GENERAL ATOMIC

E-115-751

RELIABILITY ANALYSIS REPORT

FOR

BALANCE OF PLANT

ENGINEERED SAFETY FEATURES ACTUATION SYSTEM

Contained in

Arizona Nuclear Power Project

Palo Verde Nuclear Generating Station

Units 1, 2 and 3

October 1978

CONTENTS

TABLES

FIGURES

1. SCOPE

The steps to be performed in arriving at the final Reliability Analysis Report are to:

1. Develop the reliability model.

2. Establish the probability of input challenges.

3. Determine the relationships between input and outputs; i.e., determine which inputs determine each output.

4. Develop input-to-output probability relationships using decision trees.

5. Determine the failure rate for each component in the decision tree.

6. Compute the reliability for each component in the decision tree for a mission time of 30 days (Ref. 1, page 4-25, Para. 4.6.2.9).

7. Determine the probability of success, given that the system is challenged.

8. Determine the required automatic testing interval to increase the probability of success to $1 - 1 \times 10^{-6}$ (Ref. 1, page 4-25, Para. 4.6.2.9). This may be an iterative calculation resulting from the intractable nature of the equations for component reliability calculation.

2. THE MODEL

Figure 1 is an oversimplified model of the Engineered Safety Features Actuation System (ESFAS), but it will aid in understanding the ESFAS reliability prediction.

In general, there are n inputs to the ESFAS system. These inputs are logic command signals, e.g., Fuel Building Essential Ventilation Actuation Signal (FBEVAS), etc. The system can be generalized as a set of logic functions that generate m output signals, e.g., Fuel Building Nonessential Ventilation Actuation Signal, etc. See drawing ELE 342-0100, Block Diagram, BOP ESFAS, for a more detailed view of the inputs, outputs, and logic interconnections.

Given the generalized physical model, we need a mathematical model to permit a quantitative prediction of the reliability of the ESFAS system. The mathematical model can be constructed as follows:

Let $P(I_i)/C$ = the probability that input I_i is stimulated given a system challenge.

Let $P(SO_j)/I_i$ = the probability of a successful output O_j given a stimulus at input I_i, where i ranges from 0 to n and j ranges from 0 to m.

Let $P(S)/C$ = the probability of a successful system response given a system challenge.

Let $P(SO_j)/C$ = the probability of a successful output j given a system challenge.

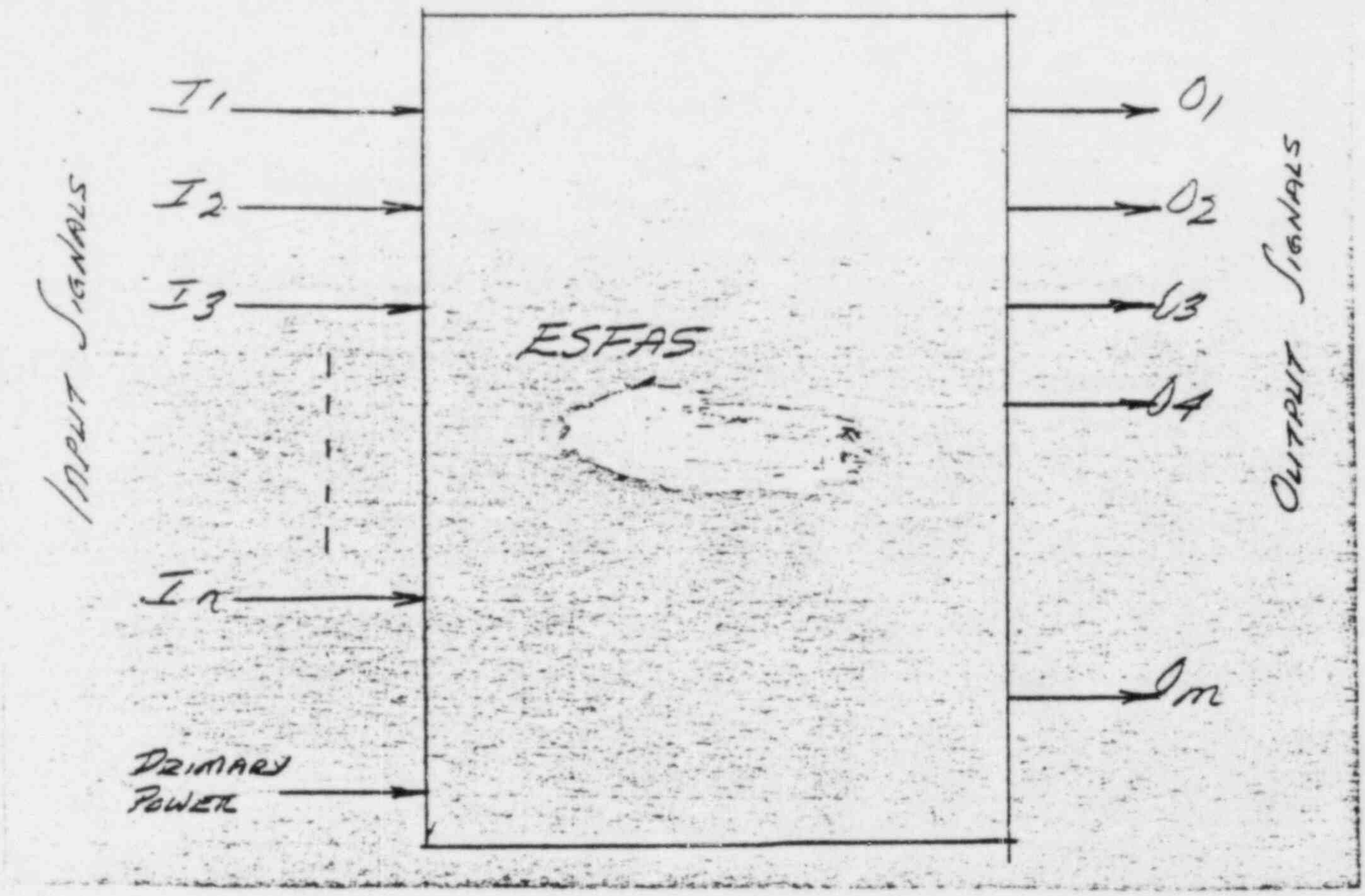


Fig. 1. Simplified model of ESFAS

Based on the above definitions and making the simplifying assumption that there is a simple one-to-one correspondence ($m = n$) between the input and outputs we obtain:

$$P(S)/C = P(I_1)/C \cdot P(SO_1)/I_1$$
$$+ P(I_2)/C \cdot P(SO_2)/I_2$$
$$\vdots$$
$$+ P(I_n)/C \cdot P(SO_n)/I_n$$
$$P(S)/C = P(SO_1)/C + P(SO_2)/C + \ldots P(SO_m)/C$$

In simple words, this states that the probability of a successful system response given a system challenge is the sum of the products of the probabilities of a given input stimulus, I_i, and the probability of successful operation of the logic components that generate the output O_i.

When there are multiple outputs for a given input the equations become slightly more complex. For simplicity assume output 2, O_2, occurs when either input 1, I_1, or input 2, I_2, occurs. Then for this specific case

$$P(S)/C = P(SO_2)/C = (P(I_1)/C \cdot P(SO_2)/I_1)$$
$$+ (P(I_2)/C \cdot P(SO_2)I_2) \quad .$$

The complementary situation, multiple inputs for a given output must also be satisfied. Assume that outputs O_1 and O_2 should both result from input I_1. Then

$$P(S)/C = P(SO_1)/C \cdot P(SO_2)/C$$

implies that the system success depends on obtaining both required outputs. Expanding this for the specific case, we obtain

$$\begin{aligned} P(S)/C &= (P(I_1)/C \cdot P(SO_1)/I_1) \cdot \\ &\quad (P(I_1)/C \cdot P(SO_2)/I_1) \\ &= P(I_1/C)\ P(SO_1)/I_1 \cdot P(SO_2)/I_1) \quad . \end{aligned}$$

Based on the above logic, the equation for the generalized model is

$$\begin{aligned} P(S)/C = P(I_1)/C\ (P(SO_1)/I_1 \times P(SO_2)/I_1 \times \ldots P(SO_m)/I_1) \\ + P(I_2)/C\ (P(SO_1)/I_2 \times P(SO_2)/I_2 \times \ldots P(SO_m)/I_2) \\ \vdots \\ + P(I_n)/C\ (P(SO_1)/I_n \times P(SO_2)/I_n \times \ldots P(SO_m)/I_n) \end{aligned}$$

In the limiting case, $P(SO_j)/I_i = 1$ when there is no required output at O_j for an input I_i. This may seem irrational at first, but the reason will become apparent when one considers that where there is no required coupling between input I_i and output O_i, then there can be no failure, i.e.,

$$P(FO_j)/I_i = 0 = \text{probability of failure at output } O_j \text{ given input } I_i$$

$$P(SO_j)/I_i = 1 - P(FO_j)/I_i = 1 - 0 = 1$$

Therefore,

$$P(SO_j)/I_i = 1 \text{ if there is not a required response at output } O_j \text{ from an input } I_i \quad .$$

3. INPUT SIGNAL ENUMERATION

The generalized model established a relationship between input or challenges to the system and the resulting output or responses by the system. We now need to enumerate those inputs. Drawing ELE 342-0100 established the block diagram between inputs and outputs.

The simple one-to-one relationship becomes more complex for the Diesel Generator Start Signal (DGSS), Loss of Power (LOP) and Load Sequencer modules. For the latter units we will consider an input to be a stimulus or combination of stimuli that would normally cause an output from the respective module. The breakdown of model inputs and their relationship to the physical system becomes:

I_1 FBEVIAS
I_2 CREFAS
I_3 CPIAS
I_4 CREVIAS (SMCROA)
I_5 CREVIAS (HCG CROA)
I_6 DGSS (Subsystem)
- LOP
- SIAS
- AFAS-1
- AFAS-2

I_7 LOP (Subsystem)
- Undervoltage 1
- Undervoltage 2
- Undervoltage 3
- Undervoltage 4

I_8 ESF Load Sequencer

FBEVAS

CREFAS

CREVIAS

LOP

DG RUN

DG BKR

SIAS

AFAS-1

AFAS-2

4. INPUT SIGNAL PROBABILITIES

With the mathematical model defined, it is necessary to determine the probability values to be used in the computations. First, the input probabilities $P(I_i)/C$ will be determined.

A system challenge is defined as the stimulus of one of the system inputs, I_i.

Let $P(IS)/C$ be defined as the probability of an input stimulus given a system challenge which is obviously equal to unity

$$P(IS)/C = \sum_{i=1}^{n} P(I_i)/C = 1.0$$

where $P(I_i)/C$ is, as previously established, the probability that input I_i is stimulated as a result of challenge, C.

Because of a lack of knowledge regarding the probability distribution among the various inputs, it will be assumed that they are equally probable, i.e.,

$$P(I_1)/C = P(I_2)/C = P(I_i)/C$$

Therefore $$\sum_{i=1}^{n} P(I_i)/C = n \cdot P(I_i)/C = 1$$

or $$P(I_i)/C = \frac{1}{n}$$

When a more rational evaluation of the distribution becomes known, it may be substituted for the equally probable distribution and the system reliability computions recalculated.

5. OUTPUT SIGNAL ENUMERATION

The system output signals applicable to the system reliability analysis are:

O_1	FBEVAS
O_2	CREFAS
O_3	CPIAS
O_4	CREVIAS
O_5	DGSS
O_6	LOP/LS
O_7	Load Sequence

6. INPUT-TO-OUTPUT RELATIONSHIPS

The Specification (Ref. 1, page 4-24, Para. 4.6.2.3) states that the "Scope of analysis shall be limited to elements of the BOP ESFAS shown in attachment 4-1." General Atomic Company (GA) prefers to use GA drawing ELE 342-0100 in place of attachment 4-1 because the drawing is more explicit in the actual implementation of the system.

The input-output relationships are estimated from drawing ELE 342-0100 as shown in Table 1. The next objective is to establish the probabilities associated with these input-output relationships.

TABLE 1
INPUT-TO-OUTPUT RELATIONSHIPS FOR EACH LOGIC MODULE

Input Sources: I_1 through I_6

Outputs		I_1 FBEVAS A	I_1 FBEVAS B	I_2 CREFAS A	I_2 CREFAS B	I_3 CPIAS A	I_3 CPIAS B	I_4 & I_5 CRVIAS A_1	A_2	B_1	B_2	I_6 DGSS STAS A_1	STAS B_1	AFAS-1 A_2	AFAS-1 B_2	AFAS-2 A_3	AFAS-2 B_3
O_1 FBEVAS Actuated Devices	A	1	1	0	0	0	0	0	0	0	0						
	B	1	1	0	0	0	0	0	0	0	0						
O_2 CREFAS Actuated Devices	A	1	0	1	1	1	0	0	0	0	0						
	B	0	1	1	1	0	1	0	0	0	0						
O_3 CPIAS Actuated Devices	A	0	0	0	0	1	1	0	0	0	0						
	B	0	0	0	0	1	1	0	0	0	0						
O_4 CRVIAS Actuated Devices	A	0	0	0	0	0	0	1	1	1	1						
	B	0	0	0	0	0	0	1	1	1	1						
O_5 DGSS	A											1	0	1	0	1	0
	B											0	1	0	1	0	1
O_6 Load Shed Actuated Devices[1]	A	0	0	0	0	0	0	0	0	0	0						
	B	0	0	0	0	0	0	0	0	0	0						
O_7 Load Sequencer Actuated Devices	A																
	B																

Input Sources: I_7 and I_8

Outputs		I_7 LOP/Load Shed 1 A	1 B	2 A	2 B	3 A	3 B	4 A	4 B	I_8 FBEVAS Output A	FBEVAS Output B	CREFAS Output A	CREFAS Output B	CRVIAS Output A	CRVIAS Output B	LOP A	LOP B	DC Run A	DC Run B	DC BKR A	DC BKR B	DGSS Outputs SIAS A	SIAS B	AFAS-1 A	AFAS-1 B	AFAS-2 A	AFAS-2 B
O_1 FBEVAS Actuated Devices	A	0	0	0	0	0	0	0	0																		
	B	0	0	0	0	0	0	0	0																		
O_2 CREFAS Actuated Devices	A	0	0	0	0	0	0	0	0																		
	B	0	0	0	0	0	0	0	0																		
O_3 CPIAS Actuated Devices	A	0	0	0	0	0	0	0	0																		
	B	0	0	0	0	0	0	0	0																		
O_4 CRVIAS Actuated Devices	A	0	0	0	0	0	0	0	0																		
	B	0	0	0	0	0	0	0	0																		
O_5 DGSS	A															1	0										
	B															0	1										
O_6 Load Shed Actuated Devices[1]	A	1	0	1	0	1	0	1	0																		
	B	0	1	0	1	0	1	0	1																		
O_7 Load Sequencer Actuated Devices	A									1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
	B									0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1

[1] For complementary module B inputs are true and A inputs are false

7. INPUT-TO-OUTPUT PROBABILITY RELATIONSHIPS

As an aid to developing the input-to-output probability relationships we should start with a block diagram of the system components that are involved. Figure 2 is a suitable block diagram.

A decision tree that "is a model that expresses system reliability in terms of component reliability" (Ref. 2) can be used as an aid to computing the probability of success in the input-to-output logical response of the ESFAS. To arrive at the decision tree, let us redraw the block diagram of Fig. 2 as a cascade of elements for which we can compute or assign reliability values. Figure 3 shows this arrangement.

The logical relationship of the elements is probably obvious, but let us review it briefly. The system can operate on the input signal if either power source and power converter are functional, i.e., we have power redundancy in the system.

The balance of the elements in this input-output relationship are in series and the output depends on all elements being operational. (There is further redundancy in the system but this is accounted for in the mathematical model by redundant paths from input to output.)

The isolator is shown as if it always appeared in the system. Only half the input-output paths have the isolator but assuming it is always present is a conservative assumption that simplifies calculation by making the successful input-to-output probabilities equal for A-input to A-output as for A-input to B-outputs.

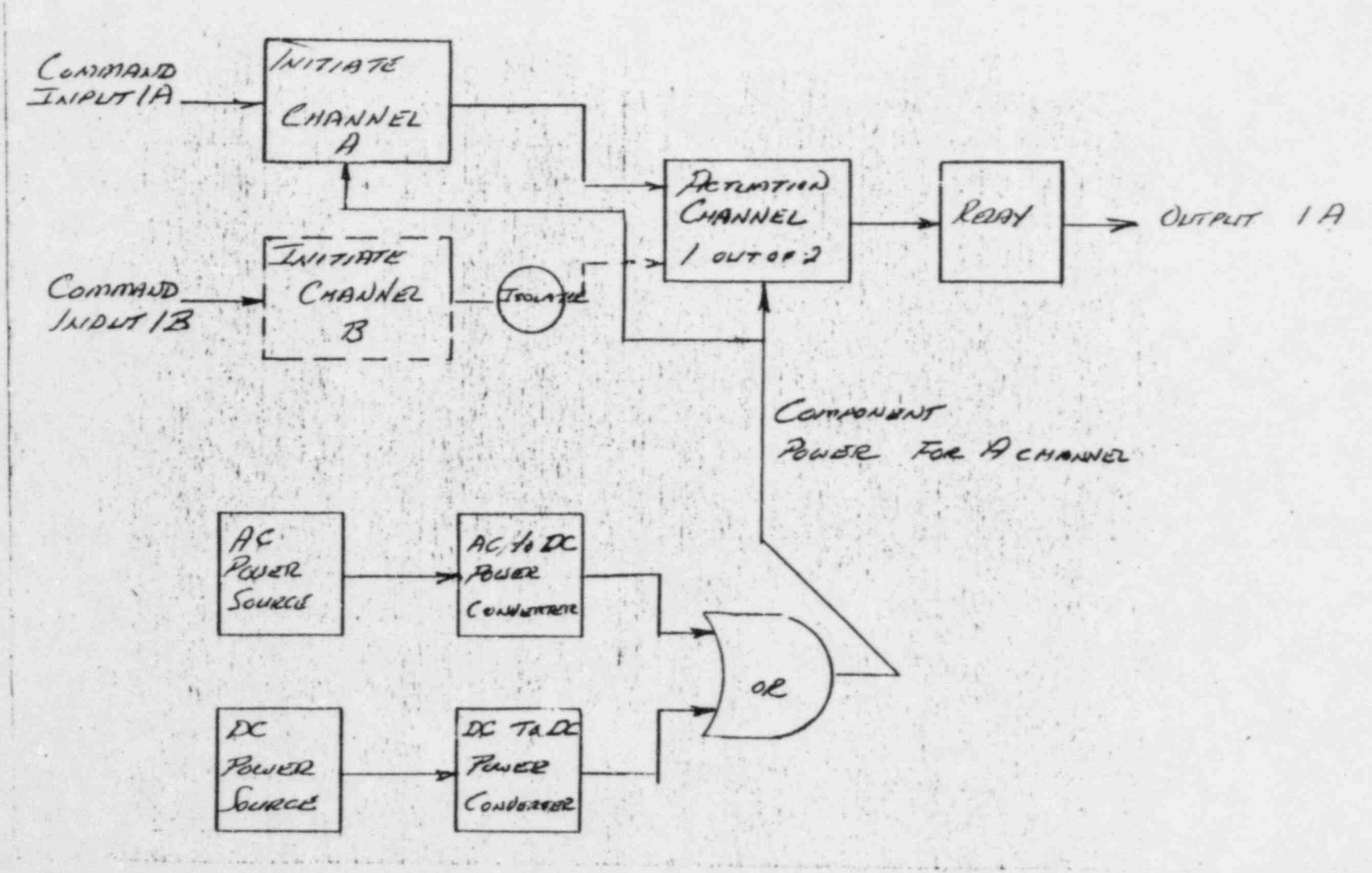


Fig. 2. Block diagram of typical input-to-output relationship

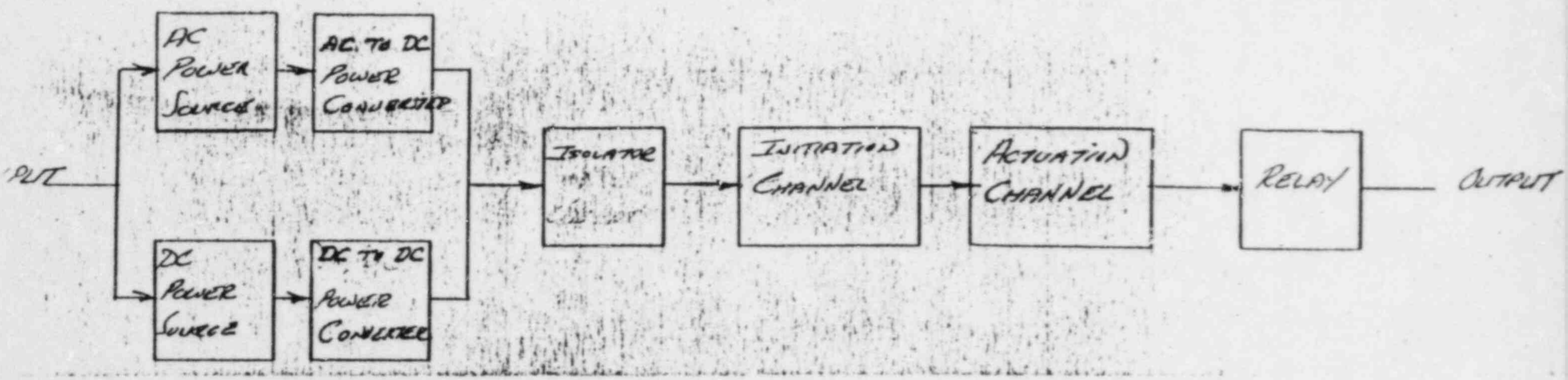


Fig. 3. Cascade model of elements required to obtain input-to-output response

The initiation-channel and the actuation-channel are the elements contained in the logic modules. The relay is directly associated with the modules but is shown separately for clarity.

Based on the model of Fig. 3, we can generate a decision tree following the ideas of Lambert (Ref. 2). To simplify our decision tree let us rearrange the series elements so that the portion with parallel or redundant elements is at the right side of the diagram as shown in Fig. 4.

7.1. DECISION TREE

A decision tree for the model of Fig. 4 is shown in Fig. 5. Each branch is labelled by the probability of success P(S) and probability of failure $P(f) = P(\bar{S}) = 1 - P(S)$. The subsystem reliability or probability of success can be computed for this tree. The equation for the probability of success of this tree is:

$$
\begin{aligned}
P(S) = {} & P(A) \cdot P(B) \cdot P(C) \cdot P(D) \cdot P(E) \\
& + P(A) \cdot P(B) \cdot P(C) \cdot P(D) \cdot P(\bar{E}) \cdot P(F) \cdot P(G) \\
& + P(A) \cdot P(B) \cdot P(C) \cdot P(\bar{D}) \cdot P(F) \cdot P(G)
\end{aligned}
$$

Before we can proceed it is necessary to consider how to combine the probabilities for the redundant one-out-of-two logic.

7.2. EFFECT OF ONE-OUT-OF-TWO REDUNDANCY ON SYSTEM RELIABILITY

The 1-out-of-2 logical combination of actuation signals within the logic is effectively a parallel redundancy. From an overall system viewpoint there is one source of input, i.e., the physical input parameter being sensed or measured and (generally) one ultimate output action, e.g., closing the dampers or starting a motor. Figure 6 depicts the situation in block diagram format.

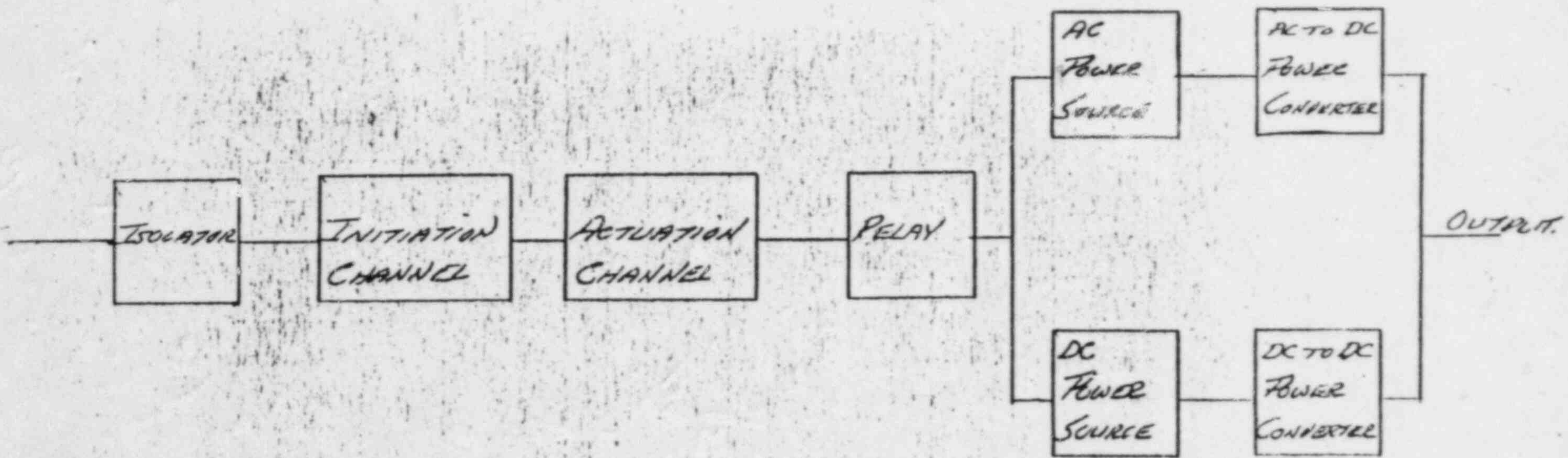


Fig. 4. Rearranged cascade model of typical input-to-output subsystem

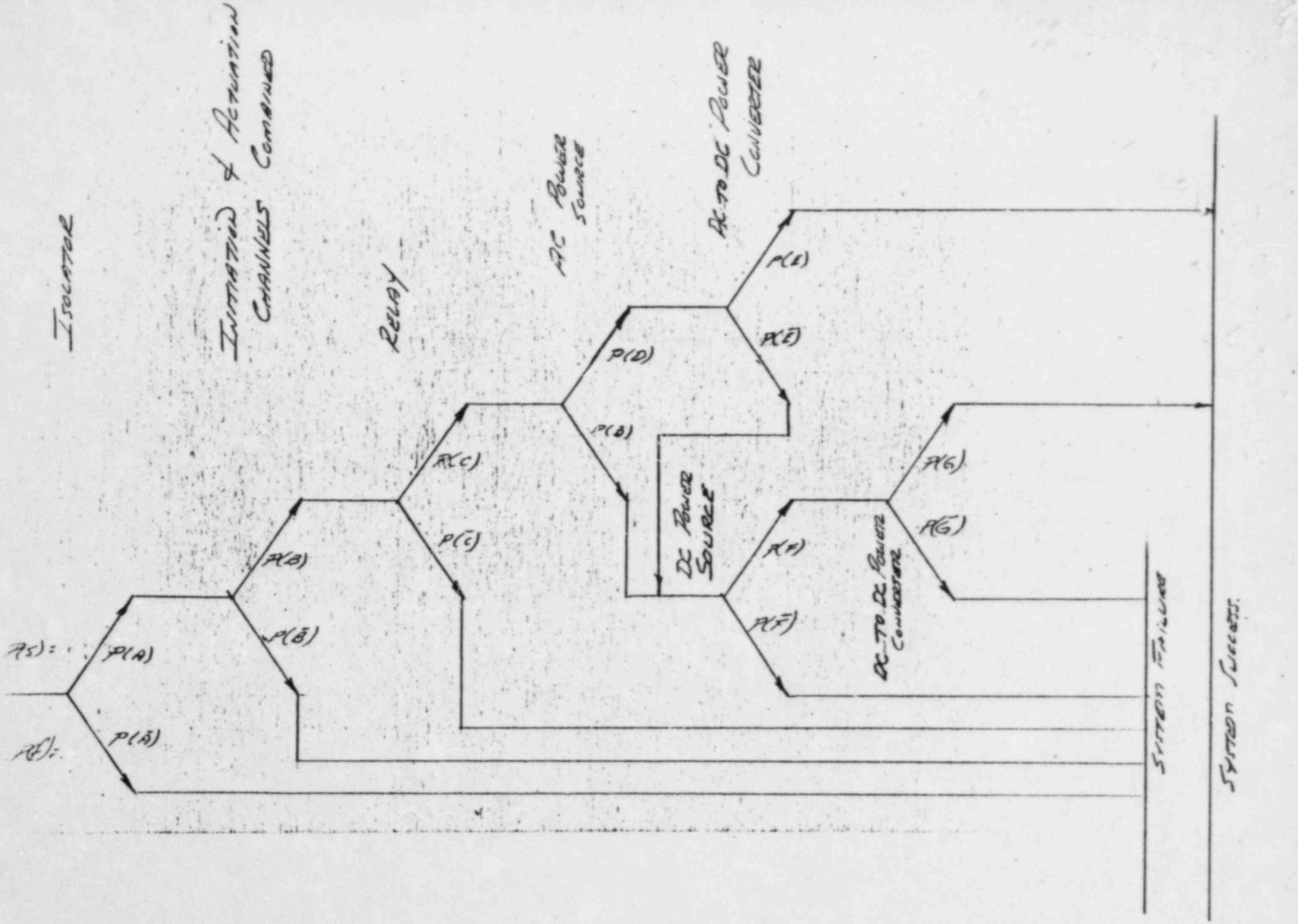


Fig. 5. Decision tree for typical input-to-output subsystem

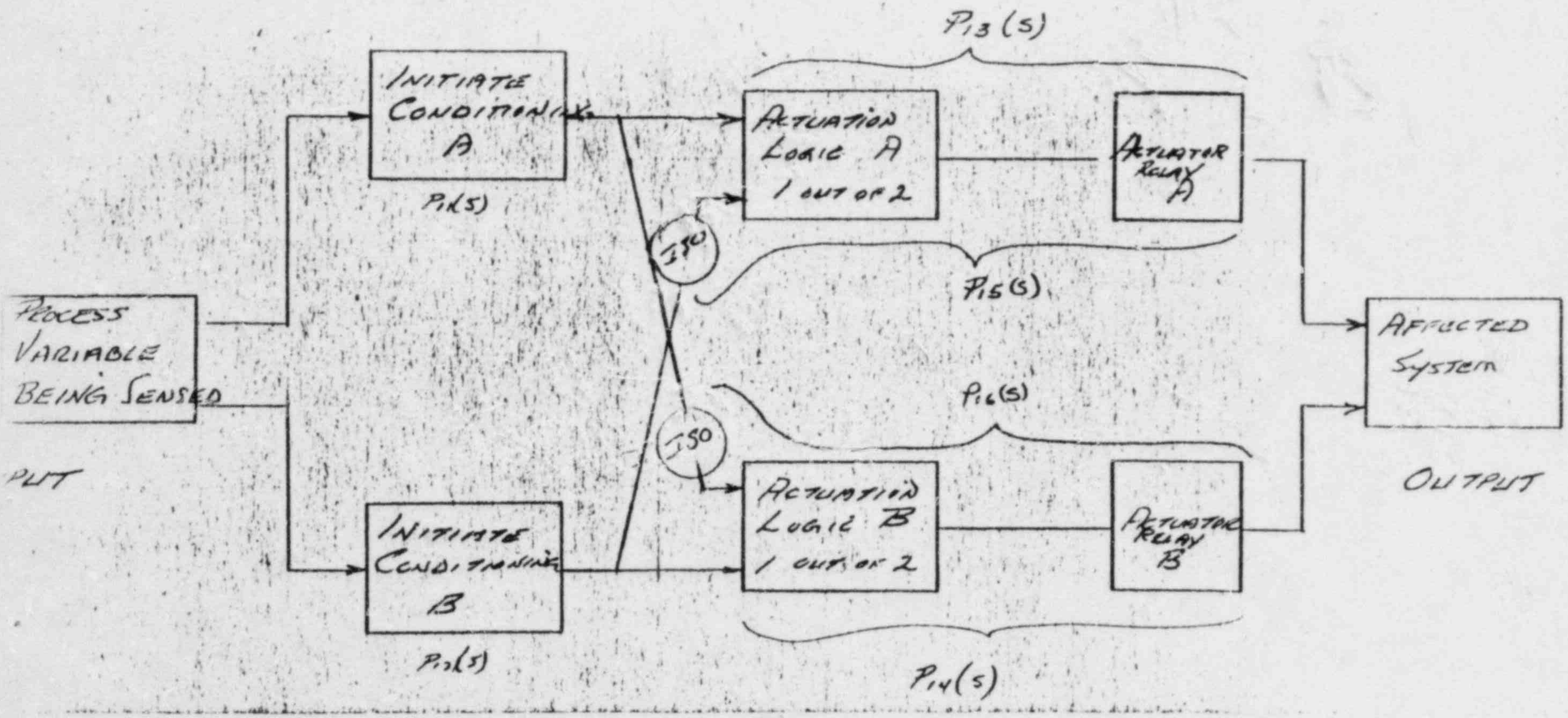


Fig. 6. Block diagram of one-out-of-two redundant logic system

Figure 7 shows the decision tree for this arrangement. The probability equation for this decision tree is

$$\begin{aligned} P\text{ (Channel Success)} = {} & P_{11}(S) \cdot P_{13}(S) \\ & + (1 - P_{11}(S)) \cdot P_{12}(S) \cdot P_{14}(S) \\ & + P_{11}(S) \cdot (1 - P_{13}(S)) \cdot P_{16}(S) \\ & + (1 - P_{11}(S)) \cdot P_{12}(S) \cdot (1 - P_{14}(S)) \\ & \cdot P_{15}(S) \end{aligned}$$

This can be factored to

$$\begin{aligned} P(CS) = {} & P_{11}(S) \{P_{13}(S) + (1 - P_{13}(S) P_{16}(S)\} \\ & + (1 - P_{11}(\overline{S}) \cdot P_{12}(S) \{P_{14}(S) + (1 - P_{14}(S)) P_{15}(S)\} \end{aligned}$$

where $P(CS) = P(OS_j)/I_i$

as $P(OS_j)/I_i$ was previously defined.

7.3. INCLUDING POWER SUPPLY RELIABILITY

It is now necessary to include the probability impact of the power supplies and power conversion equipment to complete our model for an individual input-to-output channel model. Figure 8 shows the logic tree of Fig. 7 with the power system shown as block elements. Figure 9 is a cascade diagram for the power supply systems shown as blocks in Fig. 8. Figure 10 shows the logic tree for the power supply subsystem.

The probability of a successful output from the power supply subsystem can be expressed as follows:

$$\begin{aligned} P(PS) = {} & P_{S1}(S) P_{S3}(S) + P_{S1}(S) \cdot P_{S3}(\overline{S}) \cdot P_{S2}(S) \cdot P_{S4}(S) \\ & + P_{S1}(\overline{S}) \cdot P_{S2}(S) \cdot P_{S4}(S) \end{aligned}$$

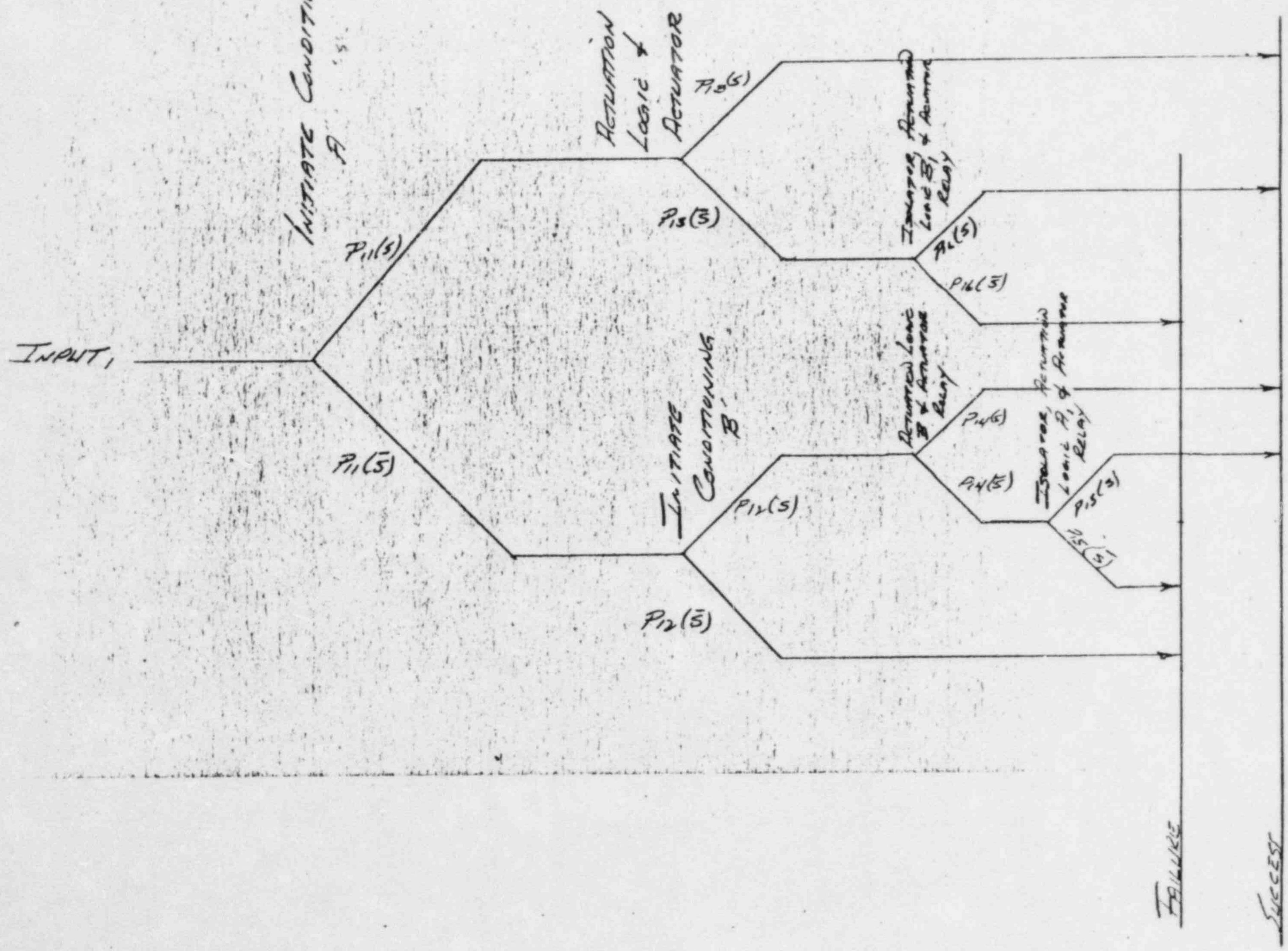


Fig. 7. Decision tree for one-out-of-two redundant logic system

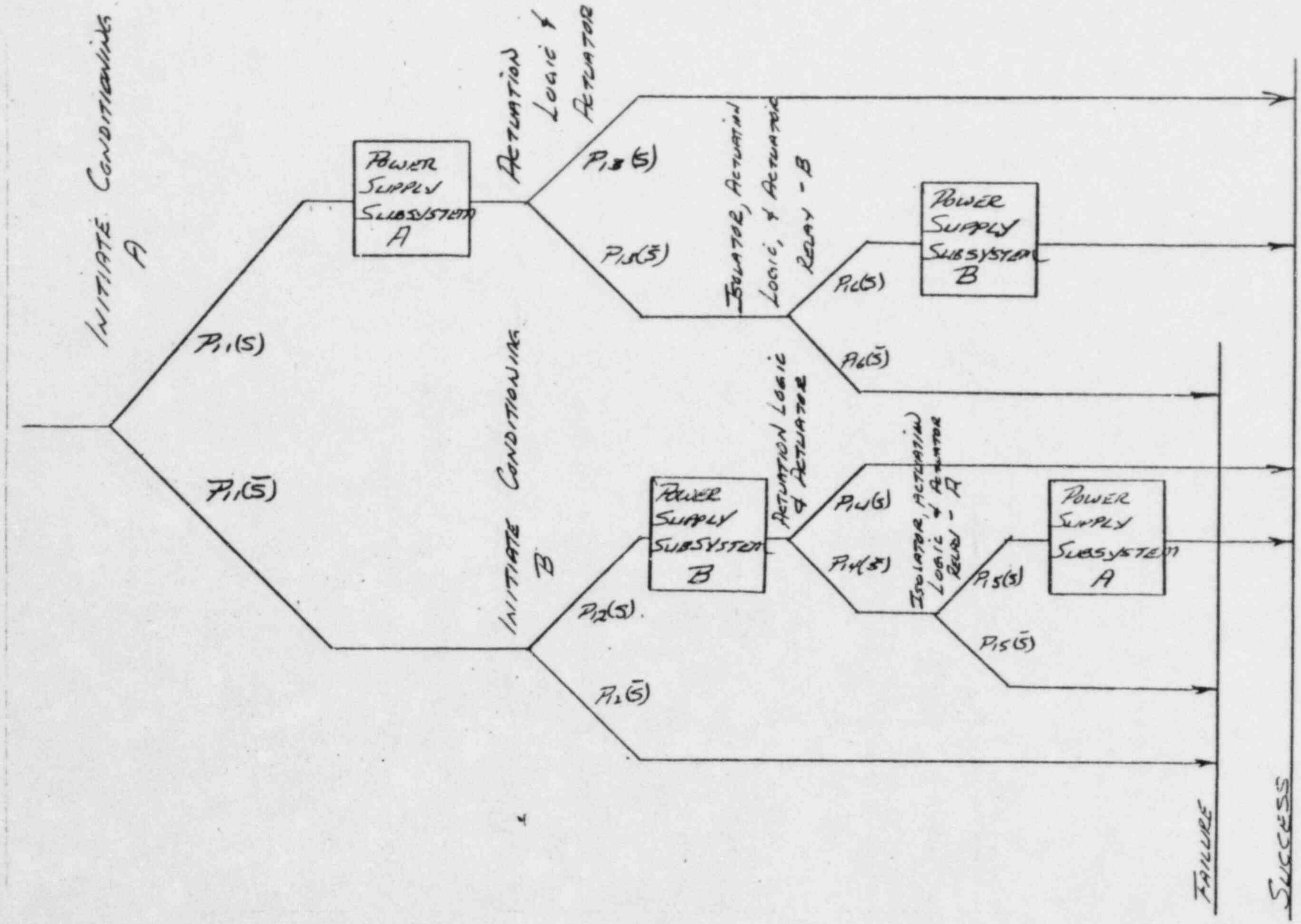


Fig. 8. Decision tree for one-out-of-two redundant logic system with power supply subsystem shown

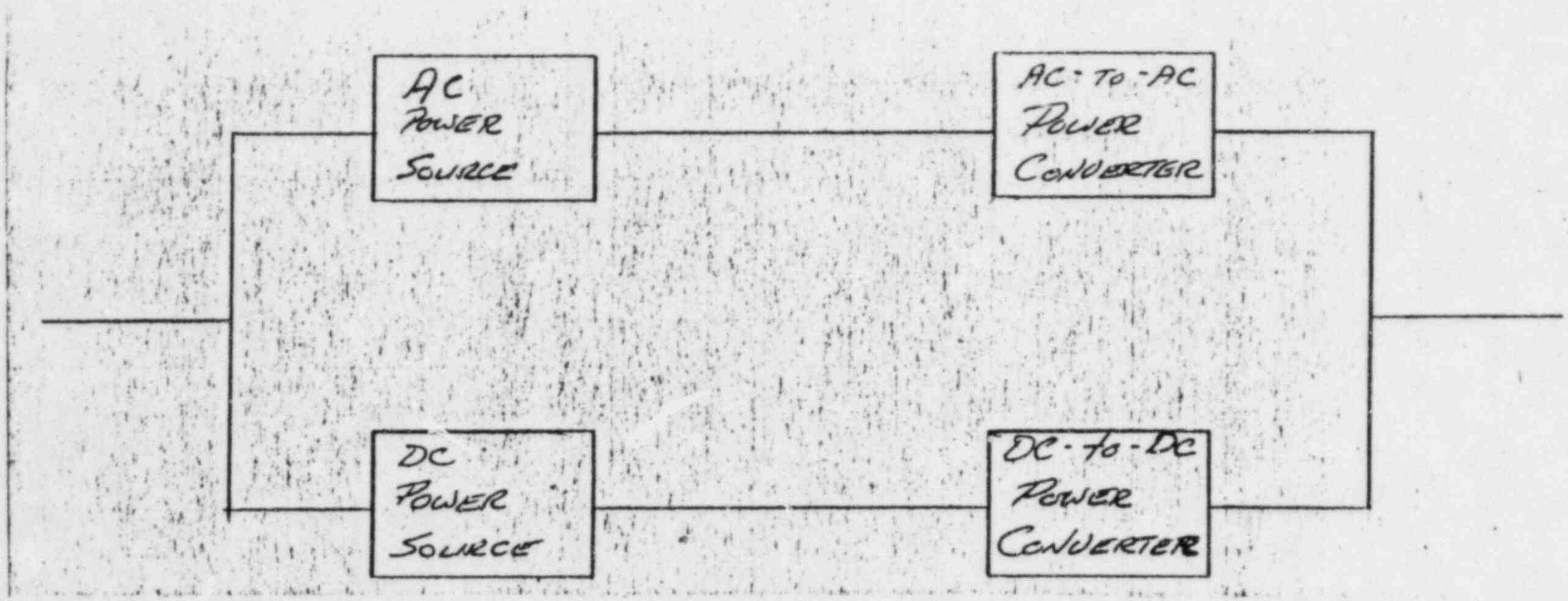


Fig. 9. Cascade diagram of power supply subsystem

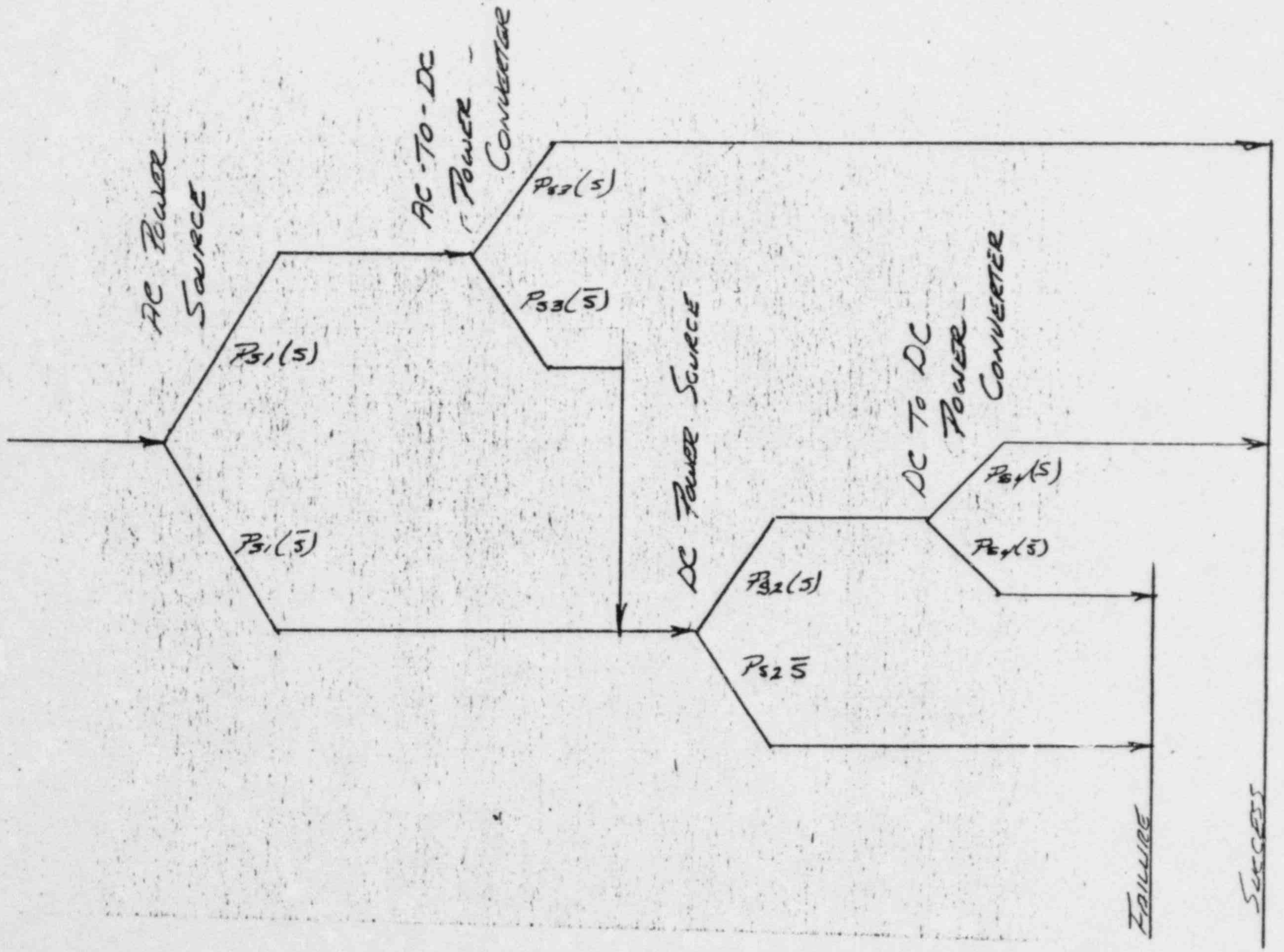


Fig. 10. Decision tree for power supply subsystem

$$P(\overline{PS}) = P_{S1}(\overline{S}) \cdot P_{S2}(\overline{S}) + P_{S1}(\overline{S}) \cdot P_{S2}(S) \cdot P_{S4}(\overline{S})$$
$$+ P_{S1}(S) \cdot P_{S3}(\overline{S}) \cdot P_{S2}(\overline{S}) + P_{S1}(S)\, P_{S3}(\overline{S})\, P_{S2}(S)\, P_{S4}(\overline{S}).$$

Now consider Fig. 11 which shows the logic tree of Fig. 7 with the power supply subsystem included. In generating the logic tree, it is necessary to take into account the dependence of the system on the power supplies.

We can now write the probability equations for the logic tree of Fig. 11 in terms of the individual decision probabilities shown. As previously defined

let $P(SO_1)/I$ = probability of a success output of channel 1 given an input to channel 1.

From the decision tree of Fig. 11 we find that

$$\begin{aligned} P(SO_1)/I_i = {} & P_{11}(S) \cdot P_{SA}(S) \cdot P_{13}(S) \\ & + P_{11}(S) \cdot P_{SA}(S) \cdot P_{13}(\overline{S}) \cdot P_{16}(S) \cdot P_{SB}(S) \\ & + P_{11}(S) \cdot P_{SA}(\overline{S}) \cdot P_{12}(S) \cdot P_{SB}(S) \cdot P_{14}(S) \\ & + P_{11}(\overline{S}) \cdot P_{12}(S) \cdot P_{SB}(S) \cdot P_{14}(S) \\ & + P_{11}(\overline{S}) \cdot P_{12}(S) \cdot P_{SB}(S) \cdot P_{14}(\overline{S}) \cdot P_{15}(S) \cdot P_{SA}(S) \end{aligned}$$

7.4. MULTIPLE OUTPUTS

With the power supply dependence incorporated into the model let us consider the complication of two or more outputs resulting from a single stimulus as shown in Fig. 12. The following analysis of Fig. 12 is predicated on the concept that all output functions resulting from a specified input function must result to have a successful operation. Mathematically this means

$$P(S)/C = \left\{ P(SO_1)/I_i \cdot P(SO_2)/I_i \right\} \cdot P(I_i)/C$$

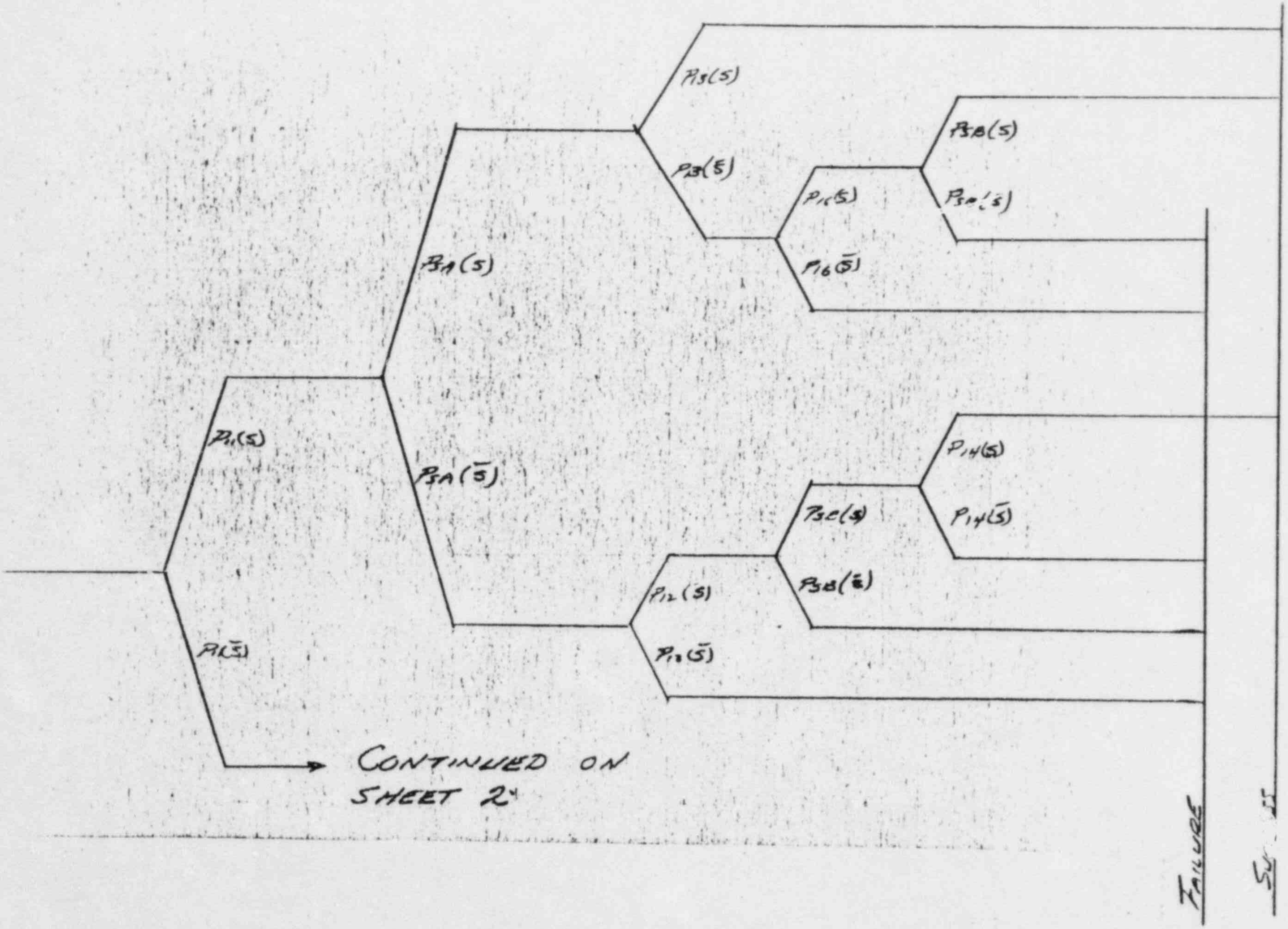


Fig. 11. Decision tree for one-out-of-two redundant logic system with power supply subsystem included (sheet 1 of 2)

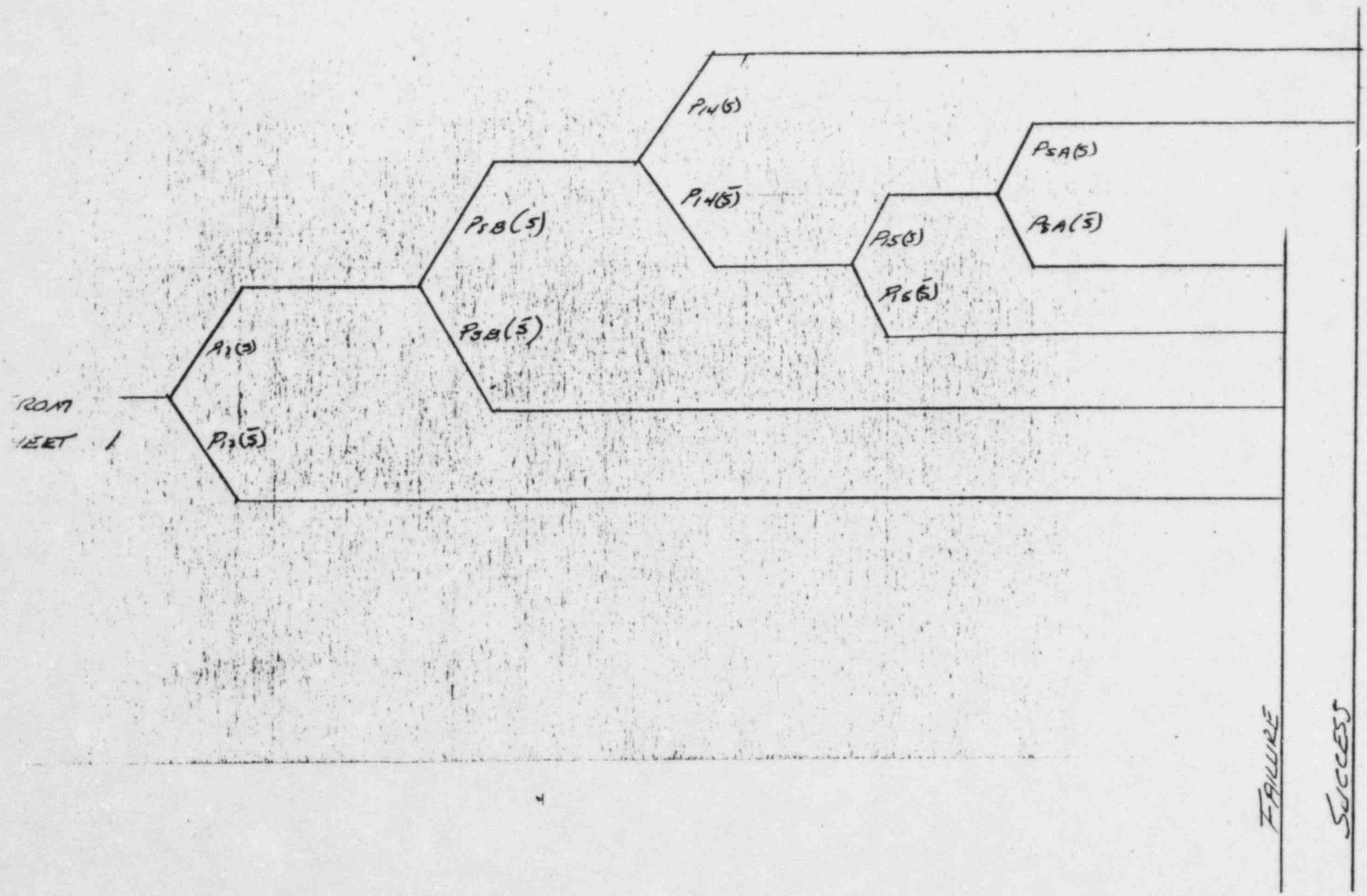


Fig. 11. Decision tree for one-out-of-two redundant logic system with power supply subsystem included (sheet 2 of 2)

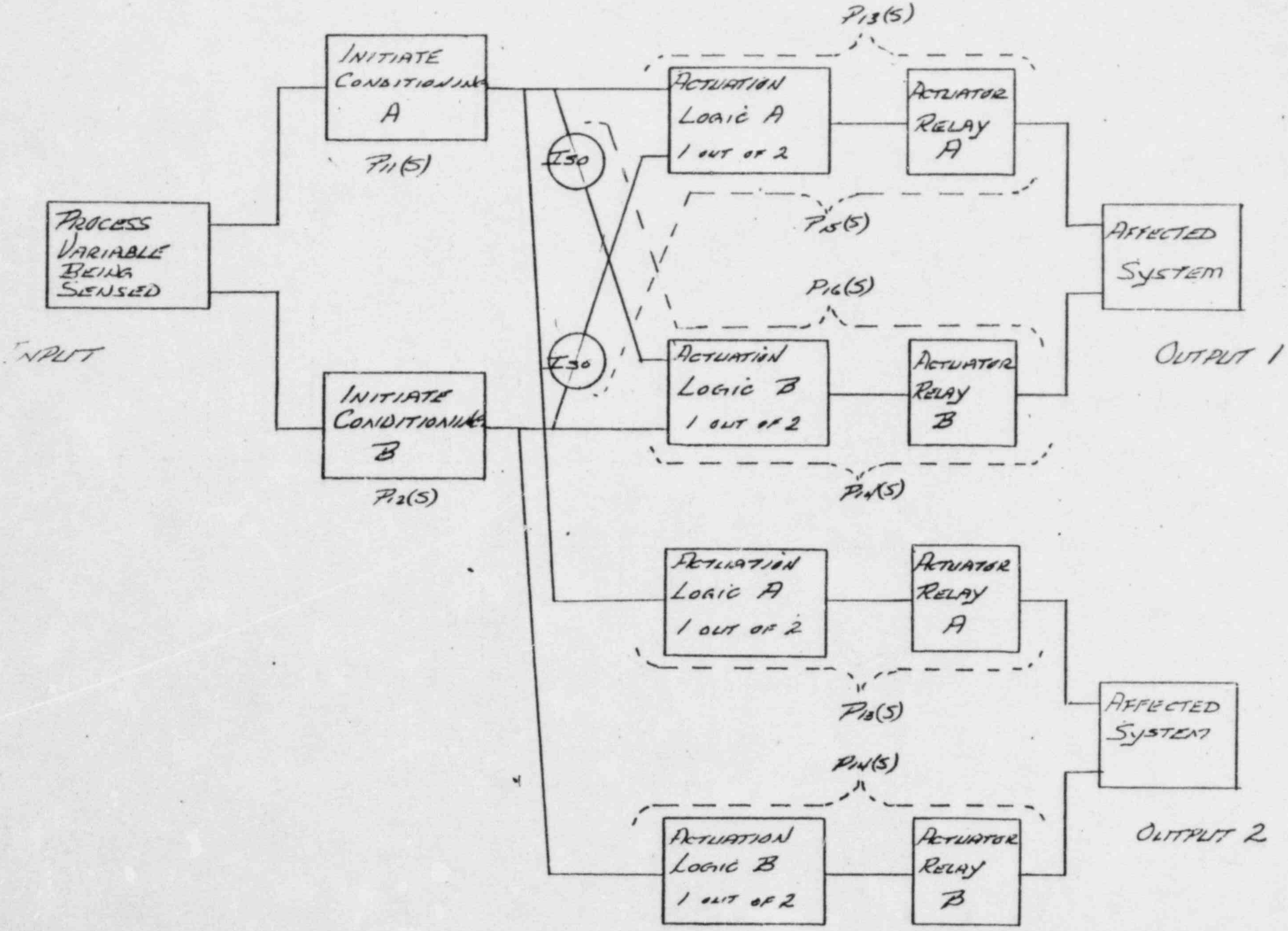


Fig. 12. Block diagram of one input/two output subsystem

$P(SO_1)/I_1$ was defined in the previous paragraph. $P(SO_2)/I_1$, the probability of output 2 given input I_1, is somewhat simpler and is based on the argument that the power supply dependence has been accounted for in $P(SO_1)/I_1$. A simplified but conservative approximation to $P(SO_2)/I_1$ is

$$P(SO_2)/I_1 = P_{13}(S) + P_{13}(\overline{S})\ P_{16}(S) \quad .$$

In general terms this implies that the probability of success for two outputs is the probability of success for a single output multiplied by the probability that Actuation Logic A or B and Actuator Relays A or B function in the output 2 train.

With the defining equations for $P(SO_1)/I_1$ and $P(SO_2)/I_1$ we have the basis for defining the probability equations for the FBEVAS, CREFAS, CPIAS and the CRVIAS channels. In general terms these are:

$$P(SO_i)/I_j = P(SO_1)/I_1 \text{ for } i = j$$

$$P(SO)_i/I_j = P(SO_2)/I_1 \text{ for } i \neq j$$

7.5. DIESEL GENERATOR START SIGNAL (DGSS) SUBSYSTEM

The DGSS module has three direct external input signals and a fourth signal which is an output of the LOP module.

Basically the DGSS module is a logical OR gate that produces an output if any input is present. Figure 13 is a block diagram for the decision tree representation for the DGSS subsystem. The decision tree is elementary as shown in Fig. 14 where $P_{DA}(S)$ and $P_{DB}(S)$ are the probability of success for the DGSS modules and $P_{SA}(S)$ and $P_{SB}(S)$ are as previously defined.

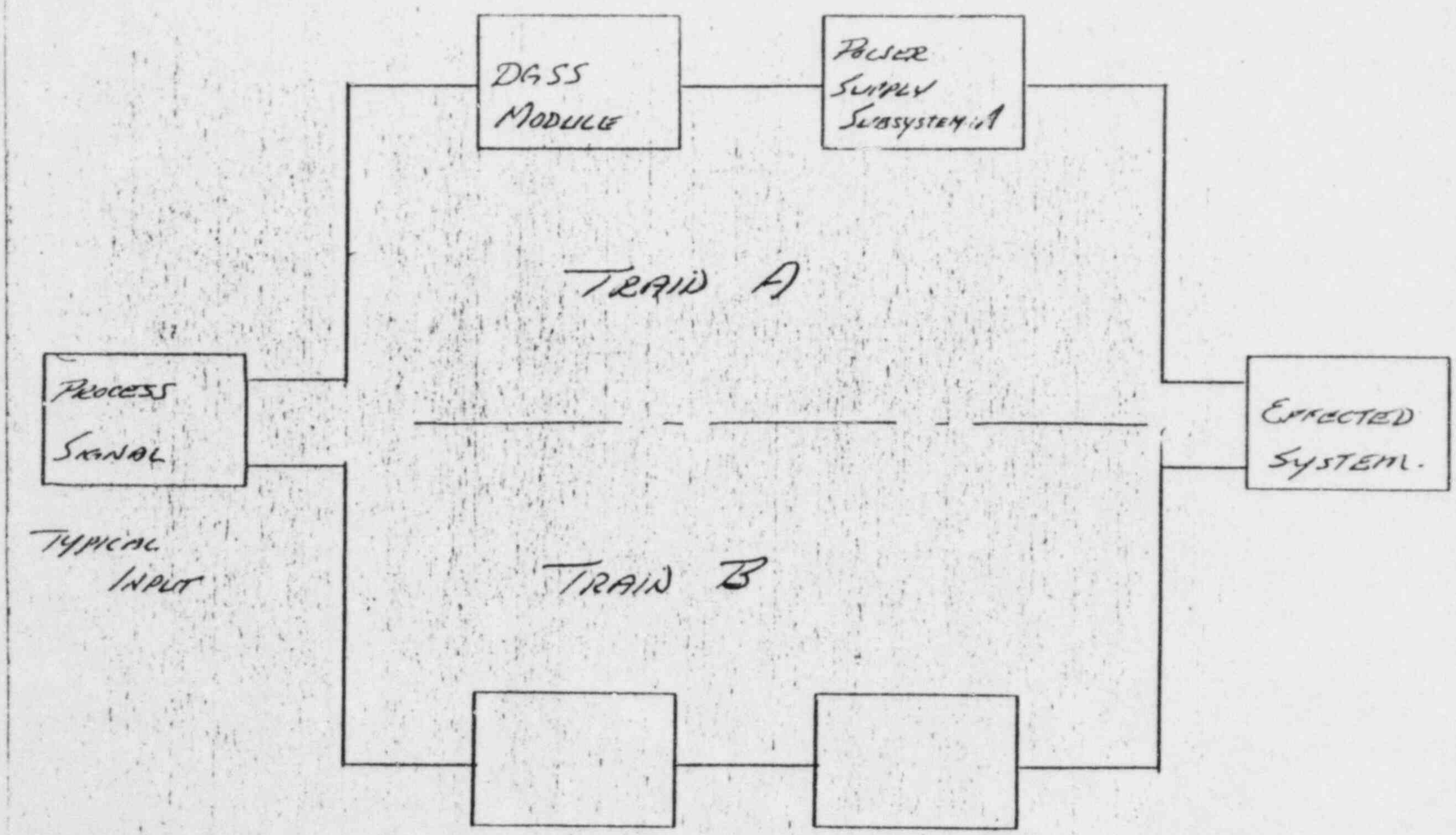


Fig. 13. Block diagram of diesel generator start signal (DGSS) subsystem

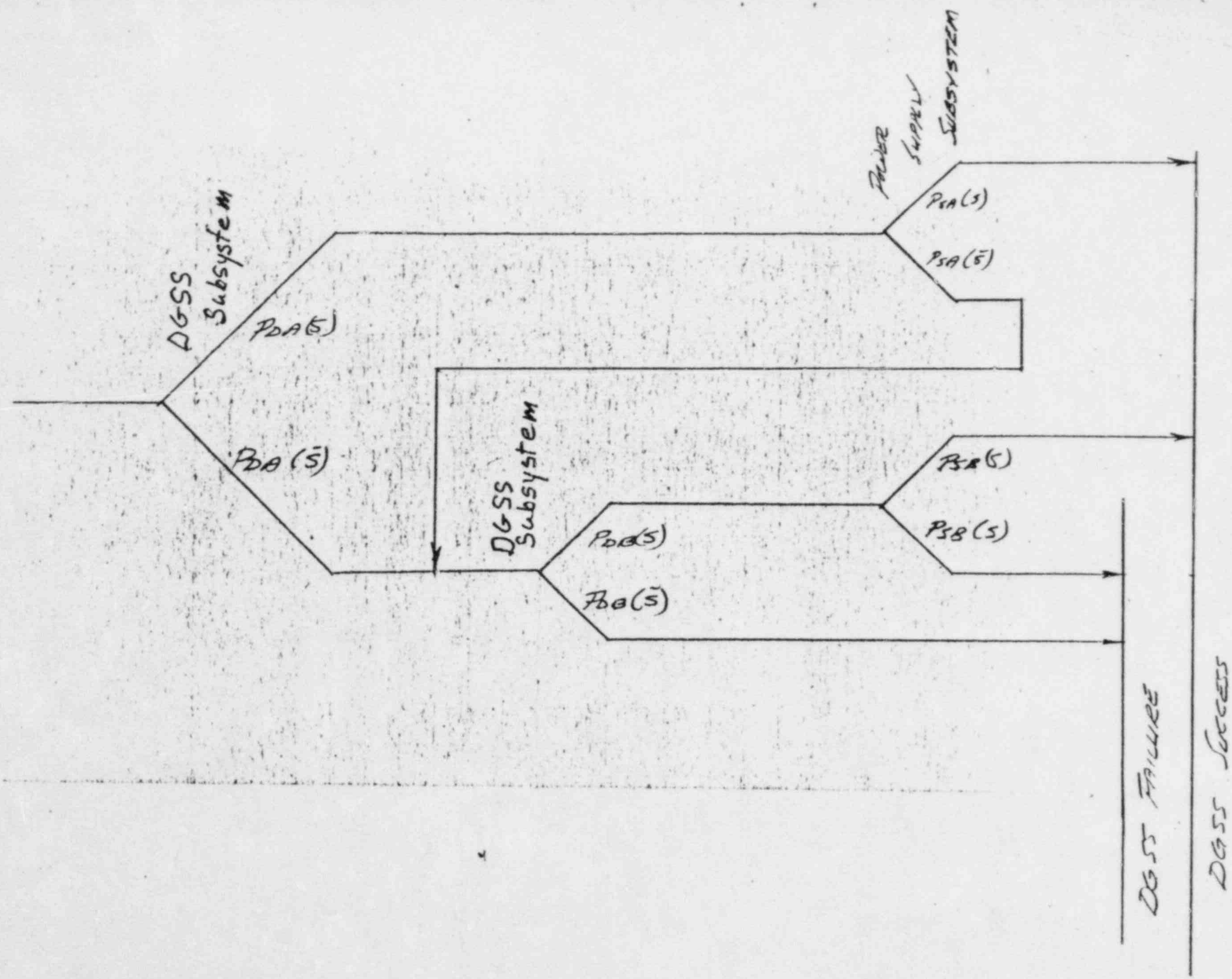


Fig. 14. Decision tree for typical input to diesel generator start signal (DGSS) subsystem

The subsystem probability of success can be written as

$$P_{DSS}(S)/I = P_{DA}(S) \cdot P_{SA}(S) + P_{DA}(S) \cdot P_{SA}(\overline{S}) \cdot P_{SB}(S) + P_{DA}(\overline{S}) \cdot P_{DB}(S) \cdot P_{SB}(S)$$

substituting $P_{DA}(S) = P_{DB}(S)$

and $P_{SA}(S) = P_{SB}(S)$

we obtain

$$P_{DSS}(S)/I = P_{DA}(S) \cdot P_{SA}(S) + P_{DA}(S) \cdot (1 - P_{SA}(S)) \cdot P_{SA}(S) + (1 - P_{DA}(S)) \cdot P_{DA}(S) \cdot P_{SA}(S) \quad .$$

7.6. LOSS-OF-POWER (LOP) LOAD SHED SUBSYSTEM

The Loss-of-Power Load Shed (LOP) subsystem is somewhat different from the subsystems discussed thus far and will require a separate though less detailed analysis.

Figure 15 shows a simplified block diagram similar to Fig. 6, but for the LOP subsystem. The significant difference is the four redundant initiation blocks and the lack of cross connection in the initiation section (see Fig. 6).

Before generating a decision tree for the LOP subsystem we will determine the probability of success for the two-out-of-four (2/4) initiation section. Figure 16 is the 2/4 decision tree. The multiple success paths are analogous to the logical success paths in the two-out-of-four logic. If A, B, C and D represent the input paths, then an output can be generated

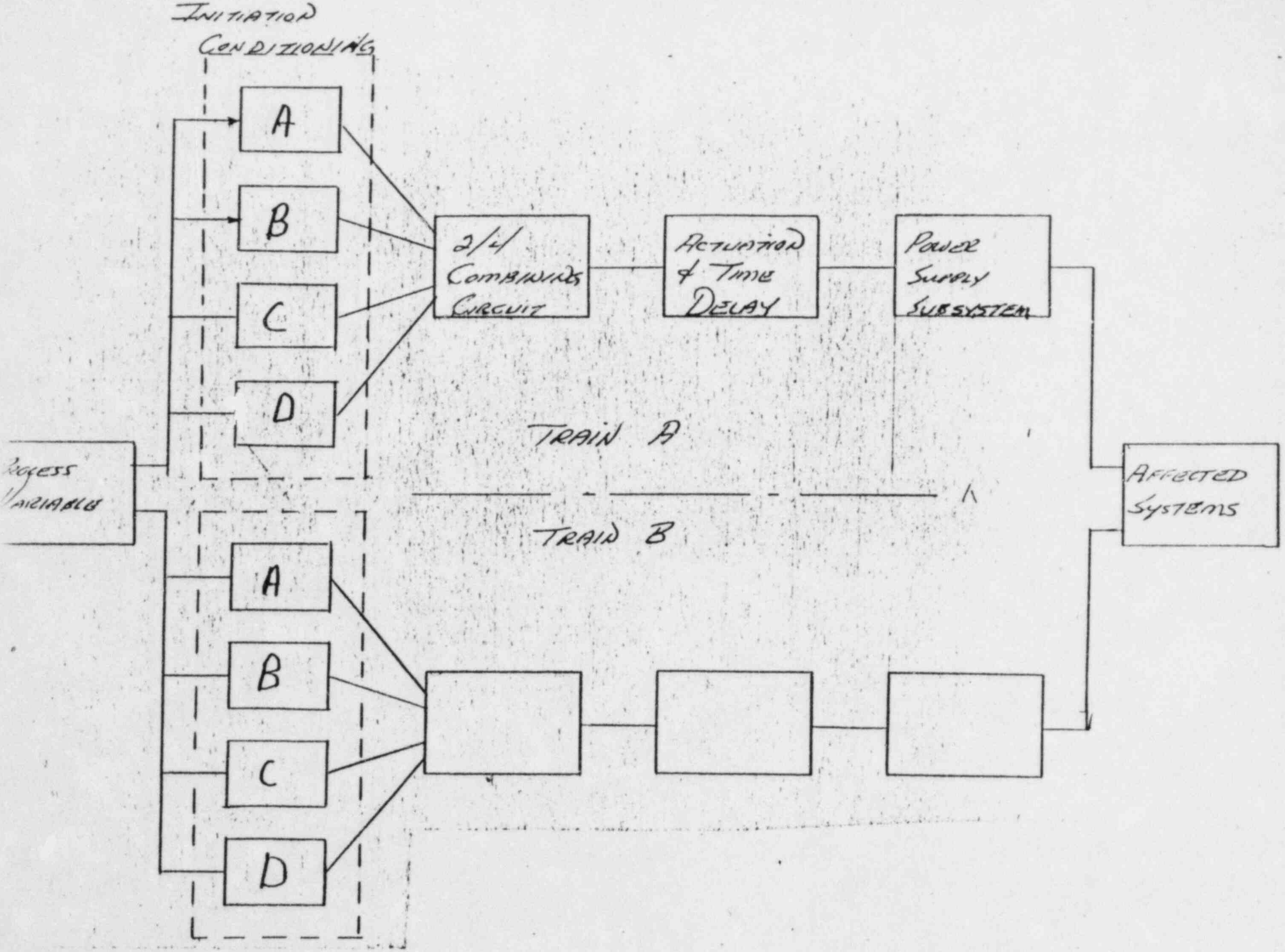


Fig. 15. Block diagram of loss-of-power (LOP) load shed subsystem

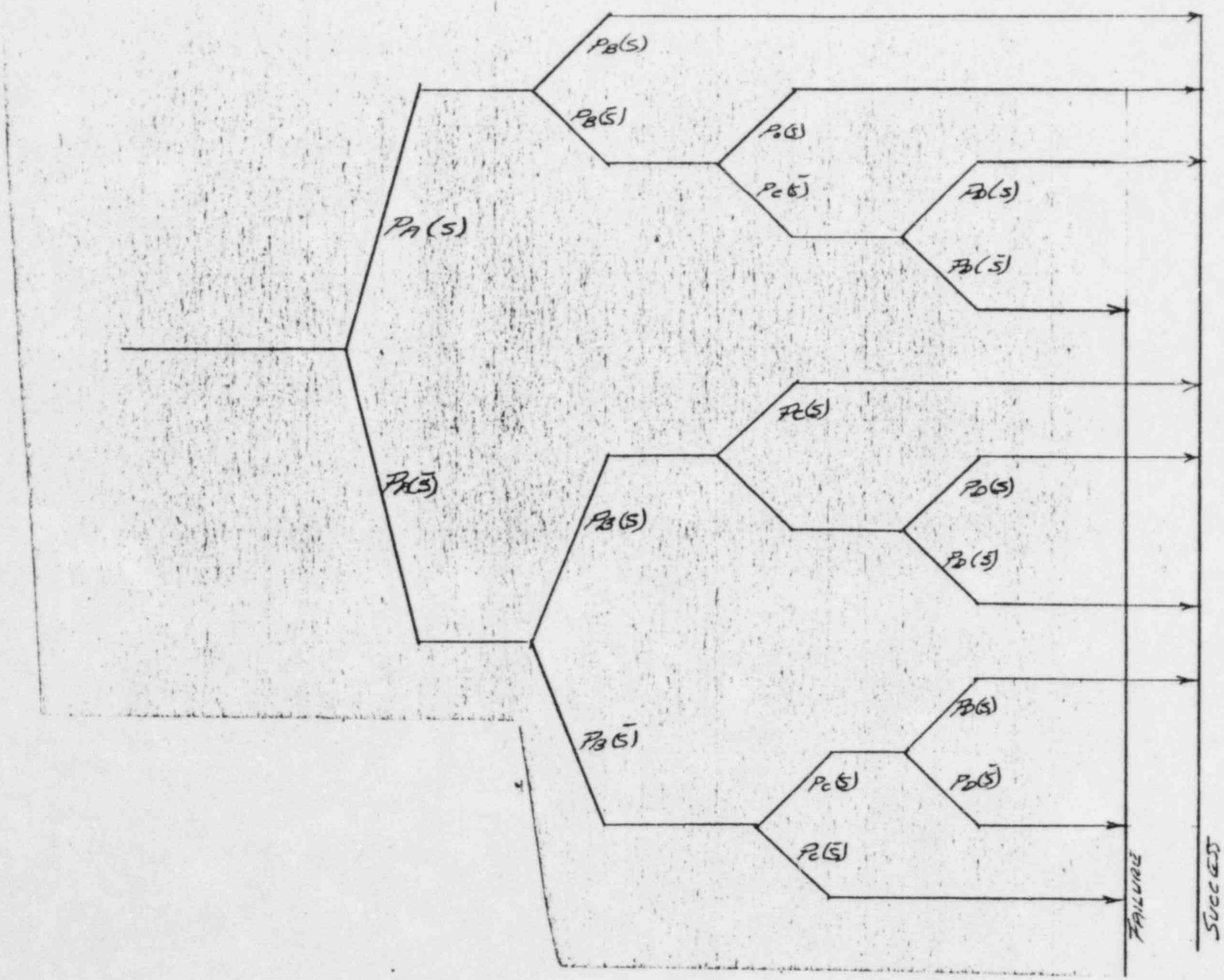


Fig. 16. Decision tree for two-out-of-four initiation section

by AB + AC + AD + BC + BD + CD. The probability of success is the same for any path and is defined as $P_A(S)$. Therefore the probability of success for the 2/4 initiation network is:

$$
\begin{aligned}
P_I(S) = {} & P_A(S) \cdot P_B(S) \\
& + P_A(S) \cdot P_B(\bar{S}) \cdot P_C(S) \\
& + P_A(S) \cdot P_B(\bar{S}) \cdot P_C(\bar{S}) \cdot P(D) \\
& + P_A(\bar{S}) \cdot P_B(S) \cdot P_C(S) \\
& + P_A(\bar{S}) \cdot P_B(S) \cdot P_C(\bar{S}) \cdot P_D(S) \\
& + P_A(\bar{S}) \cdot P_B(\bar{S}) \cdot P_C(S) \cdot P_D(S)
\end{aligned}
$$

Based on $P_A(S) = P_B(S) = \ldots P_D(S)$

$$
\begin{aligned}
P_I(S) = {} & (P_A(S))^2 \\
& + (1 - P_A(S))\, P_A(S)^2 \\
& + (1 - P_A(S))^2\, P_A(S)^2 \\
& + (1 - P_A(S))\, P_A(S)^2 \\
& + (1 - P_A(S))^2\, P_A(S)^2 \\
& + (1 - P_A(S))^2\, P_A(S)^2 \\
= {} & P_A(S)^2 + 2(1 - P_A(S))\, P_A(S)^2 + 3(1 - P_A(S))^2\, P_A(S)^2
\end{aligned}
$$

$$P_I(S) = P_A(S)^2\, (1 + 2\,(1 - P_A(S)) + 3(1 - P_A(S))^2) \quad .$$

We can now write the probability expression for the LOP subsystem from the decision tree of Fig. 17.

$$
\begin{aligned}
P_{LOP}(S) = {} & P_I(S) \cdot P_{24}(S) \cdot P_{AD}(S) \cdot P_{SA}(S) \\
& + \{1 - (P_I(S) \cdot P_{24}(S) \cdot P_{AD}(S) \cdot P_{SA}(S))\} \\
& \cdot P_I(S) \cdot P_{24}(S) \cdot P_{AD}(S) \cdot P_{SA}(S)
\end{aligned}
$$

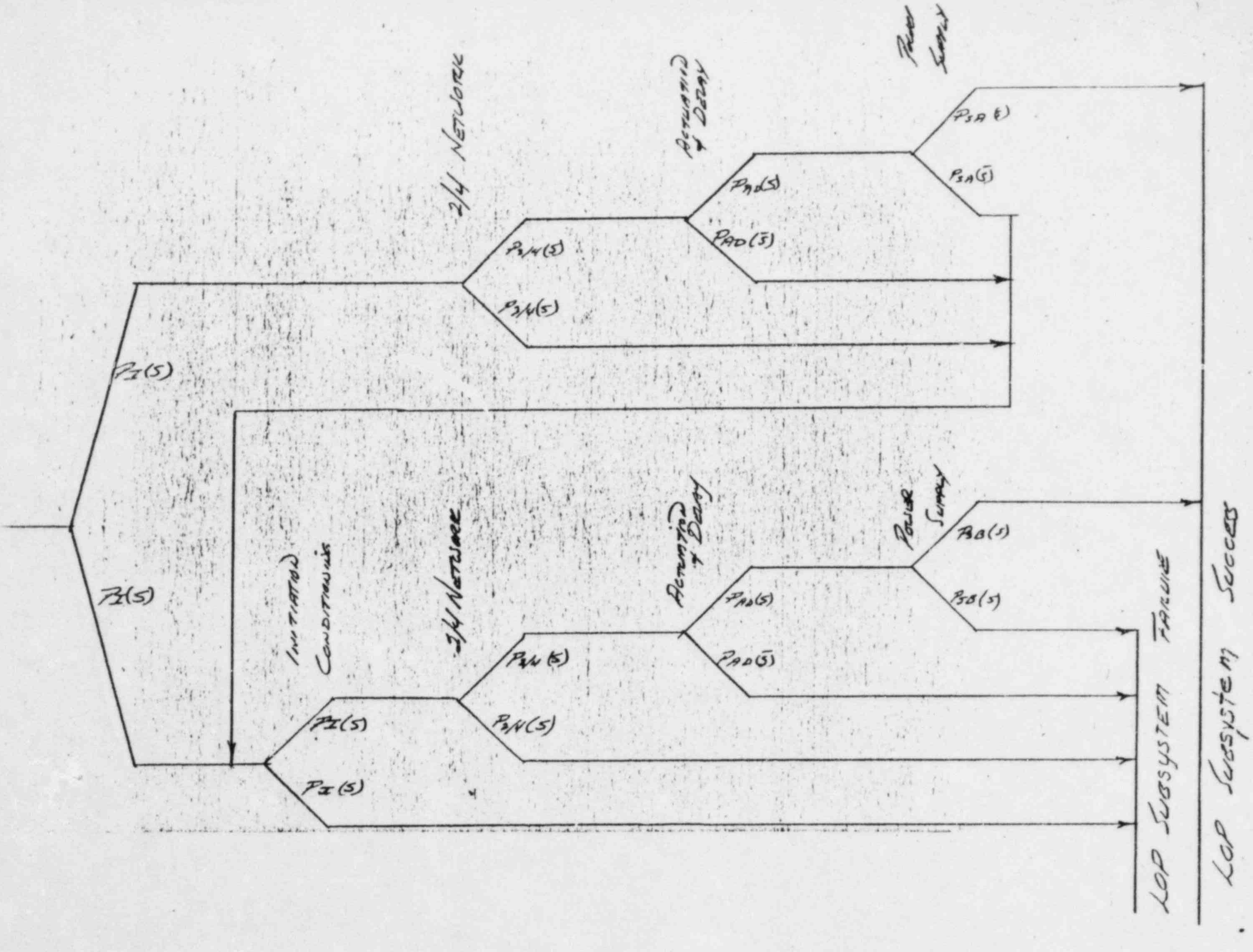


Fig. 17. Decision tree for loss-of-power (LOP) load shed subsystem

Let $P_L(S) = P_I(S) \cdot P_{24}(S) \cdot P_{AD}(S) \cdot P_{SA}(S)$

$$P_{LOP}(S) = P_L(S) + (1 - P_L(S)) P_L(S)$$

where $P_I(S)$ = Probability of successful operation of the 2/4 redundant initiation section

$P_{24}(S)$ = Probability of successful operation of the 2/4 combining network

P_{AD} = Probability of successful operation of the actuation and time delay circuits

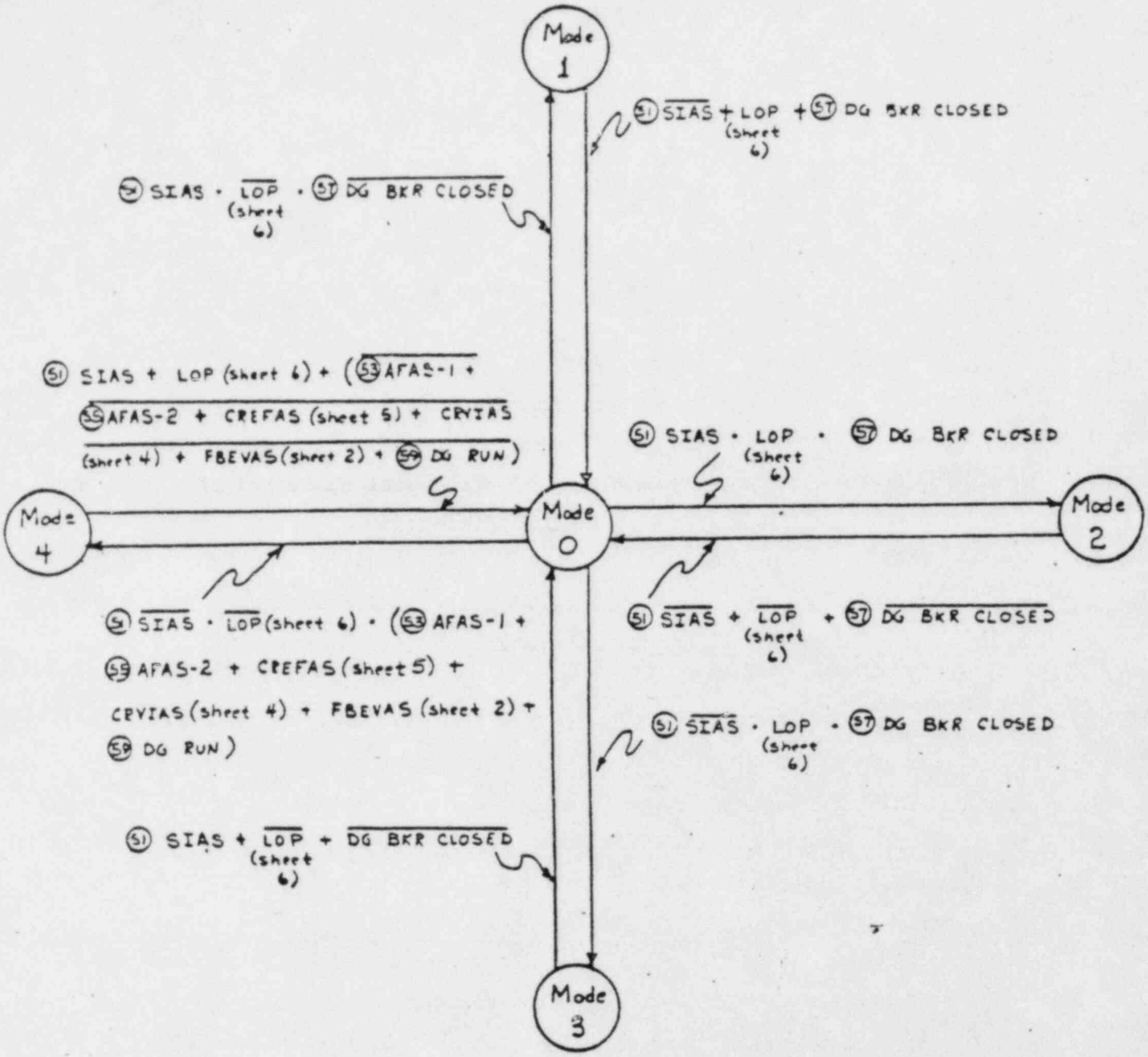
$P_{SA}(S) = P_{SB}(S)$ = Probability of successful operation of the power supply subsystem.

7.7. LOAD SEQUENCER AND AUTO TEST

The load sequencer has 10 possible input signals, 8 of which are generated within the ESFAS and two, DG RUN and DG BKR, are generated externally from LOP module output signals. See drawing ELE 342-0100 for details.

To determine the probability of subsystem success it is necessary to determine how much of the supporting subsystems must be functional. Examination of the ESF Load Sequencer State Diagram of Ref. 1 (see Fig. 18) reveals that three input signal sections must function to go from the normal state, Mode 0, to one of the active states, Mode 1, Mode 2, Mode 3, or Mode 4. SIAS and LOP signals appear in all 4. The third signal varies with mode. For analysis we will use DG BKR because it is involved in the greatest number of modes.

The decision tree block diagram is shown in Fig. 19.



Notes:

1. State diagram shown for Subsystem A only, same for Subsystem B.
2. Mode 4 sub-sequence outputs are developed by logically AND gating the timed outputs with the accident signals as outlined in Attach. 4-2, Table 9.

Fig. 18. State diagram of ESF

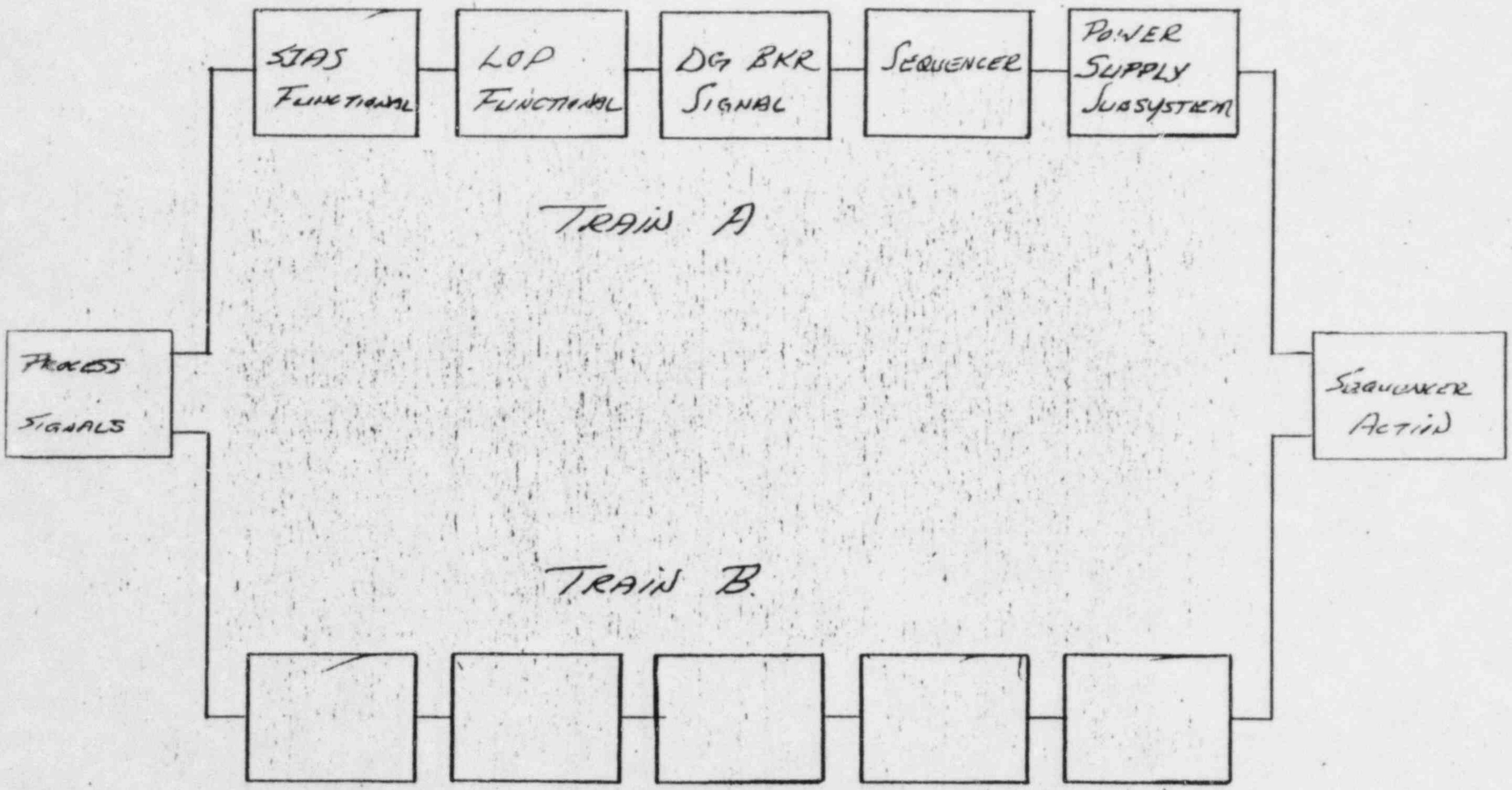


Fig. 19. Block diagram of load sequencer and auto test

Figure 20 shows the load sequencer decision tree from which the probability of success for the sequencer can be written by inspection.

To simplify writing the probability of success for the tree, let

$$P_{LS_A}(S) = P_{SI}(S) \cdot P_{LOP}(S) \cdot P_{BKR}(S) \cdot P_Q(S) \cdot P_{SA}(S)$$

Then

$P_{LS}(S)$ = Probability of successful operation of the load sequencer

$$P_{LS}(S) = P_{LS_A}(S) + (1 - P_{LS_A}(S))\, P_{LS_A}(S) \quad .$$

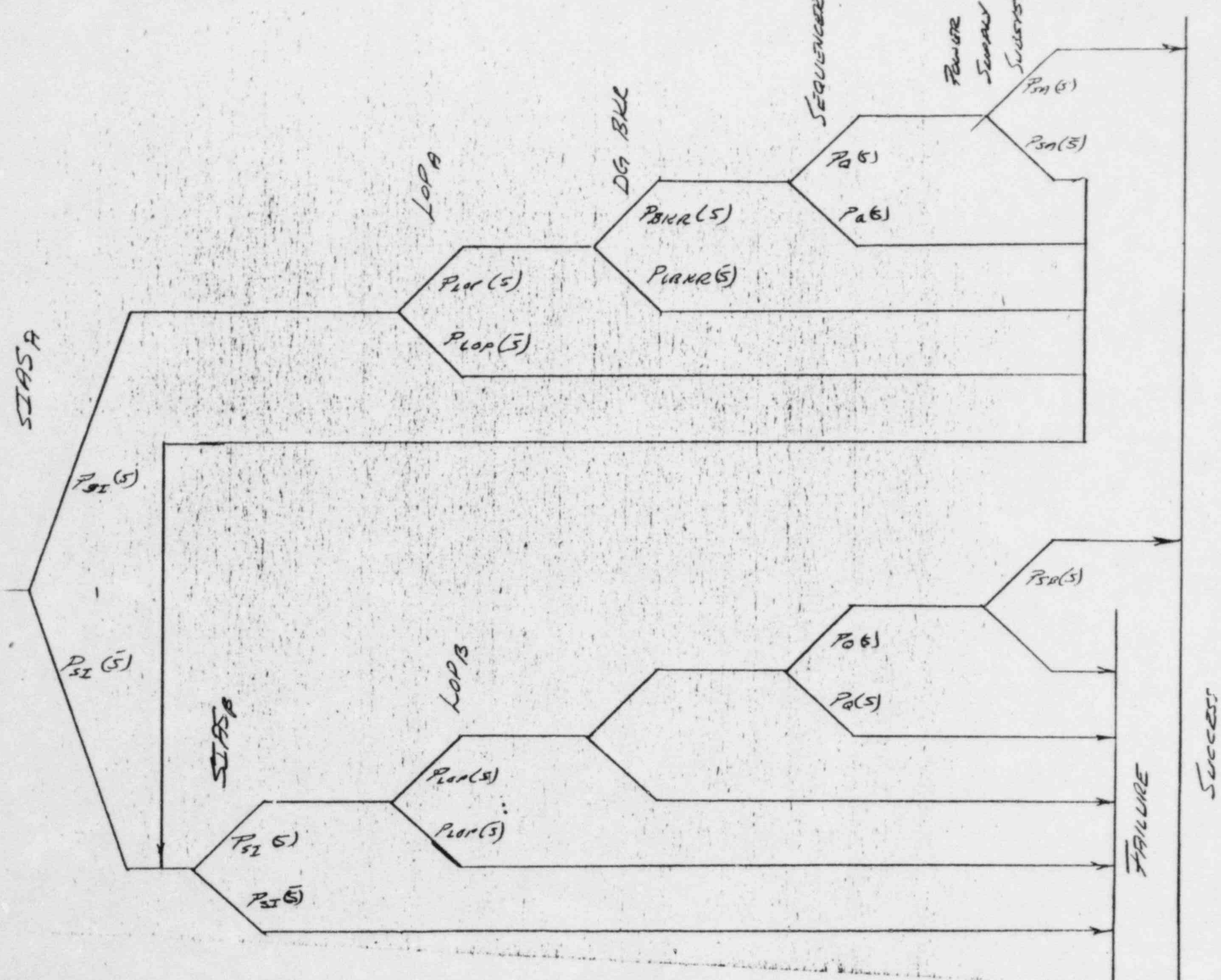


Fig. 20. Decision tree for load sequencer and auto test

8. EQUATIONS FOR COMPOSITE SYSTEM RELIABILITY

In the preceding sections the system model was established and a generalized set of probability equations were derived. Following the generalization, equations were presented for the individual subsystems. This section ties the generalized approach to the individual subsystem equations and permits computation of the system reliability for any mission time.

Table 2 summarizes the subsystem component failure rate values that will be substituted in the model equations to compute the system reliability.

$$
\begin{aligned}
P(S)/C = {} & P(I_1)/C \cdot \{P(SO_1)/I_1 \cdot P(SO_2)/I_1 \cdot P(SO_3)/I_1 \\
& \cdot P(SO_4)I_1 \cdot P(SO_5)/I_1 \cdot P(SO_6)/I_1 \cdot P(SO_7/I_1\} \\
& + P(I_2)/C \cdot \{P(SO_1)/I_2 \cdot P(SO_2)/I_2 \cdot P(SO_3)/I_2 \\
& \cdot P(SO_4/I_2 \cdot P(SO_5)/I_2 \cdot P(SO_6)/I_2 \cdot P(SO_7)/I_2\} \\
& + P(I_3)/C \cdot \{P(SO_1)/I_3 \cdot P(SO_2)/I_3 \cdot P(SO_3)/I_3 \\
& \cdot P(SO_4)/I_3 \cdot P(SO_5)/I_3 \cdot P(SO_6)/I_3 \cdot P(SO_7)/I_3\} \\
& + P(I_4)/C \cdot \{P(SO_1)/I_4 \cdot P(SO_2)/I_4 \cdot P(SO_3)/I_4 \\
& \cdot P(SO_4)/I_4 \cdot P(SO_5)/I_4 \cdot P(SO_6)/I_4 \cdot P(SO_7)/I_4\} \\
& + P(I_5)/C \cdot \{P(SO_1)/I_5 \cdot P(SO_2)/I_5 \cdot P(SO_3)/I_5 \\
& \cdot P(SO_4)/I_5 \cdot P(SO_5)/I_5 \cdot P(SO_6)/I_5 \cdot P(SO_7)/I_5\} \\
& + P(I_6)/C \cdot \{P(SO_1)/I_6 \cdot P(SO_2)/I_6 \cdot P(SO_3)/I_6 \\
& \cdot P(SO_4)/I_6 \cdot P(SO_5)/I_6 \cdot P(SO_6)/I_6 \cdot P(SO_7)/I_6\} \\
& + P(I_7)/C \cdot \{P(SO_1)/I_7 \cdot P(SO_2)/I_7 \cdot P(SO_3)/I_7 \\
& \cdot P(SO_4)/I_7 \cdot P(SO_5)/I_7 \cdot P(SO_6)/I_7 \cdot P(SO_7)/I_7\}
\end{aligned}
$$

TABLE 2
SUBSYSTEM COMPONENT FAILURE RATE VALUES

Subsystem Component	Failure Rate $x10^{-6}$	Reliability for 720 hr	Prob Symbol	Source of Failure Rate Data
Initiating Channel for FBEVAS, CREFAS, CPIAS	12.5	0.9910	P_{11}, P_{12}	Calculated by MIL-HBK 217A
Actuating Channel and Relays for FBEVAS, CREFAS, CPIAS	7.17	0.9948	P_{13}, P_{14}, P_{15}, P_{16}	Calculated by MIL-HBK 217A
Ac Power Source	40	0.9716	P_{S1}	Provided in Ref. 1 MTBF = 2.85 yr or 25,966 hr
Dc Power Source	4	0.9971	P_{S2}	Estimated
Ac to dc power supply	25	0.9822	P_{S3}	Power supply mfg data; see Appendix B
Dc to dc power supply	25	0.9822	P_{S4}	Power supply mfg data; see Appendix B
Initiating Channel for CRVIAS	15.8		P_{11A}, P_{12A}	Calculated by MIL-HBK 217A
Actuating Channel for CRVIAS	7.87		P_{13A}, P_{14A}, P_{15A}, P_{16A}	Calculated by MIL-HBK 217A
LOP/LS Module				
a. Trip Section	5.77		$P_A(S)$	Calculated by MIL-HBK 217A
b. 2/4 and output actuation	11.78		$P_{24}(S)$ · $P_{AD}(S)$	Calculated by MIL-HBK 217A

TABLE 2 (continued)

Subsystem Component	Failure Rate $x10^{-6}$	Reliability for 720 hr	Prob Symbol	Source of Failure Rate Data
DGSS Module	11.6		$P_{AD}(S)$	Calculated by MIL-HBK-217A
ESF Load Sequencer	20.7		$P_Q(S)$	Calculated by MIL-HBK 217A

$$+ P(I_8)/C \cdot \{P(SO_1)/I_8 \cdot P(SO_2)/I_8 \cdot P(SO_3)/I_8 \cdot P(SO_4)/I_8 \cdot P(SO_5)/I_8 \cdot P(SO_6)/I_8 \cdot P(SO_7)/I_8\} .$$

The variables for the preceding equations are summarized below.

As previously defined $P(I_1)/C = P(I_2)/C = \ldots P(I_8)/C = 1/n = 1/8 = 0.1$.

Now consider the outputs dependent on input I_1, FBEVAS

$$\begin{aligned} P(SO_1)/I_1 = {} & P_{11}(S) \cdot P_{SA}(S) \cdot P_{13}(S) \\ & + P_{11}(S) \cdot P_{SA}(S) \cdot P_{15}(\overline{S}) \cdot P_{16}(S) \cdot P_{SB}(S) \\ & + P_{11}(S) \cdot P_{SA}(\overline{S}) \cdot P_{12}(S) \cdot P_{SB}(S) \cdot P_{14}(S) \\ & + P_{11}(\overline{S}) \cdot P_{12}(S) \cdot P_{SB}(S) \cdot P_{14}(S) \\ & + P_{11}(\overline{S}) \cdot P_{12}(S) \cdot P_{SB}(S) \cdot P_{14}(\overline{S}) \cdot P_{15}(S) \cdot P_{SA}(S) \end{aligned}$$

$$P(SO_2)/I_1 = P_{13}(S) + (1 - P_{13}(S)) \cdot P_{16}(S)$$

$$P(SO_3)/I_1 = P(SO_4)/I_1 = P(SO_5)/I_1 = P(SO_6)/I_1 = P(SO_7)/I_1 = 1 ,$$

P_{11} = See Table 2

P_{13} = See Table 2

P_{15} = See Table 2

P_{16} = See Table 2 .

Now consider outputs dependent on input I_2, CREFAS

$$P(SO_1)/I_2 = 1$$

because output 0_1 is independent of input I_2

$$P(SO_2)/I_2 = P(SO_1)/I_1$$

because the same relationship holds true

$$P(SO_3)/I_2 = P(SO_2)/I_1$$

because this subsystem is the same as the preceding FBEVAS subsystem

$$P(SO_4)/I_2 = P(SO_5)/I_2 = P(SO_6)/I_2 = P(SO_7)/I_2 = 1$$

because these outputs are independent of the I_2, CREFAS, input.

The power supply subsystem was defined by the following equation:

$$\begin{aligned} P_{PSA}(S) = P_{PSB}(S) = {} & P_{S1}(S) \cdot P_{S3}(S) \\ & + P_{S1}(S) \cdot P_{S3}(\overline{S}) \cdot P_{S2}(S) \cdot P_{S4}(S) \\ & + P_{S1}(\overline{S}) \cdot P_{S2}(S) \cdot P_{S4}(S) \end{aligned}$$

where $P_{S1}(S)$, $P_{S2}(S)$, $P_{S3}(S)$ and $P_{S4}(S)$ are defined in Table 2.

Now consider outputs dependent on input, I_3, CPIAS.

$$P(SO_1)/I_3 = P(SO_2)/I_3 = 1$$

because outputs are independent of input I_3.

$$P(SO_3)/I_3 = P(SO_1)/I_1$$

because the same 1-out-of-2 configuration as the FBEVAS subsystem.

$$P(SO_4)/I_3 = P(SO_5)/I_3 = P(SO_6)/I_3 = P(SO_7)/I_3 = 1$$

because outputs are independent of input.

Now consider outputs dependent on input I_4, CRVIAS (SMCROA)

$$P(SO_1)/I_4 = P(SO_2)/I_4 = P(SO_3)/I_4 = 1$$

because these outputs are independent of input I_4.

$$P(SO_4)/I_4$$

is almost equal to $P(SO_1)/I_1$.

Examination of Table 2 reveals that the failure rates for the CRVIAS channel components are somewhat greater than for the FBEVAS channel components. Therefore,

$$\begin{aligned} P(SO_4)/I_4 = {} & P_{11A}(S) \cdot P_{SA}(S) \cdot P_{13A}(S) \\ & + P_{11A}(S) \cdot P_{SA}(S) \cdot P_{15A}(\overline{S}) \cdot P_{16A}(S) \cdot P_{SB}(S) \\ & + P_{11A}(S) \cdot P_{SA}(\overline{S}) \cdot P_{12A}(S) \cdot P_{SB}(S) \cdot P_{14A}(S) \\ & + P_{11A}(\overline{S}) \cdot P_{12A}(S) \cdot P_{SB}(S) \cdot P_{14A}(S) \\ & + P_{11A}(\overline{S}) \cdot P_{12A}(S) \cdot P_{SB}(S) \cdot P_{14A}(\overline{S}) \cdot P_{15A}(S) \\ & \cdot P_{SA}(S) \quad . \end{aligned}$$

$$P(SO_5)/I_4 = P(SO_6)/I_4 = P(SO_7)/I_4 = 1$$

because these outputs are independent of input I_4, CRVIAS (SMCROA).

Now consider outputs dependent on input I_5, CREVIAS, (HGC CROA).

$$P(SO_4)/I_5 = P(SO_4)/I_4$$

because of the same 1-out-of-2 relationship.

$$P(SO_1)/I_5 = P(SO_2)/I_5 = P(SO_3)/I_5 = P(SO_5)/I_5 =$$
$$P(SO_6)/I_5 = P(SO_7)/I_5 = 1$$

because these outputs are independent of input I_5, CRVIAS (HGC CROA).

Now consider outputs dependent on input I_6 DGSS. O_5, the DGSS output, is the only output dependent on I_6, the DGSS input. From a previous section we have

$$\begin{aligned} P(SO_5)/I_6 &= P_{DSS}(S)/I \\ &= P_{DA}(S) \quad P_{SA}(S) \\ &\quad + P_{DA}(S) \quad (1 - P_{SA}(S)) \quad P_{SA}(S) \\ &\quad + (1 - P_{DA}(S)) \quad P_{DA}(S) \quad P_{SA}(S) \end{aligned}$$

and

$$\begin{aligned} P(SO_1)/I_6 &= P(SO_2)/I_6 = P(SO_3)/I_6 = P(SO_4)/I_6 \\ &= P(SO_6)/I_6 = P(SO_7)/I_6 = 1 \end{aligned}$$

because of the independence of these outputs.

$P_{DA}(S)$ is defined by Table 2.

$P_{SA}(S)$ is the power system reliability as previously defined.

Now consider outputs dependent on input I_7, the LOP subsystem. Output O_6 is the only dependent output. The previously established relationship is

$$P(SO_6)/I_7 = P_L(S) + (1 - P_L(S)) \; P_L(S)$$

where $P_L(S) = P_I(S) \cdot P_{24}(S) \cdot P_{AD}(S) \cdot P_{SA}(S)$

and $P_I(S) = P_A(S)^2 \left\{1 + 2(1 - P_A(S)) + 3(1 - P_A(S))^2\right\}$

and $$P(SO_1)/I_7 = P(SO_2)/I_7 = P(SO_3)/I_7 = P(SO_4)/I_7$$
$$= P(SO_5)/I_7 = P(SO_7)/I_7 = 1$$

because of independence.

$P_A(S)$ is defined in Table 2.

$P_{24}(S) \cdot P_{AD}(S)$ is defined in Table 2.

$P_{SA}(S)$ is the power system reliability as previously defined.

The output dependent on I_8, the load sequencer inputs, is similar to those already done. As previously explained, the output is a function of the input state defined by several input signals defined by the input challenge I_8. The equation for the probability of success for the Load Sequencer was derived earlier as:

$$P(SO_7)/I_8 = P_{LS_A}(S) + (1 - P_{LS_A}(S))\ P_{LS_A}(S)$$

where $$P_{LS_A}(S) = P_{SI}(S) \cdot P_{LOP}(S) \cdot P_{BKR}(S) \cdot P_Q(S) \cdot P_{SA}(S)$$

$P_{SI}(S) = 1$ (direct external signal from field contacts)

$P_{LOP}(S) = P(SO_6)/I_7$ (probability of successful operation of LOP subsystem)

$P_{BKR}(S) = 1$ (direct external signal from field contacts)

$P_Q(S) =$ Value stated in Table 2

$P_{SA}(S) =$ Power system reliability as previously defined.

9. COMPUTATION OF RELIABILITY

A computer program was employed to compute the system reliability for various mission times. Appendix C contains the results of the computer calculations. The module, subsystem, and system reliability results are presented for several operation or mission times ranging from 0 to 960 hrs. The mission time corresponding to 30 days is 720 hours.

The computer program used to perform the calculations was written in the BASIC language. A complete listing of the program is contained in Appendix D. The program computations parallel the equations stated in Section 8.

10. REFERENCES

1. "Section 4, Technical Requirements for Balance of Plant Engineering Safety Features Actuation System for the Arizona Public Service Company Palo Verde Nuclear Generating Station, Units 1, 2, and 3," Specification 13-JM-104, Rev. No. 1, September 14, 1976.
2. Lambert, H. E., "System Safety Analysis and Fault Tree Analysis," Lawrence Livermore Laboratory Report, March 14, 1973.

APPENDIX A

GENERAL ATOMIC COMPONENT RELIABILITY CALCULATIONS

(Component failure rates based on MIL-HBK 217A, Table IV-IX, pg. 4-32.)

NOTE

Failure rates chosen from Table IV-IX are either minimum or average values dependent on stress levels calculated for each part:

Stress ≤0.25 chose min. fig.

Stress >0.25 chose avg. fig.

FBEVAS, CREFAS, CPIAS MODULE FAILURE RATE - INITIATING CHANNEL

Component	Quantity	Failure Rate ($x10^{-6}$ hr)	Total Failure Rate (Failures/10^6 hr)
Semiconductors			
Diodes	15	0.1	1.5
Varistors	7	0.2	1.4
Resistors			
A. MIL-R-10509 fixed film (including R packs)			
1.	24	0.07	1.68
2.	4	1.5	6.0
B. MIL-R-26 fixed power wire-wound	4	0.07	0.28
Capacitors			
A. MIL-C-26655 solid tantalum	4	0.058	0.232
B. MIL-C-11015 general purpose ceramic	10	0.02	0.2
Connectors	5	0.01	0.05
Relays	3	0.01	0.03
Switches	7	0.02	0.14
Integrated Circuits	20	0.4	8.0
Low Population Parts (Table VII-XXV, pp 7.12-3; 217A)			
Incandescent lamps	5	1.0	5.0
λ_{total}/initiating channel =			24.5

= 12.5 neglecting lamps and associated components

FBEVAS, CREFAS, CPIAS MODULE FAILURE RATE - ACTUATING CHANNEL

Component	Quantity	Failure Rate ($x10^{-6}$ hr)	Total Failure Rate (Failures/10^6 hr)
Semiconductors			
Diodes	8	0.1	0.8
Varistors	3	0.2	0.6
Resistors			
A. MIL-R-10509 fixed film (including R-packs)			
1.	9	0.07	0.63
2.	3	1.5	4.5
B. MIL-R-26 fixed power wire-wound	4	0.07	0.28
Capacitors			
A. MIL-C-26655 solid tantalum	2	0.058	0.116
B. MIL-C-11015 general purpose ceramic	4	0.02	0.08
Connectors	3	0.01	0.03
Relays	5	0.01	0.05
Switches	1	0.02	0.02
Integrated Circuits	13	0.04	5.2
Low Population Parts (Table VII-XXVI, pp. 7.12-3; 217A)	3	1.0	3.0
λ_{total} =			15.306

= 7.17 neglecting lamps and associated circuits

CRVIAS MODULE FAILURE RATE - INITIATING CHANNELS (2 EA)

Component	Quantity	Failure Rate ($x10^{-6}$ hr)	Total Failure Rate (Failures/10^6 hr)
Semiconductors			
Diodes	26	0.1	2.6
Varistors	8	0.2	1.6
Resistors			
A. MIL-R-10509 fixed film (including R-packs)			
1.	32	0.07	2.24
2.	8	1.5	12.0
B. MIL-R-26 fixed power wire-wound	8	0.07	0.56
Capacitors			
A. MIL-C-26655 solid tantalum	5	0.058	0.29
B. MIL-C-11015 general purpose ceramic	14	0.02	0.28
Connectors	6	0.01	0.06
Relays	4	0.01	0.04
Switches	10	0.02	0.2
Integrated Circuits	25	0.4	10
Low Population Parts (Table VII-XXVI, pp. 7.12-3; 217A)	8	1.0	8
λ_{total} =			37.87

= 15.83 neglecting lamps and associated components and annunciator relay

CRVIAS MODULE FAILURE RATE - ACTUATING CHANNEL

Component	Quantity	Failure Rate ($x10^{-6}$ hr)	Total Failure Rate (Failures/10^6 hr)
Semiconductors			
Diodes	11	0.1	1.1
Varistors	4	0.2	0.8
Resistors			
A. MIL-R-10509 fixed film (including R-packs)			
1.	12	0.07	0.84
2.	4	1.5	6.0
B. MIL-R-26 fixed power wire-wound	4	0.07	0.28
Capacitors			
A. MIL-C-26655 solid tantalum	4	0.058	0.232
B. MIL-C-11015 general purpose ceramic	3	0.02	0.06
Connectors	4	0.01	0.04
Relays	4	0.01	0.04
Switches	1	0.02	0.02
Integrated Circuits	13	0.04	5.2
Low Population Parts (Table VII-XXVI, pp. 7.12-3; 217A)	4	1.0	4
λ_{total} =			18.612

= 7.812 neglected lamps and associated components and annunciator relays

DGSS MODULE FAILURE RATE

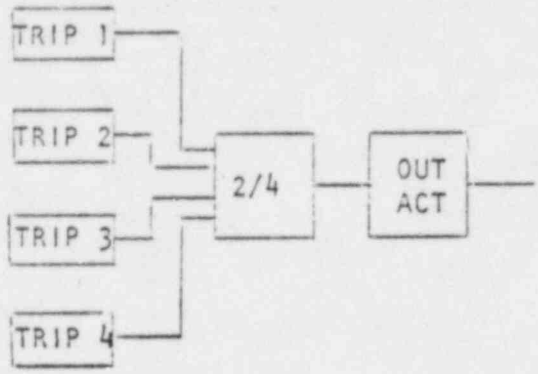
Component	Quantity	Failure Rate ($x10^{-6}$ hr)	Total Failure Rate (Failures/10^6 hr)
Semiconductors			
Diodes	29	0.1	2.9
Varistors	3	0.2	0.6
Resistors			
A. MIL-R-10509 fixed film (including R-packs)			
1. (RN60, C,D)	24	0.07	1.68
2. (Corning C5)	6	1.5	9.0
B. MIL-R-26 fixed power wire-wound	3	0.07	0.21
Capacitors			
A. MIL-C-26655 solid tantalum	5	0.058	0.29
B. MIL-C-11015 general purpose ceramic	12	0.02	0.24
Connectors	6	0.01	0.06
Relays	3	0.01	0.03
Switches	9	0.02	0.18
Integrated Circuits	21	0.4	8.4
Lamps Incandescent (Low population parts Table VII-XXVI, pp. 7.12-3, 217A)	10	1.0	10.0
λ_{total} =			33.57

= 11.57 neglecting lamps, annunciators, relays and associated components

LOP/LS MODULE FAILURE RATE

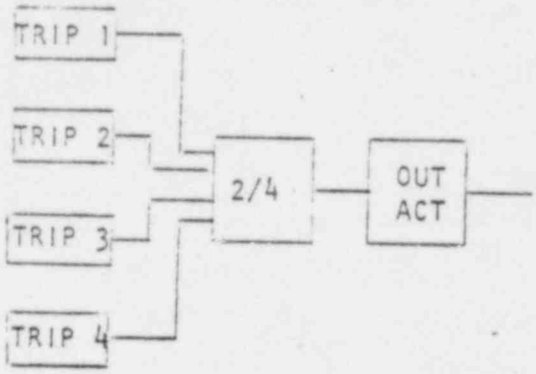
Component	Quantity	Failure Rate ($x10^{-6}$ hr)	Total Failure Rate (Failures/10^6 hr)
Semiconductors			
Diodes	38	0.1	3.8
Varistors	12	0.2	2.4
Resistors			
A. MIL-R-10509 fixed film (including R-packs)			
1.	55	0.07	3.85
2.	14	1.5	21.00
B. MIL-R-26 fixed power wire-wound	16	0.07	1.12
Capacitors			
A. MIL-C-26655 solid tantalum	10	0.058	0.58
B. MIL-C-11015 general purpose ceramic	24	0.02	0.48
Connectors	13	0.01	0.13
Relays	18	0.01	0.18
Switches	9	0.02	0.18
Integrated Circuits	69	0.4	27.6
Lamps, Incandescent (Low Population Parts Table VII-XXVI, pp. 7.12-3; 217A)	14	1.0	14.0
λ_{total} =			76.44

= 35.51 neglecting lamps, annunciators, and associated components



FAILURE RATE FOR EACH TRIP SECTION

Component	Quantity	Failure Rate ($x10^{-6}$ hr)	Total Failure Rate (Failures/10^6 hr)
Semiconductors			
Diodes	2	0.1	0.2
Varistors	3	0.2	0.6
Resistors			
A. MIL-R-10509 fixed film	7	0.07	0.49
B. MIL-R-26 fixed power wire-wound	3	0.07	0.21
Capacitors			
A. MIL-C-26655 solid tantalum	2	0.058	0.116
B. MIL-C-11015 general purpose ceramic	4	0.02	0.08
Connectors	3	0.01	0.03
Relays	0		
Switches	2	0.02	0.04
Integrated Circuits	10	0.4	4.0
$\lambda_{total/trip\ section}$ = 5.766 x 4 =			23.064



FAILURE RATE FOR 2/4 LOGIC AND OUTPUT ACTUATION
(Discounting lamps, annunciator outputs and associated components)

Component	Quantity	Failure Rate ($x10^{-6}$ hr)	Total Failure Rate (Failures/10^6 hr)
Semiconductors			
Diodes	0		
Varistors	0		
Resistors			
A. MIL-R-10509 fixed film	35	0.07	2.45
B. MIL-R-26 fixed power wire-wound	2	0.07	0.14
Capacitors			
A. MIL-C-26655 solid tantalum	2	0.058	0.116
B. MIL-C-11015 general purpose ceramic	8	0.02	0.16
Connectors	4	0.01	0.04
Relays	5	0.01	0.05
Switches	1	0.02	0.02
Integrated Circuits	22	0.4	8.8
λ_{total}/2x4 and Out Act =			11.776

ESF LOAD SEQUENCER/AUTO TEST MODULE FAILURE RATE

Component	Quantity	Failure Rate ($x10^{-6}$ hr)	Total Failure Rate (Failures/10^6 hr)
Semiconductors			
Diodes	19	0.01	0.19
Varistors	3	0.02	0.06
Resistors			
A. MIL-R-10509 fixed film			
1.	74	0.07	5.18
2.	39	1.5	50.5
B. MIL-R-26 fixed power wire-wound	6	0.07	0.42
Capacitors			
A. MIL-C-26655 solid tantalum	7	0.058	0.406
B. MIL-C-11015 general purpose ceramic	15	0.02	0.3
Connectors	13	0.01	0.13
Relays	21	0.01	0.21
Switches	24	0.02	0.48
Integrated Circuits	37	0.4	14.8
Lamps, Incandescent (Low Population Parts Table VII-XXVI, pp. 7.12-3; 217A)	39	1.0	39
λ_{total} =			119.7

= 20.7 neglecting lamps, annunciators, and associated components

APPENDIX B

SUPPLIER COMPONENT RELIABILITY CALCULATIONS

Pioneer Magnetics

July 19, 1978

Mr. Robert C. Weddle (SP251)
General Atomics Company
P. O. Box 81608
San Diego, California 92138

Subject: MTBF Calculations

Dear Mr. Weddle:

Pursuant to our conversations enclosed are MTBF calculations per MIL-HDBK-217A for the Model PM2497 power supply. The PM2722 is very similar in construction except that it has fewer components.

Very truly yours,

Arnold Hagiwara
Director of Administrative Operations

AH:mtt

Enclosure

cc: M. MacKrell

September 25, 1974

MTBF Calculation for 6VDC, 100 Amp. Power Supply Model PM2~~489~~497

QTY.	COMP. TYPE	RATING	STRESS	λea	λtot.
43	RC20		-	.021	.903
8	RN60C		-	.003	.024
3	Res. Var.	.25W	-	1.000	3.000
3	RC20		.52	.021	.063
2	RC30		.55	.021	.042
2	RC20		.60	.021	.042
1	RC30		-	.021	.021
2	Res. WW	10W	.25	.100	.200
1	Res. WW	20W	.80	.590	.590
1	Res. WW	5W	-	.067	.067
1	RC20		.38	.021	.021
2	Res. CC	2W	.54	.021	.042
1	Cap. Alum.	7.5 V	.80	.039	.039
1	Cap. Alum.	50 V	.70	.032	.032
1	Cap. Alum.	400 V	.80	.039	.039
4	Cap. Mica	500 V	-	.0003	.0012
2	Cap. Mylar	200 V	-	.002	.004
8	Cap. Mylar	100 V	-	.002	.016
2	Cap. Mylar	600 V	.54	.003	.006
2	Cap. Mylar	200 V	.90	.020	.040
1	Cap. Mylar	1600 V	.20	.002	.002
1	Cap. Mylar	400 V	-	.002	.002
1	Cap. Tant.	10 V	.50	.102	.102
1	Cap. Tant.	10 V	-	.018	.018
1	Cap. Tant.	50 V	.70	.039*	.039

MTBF Calculation for 6VDC, 100 Amp. Power Supply Model PM2489

QTY.	COMP. TYPE	RATING	Tjn or TEMP.	λea	λtot.
8	NPN Sil.	> 1W	-	.200	1.600
1	SCR	> 1W	-	.200	.200
1	NPN Sil.	< 1W	.33	.432	.432
7	NPN Sil.	< 1W	-	.150	1.050
1	Triac	< 1W	-	.200	.200
1	SCR	< 1W	-	.200	.200
1	SCR	> 1W	.20	.390	.390
15	Diode Sil.	< 1W	-	.150	2.250
2	Diode Zener	< 1W	-	.300	.600
2	Diode Zener	< 1W	.17	.495	.990
24	Diode Sil.	≥ 1W	-	.100	2.400
3	I.C.		-	.400	1.200
2	Transf.	A	50° C	.350	.700
2	Transf.	A	60° C	.350	.700
2	Transf.	B	70° C	.350	.700
1	Transf.	B	90° C	.350	.350
1	Transf.	B	95° C	.350	.350
1	Fan		50° C	1.850	1.850
2	Therm. Sw.			.200	.200
1	Fuse			.100	.100
2	PNP Sil.	< 1W	-	.300	.600
				λTOTAL	22.5192
				MTBF	44,406 hrs.

PIONEER MAGNETICS, INC.
1745 Berkeley

September 25, 1974

MTBF Calculation for 17VDC, 45 Amp. Power Supply Model PM2490

QTY.	COMP. TYPE	RATING	STRESS	λea	λtot.
43	RC20		-	.021	.903
8	RN60C		-	.003	.024
3	Res. Var.	.25W	-	1.000	3.000
4	RC20		.52	.021	.084
2	RC30		.55	.021	.042
1	RC20		.60	.021	.021
1	RC30		-	.021	.021
2	Res. WW	10W	.25	.100	.200
1	Res. WW	20W	.80	.590	.590
1	Res. WW	5W	-	.067	.067
1	RC20		.38	.021	.021
2	Res. CC	2W	.54	.021	.042
1	Cap. Alum.	25 V	.70	.032	.032
1	Cap. Alum.	50 V	.70	.032	.032
1	Cap. Alum	400 V	.80	.039	.039
4	Cap. Mica	500 V	-	.0003	.0012
2	Cap. Mylar	200 V	-	.002	.004
8	Cap. Mylar	100 V	-	.002	.016
2	Cap. Mylar	600 V	.54	.003	.006
2	Cap. Mylar	200 V	.90	.020	.040
1	Cap. Mylar	1600 V	.20	.002	.002
1	Cap. Mylar	400 V	-	.002	.002
1	Cap. Tant.	10 V	.50	.102	.102
1	Cap. Tant.	10 V	-	.018	.018
1	Cap. Tant.	50 V	.70	.039*	.039
1	Cap. Tant.	25 V	.50	.102	.102

* series impedance greater than 2 ohms

MTBF Calculation for 17VDC, 45 Amp. Power Supply Model PM2490

QTY.	COMP. TYPE	RATING	Tjn or TEMP.	λea	λtot.
8	NPN Sil.	> 1W	-	.200	1.600
1	SCR	> 1W	-	.200	.200
1	NPN Sil.	< 1W	.33	.432	.432
7	NPN Sil.	< 1W	-	.150	1.050
2	PNP Sil.	< 1W	-	.300	.600
1	Triac	< 1W	-	.200	.200
1	SCR	< 1W	-	.200	.200
1	SCR	> 1W	.20	.390	.390
15	Diode Sil.	< 1W	-	.150	2.250
2	Diode Zener	< 1W	-	.300	.600
2	Diode Zener	< 1W	.17	.495	.990
22	Diode Sil.	> 1W	-	.100	2.200
3	I.C.		-	.400	1.200
2	Transf.	A	50° C	.350	.700
2	Transf.	A	60° C	.350	.700
2	Transf.	B	70° C	.350	.700
1	Transf.	B	90° C	.350	.350
1	Transf.	B	95° C	.350	.350
1	Fan		50° C	1.850	1.850
2	Therm. Sw.			.200	.200
1	Fuse			.100	.100
				λTOTAL	22.3122
				MTBF	44,819 hrs.

PIONEER MAGNETICS, INC.
1745 Berkeley
Santa Monica, California 90404

Basis For Reliability Analysis

The reliability analyses were performed in accordance with the following guidelines:

a. The stress ratio vs. failure rate data is per MIL-HDBK-217A.

b. Ground K factors were used throughout.

c. All stress ratios and normalized junction temperatures were calculated for a 25° C ambient.

d. When the manufacturer of a semiconductor did not state the temperature at which derating was to begin, 25° C was assumed.

e. For SCR and Triac devices, the failure rates for NPN silicon transistors were used.

f. For devices which operate only in a fault mode, e.g., the OVP SCR, the normal operating stresses and normalized junction temperatures were used.

g. A dash in the stress or normalized junction temperature column indicates a value of less than 0.1.

PIONEER MAGNETICS, INC.
1745 Berkeley
Santa Monica, California 90404

APPENDIX C

COMPUTER CALCULATIONS

APPENDIX C

COMPUTER RELIABILITY COMPUTATION

FOR

PALO VERDE NUCLEAR GENERATING STATION
BALANCE OF PLANT ENGINEERED SAFETY
FEATURES ACTUATION SYSTEM

BECHTEL JOB 10407
PURCHASE ORDER 10407-13-JM-104

SEPTEMBER 22, 1978

PROJECT NO. 2192

GENERAL ATOMIC COMPANY
ELECTRONIC SYSTEMS DIVISION
P O BOX 81608
SAN DIEGO, CALIFORNIA 92138

MISSION TIME:0

COMPONENT RELIABILITY DATA TABLE

SUBSYSTEM COMPONENT	FAILURE RATE PER MILLION HRS	RELIABILITY FOR 0 HRS
INITIATING CHANNEL FOR FBEVAS, CREFAS, CPIAS	12.5	1
ACTUATING CHANNEL & RELAYS FOR FBEVAS, CREVAS, CPIAS	7.17	1
AC POWER SOURCE	40	1
DC POWER SOURCE	4	1
AC TO DC POWER SUPPLY	25	1
DC TO DC POWER SUPPLY	25	1
INITIATING CHANNEL FOR CREVIAS	15.8	1
ACTUATING CHANNEL FOR CREVIAS	7.87	1
LOP/LS MODULE		
A. TRIP SECTION	5.77	1
B. 2/4 AND OUTPUT	0	1
DGSS	0	1
ESF LOAD SEQUENCER	20.7	1

RELIABILITY BY SUBSYSTEM

SUBSYSTEM	RELIABILITY
POWER SUPPLY	1
FBEVAS	1
CREFAS	1
CPIAS	1
CREVIAS(SMCROA)	1
CREVIAS(HGCROA)	1
DGSS	1
LOSS OF POWER	1
LOAD SEQUENCER	1

TOTAL SYSTEM RELIABILITY FOR 0 HOUR MISSION TIME: 1

MISSION TIME:48

COMPONENT RELIABILITY DATA TABLE

SUBSYSTEM COMPONENT	FAILURE RATE PER MILLION HRS	RELIABILITY FOR 48 HRS
INITIATING CHANNEL FOR FBEVAS, CREFAS, CPIAS	12.5	.9994
ACTUATING CHANNEL & RELAYS FOR FBEVAS, CREVAS, CPIAS	7.17	.999656
AC POWER SOURCE	40	.998082
DC POWER SOURCE	4	.999808
AC TO DC POWER SUPPLY	25	.998801
DC TO DC POWER SUPPLY	25	.998801
INITIATING CHANNEL FOR CREVIAS	15.8	.999242
ACTUATING CHANNEL FOR CREVIAS	7.87	.999622
LOP/LS MODULE		
A. TRIP SECTION	5.77	.999723
B. 2/4 AND OUTPUT	0	.999434
DGSS	0	.999443
ESF LOAD SEQUENCER	20.7	.999007

RELIABILITY BY SUBSYSTEM

SUBSYSTEM	RELIABILITY
POWER SUPPLY	.999996
FBEVAS	.999999
CREFAS	.999999
CPIAS	.999999
CREVIAS(SMCROA)	.999999
CREVIAS(HGCROA)	.999999
DGSS	1
LOSS OF POWER	1
LOAD SEQUENCER	.999999

TOTAL SYSTEM RELIABILITY FOR 48 HOUR MISSION TIME: .999999

MISSION TIME:96

COMPONENT RELIABILITY DATA TABLE

SUBSYSTEM COMPONENT	FAILURE RATE PER MILLION HRS	RELIABILITY FOR 96 HRS
INITIATING CHANNEL FOR FBEVAS, CREFAS, CPIAS	12.5	.998801
ACTUATING CHANNEL & RELAYS FOR FBEVAS, CREVAS, CPIAS	7.17	.999312
AC POWER SOURCE	40	.996167
DC POWER SOURCE	4	.999616
AC TO DC POWER SUPPLY	25	.997603
DC TO DC POWER SUPPLY	25	.997603
INITIATING CHANNEL FOR CREVIAS	15.8	.998484
ACTUATING CHANNEL FOR CREVIAS	7.87	.999245
LOP/LS MODULE		
A. TRIP SECTION	5.77	.999446
B. 2/4 AND OUTPUT	0	.998868
DGSS	0	.998887
ESF LOAD SEQUENCER	20.7	.998015

RELIABILITY BY SUBSYSTEM

SUBSYSTEM	RELIABILITY
POWER SUPPLY	.999983
FBEVAS	.999997
CREFAS	.999997
CPIAS	.999998
CREVIAS(SMCROA)	.999997
CREVIAS(HGCROA)	.999997
DGSS	.999999
LOSS OF POWER	.999999
LOAD SEQUENCER	.999996

TOTAL SYSTEM RELIABILITY FOR 96 HOUR MISSION TIME: .999997

MISSION TIME:144

COMPONENT RELIABILITY DATA TABLE

SUBSYSTEM COMPONENT	FAILURE RATE PER MILLION HRS	RELIABILITY FOR 144 HRS
INITIATING CHANNEL FOR FBEVAS, CREFAS, CPIAS	12.5	.998201
ACTUATING CHANNEL & RELAYS FOR FBEVAS, CREVAS, CPIAS	7.17	.998968
AC POWER SOURCE	40	.994257
DC POWER SOURCE	4	.999424
AC TO DC POWER SUPPLY	25	.996406
DC TO DC POWER SUPPLY	25	.996406
INITIATING CHANNEL FOR CREVIAS	15.8	.997727
ACTUATING CHANNEL FOR CREVIAS	7.87	.998867
LOP/LS MODULE		
A. TRIP SECTION	5.77	.999169
B. 2/4 AND OUTPUT	0	.998302
DGSS	0	.998331
ESF LOAD SEQUENCER	20.7	.997023

RELIABILITY BY SUBSYSTEM

SUBSYSTEM	RELIABILITY
POWER SUPPLY	.999961
FBEVAS	.999994
CREFAS	.999994
CPIAS	.999995
CREVIAS(SMCROA)	.999993
CREVIAS(HGCROA)	.999993
DGSS	.999997
LOSS OF POWER	.999997
LOAD SEQUENCER	.999991

TOTAL SYSTEM RELIABILITY FOR 144 HOUR MISSION TIME: .999995

MISSION TIME:192

COMPONENT RELIABILITY DATA TABLE

SUBSYSTEM COMPONENT	FAILURE RATE PER MILLION HRS	RELIABILITY FOR 192 HRS
INITIATING CHANNEL FOR FBEVAS, CREFAS, CPIAS	12.5	.997603
ACTUATING CHANNEL & RELAYS FOR FBEVAS, CREVAS, CPIAS	7.17	.998624
AC POWER SOURCE	40	.992349
DC POWER SOURCE	4	.999232
AC TO DC POWER SUPPLY	25	.995211
DC TO DC POWER SUPPLY	25	.995211
INITIATING CHANNEL FOR CREVIAS	15.8	.996971
ACTUATING CHANNEL FOR CREVIAS	7.87	.99849
LOP/LS MODULE		
A. TRIP SECTION	5.77	.998893
B. 2/4 AND OUTPUT	0	.997737
DGSS	0	.997775
ESF LOAD SEQUENCER	20.7	.996033

RELIABILITY BY SUBSYSTEM

SUBSYSTEM	RELIABILITY
POWER SUPPLY	.999931
FBEVAS	.99999
CREFAS	.99999
CPIAS	.999992
CREVIAS(SMCROA)	.999988
CREVIAS(HGCROA)	.999988
DGSS	.999995
LOSS OF POWER	.999995
LOAD SEQUENCER	.999984

TOTAL SYSTEM RELIABILITY FOR 192 HOUR MISSION TIME: .99999

MISSION TIME:240

COMPONENT RELIABILITY DATA TABLE

SUBSYSTEM COMPONENT	FAILURE RATE PER MILLION HRS	RELIABILITY FOR 240 HRS
INITIATING CHANNEL FOR FBEVAS, CREFAS, CPIAS	12.5	.997004
ACTUATING CHANNEL & RELAYS FOR FBEVAS, CREVAS, CPIAS	7.17	.998281
AC POWER SOURCE	40	.990446
DC POWER SOURCE	4	.99904
AC TO DC POWER SUPPLY	25	.994018
DC TO DC POWER SUPPLY	25	.994018
INITIATING CHANNEL FOR CREVIAS	15.8	.996215
ACTUATING CHANNEL FOR CREVIAS	7.87	.998113
LOP/LS MODULE		
A. TRIP SECTION	5.77	.998616
B. 2/4 AND OUTPUT	0	.997172
DGSS	0	.99722
ESF LOAD SEQUENCER	20.7	.995044

RELIABILITY BY SUBSYSTEM

SUBSYSTEM	RELIABILITY
POWER SUPPLY	.999893
FBEVAS	.999984
CREFAS	.999984
CPIAS	.999987
CREVIAS(SMCROA)	.999981
CREVIAS(HGCROA)	.999981
DGSS	.999992
LOSS OF POWER	.999991
LOAD SEQUENCER	.999974

TOTAL SYSTEM RELIABILITY FOR 240 HOUR MISSION TIME: .999984

MISSION TIME:288

COMPONENT RELIABILITY DATA TABLE

SUBSYSTEM COMPONENT	FAILURE RATE PER MILLION HRS	RELIABILITY FOR 288 HRS
INITIATING CHANNEL FOR FBEVAS, CREFAS, CPIAS	12.5	.996406
ACTUATING CHANNEL & RELAYS FOR FBEVAS, CREVAS, CPIAS	7.17	.997937
AC POWER SOURCE	40	.988546
DC POWER SOURCE	4	.998849
AC TO DC POWER SUPPLY	25	.992826
DC TO DC POWER SUPPLY	25	.992826
INITIATING CHANNEL FOR CREVIAS	15.8	.99546
ACTUATING CHANNEL FOR CREVIAS	7.87	.997736
LOP/LS MODULE		
A. TRIP SECTION	5.77	.99834
B. 2/4 AND OUTPUT	0	.996607
DGSS	0	.996665
ESF LOAD SEQUENCER	20.7	.994056

RELIABILITY BY SUBSYSTEM

SUBSYSTEM	RELIABILITY
POWER SUPPLY	.999846
FBEVAS	.999977
CREFAS	.999977
CPIAS	.999981
CREVIAS(SMCROA)	.999972
CREVIAS(HGCROA)	.999972
DGSS	.999988
LOSS OF POWER	.999987
LOAD SEQUENCER	.999963

TOTAL SYSTEM RELIABILITY FOR 288 HOUR MISSION TIME: .999977

MISSION TIME:336

COMPONENT RELIABILITY DATA TABLE

SUBSYSTEM COMPONENT	FAILURE RATE PER MILLION HRS	RELIABILITY FOR 336
INITIATING CHANNEL FOR FBEVAS, CREFAS, CPIAS	12.5	.995809
ACTUATING CHANNEL & RELAYS FOR FBEVAS, CREVAS, CPIAS	7.17	.997594
AC POWER SOURCE	40	.98665
DC POWER SOURCE	4	.998657
AC TO DC POWER SUPPLY	25	.991635
DC TO DC POWER SUPPLY	25	.991635
INITIATING CHANNEL FOR CREVIAS	15.8	.994705
ACTUATING CHANNEL FOR CREVIAS	7.87	.997359
LOP/LS MODULE		
A. TRIP SECTION	5.77	.998063
B. 2/4 AND OUTPUT	0	.996043
DGSS	0	.99611
ESF LOAD SEQUENCER	20.7	.993069

RELIABILITY BY SUBSYSTEM

SUBSYSTEM	RELIABILITY
POWER SUPPLY	.999791
FBEVAS	.999968
CREFAS	.999968
CPIAS	.999974
CREVIAS(SMCROA)	.999962
CREVIAS(HGCROA)	.999962
DGSS	.999984
LOSS OF POWER	.999983
LOAD SEQUENCER	.999949

TOTAL SYSTEM RELIABILITY FOR 336 HOUR MISSION TIME: .999969

MISSION TIME:384

COMPONENT RELIABILITY DATA TABLE

SUBSYSTEM COMPONENT	FAILURE RATE PER MILLION HRS	RELIABILITY FOR 384 HRS
INITIATING CHANNEL FOR FBEVAS, CREFAS, CPIAS	12.5	.995211
ACTUATING CHANNEL & RELAYS FOR FBEVAS, CREVAS, CPIAS	7.17	.99725
AC POWER SOURCE	40	.984757
DC POWER SOURCE	4	.998465
AC TO DC POWER SUPPLY	25	.990446
DC TO DC POWER SUPPLY	25	.990446
INITIATING CHANNEL FOR CREVIAS	15.8	.993951
ACTUATING CHANNEL FOR CREVIAS	7.87	.996982
LOP/LS MODULE		
A. TRIP SECTION	5.77	.997787
B. 2/4 AND OUTPUT	0	.995479
DGSS	0	.995556
ESF LOAD SEQUENCER	20.7	.992083

RELIABILITY BY SUBSYSTEM

SUBSYSTEM	RELIABILITY
POWER SUPPLY	.999727
FBEVAS	.999958
CREFAS	.999958
CPIAS	.999965
CREVIAS(SMCROA)	.999949
CREVIAS(HGCROA)	.999949
DGSS	.999979
LOSS OF POWER	.999977
LOAD SEQUENCER	.999933

TOTAL SYSTEM RELIABILITY FOR 384 HOUR MISSION TIME: .999959

MISSION TIME:432

COMPONENT RELIABILITY DATA TABLE

SUBSYSTEM COMPONENT	FAILURE RATE PER MILLION HRS	RELIABILITY FOR 432 HRS
INITIATING CHANNEL FOR FBEVAS, CREFAS, CPIAS	12.5	.994614
ACTUATING CHANNEL & RELAYS FOR FBEVAS, CREVAS, CPIAS	7.17	.996907
AC POWER SOURCE	40	.982868
DC POWER SOURCE	4	.998273
AC TO DC POWER SUPPLY	25	.989258
DC TO DC POWER SUPPLY	25	.989258
INITIATING CHANNEL FOR CREVIAS	15.8	.993198
ACTUATING CHANNEL FOR CREVIAS	7.87	.996606
LOP/LS MODULE		
A. TRIP SECTION	5.77	.99751
B. 2/4 AND OUTPUT	0	.994915
DGSS	0	.995001
ESF LOAD SEQUENCER	20.7	.991097

RELIABILITY BY SUBSYSTEM

SUBSYSTEM	RELIABILITY
POWER SUPPLY	.999655
FBEVAS	.999946
CREFAS	.999946
CPIAS	.999956
CREVIAS(SMCROA)	.999935
CREVIAS(HGCROA)	.999935
DGSS	.999973
LOSS OF POWER	.999971
LOAD SEQUENCER	.999914

TOTAL SYSTEM RELIABILITY FOR 432 HOUR MISSION TIME: .999947

MISSION TIME:480

COMPONENT RELIABILITY DATA TABLE

SUBSYSTEM COMPONENT	FAILURE RATE PER MILLION HRS	RELIABILITY FOR 480 HRS
INITIATING CHANNEL FOR FBEVAS, CREFAS, CPIAS	12.5	.994018
ACTUATING CHANNEL & RELAYS FOR FBEVAS, CREVAS, CPIAS	7.17	.996564
AC POWER SOURCE	40	.980983
DC POWER SOURCE	4	.998082
AC TO DC POWER SUPPLY	25	.988072
DC TO DC POWER SUPPLY	25	.988072
INITIATING CHANNEL FOR CREVIAS	15.8	.992445
ACTUATING CHANNEL FOR CREVIAS	7.87	.996229
LOP/LS MODULE		
A. TRIP SECTION	5.77	.997234
B. 2/4 AND OUTPUT	0	.994352
DGSS	0	.994447
ESF LOAD SEQUENCER	20.7	.990113

RELIABILITY BY SUBSYSTEM

SUBSYSTEM	RELIABILITY
POWER SUPPLY	.999575
FBEVAS	.999933
CREFAS	.999933
CPIAS	.999944
CREVIAS(SMCROA)	.999919
CREVIAS(HGCROA)	.999919
DGSS	.999967
LOSS OF POWER	.999963
LOAD SEQUENCER	.999893

TOTAL SYSTEM RELIABILITY FOR 480 HOUR MISSION TIME: .999934

MISSION TIME:528

COMPONENT RELIABILITY DATA TABLE

SUBSYSTEM COMPONENT	FAILURE RATE PER MILLION HRS	RELIABILITY FOR 528 HRS
INITIATING CHANNEL FOR FBEVAS, CREFAS, CPIAS	12.5	.993422
ACTUATING CHANNEL & RELAYS FOR FBEVAS, CREVAS, CPIAS	7.17	.996221
AC POWER SOURCE	40	.979101
DC POWER SOURCE	4	.99789
AC TO DC POWER SUPPLY	25	.986887
DC TO DC POWER SUPPLY	25	.986887
INITIATING CHANNEL FOR CREVIAS	15.8	.991692
ACTUATING CHANNEL FOR CREVIAS	7.87	.995853
LOP/LS MODULE		
A. TRIP SECTION	5.77	.996958
B. 2/4 AND OUTPUT	0	.993789
DGSS	0	.993894
ESF LOAD SEQUENCER	20.7	.98913

RELIABILITY BY SUBSYSTEM

SUBSYSTEM	RELIABILITY
POWER SUPPLY	.999487
FBEVAS	.999917
CREFAS	.999917
CPIAS	.999932
CREVIAS(SMCROA)	.999901
CREVIAS(HGCROA)	.999901
DGSS	.999959
LOSS OF POWER	.999955
LOAD SEQUENCER	.99987

TOTAL SYSTEM RELIABILITY FOR 528 HOUR MISSION TIME: .999919

MISSION TIME:576

COMPONENT RELIABILITY DATA TABLE

SUBSYSTEM COMPONENT	FAILURE RATE PER MILLION HRS	RELIABILITY FOR 576 HRS
INITIATING CHANNEL FOR FBEVAS, CREFAS, CPIAS	12.5	.992826
ACTUATING CHANNEL & RELAYS FOR FBEVAS, CREVAS, CPIAS	7.17	.995879
AC POWER SOURCE	40	.977223
DC POWER SOURCE	4	.997699
AC TO DC POWER SUPPLY	25	.985703
DC TO DC POWER SUPPLY	25	.985703
INITIATING CHANNEL FOR CREVIAS	15.8	.99094
ACTUATING CHANNEL FOR CREVIAS	7.87	.995477
LOP/LS MODULE		
A. TRIP SECTION	5.77	.996682
B. 2/4 AND OUTPUT	0	.993226
DGSS	0	.993341
ESF LOAD SEQUENCER	20.7	.988148

RELIABILITY BY SUBSYSTEM

SUBSYSTEM	RELIABILITY
POWER SUPPLY	.999391
FBEVAS	.999901
CREFAS	.999901
CPIAS	.999918
CREVIAS(SMCROA)	.999881
CREVIAS(HGCROA)	.999881
DGSS	.999951
LOSS OF POWER	.999946
LOAD SEQUENCER	.999843

TOTAL SYSTEM RELIABILITY FOR 576 HOUR MISSION TIME: .999903

MISSION TIME:624

COMPONENT RELIABILITY DATA TABLE

SUBSYSTEM COMPONENT	FAILURE RATE PER MILLION HRS	RELIABILITY FOR 624 HRS
INITIATING CHANNEL FOR FBEVAS, CREFAS, CPIAS	12.5	.99223
ACTUATING CHANNEL & RELAYS FOR FBEVAS, CREVAS, CPIAS	7.17	.995536
AC POWER SOURCE	40	.975349
DC POWER SOURCE	4	.997507
AC TO DC POWER SUPPLY	25	.984521
DC TO DC POWER SUPPLY	25	.984521
INITIATING CHANNEL FOR CREVIAS	15.8	.990189
ACTUATING CHANNEL FOR CREVIAS	7.87	.995101
LOP/LS MODULE		
A. TRIP SECTION	5.77	.996406
B. 2/4 AND OUTPUT	0	.992664
DGSS	0	.992788
ESF LOAD SEQUENCER	20.7	.987166

RELIABILITY BY SUBSYSTEM

SUBSYSTEM	RELIABILITY
POWER SUPPLY	.999287
FBEVAS	.999882
CREFAS	.999882
CPIAS	.999902
CREVIAS(SMCROA)	.999858
CREVIAS(HGCROA)	.999858
DGSS	.999942
LOSS OF POWER	.999935
LOAD SEQUENCER	.999815

TOTAL SYSTEM RELIABILITY FOR 624 HOUR MISSION TIME: .999884

MISSION TIME:672

COMPONENT RELIABILITY DATA TABLE

SUBSYSTEM COMPONENT	FAILURE RATE PER MILLION HRS	RELIABILITY FOR 672 HRS
INITIATING CHANNEL FOR FBEVAS, CREFAS, CPIAS	12.5	.991635
ACTUATING CHANNEL & RELAYS FOR FBEVAS, CREVAS, CPIAS	7.17	.995193
AC POWER SOURCE	40	.973478
DC POWER SOURCE	4	.997315
AC TO DC POWER SUPPLY	25	.98334
DC TO DC POWER SUPPLY	25	.98334
INITIATING CHANNEL FOR CREVIAS	15.8	.989438
ACTUATING CHANNEL FOR CREVIAS	7.87	.994725
LOP/LS MODULE		
A. TRIP SECTION	5.77	.99613
B. 2/4 AND OUTPUT	0	.992102
DGSS	0	.992235
ESF LOAD SEQUENCER	20.7	.986186

RELIABILITY BY SUBSYSTEM

SUBSYSTEM	RELIABILITY
POWER SUPPLY	.999175
FBEVAS	.999862
CREFAS	.999862
CPIAS	.999885
CREVIAS(SMCROA)	.999834
CREVIAS(HGCROA)	.999834
DGSS	.999933
LOSS OF POWER	.999924
LOAD SEQUENCER	.999784

TOTAL SYSTEM RELIABILITY FOR 672 HOUR MISSION TIME: .999865

MISSION TIME:720

COMPONENT RELIABILITY DATA TABLE

SUBSYSTEM COMPONENT	FAILURE RATE PER MILLION HRS	RELIABILITY FOR 720 HRS
INITIATING CHANNEL FOR FBEVAS, CREFAS, CPIAS	12.5	.99104
ACTUATING CHANNEL & RELAYS FOR FBEVAS, CREVAS, CPIAS	7.17	.994851
AC POWER SOURCE	40	.971611
DC POWER SOURCE	4	.997124
AC TO DC POWER SUPPLY	25	.982161
DC TO DC POWER SUPPLY	25	.982161
INITIATING CHANNEL FOR CREVIAS	15.8	.988688
ACTUATING CHANNEL FOR CREVIAS	7.87	.99435
LOP/LS MODULE		
A. TRIP SECTION	5.77	.995854
B. 2/4 AND OUTPUT	0	.99154
DGSS	0	.991683
ESF LOAD SEQUENCER	20.7	.985206

RELIABILITY BY SUBSYSTEM

SUBSYSTEM	RELIABILITY
POWER SUPPLY	.999055
FBEVAS	.999839
CREFAS	.999839
CPIAS	.999866
CREVIAS(SMCROA)	.999808
CREVIAS(HGCROA)	.999808
DGSS	.999922
LOSS OF POWER	.999912
LOAD SEQUENCER	.99975

TOTAL SYSTEM RELIABILITY FOR 720 HOUR MISSION TIME: .999843

MISSION TIME:768

COMPONENT RELIABILITY DATA TABLE

SUBSYSTEM COMPONENT	FAILURE RATE PER MILLION HRS	RELIABILITY FOR 768 HRS
INITIATING CHANNEL FOR FBEVAS, CREFAS, CPIAS	12.5	.990446
ACTUATING CHANNEL & RELAYS FOR FBEVAS, CREVAS, CPIAS	7.17	.994509
AC POWER SOURCE	40	.969747
DC POWER SOURCE	4	.996933
AC TO DC POWER SUPPLY	25	.980983
DC TO DC POWER SUPPLY	25	.980983
INITIATING CHANNEL FOR CREVIAS	15.8	.987939
ACTUATING CHANNEL FOR CREVIAS	7.87	.993974
LOP/LS MODULE		
A. TRIP SECTION	5.77	.995578
B. 2/4 AND OUTPUT	0	.990979
DGSS	0	.991131
ESF LOAD SEQUENCER	20.7	.984228

RELIABILITY BY SUBSYSTEM

SUBSYSTEM	RELIABILITY
POWER SUPPLY	.998927
FBEVAS	.999815
CREFAS	.999815
CPIAS	.999845
CREVIAS(SMCROA)	.999779
CREVIAS(HGCROA)	.999779
DGSS	.999911
LOSS OF POWER	.999898
LOAD SEQUENCER	.999713

TOTAL SYSTEM RELIABILITY FOR 768 HOUR MISSION TIME: .99982

MISSION TIME:816

COMPONENT RELIABILITY DATA TABLE

SUBSYSTEM COMPONENT	FAILURE RATE PER MILLION HRS	RELIABILITY FOR 816 HRS
INITIATING CHANNEL FOR FBEVAS, CREFAS, CPIAS	12.5	.989852
ACTUATING CHANNEL & RELAYS FOR FBEVAS, CREVAS, CPIAS	7.17	.994166
AC POWER SOURCE	40	.967887
DC POWER SOURCE	4	.996741
AC TO DC POWER SUPPLY	25	.979807
DC TO DC POWER SUPPLY	25	.979807
INITIATING CHANNEL FOR CREVIAS	15.8	.98719
ACTUATING CHANNEL FOR CREVIAS	7.87	.993599
LOP/LS MODULE		
A. TRIP SECTION	5.77	.995303
B. 2/4 AND OUTPUT	0	.990417
DGSS	0	.990579
ESF LOAD SEQUENCER	20.7	.983251

RELIABILITY BY SUBSYSTEM

SUBSYSTEM	RELIABILITY
POWER SUPPLY	.998792
FBEVAS	.999789
CREFAS	.999789
CPIAS	.999823
CREVIAS(SMCROA)	.999748
CREVIAS(HGCROA)	.999748
DGSS	.999899
LOSS OF POWER	.999884
LOAD SEQUENCER	.999674

TOTAL SYSTEM RELIABILITY FOR 816 HOUR MISSION TIME: .999794

MISSION TIME:864

COMPONENT RELIABILITY DATA TABLE

SUBSYSTEM COMPONENT	FAILURE RATE PER MILLION HRS	RELIABILITY FOR 864 HRS
INITIATING CHANNEL FOR FBEVAS, CREFAS, CPIAS	12.5	.989258
ACTUATING CHANNEL & RELAYS FOR FBEVAS, CREVAS, CPIAS	7.17	.993824
AC POWER SOURCE	40	.96603
DC POWER SOURCE	4	.99655
AC TO DC POWER SUPPLY	25	.978632
DC TO DC POWER SUPPLY	25	.978632
INITIATING CHANNEL FOR CREVIAS	15.8	.986441
ACTUATING CHANNEL FOR CREVIAS	7.87	.993223
LOP/LS MODULE		
A. TRIP SECTION	5.77	.995027
B. 2/4 AND OUTPUT	0	.989857
DGSS	0	.990028
ESF LOAD SEQUENCER	20.7	.982274

RELIABILITY BY SUBSYSTEM

SUBSYSTEM	RELIABILITY
POWER SUPPLY	.998649
FBEVAS	.999761
CREFAS	.999761
CPIAS	.9998
CREVIAS(SMCROA)	.999714
CREVIAS(HGCROA)	.999714
DGSS	.999885
LOSS OF POWER	.999868
LOAD SEQUENCER	.999632

TOTAL SYSTEM RELIABILITY FOR 864 HOUR MISSION TIME: .999767

MISSION TIME:912

COMPONENT RELIABILITY DATA TABLE

SUBSYSTEM COMPONENT	FAILURE RATE PER MILLION HRS	RELIABILITY FOR 912 HRS
INITIATING CHANNEL FOR FBEVAS, CREFAS, CPIAS	12.5	.988665
ACTUATING CHANNEL & RELAYS FOR FBEVAS, CREVAS, CPIAS	7.17	.993482
AC POWER SOURCE	40	.964177
DC POWER SOURCE	4	.996359
AC TO DC POWER SUPPLY	25	.977458
DC TO DC POWER SUPPLY	25	.977458
INITIATING CHANNEL FOR CREVIAS	15.8	.985694
ACTUATING CHANNEL FOR CREVIAS	7.87	.992848
LOP/LS MODULE		
A. TRIP SECTION	5.77	.994752
B. 2/4 AND OUTPUT	0	.989296
DGSS	0	.989477
ESF LOAD SEQUENCER	20.7	.981299

RELIABILITY BY SUBSYSTEM

SUBSYSTEM	RELIABILITY
POWER SUPPLY	.998498
FBEVAS	.999731
CREFAS	.999731
CPIAS	.999774
CREVIAS(SMCROA)	.999679
CREVIAS(HGCROA)	.999679
DGSS	.999871
LOSS OF POWER	.999851
LOAD SEQUENCER	.999587

TOTAL SYSTEM RELIABILITY FOR 912 HOUR MISSION TIME: .999738

MISSION TIME:960

COMPONENT RELIABILITY DATA TABLE

SUBSYSTEM COMPONENT	FAILURE RATE PER MILLION HRS	RELIABILITY FOR 960 HRS
INITIATING CHANNEL FOR FBEVAS, CREFAS, CPIAS	12.5	.988072
ACTUATING CHANNEL & RELAYS FOR FBEVAS, CREVAS, CPIAS	7.17	.99314
AC POWER SOURCE	40	.962328
DC POWER SOURCE	4	.996167
AC TO DC POWER SUPPLY	25	.976286
DC TO DC POWER SUPPLY	25	.976286
INITIATING CHANNEL FOR CREVIAS	15.8	.984947
ACTUATING CHANNEL FOR CREVIAS	7.87	.992473
LOP/LS MODULE		
A. TRIP SECTION	5.77	.994476
B. 2/4 AND OUTPUT	0	.988736
DGSS	0	.988926
ESF LOAD SEQUENCER	20.7	.980324

RELIABILITY BY SUBSYSTEM

SUBSYSTEM	RELIABILITY
POWER SUPPLY	.998339
FBEVAS	.999699
CREFAS	.999699
CPIAS	.999746
CREVIAS(SMCROA)	.99964
CREVIAS(HGCROA)	.99964
DGSS	.999856
LOSS OF POWER	.999833
LOAD SEQUENCER	.999539

TOTAL SYSTEM RELIABILITY FOR 960 HOUR MISSION TIME: .999707

APPENDIX D

COMPUTER RELIABILITY COMPUTATION PROGRAM

APPENDIX D

COMPUTER RELIABILITY COMPUTATION PROGRAM

FOR

PALO VERDE NUCLEAR GENERATING STATION
BALANCE OF PLANT ENGINEERED SAFETY
FEATURES ACTUATION SYSTEM

BECHTEL JOB 10407
PURCHASE ORDER 10407-13-JM-104

SEPTEMBER 22,1978

PROJECT NO. 2192

GENERAL ATOMIC COMPANY
ELECTRONIC SYSTEMS DIVISION
P O BOX 81608
SAN DIEGO, CALIFORNIA 92138

```
DIM SUB.SYS$(IN.NUM)
REM      EQUATES
SUB.SYS$(1)='FBEVAS'
SUB.SYS$(2)='CREFAS'
SUB.SYS$(3)='CPIAS'
SUB.SYS$(4)='CREVIAS(SMCROA)'
SUB.SYS$(5)='CREVIAS(HGCROA)'
SUB.SYS$(6)='DGSS'
SUB.SYS$(7)='LOSS OF POWER'
SUB.SYS$(8)='LOAD SEQUENCER'
REM      THIS PROGRAM WILL CALCULATE THE RELIABILITY OVER
REM      AN INTERVAL OF TIME IN STEPS OF INTEGER HOURS.
REM      THE STARTING TIME, THE ENDING TIME AND THE
REM      NUMBER OF HOURS IN EACH TIME STEP MUST BE
REM      SPECIFIED.
INPUT 'STARTING TIME'; START.TIME
INPUT 'ENDING TIME'; STOP.TIME
INPUT 'TIME STEP IN HOURS'; TIME.STEP
REM      DEFINE FUNCTIONS
DEF FNRELIABILITY(N,T)=1/EXP(N*(1E-6)*T)
RETURN
REM###################################################
2000     REM    SUBROUTINE: PRINT FRONT PAGE OF APPENDIX
REM      LIST TITLE LINES TO BE USED
TITLE1$='APPENDIX C'
TITLE2$='COMPUTER RELIABILITY COMPUTATION'
TITLE2A$='FOR'
TITLE3$='PALO VERDE NUCLEAR GENERATING STATION'
TITLE4$='BALANCE OF PLANT ENGINEERED SAFETY'
TITLE5$='FEATURES ACTUATION SYSTEM'
TITLE6$='BECHTEL JOB 10407'
TITLE7$='PURCHASE ORDER 10407-13-JM-104'
TITLE8$='PROJECT NO. 2192'
REM      INPUT TITLE SPACING DATA
READ N1,N2,N3,N4,N5,N6
DATA  5, 6, 3, 8, 8, 0
REM      START NEW PAGE
```

```
PRINT NEW.PAGE$
FOR I=1 TO N1
       PRINT
NEXT I

REM     PRINT APPENDIX HEADING

Q=LEN(TITLE1$)
R=(80-Q)/2
PRINT TAB (R);TITLE1$

FOR I=1 TO N2
       PRINT
NEXT I

Q=LEN(TITLE2$)
PRINT TAB((80-Q)/2);TITLE2$

FOR I=1 TO N3
       PRINT
NEXT I
PRINT TAB((80-LEN(TITLE2A$))/2);TITLE2A$
FOR I = 1 TO N3
       PRINT
NEXT I
Q=LEN(TITLE3$)
PRINT TAB((80-Q)/2);TITLE3$
Q=LEN(TITLE4$)
PRINT TAB((80-Q)/2);TITLE4$
Q=LEN(TITLE5$)
PRINT TAB((80-Q)/2);TITLE5$
FOR I=1 TO N3
       PRINT
NEXT I
PRINT TAB((80-LEN(TITLE6$))/2);TITLE6$
PRINT TAB((80-LEN(TITLE7$))/2);TITLE7$
FOR I = 1 TO N4
       PRINT
NEXT I
Q=LEN(DATE$)
PRINT TAB((80-Q)/2);DATE$
FOR I=1 TO N5
       PRINT
NEXT I
PRINT TAB((80-LEN(TITLE8$))/2);TITLE8$
PRINT:PRINT

REM     WRITE COMPANY ADDRESS BLOCK

GOSUB 2500

REM     GO TO THE NEXT PAGE

PRINT NEW.PAGE$

RETURN
```

```
REM#######################################################

2500    REM    SUBROUTINE TO PRINT GENERAL ATOMIC
REM    ADDRESS BLOCK

LINE1$='GENERAL ATOMIC COMPANY'
LINE2$='ELECTRONIC SYSTEMS DIVISION'
LINE3$='P O BOX 81608'
LINE4$='SAN DIEGO, CALIFORNIA 92138'

PRINT TAB((80-LEN(LINE1$))/2);LINE1$
PRINT TAB((80-LEN(LINE2$))/2);LINE2$
PRINT TAB((80-LEN(LINE3$))/2);LINE3$
PRINT TAB((80-LEN(LINE4$))/2);LINE4$

RETURN


REM#######################################################

3000    REM    SUBROUTINE FOR DATA INPUT

REM    INPUT THE FAILURE RATE DATA

READ L.11, L.13, L.S1, L.S2, L.S3, L.S4, L.11A
READ L.13A,  L.A,  L.24.PLUS.L.AD, L.DA, L.Q

DATA 12.5, 7.17, 40.0, 4.00, 25.0, 25.0, 15.8
DATA 7.87, 5.77, 11.8, 11.6, 20.7

RETURN



REM#######################################################

4000    REM    SUBROUTINE TO CALCULATE COMPONENT
REM            RELIABILITY

T=TIME
P.11=FNRELIABILITY(L.11,T)
P.13=FNRELIABILITY(L.13,T)
P.S1=FNRELIABILITY(L.S1,T)
P.S2=FNRELIABILITY(L.S2,T)
P.S3=FNRELIABILITY(L.S3,T)
P.S4=FNRELIABILITY(L.S4,T)
P.11A =FNRELIABILITY(L.11A ,T)
P.13A =FNRELIABILITY(L.13A ,T)
P.A =FNRELIABILITY(L.A ,T)
P.24XP.AD=FNRELIABILITY(L.24.PLUS.L.AD,T)
P.DA=FNRELIABILITY(L.DA,T)
P.Q =FNRELIABILITY(L.Q ,T)

RETURN
```

```
REM##########################################################

5000    REM    SUBROUTINE TO CALCULATE THE SUBSYSTEM
REM    RELIABILITIES

REM     THE FOLLOWING EQUALITIES WERE ESTABLISHED
REM     IN THE REPORT.

P.12=P.11
P.14=P.13
P.15=P.13
P.16=P.13
P.12A=P.11A
P.14A=P.13A
P.15A=P.13A
P.16A=P.13A

REM     THE COMPUTER DOES NOT ALLOW COMPLETE FLEXIBILITY
REM     IN CHOOSING SYMBOLS IN THE COMPUTATIONAL SECTION
REM     THEREFORE, THE FOLLOWING CHANGE OF SYMBOLS
REM     WILL BE EMPLOYED.
REM
REM     SYMBOLS USE IN REPORT          SYMBOLS IN THIS SECTION

REM     P(SO1)/I1                     P.GI1.SO(1)

REM     EITHER IS READ AS 'THE PROBABILITY OF SUCCESS
REM     AT OUTPUT ONE GIVEN INPUT ONE.



REM            ----------------
REM     FOR THE POWER SUPPLY SUBSYSTEM

A=P.S1*P.S3
B=P.S1*(1-P.S3)*P.S2*P.S4
C=(1-P.S1)*P.S2*P.S4
P.SA=A+B+C
P.SB=P.SA




REM            ----------------
REM     FOR OUTPUTS RELATED TO INPUT I1 (FBVAS),
REM     CALCULATE THE FOLLOWING:

REM     FOR S(SO1)/I1:

A=P.11*P.SA*P.13
B=P.11*P.SA*(1-P.15)*P.16*P.SB
C=P.11*(1-P.SA)*P.12*P.SB*P.14
D=(1-P.11)*P.12*P.SB*P.14
```

```
E=(1-P.11)*P.12*P.SB*(1-P.14)*P.15*P.SA
P.GI1.SO(1)=A+B+C+D+E
REM      FOR P(SO2)/I1
P.GI1.SO(2)=P.13+(1-P.13)*P.16
FOR K = 3 TO OUT.NUM
         P.GI1.SO(K)=1
NEXT K
P.SO.GI(1)=1
FOR K = 1 TO OUT.NUM
         P.SO.GI(1)=P.SO.GI(1)*P.GI1.SO(K)
NEXT K
REM      .         ----------------
REM      FOR OUTPUTS RELATED TO INPUT I2 (CREFAS),
REM      CALCULATE THE FOLLOWING:
P.GI2.SO(1)=1
REM      FOR P(SO2)/I2
P.GI2.SO(2)=P.GI1.SO(1)
REM      FOR P(SO3)/I2
P.GI2.SO(3)=P.GI1.SO(2)
FOR K = 4 TO OUT.NUM
         P.GI2.SO(K)=1
NEXT K
P.SO.GI(2)=1
FOR K = 1 TO OUT.NUM
         P.SO.GI(2)=P.SO.GI(2)*P.GI2.SO(K)
NEXT K
REM                ----------------
REM      FOR OUTPUTS RELATED TO INPUT I3 (CPIAS),
REM      CALCULATE THE FOLLOWING:
FOR K= 1 TO 2
         P.GI3.SO(K)=1
NEXT K
REM      FOR P(SO3)/I3
P.GI3.SO(3)=P.GI1.SO(1)
```

```
FOR K = 4 TO OUT.NUM
        P.GI3.SO(K)=1
NEXT K

P.SO.GI(3)=1
FOR K = 1 TO OUT.NUM
        P.SO.GI(3)=P.SO.GI(3)*P.GI3.SO(K)
NEXT K



REM             ----------------
REM     FOR OUTPUTS RELATED TO INPUT I4 (CREVIAS-SMCROA),
REM     CALCULATE THE FOLLOWING:

FOR K = 1 TO 3
        P.GI4.SO(K)=1
NEXT K

REM     FOR P(SO4)/I4

AA=P.11A*P.SA*P.13A
BA=P.11A*P.SA*(1-P.15A)*P.16A*P.SB
CA=P.11A*(1-P.SA)*P.12A*P.SB*P.14A
DA=(1-P.11A)*P.12A*P.SB*P.14A
EA=(1-P.11A)*P.12A*P.SB*(1-P.14A)*P.15A*P.SA

P.GI4.SO(4)=AA+BA+CA+DA+EA

FOR K = 5 TO OUT.NUM
        P.GI4.SO(K)=1
NEXT K

P.SO.GI(4)=1
FOR K = 1 TO OUT.NUM
        P.SO.GI(4)=P.SO.GI(4)*P.GI4.SO(K)
NEXT K



REM             ----------------
REM     FOR OUTPUTS RELATED TO INPUT I5 (CREVIAS-HGCROA),
REM     CALCULATE THE FOLLOWING:

FOR K = 1 TO 3
        P.GI5.SO(K)=1
NEXT K

REM     FOR P(SO4)/I5

P.GI5.SO(4)=P.GI4.SO(4)

FOR K = 5 TO OUT.NUM
        P.GI5.SO(K)=1
NEXT K
```

```
P.SO.GI(5)=1
FOR K = 1 TO OUT.NUM
        P.SO.GI(5)=P.SO.GI(5)*P.GI5.SO(K)
NEXT K



REM               ----------------
REM      FOR OUTPUTS RELATED TO INPUT I6 (DGSS),
REM      CALCULATE THE FOLLOWING:


FOR K = 1 TO 4
        P.GI6.SO(K)=1
NEXT K


REM      FOR P(SO5)/I6

F=P.DA*P.SA
G=P.DA*(1-P.SA)*P.SA
H=(1-P.DA)*P.DA*P.SA

P.GI6.SO(5)=F+G+H

FOR K = 6 TO OUT.NUM
        P.GI6.SO(K)=1
NEXT K

P.SO.GI(6)=1
FOR K = 1 TO OUT.NUM
        P.SO.GI(6)=P.SO.GI(6)*P.GI6.SO(K)
NEXT K



REM               ----------------
REM      FOR OUTPUTS RELATED TO INPUT I7 (LOSS OF POWER),
REM      CALCULATE THE FOLLOWING:


FOR K = 1 TO 5
        P.GI7.SO(K)=1
NEXT K

P.I=(P.A^2)*(1+2*(1-P.A)+3*(1-P.A)^2)

P.L=P.I*P.24XP.AD*P.SA

P.GI7.SO(6)=P.L+(1-P.L)*P.L

FOR K = 7 TO OUT.NUM
        P.GI7.SO(K)=1
NEXT K
```

```
P.SO.GI(7)=1
FOR K = 1 TO OUT.NUM
        P.SO.GI(7)=P.SO.GI(7)*P.GI7.SO(K)
NEXT K
REM            ----------------
REM     FOR OUTPUTS RELALATED TO INPUT I8 (LOAD SEQUENCER),
REM     CALCULATE THE FOLLOWING:
FOR K = 1 TO 6
        P.GI8.SO(K)=1
NEXT K
P.LOP=P.GI7.SO(6)
P.SI=1
P.BKR=1
P.LS.A=P.SI*P.LOP*P.BKR*P.Q*P.SA
P.GI8.SO(7)=P.LS.A+(1-P.LS.A)*P.LS.A
P.SO.GI(8)=1
FOR K = 1 TO OUT.NUM
        P.SO.GI(8)=P.SO.GI(8)*P.GI8.SO(K)
NEXT K
RETURN
REM#####################################################
6000    REM    SUBROUTINE TO CALCULATE TOTAL SYSTEM RELIABILITY
P.SYSTEM=0
FOR K = 1 TO IN.NUM
        P.SYSTEM=P.SYSTEM+(1/IN.NUM)*P.SO.GI(K)
NEXT K
RETURN
REM#####################################################
7000    REM    SUBROUTINE TO PRINT THE RELIABILITY
REM    RESULTS FOR ONE TIME STEP
REM     PRINT THE HEADING ON THE PAGE
PRINT TAB(55),'MISSION TIME:';TIME
```

```
REM     PRINT FAILURE RATE & RELIABILITY COMPONENT DATA
GOSUB 7020
REM     PRINT SUBSYSTEM RELIABILITY DATA
GOSUB 7030
REM     PRINT SYSTEM RELIABILITY
GOSUB 7040
FOR I = 1 TO 4
        PRINT
NEXT I
PRINT DATE2$
PRINT NEW.PAGE$
RETURN
REM#####################################################
7020    REM     SUBROUTINE TO PRINT THE COMPONENT RELIABILITY DATA
PRINT
PRINT TAB(20);'COMPONENT RELIABILITY DATA TABLE'
PRINT:PRINT
PRINT '================================================';
PRINT '===================='
PRINT TAB(T3);'FAILURE';TAB(T4);'RELIABILITY'
PRINT TAB(10);'SUBSYSTEM COMPONENT';TAB(T3);'RATE PER';
PRINT TAB(T4);'FOR ';TIME;' HRS'
PRINT TAB(T3);'MILLION HRS'
PRINT '------------------------------------------------';
PRINT '--------------------'
PRINT
PRINT 'INITIATING CHANNEL FOR';TAB(T3);L.11;TAB(T4);P.11
PRINT 'FBEVAS, CREFAS, CPIAS'
PRINT
PRINT 'ACTUATING CHANNEL & RELAYS';
PRINT TAB(T3);L.13;TAB(T4);P.13
PRINT 'FOR FBEVAS, CREVAS, CPIAS'
PRINT
PRINT 'AC POWER SOURCE';TAB(T3);L.S1;TAB(T4);P.S1
PRINT
PRINT 'DC POWER SOURCE';TAB(T3);L.S2;TAB(T4);P.S2
PRINT
PRINT 'AC TO DC POWER SUPPLY';TAB(T3);L.S3;TAB(T4);P.S3
```

```
PRINT
PRINT 'DC TO DC POWER SUPPLY';TAB(T3);L.S4;TAB(T4);P.S4
PRINT
PRINT 'INITIATING CHANNEL FOR CREVIAS';
PRINT TAB(T3);L.11A;TAB(T4);P.11A
PRINT
PRINT 'ACTUATING CHANNEL FOR CREVIAS';
PRINT TAB(T3);L.13A;TAB(T4);P.13A
PRINT
PRINT 'LOP/LS MODULE'
PRINT '    A. TRIP SECTION';TAB(T3);L.A;TAB(T4);P.A
PRINT '    B. 2/4 AND OUTPUT';TAB(T3);L.24;TAB(T4);P.24XP.AD
PRINT
PRINT 'DGSS';TAB(T3);L.AD;TAB(T4);P.DA
PRINT
PRINT 'ESF LOAD SEQUENCER';TAB(T3);L.Q;TAB(T4);P.Q
PRINT '-------------------------------------------------';
PRINT '---------------------'


RETURN



REM####################################################

7030    REM    SUBROUTINE TO PRINT THE SUBSYSTEM RELIABILITY DATA

PRINT
PRINT TAB(15);'RELIABILITY BY SUBSYSTEM'
PRINT TAB(15);'----------- -- ---------'
PRINT
PRINT TAB(T1),'SUBSYSTEM';TAB(T2);'RELIABILITY'
PRINT
PRINT TAB(T1);'POWER SUPPLY';TAB(T2);P.SA
FOR I = 1 TO IN.NUM
       PRINT TAB(T1);SUB.SYS$(I);TAB(T2);P.SO.GI(I)
NEXT I

RETURN


REM####################################################

7040    REM    SUBROUTINE TO PRINT THE SYSTEM RELIABILITY FOR
REM     THE CURRENT MISSION TIME

PRINT
PRINT 'TOTAL SYSTEM RELIABILITY FOR ';TIME;
PRINT 'HOUR MISSION TIME: ';P.SYSTEM
RETURN


REM####################################################
```

```
671:  END
   0 ERRORS DETECTED
```