Pickard, Lowe and Garrick, Inc.
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INDIAN POINT 3
CONTAINMENT FAN COOLING (CF) SYSTEM

A. SUMMARY

A.1 INTRODUCTION

Following a LOCA, five containment building ventilation fan cooler units will be transferred to their accident mode of operation and will serve to keep containment pressure below design pressure. Three of the five units are sufficient to perform this function and can be used in lieu of the containment spray system.

If, as a result of the LOCA, iodine is released to the containment, the charcoal filter beds in each of the fan cooler units will adsorb this radioactive material.

The analysis is carried out under the following conditions:

- The safeguards actuation signal is present.
- Service water is available at the isolation valves for each fan cooler unit.

A.2 RESULTS

Failure of the containment fan cooling system to operate in the accident mode following activation during a safety injection sequence has been determined by using generic data which has been updated as applicable with specific historical data from Indian Point Unit 3.

The expected unavailability of the fan cooler unit system (including iodine removal) has been rigorously calculated for those states of electric power which failed two or less fan cooler units. The remaining electric power states where power was unavailable to three or more fan cooler units resulted in system failure and were not analyzed further. Each state was evaluated asssuming that:

- Offsite power is available.
- Offsite power is unavailable and the diesel generators are required to supply electrical loads.

The results of these calculations are summarized in Tables 2 and 3.

The analysis has revealed the following dominant contributions to system unavailability:

- <u>With Power On All Buses</u>

Offsite power available	Mean
- TCV 1104 and TCV 1105 fail to open	6.2×10^{-7} (98%)

	Mean
Offsite power lost	
- TCV 1104 and TCV 1105 fail to open	6.2×10^{-7} (62%)
- Three of five fan cooler units fail to start and operate	3.3×10^{-7} (33%)
• Bus 6A Unavailable	
Offsite power available	
- Maintenance	1.8×10^{-6} (46%)
- Three of five fan cooler units fail to start and operate	1.5×10^{-6} (38%)
Offsite power lost	
- Three of five fan cooler units fail to start and operate	2.1×10^{-5} (75%)
- Maintenance	6.6×10^{-6} (23%)
• Bus (2A, 3A) or 5A Unavailable	
Offsite power available	
- Maintenance	1.5×10^{-3} (53%)
- Three of five fan cooler units fail to start and operate	1.3×10^{-3} (46%)
Offsite power lost	
- Maintenance	7.9×10^{-3} (71%)
- Three of five fan cooler units fail to start and operate	3.2×10^{-3} (29%)

A.3 CONCLUSIONS

Each fan cooler unit is tranferred to the accident mode of operation by the safety injection signal which initiates internal damper repositioning and the starting of any standby units. Four fan coolers are normally in operation and this serves to minimize system unavailability in that four of the five fan coolers are not required to start but only to shift to the accident mode of operation. Following an interruption of power to the 480 essential switchgear buses, the fan coolers are reenergized by the safeguards sequencers. System unavailability is increased in that the coolers must now successfully start and transfer to the accident mode.

The effects of maintenance on system unavailability increases dramatically when less than optimum electric power states are considered. Maintenance becomes the dominant effect when two fan cooler units are failed due to electric power unavailability.

System unavailability is summarized below:

Electric Power State	Mean Unavailability	
	Offsite Power Available	Offsite Power Lost
All power	6.3×10^{-7}	1.0×10^{-6}
6A unavailable	3.9×10^{-6}	2.8×10^{-5}
(2A, 3A) or 5A unavailable	2.8×10^{-3}	1.1×10^{-2}

The probability distributions associated with each of the above mean unavailabilities are displayed in Figure A-1 and A-2. Due to the absence of fan cooler units in the plant analyzed by WASH-1400, a comparison of system unavailability was not made.

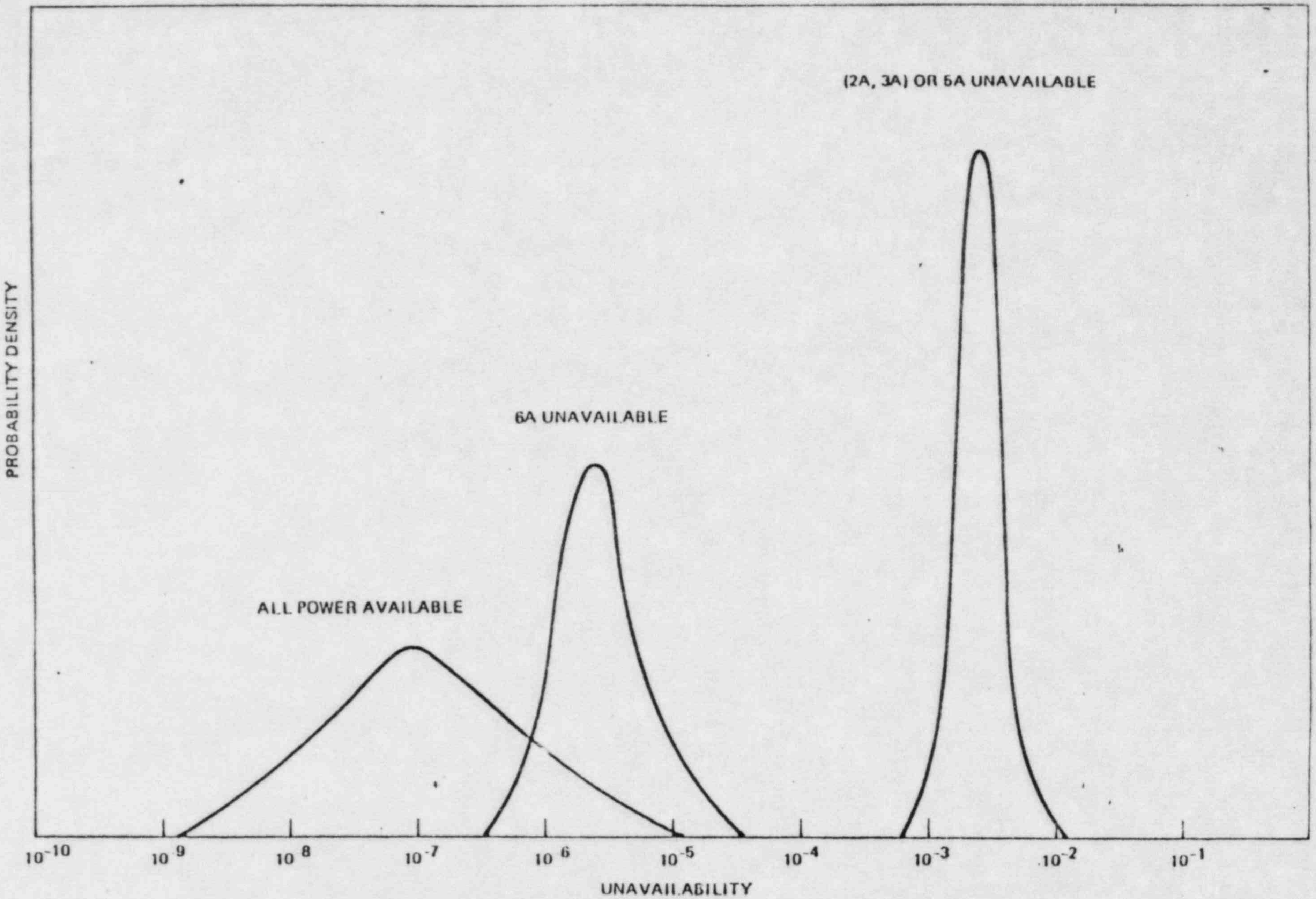

Figure A-1. Probability Distribution of System Unavailability
Offsite Power Available

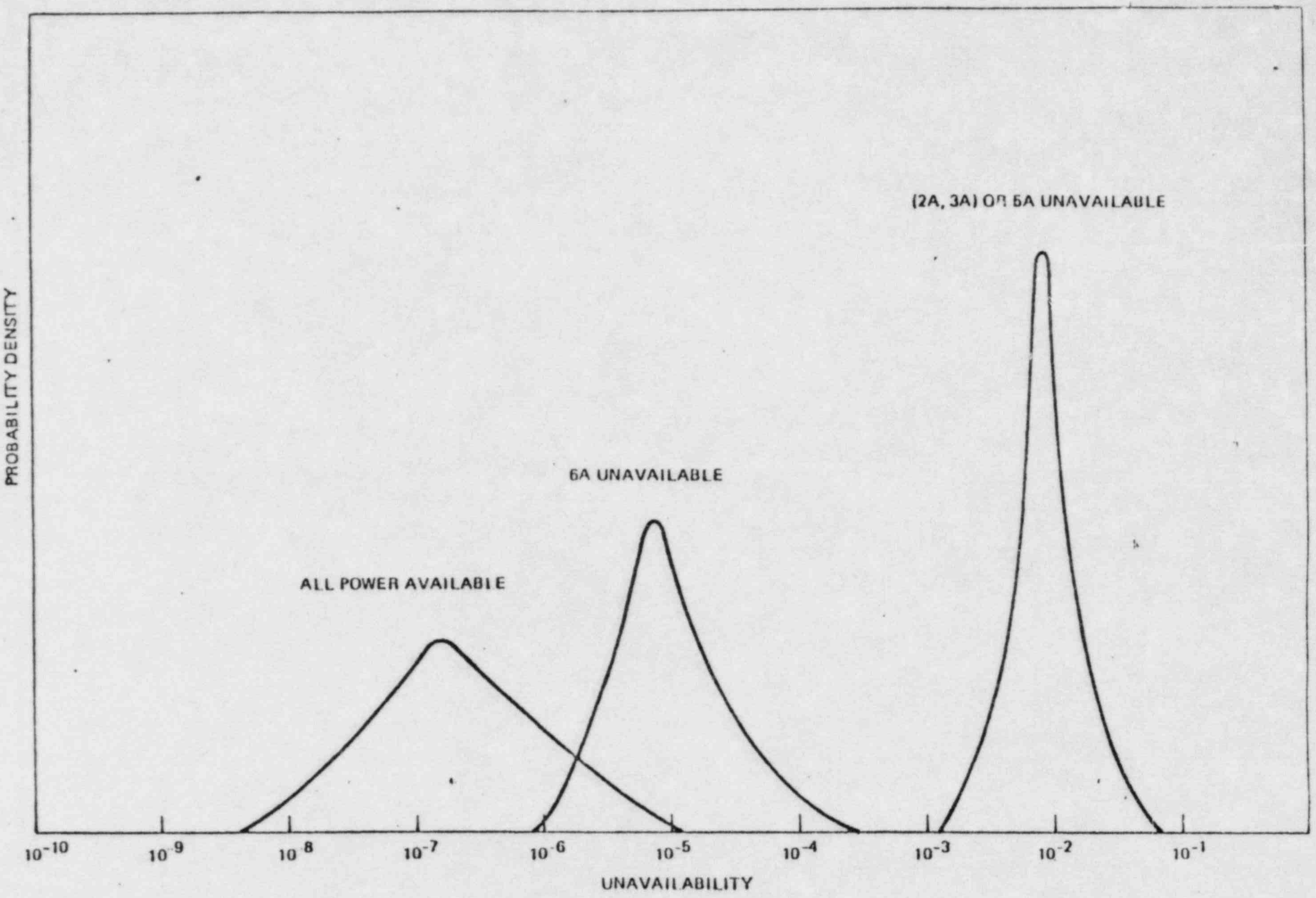

Figure A-2. Probability Distribution of System Unavailability Offsite Power Unavailable

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B. SYSTEM DESCRIPTION

B.1 SYSTEM FUNCTION

The primary functions of the containment fan cooling and iodine removal system are:

- To reduce the pressure in containment following a loss of coolant accident, or a steam line break inside containment.
- To remove fission products from the containment atmosphere should they be released in the event of a loss of coolant accident.

The five containment fan cooling units are used to cool the containment building atmosphere following a LOCA. The units will be transferred to their accident mode, and at least three of the five are required for a large LOCA if the containment spray system is inoperative (less than three units may be adequate in small LOCAs). Heat removed by the units is rejected to the ultimate heat sink via the service water system through an air-water heat exchanger.

B.2 SYSTEM SUCCESS CRITERIA

Any three of the five fan cooler units with their charcoal filter beds operating in the accident mode are capable of removing heat, iodine particles, and water vapor from containment following a LOCA.

B.3 BASIC DESCRIPTION

The system consists of five fan cooler units, each consisting of a motor-driven fan, cooling coils, moisture separators, HEPA filters, charcoal filters, dampers, and an air discharge duct. The units are located on the 68' elevation between the containment wall and the crane wall. The moisture separators, HEPA filters, and the charcoal filter assembly are normally isolated from the main air recirculation stream. In the event of an accident, part of the air flow is redirected through the filtration section of the unit (moisture separator, HEPA filters, and charcoal filter assembly) to remove volatile iodine. Duct work distributes the exhaust air to a discharge header common to all fan cooler units during all modes of operation. Figure 1 shows a simplified drawing of a fan cooler unit. The cooling water for all five fan cooling units during both normal and accident conditions is supplied by the essential service water system as illustrated in Figure 2.

Each fan cooling unit is provided with four dampers and a blow-in door. During normal operation, air flow enters through dampers "A" (26600CFM), "B" (27600CFM), and "C" (15800CFM). It is then drawn through the cooling coils into the fan suction. The fan exhausts 70,000 CFM of cooled air into a 64" header common to all fan cooler units where it is distributed to various locations throughout the containment. Four fan cooler units are normally operated in this mode to control containment humidity and temperature.

In the event of a safety injection actuation signal, damper "D" and the blow-in door open; dampers "A" and "B" shut. Damper "C" then moves to a preset position which results in an airflow of 8,000 CFM entering at the blow-in door and passing through the charcoal beds and 26,000 CFM entering the fan cooler unit through damper "C" bypassing the filtration section. The combined flow then passes through the cooling coils and exits as previously described. Any nonoperating fan cooler is automatically started and aligned to this LOCA configuration. Control switches and indicating lights necessary for manual damper control are provided on the supervisory panel (SBF-2).

Redundant electrically operated three-way solenoid valves are used with the dampers and blow-in door to control the instrument air supply for the air control cylinders. Upon manual or automatic actuation of the safety injection safeguards sequence, the dampers and door are tripped to accident positions.

Damper "A" is mounted vertically on the side of each unit and is open during normal conditions and closed during a LOCA. The damper will fail closed by a weighted arm upon loss of electrical power or air to the three-way solenoid. A limit switch provides damper position indication to the control room.

Damper "B" is identical to damper "A" except that its physical dimensions are slightly different. Damper "A" and "B" pneumatic control is by a common solenoid valve and common control switches and indicating lights in the control room.

Damper "C" is mounted vertically and is throttled open during normal operation and full open during LOCA conditions. Pneumatic control is provided by a solenoid valve for each unit and in the event of loss of power or air, damper "C" is positioned to its accident configuration by a weighted arm. Control switches and indicating lights are provided in the control room.

Damper "D" is mounted vertically between the filtration section and the cooling coil compartment of the fan cooler unit. The damper is closed during normal operation and serves to isolate the filtration unit from the recirculation air flow. In the event of a LOCA condition, damper "D" is opened to initiate flow through the charcoal beds. The damper will fail open by a weighted arm with assistance from offset blades in the event of loss of electrical power or air to the three-way solenoid.

The blow-in door is mounted on the inlet side of the filtration assembly. The door is held into position by magnetic latches and is designed to open either by an external overpressure of 0.5 psi, and/or by a pneumatic air cylinder pull cable. A limit switch is positioned so that door opening will be detectable. The blow-in door and damper "D" for each fan cooler have a common pneumatic control solenoid, control switch, and indicating light.

The moisture separators are designed to protect the HEPA filters from differential pressure due to water buildup following a loss of coolant accident. The moisture separator elements are of fire resistant construction, and consist of mats of stainless steel wire mesh with a small amount of fiberglass. The high efficiency particulate air (HEPA) filters are capable of 99.97% removal for 0.3 micron particles at the post-accident design conditions. The filter media is made of glass fiber and can withstand the accident ambient steam/air temperature conditions and 100% relative humidity.

The charcoal filter for each fan cooler unit consists of 12 cells in a 2-1/2 foot wide by 8-foot high array. The mounting rack arrangement permits removal of individual cells from the upstream side of the plenum. The elements are sealed so that air flow cannot bypass the filters. The design flow rate through the charcoal is 8,000 CFM and is only initiated during LOCA conditions. The charcoal is designed to remove both elemental (I-131) and organic iodine (CH_3I) and is 90% and 5% efficient, respectively, in iodine type removal. The elemental iodine is removed as the mixture flows into the multitude of submicroscopic pores and is absorbed on the internal surfaces. To remove organic iodine, the charcoal is impregnated with a stable form of iodine 127. By simple mechanical interchange, the organic iodine molecules substitute for the stable I-127 contained in the charcoal and the filtered gas emerges less radioactive.

Charcoal efficiency can be reduced by water-logging or exposure to temperatures high enough to cause accelerated oxidation of the charcoal grain surface. To protect against these conditions, individual charcoal cells and sample pieces of charcoal are removed periodically and tested for their effectiveness in iodine removal. The banks are further fitted with temperature sensing elements to provide warning of abnormal temperature conditions.

Capability for detecting and alarming the presence of fires and localized hot spots in the carbon filters is provided by a system of temperature switches uniformly distributed in the charcoal beds. The temperature switches are set to close at 400°F (which is significantly below the carbon ignition temperature of 680°F) and are wired in parallel to a common alarm for each fan cooler unit on the safety injection supervisory panel in the control room. The closing of a single switch will actuate the alarm to indicate a high temperature condition in the filter plenum.

Upon a signal of high temperature, the control room operator initiates the water dousing system provided with each charcoal filter plenum. This system is designed to drench the absorbers thoroughly in the extremely unlikely event of a carbon fire during the post-accident recovery. Water is obtained from the main headers of the containment spray system.

The portion of a fan cooler unit normally operating consists of the motor and fan, motor cooler, and air flow cooling coils.

The air flow cooling coil assembly consists of eight coil units mounted in two banks of four coils high. These banks are located one behind the other for horizontal series air flow, and the tubes of the coil are horizontal with vertical fins. An air-to-water heat exchanger is connected to the motor to form an entirely enclosed cooling system. Air movement is through the heat exchanger and is returned to the motor.

Both of the above heat exchangers are supplied by the service water system. When the safeguards signal is actuated, two normally closed valves (TCV-1104, TCV-1105) fully open and bypass service water flow around the normal temperature control valve (TCV-1103) on the common discharge line from the five units. Both of these valves fail open on loss of air, and either valve is capable of passing full flow. Manual control of the two valves is provided by an open-close switch on the SB-1 safeguards panel in the CCR. Position indication lights from the limit switches on the valves are also provided above the controls. On the occasion that flow was not up to the requirements for accident conditions, the alarm "CB Vent Fan Cooling Water Low Flow, 2,000" on safeguards panel SB-2 would annunciate. (This alarm, however, is normally out of service until the safeguards sequence signal arms it.)

The drainage from the cooling coils, moisture separators, charcoal dousing and the motor heat exchangers is collected from each unit and directed to a vertical, 6-inch diameter standpipe which is fitted with a V-notch (triangular) weir. Using this device, the flow rate of the water can be calculated. After passing over the V-notch weir, the drains empty into the containment sump which is small in surface area and minimizes the amount of reevaporation.

If the drainage rate for all five units is nearly the same, it may be concluded that this water is condensate from the containment atmosphere. A high drainage rate in a particular unit with respect to the other units, however, is indicative of a leak in one of the cooling coils. The leak rate of this service water could then be estimated as the difference between the flow from the particular fan unit and the average flow through the other four V-notch weirs. The drain rate for each fan cooler unit is alarmed in the control room at 1/2 gpm.

The fans are centrifugal-type and deliver 34,000 CFM at accident conditions and 70,000 CFM at normal conditions. The motors have "Stop-Auto-Start" switches with indicating lights on the SB-2 safeguards panel in the CCR. Fan control is also possible from a local control panel on the 15-foot elevation of the control building. (Should control be placed in "local," the "Control Transferred to Local" alarms on SB-1 safeguards panel would annunciate.)

The motors are 225 HP, 720 rpm direct drive and are self-contained and fitted with heat exchangers cooled by service water. The supply and discharge service water are common with the service water supply and discharge of each unit's cooling coils. The discharge from each motor heat exchanger is provided with an individual manual flow control valve which allows adjustment of motor operating temperature.

Both the fan and motor are fitted with vibration detectors. Each detector is resettable below the alarm setpoint by a common button on the SB-2 safeguards panel in the CCR. Should vibration levels reach the alarm level (initially this setpoint will be .4g above the normal zero setting for the Vibraswitch with the motor operating at normal conditions), an alarm on the SB-1 safeguards panel ("Control Recirculation Fan Motor Bearing Vibration") is annunciated. At the same time, one of the five individual alarm lights will illuminate on the SB-2 safeguards panel (next to the reset button).

Fan bearing temperature is also monitored. Both the inner and outer bearing temperatures for all five fans are indicated on the bearing monitor safeguards panel (SK). Should either reach a temperature of 190°F, an alarm "bearing monitor" on the SE safeguards panel would annunciate and particular information as to which bearing is hot would be provided by the readout of the bearing monitor. Overload protection for the fan motors is provided at the switchgear by overcurrent trip devices in the motor feeder breakers. The breakers can be operated from the CCR or from the local panel on the 15-foot elevation of the control building. This will allow for fan manipulations if necessary.

Located just upstream of each fan cooler unit is a temperature detector and a humidity detector. The humidity detector is a dynalog electronic-type element which uses a coil of gold wire that will vary in electrical resistance as a function of the moisture content of the containment atmosphere. The information provided by this element and the temperature detector is used to determine the dew point in containment. This information provides an excellent indication of leakage from either the primary or secondary systems into the containment.

B.4 INTERFACING SYSTEMS

The fan cooler units interface with the following systems:

- Electrical Power
- Service Water
- Safeguards Actuation System

Electric power is supplied from the buses noted below:

• Motor 31	Bus 5A
• Motor 32	Bus 2A
• Motor 33	Bus 5A
• Motor 34	Bus 3A
• Motor 35	Bus 6A

B.5 TECHNICAL SPECIFICATIONS

The reactor is not made critical unless all five fan cooler and charcoal filter units are entirely operable. During operation one fan cooler unit may be out of service for 24 hours (coolers 32, 34, 35) or 7 days (coolers 31 or 33) without necessitating a shutdown to the hot standby condition provided both containment spray pumps are checked operable daily. Fan cooler unit failures must be corrected within the specified periods or the reactor is placed in the hot shutdown condition using normal operating procedures. If the requirements are not satisfied within an additional 48 hours, the reactor is placed in the cold shutdown condition.

B.6 TEST AND MAINTENANCE

Corrective maintenance is only performed on the units when a failure occurs. Periodic maintenace is performed on a scheduled frequency. Periodic surveillance tests are performed on the accident dampers and the fan cooler motors to test damper switching and operation. Tests are performed both monthly and quarterly during unit operation. The units are run in the accident mode for about 15 minutes per month. Operation is from the control room. Since the tests place the system in the accident mode, there is no adverse effect on system availability. Additional, more detailed, testing of the dampers is conducted during each refueling.

Visual inspection of the filter installation is performed every refueling, or at any time work on the filters could alter their integrity. Measurement of the pressure drop across the moisture separators and HEPA filters is performed at each refueling. The HEPA filter banks are tested with locally generated DOP (dioctylphthalate particles test) at each refueling.

Periodic in-place testing of the filtration assemblies is made by injection of a freon aerosol in the air stream at the filter inlet to verify the leaktightness of individual filter elements and their frame seals.

The iodine removal efficiency of at least one charcoal filter charcoal coupon (samples) from each unit is tested at every refueling. If the filter test fails, the charcoal in that unit is replaced.

B.7 OPERATOR INTERACTION

Because the fan cooler units operate more or less continuously in the normal mode, and there is no testing except during the annual outage, there is very little cause for human action and, therefore, little chance for human error. During accident conditions, the fan coolers are switched automatically to the accident mode. Failure of the automatic start system can be compensated for by operator action. There are sufficient indicators on alarms such that the operator would be immediately aware that the units had not switched to the accident mode and, therefore, he would start the units manually. A human error of this kind should, consequently, be low.

6.8 COMMON CAUSE EFFECTS

It is conceivable that the operation of all five fan cooler units could be effected by an occurrence which simultaneously results in the plugging of the charcoal filter beds with airborne debris or the cooling coil tubes with material entrained in the service water supply. Due to the rigid cleanliness requirements in containment and the straining of the service water source, it is felt that these modes of failure are of little significance and can be discounted when compared with system unavailability due to hardware and maintenance.

C. LOGIC MODEL

C.1 TOP EVENT

The top undesired events for cooling and iodine removal are derived from the primary functions of the system, and are:

- Failure to circulate containment atmosphere and maintain containment pressure below maximum design pressure.
- Insufficient iodine removal by charcoal filters.

C.2 SYSTEM FAULT TREE

The fault trees used to analyze the accident operation of the containment fan cooling (CF) are shown in Figure 3. Only hardware failure events are modeled; other causes are accounted for during the quantitative analysis in Section D. The SI actuation signal is required to initiate fan cooler operation and to shift the air flow dampers and service water valves while electric power is required for fan operation. Both are modeled as house events.

During normal operation four fan coolers are utilized to maintain containment humidity and temperature. In the event that the accident mode of operation is required the scenario of system response is dependent upon the availability of power at the 480V essential switchgear buses.

When the continuity of power is maintained to the 480V essential switchgear buses, the safety injection signal starts the nonoperating fan cooler unit and shifts the dampers in all five units to the accident positions.

Should the normal source of power be interrupted to the fan cooler units, all five units must then start and shift to the accident mode when the diesel generators restore electrical power.

D. QUANTIFICATION

D.1 RANDOM HARDWARE FAILURES

Hardware failures in the fan cooling system can be attributed to either a failure in the fan cooling unit itself or an interruption of the service water supply to one of the heat exchangers contained in the cooling unit. Figure 4 outlines components which must function to yield system success. Supercomponent A requires the operation of three of the five cooling units for twenty-four hours. Supercomponent B displays the requirement that one of the two temperature control valve bypass valves opens in the common service water discharge from the five cooling units.

The unavailability of a single operating fan cooler to shift and operate in the accident mode can be calculated as follows:

Component	Failure Mode	Quantity	Mean Failure (Q)/d from Table B.2-2
Fan Cooler	Fails to shift and run	1	9.79×10^{-6}
Iso MOVs	Closes (Mechanically during operation)	3	9.15×10^{-8}
Heat Exchangers	Rupture	2	9.73×10^{-7}
Fan Coolers	Fails to Start on Demand	1	7.80×10^{-4}

$$Q_{HC_0} = 24 \text{ hours} \left(Q_{C_{run}} + 3Q_V + 2Q_{HE} \right)$$

This yields a

Mean: 2.9×10^{-4}

Variance: 1.2×10^{-7}.

Should power be interrupted, the above expression is modified to reflect the subsequent starting of the fan cooler unit during sequencing.

$$Q_{HC_s} = Q_{C_{start}} + \left(1 - Q_{C_{start}} \right) Q_{HC_0}$$

This results in a

Mean: 1.1×10^{-3}

Variance: 2.3×10^{-6}.

The hardware unavailability of supercomponent A (three or more fan cooler units fail) with all 480V essential switchgear buses energized is the sum of the unavailabilities for the 16 possible combinations where three or more fan coolers are inoperative. With no electrical power interruption, the unavailability of supercomponent A is dependent upon the shifting to the accident mode of four normally operating units and the starting and shifting of the standby unit.

$$Q_{HA} = 6 \begin{pmatrix} Q_{HC} \\ O \end{pmatrix}^2 \begin{pmatrix} Q_{HC} \\ S \end{pmatrix} + 4 \begin{pmatrix} Q_{HC} \\ O \end{pmatrix}^3 + 4 \begin{pmatrix} Q_{HC} \\ O \end{pmatrix}^3 \begin{pmatrix} Q_{HC} \\ S \end{pmatrix} + \begin{pmatrix} Q_{HC} \\ O \end{pmatrix}^4 + \begin{pmatrix} Q_{HC} \\ O \end{pmatrix}^4 \begin{pmatrix} Q_{HC} \\ S \end{pmatrix}$$

With an electrical power interruption, the unavailability of supercomponent A is dependent upon the successful starting and shifting to the accident mode of all five fan cooler units.

$$Q_{HA} = 10 \begin{pmatrix} Q_{HC} \\ S \end{pmatrix}^3 + 5 \begin{pmatrix} Q_{HC} \\ S \end{pmatrix}^4 + \begin{pmatrix} Q_{HC} \\ S \end{pmatrix}^5$$

The results of the above calculations are summarized in Tables 2 and 3.

For the remaining states of electric power considered, the calculation is altered in that a reduced number of hardware failures are required to fail supercomponent A.

With power unavailable at bus 6A, and the continuity of power maintained at all other buses, the expression for the unavailability of supercomponent A becomes:

$$Q_{HA} = .2 \left[6 \begin{pmatrix} Q_{HC} \\ O \end{pmatrix}^2 + 4 \begin{pmatrix} Q_{HC} \\ O \end{pmatrix}^3 + \begin{pmatrix} Q_{HC} \\ O \end{pmatrix}^4 \right] + .8 \left[3 \begin{pmatrix} Q_{HC} \\ O \end{pmatrix}^2 + 3 \begin{pmatrix} Q_{HC} \\ O \end{pmatrix} \begin{pmatrix} Q_{HC} \\ S \end{pmatrix} + 3 \begin{pmatrix} Q_{HC} \\ O \end{pmatrix}^2 \begin{pmatrix} Q_{HC} \\ S \end{pmatrix} + \begin{pmatrix} Q_{HC} \\ O \end{pmatrix}^3 + \left(Q_{HC} \right)^3 \begin{pmatrix} Q_{HC} \\ S \end{pmatrix} \right]$$

The first term represents the situation where the cooler rendered inoperative by the bus unavailability (6A) is also the standby cooler, while, the second term describes the situation where the loss of the bus fails one of the four normally operating fan coolers.

When the continuity of power is not maintained with power unavailable at bus 6A, the hardware unavailability of supercomponent A is:

$$Q_{HA} = 6 \begin{pmatrix} Q_{HC} \\ S \end{pmatrix}^2 + 4 \begin{pmatrix} Q_{HC} \\ S \end{pmatrix}^3 + \begin{pmatrix} Q_{HC} \\ S \end{pmatrix}^4$$

With power unavailable to either 2A and 3A or 5A, supercomponent A is reduced to three cooler units and any single failure will render the system failed. In this case, the hardware unavailability of supercomponent A with electrical power continuity is:

$$Q_{HA} = .4 \left[3 \begin{pmatrix} Q_{HC} \\ O \end{pmatrix} \right] + .6 \left[2 \begin{pmatrix} Q_{HC} \\ O \end{pmatrix} + \begin{pmatrix} Q_{HC} \\ S \end{pmatrix} \right]$$

The significance of the terms in the equation is identical to that in the bus 6A unavailable condition.

When the continuity of power is not maintained the hardware unavailability of supercomponent A becomes:

$$Q_{HA} = 3 \begin{pmatrix} Q_{HC} \\ S \end{pmatrix}$$

The unavailability of supercomponent B is unaffected by electric power state and is determined by squaring the mean unavailability of each of the air-operated temperature control valves to open on demand (TCV Mean = 4.95×10^{-4}--Table B.2-2).

Total system unavailability resulting from hardware failure (Q_H system) for each electric power state and is the sum of those determined for supercomponents A and B. The results are contained in Tables 2 and 3.

D.1.1 TEST

The fan cooler units are in operation in their normal mode whenever the plant is operating. Testing is either done during the annual refueling or by running the units for short periods in the accident mode. Therefore, there is no testing impact on system unavailability.

D.1.2 MAINTENANCE

Indian Point 3 maintenance experience yields a fan cooler unit unavailability (Q_{CM}) of:

Mean:	5.2×10^{-4}
Variance:	4.5×10^{-8}.

Maintenance is only performed on the units when a failure occurs and only one fan cooler may be out of service during normal operation without necessitating a unit shutdown. With electric power available to all buses, system unavailability due to maintenance (Q_{SM}) results when, with one cooler secured for maintenance, two additional fan cooling units become inoperative as a result of hardware failures. This situation is represented by:

$$Q_{SM} = 5(Q_{CM}) \left[6\begin{pmatrix} Q_{HC} \\ 0 \end{pmatrix}^2 + 4\begin{pmatrix} Q_{HC} \\ 0 \end{pmatrix}^3 + \begin{pmatrix} Q_{HC} \\ 0 \end{pmatrix}^4 \right]$$

With electric power unavailable to one cooling unit (failure of bus 6A), system unavailability due to maintenance becomes:

$$Q_{SM} = 4Q_{CM} \left[3\begin{pmatrix} Q_{HC} \\ 0 \end{pmatrix} + 3\begin{pmatrix} Q_{HC} \\ 0 \end{pmatrix}^2 + \begin{pmatrix} Q_{HC} \\ 0 \end{pmatrix}^3 \right]$$

Failure of electric power to two cooler units (failure of bus 5A, 2A or 3A) results in a system unavailability due to maintenance of:

$$Q_{SM} = 3Q_{CM} + 6Q_{CM}\begin{pmatrix} Q_{HC} \\ 0 \end{pmatrix} + 3Q_{CM}\begin{pmatrix} Q_{HC} \\ 0 \end{pmatrix}^2$$

A summary of the maintenance unavailabilities for each of the electric power states is contained in Tables 2 and 3.

D.1.3 STATISTICAL SUMMARY

Overall system unavailability is the sum of the contributions from hardware ($Q_{Hsystem}$) + maintenance (Q_{SM}) for each of the states of electric power analyzed. A summary of these calculations is contained in Tables 2 and 3.

TABLE I

SYSTEMS COMPONENTS

Component and Fault Tree Code	Failure Mode	Normal Position	Failure Rate/d Mean/Variance	Data Source Table B.2-2 Item No.
Service Water Values				
TSW1104Q	Failure to open	Closed	4.98 - 4/ 4.03 - 7	8
TSW1105Q	Failure to open	Closed		
TSW41NC	Transfers closed	Open	9.15 - 8/ 1.01 - 14	1
TSW44NC	Transfers closed	Open		
TSW71NC	Transfers closed	Open		
Heat Exchangers				
KHECL	Rupture or gross leakage	Passive	9.73 - 7/ 3.34 - 12	24
KHEML	Rupture or gross leakage	Passive		
Fan Cooler				
KBL2NN	Fails to start		7.80 - 4/ 2.56 - 6	22
KBL2NS	Failure to switch to and operate in LOCA mode		9.79 - 6/ 2.23 - 10	23

TABLE 2

STATISTICAL SUMMARY
CONTAINMENT FAN COOLER UNAVAILABILITY
Offsite Power Available

Unavailability Of		Electric Power States		
		All Power Available	6A Unavailable	(2A, 3A) or 5A Unavailable
Supercomponent A Hardware Failures (Q_{HA})	Mean	2.7×10^{-9}	1.5×10^{-6}	1.3×10^{-3}
	Variance	5.6×10^{-16}	2.0×10^{-11}	1.5×10^{-6}
Supercomponent B Hardware Failures (Q_{HB})	Mean	6.2×10^{-7}	6.2×10^{-7}	6.2×10^{-7}
	Variance	1.6×10^{-11}	1.6×10^{-11}	1.6×10^{-11}
System Hardware ($Q_{Hsystem}$)	Mean	6.3×10^{-7}	2.1×10^{-6}	1.3×10^{-3}
	Variance	8.5×10^{-12}	2.9×10^{-11}	1.4×10^{-6}
System Maintenance (Q_{SM})	Mean	3.1×10^{-9}	1.8×10^{-6}	1.5×10^{-3}
	Variance	2.5×10^{-16}	5.7×10^{-12}	4.0×10^{-7}
Total System (Q_{system})	Mean	6.3×10^{-7}	3.9×10^{-6}	2.8×10^{-3}
	Variance	8.3×10^{-12}	3.4×10^{-11}	1.8×10^{-6}
	5th	4.6×10^{-9}	6.0×10^{-7}	1.3×10^{-3}
	Median	9.1×10^{-8}	2.1×10^{-6}	2.5×10^{-3}
	95th	1.7×10^{-6}	9.7×10^{-6}	4.8×10^{-3}

TABLE 3

STATISTICAL SUMMARY
CONTAINMENT FAN COOLER UNAVAILABILITY
Offsite Power Unavailable

Unavailability Of		Electric Power States		
		All Power Available	6A Unavailable	(2A, 3A) or 5A Unavailable
Supercomponent A Hardware Failures (Q_{HA})	Mean	3.3×10^{-7}	2.1×10^{-5}	3.2×10^{-3}
	Variance	3.0×10^{-11}	2.1×10^{-7}	2.0×10^{-5}
Supercomponent B Hardware Failures (Q_{HB})	Mean	6.2×10^{-7}	6.2×10^{-7}	6.2×10^{-7}
	Variance	1.6×10^{-11}	1.6×10^{-11}	1.6×10^{-11}
System Hardware (Q_H system)	Mean	9.6×10^{-11}	2.1×10^{-5}	3.2×10^{-3}
	Variance	4.0×10^{-11}	2.0×10^{-8}	2.0×10^{-5}
System Maintenance (Q_{SM})	Mean	5.3×10^{-8}	6.6×10^{-6}	7.9×10^{-3}
	Variance	1.4×10^{-13}	1.1×10^{-10}	8.1×10^{-5}
Total System (Q_{system})	Mean	1.0×10^{-6}	2.8×10^{-5}	1.1×10^{-2}
	Variance	3.9×10^{-11}	2.0×10^{-8}	9.9×10^{-5}
	5th	3.5×10^{-9}	2.0×10^{-6}	3.6×10^{-3}
	Median	1.5×10^{-7}	8.0×10^{-6}	7.7×10^{-3}
	95th	2.4×10^{-6}	5.7×10^{-5}	2.4×10^{-2}

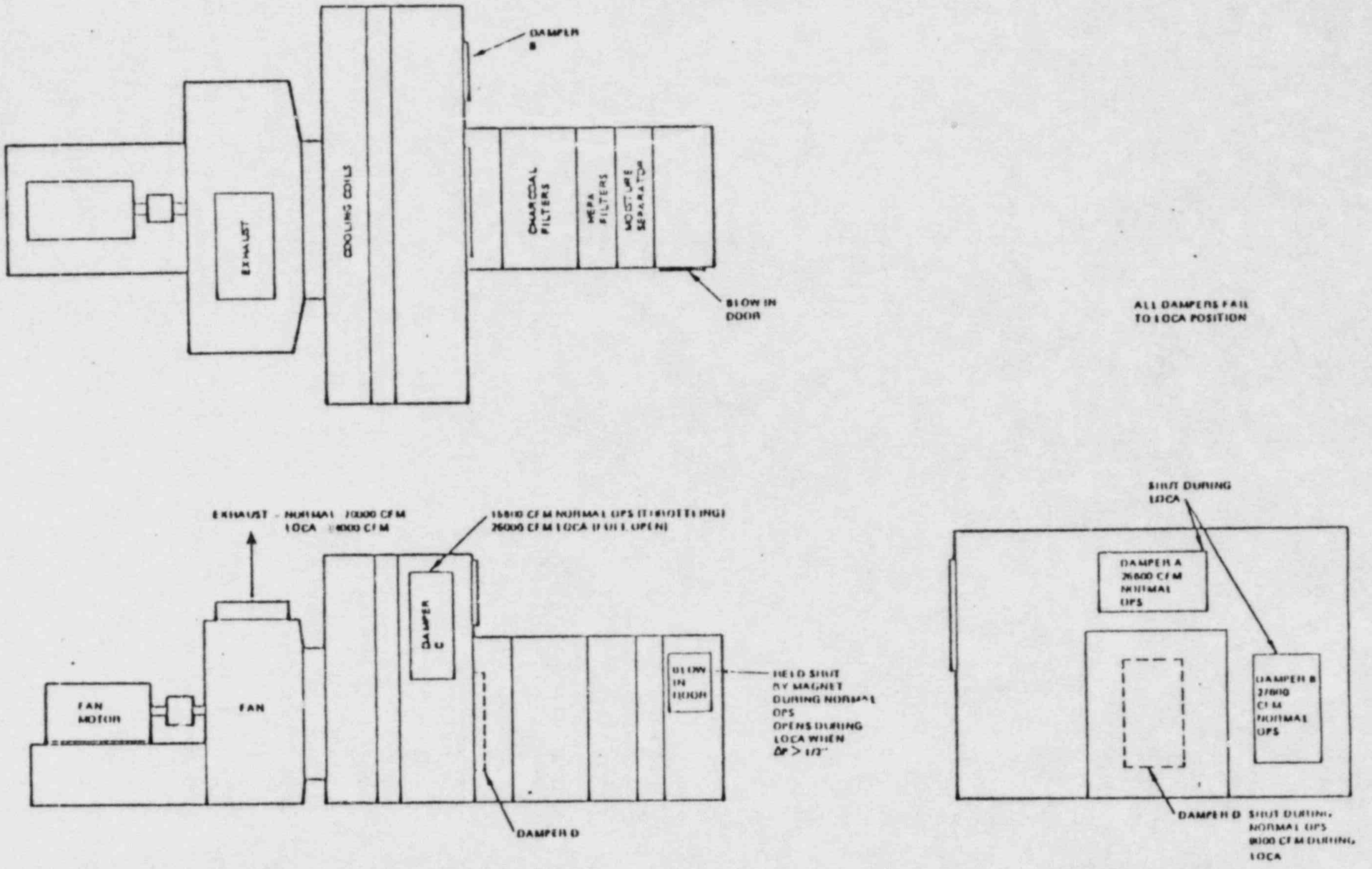


Figure 1. Diagram of Fan Cooler Unit

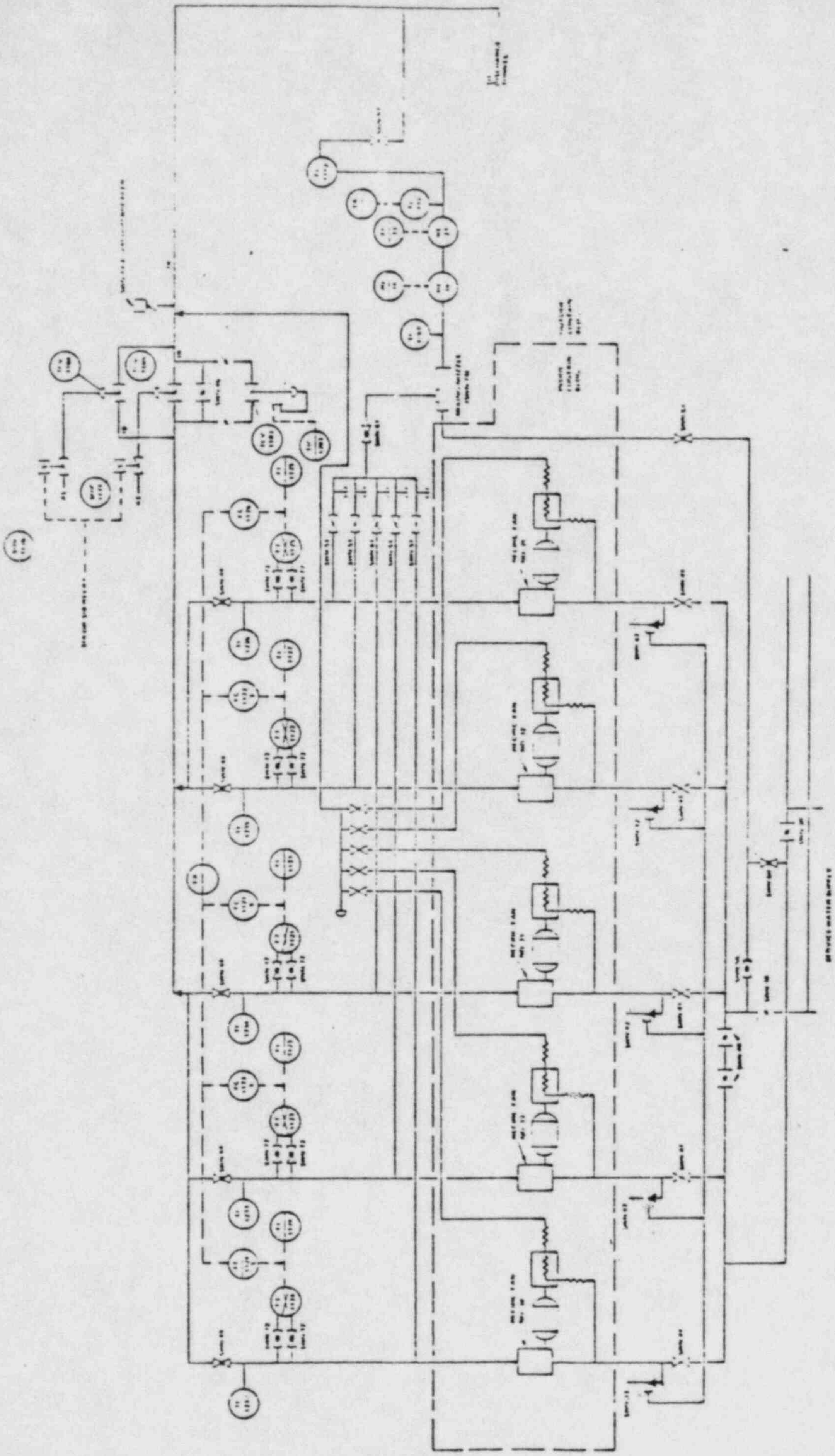


Figure 2. Simplified P&ID of Service Water Supply to Indian Point 3 Fan Cooler Units

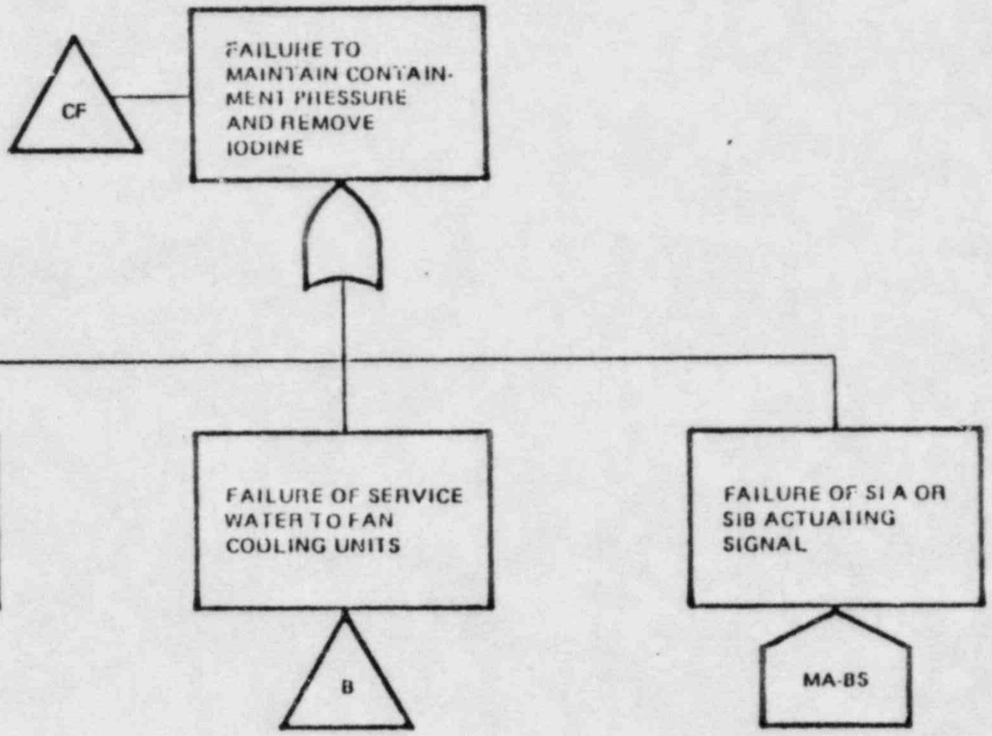


Figure 3. Fault Tree of Fan Cooler System
(Sheet 1 of 5)

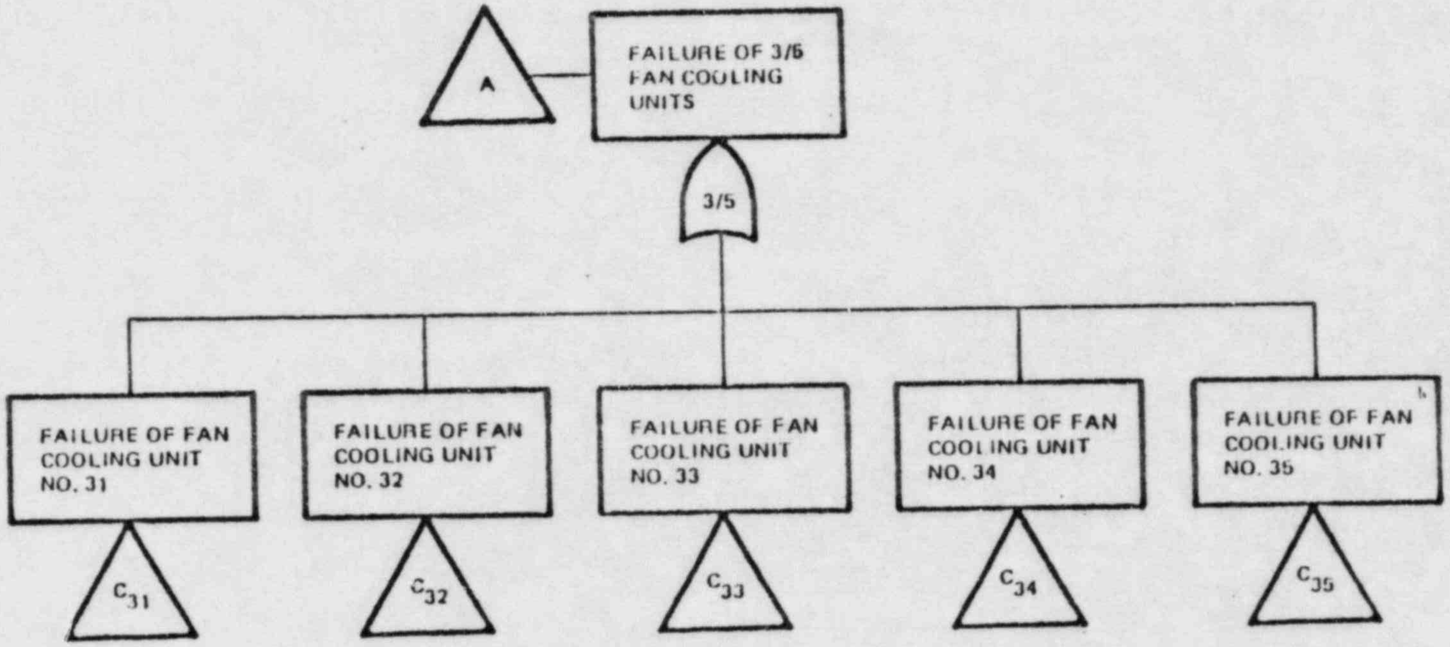


Figure 3. (Sheet 2 of 5)

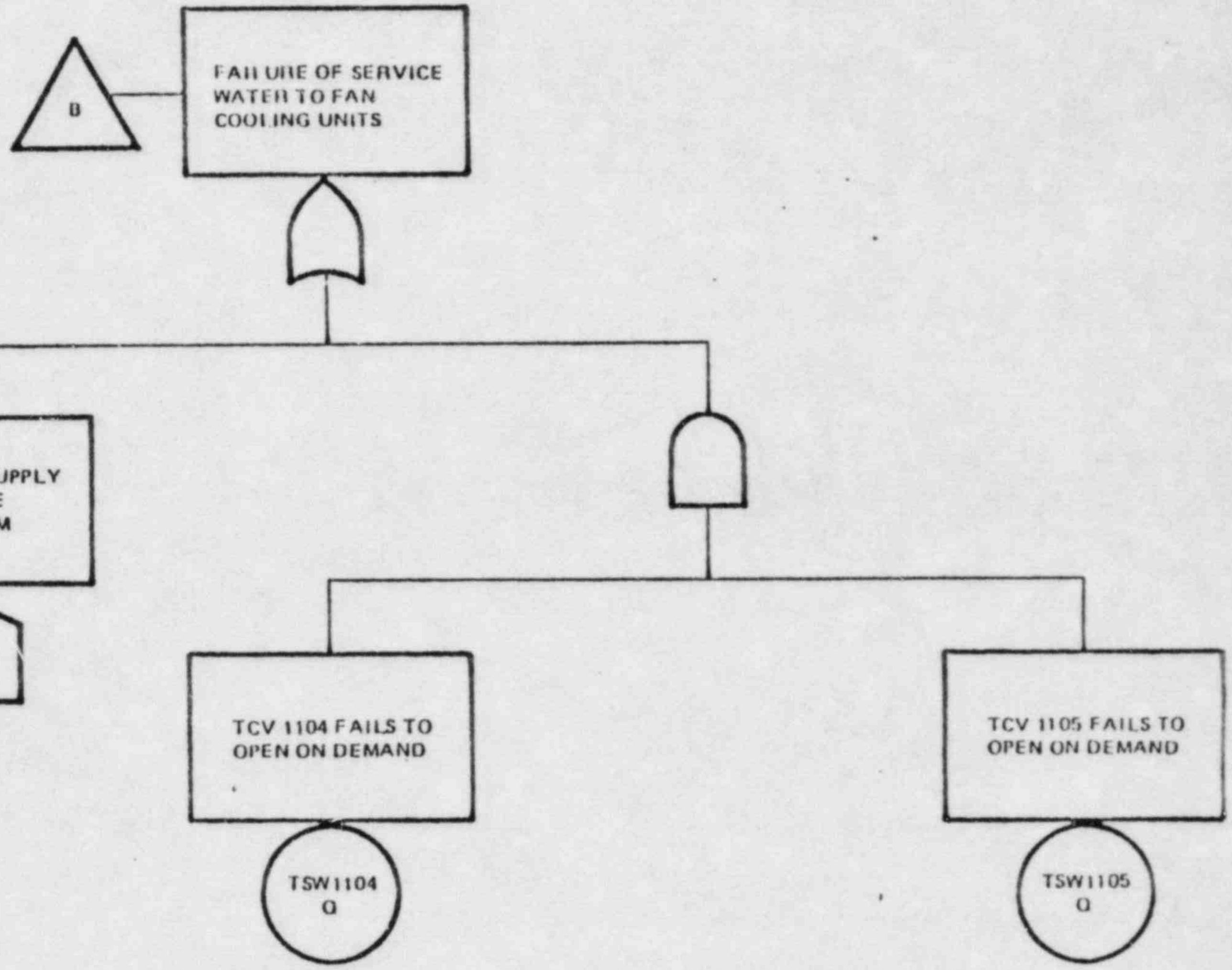
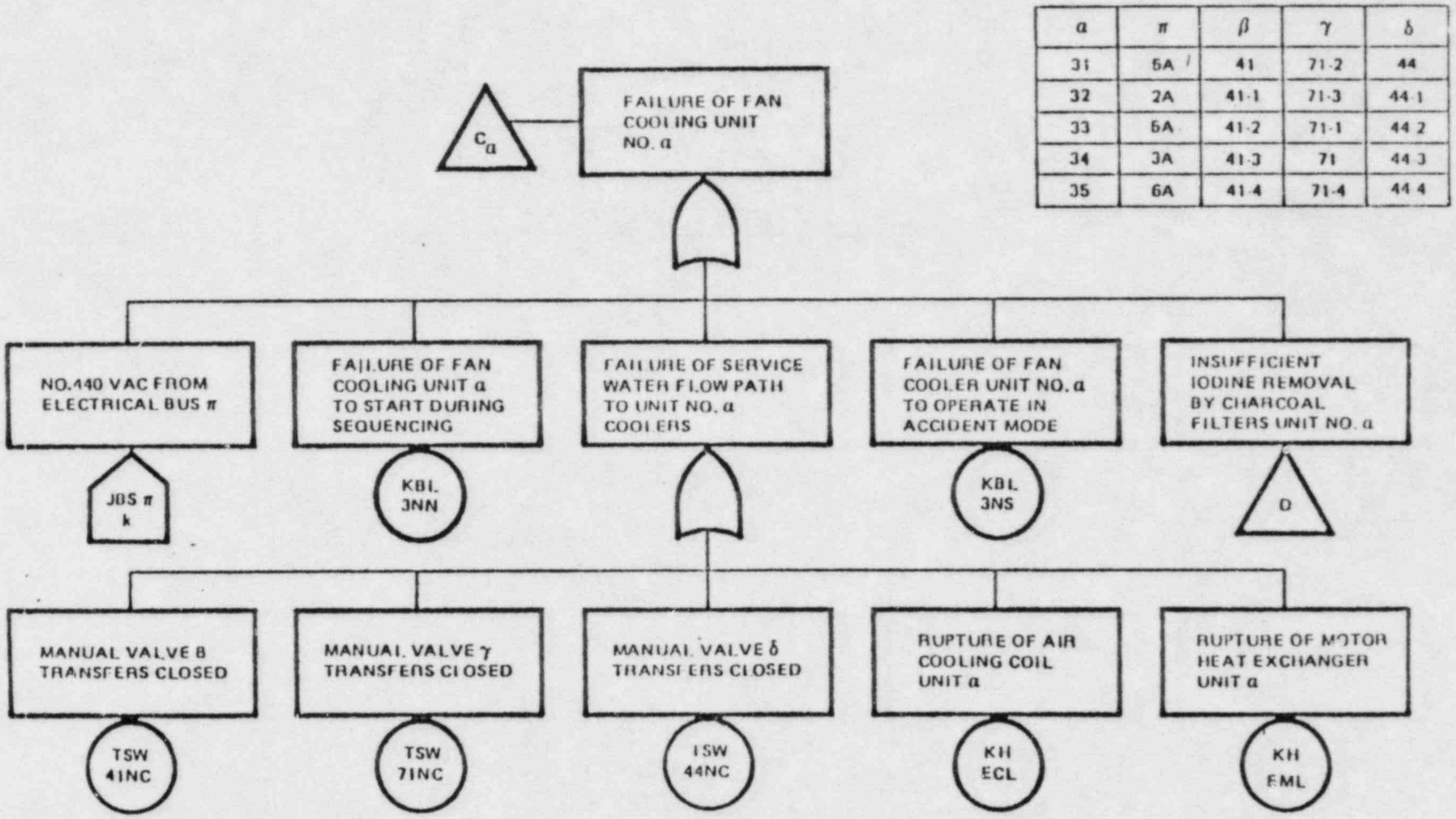
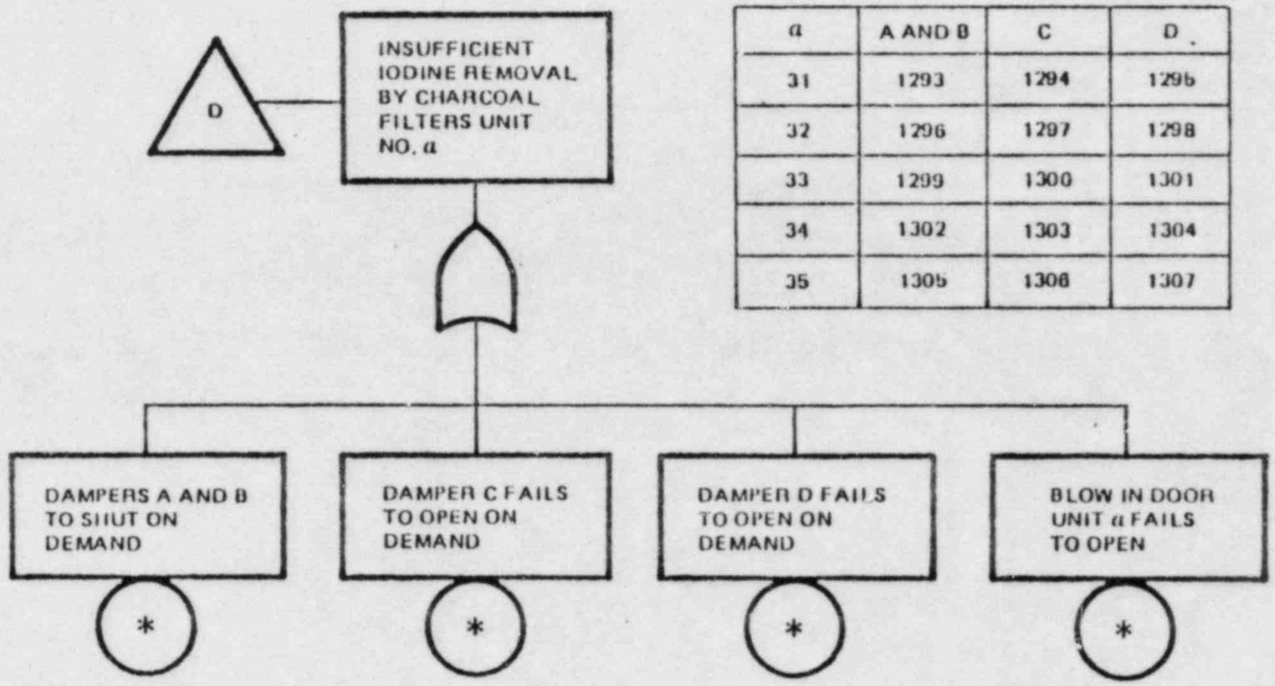


Figure 3. (Sheet 3 of 5)



α	π	β	γ	δ
31	5A	41	71-2	44
32	2A	41-1	71-3	44-1
33	6A	41-2	71-1	44-2
34	3A	41-3	71	44-3
35	6A	41-4	71-4	44-4

Figure 3. (Sheet 4 of 5)



a	A AND B	C	D
31	1293	1294	1295
32	1296	1297	1298
33	1299	1300	1301
34	1302	1303	1304
35	1305	1306	1307

* INCLUDED WITH KBL2NS

Figure 3. (Sheet 5 of 5)

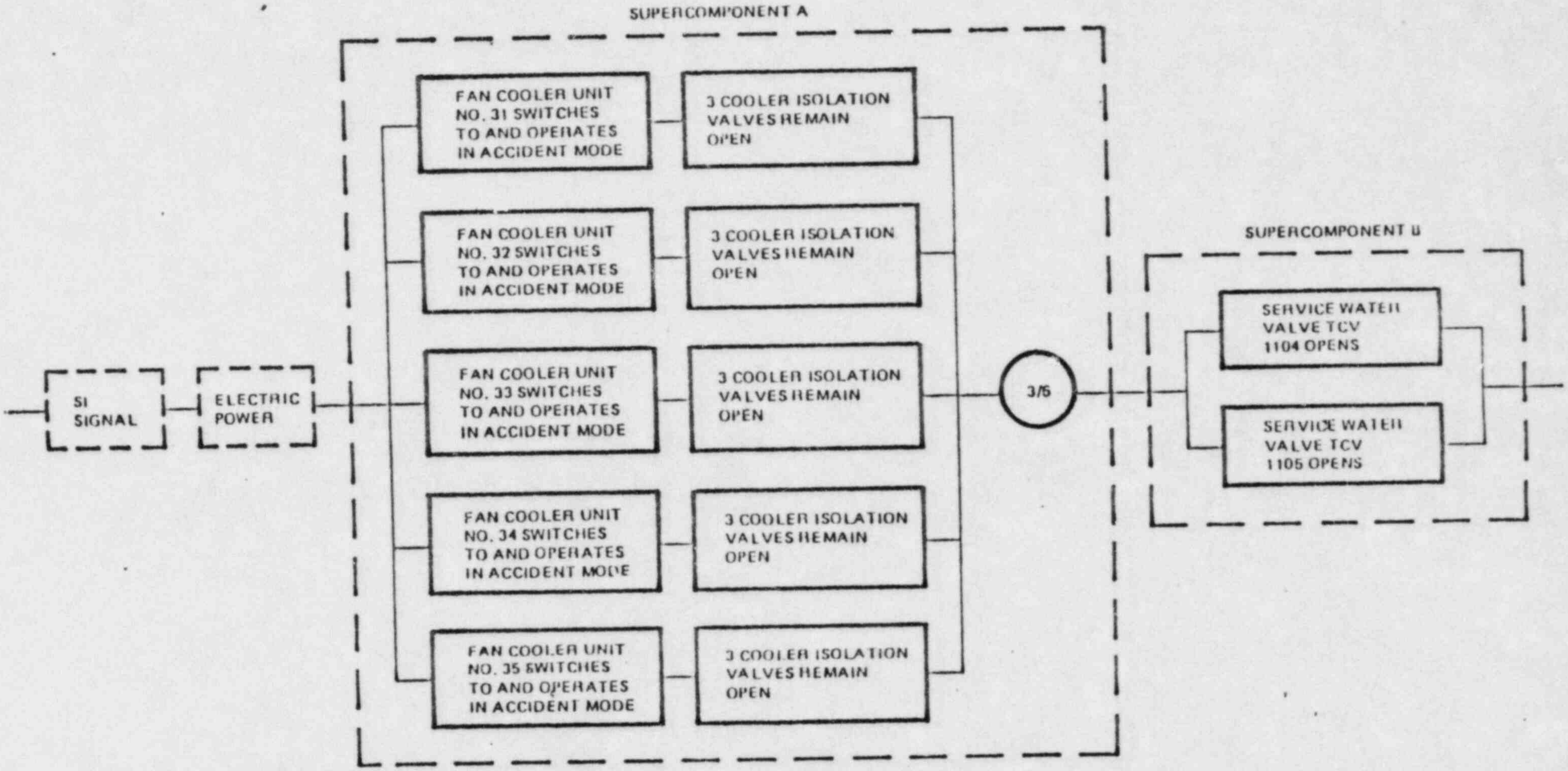


Figure 4. Reliability Block Diagram of Fan Cooler System