Battelle Columbus

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PNL

BROWNS FERRY 3 SYSTEMS INTERACTION EXAMPLE

Figures & Tables — Pages

Figures & Tables | Pages

QUALITATIVE SYSTEMS INTERACTION EVALUATION

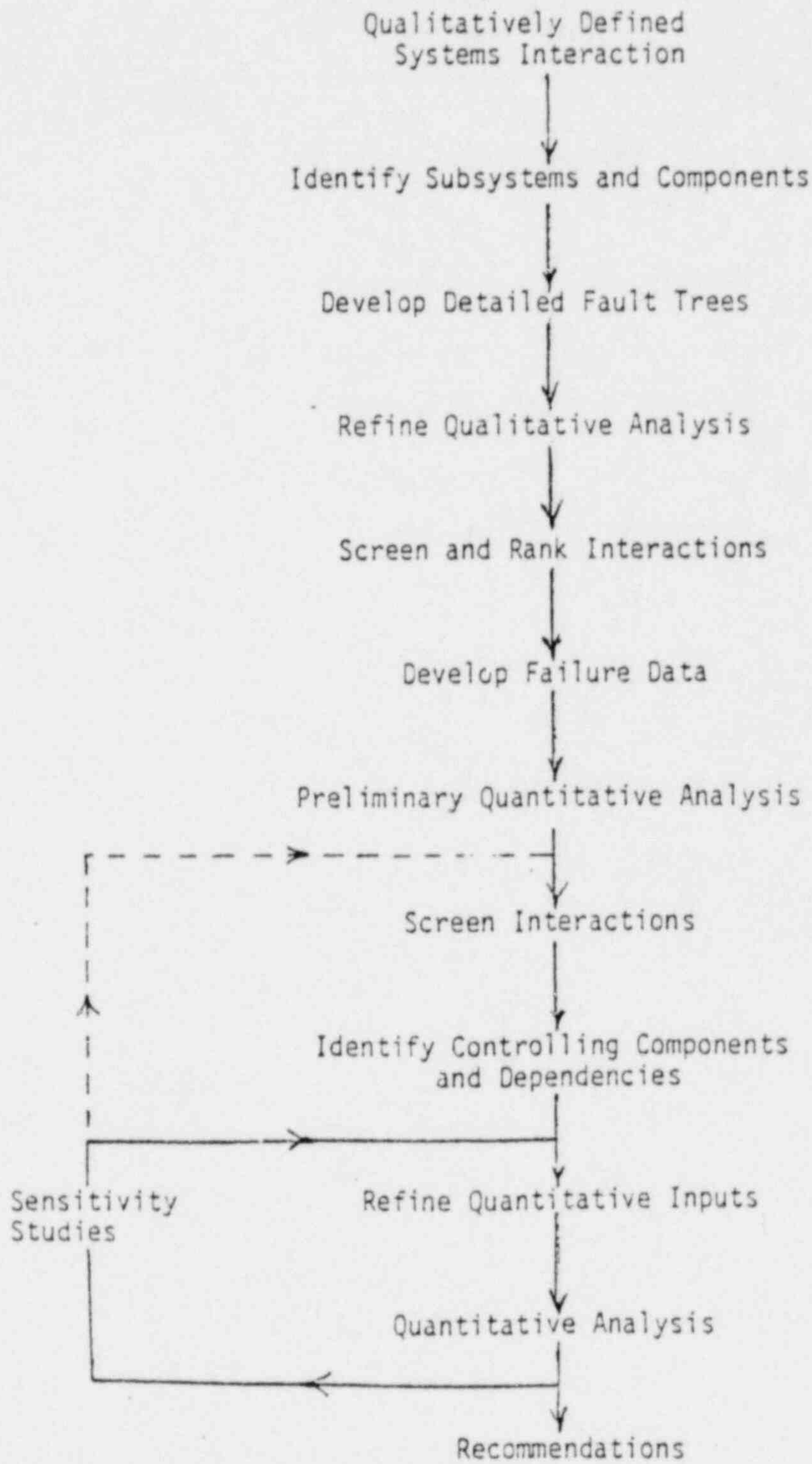


FIGURE 1

QUANTITATIVE SYSTEMS INTERACTION EVALUATION

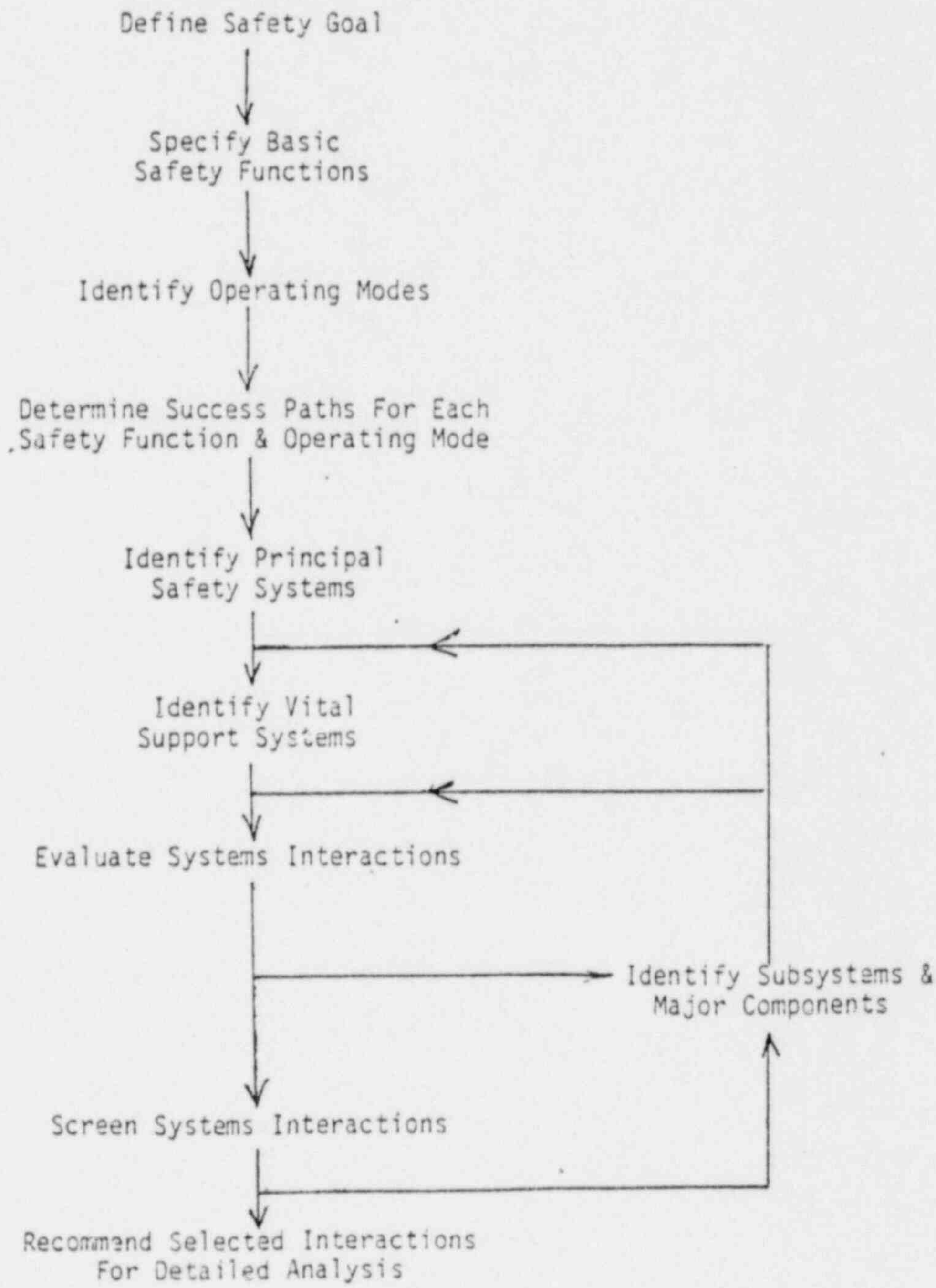


FIGURE 2

SYSTEMS ANALYSIS - SUCCESS TREE APPROACH

- For each safety function during a specific plant mode:

    - Determine system success paths
    - Identify subsystems & major components
    - Define support systems, subsystems, & major components
    - Determine systems interactions that are possible through:

        - Sequential operation of systems, subsystems, or components
        - Sharing of a subsystem or component by two or more systems
        - Support systems, subsystems, or components common to two or more systems
        - Common links among subsystems or components in two or more systems

TABLE 1

REGULATORY REVIEW OF COMMON LINKING CHARACTERISTICS

Common Links	Review Element
• Physical • Electrical • Mechanical • Hydraulic • Pneumatic	Systems Analysis
• Spatial • Thermal • Fluid • Mechanical • Radiation	Plant Walk-Through
• Inherent • Common Manufacturer • Similar Technology • Equal Aging or Wear • Shared Components	Systems Analysis
• Human • Dynamic • Latent	Review of Plant Procedures & Technical Specifications

TABLE 2

SAFETY FUNCTIONS

Safety Function	Purpose
• Reactor Control ✓	Maintain desired power level and shutdown reactor when required.
• Reactor Coolant System Inventory Control	Maintain a suitable coolant medium around the core.
• Reactor Coolant System Pressure Control	Maintain the coolant in the proper state.
• Core Heat Removal	Transfer heat from the core to the coolant.
• Reactor Coolant System Heat Removal	Remove heat from the primary system.
• Containment Isolation	Maintain containment integrity to prevent radiation releases.
• Containment Temperature and Pressure Control	Avoid potential damage to containment and vital equipment.
• Combustible Gas Control	Remove and/or redistribute hydrogen to avoid potentially damaging reactions.
• Maintenance of Vital Auxiliaries	Maintain operability of systems needed to support safety systems.
• Indirect Radioactivity Release Control	Contain miscellaneous stored radioactivity to protect the public and the environment.

✓ Applicable to Browns Ferry 3 Incident

TABLE 3

PLANT MODES

- Startup
- Power Operation*
- Hot Standby
- Hot Shutdown*
- Cold Shutdown
- Refueling

*Applicable to Browns Ferry 3 Incident.
(Transition from Power Operation to Hot Shutdown)

TABLE 4

SUCCESS PATH WITH REQUIRED SYSTEMS & MAJOR COMPONENTS FOR REACTOR CONTROL DURING TRANSITION FROM POWER OPERATION TO HOT SHUTDOWN

Path #	Systems	Major Components
1	Control Rod Scram (High Pressure)	183/185 Hydraulic Control Units, each requiring: 1/1 Diaphragm-Operated Scram Inlet Valve 1/1 Diaphragm-Operated Scram Exhaust Valve 1/1 Ball-Check (Shuttle) Valve 2/2 Three-way Solenoid Scram Pilot Valves or 2/2 Pairs of Three-way Solenoid Backup Scram Pilot Valves (1/2 required per pair) 2/2 Pairs of Scram Discharge Volumes & Diaphragm-Operated SDV Vent Valves 1/1 Scram Instrument Volume 1/1 Diaphragm-Operated SIV Drain Valve
2	Standby Liquid Control	1/1 Tank 1/2 Positive-Displacement Pumps 1/2 Explosive Valves
	Reactor Water Cleanup (Isolation only)	1/2 Motor-Operated Isolation Valves

TABLE 5

CONTROL ROD SCRAM SYSTEM SCHEMATIC

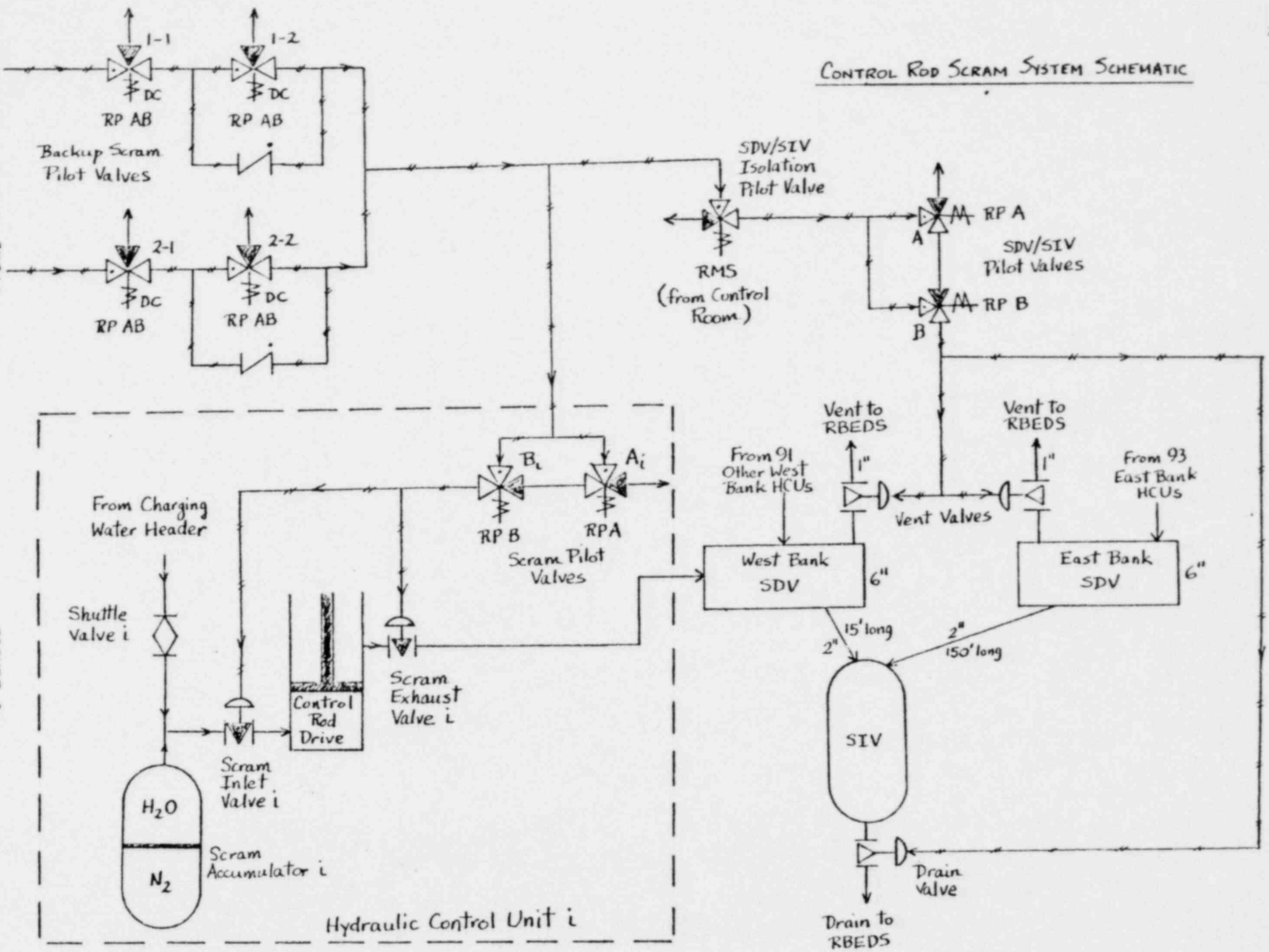
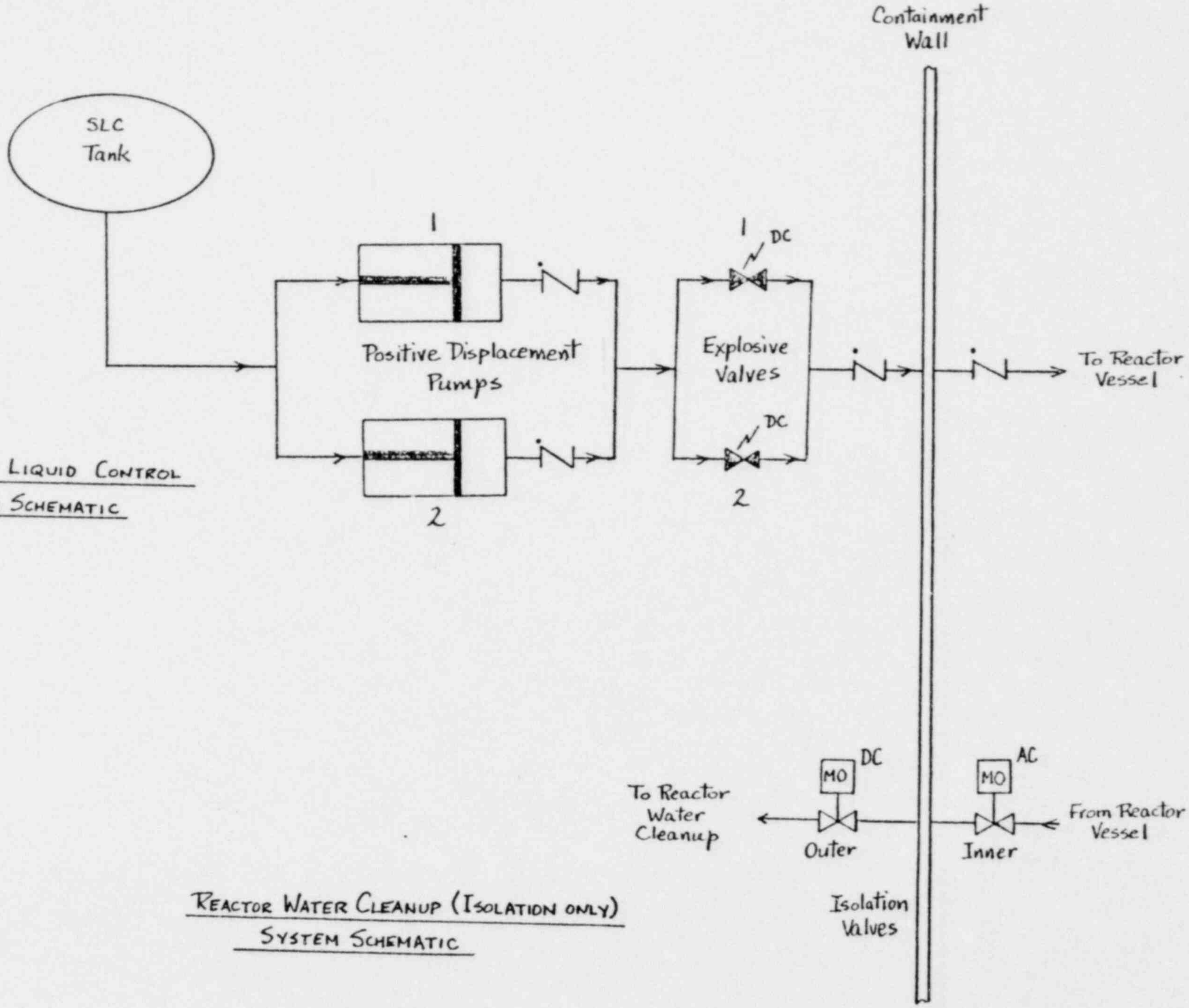


FIGURE 3



STANDBY LIQUID CONTROL SYSTEM SCHEMATIC

REACTOR WATER CLEANUP (ISOLATION ONLY) SYSTEM SCHEMATIC

FIGURE 4

TABLE 6

SYSTEM	MAJOR COMPONENTS	LOCATION BLDG.	LOCATION ELEV.	LOCATION COORD.	MAIN SUPPORTS	
Standby Liquid Control	Standby Liquid Control Tank	Unit 3 Reactor Bldg.	639	$QP/R_{19}R_{20}$	None	
	Positive-Displacement Pump 1				AC Power from 480v AC Shutdown Board 3A	
	Positive Displacement Pump 2				AC Power from 480 v AC Shutdown Board 3B	
	Explosive Valve 1					
	Explosive Valve 2				DC Power from 250v DC Battery Boards 2 or 3	
Reactor Water Cleanup (Isolation Only)	DC Motor-Operated Isolation Valve (Outside drywell)					
	AC Motor-Operated Isolation Valve (inside drywell)		Inside Drywell		AC Power from 480 v AC Reactor MOV Board 3A	
Control Rod Scram (High Pressure)	185 Control Rods & Drives				185 Hydraulic Control Units (HUCs)	
	185 HCUs (93-East Bank 92-West Bank)		565	SQ/ $R_{15}R_{16}$(West) $R_{20}R_{21}$(East)	See individual components	
For each HCU	Diaphragm-Operated Scram Inlet Valve i				Three-way Solenoid Scram Pilot Valves A & B	Control Air (open upon loss)
For each HCU	Diaphragm-Operated Scram Exhaust Valve i					
For each HCU	Three-way Solenoid Scram Pilot Valve A				RP Trip-Logic Channel A	
For each HCU	Three-way Solenois Scram Pilot Valve B				RP Trip-Logic Channel B	

TABLE 6 (cont.)

SYSTEM		MAJOR COMPONENTS	LOCATION BLDG.	ELEV.	COORD.	MAIN SUPPORTS	
Control Rod Scram (High Pressure)	For ea. HCU	Ball-Check Shuttle Valve i	Unit 3 Reactor Bldg.	Inside Drywell		None	
		Three-way Solenoid Backup Scram Pilot Valve 1-1				RP Close-Logic Channels A & B	DC Power from 250v DC Battery Boards 1, 2, or 3
		Three-way Solenoid Backup Scram Pilot Valve 1-2					
		Three-way Solenoid Backup Scram Pilot Valve 2-1					
		Three-way Solenoid Backup Scram Pilot Vavle 2-2					
		West Bank Scram Discharge Volume (SDV)				Ventilation through Reactor Bldg. Equipment Drain Sump (RBEDS)	
		East Bank SDV					
		Scram Instrument Volume (SIV)				None	
		2" Drain Line from West Bank SDV to SIV (15' long)					
		2" Drain Line from East Bank SDV to SIV (150' long)					
		Drain Line from SIV to RBEDS					
		1" Vent Line from West Bank SDV to RBEDS					

TABLE 6 (cont.)

SYSTEM	MAJOR COMPONENTS	LOCATION BLDG.	ELEV.	COORD.	MAIN SUPPORTS	
Control Rod Scram (High Pressure)	1" Vent Line from East Bank SDV to RBEDS	Unit 3 Reactor Bldg.			None	
	Diaphragm-Operated West Bank SDV Vent Valve				Three-way Solenoid SDV/SIV Pilot Valves A & B or Three-way Solenoid SDV/SIV Isolation Pilot Valve	Control Air -lose upon loss)
	Diaphragm-Operated East Bank SDV Vent Valve					
	Diaphragm-Operated SIV Drain Valve					
	Three-way Solenoid SDV/SIV Pilot Valve A				RP Trip-Logic Channel A	
	Three-way Solenoid SDV/SIV Pilot Valve B				RP Trip-Logic Channel B	
	Three-way Solenoid SDV/SIV Isolation Pilot Valve				Remote Manual Signal from Control Room	
Reactor Protection	Trip-Logic Channel A				Fail-safe upon loss of AC power	
	Trip-Logic Channel B					
	Close-Logic Channel A					
	Close-Logic Channel B					
Reactor Building Equipment Drain Sump (Ventilation only)	RBEDS Exhaust Fan 1	Unit 3 Reactor Bldg.			AC Power from 480v AC Reactor Bldg. Vent Board 3A.	
	RBEDS Exhaust Fan 2				AC Power from 480v AC Reactor Bldg. Vent Board 3B	
Control Air	Air Compressor A	Turbine Bldg.	565	MJ/T_1T_2	AC Power from 480v AC Shutdown Board 1A	
	Air Compressor B				AC Power from 480v AC Shutdown Board 2A	
	Air Compressor C				AC Power from 480v AC Common Board 1	

TABLE 6 (cont.)

SYSTEM	MAJOR COMPONENTS	LOCATION BLDG.	LOCATION ELEV.	LOCATION COORD.	MAIN SUPPORTS	
Control Air	Air Compressor D	Turbine Bldg	565	MJ/T_1T_2	AC Power from 480v AC Common Board 2	
250v DC	250v DC Battery Board 1	Unit 1 Reac. Bldg.	593	$PN/R_{3.5}R_4$	DC Power from 250v DC Battery 1	or Battery Chargers 1, 2, 3 or Spare
	250v DC Battery Board 2	Unit 2 Reac. Bldg.		$PN/R_{9.5}R_{10}$	DC Power from 250v DC Battery 2	or Battery Chargers 1, 2, 3 or Spare
	250v DC Battery Board 3	Unit 3 Reac. Bldg.		$PN/R_{18}R_{18.5}$	DC Power from 250v DC Battery 3	or Battery Chargers 1, 2, 3 or Spare
	250v DC Battery Charger 1				AC Power from 480v AC Shutdown Board 1A	or Common Board 1
	250v DC Battery Charger 2				AC Power from 480v AC Shutdown Board 2A	or Common Board 1
	250v DC Battery Charger 3				AC Power from 480v AC Shutdown Board 3A	or Common Board 1
	250v DC Spare Battery Charger				AC Power from 480v AC Shutdown Board 2B	or Common Board 1
	250v DC Battery 1	Unit 1 Reac. Bldg.	593	$PN/R_{2.5}R_{3.5}$	None	
	250v DC Battery 2	Unit 2 Reac. Bldg.		$PN/R_{10}R_{11}$		
	250v DC Battery 3	Unit 3 Reac. Bldg.		$PN/R_{18.5}R_{19.5}$		
AC Reactor Bldg. Vent (Unit 3 only)	480v AC Reactor Bldg. Vent Board 3A		734	$QN/R_{18}R_{19}$	AC Power from 480v AC Common Board 3 or Unit Board 3A	
	480v AC Reactor Bldg. Vent Board 3B		565	$UT/R_{19}R_{20}$		
AC Reactor MOV (Unit 3, Board 3A only)	480v AC Reactor MOV Board 3A		621	$RP/R_{20}R_{21}$	AC Power from 480v AC Shutdown Boards 3A or 3B	DC Power from 250v DC Battery Boards 2 or 3

TABLE 6 (cont.)

SYSTEM	MAJOR COMPONENTS	LOCATION			MAIN SUPPORTS
		BLDG.	ELEV.	COORD.	
AC Common (excluding 4.16kv AC Common Start Board 2)	480v AC Common Board 1	Turbine Bldg.	586	KJ/T_6T_7	AC Power from 4160/480v AC Common Transformers 1A or 1B
	480v AC Common Board 2		604	CB/T_6T_8	AC Power from 4160/480v AC Common Transformers 2A or 2B
	480V AC Common Board 3		586	$HG/T_{11}T_{12}$	AC Power from 4160/480v AC Common Transformers 3A or 3B
	4160/480v AC Common Transformer EA		604	$CB/T_{12}T_{13}$	AC Power from 4.16kV AC Common Board A

TABLE 6 (cont.)

SYSTEM	MAJOR COMPONENTS	LOCATION			MAIN SUPPORTS
		BLDG.	ELEV.	COORD.	
AC Common	4160/480v AC Common Transformer 1A	Turbine Bldg.	586	KJ/T_6T_7	AC Power from 4.16kV AC Common Board A
	4160/480v AC Common Transformer 2A		604	CB/T_7T_8	
	4160/480v AC Common Transformer 3A		586	HG/$T_{11}T_{12}$	
	4160/480v AC Common Transformer 1B			KJ/T_6T_7	AC Power from 4.16kV AC Common Board B
	4160/480v AC Common Transformer 2B		604	CB/T_6T_7	
	4160/480v AC Common Transformer 3B		586	HG/$T_{11}T_{12}$	
	4.16kv AC Common Board A		604	CB/T_1T_2	AC Power from 20.7/4.16kv AC Unit Station Service Transformer 1
	4.15kv AC Common Board B			CB/$T_{10}T_{11}$	AC Power from 20.7/4.16kv AC Unit Station Service Transformer 2
	4.16 kV AC Common Start Board 1			BA/T_1T_2	AC Power from 161/4.16kV AC Common Station Service Transformers A or B
	161/4.16 kv AC Common Station Service Transformer A	Switchyard			AC Power from 161 kv AC Athens or Trinity Off-site Power Supply
	161/4.16 kv AC Common Station Service Transformer B				
	161 kv AC Athens Off-Site Power Supply				AC Off-Site Power Grid
	161 kv AC Trinity Off-Site Power Supply				

SYSTEM	MAJOR COMPONENTS	LOCATION			MAIN SUPPORTS	
		Bldg	Elev.	Coord		
AC Shutdown (excluding 480v AC Shutdown Board 1B)	480v AC Shutdown Board 1A	Unit 1 Reactor Bldg	621	TS/$R_1R_{1.5}$	AC Power from 4160/480v AC Shutdown Transformers 1A or 1E	DC Power from 250v DC Batteries 1,2, or 3
	480v AC Shutdown Board 2A	Unit 2 Reactor Bldg		TS/$R_{13}R_{13.5}$	AC Power from 4160/480v AC Shutdown Transformers 2A or 2E	
	480v AC Shutdown Board 2B			TS/$R_{13.5}R_{14}$	AC Power from 4160/480v AC Shutdown Transformers 2B or 2E	
	480v AC Shutdown Board 3A	Unit 3 Reactor Bldg		SR/$R_{20}R_{20.5}$	AC Power from 4160/480v AC Shutdown Transformers 3A or 3E	
	480v AC Shutdown Board 3B			SR/$R_{20.5}R_{21}$	AC Power from 4160/480v AC Shutdown Transformers 3B or 3E	
	4160/480v AC Shutdown Transformer 3B			SR/$R_{20.5}R_{21}$	AC Power from 4.16 kV AC Shutdown Board A	
	4160/480v AC Shutdown Transformer 1A	Unit 1 Reactor Bldg		SR/$R_1R_{1.5}$		
	4160/480v AC Shutdown Transformer 1E		639	SR/R_1R_2	AC Power from 4.16 kV AC Shutdown Board B	
	4160/480v AC Shutdown Transformer 2A	Unit 2 Reactor Bldg	621	SR/$R_{13}R_{13.5}$		
	4160/480v AC Shutdown Transformer 2E		639	SR/$R_{13}R_{14}$	AC Power from 4.16 kV AC Shutdown Board C	
	4160/480v AC Shutdown Transformer 3A	Unit 3 Reactor Bldg	621	SR/$R_{20}R_{20.5}$		
	4160/480v AC Shutdown Transformer 3E		639	SR/$R_{20}R_{21}$	AC Power from 4.16 kV AC Shutdown Board D	
	4160/480v AC Shutdown Transformer 2B	Unit 2 Reactor Bldg	621	SR/$R_{13.5}R_{14}$		

TABLE 6 (cont.)

TABLE 6 (cont.)

SYSTEM	MAJOR COMPONENTS	LOCATION Bldg	Elev.	Coord	MAIN SUPPORTS		
AC Shutdown (excluding 480v AC Shutdown Board 1B)	4.16 kV AC Diesel Generator A	Diesel Generator	565	Room A	Not resolved		
	4.16 kV AC Diesel Generator B			Room B			
	4.16 kV AC Diesel Generator C			Room C			
	4.16 kV AC Diesel Generator D			Room D			
	4.16 kV AC Shutdown Board A	Unit 1 Reactor Bldg	621	SP/R_1R_2	AC Power from 4.16 kV AC Diesel Generator A	or Shutdown Bus 1 or 2	DC Power from 250v DC Batteries 1,2, or 3
	4.16 kV AC Shutdown Board B		593		AC Power from 4.16 kV AC Diesel Generator B		
	4.16 kV AC Shutdown Board C	Unit 2 Reactor Bldg	621	$SP/R_{13}R_{14}$	AC Power from 4.16 kV AC Diesel Generator C		
	4.16 kV AC Shutdown Board D		593		AC Power from 4.16 kV AC Diesel Generator D		
	4.16 kV AC Shutdown Bus 1				AC Power from 4.16 kV AC Unit Boards 1A, 2B, or 3A		
	4.16 kV AC Shutdown Bus 2				AC Power from 4.16 kV AC Unit Boards, 1B, 2A, or 3B		
AC Unit (including only 480v AC Unit Board 3A from among all 480V AC Unit Boards; excluding 4.16 kV AC Unit Boards 1C,2C, &3C)	480V AC Unit Board 3A	Turbine Bldg	586	$DC/T_{11}T_{12}$	AC Power from 4160/480v AC Unit Transformer 3A or Common Transformer EA		
	4160/480v AC Unit Transformer 3A				AC Power from 4.16 kV AC Unit Board 3A		
	4.16 kV AC Unit Board 1A		604	CB/T_1T_2	AC Power from 20.7/4.16 kV AC Unit Station Service Transformer 1	or 4.16 kV AC Common Start Board 1	
	4.16 kV AC Unit Board 1B		586				

TABLE 6 (cont.)

SYSTEM	MAJOR COMPONENTS	LOCATION			MAIN SUPPORTS
		Bldg	Elev	Coord	
AC Unit (Including only 480v AC Unit Board 3A from among all 480V AC Unit Boards; excluding 4.16 kV AC Unit Boards 1C,2C &3C)	4.16 kV AC Unit Board 2A		604	CB/$T_{10}T_{11}$	AC Power from 20.7/4.16 kV AC Unit Station Service Transformer 2 or 4.16 kV AC Common Start Board 1
	4.16 kV AC Unit Board 2B		586		
	4.16 kV AC Unit Board 3A		604	CB/$T_{16}T_{17}$	AC Power from 20.7/4.16 kV AC Unit Station Service Transformer 3 or 4.16 kV AC Common Start Board 1
	4.16 kV AC Unit Board 3B		586		
	20.7/4.16 kV AC Unit Station Service Transformer 1	Switchyard			AC Power from 22 kV AC Main Generator 1 or 500/20.7 kV AC Main Transformer 1
	20.7/4.16 kV AC Unit Station Service Transformer 2				AC Power from 22 kV AC Main Generator 2 or 500/20.7 kV AC Main Transformer 2
	20.7/4.16 kV AC Unit Station Service Transformer 3				AC Power from 22 kV AC Main Generator 3 or 500/20.7 kV AC Main Transformer 3
	22 kV AC Main Generator 1	Turbine Bldg	621	DB/$T_{2.5}T_{3.5}$	Not Resolved
	22 kV AC Main Generator 2			DB/$T_{8.5}T_{9.5}$	
	22 kV AC Main Generator 3			DB/$T_{14.5}T_{15.5}$	
	500/20.7 kV AC Main Transformer 1	Switchyard			AC Power from 500 kV AC Off-Site Power Supply
	500/20.7 kV AC Main Transformer 2				
	500/20.7 kV AC Main Transformer 3				
	500 kV AC Off-Site Power Supply				AC Off-Site Power Grid

Key to Success Tree Symbols

Components

A = 4.16kV AC Board/Bus
a = 480v AC Board
B = 250v DC Battery
C = RP Logic Channel
D = 250v DC Battery Board
F = Fan
G = Multi-kV AC Generator
H = 250v DC Battery Charger
K = Multi-kV AC Off-Site Power Supply
L = Drain/Vent Pipeline
M = Manual Signal
P = Pump
Q = Air Compressor
T = > 4.16kV AC Transformer
ϒ = < 4.16 kV AC Transformer
V = Valve
W = Reactor Water

Systems

B = RBEDS (Reactor Bldg. Equipment Drain Sump)
C = CRS (Control Rod Scram)
D = 250v DC
H = AC Shutdown
M = AC Reactor MOV (Motor-Operated Valve)
N = AC Common
P = RP (Reactor Protection)
Q = Control Air
S = SLC (Standby Liquid Control)
U = AC Unit
V = AC Reactor Bldg. Vent
W = RWC (Reactor Water Cleanup)

Notation Scheme

B ←- System (B = RBEDS)
Component Type ⟶ F
(F = Fan)
1 ←- Identifier (if necessary)

This represents RBEDS Exhaust Fan #1 (operable).

TABLE 7

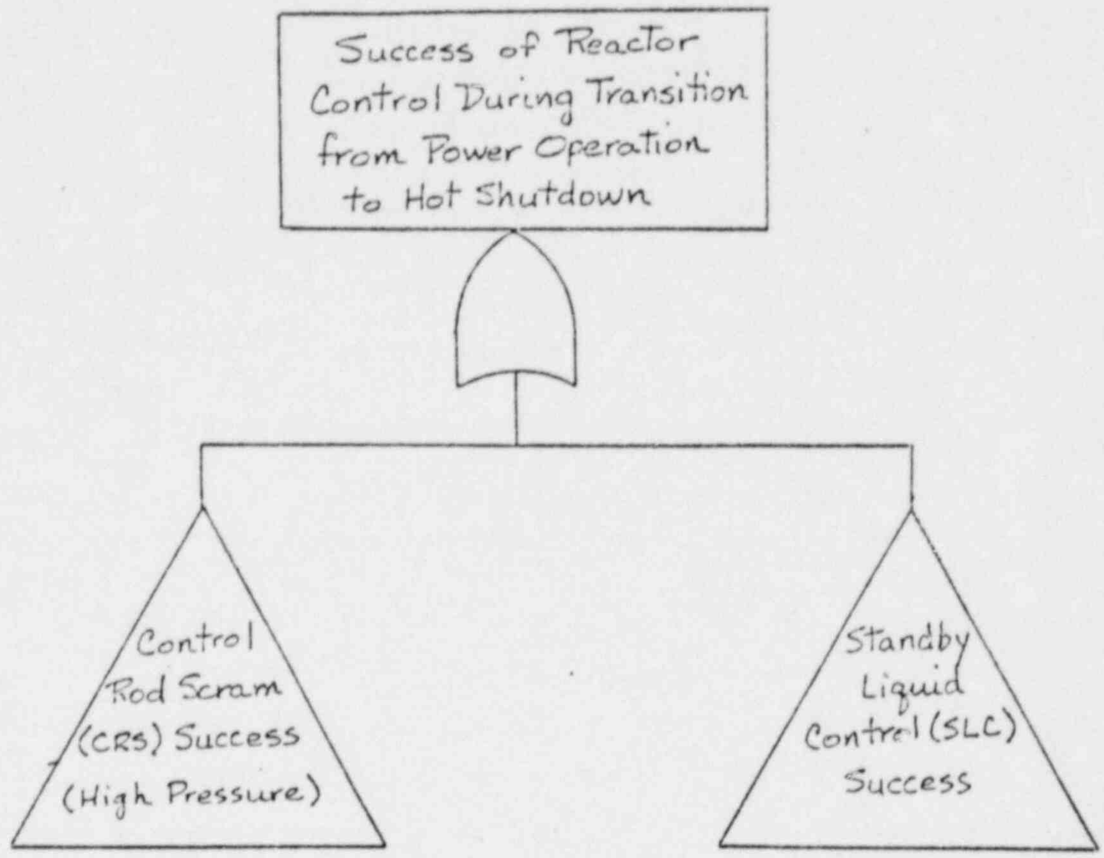

Success of Reactor Control During Transition from Power Operation to Hot Shutdown
Control Rod Scram (CRS) Success (High Pressure)
Standby Liquid Control (SLC) Success

FIGURE 5

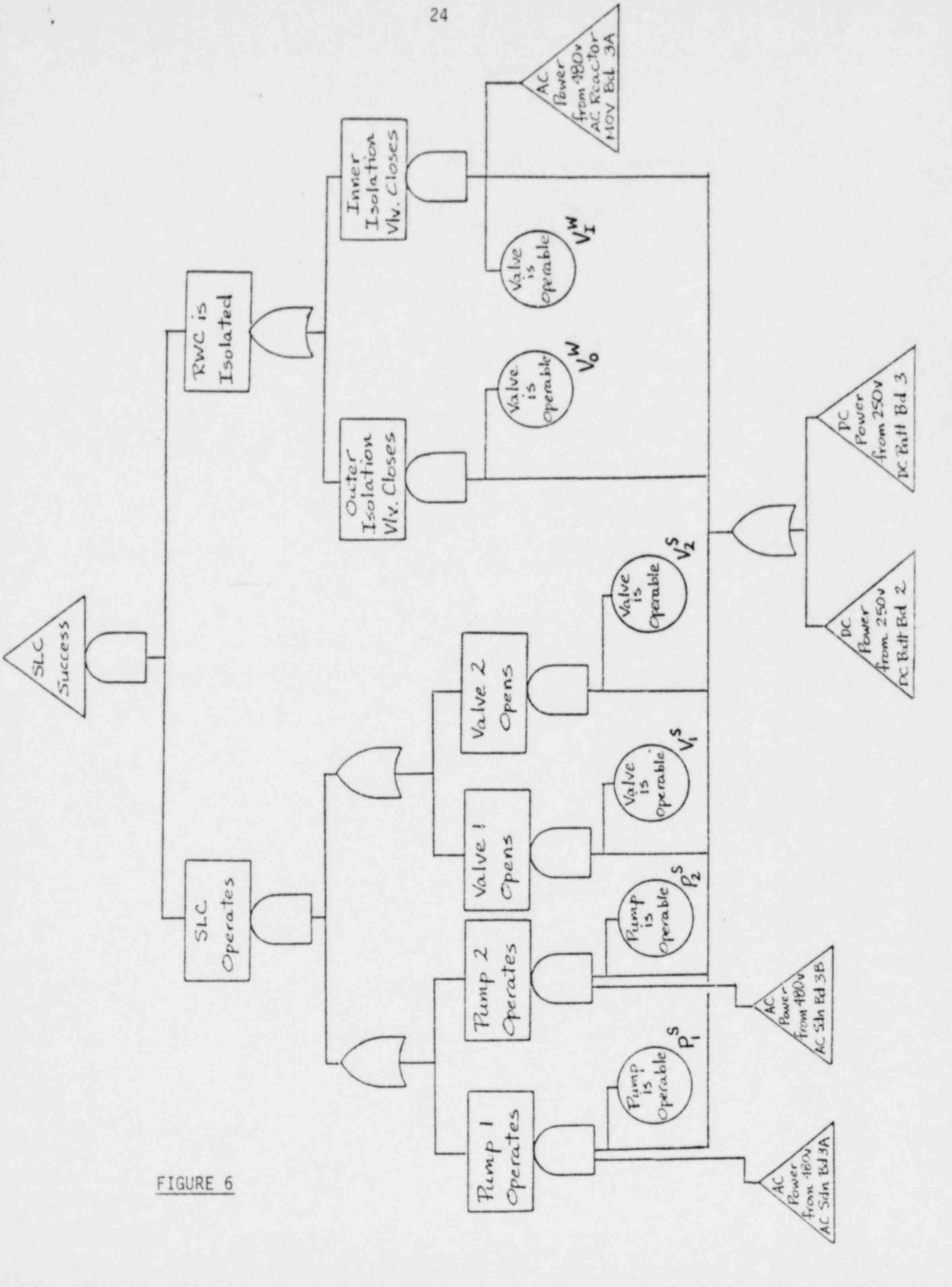

SLC Success
SLC Operates
RWC is Isolated
Pump 1 Operates
Pump 2 Operates
Valve 1 Opens
Valve 2 Opens
Outer Isolation Vlv. Closes
Inner Isolation Vlv. Closes
Pump is Operable
P_1^S
Pump is Operable
P_2^S
Valve is Operable
V_1^S
Valve is Operable
V_2^S
Valve is Operable
V_O^W
Valve is Operable
V_I^W
AC Power from 480v AC Sdn Bd 3A
AC Power from 480v AC Sdn Bd 3B
DC Power from 250v DC Batt Bd 2
DC Power from 250v DC Batt Bd 3
AC Power from 480v AC Reactor MOV Bd 3A

FIGURE 6

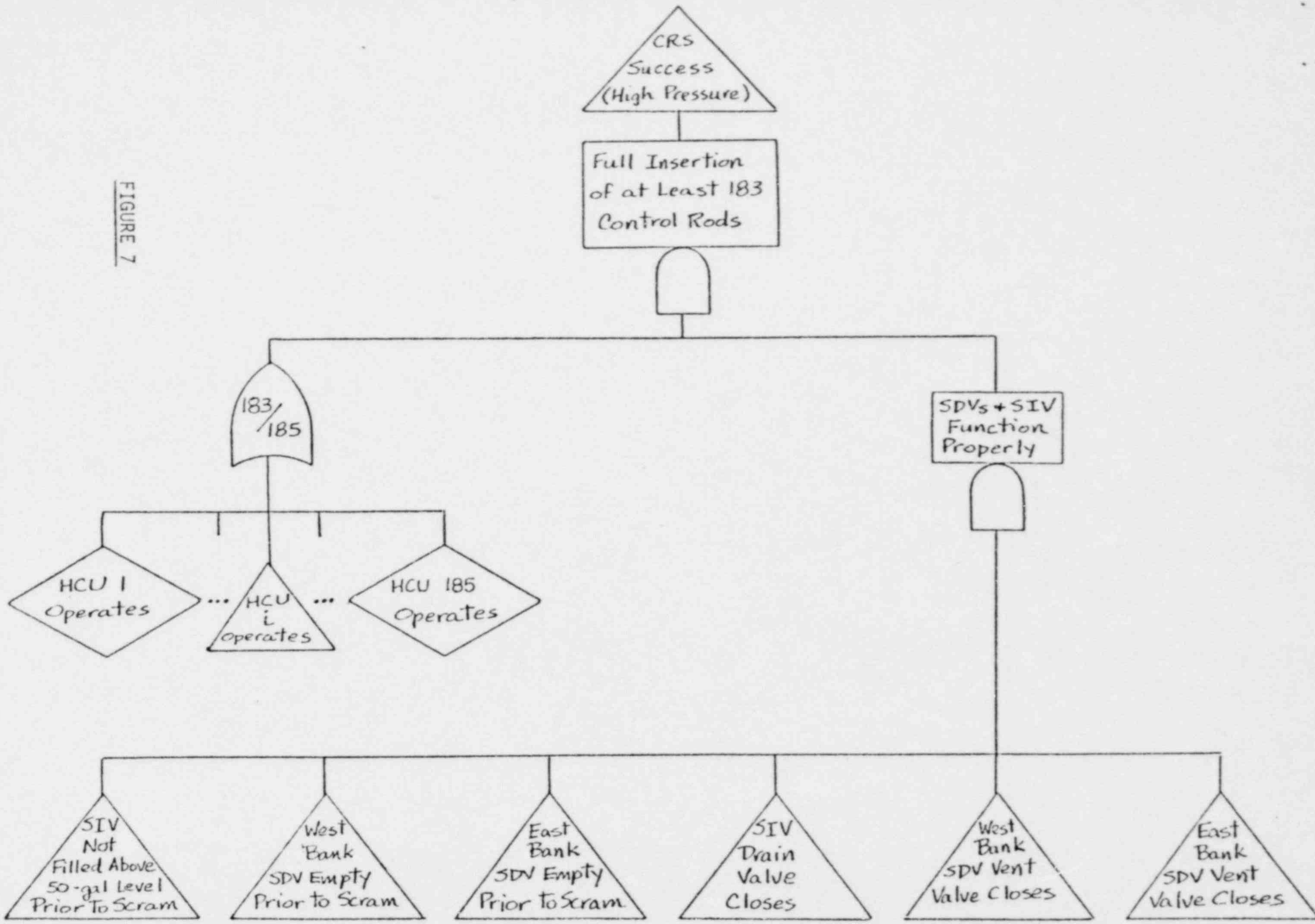
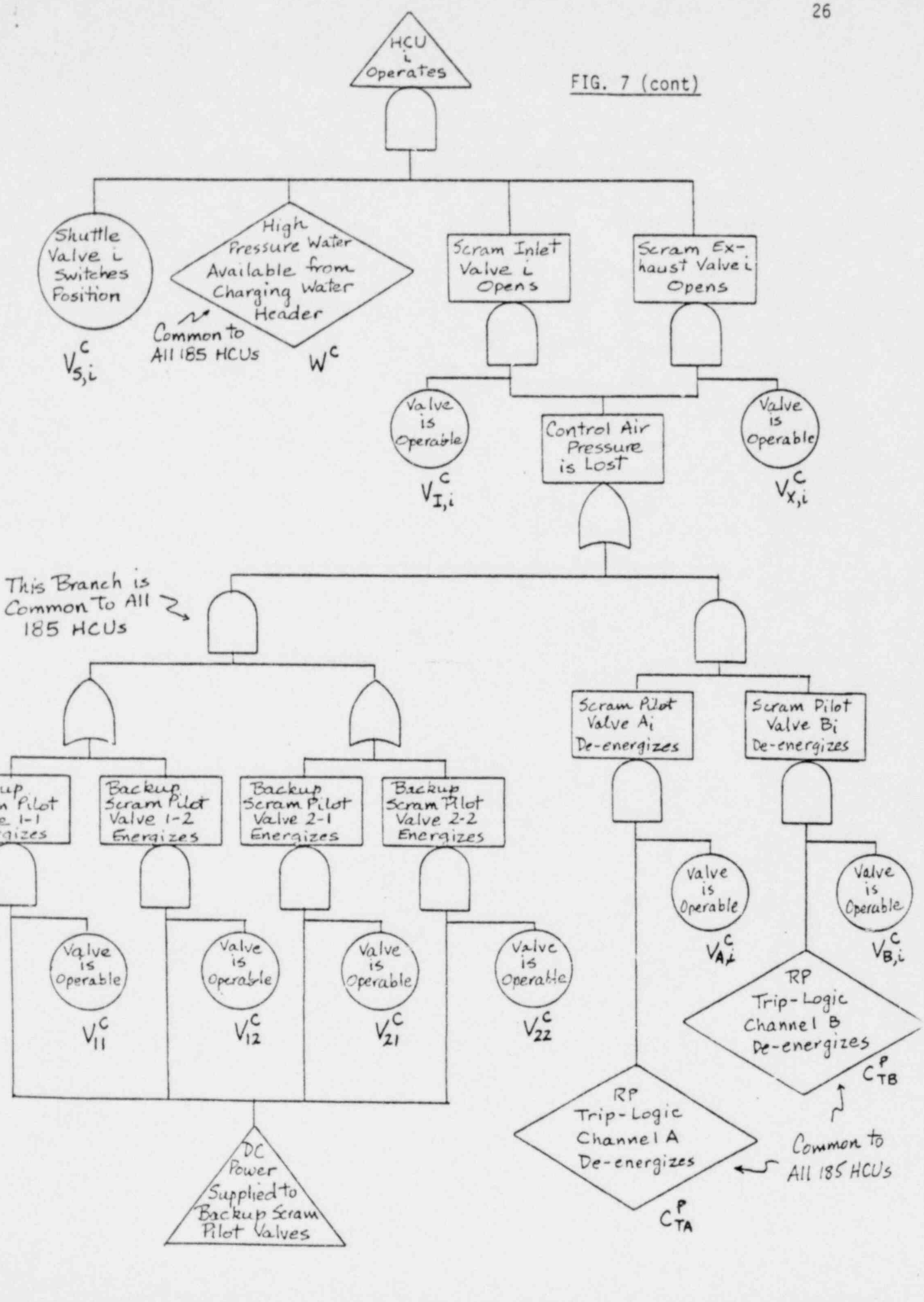

CRS Success (High Pressure)
Full Insertion of at Least 183 Control Rods
183/185
SDVs + SIV Function Properly
HCU 1 Operates
HCU i Operates
HCU 185 Operates
SIV Not Filled Above 50-gal Level Prior To Scram
West Bank SDV Empty Prior to Scram
East Bank SDV Empty Prior to Scram
SIV Drain Valve Closes
West Bank SDV Vent Valve Closes
East Bank SDV Vent Valve Closes

FIGURE 7

FIG. 7 (cont)


HCU i Operates
Shuttle Valve i Switches Position
$V^C_{S,i}$
High Pressure Water Available from Charging Water Header
Common to All 185 HCUs
W^C
Scram Inlet Valve i Opens
Scram Exhaust Valve i Opens
Valve is Operable
$V^C_{I,i}$
Control Air Pressure is Lost
Valve is Operable
$V^C_{X,i}$
This Branch is Common To All 185 HCUs
Scram Pilot Valve A_i De-energizes
Scram Pilot Valve B_i De-energizes
Backup Scram Pilot Valve 1-1 Energizes
Backup Scram Pilot Valve 1-2 Energizes
Backup Scram Pilot Valve 2-1 Energizes
Backup Scram Pilot Valve 2-2 Energizes
Valve is Operable
$V^C_{A,i}$
Valve is Operable
$V^C_{B,i}$
Valve is Operable
V^C_{11}
Valve is Operable
V^C_{12}
Valve is Operable
V^C_{21}
Valve is Operable
V^C_{22}
RP Trip-Logic Channel B De-energizes
C^P_{TB}
RP Trip-Logic Channel A De-energizes
C^P_{TA}
Common to All 185 HCUs
DC Power Supplied to Backup Scram Pilot Valves

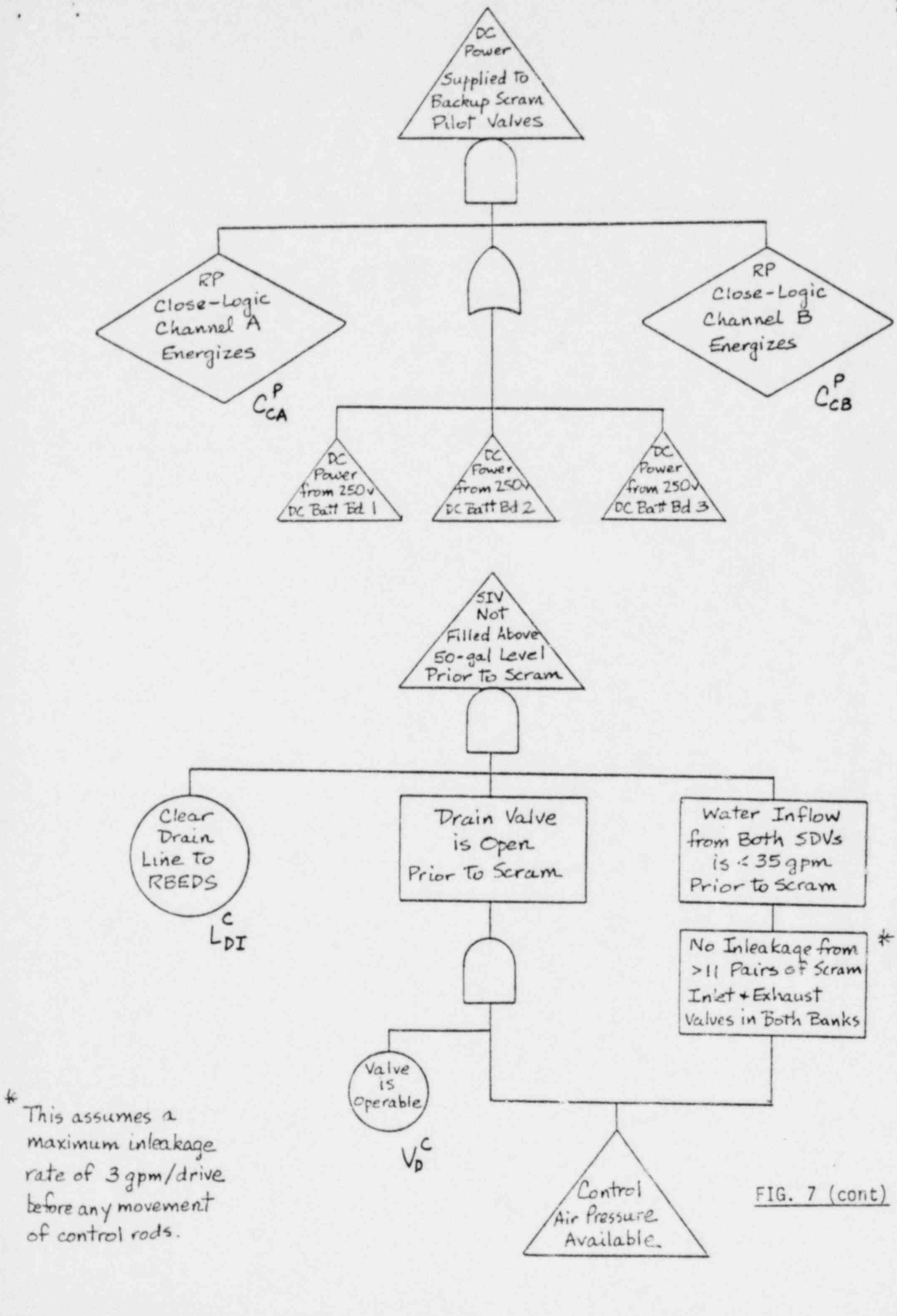
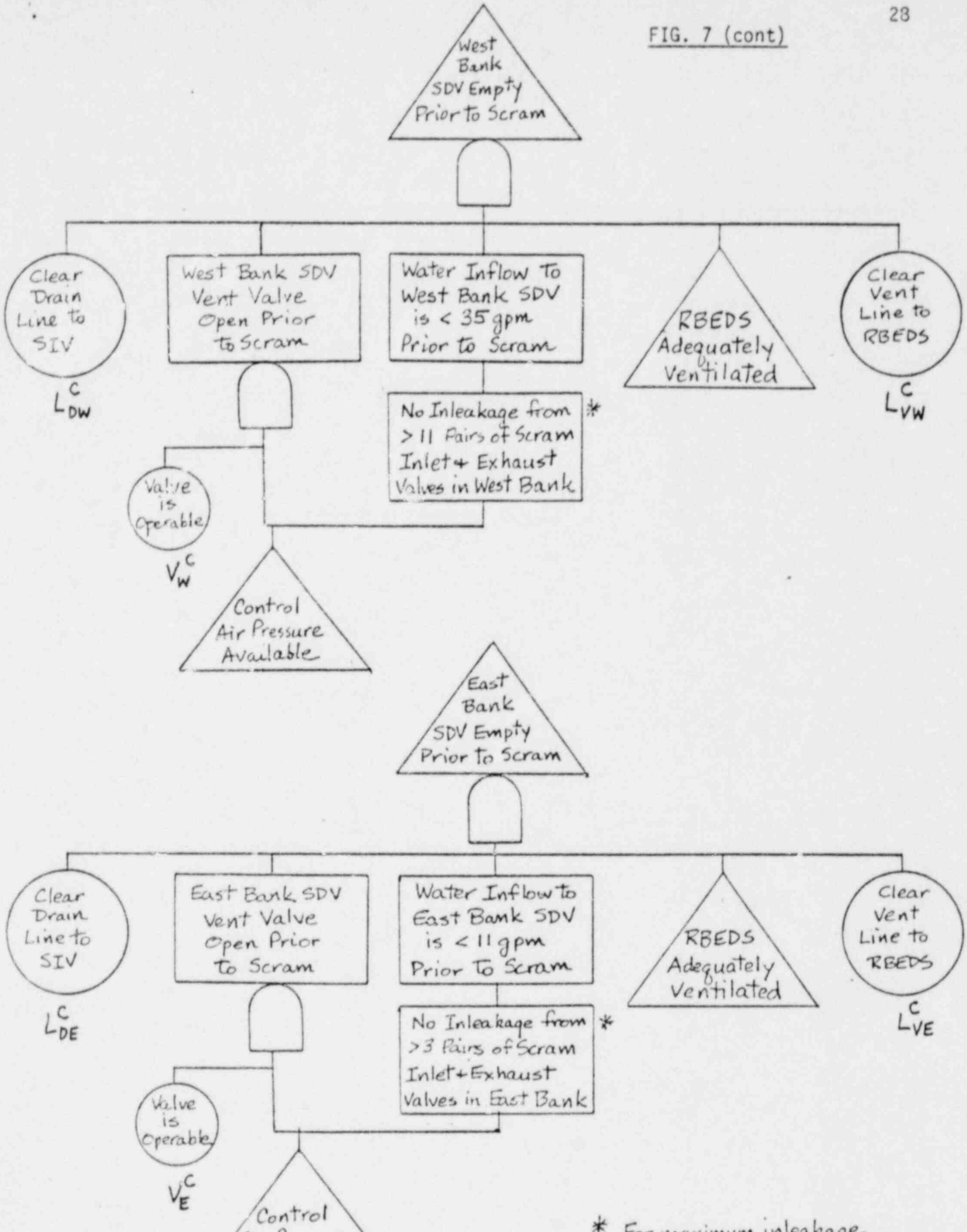
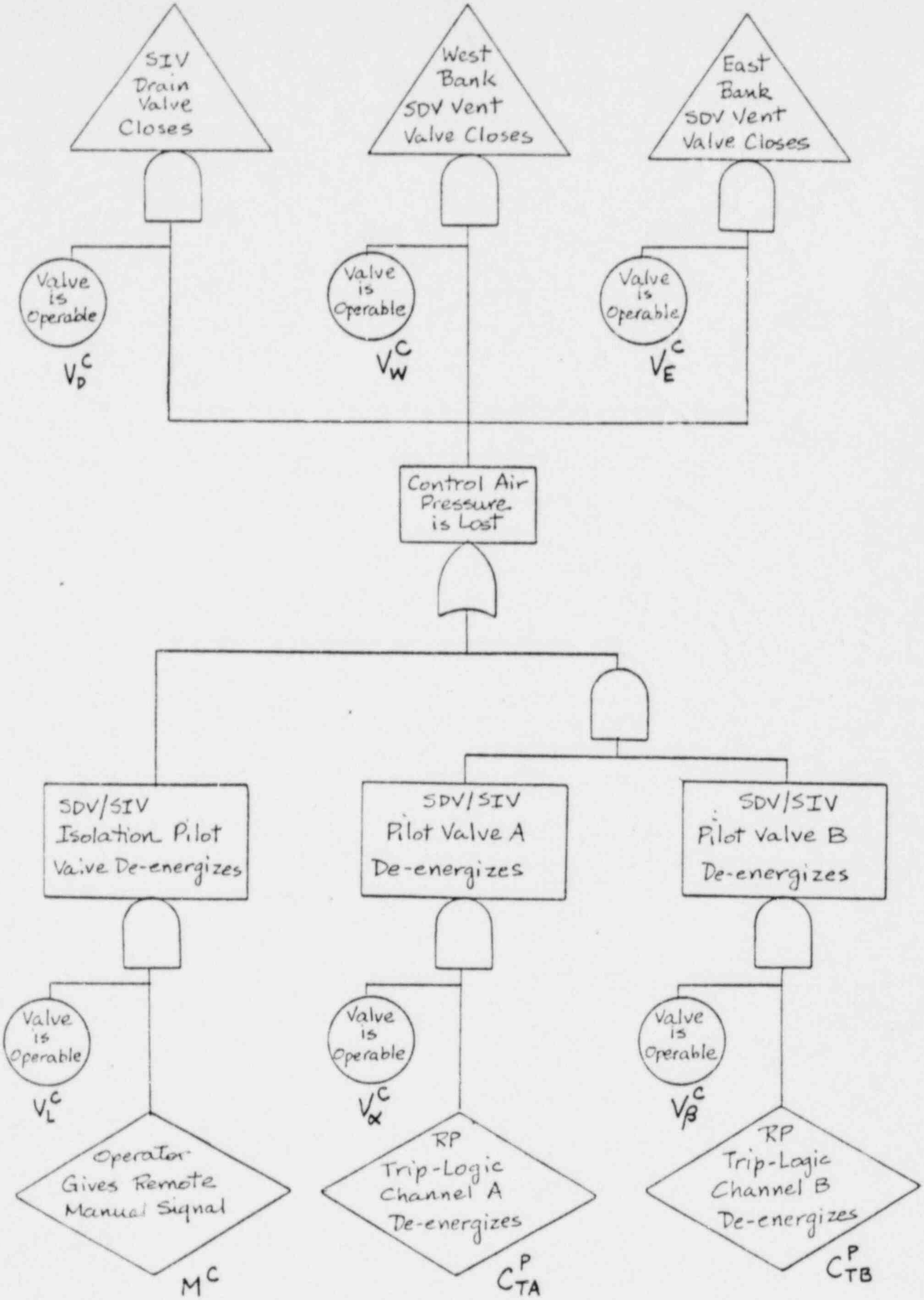

DC Power Supplied To Backup Scram Pilot Valves
RP Close-Logic Channel A Energizes
C_{CA}^{P}
RP Close-Logic Channel B Energizes
C_{CB}^{P}
DC Power from 250v DC Batt Bd 1
DC Power from 250v DC Batt Bd 2
DC Power from 250v DC Batt Bd 3
SIV Not Filled Above 50-gal Level Prior To Scram
Clear Drain Line To RBEDS
L_{DI}^{C}
Drain Valve is Open Prior To Scram
Water Inflow from Both SDVs is < 35 gpm Prior to Scram
No Inleakage from >11 Pairs of Scram Inlet + Exhaust Valves in Both Banks *
Valve is Operable
V_{D}^{C}
Control Air Pressure Available
* This assumes a maximum inleakage rate of 3 gpm/drive before any movement of control rods.

FIG. 7 (cont)

FIG. 7 (cont)



* For maximum inleakage rate of 3 gpm/drive.



SIV Drain Valve Closes
West Bank SDV Vent Valve Closes
East Bank SDV Vent Valve Closes
Valve is Operable
V_D^C
Valve is Operable
V_W^C
Valve is Operable
V_E^C
Control Air Pressure is Lost
SDV/SIV Isolation Pilot Valve De-energizes
SDV/SIV Pilot Valve A De-energizes
SDV/SIV Pilot Valve B De-energizes
Valve is Operable
V_L^C
Valve is Operable
V_α^C
Valve is Operable
V_β^C
Operator Gives Remote Manual Signal
M^C
RP Trip-Logic Channel A De-energizes
C_{TA}^P
RP Trip-Logic Channel B De-energizes
C_{TB}^P

FIG. 7 (cont)

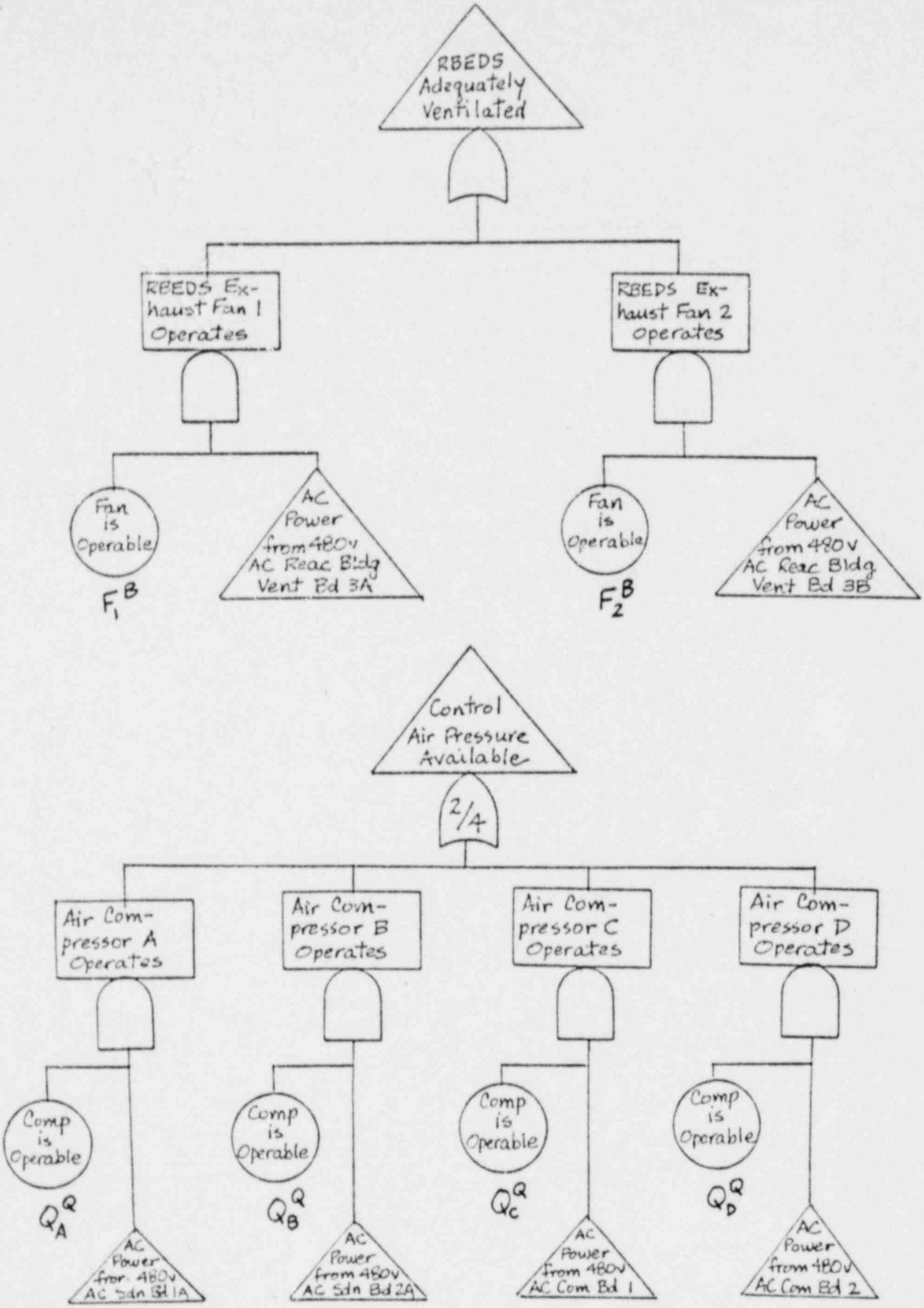

RBEDS Adequately Ventilated
RBEDS Exhaust Fan 1 Operates
RBEDS Exhaust Fan 2 Operates
Fan is Operable
AC Power from 480v AC Reac Bldg Vent Bd 3A
Fan is Operable
AC Power from 480v AC Reac Bldg Vent Bd 3B
F_1^B
F_2^B
Control Air Pressure Available
2/4
Air Compressor A Operates
Air Compressor B Operates
Air Compressor C Operates
Air Compressor D Operates
Comp is Operable
Comp is Operable
Comp is Operable
Comp is Operable
Q_A^Q
Q_B^Q
Q_C^Q
Q_D^Q
AC Power from 480v AC Sdn Bd 1A
AC Power from 480v AC Sdn Bd 2A
AC Power from 480v AC Com Bd 1
AC Power from 480v AC Com Bd 2

FIGURE 8

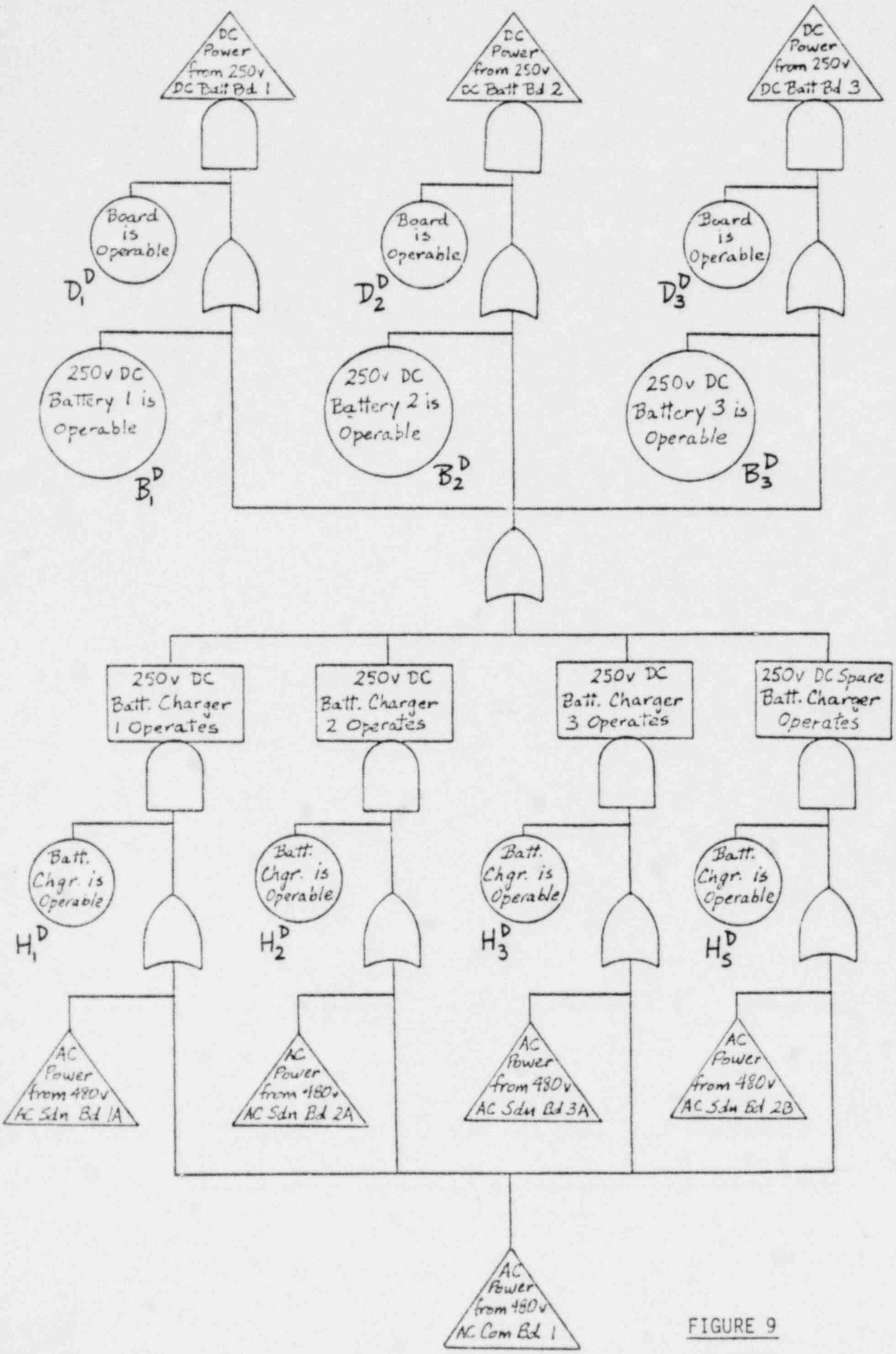

DC Power from 250v DC Batt Bd 1
DC Power from 250v DC Batt Bd 2
DC Power from 250v DC Batt Bd 3
Board is Operable
D_1^D
Board is Operable
D_2^D
Board is Operable
D_3^D
250v DC Battery 1 is Operable
B_1^D
250v DC Battery 2 is Operable
B_2^D
250v DC Battery 3 is Operable
B_3^D
250v DC Batt. Charger 1 Operates
250v DC Batt. Charger 2 Operates
250v DC Batt. Charger 3 Operates
250v DC Spare Batt. Charger Operates
Batt. Chgr. is Operable
H_1^D
Batt. Chgr. is Operable
H_2^D
Batt. Chgr. is Operable
H_3^D
Batt. Chgr. is Operable
H_S^D
AC Power from 480v AC Sdn Bd 1A
AC Power from 480v AC Sdn Bd 2A
AC Power from 480v AC Sdn Bd 3A
AC Power from 480v AC Sdn Bd 2B
AC Power from 480v AC Com Bd 1

FIGURE 9

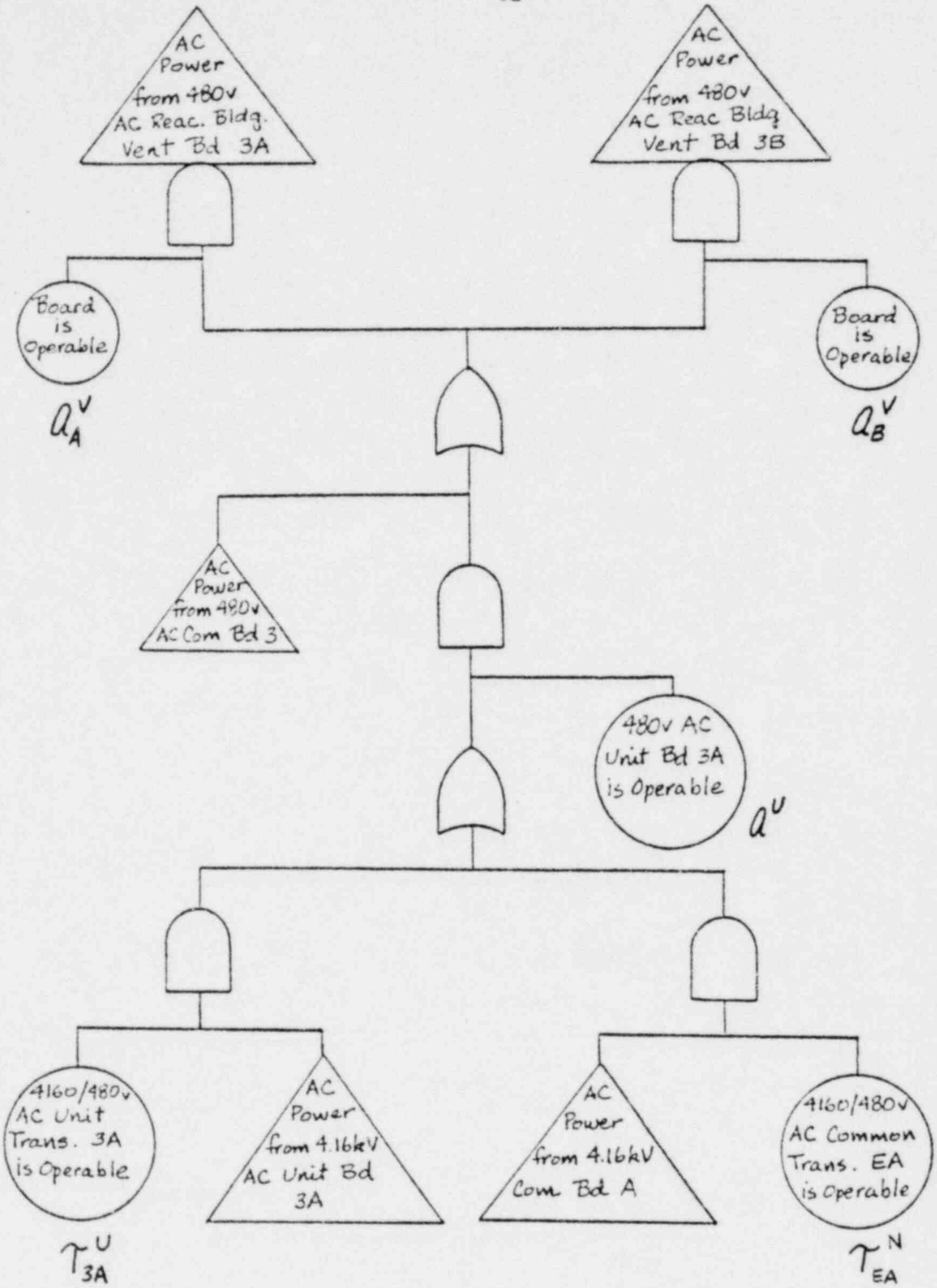

AC Power from 480v AC Reac. Bldg. Vent Bd 3A
AC Power from 480v AC Reac Bldg Vent Bd 3B
Board is Operable
Board is Operable
Q_A^V
Q_B^V
AC Power from 480v AC Com Bd 3
480v AC Unit Bd 3A is Operable
Q^U
4160/480v AC Unit Trans. 3A is Operable
AC Power from 4.16kV AC Unit Bd 3A
AC Power from 4.16kV Com Bd A
4160/480v AC Common Trans. EA is Operable
T_{3A}^U
T_{EA}^N

FIGURE 10

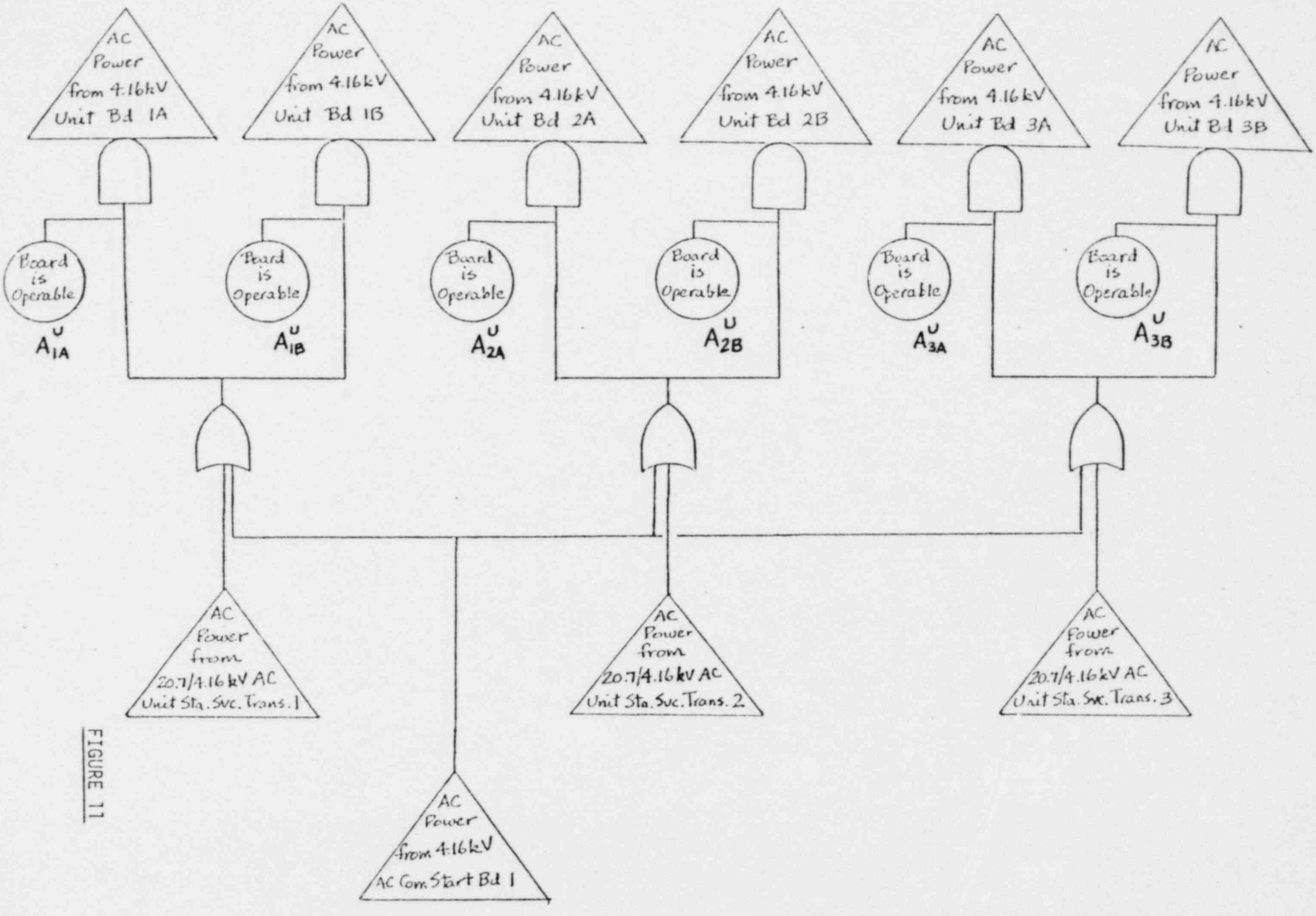

AC Power from 4.16kV Unit Bd 1A
AC Power from 4.16kV Unit Bd 1B
AC Power from 4.16kV Unit Bd 2A
AC Power from 4.16kV Unit Bd 2B
AC Power from 4.16kV Unit Bd 3A
AC Power from 4.16kV Unit Bd 3B
Board is Operable
A^{U}_{1A}
Board is Operable
A^{U}_{1B}
Board is Operable
A^{U}_{2A}
Board is Operable
A^{U}_{2B}
Board is Operable
A^{U}_{3A}
Board is Operable
A^{U}_{3B}
AC Power from 20.7/4.16kV AC Unit Sta. Svc. Trans. 1
AC Power from 20.7/4.16kV AC Unit Sta. Svc. Trans. 2
AC Power from 20.7/4.16kV AC Unit Sta. Svc. Trans. 3
AC Power from 4.16kV AC Com. Start Bd 1

FIGURE 11

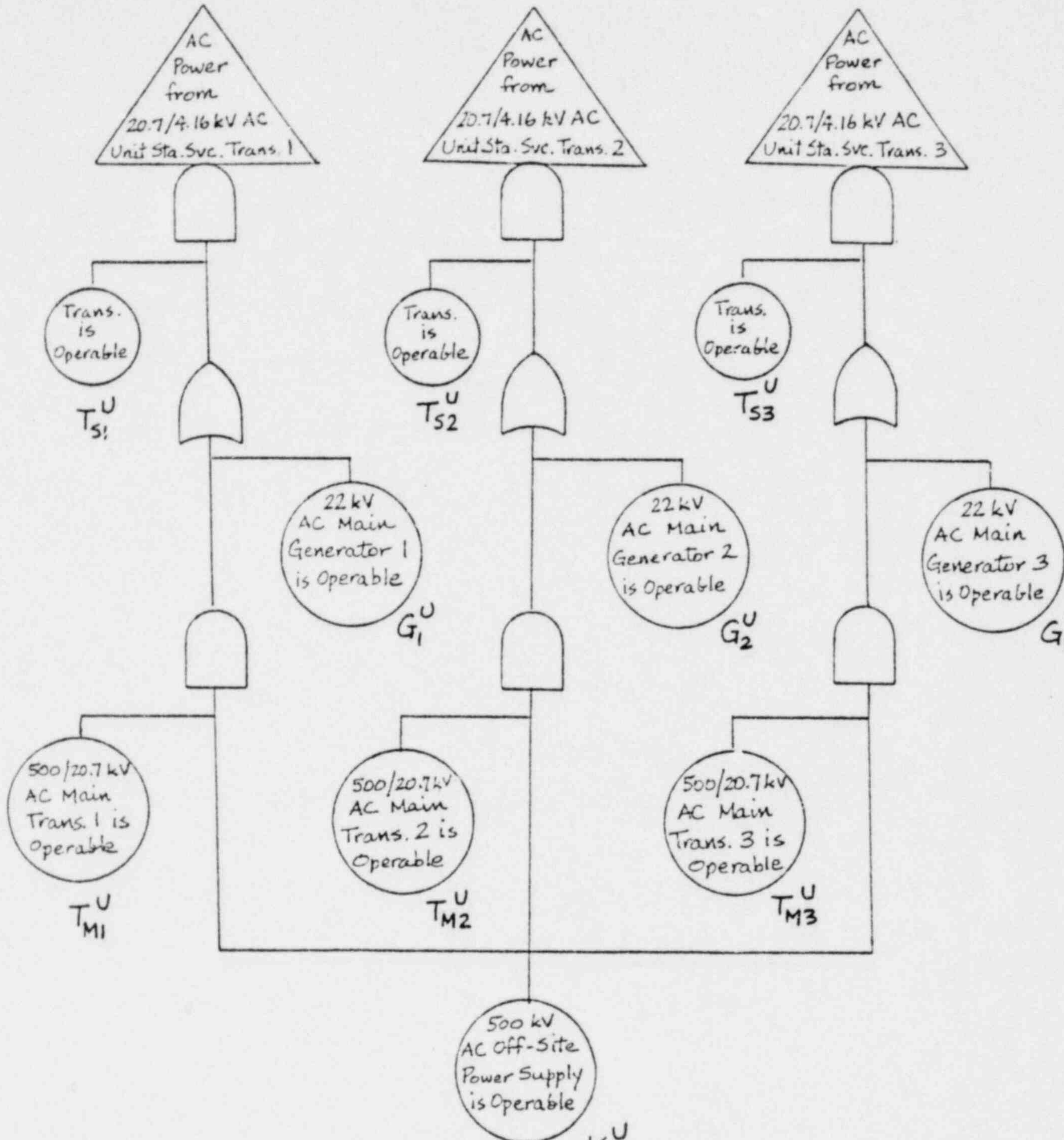

AC Power from 20.7/4.16 kV AC Unit Sta. Svc. Trans. 1
AC Power from 20.7/4.16 kV AC Unit Sta. Svc. Trans. 2
AC Power from 20.7/4.16 kV AC Unit Sta. Svc. Trans. 3
Trans. is Operable
T_{S1}^U
Trans. is Operable
T_{S2}^U
Trans. is Operable
T_{S3}^U
22 kV AC Main Generator 1 is Operable
G_1^U
22 kV AC Main Generator 2 is Operable
G_2^U
22 kV AC Main Generator 3 is Operable
G_3^U
500/20.7 kV AC Main Trans. 1 is Operable
T_{M1}^U
500/20.7 kV AC Main Trans. 2 is Operable
T_{M2}^U
500/20.7 kV AC Main Trans. 3 is Operable
T_{M3}^U
500 kV AC Off-Site Power Supply is Operable
K^U

FIG. 11 (cont)

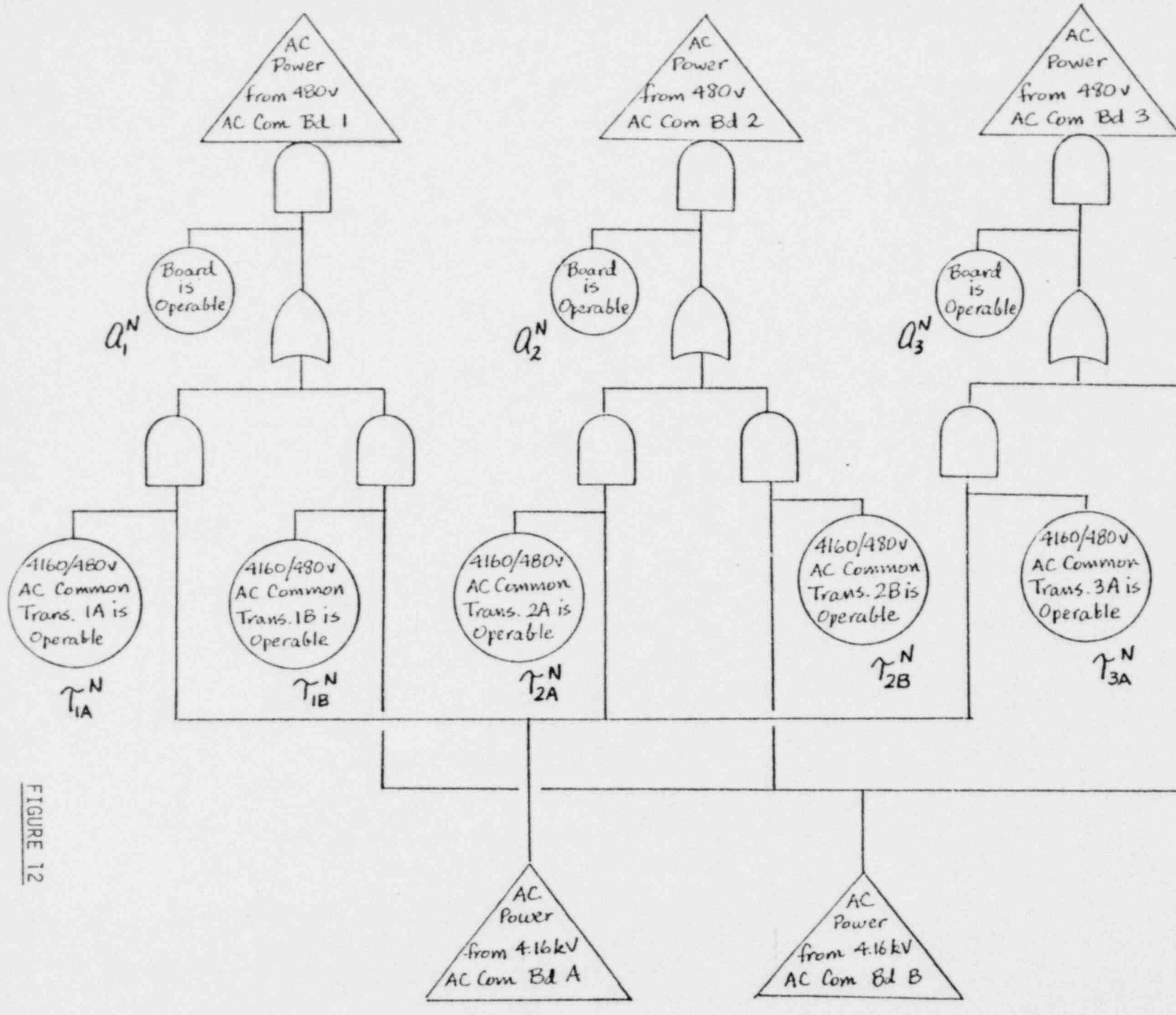

AC Power from 480v AC Com Bd 1
AC Power from 480v AC Com Bd 2
AC Power from 480v AC Com Bd 3
Board is Operable
Board is Operable
Board is Operable
a_1^N
a_2^N
a_3^N
4160/480v AC Common Trans. 1A is Operable
4160/480v AC Common Trans. 1B is Operable
4160/480v AC Common Trans. 2A is Operable
4160/480v AC Common Trans. 2B is Operable
4160/480v AC Common Trans. 3A is Operable
4160/480v AC Common Trans. 3B is Operable
τ_{1A}^N
τ_{1B}^N
τ_{2A}^N
τ_{2B}^N
τ_{3A}^N
τ_{3B}^N
AC Power from 4.16kV AC Com Bd A
AC Power from 4.16kV AC Com Bd B

FIGURE 12

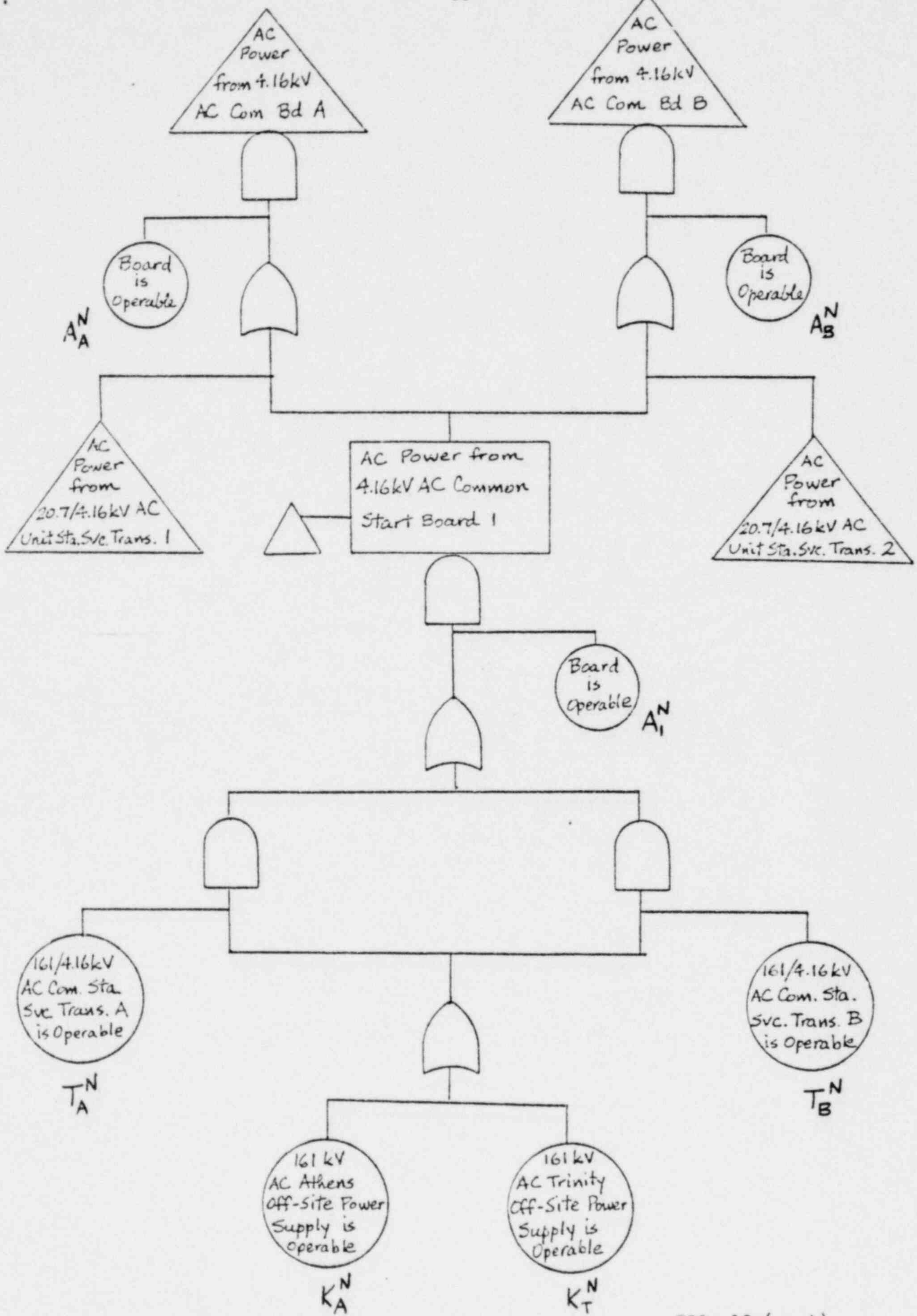

AC Power from 4.16kV AC Com Bd A
AC Power from 4.16kV AC Com Bd B
Board is Operable
A_A^N
Board is Operable
A_B^N
AC Power from 20.7/4.16kV AC Unit Sta. Svc. Trans. 1
AC Power from 4.16kV AC Common Start Board 1
AC Power from 20.7/4.16kV AC Unit Sta. Svc. Trans. 2
Board is Operable
A_1^N
161/4.16kV AC Com. Sta. Svc. Trans. A is Operable
T_A^N
161/4.16kV AC Com. Sta. Svc. Trans. B is Operable
T_B^N
161 kV AC Athens Off-Site Power Supply is operable
K_A^N
161 kV AC Trinity Off-Site Power Supply is Operable
K_T^N

FIG. 12 (cont)

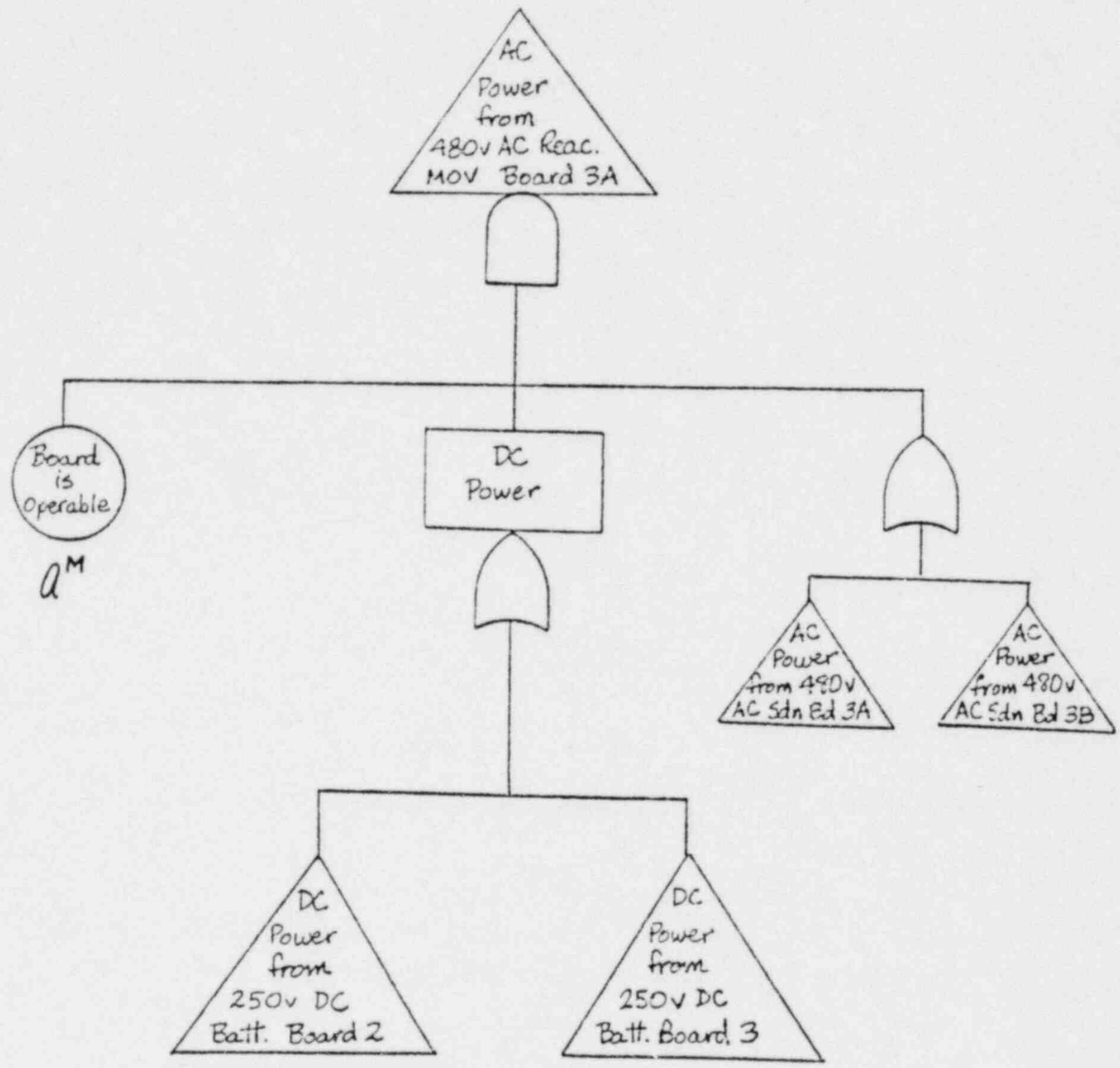

AC Power from 480v AC Reac. MOV Board 3A
Board is Operable
a^M
DC Power
AC Power from 480v AC Sdn Bd 3A
AC Power from 480v AC Sdn Bd 3B
DC Power from 250v DC Batt. Board 2
DC Power from 250v DC Batt. Board 3

FIGURE 13

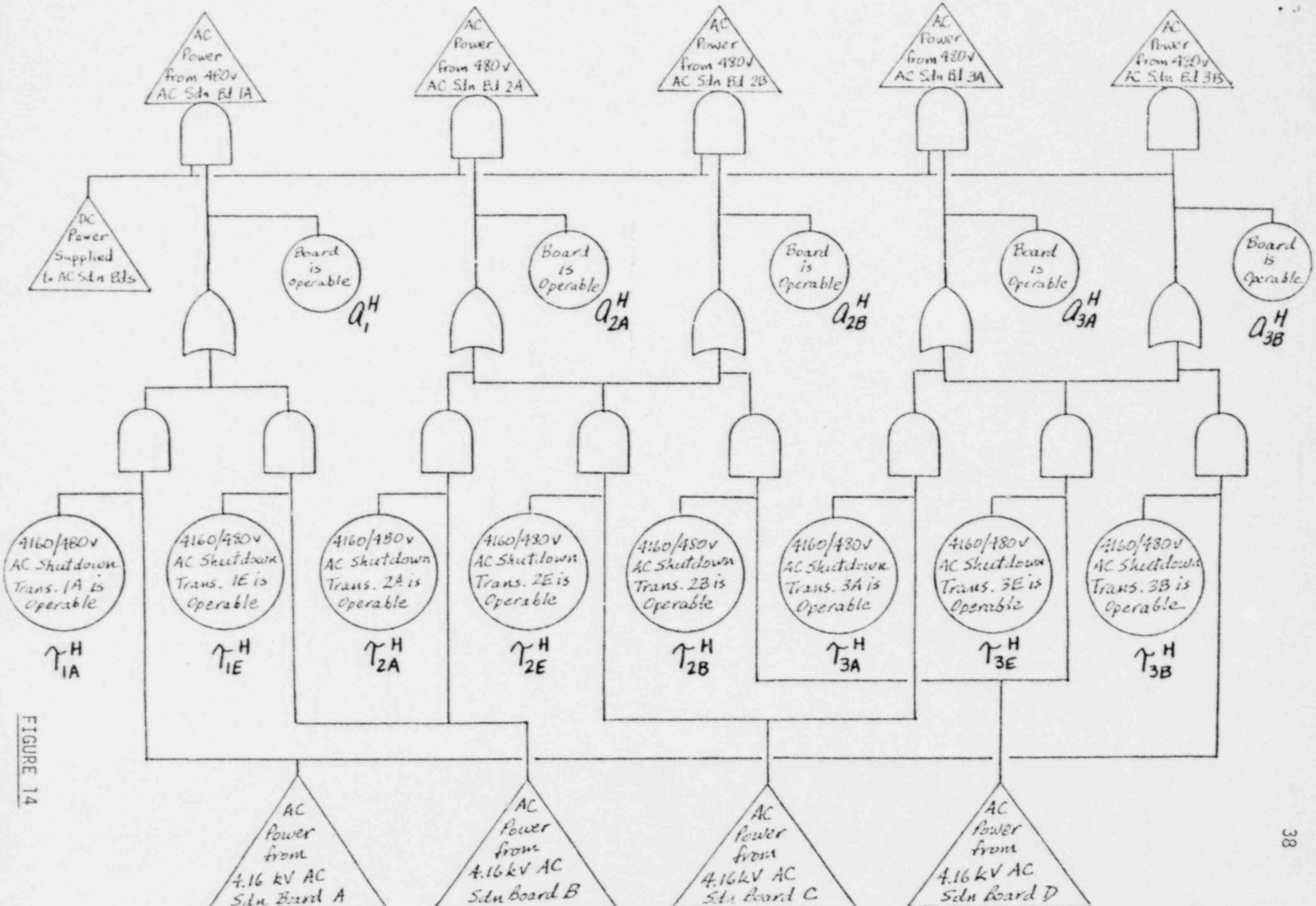

AC Power from 480v AC Sdn Bd 1A
AC Power from 480v AC Sdn Bd 2A
AC Power from 480V AC Sdn Bd 2B
AC Power from 480v AC Sdn Bd 3A
AC Power from 480v AC Sdn Bd 3B
DC Power Supplied to AC Sdn Bds
Board is operable
a_1^H
Board is Operable
a_{2A}^H
Board is Operable
a_{2B}^H
Board is Operable
a_{3A}^H
Board is Operable
a_{3B}^H
4160/480v AC Shutdown Trans. 1A is Operable
τ_{1A}^H
4160/480v AC Shutdown Trans. 1E is Operable
τ_{1E}^H
4160/480v AC Shutdown Trans. 2A is Operable
τ_{2A}^H
4160/480V AC Shutdown Trans. 2E is Operable
τ_{2E}^H
4160/480V AC Shutdown Trans. 2B is Operable
τ_{2B}^H
4160/480V AC Shutdown Trans. 3A is Operable
τ_{3A}^H
4160/480V AC Shutdown Trans. 3E is Operable
τ_{3E}^H
4160/480V AC Shutdown Trans. 3B is Operable
τ_{3B}^H
AC Power from 4.16 kV AC Sdn Board A
AC Power from 4.16kV AC Sdn Board B
AC Power from 4.16kV AC Sdn Board C
AC Power from 4.16 kV AC Sdn Board D

FIGURE 14

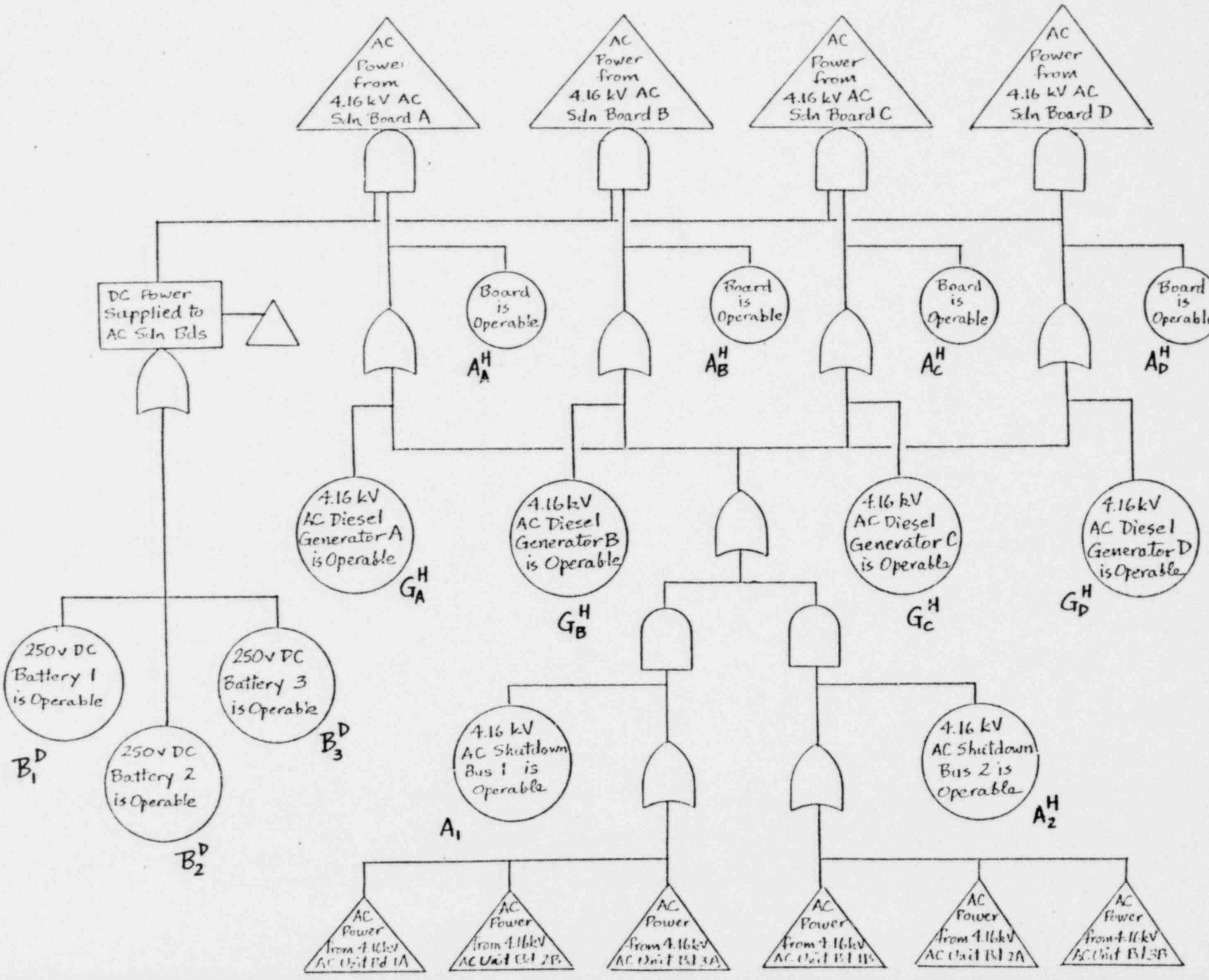

AC Power from 4.16 kV AC Sdn Board A
AC Power from 4.16 kV AC Sdn Board B
AC Power from 4.16 kV AC Sdn Board C
AC Power from 4.16 kV AC Sdn Board D
DC Power Supplied to AC Sdn Bds
Board is Operable
A_A^H
Board is Operable
A_B^H
Board is Operable
A_C^H
Board is Operable
A_D^H
4.16 kV AC Diesel Generator A is Operable
G_A^H
4.16 kV AC Diesel Generator B is Operable
G_B^H
4.16 kV AC Diesel Generator C is Operable
G_C^H
4.16 kV AC Diesel Generator D is Operable
G_D^H
250 v DC Battery 1 is Operable
B_1^D
250 v DC Battery 2 is Operable
B_2^D
250 v DC Battery 3 is Operable
B_3^D
4.16 kV AC Shutdown Bus 1 is Operable
A_1
4.16 kV AC Shutdown Bus 2 is Operable
A_2^H
AC Power from 4.16 kV AC Unit Bd 1A
AC Power from 4.16 kV AC Unit Bd 2B
AC Power from 4.16 kV AC Unit Bd 3A
AC Power from 4.16 kV AC Unit Bd 1B
AC Power from 4.16 kV AC Unit Bd 2A
AC Power from 4.16 kV AC Unit Bd 3B

FIG. 14 (cont)

TABLE 8

NUMBERING SCHEME FOR SUCCESS/FAULT TREES FOR COMPUTER RUNS

Numbers	Systems	Components
1-9	AC Reactor Bldg Vent	480v AC Boards
10-19	AC Reactor MOV	480v AC Board
20-29	AC Unit	480v AC Boards
30-39	"	4160/480v AC Transformers
40-49	"	4.16 kV AC Boards
50-59	"	20.7/4.16 kV AC Transformers
60-69	"	22 kV AC Generators
70-79	"	500/20.7 kV AC Transformers
80-89	"	500 kV AC Off-Site Power
90-99	AC Common	480v AC Boards
100-109	"	4160/480v AC Transformers
110-119	"	4.16 kV AC Boards
120-129	"	4.16 kV AC Start Board
130-139	"	161/4.16 kV AC Transformers
140-149	"	161 kV AC Off-Site Power
150-159	AC Shutdown	480v AC Boards
160-169	"	4160/480v AC Transformers
170-179	"	4.16 kV AC Boards
180-189	AC Shutdown	4.16 kV AC Generators
190-199	"	4.16 kV AC Buses
200-209	250v DC	250v DC Battery Boards
210-219	"	250v DC Batteries
220-229	"	250v DC Battery Chargers
230-299	Other Gates for Electrical Components	
300-309	CRS	HCU Shuttle Valves & Charging Water
310-319	"	HCU Scram Inlet & Exhaust Valves
320-329	"	HCU Scram Pilot Valves
330-339	"	Backup Scram Pilot Valves
340-349	"	SIV Drain Line & Valve
350-359	"	West Bank SDV Lines & Valve
360-369	"	East Bank SDV Lines & Valve

NUMBERING SCHEME FOR SUCCESS/FAULT TREES FOR COMPUTER RUNS (cont)

Numbers	Systems	Components
370-379	CRS	SDV/SIV Pilot Valves
380-389	"	Manual Signal
390-399	RP	Trip-Logic Channels
400-409	"	Close-Logic Channels
410-419	RBEDS	Exhaust Fans
420-429	Control Air	Air Compressors
430-439	SLC	Pumps
440-449	"	Valves
450-459	RWC	Isolation Valves
460-512	Other Gates for Non-Electrical Components	

TAB. 8 (cont)

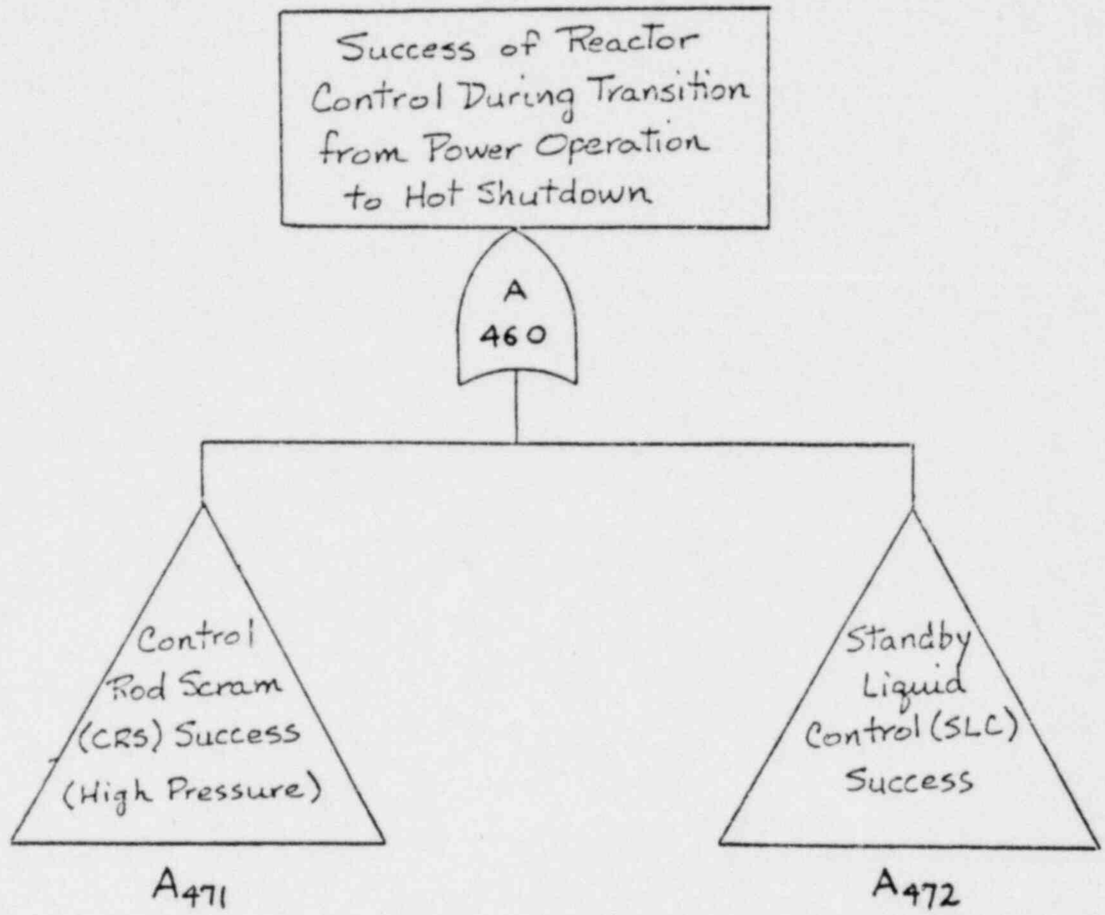

Success of Reactor Control During Transition from Power Operation to Hot Shutdown
A 460
Control Rod Scram (CRS) Success (High Pressure)
A471
Standby Liquid Control (SLC) Success
A472

FIGURE 15

FIGURE 16

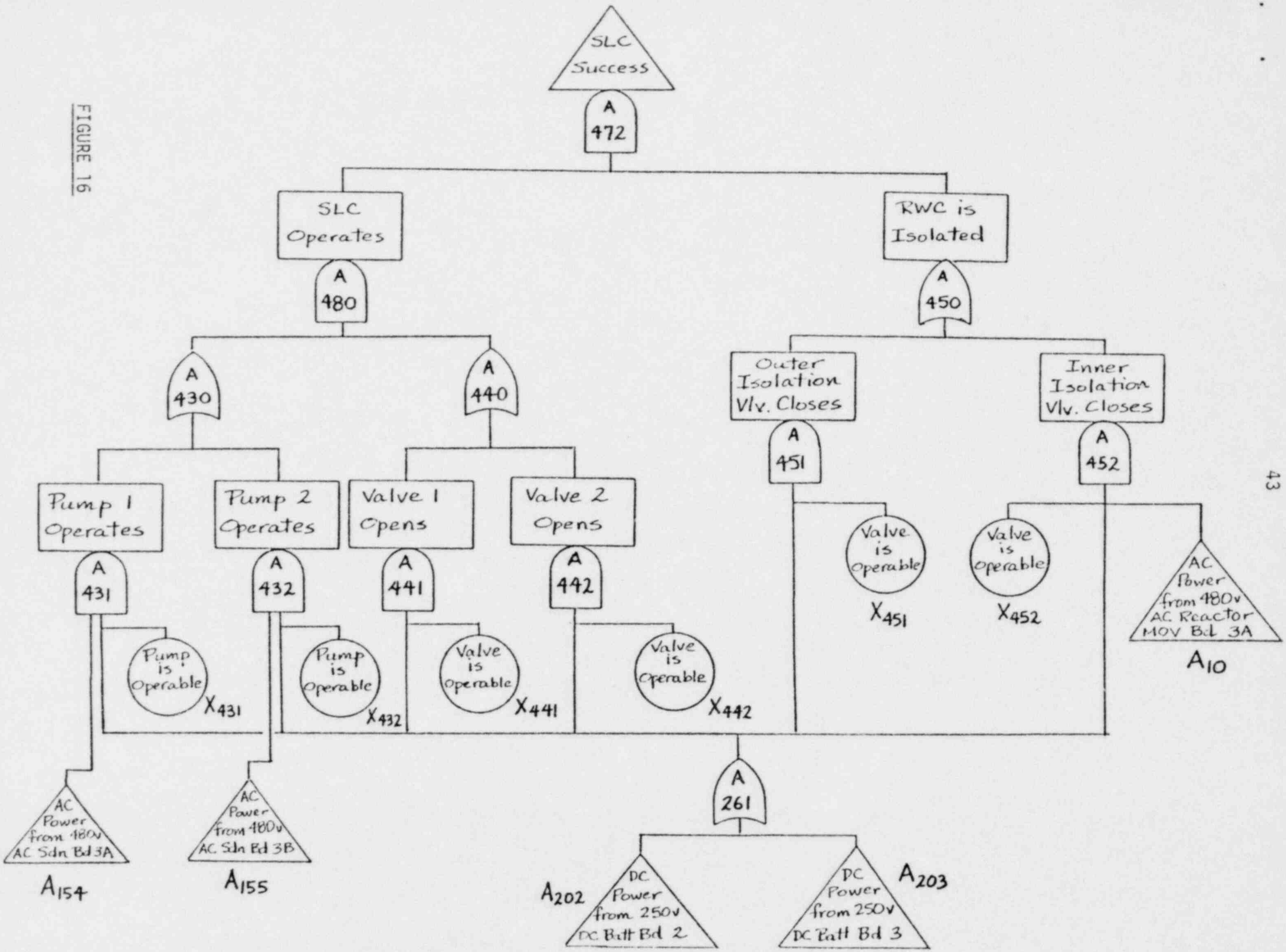

SLC Success
A 472
SLC Operates
RWC is Isolated
A 480
A 450
A 430
A 440
Outer Isolation Vlv. Closes
Inner Isolation Vlv. Closes
A 451
A 452
Pump 1 Operates
Pump 2 Operates
Valve 1 Opens
Valve 2 Opens
A 431
A 432
A 441
A 442
Valve is operable
X_{451}
Valve is operable
X_{452}
AC Power from 480v AC Reactor MOV Bd 3A
A_{10}
Pump is Operable
X_{431}
Pump is Operable
X_{432}
Valve is Operable
X_{441}
Valve is Operable
X_{442}
A 261
AC Power from 480v AC Sdn Bd 3A
A_{154}
AC Power from 480v AC Sdn Bd 3B
A_{155}
A_{202}
DC Power from 250v DC Batt Bd 2
DC Power from 250v DC Batt Bd 3
A_{203}

FIGURE 17

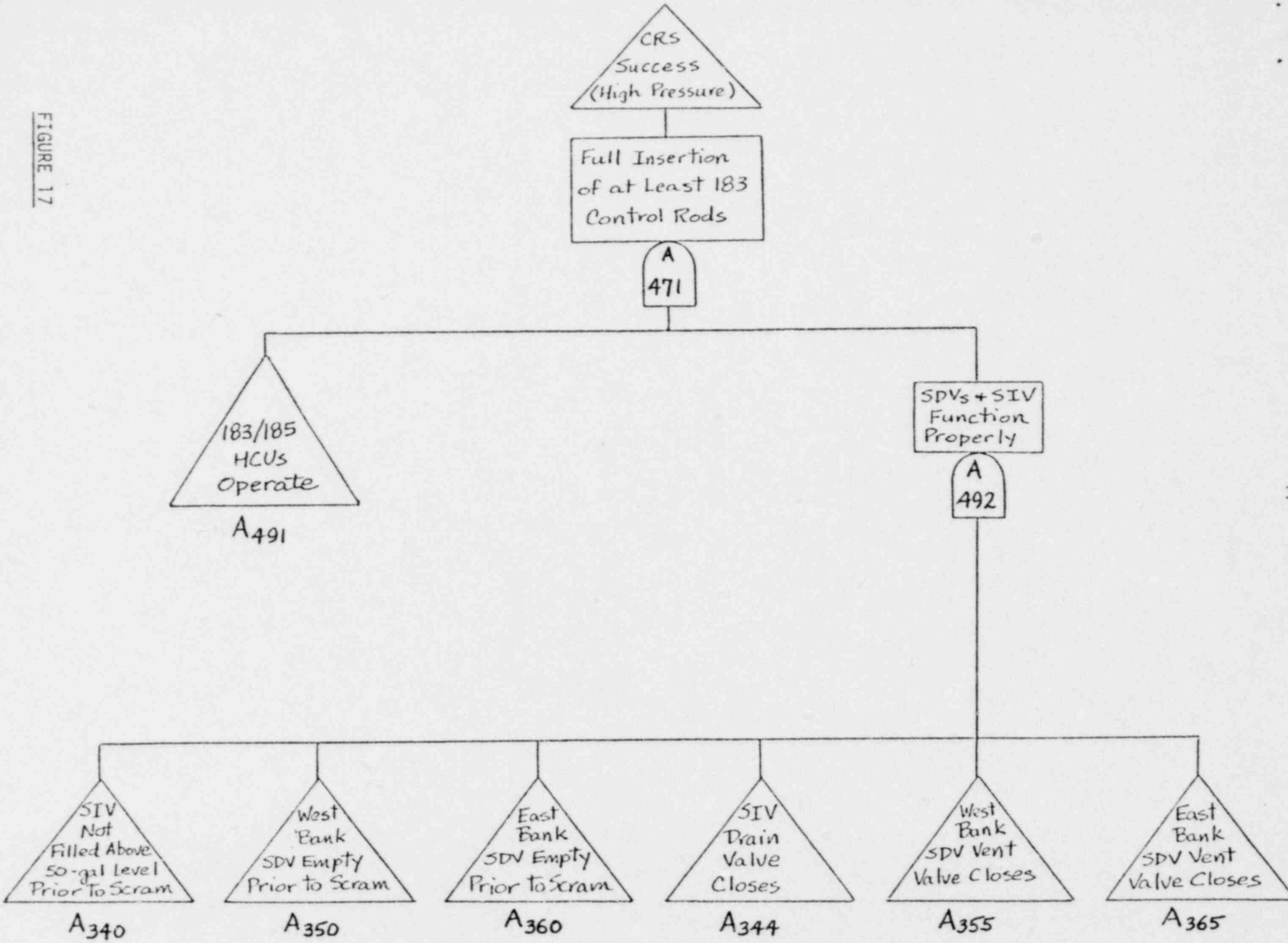
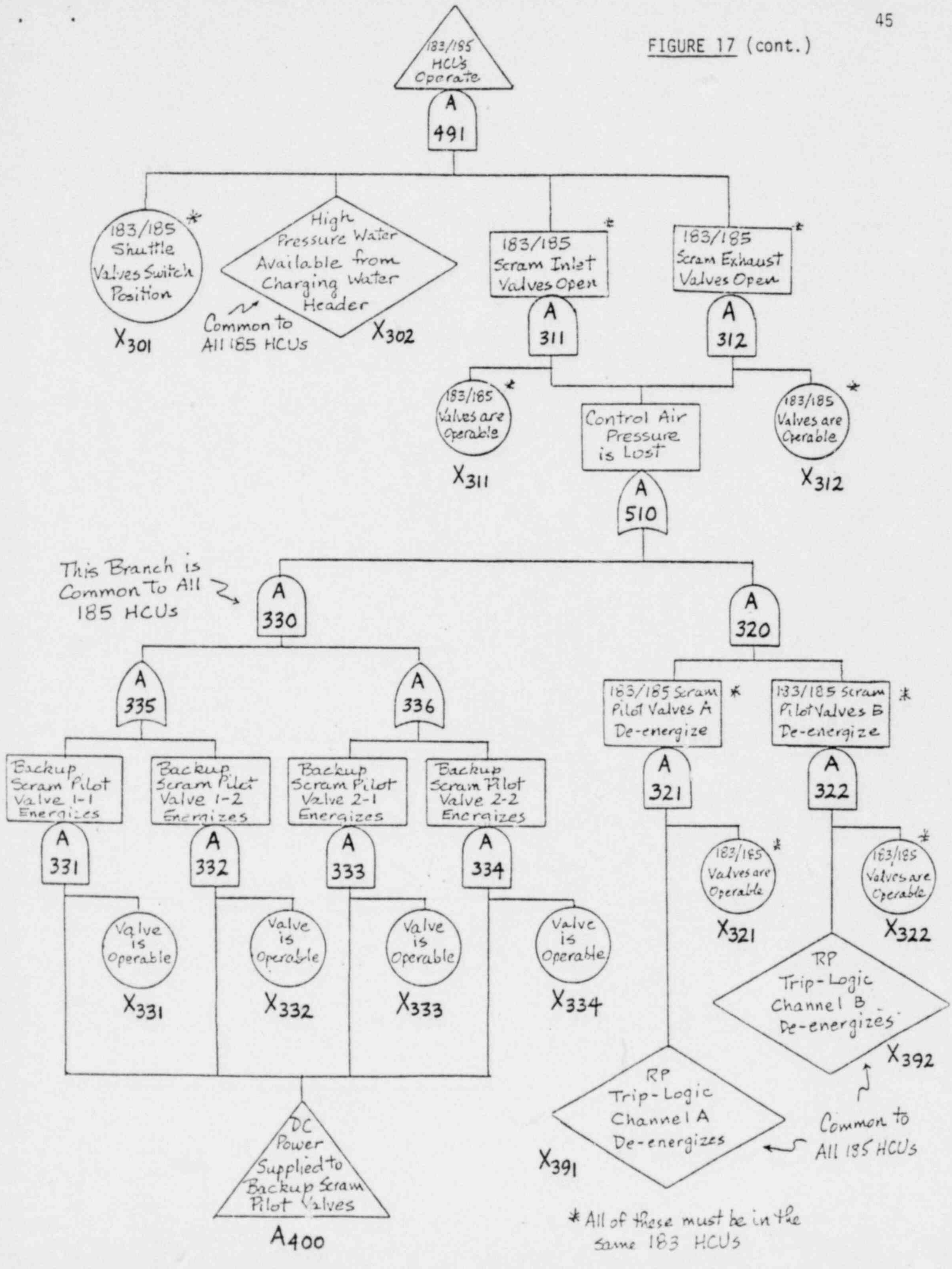
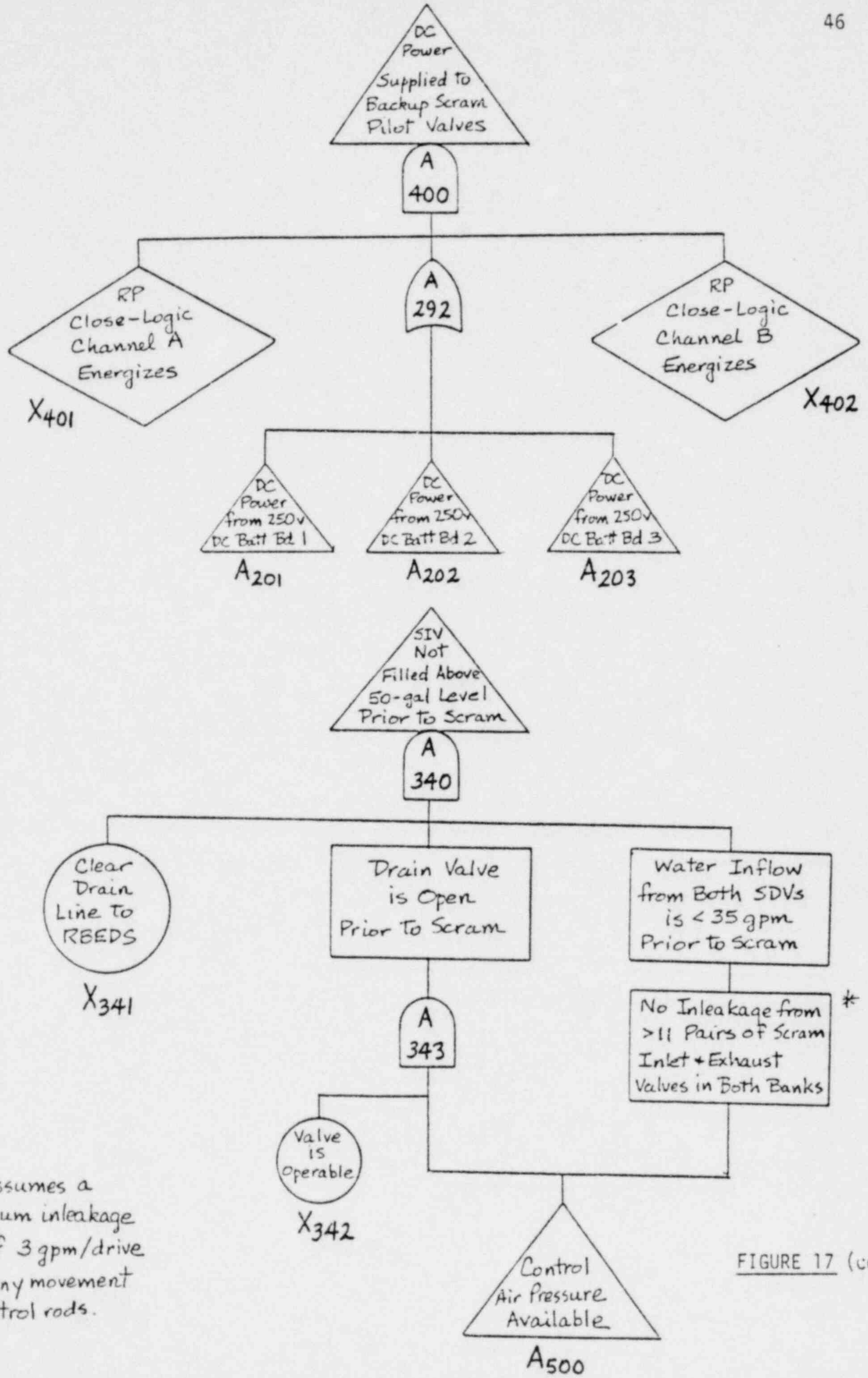

CRS Success (High Pressure)
Full Insertion of at Least 183 Control Rods
A 471
183/185 HCUs Operate
A_{491}
SDVs + SIV Function Properly
A 492
SIV Not Filled Above 50-gal level Prior To Scram
A_{340}
West Bank SDV Empty Prior to Scram
A_{350}
East Bank SDV Empty Prior to Scram
A_{360}
SIV Drain Valve Closes
A_{344}
West Bank SDV Vent Valve Closes
A_{355}
East Bank SDV Vent Valve Closes
A_{365}

FIGURE 17 (cont.)

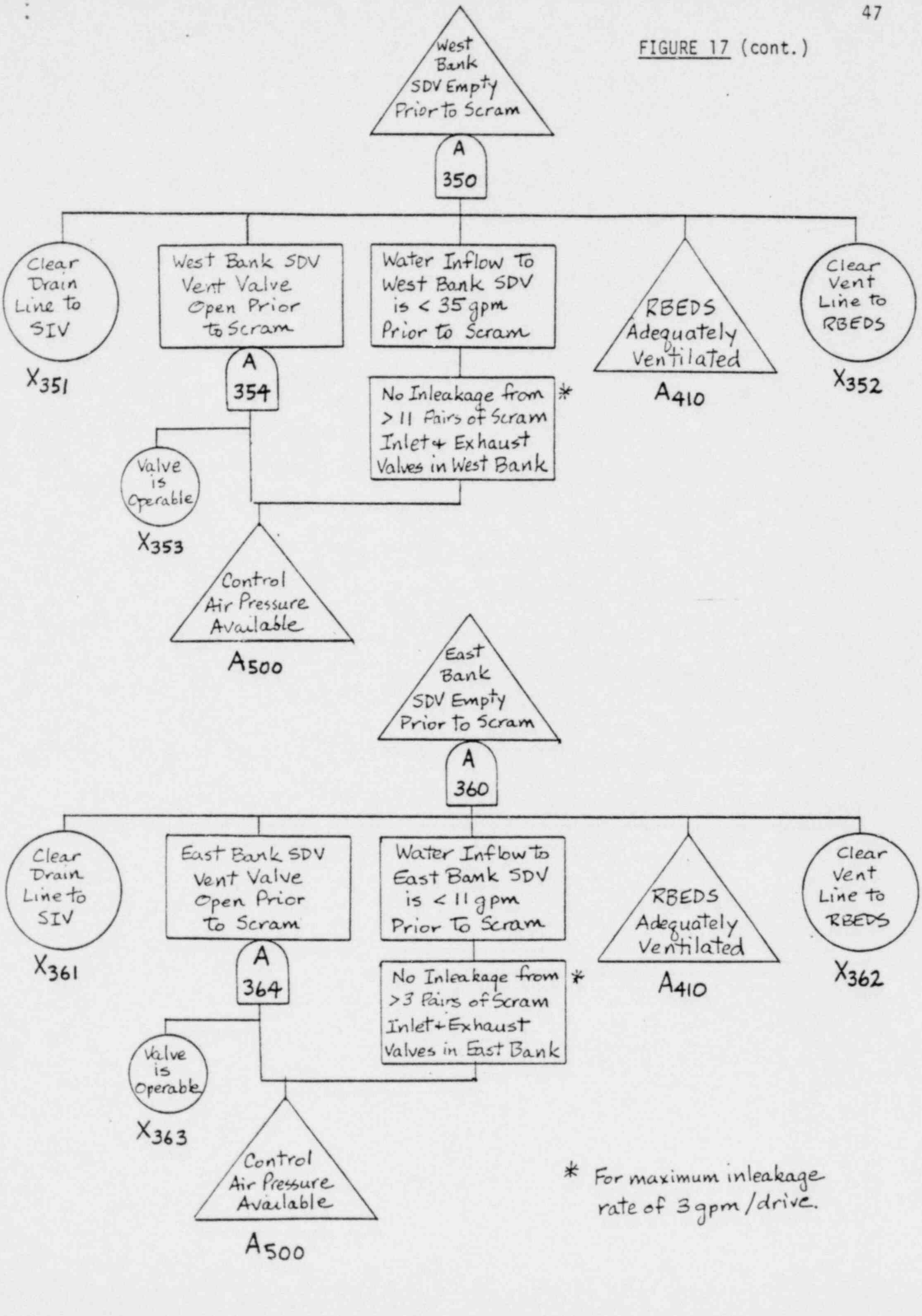




* This assumes a maximum inleakage rate of 3 gpm/drive before any movement of control rods.

FIGURE 17 (cont.)

FIGURE 17 (cont.)



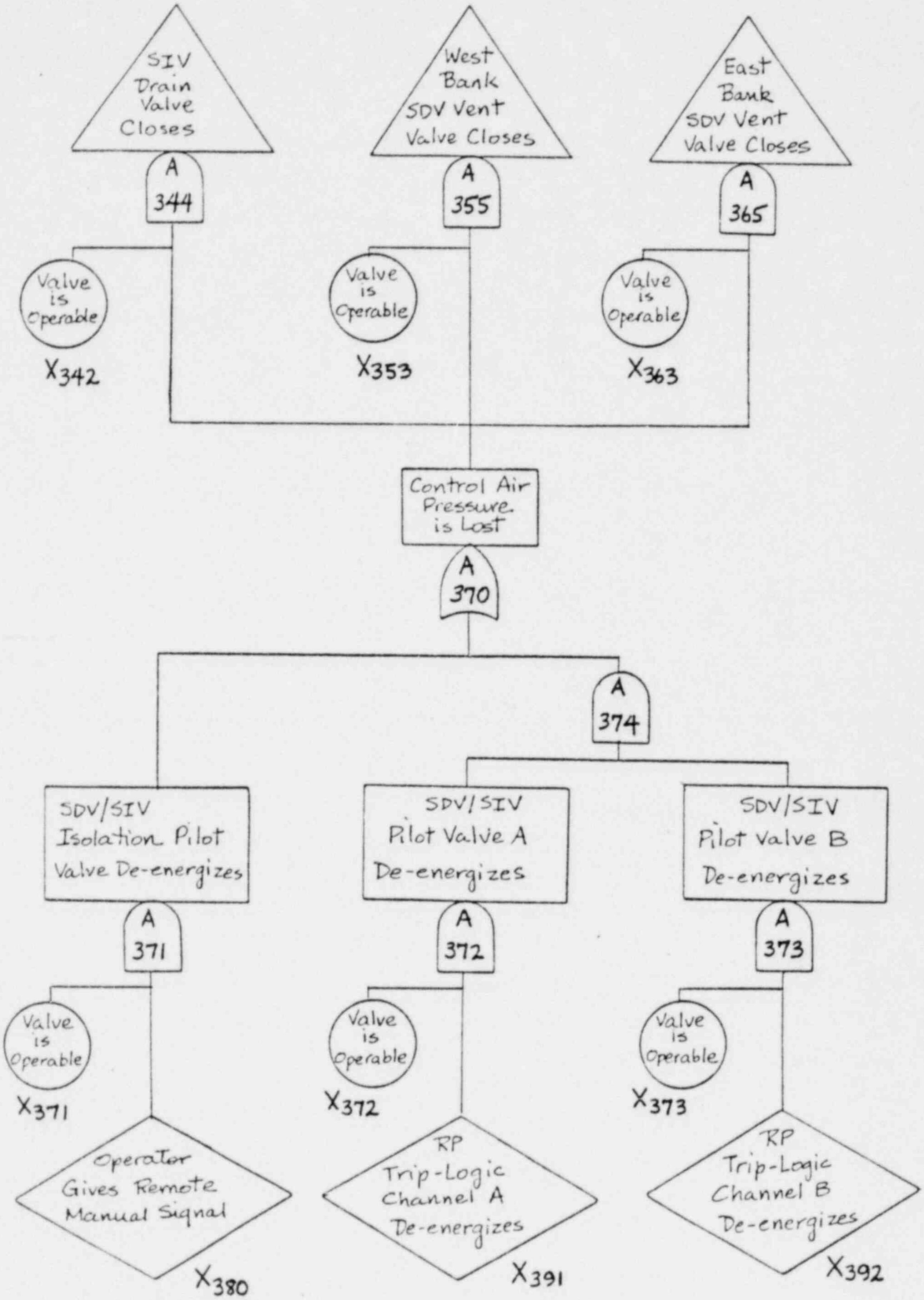


FIGURE 17 (cont.)

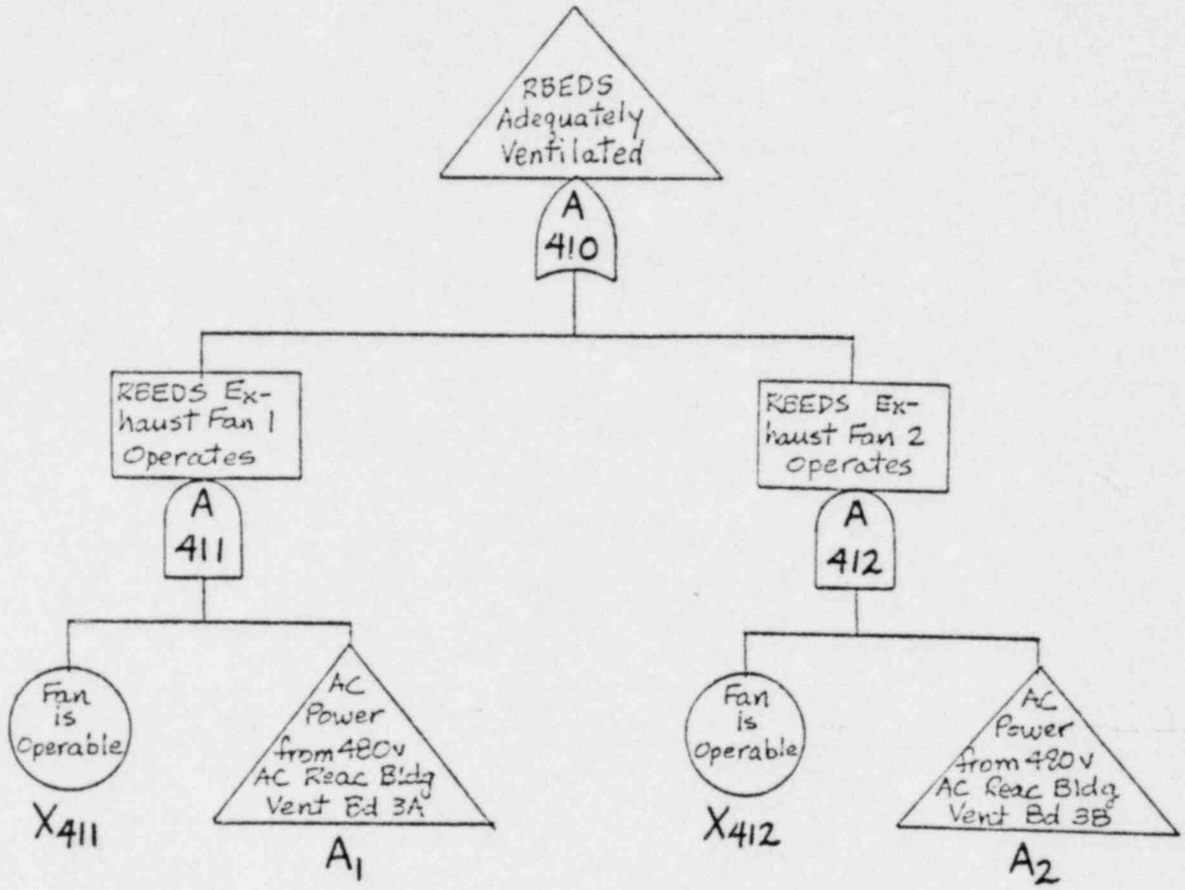

RBEDS
Adequately
Ventilated
A
410
RBEDS Exhaust Fan 1 Operates
A
411
RBEDS Exhaust Fan 2 Operates
A
412
Fan is Operable
X411
AC Power from 480v AC Reac Bldg Vent Bd 3A
A1
Fan is Operable
X412
AC Power from 480v AC Reac Bldg Vent Bd 3B
A2

FIGURE 18

This is an equivalent representation of the 2/4 success logic.

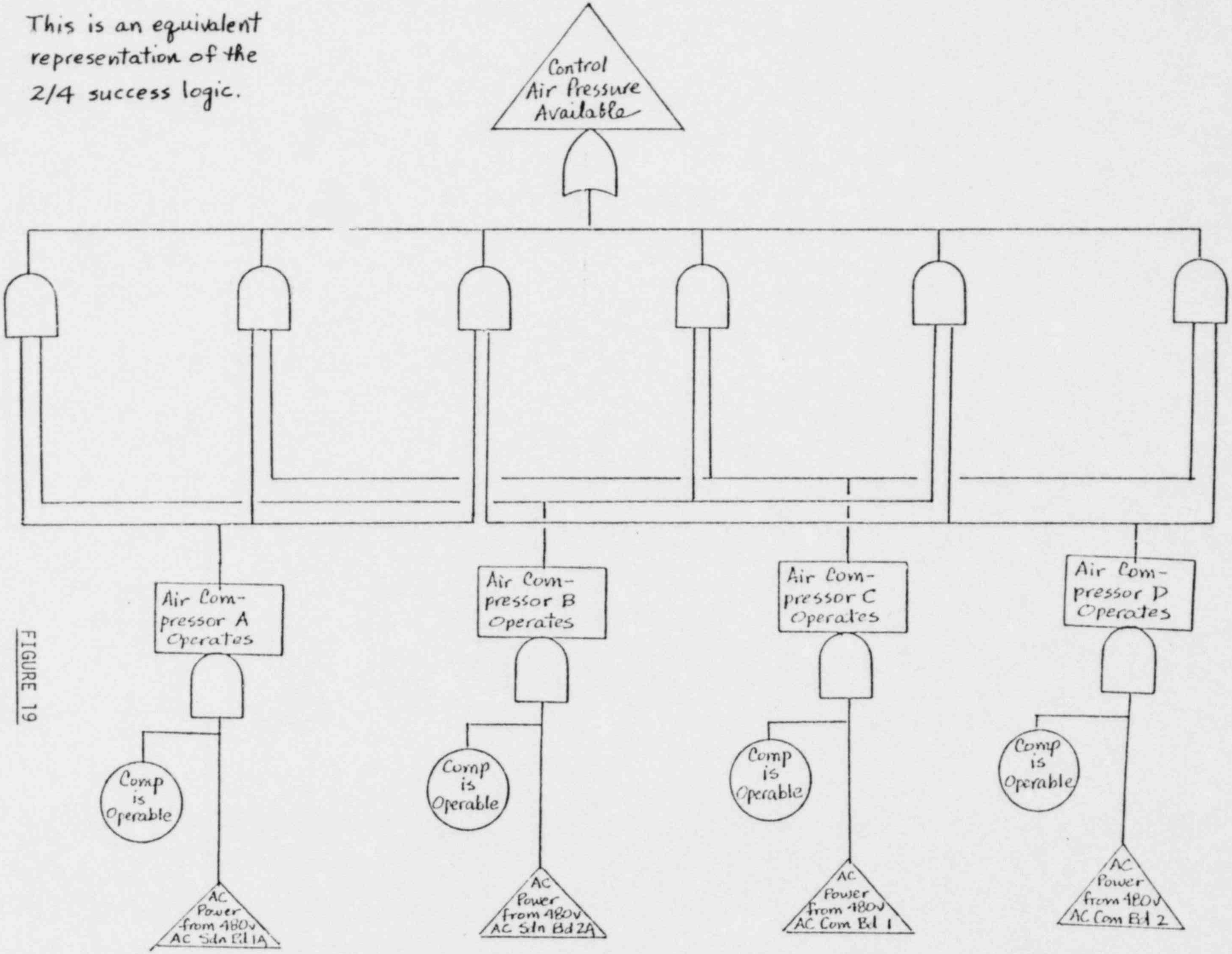


FIGURE 19

This is an equivalent representation of the 3/4 failure logic (the complement of the 2/4 success logic).

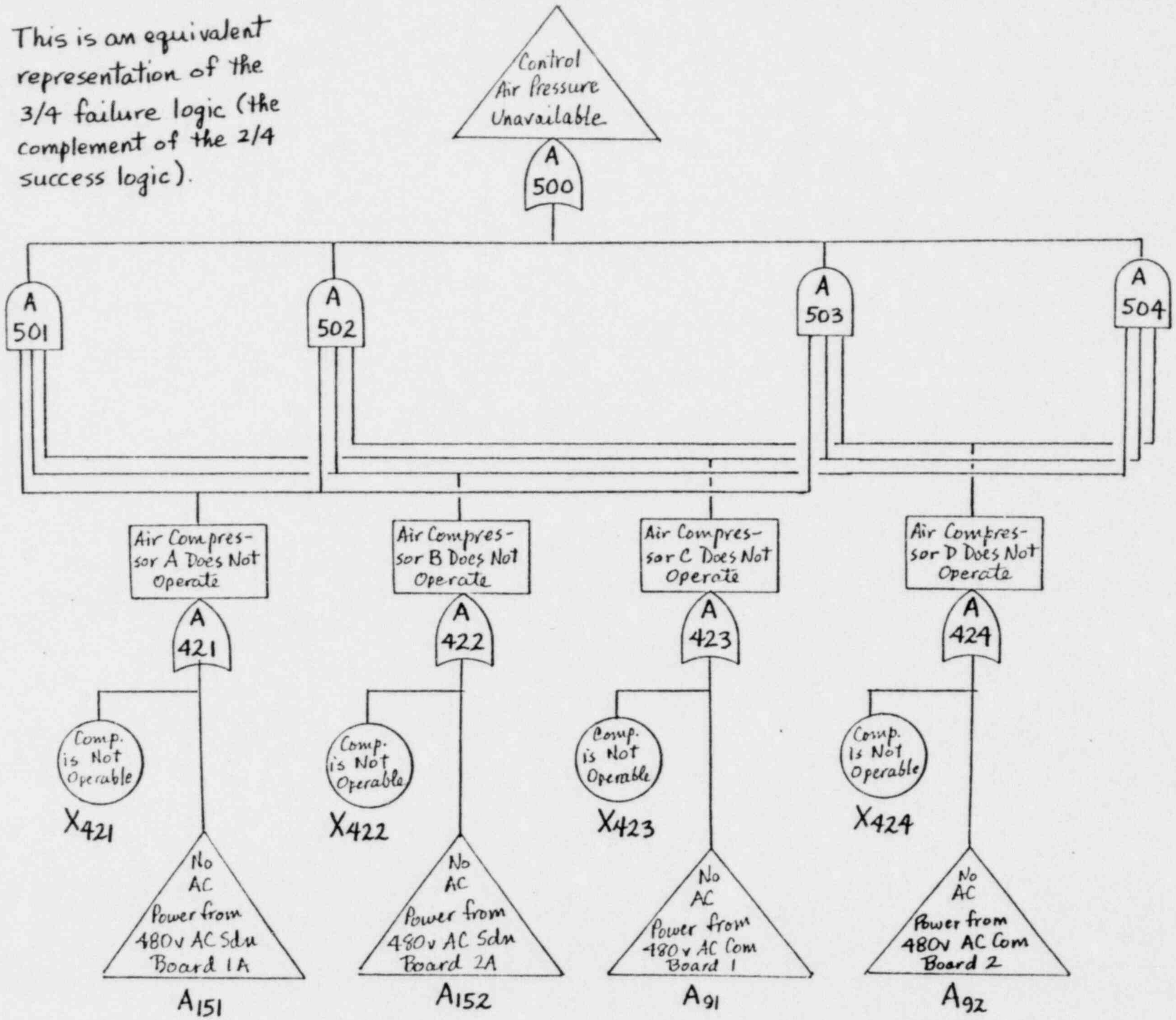


FIGURE 20

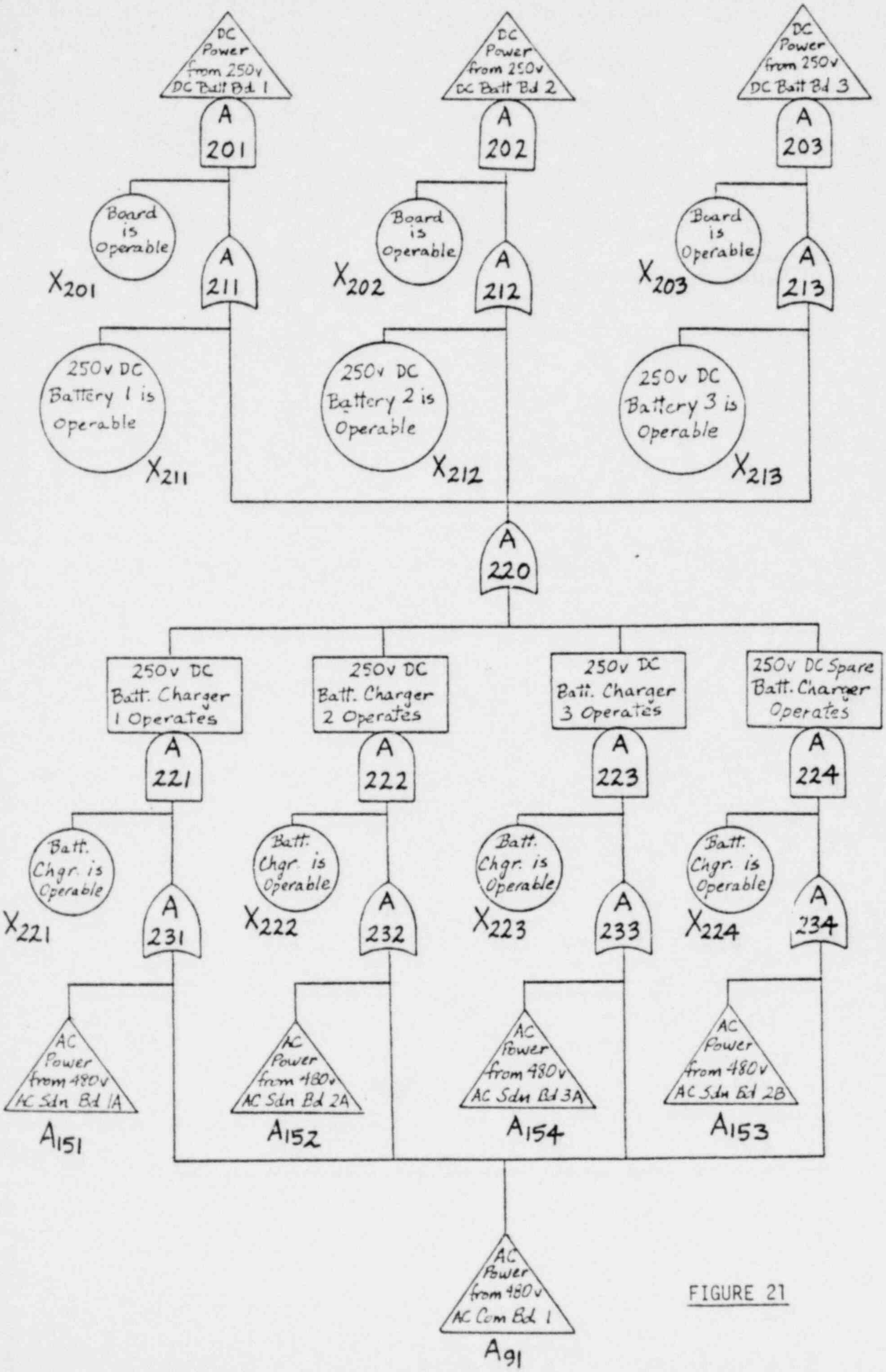

DC Power from 250v DC Batt Bd 1
DC Power from 250v DC Batt Bd 2
DC Power from 250v DC Batt Bd 3
A 201
A 202
A 203
Board is Operable
X201
Board is Operable
X202
Board is Operable
X203
A 211
A 212
A 213
250v DC Battery 1 is Operable
X211
250v DC Battery 2 is Operable
X212
250v DC Battery 3 is Operable
X213
A 220
250v DC Batt. Charger 1 Operates
250v DC Batt. Charger 2 Operates
250v DC Batt. Charger 3 Operates
250v DC Spare Batt. Charger Operates
A 221
A 222
A 223
A 224
Batt. Chgr. is Operable
X221
Batt. Chgr. is Operable
X222
Batt. Chgr. is Operable
X223
Batt. Chgr. is Operable
X224
A 231
A 232
A 233
A 234
AC Power from 480v AC Sdn Bd 1A
A151
AC Power from 480v AC Sdn Bd 2A
A152
AC Power from 480v AC Sdn Bd 3A
A154
AC Power from 480v AC Sdn Bd 2B
A153
AC Power from 480v AC Com Bd 1
A91

FIGURE 21

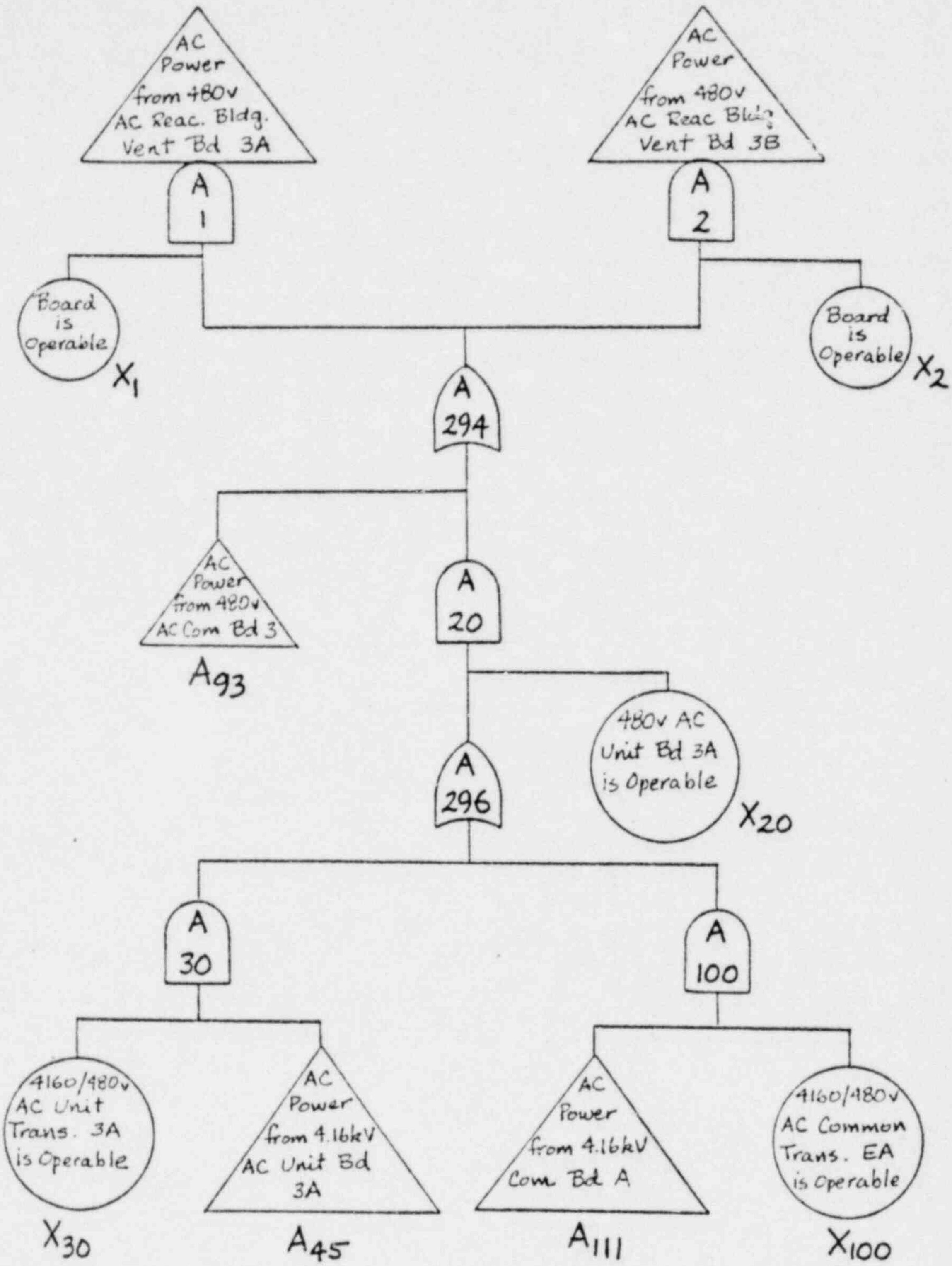
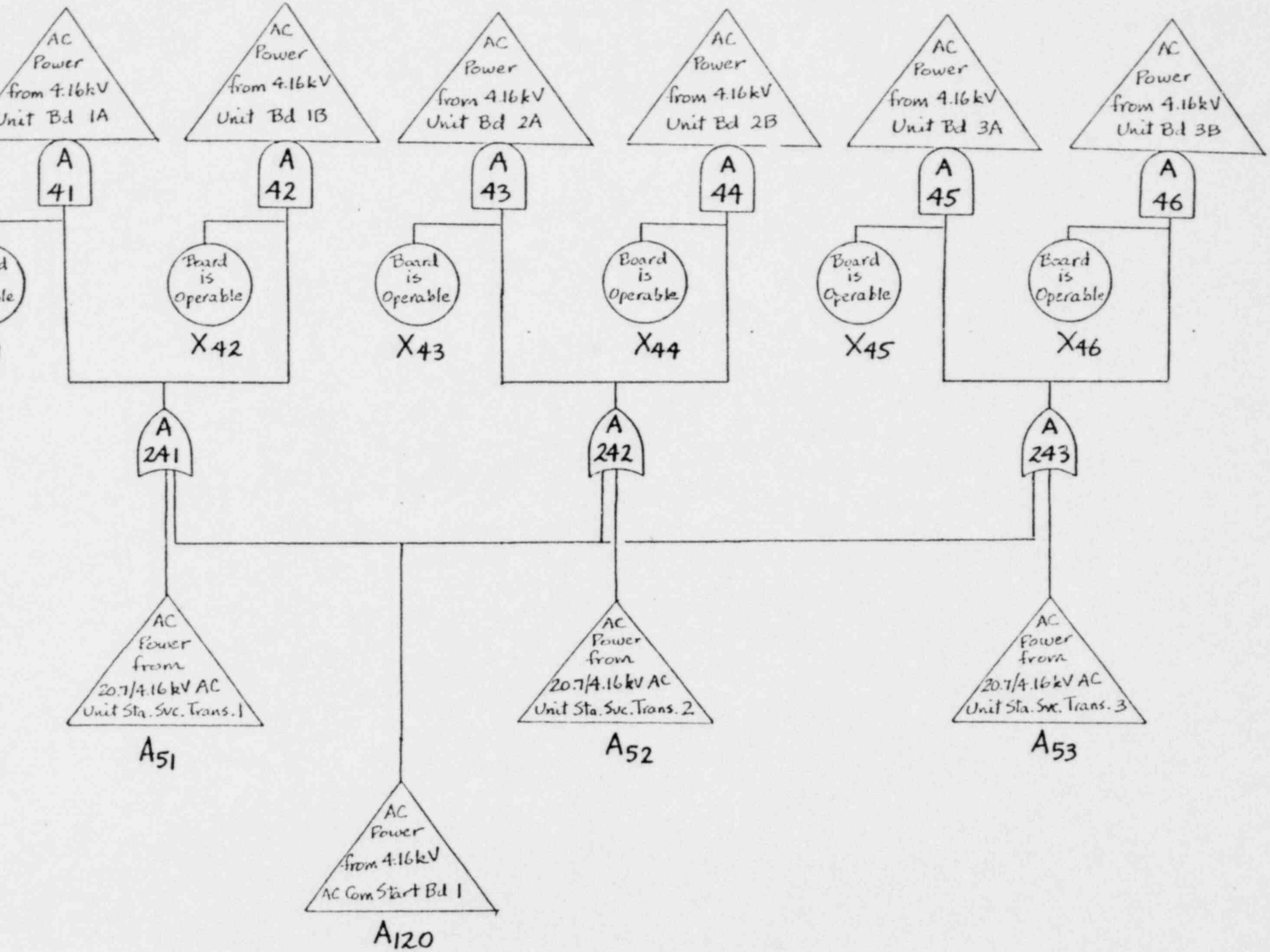

AC Power from 480v AC Reac. Bldg. Vent Bd 3A
AC Power from 480v AC Reac Bldg Vent Bd 3B
A 1
A 2
Board is Operable
X1
Board is Operable
X2
A 294
AC Power from 480v AC Com Bd 3
A93
A 20
480v AC Unit Bd 3A is Operable
X20
A 296
A 30
A 100
4160/480v AC Unit Trans. 3A is Operable
X30
AC Power from 4.16kV AC Unit Bd 3A
A45
AC Power from 4.16kV Com. Bd A
A111
4160/480v AC Common Trans. EA is Operable
X100

FIGURE 22



AC Power from 4.16kV Unit Bd 1A
AC Power from 4.16kV Unit Bd 1B
AC Power from 4.16kV Unit Bd 2A
AC Power from 4.16kV Unit Bd 2B
AC Power from 4.16kV Unit Bd 3A
AC Power from 4.16kV Unit Bd 3B
A 41
A 42
A 43
A 44
A 45
A 46
Board is Operable
Board is Operable
Board is Operable
Board is Operable
Board is Operable
Board is Operable
X41
X42
X43
X44
X45
X46
A 241
A 242
A 243
AC Power from 20.7/4.16kV AC Unit Sta. Svc. Trans. 1
AC Power from 20.7/4.16kV AC Unit Sta. Svc. Trans. 2
AC Power from 20.7/4.16kV AC Unit Sta. Svc. Trans. 3
A51
A52
A53
AC Power from 4.16kV AC Com Start Bd 1
A120

FIGURE 23

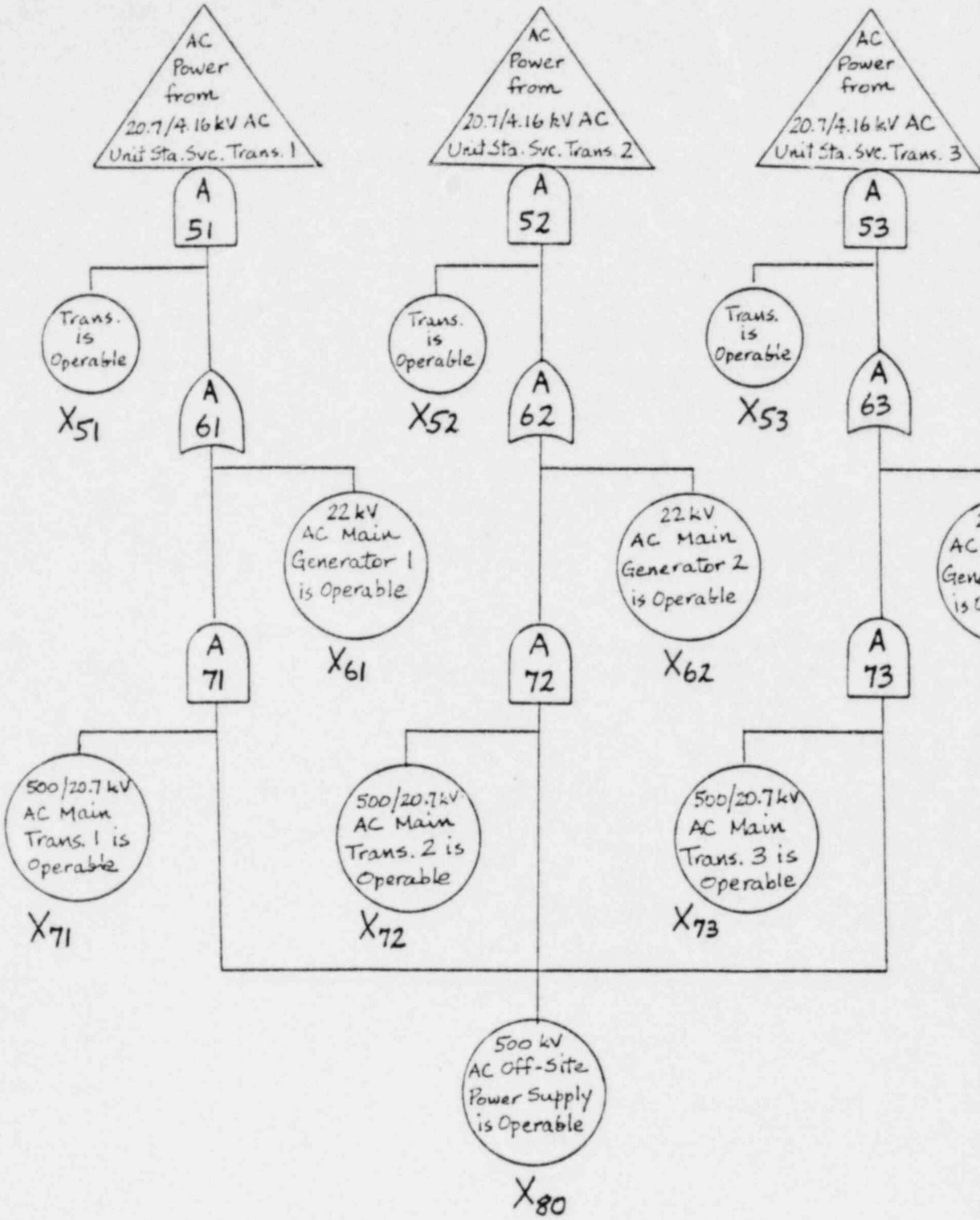


FIGURE 23 (cont.)

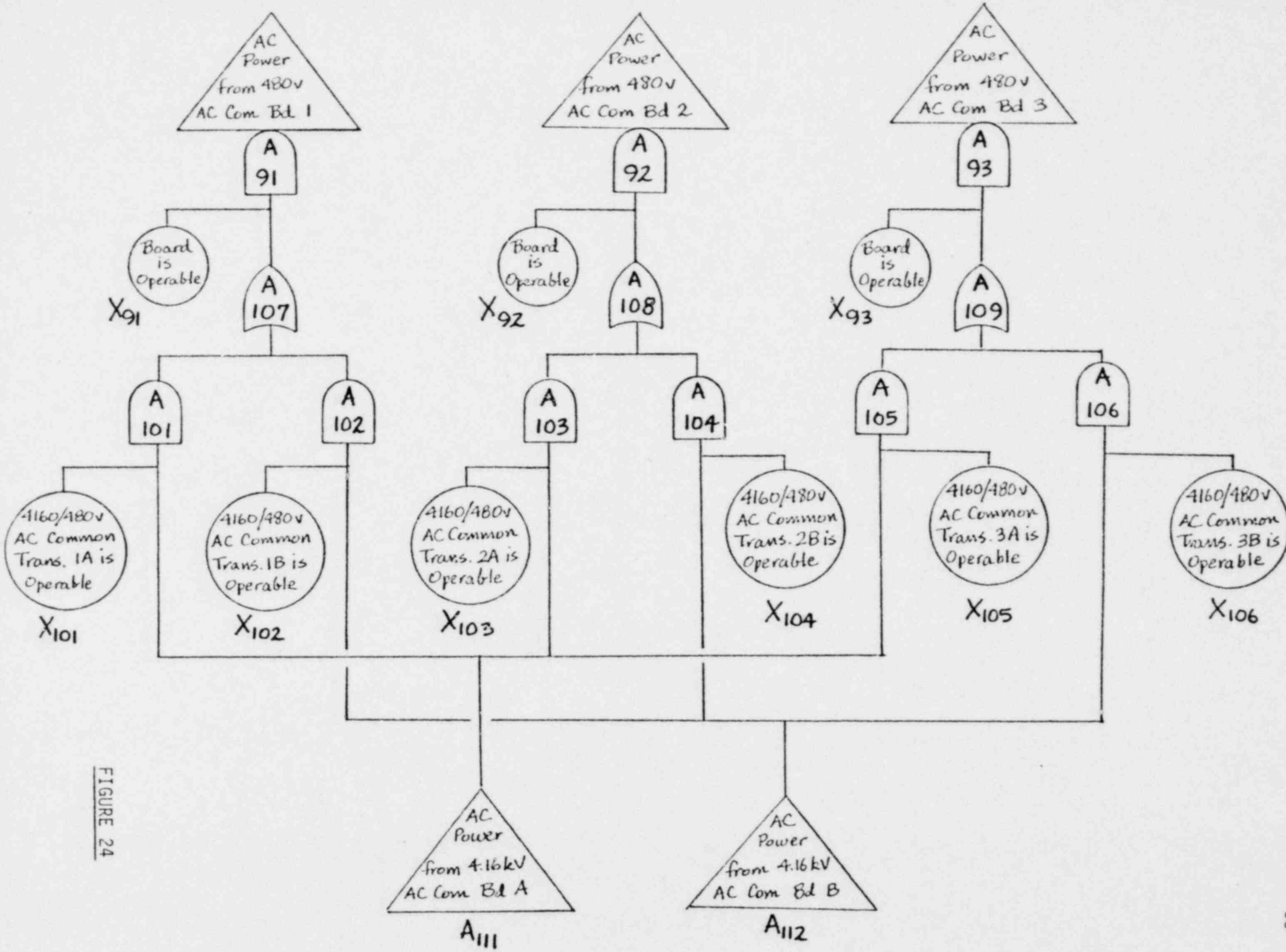

AC Power from 480v AC Com Bd 1
A 91
Board is Operable
X91
A 107
AC Power from 480v AC Com Bd 2
A 92
Board is Operable
X92
A 108
AC Power from 480v AC Com Bd 3
A 93
Board is Operable
X93
A 109
A 101
A 102
A 103
A 104
A 105
A 106
4160/480v AC Common Trans. 1A is Operable
X101
4160/480v AC Common Trans. 1B is Operable
X102
4160/480v AC Common Trans. 2A is Operable
X103
4160/480v AC Common Trans. 2B is Operable
X104
4160/480v AC Common Trans. 3A is Operable
X105
4160/480v AC Common Trans. 3B is Operable
X106
AC Power from 4.16kV AC Com Bd A
A111
AC Power from 4.16kV AC Com Bd B
A112

FIGURE 24

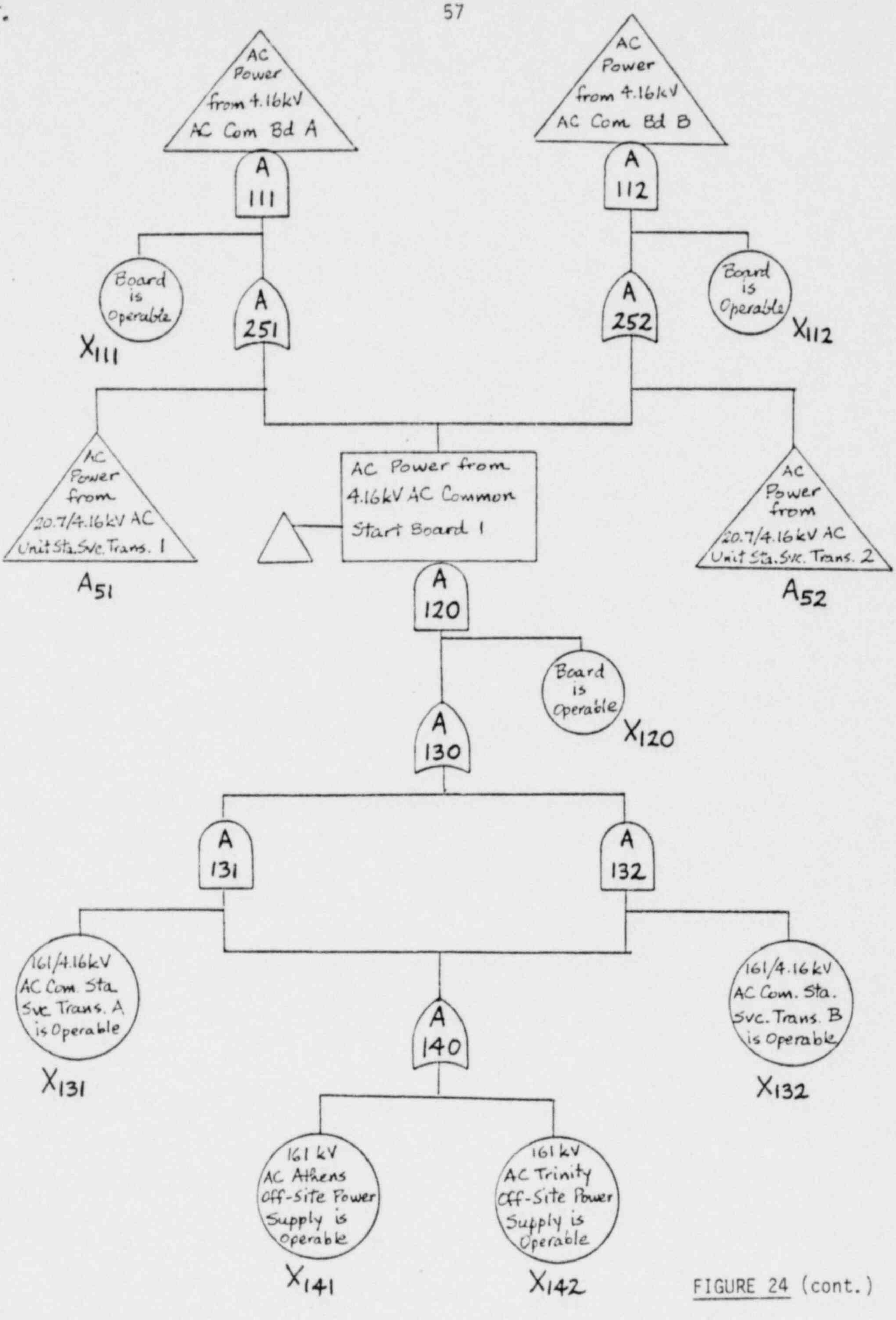


FIGURE 24 (cont.)

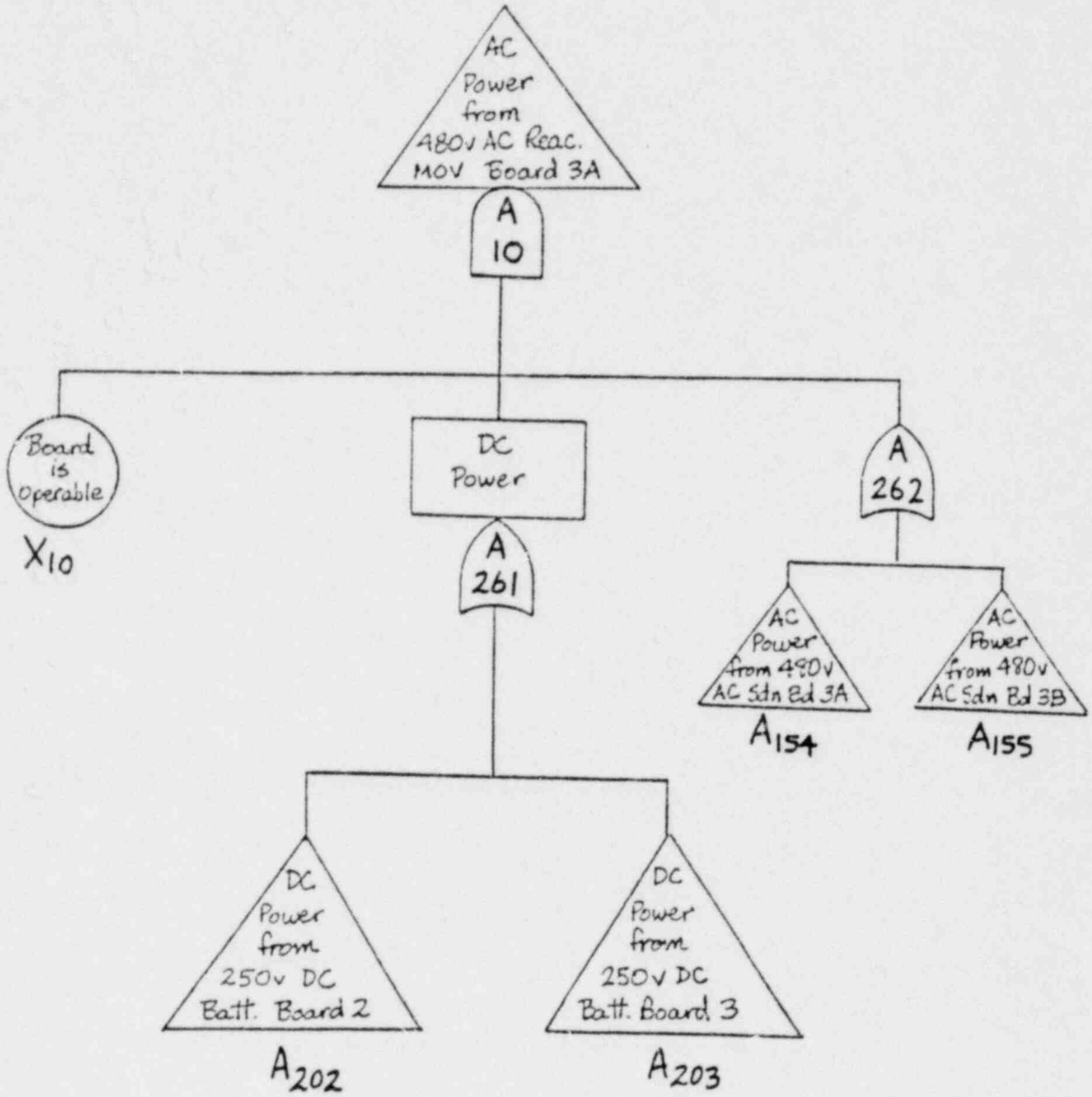

AC
Power
from
480v AC Reac.
MOV Board 3A
A
10
Board
is
Operable
X10
DC
Power
A
261
A
262
AC
Power
from 480v
AC Sdn Bd 3A
A154
AC
Power
from 480v
AC Sdn Bd 3B
A155
DC
Power
from
250v DC
Batt. Board 2
A202
DC
Power
from
250v DC
Batt. Board 3
A203

FIGURE 25

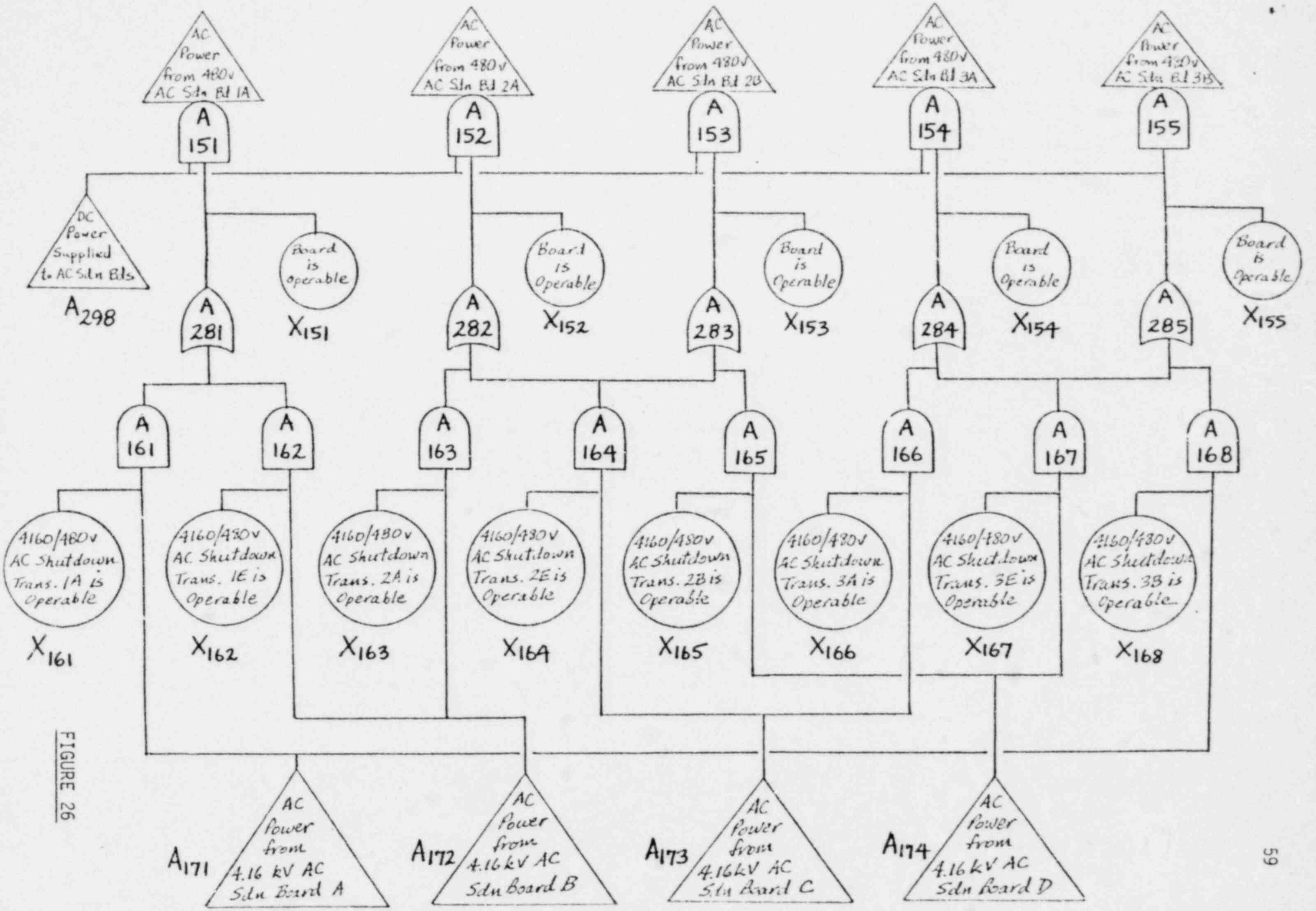

AC Power from 480v AC Sdn Bd 1A
A 151
AC Power from 480v AC Sdn Bd 2A
A 152
AC Power from 480v AC Sdn Bd 2B
A 153
AC Power from 480v AC Sdn Bd 3A
A 154
AC Power from 480v AC Sdn Bd 3B
A 155
DC Power Supplied to AC Sdn Bds
A298
Board is Operable
X151
A 281
Board is Operable
X152
A 282
Board is Operable
X153
A 283
Board is Operable
X154
A 284
Board is Operable
X155
A 285
A 161
A 162
A 163
A 164
A 165
A 166
A 167
A 168
4160/480v AC Shutdown Trans. 1A is Operable
X161
4160/480v AC Shutdown Trans. 1E is Operable
X162
4160/480v AC Shutdown Trans. 2A is Operable
X163
4160/480v AC Shutdown Trans. 2E is Operable
X164
4160/480v AC Shutdown Trans. 2B is Operable
X165
4160/480v AC Shutdown Trans. 3A is Operable
X166
4160/480v AC Shutdown Trans. 3E is Operable
X167
4160/480v AC Shutdown Trans. 3B is Operable
X168
A171
AC Power from 4.16 kV AC Sdn Board A
A172
AC Power from 4.16 kV AC Sdn Board B
A173
AC Power from 4.16 kV AC Sdn Board C
A174
AC Power from 4.16 kV AC Sdn Board D

FIGURE 26

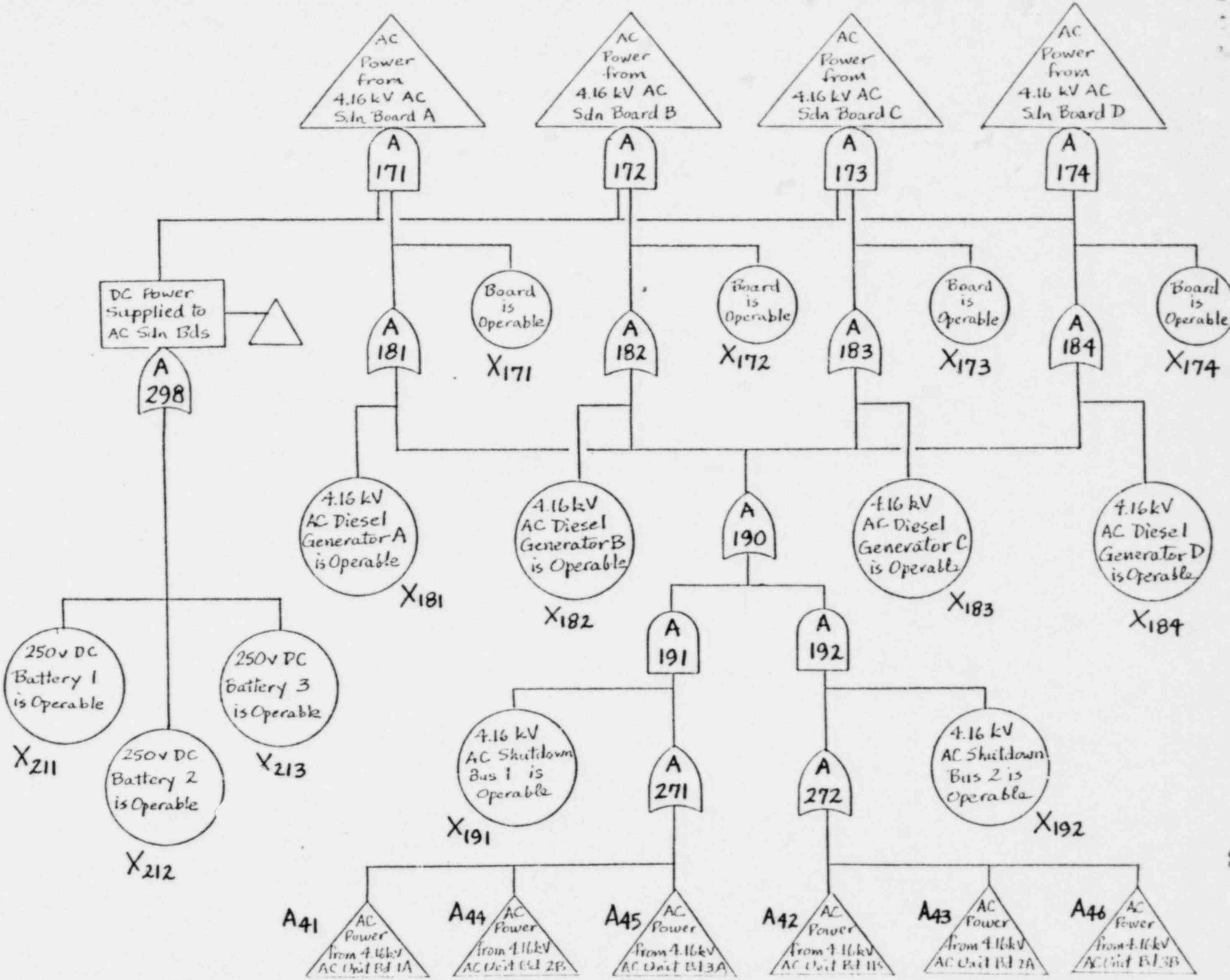

AC Power from 4.16 kV AC S.dn Board A
AC Power from 4.16 kV AC Sdn Board B
AC Power from 4.16 kV AC Sdn Board C
AC Power from 4.16 kV AC S.dn Board D
A 171
A 172
A 173
A 174
DC Power Supplied to AC S.dn Bds
A 298
A 181
A 182
A 183
A 184
Board is Operable
X171
X172
X173
X174
4.16 kV AC Diesel Generator A is Operable
X181
4.16 kV AC Diesel Generator B is Operable
X182
4.16 kV AC Diesel Generator C is Operable
X183
4.16 kV AC Diesel Generator D is Operable
X184
A 190
A 191
A 192
250v DC Battery 1 is Operable
X211
250v DC Battery 2 is Operable
X212
250v DC Battery 3 is Operable
X213
4.16 kV AC Shutdown Bus 1 is Operable
X191
4.16 kV AC Shutdown Bus 2 is Operable
X192
A 271
A 272
A41 AC Power from 4.16 kV AC Unit Bd 1A
A44 AC Power from 4.16 kV AC Unit Bd 2B
A45 AC Power from 4.16 kV AC Unit Bd 3A
A42 AC Power from 4.16 kV AC Unit Bd 1B
A43 AC Power from 4.16 kV AC Unit Bd 2A
A46 AC Power from 4.16 kV AC Unit Bd 3B

FIG. 26 (cont)

TABLE 9. – MINIMAL CUT SETS FOR STANDBY LIQUID CONTROL

1-ELEMENT

None

4-ELEMENT

None

2-ELEMENT

CUT SET

441	442
202	203
431	432
154	432
155	431
154	155
451	452
10	451

5-ELEMENT

CUT SET

167	183	191	192	432
174	183	191	192	432
166	184	191	192	432
173	184	191	192	432
183	184	191	192	432
155	167	183	191	192
155	174	183	191	192
155	166	184	191	192
155	173	184	191	192
155	183	184	191	192
167	168	183	191	192
168	174	183	191	192
167	171	183	191	192
171	174	183	191	192
168	184	191	192	431
154	168	184	191	192
166	168	184	191	192
168	173	184	191	192
168	183	184	191	192
171	184	191	192	431
154	171	184	191	192
166	171	184	191	192
171	173	184	191	192
171	183	184	191	192
167	181	191	192	431
154	167	181	191	192
166	167	181	191	192
167	173	181	191	192
167	181	183	191	192
174	181	191	192	431
154	174	181	191	192
166	174	181	191	192
173	174	181	191	192
174	181	183	191	192
181	184	191	192	431
154	181	184	191	192
166	181	184	191	192
173	181	184	191	192
181	183	184	191	192

3-ELEMENT

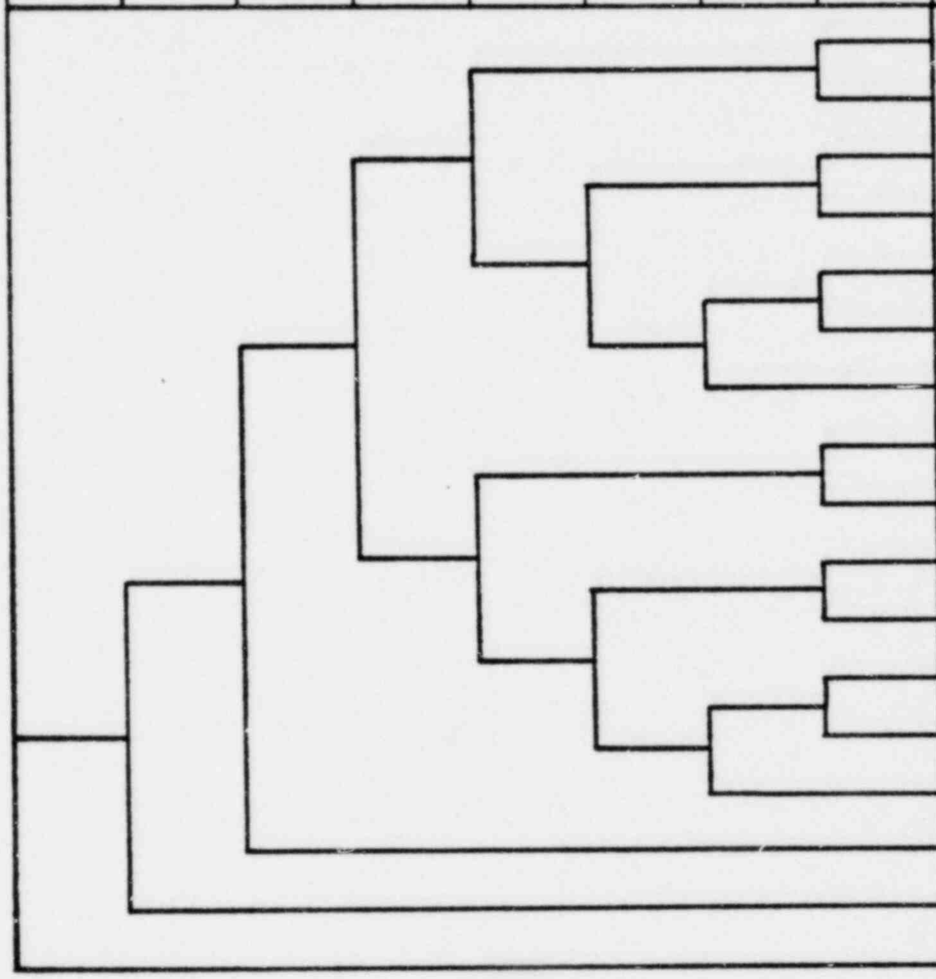
CUT SET

211	212	213
166	167	432
167	173	432
166	174	432
173	174	432
155	166	167
155	167	173
155	166	174
155	173	174
167	168	431
154	167	168
166	167	168
167	168	173
168	174	431
154	168	174
166	168	174
168	173	174
167	171	431
154	167	171
166	167	171
167	171	173
171	174	431
154	171	174
166	171	174
171	173	174

Note: Cut set elements correspond to "X" labels for components in Figures 16-26.

Lawrence Livermore

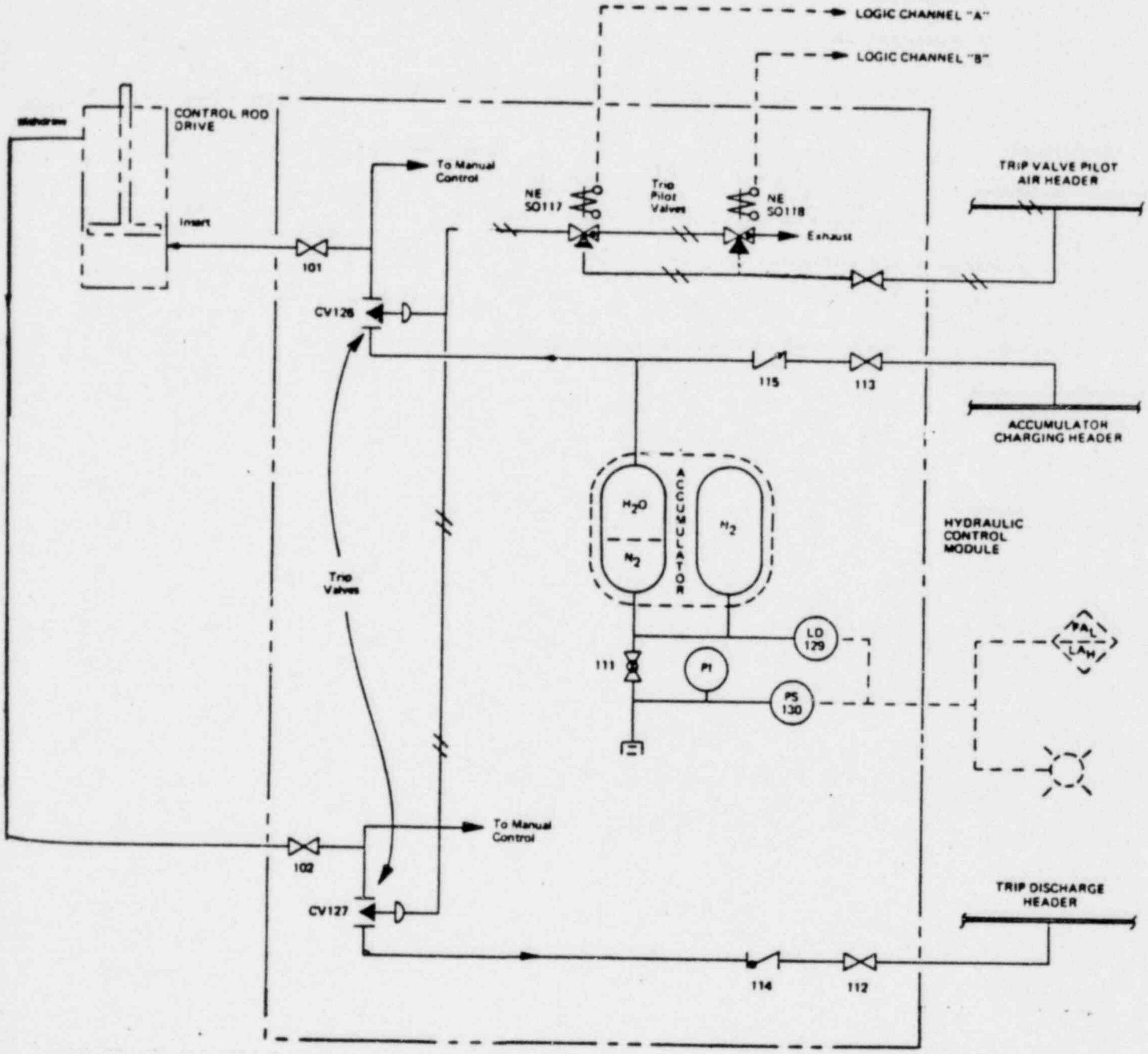
AT	RS	S/R VO	S/R VR	FW	HPCI or RCIC	LP ECCS	RHR & HPSW or PCS
T	C	M	P	Q	U	V	W



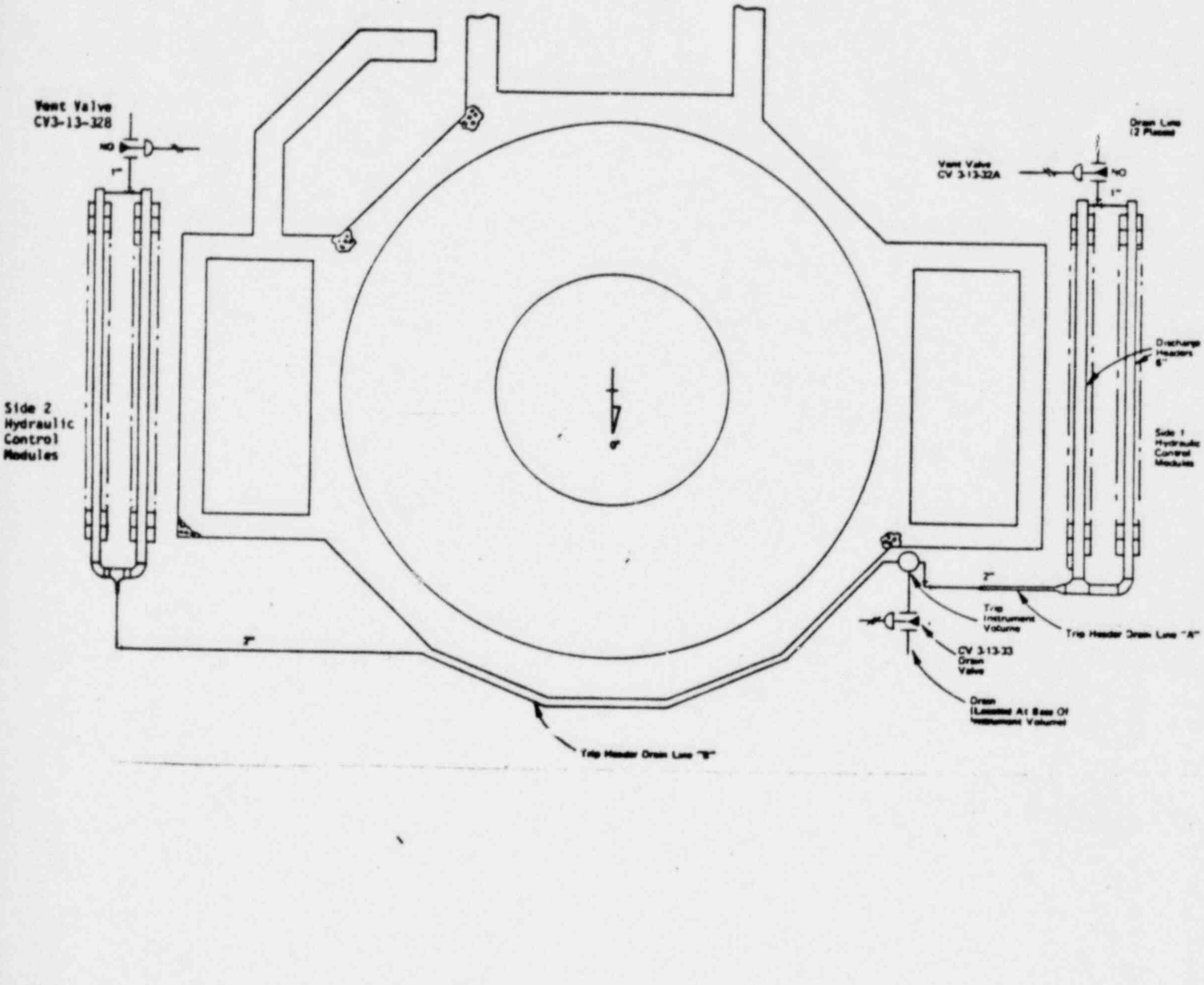
SEQUENCE	CORE DEGRADATION
1. T	NO
2. TW	YES
3. TQ	NO
4. TQW	YES
5. TQU	NO
6. TQUW	YES
7. TQUV	YES
8. TP	NO
9. TPW	YES
10. TPQ	NO
11. TPQW	YES
12. TPQU	NO
13. TPQUW	YES
14. TPQUV	YES
15. TM	YES
16. TC	YES

BWR TRANSIENT EVENT TREE (Wash 1400)

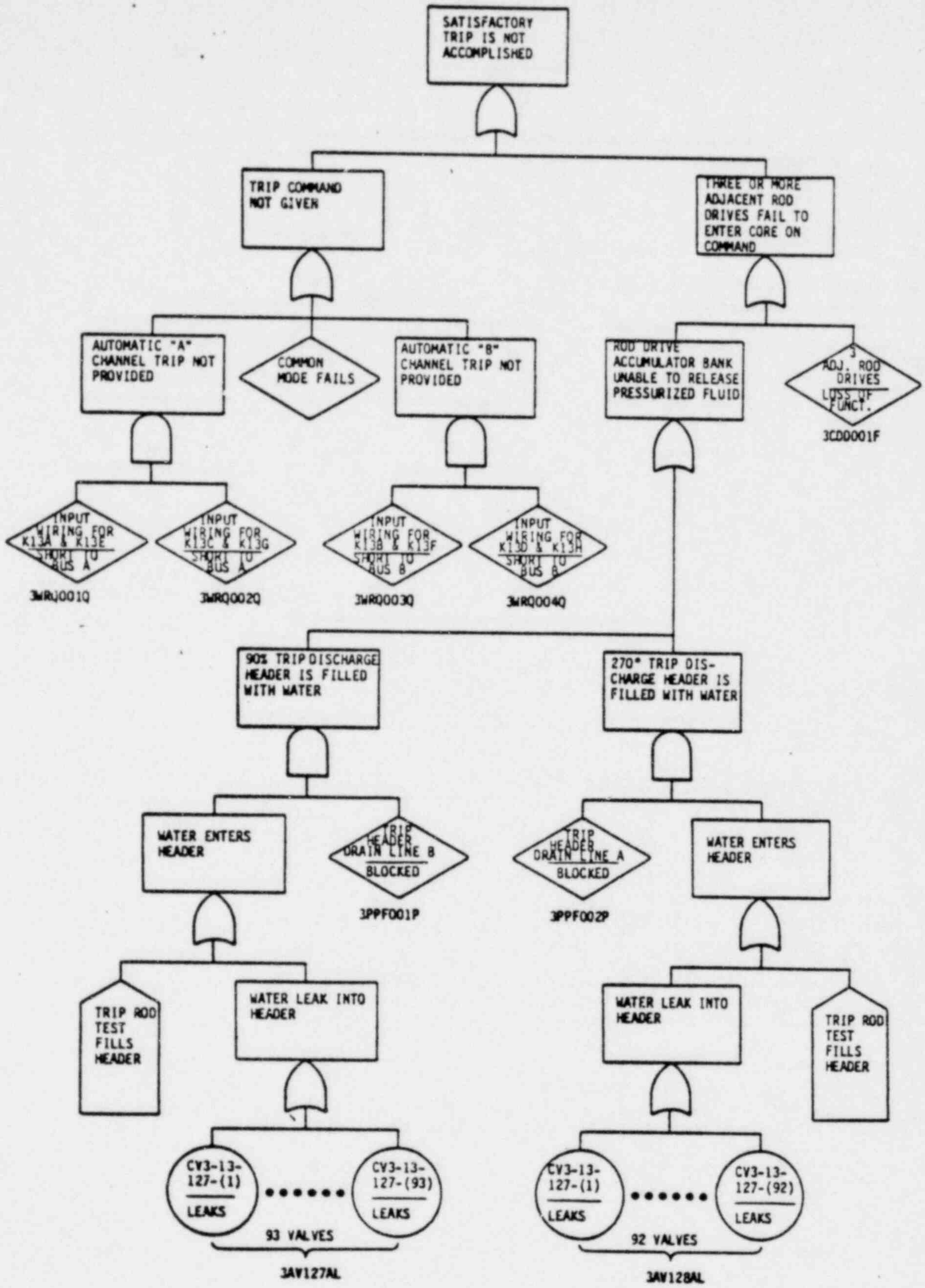
Brown's Ferry Failure to Scram



REACTOR PROTECTION SYSTEM CONTROL ROD DRIVE HYDRAULIC SCHEMATIC



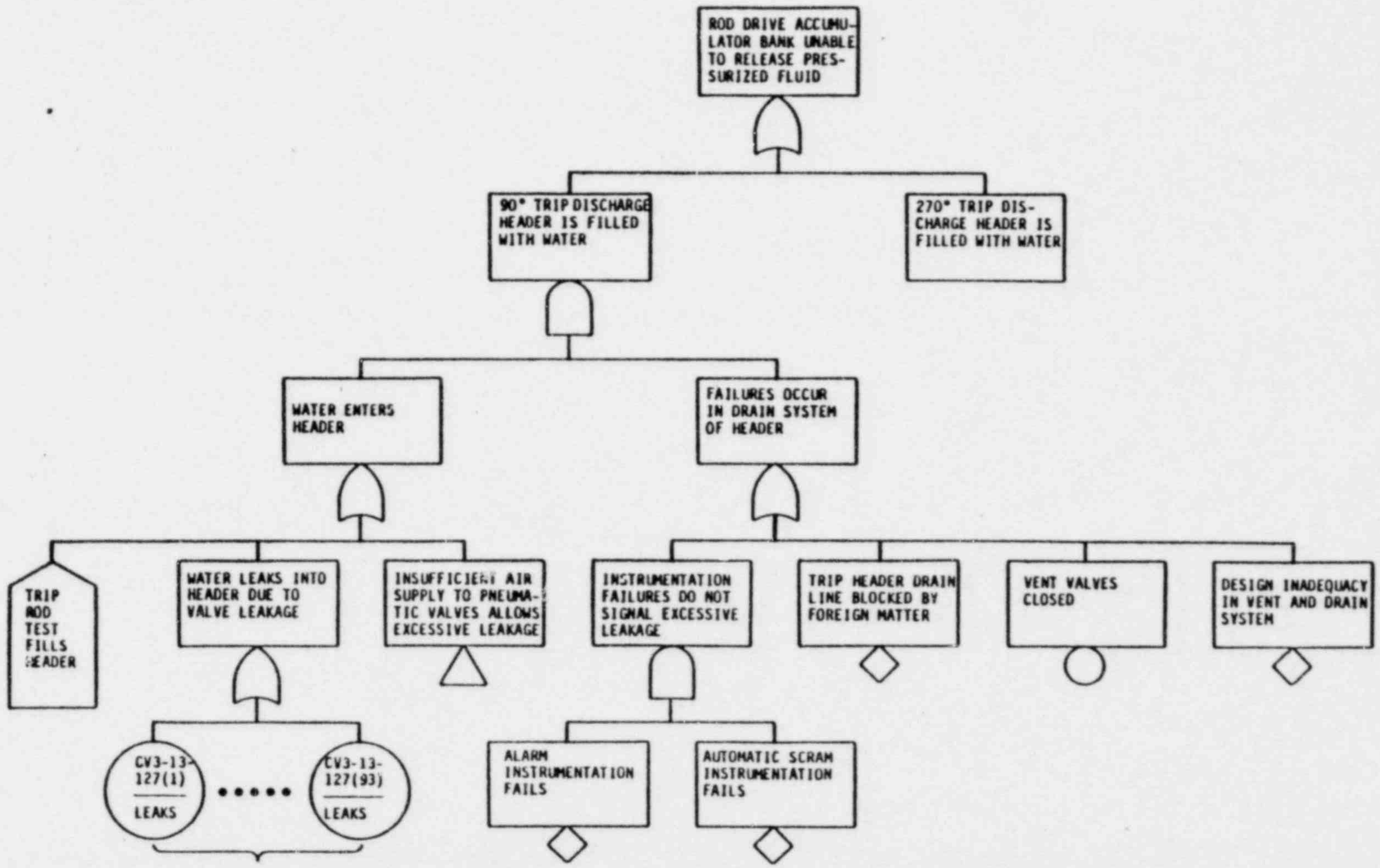
REACTOR PROTECTION SYSTEM TRIP DISCHARGE HEADERS



REACTOR PROTECTION SYSTEM REDUCED FAULT TREE

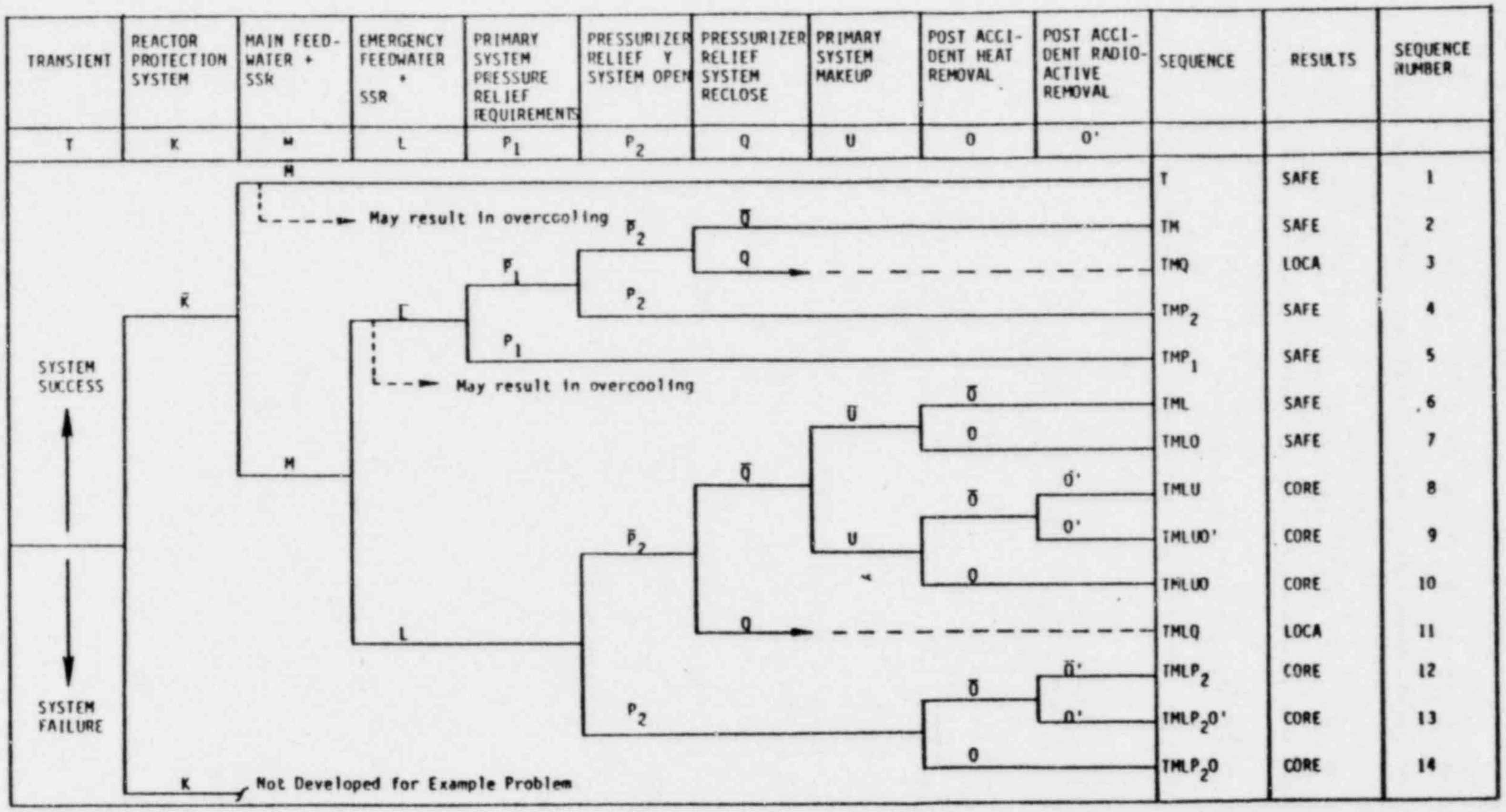
REACTOR PROTECTION SYSTEM

COMPONENT	AC POWER	DC POWER	SERVICE WATER	I&C	HVAC	COMPONENT COOLING	HUMAN ERROR MAINTENANCE	HUMAN ERROR OPERATIVE	ACTUATION SYSTEM	OTHER
Discharge Header							X			
Vent Valve										
Intake Valves							X			
Exhaust Valves										X
Drain Line							X			
Instrumentation Volume										
Alarm Level Sensor										X
Autoscram Level Sensor										X

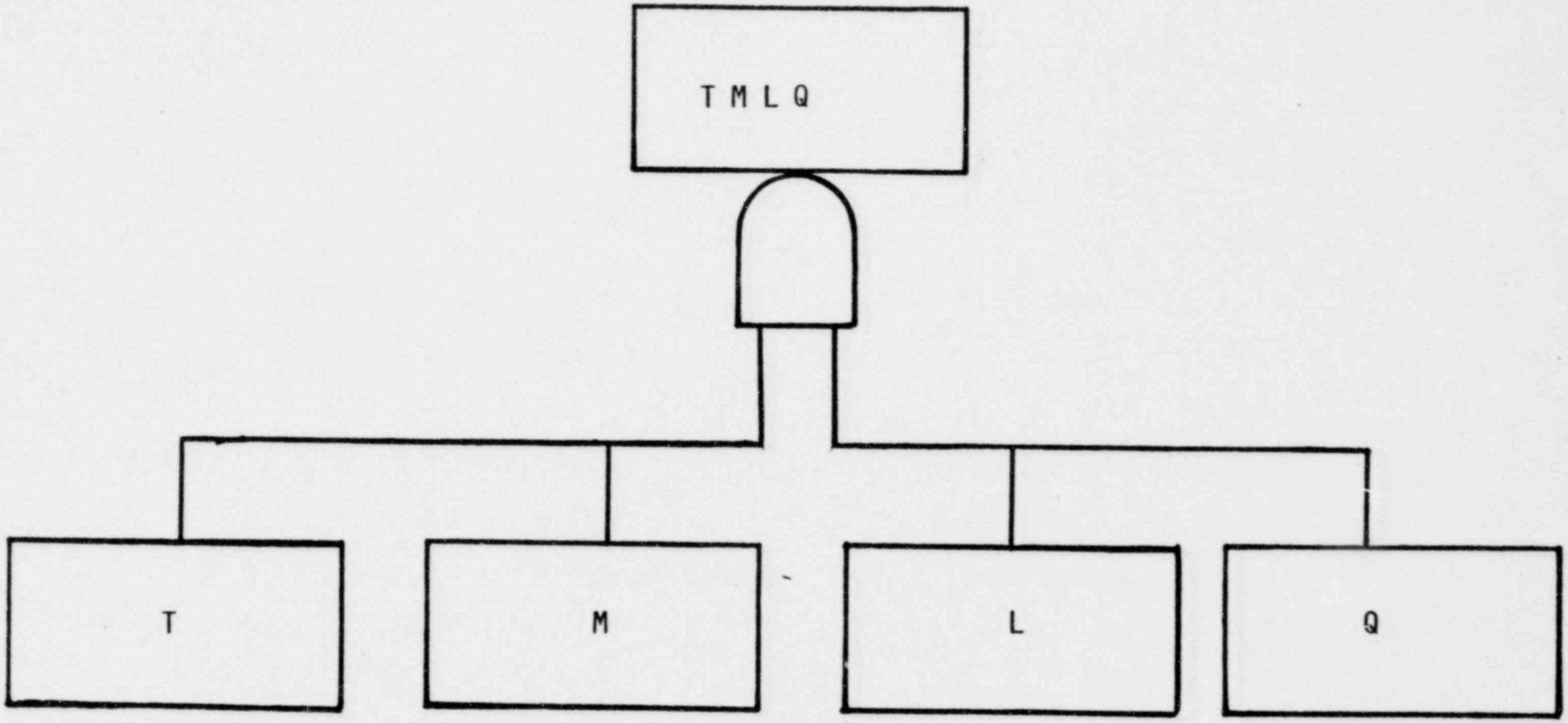

ROD DRIVE ACCUMULATOR BANK UNABLE TO RELEASE PRESSURIZED FLUID
90° TRIP DISCHARGE HEADER IS FILLED WITH WATER
270° TRIP DISCHARGE HEADER IS FILLED WITH WATER
WATER ENTERS HEADER
FAILURES OCCUR IN DRAIN SYSTEM OF HEADER
TRIP ROD TEST FILLS HEADER
WATER LEAKS INTO HEADER DUE TO VALVE LEAKAGE
INSUFFICIENT AIR SUPPLY TO PNEUMATIC VALVES ALLOWS EXCESSIVE LEAKAGE
INSTRUMENTATION FAILURES DO NOT SIGNAL EXCESSIVE LEAKAGE
TRIP HEADER DRAIN LINE BLOCKED BY FOREIGN MATTER
VENT VALVES CLOSED
DESIGN INADEQUACY IN VENT AND DRAIN SYSTEM
CV3-13-127(1) LEAKS
CV3-13-127(93) LEAKS
ALARM INSTRUMENTATION FAILS
AUTOMATIC SCRAM INSTRUMENTATION FAILS

CRYSTAL RIVER UNIT 3

1. LOSS OF NNIX BUS
2. PORV OPEN
3. REACTOR/TURBINE/GENERATOR TRIP ON HIGH PRESSURE IN RCS
4. SIGNALS INDICATED NEED FOR MORE HPI FLOW
5. HIGH LEVEL ALARM IN DRAIN TANK (INDICATES OPEN PORV)
6. HPI ACTUATED
7. PORV BLOCK VALVE CLOSED
8. "A" STEAM GENERATOR DRY; "B" STEAM GENERATOR INDICATES SOME LEVEL
9. MFW PUMP A TRIPS
10. EMERGENCY FEEDWATER PUMP STARTED
11. CODE SAFETY VALVE (RCV-8) OPENS
12. FEEDWATER SUPPLY TO B STEAM GENERATOR WAS SHUT OFF
13. NNI "X" POWER SUPPLY RESTORED
14. LETDOWN FROM RCS ESTABLISHED
15. MFW PUMP 3B TRIP; TURBINE DRIVEN EFW PUMP STARTED
16. HPI TERMINATED
17. TURBINE DRIVEN EFW PUMP STOPPED

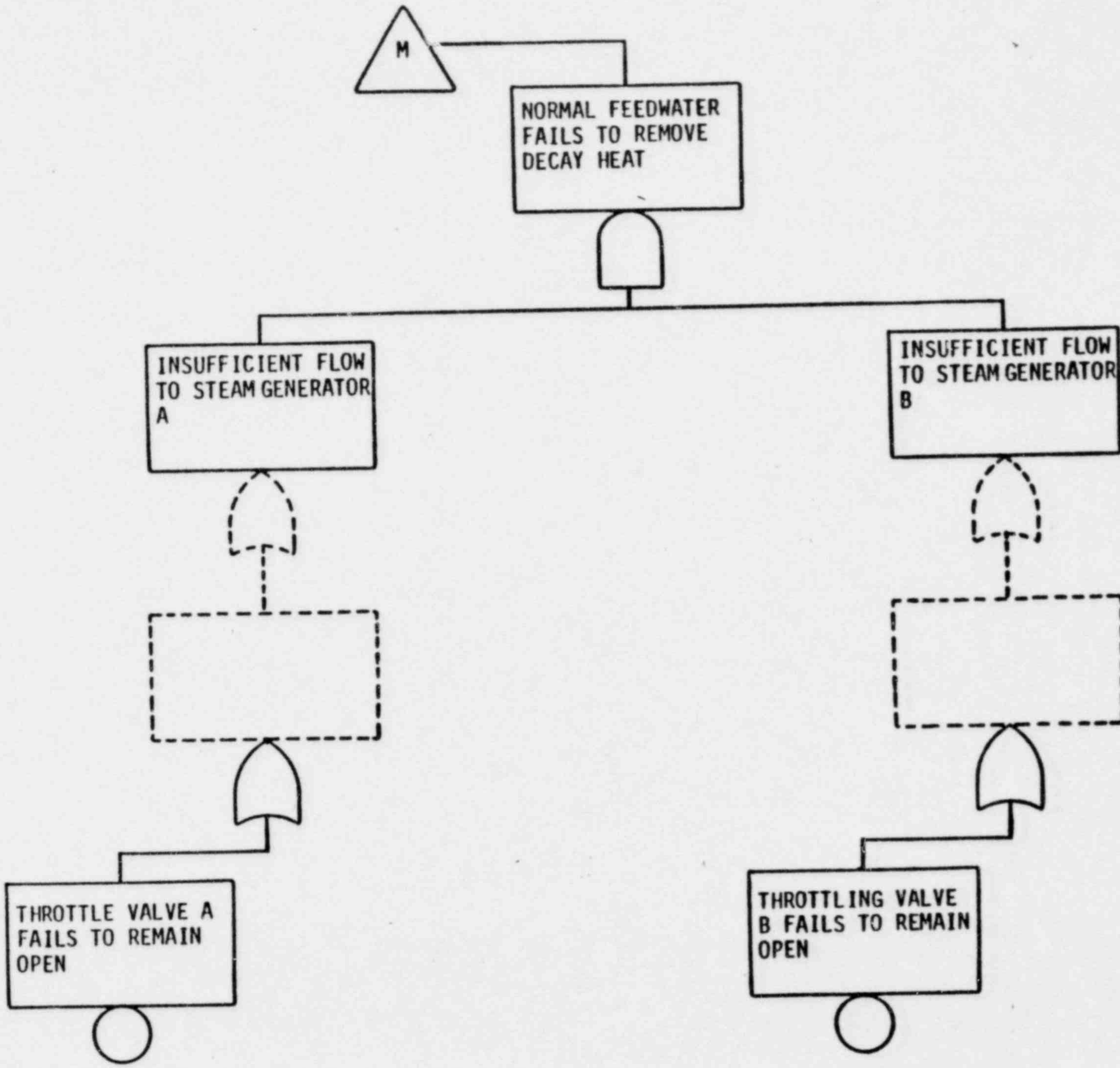


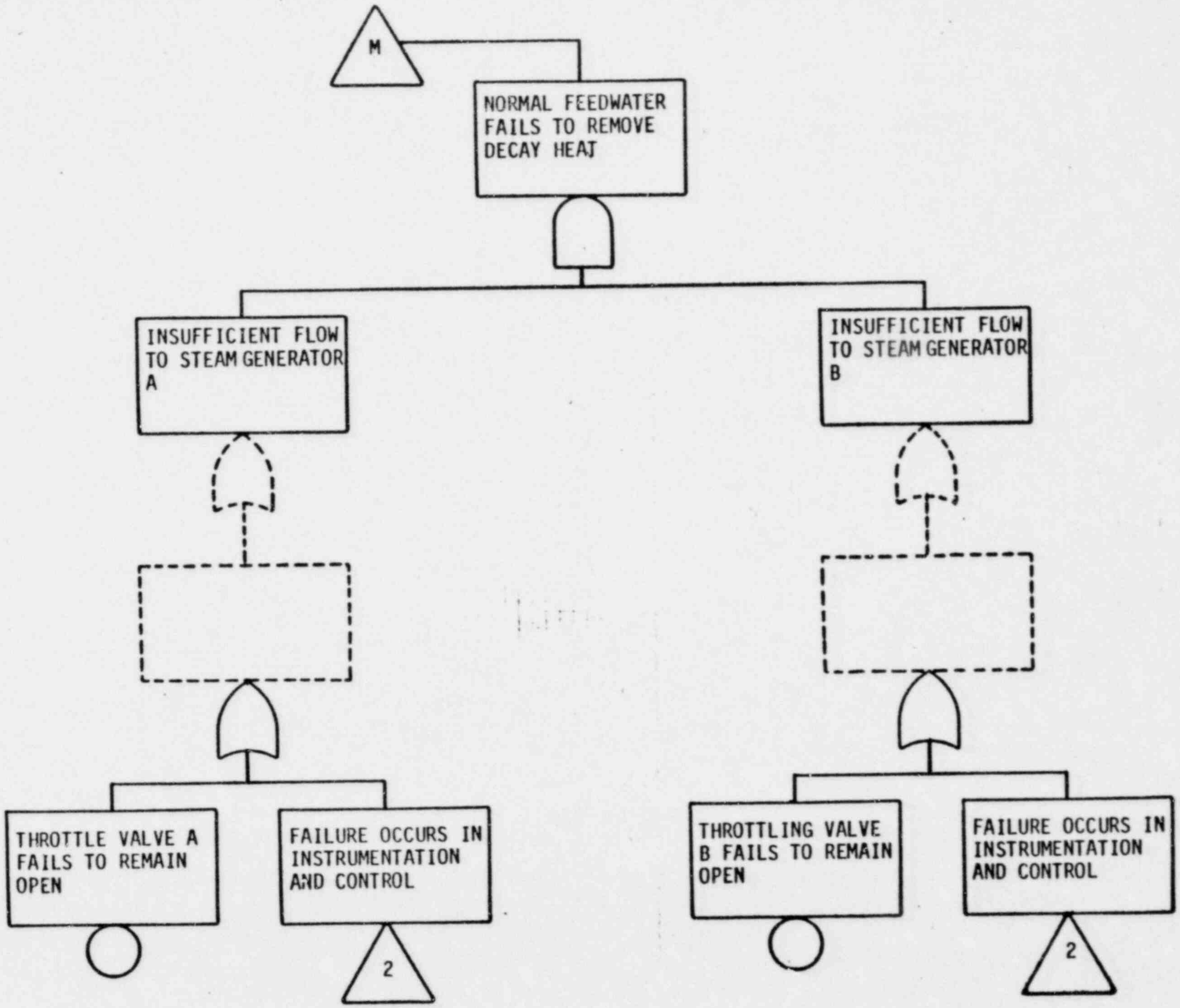
Crystal River


TMLQ
T
M
L
Q

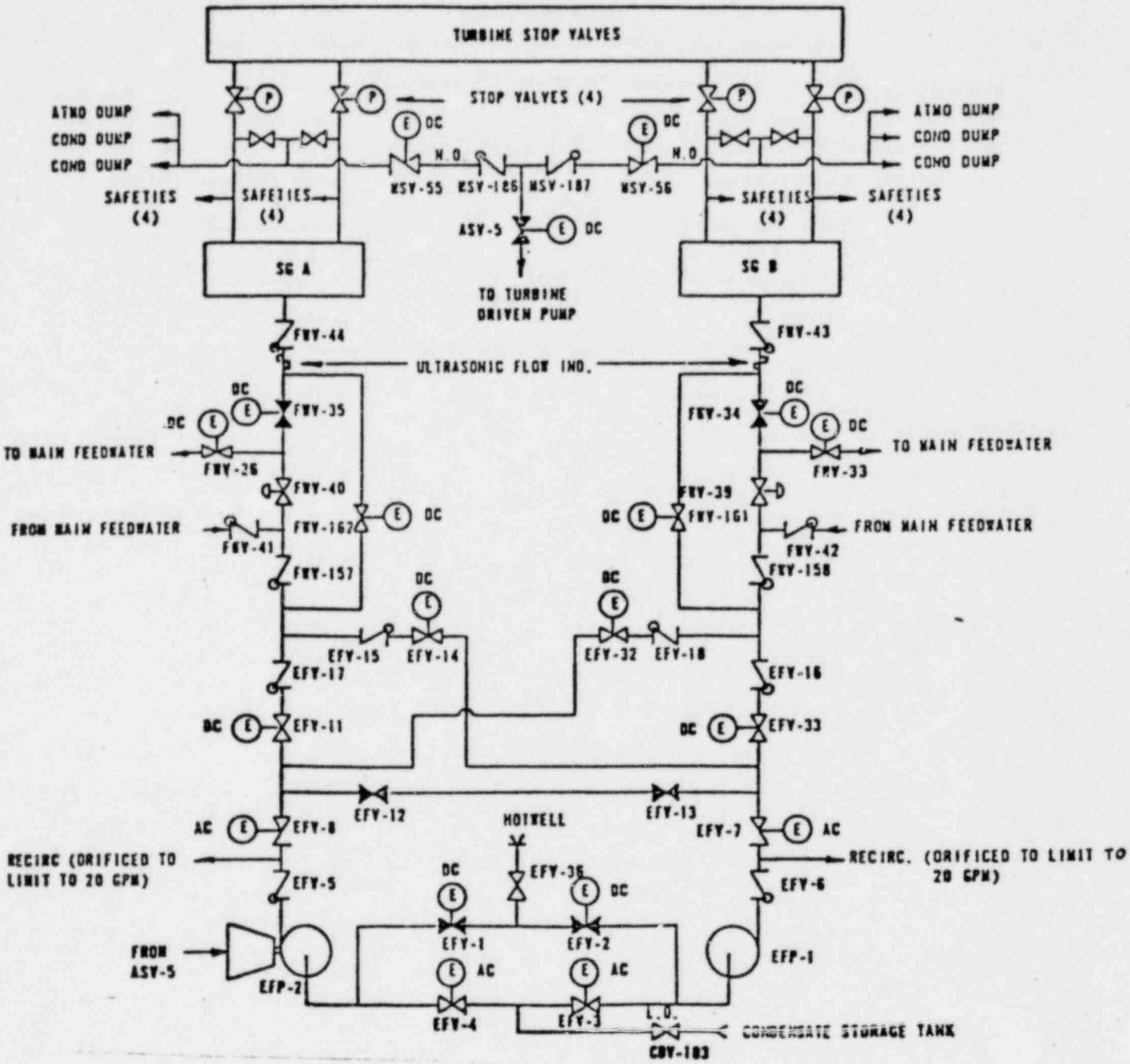
MAIN FEEDWATER

COMPONENT	AC POWER	DC POWER	SERVICE WATER	I&C	HVAC	COMPONENT COOLING	HUMAN ERROR MAINTENANCE	HUMAN ERROR OPERATIVE	ACTUATION SYSTEM	OTHER
Steam Gen A										
Steam Gen B										
MOV A1										
MOV B1										
Throttle Valve A				X						
Throttle Valve B				X						
.										
.										
.										
Pump A	X		X		X	X	X	X		
Pump B	X		X		X	X	X	X		


M
NORMAL FEEDWATER FAILS TO REMOVE DECAY HEAT
INSUFFICIENT FLOW TO STEAM GENERATOR A
INSUFFICIENT FLOW TO STEAM GENERATOR B
THROTTLE VALVE A FAILS TO REMAIN OPEN
THROTTLING VALVE B FAILS TO REMAIN OPEN



M
NORMAL FEEDWATER FAILS TO REMOVE DECAY HEAT
INSUFFICIENT FLOW TO STEAM GENERATOR A
INSUFFICIENT FLOW TO STEAM GENERATOR B
THROTTLE VALVE A FAILS TO REMAIN OPEN
FAILURE OCCURS IN INSTRUMENTATION AND CONTROL
2
THROTTLING VALVE B FAILS TO REMAIN OPEN
FAILURE OCCURS IN INSTRUMENTATION AND CONTROL
2



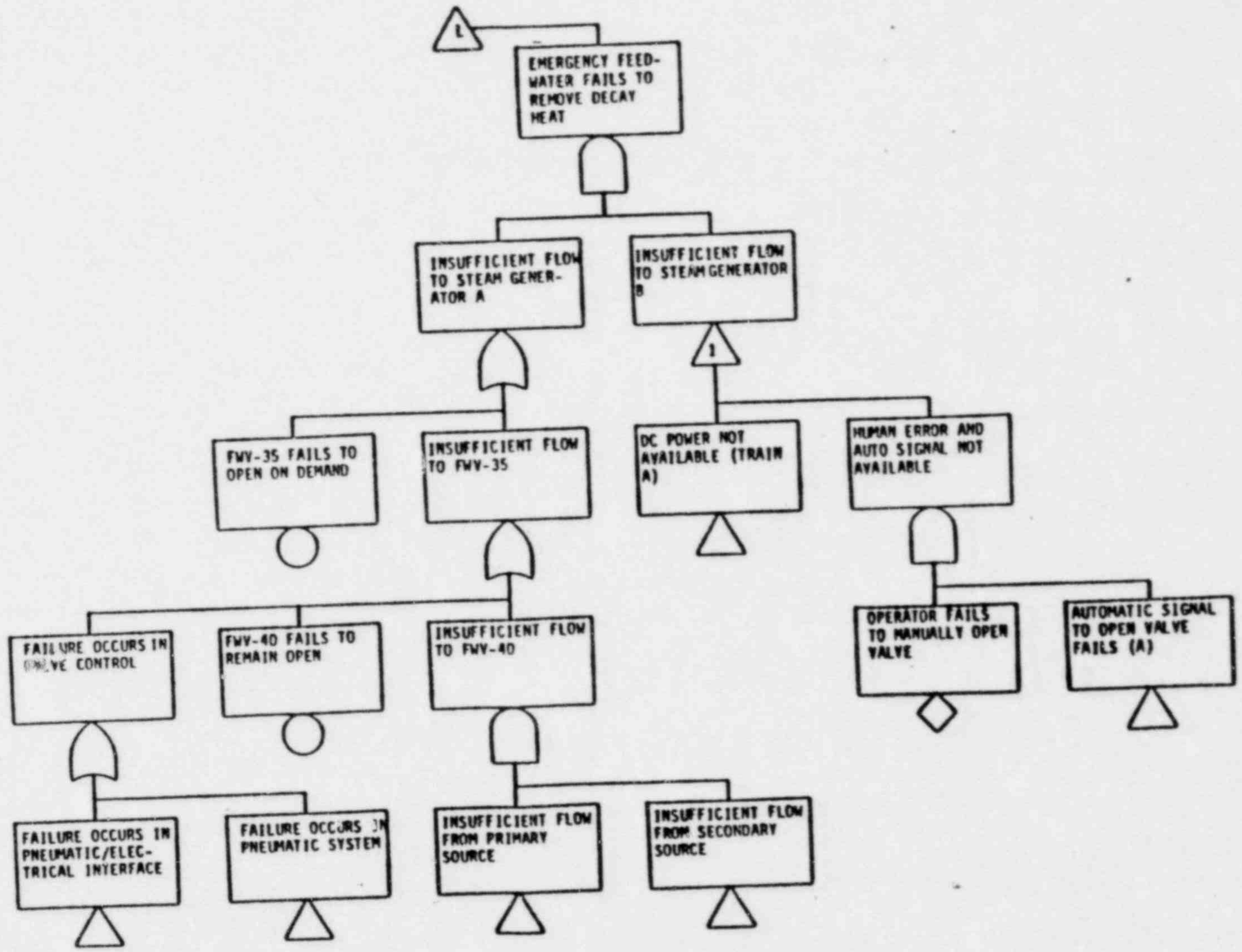
EMERGENCY FEEDWATER SYSTEM SCHEMATIC DIAGRAM

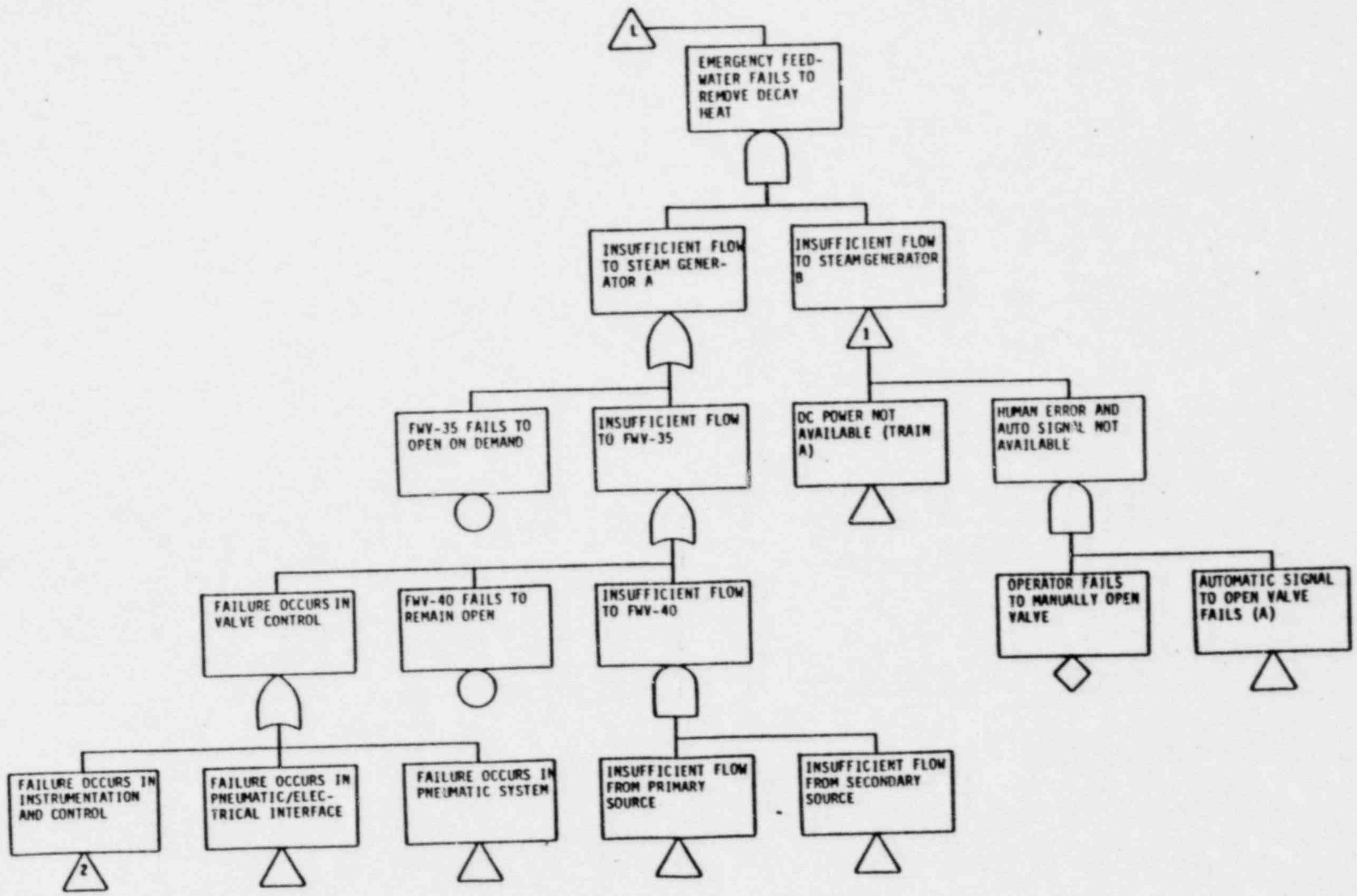
SYSTEM: EMERGENCY FEEDWATER

COMPONENT	AC POWER	DC POWER	SERVICE WATER	I&C	HVAC	COMPONENT COOLING	HUMAN ERROR MAINTENANCE	HUMAN ERROR OPERATIVE	ACTUATION SYSTEM	OTHER
Atmos Dump Valve 1A										
Atmos Dump Valve 2A										
Atmos Dump Valve 1B										
Cond. Dump Valve 2B										
Cond. Dump Valve 1A										
Cond. Dump Valve 1B										
Steam Gen. A										
Steam Gen. B										
FWV-34		X								
FWV-35		X								
FWV-33		X								
FWV-36		X								
Ultrasonic Flow Ind. A										
Ultrasonic Flow Ind. B										

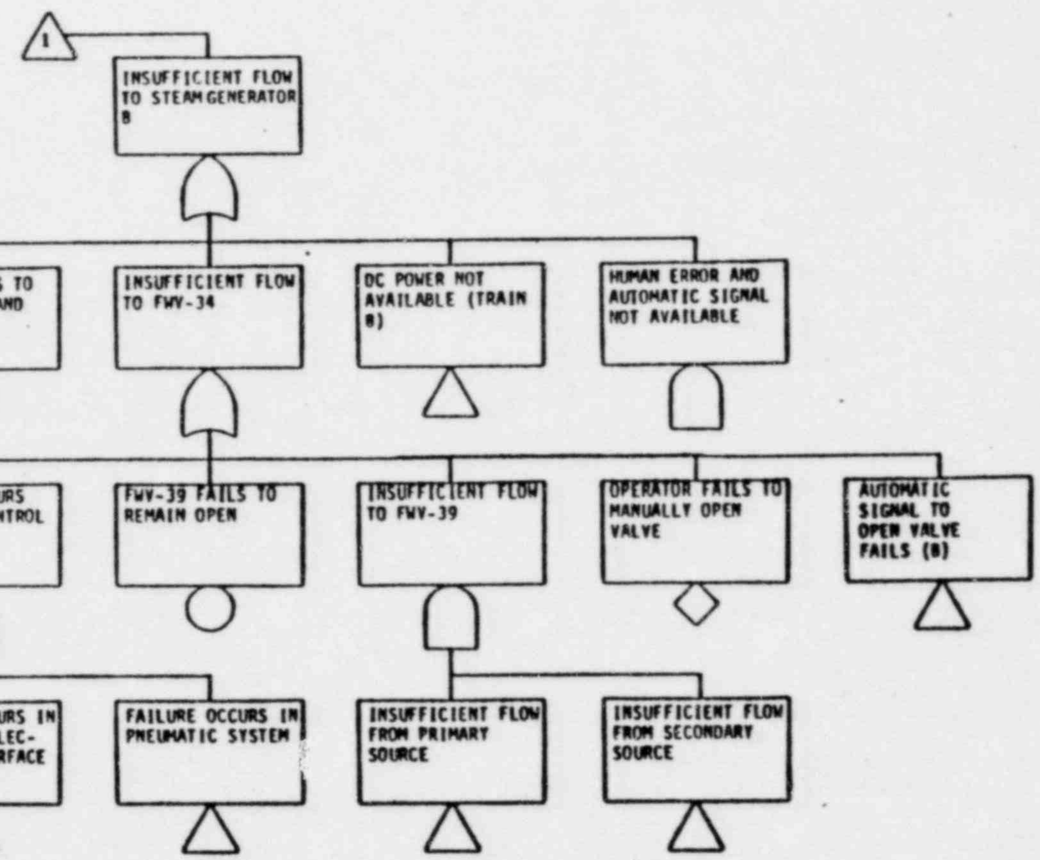
SYSTEM: EMERGENCY FEEDWATER (CONTINUED)

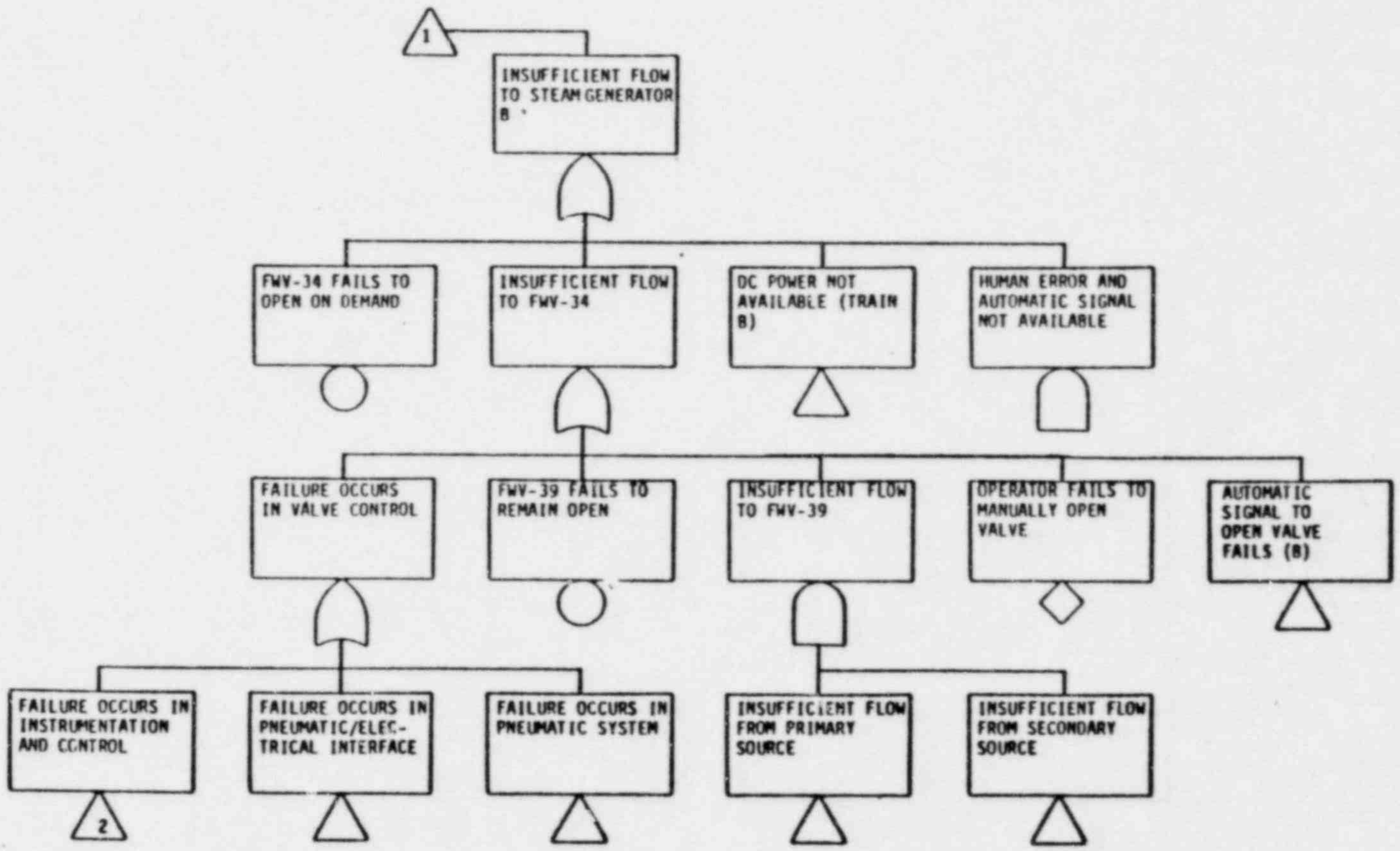
COMPONENT	AC POWER	DC POWER	SERVICE WATER	I&C	HVAC	COMPONENT COOLING	HUMAN ERROR MAINTENANCE	HUMAN ERROR OPERATIVE	ACTUATION SYSTEM	OTHER
FWV-39				X						
FWV-40				X						
FWV-1G1		X								
FWV-1G2		X								
EFWV-14		X								
EFWV-32		X								
EFWV-11		X								
EFWV-33		X								
EFWV-8	X									
EFWV-7	X									
EFW PUMP 2 (Turbine Driven)			X		X		X			
EFW PUMP 1	X	X	X		X		X			
EFWV-5		X								
EFWV-4	X									
EFWV-3	X									
EFWV-2		X								
EFWV-1		X								

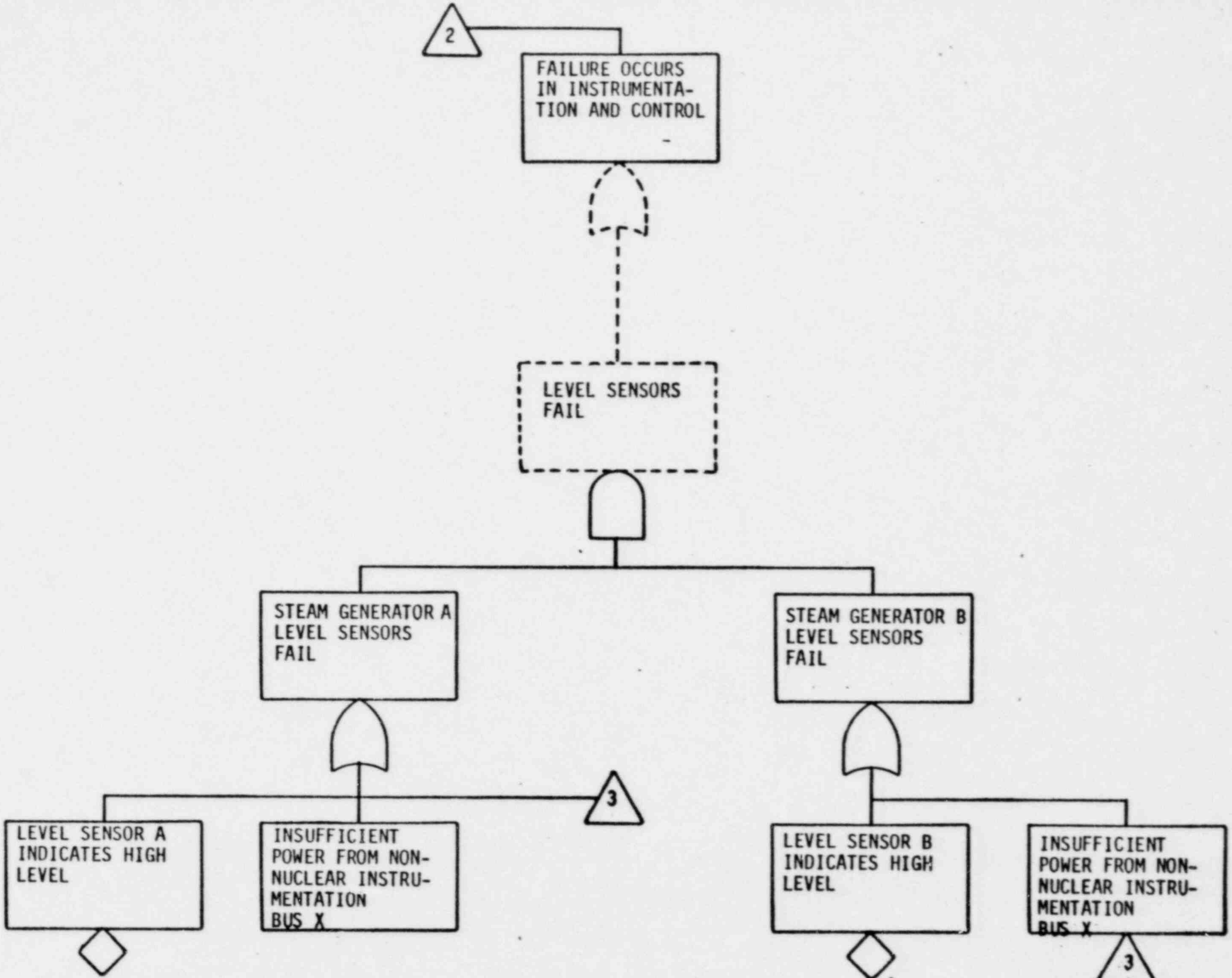

EMERGENCY FEED-WATER FAILS TO REMOVE DECAY HEAT
INSUFFICIENT FLOW TO STEAM GENERATOR A
INSUFFICIENT FLOW TO STEAMGENERATOR B
1
FWV-35 FAILS TO OPEN ON DEMAND
INSUFFICIENT FLOW TO FWV-35
DC POWER NOT AVAILABLE (TRAIN A)
HUMAN ERROR AND AUTO SIGNAL NOT AVAILABLE
FWV-40 FAILS TO REMAIN OPEN
INSUFFICIENT FLOW TO FWV-40
OPERATOR FAILS TO MANUALLY OPEN VALVE
AUTOMATIC SIGNAL TO OPEN VALVE FAILS (A)
FAILURE OCCURS IN PNEUMATIC/ELECTRICAL INTERFACE
INSUFFICIENT FLOW FROM PRIMARY SOURCE
INSUFFICIENT FLOW FROM SECONDARY SOURCE

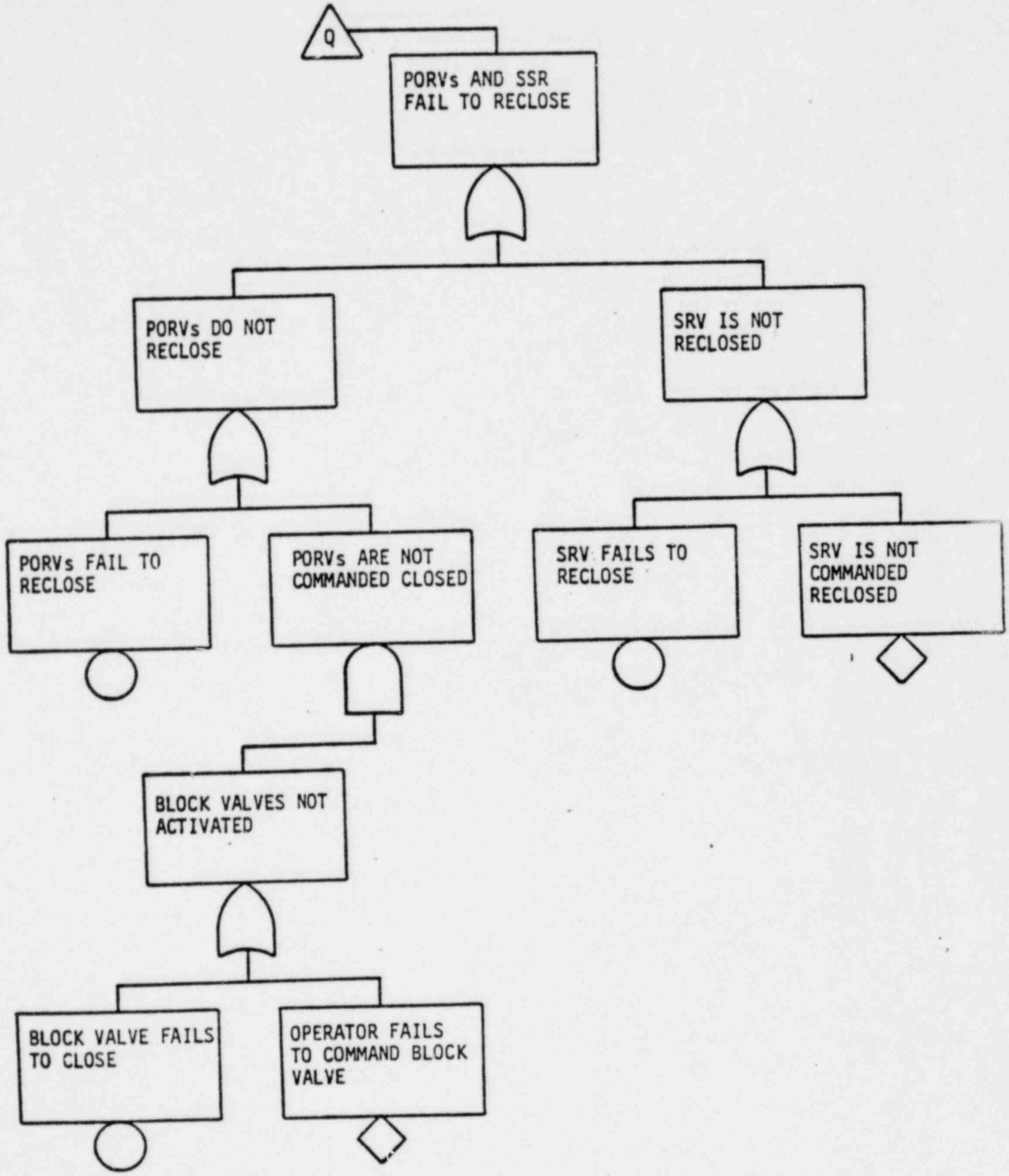


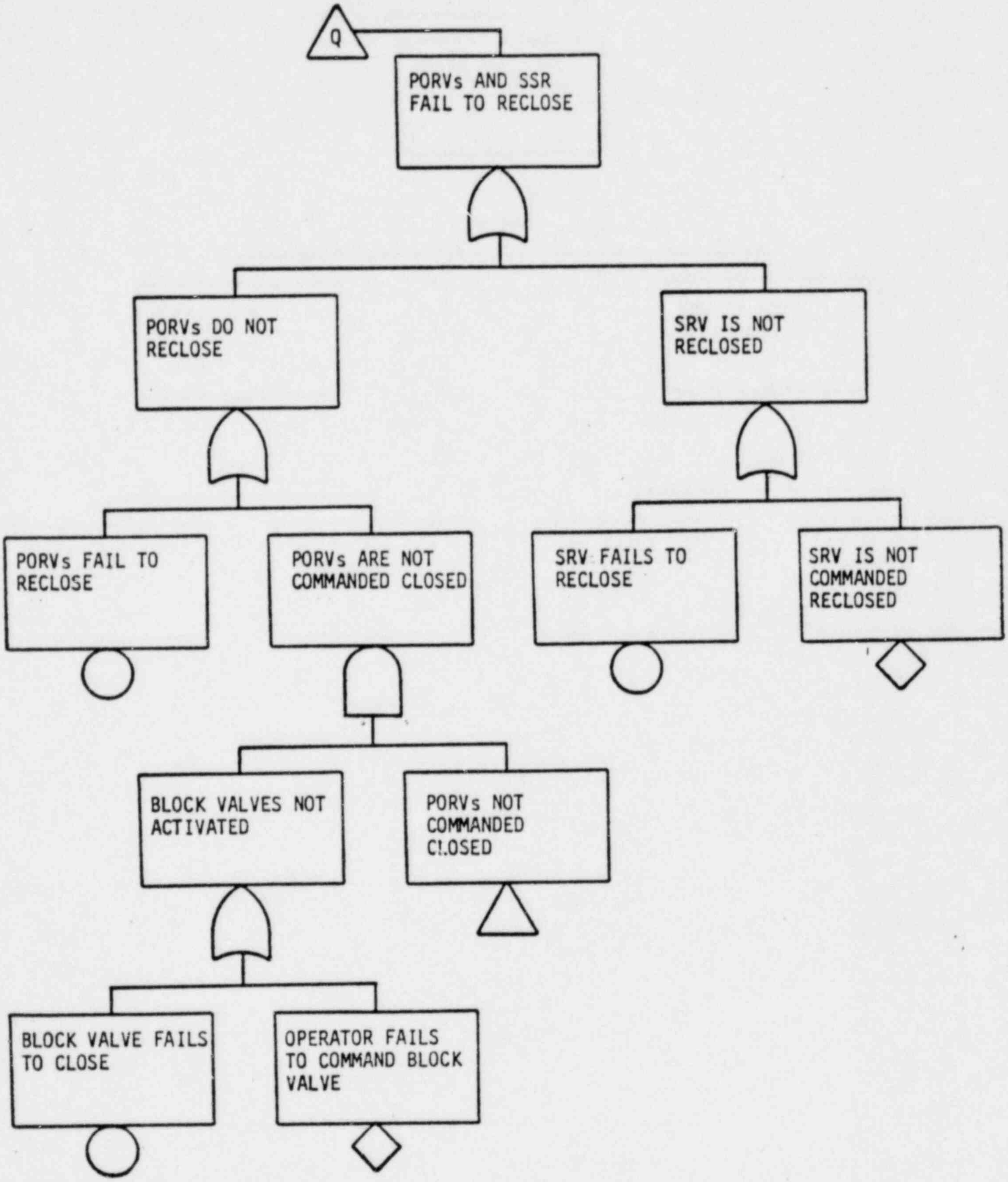
1
EMERGENCY FEED-WATER FAILS TO REMOVE DECAY HEAT
INSUFFICIENT FLOW TO STEAM GENERATOR A
INSUFFICIENT FLOW TO STEAM GENERATOR B
1
FWV-35 FAILS TO OPEN ON DEMAND
INSUFFICIENT FLOW TO FWV-35
DC POWER NOT AVAILABLE (TRAIN A)
HUMAN ERROR AND AUTO SIGNAL NOT AVAILABLE
FAILURE OCCURS IN VALVE CONTROL
FWV-40 FAILS TO REMAIN OPEN
INSUFFICIENT FLOW TO FWV-40
OPERATOR FAILS TO MANUALLY OPEN VALVE
AUTOMATIC SIGNAL TO OPEN VALVE FAILS (A)
FAILURE OCCURS IN INSTRUMENTATION AND CONTROL
2
FAILURE OCCURS IN PNEUMATIC/ELECTRICAL INTERFACE
FAILURE OCCURS IN PNEUMATIC SYSTEM
INSUFFICIENT FLOW FROM PRIMARY SOURCE
INSUFFICIENT FLOW FROM SECONDARY SOURCE


1
INSUFFICIENT FLOW TO STEAM GENERATOR B
FWV-34 FAILS TO OPEN ON DEMAND
INSUFFICIENT FLOW TO FWV-34
DC POWER NOT AVAILABLE (TRAIN B)
HUMAN ERROR AND AUTOMATIC SIGNAL NOT AVAILABLE
FAILURE OCCURS IN VALVE CONTROL
FWV-39 FAILS TO REMAIN OPEN
INSUFFICIENT FLOW TO FWV-39
OPERATOR FAILS TO MANUALLY OPEN VALVE
AUTOMATIC SIGNAL TO OPEN VALVE FAILS (B)
FAILURE OCCURS IN PNEUMATIC/ELECTRICAL INTERFACE
FAILURE OCCURS IN PNEUMATIC SYSTEM
INSUFFICIENT FLOW FROM PRIMARY SOURCE
INSUFFICIENT FLOW FROM SECONDARY SOURCE


1
INSUFFICIENT FLOW TO STEAM GENERATOR B
FWV-34 FAILS TO OPEN ON DEMAND
INSUFFICIENT FLOW TO FWV-34
DC POWER NOT AVAILABLE (TRAIN B)
HUMAN ERROR AND AUTOMATIC SIGNAL NOT AVAILABLE
FAILURE OCCURS IN VALVE CONTROL
FWV-39 FAILS TO REMAIN OPEN
INSUFFICIENT FLOW TO FWV-39
OPERATOR FAILS TO MANUALLY OPEN VALVE
AUTOMATIC SIGNAL TO OPEN VALVE FAILS (B)
FAILURE OCCURS IN INSTRUMENTATION AND CONTROL
2
FAILURE OCCURS IN PNEUMATIC/ELECTRICAL INTERFACE
FAILURE OCCURS IN PNEUMATIC SYSTEM
INSUFFICIENT FLOW FROM PRIMARY SOURCE
INSUFFICIENT FLOW FROM SECONDARY SOURCE


2
FAILURE OCCURS IN INSTRUMENTATION AND CONTROL
LEVEL SENSORS FAIL
STEAM GENERATOR A LEVEL SENSORS FAIL
STEAM GENERATOR B LEVEL SENSORS FAIL
3
LEVEL SENSOR A INDICATES HIGH LEVEL
INSUFFICIENT POWER FROM NON-NUCLEAR INSTRUMENTATION BUS X
LEVEL SENSOR B INDICATES HIGH LEVEL
INSUFFICIENT POWER FROM NON-NUCLEAR INSTRUMENTATION BUS X
3


Q
PORVs AND SSR FAIL TO RECLOSE
PORVs DO NOT RECLOSE
SRV IS NOT RECLOSED
PORVs FAIL TO RECLOSE
PORVs ARE NOT COMMANDED CLOSED
SRV FAILS TO RECLOSE
SRV IS NOT COMMANDED RECLOSED
BLOCK VALVES NOT ACTIVATED
BLOCK VALVE FAILS TO CLOSE
OPERATOR FAILS TO COMMAND BLOCK VALVE


Q
PORVs AND SSR FAIL TO RECLOSE
PORVs DO NOT RECLOSE
SRV IS NOT RECLOSED
PORVs FAIL TO RECLOSE
PORVs ARE NOT COMMANDED CLOSED
SRV FAILS TO RECLOSE
SRV IS NOT COMMANDED RECLOSED
BLOCK VALVES NOT ACTIVATED
PORVs NOT COMMANDED CLOSED
BLOCK VALVE FAILS TO CLOSE
OPERATOR FAILS TO COMMAND BLOCK VALVE

ONE INDEPENDENT EVENT CUT SET

(T)(A THROTTLE VALVE)(B THROTTLE VALVE)(FWV40)(FWV39)(PORV)

DEPENDENT EVENT CUT SET

(T)(NNIX)

SYSTEMS INTERACTION ANALYSIS EXAMPLE

SUBJECT: CRYSTAL RIVER UNIT 3

OBJECTIVE: DEMONSTRATE THAT THE PROPOSED METHODOLOGY WILL IDENTIFY THE SYSTEMS INTERACTIONS CONTRIBUTIONS TO THE LOCA EVENT OF FEBRUARY 26, 1980.

APPROACH: IDENTIFY LINKAGES BETWEEN SUBSYSTEMS AND COMPONENTS. EVALUATE LINKAGES TO DETERMINE VALID SYSTEMS INTERACTIONS.

SCOPE OF ANALYSIS:

- RCS HEAT REMOVAL FUNCTION
- CONTROL & INSTRUMENTATION
- STEAM & POWER CONVERSION SYSTEM
- POWER OPERATION (MODE 1)

ANALYTIC PROCEDURES:

- IDENTIFY SUBSYSTEMS AND COMPONENTS.
- IDENTIFY CONTROLLED COMPONENTS AND CONTROL SIGNAL SOURCES.
- EVALUATE FOR SYSTEMS INTERACTIONS.
- SCREEN POTENTIAL SYSTEMS INTERACTIONS.
- PERFORM DETAILED ANALYSIS OF SELECTED INTERACTIONS.

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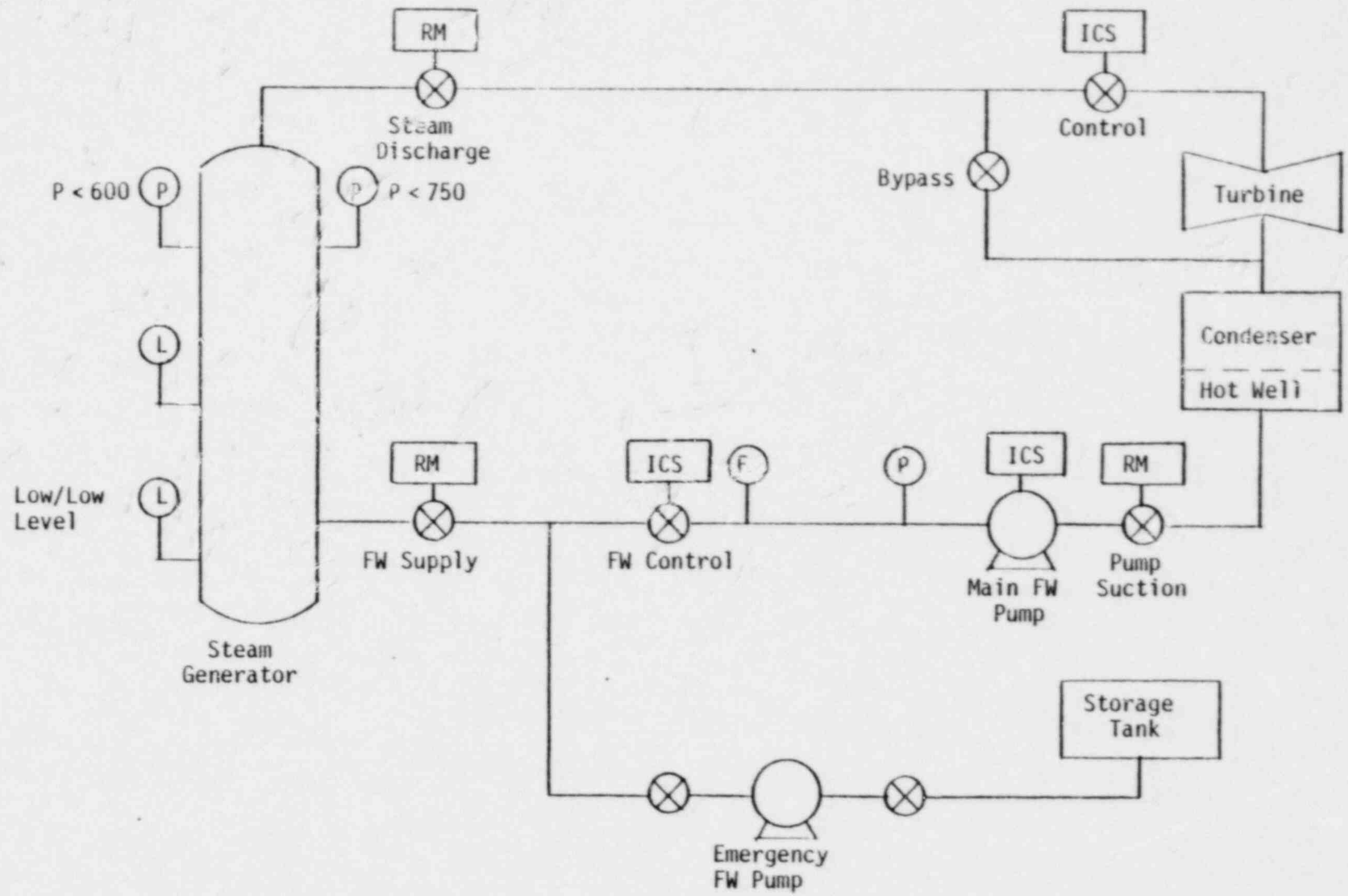
Dupe of 8102190088


RM
Steam Discharge
ICS
Control
Bypass
Turbine
P < 600
P
P
P < 750
L
L
Low/Low Level
Condenser
Hot Well
RM
FW Supply
ICS
F
FW Control
P
ICS
Main FW Pump
RM
Pump Suction
Steam Generator
Storage Tank
Emergency FW Pump

Operational survey of Steam and Power Conversion System shows that ICS and Rupture Matrix are control signal sources.

Functions Controlled by ICS:

- Main feedwater control valve
- Main feedwater pump
- Turbine control valve

Related ICS Input Signals:

- Steam generator pressure
- Steam generator level
- Main feedwater flow
- Feedwater temperature
- Turbine inlet temperature
- RCS flow
- RCS temperature

Functions Controlled by Rupture Matrix:

- Feedwater supply valve
- Steam discharge valve
- Main feedwater pump

Related Rupture Matrix Input Signals:

- Steam generator pressure, $P < 750$ psia
- Steam generator pressure, $P < 600$ psia

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Columbus Laboratories

Operational survey of related instrumentation shows the following are powered by the NNI-X power supply:

- Steam generator pressure, $P < 600$ psi
- Steam generator level
- Main feedwater flow

Survey of the NNI-X power distribution shows that the following are also dependent on this bus:

- Steam generator low/low pressure instrument
- PORV controller
- Control room indicators

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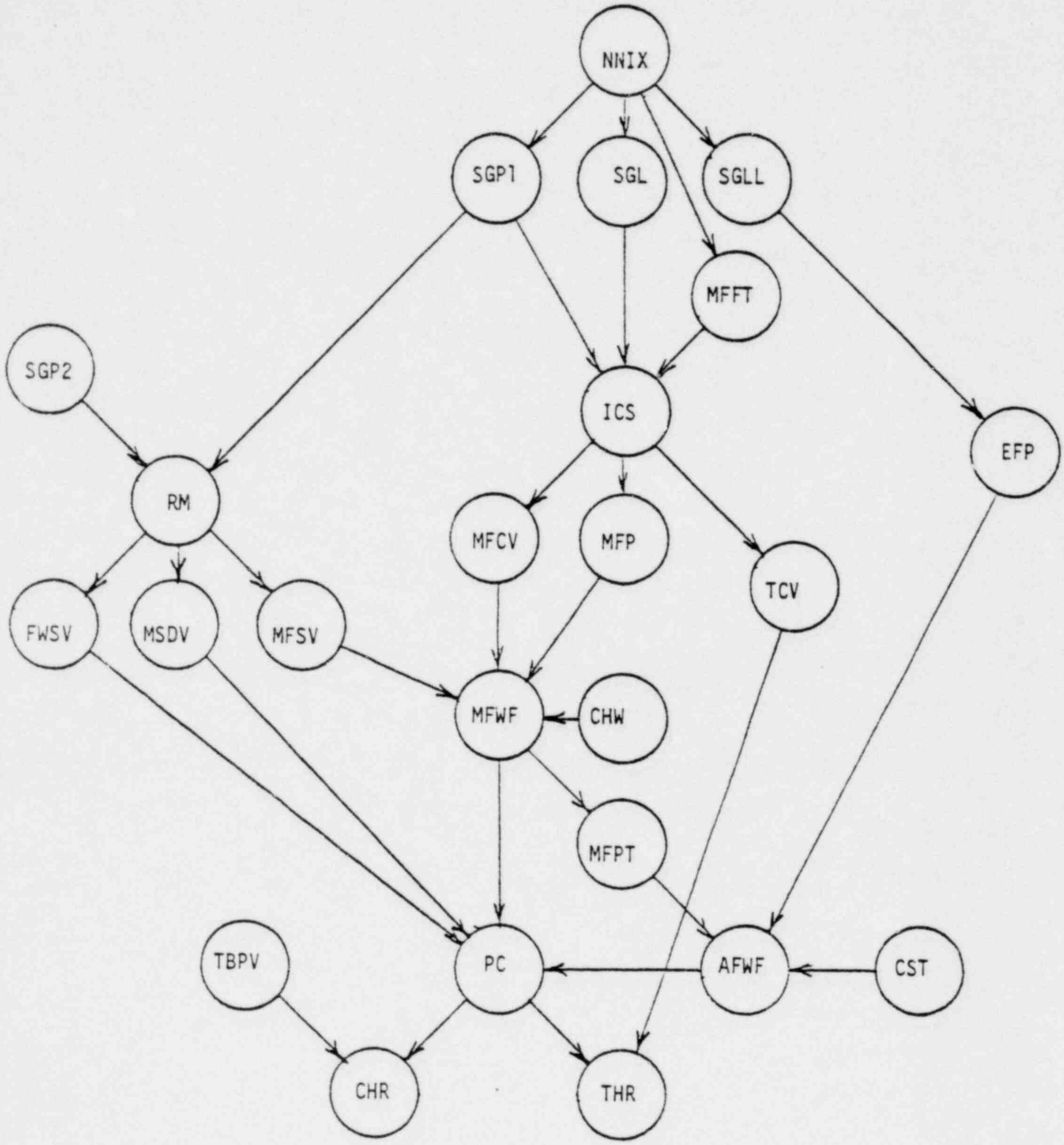
	CHR	TBPV	PC	MFWF	CHW	MFP	MFCV	MFSV	ICS	FWSV	MSDV	RM	THR	TCV	SGP1	SGL	MFFT	SGP2	NNIX	SGLL	EFP	AFWF	CST	MFPT
CHR	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TBPV	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PC	0	0	0	1	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	1	0	0
MFWF	0	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CHW	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MFP	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MFCV	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MFSV	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
ICS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0
FWSV	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
MSDV	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
RM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0
THR	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
TCV	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SGP1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
SGL	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
MFFT	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
SGP2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NNIX	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SGLL	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
EFP	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
AFWF	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1
CST	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MFPT	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0



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FMEA OF NNI-X FAILURE

Signal or Component	Effect of Failure
Main feedwater flow	Feedwater control valves fail to 50% open
Feedwater temperature	a. Increase reactor power b. Reduce feedwater pump speed
Steam generator level	Reduce feedwater pump speed
Steam generator pressure	Reduce feedwater pump speed
Turbine inlet temperature	Open turbine control valves
RCS flow	Reduce feedwater pump speed
RCS temperature	Increase reactor power
Steam generator low/low pressure	Disable emergency feedwater pump auto-start
Control room indicators	Fail to midscale
PORV controller*	a. PORV opens b. PORV locked open

* Based on short to ground on positive bus, followed by automatic isolation of both buses.

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COMBINED EFFECTS OF NNI-X FAILURE

- REACTOR POWER INCREASES
- MAIN FEEDWATER FLOW DECREASES
- RCS OVERPRESSURIZES
- PORV OPENS PREMATURELY
- PORV FAILS TO CLOSE AT DESIGN PRESSURE
- EMERGENCY FEEDWATER AUTO-START DISABLED
- STEAM GENERATOR ISOLATED
- MAJORITY OF CONTROL ROOM INDICATORS DISABLED

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