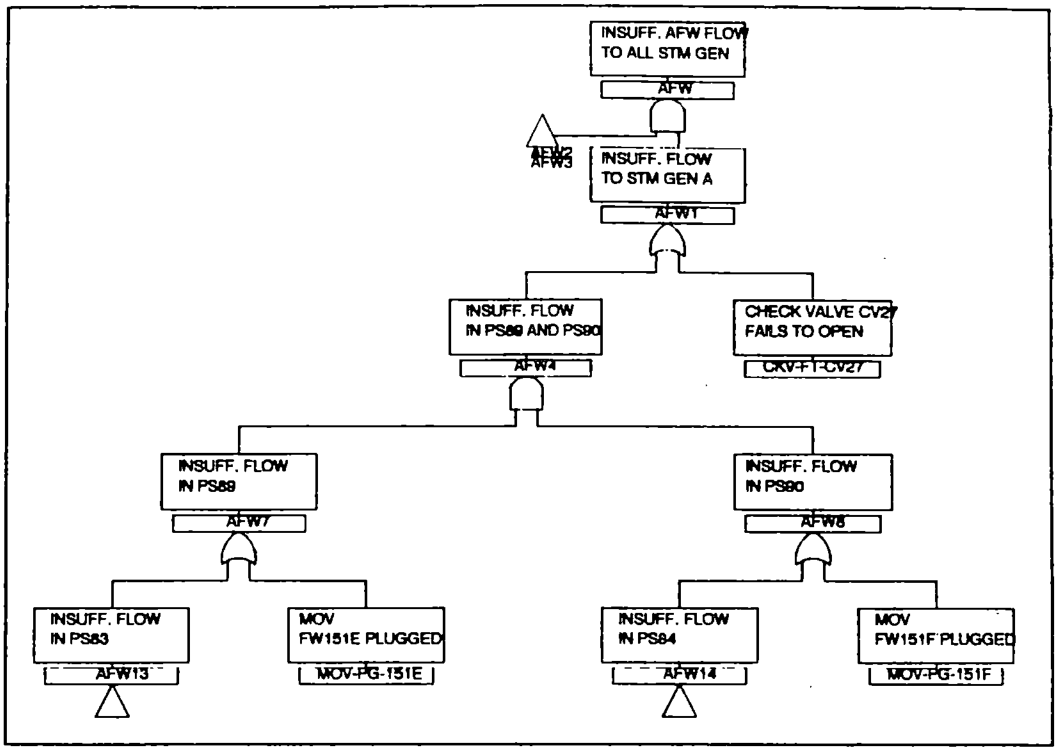
RISK ASSESSMENT OF THE SURRY AFW SYSTEM TECHNICAL SPECIFICATION



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APPENDIX 1

SUMMARY REPORT

IMPELL PROBABILISTIC RISK ANALYSIS

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1.0 INTRODUCTION

As part of a program to evaluate the operational readiness of plant systems, Virginia Power performed a Safety System Functional Inspection (SSFI) to assess the Auxiliary Feedwater (AFW) system design. This review covered several areas including plant modifications, design control, maintenance, and testing.

As a result of the review, it was determined that an inconsistency existed between the plant Technical Specifications requirements that govern the AFW system unit cross-connect capability and the safety analysis assumptions for Surry Units 1 and 2. This inconsistency occurs as a result of a very low probability scenario for a high energy line break in the main steam valve house of an operating unit with the other unit in cold shutdown. During this scenario, the high energy line break in the main steam valve house may cause failure of all three AFW pumps due to environmental qualification considerations. This, in combination with a single active failure in the shutdown unit, could result in a loss of all AFW capability since the current Technical Specifications only require one AFW pump to be available on the shutdown unit.

To address this issue, Virginia Power determined that a revision to the current plant Technical Specifications would ensure that a single active failure in the shutdown unit would not result in loss of all AFW capability. Due to various plant considerations, however, the current Allowable Outage Time (AOT) for the action statements in the governing sections of the Technical Specifications is too restrictive for a unit in a cold or refueling shutdown.

As a result, Virginia Power contracted with Impell Corporation to perform a risk assessment to evaluate the contribution to core melt as a result of implementing a longer AOT for the action statements. This report presents the analysis and results of the risk assessment. The results of this conservative analysis show that an AOT of fourteen days results in a negligible impact upon core melt risk for the scenario mentioned above. In addition, the new requirement to maintain two additional AFW pumps operable enhances the level of safety for all other core damage sequences that challenge the AFW system. For these reasons, it is concluded that the AOT of fourteen days for the "cross-connect" AFW trains is acceptable.

2.0 ANALYSIS METHODOLOGY

The analysis of the Surry AFW system used traditional fault tree analysis techniques. The basis for the analysis was the fault tree models and data from NUREG/CR 4550 Volume 3. Use of these fault tree models and data allow for a direct comparison to core melt probability as calculated in the subject NUREG. The minimal cut set generation and quantification of the fault tree was performed using the microcomputer code IRRAS, Version 1.0.

The fault tree model developed for the cross connect capability of the AFW system was developed using the same methodology outlined in NUREG/CR 4550 and is presented in Appendix A of this report. Diesel generator dependencies were modeled per the Boolean expressions presented in Section IV.5.15.4 of NUREG/CR 4550 Volume 3.

To verify that the results obtained from this analysis were comparable with the above NUREG, a bench mark test case was analyzed. This analysis case (CASE 1) modeled the NUREG/CR 4550 AFW fault tree exactly and duplicated the NUREG results using the identical failure rate data.

The following scenario was analyzed from a reliability basis:

> **Unit 1 is operating with Unit 2 in a cold shutdown mode. The assumption of Unit 2 being in the cold shutdown mode is conservative for this analysis because it precludes utilization of the Unit 2 turbine driven pump to supply AFW flow to Unit 1.**

LCO time periods of fourteen, twenty-one, and thirty days were evaluated. The event scenario included a HELB in the vicinity of the operating unit's AFW pumps (thus failing the pumps). In addition, loss of offsite power events (LOSP) were evaluated to a lesser extent. This is because a LOSP initiator by itself will not fail the AFW pumps in the operating unit, thus the initiator is not limiting. A combined LOSP/HELB event would challenge the diesel generators and fail the operating unit AFW pumps; however, the event frequency is so small (about 2E-6), that this initiator with subsequent AFW failure is not the limiting risk associated with an increased AOT.

Specifically, the cases analyzed were:

- Case 1 - AFW system without transient failures. This case was used to compare the system reliability results with the NUREG/CR 4550 results as a bench mark test case.
- Case 2 - AFW with LOSP, no credit for cross connect capability.

- Case 3 - AFW with LOSP, credit for cross connect capability, no extended LCO requirements.
- Case 4 - AFW with HELB, no extended LCO requirements on AFW cross connect train.
- Case 5 - AFW with HELB, 14 day LCO requirements on AFW cross connect train.
- Case 6 - AFW with HELB, 21 day LCO requirements on AFW cross connect train.
- Case 7 - AFW with HELB, 30 day LCO requirements on AFW cross connect train.

3.0 AFW SYSTEM DESCRIPTION

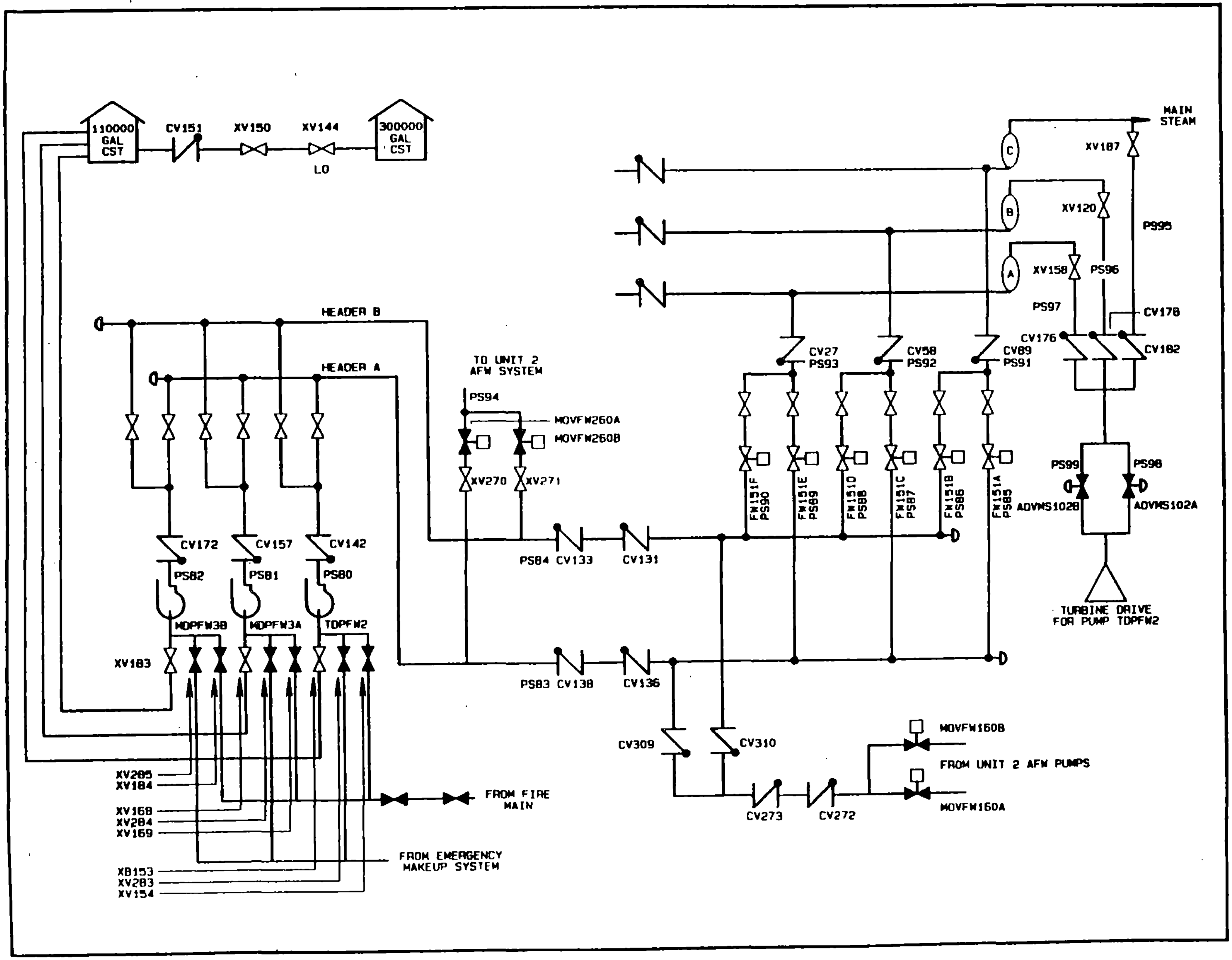
The following system description is quoted from NUREG/CR 4550 Volume 3 and is provided for information.

"The Surry AFW is a three train system, two electric motor driven pumps and one steam driven pump. Each pump draws suction through an independent line from the 110,000 gallon condensate storage tank (CST). In addition, a 300,000 gallon CST, a 100,000 gallon emergency makeup tank and the fire main can be used as water supplies for the AFW pumps. Each AFW pump discharges to parallel headers. Each of these headers can provide auxiliary feedwater flow to any or all of the three steam generators. Flow from each header to any one Steam Generator is through a normally open MOV and a locked open valve in series, paralleled with a line from the other header. These lines feed one line containing a check valve which joins the main feedwater line to a steam generator."

"The motor driven AFW pumps automatically start on receipt of an SIAS signal, loss of main feedwater, low steam generator level in any steam generator, or loss of offsite power. The turbine driven AFW pump automatically starts on receipt of indication of low steam generator level in two of the three steam generators or under voltage of any of the three main RCS pumps. These signals also ensure that the system MOV's are in the correct position."

The emergency electrical power system at Surry consists of three diesel generators, with one diesel generator aligned to each unit and the remaining diesel generator designated as a "swing" diesel. Upon receipt of a Safety Injection signal, the swing diesel will automatically align to the "affected" unit.

In addition, the AFW system has the ability to provide AFW flow to the opposite unit through a cross-tie header. The flow can be provided from the motor driven AFW pumps or the turbine driven AFW pump. For conservatism, the analysis assumed that the "un-affected" unit is in a cold shutdown condition and the turbine driven pump is not available. A simplified flow schematic is presented on the following page.


110000 GAL CST
CV151
XV150
XV144
LO
300000 GAL CST
MAIN STEAM
XV187
XV120
PS95
XV158
PS96
PS97
CV178
CV176
CV182
CV27
PS93
CV58
PS92
CV89
PS91
HEADER B
HEADER A
TO UNIT 2 AFW SYSTEM
PS94
MOVFW260A
MOVFW260B
XV270
XV271
FW151F PS90
FW151E PS89
FW151D PS88
FW151C PS87
FW151B PS86
FW151A PS85
PS99
PS98
ADVMS102B
ADVMS102A
TURBINE DRIVE FOR PUMP TDPFW2
CV172
CV157
CV142
PS82
PS81
PS80
MDPFW3B
MDPFW3A
TDPFW2
XV183
PS84 CV133
CV131
PS83 CV138
CV136
CV309
CV310
MOVFW160B
FROM UNIT 2 AFW PUMPS
MOVFW160A
CV273
CV272
XV285
XV184
XV168
XV284
XV169
FROM FIRE MAIN
FROM EMERGENCY MAKEUP SYSTEM
XB153
XV283
XV154

4.0 ANALYSIS ASSUMPTIONS

The following conservative assumptions and ground rules were used in this analysis:

- The loss of offsite power event was assumed to affect both Unit 1 and Unit 2, although the analysis was performed for Unit 1. Should diesel generator #2 (dedicated to unit 2) fail to start or run, diesel generator #3 would align to Unit 2, thereby making it unavailable for Unit 1. This assumption is extremely conservative since the Unit 2 power requirements would be reduced while in a shutdown condition. For power supplies to Unit 2 AFW pumps a similar assumption is made. If Diesel Generator #1 fails then Diesel Generator # 3 is assumed unavailable to supply power to Unit 2. It is assumed that for a simultaneous loss of off site power and HELB, the swing diesel would automatically align to Unit 1. This will necessitate the operator to manually align the diesel to Unit 2 to provide cross-tie flow capability. This operator action is viewed as an independent action from manually aligning the Unit 2 AFW flow path.
- Failure of the Unit 2 cross-connect in the open position is assumed to fail the Unit 1 AFW due to flow diversion to the shut down unit. This is only true if the Unit 1 AFW pumps are operating. If the Unit 2 pumps are providing AFW to Unit 1 through the cross connect, flow diversion back to Unit 2 is not considered credible since failure of two check valves in series would be required in addition to the cross connect valve failing in the open position while indicating closed. The use of the 300,000 gallon CST, the emergency makeup tank, or the fire main as a backup to the CST were not considered as recovery actions for conservatism.
- All failure rates and probabilities used in the analysis were obtained from NUREG/CR 4550 Volume 3 with the exception of the extended LCO unavailability. The extended LCO unavailability was derived for this analysis.
- The shut down unit is assumed to enter into an extended LCO once every eighteen months for any given train of AFW on the "un-affected" unit. For this analysis, the fault tree model assumes that Train A is the AFW train that enters into the LCO condition. Since the AFW trains are identical, modeling AFW Train B as the "LCO" train would give identical results.
- The shut down unit is assumed to enter into an LCO once every three fuel cycles (approximately 4.5 years) that affects both trains of AFW on the shutdown unit. The AOT for this LCO is three days (72 hours). The only situation that would require an outage of 72 hours is major piping work on the cross tie header between the two units, therefore this is assumed to be an infrequent event.

5.0 ANALYSIS RESULTS

The following initiator frequencies from NUREG/CR 4550 Volume 3 were used for this analysis:

Loss of offsite power 7.0E-2/yr

High Energy Pipe Rupture in AFW Room 3.0E-5/yr

SUMMARY OF RESULTS

ANALYSIS CASE	FAILURE PROBABILITY	INITIATOR FREQUENCY	RESULTANT FAILURE RATE	CHANGE IN RISK
CASE 1-Bench Mark Case	2.34E-4	N/A	N/A	N/A
CASE 2-LOSP, no cross-connect	2.58E-4	7.0E-2	1.8E-5	N/A
CASE 3-LOSP, cross-connect, no AOT	2.38E-4	7.0E-2	1.7E-5	(1.0E-6)
CASE 4-HELB, no AOT	4.45E-3	3.0E-5	1.3E-7	N/A
CASE 5A-HELB, 14 day AOT	6.56E-3	3.0E-5	2.0E-7	7.0E-8
CASE 5B-LOSP/HELB, 14 day AOT	8.07E-3	2.1E-6	1.7E-8	N/A
CASE 6-HELB, 21 day AOT	6.71E-3	3.0E-5	2.0E-7	7.0E-8
CASE 7-HELB, 30 day AOT	6.90E-3	3.0E-5	2.1E-7	8.0E-8

Case 1 results were compared to the results obtained in NUREG/CR 4550 Volume 3 to provide a bench mark test case. NUREG/CR 4550 Volume 3 failure rate for the AFW system is 2E-4 (the report only presents the first significant digit). The results of Case 1 are consistent with NUREG/CR 4550 Volume 3, therefore the analytical tools used for this analysis are valid and the results obtained in Cases 2 through 7 can be compared with the NUREG/CR 4550 Volume 3 core melt probabilities.

As a means of comparison, the values presented above are compared to the Surry dominant accident sequences identified in Table IV.9-2 (page IV-242) of NUREG/CR 4550 Volume 3. For Case 5A (14 day LCO) above, if the assumption is made that the design basis event and subsequent failure of the AFW system resulted in core melt, then the Case 5A result would be approximately 0.8% of the total core melt frequency (2.5E-5). This is conservative because no credit is being given to other actions the plant may take such as entering into "feed and bleed" operation. NUREG/CR 4550 Volume 3 credits "feed and bleed" as a recovery path. This recovery action would improve the results by approximately an order of magnitude. In addition, credit is not given for the availability of the main feedwater pumps, which may still be operable for a HELB event. This is also conservative by approximately an order of magnitude.

As a comparison, the analysis also evaluated the LOSP initiating event. NUREG/CR 4550 showed that the LOSP/AFW failure events were significant contributors to core melt frequency. The Technical Specification proposed does not impact the NUREG/CR 4550 analysis because credit for the cross connect capability is not given in the subject NUREG. As Case 3 results show, there is relatively little improvement in the reliability of the AFW system when crediting the cross connect capability for the non-HELB sequences. This result demonstrates that for LOSP initiators, the failure probability of the AFW system is relatively insensitive to the AOT for the cross-connect capability, because the AFW failure probability will be between the Case 2 result and the Case 3 result for any given AOT.

A combined LOSP/HELB event was also evaluated and the results are presented as Case 5B. This event is assumed to result in a loss of the operating unit AFW pumps and the requirement to rely on the diesel generators for emergency power. As can be seen by the result, the overall failure probability is less than Case 5A due to the low probability of the combined LOSP/HELB event. In addition, the AFW failure probability is only slightly greater than when on-site power is available.

The results presented are based upon an analysis which contains a significant amount of conservatism. Specifically:

- *credit is not given for additional actions such a "feed and bleed" operations to prevent core melt (conservative by an order of magnitude),*
- *credit is not given for the availability of the main feed water pumps for the HELB initiating event (conservative by an order of magnitude),*
- *the Unit 1/Unit 2 operating/shutdown configuration is assumed to be 100% during any given year (conservative by an approximate factor of two).*

The results above show that an extended AOT time frame to 14 days results in a negligible (approximately 7.0E-8) increase in core melt risk with respect to the case with no AOT (Case 4). In addition, the new requirement to maintain two additional AFW pumps operable enhances the level of safety for all other core damage sequences that challenge the AFW system, thus a net reduction in core melt risk is achieved.

Based on the above analysis, it is concluded that an allowed outage time of fourteen days does not present an increase in the probability for core melt.

6.0 REFERENCES

1. NUREG/CR-4550/Vol. 3, *ANALYSIS OF CORE DAMAGE FREQUENCY FROM INTERNAL EVENTS: SURRY, UNIT 1*, printed November 1986.

2. Memorandum to Mr. E.S. Grecheck - Surry P/S, from Mr. R.W. Calder, dated July 7, 1987, *DEVIATION REPORT AUXILIARY FEEDWATER SYSTEM CROSS-CONNECT SURRY POWER STATION.*

3. *SURRY POWER STATION UFSAR*, Revision 1, 6/83.

4. *SURRY POWER STATION TECHNICAL SPECIFICATIONS*, Section 3.6, 10-12-84.

5. *Drawing Number 11448-FM-68A*, Revision 20.

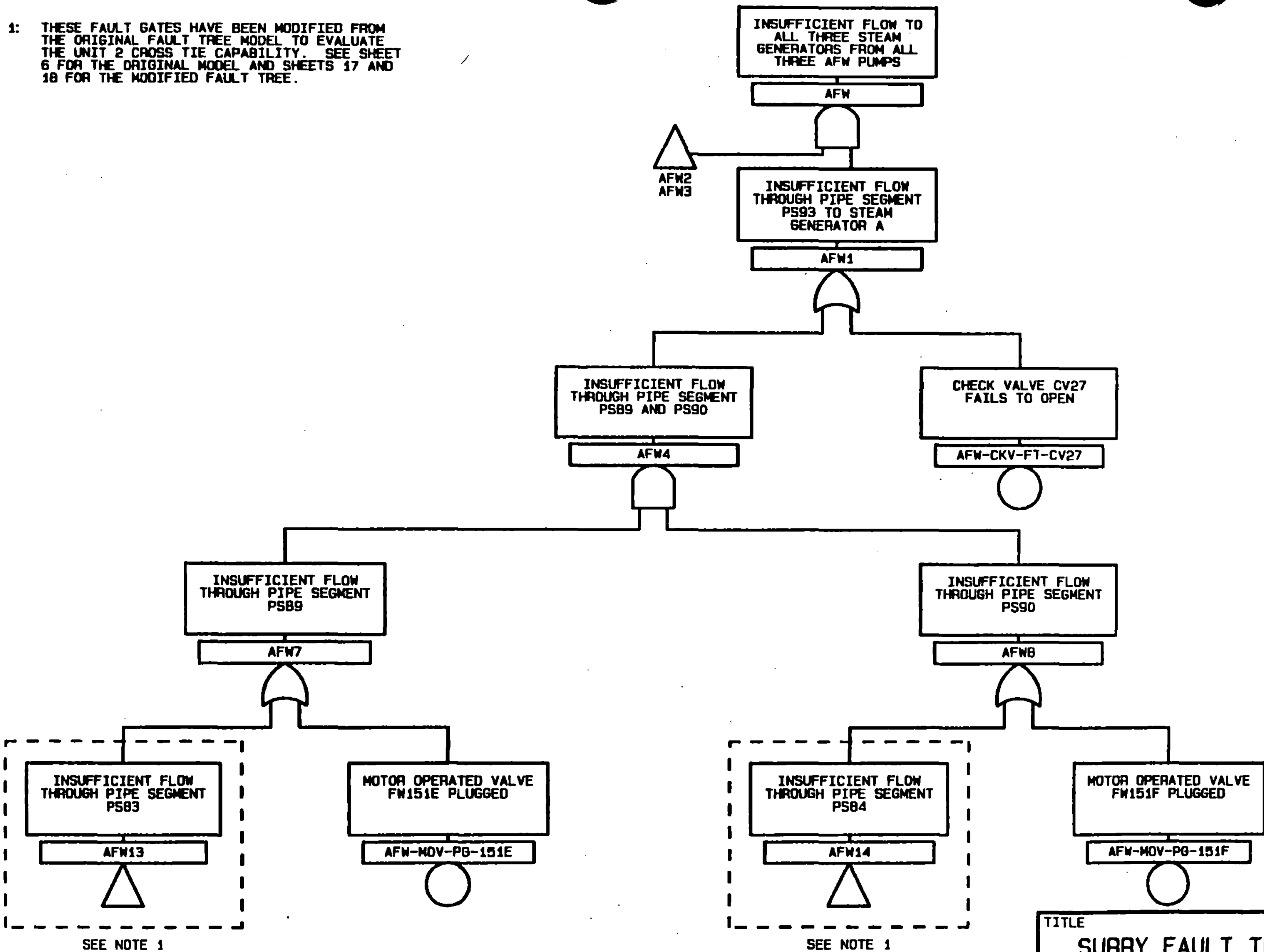
6. *Drawing Number 11448-FM-68B*, Revision 14.

7. *Drawing Number 11448-FM-18B,* Revision 8.

APPENDIX A

AFW FAULT TREES

NOTE 1: THESE FAULT GATES HAVE BEEN MODIFIED FROM THE ORIGINAL FAULT TREE MODEL TO EVALUATE THE UNIT 2 CROSS TIE CAPABILITY. SEE SHEET 6 FOR THE ORIGINAL MODEL AND SHEETS 17 AND 18 FOR THE MODIFIED FAULT TREE.



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SHEET 1/19	
CALC NUMBER	REV
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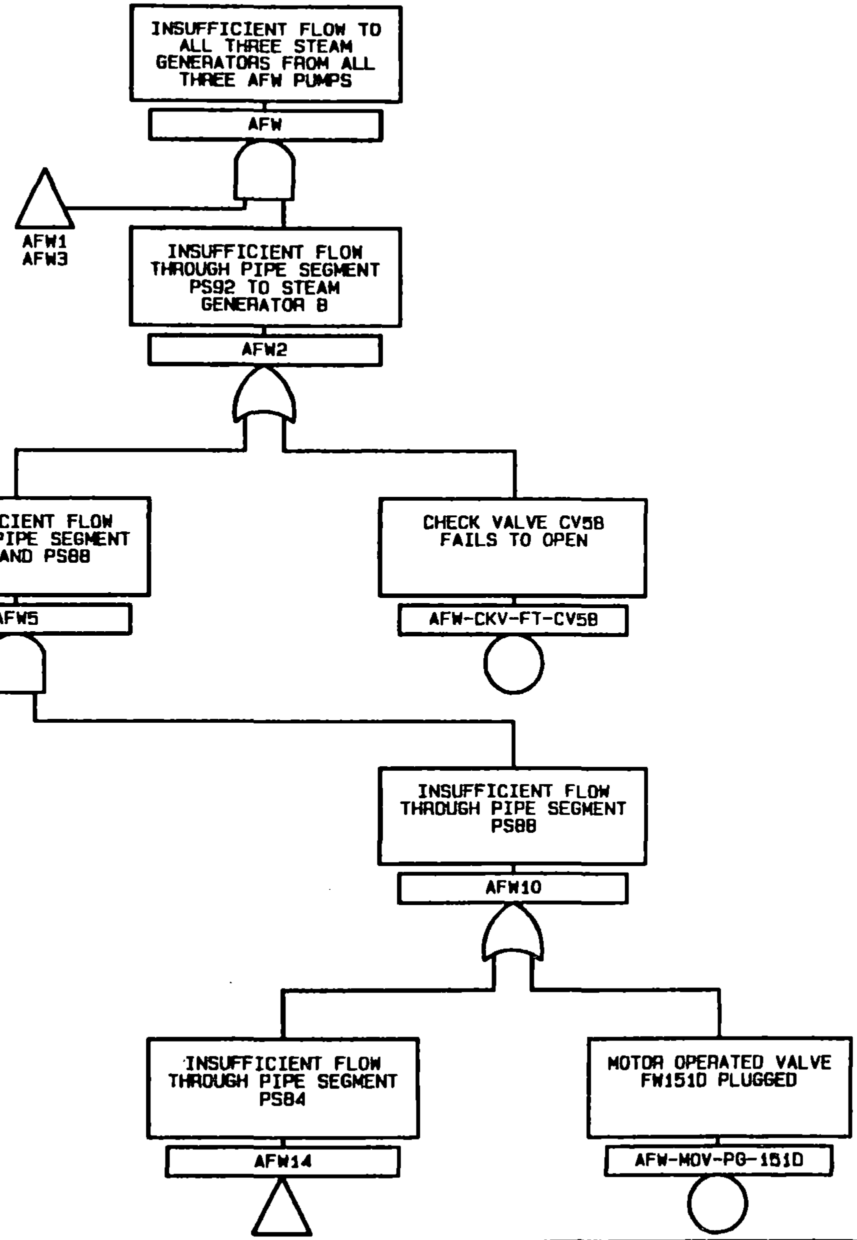

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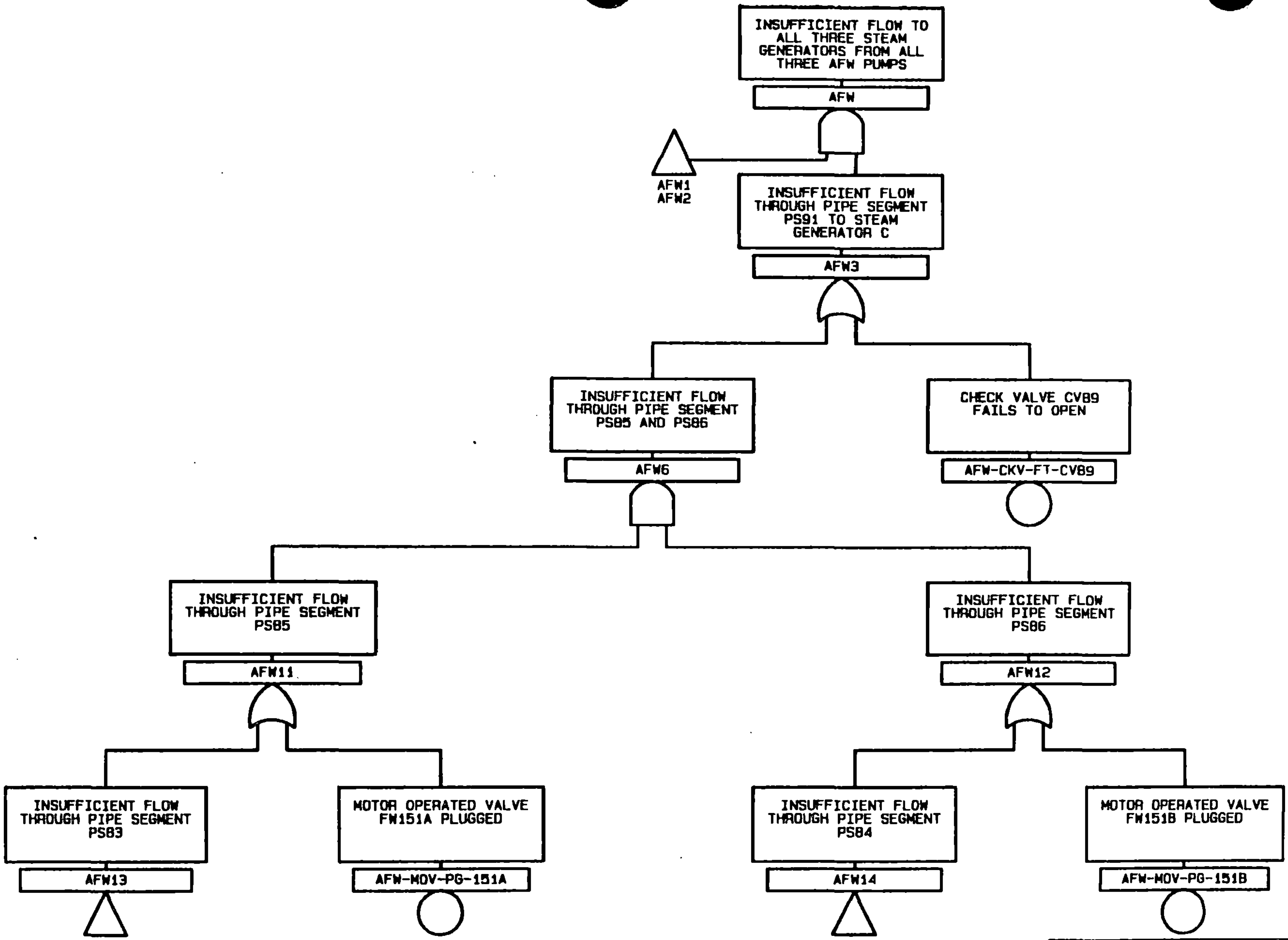

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CALC NUMBER	REV
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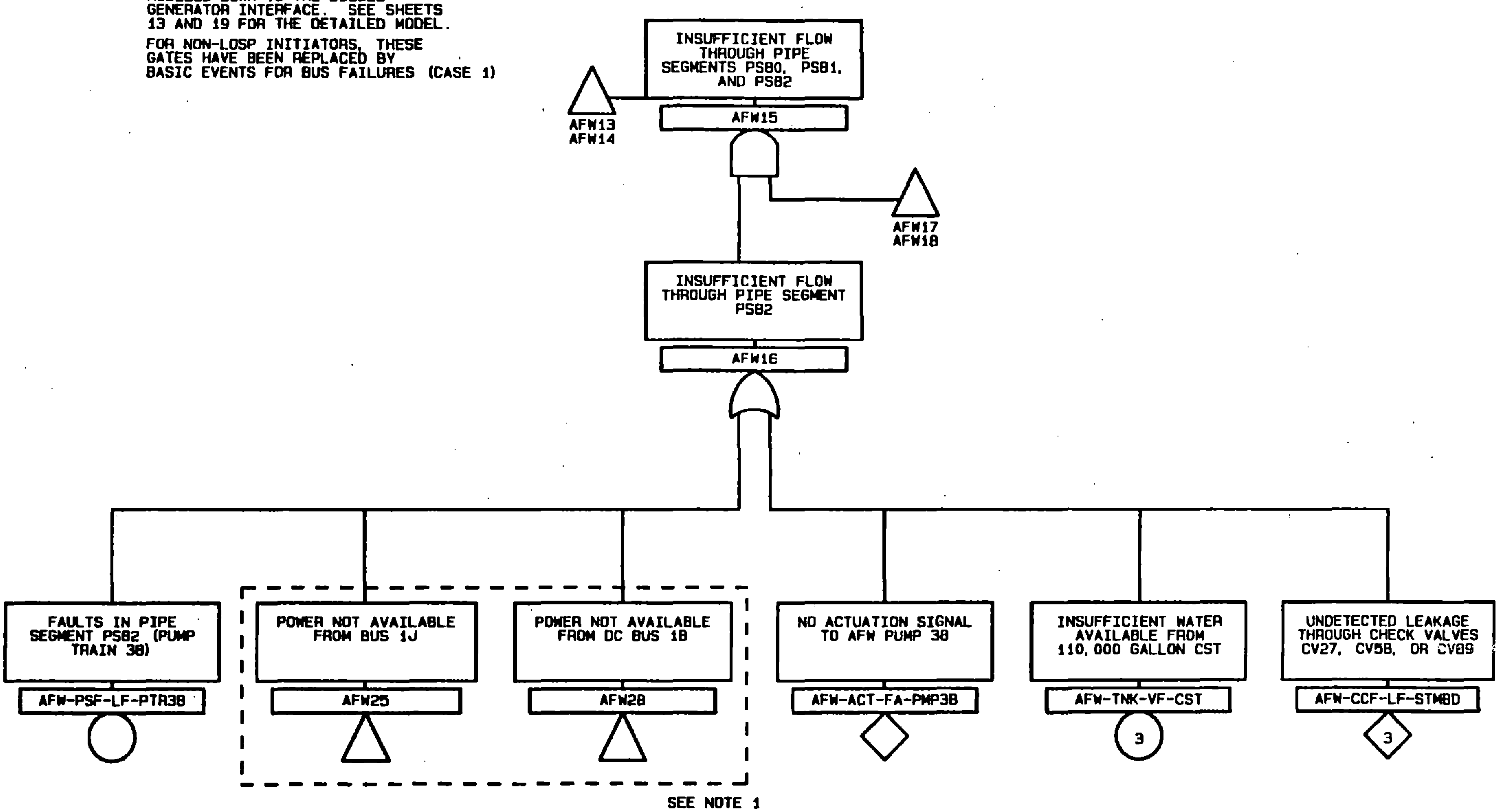
NOTE 1: FOR THE LOSP INITIATOR, THESE EVENTS HAVE BEEN SEPARATELY MODELED DOWN TO THE DIESEL GENERATOR INTERFACE. SEE SHEETS 13 AND 19 FOR THE DETAILED MODEL.

FOR NON-LOSP INITIATORS, THESE GATES HAVE BEEN REPLACED BY BASIC EVENTS FOR BUS FAILURES (CASE 1)



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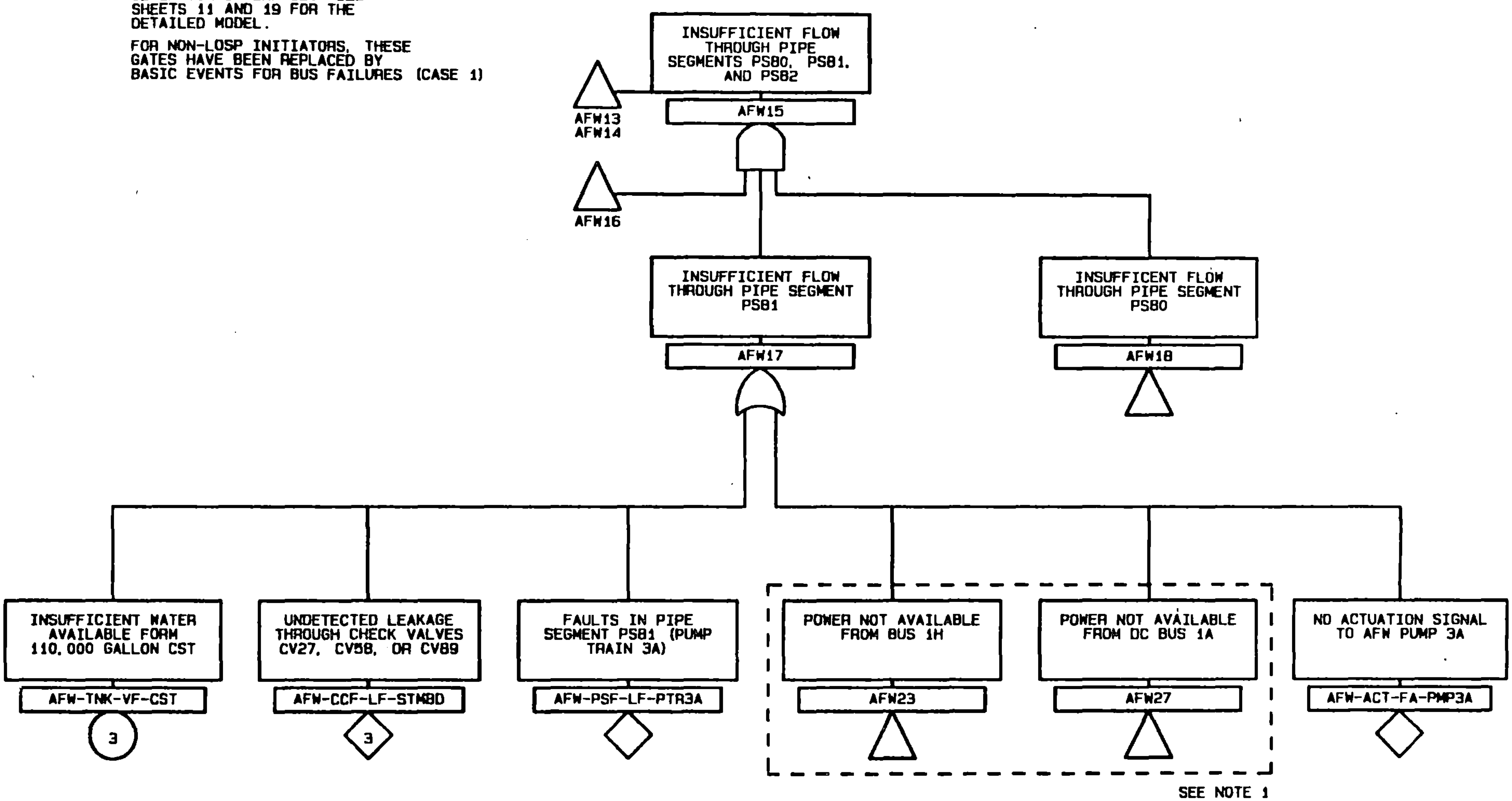
CALC NUMBER: 1250-054-C002	REV: 0

NOTE 1: FOR LOSP INITIATOR, THESE EVENTS HAVE BEEN SEPARATELY MODELED DOWN TO THE DIESEL GENERATOR INTERFACE. SEE SHEETS 11 AND 19 FOR THE DETAILED MODEL.

FOR NON-LOSP INITIATORS, THESE GATES HAVE BEEN REPLACED BY BASIC EVENTS FOR BUS FAILURES (CASE 1)



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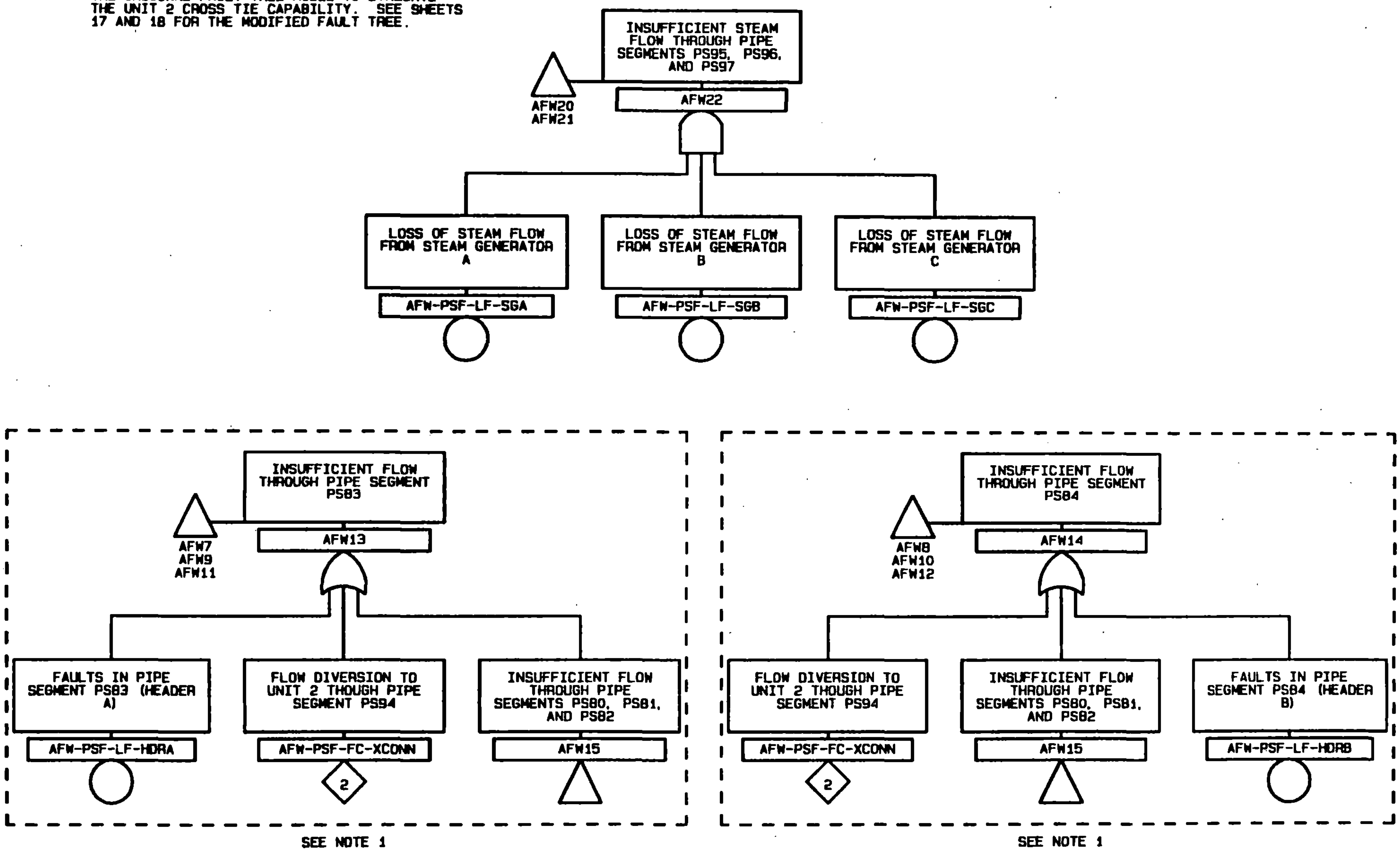
CALC NUMBER 1250-054-C002	REV 0

NOTE 1: THESE FAULT GATES HAVE BEEN MODIFIED FROM THE ORIGINAL FAULT TREE MODEL TO EVALUATE THE UNIT 2 CROSS TIE CAPABILITY. SEE SHEETS 17 AND 18 FOR THE MODIFIED FAULT TREE.



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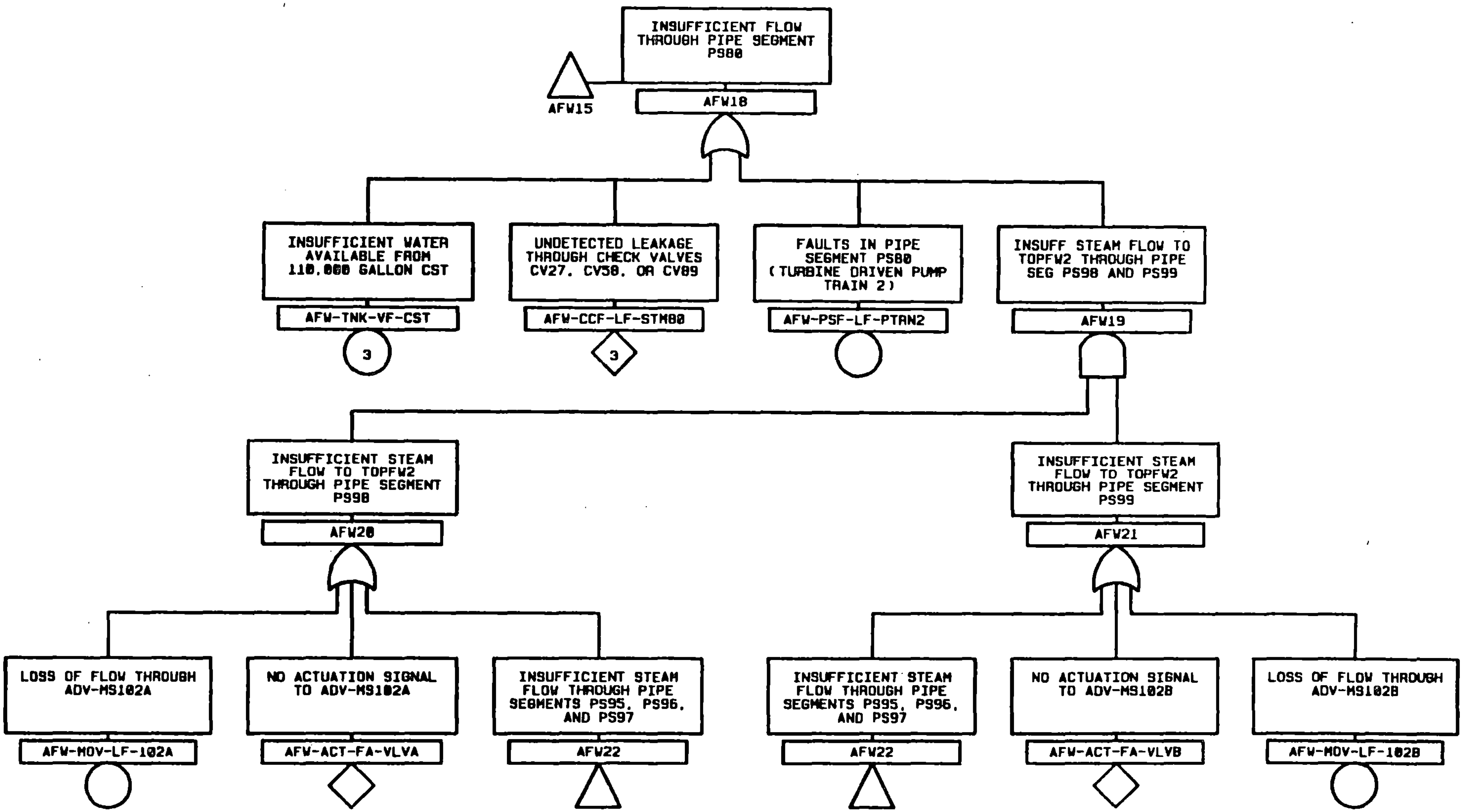

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AFW-L

DRAWING NUMBER
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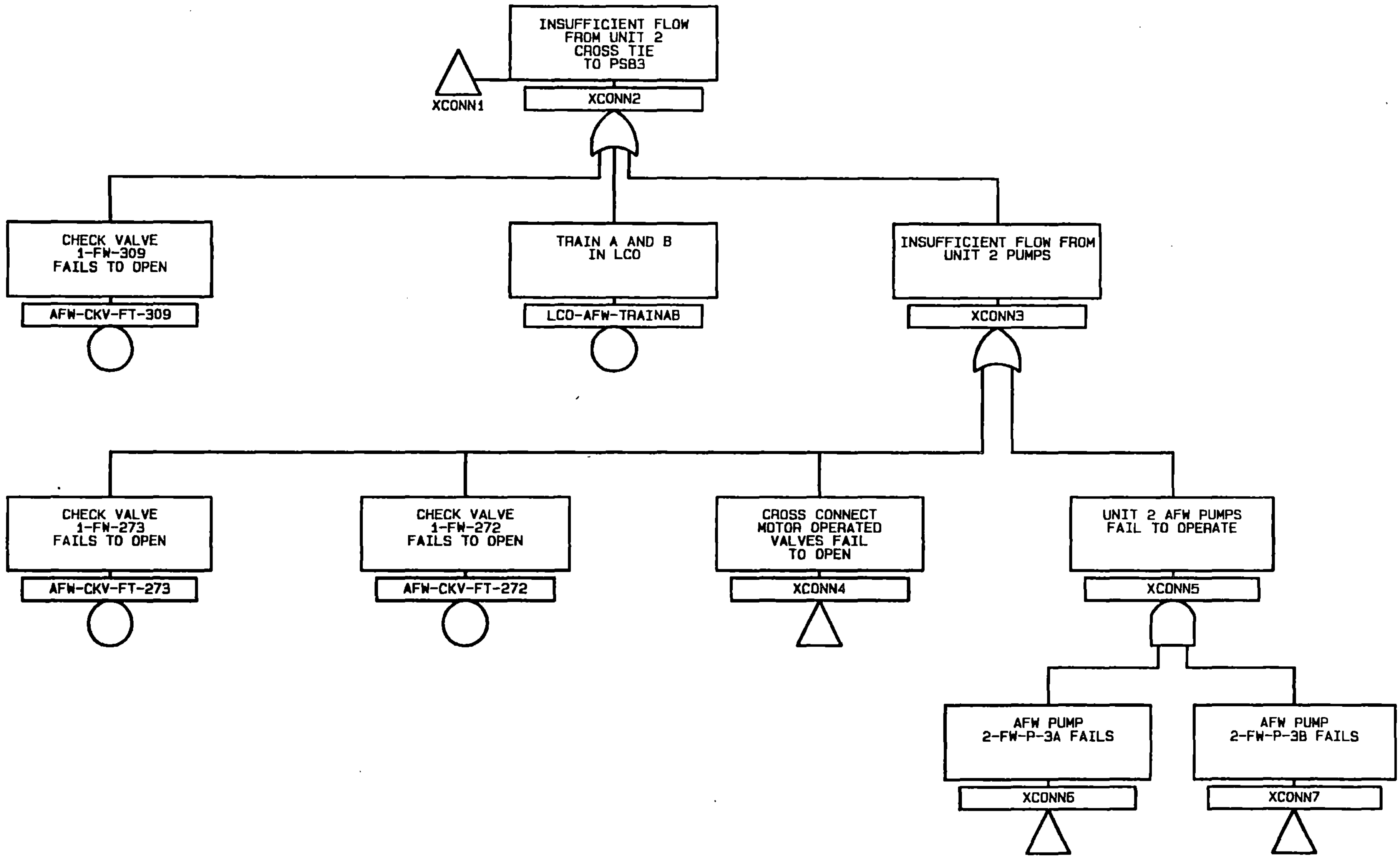

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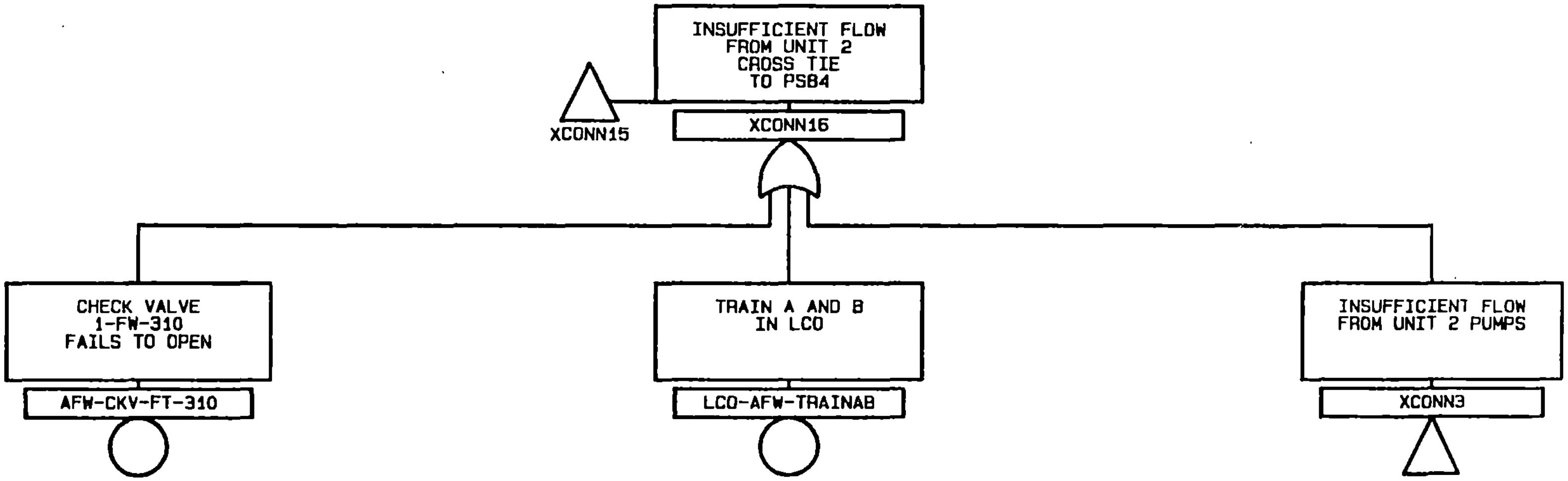

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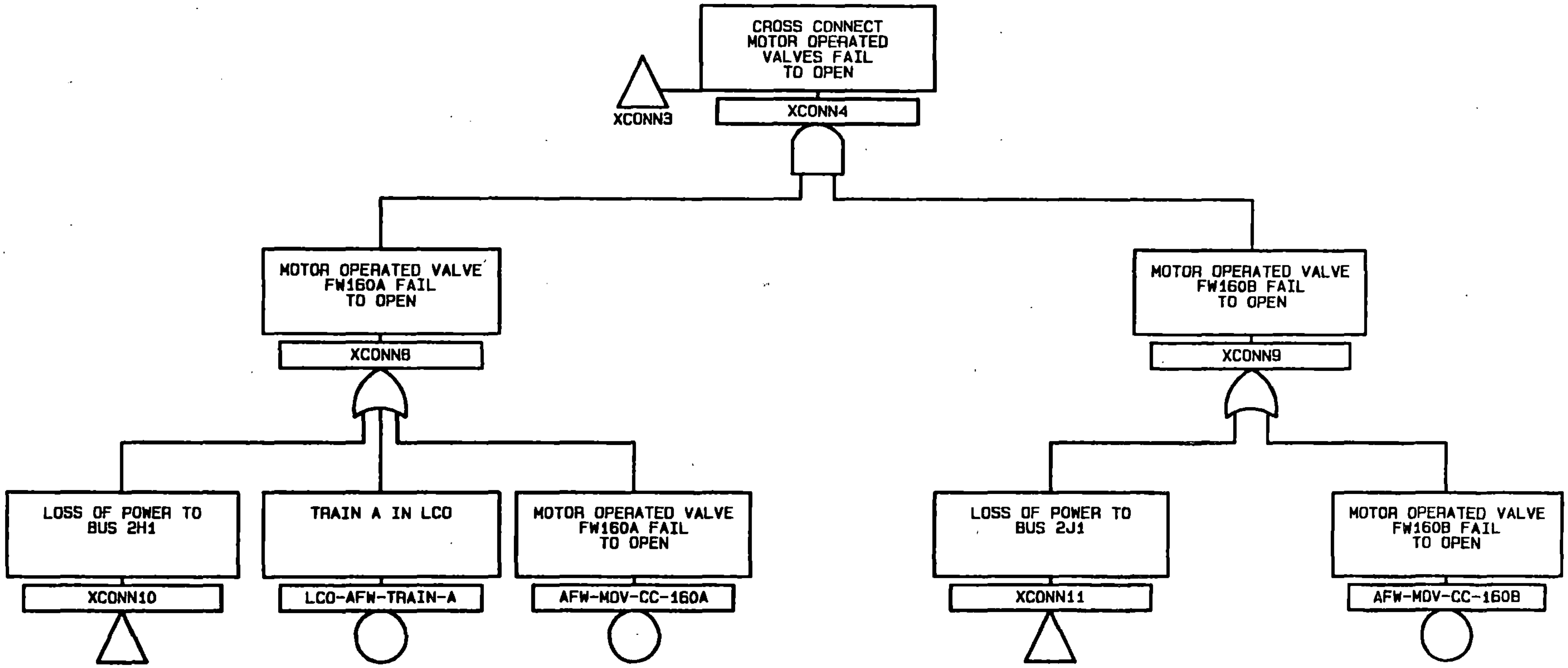

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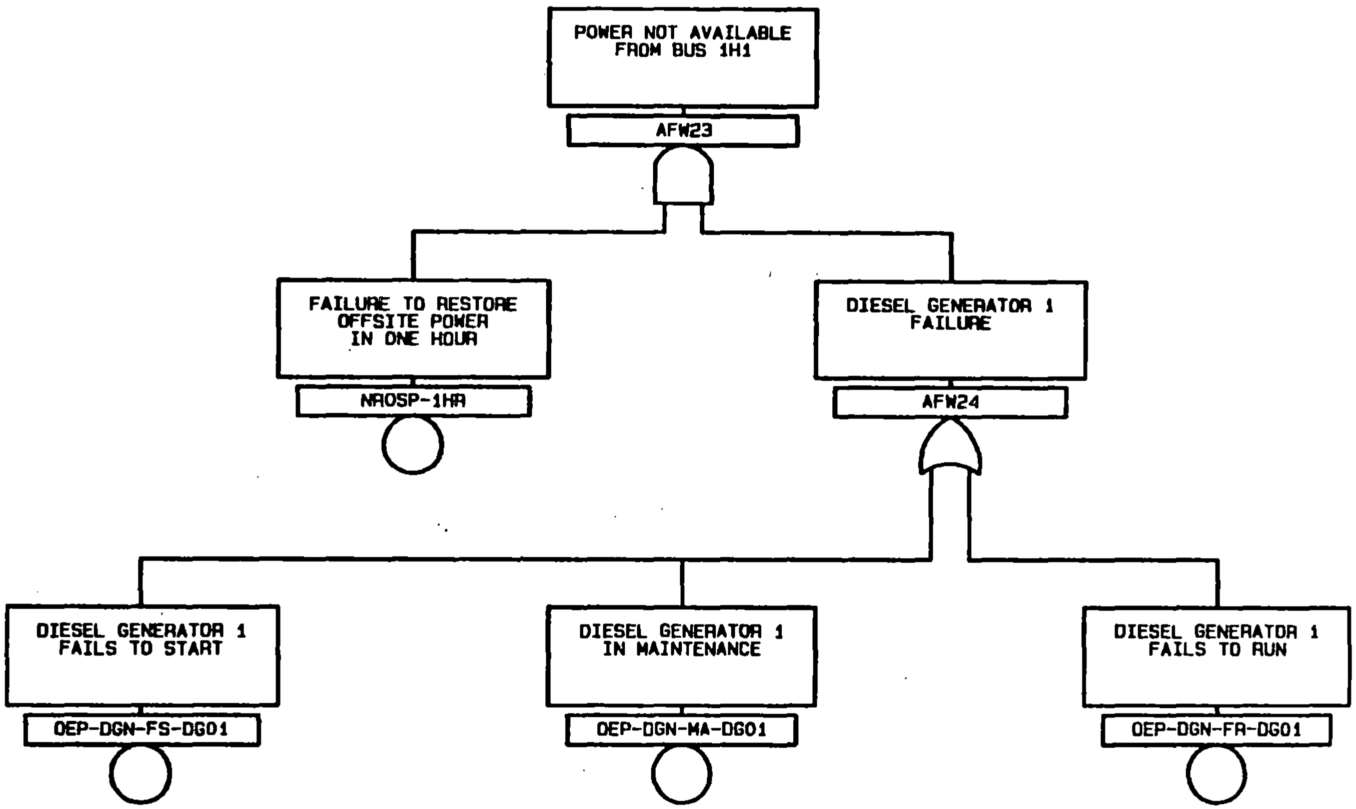

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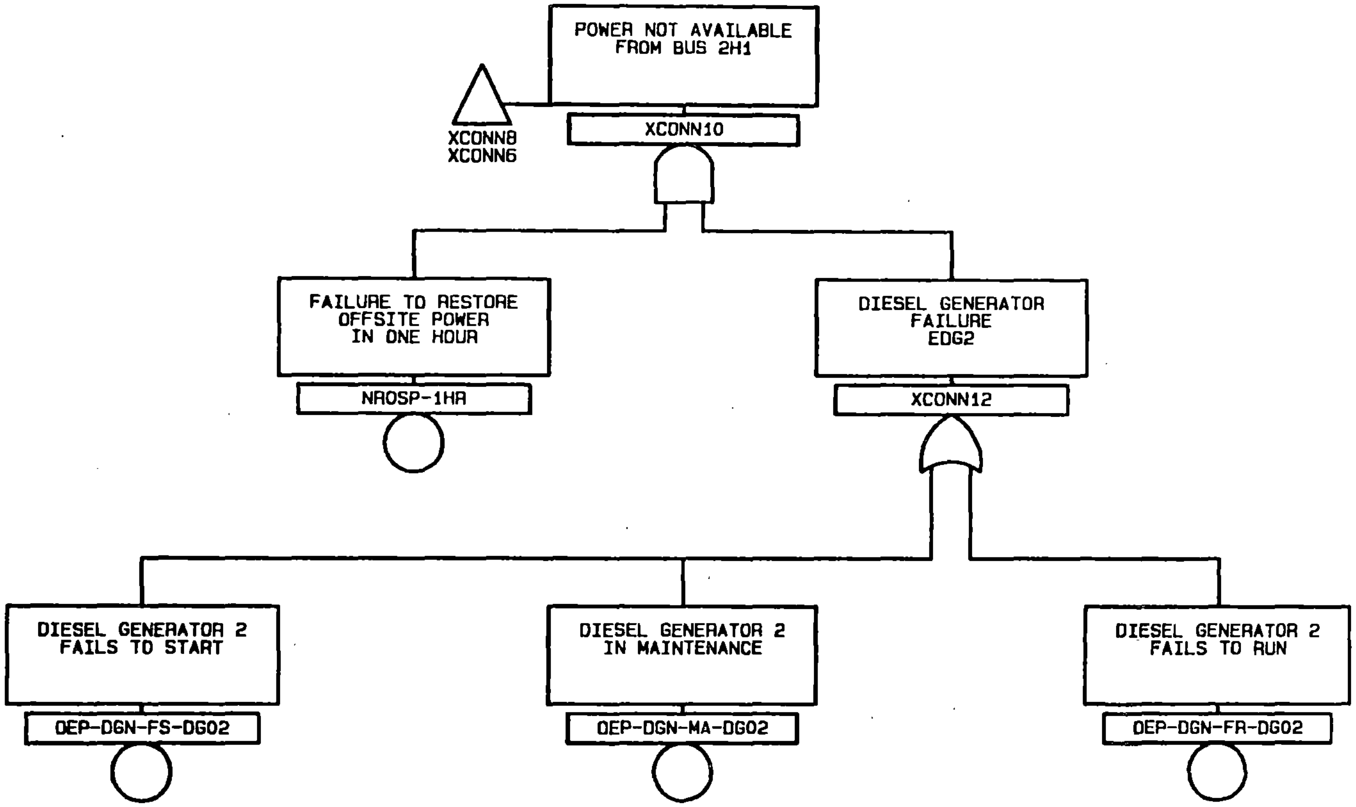

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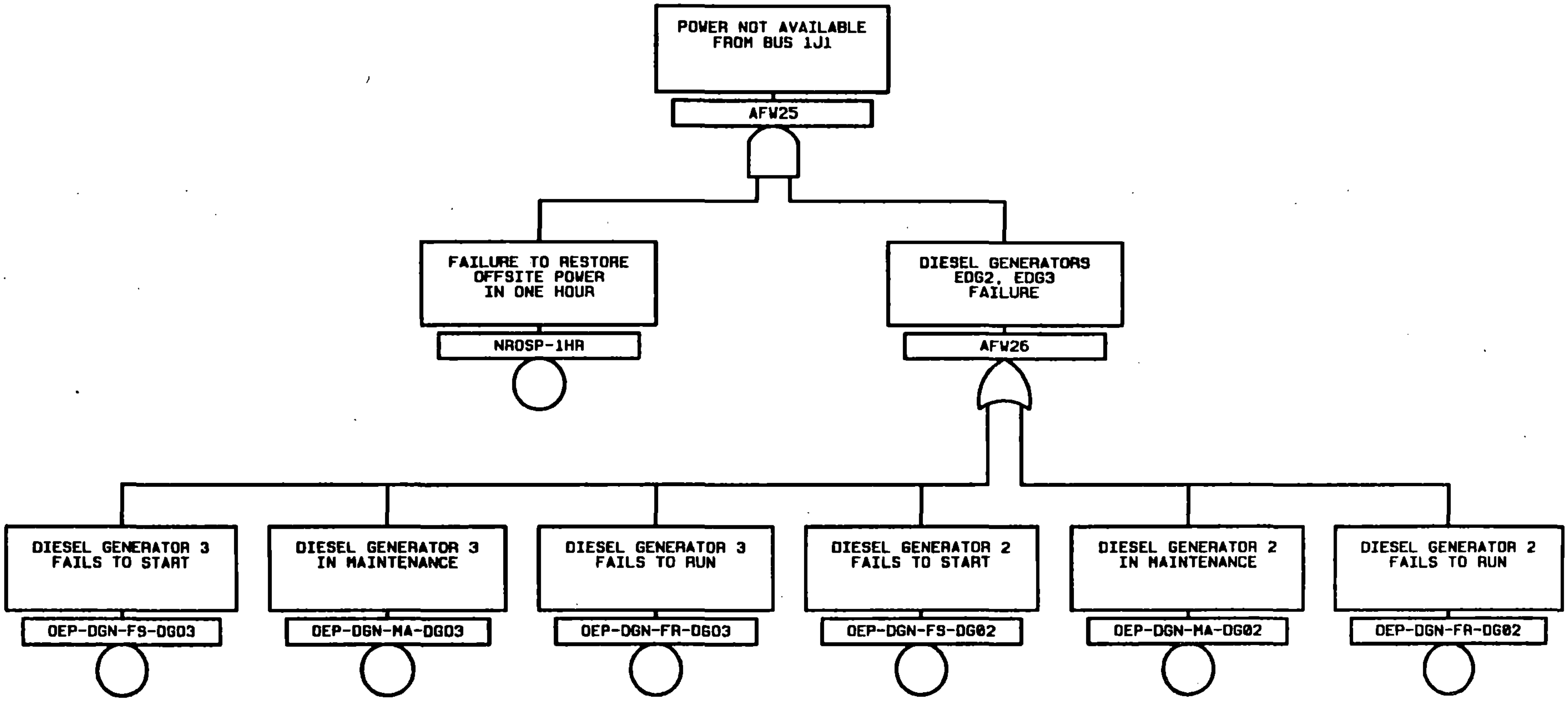

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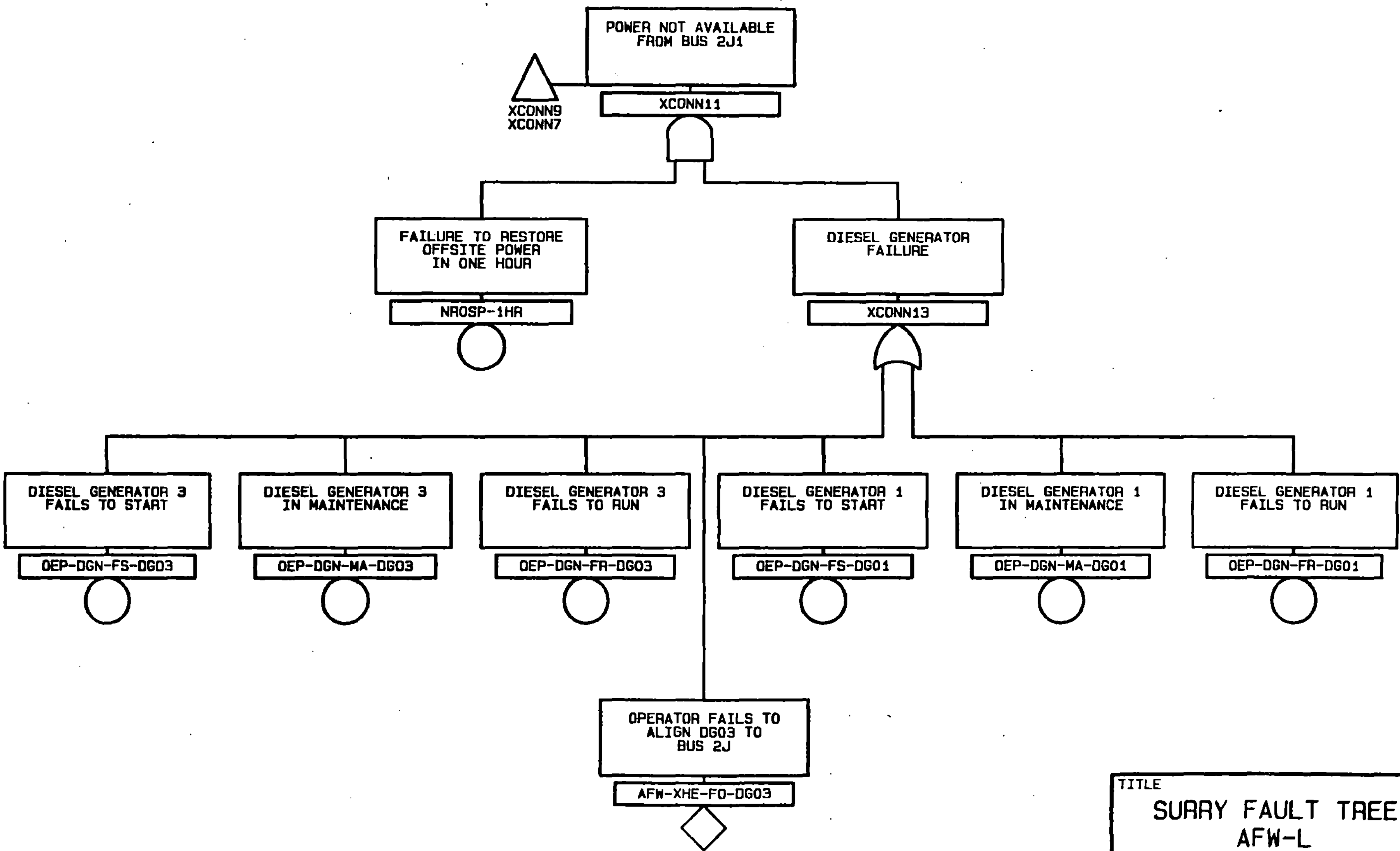

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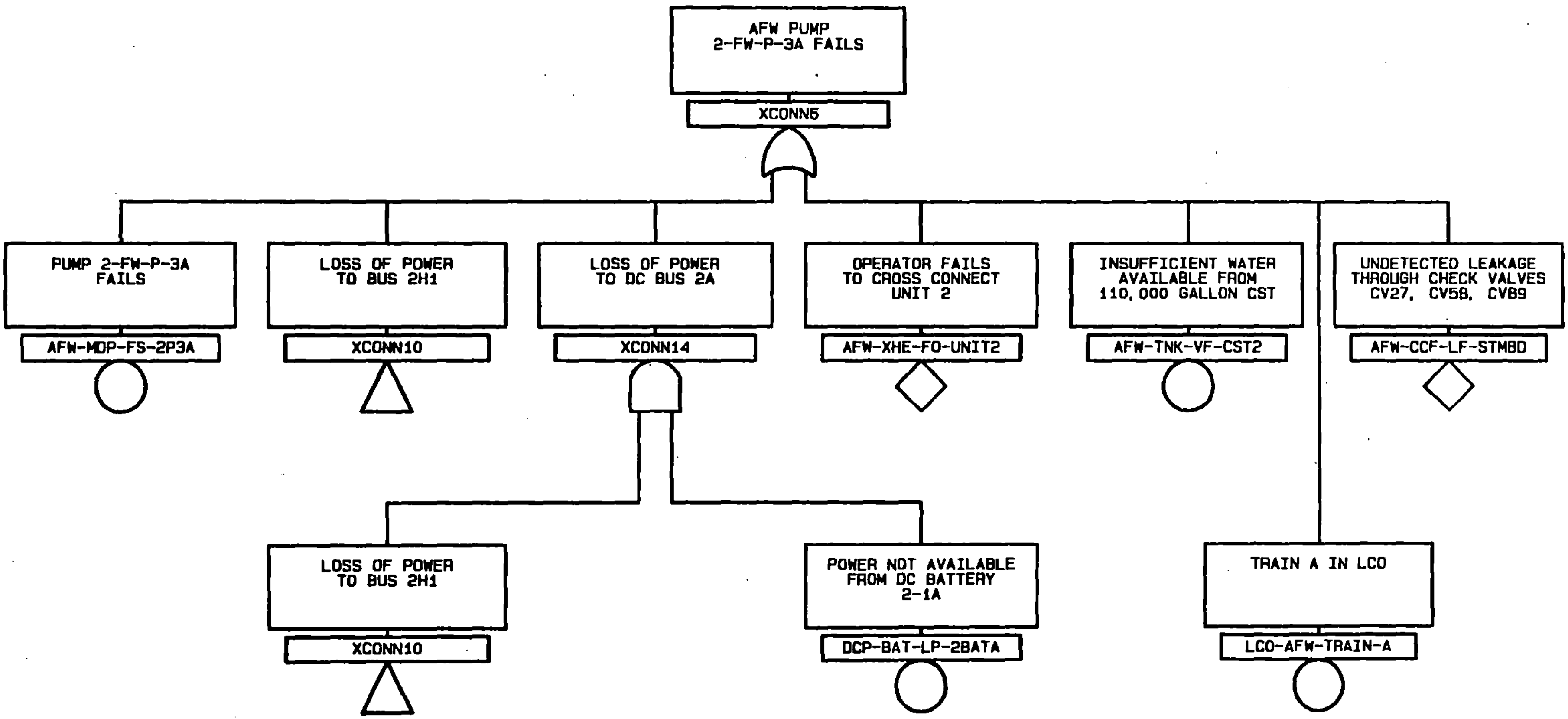

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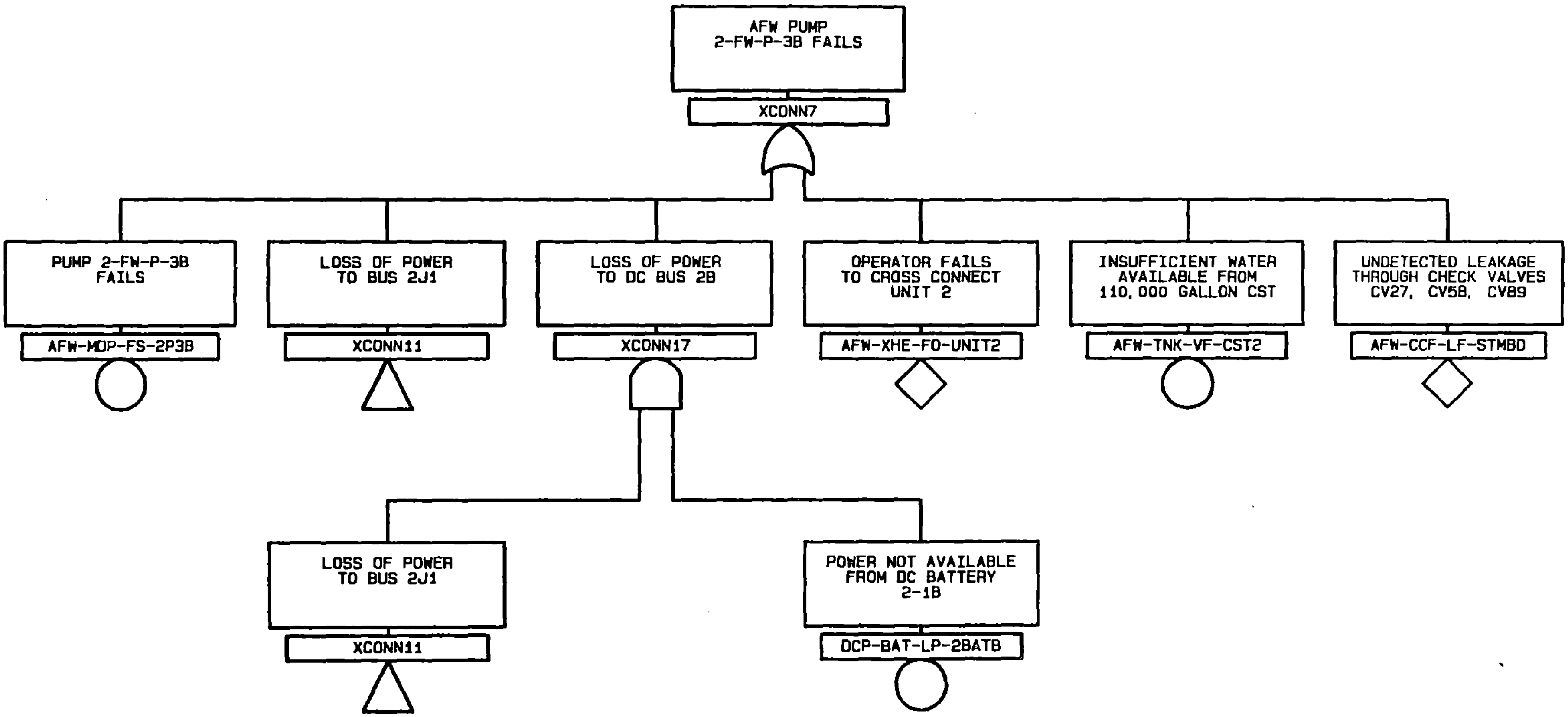

TITLE
SURRY FAULT TREE
AFW-L

DRAWING NUMBER
SHEET 16/19

CALC NUMBER
1250-054-C002

REV
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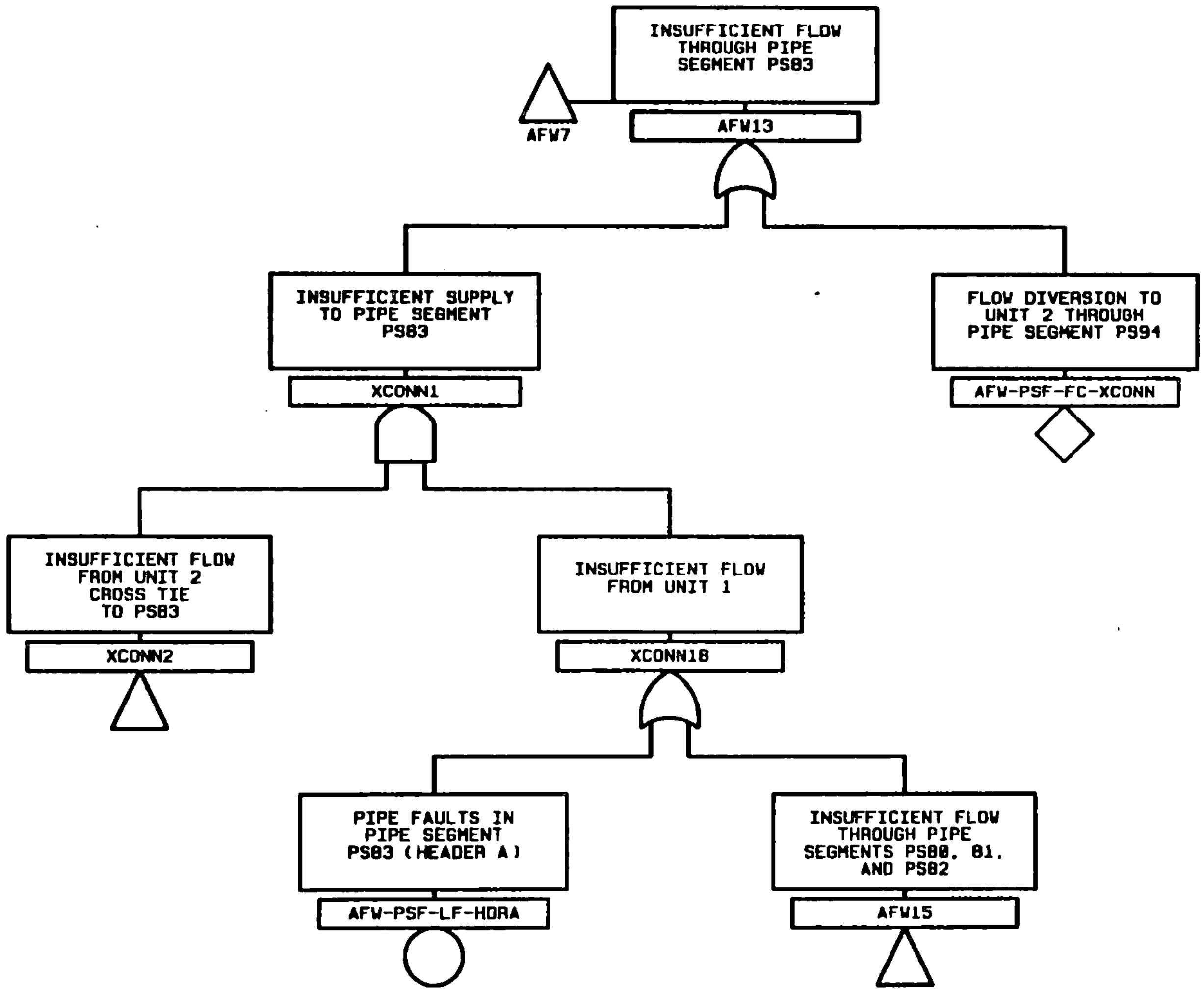
NOTE: THIS IS THE MODIFIED FAULT TREE TO ACCOUNT FOR THE CROSS TIE CAPABILITY BETWEEN SURRY UNITS



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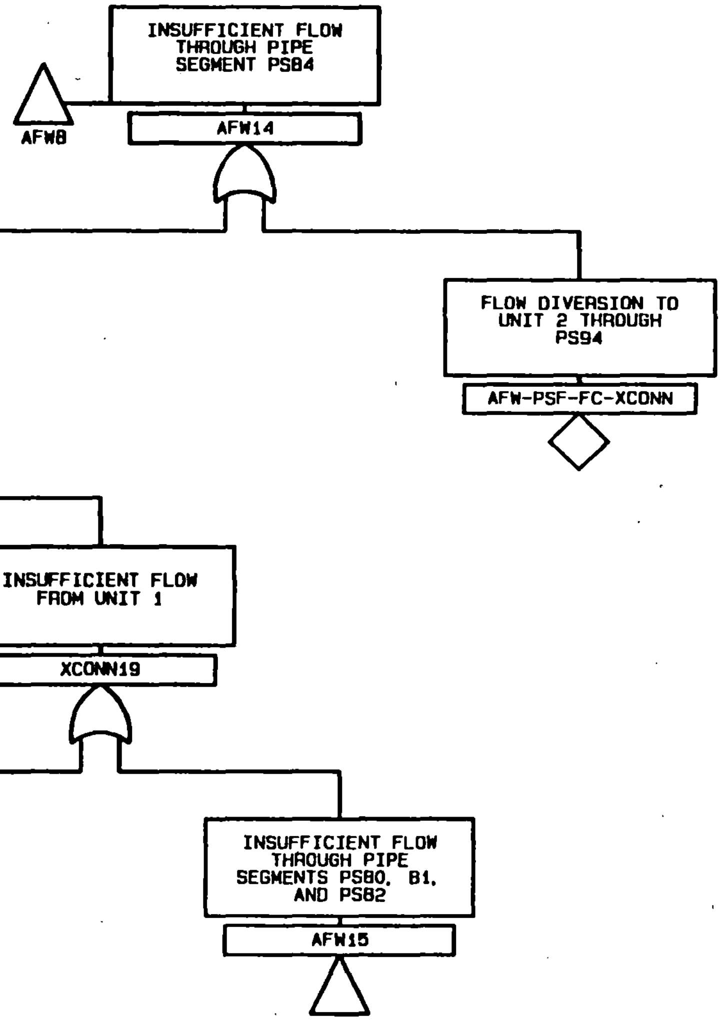
NOTE: THIS IS THE MODIFIED FAULT TREE TO ACCOUNT FOR THE CROSS TIE CAPABILITY BETWEEN SURRY UNITS



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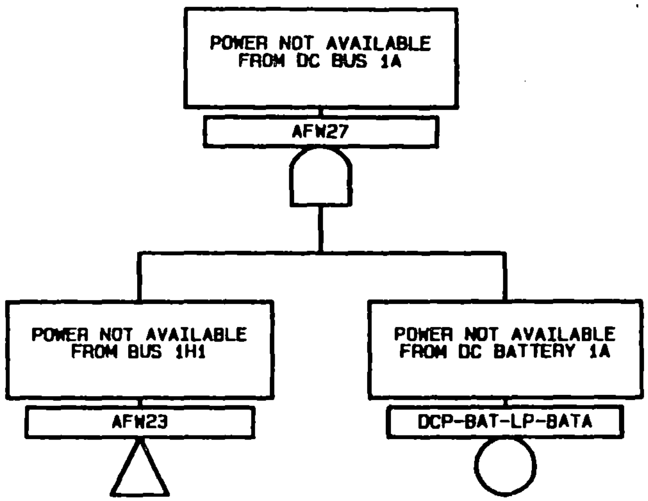

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APPENDIX B

MAJOR CUTSETS AND FAILURE RATES

This appendix presents the major minimal cutsets for the following analysis cases:

- Case 1 - AFW system without transient failures. This case was used to compare the system reliability results with the NUREG/CR 4550 results as a bench mark test case.

- Case 2 - AFW with LOSP, no credit for cross connect capability.

- Case 3 - AFW with LOSP, credit for cross connect capability, no extended LCO requirements.

- Case 4 - AFW with HELB, no extended LCO requirements on AFW cross connect train.

- Case 5 - AFW with HELB, 14 day LCO requirements on AFW cross connect train.

- Case 6 - AFW with HELB, 21 day LCO requirements on AFW cross connect train.

- Case 7 - AFW with HELB, 30 day LCO requirements on AFW cross connect train.

MAJOR MINIMAL CUT SETS FOR CASE 1

AFW SYSTEM WITHOUT TRANSIENT FAILURES

*** Min Cut Upper Bound = = = 2.34E-004

FAIL PROB CUTSET

1.30E-004 AFW-PSF-FC-XCONN

1.00E-004 AFW-CCF-LF-STMBD

2.24E-006 AFW-PSF-LF-PTR3A AFW-PSF-LF-PTR3B
AFW-PSF-LF-PTRN2

1.30E-006 AFW-TNK-VF-CST

1.66E-007 AFW-ACT-FA-PMP3A AFW-PSF-LF-PTR3B
AFW-PSF-LF-PTRN2

1.66E-007 AFW-ACT-FA-PMP3B AFW-PSF-LF-PTR3A
AFW-PSF-LF-PTRN2

FAILURE RATES

COMPONENT ID	FAILURE RATE	DESCRIPTION
AFW-ACT-FA-PMP3A	6.30E-004	Auto Initiation of Pump 3A fails
AFW-ACT-FA-PMP3B	6.30E-004	Auto Initiation of Pump 3B fails
AFW-CCF-LF-STMBD	1.00E-004	Leakage thru check vlvs 27, 58, 89
AFW-PSF-FC-XCONN	1.30E-004	Flow diversion to Unit 2
AFW-PSF-LF-PTR3A	8.50E-003	Faults in Pump Train 3A
AFW-PSF-LF-PTR3B	8.50E-003	Faults in Pump Train 3B
AFW-PSF-LF-PTRN2	3.10E-002	Faults in Turbine Pump Unit 1
AFW-TNK-VF-CST	1.30E-006	Insuff. water in CST

MINIMAL CUT SETS FOR CASE 2

AFW WITH LOSP, NO CROSS-CONNECT

*** Min Cut Upper Bound = = = 2.58E-004

FAIL PROB CUTSET

1.30E-004 AFW-PSF-FC-XCONN

1.00E-004 AFW-CCF-LF-STMBD

2.24E-006 AFW-PSF-LF-PTR3A AFW-PSF-LF-PTR3B
AFW-PSF-LF-PTRN2

1.30E-006 AFW-TNK-VF-CST

FAILURE RATES

COMPONENT ID	FAILURE RATE	DESCRIPTION
AFW-CCF-LF-STMBD	1.00E-004	Leakage thru check vlvs 27, 58, 89
AFW-PSF-FC-XCONN	1.30E-004	Flow diversion to Unit 2
AFW-PSF-LF-PTR3A	8.50E-003	Faults in Pump Train 3A
AFW-PSF-LF-PTR3B	8.50E-003	Faults in Pump Train 3B
AFW-PSF-LF-PTRN2	3.10E-002	Faults in Turbine Pump Unit 1
AFW-TNK-VF-CST	1.30E-006	Insuff. water in CST

MINIMAL CUT SETS FOR CASE 3

AFW WITH LOSP, CROSS-CONNECT

*** Min Cut Upper Bound = = = 2.38E-004

FAIL PROB   CUTSET

1.30E-004 AFW-PSF-FC-XCONN

1.00E-004 AFW-CCF-LF-STMBD

1.16E-006 AFW-PSF-LF-PTRN2 NROSP-1HR

OEP-DGN-FS-DG01 OEP-DGN-FS-DG02

1.16E-006 AFW-PSF-LF-PTRN2 NROSP-1HR

OEP-DGN-FS-DG01 OEP-DGN-MA-DG02

1.16E-006 AFW-PSF-LF-PTRN2 NROSP-1HR

OEP-DGN-FS-DG02 OEP-DGN-MA-DG01

1.16E-006 AFW-PSF-LF-PTRN2 NROSP-1HR

OEP-DGN-MA-DG01 OEP-DGN-MA-DG02**

8.03E-007 AFW-PSF-LF-PTRN2 NROSP-1HR

OEP-DGN-FR-DG01 OEP-DGN-FS-DG02

8.03E-007 AFW-PSF-LF-PTRN2 NROSP-1HR

OEP-DGN-FR-DG01 OEP-DGN-MA-DG02

8.03E-007 AFW-PSF-LF-PTRN2 NROSP-1HR

OEP-DGN-FR-DG02 OEP-DGN-FS-DG01

8.03E-007 AFW-PSF-LF-PTRN2 NROSP-1HR

OEP-DGN-FR-DG02 OEP-DGN-MA-DG01

5.55E-007 AFW-PSF-LF-PTRN2 NROSP-1HR

OEP-DGN-FR-DG01 OEP-DGN-FR-DG02

** This cutset places the unit in a more restrictive LCO action statement.

FAILURE RATES

COMPONENT ID	FAILURE RATE	DESCRIPTION
AFW-CCF-LF-STMBD	1.00E-004	Leakage thru check vlvs 27, 58, 89
AFW-PSF-FC-XCONN	1.30E-004	Flow diversion to Unit 2
AFW-PSF-LF-PTRN2	3.10E-002	Faults in Turbine Pump Unit 1
NROSP-1HR	3.10E-001	Failure to restore offsite power
OEP-DGN-FR-DG01	7.60E-003	DG 01 fails to run
OEP-DGN-FR-DG02	7.60E-003	DG 02 fails to run
OEP-DGN-FS-DG01	1.10E-002	DG 01 fails to start
OEP-DGN-FS-DG02	1.10E-002	DG 02 fails to start
OEP-DGN-MA-DG01	1.10E-002	DG 01 in maintenance
OEP-DGN-MA-DG02	1.10E-002	DG 02 in maintenance

MINIMAL CUT SETS FOR CASE 4

AFW WITH HELB, CROSS-CONNECT

*** Min Cut Upper Bound = = = 4.45E-003

FAIL PROB CUTSET

4.00E-003 AFW-PSF-LF-PTR3A AFW-PSF-LF-PTR3B
AFW-PSF-LF-PTRN2 AFW-XHE-FO-UNIT2

1.30E-004 AFW-CKV-FT-272 AFW-PSF-LF-PTR3A
AFW-PSF-LF-PTR3B AFW-PSF-LF-PTRN2

1.30E-004 AFW-CKV-FT-273 AFW-PSF-LF-PTR3A
AFW-PSF-LF-PTR3B AFW-PSF-LF-PTRN2

1.00E-004 AFW-CCF-LF-STMBD

7.22E-005 AFW-MDP-FS-2P3A AFW-MDP-FS-2P3B
AFW-PSF-LF-PTR3A AFW-PSF-LF-PTR3B
AFW-PSF-LF-PTRN2

1.44E-005 AFW-MOV-CC-160A AFW-MOV-CC-160B
AFW-PSF-LF-PTR3A AFW-PSF-LF-PTR3B
AFW-PSF-LF-PTRN2

FAILURE RATES

COMPONENT ID	FAILURE RATE	DESCRIPTION
AFW-CCF-LF-STMBD	1.00E-004	Leakage thru check vlvs 27, 58, 89
AFW-CKV-FT-272	1.30E-004	Check valve fails
AFW-CKV-FT-273	1.30E-004	Check valve fails
AFW-MDP-FS-2P3A	8.50E-003	Unit 2 pump 3A fails
AFW-MDP-FS-2P3B	8.50E-003	Unit 2 pump 3B fails
AFW-PSF-LF-PTR3A	1.00E+000	Faults in Pump Train 3A
AFW-PSF-LF-PTR3B	1.00E+000	Faults in Pump Train 3B
AFW-PSF-LF-PTRN2	1.00E+000	Faults in Turbine Pump Unit 1
AFW-XHE-FO-UNIT2	4.00E-003	Operator fails to cross connect

MINIMAL CUT SETS FOR CASE 5

AFW WITH HELB, 14 DAY AOT

*** Min Cut Upper Bound = = = 6.56E-003

FAIL PROB CUTSET

4.00E-003 AFW-PSF-LF-PTR3A AFW-PSF-LF-PTR3B
AFW-PSF-LF-PTRN2 AFW-XHE-FO-UNIT2

1.80E-003 AFW-PSF-LF-PTR3A AFW-PSF-LF-PTR3B
AFW-PSF-LF-PTRN2 LCO-AFW-TRAINAB

2.21E-004 AFW-MDP-FS-2P3B AFW-PSF-LF-PTR3A
AFW-PSF-LF-PTR3B AFW-PSF-LF-PTRN2
LCO-AFW-TRAIN-A

1.30E-004 AFW-CKV-FT-272 AFW-PSF-LF-PTR3A
AFW-PSF-LF-PTR3B AFW-PSF-LF-PTRN2

1.30E-004 AFW-CKV-FT-273 AFW-PSF-LF-PTR3A
AFW-PSF-LF-PTR3B AFW-PSF-LF-PTRN2

1.00E-004 AFW-CCF-LF-STMBD

9.88E-005 AFW-MOV-CC-160B AFW-PSF-LF-PTR3A
AFW-PSF-LF-PTR3B AFW-PSF-LF-PTRN2
LCO-AFW-TRAIN-A

7.22E-005 AFW-MDP-FS-2P3A AFW-MDP-FS-2P3B
AFW-PSF-LF-PTR3A AFW-PSF-LF-PTR3B
AFW-PSF-LF-PTRN2

FAIL PROB CUTSET

1.44E-005 AFW-MOV-CC-160A AFW-MOV-CC-160B
AFW-PSF-LF-PTR3A AFW-PSF-LF-PTR3B
AFW-PSF-LF-PTRN2

FAILURE RATES

COMPONENT ID	FAILURE RATE	DESCRIPTION
AFW-CCF-LF-STMBD	1.00E-004	Leakage thru check vlvs 27, 58, 89
AFW-CKV-FT-272	1.30E-004	Check valve fails
AFW-CKV-FT-273	1.30E-004	Check valve fails
AFW-MDP-FS-2P3A	8.50E-003	Unit 2 pump 3A fails
AFW-MDP-FS-2P3B	8.50E-003	Unit 2 pump 3B fails
AFW-MOV-CC-160A	3.80E-003	MOV fails closed
AFW-MOV-CC-160B	**3.80E-003**	**MOV fails closed**
AFW-PSF-LF-PTR3A	1.00E+000	Faults in Pump Train 3A
AFW-PSF-LF-PTR3B	1.00E+000	Faults in Pump Train 3B
AFW-PSF-LF-PTRN2	1.00E+000	Faults in Turbine Pump Unit 1
AFW-XHE-FO-UNIT2	4.00E-003	Operator fails to cross connect
LCO-AFW-TRAIN-A	2.60E-002	Train A in LCO
LCO-AFW-TRAINAB	1.80E-003	Train A and B in LCO

MINIMAL CUT SETS FOR CASE 6

AFW WITH HELB, 21 DAY AOT

*** Min Cut Upper Bound = = = 6.71E-003

FAIL PROB CUTSET

4.00E-003 AFW-PSF-LF-PTR3A AFW-PSF-LF-PTR3B
AFW-PSF-LF-PTRN2 AFW-XHE-FO-UNIT2

1.80E-003 AFW-PSF-LF-PTR3A AFW-PSF-LF-PTR3B
AFW-PSF-LF-PTRN2 LCO-AFW-TRAINAB

3.23E-004 AFW-MDP-FS-2P3B AFW-PSF-LF-PTR3A
AFW-PSF-LF-PTR3B AFW-PSF-LF-PTRN2
LCO-AFW-TRAIN-A

1.44E-004 AFW-MOV-CC-160B AFW-PSF-LF-PTR3A
AFW-PSF-LF-PTR3B AFW-PSF-LF-PTRN2
LCO-AFW-TRAIN-A

1.30E-004 AFW-CKV-FT-272 AFW-PSF-LF-PTR3A
AFW-PSF-LF-PTR3B AFW-PSF-LF-PTRN2

1.30E-004 AFW-CKV-FT-273 AFW-PSF-LF-PTR3A
AFW-PSF-LF-PTR3B AFW-PSF-LF-PTRN2

1.00E-004 AFW-CCF-LF-STMBD

7.22E-005 AFW-MDP-FS-2P3A AFW-MDP-FS-2P3B
AFW-PSF-LF-PTR3A AFW-PSF-LF-PTR3B
AFW-PSF-LF-PTRN2

FAIL PROB CUTSET

1.44E-005 AFW-MOV-CC-160A AFW-MOV-CC-160B
AFW-PSF-LF-PTR3A AFW-PSF-LF-PTR3B
AFW-PSF-LF-PTRN2

FAILURE RATES

COMPONENT ID	FAILURE RATE	DESCRIPTION
AFW-CCF-LF-STMBD	1.00E-004	Leakage thru check vlvs 27, 58, 89
AFW-CKV-FT-272	1.30E-004	Check valve fails
AFW-CKV-FT-273	1.30E-004	Check valve fails
AFW-MDP-FS-2P3A	8.50E-003	Unit 2 pump 3A fails
AFW-MDP-FS-2P3B	8.50E-003	Unit 2 pump 3B fails
AFW-MOV-CC-160A	3.80E-003	MOV fails closed
AFW-MOV-CC-160B	3.80E-003	MOV fails closed
AFW-PSF-LF-PTR3A	1.00E+000	Faults in Pump Train 3A
AFW-PSF-LF-PTR3B	1.00E+000	Faults in Pump Train 3B
AFW-PSF-LF-PTRN2	1.00E+000	Faults in Turbine Pump Unit 1
AFW-XHE-FO-UNIT2	4.00E-003	Operator fails to cross connect
LCO-AFW-TRAIN-A	3.80E-002	Train A in LCO
LCO-AFW-TRAINAB	1.80E-003	Train A and B in LCO

MINIMAL CUT SETS FOR CASE 7

AFW WITH HELB, 30 DAY AOT

*** Min Cut Upper Bound = = = 6.91E-003

FAIL PROB CUTSET

4.00E-003 AFW-PSF-LF-PTR3A AFW-PSF-LF-PTR3B
AFW-PSF-LF-PTRN2 AFW-XHE-FO-UNIT2

1.80E-003 AFW-PSF-LF-PTR3A AFW-PSF-LF-PTR3B
AFW-PSF-LF-PTRN2 LCO-AFW-TRAINAB

4.59E-004 AFW-MDP-FS-2P3B AFW-PSF-LF-PTR3A
AFW-PSF-LF-PTR3B AFW-PSF-LF-PTRN2
LCO-AFW-TRAIN-A

2.05E-004 AFW-MOV-CC-160B AFW-PSF-LF-PTR3A
AFW-PSF-LF-PTR3B AFW-PSF-LF-PTRN2
LCO-AFW-TRAIN-A

1.30E-004 AFW-CKV-FT-272 AFW-PSF-LF-PTR3A
AFW-PSF-LF-PTR3B AFW-PSF-LF-PTRN2

1.30E-004 AFW-CKV-FT-273 AFW-PSF-LF-PTR3A
AFW-PSF-LF-PTR3B AFW-PSF-LF-PTRN2

1.00E-004 AFW-CCF-LF-STMBD

7.22E-005 AFW-MDP-FS-2P3A AFW-MDP-FS-2P3B
AFW-PSF-LF-PTR3A AFW-PSF-LF-PTR3B
AFW-PSF-LF-PTRN2

FAIL PROB CUTSET

1.44E-005 AFW-MOV-CC-160A AFW-MOV-CC-160B
AFW-PSF-LF-PTR3A AFW-PSF-LF-PTR3B
AFW-PSF-LF-PTRN2

FAILURE RATES

COMPONENT ID	FAILURE RATE	DESCRIPTION
AFW-CCF-LF-STMBD	1.00E-004	Leakage thru check vlvs 27, 58, 89
AFW-CKV-FT-272	1.30E-004	Check valve fails
AFW-CKV-FT-273	1.30E-004	Check valve fails
AFW-MDP-FS-2P3A	8.50E-003	Unit 2 pump 3A fails
AFW-MDP-FS-2P3B	8.50E-003	Unit 2 pump 3B fails
AFW-MOV-CC-160A	3.80E-003	MOV fails closed
AFW-MOV-CC-160B	3.80E-003	MOV fails closed
AFW-PSF-LF-PTR3A	1.00E+000	Faults in Pump Train 3A
AFW-PSF-LF-PTR3B	1.00E+000	Faults in Pump Train 3B
AFW-PSF-LF-PTRN2	1.00E+000	Faults in Turbine Pump Unit 1
AFW-XHE-FO-UNIT2	4.00E-003	Operator fails to cross connect
LCO-AFW-TRAIN-A	5.40E-002	Train A in LCO
LCO-AFW-TRAINAB	1.80E-003	Train A and B in LCO