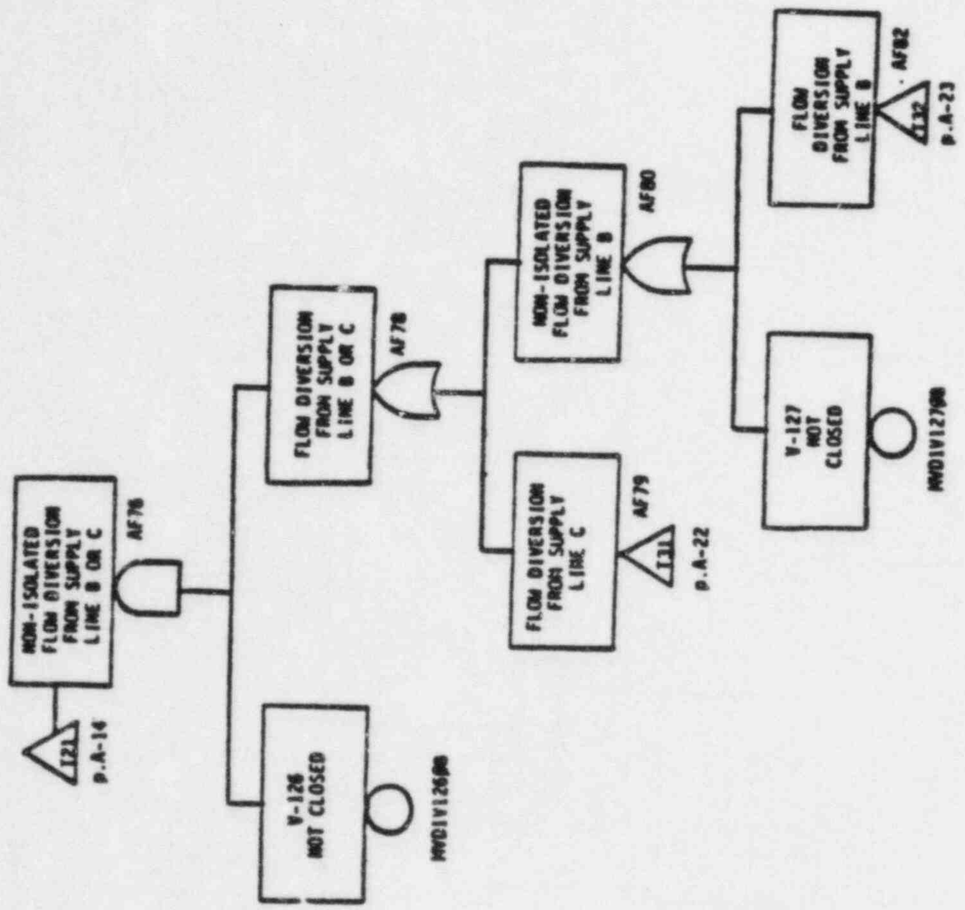
NO AUX. FEED FLOW TO S.G.A
T9
p.A-7
AF56
FV4214 CLOSED
AF57
OR
MVD14214MD
MVD14214ØD
MVD14214MØ
MVD14214ØØ
V-75 CLOSED
AF58
OR
MVDIV75AMD
MVDIV75AØD
MVDIV75AØØ
MVDIV75AMØ
INSUFFICIENT FLOW TO SUPPLY LINE A
AF59
V-76 FAILS TO OPEN
MVAIV76AMA
NO FLOW TO SUPPLY LINE A
AF59A
FLOW DIVERSION FROM SUPPLY LINE A
T29
p.A-20
NON-ISOLATED FLOW DIVERSION FROM SUPPLY LINE B, C OR D
AF72
NON-ISOLATED FLOW DIVERSION FROM SUPPLY HEADER
T22
AF83
NO FLOW TO SUPPLY HEADER FROM SUFP P-113
A
SUP1
p.A-21
NO FLOW FROM P-37B
AF123
NO FLOW TO SUPPLY HEADER FROM P-37A
T60
AF91
p.A-31
FLOW DIVERSION FROM SUPPLY LINE B, C OR D
AF73
V-125 NOT MANUALLY CLOSED
MVDIV125ØØ
NO FLOW TO SUPPLY HEADER FROM P-37B
T61
AF127
p.A-32
V-125 CLOSED
T24
p.A-28
p.A-29
p.A-30
AF124
OR
MVDIV125MD
MVDIV125ØD
MVDIV125ØØ
V-126 CLOSED
T25
p.A-28
p.A-29
p.A-30
AF125
OR
MVDIV126MD
MVDIV126ØD
MVDIV126ØØ
V-127 CLOSED
T26
p.A-28
p.A-29
p.A-30
AF126
OR
MVDIV127MD
MVDIV127ØD
MVDIV127ØØ
NON-ISOLATED FLOW DIVERSION FROM SUPPLY LINE B OR C
T21
AF76
p.A-18
FLOW DIVERSION FROM SUPPLY LINE D
T30
AF75
p.A-21

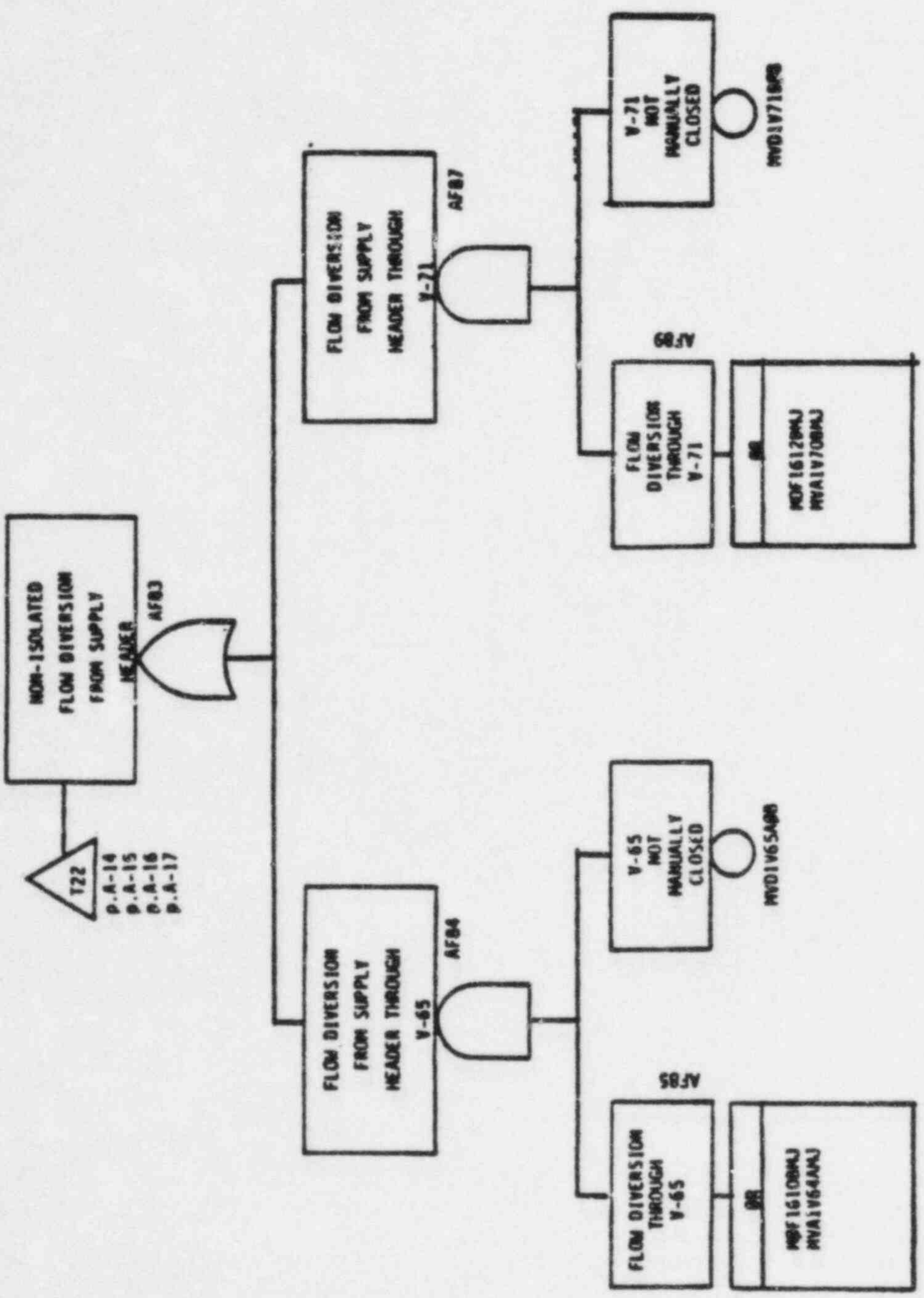

NO AUX. FEED FLOW TO S.G.D
AF60
T10
p.A-8
FV-0224 CLOSED
AF61
V-87 CLOSED
AF62
INSUFFICIENT FLOW TO SUPPLY LINED
AF63
V-94 FAILS TO OPEN
NON-ISOLATED FLOW DIVERSION THROUGH SUPPLY LINE A
NON-ISOLATED FLOW DIVERSION FROM SUPPLY HEADER
AF83
T22
NON-ISOLATED FLOW DIVERSION THROUGH SUPPLY LINE B
AF143
FLOW DIVERSION FROM SUPPLY LINE D
AF75
T30
p.A-21
NO FLOW TO SUPPLY LINE D
AF144
T37
NON-ISOLATED FLOW DIVERSION THROUGH SUPPLY LINE C
AF142
FLOW DIVERSION FROM SUPPLY LINE A
T29
p.A-20
V-125 NOT MANUALLY CLOSED
V-126 NOT MANUALLY CLOSED
FLOW DIVERSION FROM SUPPLY LINE B
AF82
T32
p.A-23
V-127 NOT MANUALLY CLOSED
FLOW DIVERSION FROM SUPPLY LINE C
AF79
T31
p.A-22
V-126 NOT MANUALLY CLOSED

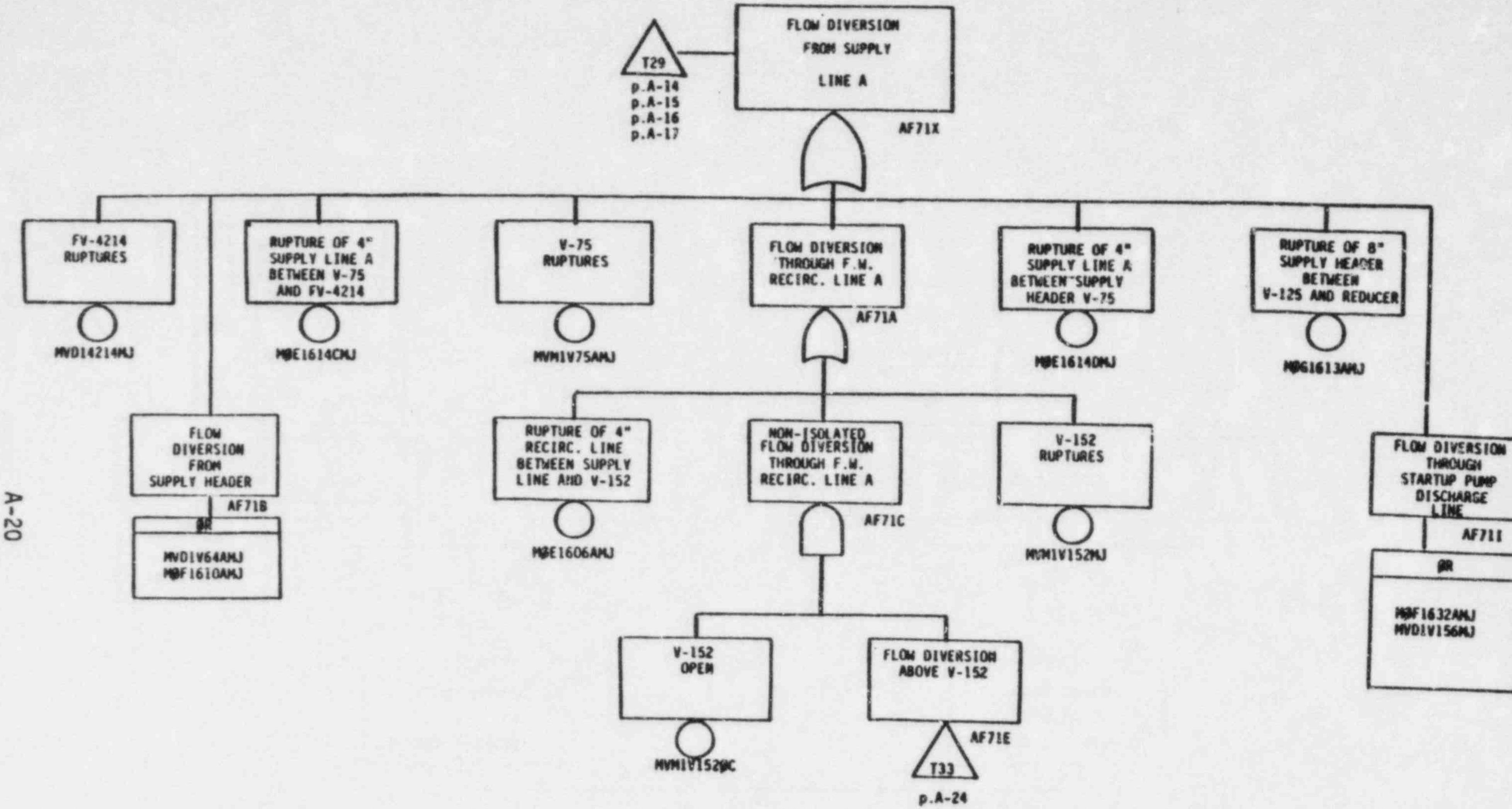

NO AUX. FEED FLOW TO S.G.C
AF64
T11
p.A-9
FV-4234 CLOSED
AF65
OR
MVD14234MO
MVD14234BO
MVD14234HO
MVD14234BO
V-93 CLOSED
AF66
OR
MVD1V93CMO
MVD1V93CBO
MVD1V93CHO
MVD1V81BMO
INSUFFICIENT FLOW TO SUPPLY LINE C
AF67
V-88 FAILS TO OPEN
MVA1V88CNA
NON-ISOLATED FLOW DIVERSION FROM SUPPLY LINE D
AF148
NON-ISOLATED FLOW DIVERSION FROM SUPPLY HEADER
AF83
T22
p.A-19
NON-ISOLATED FLOW DIVERSION FROM SUPPLY LINE A
AF147
FLOW DIVERSION FROM SUPPLY LINE C
AF79
T31
p.A-22
NO FLOW TO SUPPLY LINE C
AF150
T38
p.A-29
NON-ISOLATED FLOW DIVERSION FROM SUPPLY LINE B
AF149
FLOW DIVERSION FROM SUPPLY LINE D
AF75
T30
p.A-21
V-126 NOT CLOSED
MVD1V126BO
V-125 NOT CLOSED
MVD1V125BO
FLOW DIVERSION FROM SUPPLY LINE A
AF71X
T29
p.A-20
V-126 NOT CLOSED
MVD1V126BO
FLOW DIVERSION FROM SUPPLY LINE B
AF82
T32
p.A-23
V-127 NOT CLOSED
MVD1V127BO

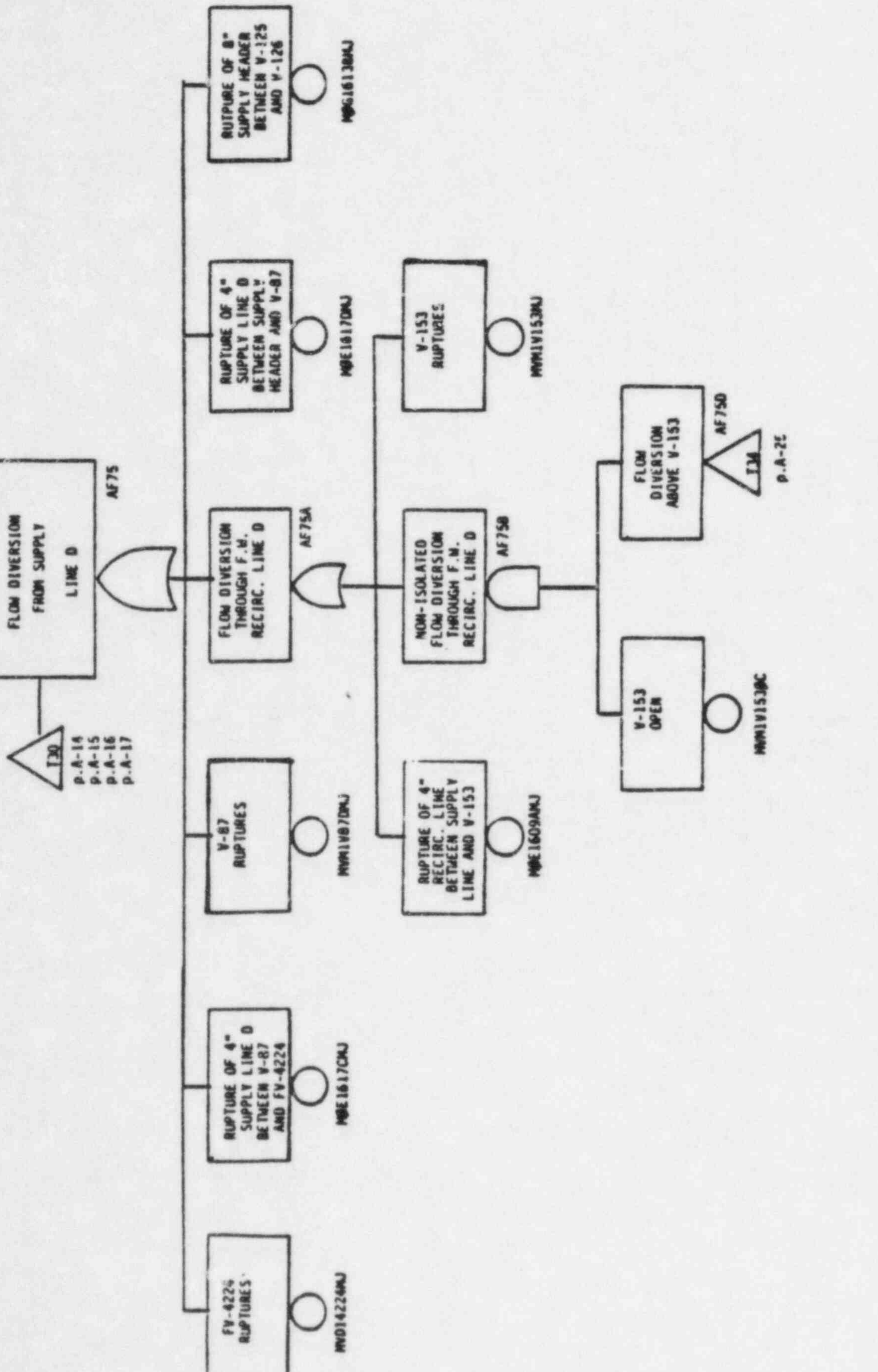


NO AUX. FEED FLOW TO S.G.B
AF68
T112
p.A-10
FV-4224 CLOSED
AF69
MVD14224MD
MVD14224RD
MVD14224MB
MVD14224RB
V-81 CLOSED
AF70
MVD1V81BMD
MVD1V81RD
MVD1V81RB
MVD1V93CMB
INSUFFICIENT FLOW TO SUPPLY LINE B
AF71
V-82 FAILS TO OPEN
MVA1V82BMA
NON-ISOLATED FLOW DIVERSION FROM SUPPLY LINE C
AF155
NON-ISOLATED FLOW DIVERSION SUPPLY HEADER
AF83
T22
p.A-19
NON-ISOLATED FLOW DIVERSION FROM SUPPLY LINE D
AF154
FLOW DIVERSION FROM SUPPLY LINE B
AF82
T32
p.A-23
NO FLOW TO SUPPLY LINE B
AF156
T39
p.A-30
NON-ISOLATED FLOW DIVERSION FROM SUPPLY LINE A
AF153
FLOW-DIVERSION FROM SUPPLY LINE C
AF79
T31
p.A-22
V-127 NOT CLOSED
MVD1V127MB
FLOW DIVERSION FROM SUPPLY LINE D
AF75
T30
p.A-21
V-125 NOT CLOSED
MVD1V125MB
V-126 NOT MANUALLY CLOSED
MVD1V126MB
FLOW DIVERSION FROM SUPPLY LINE A
AF71X
T29
p.A-20
V-125 NOT MANUALLY CLOSED
MVD1V125MB
V-126 NOT MANUALLY CLOSED
MVD1V126MB
V-127 NOT MANUALLY CLOSED
MVD1V127MB

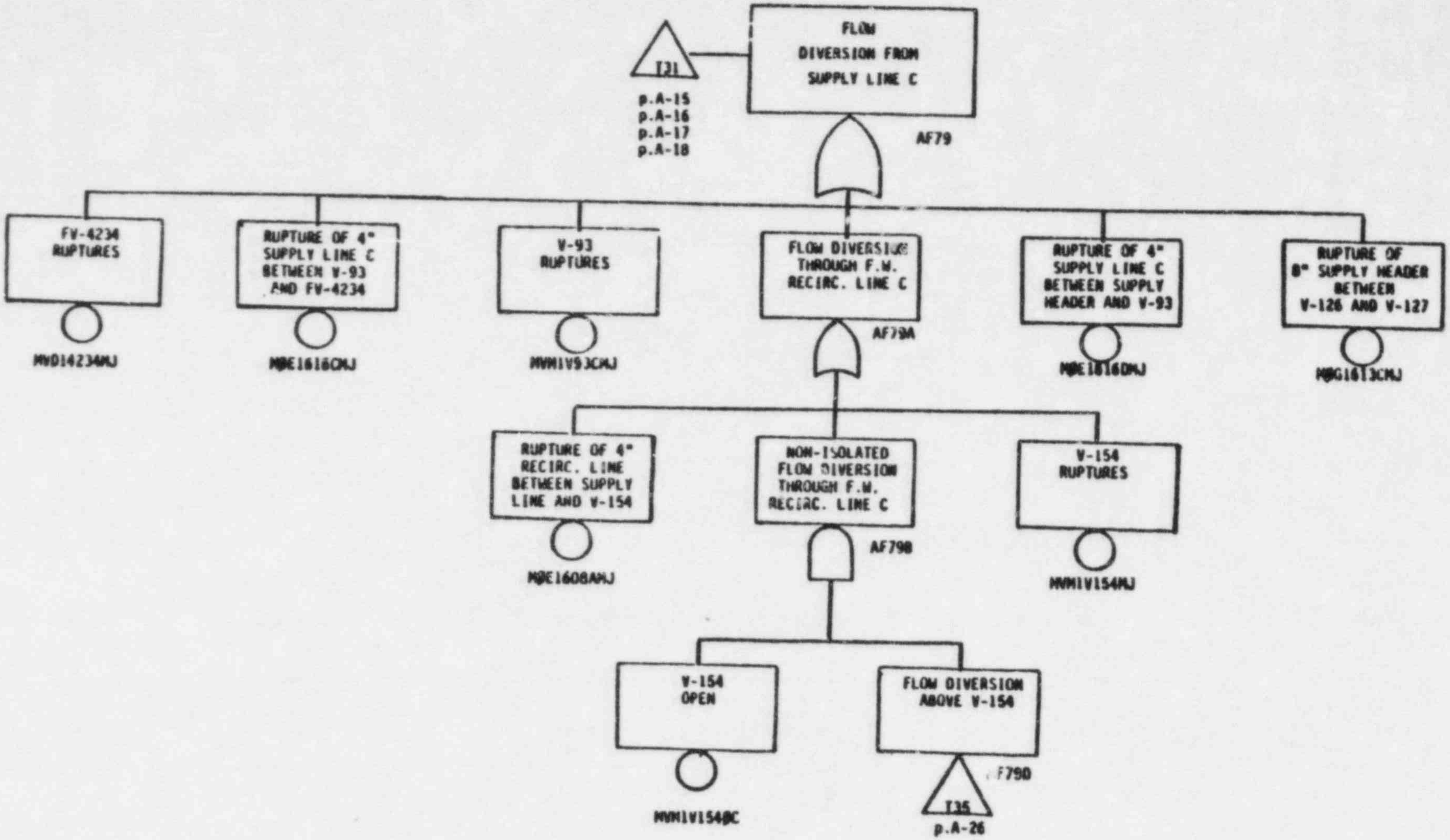

NON-ISOLATED FLOW DIVERSION FROM SUPPLY LINE B OR C
AF76
T21
p.A-14
V-126 NOT CLOSED
FLOW DIVERSION FROM SUPPLY LINE B OR C
AF78
FLOW DIVERSION FROM SUPPLY LINE C
AF79
T31
p.A-22
NON-ISOLATED FLOW DIVERSION FROM SUPPLY LINE B
AF80
V-127 NOT CLOSED
FLOW DIVERSION FROM SUPPLY LINE B
AF82
T32
p.A-23

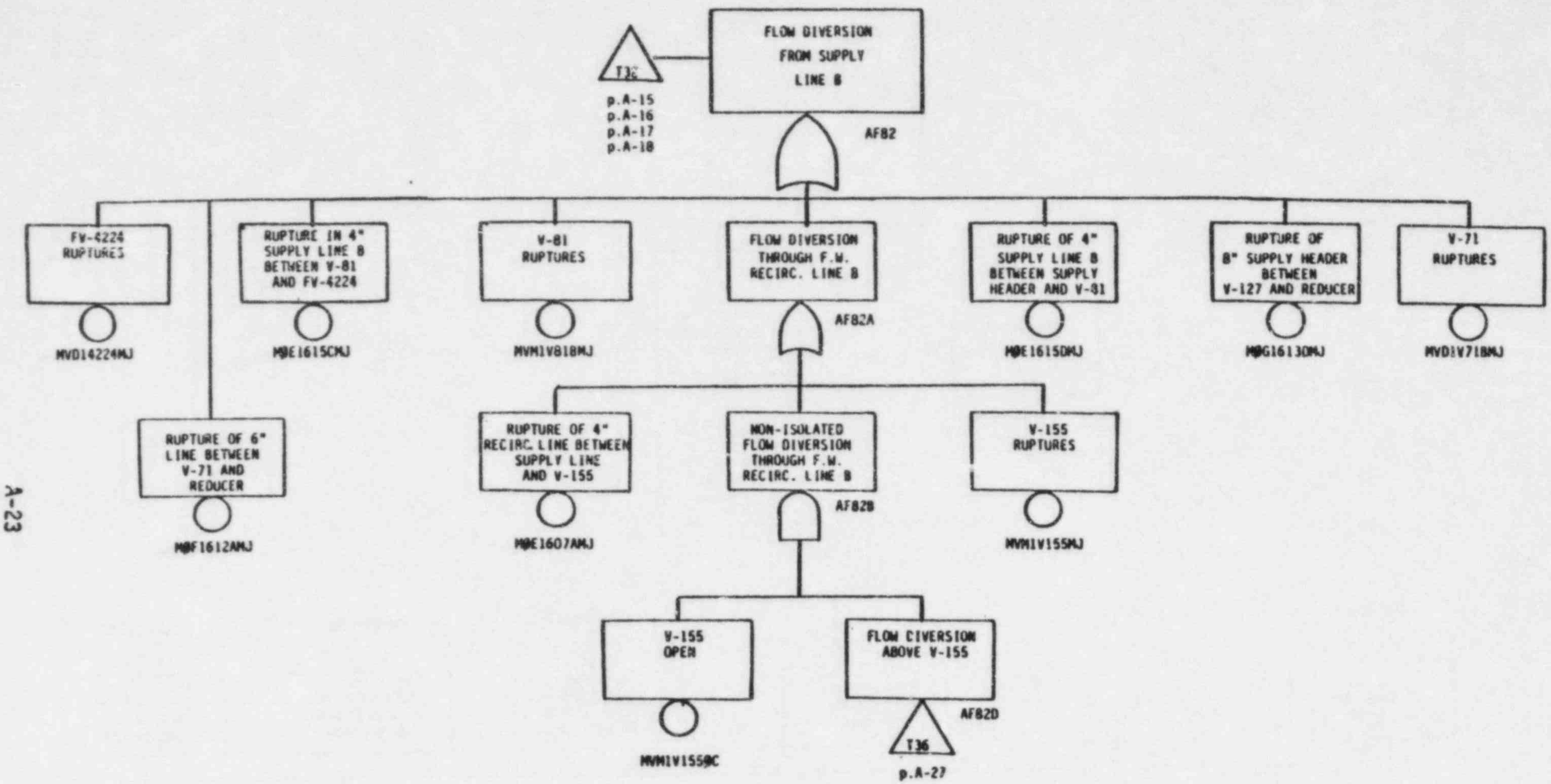

NON-ISOLATED FLOW DIVERSION FROM SUPPLY HEADER
AF83
T22
P.A-14
P.A-15
P.A-16
P.A-17
FLOW DIVERSION FROM SUPPLY HEADER THROUGH V-65
AF84
FLOW DIVERSION FROM SUPPLY HEADER THROUGH V-71
AF87
FLOW DIVERSION THROUGH V-65
AF85
OR
V-65 NOT MANUALLY CLOSED
FLOW DIVERSION THROUGH V-71
AF89
OR
V-71 NOT MANUALLY CLOSED

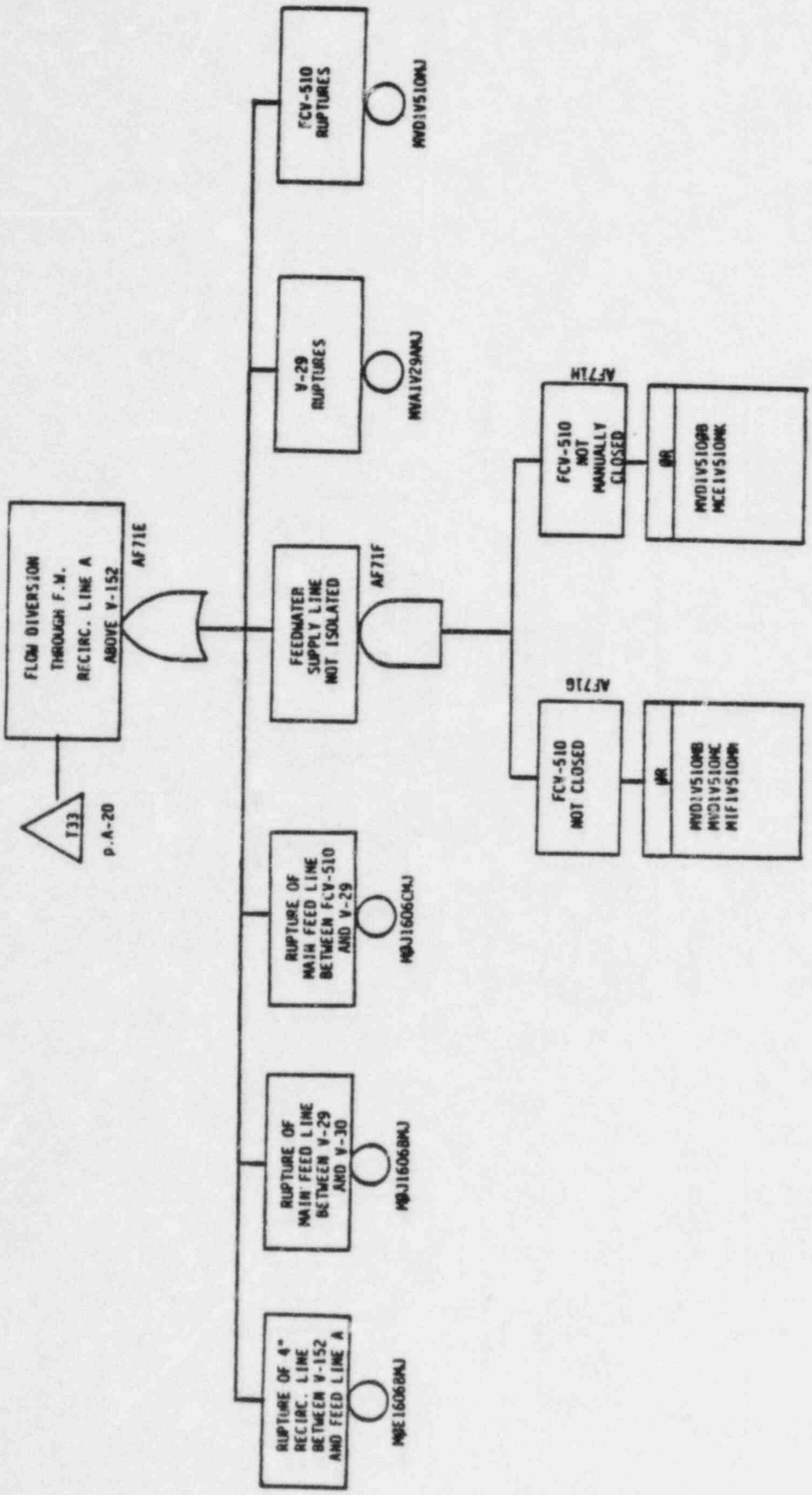

FLOW DIVERSION FROM SUPPLY LINE A
AF71X
T29
p.A-14
p.A-15
p.A-16
p.A-17
FV-4214 RUPTURES
MVD14214MJ
RUPTURE OF 4" SUPPLY LINE A BETWEEN V-75 AND FV-4214
MØE1614CMJ
V-75 RUPTURES
MVM1V75AMJ
FLOW DIVERSION THROUGH F.W. RECIRC. LINE A
AF71A
RUPTURE OF 4" SUPPLY LINE A BETWEEN SUPPLY HEADER V-75
MØE1614DMJ
RUPTURE OF 8" SUPPLY HEADER BETWEEN V-125 AND REDUCER
MØG1613AMJ
FLOW DIVERSION FROM SUPPLY HEADER
AF71B
ØR
MVD1V64AMJ
MØF1610AMJ
RUPTURE OF 4" RECIRC. LINE BETWEEN SUPPLY LINE AND V-152
MØE1606AMJ
NON-ISOLATED FLOW DIVERSION THROUGH F.W. RECIRC. LINE A
AF71C
V-152 RUPTURES
MVM1V152MJ
FLOW DIVERSION THROUGH STARTUP PUMP DISCHARGE LINE
AF71I
ØR
MØF1632AMJ
MVD1V156MJ
V-152 OPEN
MVM1V152ØC
FLOW DIVERSION ABOVE V-152
AF71E
T33
p.A-24

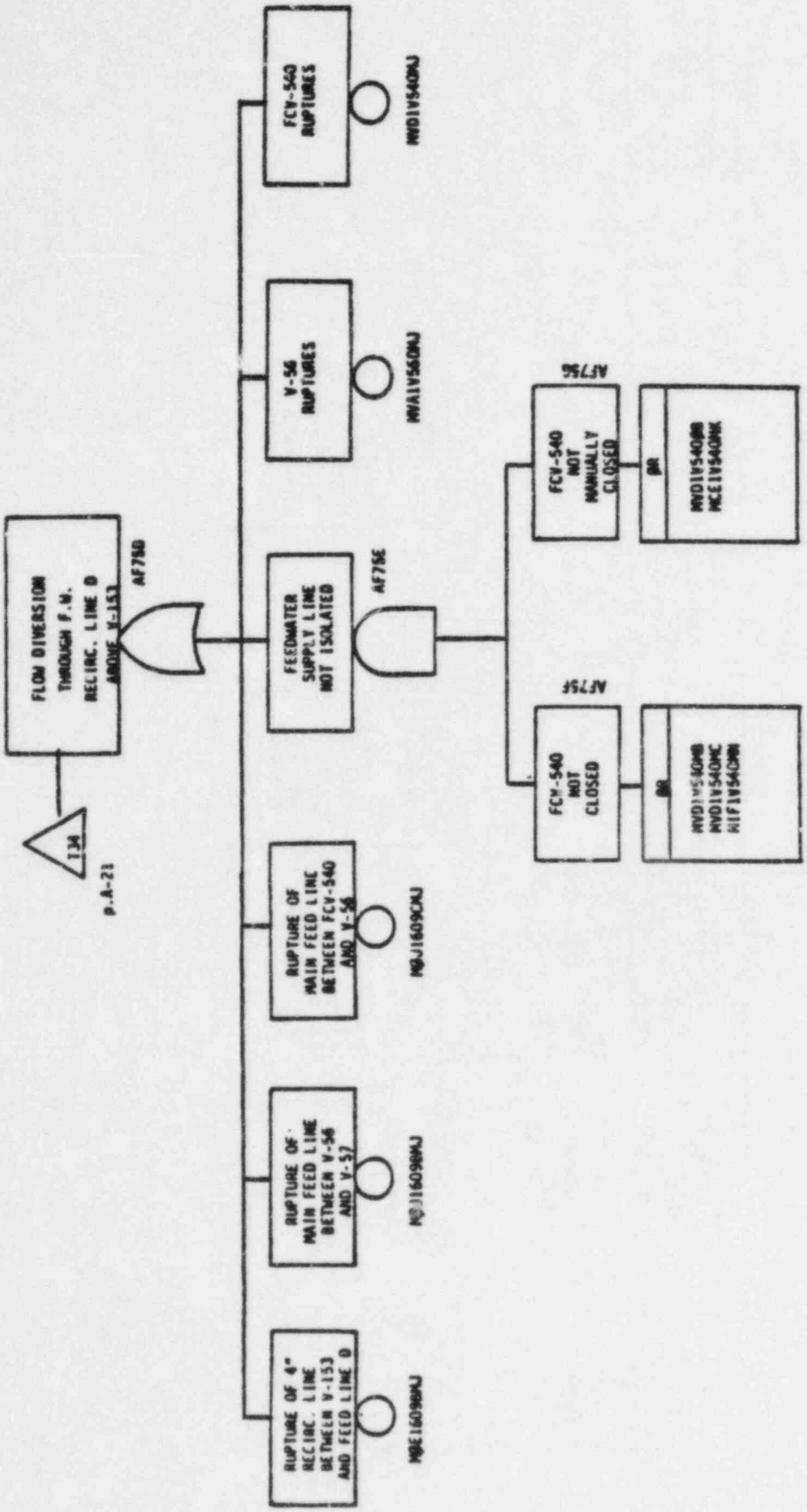


FLOW DIVERSION FROM SUPPLY LINE D
AF75
T30
p.A-14
p.A-15
p.A-16
p.A-17
FLOW DIVERSION THROUGH F.W. RECIRC. LINE D
AF75A
NON-ISOLATED FLOW DIVERSION THROUGH F.W. RECIRC. LINE D
AF75B
FLOW DIVERSION ABOVE V-153
AF75D
T34
p.A-25
V-153 OPEN
MVM1V153BC
V-153 RUPTURES
MVM1V153AJ
RUPTURE OF 4" RECIRC. LINE BETWEEN SUPPLY LINE AND V-153
MBE1609AAJ
RUPTURE OF 8" SUPPLY HEADER BETWEEN V-125 AND V-126
MBG16138AJ
RUPTURE OF 4" SUPPLY LINE D BETWEEN SUPPLY HEADER AND V-87
MBE1617DAJ
V-87 RUPTURES
MVM1V87DAJ
RUPTURE OF 4" SUPPLY LINE D BETWEEN V-87 AND FV-4224
MBE1617CAJ
FV-4224 RUPTURES
MVD14224AJ

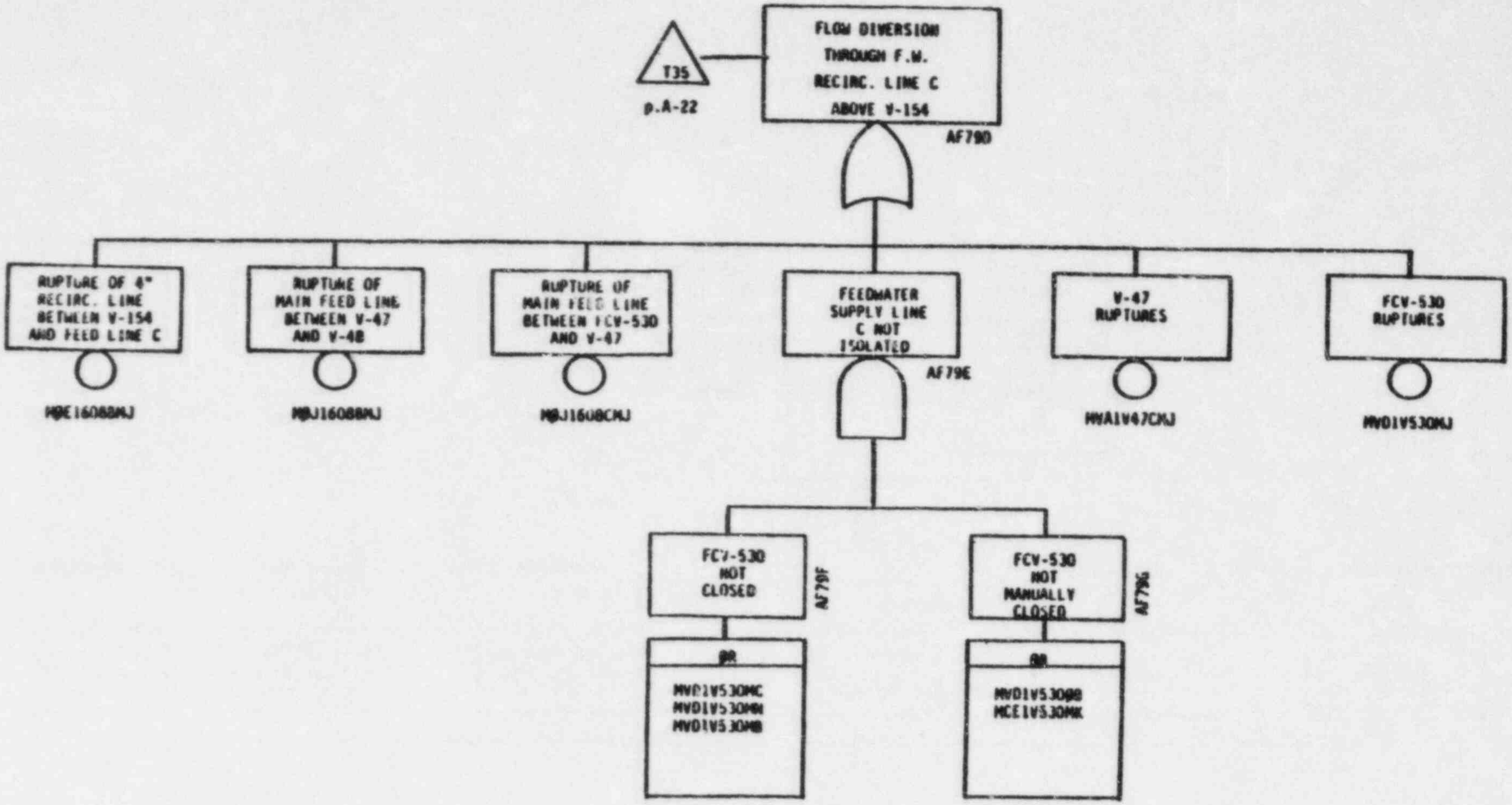

FLOW DIVERSION FROM SUPPLY LINE C
AF79
T31
p.A-15
p.A-16
p.A-17
p.A-18
FV-4234 RUPTURES
MVD14234MJ
RUPTURE OF 4" SUPPLY LINE C BETWEEN V-93 AND FV-4234
MØE1616CMJ
V-93 RUPTURES
MVM1V93CMJ
FLOW DIVERSION THROUGH F.W. RECIRC. LINE C
AF79A
RUPTURE OF 4" SUPPLY LINE C BETWEEN SUPPLY HEADER AND V-93
MØE1616DMJ
RUPTURE OF 8" SUPPLY HEADER BETWEEN V-126 AND V-127
MØG1613CMJ
RUPTURE OF 4" RECIRC. LINE BETWEEN SUPPLY LINE AND V-154
MØE1608AMJ
NON-ISOLATED FLOW DIVERSION THROUGH F.W. RECIRC. LINE C
AF79B
V-154 RUPTURES
MVM1V154MJ
V-154 OPEN
MVM1V154ØC
FLOW DIVERSION ABOVE V-154
F79D
T35
p.A-26

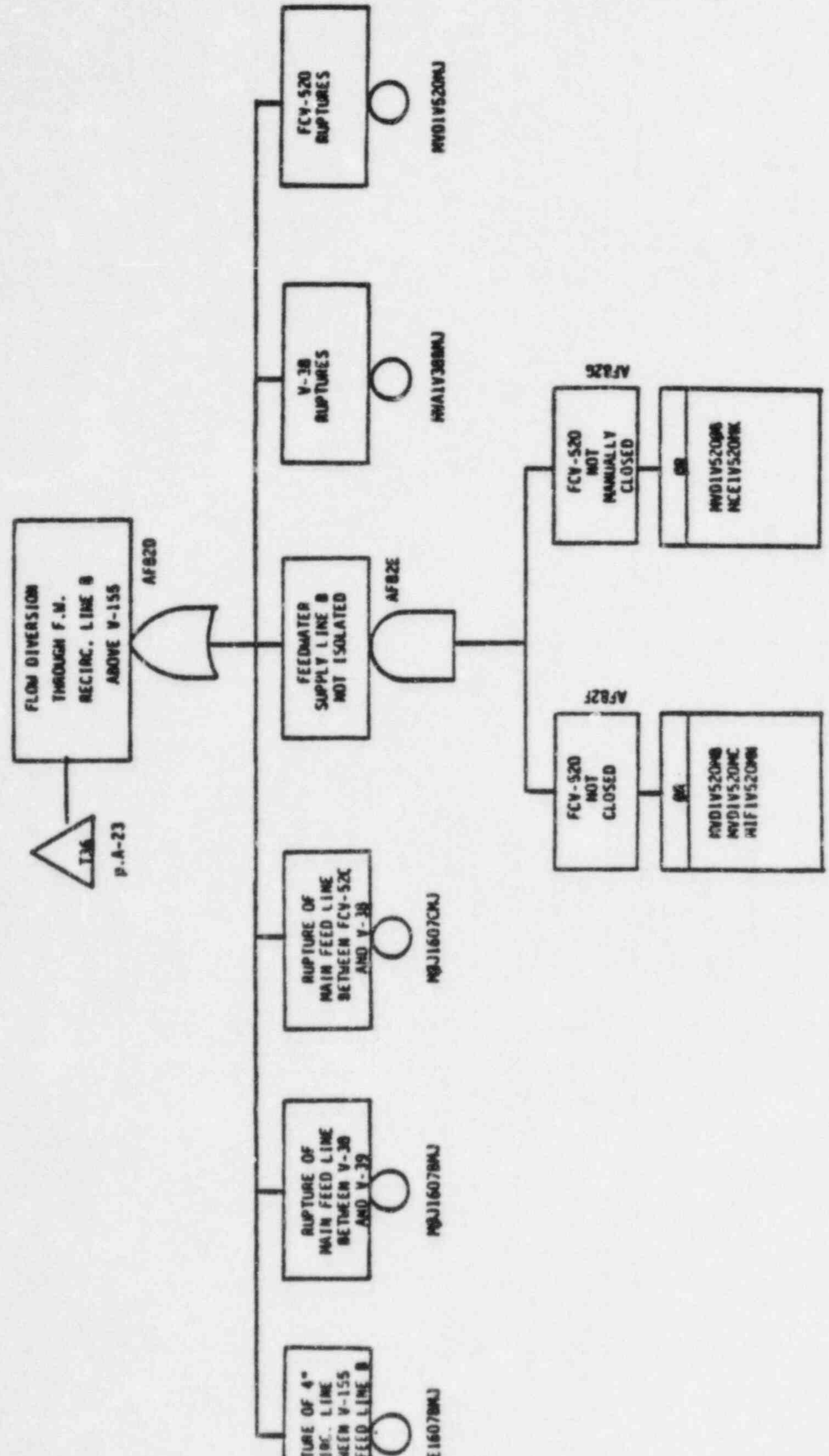

FLOW DIVERSION FROM SUPPLY LINE B
T36
p.A-15
p.A-16
p.A-17
p.A-18
AF82
FV-4224 RUPTURES
MVD14224MJ
RUPTURE IN 4" SUPPLY LINE B BETWEEN V-81 AND FV-4224
M0E1615CMJ
V-81 RUPTURES
MVM1V818MJ
FLOW DIVERSION THROUGH F.W. RECIRC. LINE B
AF82A
RUPTURE OF 4" SUPPLY LINE B BETWEEN SUPPLY HEADER AND V-81
M0E1615DMJ
RUPTURE OF 8" SUPPLY HEADER BETWEEN V-127 AND REDUCER
M0G1613DMJ
V-71 RUPTURES
MVD1V71BMJ
RUPTURE OF 6" LINE BETWEEN V-71 AND REDUCER
M0F1612AMJ
RUPTURE OF 4" RECIRC. LINE BETWEEN SUPPLY LINE AND V-155
M0E1607AMJ
NON-ISOLATED FLOW DIVERSION THROUGH F.W. RECIRC. LINE B
AF82B
V-155 RUPTURES
MVM1V155MJ
V-155 OPEN
MVM1V1550C
FLOW CIVERSION ABOVE V-155
AF82D
T36
p.A-27

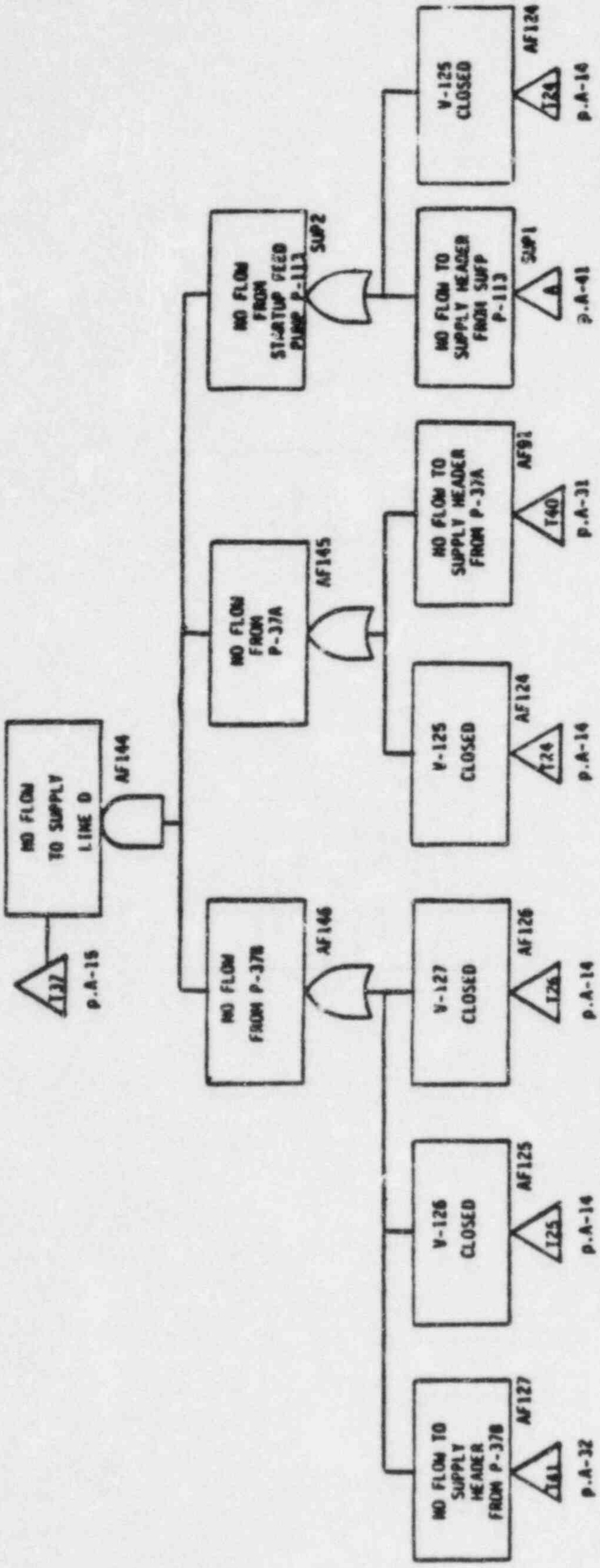

FLOW DIVERSION THROUGH F.W. RECIRC. LINE A ABOVE V-152
AF71E
T33
p.A-20
FEEDWATER SUPPLY LINE NOT ISOLATED
AF71F
V-29 RUPTURES
MVA1V29AMJ
FCV-510 RUPTURES
MVD1V510MJ
RUPTURE OF MAIN FEED LINE BETWEEN FCV-510 AND V-29
MBJ1606CMJ
RUPTURE OF MAIN FEED LINE BETWEEN V-29 AND V-30
MBJ1606BMJ
RUPTURE OF 4" RECIRC. LINE BETWEEN V-152 AND FEED LINE A
MBE1606BMJ
FCV-510 NOT MANUALLY CLOSED
AF71H
OR
MVD1V510QB
MCE1V510MK
FCV-510 NOT CLOSED
AF71G
OR
MVD1V510MB
MVD1V510MC
MIF1V510MR

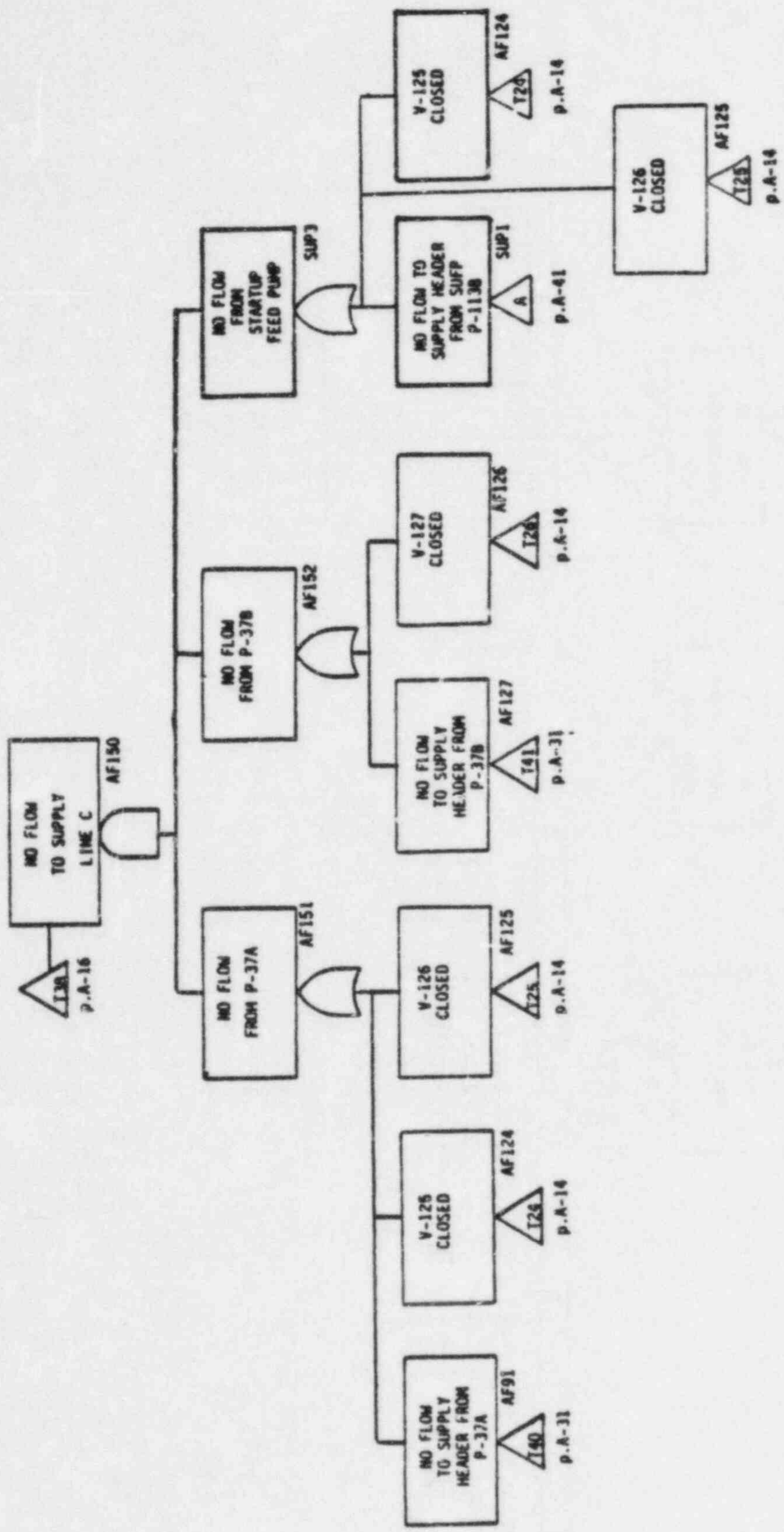


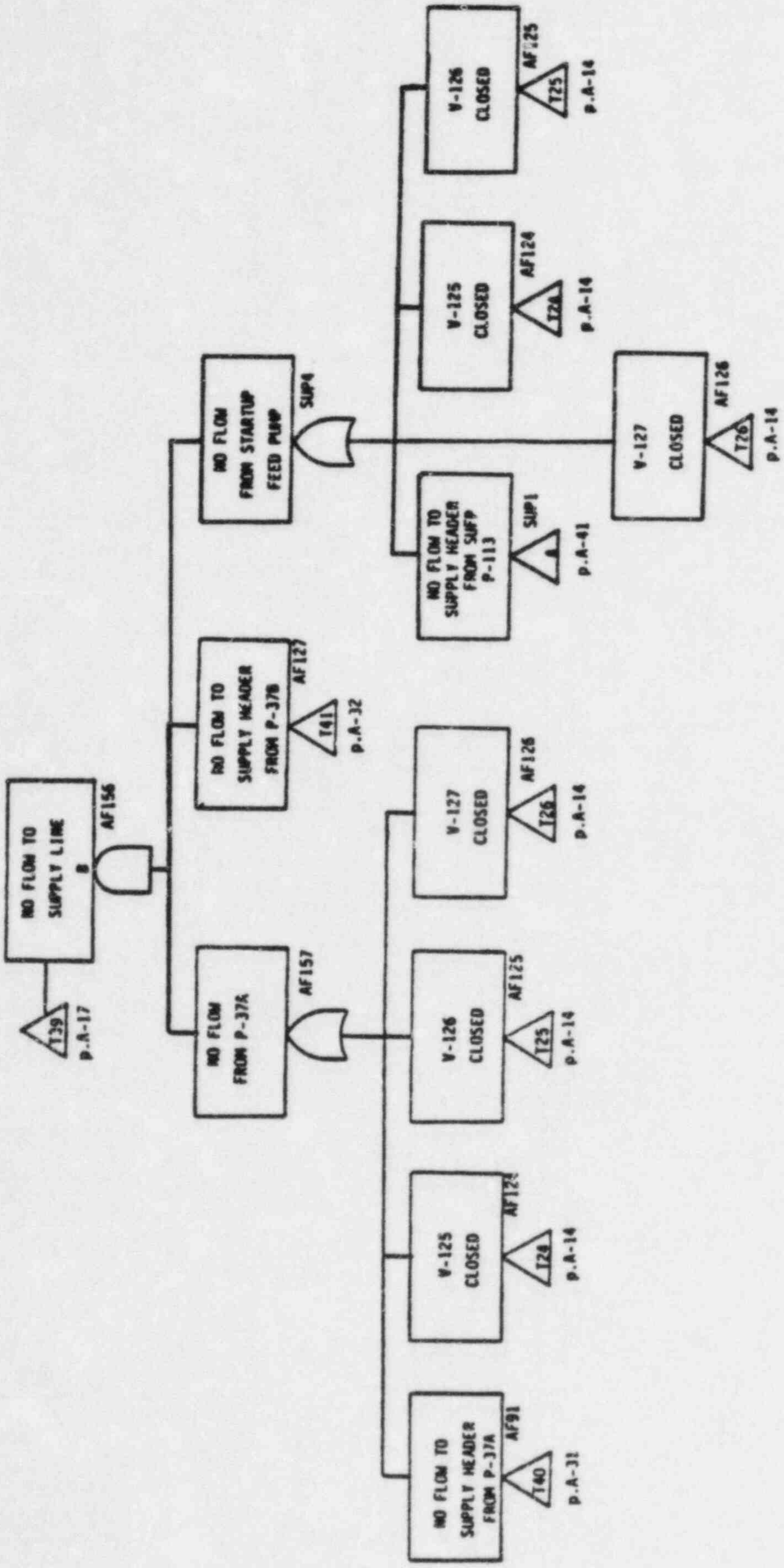
FLOW DIVERSION THROUGH F.W. RECIRC. LINE D ABOVE V-153
AF75D
134
p.A-21
FCV-540 RUPTURES
HVD1V540NJ
V-56 RUPTURES
HWA1V56ONJ
FEEDWATER SUPPLY LINE NOT ISOLATED
AF75E
RUPTURE OF MAIN FEED LINE BETWEEN FCV-540 AND V-56
MDJ1609CNJ
RUPTURE OF MAIN FEED LINE BETWEEN V-56 AND V-57
MDJ1609BNJ
RUPTURE OF 4" RECIRC. LINE BETWEEN V-153 AND FEED LINE D
MBE1609BNJ
FCV-540 NOT MANUALLY CLOSED
AF75G
OR
HVD1V540HR
HCE1V540HK
FCV-540 NOT CLOSED
AF75F
OR
HVD1V540HB
HVD1V540HC
HIF1V540HN

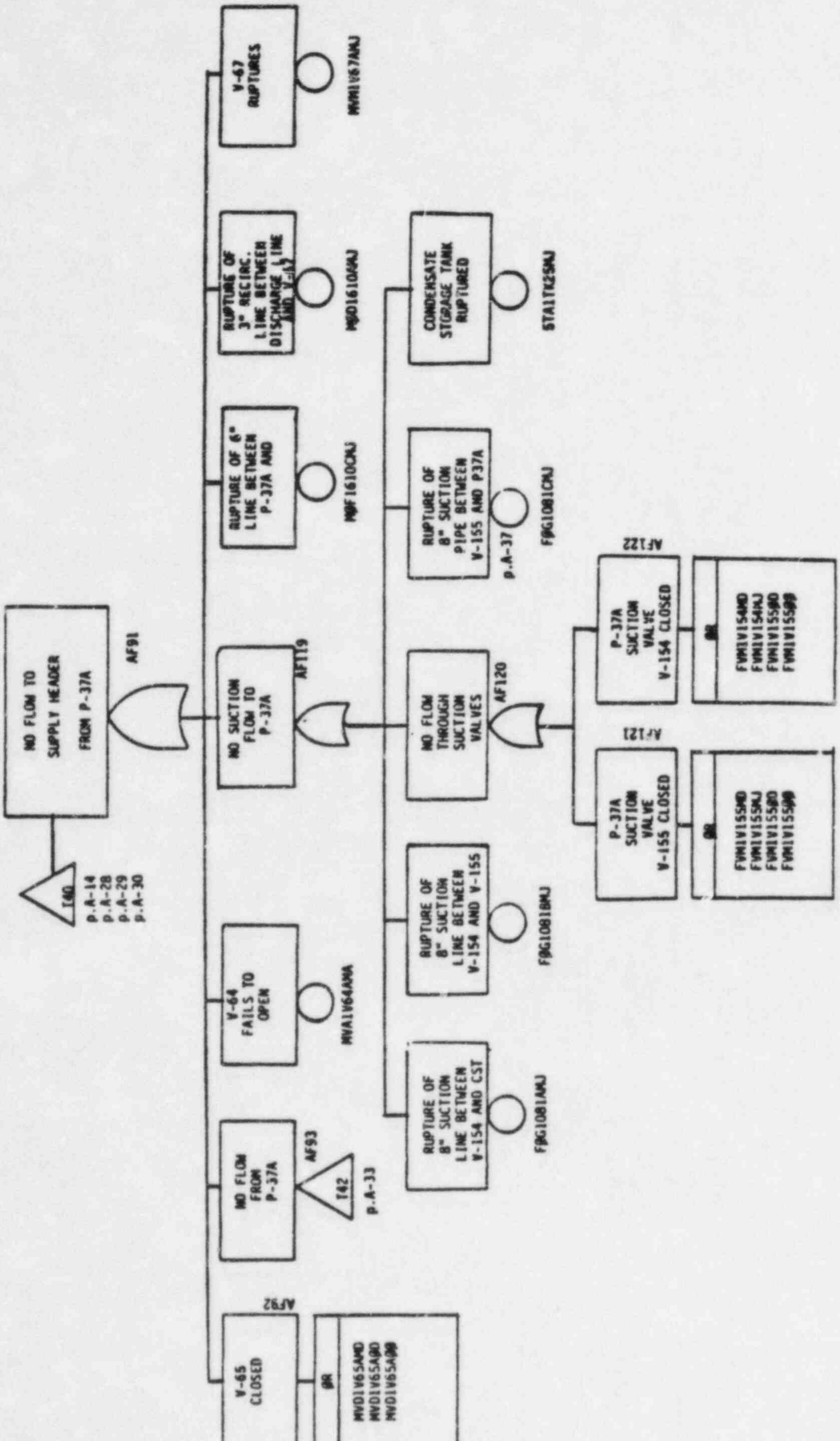

T35
p.A-22
FLOW DIVERSION THROUGH F.W. RECIRC. LINE C ABOVE V-154
AF79D
RUPTURE OF 4" RECIRC. LINE BETWEEN V-154 AND FEED LINE C
RUPTURE OF MAIN FEED LINE BETWEEN V-47 AND V-48
RUPTURE OF MAIN FEED LINE BETWEEN FCV-530 AND V-47
FEEDWATER SUPPLY LINE C NOT ISOLATED
AF79E
V-47 RUPTURES
FCV-530 RUPTURES
MVA1V47CMJ
MVD1V530MJ
FCV-530 NOT CLOSED
AF79F
FCV-530 NOT MANUALLY CLOSED
AF79G
OR
MVD1V530MC
MVD1V530MN
MVD1V530MB
OR
MCE1V530MK


FLOW DIVERSION THROUGH F.W. RECIRC. LINE B ABOVE V-155
AFB2D
T36
p.A-23
FCV-52D RUPTURES
V-38 RUPTURES
FEEDWATER SUPPLY LINE B NOT ISOLATED
AFB2E
FCV-52D NOT MANUALLY CLOSED
AFB2G
OR
FCV-52D NOT CLOSED
AFB2F
OR
RUPTURE OF MAIN FEED LINE BETWEEN FCV-52C AND V-38
MBJ1607CMJ
RUPTURE OF MAIN FEED LINE BETWEEN V-38 AND V-39
MBJ1607BMJ
RUPTURE OF 4" RECIRC. LINE BETWEEN V-155 AND FEED LINE B
MBE1607BMJ

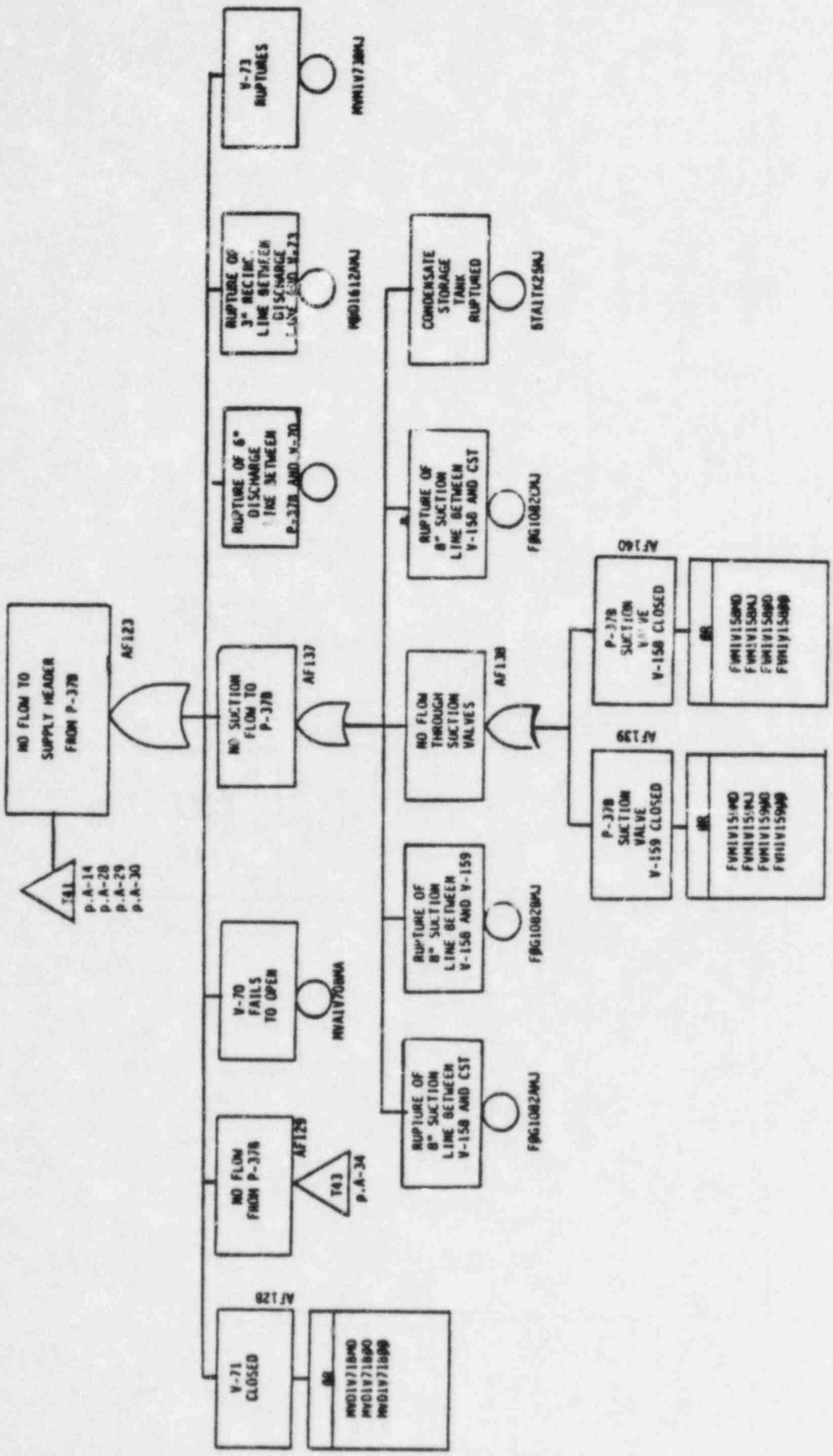

NO FLOW TO SUPPLY LINE D
AF144
T32
p.A-15
NO FLOW FROM P-37B
AF146
NO FLOW FROM P-37A
AF145
NO FLOW FROM STARTUP FEED PUMP P-113
SUP2
NO FLOW TO SUPPLY HEADER FROM P-37B
AF127
T41
p.A-32
V-126 CLOSED
AF125
T25
p.A-14
V-127 CLOSED
AF126
T26
p.A-14
V-125 CLOSED
AF124
T24
p.A-14
NO FLOW TO SUPPLY HEADER FROM P-37A
AF92
T40
p.A-31
NO FLOW TO SUPPLY HEADER FROM SUFP P-113
SUP1
A
p.A-41
V-125 CLOSED
AF124
T24
p.A-14

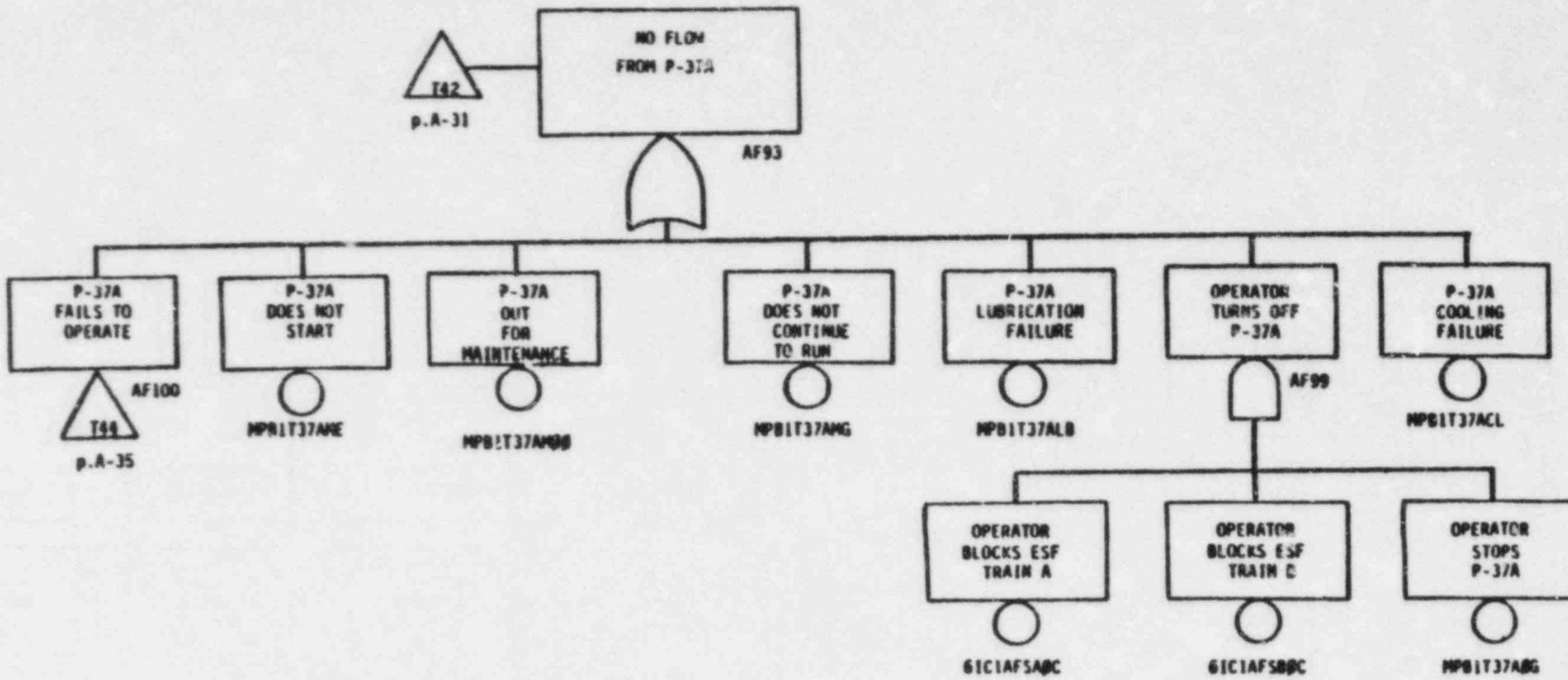

NO FLOW TO SUPPLY LINE C
AF150
T38
p.A-16
NO FLOW FROM P-37A
AF151
NO FLOW FROM P-37B
AF152
NO FLOW FROM STARTUP FEED PUMP
SUP3
NO FLOW TO SUPPLY HEADER FROM P-37A
AF91
T40
p.A-31
V-125 CLOSED
AF124
T24
p.A-14
V-126 CLOSED
AF125
T25
p.A-14
NO FLOW TO SUPPLY HEADER FROM P-37B
AF127
T41
p.A-31
V-127 CLOSED
AF126
T26
p.A-14
NO FLOW TO SUPPLY HEADER FROM SUFP P-113B
SUP1
A
p.A-41
V-125 CLOSED
AF124
T24
p.A-14
V-126 CLOSED
AF125
T25
p.A-14

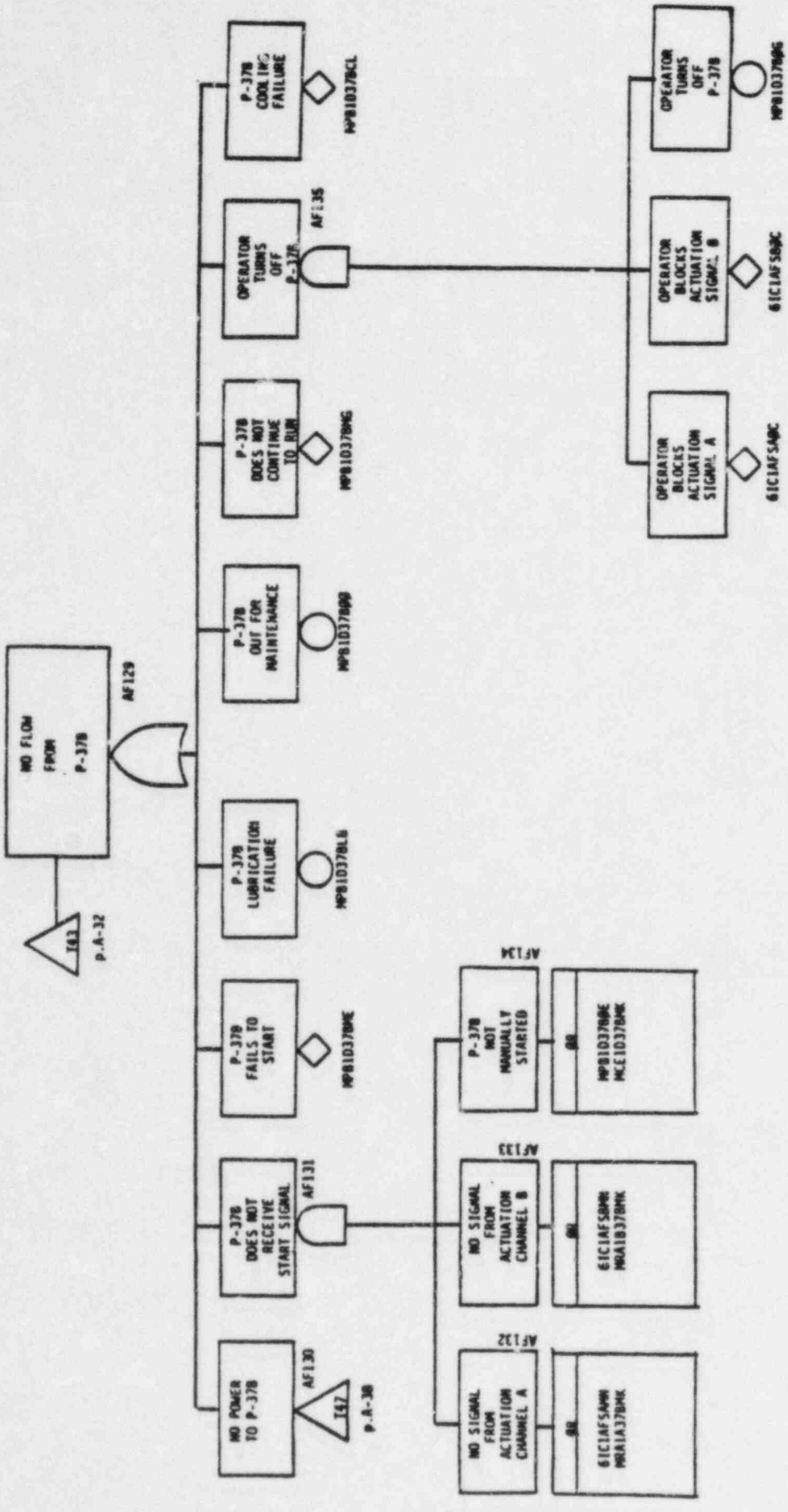

NO FLOW TO SUPPLY LINE B
AF156
T39
p.A-17
NO FLOW FROM P-37A
AF157
NO FLOW TO SUPPLY HEADER FROM P-37B
AF127
T41
p.A-32
NO FLOW FROM STARTUP FEED PUMP
SUP4
NO FLOW TO SUPPLY HEADER FROM P-37A
AF91
T40
p.A-31
V-125 CLOSED
AF124
T24
p.A-14
V-126 CLOSED
AF125
T25
p.A-14
V-127 CLOSED
AF126
T26
p.A-14
NO FLOW TO SUPPLY HEADER FROM SUFP P-113
SUP1
A
p.A-41
V-125 CLOSED
AF124
T24
p.A-14
V-126 CLOSED
AF125
T25
p.A-14
V-127 CLOSED
AF126
T26
p.A-14

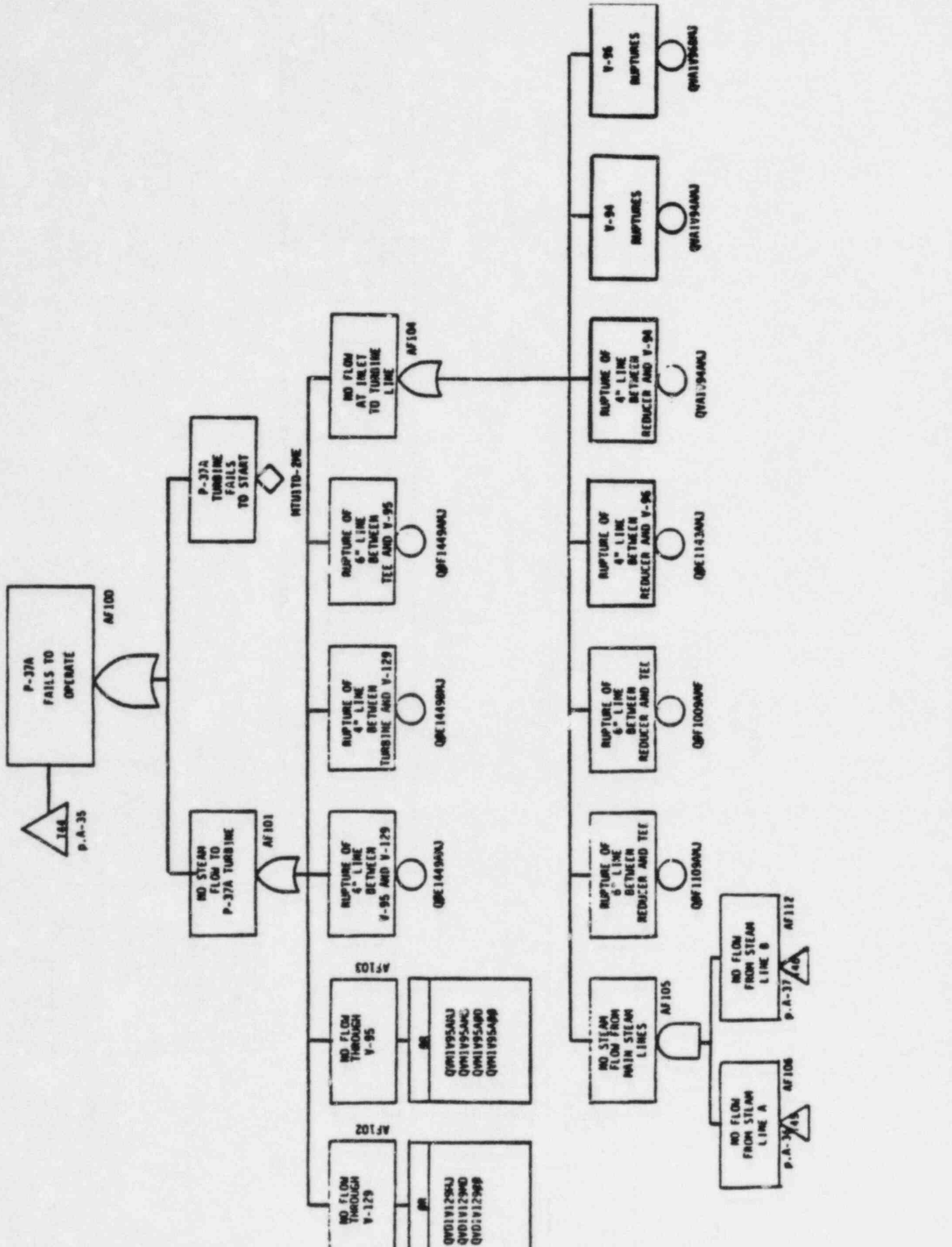


NO FLOW TO SUPPLY HEADER FROM P-37A
AF91
T40
p.A-14
p.A-28
p.A-29
p.A-30
NO SUCTION FLOW TO P-37A
AF119
V-65 CLOSED
AF92
OR
MVD1V65AMD
MVD1V65AQD
MVD1V65AQQ
NO FLOW FROM P-37A
AF93
T42
p.A-33
V-64 FAILS TO OPEN
MVA1V64AMA
RUPTURE OF 6" LINE BETWEEN P-37A AND
MDF1610CMJ
RUPTURE OF 3" RECIRC. LINE BETWEEN DISCHARGE LINE AND V-67
MQD1610AMJ
V-67 RUPTURES
MVM1V67AMJ
RUPTURE OF 8" SUCTION LINE BETWEEN V-154 AND CST
FQG1081AMJ
RUPTURE OF 8" SUCTION LINE BETWEEN V-154 AND V-155
FQG1081BMJ
NO FLOW THROUGH SUCTION VALVES
AF120
RUPTURE OF 8" SUCTION PIPE BETWEEN V-155 AND P37A
p.A-37
FQG1081CMJ
CONDENSATE STORAGE TANK RUPTURED
STA1TK25MJ
P-37A SUCTION VALVE V-155 CLOSED
AF121
OR
FVM1V155MD
FVM1V155MJ
FVM1V155QD
FVM1V155QQ
P-37A SUCTION VALVE V-154 CLOSED
AF122
OR
FVM1V154MD
FVM1V154MJ
FVM1V155QD
FVM1V155QQ

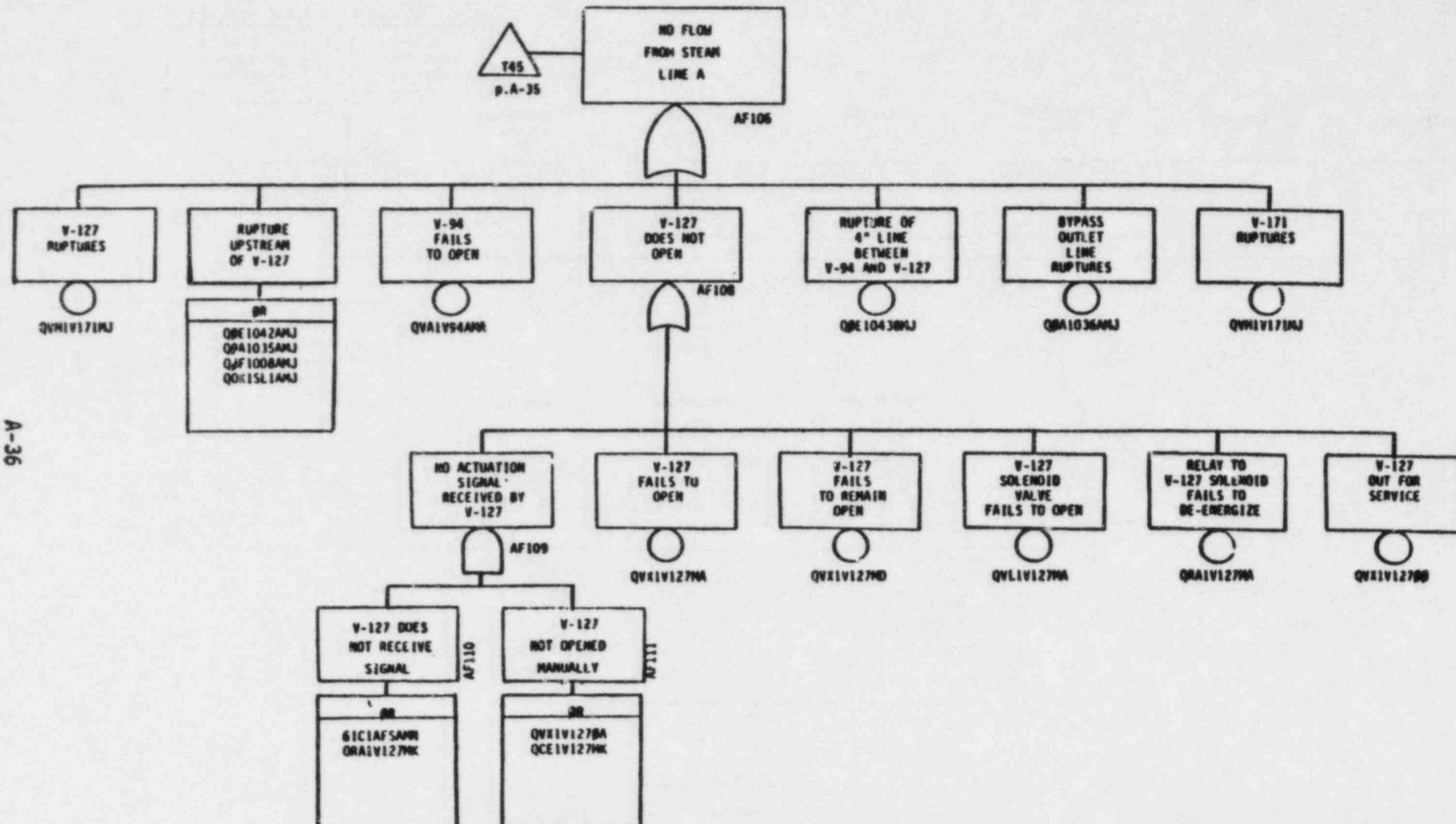

NO FLOW TO SUPPLY HEADER FROM P-37B
AF123
T41
p.A-14
p.A-28
p.A-29
p.A-30
V-71 CLOSED
AF128
OR
NO FLOW FROM P-37B
AF125
T43
p.A-34
V-70 FAILS TO OPEN
NO SUCTION FLOW TO P-37B
AF137
RUPTURE OF 6" DISCHARGE LINE BETWEEN P-37B AND V-70
RUPTURE OF 3" RECIRC. LINE BETWEEN DISCHARGE LINE AND V-73
V-73 RUPTURES
RUPTURE OF 8" SUCTION LINE BETWEEN V-158 AND CST
RUPTURE OF 8" SUCTION LINE BETWEEN V-158 AND V-159
NO FLOW THROUGH SUCTION VALVES
AF138
RUPTURE OF 8" SUCTION LINE BETWEEN V-158 AND CST
CONDENSATE STORAGE TANK RUPTURED
P-37B SUCTION VALVE V-159 CLOSED
AF139
OR
P-37B SUCTION VALVE V-158 CLOSED
AF140
OR


NO FLOW
FROM P-37A
T42
p.A-31
AF93
P-37A
FAILS TO
OPERATE
AF100
T44
p.A-35
P-37A
DOES NOT
START
MPB1T37AME
P-37A
OUT
FOR
MAINTENANCE
MPB1T37AM00
P-37A
DOES NOT
CONTINUE
TO RUN
MPB1T37AMG
P-37A
LUBRICATION
FAILURE
MPB1T37ALB
OPERATOR
TURNS OFF
P-37A
AF99
P-37A
COOLING
FAILURE
MPB1T37ACL
OPERATOR
BLOCKS ESF
TRAIN A
6IC1AFSA0C
OPERATOR
BLOCKS ESF
TRAIN C
6IC1AFSB0C
OPERATOR
STOPS
P-37A
MPB1T37A0G

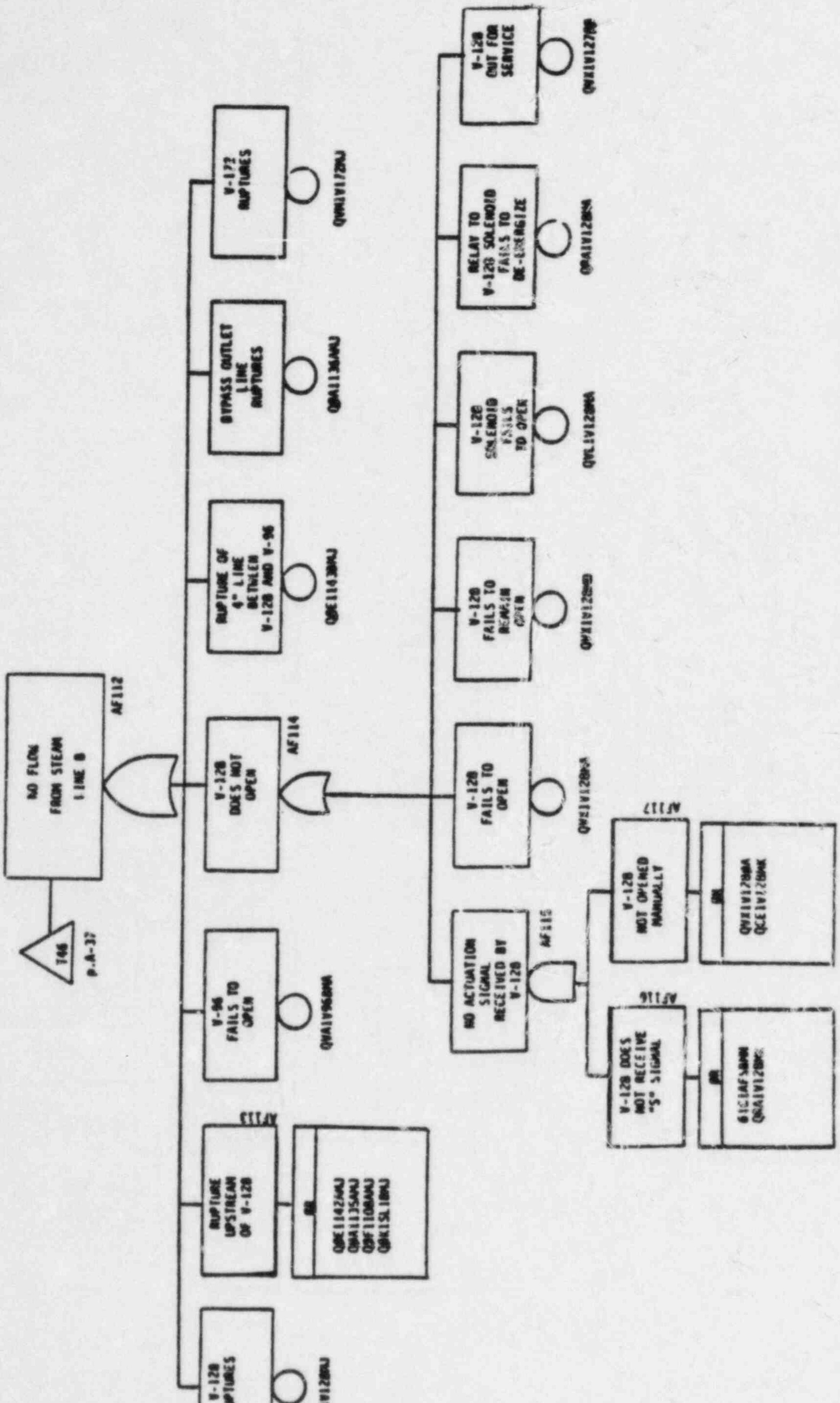

NO FLOW FROM P-37B
AF129
T43
p.A-32
NO POWER TO P-37B
AF130
T42
p.A-38
P-37B DOES NOT RECEIVE START SIGNAL
AF131
P-37B FAILS TO START
MPB1D37BME
P-37B LUBRICATION FAILURE
P-37B OUT FOR MAINTENANCE
P-37B DOES NOT CONTINUE TO RUN
MPB1D37BNG
OPERATOR TURNS OFF P-37B
AF135
P-37B COOLING FAILURE
MPB1D37BCL
NO SIGNAL FROM ACTUATION CHANNEL A
AF132
OR
6IC1AFSAMM
MRA1A37BMK
NO SIGNAL FROM ACTUATION CHANNEL B
AF133
OR
6IC1AFSBMM
MRA1B37BMK
P-37B NOT MANUALLY STARTED
AF134
OR
MPB1D37BME
MCE1D37BMK
OPERATOR BLOCKS ACTUATION SIGNAL A
OPERATOR BLOCKS ACTUATION SIGNAL B
OPERATOR TURNS OFF P-37B

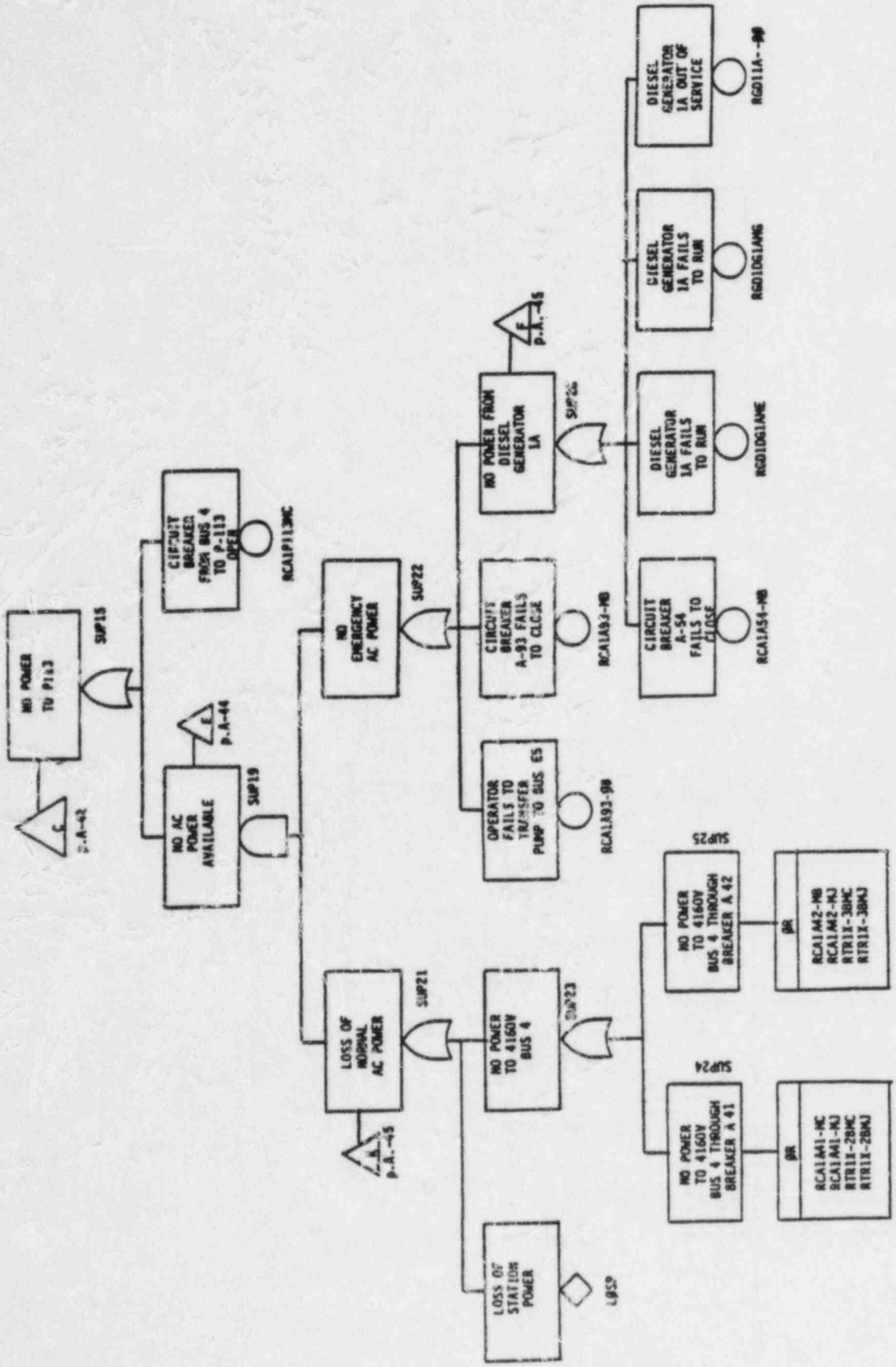


P-37A FAILS TO OPERATE
AF100
p.A-35
NO STEAM FLOW TO P-37A TURBINE
AF101
P-37A TURBINE FAILS TO START
NO FLOW THROUGH V-129
AF102
NO FLOW THROUGH V-95
AF103
RUPTURE OF 4" LINE BETWEEN V-95 AND V-129
RUPTURE OF 4" LINE BETWEEN TURBINE AND V-129
RUPTURE OF 6" LINE BETWEEN TEE AND V-95
NO FLOW AT INLET TO TURBINE LINE
AF104
NO STEAM FLOW FROM MAIN STEAM LINES
AF105
RUPTURE OF 6" LINE BETWEEN REDUCER AND TEE
RUPTURE OF 6" LINE BETWEEN REDUCER AND TEE
RUPTURE OF 4" LINE BETWEEN REDUCER AND V-96
RUPTURE OF 4" LINE BETWEEN REDUCER AND V-94
V-94 RUPTURES
V-96 RUPTURES
NO FLOW FROM STEAM LINE A
AF106
NO FLOW FROM STEAM LINE B
AF112

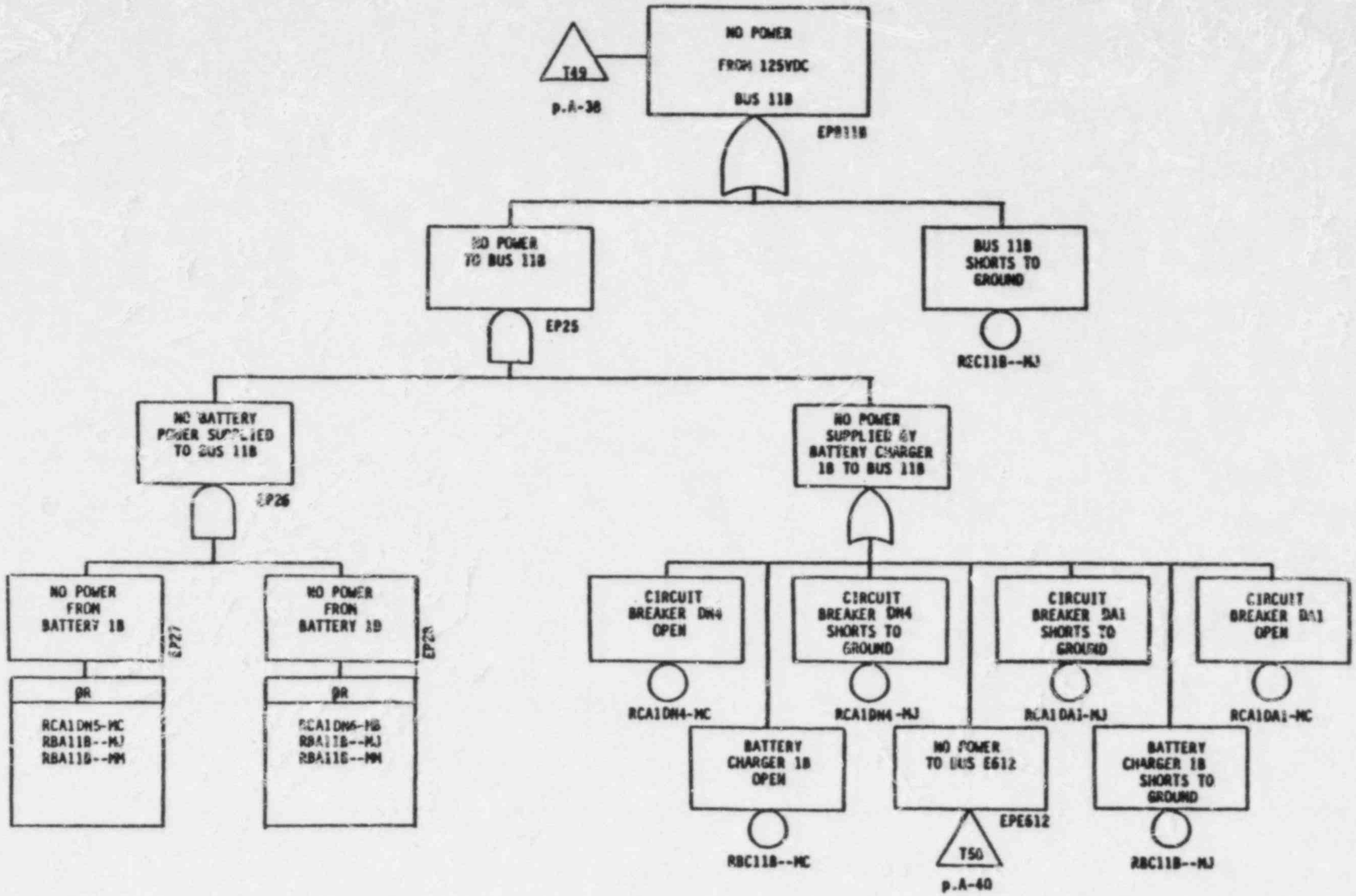


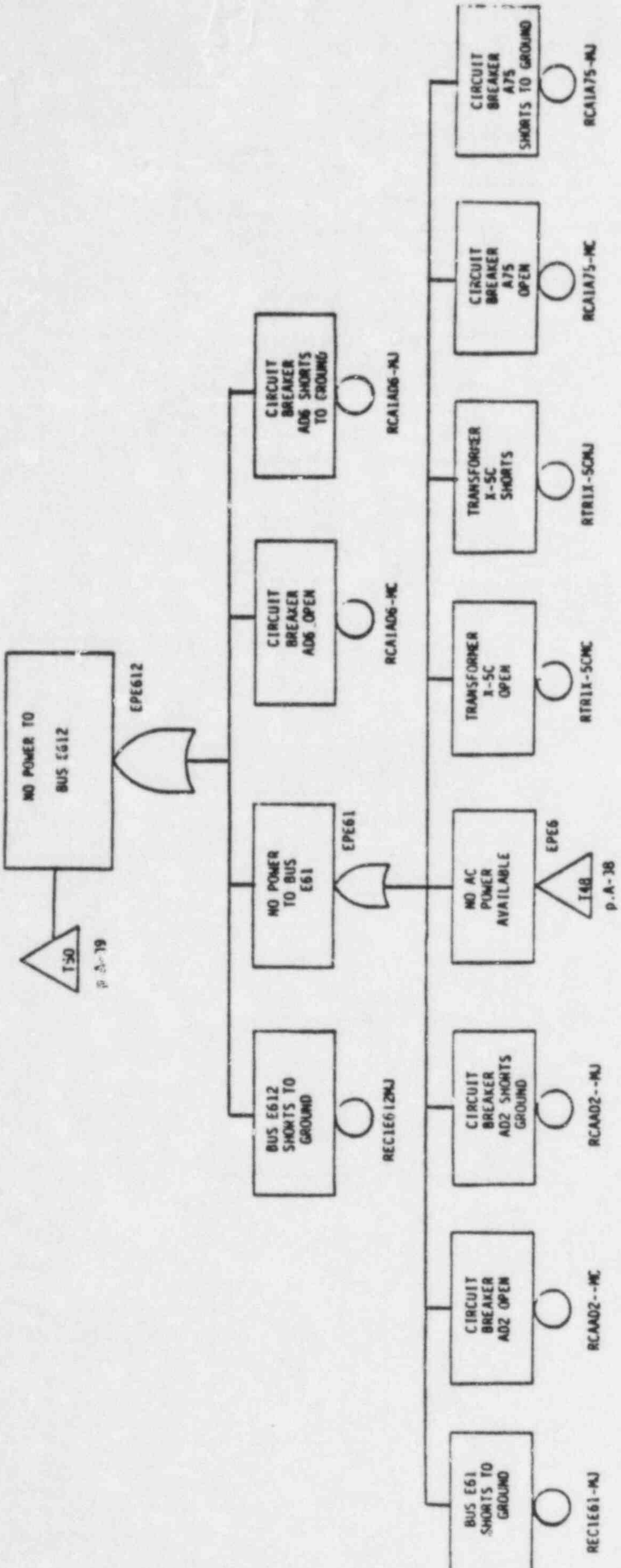
T45
p.A-35
NO FLOW FROM STEAM LINE A
AF106
V-127 RUPTURES
QVH1V171MJ
RUPTURE UPSTREAM OF V-127
OR
QBE1042AMJ
QPA1035AMJ
QPF1008AMJ
QOK1SL1AMJ
V-94 FAILS TO OPEN
QVA1V94AHA
V-127 DOES NOT OPEN
AF108
RUPTURE OF 4" LINE BETWEEN V-94 AND V-127
QBE1043BMJ
BYPASS OUTLET LINE RUPTURES
QBA1036AMJ
V-171 RUPTURES
QVH1V171MJ
NO ACTUATION SIGNAL RECEIVED BY V-127
AF109
V-127 FAILS TO OPEN
QVX1V127NA
V-127 FAILS TO REMAIN OPEN
QVX1V127ND
V-127 SOLENOID VALVE FAILS TO OPEN
QVL1V127NA
RELAY TO V-127 SOLENOID FAILS TO DE-ENERGIZE
QRA1V127NA
V-127 OUT FOR SERVICE
QVX1V127
V-127 DOES NOT RECEIVE SIGNAL
AF110
OR
GIC1AFSAMM
QRA1V127MK
V-127 NOT OPENED MANUALLY
AF111
OR
QVX1V127BA
QCE1V127MK

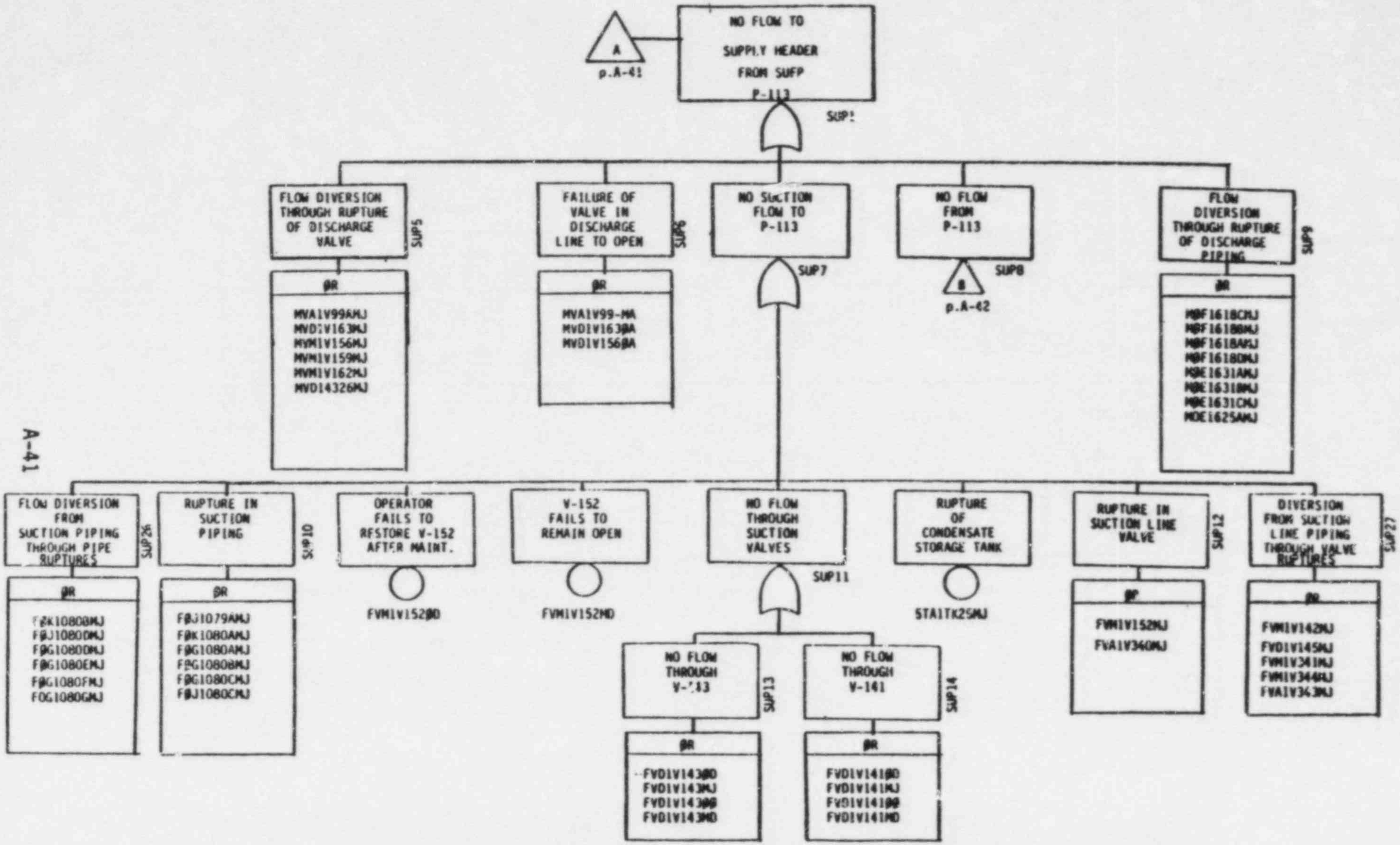

NO FLOW FROM STEAM LINE B
AF112
T46
p.A-37
V-128 RUPTURES
RUPTURE UPSTREAM OF V-128
AF113
OR
V-96 FAILS TO OPEN
V-128 DOES NOT OPEN
AF114
RUPTURE OF 4" LINE BETWEEN V-128 AND V-96
BYPASS OUTLET LINE RUPTURES
V-172 RUPTURES
NO ACTUATION SIGNAL RECEIVED BY V-128
AF115
V-128 FAILS TO OPEN
V-128 FAILS TO REMAIN OPEN
V-128 SOLENOID FAILS TO OPEN
RELAY TO V-128 SOLENOID FAILS TO DE-ENERGIZE
V-128 OUT FOR SERVICE
V-128 DOES NOT RECEIVE "S" SIGNAL
AF116
V-128 NOT OPENED MANUALLY
AF117

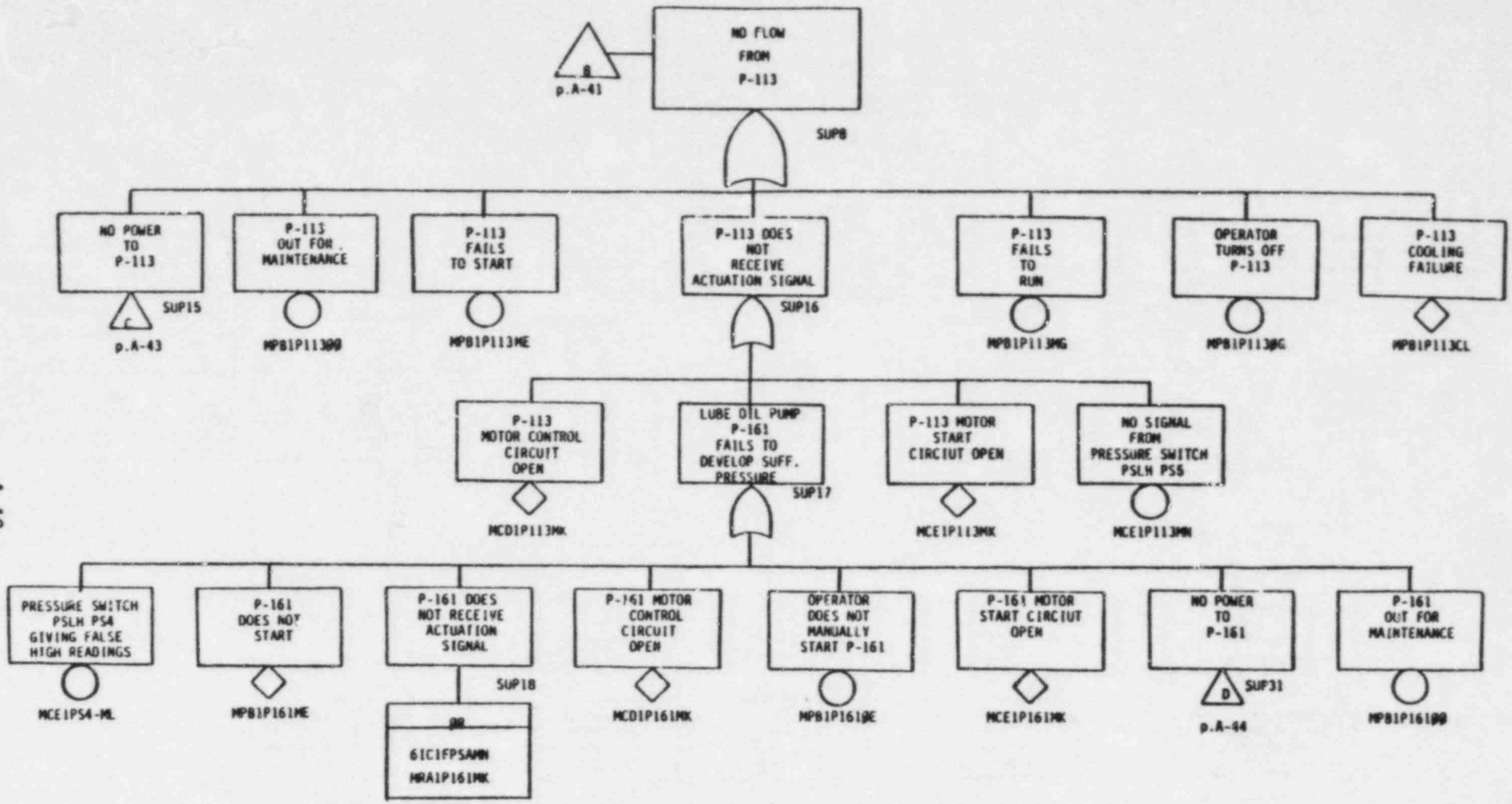


NO POWER TO P113
SUP15
CIRCUIT BREAKER FROM BUS 4 TO P-113 OPEN
RCA1P113MC
p.A-42
NO AC POWER AVAILABLE
SUP19
p.A-44
NO EMERGENCY AC POWER
SUP22
LOSS OF NORMAL AC POWER
SUP21
p.A-45
NO POWER TO 4160V BUS 4
SUP23
LOSS OF STATION POWER
LOSP
OPERATOR FAILS TO TRANSFER PUMP TO BUS E5
CIRCUIT BREAKER A-93 FAILS TO CLOSE
RCA1A93-MB
NO POWER FROM DIESEL GENERATOR 1A
p.A-45
CIRCUIT BREAKER A-54 FAILS TO CLOSE
RCA1A54-MB
DIESEL GENERATOR 1A FAILS TO RUN
RGD1DG1AME
DIESEL GENERATOR 1A FAILS TO RUN
RGD1DG1AMG
DIESEL GENERATOR 1A OUT OF SERVICE
NO POWER TO 4160V BUS 4 THROUGH BREAKER A 41
SUP24
OR
RCA1A41-MC
RCA1A41-MJ
RTR1X-2BMC
RTR1X-2BMJ
NO POWER TO 4160V BUS 4 THROUGH BREAKER A 42
SUP25
OR
RCA1A42-MB
RCA1A42-MJ
RTR1X-3BMC
RTR1X-3BMJ

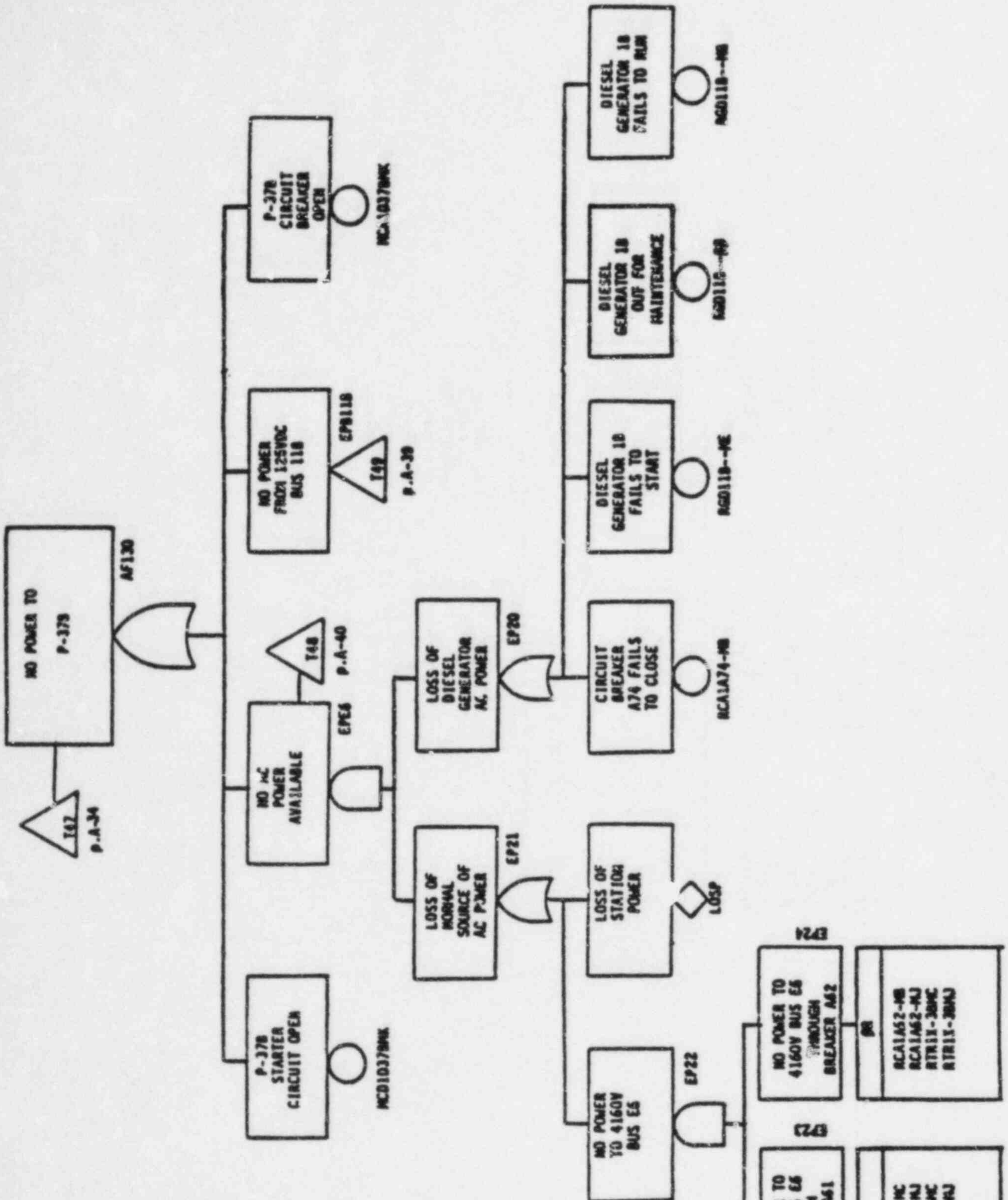

T49
p.A-38
NO POWER FROM 125VDC BUS 11B
EP11B
NO POWER TO BUS 11B
EP25
BUS 11B SHORTS TO GROUND
REC11B--MJ
NO BATTERY POWER SUPPLIED TO BUS 11B
EP26
NO POWER SUPPLIED BY BATTERY CHARGER 1B TO BUS 11B
NO POWER FROM BATTERY 1B
EP27
OR
RCA1DH5-MC
RBA11B--MJ
RBA11B--MM
NO POWER FROM BATTERY 1B
EP28
OR
RCA1DH4-MB
RBA11B--MJ
RBA11B--MM
CIRCUIT BREAKER DH4 OPEN
RCA1DH4-MC
CIRCUIT BREAKER DH4 SHORTS TO GROUND
RCA1DH4-MJ
CIRCUIT BREAKER DA1 SHORTS TO GROUND
RCA1DA1-MJ
CIRCUIT BREAKER DA1 OPEN
RCA1DA1-MC
BATTERY CHARGER 1B OPEN
RBC11B--MC
NO POWER TO BUS E612
EPE612
T50
p.A-40
BATTERY CHARGER 1B SHORTS TO GROUND
RBC11B--MJ

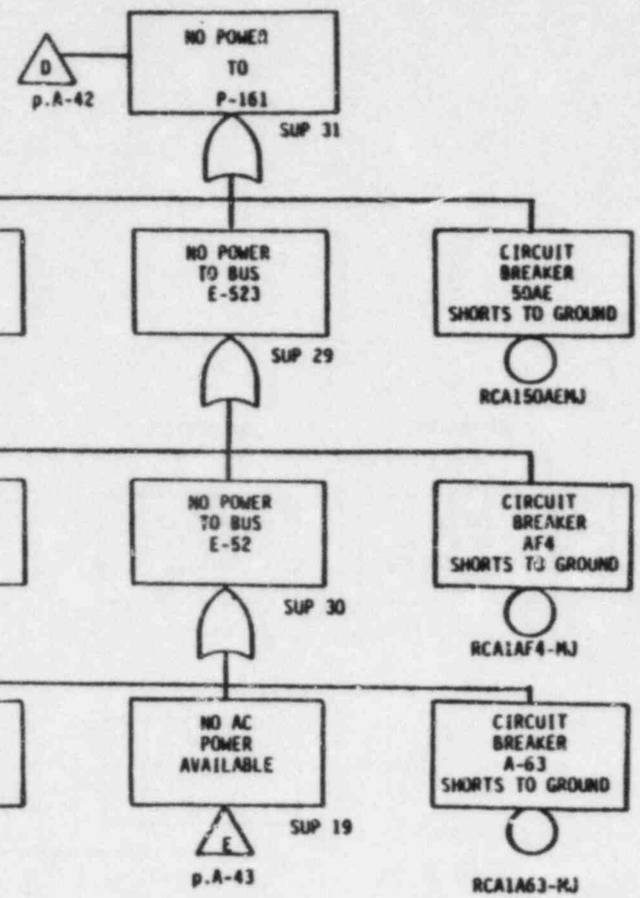

NO POWER TO BUS EG12
EPE612
T50
p.A-19
BUS E612 SHORTS TO GROUND
REC1E612MJ
NO POWER TO BUS E61
EPE61
CIRCUIT BREAKER AD6 OPEN
RCA1AD6-MC
CIRCUIT BREAKER AD6 SHORTS TO GROUND
RCA1AD6-MJ
BUS E61 SHORTS TO GROUND
REC1E61-MJ
CIRCUIT BREAKER AD2 OPEN
RCAAD2--MC
CIRCUIT BREAKER AD2 SHORTS GROUND
RCAAD2--MJ
NO AC POWER AVAILABLE
EPE6
T48
p.A-38
TRANSFORMER X-5C OPEN
RTR1X-5CMC
TRANSFORMER X-5C SHORTS
RTR1X-5CMJ
CIRCUIT BREAKER A75 OPEN
RCA1A75-MC
CIRCUIT BREAKER A75 SHORTS TO GROUND
RCA1A75-MJ


NO FLOW TO SUPPLY HEADER FROM SUFP P-113
SUP1
A
p.A-41
FLOW DIVERSION THROUGH RUPTURE OF DISCHARGE VALVE
SUP5
OR
MVA1V99AMJ
MVD1V163MJ
MVM1V156MJ
MVM1V159MJ
MVM1V162MJ
MVD14326MJ
FAILURE OF VALVE IN DISCHARGE LINE TO OPEN
SUP6
OR
MVA1V99-MA
MVD1V163ØA
MVD1V156ØA
NO SUCTION FLOW TO P-113
SUP7
NO FLOW FROM P-113
SUP8
B
p.A-42
FLOW DIVERSION THROUGH RUPTURE OF DISCHARGE PIPING
SUP9
OR
MØF1618CMJ
MØF1618BMJ
MØF1618AMJ
MØF1618DMJ
MØE1631AMJ
MØE1631BMJ
MØE1631CMJ
MØE1625AMJ
FLOW DIVERSION FROM SUCTION PIPING THROUGH PIPE RUPTURES
SUP26
OR
FØK1080BMJ
FØJ1080DMJ
FØG1080DMJ
FØG1080EMJ
FØG1080FMJ
FØG1080GMJ
RUPTURE IN SUCTION PIPING
SUP10
OR
FØJ1079AMJ
FØK1080AMJ
FØG1080AMJ
FØG1080BMJ
FØG1080CMJ
FØJ1080CMJ
OPERATOR FAILS TO RESTORE V-152 AFTER MAINT.
FVM1V1520D
V-152 FAILS TO REMAIN OPEN
FVM1V152MD
NO FLOW THROUGH SUCTION VALVES
SUP11
NO FLOW THROUGH V-?13
SUP13
OR
FVD1V143ØD
FVD1V143MJ
FVD1V143ØØ
FVD1V143MD
NO FLOW THROUGH V-141
SUP14
OR
FVD1V141ØD
FVD1V141MJ
FVD1V141ØØ
FVD1V141MD
RUPTURE OF CONDENSATE STORAGE TANK
STA1TK25MJ
RUPTURE IN SUCTION LINE VALVE
SUP12
OR
FVM1V152MJ
FVA1V340MJ
DIVERSION FROM SUCTION LINE PIPING THROUGH VALVE RUPTURES
SUP27
OR
FVM1V142MJ
FVD1V145MJ
FVM1V341MJ
FVM1V344MJ
FVA1V343MJ

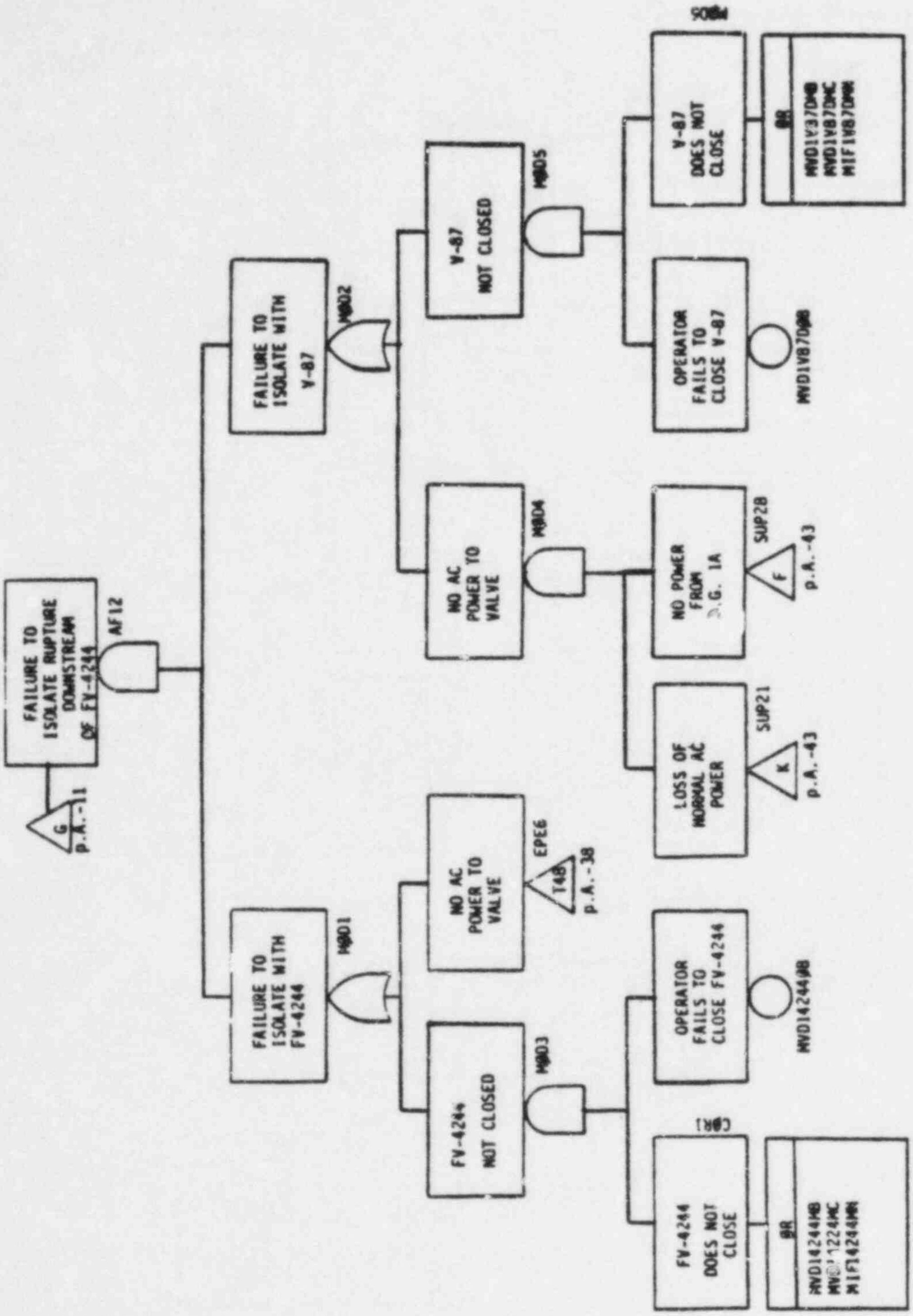


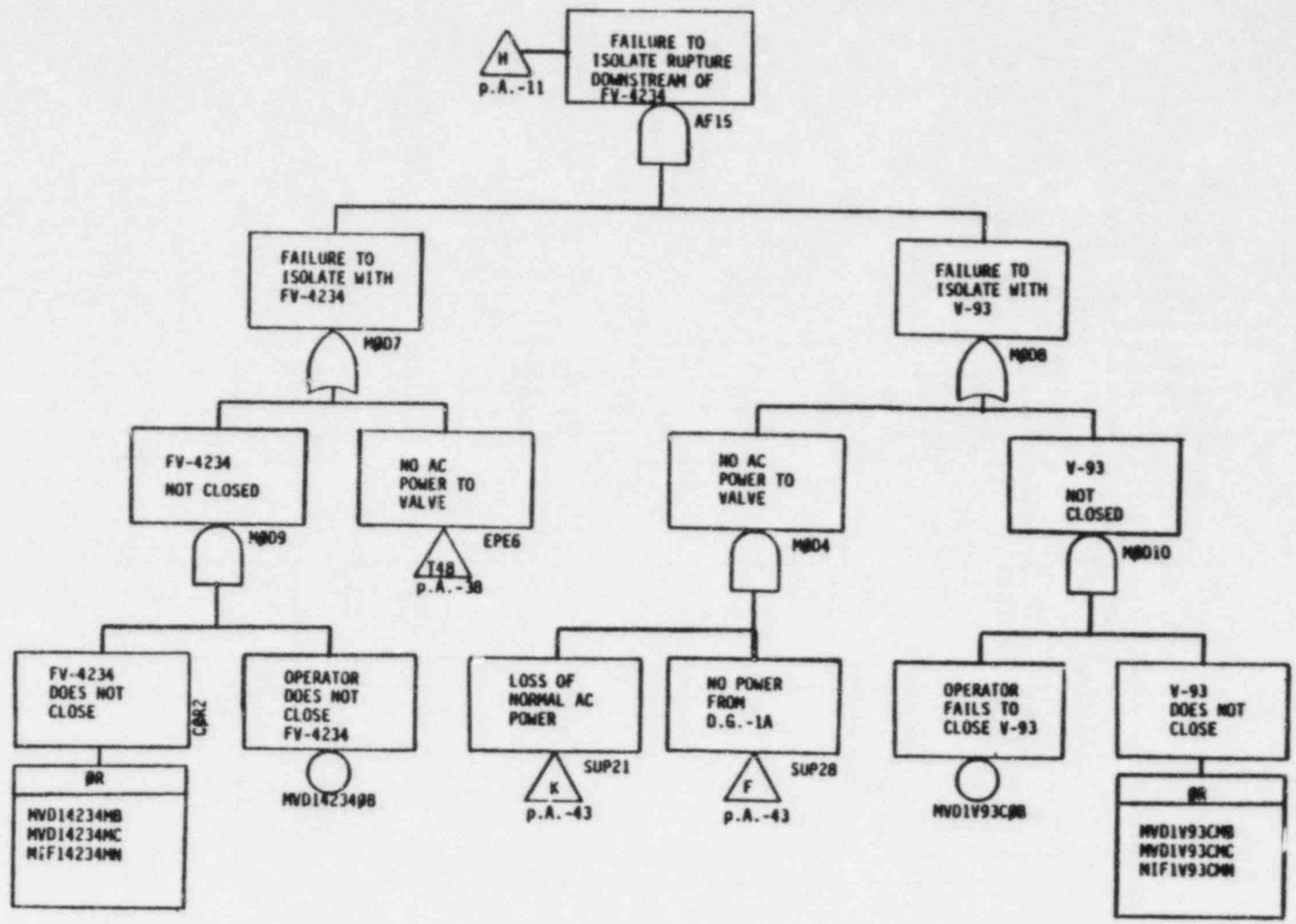
NO FLOW FROM P-113
B
p.A-41
SUP8
NO POWER TO P-113
C
SUP15
p.A-43
P-113 OUT FOR. MAINTENANCE
MPB1P113ØØ
P-113 FAILS TO START
MPB1P113ME
P-113 DOES NOT RECEIVE ACTUATION SIGNAL
SUP16
P-113 FAILS TO RUN
MPB1P113MG
OPERATOR TURNS OFF P-113
MPB1P113ØG
P-113 COOLING FAILURE
MPB1P113CL
P-113 MOTOR CONTROL CIRCUIT OPEN
MCD1P113MK
LUBE OIL PUMP P-161 FAILS TO DEVELOP SUFF. PRESSURE
SUP17
P-113 MOTOR START CIRCIUT OPEN
MCE1P113MK
NO SIGNAL FROM PRESSURE SWITCH PSLH PS5
MCE1P113MN
PRESSURE SWITCH PSLH PS4 GIVING FALSE HIGH READINGS
MCE1PS4-ML
P-161 DOES NOT START
MPB1P161ME
P-161 DOES NOT RECEIVE ACTUATION SIGNAL
SUP18
OR
6IC1FPSAMN
MRA1P161MK
P-161 MOTOR CONTROL CIRCUIT OPEN
MCD1P161MK
OPERATOR DOES NOT MANUALLY START P-161
MPB1P161ØE
P-161 MOTOR START CIRCIUT OPEN
MCE1P161MK
NO POWER TO P-161
D
SUP31
p.A-44
P-161 OUT FOR MAINTENANCE
MPB1P161ØØ

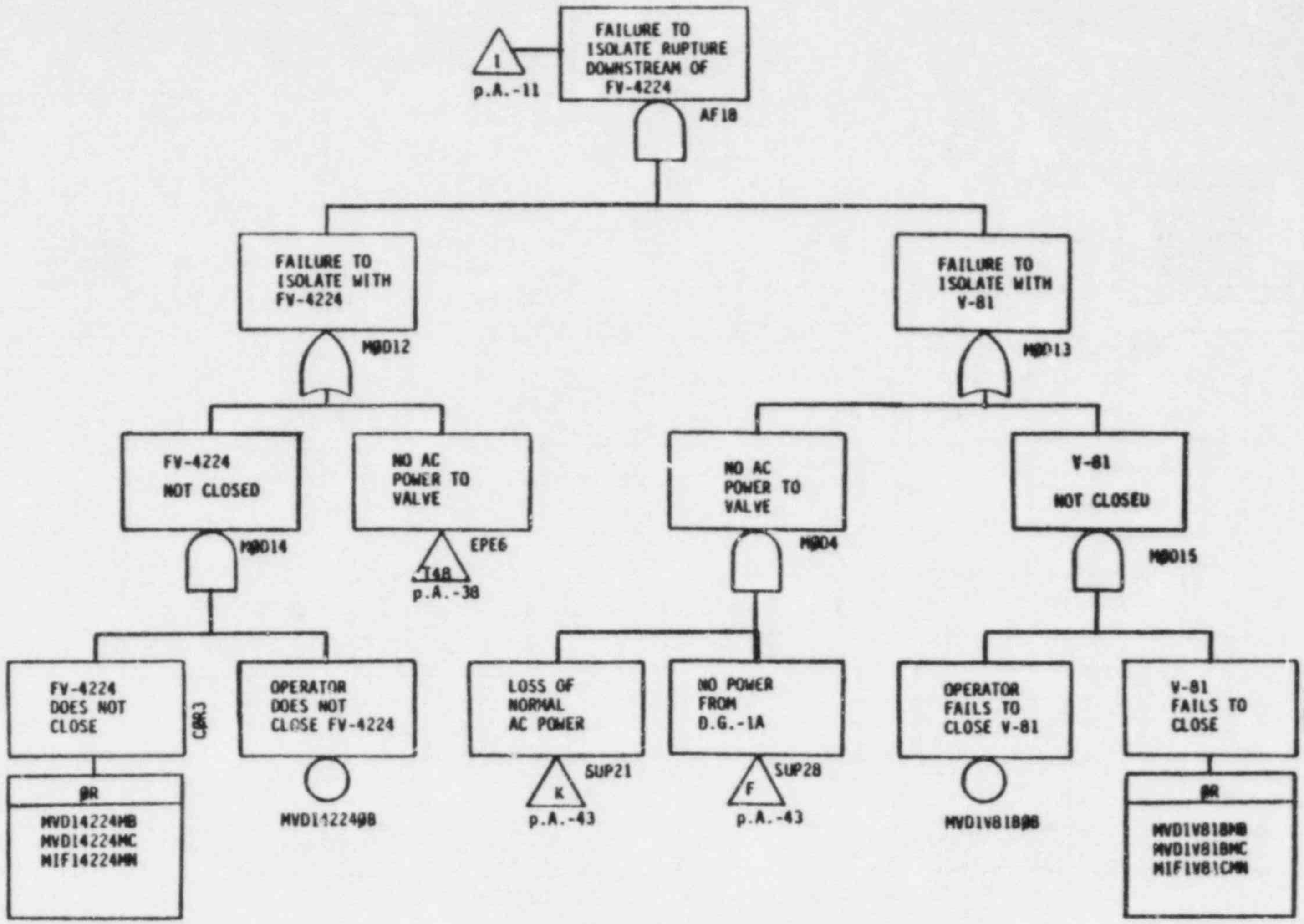

NO POWER TO P-37B
AF130
T62
p.A-34
P-37B STARTER CIRCUIT OPEN
NO AC POWER AVAILABLE
EPE6
T48
p.A-40
NO POWER FROM 125VDC BUS 11B
EPB11B
T49
p.A-39
P-37B CIRCUIT BREAKER OPEN
LOSS OF NORMAL SOURCE OF AC POWER
EP21
LOSS OF DIESEL GENERATOR AC POWER
EP20
LOSS OF STATION POWER
LOSP
CIRCUIT BREAKER A74 FAILS TO CLOSE
DIESEL GENERATOR 1B FAILS TO START
DIESEL GENERATOR 1B OUT FOR MAINTENANCE
DIESEL GENERATOR 1B FAILS TO RUN
NO POWER TO 4160V BUS E6
EP22
NO POWER TO 4160V BUS E6 THROUGH BREAKER A61
EP23
NO POWER TO 4160V BUS E6 THROUGH BREAKER A62
EP24
OR

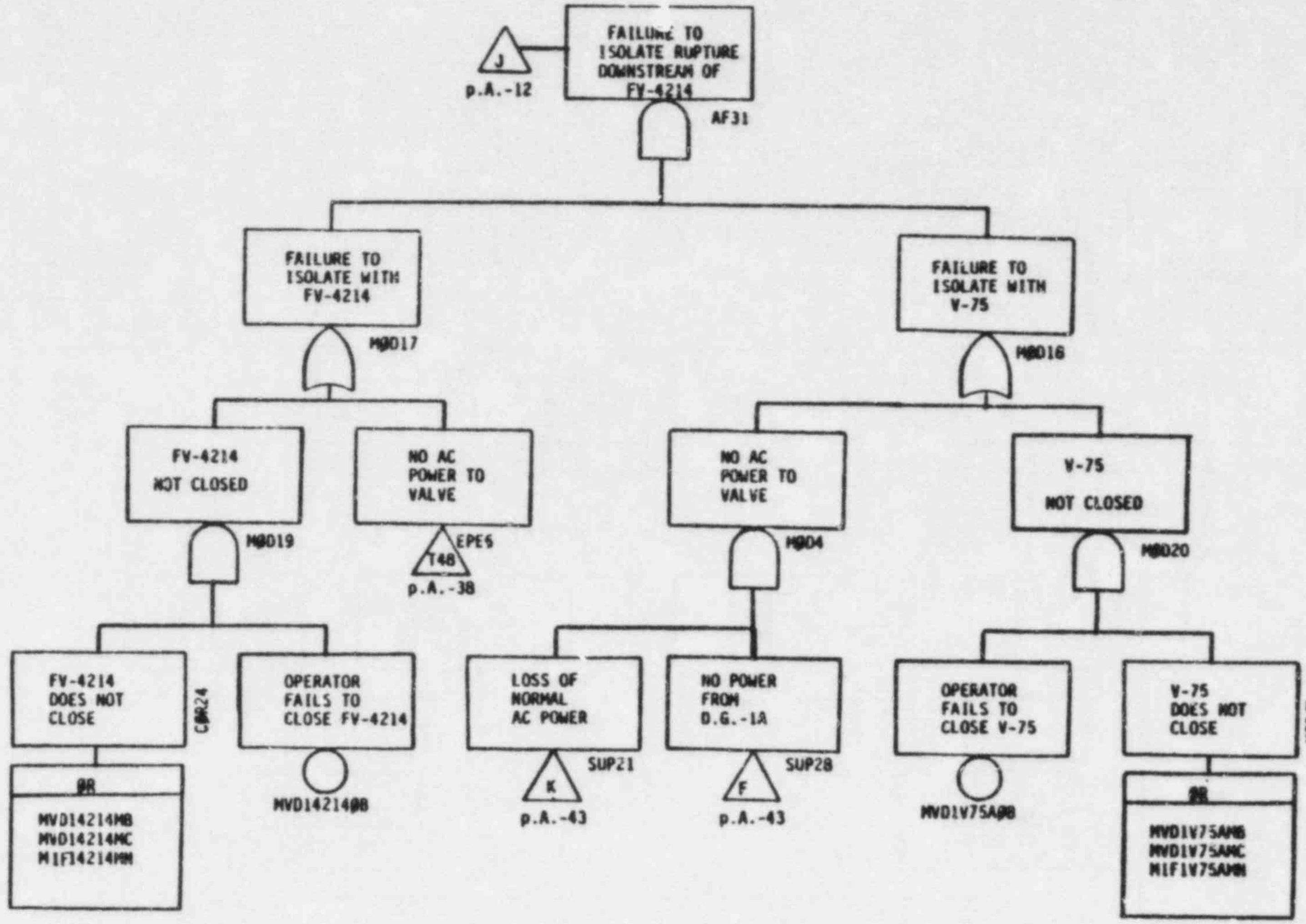


NO POWER TO P-161
D
p.A-42
SUP 31
CIRCUIT BREAKER 50AE OPEN
RCA150AEMC
NO POWER TO BUS E-523
SUP 29
CIRCUIT BREAKER 50AE SHORTS TO GROUND
RCA150AEMJ
CIRCUIT BREAKER AF4 OPEN
RCA1AF4-MC
NO POWER TO BUS E-52
SUP 30
CIRCUIT BREAKER AF4 SHORTS TO GROUND
RCA1AF4-MJ
CIRCUIT BREAKER A-63 OPEN
RCA1A63-MC
NO AC POWER AVAILABLE
E
p.A-43
SUP 19
CIRCUIT BREAKER A-63 SHORTS TO GROUND
RCA1A63-MJ


FAILURE TO ISOLATE RUPTURE DOWNSTREAM OF FV-4244
AF12
G
p.A.-11
FAILURE TO ISOLATE WITH FV-4244
MB01
FAILURE TO ISOLATE WITH V-87
MB02
FV-4244 NOT CLOSED
MB03
NO AC POWER TO VALVE
EPE6
T48
p.A.-38
NO AC POWER TO VALVE
MB04
V-87 NOT CLOSED
MB05
FV-4244 DOES NOT CLOSE
OPERATOR FAILS TO CLOSE FV-4244
LOSS OF NORMAL AC POWER
SUP21
K
p.A.-43
NO POWER FROM D.G. 1A
SUP28
F
p.A.-43
OPERATOR FAILS TO CLOSE V-87
V-87 DOES NOT CLOSE
MB06
OR
OR
MVDIV87DMB


FAILURE TO ISOLATE RUPTURE DOWNSTREAM OF FV-4234
AF15
H
p.A.-11
FAILURE TO ISOLATE WITH FV-4234
MØ07
FAILURE TO ISOLATE WITH V-93
MØ08
FV-4234 NOT CLOSED
MØ09
NO AC POWER TO VALVE
EPE6
T48
p.A.-38
NO AC POWER TO VALVE
MØ04
V-93 NOT CLOSED
MØ010
FV-4234 DOES NOT CLOSE
CØR2
ØR
MVD14234MB
MVD14234MC
MiF14234MN
OPERATOR DOES NOT CLOSE FV-4234
MVD14234ØB
LOSS OF NORMAL AC POWER
SUP21
K
p.A.-43
NO POWER FROM D.G.-1A
SUP28
F
p.A.-43
OPERATOR FAILS TO CLOSE V-93
MVD1V93CØB
V-93 DOES NOT CLOSE
MØ011
ØR
MVD1V93CMB
MVD1V93CMC
NIF1V93CMN


FAILURE TO ISOLATE RUPTURE DOWNSTREAM OF FV-4224
AF18
I
p.A.-11
FAILURE TO ISOLATE WITH FV-4224
MØD12
FAILURE TO ISOLATE WITH V-81
MØD13
FV-4224 NOT CLOSED
MØD14
NO AC POWER TO VALVE
EPE6
T48
p.A.-38
NO AC POWER TO VALVE
MØD4
V-81 NOT CLOSED
MØD15
FV-4224 DOES NOT CLOSE
CØR3
ØR
MVD14224MB
MVD14224MC
MIF14224MN
OPERATOR DOES NOT CLOSE FV-4224
MVD14224ØB
LOSS OF NORMAL AC POWER
SUP21
K
p.A.-43
NO POWER FROM D.G.-1A
SUP28
F
p.A.-43
OPERATOR FAILS TO CLOSE V-81
MVD1V81BØB
V-81 FAILS TO CLOSE
MØD16
ØR
MVD1V81BMB
MVD1V81BMC
MIF1V81CMN


FAILURE TO ISOLATE RUPTURE DOWNSTREAM OF FV-4214
AF31
J
p.A.-12
FAILURE TO ISOLATE WITH FV-4214
MØD17
FAILURE TO ISOLATE WITH V-75
MØD16
FV-4214 NOT CLOSED
MØD19
NO AC POWER TO VALVE
EPES
T48
p.A.-38
NO AC POWER TO VALVE
MØD4
V-75 NOT CLOSED
MØD20
FV-4214 DOES NOT CLOSE
CØR24
ØR
MVD14214MB
MVD14214MC
M1F14214MM
OPERATOR FAILS TO CLOSE FV-4214
MVD14214ØB
LOSS OF NORMAL AC POWER
SUP21
K
p.A.-43
NO POWER FROM D.G.-1A
SUP28
F
p.A.-43
OPERATOR FAILS TO CLOSE V-75
MVD1V75AØB
V-75 DOES NOT CLOSE
MØD21
ØR
MVD1V75AMB
MVD1V75AMC
M1F1V75AMM

APPENDIX B

FAULT TREE DATA

TABLE B.1

MECHANICAL AND ELECTRICAL COMPONENT FAILURE RATES

CATEGORY	COMPONENT	FAILURE MODE	FAILURE RATE: WASH-1400	FAILURE RATE: GE	FAILURE RATE: NRC BWR	FAILURE RATE: NRC PWR	FAILURE RATE: IEEE-500	FAILURE RATE: RECOMMENDED
Pumps	Pump (Motor Driven)	Fails to start	1×10^{-3}/d	7.9×10^{-6}/hr.	3.7×10^{-4}/d	5.3×10^{-4}/d (2.4×10^{-3}/d)*		2.4×10^{-3}/d
		Fails to run	3×10^{-5}/hr.		8.4×10^{-6}/hr	3×10^{-6}/hr. (3.4×10^{-3}/d)*		3.4×10^{-3}/d
	Pumps (Turbine Driven)	Fails to start	3×10^{-3}/d	7.9×10^{-6}/hr.	5.5×10^{-4}/d	4×10^{-3}/d (8.4×10^{-3}/d)*		8.4×10^{-3}/d
		Fails to run	3×10^{-5}/hr.		8.4×10^{-6}/hr	3×10^{-6}/hr. (5.7×10^{-3}/d)*		5.7×10^{-3}/d
Motors	Motor	Fails to start	3×10^{-4}/d					3×10^{-4}/d
		Fails to run	1×10^{-5}/hr.	1×10^{-6}/hr.				1×10^{-5}/hr
Diesel	Diesels	Fails to start	3×10^{-2}/d			4.0×10^{-2}/d (monthly)		4.0×10^{-2}/d
		Fails to run	3×10^{-3}/hr.			3.0×10^{-2}/hr (monthly)		3.0×10^{-2}/hr.
Pipe	Pipe ≤ 3"	Rupture	1×10^{-9}/hr.					1×10^{-9}/hr
	Pipe > 3"	Rupture	1×10^{-10}/hr.					1×10^{-10}/hr
Valves	Motor Operated	NO FO	1×10^{-3}/d	1.6×10^{-6}/hr	3×10^{-3}/d	2×10^{-3}/d		2×10^{-3}/d
		NC FC	1×10^{-3}/d	1.5×10^{-6}/hr				1×10^{-3}/d
		NO FC	1×10^{-4}/d	0.15×10^{-6}/hr	1×10^{-3}/d	5×10^{-4}/d		5×10^{-4}/d
		NC FO	1×10^{-4}/d	0.16×10^{-6}/hr				1×10^{-4}/d
		Rupture	1×10^{-8}/hr.					1×10^{-8}/hr
	Check Valve	Fails to open	1×10^{-4}/d	0.15×10^{-6}/d	1×10^{-4}/d	2×10^{-4}/d ***		2×10^{-4}/d
		Internal Leak	3×10^{-7}/hr.**	1.6×10^{-6}/hr	1.2×10^{-6}/hr	4.7×10^{-7}/hr		4.7×10^{-7}/hr
		Rupture	1×10^{-8}/hr					1×10^{-8}/hr
	Manual Valve	FTRO (plug)	1×10^{-4}/d					1×10^{-4}/d
		Rupture	1×10^{-8}/hr.		1×10^{-7}/hr	2×10^{-8}/hr		2×10^{-8}/hr
		Fail to operate			1×10^{-4}/d	8×10^{-5}/d		3×10^{-5}/d
	Motor Driven Operators	Spurious Opening					1.2×10^{-7}/hr	1.2×10^{-7}/hr
		Spurious Closing					1.2×10^{-7}/hr	1.2×10^{-7}/hr
		Fail to Open					2.5×10^{-6}/d	2.5×10^{-6}/d
		Fail to Close					2.5×10^{-6}/d	2.5×10^{-6}/d

* Specific to Aux. Feed Pumps

** 95 percent confidence bound

*** Value for Westinghouse

TABLE B.1

MECHANICAL AND ELECTRICAL COMPONENT FAILURE RATES

CATEGORY	COMPONENT	FAILURE MODE	FAILURE RATE: WASH-1400	GE	NRC: BWR	NRC: PWR	IEEE-500	RECOMMENDED
Valves (cont'd)	Solenoid Operated	Fail to operate	1×10^{-3}/d					1×10^{-3}/d
		FTRO (plug)	1×10^{-4}/d					1×10^{-1}/d
		Rupture	1×10^{-8}/hr					1×10^{-8}/hr
	Air Operated	Fail to operate	3×10^{-4}/d		3×10^{-2}/d	9×10^{-4}/d		9×10^{-4}/d
		FTRO (plug)	1×10^{-4}/d			1×10^{-7}/hr		1×10^{-4}/d
		Rupture	1×10^{-8}/hr		4×10^{-7}/hr	1×10^{-7}/hr		1×10^{-7}/hr
	Relief Valves	Fail to open	1×10^{-5}/d		8×10^{-3}/d			8×10^{-3}/d
		Premature open	1×10^{-5}/hr		4×10^{-3}/d	1.0×10^{-5}/hr		1.6×10^{-5}/hr
		Fail to close			5×10^{-3}/d			5×10^{-3}/d
	Safety Valves (PWR)	Fail to open	3×10^{-3}/d			6.2×10^{-3}/d		6.2×10^{-3}/d
		Premature open	3×10^{-6}/hr			1×10^{-5}/hr		1×10^{-5}/hr
		Fail to close	1×10^{-2}/d					1×10^{-2}/d
Valve Actuators	Solenoid: Normally open	Spurious energization					3.4×10^{-8}/hr	3.4×10^{-8}/hr
		Spurious de-energization					7.1×10^{-7}/hr	7.1×10^{-7}/hr
		Fail to energize					1.6×10^{-6}/d	1.6×10^{-6}/d
		Fail to de-energize					1.4×10^{-6}/d	1.4×10^{-6}/d
	Solenoid: Normally closed	Spurious energization					4.4×10^{-8}/hr	4.4×10^{-8}/hr
		Spurious de-energization					9.0×10^{-7}/hr	9.0×10^{-7}/hr
		Fail to energize					2.0×10^{-6}/d	2.0×10^{-6}/d
		Fail to de-energize					1.5×10^{-6}/d	1.5×10^{-6}/d
	Piston: Double Acting	Spurious open					4.5×10^{-7}/hr	4.5×10^{-7}/hr
		Spurious close					4.5×10^{-7}/hr	4.5×10^{-7}/hr
		Fail open					8.7×10^{-7}/d	8.7×10^{-7}/d
		Fail to close					1.1×10^{-6}/d	1.1×10^{-6}/d
	Piston: Single Acting	Spurious open					3.2×10^{-7}/hr	3.2×10^{-7}/hr
		Spurious close					3.5×10^{-7}/hr	3.5×10^{-7}/hr
		Fail to open					1.2×10^{-6}/d	1.2×10^{-6}/d
		Fail to close					1.6×10^{-6}/d	1.6×10^{-6}/d

TABLE B.1

MECHANICAL AND ELECTRICAL COMPONENT FAILURE RATES

CATEGORY	COMPONENT	FAILURE MODE	FAILURE RATE: WASH-1400	GE	NRC: BWR	NRC: PWR	IEEE-500	RECOMMENDED
Valve Actuators (cont'd)	Diaphragm	Spurious open					1.7×10^{-7}/hr	1.7×10^{-7}/hr
		Spurious close					1.6×10^{-7}/hr	1.6×10^{-7}/hr
		Fail to open					2.5×10^{-7}/d	2.5×10^{-7}/d
		Fail to close					3.2×10^{-7}/d	3.2×10^{-7}/d
Battery	Wet Cell Batteries	Fail to provide proper output	3×10^{-6}/hr				1.5×10^{-6}/hr	3×10^{-6}/hr
Battery Chargers	Battery charger	Fail to provide proper output					1.2×10^{-4}/hr	1.2×10^{-4}/hr
Circuit Breakers	Fuses	Fail to open	1×10^{-5}/d					1×10^{-5}/d
		Premature open	1×10^{-6}/hr					
	< 1000 v	Premature open					2.1×10^{-8}/hr	2.1×10^{-8}/hr
	1000-3000 v	Premature open					1.1×10^{-8}/hr	1.1×10^{-8}/hr
	Circuit Breakers	Fail to transfer	1×10^{-3}/d					1×10^{-3}/d
		Premature transfer	1×10^{-6}/d					
	(AC)	Fail to open					1.9×10^{-4}/d	1.9×10^{-4}/d
		Fail to close					4.4×10^{-6}/d	4.4×10^{-6}/d
	(DC)	Fail to open					1.8×10^{-4}/d	1.8×10^{-4}/d
	Relays (Protective)	Fail to open					$.50 \times 10^{-6}$/d	$.5 \times 10^{-6}$/d
		Fail to close					2.9×10^{-6}/d	2.9×10^{-6}/d
	(Control and Sequentially Programmed)	Fail to open					3.1×10^{-6}/d	3.1×10^{-6}/d
		Fail to close					3.9×10^{-6}/d	3.9×10^{-6}/d

TABLE B.1

MECHANICAL AND ELECTRICAL COMPONENT FAILURE RATES

CATEGORY	COMPONENT	FAILURE MODE	FAILURE RATE: WASH-1400	GE	NRC: BWR	NRC: PWR	IEEE-500	RECOMMENDED
Circuit Breakers (cont'd)	Relays (Motors)	Failure to energize	1×10^{-4}/d					1×10^{-4}/d
		Coil open	1×10^{-7}/hr					1×10^{-7}/hr
		Coil short to power	1×10^{-8}/hr					1×10^{-8}/hr
Transformers	Transformers	Open circuit: Primary or Secondary	1×10^{-6}/hr					1×10^{-5}/hr
		Short: Primary to Secondary	1×10^{-6}/hr					1×10^{-6}/hr
	Single Phase: 2 - 30KV	Open					3.2×10^{-8}/hr	3.2×10^{-8}/hr
	Three phase:							
	Dry 15 - 40KV	Open					7.4×10^{-8}/hr	7.4×10^{-8}hr
	601V - 15KV	Open					3.9×10^{-8}/hr	3.9×10^{-8}/hr
	Liquid 2 - 30 KV	Open					3.6×10^{-8}/hr	3.6×10^{-8}/hr
	31 - 72 KV	Open					5.2×10^{-8}/hr	5.2×10^{-8}/hr
	73 - 145KV	Open					8.6×10^{-9}/hr	8.6×10^{-9}/hr
	146 - 242KV	Open					1.9×10^{-8}/hr	1.9×10^{-8}/hr
	243 - 346KV	Open					9.2×10^{-9}/hr	9.2×10^{-9}/hr
	347 - 550KV	Open					5.4×10^{-8}/hr	5.4×10^{-8}/hr
Electrical Distribution	Bus	Open					4.2×10^{-9}/hr	4.2×10^{-9}/hr
		Short					7×10^{-8}/hr	7.0×10^{-8}/hr
	Wires	Open Circuit	3×10^{-6}/hr					3×10^{-6}/hr
		Short to Ground	3×10^{-7}/hr					3×10^{-7}/hr
		Short to Power	1×10^{-5}/hr					1×10^{-5}/hr
	Power Supply	No Output					1.4×10^{-6}/hr	1.4×10^{-6}/hr

TABLE B.1

MECHANICAL AND ELECTRICAL COMPONENT FAILURE RATES

CATEGORY	COMPONENT	FAILURE MODE	FAILURE RATE: WASH-1400	GE	NRC: BWR	NRC: PWR	IEEE-500	RECOMMENDED
Electrical Distribution (Cont'd)	Cable Power: Copper	Open circuit					9.1×10^{-7}/hr	9.1×10^{-7}/hr
		Short to ground					1.7×10^{-6}/hr	1.7×10^{-6}/hr
		Short to power					1.0×10^{-6}/hr	1.0×10^{-6}/hr
	Aluminum	Open circuit					1.1×10^{-6}/hr	1.1×10^{-6}/hr
		Short to ground					3.9×10^{-6}/hr	3.9×10^{-6}/hr
		Short to power					1.5×10^{-6}/hr	1.5×10^{-6}/hr
	Control: Copper	Open circuit					9.1×10^{-7}/hr	9.1×10^{-7}/hr
		Short to ground					2.4×10^{-6}/hr	2.4×10^{-6}/hr
		Short to power					1.0×10^{-6}/hr	1.0×10^{-6}/hr
	Terminal Boards	Open	1×10^{-7}/hr				3.3×10^{-6}/hr	$3.3. \times 10^{-6}$/hr
		Short	1×10^{-8}/hr				1.4×10^{-6}/hr	1.4×10^{-6}/hr
Instrumentation and Controls	Relay	Coil fails to operate	1×10^{-4}/d	$.4 \times 10^{-6}$/hr				1×10^{-4}/d
		Coil fails to open	3×10^{-7}/hr	$.08 \times 10^{-6}$/hr				3×10^{-7}/hr
	Temperature Sensing Device [3]	Fails to operate				1.4×10^{-6}/hr		1.4×10^{-6}/hr
		Degraded operation				6.6×10^{-7}/hr		6.6×10^{-7}/hr
	Temperature Element	Fail to operate					1.8×10^{-6}/hr	1.8×10^{-6}/hr
		Degraded operation					1.2×10^{-6}/hr	1.2×10^{-6}/hr
	Temperature Transmitter	Fails to operate					3.8×10^{-7}/hr	3.8×10^{-7}/hr
		Degraded operation					3.6×10^{-7}/hr	3.6×10^{-7}/hr

[3] Sensing Device includes switch, monitor, sensor, and transmitter

TABLE B.1

MECHANICAL AND ELECTRICAL COMPONENT FAILURE RATES

CATEGORY	COMPONENT	FAILURE MODE	FAILURE RATE: WASH-1400	GE	NRC: BWR	NRC: PWR	IEEE-500	RECOMMENDED
Instrumentation and Control (Cont'd)	Temperature Switches	Failed to operate		2.3×10^{-6}/hr			1.2×10^{-7}/d	1.2×10^{-7}/d
		Spurious operation					1.4×10^{-7}/d	1.4×10^{-7}/d
		Degraded operation					4.8×10^{-7}/d	4.8×10^{-7}/d
		Fails closed		$.33 \times 10^{-6}$/hr				$.33 \times 10^{-6}$/hr
	Pressure Sensing Device	Fails to operate			7.1×10^{-7}/hr	6×10^{-7}/hr		6×10^{-7}/hr
		Degraded operation			8.3×10^{-6}/hr	3.7×10^{-6}/hr		3.7×10^{-6}/hr
	Pressure Element	Fails to operate		1.1×10^{-6}/hr				1.1×10^{-6}/hr
	Pressure Transmitter	Fails to operate					9.2×10^{-7}/hr	9.2×10^{-7}/hr
		Degraded operation					6.3×10^{-7}/hr	6.3×10^{-7}/hr
	Pressure Switch	Fails to operate	1×10^{-4}/d				2.0×10^{-7}/d	2.0×10^{-7}/d
		Spurious operation					4.8×10^{-8}/d	4.8×10^{-8}/d
		Degraded operation					5.7×10^{-8}/d	5.7×10^{-8}/d
	Flow Sensing Device	Fail to operate			5.9×10^{-7}/hr	4.8×10^{-6}/hr		4.8×10^{-6}/hr
		Degraded operation			2.9×10^{-6}/hr	2.5×10^{-6}/hr		2.5×10^{-6}/hr
	Flow Element	Fail to operate					3.1×10^{-7}/hr	3.1×10^{-7}/hr
		Degraded operation					1.8×10^{-7}/hr	1.8×10^{-7}/hr
	Flow Controller	Fail to operate		4.2×10^{-6}/hr				4.2×10^{-6}/hr
	Flow Transmitters	Fail to operate					1.4×10^{-6}/hr	1.4×10^{-6}/hr
		Degraded operation					1.4×10^{-6}/hr	1.4×10^{-6}/hr
	Flow Switches	Fail to operate		4.2×10^{-6}/hr			1.3×10^{-8}/d	1.3×10^{-8}/d
		Spurious operation					1.2×10^{-8}/d	1.2×10^{-8}/d
		Degraded operation					1.7×10^{-8}/d	1.7×10^{-3}/d
	Limit Switch	Fail to operate	3.4×10^{-4}/d					3.4×10^{-4}/d
	Manual Switch	Fail to transfer	1×10^{-5}/d					1×10^{-5}/d

TABLE B.1

MECHANICAL AND ELECTRICAL COMPONENT FAILURE RATES

CATEGORY	COMPONENT	FAILURE MODE	FAILURE RATE: WASH-1400	GE	NRC: BWR	NRC: PWR	IEEE-500	RECOMMENDED
Instrumentation and Control (Cont'd)	Level Sensing Device	Fail to operate			3.1×10^{-6}/hr	2.6×10^{-6}/hr		2.6×10^{-6}/hr
		Degraded operation			5.7×10^{-6}/hr	5.2×10^{-6}/hr		5.2×10^{-6}/hr
	Level Element			3.9×10^{-5}/hr				3.9×10^{-6}/hr
	Level Transmitter	Fail to operate					1.4×10^{-6}/hr	1.4×10^{-6}/hr
		Degraded operation					1.1×10^{-6}/hr	1.1×10^{-5}/hr
	Level Switch	Fail to operate					3×10^{-7}/d	3×10^{-7}/d
		Spurious operations					3.4×10^{-8}/d	3.4×10^{-8}/d
		Degraded operations					4.5×10^{-7}/d	4.5×10^{-7}/d
	Level Controller	Fail to operate					1×10^{-6}/hr	1×10^{-6}/hr
		Spurious operations					1×10^{-6}/hr	1×10^{-6}/hr
		Degraded operation					2×10^{-6}/hr	2×10^{-6}/hr
	E/S Converter	Fail to operate		4.2×10^{-6}/hr				4.2×10^{-6}/hr
	Square Root Converter	Fail to operate		4.2×10^{-6}/hr				4.2×10^{-6}/hr
	Power Supply	Fail to operate		4.2×10^{-6}/hr			2.8×10^{-6}/hr	2.8×10^{-6}/hr
		Degraded operation					1.9×10^{-6}/hr	1.9×10^{-6}/hr
	Solid State: Low Power	Fails to Function	1×10^{-6}/hr					1×10^{-6}/hr
		Fails Shorted	1×10^{-7}/hr					1×10^{-6}/hr
	High Power	Fails to Function	3×10^{-6}/hr					3×10^{-6}/hr
		Fails Shorted	1×10^{-6}/hr					1×10^{-6}/hr
	Torque Switch	Fails to operate	1×10^{-4}/d					1×10^{-4}/d
	Switch Contacts	Normally open switches fail to close	1×10^{-7}/hr					1×10^{-7}/hr
		Normally closed switches fail to close	3×10^{-8}/hr					3×10^{-8}/hr
		Short across contacts	1×10^{-8}/hr					1×10^{-8}/hr

TABLE B.2

FAULT IDENTIFIERS FOR THE SEABROOK EMERGENCY FEED STATION

FAULT IDENTIFIER	DESCRIPTION	UNAVAILABILITY	FAILURE RATE
QVB1SGARØH	S.G.A. Relief Valve Calibration Valve	6.0×10^{-7}	1.2×10^{-6}/hr
QVB1SGDRØH	S.G.D. Relief Valve Calibration Shift	6.0×10^{-7}	1.2×10^{-6}/hr
QVB1SGCRØH	S.G.C. Relief Valve Calibration Shift	6.0×10^{-7}	1.2×10^{-6}/hr
QVB1SGRRØH	S.G.B. Relief Valve Calibration Shift	6.0×10^{-7}	1.2×10^{-6}/hr
QVB1SGARMM	S.G.A Relief Valve Control Wiring Reversed	4.2×10^{-8}	8.4×10^{-8}/hr
QIX1SGDRMM	S.G.D Relief Valve Control Wiring Reversed	4.2×10^{-8}	8.4×10^{-8}/hr
QIX1SGCRMM	S.G.C Relief Valve Control Wiring Reversed	4.2×10^{-8}	8.4×10^{-8}/hr
QIX1SGBRMM	S.G.B Relief Valve Control Wiring Reversed	4.2×10^{-8}	8.4×10^{-8}/hr
MPB1T37AMG	Turbine Driven Pump P-37A Fails to Run	5.7×10^{-3}	5.7×10^{-3}/d
MPB1D37BMG	Motor Driven Pump P-37B Fails to Run	3.4×10^{-3}	3.4×10^{-3}/d
MVD1V30AMJ	Isolation Valve V-30 In Feedwater Supply Line to S.G.A Ruptures	5×10^{-8}	1×10^{-7}/hr
MVA1V29AMJ	Check Valve V-29 In Feedwater Supply Line To S.G.A Ruptures	5×10^{-9}	1×10^{-8}/hr
MVA1V29AMJ	Stop Check Valve V-76 In Aux. Feed. Supply Line A Ruptures	5×10^{-9}	1×10^{-8}/hr
MVD14214MJ	Flow Control Valve FV-4214 In Aux. Feed. Supply Line A Ruptures	5×10^{-8}	1×10^{-7}/hr
MVA1V94DMJ	Stop Check Valve V-94 In Aux. Feed. Supply Line D Rupture	5×10^{-9}	1×10^{-8}/hr
MVD14244MJ	Flow Control Valve FV-4244 In Aux. Feed. Supply Line D Ruptures	5×10^{-8}	1×10^{-7}/hr
MVA1V88CMJ	Stop Check Valve V-88 In Aux. Feed. Supply Line C Rupture	5×10^{-9}	1×10^{-8}/hr

TABLE B.2 (Continued)

FAULT IDENTIFIERS FOR THE SEABROOK EMERGENCY FEED STATION

FAULT IDENTIFIER	DESCRIPTION	UNAVAILABILITY	FAILURE RATE
MVD14234MJ	Flow Control Valve FV-4234 In Aux. Feed Supply Line C Ruptures	5×10^{-6}	1×10^{-7}/hr
MVA1V82BMJ	Stop Check Valve V-82 In Aux. Feed. Supply Line B Ruptures	5×10^{-9}	1×10^{-8}/hr
MVD14224MJ	Flow Control Valve FV-4244 In Aux. Feed. Supply Line B Ruptures	5×10^{-8}	1×10^{-7}/hr
MVD1V57DMJ	Isolation Valve V-57 In Feedwater Supply Line D Ruptures	5×10^{-8}	1×10^{-7}/hr
MVA1V56DMJ	Check Valve V-56 In Feedwater Supply Line D Ruptures	5×10^{-9}	1×10^{-8}/hr
MVD1V48CMJ	Isolation Valve V-48 In Feedwater Supply Line C Ruptures	5×10^{-8}	1×10^{-7}/hr
MVA1V47CMJ	Check Valve V-47 In Feedwater Supply Line C Ruptures	5×10^{-9}	1×10^{-8}/hr
MVD1V39BMJ	Isolation Valve V-39 In Feedwater Supply Line B Ruptures	5×10^{-8}	1×10^{-7}/hr
MVA1B38BMJ	Check Valve V-38 In Feedwater Supply Line B Ruptures	5×10^{-9}	1×10^{-8}/hr
MVM1V75AMJ	Manual Valve V-75 In Aux. Feed. Supply Line A Ruptures	1×10^{-8}	2×10^{-8}/hr
VMD1V65AMJ	Gear Driven Valve V-65 In P-37A Discharge Line Ruptures	5×10^{-9}	1×10^{-8}/jr
MVM1V152MJ	Manual Valve V-152 In Feedwater Recirc. Line A Ruptures	1×10^{-8}	2×10^{-8}/hr
MVD1V156MJ	Gear Driven Valve V-156 In Start-up Feed Pump Discharge Line Rup.	5×10^{-9}	1×10^{-8}/hr
MVD1V510MJ	Flow Control Valve FCV-510 In Feed. Supply Line A Ruptures	5×10^{-8}	1×10^{-7}/hr
MVM1V87DMJ	Manual Valve V-87 In Aux. Feed. Supply Line D Ruptures	1×10^{-8}	2×10^{-8}/hr
MVM1V153MJ	Manual Valve V-153 In Feedwater Recirc. Line D Ruptures	1×10^{-8}	2×10^{-8}/hr
MVD1V540MJ	Flow Control Valve FCV-540 In Feed. Supply Line D Ruptures	5×10^{-8}	1×10^{-7}/hr

TABLE B.2 (Continued)

FAULT IDENTIFIERS FOR THE SEABROOK EMERGENCY FEED STATION

FAULT IDENTIFIER	DESCRIPTION	UNAVAILABILITY	FAILURE RATE
MVM1V93CMJ	Manual Valve V-93 In Aux. Feed. Supply Line C Ruptures	1×10^{-8}	2×10^{-8}/hr
MVM1V154MJ	Manual Valve V-154 In Feedwater Recirc. Line C Ruptures	1×10^{-8}	2×10^{-8}/hr
MDV1V530MJ	Flow Control Valve FCV-530 In Feed. Supply Line C Ruptures	5×10^{-8}	1×10^{-7}/hr
MVM1V81BMJ	Manual Valve V-81 In Aux. Feed. Line B Ruptures	1×10^{-8}	2×10^{-8}/hr
MVD1V71BMJ	Gear Driven Valve V-71 In P-37B Discharge Line Rupture	5×10^{-9}	1×10^{-8}/hr
MVM1V155MJ	Manual Valve V-155 In Feedwater Recirc. Line B Ruptures	1×10^{-8}	2×10^{-8}/hr
MVD1V520MJ	Flow Control Valve FCV-520 In Feed. Supply Line B Ruptures	5×10^{-8}	1×10^{-7}/hr
MVA1V64AMJ	Check Valve V-64 In P-37A Discharge Line Ruptures	5×10^{-9}	1×10^{-8}/hr
MVA1V70BMJ	Check Valve V-70 In P-38B Discharge Line Ruptures	5×10^{-9}	1×10^{-8}/hr
QVD1V129MJ	Valve V-129 In P-37A Turbine Steam Inlet Line Ruptures	5×10^{-9}	1×10^{-8}/hr
QVM1V95AMJ	Manual Valve V-95 In P-37A Turbine Steam Inlet Line Ruptures	1×10^{-8}	2×10^{-8}/hr
QVA1V94AMJ	Check Valve V-94 In Steam Supply Line A to P-37A Ruptures	5×10^{-9}	1×10^{-8}/hr
QVA1V96BMJ	Check Valve V-96 In Steam Supply Line A to P-37A Ruptures	5×10^{-9}	1×10^{-8}/hr
QVX1V127MJ	Steam Supply Line A Control Valve V-127 Ruptures	5×10^{-8}	1×10^{-7}/hr
QVM1V171MJ	Steam Supply Line A Manual Bypass Valve V-171 Ruptures	1×10^{-8}	2×10^{-8}/hr
QVX1V128MJ	Steam Supply Line B Control Valve V-128 Ruptures	5×10^{-8}	1×10^{-7}/hr
QMV1V172MJ	Steam Supply Line B Manual Bypass Valve V-172 Ruptures	1×10^{-8}	2×10^{-8}/hr

TABLE B.2 (Continued)

FAULT IDENTIFIERS FOR THE SEABROOK EMERGENCY FEED STATION

FAULT IDENTIFIER	DESCRIPTION	UNAVAILABILITY	FAILURE RATE
FVM1V155MJ	Manual Valve V-155 In P-37A Suction Line Ruptures	1×10^{-8}	2×10^{-8}/hr
FVM1V154MJ	Manual Valve V-154 In P-37A Suction Line Ruptures	1×10^{-8}	2×10^{-8}/hr
FVM1V159MJ	Manual Valve V-159 In P-27A Suction Line Ruptures	1×10^{-8}	2×10^{-8}/hr
FVM1V158MJ	Manual Valve V-158 In P-37A Suction Line Ruptures	1×10^{-8}	2×10^{-8}/hr
MVD1V3ØAMB	Isolation Valve V-30 In Feedwater Supply Line A Fails To Close	9×10^{-4}	9×10^{-4}/d
MVD14244MB	Flow Control Valve FV-4244 In Aux. Feed Supply Line D Fails To Close	2×10^{-3}	2×10^{-3}/d
MVD14234MB	Flow Control Valve FV-4234 In Aux. Feed. Supply Line D Fails To Close	9×10^{-4}	9×10^{-4}/d
MVD14224MB	Flow Control Valve FV-4224 In Aux. Feed. Supply Line D Fails To Close	9×10^{-4}	9×10^{-4}/d
MVD1V57DMB	Isolation Valve V-57 In Feedwater Supply Line D Fails To Close	9×10^{-4}	9×10^{-4}/d
MVD14214MB	Flow Control Valve FV-4214 In Aux. Feed. Supply Line A Fails To Close	9×10^{-4}	2×10^{-3}/d
MVD1V48CMB	Isolation Valve V-48 In Feedwater Supply Line C Fails To Close	9×10^{-4}	9×10^{-4}/d
MVD1V39BMB	Isolation Valve V-39 In Feedwater Supply Line C Fails To Close	9×10^{-4}	9×10^{-4}/d
MVD1V510MB	Flow Control Valve FCV-510 In Feed. Supply Line A Fails To Close	9×10^{-4}	9×10^{-4}/d
MVD1V540MB	Flow Control Valve FCV-540 In Feed. Supply Line D Fails to Close	9×10^{-4}	9×10^{-4}/d
MVD1V530MB	Flow Control Valve FCV-530 In Feed. Supply Line C Fails To Close	9×10^{-4}	9×10^{-4}/d
MVD1V520MB	Flow Control Valve FCV-520 In Feed. Supply Line B Fails To Close	9×10^{-4}	9×10^{-4}/d
MVD1V30AMC	Isolation Valve V-30 In Feedwater Supply Line A Fails To Remain Cl.	2.3×10^{-7}	4.5×10^{-7}/hr

FAULT IDENTIFIERS FOR THE SEABROOK EMERGENCY FEED STATION

FAULT IDENTIFIER	DESCRIPTION	UNAVAILABILITY	FAILURE RATE
MVD14244MC	Flow Control Valve FV-4244 In Aux. Feed. Supply Line D Fails To Remain Closed	6.0×10^{-8}	1.2×10^{-7}/hr
MVD14234MC	Flow Control Valve FV-4234 In Aux. Feed. Supply Line C Fails To Remain Closed	6.0×10^{-8}	1.2×10^{-7}/hr
MVD14224MC	Flow Control Valve FV-4224 In Aux. Feed. Supply Line B Fails To Remain Closed	6.0×10^{-8}	1.2×10^{-7}/hr
MVD1V57DMC	Isolation Valve V-57 In Feedwater Supply Line D Fails To Remain Closed	2.3×10^{-7}	4.5×10^{-7}/hr
MVD14214MC	Flow Control Valve FV-4214 In Aux. Feed. Supply Line A Fails To Remain Closed	6.0×10^{-8}	1.2×10^{-7}/hr
MVD1V48CMC	Isolation Valve V-48 In Feedwater Supply Line C Fails To Remain Closed	2.3×10^{-7}	4.5×10^{-7}/hr
MVD1V39BMC	Isolation Valve V-39 In Feedwater Supply Line B Fails To Remain Closed	2.3×10^{-7}	4.5×10^{-7}/hr
MVD1V510MC	Flow Control Valve FCV-150 In Feed. Supply Line A Fails To Remain Closed	8.5×10^{-8}	1.7×10^{-7}/hr
MVD1V540MC	Flow Control Valve FCV-540 In Feed. Supply Line D Fails To Remain Closed	8.5×10^{-8}	1.7×10^{-7}/hr
MVD1V530MC	Flow Control Valve FCV-530 In Feed. Supply Line C Fails To Remain Closed	8.5×10^{-8}	1.7×10^{-7}/hr
MVD1V520MC	Flow Control Valve FCV-520 In Feed. Supply Line B Fails To Remain Closed	8.5×10^{-8}	1.7×10^{-7}/hr
MVD14214MD	Flow Control Valve FV-4214 Fails To Remain Open	8×10^{-8}	1.6×10^{-7}/hr
MVD14244MD	Flow Control Valve FV-4244 Fails To Remain Open	8×10^{-8}	1.6×10^{-7}/hr
MVD14234MD	Flow Control Valve FV-4234 Fails To Remain Open	8×10^{-8}	1.6×10^{-7}/hr
MVD14224MD	Flow Control Valve FV-4224 Fails To Remain Open	8×10^{-8}	1.6×10^{-7}/hr
MVD1V65AMD	Isolation Valve V-65 Fails To Remain Open (Plugged)	1×10^{-4}	1×10^{-4}/d
QVD1V129MD	Steam Supply Inlet Valve V-129 Fails To Remain Open	2.3×10^{-7}	4.5×10^{-7}/hr

TABLE B.2 (Continued)

FAULT IDENTIFIERS FOR THE SEABROOK EMERGENCY FEED STATION

FAULT IDENTIFIER	DESCRIPTION	UNAVAILABILITY	FAILURE RATE
MVD1V125MD	Isolation Valve V-125 Fails To Remain Open (Plugged)	1×10^{-4}	1×10^{-4}/d
MVD1V126MD	Isolation Valve V-126 Fails To Remain Open (Plugged)	1×10^{-6}	1×10^{-4}/d
MVD1V127MD	Isolation Valve V-127 Fails To Remain Open (Plugged)	1×10^{-4}	1×10^{-4}/d
MVD1V71BMD	Isolation Valve V-71 Fails To Remain Open (Plugged)	1×10^{-4}	1×10^{-4}/d
QVX1V127MA	Steam Supply Line A Flow Valve V-127 Fails To Open	9×10^{-4}	9×10^{-4}/d
QVX1V128MA	Steam Supply Line B Flow Valve V-128 Fails To Open	9×10^{-4}	9×10^{-4}/d
QVX1V127MD	Steam Supply Line A Flow Valve V-127 Fails To Remain Open	2.3×10^{-7}	4.5×10^{-7}/hr
QVX1V128MD	Steam Supply Line B Fails To Remain Open	2.3×10^{-7}	4.5×10^{-7}/hr
MVA1V76AMA	Stop Check Valve V-76 Fails To Open	2×10^{-4}	2×10^{-4}/d
MVA1V94DMA	Stop Check Valve V-94 Fails To Open	2×10^{-4}	2×10^{-4}/d
MVA1V88CMA	Stop Check Valve V-88 Fails To Open	2×10^{-4}	2×10^{-4}/d
MVA1V82BMA	Stop Check Valve V-82 Fails To Open	2×10^{-4}	2×10^{-4}/d
MVA1V64AMA	Check Valve V-64 Fails To Open	2×10^{-4}	2×10^{-4}/d
QVA1V94AMA	Steam Supply Line A Check Valve V-94 Fails To Open	2×10^{-4}	2×10^{-4}/d
QVA1V96BMA	Steam Supply Line B Check Valve V-96 Fails To Open	2×10^{-4}	2×10^{-4}/d
MVA1V70BMA	Check Valve V-70 Fails To Open	2×10^{-4}	2×10^{-4}/d
MVD1V75AMD	Valve V-75 In Aux. Feed Supply Line A Plugged	1×10^{-4}	1×10^{-4}/d

TABLE B.2 (Continued)

FAULT IDENTIFIERS FOR THE SEABROOK EMERGENCY FEED STATION

FAULT IDENTIFIER	DESCRIPTION	UNAVAILABILITY	FAILURE RATE
MVD1V87DMD	Valve V-87 In Aux. Feed Supply Line D Plugged	1×10^{-4}	1×10^{-4}/d
MVD1V93CMD	Valve V-93 In Aux. Feed Supply Line C Plugged	1×10^{-4}	1×10^{-4}/d
MVD1V81BMD	Valve V-81 In Aux. Feed Supply Line B Plugged	1×10^{-4}	1×10^{-4}/d
QVM1V95AMD	Manual Valve V-95 In Turbine Steam Supply Line Plugged	1×10^{-4}	1×10^{-4}/d
FVM1V155MD	Manual Valve V-155 In P-37A Suction Line Plugged	1×10^{-4}	1×10^{-4}/d
FVM1V154MD	Manual Valve V-154 In P-37A Suction Line Plugged	1×10^{-4}	1×10^{-4}/d
FVM1V159MD	Manual Valve V-159 In P-37B Suction Line Plugged	1×10^{-4}	1×10^{-4}/d
FVM1V158MD	Manual Valve V-158 In P-37B Suction Line Plugged	1×10^{-4}	1×10^{-4}/d
MØJ1606BMJ	Feedwater Supply Line Ruptures Between V-20 and V-30	5×10^{-11}	1×10^{-10}/hr
MØJ1606AMJ	Feedwater Supply Line Ruptures Between V-30 and S.G.A	5×10^{-11}	1×10^{-10}/hr
MØE1614AMJ	Aux. Feed. Supply Line A Ruptures Between V-76 and Main Supply Line A	5×10^{-11}	1×10^{-10}/hr
MØE1614BMJ	Aux. Feed. Supply Line A Ruptures Between FV-4214 and V-76	5×10^{-11}	1×10^{-10}/hr
MØJ1609AMJ	Feedwater Supply Line D Ruptures Between V-57 and S.G.D	5×10^{-11}	1×10^{-10}/hr
MØE1617AMJ	Aux. Feed Supply Line D Ruptures Between V-94 and Main Feed. Supply Line D	5×10^{-11}	1×10^{-10}/hr
MØJ1608AMJ	Feedwater Supply Line C Ruptures Between V-48 and S.G.C	5×10^{-11}	1×10^{-10}/hr
MØE1616AMJ	Aux. Feed. Supply Line C Ruptures Between V-38 and Main Feed. Supply Line C	5×10^{-11}	1×10^{-10}/hr
MØE1616BMJ	Aux. Feed Supply Line C Ruptures Between FV-4234 and V-88	5×10^{-11}	1×10^{-10}/hr

FAULT IDENTIFIERS FOR THE SEABROOK EMERGENCY FEED STATION

FAULT IDENTIFIER	DESCRIPTION	UNAVAILABILITY	FAILURE RATE
MØJ1607AMJ	Feedwater Supply Line B Ruptures Between V-39 and S.G.B	5×10^{-11}	1×10^{-10}/hr
MØE1615AMJ	Aux. Feed. Supply Line B Ruptures Between V-82 and Main Feed. Supply Line B	5×10^{-11}	1×10^{-10}/hr
MØE1615BMJ	Aux. Feed. Supply Line B Ruptures Between V-4224 and V-82	5×10^{-11}	1×10^{-10}/hr
MØE1609BMJ	Feedwater Supply Line D Ruptures Between V-56 and V-57	5×10^{-11}	1×10^{-10}/hr
MØJ1608BMJ	Feedwater Supply Line C Ruptures Between V-47 and V-48	5×10^{-11}	1×10^{-10}/hr
MØJ1607BMJ	Feedwater Supply Line B Ruptures Between V-38 and V-39	5×10^{-11}	1×10^{-10}/hr
MØE1614CMJ	Aux. Feed Supply Line A Ruptures Between V-75 and FV-4214	5×10^{-11}	1×10^{-10}/hr
MØE1614DMJ	Aux. Feed. Supply Line A Ruptures Between V-75 and Aux. Feed Supply Header	5×10^{-11}	1×10^{-10}/hr
MØG1613AMJ	Aux. Feed Supply Header Ruptures Between V-125 and Reducer	5×10^{-11}	1×10^{-10}/hr
MØF1610AMJ	Aux. Feed Pump P-37A Discharge Piping Ruptures Between V-65 and Supply Header	5×10^{-11}	1×10^{-10}/hr
MØF1606AMJ	Feedwater Recirc. Line A Ruptures Between Aux. Feed. Supply A and V-152	5×10^{-11}	1×10^{-10}/hr
MØF1632AMJ	Startup Feed Pump Discharge Line Ruptures Between V-156 and Aux. Feed. Supply Header	5×10^{-11}	1×10^{-10}/hr
MØE1606BMJ	Feedwater Recirc. Line A Ruptures Between V-152 and Main Feed Supply Line A	5×10^{-11}	1×10^{-10}/hr
MØJ1606CMJ	Feedwater Supply Line A Ruptures Between FCV-510 and V-29	5×10^{-11}	1×10^{-10}/hr
MØE1617CMJ	Aux. Feed Supply Line D Ruptures Between V-87 and FV-4224	5×10^{-11}	1×10^{-10}/hr
MØE1617DMJ	Aux. Feed Supply Line D Ruptures Between V-87 and Aux. Feed Supply Header	5×10^{-11}	1×10^{-10}/hr
MØG1613BMJ	Aux. Feed. Supply Header Ruptures Between V-87 and V-126	5×10^{-11}	1×10^{-10}/hr

TABLE B.2 (Continued)

FAULT IDENTIFIERS FOR THE SEABROOK EMERGENCY FEED STATION

FAULT IDENTIFIER	DESCRIPTION	UNAVAILABILITY	FAILURE RATE
MØE1609AMJ	Feedwater Recirc. Line D Ruptures Between Aux. Feed. Supply Line D and V-153	5×10^{-11}	1×10^{-10}/hr
MB1609BMJ	Feedwater Recirc. Line D Ruptures Between V-153 and Main Feedwater Supply Line D	5×10^{-11}	1×10^{-10}/hr
MØJ1609CMJ	Feedwater Supply Line D Ruptures Between FCV-540 and V-56	5×10^{-11}	1×10^{-10}/hr
MØE1616CMJ	Aux. Feed. Supply Line C Ruptures Between V-93 and FV-5234	5×10^{-11}	1×10^{-10}/hr
MØE1616DMJ	Aux. Feed Supply Line C Ruptures Between V-93 and Aux. Feed. Supply Header	5×10^{-11}	1×10^{-10}/hr
MØG1613CMJ	Aux. Feed Supply Header Ruptures Between V-126 and V-127	5×10^{-11}	1×10^{-10}/hr
MØE1608AMJ	Feedwater Recirc. Line C Ruptures Between Aux. Feed. Supply Line C and V-154	5×10^{-11}	1×10^{-10}/hr
MØE1608BMJ	Feedwater Recir. Line C Ruptures Between V-154 and Main Feedwater Supply Line C	5×10^{-11}	1×10^{-10}/hr
MØJ1608CMJ	Feedwater Supply Line C Ruptures Between FCV-530 and V-47	5×10^{-11}	1×10^{-10}/hr
MØE1615CMJ	Aux. Feed Supply Line B Ruptures Between V-81 and FV-4224	5×10^{-11}	1×10^{-10}/hr
MØE1615DMJ	Aux. Feed Supply Line B Ruptures Between V-81 and Aux. Feed Supply Header	5×10^{-11}	1×10^{-10}/hr
MØG1613DMJ	Aux. Feed Supply Header Ruptures Between V-127 and Reducer	5×10^{-11}	1×10^{-10}/hr
MØF1612AMJ	Feed. Pump P-37B Discharge Line Ruptures Between V-71 & Reducer	5×10^{-11}	1×10^{-10}/hr
MØE1607AMJ	Feedwater Recirc. Line B Ruptures Between Aux. Feed Supply Line B and V-155	5×10^{-11}	1×10^{-10}/hr
MØE1607BMJ	Feedwater Recirc. Line B Ruptures Between V-155 and Main Feedwater Supply Line B	5×10^{-11}	1×10^{-10}/hr
MØJ1607CMJ	Feedwater Supply Line B Ruptures Between FCV-520 and V-38	5×10^{-11}	1×10^{-10}/hr
MØF1610BMJ	Feed. Pump P-37A Discharge Line Ruptures Between V-64 and V-65	5×10^{-11}	1×10^{-10}/hr

FAULT IDENTIFIERS FOR THE SEABROOK EMERGENCY FEED STATION

FAULT IDENTIFIER	DESCRIPTION	UNAVAILABILITY	FAILURE RATE
MØF1612BMJ	Feed Pump P-37B Discharge Line Ruptures Between V-70 and V-71	5×10^{-11}	1×10^{-10}/hr
MØF1612CMJ	Feed Pump P-37A Discharge Line Ruptures Between P-37A and V-64	5×10^{-11}	1×10^{-10}/hr
MØD1610AMJ	Feed Pump P37A Recirc. Line Ruptures Between V-67 and Pump Discharge Line	5×10^{-10}	1×10^{-9}/hr
QØE1449AMJ	Turbine Steam Supply Line Ruptures Between V-95 and V-129	5×10^{-11}	1×10^{-10}/hr
QØE1449BMJ	Turbine Steam Supply Line Ruptures Between V-129 and Turbine	5×10^{-11}	1×10^{-10}/hr
QØF1449AMJ	Turbine Steam Supply Line Ruptures Between Tee and V95	5×10^{-11}	1×10^{-10}/hr
QØF1109AMJ	Steam Supply Line B Ruptures Between Reducer and Turbine Inlet Line Tee	5×10^{-11}	1×10^{-10}/hr
QØF1009AMJ	Steam Supply Line A Ruptures Between Reducer and Turbine Inlet Line Tee	5×10^{-11}	1×10^{-10}/hr
QØE1143AMJ	Steam Supply Line B Ruptures Between V-128 and V-96	5×10^{-11}	1×10^{-10}/hr
QØE1043AMJ	Steam Supply Line A Ruptures Between V-127 and V-94	5×10^{-11}	1×10^{-10}/hr
QØE1043BMJ	Steam Supply Line A Ruptures Between V-94 and Reducer	5×10^{-11}	1×10^{-10}/hr
QØA1036AMJ	Steam Bypass Exit Line Ruptures Between V-171 and Steam Supply Line A	5×10^{-10}	1×10^{-9}/hr
QØE1042AMJ	Steam Supply Line A Ruptures Between Reducer and V-127	5×10^{-11}	1×10^{-10}/hr
QØA1035AMJ	Steam Bypass Inlet Line Ruptures Between Steam Supply Line A and V-171	5×10^{-10}	1×10^{-9}/hr
QØF1008AMJ	Steam Supply Line A Ruptures Between Main Steam Line A and Reducer	5×10^{-11}	1×10^{-10}/hr
QØK1SL1AMJ	Main Steam Line A Ruptures	5×10^{-11}	1×10^{-10}/hr
QØF1143BMJ	Steam Supply Line B Ruptures Between V-96 and Reducer	5×10^{-11}	1×10^{-10}/hr

TABLE B.2 (Continued)

FAULT IDENTIFIERS FOR THE SEABROOK EMERGENCY FEED STATION

FAULT IDENTIFIER	DESCRIPTION	UNAVAILABILITY	FAILURE RATE
QØA1136AMJ	Steam Bypass Exit Line Ruptures Between V-172 and Steam Supply Line B	5×10^{-10}	1×10^{-9}/hr
QØE1142AMJ	Steam Supply Line B Ruptures Between Reducer and V-128	5×10^{-11}	1×10^{-10}/hr
QØA1135AMJ	Steam Bypass Inlet Line Ruptures Between V-172 and Steam Supply Line B	5×10^{-10}	1×10^{-9}/hr
QØF1108AMJ	Steam Supply Line B Ruptures Between Main Steam Line B and Reducer	5×10^{-11}	1×10^{-10}/hr
QØK1SL1BMJ	Main Steam Line B Ruptures	5×10^{-11}	1×10^{-10}/hr
FØG1081AMJ	Feed Pump P-37A Suction Line Ruptures Between V-15 and Pump Inlet	5×10^{-11}	1×10^{-10}/hr
FØG1081BMJ	Feed Pump P-37A Suction Line Ruptures Between V-154 and V-155	5×10^{-11}	1×10^{-10}/hr
FØG1081CMJ	Feed Pump P-37A Suction Line Ruptures Between Condensate Tank and V-154	5×10^{-11}	1×10^{-10}/hr
MØE1612CMJ	Feed PumpP-37B Discharge Line Ruptures Between P-37B and V-70	5×10^{-11}	1×10^{-10}/hr
MØD1612AMJ	Feed Pump P-37B Recirc. Line Ruptures Between V-73 and Pump Discharge Line	5×10^{-11}	1×10^{-9}/hr
FØG1082AMJ	Feed Pump P-37B Suction Line Ruptures Between V-159 and Pump Inlet	5×10^{-11}	1×10^{-10}/hr
FØG1082BMJ	Feed Pump P-37B Suction Line Ruptures Between V-158 and V-159	5×10^{-11}	1×10^{-10}/hr
FØG1082CMJ	Feed Pump P-37B Suction Line Ruptures Between Condensate Tank and V-158	5×10^{-11}	1×10^{-10}/hr
MPB1T37AME	Turbine Driven Feed Pump-37A Fails To Start	8.4×10^{-3}	8.4×10^{-3}/d
MPB1D37BME	Motor Driven Feed Pump P-37B Fails To Start	2.4×10^{-3}	2.4×10^{-3}/d
MPB1T37AØØ	Turbine Driven Feed P-37A Out of Service	4.2×10^{-4}	
MPB1D37BØØ	Motor Driven Feed Pump P-37B Out Of Service	9.4×10^{-4}	

TABLE B.2 (Continued)

FAULT IDENTIFIERS FOR THE SEABROOK EMERGENCY FEED STATION

FAULT IDENTIFIER	DESCRIPTION	UNAVAILABILITY	FAILURE RATE
MVD14214ØØ	Flow Control Valve FV-4214 Out of Service	8.5×10^{-4}	
MVD1V75AØØ	Valve Out of Service	8.5×10^{-4}	
MVD14224ØØ	Flow Control Valve FV-4244 Out of Service	8.5×10^{-4}	
MVD1V87DØØ	Valve V-87 Out of Service	8.5×10^{-4}	
MVD14234ØØ	Flow Control Valve FV-4234 Out of Service	8.5×10^{-4}	
MVD1V93CØØ	Valve V-93 Out of Service	8.5×10^{-4}	
MVD14224ØØ	Flow Control Valve FV-4224 Out of Service	8.5×10^{-4}	
MVD1V81BØØ	Valve V-81 Out of Service	8.5×10^{-4}	
MVD1V65AØØ	Isolation Valve V-65 Out of Service	2.0×10^{-3}	
QVD1V129ØØ	Steam Supply Valve V-129 Out of Service	1.0×10^{-4}	
QMV1V95AØØ	Manual Valve V-95 Out of Service	0.0	
QVX1V127ØØ	Steam Supply Valve V-127 Out of Service	8.7×10^{-4}	
QVX1V128ØØ	Steam Supply Valve V-128 Out of Service	8.7×10^{-4}	
FVM1V155ØØ	P-37A Suction Valve V-155 Out of Service	0.0	
FVM1V154ØØ	P-37A Suction Valve V-154 Out of Service	0.0	
MVD1V125ØØ	Isolation Valve V-125 Out of Service	0.0	
MVD1V126ØØ	Isolation Valve V-126 Out of Service	0.0	

TABLE B.2 (Continued)

FAULT IDENTIFIERS FOR THE SEABROOK EMERGENCY FEED STATION

FAULT IDENTIFIER	DESCRIPTION	UNAVAILABILITY	FAILURE RATE
MVD1V127ØØ	Isolation Valve V-127 Out of Service	0.0	
MVD1V71BØØ	Isolation Valve V-71 Out of Service	2.0×10^{-3}	
FVM1V159ØØ	P-37B Suction Valve V-159 Out of Service	0.0	
FVM1V158ØØ	P-37B Suction Valve V-158 Out of Service	0.0	
QVX1V127ØA	Operator Fails to Open Steam Supply Valve V-127	5×10^{-3}	5×10^{-3}/d
QVX1V128ØA	Operator Fails to Open Steam Supply Valve V-128	5×10^{-3}	5×10^{-3}/d
MVD1V3ØAØB	Operator Fails to Close Feedwater Supply Line A Isolation Valve V-30	5×10^{-3}	5×10^{-3}/d
MVD14224ØB..	Operator Fails to Close Flow Control Valve FV-4224	5×10^{-3}	5×10^{-3}/d
MVD14224ØB	Operator Fails to Close Flow Control Valve FV-4234	5×10^{-3}	5×10^{-3}/d
MVD14244ØB	Operator Fails to Close Flow Control Valve FV-4244	5×10^{-3}	5×10^{-3}/d
MVD1V57DØB	Operator Fails to Close Feedwater Supply Line D isolation Valve V-57	5×10^{-3}	5×10^{-3}/d
MVD14214ØB	Operator Fails to Close Flow Control Valve FV-4214	5×10^{-3}	5×10^{-3}/d
MDV1V48CØB	Operator Fails to Close Feedwater Supply Line C Isolation Valve V-48	5×10^{-3}	5×10^{-3}/d
MVD1B39BØB	Operator Fails to Close Feedwater Supply Line B Isolation Valve V-39	5×10^{-3}	5×10^{-3}/d
MVD1V51ØØB	Operator Fails to Close Feedwater Flow Control Valve FCV-510	5×10^{-3}	5×10^{-3}/d
MVD1V125ØB	Operator Fails to Close Supply Header Isolation Valve V-125	.9	.9
MVD1V54ØØB	Operator Fails to Close Feedwater Flow Control Valve FCV-540	5×10^{-3}	5×10^{-3}/d

TABLE B.2 (Continued)

FAULT IDENTIFIERS FOR THE SEABROOK EMERGENCY FEED STATION

FAULT IDENTIFIER	DESCRIPTION	UNAVAILABILITY	FAILURE RATE
MVD1V126ØB	Operator Fails to Close Supply Header Isolation Valve V-126	.9	.9
MVD1V530ØB	Operator Fails to Close Feedwater Flow Control Valve FCV-530	5×10^{-3}	5×10^{-3}/d
MDV1V127ØB	Operator Fails to Close Supply Header Isolation Valve V-127	.9	.9
MVD1V520ØB	Operator Fails to Close Feedwater Flow Control Valve FCV-520	5×10^{-3}	5×10^{-3}/d
MVD1V65AØB	Operator Fails to Close P-37B Discharge Isolation Valve V-65	.9	.9
MVD1V71BØB	Operator Fails to Close P-37B Discharge Isolation Valve V-71	.9	.9
MVM1V152ØC	Operator Fails to Restore Manual Valve V-152	1×10^{-3}	1×10^{-3}/d
MVM1V153ØC	Operator Fails to Restore Manual Valve V-153	1×10^{-3}	1×10^{-3}/d
MVM1V154ØC	Operator Fails to Restore Manual Valve V-154	1×10^{-3}	2×10^{-3}/d
MVM1V155ØC	Operator Fails to Restore Manual Valve V-155	1×10^{-3}	1×10^{-3}/d
6IC1AFSAØC	Operator Defeats Train A"S" Signal	1×10^{-4}	1×10^{-4}/d
6IC1AFSBØC	Operator Defeats Train B"S" Signal	1×10^{-4}	1×10^{-4}/d
MVD142140D	Operator Inadvertently Closes Flow Control Valve FV-4214	1×10^{-4}	1×10^{-4}/d
MVD1V75AØD	Operator Inadvertently Closes Valve V-75	1×10^{-4}	1×10^{-4}/d
MVM142440D	Operator Inadvertently Closes Flow Control Valve FV-4244	1×10^{-4}	1×10^{-4}/d
MVD1V87DØD	Operator Inadvertently Closes Valve V-87	1×10^{-4}	1×10^{-4}/d
MVD142340D	Operator Inadvertently Closes Flow Control Valve FV-4234	1×10^{-4}	1×10^{-4}/d

TABLE B.2 (Continued)

FAULT IDENTIFIERS FOR THE SEABROOK EMERGENCY FEED STATION

FAULT IDENTIFIER	DESCRIPTION	UNAVAILABILITY	FAILURE RATE
MVD1V93CØD	Operator Inadvertently Closes Valve V-93	1×10^{-4}	1×10^{-4}/d
MVD142240D	Operator Inadvertently Closes Flow Control Valve FV-4224	1×10^{-4}	1×10^{-4}/d
MVD1V81BØD	Operator Inadvertently Closes Valve V-81	1×10^{-4}	1×10^{-4}/d
MVM1V65AØD	Operator Fails to Restore P-37A Isolation Valve V-65	1×10^{-4}	1×10^{-4}/d
QVD1V95AØD	Operator Fails to Restore Manual Valve V-95	1×10^{-3}	1×10^{-3}/d
FMV1V155ØD	Operator Fails to Restore P-37A Suction Valve V-155	1×10^{-3}	1×10^{-3}/d
FVM1V154ØD	Operator Fails to Restore P-27A Suction Valve V-154	1×10^{-3}	1×10^{-3}/d
MVD1V125ØD	Operator Fails to Restore Supply Header Valve V-125	1×10^{-3}	1×10^{-3}/d
MVD1V125ØD	Operator Fails to Restore Supply Header Valve V-126	1×10^{-3}	1×10^{-3}/d
MVD1V127ØD	Operator Fails to Restore Supply Header Valve V-127	1×10^{-3}	1×10^{-3}/d
MVD1V71BØD	Operator Fails to Restore P-37B Discharge Isolation Valve V-71	1×10^{-4}	1×10^{-4}/d
FVM1V159ØD	Operator Fails to Restore P-37B Suction Valve V-159	1×10^{-3}	1×10^{-3}/d
FVM1V158ØD	Operator Fails to Restore P-37B Suction Valve V-158	1×10^{-3}	1×10^{-3}/d
MPB1D37BØE	Operator Fails to Start Motor Driven Pump P-37B	1×10^{-3}	1×10^{-3}/d
MPB1T37AØG	Operator Turns Off Turbine Driven Pump P-37A	1×10^{-4}	1×10^{-4}/d
MPB1D37BØG	Operator Turns Off Motor Driven Pump P-37B	1×10^{-4}	1×10^{-4}/d
MCA2D37BMK	Circuit Breaker to Motor Driven Pump P-37B Open	1.5×10^{-6}	4.2×10^{-9}/hr

TABLE B.2 (Continued)

FAULT IDENTIFIERS FOR THE SEABROOK EMERGENCY FEED STATION

FAULT IDENTIFIER	DESCRIPTION	UNAVAILABILITY	FAILURE RATE
QRA2V127MK	Control Circuit to Steam Supply Valve V-127 Open	6.5×10^{-4}	9.1×10^{-7}/hr
QRA1V128MK	Control Circuit to Steam Supply Valve V-128 Open	6.5×10^{-4}	9.1×10^{-7}/hr
MRA1A37BMK	Train A Control Circuit to Motor Pump P-37B Open	5.9×10^{-3}	9.1×10^{-7}/hr
MRA1B37BMK	Train B Control Circuit to Motor Pump P-37B Open	5.9×10^{-3}	9.1×10^{-7}/hr
MCE1V510MK	Flow Control Valve FCV-510 Flow Control Switch Open	1.5×10^{-8}	3×10^{-8}/hr
MCE1V540MK	Flow Control Valve FCV-540 Flow Control Switch Open	1.5×10^{-8}	3×10^{-8}/hr
MCE1V530MK	Flow Control Valve FCV-530 Flow Control Switch Open	1.5×10^{-8}	3×10^{-8}/hr
MCE1V520MK	Flow Control Valve FCV-520 Flow Control Switch Open	1.5×10^{-8}	3×10^{-8}/hr
QCE1V127MK	Steam Supply Valve V-127 Switch Open	2.2×10^{-5}	3×10^{-8}/hr
MCE1D37BMK	P-37B Motor Controller Circuit Open	3.3×10^{-4}	9.1×10^{-7}/hr
MCK1D37BMK	P-37B Motor Starter Circuit Open	1.2×10^{-3}	1.2×10^{-3}/d
MPB1T37ALB	Turbine Driven Feed Pump P-37A Lubrication Failure	0.0	
MPB1D37BLB	Motor Driven Feed Pump P-37B Lubrication Failure	0.0	
LOSP	Loss of Station Power	7×10^{-6}	1.4×10^{-5}/hr
5TA1TK25MJ	Condensate Storage Tank Ruptured	5×10^{-11}	1×10^{-10}/hr
6IC1FWIAMN	No Train A Feedwater Isolation Signal	5.8×10^{-3}	5.8×10^{-3}/d
MIF14224MN	No Signal From FE-4224 to Flow Control Valve FV-4224	2.0×10^{-3}	3.1×10^{-7}/hr

TABLE B.2 (Continued)

FAULT IDENTIFIERS FOR THE SEABROOK EMERGENCY FEED STATION

FAULT IDENTIFIER	DESCRIPTION	UNAVAILABILITY	FAILURE RATE
MIF14234MN	No Signal From FE-4234 to Flow Control Valve FV-4234	2.0×10^{-3}	3.1×10^{-7}/hr
MIF14244MN	No Signal From FE-4224 to Flow Control Valve FV-4244	2.0×10^{-3}	3.1×10^{-7}/hr
MIF14214MN	No Signal From FE-4214 to Flow Control Valve FV-4214	2.0×10^{-3}	3.1×10^{-7}/hr
6IC1FWBMN	No Train B Feedwater Isolation Signal	5.8×10^{-3}	5.8×10^{-3}/d
MIF1V510MN	No Signal From FE-510 to Flow Control Valve FCV-510	1.5×10^{-7}	3.1×10^{-7}/hr
MIF1V540MN	No Signal From FE-540 to Flow Control Valve FCV-540	1.5×10^{-7}	3.1×10^{-7}/hr
MIF1V530MN	No Signal From FE-530 to Flow Control Valve FCV-530	1.5×10^{-7}	3.1×10^{-7}/hr
MIF1V520MN	No Signal From FE-520 to Flow Control Valve FCV-520	1.5×10^{-7}	3.1×10^{-7}/hr
6IC1AFSAMN	No Signal From Safety Injection Signal Train A	5.8×10^{-3}	5.8×10^{-3}/d
6IC1AFSBNM	No Signal From Safety Injection Signal Train B	5.8×10^{-3}	5.8×10^{-3}/d
MVD14214MØ	Spurious Signal to Flow Control Valve FV-4214	1.2×10^{-8}	1.2×10^{-8}/d
MVD14244MØ	Spurious Signal to Flow Control Valve FV-4244	1.2×10^{-8}	1.2×10^{-8}/d
MVD14234MØ	Spurious Signal to Flow Control Valve FV-4234	1.2×10^{-8}	1.2×10^{-8}/d
MVD14224MØ	Spurious Signal to Flow Control Valve FV-4224	1.2×10^{-8}	1.2×10^{-8}/d
REC11B--MJ	125 DC Bus 11B Shorts to Ground	3.5×10^{-8}	7×10^{-8}/hr
REC1E612MJ	460 V AC Bus E612 Shorts to Ground	3.5×10^{-8}	7×19^{-3}/hr
REC1E61-MJ	480 V AC Bus E61 Shorts to Ground	3.5×10^{-8}	7×10^{-8}/hr

TABLE B.2

FAULT IDENTIFIERS FOR THE SEABROOK EMERGENCY FEED STATION

FAULT IDENTIFIER	DESCRIPTION	UNAVAILABILITY	FAILURE RATE
RCA1A74-MB	Diesel Generator DG-1B Circuit Breaker A74 Fails to Close	1×10^{-3}	1×10^{-3}/d
RCA1DN6-MB	Crossover Circuit Breaker DN6 Fails to Close	1×10^{-3}	1×10^{-3}/d
RCA2A61--MC	Circuit Breaker A61 Open	2.1×10^{-9}	4.2×10^{-9}/hr
RCA1A62--MF	Circuit Breaker A62 Fails to Close	1×10^{-3}	1×10^{-3}/d
RCA1DN4-MC	Circuit Breaker DN4 Open	2.1×10^{-9}	4.2×10^{-9}/hr
RCA1DN5-MC	Circuit Breaker DN5 Open	2.1×10^{-9}	4.2×10^{-9}/hr
RCA1DA1-MC	Circuit Breaker DA1 Open	2.1×10^{-9}	4.2×10^{-9}/hr
RCA1AD6-MC	Circuit Breaker AD6 Open	2.1×10^{-9}	4.2×10^{-9}/hr
RCA1AD2-MC	Circuit Breaker AD2 Open	2.1×10^{-9}	4.2×10^{-9}/hr
RCA1A41-MC	Circuit Breaker A41 Open	2.1×10^{-9}	4.2×10^{-9}/hr
RCA1A41-MJ	Circuit Breaker A41 Shorts to Ground	3.5×10^{-8}	7×10^{-8}/hr
RCA1A42-MB	Circuit Breaker A42 Fails to Close	1×10^{-3}	1×10^{-3}/d
RCA1A42-MJ	Circuit Breaker A42 Shorts to Ground	3.5×10^{-8}	7×10^{-8}/hr
RCA1A61-MJ	Circuit Breaker A61 Shorts to Ground	3.5×10^{-8}	7×10^{-8}/hr
RCA1A62-MJ	Circuit Breaker A62 Shorts to Ground	3.5×10^{-8}	7×10^{-8}/hr
RCA1DN5-MJ	Circuit Breaker DN5 Shorts to Ground	3.5×10^{-8}	7×19^{-8}/hr
RCA1DA1-MJ	Circuit Breaker DA1 Shorts to Ground	3.5×10^{-8}	7×10^{-8}/hr

TABLE B.2 (Continued)

FAULT IDENTIFIERS FOR THE SEABROOK EMERGENCY FEED STATION

FAULT IDENTIFIER	DESCRIPTION	UNAVAILABILITY	FAILURE RATE
RCA1AD6--MJ	Circuit Breaker AD6 Shorts to Ground	3.5×10^{-8}	7×10^{-8}/hr
RCA1AD2-MJ	Circuit Breaker AS2 Shorts to Ground	3.5×10^{-8}	7×10^{-8}/hr
RCA1A75-MJ	Circuit Breaker A75 Shorts to Ground	3.5×10^{-8}	7×10^{-8}/hr
RBC11B--MC	Battery Charger 1B Opens	2.1×10^{-9}	4.2×10^{-9}/hr
RBC11B--MJ	Battery Charger 1B Shorts to Ground	3.5×10^{-8}	7×10^{-8}/hr
RBA11B--MJ	Battery 1B Shorts to Ground	3.5×10^{-8}	7×10^{-8}/hr
RBA11D--MJ	Battery 1D Shorts to Ground	3.6×10^{-8}	7×10^{-8}/hr
RBA11B--MM	Battery 1B Undercharged	1.3×10^{-6}	3×10^{-6}/hr
RBA11D--MM	Battery 1D Undercharged	1.5×10^{-6}	3×10^{-6}/hr
RTR1X-5CMC	Transformer X-5c Open	5×10^{-7}	1×10^{-6}/hr
RTR1X-2BMJ	Transformer S-2B Shorts	5×10^{-7}	1×10^{-6}/hr
RTR1X-2BMC	Transformer S-2B Opens	5×10^{-7}	1×10^{-6}/hr
RTR1X-5CMJ	Transformer X-5C Shorts	5×10^{-7}	1×10^{-6}/hr
RTR1X-3BMC	Transformer X-3B Opens	5×10^{-7}	1×10^{-6}/hr
RTR1X-3BMJ	Transformer X-3B Shorts	5×10^{-7}	1×10^{-6}/hr
RGD11B--ME	Diesel Generator DG-1B Fails to Start	1.0×10^{-2}	1.0×10^{-2}/d
RGD11B--MG	Diesel Generator DG-1B Fails to Run	3.0×10^{-3}	6.0×10^{-3}/hr

TABLE B.2 (Continued)

FAULT IDENTIFIERS FOR THE SEABROOK EMERGENCY FEED STATION

FAULT IDENTIFIER	DESCRIPTION	UNAVAILABILITY	FAILURE RATE
RGD11B--ØØ	Diesel Generator DG-1B Out of Service	7×10^{-4}	
RGD11A--ØØ	Diesel Generator DG-1A Out of Service	7×10^{-4}	
MHX1TBRAMJ	S.G.A Steam Line Rupture	5×10^{-11}	1×10^{-10}/hr
MHX1SHRAMJ	S.G.S Shell Rupture	5×10^{-11}	1×10^{-10}/hr
MHX1TBRDMJ	S.G.D Steam Line Rupture	5×10^{-11}	1×10^{-10}/hr
MHX1SHRDMJ	S.G.D Shell Rupture	5×10^{-11}	1×10^{-10}/hr
MHX1TBRCMJ	S.G.C Steam Line Rupture	5×10^{-11}	1×10^{-10}/hr
MHX1SHRCMJ	S.G.C Shell Rupture	5×10^{-11}	1×10^{-10}/hr
MHX1TBRBMJ	S.G.B Steam Line Rupture	5×10^{-11}	1×10^{-10}/hr
MHX1SHRBMJ	S.G.B Shell Rupture	5×10^{-11}	1×10^{-10}/hr
MPB1T37ACL	Turbine Driven Feed Pump P-37A Cooling Loss	0.0	
MPB1D37BCL	Motor Driven Feed Pump P-37B Cooling Loss	0.0	
MTU1TD-2ME	Turbine Fails to Start	0.0	
QRA1C127MA	Control Relay on Solenoid Valve to Steam Supply Valve V-127 Fails to Open	3.1×10^{-6}	3.1×10^{-6}/d
QRA1V128MA	Control Relay on Solenoid Valve to Steam Supply Valve V-128 Fails to Open	3.1×10^{-6}	3.1×10^{-6}/d
QVL1V127MA	Solenoid Valve on Steam Valve to Steam Supply Valve V-128 Fails to Open	1.4×10^{-6}	1.4×10^{-6}/d
QLV1V128MA	Solenoid Valve on Steam Supply Valve V-128 Fails to Open	1.4×10^{-6}	$1,4 \times 10^{-6}$/d

TABLE B.2 (Continued)

FAULT IDENTIFIERS FOR THE SEABROOK EMERGENCY FEED STATION

FAULT IDENTIFIER	DESCRIPTION	UNAVAILABILITY	FAILURE RATE
QVB1V06AMC	Safety Valve V-6 on Steam Line A Opens	5×10^{-6}	1×10^{-5}/hr
QVB1V07AMC	Safety Valve V-7 on Steam Line A Opens	5×10^{-6}	1×10^{-5}/hr
QVB1V10AMC	Safety Valve V-10 on Steam Line A Opens	5×10^{-6}	1×10^{-5}/hr
QVB1V08AMC	Safety Valve V-8 on Steam Line A Opens	5×10^{-6}	1×10^{-5}/hr
QVB1V09AMC	Safety Valve V-9 on Steam Line A Opens	5×10^{-6}	1×10^{-5}/hr
QVB1SGARMC	Relief Valve on Main Steam Line A Opens	5×10^{-6}	1×10^{-5}/hr
QVB1V50DMC	Safety Valve V-50 on Steam Line D Opens	5×10^{-6}	1×10^{-5}/hr
QVB1V51DMC	Safety Valve V-51 on Steam Line D Opens	5×10^{-6}	1×10^{-5}/hr
QVB1V52DMC	Safety Valve V-52 on Steam Line D Opens	5×10^{-6}	1×10^{-5}/hr
QVB1V53DMC	Safety Valve V-53 on Steam Line D Opens	5×10^{-6}	1×10^{-5}/hr
QVB1V54DMC	Safety Valve V-54 on Steam Line D Opens	5×10^{-6}	1×10^{-5}/hr
QVB1SGDRMC	Relief Valve on Main Steam Line D Opens	5×10^{-6}	1×10^{-5}/hr
QVB1V36CMC	Safety Valve V-36 on Steam Line C Opens	5×10^{-6}	1×10^{-5}/hr
QVB1V37CMC	Safety Valve V-37 on Steam Line C Opens	5×10^{-6}	1×10^{-5}/hr
QVB1V38CMC	Safety Valve V-38 on Steam Line C Opens	5×10^{-6}	1×10^{-5}/hr
QVB1V39CMC	Safety Valve V-39 on Steam Line C Opens	5×10^{-6}	1×10^{-5}/hr
QVB1V4ØCMC	Safety Valve V-40 on Steam Line C Opens	5×10^{-6}	1×10^{-5}/hr

TABLE B.2 (Continued)

FAULT IDENTIFIERS FOR THE SEABROOK EMERGENCY FEED STATION

FAULT IDENTIFIER	DESCRIPTION	UNAVAILABILITY	FAILURE RATE
QVB1SGCRMC	Relief Valve on Main Steam Line C Opens	5×10^{-6}	1×10^{-5}/hr
QVB1V22BMC	Safety Valve V-22 on Steam Line B Opens	5×10^{-6}	1×10^{-5}/hr
QVB1V23BMC	Safety Valve V-23 on Steam Line B Opens	5×10^{-6}	1×10^{-5}/hr
QVB1V24BMC	Safety Valve V-24 on Steam Line B Opens	5×10^{-6}	1×10^{-5}/hr
QVB1V25BMC	Safety Valve V-25 on Steam Line B Opens	5×10^{-6}	1×10^{-6}/hr
QVB1V26BMC	Safety Valve V-26 on Steam Line B Opens	5×10^{-6}	1×10^{-6}/hr
QVB1SGBRMC	Relief Valve on Main Steam Line B Opens	5×10^{-6}	1×10^{-5}/hr
ØEC1SGARMM	Loss of Voltage on S.G.A Relief Valve Controller	7×17^{-7}	1.4×10^{-6}/hr
ØEC1SGBRMM	Loss of Voltage onS.G.B Relief Valve Controller	7×10^{-7}	1.4×10^{-6}/hr
ØEC1SGCRMM	Loss of Voltage on S.G.A Relief Valve Controller	7×10^{-7}	1.4×10^{-6}/hr
ØEC1SGDRMM	Loss of Voltage of S.G.D Relief Valve Controller	7×10^{-7}	1.4×10^{-6}/hr
MVD1V87ØØB	Operator Fails to Close V-87	5×10^{-3}	5×10^{-3}/d
MVD1V93CØB	Operator Fails to Close V-93	5×10^{-3}	5×10^{-3}/d
MVD1V81BØB	Operator Fails to Close V-81	5×10^{-3}	5×10^{-3}/d
MVD1V75AØB	Operator Fails to Close V-75	5×10^{-3}	5×10^{-3}/d
MVD1V87DMB	Valve V-87 Does Not Close	2×10^{-3}	2×10^{-3}/d
MVD1V93CMB	Valve V-93 Does Not Close	2×10^{-3}	2×10^{-3}/d

TABLE B.2 (Continued)

FAULT IDENTIFIERS FOR THE SEABROOK EMERGENCY FEED STATION

FAULT IDENTIFIER	DESCRIPTION	UNAVAILABILITY	FAILURE RATE
MVD1V81BMB	Valve V-81 Does Not Close	2×10^{-3}	2×10^{-3}/d
MVD1V75AMB	Valve V-75 Does Not Close	2×10^{-3}	2×10^{-3}/d
MVD1V87DMC	Valve V-87 Fails to Remain Closed	6×10^{-8}	1.2×10^{-7}/hr
MVD1V93CMC	Valve V-93 Fails to Remain Closed	6×10^{-8}	1.2×10^{-7}/hr
MVD1V81BMC	Valve V-81 Fails to Remain Closed	6×10^{-8}	1.2×10^{-7}/hr
MVD1V75AMC	Valve V-75 Fails to Remain Closed	6×10^{-8}	1.2×10^{-7}/hr
MIF1V87DMN	Valve V-87 Fails to Receive Signal	2×10^{-3}	2×10^{-3}/d
MIF1V93CMN	Valve V-93 Fails to Receive Signal	2×10^{-3}	2×10^{-3}/d
MIF1V81BMN	Valve V-81 Fails to Receive Signal	2×10^{-3}	2×10^{-3}/d
MIF1V75AMN	Valve V-75 Fails to Receive Signal	2×10^{-3}	2×10^{-3}/d
MØF1618CMJ	Rupture of 6" Line Between V-99 and Tee	5×10^{-11}	1×10^{-10}/hr
MØF1618BMJ	Rupture of 6" Line Between V-163 and Tee	5×10^{-11}	1×10^{-10}/hr
MØF1618AMJ	Rupture of 6" Line Between V-163 and V-156	5×10^{-11}	1×10^{-10}/hr
MØF1618DMJ	Rupture of 6" Line Between P-113 and V-99	5×10^{-11}	1×10^{-10}/hr
MØE1631AMJ	Rupture of 4" Line Between Discharge Pipe and FW V-156	5×10^{-11}	1×10^{-10}/hr
MØE1631BMJ	Rupture of 4" Line Between Discharge Pipe and FW V-159	5×10^{-11}	1×10^{-10}/hr
MØE1631CMJ	Rupture of 4" Line Between Discharge Pipe and FW V-162	5×10^{-11}	1×10^{-10}/hr

TABLE B.2 (Continued)

FAULT IDENTIFIERS FOR THE SEABROOK EMERGENCY FEED STATION

FAULT IDENTIFIER	DESCRIPTION	UNAVAILABILITY	FAILURE RATE
MØD1625AMJ	Rupture of 6" Line Between Discharge Pipe and PCV-4326	5×10^{-11}	1×10^{-10}/hr
FØT1079AMJ	Rupture of 16" Condensate Line Between Tank and V-141	5×10^{-11}	1×10^{-10}/hr
FØK1080AMJ	Rupture of 24" Condensate Line Between V-143 and V-141	5×10^{-11}	1×10^{-10}/hr
FØK1080BMJ	Rupture of 24" Line Between Suction Line and V-142	5×10^{-11}	1×10^{-10}/hr
FØJ1080CMJ	Rupture of 20" Suction Line Between V-143 and Tee	5×10^{-11}	1×10^{-10}/hr
FØJ1080DMJ	Rupture of 20" Suction Line Between Tee and V-145	5×10^{-11}	1×10^{-10}/hr
FØG1080AMJ	Rupture of 8" Line Between Tee and V-340	5×10^{-11}	1×10^{-10}/hr
FØF1080BMJ	Rupture of 8" Line Between V-340 and V-152	5×10^{-11}	1×10^{-10}/hr
FØG1080CMJ	Rupture of 8" Line Between V-152 and P-113	5×10^{-11}	1×10^{-10}/hr
MVA1V99AMJ	Rupture of V-99	5×10^{-9}	1×10^{-8}/hr
MVP1V163MJ	Rupture of V-163	5×10^{-9}	1×10^{-8}/hr
MVM1V156MJ	Rupture of FWV-156	1×10^{-8}	2×10^{-8}/hr
MVM1V159MJ	Rupture of FWV-159	1×10^{-8}	2×10^{-8}/hr
FØF10900MJ	Rupture of Bypass Inlet Line Between Tee and V-341	5×10^{-10}	1×10^{-10}/hr
FVM1V152MJ	Rupture of V-152	1×10^{-8}	2×10^{-8}/hr
FVA1V340MJ	Rupture of V-340	5×10^{-9}	1×10^{-8}/hr
FVM1V142MJ	Rupture of V-142	1×10^{-8}	2×10^{-8}/hr

TABLE B.2 (Continued)

FAULT IDENTIFIERS FOR THE SEABROOK EMERGENCY FEED STATION

FAULT IDENTIFIER	DESCRIPTION	UNAVAILABILITY	FAILURE RATE
FVM1V341MJ	Rupture of V-341	1×10^{-8}	2×10^{-8}/hr
MVD14326MJ	Rupture of PCV-4326	5×10^{-8}	1×10^{-7}/hr
FVD1V145MJ	Rupture of V-145	5×10^{-9}	1×10^{-8}/hr
FVA1V343MJ	Rupture of V-343	5×10^{-9}	1×10^{-8}/hr
FØG1080EMJ	Rupture of Bypass Outlet Line Between V-341 and Tee	5×10^{-10}	1×10^{-10}/hr
FØG1090FMJ	Rupture of Bypass Outlet Line Between V-344 and Tee	5×10^{-10}	1×10^{-10}/hr
FØF1080GMJ	Rupture of 8" Line Between V-344 and V-343	5×10^{-10}	1×10^{-10}/hr
FMJ1V344MJ	Rupture of V-344	1×10^{-8}	2×10^{-8}/hr
MVM1V162MJ	Rupture of FWV-162	1×10^{-8}	2×10^{-8}/hr
FVD1V143MJ	Rupture of P-113 Suction Isolation Valve V-143	5×10^{-9}	1×10^{-8}/hr
FVD1V141MJ	Rupture of P-113 Suction Isolation Valve V-141	5×10^{-9}	1×10^{-8}/hr
MVA1V99-MA	Check Valve V-99 Fails to Open	2×10^{-4}	2×10^{-4}/d
FVM1V152MD	Manual Isolation Valve V-152 Fails to Remain Open (Plugs)	1×10^{-4}	1×10^{-4}/d
FVD1V143MD	Isolation Valve V-143 Fails to Remain Open	1×10^{-4}	1×10^{-4}/d
FVD1V141MD	Isolation Valve V-143 Fails to Remain Open	1×10^{-4}	1×10^{-4}/d
MVD1V163ØA	Operator Fails to Open V-163	1×10^{-2}	1×10^{-2}/d
MVD1V156ØA	Operator Fails to Open V-156	1×10^{-2}	1×10^{-2}/d

TABLE B.2 (Continued)

FAULT IDENTIFIERS FOR THE SEABROOK EMERGENCY FEED STATION

FAULT IDENTIFIER	DESCRIPTION	UNAVAILABILITY	FAILURE RATE
FVM1V152ØD	Operator Fails to Restore V-152	1×10^{-3}	1×10^{-3}/d
FVD1V143ØD	Operator Fails to Restore V-143	1×10^{-3}	1×10^{-3}/d
FVD1V141ØD	Operator Fails to Restore V-141	1×10^{-3}	1×10^{-3}/d
MPB1P113ØØ	P-113 Out of Service	4.2×10^{-4}	
MPB1P161ØØ	P-161 Out of Service	5×10^{-4}	
MPB1P113ME	P-113 Fails to Start	4×10^{-3}	4×10^{-3}/d
MPB1P161ME	P-161 Fails to Start	4×10^{-3}	4×10^{-3}/d
RCA1E42-MJ	Circuit Breaker 1E42 Shorts to Ground	3.5×10^{-8}	7×10^{-8}/hr
RCA1A93-ØB	Operator Fails to Close Circuit Breaker A-93	1×10^{-2}	1×10^{-2}/d
RCA1A93-MB	Circuit Breaker A-93 Fails to Close	1×10^{-3}	1×10^{-3}/d
RCA1A54-MB	Diesel Generator 1A Circuit Breaker A-54 Fails to Close	1×10^{-3}	1×10^{-3}/d
RGD1DG1AME	Diesel Generator A Fails to Start	1.0×10^{-2}	1.0×10^{-2}/d
RGD1DG1AMG	Diesel Generator 1 A Fails to Run	3.0×10^{-3}	6.0×10^{-3}/hr
6IC1FPSAMN	No Actuation Signal Generated	5.8×10^{-3}	5.8×10^{-3}/d
FVD1V143ØØ	Startup Feedpump Suction Isolation Valve V-143 Out of Service	1.2×10^{-4}	
FVD1V141ØØ	Startup Feedpump Suction Isolation Valve V-141 Out of Service	0.0	

TABLE B.3

NRC-SUPPLIED DATA USED FOR PURPOSES OF CONDUCTING A COMPARATIVE ASSESSMENT OF EXISTING AFWS DESIGNS AND 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.

TABLE B.3 (Cont'd)

II. Test and Maintenance Outage Contributions:

a. Calculational Approach

1. Test Outage

$$Q_{TEST} \simeq \frac{(\ \text{hrs/test})\ (\ \text{tests/year})}{\text{hrs/year}}$$

2. Maintenance Outage

$$Q_{MAINT.} \simeq \frac{(0.22)(\ \text{hrs/maint. act})}{720}$$

b. Data Tables for Test and Maint. Outages*

SUMMARY OF TEST ACT DURATION

Component	Range on Test Act Duration Time, hr	Calculated Mean Test Act Duration Time, t_D, hr
Pumps	0.25 - 4	1.4
Valves	0.25 - 2	0.86
Diesels	0.25 - 4	1.4
Instrumentation	0.25 - 4	1.4

LOG-NORMAL MODELED MAINTENANCE ACT DURATION

Component	Range on Maintenance Act Duration Time, hr	Calculated Mean Maintenance Act Duration Time, t_D, hr
Pumps	1/2 - 24	7
	1/2 - 72	19
Valves	1/2 - 24	7
Diesels	2 - 72	21
Instrumentation	1/4 - 24	6

* Note: These data tables were taken from the Reactor Safety Study (WASH-1400) for purposes of this AFW system assessment. Where the plant technical specifications placed limits on the outage duration(s) allowed for AFW system trains, this tech spec limit was used to estimate the mean duration times for maintenance. In general, it was found that the outages allowed for maintenance dominated those contributions to AFW system unavailability from outages due to testing.

TABLE B.3 (Cont'd)

III. Human 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 Est	Est. on Error Factor	Point Value Est	Est. on Error Factor	Point Value Estimate	Est On Error Factor
a. Acts & Errors of A Pre-Accident Nature						
1. Valves Mispositioned During Test/Maint						
(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	$\frac{1}{2} \times 10^{-2} \times \frac{1}{X}$	10	$10^{-2} \times \frac{1}{X}$	10
(b) Inadvertently Leaves Correct Valve in Wrong Position	5×10^{-4}	20	5×10^{-3}	10	10^{-2}	10
2. More than one valve is affected (coupled errors)	1×10^{-4}	20	1×10^{-3}	10	3×10^{-3}	10
3. Miscalibration of Sensors/Electrical Relays						
(a) One Sensor/Relay Affected	-	-	5×10^{-3}	10	10^{-2}	10
(b) More than one Sensor/Relay Affected	-	-	1×10^{-3}	10	3×10^{-3}	10

TABLE B.3 (Cont'd)

	Time Actuation Needed	Estimated Failure Prob. for Primary Operator to Actuate AFWS	Estimated Failure Prob. of other (Backup) Control Rm. Operator to Actuate AFWS	Overall Estimate of Failure Probability	Estimated Error Factor on Overall Probability
b. <u>Acts & Errors of a Post-Accident Nature</u>					
1. Manual Actuation of AFW system from Control Room					
(a) Considering "Dedicated" Operator to Actuate AFW system and Possible Backup Actuation of AFWS	15 min.	2×10^{-3}	-	2×10^{-3}	10
	15 min.	1×10^{-3}	0.5 (mod. dep.)	5×10^{-4}	10
	30 min.	5×10^{-4}	.25 (low dep.)	10^{-4}	10
(a) Considering "Non-Dedicated" Operator to Actuate AFW system and Possible Backup Acutation of AFW system	5 min.	5×10^{-2}	-	5×10^{-2}	10
	15 min.	1×10^{-2}	0.5 (mod. dep.)	5×10^{-3}	10
	30 min.	5×10^{-3}	.25 (low dep.)	10^{-3}	10

APPENDIX C

BACKGROUND INFORMATION PROVIDED BY THE APPLICANT

BACKGROUND

The action plan developed by the NRC in response to the accident at the Three Mile Island Unit-2, NUREG-0737, required (Item II.E.1.1.) that all operating nuclear power plants or plants applying for operating licenses conduct a reliability analysis of the auxiliary feedwater (AFW) system. The analysis is to be performed using event-tree and fault-tree logic techniques and is intended to evaluate the potential for system failure during a variety of loss of main feedwater transients. The primary purpose of the reliability evaluation is to identify potential failures resulting from human errors, common causes, single-point vulnerabilities, and outages due to test and maintenance.

The stated purpose of the recommendations associated with TMI Action Plan Item II.E.11 was to decrease the unreliability of AFW systems towards a goal of 10^{-4} to 10^{-5} per demand for loss of main feedwater and loss of offsite power transients. As a result of reliability evaluations performed both by the NRC staff (NUREG-0611) and various operating license applicants, it was deemed by the staff that three AFW pumps were necessary to achieve the desired unreliability goal assuming all other AFW system safety criteria are met. Therefore, the current staff position is that applicants for operating licenses must include at least three AFW pumps in their plant design, and each pump must be capable of providing to the steam generators at least the minimum flow necessary for decay heat removal following a loss of offsite power. Also, a minimum of two of these pumps and their associated trains must be safety grade.

On October 30, 1981, the NRC staff informed the Public Service Company of New Hampshire, (PSNH) of the staff position regarding AFW system reliability, and questioned the ability of the Seabrook Nuclear Station auxiliary feedwater system to meet the specified reliability goals. The Seabrook AFW system[1] consists of a two-pump safety grade emergency feedwater (EFW) system and a non-safety grade "startup feed pump" that may operate in parallel with the emergency feed pumps. The staff's concern, as stated in the October 30 letter, related primarily to the perceived inability to power the third "start-up" pump from the emergency AC buses.

PSNH replied to the staff's concerns by letter on December 4, 1981[2]. In this response it was noted that provisions were included in the Seabrook design to allow the startup feed pump to be powered from an emergency bus if necessary. With this provision it is the position of PSNH that the Seabrook EFW system design meets the requirements of the October 30 letter from the staff.

---

1 In this report the term "auxiliary feedwater", or AFW, system as applied to Seabrook means the combined emergency feedwater and startup pump systems.

PURPOSE

The purpose of this study was to perform a reliability analysis of the Seabrook EFW system considering the use of the startup feed pump as a third source of emergency feed water and to demonstrate using the results of the study the validity of PSNH's position, i.e., that the required reliability goals as specified by the NRC staff are met by the existing Seabrook AFW system design. In addition, this study was intended to identify for PSNH and the NRC staff any dominant faults affecting the AFW system reliability under the loss of main feedwater/loss of power transient conditions specified by the staff in NUREG-0611. The techniques used to achieve these objectives were the logic modeling methods specified by NUREG-0737.

SCOPE

The EFW system design evaluated by this study is that described in Section 6.8 of the Seabrook Nuclear Station Final Safety Analysis Report (FSAR) and further described in system description document SD-1M. The design of the startup feed pump system is described in system description document SD-1Q. The primary sources of specific design information about both the systems described in these documents were facility P and I drawings and logic diagrams. A listing of all drawings used in the course of this study is provided in Table C-1.

The transient conditions under which the AFW system reliability was determined are those outlined by the NRC staff in NUREG-0611, i.e.,

- Loss of main feedwater with reactor trip;
- Loss of main feedwater with coincident loss of offsite station power;
- Loss of main feedwater with coincident loss of all station AC power.

2 Letter No. SBN 198, T.F. H4.4.98 to Mr. Frank J. Miraglia from Mr. John DeVincentis.

TABLE C.1

Engineering Drawing List for the Seabrook Nuclear Station Emergency and Startup Feedwater Systems

Drawing Title	Number
Mechanical System P&I Diagrams:	
1. Main Steam System (Sheet 1)	9763-F-202074
2. Emergency Feedwater System	9763-F-202076
3. Condensate System	9763-F-202077
4. Feedwater System	97C3-F-202079
5. Compressed Air System, Key Plan	9763-F-202105
6. Compressed Air System	9763-F-202106
7. Turbine Building Compressed Air Headers	9763-F-202107
8. Miscellaneous Buildings Compressed Air Headers	9763-F-202108
Electrical System One Line Diagrams:	
1. Unit Electrical Distribution	9763-F-310002
2. 4160V Switchgear Bus 1-E5	9763-F-310007
3. 480V Unit Substation Buses 1-E51 and 1-E52	9763-F-310013
4. 125VDC and 120VAC Instrument Buses	9763-F-310041
5. Turbine Building 480V Motor Control Center 1-E523	9763-F-310046
Logic Diagrams:	
1. Symbols	9763-M-503100
2. FW-Start-up Feed P-113	9763-M-503580
3. FW-Prelube P-161 For Start-up Feed P-113 Sht 1	9763-M-503581
4. FW Emerg Fd P-37A Steam Supply Vlv (MS-V128) Train B	9763-M-503584
5. FW Emerg Fd P-37A Stm Supply Vlv (MS-V127) Train A	9763-M-503585
6. FW-Emerg Feed P-37B	9763-M-503586

7.	FW-Emerg FW Bypass/Inop Status Alarm	9763-M-503599
8.	MS-Trip & Throttle Valve V-129	9763-M-503672
9.	FW-Emergency Valves	9763-M-504152
10.	FW-Emergency Valves	9763-M-504155
11.	FW-Valve-V148	9763-M-504156
12.	FW-Prelube P-161 For Start-up Fd P-113 Sht 2	9763-M-504157

Control Loop Diagrams:

1.	FW-Start-up Feed P-113 & Prelube Pmp P-161	9763-M-506480
2.	FW-Feed Pump P-32B Speed Control & Disch	9763-M-506481
3.	FW-Emerg Feed Pump P-37A (Turbine Driven)	9763-M-506497
4.	FW-Emerg Feed Pump P-37B Discharge Flow	9763-M-506498
5.	FW-Emerg Feed Pump P-37B TE-4271 & TE-4347	9763-M-506499
6.	MS Supply To Emerg Fd Pmp Turbine Isol Vlv	9763-M-506555
7.	FW-Emerg Feed Pump P-37A Discharge Flow	9763-M-507043
8.	FW-Emerg Feed Pump P-37B	9763-M-507044
9.	FW-Emerg FW Valve FV-4214	9763-M-507056
10.	FW-Emerg FW Valve FV-4224	9763-M-507057
11.	FW-Emerg FW Valve FV-4234	9763-M-507058
12.	FW-Emerg FW Valve FV-4244	9763-M-507059
13.	Start-up Feed Pump 1-P-113 Prelube Pump 1-P-161	9763-M-310844 SHCN1a
14.	Prelube Pump 1-P-161 Legend & Switch	9763-M-310844 SHCN1b

15.	Prelube Pump 1-P-161 Cable Schematic	9763-M-310844 SHC"1c

FSAR Drawings:

1.	Functional Diagrams-Reactor Trip Signals	Figure 7.2-1 Sheet 2
2.	Functional Diagrams-Pressurizer Trip Signals	Figure 7.2-1 Sheet 6
3.	Functional Diagrams-Steam Generator Trip Signals	Figure 7.2-1 Sheet 7
4.	Functional Diagrams-Safeguards Actuation Signals	Figure 7.2-1 Sheet 8
5.	Functional Diagrams-Auxiliary Feedwater Pumps Startup	Figure 7.2-1 Sheet 15
6.	Separation of Instrument and Control Power Sources	Figure 8.3-3

PSNH PUBLIC SERVICE
Company of New Hampshire

SEABROOK STATION
Engineering Office:
1671 Worcester Road
Framingham, Massachusetts 01701
(617) - 872 - 8100

September 7, 1982
SBN-321
T.F. H 4.4.98
B 7.1.2

United States Nuclear Regulatory Commission
Washington, D. C. 20555

Attention: Mr. Frank J. Miraglia, Chief
Licensing Branch No. 3
Division of Licensing

References:
(a) Construction Permit CPPR-135 and CPPR-136, Docket Nos. 50-443 and 50-444
(b) PSNH Letter, dated August 27, 1982, "Reliability Analysis of the Emergency Feedwater System", J. DeVincentis to F. J. Miraglia
(c) PSNH Letter, dated July 27, 1982, "Response to Requests for Additional Information (RAIs) from Instrumentation and Controls Systems Branch (ICSB); A-K", J. DeVincentis to F. J. Miraglia

Subject: Seabrook Station Emergency Feedwater System Design Changes

Dear Sir:

During the Staff review of the Seabrook Station Emergency Feedwater System (EFW), a number of design changes have been recommended and are being implemented. These design changes are based on the review of the Emergency Feedwater System Reliability Analysis [Reference (b)] and also bring the Seabrook design into compliance with the latest Standard Review Plan. These design changes will be incorporated into a revision to the Final Safety Analysis Report as soon as the final details are established.

The following describes design changes which are presently being implemented relative to the Seabrook EFW System. An attached simplified sketch is included for clarification of some of the design changes.

1. A continuous minimum flow recirculation path will be provided from each EFW pump's discharge to the condensate storage tank via the opposite pump's suction line. This recirculation path will assure a continuous flow through an EFW pump should flow to all four steam generators be reduced below that necessary to prevent pump damage. The original recirculation path will be retained for use during periodic pump performance testing.

2. Redundant, safety grade flow isolation valves will be provided in each EFW branch supply line to each steam generator. Safety grade controls will be provided at both the main control board and remote shutdown locations for these valves. Further information relative to this modification can be found in Reference (c).

3. Manual isolation valves will be provided upstream of each pair of flow isolation valves to each steam generator. These manual isolation valves will permit isolation of any EFW flow isolation valve while retaining the availability of <u>both</u> EFW pumps <u>and</u> the Startup Feedwater pump.

4. Safety grade, Seismic Category I air accumulators will be provided as a back-up air supply for the actuators of both main steam supply valves (MS-V127 and MS-V128) to the turbine-driven EFW pump, P-37A. These accumulators will be sized to provide at least two complete valve operations plus maintain the valves closed for a minimum of four hours. This safety grade air supply will upgrade the reliability of these valves consistent with the Class 1E controls presently utilized in the design.

5. The Startup Feedwater (SUF) pump discharge valve to the EFW header, FW-V156, will be relocated out of the EFW Pump Room. This will assure the ability to cross-tie the SUF pump to the EFW System should a series of potential failures render both EFW pumps inoperable and the EFW Pump Room inaccessible.

Additionally, during both our in-house and your Staff review of Reference (b), three areas were found which should be clarified or corrected.

First, on Page 12 of Reference (b), an asterisk notes that only one of the steam admission valves (MS-V127) to the turbine-driven EFW pump can be controlled from the remote shutdown panels. In conjunction with modification #4 listed above, Class 1E controls for the other steam admission valve (MS-V128) will also be provided at the remote shutdown location. These modifications will ensure the ability to start and/or stop the turbine-driven EFW pump from either the main control board or the remote shutdown panels.

Second, on Page 15 of Reference (b), relative to the manual valve realignments required to provide SUF pump flow to the EFW header, it states that the SUF pump recirculation isolation valve (FW-V109) must be closed to prevent a diversion of pump flow to the Condensate Storage Tank (CST) should the recirculation flow control valve (PCV-4326) fail open. What was not considered, however, is that the capacity of the SUF pump is significantly greater than that of an EFW pump. At a TDH equivalent to the design rating of the EFW pump, the SUF pump has a flow capacity greater than an EFW pump, even when maximum flow is diverted back to the CST through the recirculation valve. Therefore, it is unnecessary to close valve FW-V109 to ensure sufficient flow from the SUF pump to the steam generators. This is one less manual action necessary for this operation.

Third, on Page 29 of Reference (b), a note on the bottom of the page indicates that a loss of off-site power will result in closure of the

main feedwater isolation valves. This note is incorrect - the main feedwater isolation valves will not close due to a loss of off-site power. Additionally, it should be noted that the loss of off-site power does not result in a loss of control of the main feedwater regulating valves nor the main feedwater regulating bypass valves. The result is, the SUF pump can be utilized to supply feedwater to the steam generators during a loss of off-site power event without the need of manual valve alignments to provide flow through the EFW System. Flow from the SUF pump to the steam generators can be accomplished utilizing the normal main Feedwater System.

It is hoped that the above information will assist your Staff in their evaluation of the Seabrook Station Emergency Feedwater System and preparation of the Safety Evaluation Report. If further information is necessary, please feel free to contact us.

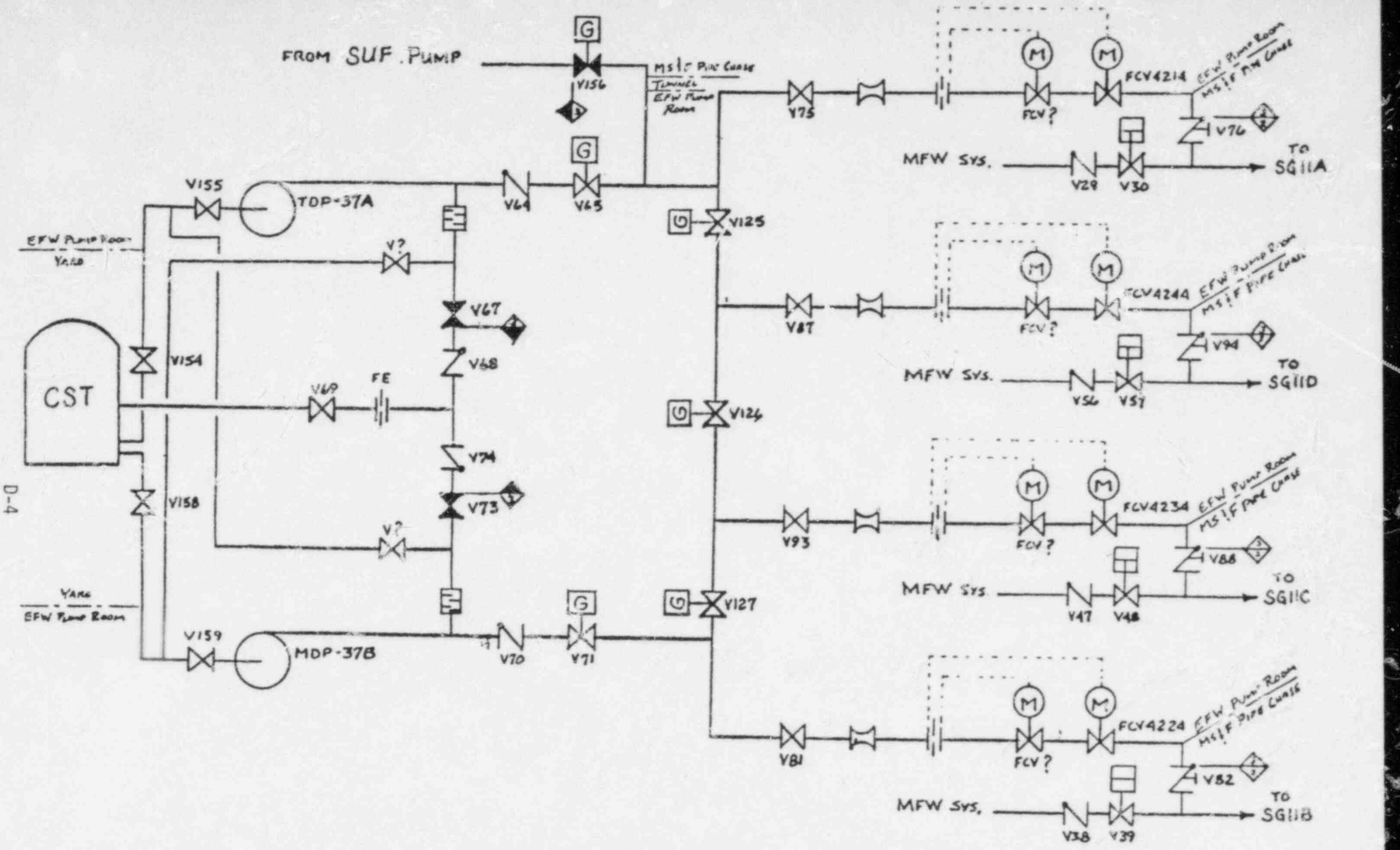
Very truly yours,

YANKEE ATOMIC ELECTRIC COMPANY

J. DeVincentis
Project Manager

PA/kac

cc: Mr. Robert Jaross, Argonne National Laboratories



D-4

YANKEE ATOMIC ELECTRIC COMPANY

NUCLEAR SERVICES DIVISION

DWG. NO. //

DRAWN BY PLA 8/23/82

CHECKED BY //

APPROVED BY //

TITLE. SIMPLIFIED SKETCH OF THE SEABROOK STATION EFW SYSTEM

SUPPLEMENT

Seabrook AFWS Revised

Reliability Assessment for

Loss of Off-Site Power (LOOP)

BROOKHAVEN NATIONAL LABORATORY

MEMORANDUM

DATE: December 2, 1982

TO: I. A. Papazoglou

FROM: R. Youngblood/A. Fresco RY A. Fresco

SUBJECT: Seabrook AFWS Revised Reliability Assessment for LOOP

In a conference call on November 17, 1982, R. Anand of the NRC-ASB and J. Tsao of the NRC-RRAB informed us of some design changes proposed by the applicant which are intended to improve the AFWS reliability under Loss of Offsite Power conditions. We were then requested to re-evaluate the unreliability for the new conditions.

This memo is divided into three parts. Part A is a description of the design changes, Part B is a justification for the human error unreliability data assumed to apply to the new conditions, and Part C is the actual quantitative results for AFWS unreliability for the proposed design changes of Part A utilizing the data of Part B. Part C also contains the segments of the original draft BNL assessment which are affected by the design revisions.

A. Seabrook AFWS Proposed Design Changes as of November 17, 1982

1. Locked-open manual valves V-163 and V-156, which isolate the SUFP from the EFW header, will be converted to motor-operated valves cperable from the Control Room.

2. Two separate breakers will be installed to eliminate the need to manually transfer the SUFP breaker from Bus 4 in the Non-Essential Switchgear Room to Bus E5 in the Essential Switchgear Room. The operator will still need to change the bus transfer switch to the E5 position.

Subsequent discussion with the applicant on November 22, 1982 clarified certain issues concerning the use of the MFW flow paths to supply water to the steam generators from the SUFPS:

1. The MFW regulating valves FCV-510, FCV-520, FCV-530 and FCV-540 are air-operated, fail-closed valves. Upon LOOP, the control signals will tend to close the valves upon reduction of the steam flow rate from the steam generators.

2. The valves require air from any one of the Instrument/Service Air Compressors to allow the operator to open them from the Control Room. There are (3) 100% capacity Instrument/Service Air Compressors. At any given time, one of the compressors is connected to Emergency Diesel Generator Train A and another to Train B. One is operating using non-emergency on-site power and the other is on standby. The third compressor is not powered except when it is used to replace one of the other two compressors.

3. Upon LOOP, the compressors are automatically loaded onto the Diesel-Generators at the end of the 2-minute sequence of loads.

The following was also discussed:

4. The only intended usage of the EFW header locked-open manual valves, V-125, V-126, and V-127 is for isolation in the event of a pipe rupture. There are no test or maintenance acts which require closure of those valves during Normal, Hot Standby, or Hot Shutdown operation. (Although it is not within the scope of the NUREG-0611 analysis, the feasibility of using these valves to isolate a rupture is very limited because they are locked-open and manually-operated. For a full guillotine rupture with both EFW pumps operating, flow would emanate from both directions, severely restricting local operator actions. In the applicant's own report, which did consider pipe ruptures, a probability of 0.9 was assumed for the operator failing to isolate a rupture).

5. The addition of the Seismic Category I, safety-class air accumulator on the air supply to the Main Steam Admission Valves, V-127 and V-128, for the turbine-driven EFW Pump P-37A has no effect on the automatic initiation of the pump.

B. <u>Quantification of Human Error Unreliability</u>

The task of the present section is to quantify the human error contribution to the failure probability of the pump, given LOOP. Recent work indicates that human errors of omission are dominated by "cognitive" failures; this idea is discussed below and applied to the present task. Errors of commission are more difficult to treat, and are not included here. It is felt that neglect of errors of commission is characteristic of the AFWS reviews which have been performed up to now.

The scenario of interest is the following. There has been a LOOP (loss of offsite power), so that the normal source of AC power to the startup feedpump (SUFP) is not available. Ordinarily, the two pumps of the EFWS (Emergency Feedwater System) should be available; one is steam turbine driven, and the other is electric motor driven and is aligned to diesel-backed AC. However, in the scenario considered here, both EFWS pumps are unavailable, for whatever reason. If the operators manually align the SUFP to a diesel-backed

bus (and if there are no more failures), it can provide feedwater. The human failure of interest is failure to align the SUFP to a diesel-backed bus.

A useful approach to this problem is afforded by the Operator Action Tree System. Full descriptions of this are given in Refs. 1 and 2. The general idea is summarized as follows. Given a situation which calls for operator action within a specified time, one divides the available time into three periods:

1) the time it takes for cues (meters, alarms, etc,) to become available to the operators, calling for action;

2) the time available for cognitive processing of the cues (the time available for planning and decision making);

3) the time required to implement the decisions reached in Phase 2.

The general idea of the OAT method is that cognitive errors in Phase 2 are the dominant contribution to failure to perform a necessary act, and that the single most important parameter determining the failure probability in Phase 2 is the available time.

For purposes of the present analysis, a 30-minute period has been adopted as the time after LOOP within which feedwater must be provided. It should be evident within a minute or so whether the EFWS is operating, so Phase 1 can essentially be neglected. Phase 3 (manual alignment of the SUFP to a diesel-backed bus) requires manipulation of breakers outside the control room. It is this procedure which has recently been streamlined. It is believed that 15 minutes is ample time for this procedure. The arguments which place all the error in Phase 2 seem to require that an ample time frame be assigned to Phase 3; otherwise, procedural errors will begin to contribute substantially to Phase 3, while at present they are implicitly being assumed to be easily recoverable. Based on a tour of this facility, our impression is that someone who knows what to do can easily accomplish the task in 15 minutes. This leaves 15 minutes for Phase 2, the decision interval.

The OAT method goes on to suggest a cognitive probability corresponding to the 15-minute intervals. At this point, however, since the control-room "thinking" phase has been separated from the out-of-control-room "acting" phase, we can consult NUREG-0611 for an applicable error probability. In Table III-2, we find that failure of an operator and his backup to actuate the AFWS within 15 minutes is assigned $5x10^{-3}$. From the arguments given above, we would apply this directly to the case at hand: for Phase 2, then, the error probability is $5x10^{-3}$.

Above, it was argued that "cognitive" errors dominate the overall failure probability. On the other hand, it is widely believed the 10^{-2} is the basic error rate for procedural acts without prospect of error recovery. Therefore,

Phase 3 will contribute significantly unless there are real opportunities for error recovery. From the previous discussion, it is clear that "real opportunity for recovery" requires ample time to perform the operation and personnel who are sufficiently trained in the operation to be able to diagnose their own errors. Since it will be quickly apparent whether the operation is successful, there appears to be abundant opportunity for recovery. On this basis, then, 10^{-3} is assigned as the probability of the failure of trained personnel to complete this action within 15 minutes of being told to perform it.

The total failure probability is therefore $6x10^{-3}$; $5x10^{-3}$ for "cognitive" errors in Phase 2, and $1x10^{-3}$ for procedural errors in Phase 3. Errors of commission have been neglected, and the low error probability assigned to Phase 3 is based on there being ample time for error recovery, etc. Note that hardware failure of the breaker involved has previously been included in the analysis.

References

1. J. Wreathall, "Operator Action Trees: An Approach to Quantifying Operator Error Probability During Accident Sequences", NUS Report #4655, NUS Corp., July 1982.

2. R. E. Hall, J. Wreathall, and J. Fragola, "Post Event Decision Errors Operator Action Tree/Time Reliability Correlation", NUREG/CR-1605 (BNL-NUREG-51601), Brookhaven National Laboratory, November 1982.

C. Calculation of the Seabrook AFWS Unreliability for the Revised Design

The objective here is to calculate the AFWS unreliability for LOOP utilizing the human error data resulting from the discussion in the previous section.

The following portions of the BNL assessment are affected:

a) Figure 11-Sheet 3: BNL Cutsets-LOOP (Start-up Feed Pump P-113), p.86.

b) Table 11: BNL Results-Unavailability of Seabrook AFWS Proposed Design Using NUREG-0611 Data-LOOP Transient, p.63.

c) Figure 1: Comparison of Reliability of Seabrook AFWS to Other AFWS Designs in Plants Using the Westinghouse NSSS, p.71.

Referring to Figure 11, Sheet-3, one of the dominant cutsets for gate SUP1, "No Flow to Supply Header From SUFP P-113", is MPB1P1610E, "Operator Fails to Start SUFP Pre-Lube Pump P-161", which was assessed at $3x10^{-2}$. This value is about 25% of the overall unavailability of SUP1. From the previous discussion, $6x10^{-3}$ will now become the new value for MPB1P1610E.

In Table 11, the value for H_3 is thereby reduced from $9.2x10^{-2}$ to $6.8x10^{-2}$. Substituting the latter value into the equations (a), (b), and (c), we obtain:

$$AFW^*_{LOOP} = 8.6x10^{-5}$$

In the assessment of Table 11, it was assumed for reasons explained in the BNL report that failures of the MFW flowpaths are a negligible contribution to the unreliability of the AFWS. However, in the ensuing discussions among BNL, NRC, and the applicant, it has been determined that the MFW regulating valves FCV-510, 520, 530 and 540 fail closed upon loss of air supply and that one of the Instrument/Service Air Compressors is required to open them as mentioned earlier. Even so, loss of the MFW flowpaths still requires multiple failures (e.g., failure to open 3 of 4 valves, or multiple compressor failures), which are substantially less likely than single failures of the SUFP train.

In addition, the capability would remain to open valves V-163 and V-156, which will now be motor-operated from the Control Room, to allow the SUFP to supply feedwater through the EFW header. Thus, the result obtained of $8.6x10^{-5}$ will not be significantly affected by the unavailability of the MFW flowpaths. Revised copies of Figure 11, Sheet 3, Table 11, and Figure 1 are attached.

SEABROOK-LOOP: EFWS 2 TRAINS + STARTUP FEEDPUMP - NUREG-0611 SCOPE

CUT SETS FOR GATE SUP1 WITH PROBABILITY .GE. 1.00E-05

1.	6.00E-03	MPB1P1610E
2.	3.00E-02	FGD1DG1AME
3.	1.00E-02	RCA1A93-OB
4.	1.00E-02	MVD1V1560A
5.	1.00E-02	MVD1V1630A
6.	6.40E-03	RGDI1A--00
7.	5.60E-03	MPB1P11300
8.	5.00E-03	MPB1P113ME
9.	5.00E-03	MPB1P161ME
10.	5.00E-03	FVM1V1520D
11.	2.00E-03	MCE1P113MN
12.	1.00E-03	RCA1A93-MB
13.	1.00E-03	RCA1A54-MB
14.	1.00E-03	FVD1V1410D
15.	1.00E-03	FVD1V1430D
16.	1.00E-04	MPB1P1130G
17.	1.00E-04	RCA150AEMC
18.	1.00E-04	RCA1AF4-MC
19.	1.00E-04	RCA1A63-MC
20.	1.00E-04	FVM1V152MD
21.	1.00E-04	FVD1V141MD
22.	1.00E-04	FVD1V143MD
23.	1.00E-04	MVA1V99-MA

1ST MOMENT= 9.3E-02

Revised

Figure 11 (Continued) BNL Cutsets - LOOP
(Sheet 3: No Flow From Start-up Feed Pump P-113).

TABLE 11

(REVISED)

BNL RESULTS
UNAVAILABILITY OF SEABROOK AFWS
PROPOSED (SUPPLEMENT) DESIGN USING NUREG-0611 DATA
LOOP TRANSIENT

1. Refer to Table 8 and 10. Again the expression for AFW* is:

$$AFW^* = (AF91)\cdot(AF127)\cdot(SUP1) + (AF127)\cdot(SUP1)\cdot(V125) + (AF91)\cdot(SUP1)\cdot(V127)$$

2. As in the Proposed Design for the LMFW transient, it is no longer necessary for the operator to open V156 or V163 so that the failure rates for those events can again be subtracted from H_3 of SUP1. The values of AF91, AF127 and SUP1 are now:

AF91	AF127	SUP1
$H_1 = 1.1\times10^{-2}$	$H_2 = 4.3\times10^{-2}$	$H_3 = 6.8\times10^{-2}$
$M_1 = 1.1\times10^{-2}$	$M_2 = 1.2\times10^{-2}$	$M_3 = 1.2\times10^{-2}$

3. Separating AFW* into Hardware Failures and Maintenance (or Test) Failures:

(a) $(AF91)\cdot(AF127)\cdot(SUP1) = H_1H_2H_3 + H_1M_2H_3 + H_1H_2M_3 + M_1H_2H_3$

(b) $(AF127)\cdot(SUP1)\cdot(V125) = (H_2H_3 + M_2H_3 + H_2M_3)\ (V125)$

(c) $(AF91)\cdot(SUP1)\cdot(V127) = (H_1H_3 + H_1M_3 + M_1H_3)\ (V127)$

4. Substituting the new value for H_3,

(a) $= 32.16 \times 10^{-6} + 8.98 \times 10^{-6} + 5.68 \times 10^{-6} + 32.16 \times 10^{-6}$

$= 78.98 \times 10^{-6}$

TABLE 11 (cont'd)

(b) $= (29.24 \times 10^{-4} + 8.16 \times 10^{-4} + 5.16 \times 10^{-4})(11 \times 10^{-4})$

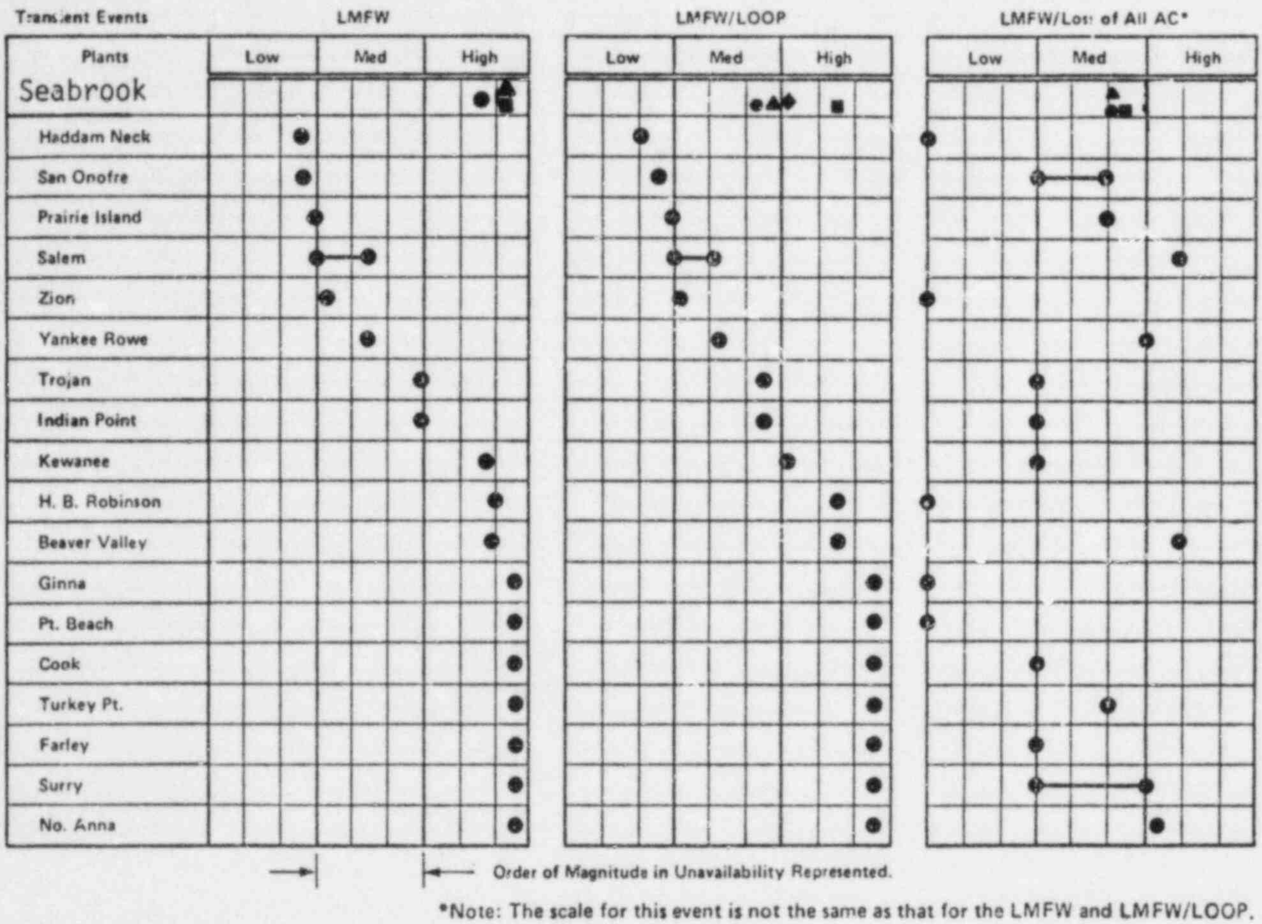
$= (42.56 \times 10^{-4})(11 \times 10^{-4}) = 4.68 \times 10^{-6}$

(c) $= (7.48 \times 10^{-4} + 1.32 \times 10^{-4} + 7.48 \times 10^{-4})(11 \times 10^{-4})$

$= (16.28 \times 10^{-4})(11 \times 10^{-4}) = 1.79 \times 10^{-6}$

$$AFW^* = (a) + (b) + (c) = 1.15 \times 10^{-4}$$

$$AFW^*_{LOOP} = 8.55 \times 10^{-5}$$



<u>BNL Assessment - NUREG-0611 Scope</u>

● Reference 3 Design

▲ Proposed Design

◆ Supplement Design (Nov. 17, 1982)

<u>Applicant's Results</u>

■ Reference 3 Design

Figure 1: Comparison of Reliability of Seabrook AFWS to Other AFWS Designs in Plants Using the Westinghouse NSSS.

☆ U.S. GOVERNMENT PRINTING OFFICE: 1984-421-297:3626

NRC FORM 335 (11-81) U.S. NUCLEAR REGULATORY COMMISSION **BIBLIOGRAPHIC DATA SHEET**	1. REPORT NUMBER (Assigned by DDC) NUREG/CR-3531 BNL-NUREG-51723
4. TITLE AND SUBTITLE (Add Volume No., if appropriate) Review of the Seabrook Units 1 and 2 Auxiliary Feedwater System Reliability Analysis	2. (Leave blank)
	3. RECIPIENT'S ACCESSION NO.
7. AUTHOR(S) Fresco A., Youngblood R., Papazoglou I.A.	5. DATE REPORT COMPLETED MONTH October YEAR 1983
9. PERFORMING ORGANIZATION NAME AND MAILING ADDRESS (Include Zip Code) Brookhaven National Laboratory Upton, NY 11973	DATE REPORT ISSUED MONTH February YEAR 1984
	6. (Leave blank)
	8. (Leave blank)
12. SPONSORING ORGANIZATION NAME AND MAILING ADDRESS (Include Zip Code) Division of Safety Technology Office of Nuclear Reactor Regulation U.S. Nuclear Regulatory Commission Washington, DC 20555	10. PROJECT/TASK/WORK UNIT NO.
	11. FIN NO. A-3933
13. TYPE OF REPORT Technical Report	PERIOD COVERED (Inclusive dates)
15. SUPPLEMENTARY NOTES	14. (Leave blank)

16. ABSTRACT (200 words or less)

This report presents the results of a review of the Emergency Feedwater System Reliability Analysis for Seabrook Nuclear Station Units 1 and 2. The objective of this report is to estimate the probability that the Emergency Feedwater System will fail to perform its mission for each of three different initiators: (1) loss of main feedwater with offsite power available, (2) loss of offsite power, (3) loss of all AC power except vital instrumentation and control 125 VDC/120 VAC power. The scope, methodology, and failure data are prescribed by NUREG-0611, Appendix III. The results are compared with those obtained in NUREG-0611 for other Westinghouse plants.

17. KEY WORDS AND DOCUMENT ANALYSIS

17a. DESCRIPTORS

Reliability Analysis
Auxiliary Feedwater System
Seabrook Nuclear Power Plant Units 1 and 2
Pump and Valve Failure Rates

17b. IDENTIFIERS/OPEN-ENDED TERMS

18. AVAILABILITY STATEMENT	19. SECURITY CLASS (This report)	21. NO. OF PAGES
Unlimited	Unclassified	
	20. SECURITY CLASS (This page) Unclassified	22. PRICE $

NRC FORM 335 (11-81)

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

OFFICIAL BUSINESS
PENALTY FOR PRIVATE USE, $300

FOURTH CLASS MAIL
POSTAGE & FEES PAID
USNRC
WASH. D.C.
PERMIT No. G 67

120555078877 1 1AN
US NRC
ADM-DIV OF TIDC
POLICY & PUB MGT BR-PDR NUREG
W-501
WASHINGTON DC 20555