ATTACHMENT

Consumers Power Company
Palisades Plant
Docket 50-255

AUXILIARY FEEDWATER SYSTEM RELIABILITY ANALYSIS

March 21, 1986

131 Pages

PALISADES PLANT

AUXILIARY FEEDWATER SYSTEM RELIABILITY ANALYSIS

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AUXILIARY FEEDWATER SYSTEM
RELIABILITY ANALYSIS

1.0 BACKGROUND

As a result of the Palisades Main Steam Line Break submittal, concern has been raised, by the NRC, regarding the adequacy of the existing Palisades auxiliary feedwater system (AFW). This concern is based on the evaluation of the AFW model used in the Main Steam Line Break (MSLB) submittal. Because of the importance of the issue, this report was created to clarify any potential misinterpretation of the results of the AFW system model analysis included in the MSLB submittal. The intent of this report is to provide information in support of the position that the AFW system model, as used in the MSLB submittal, should not be construed to represent the reliability of the system. This report focuses on two main elements 1) an analysis which more closely represents our state of knowledge regarding the reliability of the AFW system design and operation, and 2) a discussion of the results derived for the MSLB AFW model and why a significant portion is inappropriate in the context of the overall system reliability (refer to sections 2.1 and 3.0).

In order to accomplish item 1), a separate analysis of the AFW system was conducted using the guidelines of NUREG-0635. The reasons for using NUREG-0635 are;

a) to maintain consistency in the method of analysis (the system has undergone two previous analyses using these criteria).

b) the system has been significantly modified since the first analysis, using the same criteria allows direct comparison of the new results to the original results.

c) the results of the new analysis can be compared to the results for other plants already analyzed using the same criteria.

As indicated in a) above, two previous reliability analyses have been conducted. The purpose of the second analysis was to demonstrate the level of increased reliability attainable from proposed modifications to the system. A recent review of this second analysis showed that the fault tree models already developed could be used for an analysis of our existing system. Necessary corrections and alterations to the models were made and are identified in section 2.5.

As indicated in b) above, modifications to the system to improve reliability by minimizing the failure effects of human error, common causes, and single- or double-point vulnerabilities were completed after NUREG-0635 was published. Therefore, the results obtained by the original analysis are no longer accurate. Several of the significant modifications are listed below.

1. Addition of a third dedicated AFW pump.
2. Manual or automatic flow initiation on receipt of low steam generator water level, and manual or automatic isolation of the depressurized steam generator following secondary system line breaks.
3. Safety grade AFW flow indication to the main control room.
4. Redundant emergency power supply for the electrical equipment, instrumentation, and control circuits associated with the modifications.
5. Testability of AFW control circuits.
6. Seismic and environmental qualification to meet applicable Palisades guidelines.

2.0 RELIABILITY ANALYSIS

2.1 METHODOLOGY

Fault tree analysis was used to identify those potential failures that could be chief contributors to AFW system unreliability during the three transient conditions listed below.

LMFW - Loss of main feedwater with concurrent reactor trip and with offsite power available.

LMFW/LOOP - LMFW with concurrent reactor trip and loss of offsite power (LOOP). Onsite emergency power sources remain available.

LMFW/LOAC - LMFW and concurrent loss of all alternating current power (LOAC), except that which is battery derived.

The model used in the current analysis is not the same as the model used in the MSLB submittal. The reasons for using a different model are detailed below.

1) The time interval of interest as stated in NUREG-0635 is the unavailability of the AFW system during period of time to boil the steam generator dry which for Palisades has been established as 15 minutes. The model used in the MSLB submittal is based on a 24 hour mission time and therefore introduces significant contributions from failures of the system to continue to function.

2) The model used in the MSLB submittal is a modified version of the complete AFW fault tree. A discussion of the differences is provided in section 3.0 "MSLB AFW Model". However, a major difference in the models is due to an arbitrary assumption that the failed steam generator was unavailable. This assumption effectively eliminates the redundancy in flow paths from the AFW pumps to the steam generators.

3) The level of detail in the current plant model goes well beyond the level of detail prescribed by NUREG-0635. Since part of the concern is based on the degree of reliability as compared to other plants or proposed goals, it was decided that the reliability analysis should be completed in a manner that allows such comparisons.

As additional insight, each model was evaluated with two sets of data. The first set of data is generic as provided by NUREG-0635. The second set includes plant specific data where such data was available. When plant specific data was not available, generic data was used. This allows comparison of the relative impact of the use of plant specific data to generic data.

Analysis of the fault trees was conducted using the WAMCUT computer code.

2.2 FAULT TREES

Three fault tree models were used. The fault trees include random failures of electrical and mechanical components and the effects of testing and maintenance, and human error. The fault trees are shown in appendices D, E, and F.

The trees were examined for causes of specific component failure modes and evaluation of their likelihood of occurrence. The causes considered were:

Random independent failures;
Test and maintenance; and
Human error.

Each of the three master trees was developed for the loss of main feedwater (LMFW) transient condition. For other transient conditions - LMFW with loss of offsite power (LMFW/LOOP) or LMFW with loss of all alternating current power (LMFW/LOAC) - some systems or components are unavailable. Those systems or components were deleted before analysis.

NUREG-0635 was used to establish the top event of the master fault tree, set the initiating events, and as the basic guide for the analysis. The top event is taken from NUREG-0635 which states;

The time interval of interest for all transient events considered is the unavailability of the auxiliary feedwater system during the period of time required to boil the steam generator dry. (Reference 2, page III-10)

The fault tree models were developed assuming statistical independence for hardware/operator failures, human error, and test and maintenance failures.

2.3 CRITERIA AND ASSUMPTIONS

The following analytical criteria and assumptions were used.

- AFW system availability is defined as successful system startup within the steam generator boil dry time of 15 minutes.
- The availability conditions for AFW system power sources during the analyzed transients were as follows;

    1) LMFW - All alternating and direct current power available.
    2) LMFW/LOOP - Two diesel generators and battery backup available.
    3) LMFW/LOAC - Direct current and battery-backed alternating current available (instrument and control power available only)

- Although water from the fire protection system and service water system is available to backup the AFW system condensate storage tank, these sources were not considered in the fault tree analysis.
- All component and operator actions were assumed to be either successes or failures. No partial successes were considered.
- Top event failure probability will be calculated by summing the failure probabilities from hardware, test and maintenance, and human error contributions. The probabilities for each category are rare event approximations.
- Human error probability has been considered in the Hardware and Test and Maintenance fault trees.
- Component outage due to maintenance will only be considered for active components (pumps, control valves, etc). Maintenance on manual valves is considered negligible.

2.4 DATA SOURCES

Data used for the component failure rates in the hardware and test and maintenance trees was taken from the NRC data found in Appendix III, Table III-3 of NUREG-0635. Electrical tree component data was taken from IEEE Std 500. Human error probabilities were drawn from NUREG-1278 and NUREG-0635. Specific component failure data is listed in Appendix G.

2.5 CORRECTIONS TO FAULT TREES

As part of the preparation for this analysis, the fault trees utilized in the second reliability analysis were reviewed for accuracy. Several discrepancies were identified and corrected. Changes made are indicated on the fault trees and discussed below.

2.5.1 Hardware fault tree

1) Operator errors had been treated as independent events. Since each operator error in this tree involved operator response to a failure of the automatic initiation of the system, it was decided that a high degree of dependence was involved. Based on this decision, all operator actions were grouped into three basic types; a) failure to actuate the system from the control room, b) failure to actuate the system locally, and c) failure to manually operate components.

2) The original hardcopy of the model did not identify the primary events representing the failure of preferred ac power for instrumentation and control. These events were added to the model.

3) The failure mode for the motor-operated valves in the AFW flow paths was originally identified as fail to open. These valves are normally open and should be identified as fail to remain open. The correction to the fault trees did not get accomplished. However, in the examination of the system cutsets it was noted that the failure of these valves did not contribute significantly to the system unavailability. Therefore, no corrections were made since the only impact was a slight conservatism in the numerical results and relative ranking of cutsets of intermediate to low contribution.

2.5.2 Test and maintenance fault tree

1) As in 2.5.1 (1) above, the human error associated with restoration of the outlet valves from the condensate storage tank to the AFW pumps was treated as independent for each valve. Because of the location and basis for restoration (ie if isolation was necessary at that point then both valves must be closed and restored), the separate events were combined into one.

2) Credit was taken for a manual valve which bypasses the pressure control valve in the steam line to the turbine-driven pump. The current PRA model does not take credit for successful operation of this valve. While it may be possible to control steam inlet pressure to the turbine driver by manually regulating a gate valve, the ability to do this efficiently and consistently has not been demonstrated and it was deleted from the model.

3) In several cases, maintenance on valves was included when a) it is not physically possible to isolate these valves during power operation or b) isolation would disable 2 of the 3 pumps which is not allowed by Technical Specifications. Each of these valves was removed from the WAMCUT input deck and are shown lined-out in the model in Appendix E.

2.5.3 Electrical fault trees.

The majority of the failure probabilities for electrical components were derived by treating the components as standby with a monthly testing interval. Since several of the components are performing their normal function and failures associated with them would be immediately detectable, while this treatment is inaccurate its importance was not obvious. Since the failure of power is represented in the master tree as basic events with a probability derived from the output of the evaluation of the appropriate electrical tree, the impact of this treatment was determined by reevaluating the electrical trees and by examining the cutsets from the three transient cases using generic data to determine the importance of loss of power as a contributor to system unavailability.

The reevaluation of the electrical trees was accomplished by changing the failure probability of components which do not experience demands to probabilities of mission time failures of 8 hours (first reevaluation) and 15 minutes (second reevaluation). In general the changes resulted in reduced unavailabilities for the electric power sources.

The examination of system cutsets disclosed that the only case where the failure of electric power was identified as a significant contributor (>1%) to system unavailability was for the transient initiator loss of main feedwater with concurrent loss of offsite power. In this case, the failure of bus 1D and/or bus 1C contributed substantially to the system unavailability. However, the change in unavailability (using 8 hour or 15 minute mission times) for these buses under loss of offsite power conditions was insignificant (changed from 3.06E-02 to 3.05E-02). The reason for the lack of difference is that the dominant failures for these buses under loss of offsite power are actual demand failures of the diesel generators and their output breakers.

Based on these results, the system fault trees were not rerun with the revised electrical failure data. The results from the analyses with the initial electrical data were retained while recognizing that they were numerically conservative with respect to the electrical failures.

2.6 RESULTS

The results of the analyses of the system fault trees are included in Appendix A and are discussed in the following sections. The information provided in Appendix A is arranged as follows.

Page 1 is a presentation in table form of the numerical unavailabilities of electrical power and the system for each transient case analyzed for both generic and plant specific data. The contributions from hardware, maintenance, and human error were derived by an arbitrary reorganization of cutsets. The reorganization was completed by 1) moving all cutsets containing an operator error to a separate group (human error), 2) of the remaining cutsets any which incuded maintenance were separated into another group (maintenance), and 3) the remaining cutsets were identified as hardware.

The remainder of the Appendix is comprised of listings of the cutsets for each transient case. Pages two through seven involve the output from the use of generic data. Pages eight through thirteen is the output from plant specific data. For each type of data, three pages represent unavailabilities from the master hardware tree for each transient and three pages for unavailabilities from all considerations for each transient. Each page includes a listing of dominant cutsets and the contribution of each (cutset unavailability/system unavailability) and a listing of the basic events which contribute substantially to the system unavailability (sum of the unavailabilities of the cutsets containing the basic event/system unavailability).

2.6.1 Results from Generic Data Evaluation

2.6.1.1 General Results

The analysis indicates the factor having the greatest impact on the unavailability in all three cases was failure of the relief valve at the discharge of pumps P8A and P8B failing to remain closed, either as a single or in combination with the unavailability of pump P8C or its flow paths. Other significant contributors are: failure of P8C either as a pump failure or due to loss of bus 1D; maintenance on control valves or check valves; operator error; and various causes of P8C or P8B pump trains (ie maintenance, power failure, or valve failures).

2.6.1.2 Loss of Main Feedwater

The dominant failure modes for this transient are double faults. The most significant cutset contribution is the failure of the pump discharge relief valve to remain closed and the failure of P8C to start. The relief valve failure represents the common mode failure of pumps P8A and P8B. Primary event contributors in order of significance are: failure of the relief valve; failure of P8C to start; maintenance on control valves, check valves and P8C; and operator errors involving restoration of valves after testing or maintenance.

2.6.1.3 Loss of Main Feedwater/Loss of Offsite Power

The dominant failure modes for this transient are also double faults. The most significant cutset contributor is the relief valve and the loss of power to P8C. Primary event contributions in order of importance are: the relief valve; loss of power from bus 1D; P8C fail to start; loss of power from bus 1C; maintenance on control valves, check valves, or P8C; operator restoration errors; and maintenance on P8B, a pressure regulating valve, and a check valve.

2.6.1.4 Loss of Main Feedwater/Loss of all AC

The dominant failure modes for this transient are single faults. The dominant contributors are: the relief valve; maintenance on P8B, its check valve, and its pressure regulating valve; and P8B fails to start and operator restoration errors.

2.6.2 Results from Plant Specific Data Evaluation

2.6.2.1 General Results

The failures representing the largest contribution to unavailability in all three transients is pump fails to start. Other general contributors are: the relief valve failing to remain closed; failure of the auto start circuitry and the operator error associated with placing the system in service.

2.6.2.2 Loss of Main Feedwater

The dominant failures modes for this transient are triple faults. The most significant contribution is made by the first cutset (approximately 24%). This cutset represents the combination of all three pumps failing to start. The more important primary event contributions in order of significance are: P8C fails to start; P8A fails to start; P8C fails to start; the relief valve fails to remain closed; and failure of the auto start circuit and the associated operator error in response to the failure of the start circuitry.

2.6.2.3 Loss of Main Feedwater/Loss of Offsite Power

The dominant failure modes for this transient are again triple failures. The largest contribution to the system unavailability (approximately 47%) is identified in the first four cutsets. These cutsets represent failure of all three pumps. They include combinations of pumps failing to start and loss of power to P8A and/or P8C. The significant primary event contributions include: P8B fails to start; loss of power from bus 1C; loss of power from bus 1D; P8C fails to start; and P8A fails to start.

2.6.2.4 Loss of Main Feedwater/Loss of all AC

The dominant contributors to this transient are single faults. The most significant contribution is the failure of P8B to start (approximately 72%). Other contributors are: maintenance on P8B, its steam pressure regulating valve, or its discharge check valve; and operator restoration errors associated with test and maintenance.

2.6.3 General Conclusions

In comparing the results from generic data versus plant specific data, the calculated system unavailability is not significantly different. The major difference in the results was a reorganization of the importance of the primary events in their contribution to the system unavailability. In the analyses using generic data, the failure of the pump discharge relief valve for P8A and P8B is the dominant contributor in both cutset and primary event contribution. For analyses using plant specific data, the combination of all available pumps failing to start is the dominant contributor in both cutsets and primary event contribution.

In evaluating the results from the analyses using plant specific data, no serious deficiencies were identified. There were no single point vulnerabilities associated with hardware or maintenance identified. Any further changes considered should be made only after careful evaluation of costs, benefits and importance in relation to the results of the analysis of the plant integrated risk model.

3.0 MSLB AFW MODEL

In this section, the reliability of the auxiliary feedwater system as developed for examination of main steam line break issues is discussed (ref CPC to NRC May 23, 1985). The purpose of the main steam line break logic models was to determine the risks associated with steam generator blowdown events and to determine the benefits of various backfits being proposed to minimize these risks. In this regard, assumptions were made that significantly alter the system configuration (ie eliminated redundant portions of the system) and therefore bias the numerical results of the analysis in a way that make it inappropriate to use these logic models for comparison with other risk based AFW reliability analyses such as that presented in the preceding section. Some of the more significant assumptions include:

- those particular to the main steam line break transient which artificially enhance the benefits of some of the proposed backfits,
- those conservative with respect to system reliability that had no affect on the outcome of the main steam line break analysis and were therefore left uncorrected,
- the exclusion of any repair or recovery of failed hardware and
- an explicit attempt to model common cause events (those component failures which result from common manufacturer, function, etc).

The auxiliary feedwater cutsets extracted from the main steam line break report are included in appendix B. They are rearranged into sections to permit an understanding of the contributors to AFW failure (as developed in that specific evaluation) and to identify where the assumptions outlined above had an effect. A brief description of these cutsets follows including a discussion of their contribution to AFW unavailability.

The first group of cutsets include those independent to the auxiliary feedwater system. The independent module (AUX3IT) will be discussed in detail later. The remaining cutset contains a single operator error - AFVOT - which represents failure to increase the flow to the intact steam generator. This cutset results from the assumption that the failed steam generator is isolated following the steam line break event and remains disabled as a viable heat sink throughout the transient. In reality, feedwater can be supplied to this generator, particularly during non-steam line break transients and this operator error should not be a single. In the normal system configuration - AFVOT - would be part of group of doubles in which the second event represented the failure of the redundant flow path from a given pump train. This cutset, therefore, is a result of assumptions made that are peculiar to the steam line break evaluation. Additionally, preliminary analyses in support of the upgrade of emergency procedures indicate that the flow supplied automatically through a single AFW train may be sufficient for decay heat removal.

The second group of cutsets are associated with makeup to the condensate storage tank. Given that there is normally several hours of condensate available in the tank, these failures are more closely associated with the long term functioning of the auxiliary feedwater system than the failures which would be identified in other reliability analyses (such as NUREG 0635). This part of the steam line break analysis did not take credit for operator action to supply makeup from available systems including service water and the fire system, as outlined in plant procedures. In the normal system configuration with service water and fire water included as backups, these cutsets would become substantially lower in their contribution to the system unreliability. These cutsets, therefore, are a result of simplifying assumptions made with respect to auxiliary feedwater reliability that had little effect on the outcome of the steam line break evaluation.

The last group of cutsets identify power dependencies coupled with failures of pumps and flow control valves. The AC power system failures involve disabling of an emergency bus (Bus 1C) which in these models is assumed to take out one motor driven pump and the air pressure to steam supply valves for the steam driven pump. The models conservatively ignore the nitrogen backup to instrument air supply to the steam driven pump valves as well as the ability to operate these valves locally by hand. In the normal system configuration these cutsets would be ANDED with failures of the turbine driven pump train or an operator action to manually admit steam to the pump. Consequently, these cutsets result from uncorrected assumptions which had no affect on the outcome of the steam line break study plus a lack of accounting for repair and recovery actions. Additionally, two of the cutsets contain flow control valve failures which, like AFVOT discussed above, appear because it is assumed that only one steam generator is available. In the normal system configuration these cutsets would also include failures of the redundant flow path from the respective pump train.

The cutsets which remain are those which make up the independent module, AUX3IT, introduced above. The first group presented are those associated with the attempt to explicitly quantify common cause failures in the steam line break evaluation. Common cause events were developed for various classes of equipment in the AFW system including the pumps, air operated valves, and instrumentation required to actuate the system. Generic industry data was used to quantify these events and they end up making up the bulk of the independent module in terms of its probability. Setting the appropriateness of these values aside, there are a number of features of the plant design which deserve some discussion for which credit could be taken to mitigate these failures. Diversity in the pump design has been provided by including both turbine and motor drivers, for example. Also, the motor driven pumps are located in separate areas of the plant minimizing location dependencies. Failure of flow controllers and instrumentation can be overcome by operator action to maintain level in the steam generators rather than concentrate on AFW flow only. In addition, the valves themselves can be operated locally if necessary.

The next cutset is associated with spurious FOGG actuation (Feed Only Good Generator). The assumption that only one steam generator is available enters in to the generation of this cutset. Given that two steam generators are normally available this cutset should be ANDED with failures of components in the other flow trains. In the normal system configuration, this event would be represented by a group of triples involving spurious actuation AND failure of two flow paths. Additionally, it should be noted that FOGG signals for the two steam generators are interlocked such that FOGG isolation of one generator precludes this spurious FOGG signal for the other generator. This interlock was not included in the steam line break logic.

The next group of forty cutsets involve the loss of both flow paths to the unaffected steam generator. Again, this is a set of failures which results from assuming that only one steam generator is available as a heat sink throughout the transient. These cutsets should in fact be coupled with corresponding failures in the flow paths to the other steam generator. In the normal system configuration these cutsets would change to 3d and 4th order cutsets which represent combinations of a pump train and two flow paths; or four flow paths; or three flow paths and an operator action.

The next cutsets deal with the potential for flow diversion in the AFW pump suction. In fact, these failure modes are incorrect. A conservative assumption was made that a Y-strainer in the suction line to the AFW pumps, if left open following maintenance could lead to sufficient diversion of condensate to fail a portion of the system. Subsequent investigation reveals that the line from the strainer is small and will not divert sufficient flow to cause pump suction to drop significantly, is not only valved but capped, and if it were to be left open would result in condensate to pour on the floor of the turbine building where it would be difficult not to notice. These cutsets are a result of conservative modeling assumptions that had no affect on the outcome of the steam line break evaluation and were left uncorrected in the analysis. This failure mode has been deleted from the model.

The next group of cutsets represent human error in the calibration of instrumentation associated with AFW pump and flow control valve operation. Similar to the common cause failure of flow control instrumentation, miscalibration of this equipment will result in the operator taking feedwater flow control into manual in order to maintain steam generator inventory. This recovery action was not included in the steam line break logic. The pump suction pressure miscalibration should be a single event (as was noted in the staffs review of these cutsets). Nevertheless, it should be noted that testing of these instruments independent of their calibration occurs frequently during pump surveillance tests. Further, even if these monthly surveillances were to fail to uncover the deficiency, normal operator response to low suction trip of the AFW pumps would be to provide fire or service water pressure to the pump suction effectively eliminating the low pressure condition. Additionally, steam supply to the turbine driven pump can be provided locally even in the presence of a low suction signal. Again, recovery actions such as these were not incorporated in the steam line break models.

The final group of cutsets found in the independent module are the random pump and valve failures similar to those associated with the reliability analysis presented in the preceding section.

Given the preceding discussion, it should be clear that the main steam line break logic models were not developed with the intention of demonstrating the overall reliability of auxiliary feedwater. Assumptions specific to the main steam line break transient, assumptions that conservatively enhance the benefits of various backfits and conservative assumptions that had no affect on the outcome of the main steam line break evaluation bias the bottom line results. Explicit attempts to model common cause and a lack of obvious repair and recovery actions result in additional bias. While the modelling was sufficient for the purpose of evaluating main steam line break issues, it is not appropriate to use them to draw conclusions as to the strengths and weaknesses of the system for a spectrum of more common transients.

4.0 CONCLUSIONS

As indicated in section 1.0, the purpose of this report is to provide an analysis of the reliability of the AFW system and justification for not equating the results of the MSLB AFW model with system reliability. In section 2.0, the results of a separate reliability analysis are discussed. The results indicate that the system as modified is reliable. Additionally, in a qualitative context the system includes multiple trains any of which is capable of removing decay heat, is automatically actuated, and has no single point vulnerabilities except for perhaps some human errors associated with calibration. These are the features of an AFW system "characterized as having a high reliability" as explicitly outlined in section 4.6.1 of NUREG-0635.

In section 3.0, inconsistencies between the MSLB model and a reliability model were presented. The differences between the special case MSLB model and a general case reliability model are significant and cause a substantial disparity in both numerical and qualitative results. The MSLB model represents the system under unique conditions which do not allow an accurate derivation of the system reliability.

In addition, substantial improvement in the system reliability has been achieved through the completion of modifications as identified in section 1.0.

In conclusion, we believe the system is reliable and that the results of the reliability analysis have not disclosed any serious deficiencies in the current system.

5.0 REFERENCES

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Test and maintenance; and
Human error.

Each of the three master trees was developed for the loss of main feedwater (LMFW) transient condition. For other transient conditions - LMFW with loss of offsite power (LMFW/LOOP) or LMFW with loss of all alternating current power (LMFW/LOAC) - some systems or components are unavailable. Those systems or components were deleted before analysis.

NUREG-0635 was used to establish the top event of the master fault tree, set the initiating events, and as the basic guide for the analysis. The top event is taken from NUREG-0635 which states;

The time interval of interest for all transient events considered is the unavailability of the auxiliary feedwater system during the period of time required to boil the steam generator dry. (Reference 2, page III-10)

The fault tree models were developed assuming statistical independence for hardware/operator failures, human error, and test and maintenance failures.

2.3 CRITERIA AND ASSUMPTIONS

The following analytical criteria and assumptions were used.

- AFW system availability is defined as successful system startup within the steam generator boil dry time of 15 minutes.
- The availability conditions for AFW system power sources during the analyzed transients were as follows;

  1) LMFW - All alternating and direct current power available.

  2) LMFW/LOOP - Two diesel generators and battery backup available.

  3) LMFW/LOAC - Direct current and battery-backed alternating current available (instrument and control power available only)

- Although water from the fire protection system and service water system is available to backup the AFW system condensate storage tank, these sources were not considered in the fault tree analysis. Use of these water systems would require successful operation of manual valves, which is difficult within the 15-minute boil-dry time limit.
- All component and operator actions were assumed to be either successes or failures. No partial successes were considered.
- Top event failure probability will be calculated by summing the failure probabilities from hardware, test and maintenance, and human error contributions. The probabilities for each category are rare event approximations.
- Human error probability has been considered in the Hardware and Test and Maintenance fault trees.
- Component outage due to maintenance will only be considered for active components (pumps, control valves, etc). Maintenance on manual valves is considered negligible.

2.4 DATA SOURCES

Data used for the component failure rates in the hardware and test and maintenance trees was taken from the NRC data found in Appendix III, Table III-3 of NUREG-0635. Electrical tree component data was taken from IEEE Std 500. Human error probabilities were drawn from NUREG-1278 and NUREG-0635. Specific component failure data is listed in Appendix G.

2.5 CORRECTIONS TO FAULT TREES

As part of the preparation for this analysis the fault trees utilized in the second reliability analysis were reviewed for accuracy. Several discrepancies were identified and corrected. Changes made are indicated on the fault trees and discussed below.

2.5.1 Hardware fault tree

1) Operator errors had been treated as independent events. Since, each operator error in this tree involved operator response to a failure of the automatic initiation of the system, it was decided that a high degree of dependence was involved. Based on this decision all operator actions were grouped into three basic types - a) failure to actuate the system from the control room, b) failure to actuate the system locally, and c) failure to manually operate components.

2) The original hardcopy of the model did not identify the primary events representing the failure of preferred ac power for instrumentation and control. These events were added to the model.

3) The failure mode for the motor-operated valves in the AFW flow paths was originally identified as fail to open. These valves are normally open and should be identified as fail to remain open. The correction to the fault trees did not get accomplished. However, in the examination of the system cutsets it was noted that the failure of these valves did contribute significantly to the system unavailability. Therefore, no corrections were made since the only impact was a slight conservatism in the numerical results and relative ranking of cutsets of intermediate to low contribution.

2.5.2 Test and maintenance fault tree

1) As in 2.5.1 (1) above the human error associated with restoration of the outlet valves from the condensate storage tank to the AFW pumps was treated as independent for each valve. Because of the location and basis for restoration (ie if isolation was necessary at that point then both valves must be closed and restored), the separate events were combined into one.

2) Credit was taken for a manual valve which bypasses the pressure control valve in the steam line to the turbine-driven pump. The current PRA model does not take credit for successful operation of this valve. While it may be possible to control steam inlet pressure to the turbine driver by manually regulating a gate valve, the ability to do this efficiently and consistently has not been demonstrated and it was deleted from the model.

3) In several cases, maintenance on valves was included when a) it is not physically possible to isolate these valves during power operation or b) isolation would disable 2 of the 3 pumps which is not allowed by Technical Specifications. Each of these valves was removed from the WAMCUT input deck and are shown lined-out in the model in Appendix E.

2.5.3 Electrical fault trees.

The majority of the failure probabilities for electrical components were derived by treating the components as standby with a monthly testing interval. Since several of the components are performing their normal function and failures associated with them would be immediately detectable, while this treatment is inaccurate its importance was not obvious. Since the failure of power is represented in the master tree as basic events with a probability derived from the output of the evaluation of the appropriate electrical tree, the impact of this treatment was determined by reevaluating the electrical trees and by examining the cutsets from the three transient cases using generic data to determine the importance of loss of power as a contributor to system unavailability.

The reevaluation of the electrical trees was accomplished by changing the failure probability of components which do not experience demands to probabilities of mission time failures of 8 hours (first reevaluation) and 15 minutes (second reevaluation). In general the changes resulted in reduced unavailabilities for the electric power sources.

The examination of system cutsets disclosed that the only case where the failure of electric power was identified as a significant contributor (>1%) to system unavailability was for the transient initiator loss of main feedwater with concurrent loss of offsite power. In this case the failure of bus 1D and/or bus 1C contributed substantially to the system unavailability. However, the change in unavailability (using 8 hour or 15 minute mission times) for these buses under loss of offsite power conditions was insignificant (changed from 3.06E-02 to 3.05E-02). The reason for the lack of difference is that the dominant failures for these buses under loss of offsite power are actual demand failures of the diesel generators and their output breakers.

Based on these results the system fault trees were not rerun with the revised electrical failure data. The results from the analyses with the initial electrical data were retained while recognizing that they were numerically conservative with respect to the electrical failures.

2.6 RESULTS

The results of the analyses of the system fault trees are included in Appendix A and are discussed in the following sections. The information provided in Appendix A is arranged as follows.

Page 1 is a presentation in table form of the numerical unavailabilities of electrical power and the system for each transient case analyzed for both generic and plant specific data. The contributions from hardware, maintenance, and human error were derived by an arbitrary reorganization of cutsets. The reorganization was completed by 1) moving all cutsets containing an operator error to a separate group (human error), 2) of the remaining cutsets any which incuded maintenance were separated into another group (maintenance), and 3) the remaining cutsets were identified as hardware.

The remainder of the Appendix is comprised of listings of the cutsets for each transient case. Pages two through seven involve the output from the use of generic data. Pages eight through thirteen is the output from plant specific data. For each type of data three pages represent unavailabilities from the master hardware tree for each transient and three pages for unavailabilities from all considerations for each transient. Each page includes a listing of dominant cutsets and the contribution of each (cutset unavailability/system unavailability) and a listing of the basic events which contribute substantially to the system unavailability (sum of the unavailabilities of the cutsets containing the basic event/system unavailability).

2.6.1 Results from Generic Data Evaluation

2.6.1.1 General Results

The analysis indicates the factor having the greatest impact on the unavailability in all three cases was failure of the relief valve at the discharge of pumps P8A and P8B failing to remain closed, either as a single or in combination with the unavailability of pump P8C or its flow paths. Other significant contributors are: failure of P8C either as a pump failure or due to loss of bus 1D; maintenance on control valves or check valves; operator error; and various causes of P8C or P8B pump trains (ie maintenance, power failure, or valve failures).

2.6.1.2 Loss of Main Feedwater

The dominant failure modes for this transient are double faults. The most significant cutset contribution is the failure of the pump discharge relief valve to remain closed and the failure of P8C to start. The relief valve failure represents the common mode failure of pumps P8A and P8B. Primary event contributors in order of significance are: failure of the relief valve; failure of P8C to start; maintenance on control valves, check valves and P8C; and operator errors involving restoration of valves after testing or maintenance.

2.6.1.3 Loss of Main Feedwater/Loss of Offsite Power

The dominant failure modes for this transient are also double faults. The most significant cutset contributor is the relief valve and the loss of power to P8C. Primary event contributions in order of importance are: the relief valve; loss of power from bus 1D; P8C fail to start; loss of power from bus 1C; maintenance on control valves, check valves, or P8C; operator restoration errors; and maintenance on P8B, a pressure regulating valve, and a check valve.

2.6.1.4 Loss of Main Feedwater/Loss of all AC

The dominant failure modes for this transient are single faults. The dominant contributors are: the relief valve; maintenance on P8B, its check valve, and its pressure regulating valve; and P8B fails to start and operator restoration errors.

2.6.2 Results from Plant Specific Data Evaluation

2.6.2.1 General Results

The failures representing the largest contribution to unavailability in all three transient is pump fails to start. Other general contributors are: the relief valve failing to remain closed; failure of the auto start circuitry and the operator error associated with placing the system in service.

2.6.2.2 Loss of Main Feedwater

The dominant failures modes for this transient are triple faults. The most significant contribution is made by the first cutset (approximately 24%). This cutset represents the combination of all three pumps failing to start. The more important primary event contributions in order of significance are: P8C fails to start; P8A fails to start; P8C fails to start; the relief valve fails to remain closed; and failure of the auto start circuit and the associated operator error in response to the failure of the start circuitry.

2.6.2.3 Loss of Main Feedwater/Loss of Offsite Power

The dominant failure modes for this transient are again triple failures. The largest contribution to the system unavailability (approximately 47%) is identified in the first four cutsets. These cutsets represent failure of all three pumps. They include combinations of pumps failing to start and loss of power to P8A and/or P8C. The significant primary event contributions include: P8B fails to start; loss of power from bus 1C; loss of power from bus 1D; P8C fails to start; and P8A fails to start.

2.6.2.4 Loss of Main Feedwater/Loss of all AC

The dominant contributors to this transient are single faults. The most significant contribution is the failure of P8B to start (approximately 72%). Other contributors are: maintenance on P8B, its steam pressure regulating valve, or its discharge check valve; and operator restoration errors associated with test and maintenance.

2.6.3 General Conclusions

In comparing the results from generic data versus plant specific data, the calculated system unavailability is not significantly different. The major difference in the results was a reorganization of the importance of the primary events in their contribution to the system unavailability. In the analyses using generic data the failure of the pump discharge relief valve for P8A and P8B is the dominant contributor in both cutset and primary event contribution. For analyses using plant specific data the combination of all available pumps failing to start is the dominant contributor in both cutsets and primary event contribution.

In evaluating the results from the analyses using plant specific data no serious deficiencies were identified. There were no single point vulnerabilities associated with hardware or maintenance identified. Any further changes considered should be made only after careful evaluation of costs, benefits and importance in relation to the results of the analysis of the plant integrated risk model.

3.0 MSLB AFW MODEL

In this section the reliability of the auxiliary feedwater system as developed for examination of main steam line break issues is discussed (ref CPC to NRC May 23, 1985). The purpose of the main steam line break logic models was to determine the risks associated with steam generator blowdown events and to determine the benefits of various backfits being proposed to minimize these risks. In this regard, assumptions were made that significantly alter the system configuration (ie eliminated redundant portions of the system) and therefore bias the numerical results of the analysis in a way that make it inappropriate to use these logic models for comparison with other risk based AFW reliability analyses such as that presented in the preceding section. Some of the more significant assumptions include:

- those particular to the main steam line break transient which artificially enhance the benefits of some of the proposed backfits,
- those conservative with respect to system reliability that had no affect on the outcome of the main steam line break analysis and were therefore left uncorrected,
- the exclusion of any repair or recovery of failed hardware and
- an explicit attempt to model common cause events (those component failures which result from common manufacturer, function, etc).

The auxiliary feedwater cutsets extracted from the main steam line break report are included in appendix B. They are rearranged into sections to permit an understanding of the contributors to AFW failure (as developed in that specific evaluation) and to identify where the assumptions outlined above had an effect. A brief description of these cutsets follows including a discussion of their contribution to AFW unavailability.

The first group of cutsets include those independent to the auxiliary feedwater system. The independent module (AUX3IT) will be discussed in detail later. The remaining cutset contains a single operator error - AFVOT - which represents failure to increase the flow to the intact steam generator. This cutset results from the assumption that the failed steam generator is isolated following the steam line break event and remains disabled as a viable heat sink throughout the transient. In reality, feedwater can be supplied to this generator, particularly during non-steam line break transients and this operator error should not be a single. In the normal system configuration - AFVOT - would be part of group of doubles in which the second event represented the failure of the redundant flow path from a given pump train. This cutset, therefore, is a result of assumptions made that are peculiar to the steam line break evaluation. Additionally, preliminary analyses in support of the upgrade of emergency procedures indicate that the flow supplied automatically through a single AFW train may be sufficient for decay heat removal.

The second group of cutsets are associated with makeup to the condensate storage tank. Given that there is normally several hours of condensate available in the tank, these failures are more closely associated with the long term functioning of the auxiliary feedwater system than the failures which would be identified in other reliability analyses (such as NUREG 0635). This part of the steam line break analysis did not take credit for operator action to supply makeup from available systems including service water and the fire system, as outlined in plant procedures. In the normal system configuration with service water and fire water included as backups these cutsets would become substantially lower in their contribution to the system unreliability. These cutsets, therefore, are a result of simplifying assumptions made with respect to auxiliary feedwater reliability that had little effect on the outcome of the steam line break evaluation.

The last group of cutsets identify power dependencies coupled with failures of pumps and flow control valves. The AC power system failures involve disabling of an emergency bus (Bus 1C) which in these models is assumed to take out one motor driven pump and the air pressure to steam supply valves for the steam driven pump. The models conservatively ignore the nitrogen backup to instrument air supply to the steam driven pump valves as well as the ability to operate these valves locally by hand. In the normal system configuration these cutsets would be ANDED with failures of the turbine driven pump train or an operator action to manually admit steam to the pump. Consequently, these cutsets result from uncorrected assumptions which had no affect on the outcome of the steam line break study plus a lack of accounting for repair and recovery actions. Additionally, two of the cutsets contain flow control valve failures which, like AFVOT discussed above, appear because it is assumed that only one steam generator is available. In the normal system configuration these cutsets would also include failures of the redundant flow path from the respective pump train.

The cutsets which remain are those which make up the independent module, AUX3IT, introduced above. The first group presented are those associated with the attempt to explicitly quantify common cause failures in the steam line break evaluation. Common cause events were developed for various classes of equipment in the AFW system including the pumps, air operated valves, and instrumentation required to actuate the system. Generic industry data was used to quantify these events and they end up making up the bulk of the independent module in terms of its probability. Setting the appropriateness of these values aside, there are a number of features of the plant design which deserve some discussion for which credit could be taken to mitigate these failures. Diversity in the pump design has been provided by including both turbine and motor drivers, for example. Also, the motor driven pumps are located in separate areas of the plant minimizing location dependencies. Failure of flow controllers and instrumentation can be overcome by operator action to maintain level in the steam generators rather than concentrate on AFW flow only. In addition, the valves themselves can be operated locally if necessary. (Barry, is any of this part of current procedures?)

The next cutset is associated with spurious FOGG actuation (Feed Only Good Generator). The assumption that only one steam generator is available enters in to the generation of this cutset. Given that two steam generators are normally available this cutset should be ANDED with failures of components in the other flow trains. In the normal system configuration this event would be represented by a group of triples involving spurious actuation AND failure of two flow paths. Additionally, it should be noted that FOGG signals for the two steam generators are interlocked such that FOGG isolation of one generator precludes this spurious FOGG signal for the other generator. This interlock was not included in the steam line break logic.

The next group of forty cutsets involve the loss of both flow paths to the unaffected steam generator. Again, this is a set of failures which results from assuming that only one steam generator is available as a heat sink throughout the transient. These cutsets should in fact be coupled with corresponding failures in the flow paths to the other steam generator. In the normal system configuration these cutsets would change to 3d and 4th order cutsets which represent combinations of a pump train and two flow paths; or four flow paths; or three flow paths and an operator action.

The next cutsets deal with the potential for flow diversion in the AFW pump suction. In fact, these failure modes are incorrect. A conservative assumption was made that a Y-strainer in the suction line to the AFW pumps, if left open following maintenance could lead to sufficient diversion of condensate to fail a portion of the system. Subsequent investigation reveals that the line from the strainer is small and will not divert sufficient flow to cause pump suction to drop significantly, is not only valved but capped, and if it were to be left open would result in condensate to pour on the floor of the turbine building where it would be difficult not to notice. These cutsets are a result of conservative modeling assumptions that had no affect on the outcome of the steam line break evaluation and were left uncorrected in the analysis. This failure mode has been deleted from the model.

The next group of cutsets represent human error in the calibration of instrumentation associated with AFW pump and flow control valve operation. Similar to the common cause failure of flow control instrumentation, miscalibration of this equipment will result in the operator taking feedwater flow control into manual in order to maintain steam generator inventory. This recovery action was not included in the steam line break logic. The pump suction pressure miscalibration should be a single event (as was noted in the staffs review of these cutsets). Nevertheless, it should be noted that testing of these instruments independent of their calibration occurs frequently during pump surveillance tests. Further, even if these monthly surveillances were to fail to uncover the deficiency, normal operator response to low suction trip of the AFW pumps would be to provide fire or service water pressure to the pump suction effectively eliminating the low pressure condition. Additionally, steam supply to the turbine driven pump can be provided locally even in the presence of a low suction signal. Again, recovery actions such as these were not incorporated in the steam line break models.

The final group of cutsets found in the independent module are the random pump and valve failures similar to those associated with the reliability analysis presented in the preceding section.

Given the preceding discussion, it should be clear that the main steam line break logic models were not developed with the intention of demonstrating the overall reliability of auxiliary feedwater. Assumptions specific to the main steam line break transient, assumptions that conservatively enhance the benefits of various backfits and conservative assumptions that had no affect on the outcome of the main steam line break evaluation bias the bottom line results. Explicit attempts to model common cause and a lack of obvious repair and recovery actions result in additional bias. While the modelling was sufficient for the purpose of evaluating main steam line break issues, it is not appropriate to use them to draw conclusions as to the strengths and weaknesses of the system for a spectrum of more common transients.

4.0 CONCLUSIONS

As indicated in section 1.0 the purpose of this report is to provide an analysis of the reliability of the AFW system and justification for not equating the results of the MSLB AFW model with system reliability. In section 2.0 the results of a separate reliability analysis are discussed. The results indicate that the system as modified is reliable. Additionally in a qualitative context the system includes multiple trains any of which is capable of removing decay heat, is automatically actuated, and has no single point vulnerabilities except for perhaps some human errors associated with calibration. These are the features of an AFW system "characterized as having a high reliability" as explicitly outlined in section 4.6.1 of NUREG-0635.

In section 3.0 inconsistencies between the MSLB model and a reliability model were presented. The differences between the special case MSLB model and a general case reliability model are significant and cause a substantial disparity in both numerical and qualitative results. The MSLB model represents the system under unique conditions which do not allow an accurate derivation of the system reliability.

In addition, substantial improvement in the system reliability has been achieved through the completion of modifications as identified in section 1.0.

In conclusion we believe the system is reliable and that the results of the reliability analysis have not disclosed any serious deficiencies in the current system.

5.0 REFERENCES

1. Guide to the Collection and Presentation of Electrical, Electronic, and Sensing Component Reliability Data for, Nuclear Power Generating Stations, IEEE Std 500 (1977), Institute of Electrical and Electronics Engineers, Inc.

2. Generic Evaluation of Feedwater Transients and Small Break Loss of Coolant Accidents in Combustion Engineering Designed Operating Plants, NUREG-0635, U.S. Nuclear Regulatory Commission, January 1980.

3. Handbook of Human Reliability Analysis with Emphasis on Nuclear Power Plant Applications, NUREG/CR-1278, U.S. Nuclear Regulatory Commission, April 1980.

4. Reactor Safety Study: An Assessment of Accident Risks in U.S. Commercial Nuclear Power Plants, WASH-1400, U.S. Nuclear Regulatory Commission, 1975.

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6. Clarification of TMI Action Plan Requirements, NUREG-0737, U.S. Nuclear Regulatory Commission, October 1980.

7. Auxiliary Feedwater System (PWR), NUREG-0800, Standard Review Plan 10.4.9, U.S. Nuclear Regulatory Commission, July 1981.

APPENDIX A

SYSTEM UNAVAILABILITY RESULTS

APPENDIX A

AFW SYSTEM UNAVAILABILITIES

CONTRIBUTORS TO UNAVAILABILITY	LOSS OF FEEDWATER	LOSS OF OFFSITE POWER	LOSS OF ALL AC POWER
(GENERIC DATA)			
HARDWARE	2.04E-05	1.34E-04	5.03E-03
MAINTENANCE	3.15E-05	3.99E-05	6.46E-03
HUMAN ERROR	1.49E-05	1.76E-05	2.02E-03
TOTAL	6.68E-05	1.91E-04	1.35E-02
(PLANT SPECIFIC DATA)			
HARDWARE	1.17E-05	7.05E-05	3.11E-02
MAINTENANCE	9.17E-06	3.33E-05	8.30E-03
HUMAN ERROR	7.47E-06	1.71E-05	2.04E-03
TOTAL	2.83E-05	1.21E-04	4.14E-02

CONDITIONAL UNAVAILABILITIES OF THE ELECTRICAL POWER SUPPLY

	NO ESSENTIAL POWER AVAILABLE FROM		
CASE	AC BUS Y10(Y20)	DC BUS #1(#2)	AC BUS 1C(1D)
(GENERIC DATA)			
1	6.52E-05	6.39E-05	9.40E-05
2	7.88E-05	7.60E-05	3.06E-02
3	2.83E-03	1.67E-03	1.0
(PLANT SPECIFIC DATA)			
1	1.04E-05	3.12E-05	1.21E-05(1.03E-05)
2	1.07E-05	3.13E-05	3.43E-02(2.35E-02)
3	2.20E-04	1.15E-04	1.0

CASE 1 - LOSS OF MAIN FEEDWATER

CASE 2 - LOSS OF MAIN FEEDWATER & LOSS OF OFFSITE POWER

CASE 3 - LOSS OF MAIN FEEDWATER & LOSS OF ALL AC POWER

APPENDIX A

GENERIC DATA

DOMINANT HARDWARE CUT SETS AND BASIC EVENTS

LOSS OF MAIN FEEDWATER

RANK	UNAVAILABILITY	CUT SETS		CONTRIBUTION
1.	1.83E-05	PS8C	RV0783	91.6
2.	3.65E-07	GV0752	RV0783	1.8
2.	3.65E-07	CK0726	RV0783	1.8
2.	3.65E-07	GV0751	RV0783	1.8
2.	3.65E-07	CK0725	RV0783	1.8
3.	3.43E-07	EAC1D	RV0783	1.7
4.	2.38E-07	EACY20	RV0783	1.2

RANK	UNAVAILABILITY	BASIC EVENT	CONTRIBUTION
1.	3.65E-03	RV0783	99.5
2.	5.00E-03	PS8C	91.8
3.	1.00E-04	CK0725	1.8
3.	1.00E-04	CK0726	1.8
3.	1.00E-04	GV0751	1.8
3.	1.00E-04	GV0752	1.8
4.	9.40E-05	EAC1D	1.7
5.	6.52E-05	EACY20	1.2

APPENDIX A

GENERIC DATA

DOMINANT HARDWARE CUT SETS AND BASIC EVENTS

LOSS OF MAIN FEEDWATER AND LOSS OF OFFSITE POWER

RANK	UNAVAILABILITY	CUT SETS			CONTRIBUTION
1.	1.12E-04	EAC1D	RV0783		83.5
2.	1.83E-05	PS8C	RV0783		13.7
3.	9.36E-07	EAC1C	EAC1D	PS8B	0.7
4.	3.65E-07	GV0752	RV0783		0.3
4.	3.65E-07	GV0751	RV0783		0.3
4.	3.65E-07	CK0726	RV0783		0.3
4.	3.65E-07	CK0725	RV0783		0.3

RANK	UNAVAILABILITY	BASIC EVENT	CONTRIBUTION
1.	3.65E-03	RV0783	98.5
2.	3.06E-02	EAC1D	81.2
3.	5.00E-03	PS8C	17.3
4.	3.06E-02	EAC1C	1.2
5.	1.00E-03	PS8B	1.0
6.	1.00E-04	CK0725	0.3
6.	1.00E-04	CK0726	0.3
6.	1.00E-04	GV0751	0.3
6.	1.00E-04	GV0752	0.3

APPENDIX A

GENERIC DATA

DOMINANT HARDWARE CUT SETS AND BASIC EVENTS

LOSS OF MAIN FEEDWATER AND LOSS OF ALL ALTERNATING CURRENT

RANK	UNAVAILABILITY	CUT SETS	CONTRIBUTION
1.	3.65E-03	RV0783	72.6
2.	1.00E-03	PS8B	19.9
3.	1.00E-04	GV0742	2.0
3.	1.00E-04	CK0743	2.0
3.	1.00E-04	GV0132	2.0
4.	6.53E-05	GOVERNOR	1.3
5.	1.00E-05	PCV0521A	0.2

RANK	UNAVAILABILITY	BASIC EVENT	CONTRIBUTION
1.	3.65E-03	RV0783	72.6
2.	1.00E-03	PS8B	19.9
3.	1.00E-04	GV0742	2.0
3.	1.00E-04	CK0743	2.0
3.	1.00E-04	GV0132	2.0
4.	6.53E-05	GOVERNOR	1.3
5.	1.00E-05	PCV0521A	0.2

APPENDIX A

GENERIC DATA

DOMINANT CONTRIBUTORS TO CONDITIONAL UNAVAILABILITY

LOSS OF MAIN FEEDWATER

RANK	UNAVAILABILITY	CUT SETS		CONTRIBUTION
1.	1.83E-05	PS8C	RV0783	27.4
2.	7.81E-06	MCV0736A	RV0783	11.7
2.	7.81E-06	MCV0737A	RV0783	11.7
2.	7.81E-06	MCK0726	RV0783	11.7
2.	7.81E-06	MP8C	RV0783	11.7
3.	3.65E-06	OPE210	RV0783	5.5
3.	3.65E-06	OPE205	RV0783	5.5
3.	3.65E-06	OPE108	RV0783	5.5
3.	3.65E-06	OPE107	RV0783	5.5

RANK	UNAVAILABILITY	BASIC EVENT	CONTRIBUTION
1.	3.65E-03	RV0783	99.1
2.	5.00E-03	PS8C	27.8
3.	2.14E-03	MCV0736A	11.7
3.	2.14E-03	MCV0737A	11.7
3.	2.14E-03	MCK0726	11.7
3.	2.14E-03	MP8C	11.7
3.	1.00E-03	OPE210	5.5
3.	1.00E-03	OPE205	5.5
3.	1.00E-03	OPE108	5.5
3.	1.00E-03	OPE107	5.5

APPENDIX A

GENERIC DATA

DOMINANT CONTRIBUTORS TO CONDITIONAL UNAVAILABILITY

LOSS OF MAIN FEEDWATER AND LOSS OF OFFSITE POWER

RANK	UNAVAILABILITY	CUT SETS			CONTRIBUTION
1.	1.12E-04	EAC1D	RV0783		58.5
2.	1.83E-05	PS8C	RV0783		9.6
3.	7.81E-06	MCV0736A	RV0783		4.1
3.	7.81E-06	MCV0737A	RV0783		4.1
3.	7.81E-06	MCK0726	RV0783		4.1
3.	7.81E-06	MP8C	RV0783		4.1
4.	3.65E-06	OPE210	RV0783		1.9
4.	3.65E-06	OPE205	RV0783		1.9
4.	3.65E-06	OPE108	RV0783		1.9
4.	3.65E-06	OPE107	RV0783		1.9
5.	2.00E-06	EAC1C	EAC1D	MCK0743	1.0
5.	2.00E-06	EAC1C	EAC1D	MP8B	1.0
5.	2.00E-06	EAC1C	EAC1D	MPCV521A	1.0

RANK	UNAVAILABILITY	BASIC EVENT	CONTRIBUTION
1.	3.65E-03	RV0783	93.0
2.	3.06E-02	EAC1D	64.2
3.	5.00E-03	PS8C	10.5
4.	3.06E-02	EAC1C	5.8
5.	2.14E-03	MCV0736A	4.1
5.	2.14E-03	MCV0737A	4.1
5.	2.14E-03	MCK0726	4.1
5.	2.14E-03	MP8C	4.1
6.	1.00E-03	OPE210	1.9
6.	1.00E-03	OPE205	1.9
6.	1.00E-03	OPE108	1.9
6.	1.00E-03	OPE107	1.9
7.	2.14E-03	MCK0743	1.4
7.	2.14E-03	MP8B	1.4
7.	2.14E-03	MPCV521A	1.4

APPENDIX A

GENERIC DATA

DOMINANT CONTRIBUTORS TO CONDITIONAL UNAVAILABILITY

LOSS OF MAIN FEEDWATER AND LOSS OF ALL ALTERNATING CURRENT

RANK	UNAVAILABILITY	CUT SETS	CONTRIBUTION
1.	3.65E-03	RV0783	27.2
2.	2.14E-03	MCK0743	15.8
3.	2.14E-03	MP8B	15.8
3.	2.14E-03	MPCV521A	15.8
4.	1.00E-03	PS8B	7.4
4.	1.00E-03	OPE102	7.4
4.	1.00E-03	OPE101	7.4
5.	1.00E-04	GV0742	0.7
5.	1.00E-04	CK0743	0.7
5.	1.00E-04	GV0132	0.7
6.	6.53E-05	GOVERNOR	0.5
6.	1.00E-05	PCV0521A	0.1

RANK	UNAVAILABILITY	BASIC EVENT	CONTRIBUTION
1.	3.65E-03	RV0783	27.2
2.	2.14E-03	MCK0743	15.8
3.	2.14E-03	MP8B	15.8
3.	2.14E-03	MPCV521A	15.8
4.	1.00E-03	PS8B	7.4
4.	1.00E-03	OPE102	7.4
4.	1.00E-03	OPE101	7.4
5.	1.00E-04	GV0742	0.7
5.	1.00E-04	CK0743	0.7
5.	1.00E-04	GV0132	0.7
6.	6.53E-05	GOVERNOR	0.5
6.	1.00E-05	PCV0521A	0.1

APPENDIX A

PLANT SPECIFIC DATA

DOMINANT HARDWARE CUT SETS AND BASIC EVENTS

LOSS OF MAIN FEEDWATER

RANK	UNAVAILABILITY	CUT SETS			CONTRIBUTION
1.	6.75E-06	PS8A	PS8B	PS8C	46.5
2.	2.55E-06	PS8C	RV0783		17.6
3.	2.10E-06	AFAS	OPE1	PS8B	14.5
4.	7.00E-07	AFAS	OPE1	OPE2	4.8
5.	1.94E-07	CV0727	CV0749	PS8C	1.3
6.	1.53E-07	CK0741	PS8B	PS8C	1.1
6.	1.53E-07	CK0726	PS8A	PS8B	1.1
6.	1.53E-07	CK0725	PS8A	PS8B	1.1
7.	1.51E-07	CV0749	MO0798	PS8C	1.0
7.	1.51E-07	CV0749	MO0743	PS8C	1.0
7.	1.51E-07	CV0727	MO0760	PS8C	1.0
7.	1.51E-07	CV0727	MO0753	PS8C	1.0

RANK	UNAVAILABILITY	BASIC EVENT	CONTRIBUTION
1.	1.50E-02	PS8C	76.3
2.	3.00E-02	PS8B	65.2
3.	1.50E-02	PS8A	50.4
4.	7.00E-03	AFAS	19.5
4.	1.00E-03	OPE1	19.5
5.	1.70E-04	RV0783	18.7
6.	1.00E-03	OPE2	4.8
7.	3.60E-03	CV0727	3.5
7.	3.60E-03	CV0749	3.5
8.	2.80E-03	MO0798	2.8
8.	2.80E-03	MO0760	2.8
8.	2.80E-03	MO0753	2.8
8.	2.80E-03	MO0743	2.8
9.	3.40E-04	CK0725	1.5
9.	3.40E-04	CK0726	1.5
10.	3.40E-04	CK0741	1.1

APPENDIX A

PLANT SPECIFIC DATA

DOMINANT HARDWARE CUT SETS AND BASIC EVENTS

LOSS OF MAIN FEEDWATER AND LOSS OF OFFSITE POWER

RANK	UNAVAILABILITY	CUT SETS			CONTRIBUTION
1.	2.41E-05	EAC1C	EAC1D	PS8B	32.8
2.	1.54E-05	EAC1C	PS8B	PS8C	21.0
3.	1.06E-05	EAC1D	PS8A	PS8B	14.4
4.	6.75E-06	PS8A	PS8B	PS8C	9.2
5.	4.00E-06	EAC1D	RV0783		5.5
4.	2.55E-06	PS8C	RV0783		3.5
16.	2.10E-06	AFAS	OPE1	PS8B	2.9
13.	7.00E-07	AFAS	OPE1	OPE2	1.0

RANK	UNAVAILABILITY	BASIC EVENT	CONTRIBUTION
1.	3.00E-02	PS8B	83.0
2.	2.35E-02	EAC1D	57.4
3.	3.43E-02	EAC1C	56.5
4.	1.50E-02	PS8C	36.6
5.	1.50E-02	PS8A	24.8
6.	1.70E-04	RV0783	9.1
7.	7.00E-03	AFAS	3.9
8.	1.00E-03	OPE1	3.9
9.	1.00E-03	OPE2	1.0

APPENDIX A

PLANT SPECIFIC DATA

DOMINANT HARDWARE CUT SETS AND BASIC EVENTS

LOSS OF MAIN FEEDWATER AND LOSS OF ALL ALTERNATING CURRENT

RANK	UNAVAILABILITY	CUT SETS		CONTRIBUTION
1.	3.00E-02	PS8B		96.5
2.	3.40E-04	CK0743		1.1
3.	1.70E-04	RV0783		0.5
4.	1.10E-04	CV0522A	CV0522B	0.4
5.	1.00E-04	PCV0521A		0.3
5.	8.70E-05	GV0742		0.3
5.	8.70E-05	GV0132		0.3
6.	6.53E-05	GOVERNOR		0.2

RANK	UNAVAILABILITY	BASIC EVENT	CONTRIBUTION
1.	3.00E-02	PS8B	96.5
2.	3.40E-04	CK0743	1.1
3.	1.70E-04	RV0783	0.5
4.	1.10E-04	CV0522A	0.4
4.	1.00E-02	CV0522B	0.4
5.	1.00E-04	PCV0521A	0.3
5.	8.70E-05	GV0742	0.3
5.	8.70E-05	GV0132	0.3
6.	6.53E-05	GOVERNOR	0.2

APPENDIX A

PLANT SPECIFIC DATA

DOMINANT CONTRIBUTORS TO CONDITIONAL UNAVAILABILITY

LOSS OF MAIN FEEDWATER

RANK	UNAVAILABILITY	CUT SETS			CONTRIBUTION
1.	6.75E-06	PS8A	PS8B	PS8C	23.8
2.	2.55E-06	PS8C	RV0783		9.0
3.	2.10E-06	AFAS	OPE1	PS8B	7.4
4.	9.63E-07	MCV0737A	PS8A	PS8B	3.4
4.	9.63E-07	MCV0736A	PS8A	PS8B	3.4
4.	9.63E-07	MCK0741	PS8B	PS8C	3.4
4.	9.63E-07	MCK0726	PS8A	PS8B	3.4
5.	8.78E-07	MP8B	PS8A	PS8C	3.1
6.	7.00E-07	AFAS	OPE1	OPE2	2.5
7.	4.82E-07	MPCV521A	PS8A	PS8C	1.7
7.	4.82E-07	MCK0743	PS8A	PS8C	1.7
8.	4.50E-07	OPE210	PS8A	PS8B	1.7
8.	4.50E-07	OPE205	PS8A	PS8B	1.7
8.	4.50E-07	OPE108	PS8A	PS8B	1.7
8.	4.50E-07	OPE107	PS8A	PS8B	1.7
8.	4.50E-07	OPE102	PS8B	PS8C	1.7
8.	4.50E-07	OPE101	PS8B	PS8C	1.7
9.	3.64E-07	MCV0737A	RV0783		1.3
9.	3.64E-07	MCV0736A	RV0783		1.3
9.	3.64E-07	MCK0726	RV0783		1.3
29.	2.73E-07	AFAS	MP8B	OPE1	1.0

RANK	UNAVAILABILITY	BASIC EVENT	CONTRIBUTION
1.	3.00E-02	PS8C	57.8
2.	1.50E-02	PS8A	57.7
3.	1.50E-02	PS8B	51.6
4.	1.70E-04	RV0783	16.1
5.	7.00E-03	AFAS	12.6
5.	1.00E-03	OPE1	12.6
6.	2.14E-03	MCV0736A	5.5
6.	2.14E-03	MCV0737A	5.5
6.	2.14E-03	MCK0726	5.5
7.	3.90E-03	MP8B	4.3
8.	2.14E-03	MCK0741	3.6
8.	3.20E-04	CV0727	3.6
8.	3.20E-04	CV0749	3.6
9.	2.80E-03	MO0798	2.6
9.	2.80E-03	MO0760	2.6
9.	2.80E-03	MO0753	2.6
9.	2.80E-03	MO0743	2.6
10.	1.00E-03	OPE210	2.4
10.	1.00E-03	OPE205	2.4
10.	1.00E-03	OPE108	2.4
10.	1.00E-03	OPE107	2.4
11.	2.14E-03	MPCV521A	2.3
11.	2.14E-03	MCK0743	2.3
12.	1.00E-03	OPE102	1.6
12.	1.00E-03	OPE101	1.6

APPENDIX A

PLANT SPECIFIC DATA

DOMINANT CONTRIBUTORS TO CONDITIONAL UNAVAILABILITY

LOSS OF MAIN FEEDWATER AND LOSS OF OFFSITE POWER

RANK	UNAVAILABILITY	CUT SETS			CONTRIBUTION
1.	2.41E-05	EAC1C	EAC1D	PS8B	19.9
2.	1.54E-05	EAC1C	PS8B	PS8C	12.7
3.	1.06E-05	EAC1D	PS8A	PS8B	8.8
4.	6.75E-06	PS8A	PS8B	PS8C	5.6
5.	4.00E-06	EAC1D	RV0783		3.3
6.	3.14E-06	EAC1C	EAC1D	MP8B	2.6
7.	2.55E-06	PS8C	RV0783		2.1
8.	2.20E-06	EAC1C	MCV0737A	PS8B	1.8
8.	2.20E-06	EAC1C	MCV0736A	PS8B	1.8
8.	2.20E-06	EAC1C	MCK0726	PS8B	1.8
9.	2.10E-06	AFAS	OPE1	PS8B	1.7
9.	2.01E-06	EAC1C	MP8B	PS8C	1.7
10.	1.72E-06	EAC1C	EAC1D	MPCV521A	1.4
10.	1.72E-06	EAC1C	EAC1D	MCK0743	1.4
11.	1.51E-06	EAC1D	MCK0741	PS8B	1.2
12.	1.37E-06	EAC1D	MP8B	PS8A	1.1
13.	1.10E-06	EAC1C	MPCV521A	PS8C	1.0
13.	1.10E-06	EAC1C	MCK0743	PS8C	1.0
13.	1.03E-06	EAC1C	OPE210	PS8B	1.0 (0.8)
13.	1.03E-06	EAC1C	OPE205	PS8B	1.0
13.	1.03E-06	EAC1C	OPE108	PS8B	1.0
13.	1.03E-06	EAC1C	OPE107	PS8B	1.0

RANK	UNAVAILABILITY	BASIC EVENT	CONTRIBUTION
1.	3.00E-02	PS8B	8.2
2.	3.42E-02	EAC1C	5.4
3.	2.35E-02	EAC1D	8.7
4.	1.50E-02	PS8C	1.1
5.	1.50E-02	PS8A	4.2
6.	1.70E-04	RV0783	7.0
7.	3.90E-03	MP8B	6.5
8.	2.14E-03	MPCV521A	3.6
8.	2.14E-03	MCK0743	3.6
9.	2.14E-03	MCV0736A	3.2
9.	2.14E-03	MCV0737A	3.2
9.	2.14E-03	MCK0726	3.2
10.	7.00E-03	AFAS	2.9
10.	1.00E-03	OPE1	2.9
11.	2.14E-03	MCK0741	2.1
12.	1.00E-03	OPE104	1.6
12.	1.00E-03	OPE103	1.6
13.	1.00E-03	OPE210	1.4
13.	1.00E-03	OPE205	1.4
13.	1.00E-03	OPE108	1.4
13.	1.00E-03	OPE107	1.4

APPENDIX A

PLANT SPECIFIC DATA

DOMINANT CONTRIBUTORS TO CONDITIONAL UNAVAILABILITY

LOSS OF MAIN FEEDWATER AND LOSS OF ALL ALTERNATING CURRENT

RANK	UNAVAILABILITY	CUT SETS		CONTRIBUTION
1.	3.00E-02	PS8B		72.4
2.	3.90E-03	MP8B		9.4
3.	2.14E-03	MPCV521A		5.2
3.	2.14E-03	MCK0743		5.2
4.	1.00E-03	OPE102		2.4
4.	1.00E-03	OPE101		2.4
5.	5.00E-04	PCV0521A		1.2
6.	3.20E-04	CK0743		0.8
7.	1.70E-04	RV0783		0.4
8.	1.10E-04	CV0522A	CV0522B	0.3
9.	8.14E-05	GV0742		0.2
9.	8.14E-05	GV0132		0.2
10.	6.53E-05	GOVERNOR		0.2

RANK	UNAVAILABILITY	BASIC EVENT	CONTRIBUTION
1.	3.00E-02	PS8B	72.4
2.	3.90E-03	MP8B	9.4
3.	2.14E-03	MPCV521A	5.2
3.	2.14E-03	MCK0743	5.2
4.	1.00E-03	OPE102	2.4
4.	1.00E-03	OPE101	2.4
5.	5.00E-04	PCV0521A	1.2
6.	3.20E-04	CK0743	0.8
7.	1.70E-04	RV0783	0.4
7.	1.10E-04	CV0522A	0.4
7.	1.10E-04	CV0522B	0.4
8.	8.14E-05	GV0742	0.2
8.	8.14E-05	GV0132	0.2
9.	6.53E-05	GOVERNOR	0.2

APPENDIX B

MSLB AFW MODEL CUTSETS

APPENDIX B

AFW3 P = 5.0E-03

The following cutsets are independent to AFW

1.	2.40E-03	AUX3IT		See indep transfer description
3.	5.00E-04	AFVOT		Op fail to incr flow to good SG

The following cutsets are associated with makeup to the condensate storage tank

2.	5.63E-04	CONDTKIT		Condensate makeup indep failures
4.	3.89E-04	P221IT	XXV713MA	Loss of power to auto makeup valve and alt makeup supply failures
5.	3.89E-04	P221IT	XXV712MA	
6.	2.88E-04	P221IT	XXV107MB	
7.	5.64E-05	P221IT	XXV171MA	
8.	4.28E-05	POOLOOP	XXV712MA	
9.	4.28E-05	POOLOOP	XXV713MA	
10.	3.16E-05	POOLOOP	XXV107MB	
11.	1.96E-05	EDG11MG	POOLOOP	
12.	1.28E-05	P221IT	XOO90-02OT	
13.	1.19E-05	EDG11OO	POOLOOP	
14.	6.18E-06	POOLOOP	XXV171MA	
16.	4.28E-06	EDG11ME	POOLOOP	
17.	4.13E-06	P205DIT	POOLOOP	
18.	3.13E-06	P221IT	XLS5201MC	
19.	2.15E-06	P221IT	PCBB#105MA	
20.	2.10E-06	PTRSU1-2MT	XXV712MA	
21.	2.10E-06	PTRSU1-2MT	XXV713MA	
23.	1.66E-06	P410IT	XXV713MA	
24.	1.66E-06	P410IT	XXV712MA	
25.	1.56E-06	PTRSU1-2MT	XXV107MB	
26.	1.40E-06	POOLOOP	XOO90-02OT	
29.	1.22E-06	P410IT	XXV107MB	

The following cutsets are associated with random failures of combinations of pumps and flow control valves

15.	5.32E-06	APM8CME	PCBB#105MA	Loss of Bus 1C and Pump C
22.	2.03E-06	PCBB#105MA	PCBB#209MB	
27.	1.28E-06	AAV0749MA	PCBB#203MA	Loss of Bus 1D and Trains A&B
28.	1.28E-06	AAV0737AMA	PCBB#105MA	Loss of Bus 1C and Train C

AUX3IT -- INDEPENDENT MODULE

The following cutsets are common cause failures derived using generic industry data

1.	1.00E-03	APM8ME2CC	Pumps fail to start
3.	2.50E-04	ASGFCV8CC	Flow controller malfunction
4.	8.10E-05	ATFFCV8CC	Flow transmitter failure
6.	4.80E-05	AAVFCV4CC	Flow control valve failure
16.	1.30E-05	APM8MG2CC	Pumps fail to run

AUX3IT Continued

The following cutset is spurious FOGG isolation

2.	3.80E-04	ASSLMBMT	

The following cutsets are loss of both flow paths or one flow path with pump failure(s) in the remaining train

5.	5.40E-05	AAV0749MA	APM8CME	
7.	3.90E-05	AMV0760MD	APM8CME	
8.	3.90E-05	AMV0753MD	APM8CME	
9.	2.40E-05	AFC0749MT	APM8CME	
11.	2.05E-05	AAV0749MA	PCBB#209MB	
13.	1.48E-05	AMV0753MD	PCBB#209MB	
14.	1.48E-05	AMV0760MD	PCBB#209MB	
15.	1.30E-05	AAV0737AMA	AAV0749MA	
18.	9.36E-06	AAV0749MA	APM8CMG	
19.	9.36E-06	AAV0737AMA	AMV0760MD	
20.	9.36E-06	AAV0749MA	AMV0754MD	
21.	9.36E-06	AAV0749MA	AMV0759MD	
22.	9.36E-06	AAV0737AMA	AMV0753MD	
23.	9.12E-06	AFC0749MT	PCBB#209MB	
25.	6.76E-06	AMV0753MD	AMV0759MD	
26.	6.76E-06	AMV0759MD	AMV0760MD	
27.	6.76E-06	AMV0760MD	APM8CMG	
28.	6.76E-06	AMV0753MD	AMV0754MD	
29.	6.76E-06	AMV0753MD	APM8CMG	
30.	6.76E-06	AMV0754MD	AMV0760MD	
32.	5.76E-06	AAV0749MA	AFC0737AMT	
33.	5.76E-06	AAV0737AMA	AFC0749MT	
37.	4.80E-06	ACV0729MA	APM8CME	
38.	4.16E-06	AFC0737AMT	AMV0753MD	
39.	4.16E-06	AFC0749MT	APM8CMG	
40.	4.16E-06	AFC0737AMT	AMV0760MD	
41.	4.16E-06	AFC0749MT	AMV0759MD	
42.	4.16E-06	AFC0749MT	AMV0754MD	
46.	2.56E-06	AFC0737AMT	AFC0749MT	
49.	2.40E-06	AIP0749MT	APM8CME	
51.	1.82E-06	ACV0729MA	PCBB#209MB	
53.	1.62E-06	AAV0737AMA	APM8AME	APM8BME
54.	1.50E-06	APM8CME	ARE3P8ABMA	
55.	1.43E-06	AFE0749MK	APM8CME	
58.	1.17E-06	AMV0759MD	APM8AME	APM8BME
60.	1.17E-06	AMV0754MD	APM8AME	APM8BME
61.	1.15E-06	AAV0749MA	ACV0704MA	
62.	1.15E-06	AAV0749MA	ACV0725MA	
63.	1.15E-06	AAV0749MA	ACV0726MA	
64.	1.15E-06	AAV0737AMA	ACV0729MA	

APPENDIX B

AUX3IT Continued

The following cutsets represent pump suction flow diversion

10.	3.00E-05	APM8CME	AXV505MC	Y-strainer at suction of pumps A & B
17.	1.14E-05	AXV505MC	PCBB#209MB	
24.	7.20E-06	AAV0737AMA	AXV505MC	
34.	5.20E-06	AMV0759MD	AXV505MC	
35.	5.20E-06	APM8CMG	AXV505MC	
36.	5.20E-06	AMV0754MD	AXV505MC	
45.	3.20E-06	AFC0737AMT	AXV505MC	

The following cutsets result from human error (instrument calibration)

12.	1.60E-05	INSTRABCOH		Flow control calibration
52.	1.65E-06	APM8CME	INSTRUABOH	
43.	3.90E-06	APSP8ACOH	APM8BME	Suction pressure calibration
57.	1.30E-06	APSP8ACOH	ATBK8MG	

The following cutsets are random pump failures

31.	6.75E-06	APM8AME	APM8BME	APM8CME
44.	2.56E-06	APM8AME	APM8BME	PCBB#209MB
47.	2.56E-06	APM8BME	APM8CME	PCBB#104MB
48.	2.40E-06	APM8CME	ARV0783MC	
50.	2.25E-06	APM8AME	APM8CME	ATBK8MG
56.	1.17E-06	APM8AME	APM8BME	APM8CMG
59.	1.17E-06	APM8AMG	APM8BME	APM8CME

APPENDIX C

FIGURES AND DRAWINGS

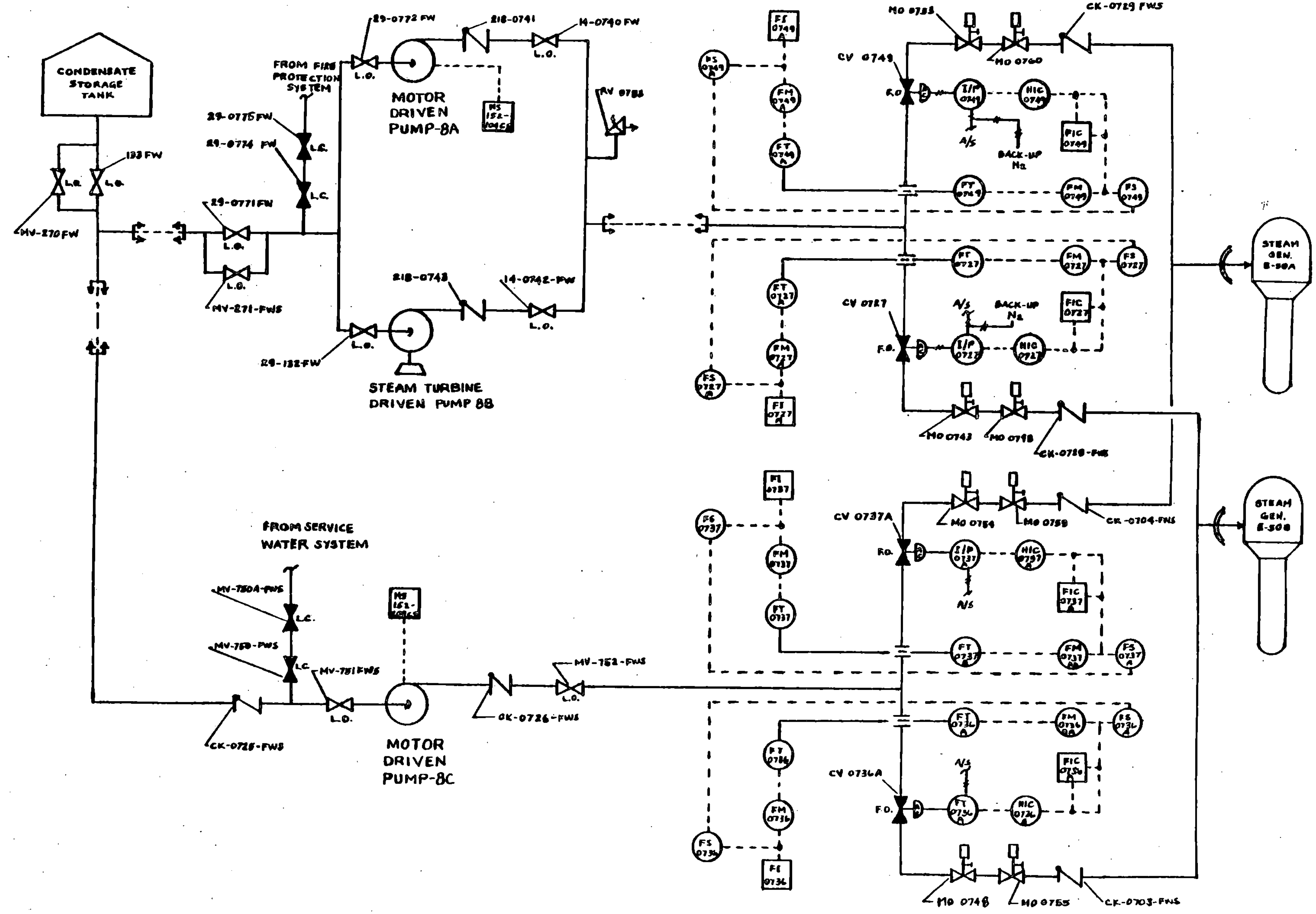


FIGURE 1
AFWS SCHEMATIC COMPONENT LABELED

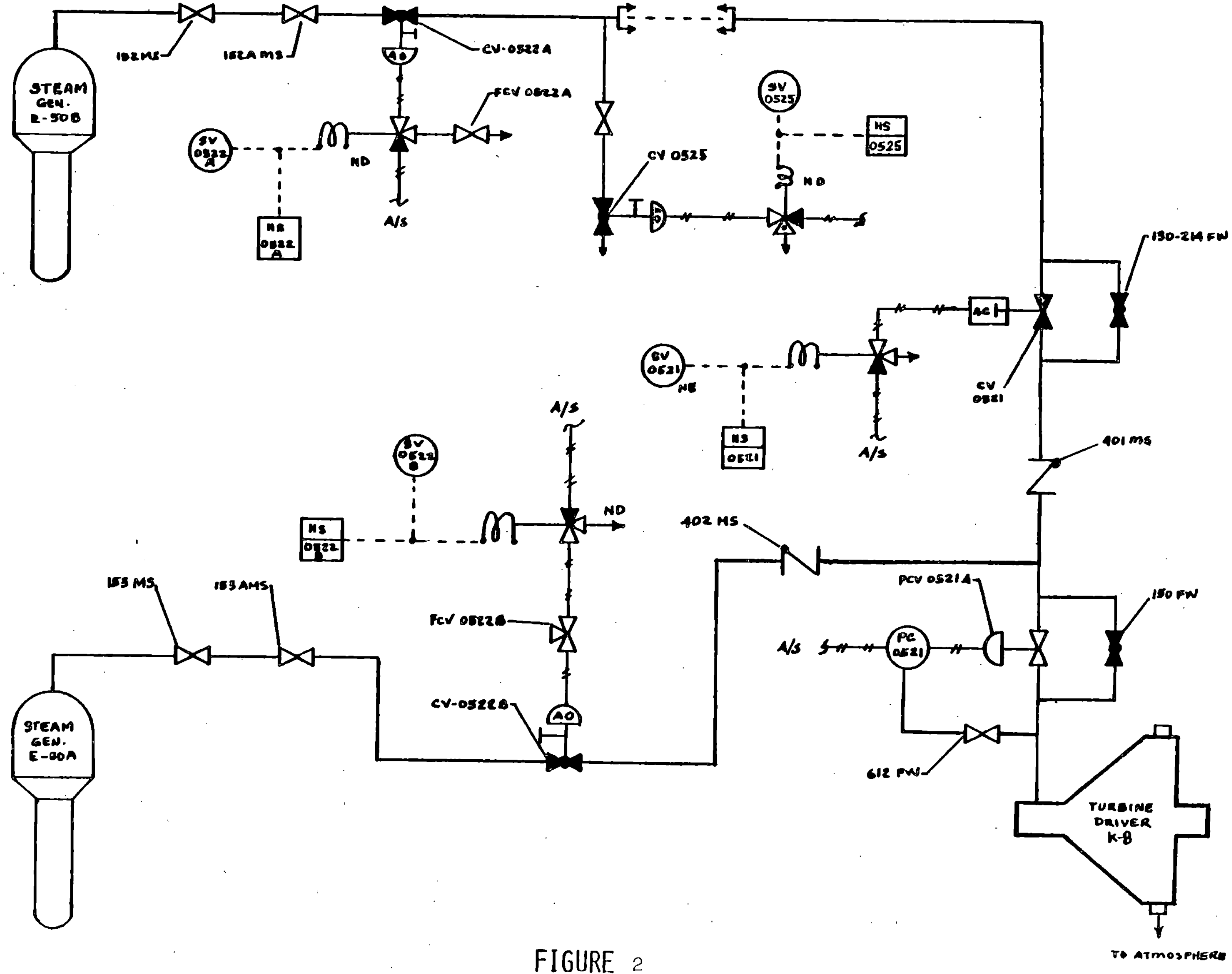
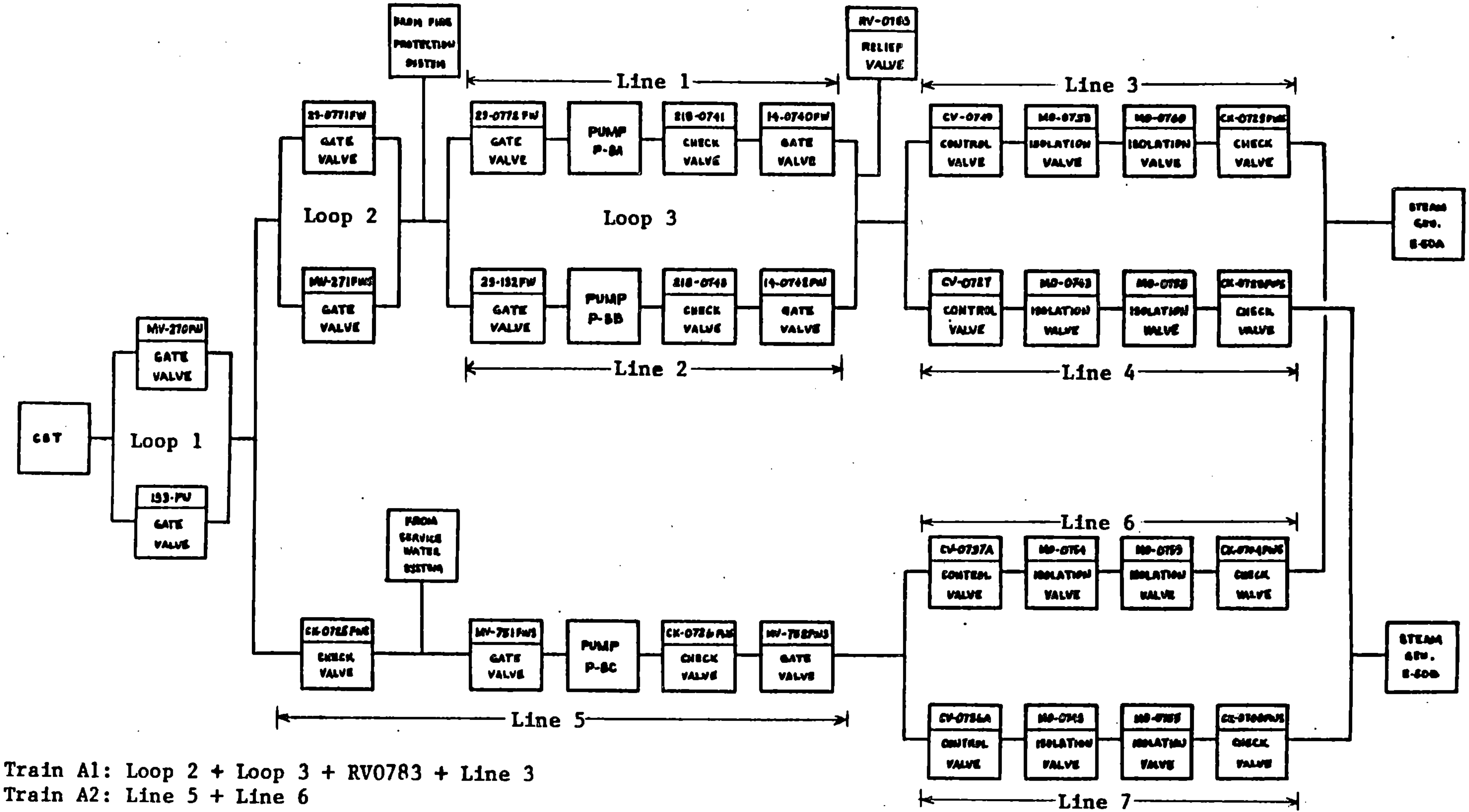


FIGURE 2
STEAM SUPPLY SYSTEM SCHEMATIC



Train A1: Loop 2 + Loop 3 + RV0783 + Line 3
Train A2: Line 5 + Line 6
Train B1: Loop 2 + Loop 3 + RV0783 + Line 4
Train B2: Line 5 + Line 7

FIGURE 3

AFWS RELIABILITY BLOCK DIAGRAM

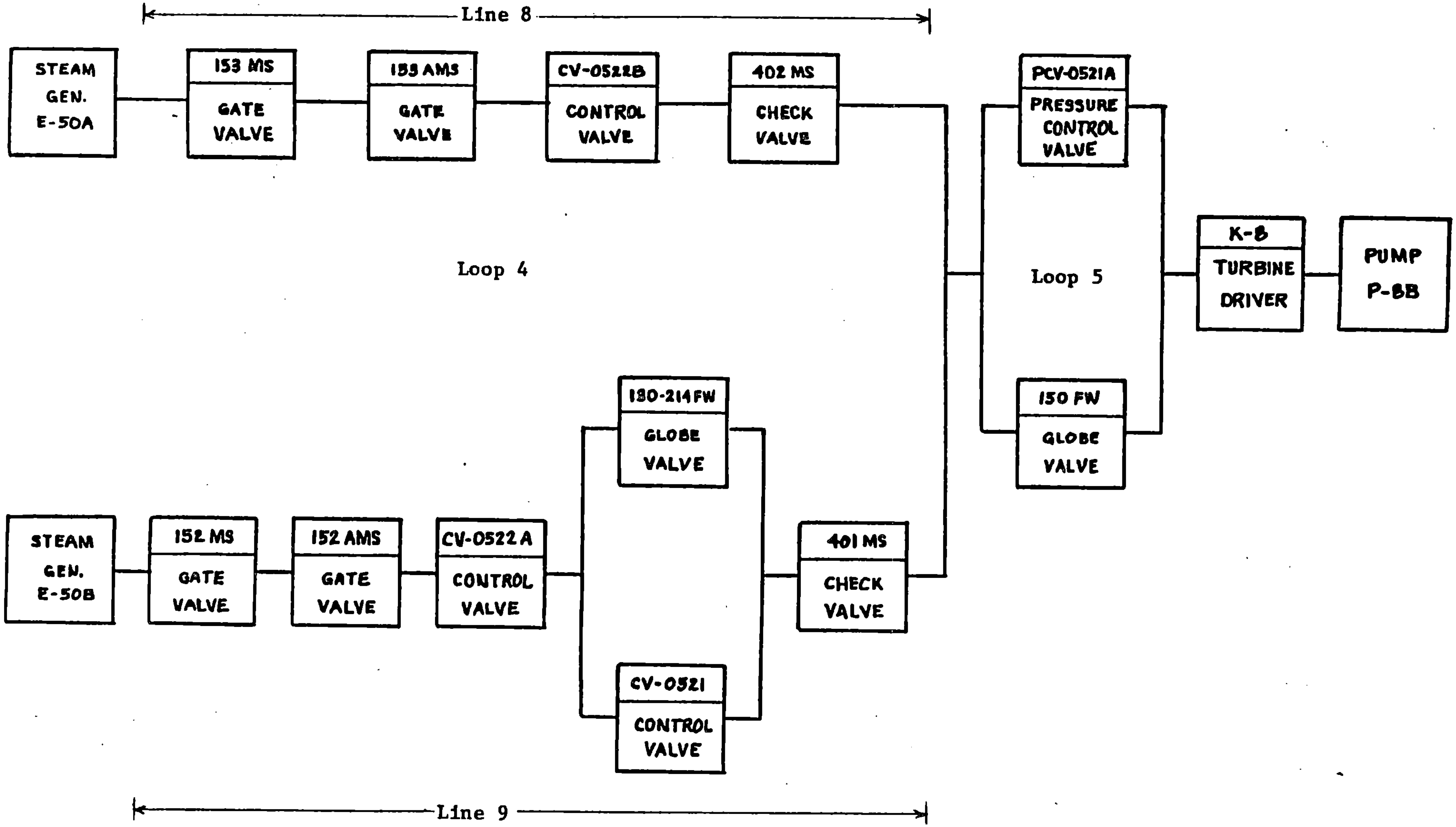


FIGURE 4
STEAM SUPPLY SYSTEM RELIABILITY BLOCK DIAGRAM

APPENDIX D

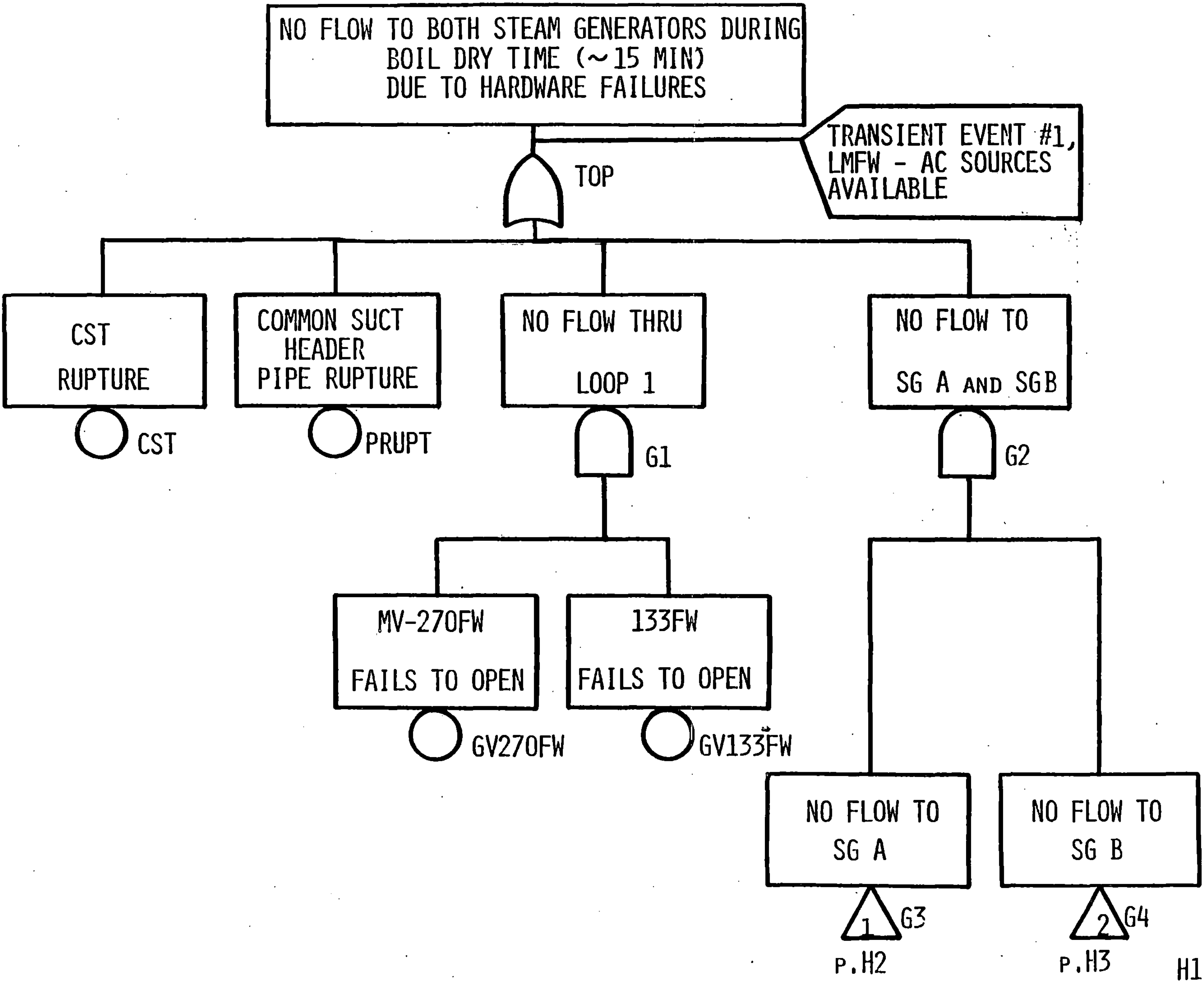
HARDWARE FAULT TREE

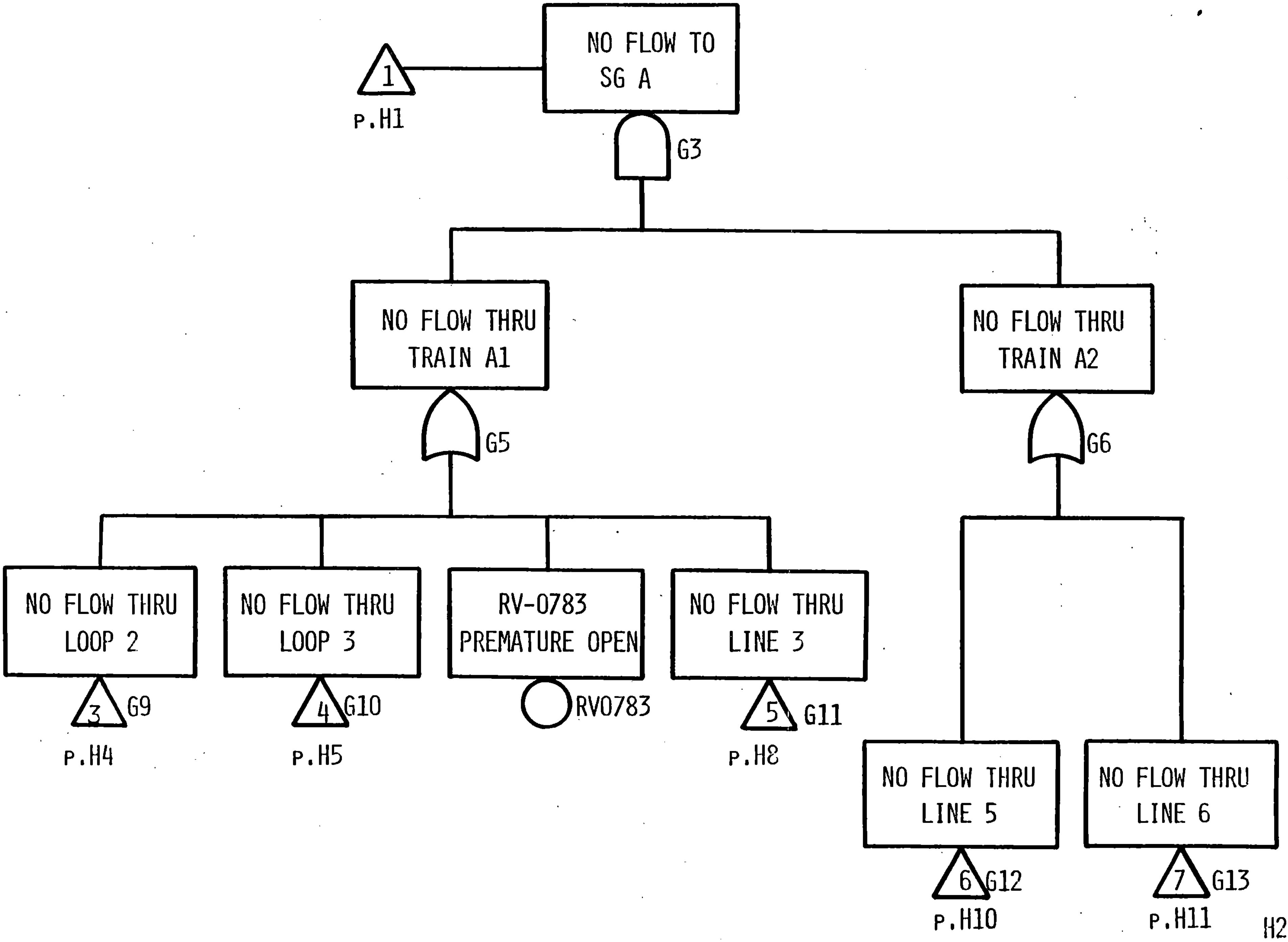
APPENDIX D

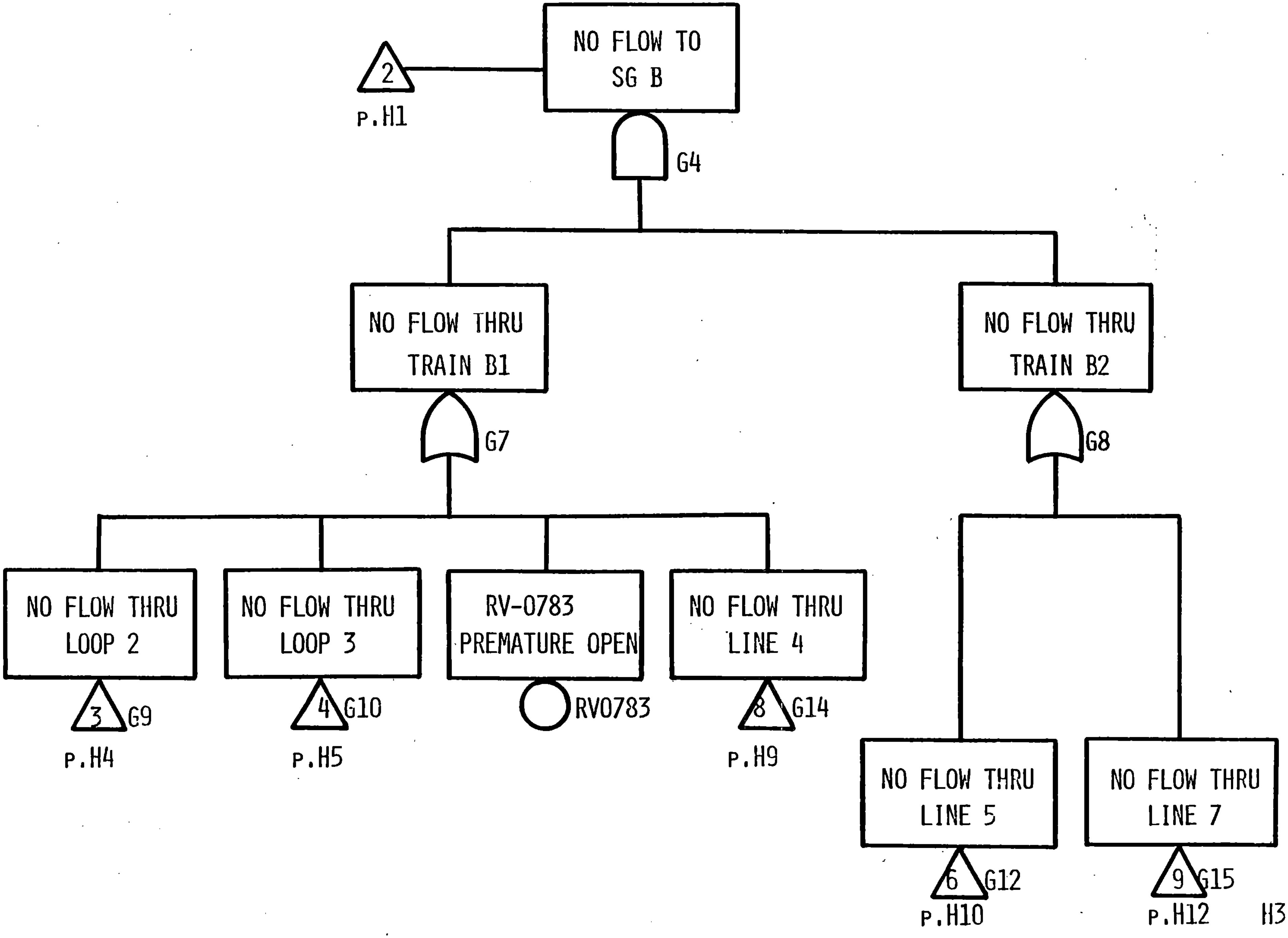
```
AFW SYSTEM RELIABILITY - HARDWARE
             1.0E-07     1    2
TOP        OR    2  2          G1        G2        CST       PRUPT
G1         AND   0  2          GV270FW   GV133FW
G2         AND   2  0          G3        G4
G3         AND   2  0          G5        G6
G4         AND   2  0          G7        G8
G5         OR    3  1          G9        G10       G11       RV0783
G6         OR    2  0          G12       G13
G7         OR    3  1          G9        G10       G14       RV0783
G8         OR    2  0          G12       G15
G9         AND   0  2          GV0771    GV0271
G10        AND   2  0          G16       G17
G11        OR    1  3          G20       MO0753    MO0760    CK0729
G12        OR    1  4          G22       CK0725    GV0751    CK0726    GV0752
G13        OR    1  3          G23       MO0754    MO0759    CK0704
G14        OR    1  3          G21       MO0743    MO0798    CK0728
G15        OR    1  3          G24       MO0748    MO0755    CK0703
G16        OR    1  3          G18       GV0772    CK0741    GV0740
G17        OR    1  3          G19       GV0132    CK0743    GV0742
G18        OR    1  3          G25       PS8A      EAC1C     EACY10
G19        OR    1  1          G28       PS8B
G20        OR    1  1          G62       CV0749
G21        OR    1  1          G47       CV0727
G22        OR    1  3          G44       PS8C      EAC1D     EACY20
G23        OR    1  1          G57       CV0737A
G24        OR    1  1          G52       CV0736A
G25        AND   1  1          G26       AFAS
G26        OR    0  3          HS104CS   OPE1      EDC1
G28        OR    2  1          G29       G301      GOVERNOR
G29        AND   2  0          G32       G33
G32        OR    1  3          G36       CK402MS   GV153AMS  GV153MS
G33        OR    3  3          G37       G38       G65       CK401MS   GV152AMS
          1         GV152MS
G36        OR    1  2          G42       CV0522B   EACY10
G37        AND   2  0          G39       G371
G38        OR    1  1          G40       CV0522A
G39        OR    0  6          OPE1      CV0521    SV0521    HS0521    EDC2
          1         EACY10
G40        AND   1  1          G41       OPE2
G41        OR    0  6          AIR1      SV0522A   FCV0522A  HS0522A   OPE1
          1         EDC1
G42        AND   2  0          G421      G422
G43        OR    1  5          G431      SV0522B   FCV0522B  HS0522B   OPE1
          1         EDC1
G44        AND   2  0          G441      G45
G45        OR    0  3          HS209CS   OPE1      EDC2
G47        AND   0  2          OPE1      FT0727A
G52        AND   0  2          OPE1      FT0736A
G57        AND   0  2          OPE1      FT0737A
G62        AND   0  2          OPE1      FT0749A
G65        AND   1  1          G66       WATER
G66        OR    1  1          G67       GV714FW
G67        OR    1  1          G68       CV0525
G68        AND   1  1          G69       OPE2
```

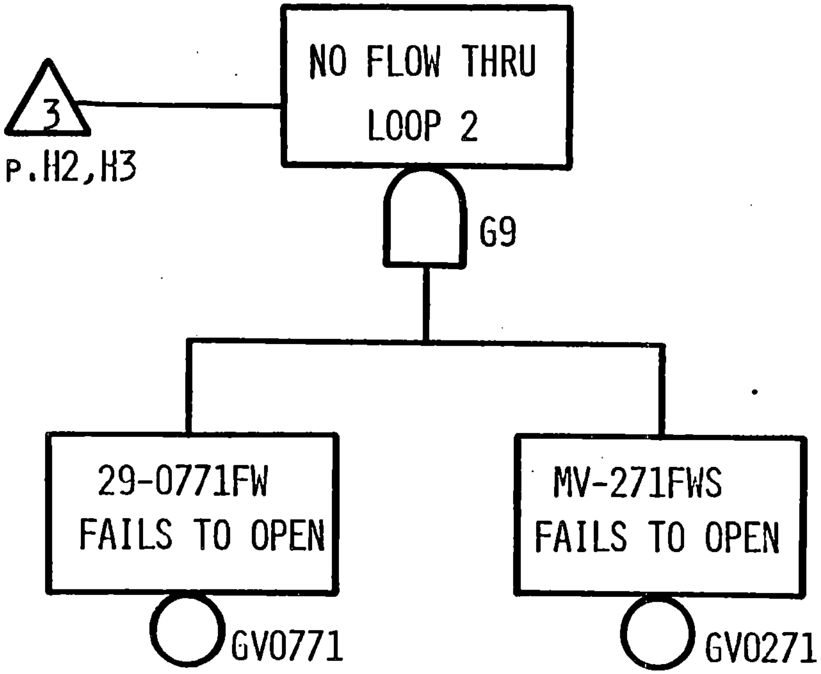
APPENDIX D

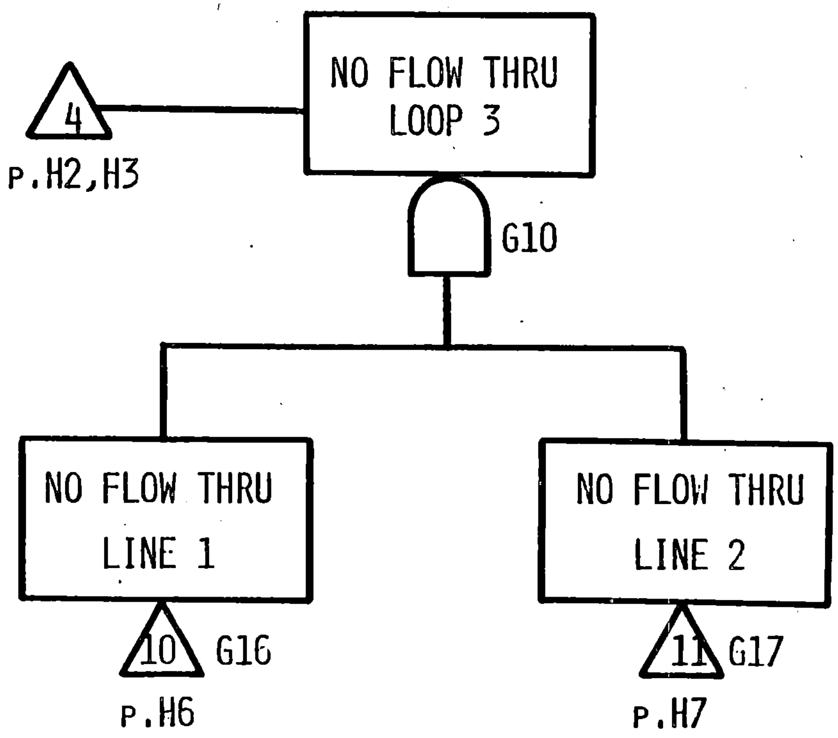
```
G69         OR      0   5       AIR3        SV0525      HS0525      OPE1        EDC1
G301        OR      1   1       G302        PCV0521A
G302        AND     0   2       NITROGEN    AIR4
G371        OR      0   2       GV0214      OPE3
G421        AND     1   1       G43         OPE2
G422        OR      1   1       G423        EDC1
G423        OR      1   1       G424        AFAS
G424        OR      2   1       G425        G426        EACY20
G425        AND     0   2       FT0736H     FT0736AH
G426        AND     0   2       FT0737H     FT0737AH
G431        AND     0   2       NITROGEN    AIR2
G441        OR      1   1       G442        AFAS
G442        OR      2   1       G443        G444        EACY10
G443        AND     0   2       FT0727H     FT0727AH
G444        AND     0   2       FT0749H     FT0749AH
END
```

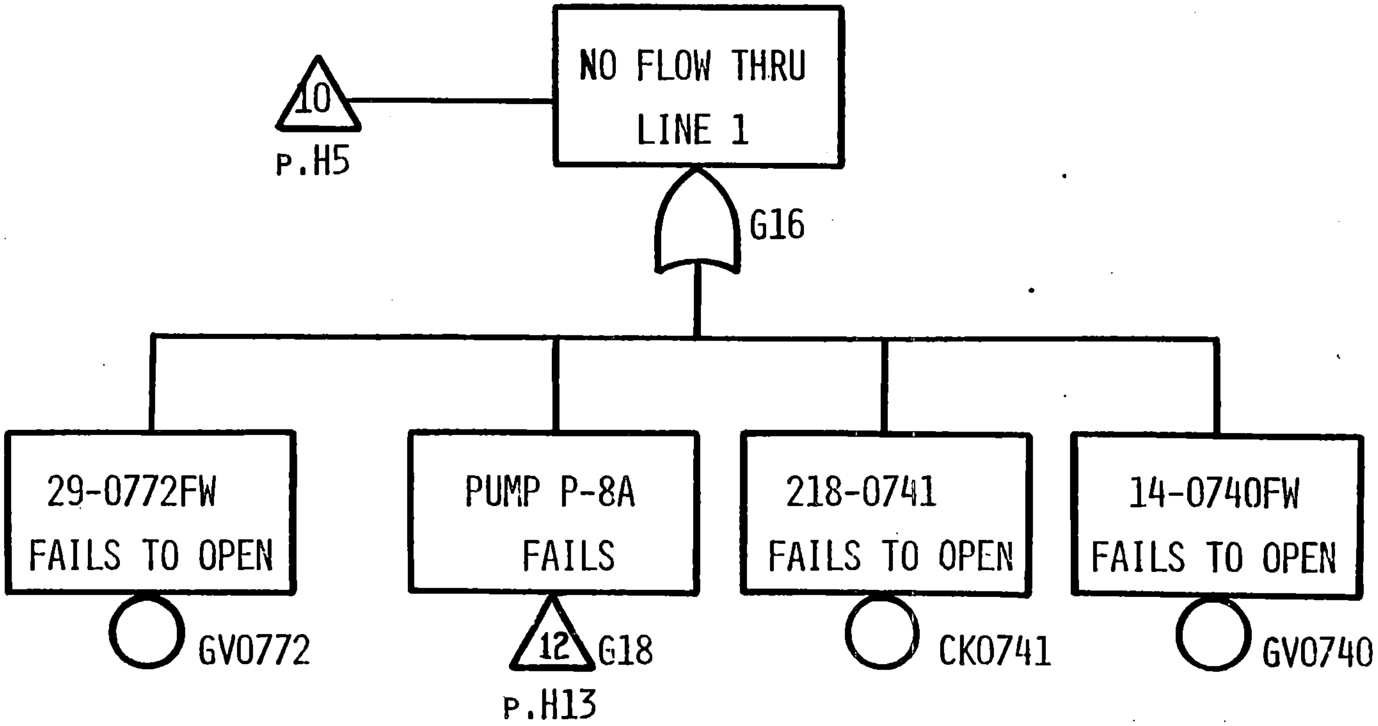

NO FLOW TO BOTH STEAM GENERATORS DURING BOIL DRY TIME (~15 MIN) DUE TO HARDWARE FAILURES
TRANSIENT EVENT #1, LMFW - AC SOURCES AVAILABLE
TOP
CST RUPTURE
CST
COMMON SUCT HEADER PIPE RUPTURE
PRUPT
NO FLOW THRU LOOP 1
G1
NO FLOW TO SG A AND SGB
G2
MV-270FW FAILS TO OPEN
GV270FW
133FW FAILS TO OPEN
GV133FW
NO FLOW TO SG A
1
G3
P.H2
NO FLOW TO SG B
2
G4
P.H3

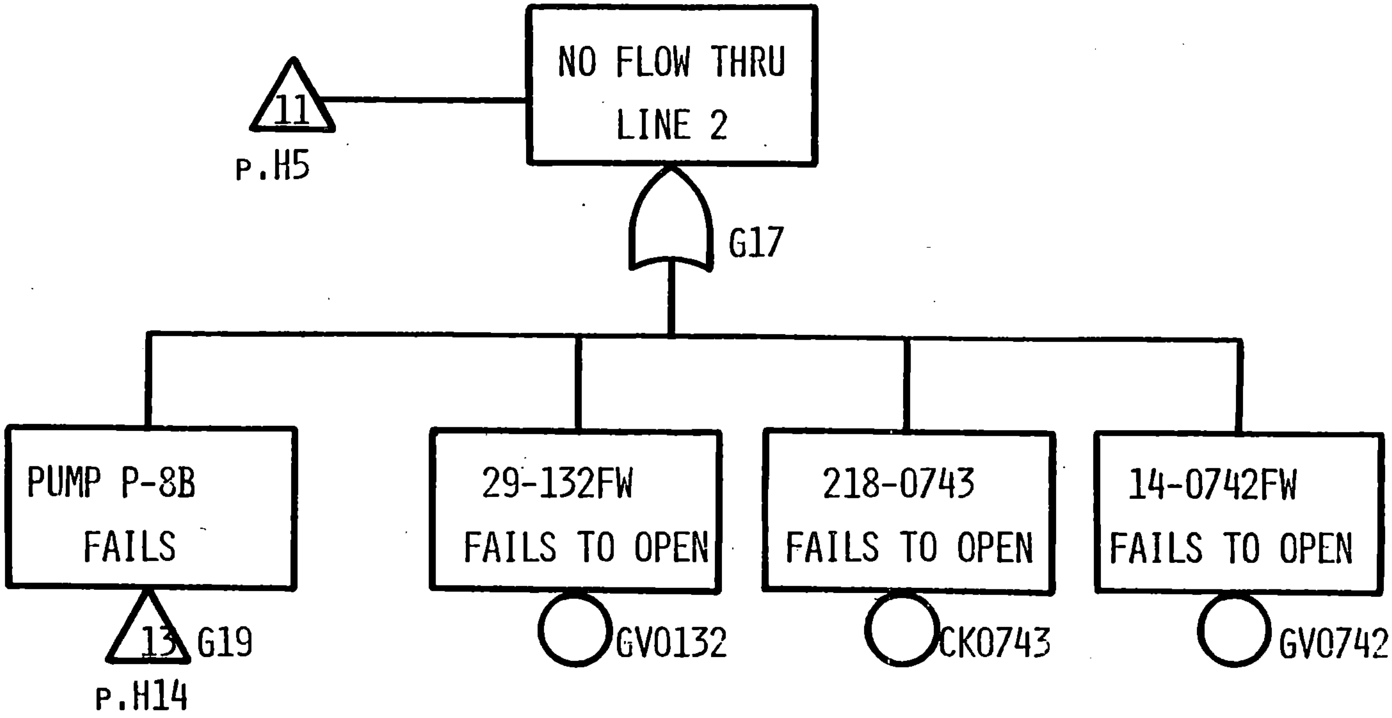

NO FLOW TO SG A
1
P.H1
G3
NO FLOW THRU TRAIN A1
G5
NO FLOW THRU TRAIN A2
G6
NO FLOW THRU LOOP 2
3
G9
P.H4
NO FLOW THRU LOOP 3
4
G10
P.H5
RV-0783 PREMATURE OPEN
RV0783
NO FLOW THRU LINE 3
5
G11
P.H8
NO FLOW THRU LINE 5
6
G12
P.H10
NO FLOW THRU LINE 6
7
G13
P.H11

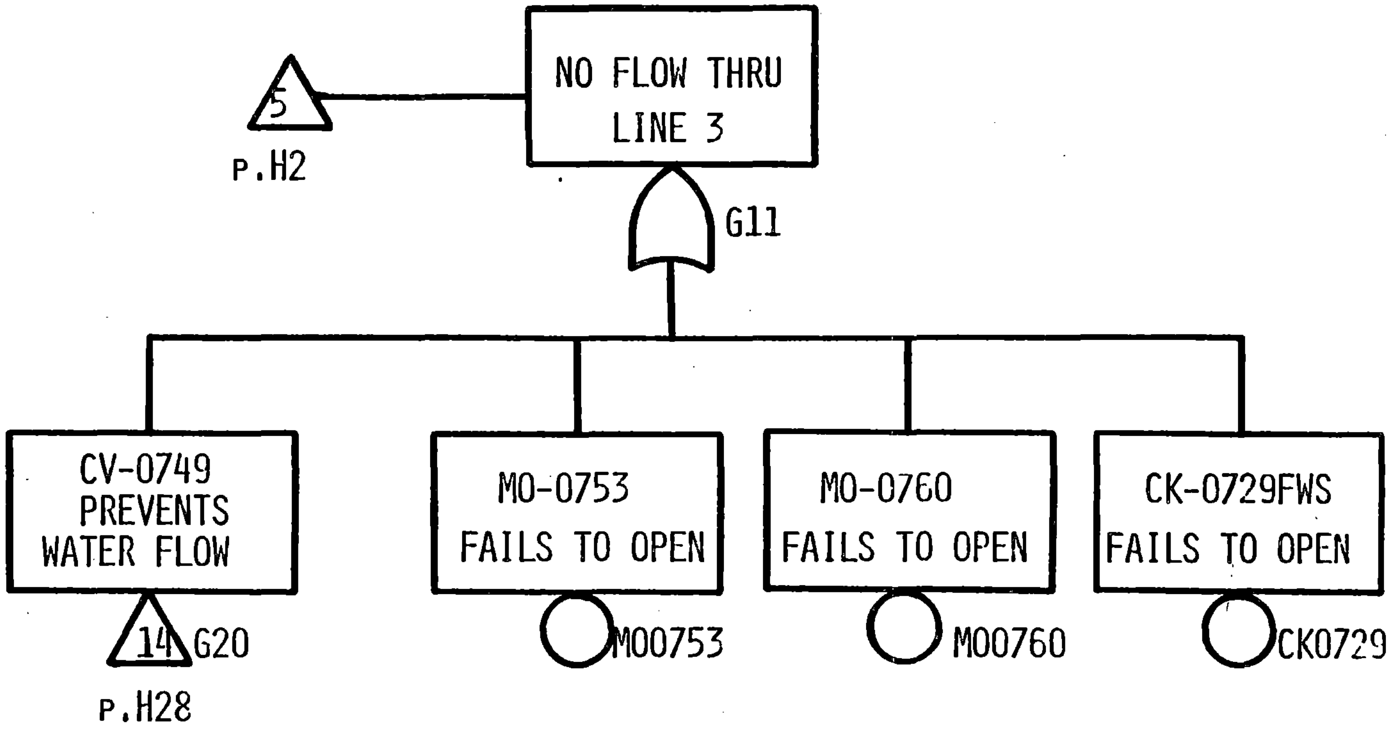

NO FLOW TO SG B
2
P.H1
G4
NO FLOW THRU TRAIN B1
NO FLOW THRU TRAIN B2
G7
G8
NO FLOW THRU LOOP 2
NO FLOW THRU LOOP 3
RV-0783 PREMATURE OPEN
NO FLOW THRU LINE 4
3
G9
P.H4
4
G10
P.H5
RV0783
8
G14
P.H9
NO FLOW THRU LINE 5
NO FLOW THRU LINE 7
6
G12
P.H10
9
G15
P.H12

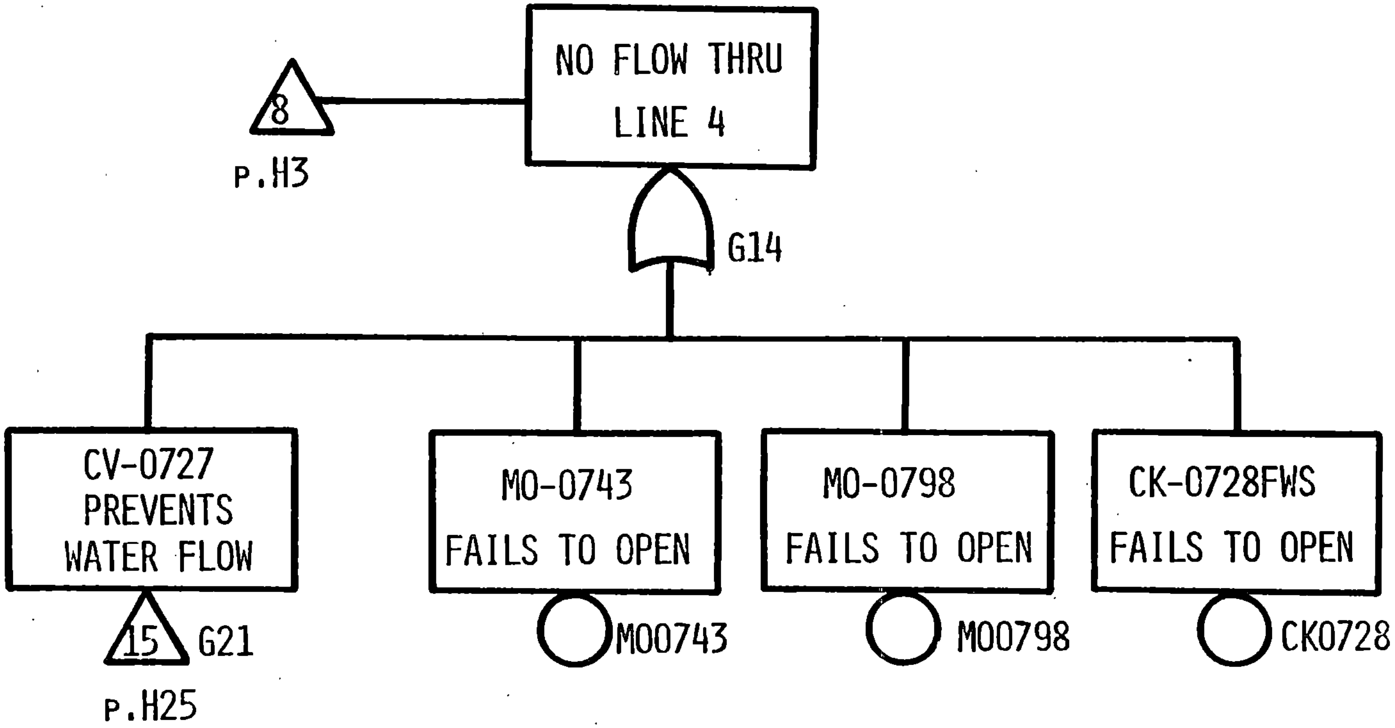

3
P.H2,H3
NO FLOW THRU LOOP 2
G9
29-0771FW FAILS TO OPEN
GV0771
MV-271FWS FAILS TO OPEN
GV0271

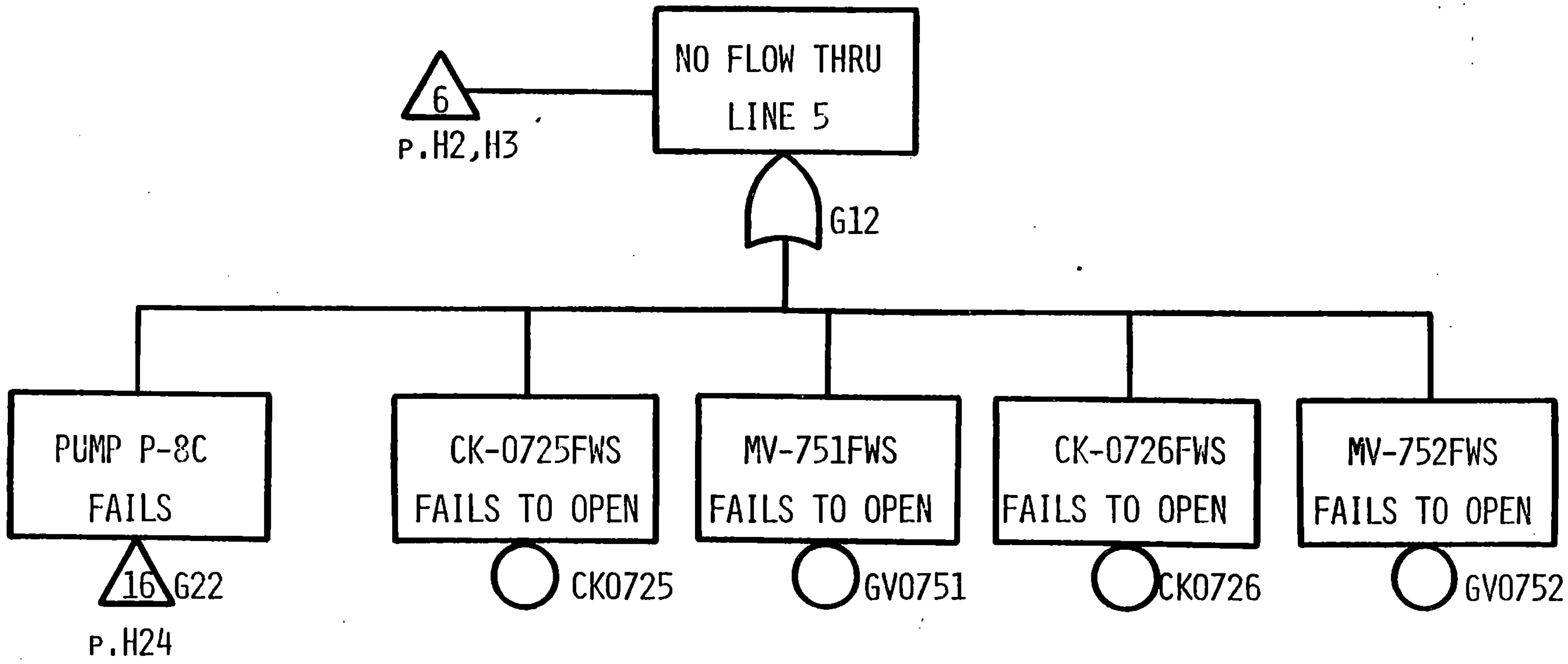

NO FLOW THRU LOOP 3
4
P.H2,H3
G10
NO FLOW THRU LINE 1
10
G16
P.H6
NO FLOW THRU LINE 2
11
G17
P.H7

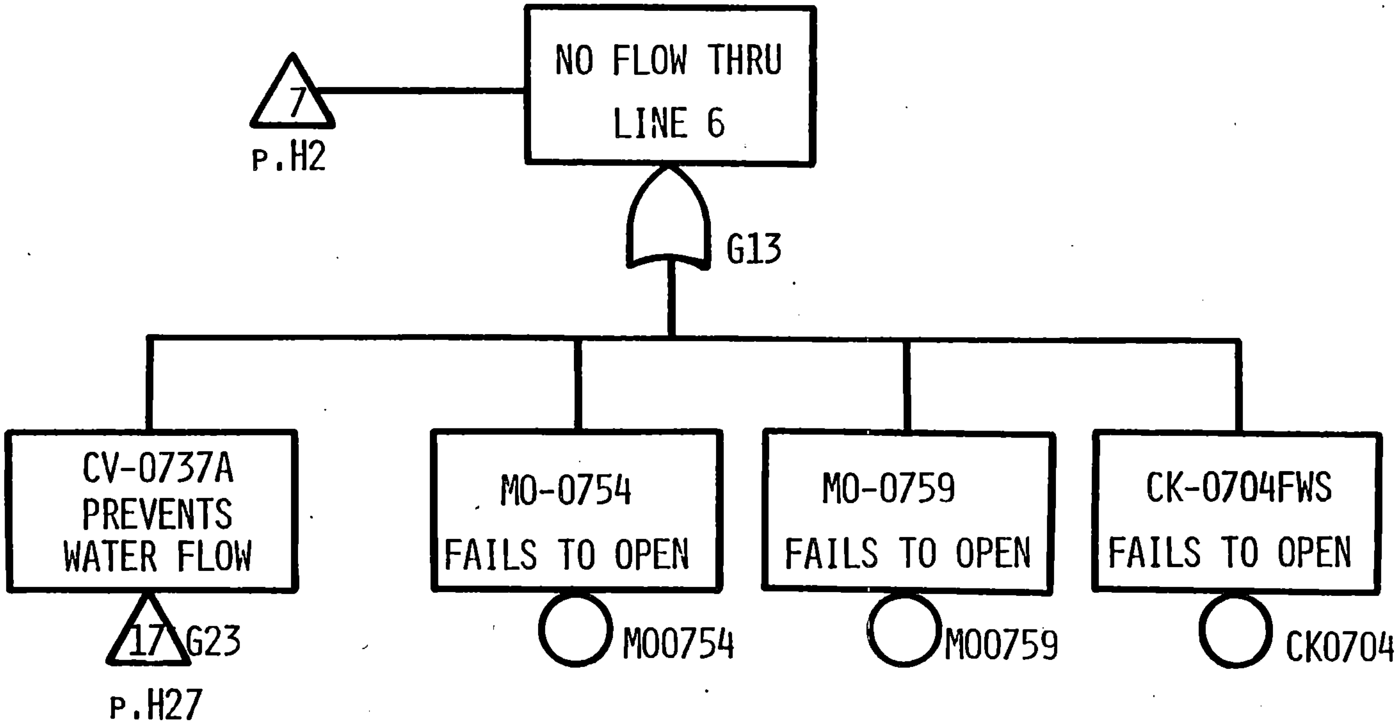

10
P.H5
NO FLOW THRU LINE 1
G16
29-0772FW FAILS TO OPEN
GV0772
PUMP P-8A FAILS
12
G18
P.H13
218-0741 FAILS TO OPEN
CK0741
14-0740FW FAILS TO OPEN
GV0740

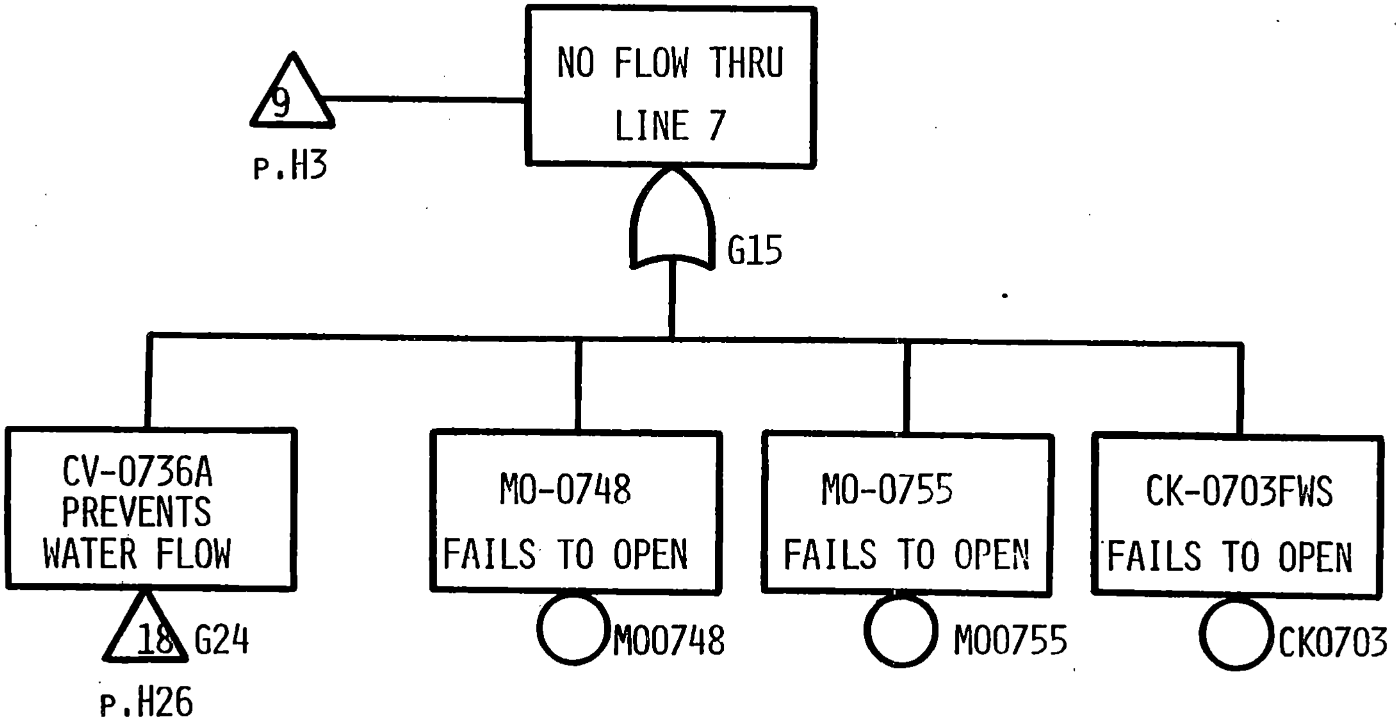

NO FLOW THRU LINE 2
11
P.H5
G17
PUMP P-8B FAILS
13
G19
P.H14
29-132FW FAILS TO OPEN
GV0132
218-0743 FAILS TO OPEN
CK0743
14-0742FW FAILS TO OPEN
GV0742

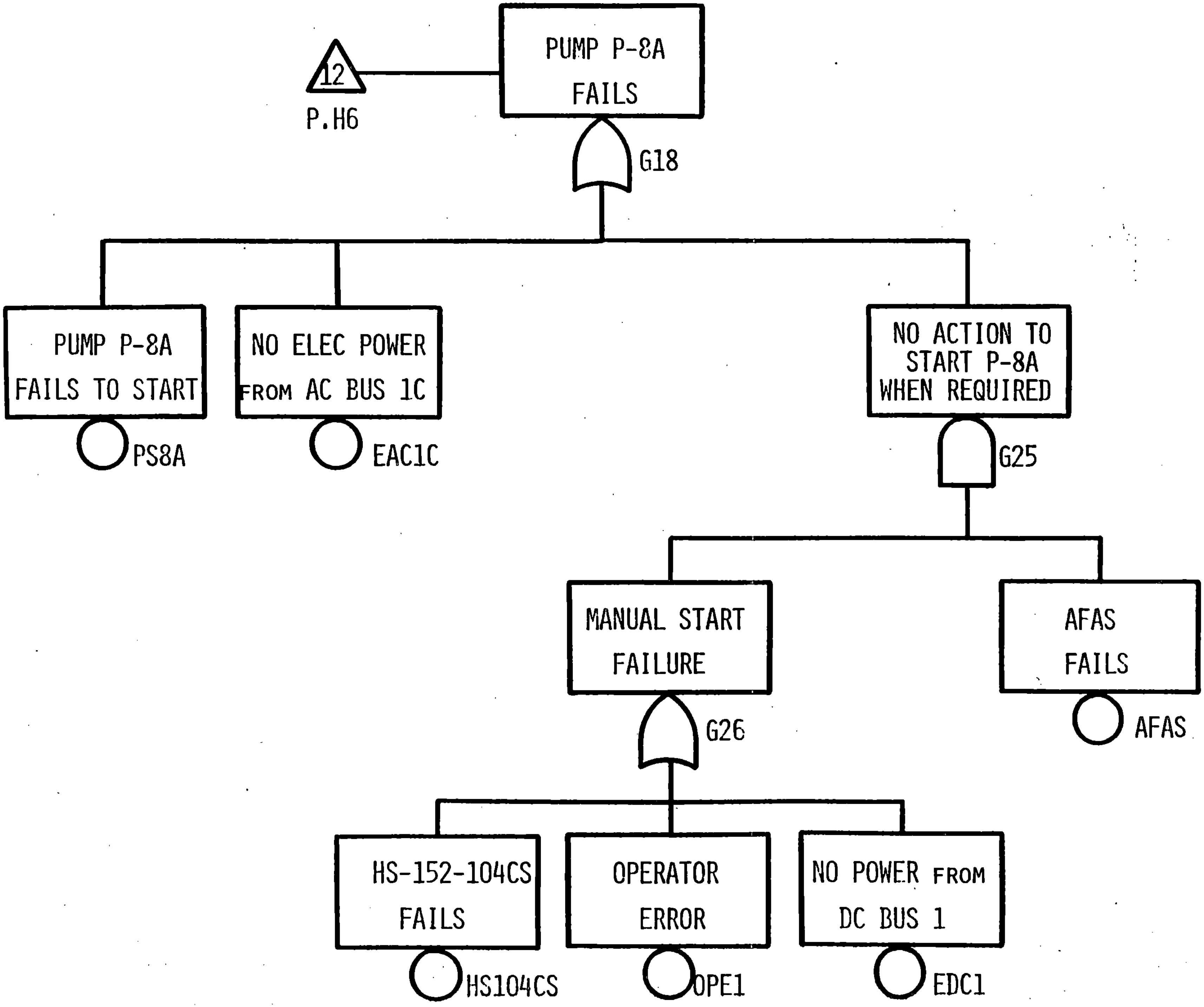

NO FLOW THRU LINE 3
5
P.H2
G11
CV-0749 PREVENTS WATER FLOW
14
G20
P.H28
MO-0753 FAILS TO OPEN
M00753
MO-0760 FAILS TO OPEN
M00760
CK-0729FWS FAILS TO OPEN
CK0729


NO FLOW THRU LINE 4
8
p.H3
G14
CV-0727 PREVENTS WATER FLOW
15
G21
p.H25
MO-0743 FAILS TO OPEN
MO0743
MO-0798 FAILS TO OPEN
MO0798
CK-0728FWS FAILS TO OPEN
CK0728

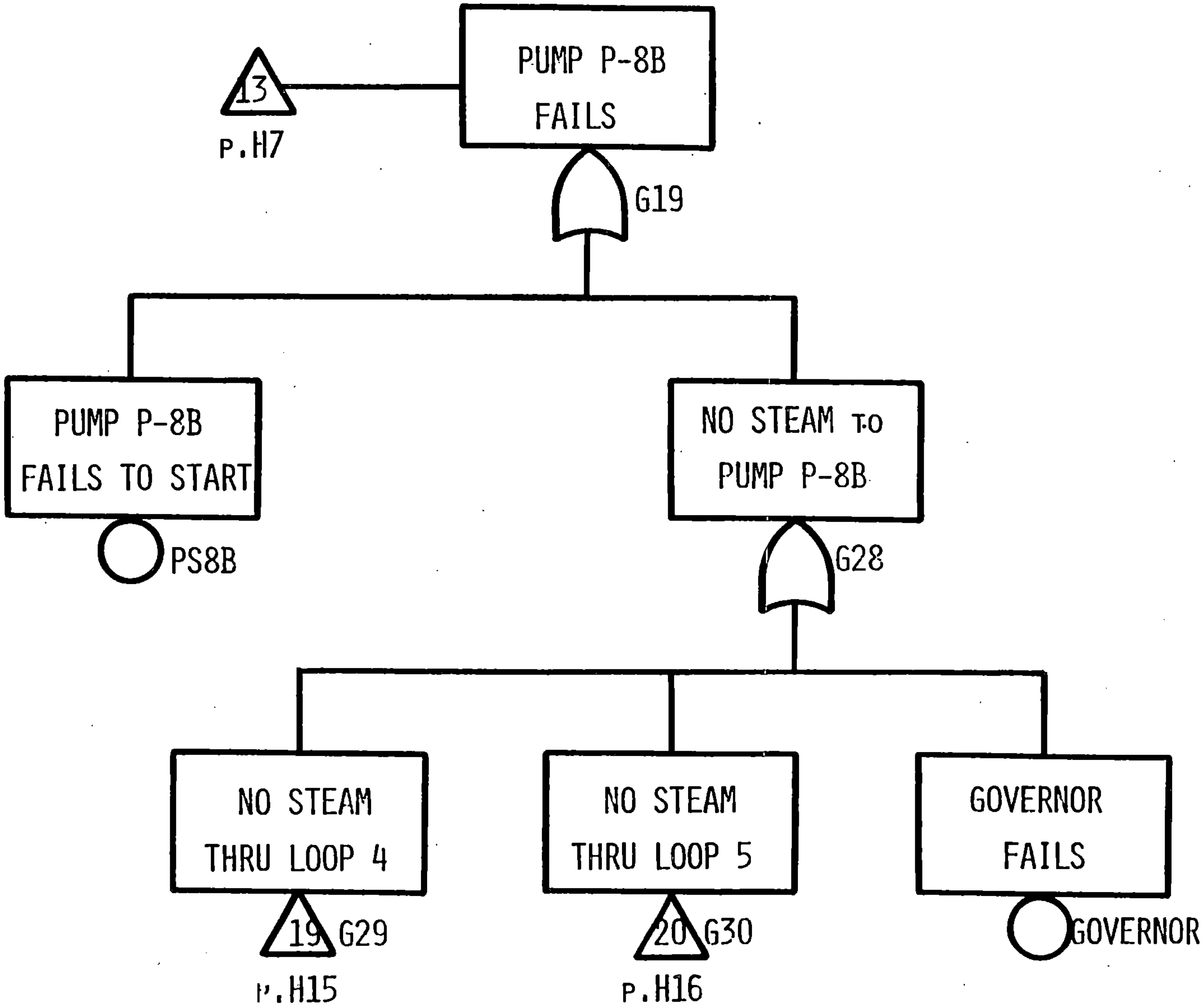

NO FLOW THRU LINE 5
6
P.H2,H3
G12
PUMP P-8C FAILS
16
G22
P.H24
CK-0725FWS FAILS TO OPEN
CK0725
MV-751FWS FAILS TO OPEN
GV0751
CK-0726FWS FAILS TO OPEN
CK0726
MV-752FWS FAILS TO OPEN
GV0752

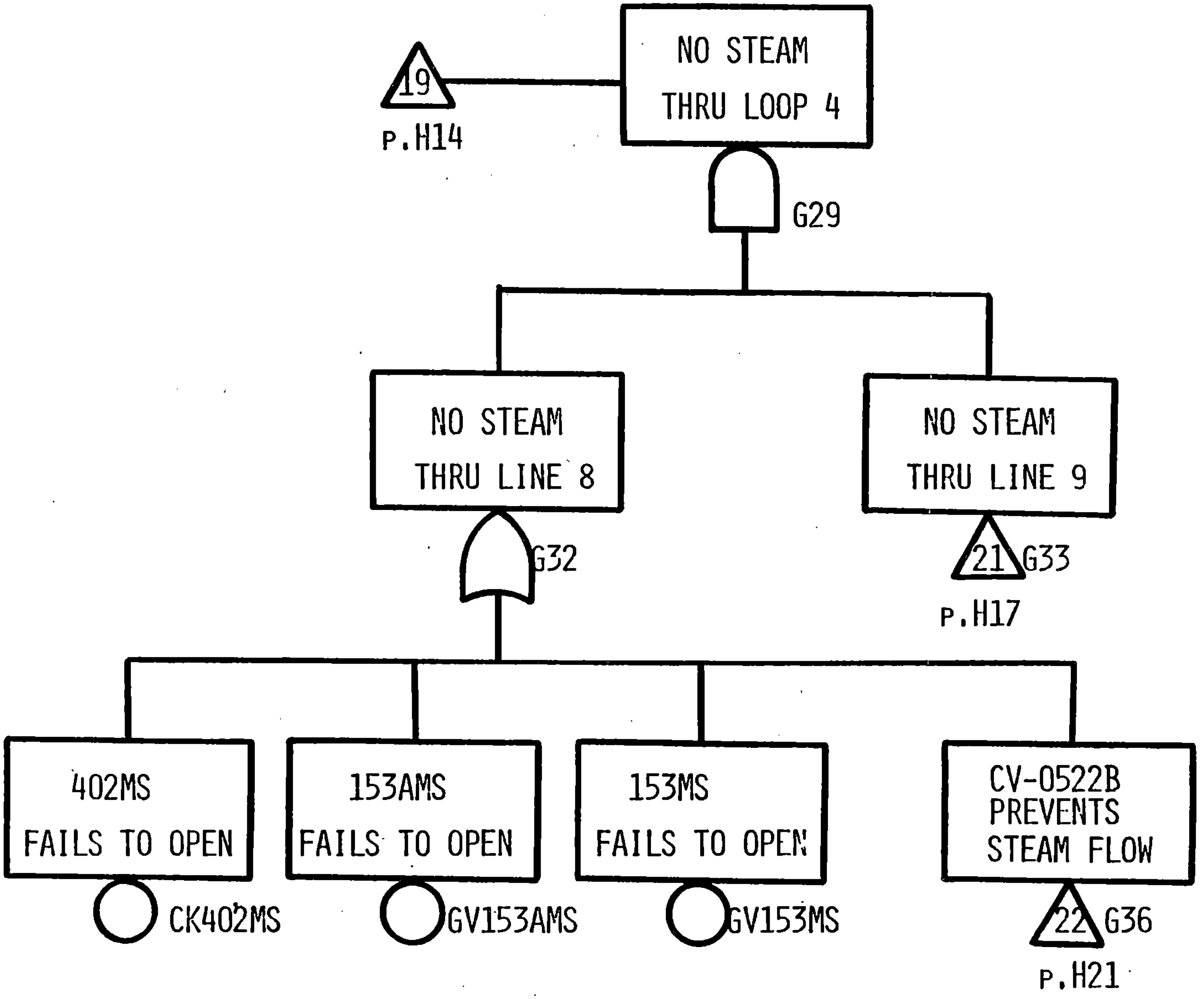

NO FLOW THRU LINE 6
7
P.H2
G13
CV-0737A PREVENTS WATER FLOW
17
G23
P.H27
MO-0754 FAILS TO OPEN
MO0754
MO-0759 FAILS TO OPEN
MO0759
CK-0704FWS FAILS TO OPEN
CK0704

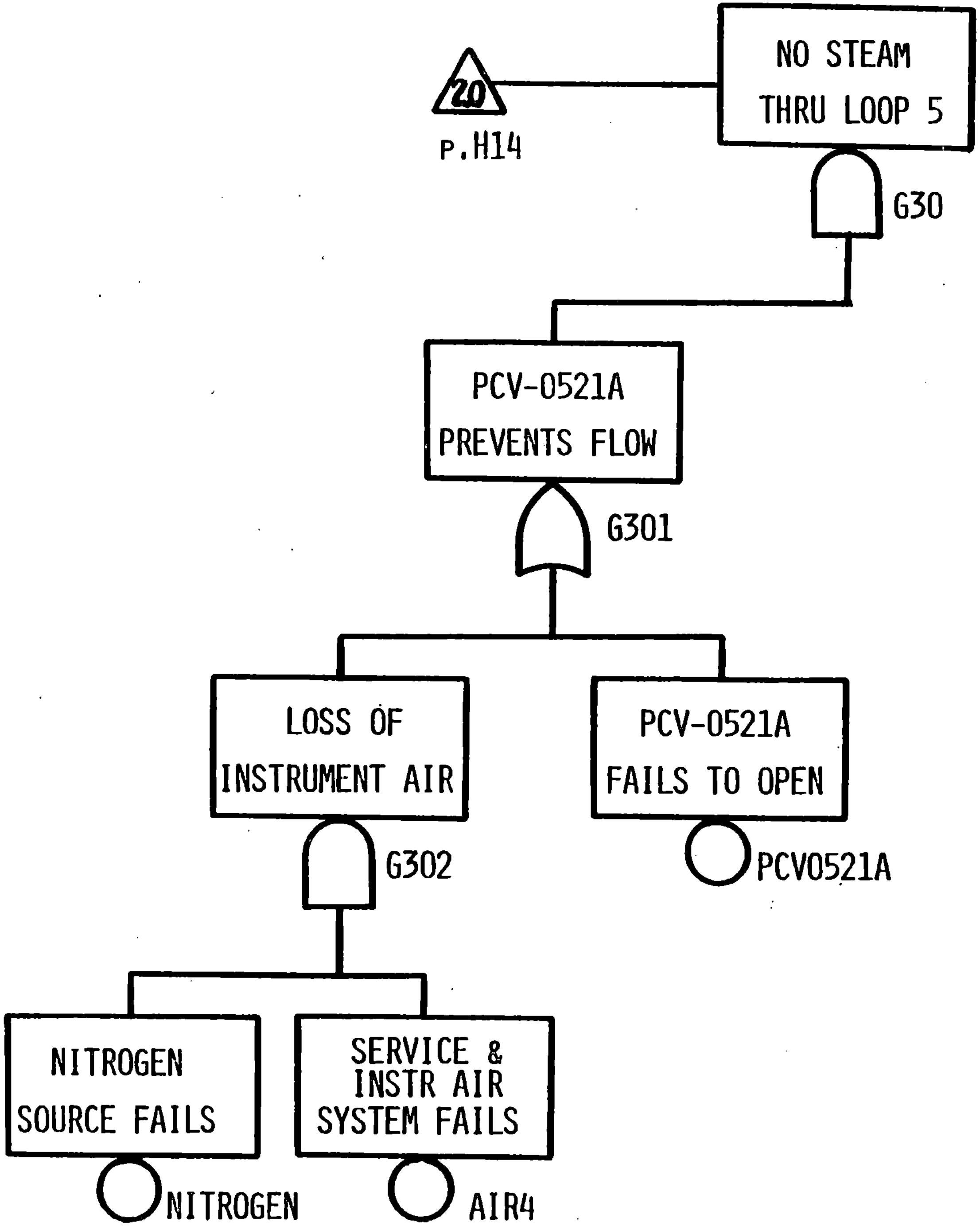

9
p.H3
NO FLOW THRU LINE 7
G15
CV-0736A PREVENTS WATER FLOW
18
G24
p.H26
MO-0748 FAILS TO OPEN
MO0748
MO-0755 FAILS TO OPEN
MO0755
CK-0703FWS FAILS TO OPEN
CK0703

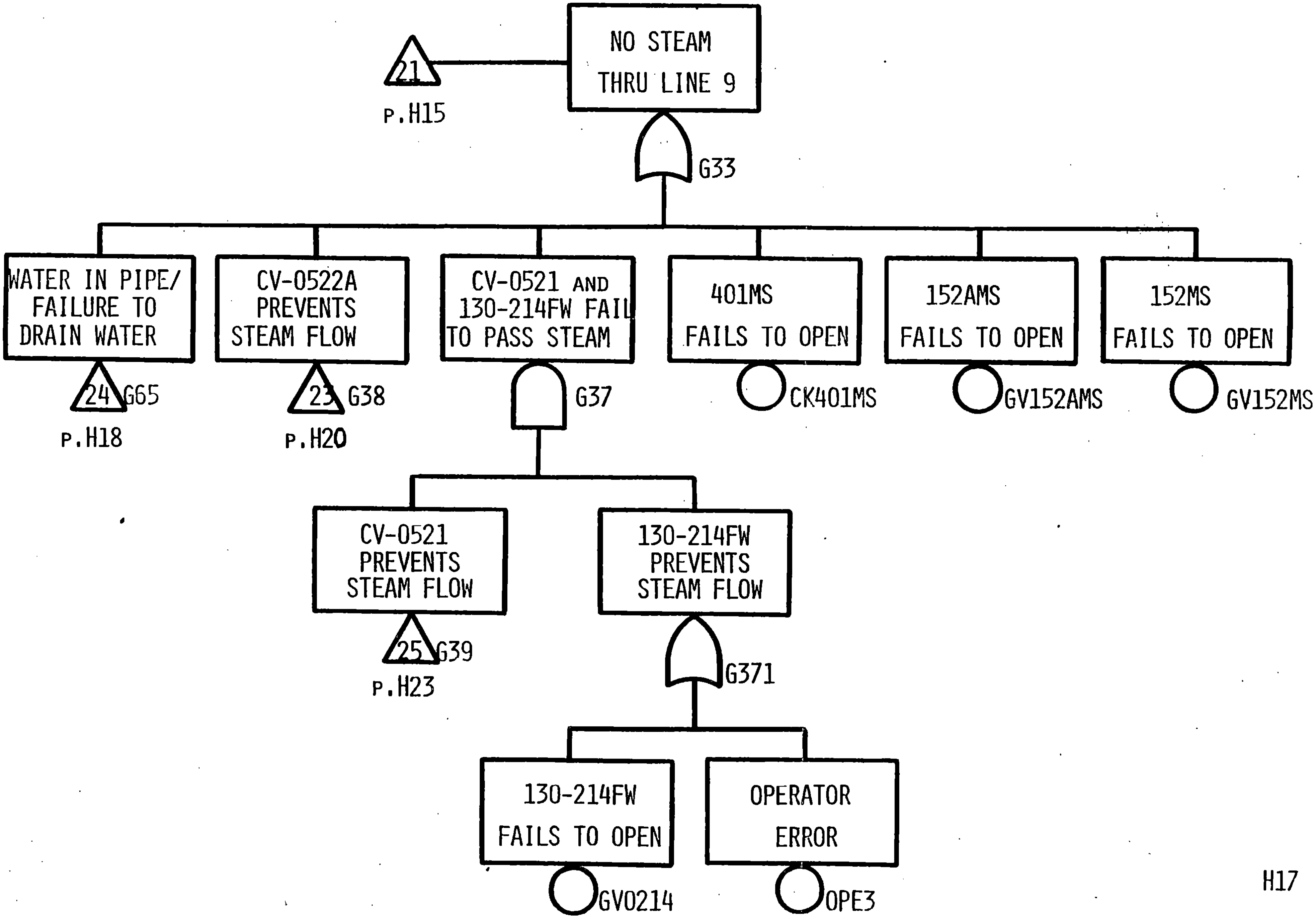


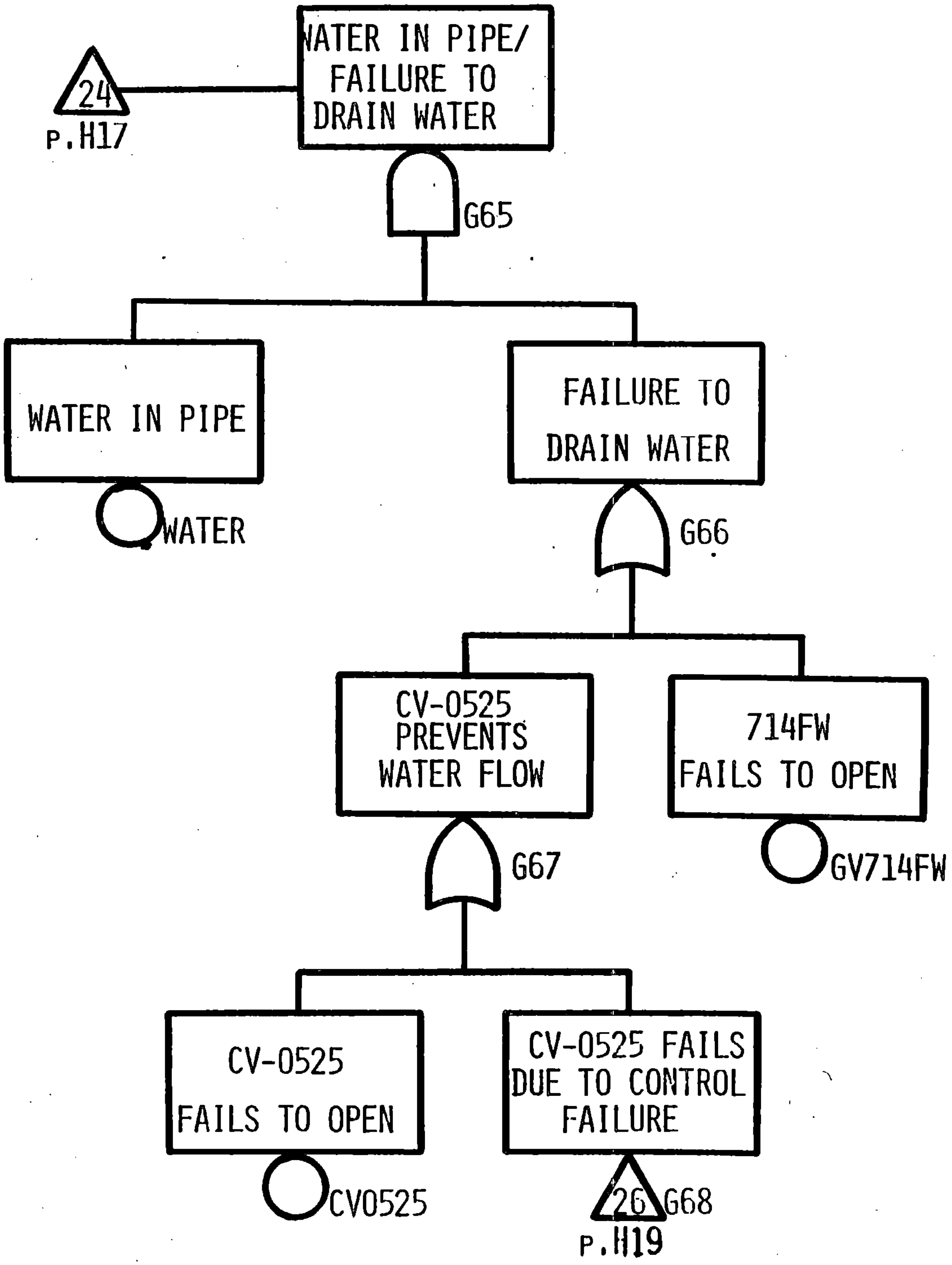
12
P.H6
PUMP P-8A FAILS
G18
PUMP P-8A FAILS TO START
PS8A
NO ELEC POWER FROM AC BUS 1C
EAC1C
NO ACTION TO START P-8A WHEN REQUIRED
G25
MANUAL START FAILURE
G26
AFAS FAILS
AFAS
HS-152-104CS FAILS
HS104CS
OPERATOR ERROR
OPE1
NO POWER FROM DC BUS 1
EDC1

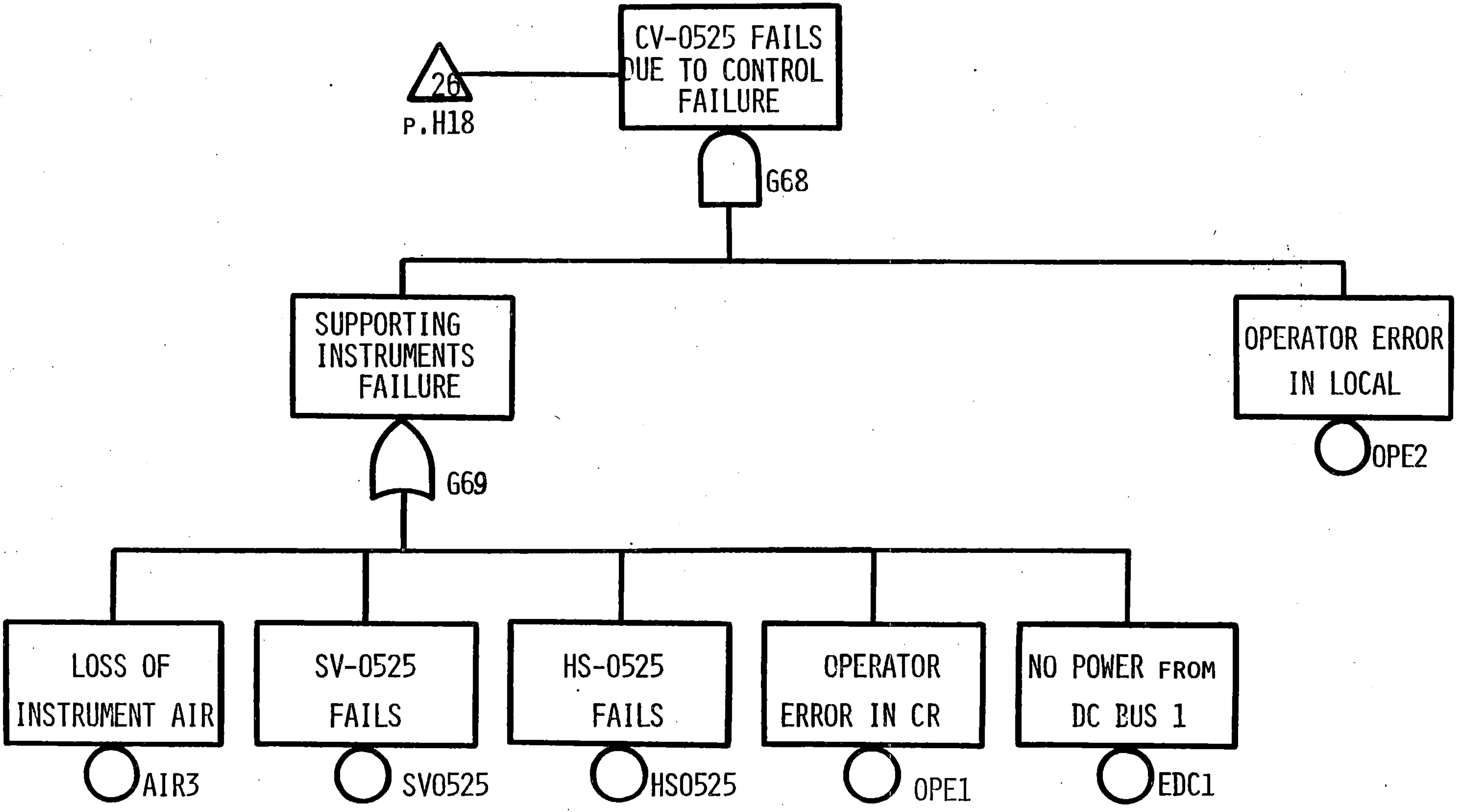

PUMP P-8B
FAILS
13
p.H7
G19
PUMP P-8B
FAILS TO START
PS8B
NO STEAM TO
PUMP P-8B
G28
NO STEAM
THRU LOOP 4
19
G29
p.H15
NO STEAM
THRU LOOP 5
20
G30
p.H16
GOVERNOR
FAILS
GOVERNOR

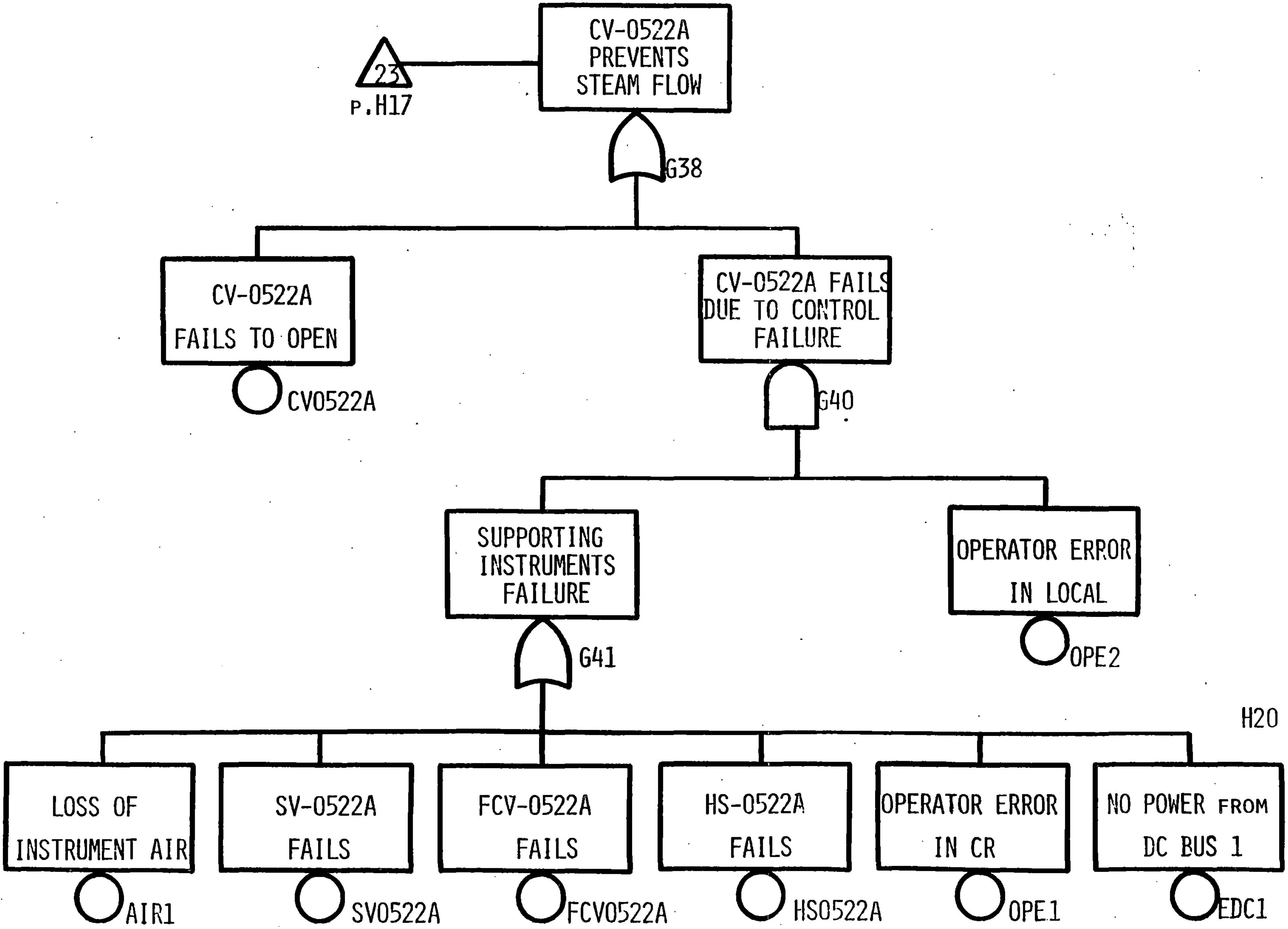

NO STEAM THRU LOOP 4
19
P.H14
G29
NO STEAM THRU LINE 8
G32
NO STEAM THRU LINE 9
21
G33
P.H17
402MS FAILS TO OPEN
CK402MS
153AMS FAILS TO OPEN
GV153AMS
153MS FAILS TO OPEN
GV153MS
CV-0522B PREVENTS STEAM FLOW
22
G36
P.H21

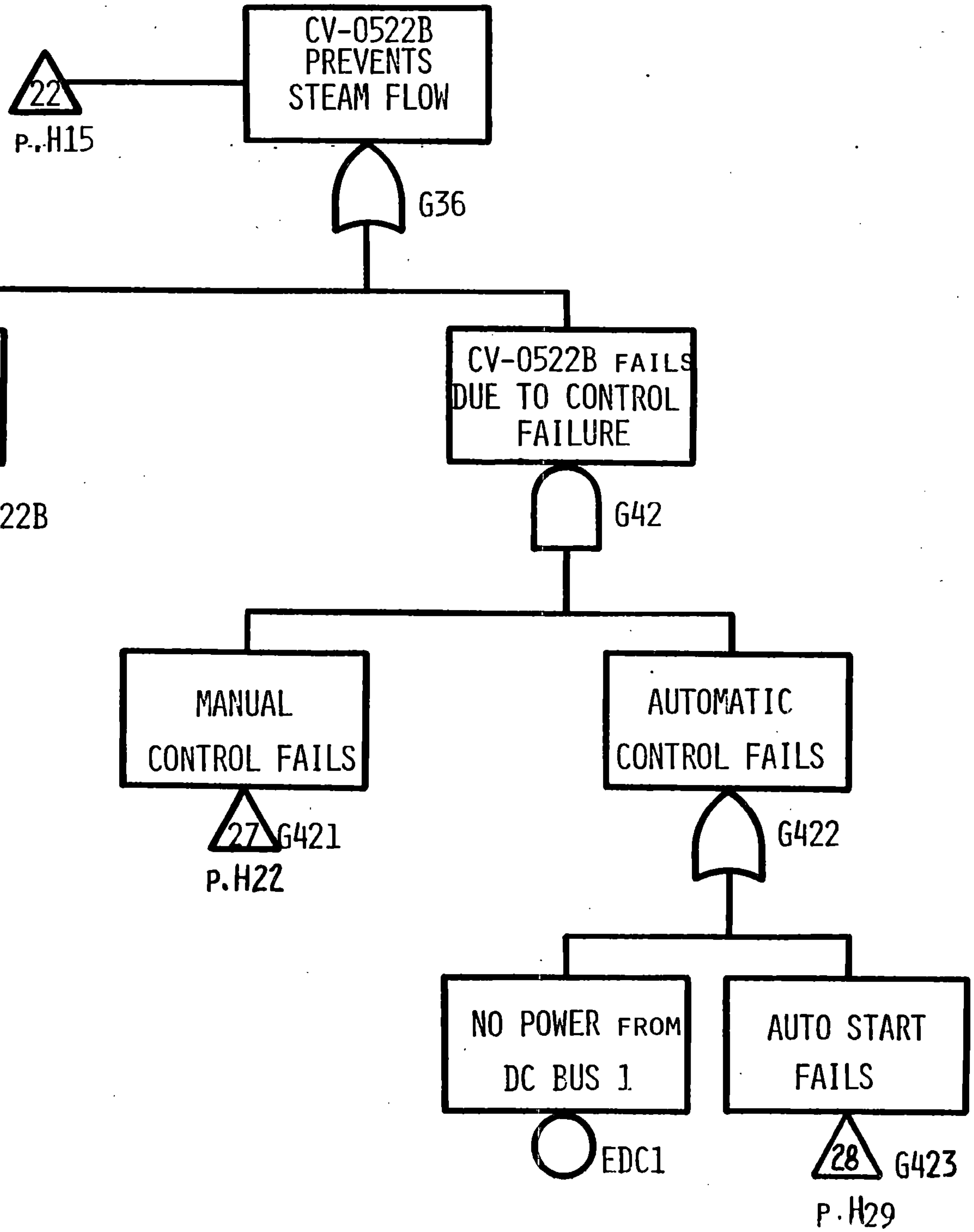

20
P.H14
NO STEAM THRU LOOP 5
G30
PCV-0521A PREVENTS FLOW
G301
LOSS OF INSTRUMENT AIR
G302
PCV-0521A FAILS TO OPEN
PCV0521A
NITROGEN SOURCE FAILS
NITROGEN
SERVICE & INSTR AIR SYSTEM FAILS
AIR4

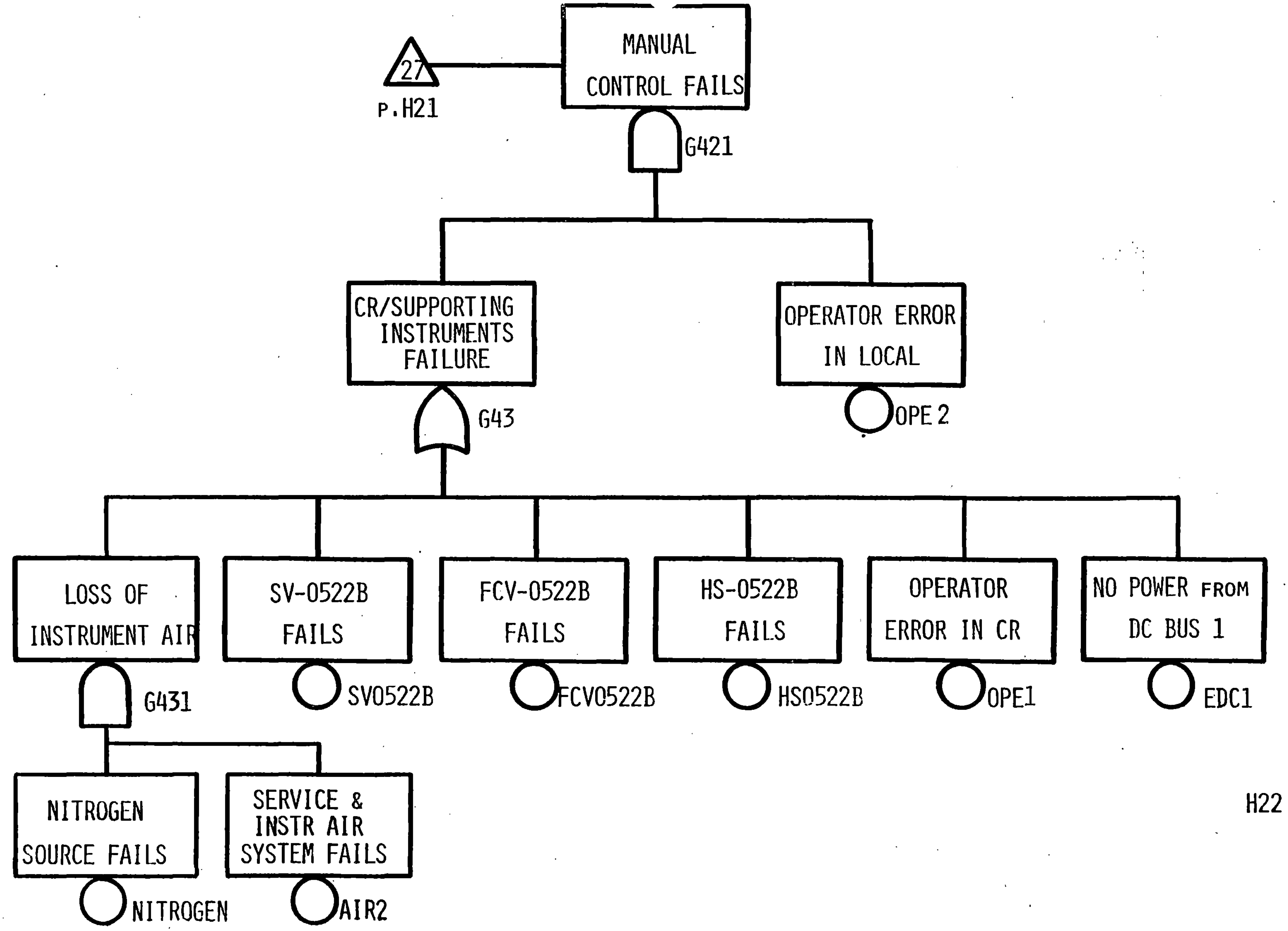

NO STEAM THRU LINE 9
21
P.H15
G33
WATER IN PIPE/ FAILURE TO DRAIN WATER
24
G65
P.H18
CV-0522A PREVENTS STEAM FLOW
23
G38
P.H20
CV-0521 AND 130-214FW FAIL TO PASS STEAM
G37
401MS FAILS TO OPEN
CK401MS
152AMS FAILS TO OPEN
GV152AMS
152MS FAILS TO OPEN
GV152MS
CV-0521 PREVENTS STEAM FLOW
25
G39
P.H23
130-214FW PREVENTS STEAM FLOW
G371
130-214FW FAILS TO OPEN
GV0214
OPERATOR ERROR
OPE3

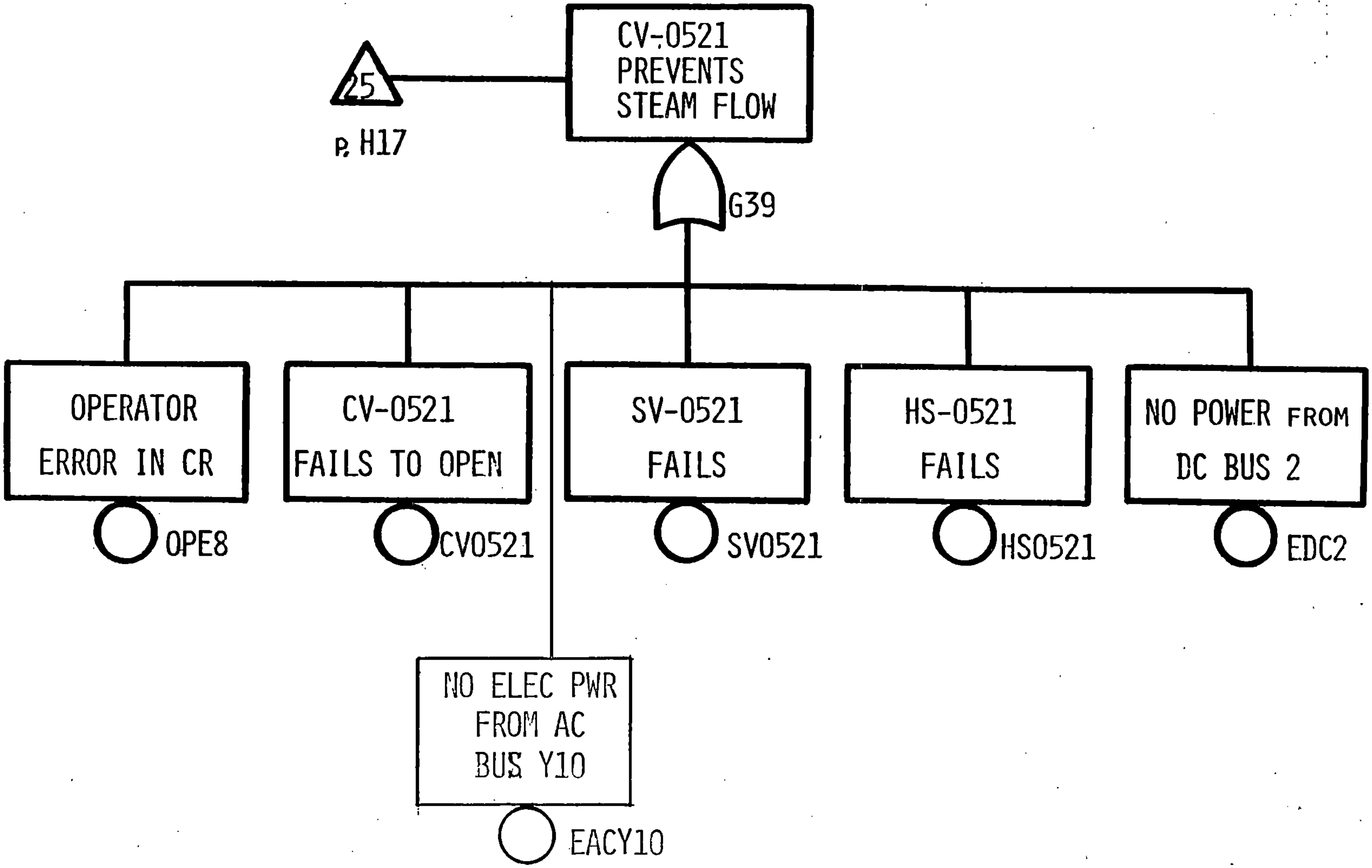

WATER IN PIPE/ FAILURE TO DRAIN WATER
24
P.H17
G65
WATER IN PIPE
WATER
FAILURE TO DRAIN WATER
G66
CV-0525 PREVENTS WATER FLOW
G67
714FW FAILS TO OPEN
GV714FW
CV-0525 FAILS TO OPEN
CV0525
CV-0525 FAILS DUE TO CONTROL FAILURE
26
G68
P.H19


26
P.H18
CV-0525 FAILS DUE TO CONTROL FAILURE
G68
SUPPORTING INSTRUMENTS FAILURE
OPERATOR ERROR IN LOCAL
OPE2
G69
LOSS OF INSTRUMENT AIR
AIR3
SV-0525 FAILS
SV0525
HS-0525 FAILS
HS0525
OPERATOR ERROR IN CR
OPE1
NO POWER FROM DC BUS 1
EDC1

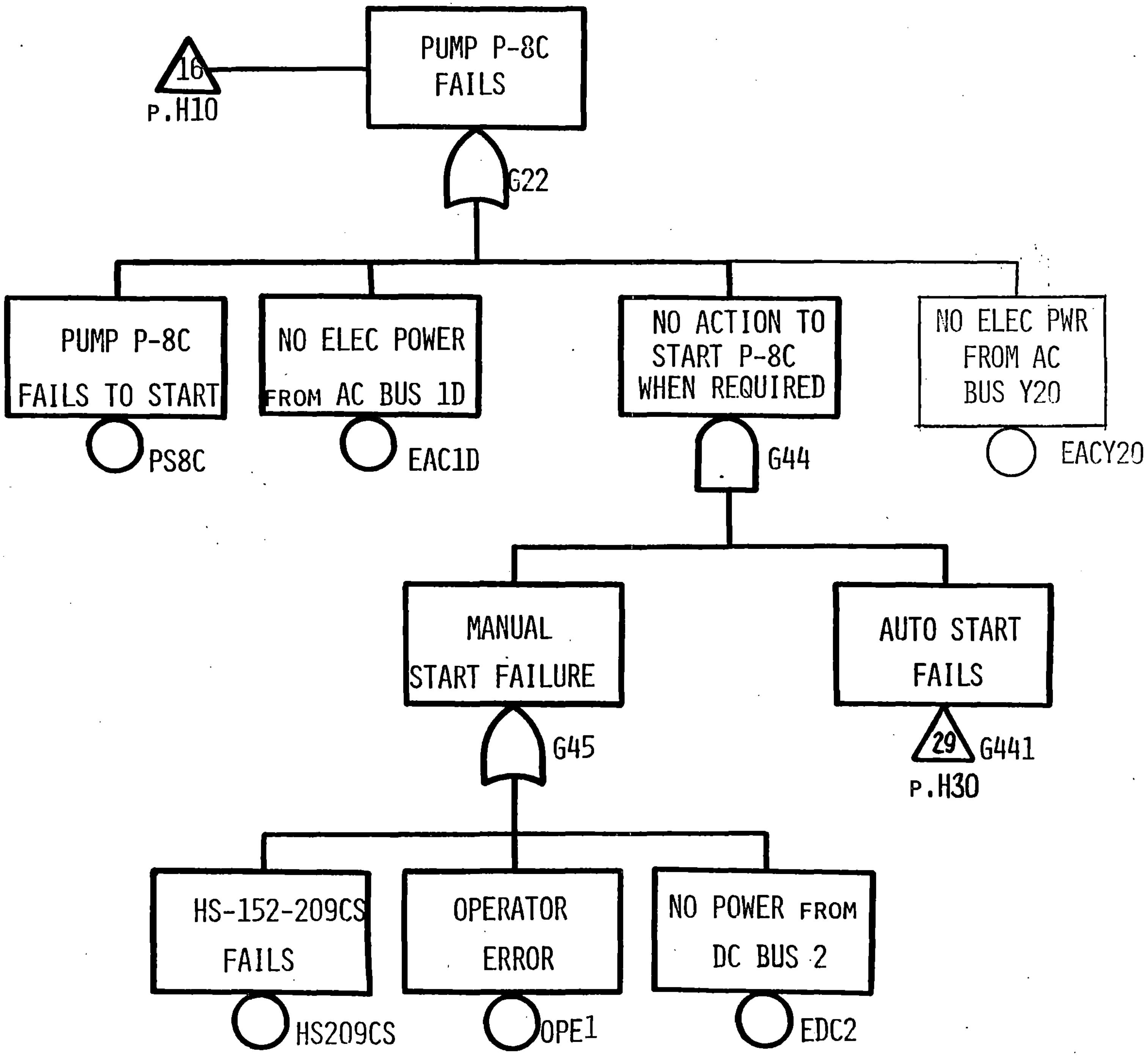

CV-0522A PREVENTS STEAM FLOW
23
P.H17
G38
CV-0522A FAILS TO OPEN
CV0522A
CV-0522A FAILS DUE TO CONTROL FAILURE
G40
SUPPORTING INSTRUMENTS FAILURE
G41
OPERATOR ERROR IN LOCAL
OPE2
LOSS OF INSTRUMENT AIR
AIR1
SV-0522A FAILS
SV0522A
FCV-0522A FAILS
FCV0522A
HS-0522A FAILS
HS0522A
OPERATOR ERROR IN CR
OPE1
NO POWER FROM DC BUS 1
EDC1

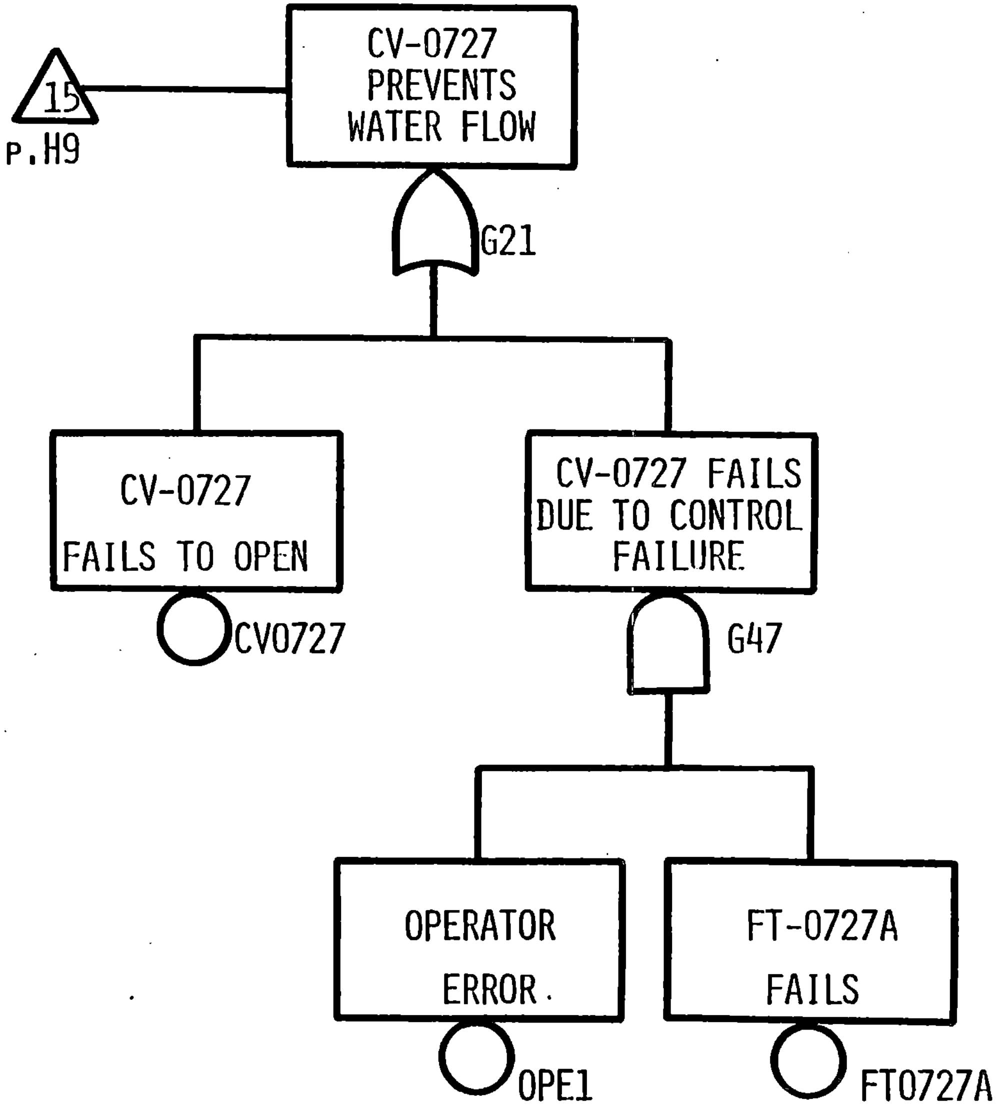

CV-0522B PREVENTS STEAM FLOW
22
P. H15
G36
CV-0522B FAILS TO OPEN
CV0522B
CV-0522B FAILS DUE TO CONTROL FAILURE
G42
MANUAL CONTROL FAILS
27
G421
P. H22
AUTOMATIC CONTROL FAILS
G422
NO POWER FROM DC BUS 1
EDC1
AUTO START FAILS
28
G423
P. H29

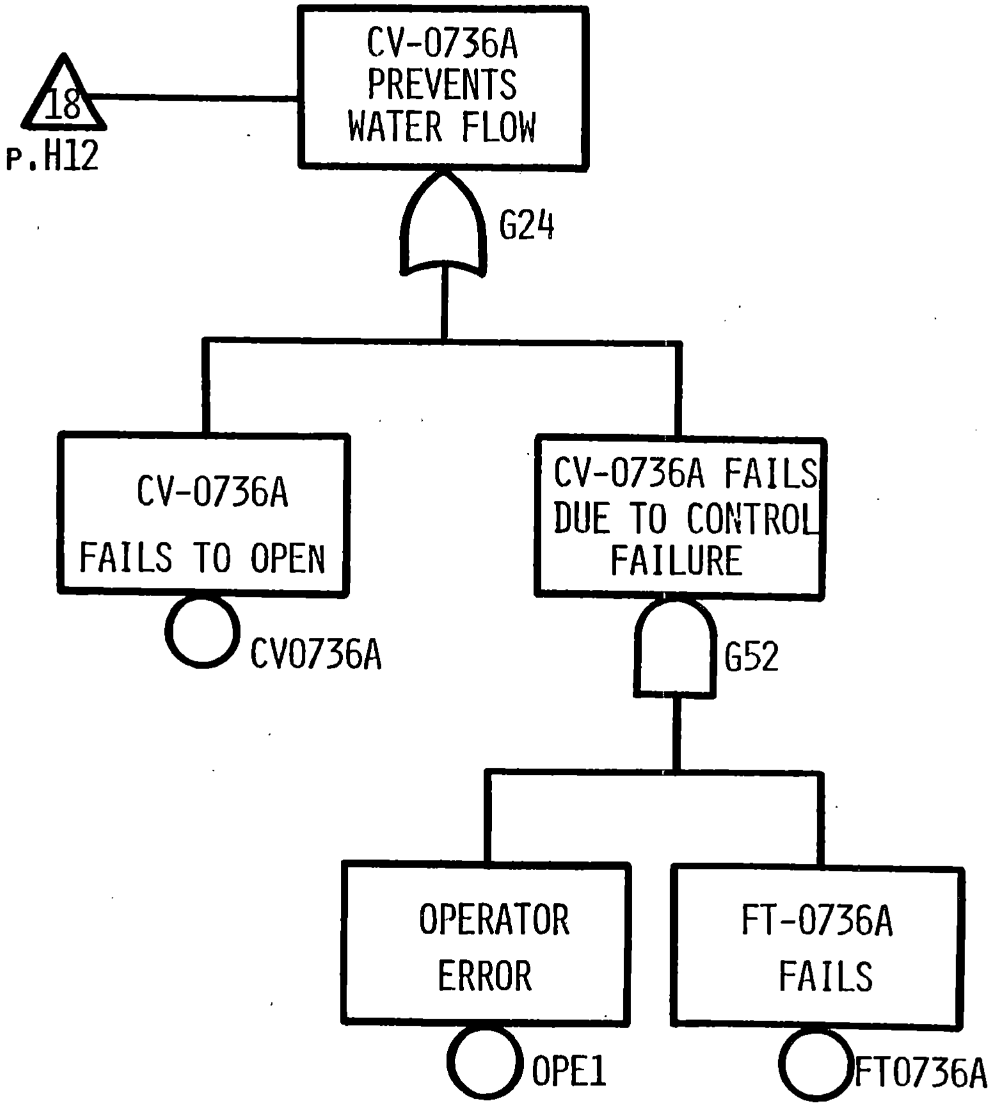

27
P.H21
MANUAL CONTROL FAILS
G421
CR/SUPPORTING INSTRUMENTS FAILURE
G43
OPERATOR ERROR IN LOCAL
OPE 2
LOSS OF INSTRUMENT AIR
G431
SV-0522B FAILS
SV0522B
FCV-0522B FAILS
FCV0522B
HS-0522B FAILS
HS0522B
OPERATOR ERROR IN CR
OPE1
NO POWER FROM DC BUS 1
EDC1
NITROGEN SOURCE FAILS
NITROGEN
SERVICE & INSTR AIR SYSTEM FAILS
AIR2

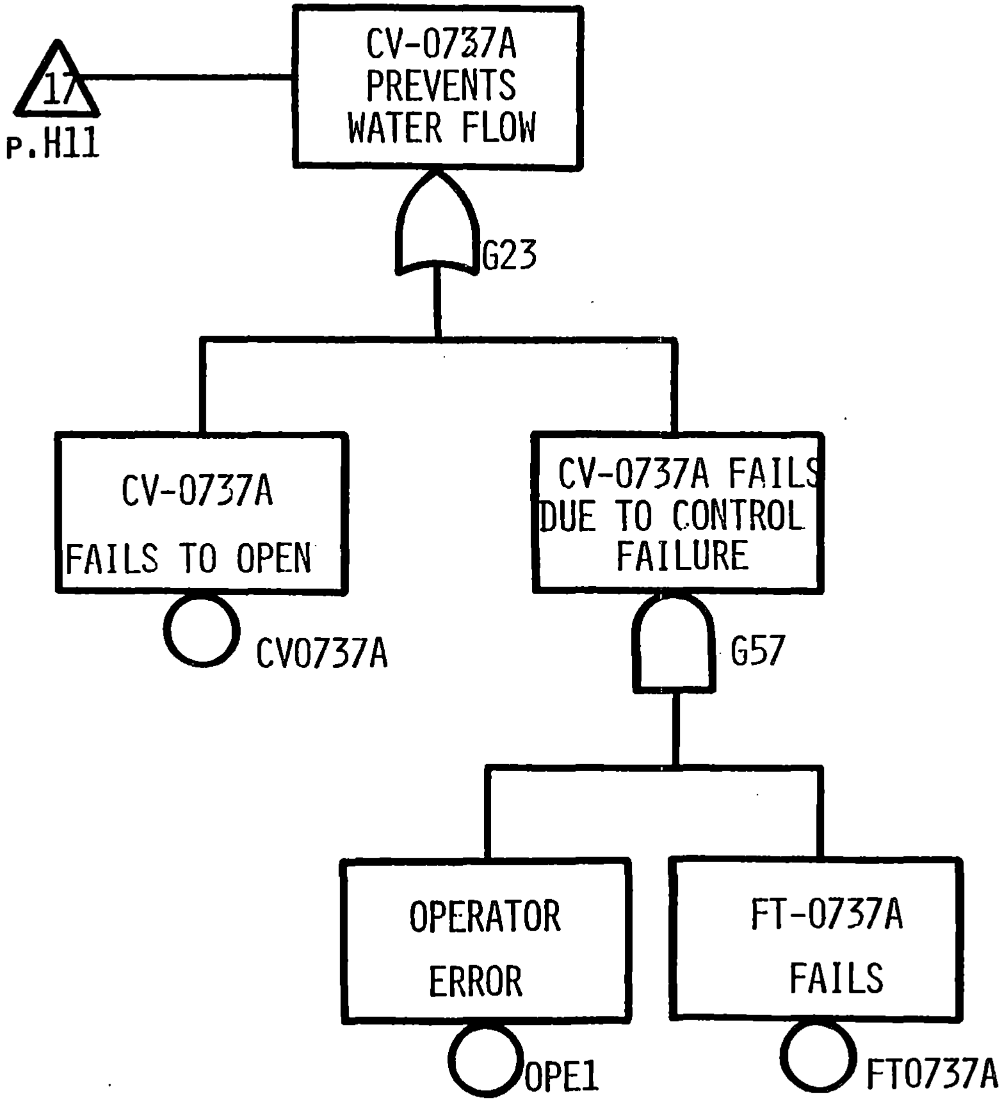


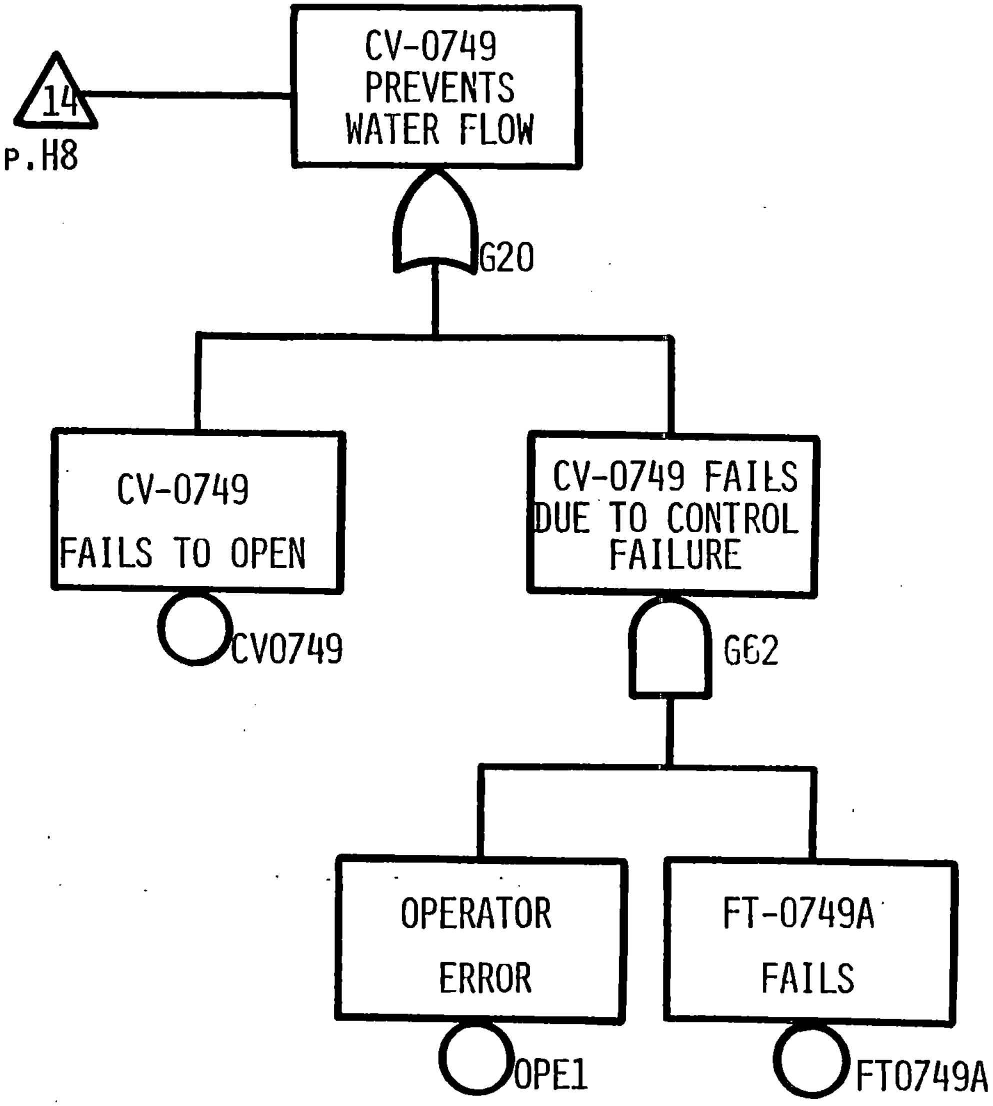
CV-0521 PREVENTS STEAM FLOW
25
p. H17
G39
OPERATOR ERROR IN CR
OPE8
CV-0521 FAILS TO OPEN
CV0521
SV-0521 FAILS
SV0521
HS-0521 FAILS
HS0521
NO POWER FROM DC BUS 2
EDC2
NO ELEC PWR FROM AC BUS Y10
EACY10

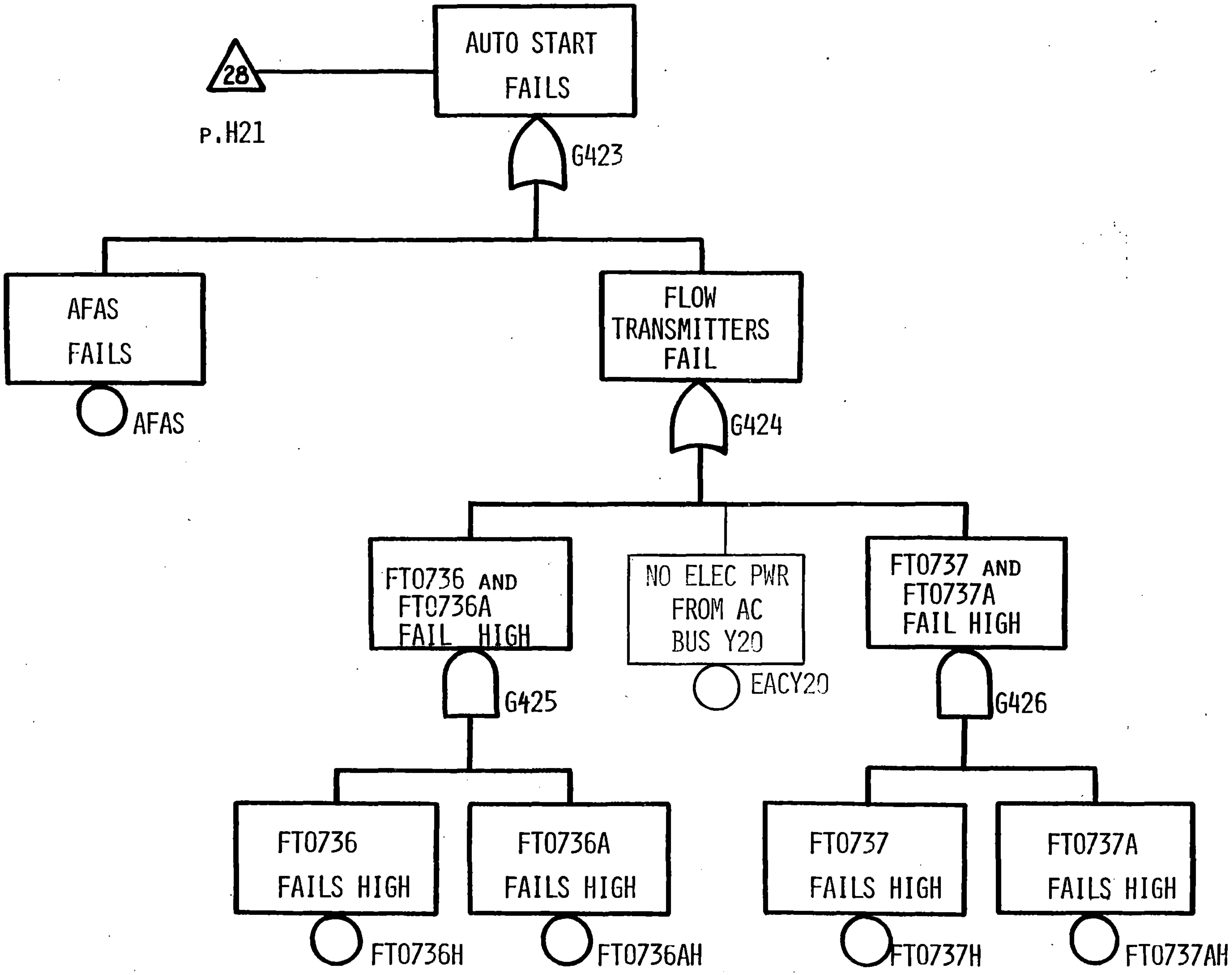

PUMP P-8C FAILS
16
P.H10
G22
PUMP P-8C FAILS TO START
PS8C
NO ELEC POWER FROM AC BUS 1D
EAC1D
NO ACTION TO START P-8C WHEN REQUIRED
G44
NO ELEC PWR FROM AC BUS Y20
EACY20
MANUAL START FAILURE
G45
AUTO START FAILS
29
G441
P.H30
HS-152-209CS FAILS
HS209CS
OPERATOR ERROR
OPE1
NO POWER FROM DC BUS 2
EDC2

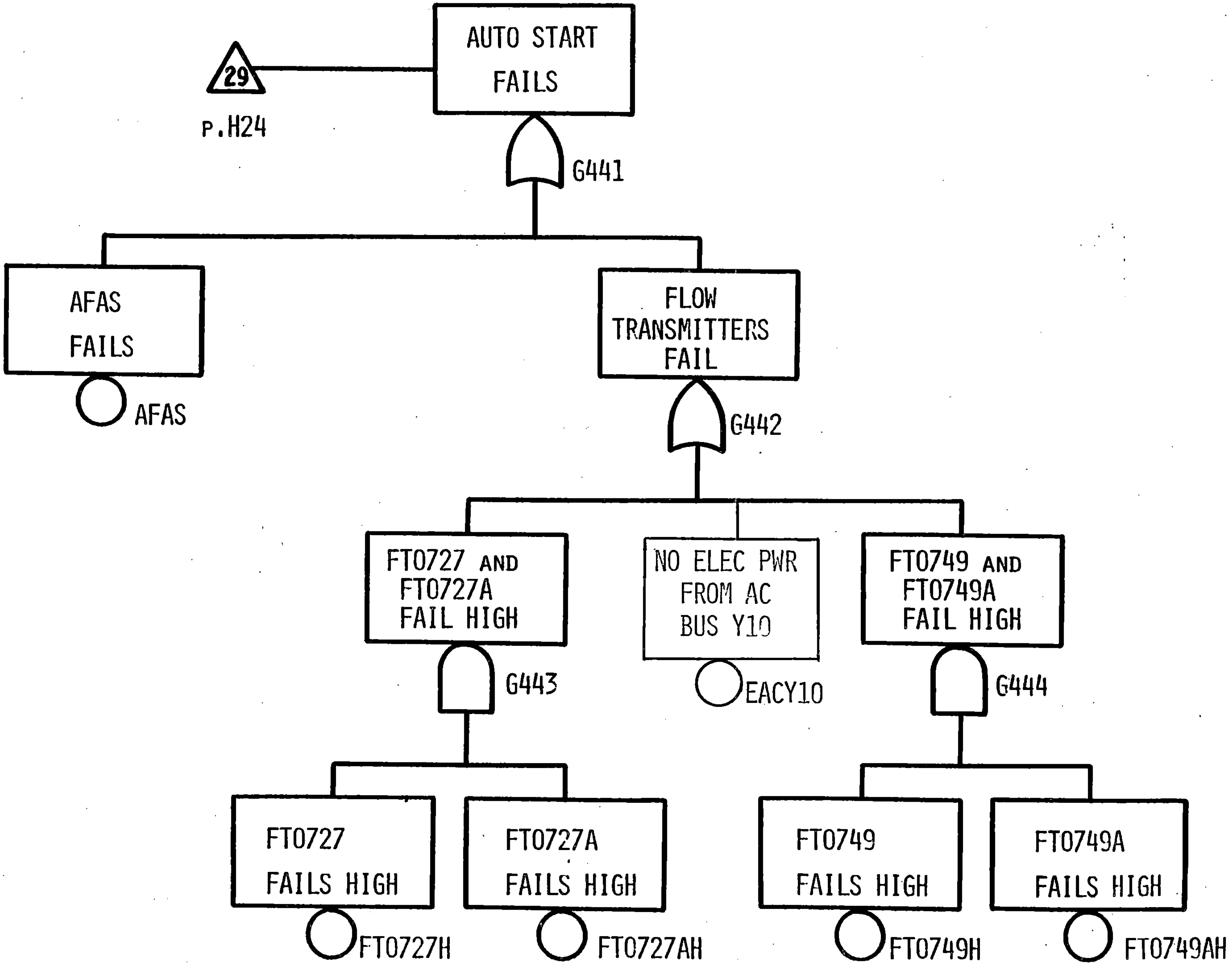

15
P.H9
CV-0727 PREVENTS WATER FLOW
G21
CV-0727 FAILS TO OPEN
CV0727
CV-0727 FAILS DUE TO CONTROL FAILURE
G47
OPERATOR ERROR
OPE1
FT-0727A FAILS
FT0727A


CV-0736A PREVENTS WATER FLOW
18
P.H12
G24
CV-0736A FAILS TO OPEN
CV0736A
CV-0736A FAILS DUE TO CONTROL FAILURE
G52
OPERATOR ERROR
OPE1
FT-0736A FAILS
FT0736A


17
P.H11
CV-0737A PREVENTS WATER FLOW
G23
CV-0737A FAILS TO OPEN
CV0737A
CV-0737A FAILS DUE TO CONTROL FAILURE
G57
OPERATOR ERROR
OPE1
FT-0737A FAILS
FT0737A


14
p.H8
CV-0749 PREVENTS WATER FLOW
G20
CV-0749 FAILS TO OPEN
CV0749
CV-0749 FAILS DUE TO CONTROL FAILURE
G62
OPERATOR ERROR
OPE1
FT-0749A FAILS
FT0749A


28
P.H21
AUTO START FAILS
G423
AFAS FAILS
AFAS
FLOW TRANSMITTERS FAIL
G424
FT0736 AND FT0736A FAIL HIGH
G425
NO ELEC PWR FROM AC BUS Y20
EACY20
FT0737 AND FT0737A FAIL HIGH
G426
FT0736 FAILS HIGH
FT0736H
FT0736A FAILS HIGH
FT0736AH
FT0737 FAILS HIGH
FT0737H
FT0737A FAILS HIGH
FT0737AH


29
p.H24
AUTO START FAILS
G441
AFAS FAILS
AFAS
FLOW TRANSMITTERS FAIL
G442
FT0727 AND FT0727A FAIL HIGH
G443
NO ELEC PWR FROM AC BUS Y10
EACY10
FT0749 AND FT0749A FAIL HIGH
G444
FT0727 FAILS HIGH
FT0727H
FT0727A FAILS HIGH
FT0727AH
FT0749 FAILS HIGH
FT0749H
FT0749A FAILS HIGH
FT0749AH

APPENDIX E

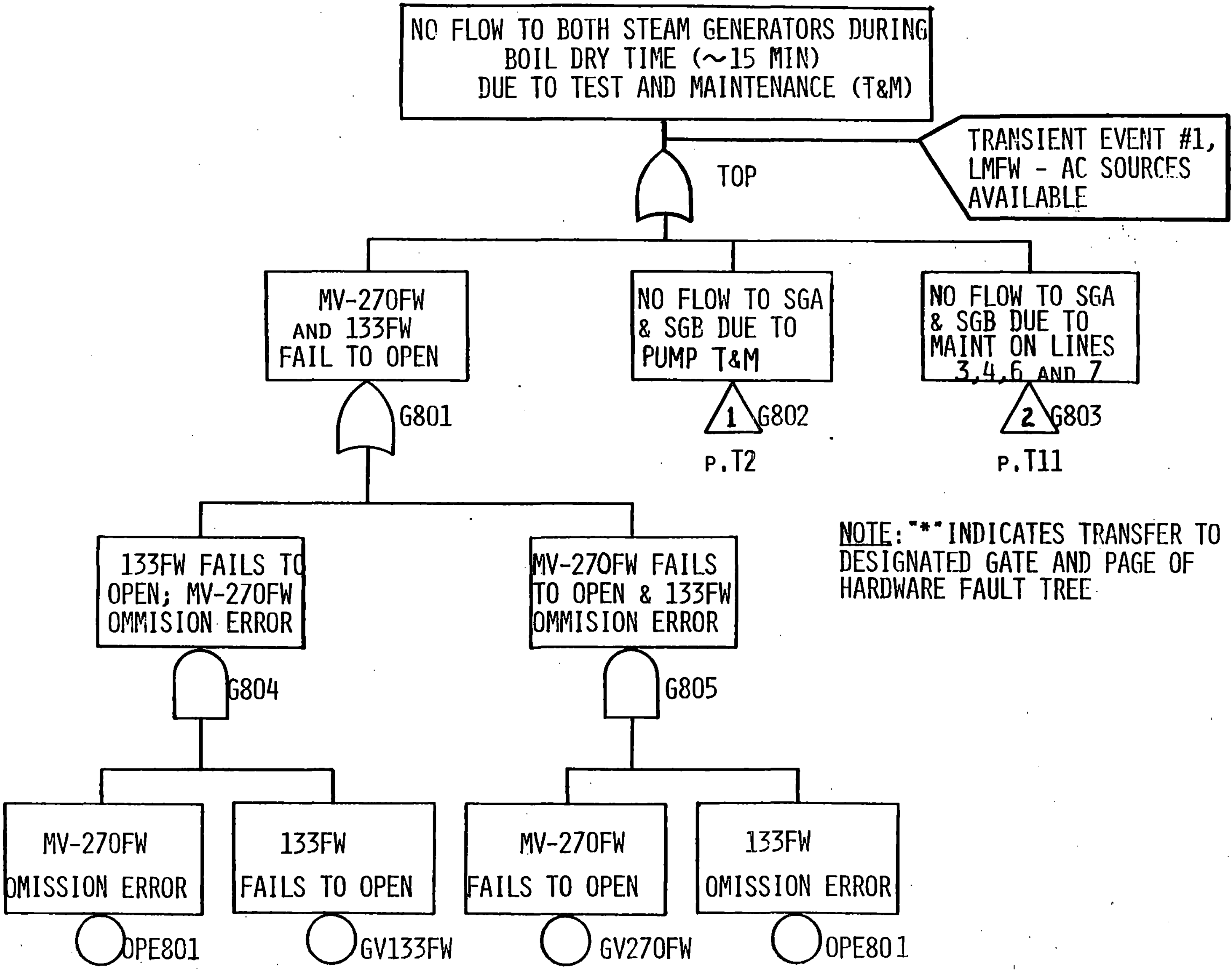
TEST AND MAINTENANCE FAULT TREE

APPENDIX E

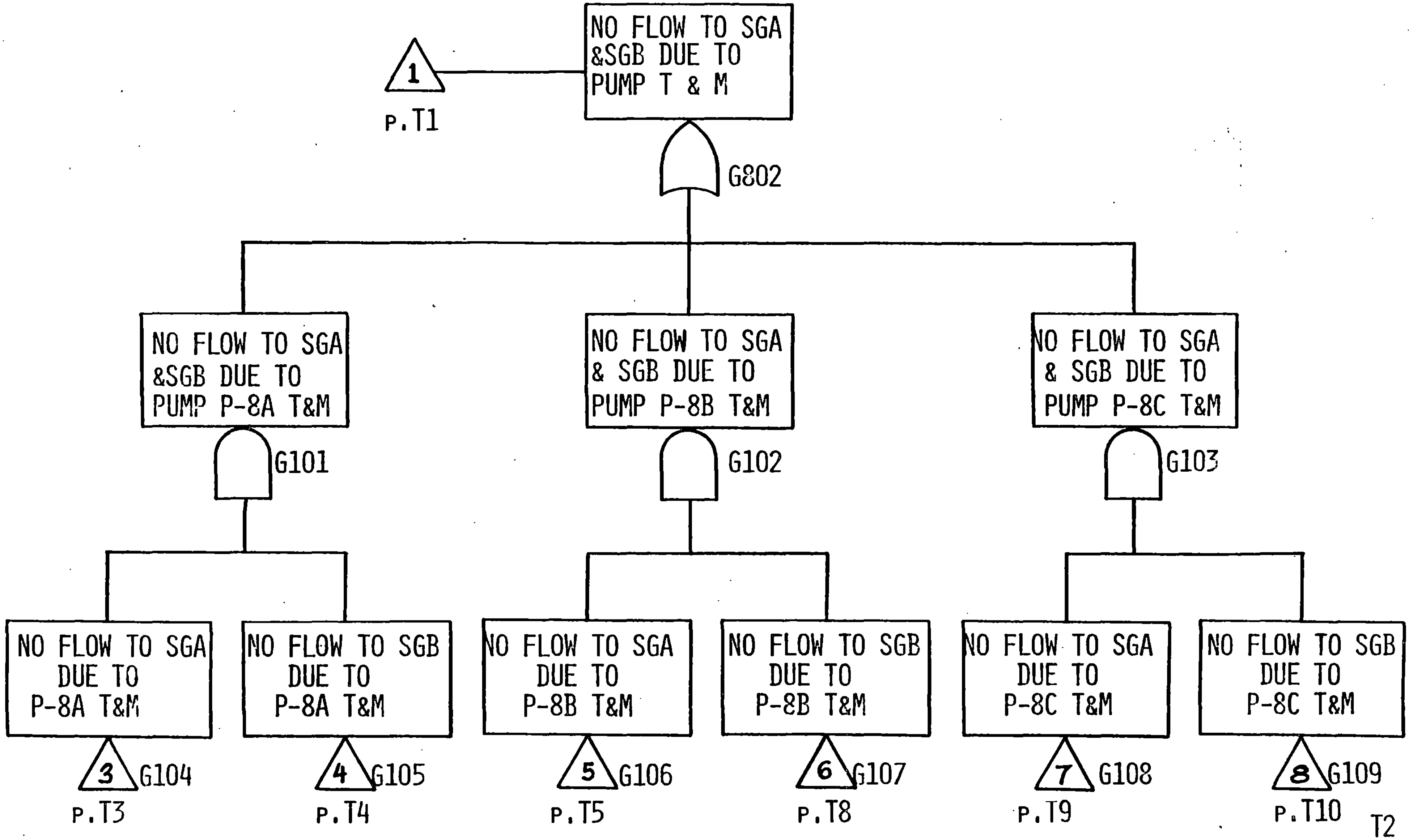
```
AFW SYSTEM RELIABILITY - TEST & MAINTENANCE
                1.0E-08     1     2
TOP          OR     3   0          G801      G802      G803
G801         OR     2   0          G804      G805
G802         OR     3   0          G101      G102      G103
G803         OR     4   0          G206      G208      G203      G204
G804         AND    0   2          OPE801    GV133FW
G805         AND    0   2          OPE801    GV270FW
G101         AND    2   0          G104      G105
G102         AND    2   0          G106      G107
G103         AND    2   0          G108      G109
G104         AND    2   0          G110      G6
G105         AND    2   0          G121      G8
G106         AND    2   0          G112      G6
G107         AND    2   0          G122      G8
G108         AND    2   0          G119      G5
G109         AND    2   0          G119      G7
G110         AND    2   0          G111      G17
G111         OR     0   5          TP8A      MP8A      MCK0741   OPE101    OPE102
G112         AND    2   0          G113      G16
G113         OR     1   5          G114      TP8B      MP8B      MCK0743   OPE103
            1           OPE104
G114         OR     2   1          G115      G116      MPCV521A
G115         AND    2   0          G117      G32
G116         AND    2   0          G118      G33
G117         OR     0   4          MCK401MS  MCV0521   OPE105    MCV0522A
G118         OR     0   3          MCK402MS  MCV0522B  OPE106
G119         OR     0   5          TP8C      MP8C      MCK0726   OPE107    OPE108
G203         OR     2   0          G209      G210
G204         OR     2   0          G211      G212
G206         AND    2   0          G217      G4
G208         AND    2   0          G223      G3
G209         AND    2   0          G225      G239
G210         AND    2   0          G228      G4
G211         AND    2   0          G230      G231
G212         AND    2   0          G233      G3
G217         AND    2   0          G218      G6
G218         OR     0   2          MMO0753   OPE202
G223         AND    2   0          G224      G8
G224         OR     0   2          MMO0743   OPE204
G225         AND    2   0          G227      G5
G227         OR     0   2          MCV0737A  OPE205
G228         AND    2   0          G229      G5
G229         OR     0   2          MMO0754   OPE206
G230         AND    2   0          G232      G5
G231         AND    2   0          G232      G7
G232         OR     0   2          MCV0736A  OPE210
G233         AND    2   0          G234      G7
G234         OR     0   2          MMO0748   OPE207
G239         AND    2   0          G227      G7
G3           AND    2   0          G5        G6
G4           AND    2   0          G7        G8
G5           OR     3   1          G9        G10       G11       RV0783
G6           OR     2   0          G12       G13
G7           OR     3   1          G9        G10       G14       RV0783
```

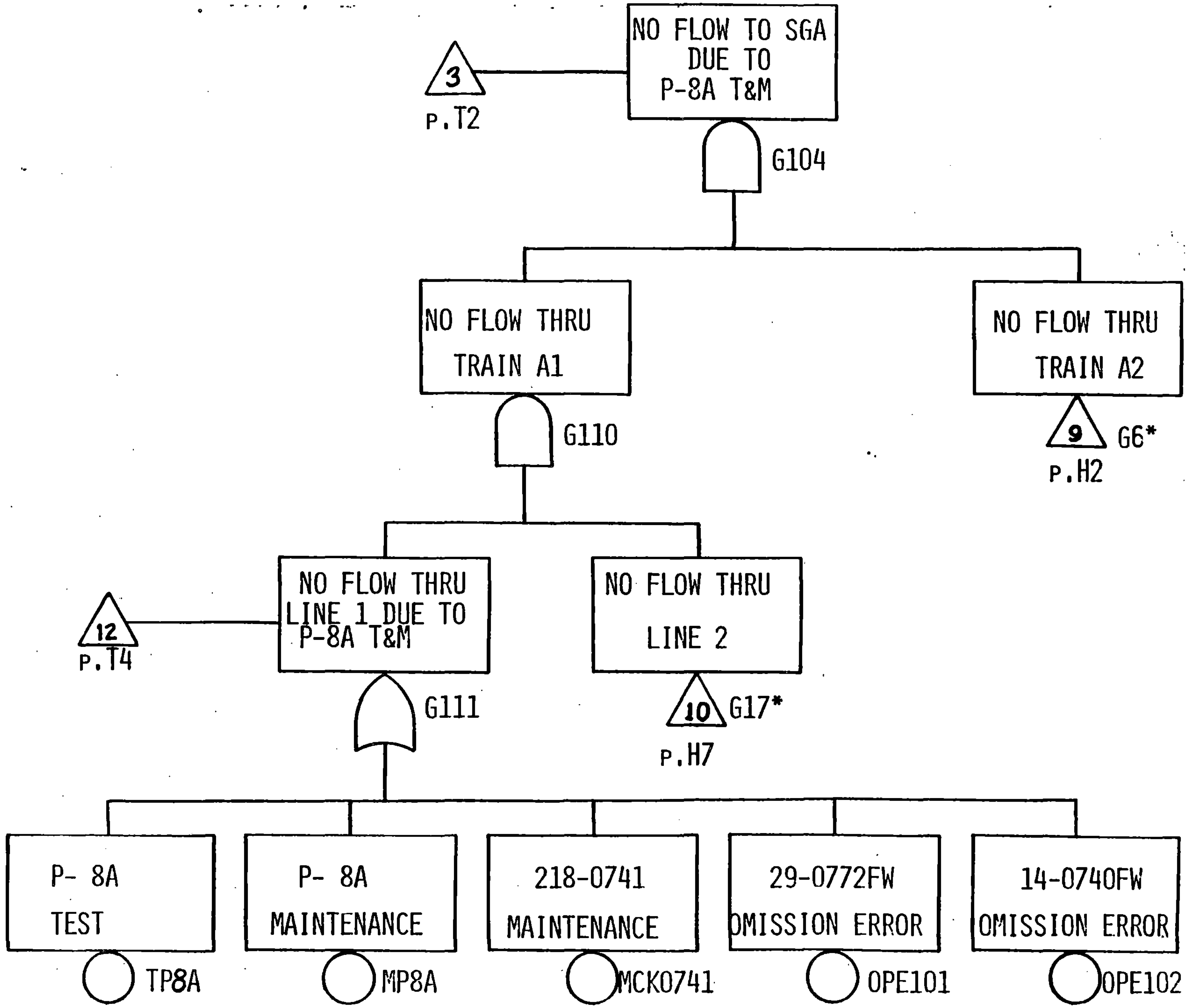
```
G8          OR    2   0          G12        G15
G9          AND   0   2          GV0771     GV0271
G10         AND   2   0          G16        G17
G11         OR    1   3          G20        MO0753     MO0760     CK0729
G12         OR    1   4          G22        CK0725     GV0751     CK0726     GV0752
G13         OR    1   3          G23        MO0754     MO0759     CK0704
G14         OR    1   3          G21        MO0743     MO0798     CK0728
G15         OR    1   3          G24        MO0748     MO0755     CK0703
G16         OR    1   3          G18        GV0772     CK0741     GV0740
G17         OR    1   3          G19        GV0132     CK0743     GV0742
G18         OR    1   3          G25        PS8A       EAC1C      EACY10
G19         OR    1   1          G28        PS8B
G20         OR    1   1          G62        CV0749
G21         OR    1   1          G47        CV0727
G22         OR    1   3          G44        PS8C       EAC1D      EACY20
G23         OR    1   1          G57        CV0737A
G24         OR    1   1          G52        CV0736A
G25         AND   1   1          G26        AFAS
G26         OR    0   3          HS104CS    OPE1       EDC1
G28         OR    2   1          G29        G301       GOVERNOR
G29         AND   2   0          G32        G33
G32         OR    1   3          G36        CK402MS    GV153AMS   GV153MS
G33         OR    3   3          G37        G38        G65        CK401MS    GV152AMS
           1          GV152MS
G36         OR    1   2          G42        CV0522B    EACY10
G37         AND   2   0          G39        G371
G38         OR    1   1          G40        CV0522A
G39         OR    0   6          OPE1       CV0521     SV0521     HS0521     EDC2
           1          EACY10
G40         AND   1   1          G41        OPE2
G41         OR    0   6          AIR1       SV0522A    FCV0522A   HS0522A    OPE1
           1          EDC1
G42         AND   2   0          G421       G422
G43         OR    1   5          G431       SV0522B    FCV0522B   HS0522B    OPE1
           1          EDC1
G44         AND   2   0          G441       G45
G45         OR    0   3          HS209CS    OPE1       EDC2
G47         AND   0   2          OPE1       FT0727A
G52         AND   0   2          OPE1       FT0736A
G57         AND   0   2          OPE1       FT0737A
G62         AND   0   2          OPE1       FT0749A
G65         AND   1   1          G66        WATER
G66         OR    1   1          G67        GV714FW
G67         OR    1   1          G68        CV0525
G68         AND   1   1          G69        OPE2
G69         OR    0   5          AIR3       SV0525     HS0525     OPE1       EDC1
G301        OR    1   1          G302       PCV0521A
G302        AND   0   2          NITROGEN   AIR4
G371        OR    0   2          GV0214     OPE3
G421        AND   1   1          G43        OPE2
G422        OR    1   1          G423       EDC1
G423        OR    1   1          G424       AFAS
G424        OR    2   1          G425       G426       EACY20
G425        AND   0   2          FT0736H    FT0736AH
G426        AND   0   2          FT0737H    FT0737AH
```

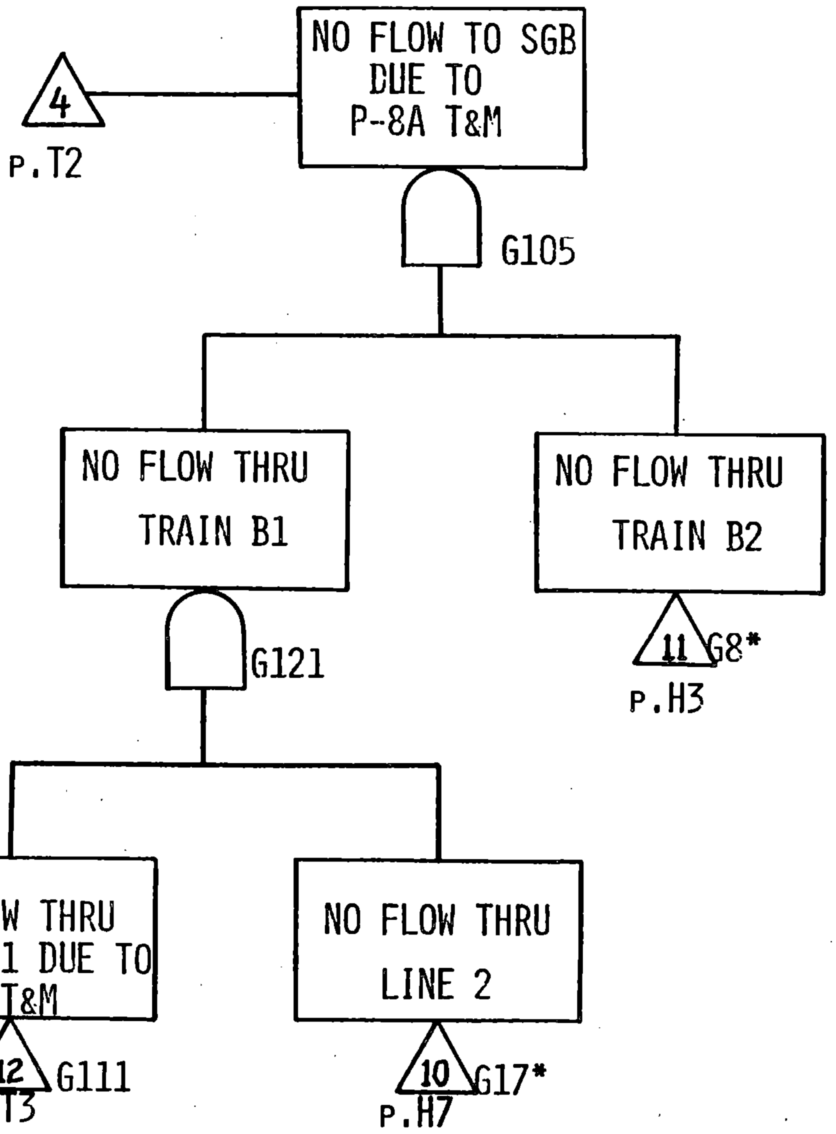
```
G431        AND    0  2        NITROGEN  AIR2
G441        OR     1  1        G442      AFAS
G442        OR     2  1        G443      G444      EACY10
G443        AND    0  2        FT0727H   FT0727AH
G444        AND    0  2        FT0749H   FT0749AH
END
```



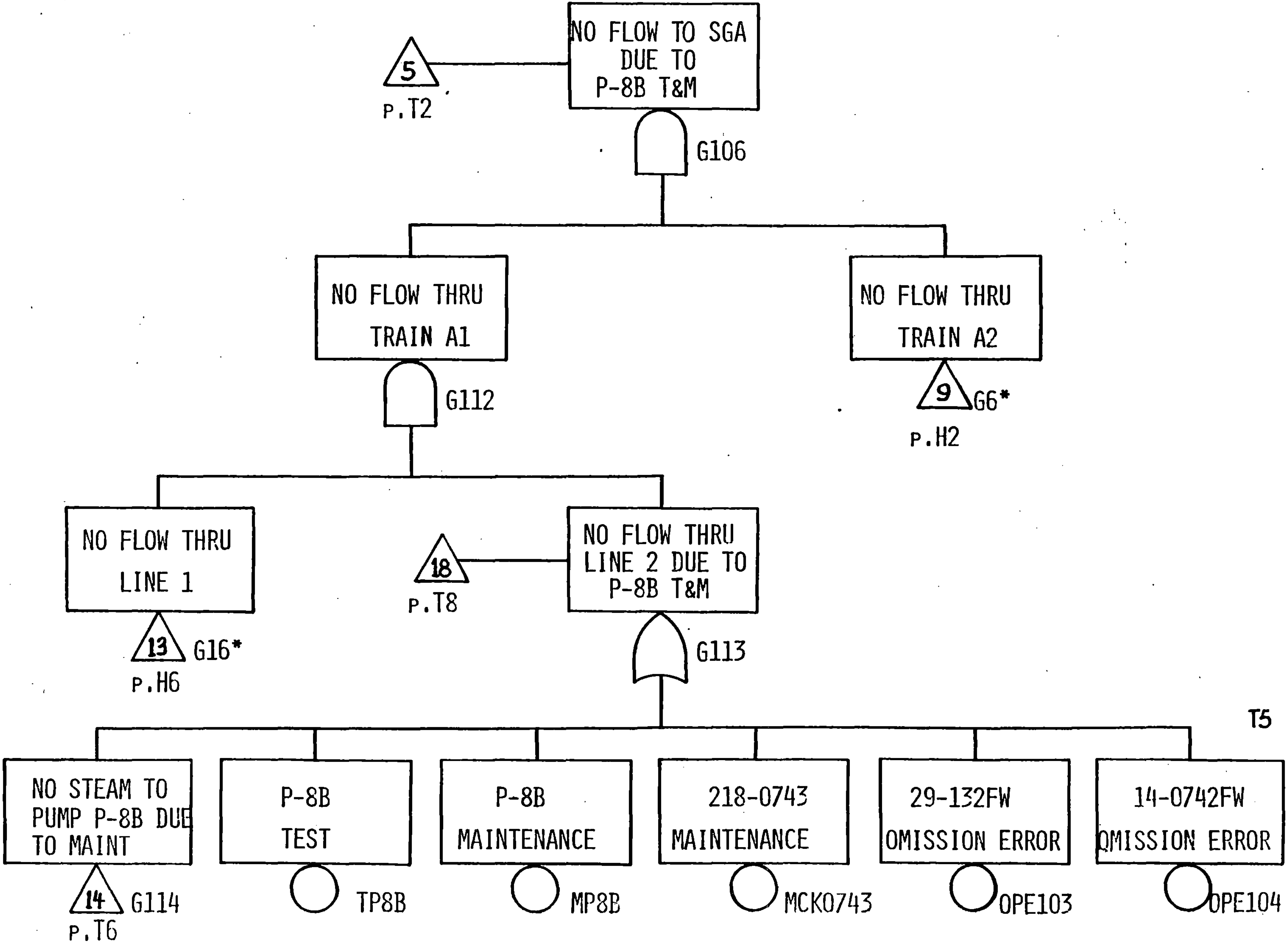
NOTE: "*" INDICATES TRANSFER TO DESIGNATED GATE AND PAGE OF HARDWARE FAULT TREE

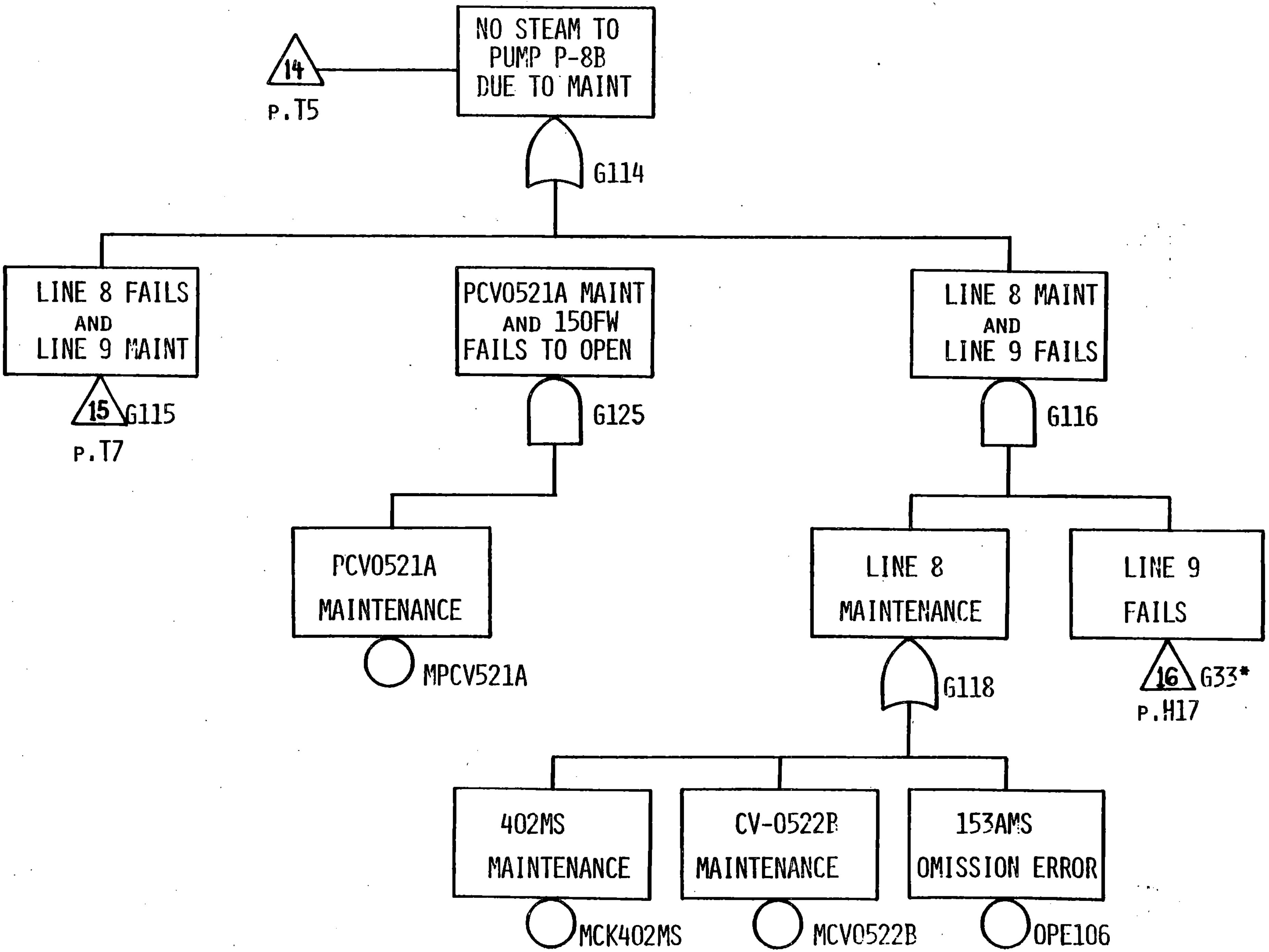

1
P.T1
NO FLOW TO SGA &SGB DUE TO PUMP T & M
G802
NO FLOW TO SGA &SGB DUE TO PUMP P-8A T&M
G101
NO FLOW TO SGA & SGB DUE TO PUMP P-8B T&M
G102
NO FLOW TO SGA & SGB DUE TO PUMP P-8C T&M
G103
NO FLOW TO SGA DUE TO P-8A T&M
3
G104
P.T3
NO FLOW TO SGB DUE TO P-8A T&M
4
G105
P.T4
NO FLOW TO SGA DUE TO P-8B T&M
5
G106
P.T5
NO FLOW TO SGB DUE TO P-8B T&M
6
G107
P.T8
NO FLOW TO SGA DUE TO P-8C T&M
7
G108
P.T9
NO FLOW TO SGB DUE TO P-8C T&M
8
G109
P.T10

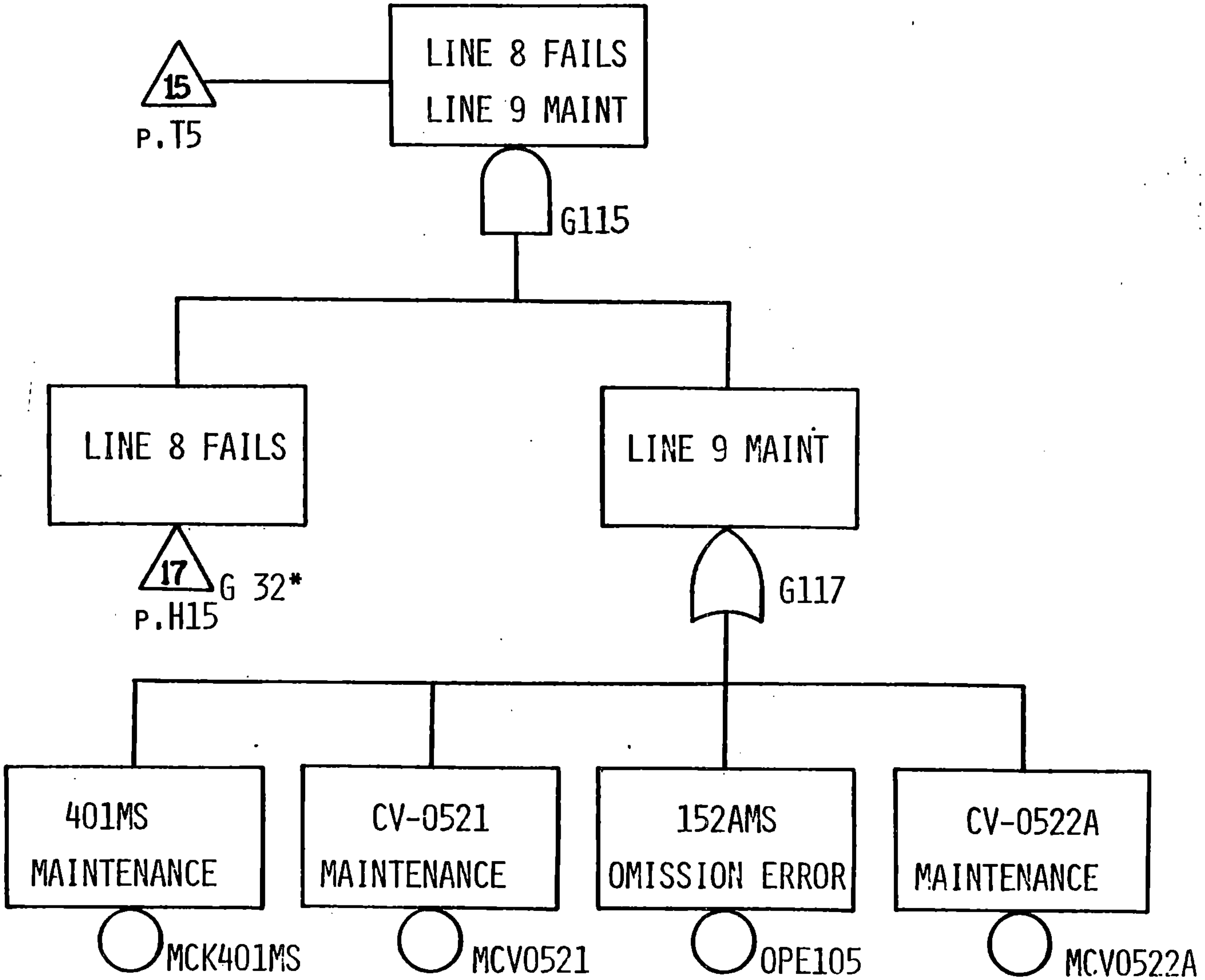

NO FLOW TO SGA DUE TO P-8A T&M
3
P.T2
G104
NO FLOW THRU TRAIN A1
NO FLOW THRU TRAIN A2
G110
9
G6*
P.H2
NO FLOW THRU LINE 1 DUE TO P-8A T&M
12
P.T4
NO FLOW THRU LINE 2
G111
10
G17*
P.H7
P- 8A TEST
TP8A
P- 8A MAINTENANCE
MP8A
218-0741 MAINTENANCE
MCK0741
29-0772FW OMISSION ERROR
OPE101
14-0740FW OMISSION ERROR
OPE102



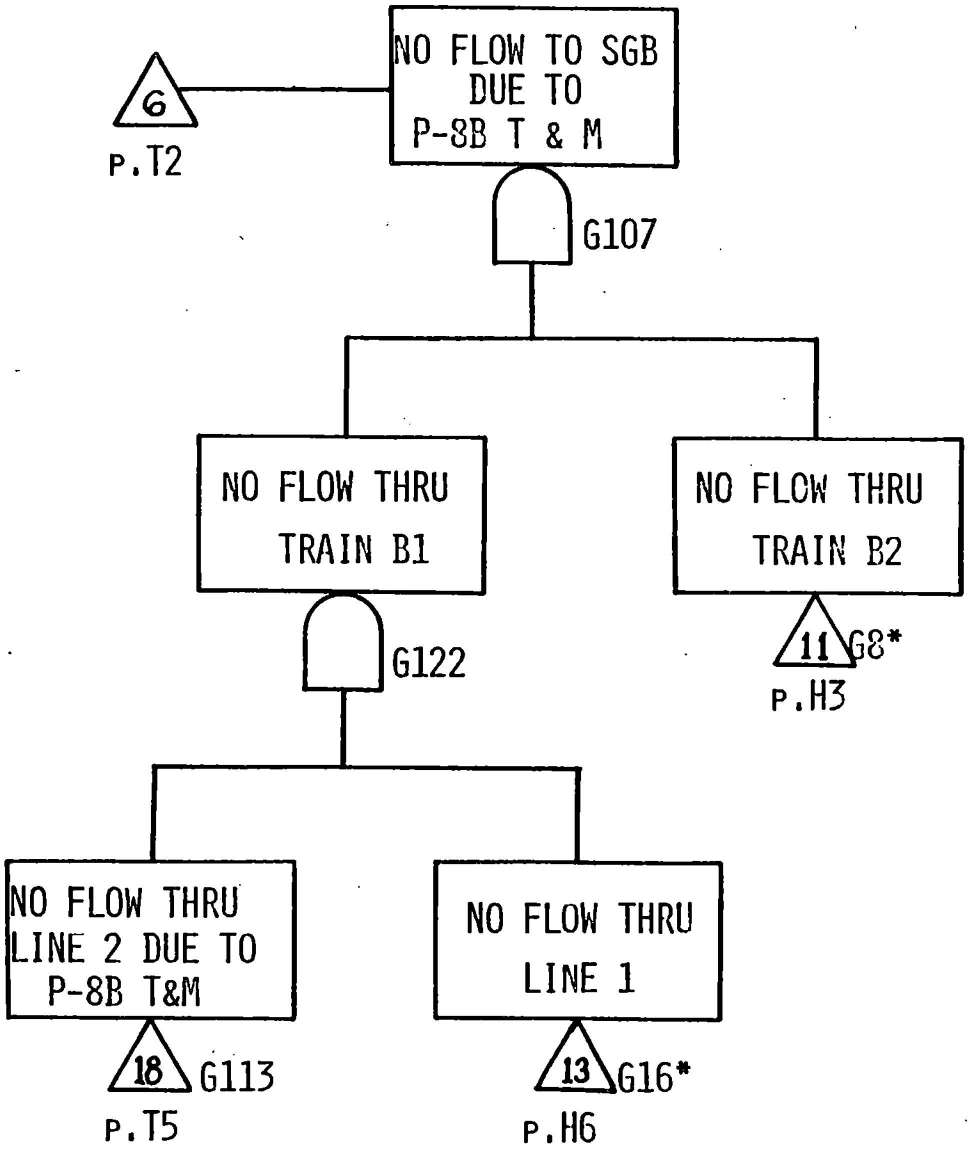
NO FLOW TO SGB DUE TO P-8A T&M
4
P.T2
G105
NO FLOW THRU TRAIN B1
NO FLOW THRU TRAIN B2
11
G8*
P.H3
G121
NO FLOW THRU LINE 1 DUE TO P-8A T&M
NO FLOW THRU LINE 2
12
G111
P.T3
10
G17*
P.H7

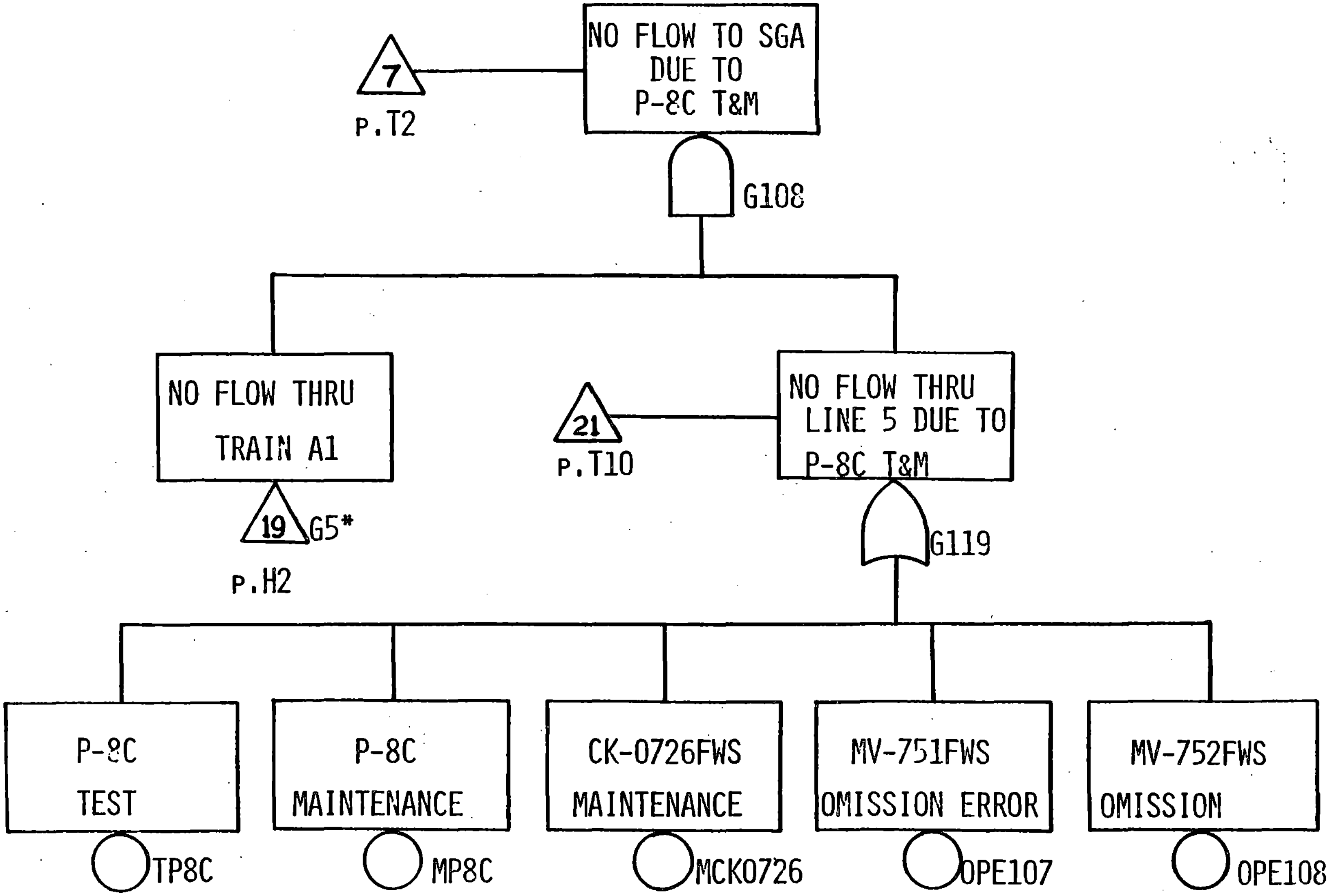

NO FLOW TO SGA DUE TO P-8B T&M
5
P.T2
G106
NO FLOW THRU TRAIN A1
G112
NO FLOW THRU TRAIN A2
9
G6*
P.H2
NO FLOW THRU LINE 1
13
G16*
P.H6
18
P.T8
NO FLOW THRU LINE 2 DUE TO P-8B T&M
G113
NO STEAM TO PUMP P-8B DUE TO MAINT
14
G114
P.T6
P-8B TEST
TP8B
P-8B MAINTENANCE
MP8B
218-0743 MAINTENANCE
MCK0743
29-132FW OMISSION ERROR
OPE103
14-0742FW OMISSION ERROR
OPE104

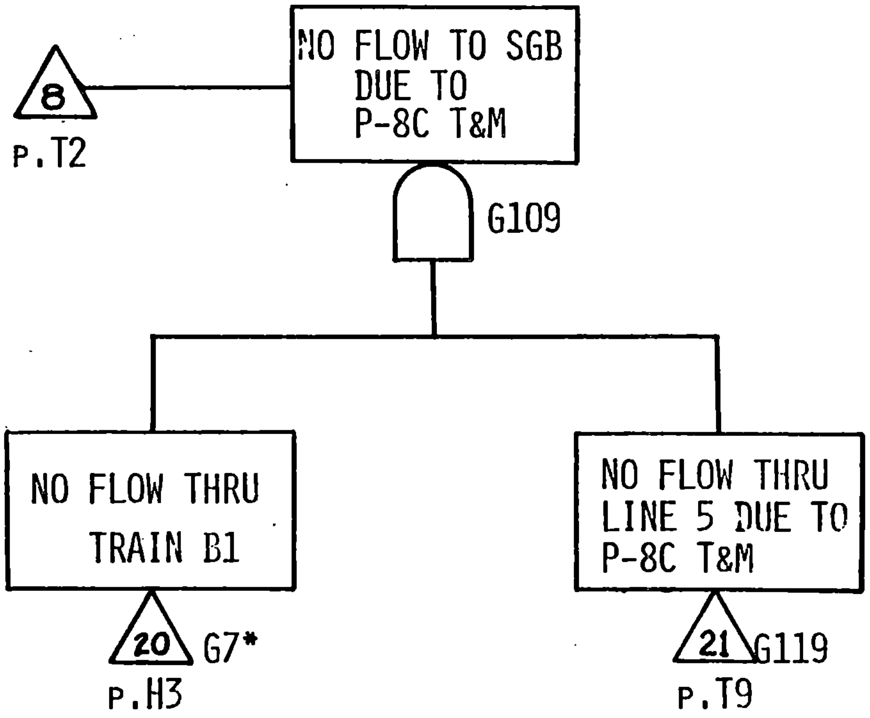

NO STEAM TO PUMP P-8B DUE TO MAINT
14
P.T5
G114
LINE 8 FAILS AND LINE 9 MAINT
15
G115
P.T7
PCV0521A MAINT AND 150FW FAILS TO OPEN
G125
LINE 8 MAINT AND LINE 9 FAILS
G116
PCV0521A MAINTENANCE
MPCV521A
LINE 8 MAINTENANCE
G118
LINE 9 FAILS
16
G33*
P.H17
402MS MAINTENANCE
MCK402MS
CV-0522B MAINTENANCE
MCV0522B
153AMS OMISSION ERROR
OPE106

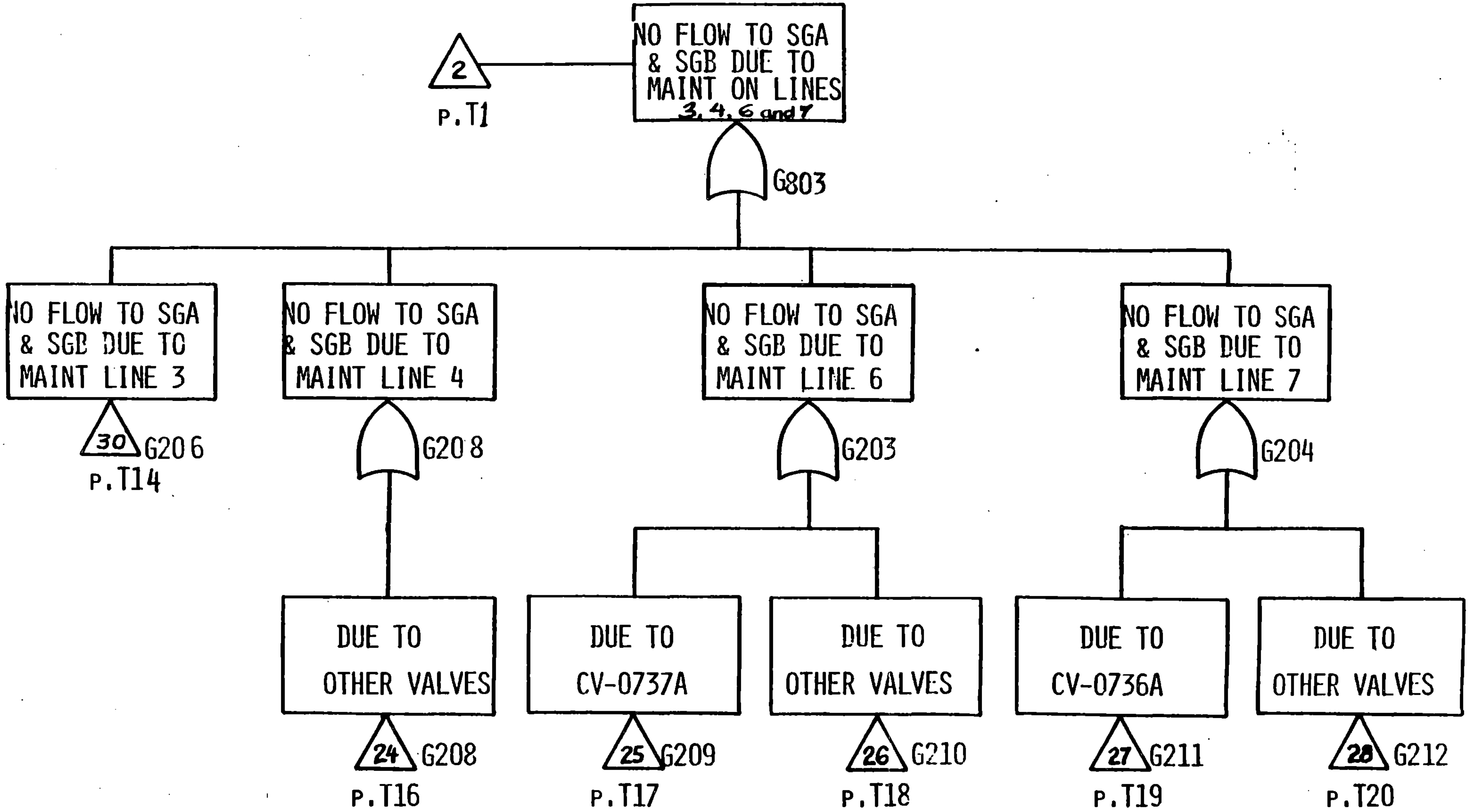


15
P. T5
LINE 8 FAILS
LINE 9 MAINT
G115
LINE 8 FAILS
17
G 32*
P. H15
LINE 9 MAINT
G117
401MS
MAINTENANCE
MCK401MS
CV-0521
MAINTENANCE
MCV0521
152AMS
OMISSION ERROR
OPE105
CV-0522A
MAINTENANCE
MCV0522A


6
P.T2
NO FLOW TO SGB DUE TO P-8B T & M
G107
NO FLOW THRU TRAIN B1
NO FLOW THRU TRAIN B2
11
G8*
P.H3
G122
NO FLOW THRU LINE 2 DUE TO P-8B T&M
NO FLOW THRU LINE 1
18
G113
P.T5
13
G16*
P.H6


NO FLOW TO SGA DUE TO P-8C T&M
7
P.T2
G108
NO FLOW THRU TRAIN A1
19
G5*
P.H2
21
P.T10
NO FLOW THRU LINE 5 DUE TO P-8C T&M
G119
P-8C TEST
TP8C
P-8C MAINTENANCE
MP8C
CK-0726FWS MAINTENANCE
MCK0726
MV-751FWS OMISSION ERROR
OPE107
MV-752FWS OMISSION
OPE108


8
P.T2
NO FLOW TO SGB DUE TO P-8C T&M
G109
NO FLOW THRU TRAIN B1
20
G7*
P.H3
NO FLOW THRU LINE 5 DUE TO P-8C T&M
21
G119
P.T9


2
P.T1
NO FLOW TO SGA & SGB DUE TO MAINT ON LINES 3, 4, 6 and 7
G803
NO FLOW TO SGA & SGB DUE TO MAINT LINE 3
30
G206
P.T14
NO FLOW TO SGA & SGB DUE TO MAINT LINE 4
G208
NO FLOW TO SGA & SGB DUE TO MAINT LINE 6
G203
NO FLOW TO SGA & SGB DUE TO MAINT LINE 7
G204
DUE TO OTHER VALVES
24
G208
P.T16
DUE TO CV-0737A
25
G209
P.T17
DUE TO OTHER VALVES
26
G210
P.T18
DUE TO CV-0736A
27
G211
P.T19
DUE TO OTHER VALVES
28
G212
P.T20

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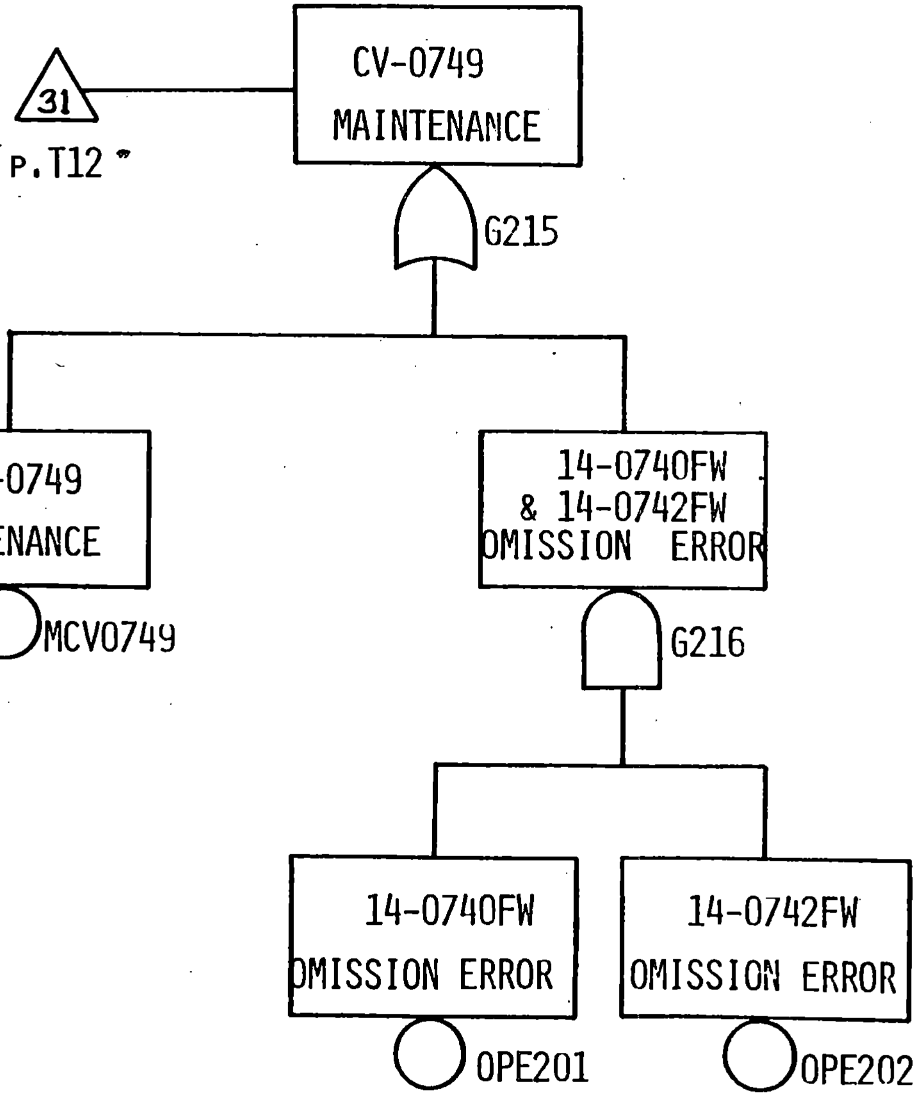
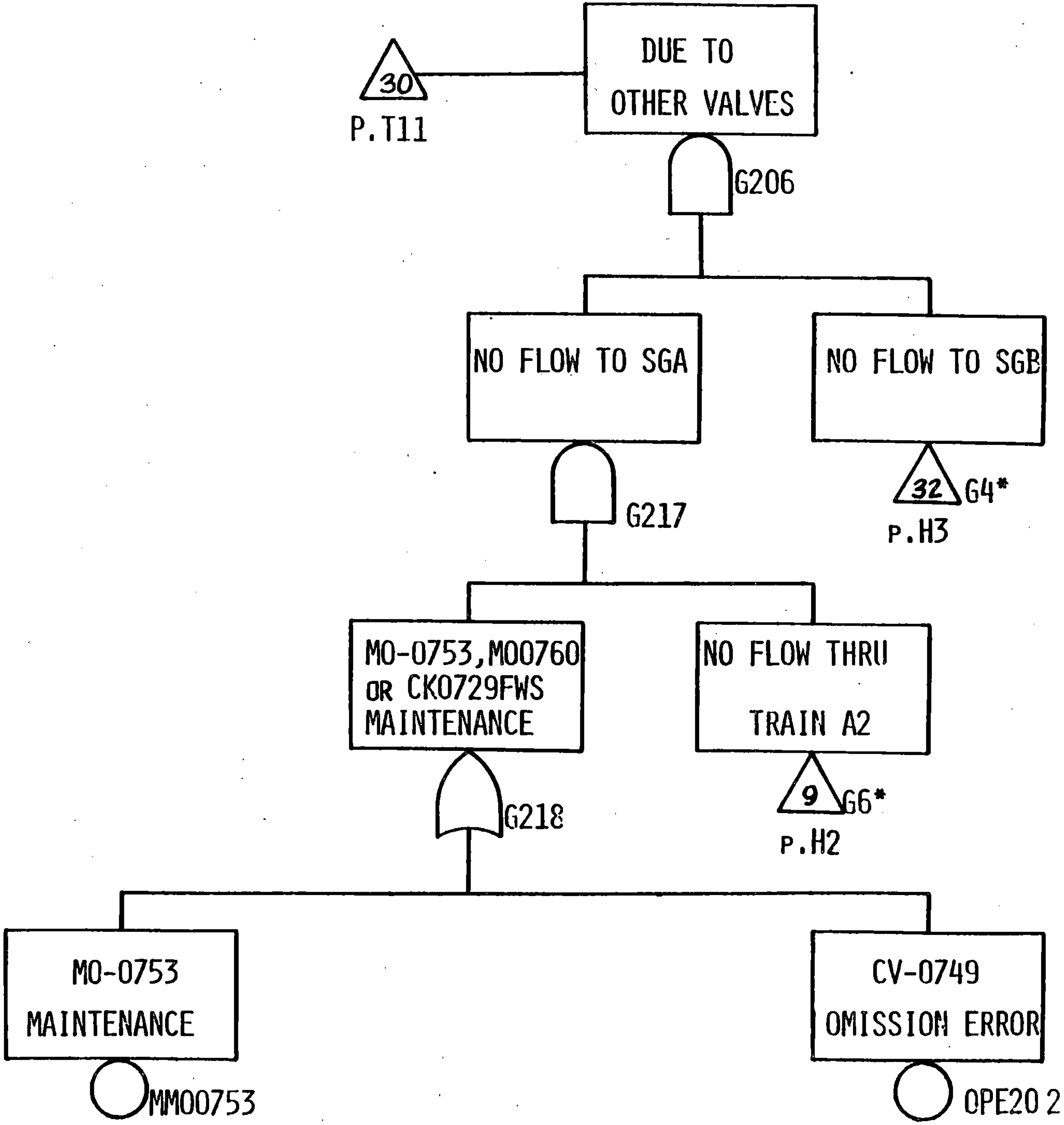

31
p.T12
CV-0749 MAINTENANCE
G215
CV-0749 MAINTENANCE
MCV0749
14-0740FW & 14-0742FW OMISSION ERROR
G216
14-0740FW OMISSION ERROR
OPE201
14-0742FW OMISSION ERROR
OPE202



30
P.T11
DUE TO OTHER VALVES
G206
NO FLOW TO SGA
NO FLOW TO SGB
G217
32
G4*
P.H3
MO-0753,MO0760 OR CK0729FWS MAINTENANCE
NO FLOW THRU TRAIN A2
G218
9
G6*
P.H2
MO-0753 MAINTENANCE
MMO0753
CV-0749 OMISSION ERROR
OPE20 2

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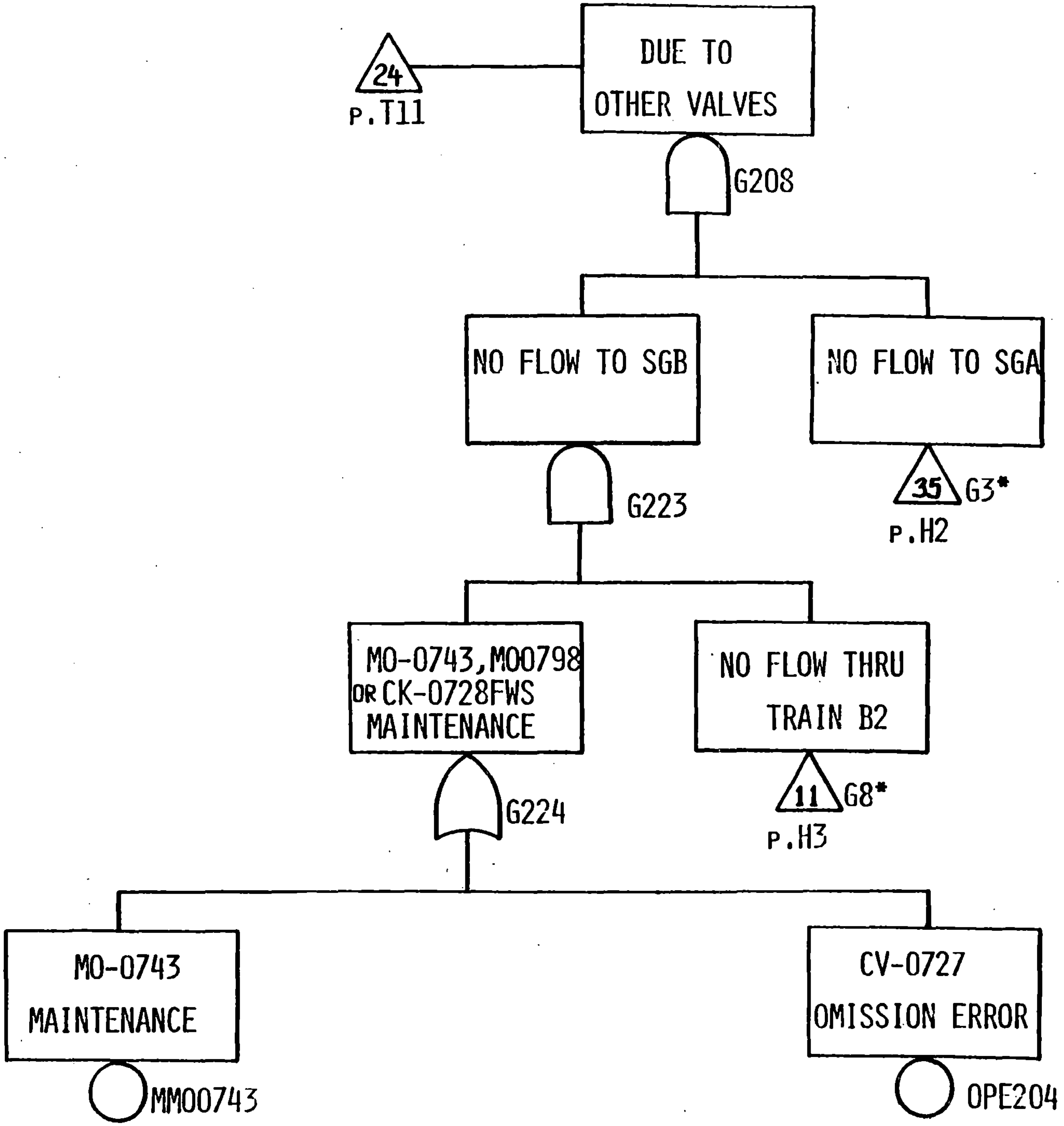
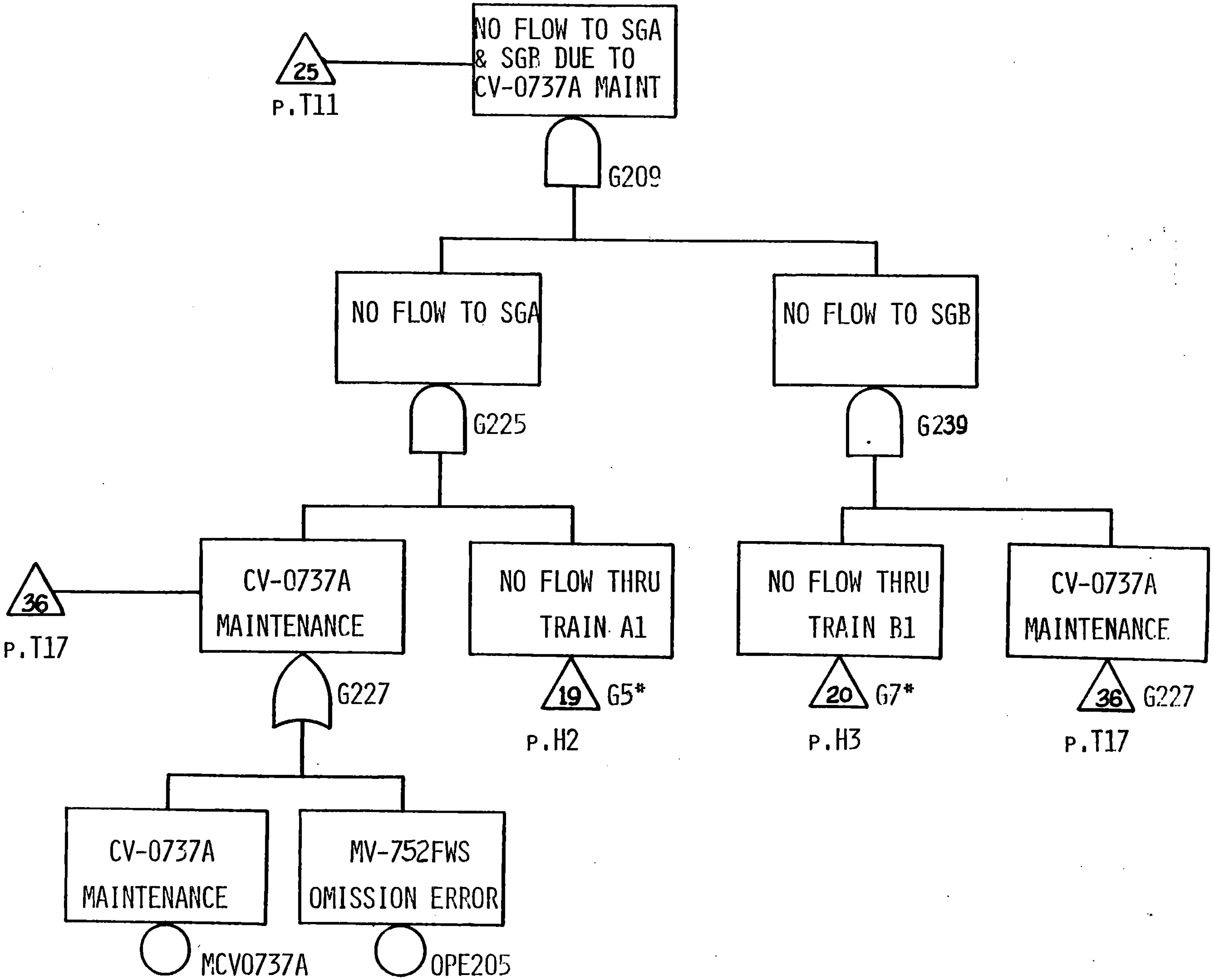
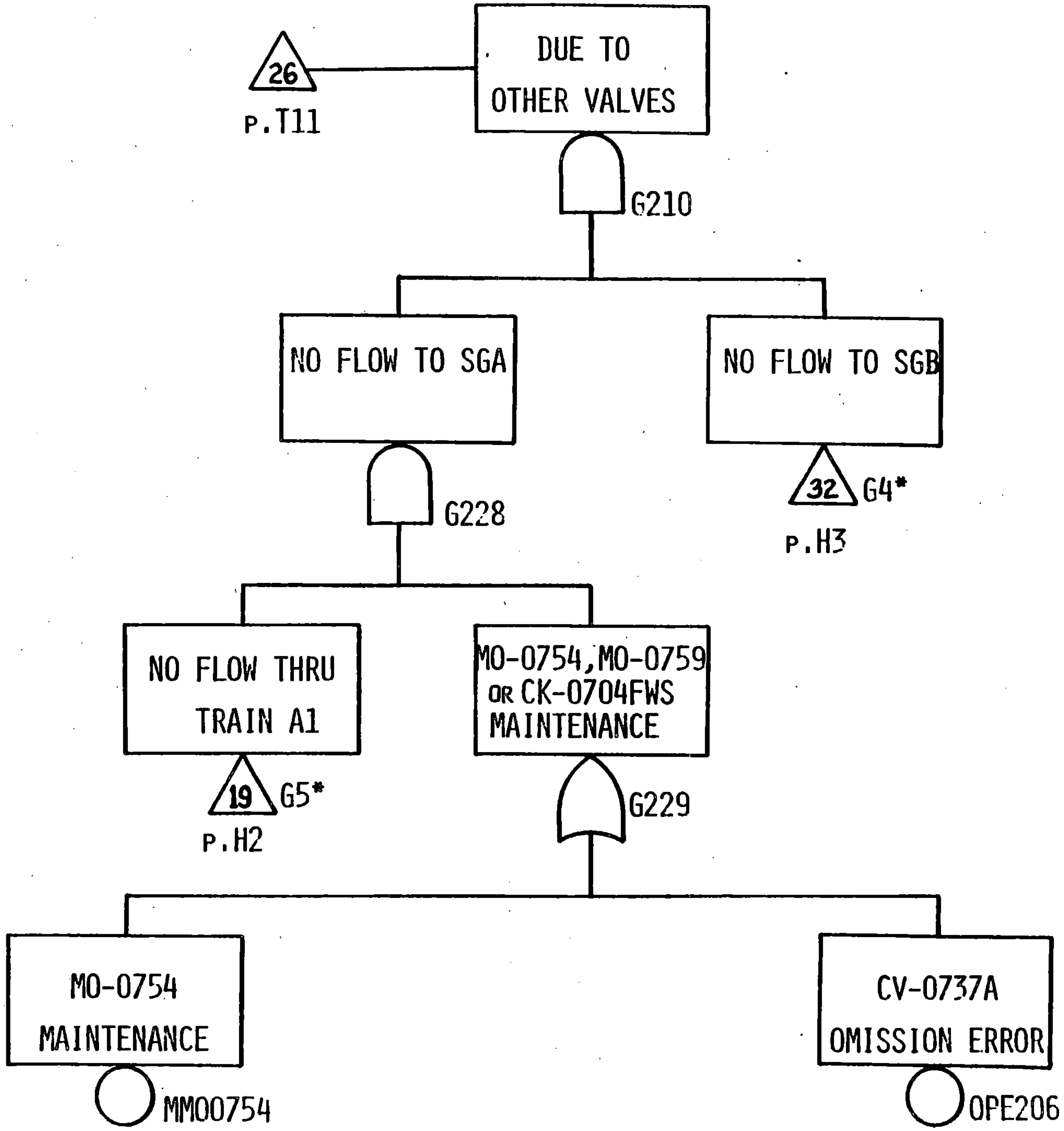
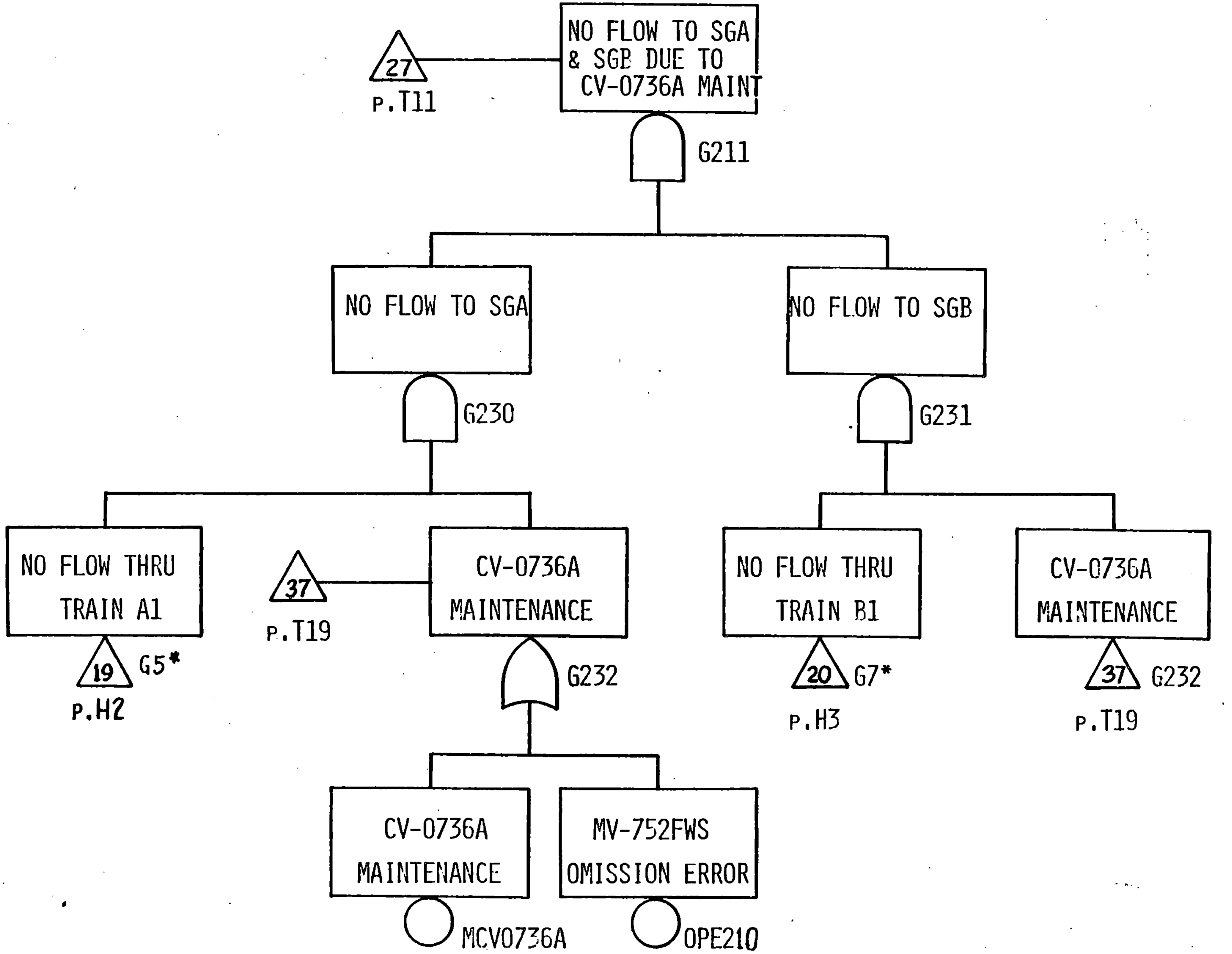
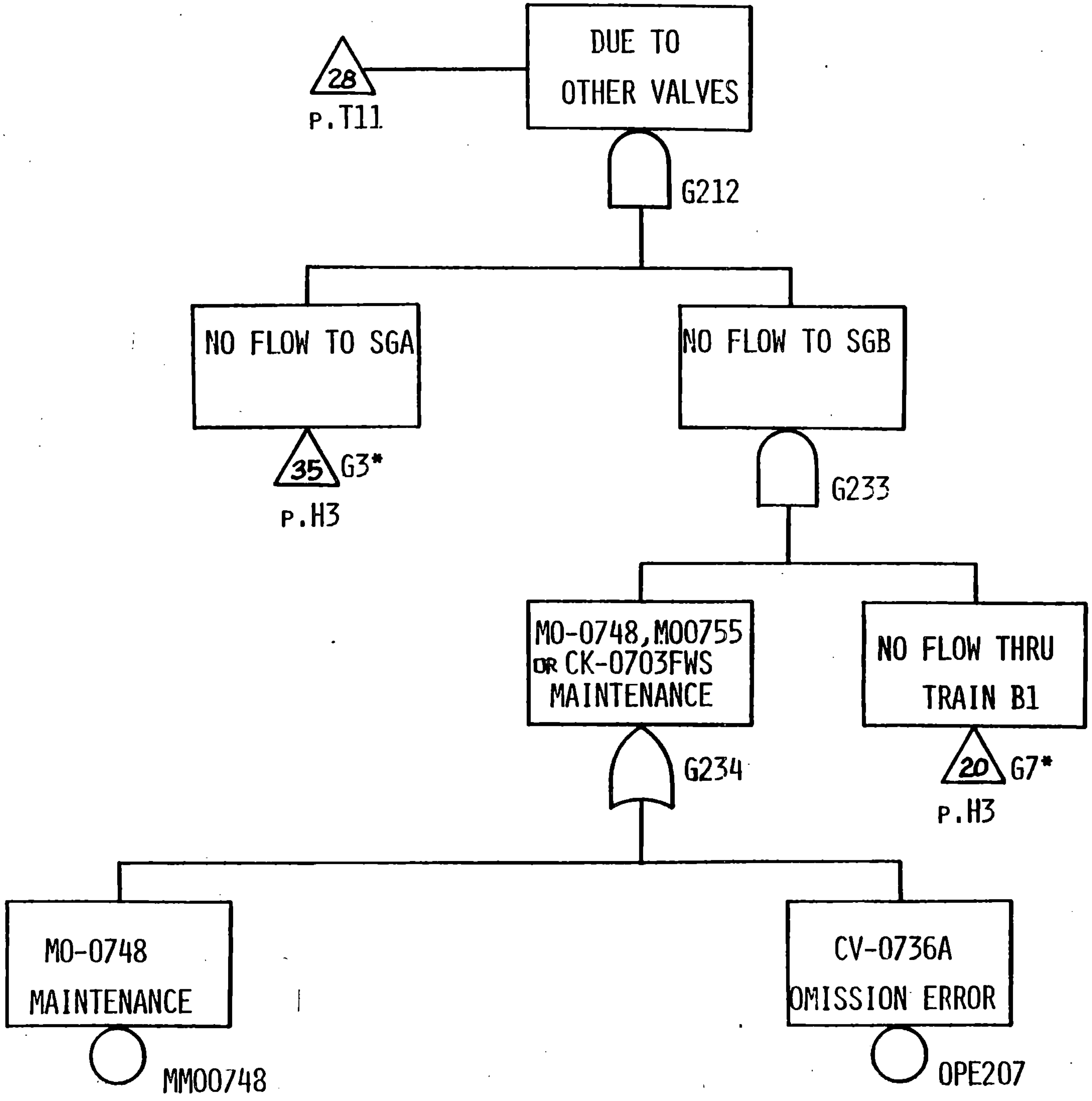
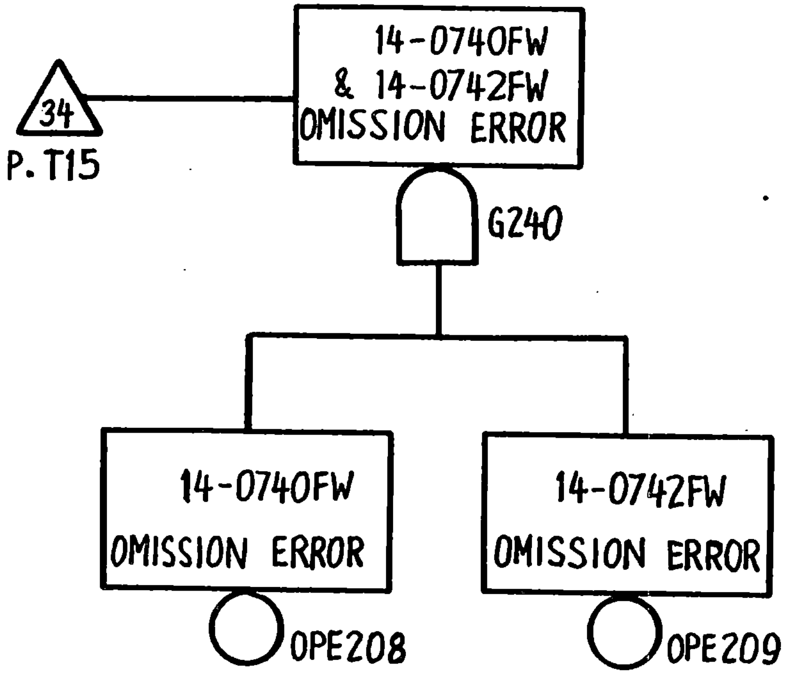

24
P.T11
DUE TO OTHER VALVES
G208
NO FLOW TO SGB
NO FLOW TO SGA
G223
35
G3*
P.H2
MO-0743,MO0798 OR CK-0728FWS MAINTENANCE
NO FLOW THRU TRAIN B2
G224
11
G8*
P.H3
MO-0743 MAINTENANCE
CV-0727 OMISSION ERROR
MM00743
OPE204


NO FLOW TO SGA & SGB DUE TO CV-0737A MAINT
25
P.T11
G209
NO FLOW TO SGA
G225
NO FLOW TO SGB
G239
CV-0737A MAINTENANCE
36
P.T17
G227
NO FLOW THRU TRAIN A1
19
G5*
P.H2
NO FLOW THRU TRAIN B1
20
G7*
P.H3
CV-0737A MAINTENANCE
36
G227
P.T17
CV-0737A MAINTENANCE
MCV0737A
MV-752FWS OMISSION ERROR
OPE205


26
p.T11
DUE TO OTHER VALVES
G210
NO FLOW TO SGA
NO FLOW TO SGB
G228
32
G4*
p.H3
NO FLOW THRU TRAIN A1
MO-0754,MO-0759 OR CK-0704FWS MAINTENANCE
19
G5*
p.H2
G229
MO-0754 MAINTENANCE
CV-0737A OMISSION ERROR
MM00754
OPE206


NO FLOW TO SGA & SGB DUE TO CV-0736A MAINT
27
p.T11
G211
NO FLOW TO SGA
G230
NO FLOW TO SGB
G231
NO FLOW THRU TRAIN A1
19
G5*
p.H2
37
p.T19
CV-0736A MAINTENANCE
G232
NO FLOW THRU TRAIN B1
20
G7*
p.H3
CV-0736A MAINTENANCE
37
G232
p.T19
CV-0736A MAINTENANCE
MCV0736A
MV-752FWS OMISSION ERROR
OPE210


DUE TO OTHER VALVES
28
P.T11
G212
NO FLOW TO SGA
35
G3*
P.H3
NO FLOW TO SGB
G233
MO-0748, M00755 OR CK-0703FWS MAINTENANCE
G234
NO FLOW THRU TRAIN B1
20
G7*
P.H3
MO-0748 MAINTENANCE
MM00748
CV-0736A OMISSION ERROR
OPE207


14-0740FW
& 14-0742FW
OMISSION ERROR
34
P.T15
G240
14-0740FW
OMISSION ERROR
OPE208
14-0742FW
OMISSION ERROR
OPE209

APPENDIX F

ELECTRICAL FAULT TREES

APPENDIX F

AFW RELIABILITY - ELECTRICAL BUS 1C

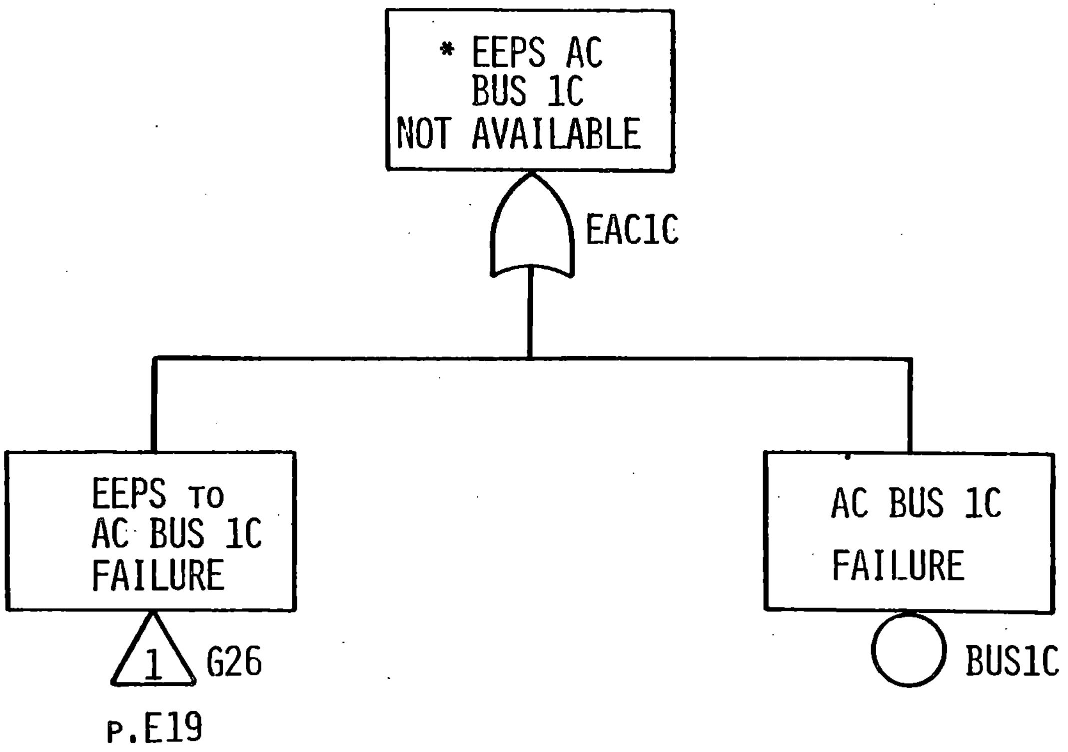
```
EAC1C       OR     1  1       G26       BUS1C
G26         AND    2  0       G31       G33
G31         OR     0  4       B18       C16       DG1-1S    DG1-1R
G33         OR     0  4       B20       C18       STUT1-2   OPRT
END
```

AFW RELIABILITY - ELECTRICAL BUS Y10

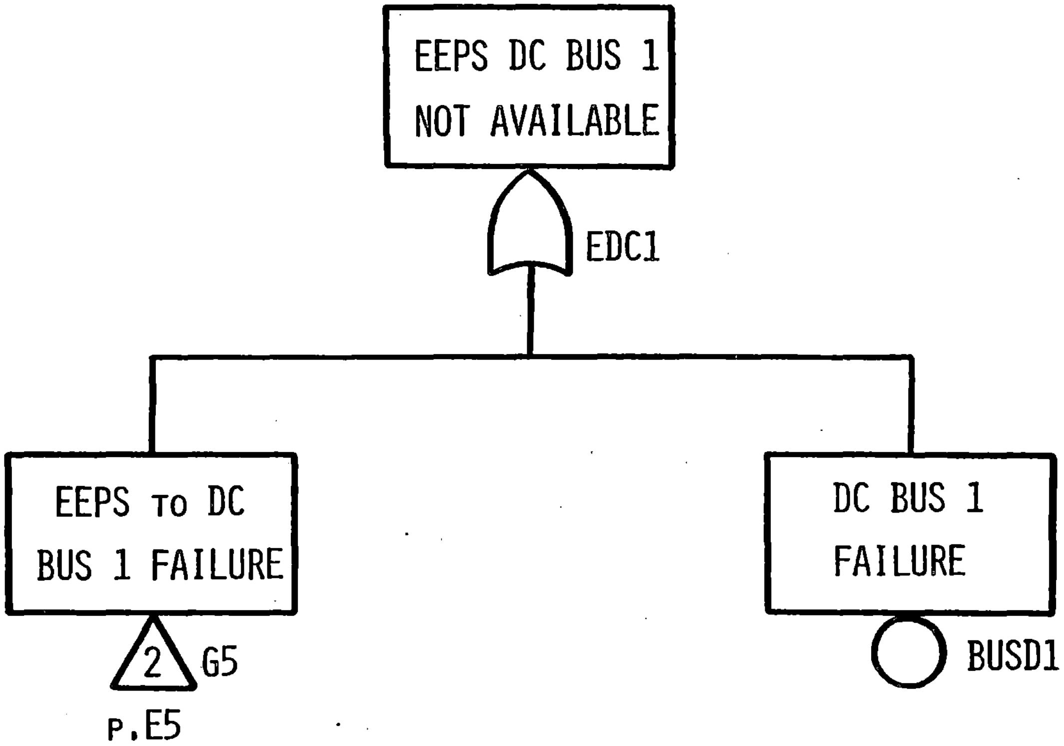
```
EACY10      OR     1  1       G1        BUSY10
G1          AND    2  0       G2        G3
G2          OR     1  4       G4        B1        C1        BYPR      BUSY01
G3          OR     1  4       G5        B2        C2        INV1      BUSD1
G4          AND    2  0       G6        G7
G5          AND    3  0       G8        G9        G10
G6          OR     1  4       G14       B3        C3        ACT1      BUSMC1
G7          OR     1  4       G11       B4        C4        ACT2      BUSMC3
G8          OR     1  3       G12       B5        C5        BATT1
G9          OR     1  3       G13       B6        C6        BUSMC2
G10         OR     1  3       G14       B7        C7        BUSMC1
G11         OR     1  2       G15       B8        C8
G12         AND    0  3       CH1       CH3       BD
G13         OR     1  3       G16       B9        C9        BUSB12
G14         OR     1  3       G17       B10       C10       BUSB11
G15         OR     1  1       G18       BUSB13
G16         AND    2  0       G19       G20
G17         AND    2  0       G21       G22
G18         AND    2  0       G181      G23
G19         OR     1  4       G24       B12       C12       STAP12    BUS1D
G20         OR     1  3       G22       B11       C11       BUSB11
G21         OR     1  3       G19       B11       C11       BUSB12
G22         OR     1  4       G26       B14       C14       STAP11    BUS1C
G23         OR     1  2       G27       BUSB14    B15
G24         AND    2  0       G28       G30
G26         AND    2  0       G31       G33
G27         OR     1  4       G34       B16       C13       STAP14    BUS1E
G28         OR     0  4       B17       C15       DG1-2S    DG1-2R
G30         OR     0  4       B22       C22       STUT1-2   OPRT
G31         OR     0  4       B18       C16       DG1-1S    DG1-1R
G33         OR     0  4       B20       C18       STUT1-2   OPRT
G34         OR     0  4       B24       C21       STUT1-2   OPRT
G181        OR     1  4       G26       B181      C181      STAP13    BUS1C
END
```

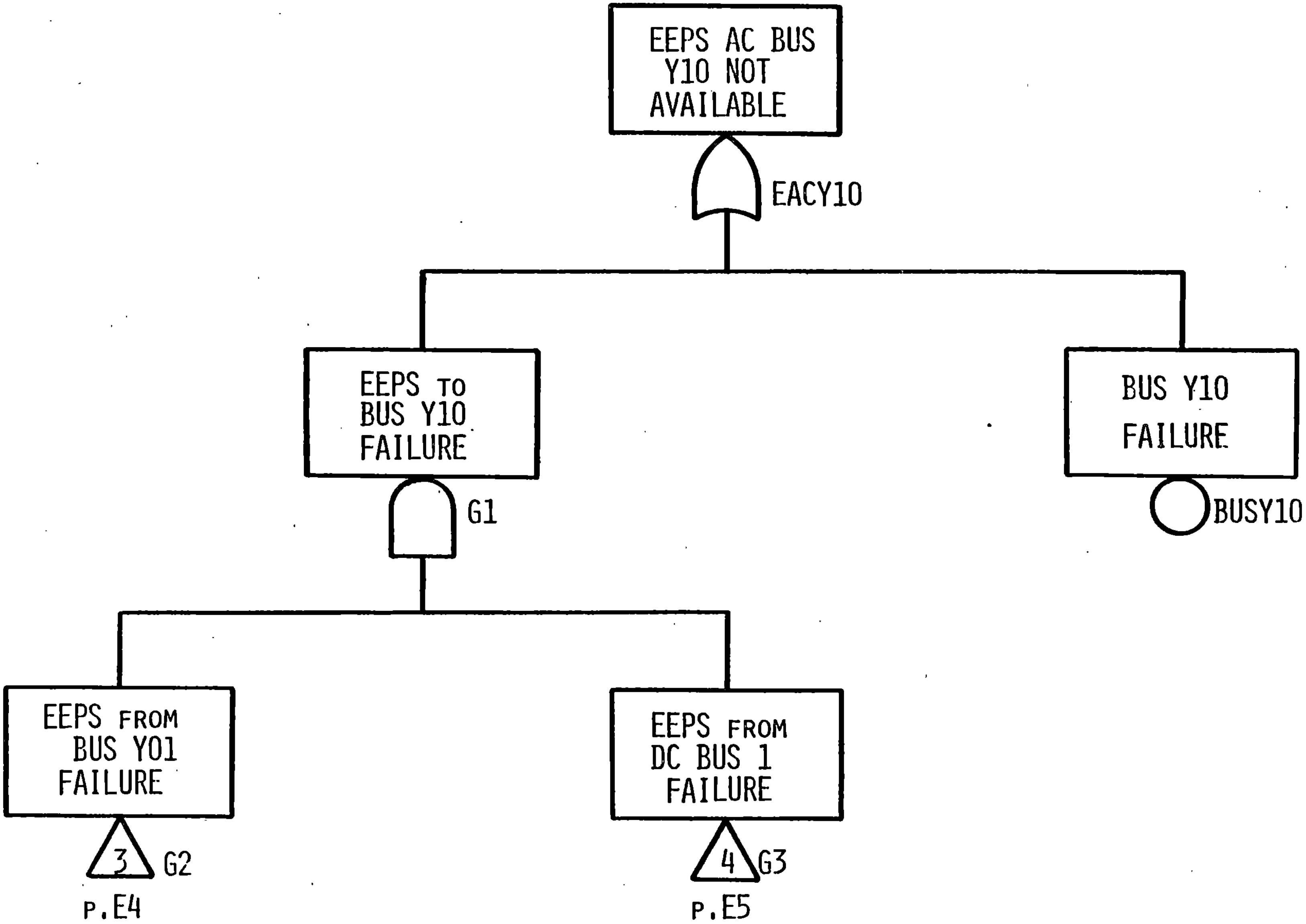
AFW RELIABILITY - ELECTRICAL DC BUS 1

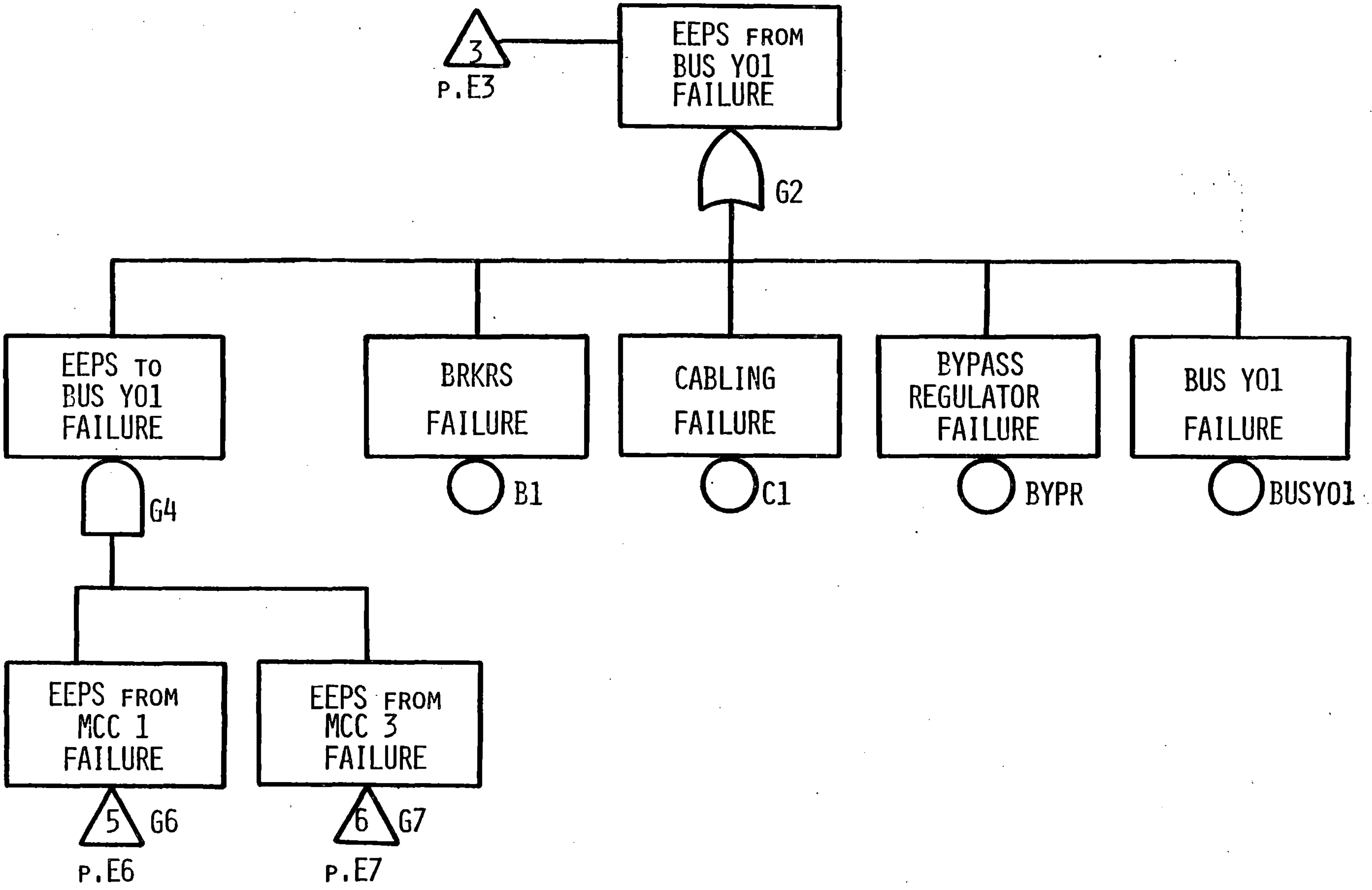
EDC1	OR	1	1	G5	BUSD1			
G5	AND	3	0	G8	G9	G10		
G8	OR	1	3	G12	B5	C5	BATT1	
G9	OR	1	3	G13	B6	C6	BUSMC2	
G10	OR	1	3	G14	B7	C7	BUSMC1	
G12	AND	0	3	CH1	CH3	BD		
G13	OR	1	3	G16	B9	C9	BUSB12	
G14	OR	1	3	G17	B10	C10	BUSB11	
G16	AND	2	0	G19	G20			
G17	AND	2	0	G21	G22			
G19	OR	1	4	G24	B12	C12	STAP12	BUS1D
G20	OR	1	3	G22	B11	C11	BUSB11	
G21	OR	1	3	G19	B11	C11	BUSB12	
G22	OR	1	4	G26	B14	C14	STAP11	BUS1C
G24	AND	2	0	G28	G30			
G26	AND	2	0	G31	G33			
G28	OR	0	4	B17	C15	DG1-2S	DG1-2R	
G30	OR	0	4	B22	C22	STUT1-2	OPRT	
G31	OR	0	4	B18	C16	DG1-1S	DG1-1R	
G33	OR	0	4	B20	C18	STUT1-2	OPRT	
END								

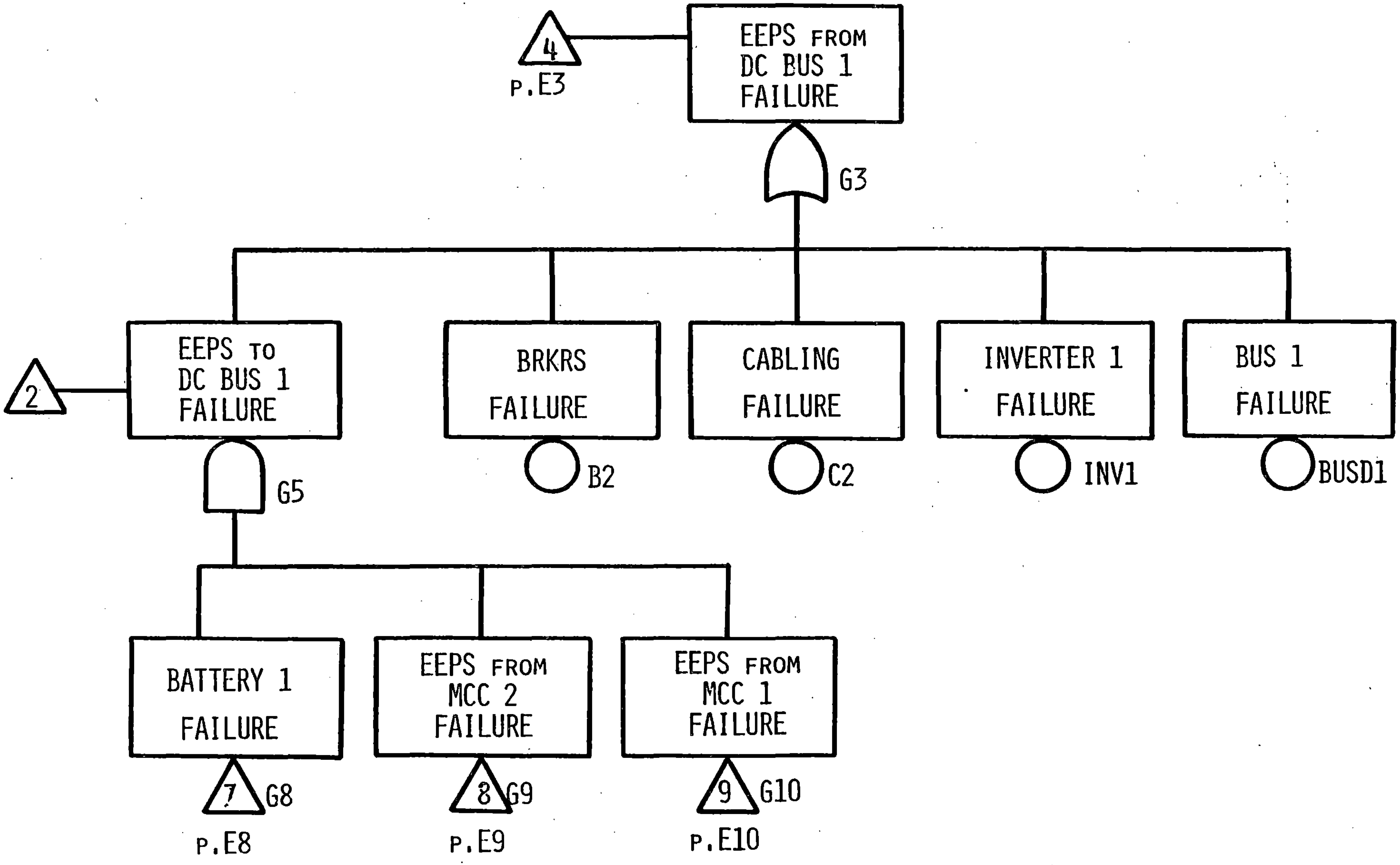


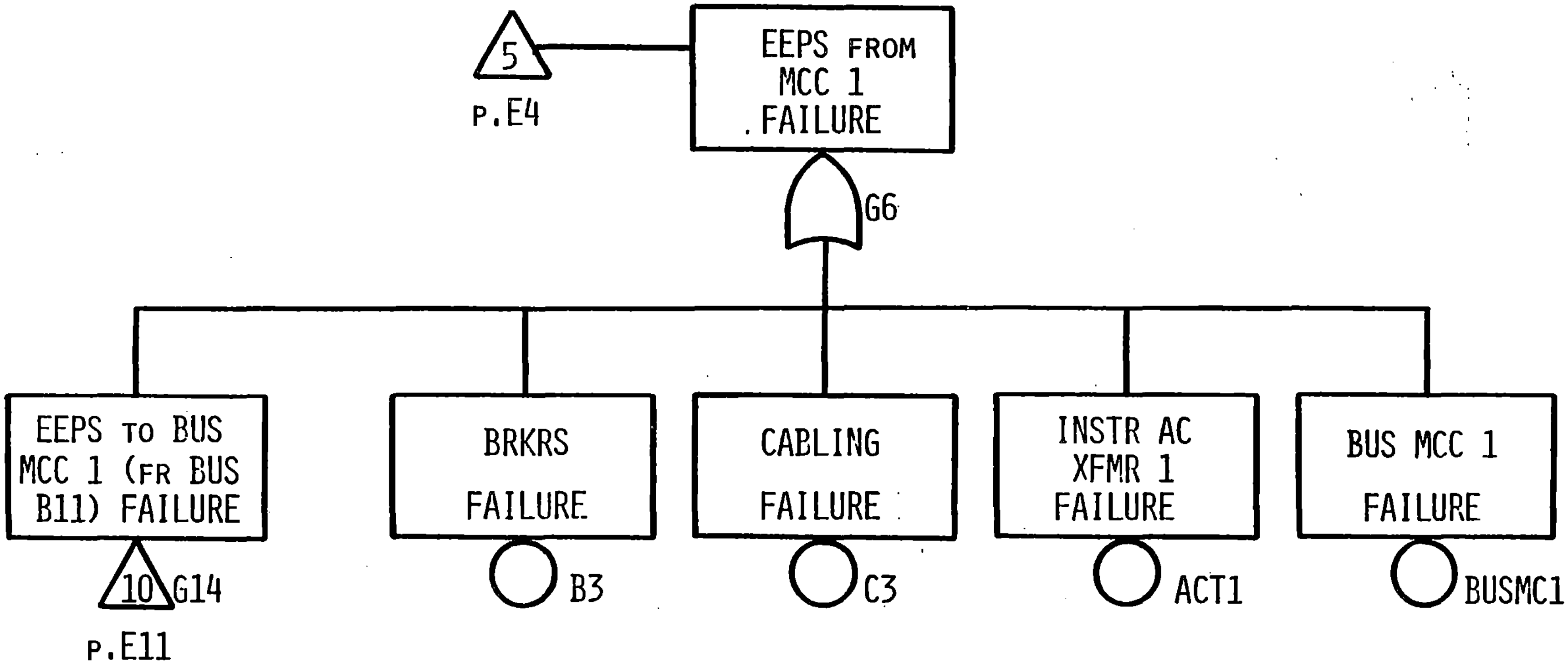
* EEPS = ESSENTIAL ELECTRICAL POWER SUPPLY

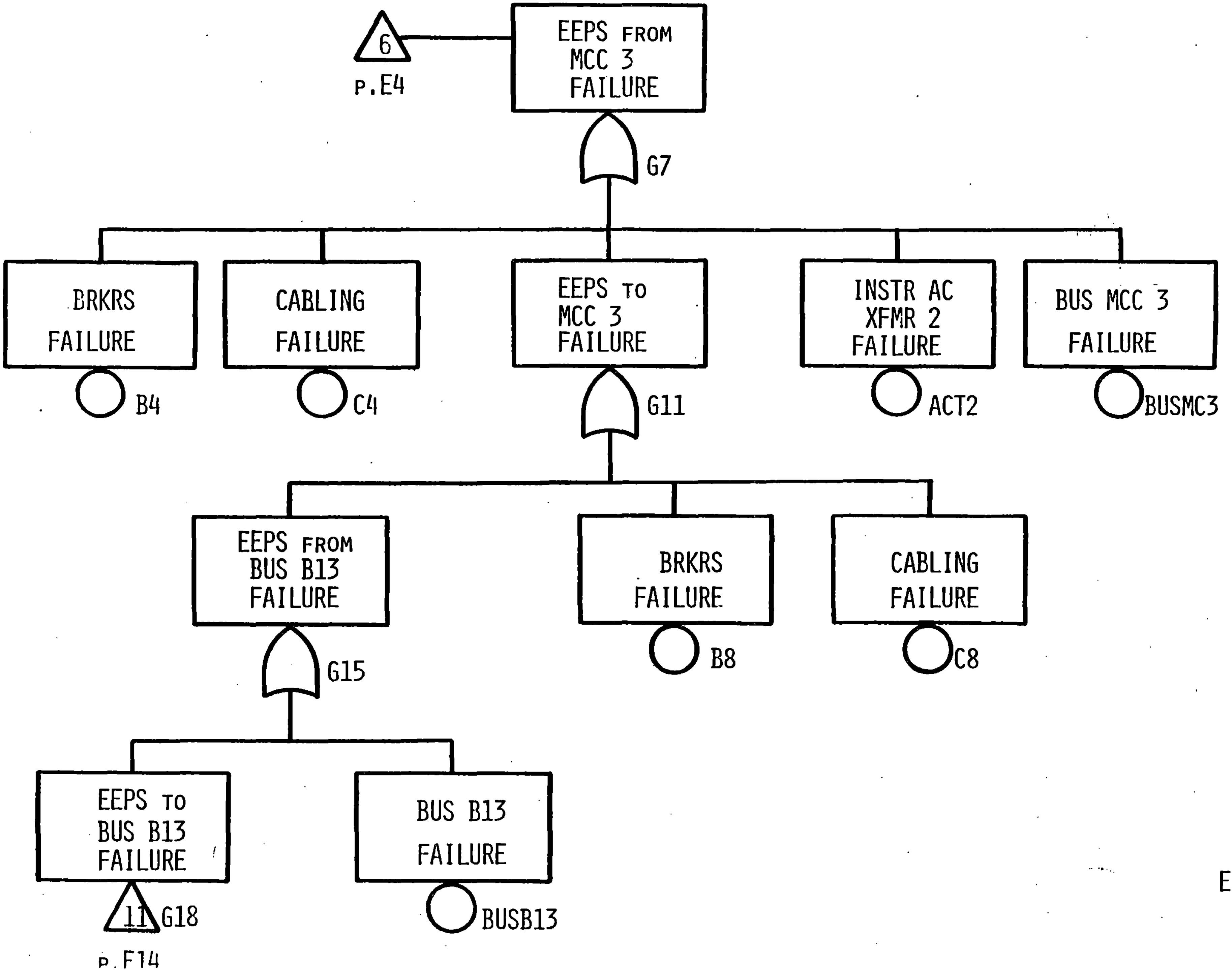

EEPS DC BUS 1 NOT AVAILABLE
EDC1
EEPS TO DC BUS 1 FAILURE
2
G5
P.E5
DC BUS 1 FAILURE
BUSD1

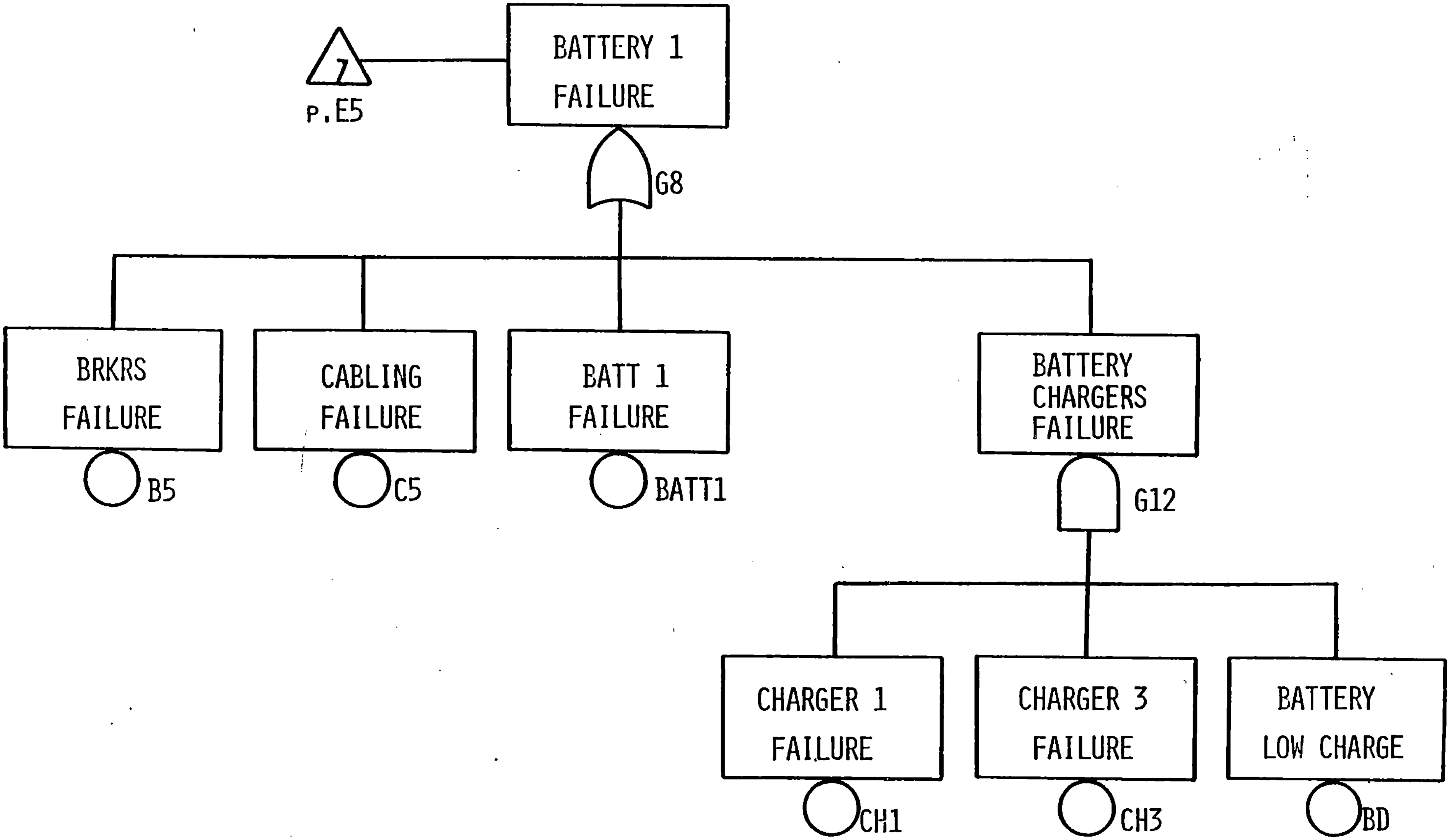

EEPS AC BUS Y10 NOT AVAILABLE
EACY10
EEPS TO BUS Y10 FAILURE
G1
BUS Y10 FAILURE
BUSY10
EEPS FROM BUS Y01 FAILURE
3
G2
P. E4
EEPS FROM DC BUS 1 FAILURE
4
G3
P. E5

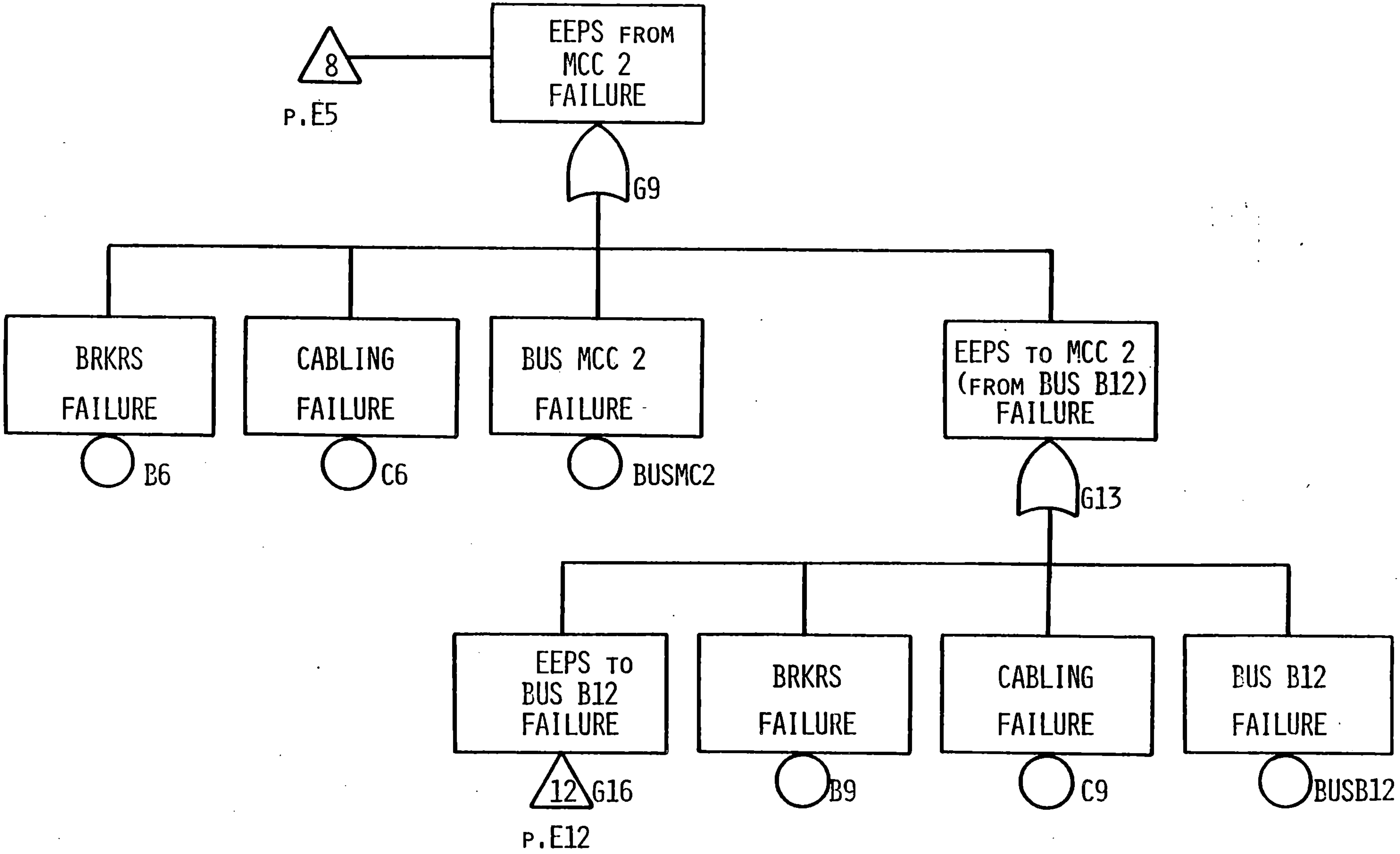

3
P.E3
EEPS FROM BUS Y01 FAILURE
G2
EEPS TO BUS Y01 FAILURE
BRKRS FAILURE
CABLING FAILURE
BYPASS REGULATOR FAILURE
BUS Y01 FAILURE
B1
C1
BYPR
BUSY01
G4
EEPS FROM MCC 1 FAILURE
EEPS FROM MCC 3 FAILURE
5
G6
P.E6
6
G7
P.E7

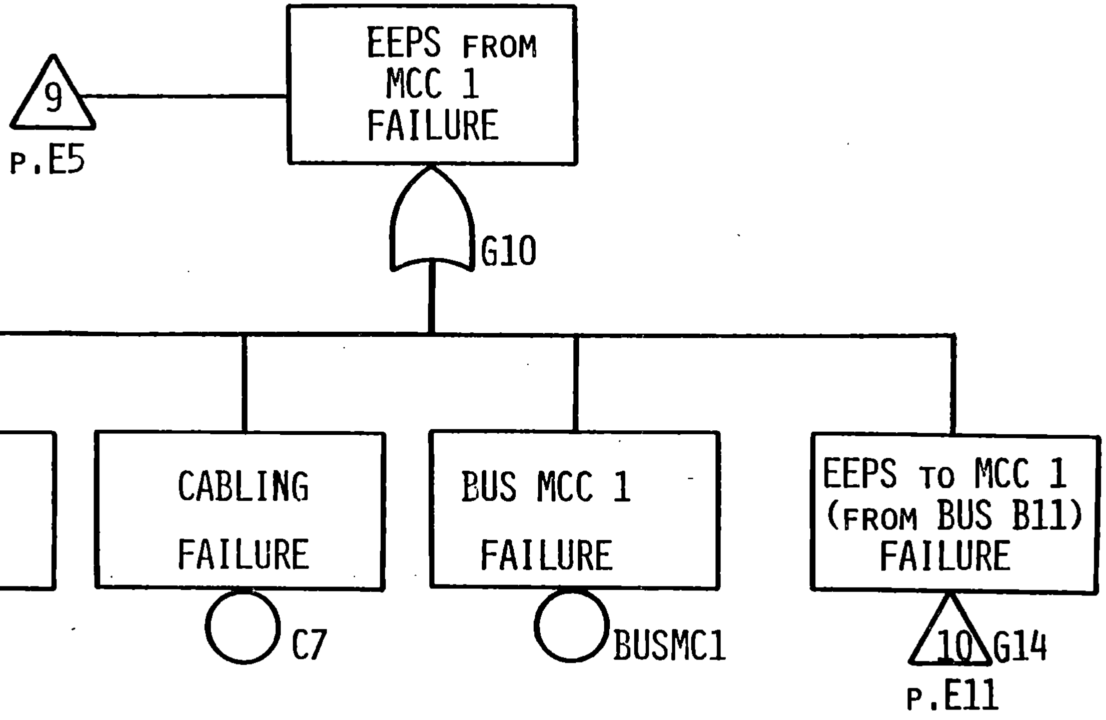

4
P.E3
EEPS FROM DC BUS 1 FAILURE
G3
2
EEPS TO DC BUS 1 FAILURE
G5
BRKRS FAILURE
B2
CABLING FAILURE
C2
INVERTER 1 FAILURE
INV1
BUS 1 FAILURE
BUSD1
BATTERY 1 FAILURE
7
G8
P.E8
EEPS FROM MCC 2 FAILURE
8
G9
P.E9
EEPS FROM MCC 1 FAILURE
9
G10
P.E10

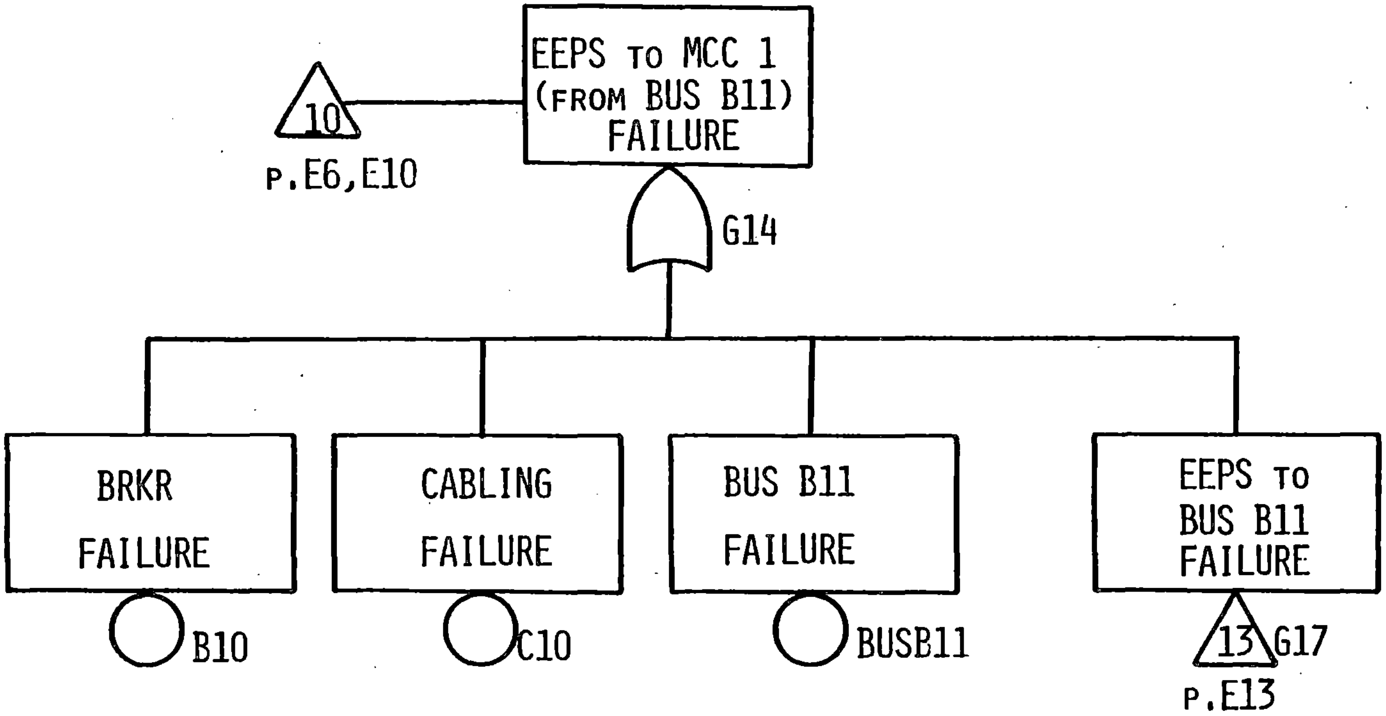

5
P.E4
EEPS FROM MCC 1 FAILURE
G6
EEPS TO BUS MCC 1 (FR BUS B11) FAILURE
10
G14
P.E11
BRKRS FAILURE
B3
CABLING FAILURE
C3
INSTR AC XFMR 1 FAILURE
ACT1
BUS MCC 1 FAILURE
BUSMC1

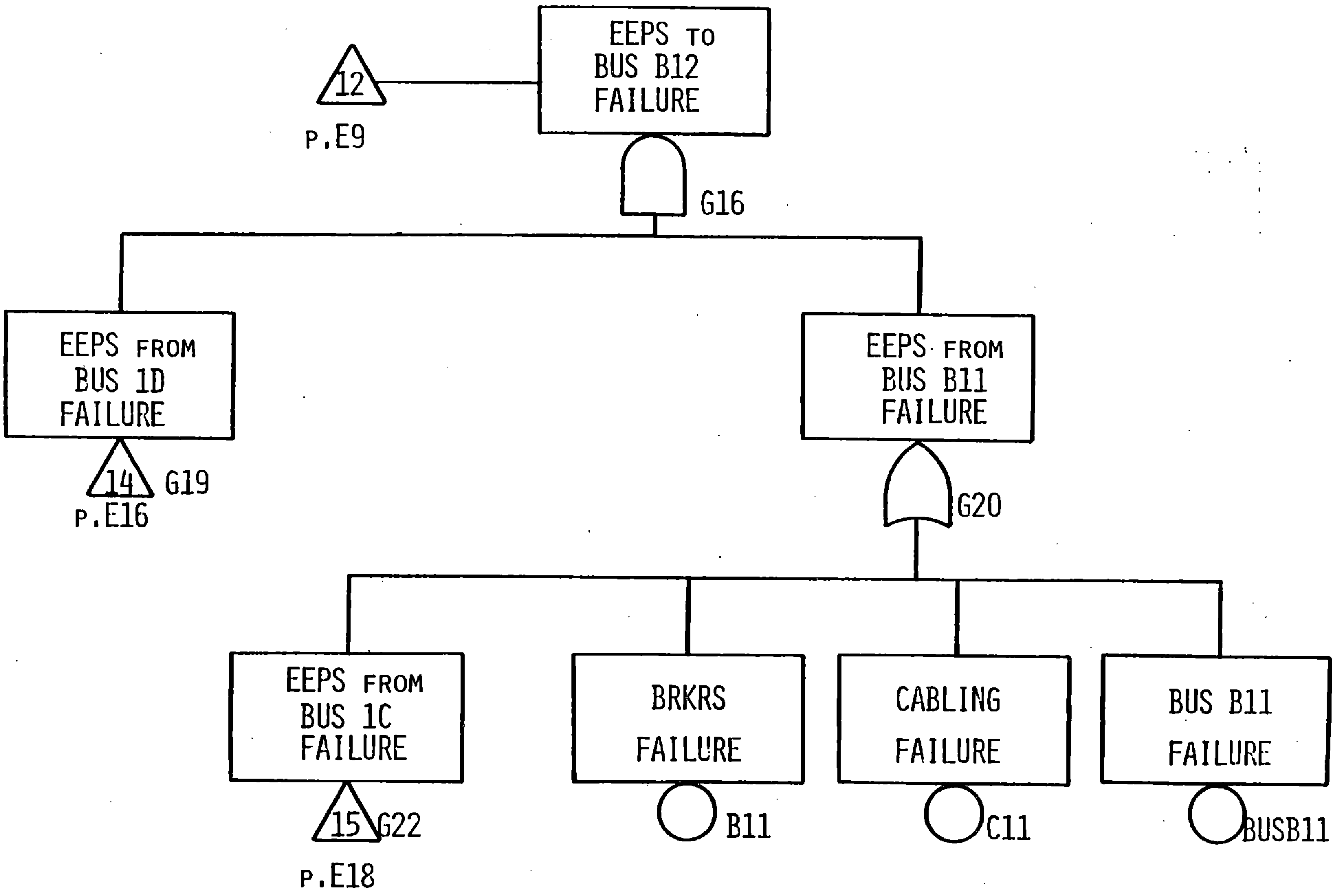

6
p.E4
EEPS FROM MCC 3 FAILURE
G7
BRKRS FAILURE
B4
CABLING FAILURE
C4
EEPS TO MCC 3 FAILURE
G11
INSTR AC XFMR 2 FAILURE
ACT2
BUS MCC 3 FAILURE
BUSMC3
EEPS FROM BUS B13 FAILURE
G15
BRKRS FAILURE
B8
CABLING FAILURE
C8
EEPS TO BUS B13 FAILURE
11
G18
p.F14
BUS B13 FAILURE
BUSB13

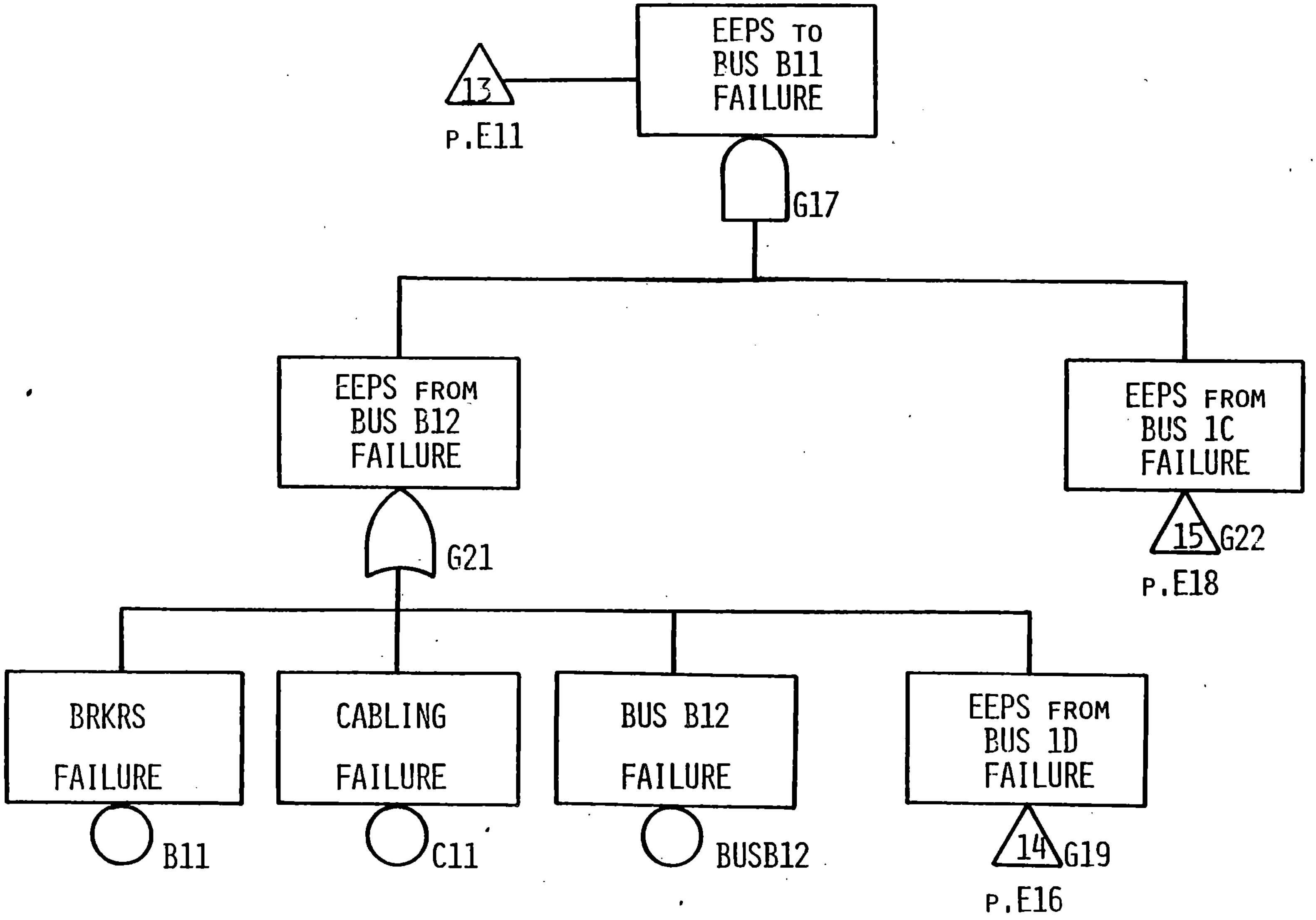

7
p.E5
BATTERY 1 FAILURE
G8
BRKRS FAILURE
B5
CABLING FAILURE
C5
BATT 1 FAILURE
BATT1
BATTERY CHARGERS FAILURE
G12
CHARGER 1 FAILURE
CH1
CHARGER 3 FAILURE
CH3
BATTERY LOW CHARGE
BD

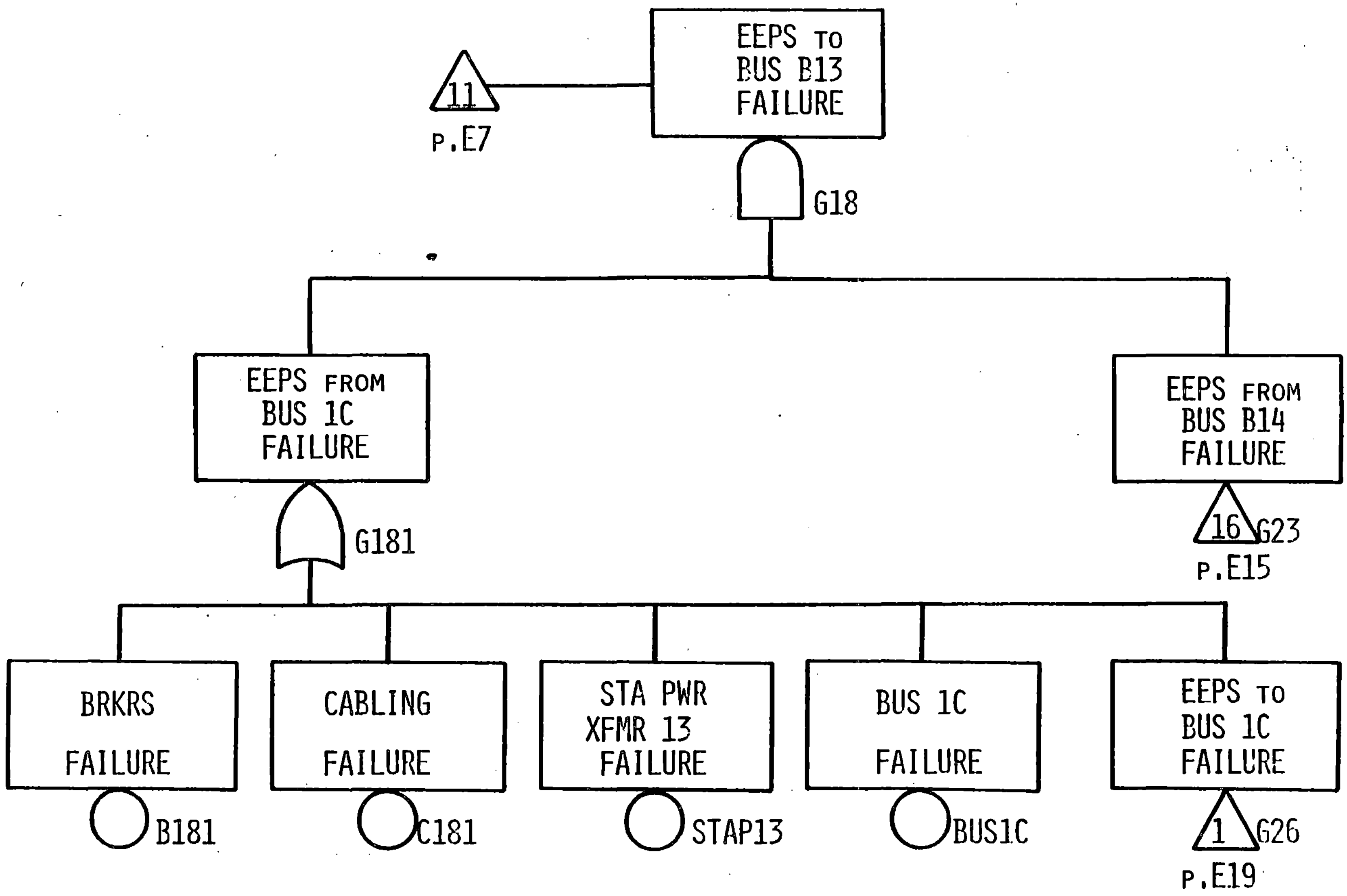

8
P.E5
EEPS FROM MCC 2 FAILURE
G9
BRKRS FAILURE
B6
CABLING FAILURE
C6
BUS MCC 2 FAILURE
BUSMC2
EEPS TO MCC 2 (FROM BUS B12) FAILURE
G13
EEPS TO BUS B12 FAILURE
12
G16
P.E12
BRKRS FAILURE
B9
CABLING FAILURE
C9
BUS B12 FAILURE
BUSB12

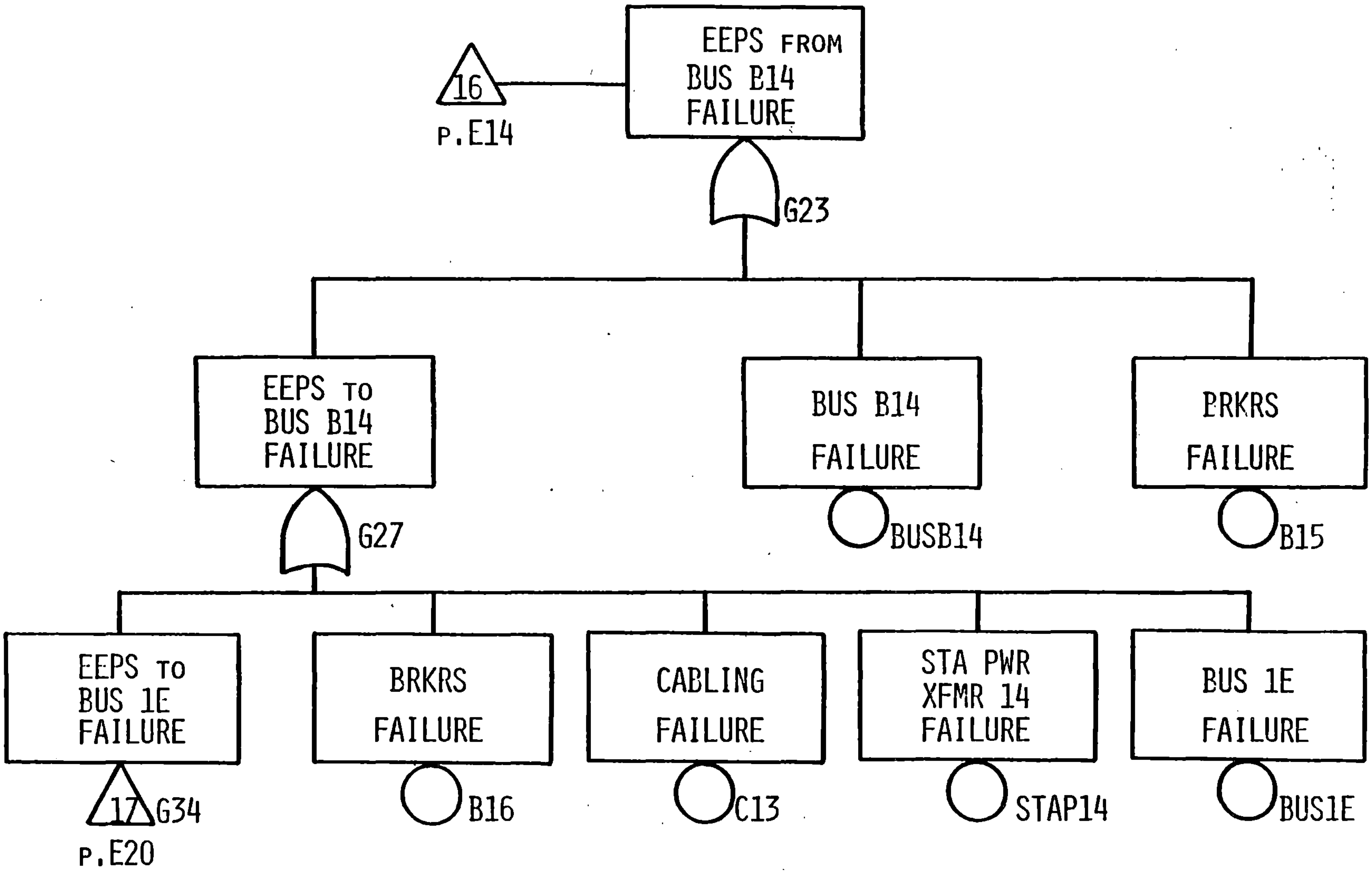

9
P.E5
EEPS FROM MCC 1 FAILURE
G10
BRKR FAILURE
B7
CABLING FAILURE
C7
BUS MCC 1 FAILURE
BUSMC1
EEPS TO MCC 1 (FROM BUS B11) FAILURE
10
G14
P.E11

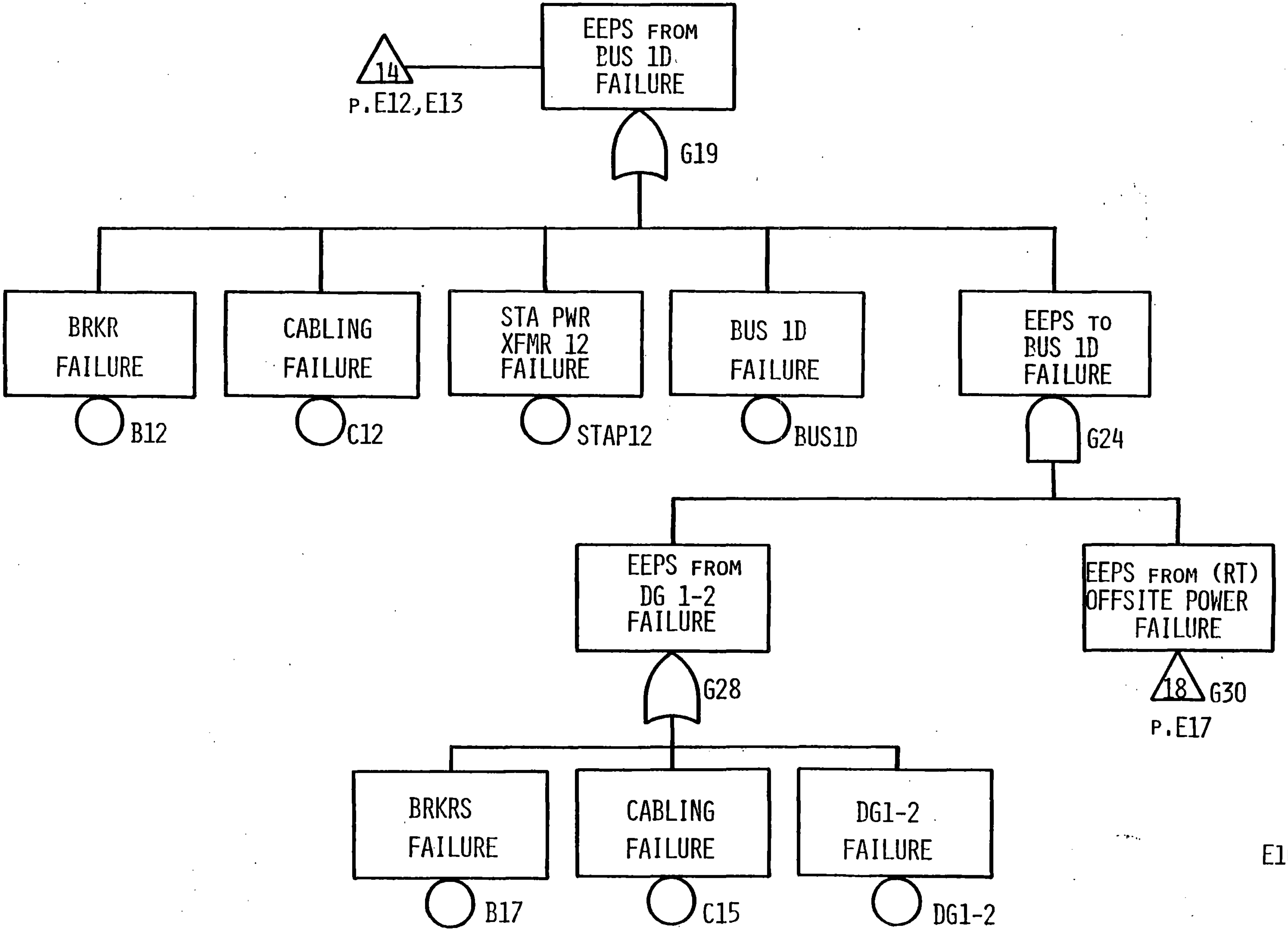

EEPS TO MCC 1 (FROM BUS B11) FAILURE
10
P.E6,E10
G14
BRKR FAILURE
B10
CABLING FAILURE
C10
BUS B11 FAILURE
BUSB11
EEPS TO BUS B11 FAILURE
13
G17
P.E13

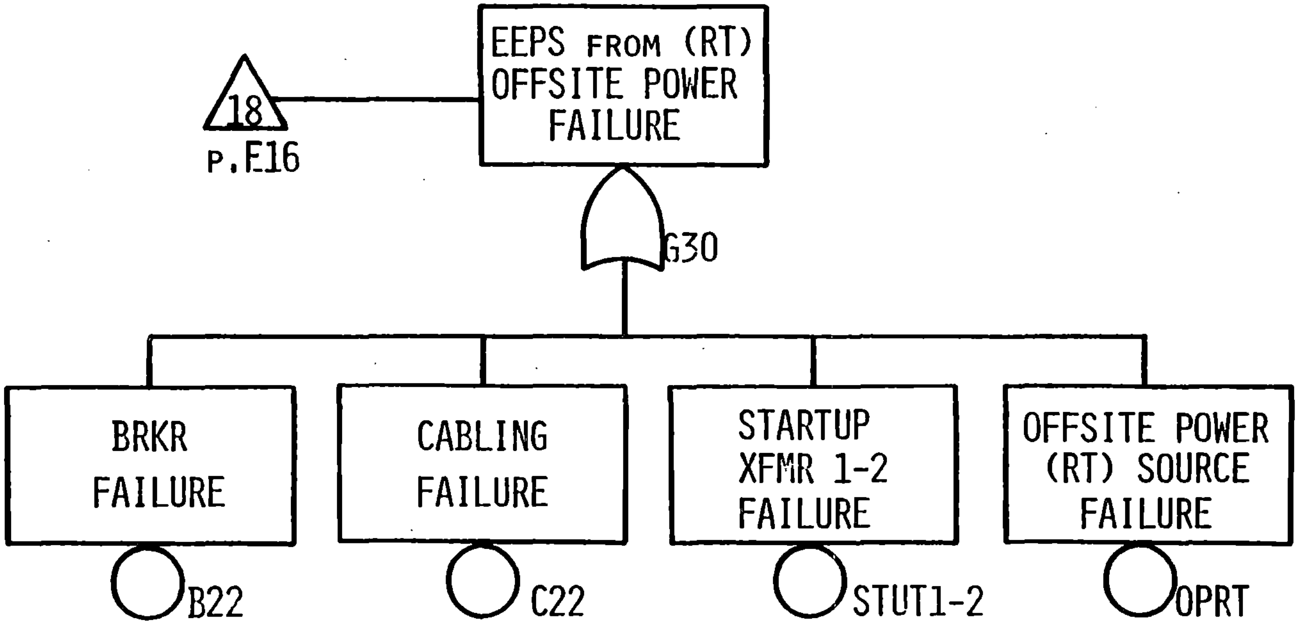

EEPS TO
BUS B12
FAILURE
12
P.E9
G16
EEPS FROM
BUS 1D
FAILURE
14
G19
P.E16
EEPS FROM
BUS B11
FAILURE
G20
EEPS FROM
BUS 1C
FAILURE
15
G22
P.E18
BRKRS
FAILURE
B11
CABLING
FAILURE
C11
BUS B11
FAILURE
BUSB11

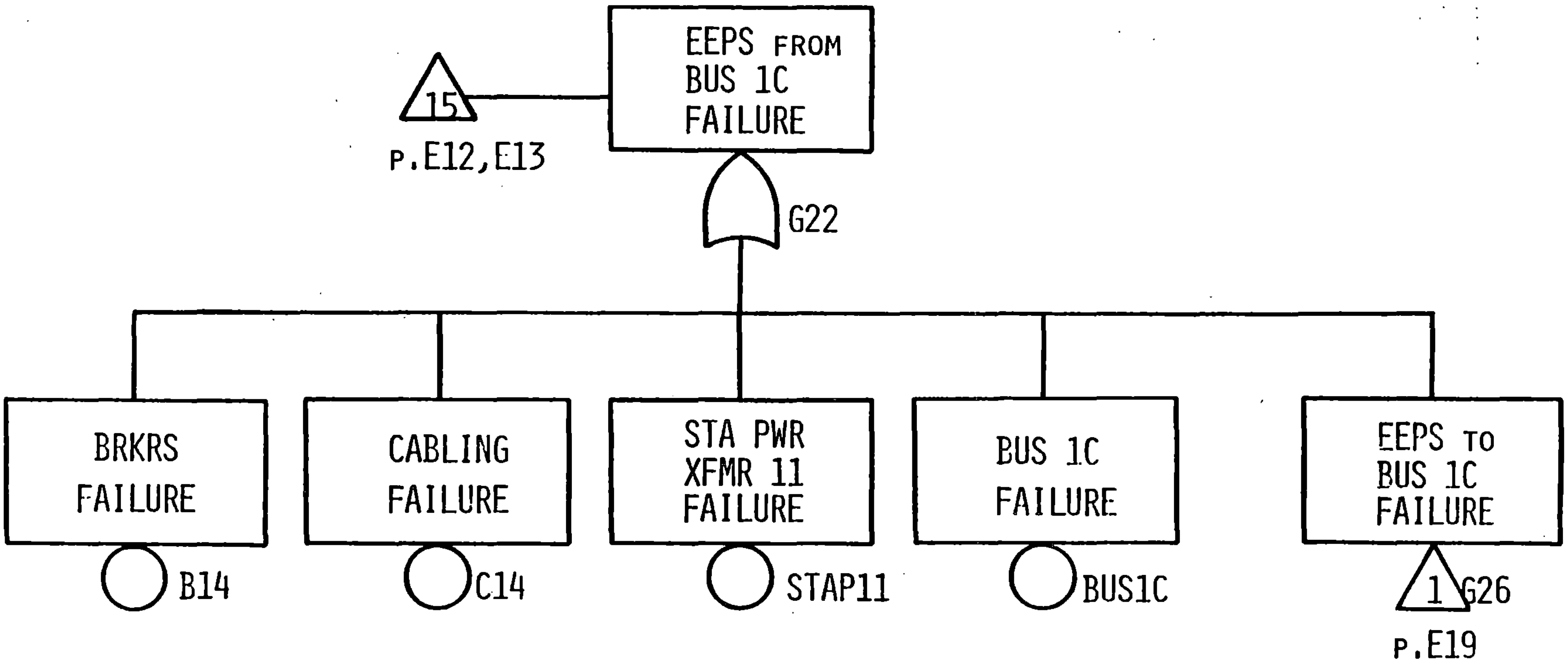

EEPS TO BUS B11 FAILURE
13
P.E11
G17
EEPS FROM BUS B12 FAILURE
G21
EEPS FROM BUS 1C FAILURE
15
G22
P.E18
BRKRS FAILURE
B11
CABLING FAILURE
C11
BUS B12 FAILURE
BUSB12
EEPS FROM BUS 1D FAILURE
14
G19
P.E16

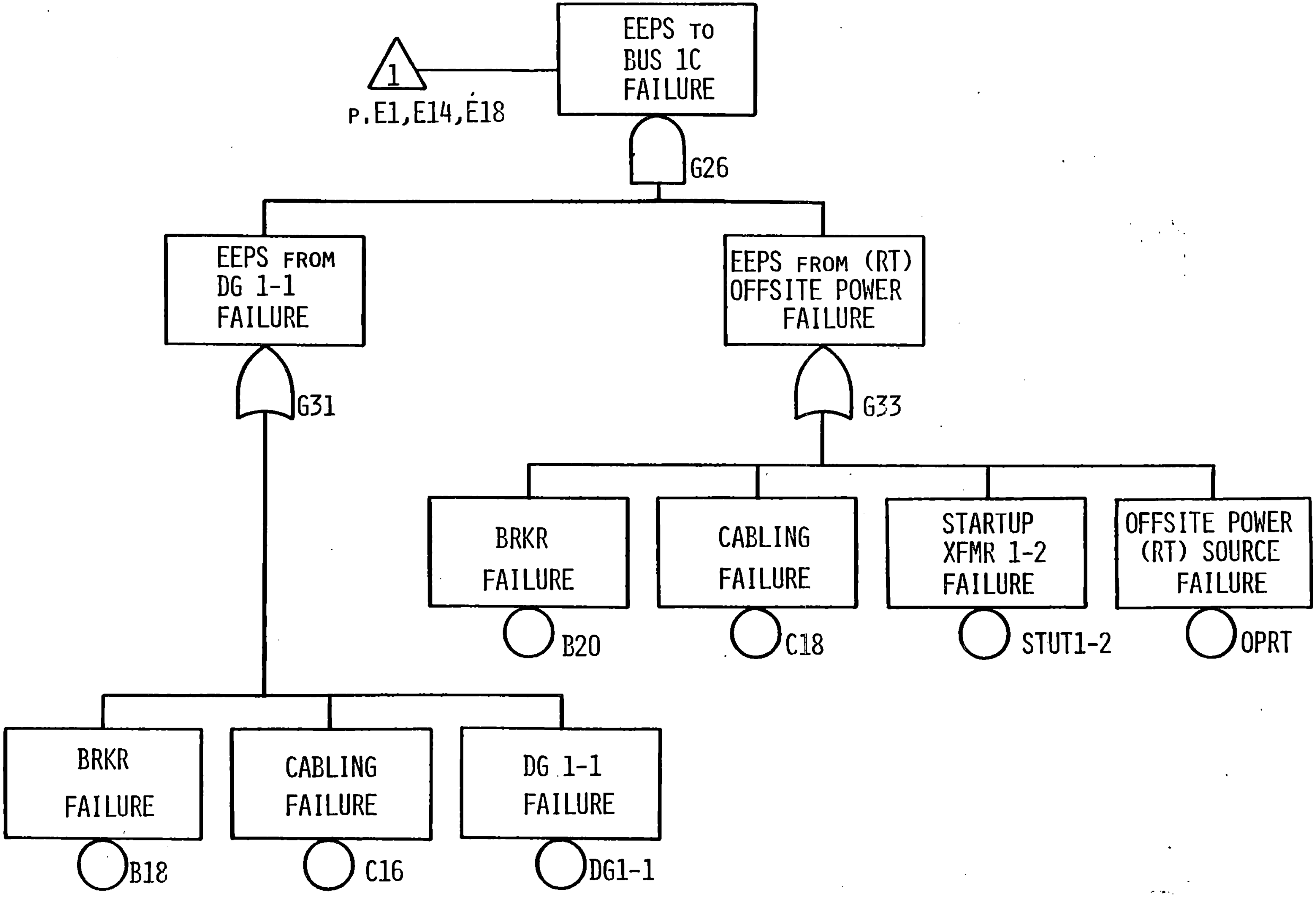

EEPS TO BUS B13 FAILURE
11
P.E7
G18
EEPS FROM BUS 1C FAILURE
G181
EEPS FROM BUS B14 FAILURE
16
G23
P.E15
BRKRS FAILURE
B181
CABLING FAILURE
C181
STA PWR XFMR 13 FAILURE
STAP13
BUS 1C FAILURE
BUS1C
EEPS TO BUS 1C FAILURE
1
G26
P.E19

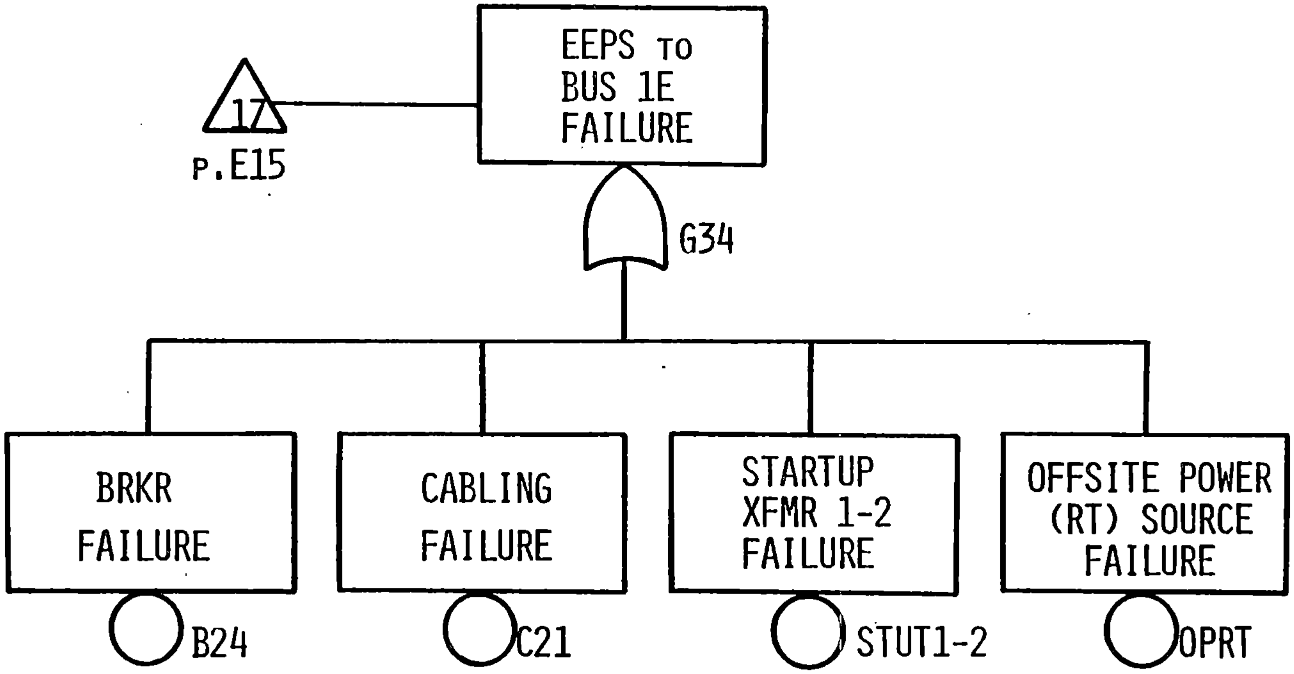

16
P.E14
EEPS FROM BUS B14 FAILURE
G23
EEPS TO BUS B14 FAILURE
G27
BUS B14 FAILURE
BUSB14
BRKRS FAILURE
B15
EEPS TO BUS 1E FAILURE
17
G34
P.E20
BRKRS FAILURE
B16
CABLING FAILURE
C13
STA PWR XFMR 14 FAILURE
STAP14
BUS 1E FAILURE
BUS1E


EEPS FROM BUS 1D FAILURE
14
P.E12,E13
G19
BRKR FAILURE
B12
CABLING FAILURE
C12
STA PWR XFMR 12 FAILURE
STAP12
BUS 1D FAILURE
BUS1D
EEPS TO BUS 1D FAILURE
G24
EEPS FROM DG 1-2 FAILURE
G28
EEPS FROM (RT) OFFSITE POWER FAILURE
18
G30
P.E17
BRKRS FAILURE
B17
CABLING FAILURE
C15
DG1-2 FAILURE
DG1-2


EEPS FROM (RT) OFFSITE POWER FAILURE
18
P. E16
G30
BRKR FAILURE
B22
CABLING FAILURE
C22
STARTUP XFMR 1-2 FAILURE
STUT1-2
OFFSITE POWER (RT) SOURCE FAILURE
OPRT


EEPS FROM BUS 1C FAILURE
15
P.E12,E13
G22
BRKRS FAILURE
B14
CABLING FAILURE
C14
STA PWR XFMR 11 FAILURE
STAP11
BUS 1C FAILURE
BUS1C
EEPS TO BUS 1C FAILURE
1
G26
P.E19


1
P.E1,E14,E18
EEPS TO BUS 1C FAILURE
G26
EEPS FROM DG 1-1 FAILURE
G31
EEPS FROM (RT) OFFSITE POWER FAILURE
G33
BRKR FAILURE
B20
CABLING FAILURE
C18
STARTUP XFMR 1-2 FAILURE
STUT1-2
OFFSITE POWER (RT) SOURCE FAILURE
OPRT
BRKR FAILURE
B18
CABLING FAILURE
C16
DG 1-1 FAILURE
DG1-1


17
P.E15
EEPS TO BUS 1E FAILURE
G34
BRKR FAILURE
B24
CABLING FAILURE
C21
STARTUP XFMR 1-2 FAILURE
STUT1-2
OFFSITE POWER (RT) SOURCE FAILURE
OPRT

APPENDIX G

DATA

APPENDIX G

FAILURE OF AFW SYSTEM COMPONENTS USING PLANT SPECIFIC DATA

COMP ID	PROBABILITY	DESCRIPTION
AFAS	7.00E-03	AFW actuation signal fails
AIR1	1.52E-03	Loss of instrument air on CV-0522A
AIR2	1.52E-03	Loss of instrument air (from air system) on CV-0522B
AIR3	1.52E-03	Loss of instrument air on CV-0525
AIR4	1.52E-03	Loss of instrument air (from air system) on PCV-0521A
CK401MS	1.00E-04	Check valve 401MS fails to open
CK402MS	1.00E-04	Check valve 402MS fails to open
CK0703	1.00E-04	Check valve CK-0703 FWS fails to open
CK0704	1.00E-04	Check valve CK-0704 FWS fails to open
CK0725	1.00E-04	Check valve CK-0725 FWS fails to open
CK0726	1.00E-04	Check valve CK-0726 FWS fails to open
CK0728	1.00E-04	Check valve CK-0728 FWS fails to open
CK0729	1.00E-04	Check valve CK-0729 FWS fails to open
CK0741	1.00E-04	Check valve CK-0741 FWS fails to open
CK0743	1.00E-04	Check valve CK-0743 FWS fails to open
CV0521	4.00E-04	Control valve CV-0521 fails to open
CV0522A	4.00E-04	Control valve CV-0522A fails to open
CV0522B	4.00E-04	Control valve CV-0522B fails to open
CV0525	4.00E-04	Control valve CV-0525 fails to open
CV0727	4.00E-04	Control valve CV-0727 fails to open
CV0736A	4.00E-04	Control valve CV-0736A fails to open
CV0737A	4.00E-04	Control valve CV-0737A fails to open
CV0749	4.00E-04	Control valve CV-0749 fails to open
EAC1C	9.40E-05	No power from ac bus 1C CASE I, TABLE 2-2
EAC1D	9.40E-05	No power from ac bus 1D CASE I, TABLE 2-2
EACY10	6.52E-05	No power from ac bus Y10 CASE I, TABLE 2-2
EACY20	6.52E-05	No power from ac bus Y20 CASE I, TABLE 2-2
EDC1	6.39E-05	No power from dc bus 1 CASE I, TABLE 2-2
EDC2	6.39E-05	No power from dc bus 1 CASE I, TABLE 2-2
FCV0522A	1.00E-05	Flow control valve FCV-0522A fails to open
FCV0522B	1.00E-05	Flow control valve FCV-0522B fails to open
FT0727A	2.17E-03	Flow transmitter FT-0727A fails
FT0736A	2.17E-03	Flow transmitter FT-0736A fails
FT0737A	2.17E-03	Flow transmitter FT-0737A fails
FT0749A	2.17E-03	Flow transmitter FT-0749A fails
FT0727H	2.17E-03	Flow transmitter FT-0727 fails
FT0727AH	2.17E-03	Flow transmitter FT-0727A fails high
FT0736H	2.17E-03	Flow transmitter FT-0736 fails high
FT0736AH	2.17E-03	Flow transmitter FT-0736A fails high
FT0737H	2.17E-03	Flow transmitter FT-0737 fails high
FT0737AH	2.17E-03	Flow transmitter FT-0737A fails high
FT0749H	2.17E-03	Flow transmitter FT-0749 fails high
FT0749AH	2.17E-03	Flow transmitter FT-0749A fails high
GOVERNOR	6.53E-05	Turbine governor K-8 fails
GV0132	1.00E-04	Gate valve 29-132FW fails to open
GV0271	1.00E-04	Gate valve MV-271FWS fails to open
GV0740	1.00E-04	Gate valve 14-0740FW fails to open
GV0742	1.00E-04	Gate valve 14-0742FW fails to open
GV0751	1.00E-04	Gate valve MV-751FWS fails to open
GV0752	1.00E-04	Gate valve MV-752FWS fails to open
GV0771	1.00E-04	Gate valve 29-0771FW fails to open

GV0772	1.00E-04	Gate valve 29-0772FW fails to open
GV133FW	1.00E-04	Gate valve 133FW fails to open
GV152MS	1.00E-04	Gate valve 152MS fails to open
GV152AMS	1.00E-04	Gate valve 152AMS fails to open
GV153MS	1.00E-04	Gate valve 153MS fails to open
GV153AMS	1.00E-04	Gate valve 153AMS fails to open
GV270FW	1.00E-04	Gate valve MV-270FW fails to open
GV714FW	1.00E-04	Gate valve 714FW fails to open
GV0214	1.00E-04	Gate valve 130-214FW fails to open
HS0521	3.00E-04	Hand switch HS-0521 fails
HS0522A	3.00E-04	Hand switch HS-0522A fails
HS0522B	3.00E-04	Hand switch HS-0522B fails
HS0525	3.00E-04	Hand switch HS-0525 fails
HS104CS	3.00E-04	Hand switch HS-104CS fails
HS209CS	3.00E-04	Hand switch HS-209CS fails
MCK401MS	2.14E-03	Maintenance on check valve 401MS
MCK402MS	2.14E-03	Maintenance on check valve 402MS
MCK0726	2.14E-03	Maintenance on check valve CK-0726FWS
MCK0741	2.14E-03	Maintenance on check valve 218-0741
MCK0743	2.14E-03	Maintenance on check valve 218-0743
MCV0521	2.14E-03	Maintenance on control valve CV-0521
MCV0522A	2.14E-03	Maintenance on control valve CV-0522A
MCV0522B	2.14E-03	Maintenance on control valve CV-05ssB
MCV0736A	2.14E-03	Maintenance on control valve CV-0736A
MCV0737A	2.14E-03	Maintenance on control valve CV-0737A
MMO0743	2.14E-03	Maintenance on motor-operated valve MO-0743
MMO0748	2.14E-03	Maintenance on motor-operated valve MO-0748
MMO0753	2.14E-03	Maintenance on motor-operated valve MO-0753
MMO0754	2.14E-03	Maintenance on motor-operated valve MO-0760
MPCV521A	2.14E-03	Maintenance on pressure control valve PCV-0521A
MP8A	2.14E-03	Maintenance on pump P8A
MP8B	2.14E-03	Maintenance on pump P8B
MP8C	2.14E-03	Maintenance on pump P8C
MO0743	1.00E-04	Motor-operated valve MO-0743 fails to open
MO0748	1.00E-04	Motor-operated valve MO-0748 fails to open
MO0753	1.00E-04	Motor-operated valve MO-0753 fails to open
MO0754	1.00E-04	Motor-operated valve MO-0754 fails to open
MO0755	1.00E-04	Motor-operated valve MO-0755 fails to open
MO0759	1.00E-04	Motor-operated valve MO-0759 fails to open
MO0760	1.00E-04	Motor-operated valve MO-0760 fails to open
MO0798	1.00E-04	Motor-operated valve MO-0798 fails to open
NITROGEN	1.52E-03	Loss of pressure from nitrogen source
OPE1	1.00E-03	Operator error
OPE101	1.00E-03	Operator error
OPE102	1.00E-03	Operator error
OPE103	1.00E-03	Operator error
OPE104	1.00E-03	Operator error
OPE105	1.00E-03	Operator error
OPE106	1.00E-03	Operator error
OPE107	1.00E-03	Operator error
OPE108	1.00E-03	Operator error
OPE2	1.00E-03	Operator error
OPE3	1.00E-03	Operator error
OPE202	1.00E-03	Operator error
OPE204	1.00E-03	Operator error

APPENDIX G

OPE205	1.00E-03	Operator error
OPE206	1.00E-03	Operator error
OPE207	1.00E-03	Operator error
OPE210	1.00E-03	Operator error
OPE801	1.00E-03	Operator error
PCV0521A	1.00E-05	Pressure control valve PCV-0521A fails to open
PS8A	5.00E-03	Electric pump P8A fails to start
PS8B	1.00E-03	Turbine-driven pump P8B fails to start
PS8C	5.00E-03	Electric pump P8C fails to start
RV0783	3.65E-03	Relief valve RV-0783 premature open
SV0521	1.00E-03	Solenoid valve SV0521 fails
SV0522A	1.00E-03	Solenoid valve SV0522A fails
SV0522B	1.00E-03	Solenoid valve SV0522B fails
SV0525	1.00E-03	Solenoid valve SV0525 fails
WATER	1.00E-03	Water in steam pipe

APPENDIX G

FAILURE OF AFW SYSTEM COMPONENTS USING PLANT SPECIFIC DATA

COMP ID	PROBABILITY	DESCRIPTION
AFAS	7.00E-03	AFW actuation signal fails
AIR1	1.52E-03	Loss of instrument air on CV-0522A
AIR2	1.52E-03	Loss of instrument air (from air system) on CV-0522B
AIR3	1.52E-03	Loss of instrument air on CV-0525
AIR4	1.52E-03	Loss of instrument air (from air system) on PCV-0521A
CK401MS	9.50E-04	Check valve 401MS fails to open
CK402MS	3.20E-04	Check valve 402MS fails to open
CK0703	3.20E-04	Check valve CK-0703 FWS fails to open
CK0704	3.20E-04	Check valve CK-0704 FWS fails to open
CK0725	3.20E-04	Check valve CK-0725 FWS fails to open
CK0726	3.20E-04	Check valve CK-0726 FWS fails to open
CK0728	3.20E-04	Check valve CK-0728 FWS fails to open
CK0729	3.20E-04	Check valve CK-0729 FWS fails to open
CK0741	3.20E-04	Check valve CK-0741 FWS fails to open
CK0743	3.20E-04	Check valve CK-0743 FWS fails to open
CV0521	8.00E-03	Control valve CV-0521 fails to open
CV0522A	1.10E-02	Control valve CV-0522A fails to open
CV0522B	3.60E-03	Control valve CV-0522B fails to open
CV0525	1.10E-02	Control valve CV-0525 fails to open
CV0727	3.60E-03	Control valve CV-0727 fails to open
CV0736A	3.60E-03	Control valve CV-0736A fails to open
CV0737A	3.60E-03	Control valve CV-0737A fails to open
CV0749	3.60E-03	Control valve CV-0749 fails to open
EAC1C	1.21E-05	No power from ac bus 1C CASE I, TABLE 2-2
EAC1D	1.03E-05	No power from ac bus 1D CASE I, TABLE 2-2
EACY10	1.04E-05	No power from ac bus Y10 CASE I, TABLE 2-2
EACY20	1.04E-05	No power from ac bus Y20 CASE I, TABLE 2-2
EDC1	3.12E-05	No power from dc bus 1 CASE I, TABLE 2-2
EDC2	3.12E-05	No power from dc bus 1 CASE I, TABLE 2-2
FCV0522A	5.50E-04	Flow control valve FCV-0522A fails to open
FCV0522B	1.90E-04	Flow control valve FCV-0522B fails to open
FT0727A	1.40E-04	Flow transmitter FT-0727A fails
FT0736A	1.40E-04	Flow transmitter FT-0736A fails
FT0737A	1.40E-04	Flow transmitter FT-0737A fails
FT0749A	1.40E-04	Flow transmitter FT-0749A fails
FT0727H	2.17E-03	Flow transmitter FT-0727 fails
FT0727AH	2.17E-03	Flow transmitter FT-0727A fails high
FT0736H	2.17E-03	Flow transmitter FT-0736 fails high
FT0736AH	2.17E-03	Flow transmitter FT-0736A fails high
FT0737H	2.17E-03	Flow transmitter FT-0737 fails high
FT0737AH	2.17E-03	Flow transmitter FT-0737A fails high
FT0749H	2.17E-03	Flow transmitter FT-0749 fails high
FT0749AH	2.17E-03	Flow transmitter FT-0749A fails high
GOVERNOR	6.53E-05	Turbine governor K-8 fails
GV0132	8.14E-05	Gate valve 29-132FW fails to open
GV0271	8.14E-05	Gate valve MV-271FWS fails to open
GV0740	8.14E-05	Gate valve 14-0740FW fails to open
GV0742	8.14E-05	Gate valve 14-0742FW fails to open
GV0751	8.14E-05	Gate valve MV-751FWS fails to open
GV0752	8.14E-05	Gate valve MV-752FWS fails to open
GV0771	8.14E-05	Gate valve 29-0771FW fails to open

GV0772	8.14E-05	Gate valve 29-0772FW fails to open
GV133FW	8.14E-05	Gate valve 133FW fails to open
GV152MS	8.14E-05	Gate valve 152MS fails to open
GV152AMS	8.14E-05	Gate valve 152AMS fails to open
GV153MS	8.14E-05	Gate valve 153MS fails to open
GV153AMS	8.14E-05	Gate valve 153AMS fails to open
GV270FW	8.14E-05	Gate valve MV-270FW fails to open
GV714FW	8.14E-05	Gate valve 714FW fails to open
GV0214	6.70E-03	Gate valve 130-214FW fails to open
HS0521	3.00E-05	Hand switch HS-0521 fails
HS0522A	1.00E-05	Hand switch HS-0522A fails
HS0522B	1.00E-05	Hand switch HS-0522B fails
HS0525	1.00E-05	Hand switch HS-0525 fails
HS104CS	1.00E-05	Hand switch HS-104CS fails
HS209CS	1.00E-05	Hand switch HS-209CS fails
MCK401MS	2.14E-03	Maintenance on check valve 401MS
MCK402MS	2.14E-03	Maintenance on check valve 402MS
MCK0726	2.14E-03	Maintenance on check valve CK-0726FWS
MCK0741	2.14E-03	Maintenance on check valve 218-0741
MCK0743	2.14E-03	Maintenance on check valve 218-0743
MCV0521	2.14E-03	Maintenance on control valve CV-0521
MCV0522A	2.14E-03	Maintenance on control valve CV-0522A
MCV0522B	2.14E-03	Maintenance on control valve CV-05ssB
MCV0736A	2.14E-03	Maintenance on control valve CV-0736A
MCV0737A	2.14E-03	Maintenance on control valve CV-0737A
MMO0743	2.14E-03	Maintenance on motor-operated valve MO-0743
MMO0748	2.14E-03	Maintenance on motor-operated valve MO-0748
MMO0753	2.14E-03	Maintenance on motor-operated valve MO-0753
MMO0754	2.14E-03	Maintenance on motor-operated valve MO-0760
MPCV521A	2.14E-03	Maintenance on pressure control valve PCV-0521A
MP8A	2.30E-04	Maintenance on pump P8A
MP8B	3.90E-03	Maintenance on pump P8B
MP8C	2.70E-04	Maintenance on pump P8C
MO0743	2.80E-03	Motor-operated valve MO-0743 fails to open
MO0748	2.80E-03	Motor-operated valve MO-0748 fails to open
MO0753	2.80E-03	Motor-operated valve MO-0753 fails to open
MO0754	2.80E-03	Motor-operated valve MO-0754 fails to open
MO0755	2.80E-03	Motor-operated valve MO-0755 fails to open
MO0759	2.80E-03	Motor-operated valve MO-0759 fails to open
MO0760	2.80E-03	Motor-operated valve MO-0760 fails to open
MO0798	2.80E-03	Motor-operated valve MO-0798 fails to open
NITROGEN	1.52E-03	Loss of pressure from nitrogen source
OPE1	1.00E-02	Operator error
OPE101	1.00E-02	Operator error
OPE102	1.00E-02	Operator error
OPE103	1.00E-03	Operator error
OPE104	1.00E-03	Operator error
OPE105	1.00E-03	Operator error
OPE106	1.00E-03	Operator error
OPE107	1.00E-03	Operator error
OPE108	1.00E-03	Operator error
OPE2	1.00E-03	Operator error
OPE3	1.00E-03	Operator error
OPE202	1.00E-03	Operator error
OPE204	1.00E-03	Operator error

OPE205	1.00E-03	Operator error
OPE206	1.00E-03	Operator error
OPE207	1.00E-03	Operator error
OPE210	1.00E-03	Operator error
OPE801	1.00E-03	Operator error
PCV0521A	5.00E-04	Pressure control valve PCV-0521A fails to open
PS8A	1.50E-02	Electric pump P8A fails to start
PS8B	3.00E-02	Turbine-driven pump P8B fails to start
PS8C	1.50E-02	Electric pump P8C fails to start
RV0783	1.70E-04	Relief valve RV-0783 premature open
SV0521	1.00E-03	Solenoid valve SV0521 fails
SV0522A	1.00E-03	Solenoid valve SV0522A fails
SV0522B	1.00E-03	Solenoid valve SV0522B fails
SV0525	1.00E-03	Solenoid valve SV0525 fails
WATER	1.00E-03	Water in steam pipe

FAILURE OF ELECTRICAL EQUIPMENT USING GENERIC DATA

COMP ID	PROBABILITY	RATE	DESCRIPTION
ACT1	1.79E-04	4.91E-07	Instr AC Transf 1 fails to function
ACT2	1.79E-04	4.91E-07	Instr AC Transf 2 fails to function
B1	5.15E-05	4.70E-08	1/3 Breakers from bypass regulator to bus Y10 ftc
B2	3.43E-05	4.70E-08	DC breaker ftc or
		4.70E-08	AC breaker ftc
B3	1.72E-05	4.70E-08	Breaker 52-145 ftc
B4	1.72E-05	4.70E-08	Breaker 52-356 ftc
B5	1.72E-05	4.70E-08	DC Breaker ftc
B6	1.72E-05	4.70E-08	Breaker 52-285 ftc
B7	1.72E-05	4.70E-08	Breaker 52-146 ftc
B8	1.72E-05	4.70E-08	Breaker 52-1301 ftc
B9	1.72E-05	4.70E-08	Breaker 52-1203 ftc
B10	1.72E-05	4.70E-08	Breaker 52-1101 ftc
B11	3.43E-05	4.70E-08	Breaker 52-1118 or breaker 52-1217 ftc
B12	3.43E-05	4.70E-08	Breaker 52-1202 ftc or
		4.70E-08	Breaker 152-201 ftc
B14	3.43E-05	4.70E-08	Breaker 52-1102 ftc or
		4.70E-08	Breaker 152-115 ftc
B15	1.72E-05	4.70E-08	Breaker 52-1310 ftc
B16	3.43E-05	4.70E-08	Breaker 52-1402 ftc or
		4.70E-08	Breaker 152-304 ftc
B17	1.72E-05	4.70E-08	Breaker 152-213 (DG1-2 output) ftc
B18	1.72E-05	4.70E-08	Breaker 152-107 (DG1-1 output) ftc
B20	1.72E-05	4.70E-08	Breaker 152-106 ftc
B22	1.72E-05	4.70E-08	Breaker 152-202 ftc
B24	1.72E-05	4.70E-08	Breaker 152-303 ftc
B181	3.43E-05	4.70E-08	Breaker 52-1302 ftc or
		4.70E-08	Breaker 252-110 ftc
BD	1.05E-03	2.88E-06	DC battery 1 degraded
BATT1	1.06E-03	2.90E-06	DC battery 1 fails
BUS1C	6.39E-05	1.75E-07	Bus 1C fails
BUS1D	6.39E-05	1.75E-07	Bus 1D fails
BUS1E	6.39E-05	1.75E-07	Bus 1E fails
BUSB11	6.39E-05	1.75E-07	Bus 11 fails
BUSB12	6.39E-05	1.75E-07	Bus 12 fails
BUSB13	6.39E-05	1.75E-07	Bus 13 fails
BUSB14	6.39E-05	1.75E-07	Bus 14 fails
BUSMC1	6.39E-05	1.75E-07	MCC 1 fails
BUSMC2	6.39E-05	1.75E-07	MCC 2 fails
BUSMC3	6.39E-05	1.75E-07	MCC 3 fails
BUSY01	6.39E-05	1.75E-07	Bus Y01 fails
BUSY10	6.39E-05	1.75E-07	Bus Y10 fails
BUSD1	6.39E-05	1.75E-07	DC Bus 1 fails
BYPR	8.40E-04	2.30E-06	Bypass regulator fails
C1	5.18E-04	1.42E-06	Cable fails
C2	5.18E-04	1.42E-06	Cable fails
C3	5.18E-04	1.42E-06	Cable fails
C4	5.18E-04	1.42E-06	Cable fails
C5	5.18E-04	1.42E-06	Cable fails
C6	5.18E-04	1.42E-06	Cable fails
C7	5.18E-04	1.42E-06	Cable fails

C8	5.18E-04	1.42E-06	Cable fails
C9	5.18E-04	1.42E-06	Cable fails
C10	5.18E-04	1.42E-06	Cable fails
C11	5.18E-04	1.42E-06	Cable fails
C12	5.18E-04	1.42E-06	Cable fails
C13	5.18E-04	1.42E-06	Cable fails
C14	5.18E-04	1.42E-06	Cable fails
C15	5.18E-04	1.42E-06	Cable fails
C16	5.18E-04	1.42E-06	Cable fails
C17	5.18E-04	1.42E-06	Cable fails
C18	5.18E-04	1.42E-06	Cable fails
C19	5.18E-04	1.42E-06	Cable fails
C20	5.18E-04	1.42E-06	Cable fails
C21	5.18E-04	1.42E-06	Cable fails
C22	5.18E-04	1.42E-06	Cable fails
C181	5.18E-04	1.42E-06	Cable fails
CH1	4.42E-03	1.21E-05	Charger fails
CH3	4.42E-03	1.21E-05	Charger fails
DG1-1S	3.00E-02		DG fails to start
DG1-2S	3.00E-02		DG fails to start
INV 1	8.40E-04	2.30E-06	Inverter 1 fails
OPRT	1.19E-04	3.26E-07	Loss of offsite power
STAP11	2.18E-04	5.96E-07	Station power transformer fails
STAP12	2.18E-04	5.96E-07	Station power transformer fails
STAP13	2.18E-04	5.96E-07	Station power transformer fails
STAP14	2.18E-04	5.96E-07	Station power transformer fails
STUT1-2	3.22E-04	8.81E-07	Start-up transformer fails

FAILURE OF ELECTRICAL EQUIPMENT USING PLANT SPECIFIC DATA

COMP ID	PROBABILITY	RATE	DESCRIPTION
ACT1	2.08E-05	2.60E-06	Instr AC Transf 1 fails to function - 8hrs
ACT2	2.08E-05	2.60E-06	Instr AC Transf 2 fails to function - 8hrs
B1	3.84E-06	1.60E-07	1/3 Breakers from bypass regulator to bus Y10 ftrc - 8hrs
B2	4.24E-06	3.70E-07 1.60E-07	DC breaker ftrc - 8hrs or AC breaker ftrc - 8hrs
B3	1.28E-06	1.60E-07	Breaker 52-145 ftrc - 8hrs
B4	1.28E-06	1.60E-07	Breaker 52-356 ftrc - 8hrs
B5	2.96E-06	3.70E-07	DC Breaker ftrc - 8hrs
B6	1.28E-06	1.60E-07	Breaker 52-285 ftrc - 8hrs
B7	1.28E-06	1.60E-07	Breaker 52-146 ftrc - 8hrs
B8	1.28E-06	1.60E-07	Breaker 52-1301 ftrc - 8hrs
B9	1.28E-06	1.60E-07	Breaker 52-1203 ftrc - 8hrs
B10	1.28E-06	1.60E-07	Breaker 52-1101 ftrc - 8hrs
B11	2.56E-06	1.60E-07	Breaker 52-1118 or breaker 52-1217 ftrc - 8hrs
B12	1.33E-05	1.60E-07 1.50E-06	Breaker 52-1202 ftrc - 8hrs or Breaker 152-201 ftrc - 8hrs
B14	1.33E-05	1.60E-07 1.50E-06	Breaker 52-1102 ftrc - 8hrs or Breaker 152-115 ftrc - 8hrs
B15	1.28E-06	1.60E-07	Breaker 52-1310 ftrc - 8hrs
B16	1.33E-05	1.60E-07 1.50E-06	Breaker 52-1402 ftrc - 8hrs or Breaker 152-304 ftrc - 8hrs
B17	2.15E-02	5.70E-05	Breaker 152-213 (DG1-2 output) ftc or ftrc DI=370hrs, MT=8hrs
B18	6.01E-03	1.60E-05	Breaker 152-107 (DG1-1 output) ftc or ftrc DI=370hrs, MT=8hrs (p-1.6E-05)
B20	1.20E-05	1.50E-06	Breaker 152-106 ftrc - 8hrs
B22	1.20E-05	1.50E-06	Breaker 152-202 ftrc - 8hrs
B24	1.20E-05	1.50E-06	Breaker 152-303 ftrc - 8hrs
B181	1.33E-05	1.60E-07 1.50E-06	Breaker 52-1302 ftrc - 8hrs or Breaker 252-110 ftrc - 8hrs
BD	9.62E-04	2.60E-06	DC battery 1 degraded - SBD, DI=370hrs
BATT1	2.08E-05	2.60E-06	DC battery 1 fails - 8hrs
BUS1C	6.40E-06	8.00E-07	Bus 1C fails - 8hrs
BUS1D	6.40E-06	8.00E-07	Bus 1D fails - 8hrs
BUS1E	6.40E-06	8.00E-07	Bus 1E fails - 8hrs
BUSB11	1.36E-06	1.70E-07	Bus 11 fails - 8hrs
BUSB12	1.36E-06	1.70E-07	Bus 12 fails - 8hrs
BUSB13	1.36E-06	1.70E-07	Bus 13 fails - 8hrs
BUSB14	1.36E-06	1.70E-07	Bus 14 fails - 8hrs
BUSMC1	1.36E-06	1.70E-07	MCC 1 fails - 8hrs
BUSMC2	1.36E-06	1.70E-07	MCC 2 fails - 8hrs
BUSMC3	1.36E-06	1.70E-07	MCC 3 fails - 8hrs
BUSY01	1.04E-05	1.30E-06	Bus Y01 fails - 8hrs
BUSY10	1.04E-05	1.30E-06	Bus Y10 fails - 8hrs
BUSD1	3.12E-05	3.90E-06	DC Bus 1 fails - 8hrs
BYPR	4.16E-05	5.20E-06	Bypass regulator fails - 8hrs
C1	6.00E-05	7.50E-06	Cable fails - 8hrs
C2	6.00E-05	7.50E-06	Cable fails - 8hrs
C3	6.00E-05	7.50E-06	Cable fails - 8hrs
C4	6.00E-05	7.50E-06	Cable fails - 8hrs
C5	6.00E-05	7.50E-06	Cable fails - 8hrs

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C6	6.00E-05	7.50E-06	Cable fails - 8hrs
C7	6.00E-05	7.50E-06	Cable fails - 8hrs
C8	6.00E-05	7.50E-06	Cable fails - 8hrs
C9	6.00E-05	7.50E-06	Cable fails - 8hrs
C10	6.00E-05	7.50E-06	Cable fails - 8hrs
C11	6.00E-05	7.50E-06	Cable fails - 8hrs
C12	6.00E-05	7.50E-06	Cable fails - 8hrs
C13	6.00E-05	7.50E-06	Cable fails - 8hrs
C14	6.00E-05	7.50E-06	Cable fails - 8hrs
C15	6.00E-05	7.50E-06	Cable fails - 8hrs
C16	6.00E-05	7.50E-06	Cable fails - 8hrs
C17	6.00E-05	7.50E-06	Cable fails - 8hrs
C18	6.00E-05	7.50E-06	Cable fails - 8hrs
C19	6.00E-05	7.50E-06	Cable fails - 8hrs
C20	6.00E-05	7.50E-06	Cable fails - 8hrs
C21	6.00E-05	7.50E-06	Cable fails - 8hrs
C22	6.00E-05	7.50E-06	Cable fails - 8hrs
C181	6.00E-05	7.50E-06	Cable fails - 8hrs
CH1	1.04E-05	1.30E-06	Charger fails - 8hrs
CH3	1.04E-05	1.30E-06	Charger fails - 8hrs
DG1-1S	6.10E-03	6.10E-03	DG fails to start - SBD
DG1-1R	2.24E-02	2.80E-03	DG fails to run - 8hrs
DG1-2S	8.10E-03	8.10E-03	DG fails to start - SBD
DG1-2R	9.60E-03	1.20E-03	DG fails to run - 8hrs
INV 1	3.12E-05	3.90E-06	Inverter 1 fails - 8hrs
OPRT	5.36E-04	6.70E-05	Loss of offsite power - 8hrs
STAP11	4.00E-06	5.00E-07	Station power transformer fails - 8hrs
STAP12	4.00E-06	5.00E-07	Station power transformer fails - 8hrs
STAP13	4.00E-06	5.00E-07	Station power transformer fails - 8hrs
STAP14	4.00E-06	5.00E-07	Station power transformer fails - 8hrs
STUT1-2	2.64E-05	3.30E-06	Start-up transformer fails - 8hrs

APPENDIX G

COMPONENT FAILURE RATE DATA CALCULATION

The following presents some calculations of component failure rate data for the AFW system unavailability estimate.

1.0 TEST AND MAINTENANCE

1.1 Pump test = 1.92E-03 (Reference 2)

$$Q_{Test} = \frac{(hrs/test)(tests/year)}{(hrs/year)} = \frac{(1.4)(12)}{8760} = 1.93E-03$$

1.2 Pump maintenance = 2.14E-03 (Reference 2)

$$Q_{Maint} = \frac{(0.22)(hrs/maint)}{720} = \frac{(0.22)(7)}{720} = 2.14E-03$$

1.3 Valve maintenance = 2.14E-03 (Reference 2)

$$Q_{Maint} = \frac{(0.22)(hrs/maint)}{720} = \frac{(0.22)(7)}{720} = 2.14E-03$$

2.0 OPERATOR ERROR

2.1 Maintenance error = 1.00E-03 (Reference 3)

The failure probability if the maintainer fails to restore a valve after this work is finished is 1.00E-02, and the checker's failure probability is (1.00E-02)(10) = 1.00E-01. Hence, the estimated error by the maintainer restoring manual valves is (1.00E-02)(1.00E-01) = 1.00E-03.

2.2 Operator error in control room (or local) = 1.00E-03 (Reference 2)

Estimated failure probability for a "dedicated" operator to actuate AFW and possible backup actuation of AFW in 15 minutes actuation time needed is 1.00E-03.

3.0 HARDWARE

3.1 Valve (check, gate) fails to open = 1.00E-04 (Reference 4)

3.2 Control valve fails to open = 4.00E-04

Q = fails to operate + failure to remain open (plug)

= 3.00E-04 + 1.00E-04 = 4.00E-04 (Reference 4)

3.3 Relief valve premature open = 3.65E-03

Relief valve premature open failure rate λ = 1.00E-05/hr (Reference 4)

By monthly testing:

$Q = \lambda \bullet 730/2 = (1.00E-05)(365) = 3.65E-03$

3.4 AFW actuation signal fails = 7.00E-03 (Reference 2)

3.5 Loss of instrument air = 1.52E-03

Failure rate λ = 4.17E-06/hr (using compressor's failure rate (Reference 1, p 120)

Using monthly testing:

$Q = \lambda \bullet 730/2 = 4.17E-06)(365) = 1.52E-03$

3.6 Flow transmitter failure = 2.17E-03

Failure rate λ = 5.95E-06/hr (Reference 1, p 432)

Using monthly testing:

$Q = (5.95E-06) \quad 730/2 = 2.17E-03$

3.7 Hand switch failure = 3.00E-04 (Reference 4)

3.8 Pressure (flow) control valve fails to open = 1.00E-05

By using relief valve fails to open data (Reference 4)

3.9 Governor failure = 6.53E-05

Failure rate λ = 1.70E-07/hr

MTTR τ = 19.13 hr (Reference 7)

$Q = \lambda\tau + \lambda \bullet 730/2 = 6.53E-05$ (using monthly testing)

3.10 Electrically driven pump fails to start = 5.00E-03

Q = mechanical components + control circuit (with monthly testing) = 1.00E-03 + 4.00E-03 = 5.00E-03 (Reference 2)

3.11 Turbine driven pump fails to start = 1.00E-03 (Reference 2)

3.12 Solenoid valve failure = 1.00E-03 (Reference 4)

3.13 Pipe rupture, condensate storage tank rupture = 4.80E-08

The pipe rupture (>3") failure rate is 1.00E-10/hr per foot (Reference 4). It was estimated that there were 20 feet of pipe length from the condensate storage tank to the double suction header and the average repair time was 24 hrs.

$Q = (20)(1.00E-010)(24) = 4.80E-08$/demand

3.14 Motor-operated valve (N.O.) fails to open (plugging)

= 1.00E-04 (Reference 2)

3.15 Water in pipe = 1.00E-03

By judgement, the estimated probability that there is sufficient condensed water in the steam pipe is 1.00E-03. It is noted that the top event unavailability will not be affected if 1.0 is used for that estimated probability.