Generation of System Notebooks for Nuclear Power Plants

Excerpted from

"Documentation Design for Probabilistic Risk Assessment," EPRI NP-3470, June 1984

APPENDIX B

SYSTEM NOTEBOOKS

The System Notebook documents the analysis performed for a system and the information used in support of this analysis. The notebook outline is essentially that presented in an EPRI document entitled "Documentation Design for Probabilistic Risk Assessment," EPRI NP-3470, June 1984.

APPENDIX B.1 Format of Notebook

The system notebook format is as follows:

1.0 FUNCTION

Describe the basic purpose of the system and its relationship to the overall plant performance of the critical functions.

2.0 SYSTEM DESCRIPTION

A simple description of the basic system configuration is provided and supported by a 1-line diagram depicting the major components of the system. Brief descriptions of the major components are included. Physical dimensions, elevations, volumes, etc. are also included if important to the system's operation.

2.1 SUPPORT SYSTEMS

The supporting systems required (e.g., electrical power, component cooling water, etc.) are identified and described. The specific interface is described and the impacts of supporting system failures are delineated.

2.2 INSTRUMENTATION AND CONTROL

The instrumentation available to monitor the performance of the system is identified and described. The control logic associated with any of the components in the system is also described. Information is provided concerning:

- o System Initiation: the parameters and setpoints used for automatic system actuation

- o Component Trips: the parameters and setpoints used to automatically prevent component operation

- o System Isolation: the parameters and setpoints used to isolate the system

2.3 TEST AND MAINTENANCE

The general schedule for system tests and the changes in system configuration during these tests is described. The maintenance schedule and procedures with respect to availability of system components is described. A description or diagram illustrating the system configuration during maintenance is provided.

2.4 TECHNICAL SPECIFICATION LIMITATIONS

The technical specifications relevant to the constraints for operating this system are identified described.

3.0 SYSTEM OPERATION

The role of the operator in system performance, including manual actuation or control capabilities, is summarized. The tasks required of the operator are identified. Recovery actions available to the operator are discussed for major component or system failure modes. The portions of the emergency operating procedures relevant to this system are summarized.

4.0 PERFORMANCE DURING ACCIDENT CONDITIONS

In this section the response of the system to important accident conditions is summarized, focusing on:

- o The performance requirements on the system in response to postulated accident conditions (success/failure criteria for important demands on the system)

- o The physical impact of accident conditions on the ability of the system to perform its functions

- o The impact of this system's failure on other important systems

5.0 LOCATION WITHIN THE PLANT

Information concerning the location of vital components within the system is included here. The proximity of the components to walls and other structures, pipes and other fluid bearing vessels, and combustibles is noted for possible future use in systems interaction analyses.

6.0 OPERATING EXPERIENCE

Relevant operating experience from this plant and others is included here. This is based on plant-specific data reviews, Nuclear Power Experience reviews, reviews of relevant published PRAs, and data developed in support of completed or on-going studies.

7.0 LOGIC MODELS

Simplified block diagrams of the system are developed and system failure logic expressions are developed for each of the important support system states and success criteria established above.

8.0 INITIATING EVENT REVIEW

The possibility of an initiating event occurring as a result of failure of components within the system is investigated.

9.0 QUANTIFICATION

The likelihood of system failure for each success criteria and important support system states is estimated based on the results of tasks 1-6.

The likelihood of failures within this system resulting in an initiating event is also estimated based on the system model and relevant plant-specific and "generic" operating experience.

No credit is taken for recovery of the system at this time. It is addressed on a sequence by sequence basis. Dependent, or common cause type, failure will be estimated and applied but only after review of plant-specific characteristics that strongly influence dependencies between "like" components in the same or similar systems.

10.0 SUMMARY OF KEY FINDINGS

The results of the analysis are summarized. Important system failures and sensitivities are discussed. Any recommendations for further enhancing the analyses are provided.

11.0 SUMMARY OF KEY REVIEW COMMENTS

Key review comments and the manner in which they were addressed is provided here.

12.0 REFERENCES

A list of reference material used in support of the analysis is provided.

EXAMPLE:

SYSTEM NOTEBOOKS

REACTOR CORE ISOLATION COOLING SYSTEM

1.0 FUNCTION

When the reactor is operating at power and loses normal feedwater flow, the resulting transient may require a backup source of high pressure makeup water to maintain vessel water level. In addition, during periods when the reactor is in hot standby, a high pressure source of makeup water is needed to maintain vessel water inventory. The RCIC system is designed to meet both of these operational requirements.

1.1 PURPOSE

The purpose of the RCIC system is to provide a source of high pressure coolant makeup water to the reactor vessel in case of a loss of feedwater flow transient. The RCIC system is also used to maintain the reactor in a hot standby condition.

For events other than pipe breaks or transient-induced loss of coolant accident (LOCAs), the RCIC system has a makeup capacity sufficient to prevent the reactor vessel water level from decreasing to the level where the core is uncovered. This is accomplished without the assistance of an emergency core cooling system.

2.0 SYSTEM DESCRIPTION

Overall Configuration: The RCIC system consists of a steam turbine assembly that drives a constant-flow pump and includes the associated piping, valves, controls, and instrumentation. Figure B-2 is a simplified diagram of the system.

The RCIC turbine is driven by steam that is generated in the reactor vessel. The steam is extracted from main steam Line C upstream of the main steam isolation valves. The turbine exhaust is directed to the suppression pool. Rupture disks in the turbine exhaust line provide turbine protection should turbine exhaust line blockage occur.

The turbine-driven pump is provided with two sources of water for injection into the reactor vessel. Normally, demineralized water from the CST is used instead of injecting the less desirable water from the suppression pool into the reactor. However, the operator does have the option to shift suction to the suppression pool if the need for this suction path arises. Water from either source is pumped into the reactor vessel via feedwater Line B.

To prevent the RCIC pump from overheating during periods of reduced system flow, a minimum-flow bypass line is provided. This line routes approximately ( ) gpm of water from the pump discharge path to the suppression pool. Flow is controlled by the minimum-flow bypass valve.

Another line in the pump discharge path is used for full-flow operational testing of the RCIC system while the plant is operating. A 1.5-inch orifice in this line provides a discharge head to simulate reactor pressure. If, during testing, an RCIC initiation signal is received, the two test line isolation valves will automatically close. One valve will also close if either of the suppression pool suction valves is opened. The other valve will close if a high drywell pressure signal is received.

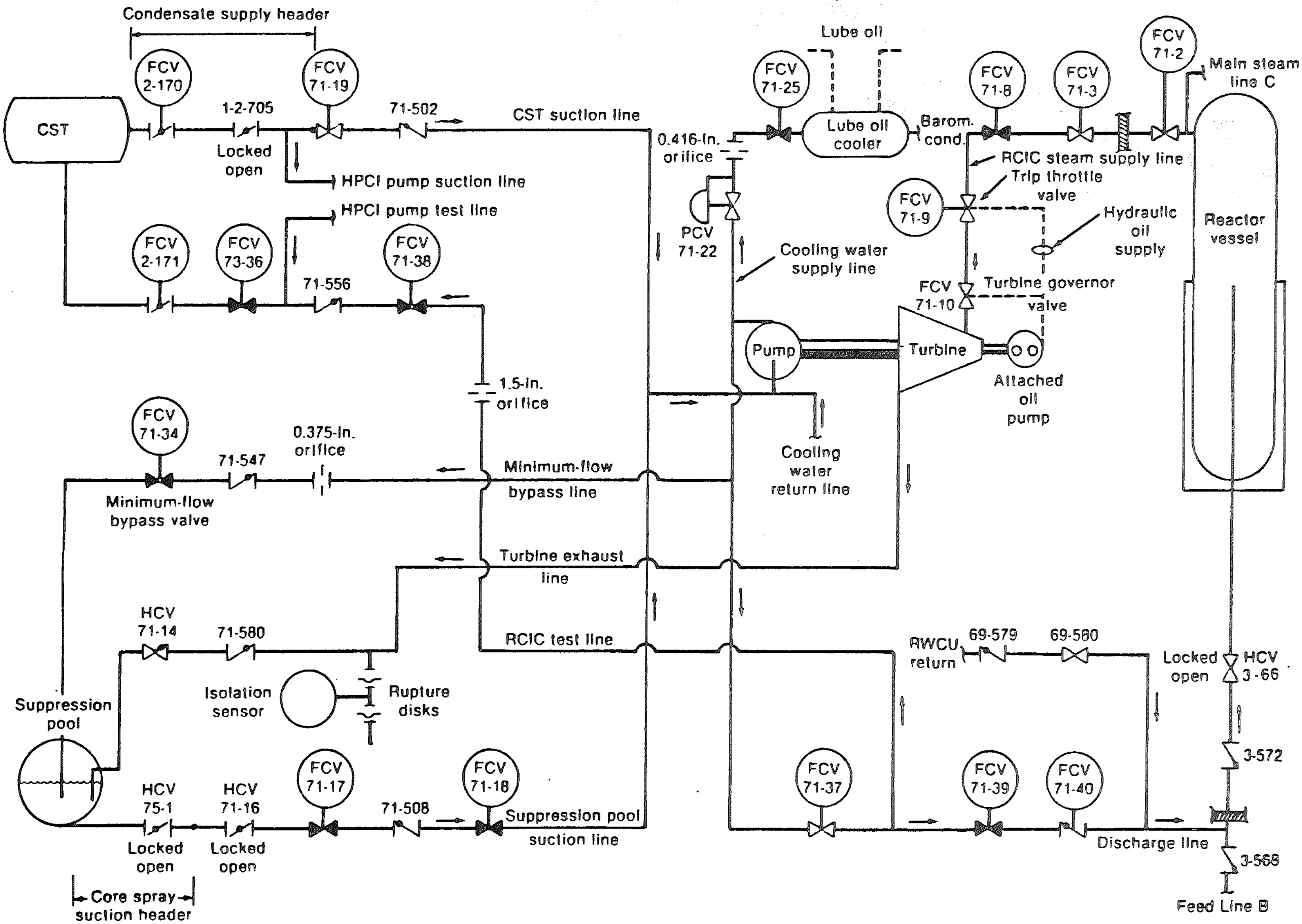


Figure B-2. RCIC system.

Some of the RCIC pump discharge flow is directed through a pressure regulator and a cooling water supply valve. The flow then passes through the tubes of the lube oil cooler and into the barometric condenser.

The lube oil cooler removes heat from the turbine lubricating oil system. Oil flow through the lube oil system is accomplished by the attached lube oil pump. The lube oil pump supplies oil to the turbine bearings, to the turbine trip throttle valve to hold it open, and to the governor control oil system. The attached lube oil pump is designed to meet total oil requirements of the lube oil system over the entire speed range of the turbine.

The barometric condenser receives drainage from the turbine gland seals, the trip throttle valve packing, the governor valve packing, and the turbine exhaust thermostatic drain pot. The steam is condensed by a water spray from the cooling water supply line. Noncondensables are removed by a DC-powered vacuum pump and discharged to the suppression pool. Condensate and liquid from the spray is collected in the receiver section of the condenser and pumped back to the suction side of the RCIC pump by a DC-powered condensate pump. Startup of the barometric condenser equipment is automatic upon RCIC system initiation. However, failure of the barometric condenser equipment does not prevent the RCIC system from fulfilling its design objectives.

The RCIC system controls automatically start the system and bring it to the design flow rate of ( ) gpm within ( ) sec after receipt of a reactor vessel low-low water level signal. The system is designed to deliver the design flow rate to the core at reactor vessel pressures ranging from ( ) to ( ) psig. The RCIC system automatically stops either when a high water level in the reactor vessel is signaled, when steam supply pressure drops below ( ) psig, or when other system parameters generate a trip signal.

RCIC system operation is designed to be completely independent of AC power although some components interface with AC power systems. Only DC power from the plant batteries and steam extracted from the reactor vessel are necessary for startup and operation of the system.

2.1 SUPPORT SYSTEMS

The RCIC system components interface with various AC and DC electrical systems, the control air system, and the EAC system. RCIC pump lubrication and control system components are integral to the RCIC system. Component/supporting system interactions are given in Table B-1.

2.2 INSTRUMENTATION AND CONTROL

RCIC system initiation, trip, and isolation are automatically controlled by various plant and system parameters.

System Initiation: The RCIC system will automatically start and inject water into the reactor vessel when a reactor vessel low water level is received at (   ) inches above vessel zero.

TABLE B-1
RCIC SYSTEM FMEA OF COMPONENT/SUPPORTING-SYSTEM INTERACTIONS

COMPONENT	SUPPORTING SYSTEM	INTERFACE	FAILURE MODE OF SUPPORT SYSTEM	LOCAL EFFECTS ON FRONT-LINE SYSTEM	REMARKS
Valve A	480 V AC	Terminal A	No power to board; breaker open	Valve remains in position	Inboard isolation valve on RCIC turbine steam line; normally open valve
	250 V DC Boards: 1 2	Isolation Relays: A B	No signal from control logic	Valve remains in position unless manually actuated	Relays A and B must fail before valve will fail to change state
Valve B	250 V DC	Terminal B	No power to board; breaker open	Valve remains in position	In series with Valve A but located outside of drywell; normally open valve
	250 V DC RMOV Boards: 1 2	Isolation Relays: C B	No signal from control logic	Valve remains in position unless manually actuated	Both Relays B and C must fail before valve will fail to change state
Valve C...etc.					
Turbine	Equipment air cooling	Core spray Pump A and C room coolers	No heat removal by EECW; no forced convection by HVAC	Turbine room will heat until turbine isolates at ( )°F	RCIC can operate for at least ( ) hours without EAC
Vacuum tank condensate pump	250 V DC	Terminal E	No power to board; breaker open	Pump inoperable; barometric condenser fills with water	RCIC can function with pump inoperable
	250 V DC Board	Level Switch A activates Relay K	No signal from control circuit	Pump must be manually activated	Starts on high vacuum tank level
Other pumps...etc.					

Four level switches are used to sense reactor vessel water level. Relays associated with these switches are arranged in a one-out-of-two-twice logic for RCIC initiation.

When the RCIC initiation signal is received, the RCIC steam supply valve opens, the RCIC pump discharge valve opens, the cooling water supply line stop valve opens and the minimum-flow bypass valve opens. The barometric condenser vacuum pump and the vacuum tank condensate return pump will start. These component responses will result in water being pumped from the CST to the reactor vessel via feedwater Line B.

In addition, the initiation signal will cause the CST suction header isolation valve to open if it is closed, unless both of the suppression pool suction isolation valves are already open. The signal will close the two test line isolation valves and if they are open. The normally open discharge line isolation valve will also open if it is closed.

The attached oil pump will meet the total requirements of the turbine hydraulic and lubrication system over the complete range of turbine speed.

When system flow reaches 120 gpm the minimum-flow bypass valve will close.

<u>Turbine Trip:</u> Any of the following conditions will cause the RCIC turbine to trip:

1. High reactor vessel water level (___ inches above vessel zero).
2. Low pump suction pressure (greater than (___ inches Hg vacuum).
3. High turbine exhaust pressure (___ psig).
4. Any isolation signal.
5. Electrical overspeed (___% of rated speed).
6. Mechanical overspeed (___% of rated speed).
7. Remote manual trip from control room.
8. Local trip with manual trip lever.

A turbine trip will cause the following system effects:

1. Turbine trip throttle valve closes.
2. Minimum-flow bypass valve closes.

The latter action is necessary to prevent drainage of the condensate storage tank to the suppression pool.

All of the turbine trip signals except the mechanical overspeed trip energize a trip solenoid valve that dumps oil from the trip throttle valve and allows spring pressure to close the valve. The solenoid deenergizes after the trip signals are clear, but the trip throttle valve must be manually reopened. This is accomplished by using manual control of the valve from the control room and running the valve to the closed position, (which relatches the trip mechanism), and then by running the valve to the open position, (which reopens the valve).

When the mechanical overspeed device trips the trip throttle valve, the overspeed device must be reset locally at the RCIC turbine before the trip throttle valve can be reopened, as discussed above.

System Isolation: Any of the following conditions will cause the RCIC system to be automatically isolated:

1. High temperature (___°F) of RCIC steam line space.

2. High differential pressure of RCIC steam line (steam line break; ___ inches of water of approximately ___% of rated flow).

3. Low RCIC steam supply pressure (low reactor pressure; ___ psig).

4. High pressure of turbine exhaust line rupture disk (___ psig in the space between rupture disks). (The rupture disks are designed to rupture at ___ psig at ___°F.)

5. Manual isolation from the control room.

The RCIC isolation signal will cause the following system effects:

1. Turbine trip:

   a. Trip throttle valve closes.
   b. Minimum-flow bypass valve closes.

2. Inboard (AC) steam line isolation valve closes.

3. Outboard (DC) steam line isolation valve closes.

All isolation signals are sealed in and must be manually reset when the condition that caused the isolation signal has cleared. An RCIC control panel push button is provided for this purpose.

2.3 TEST AND MAINTENANCE

Testing: RCIC system testing requirements are summarized in Table B-2. When a test places any part of the RCIC system in a condition that would preclude proper system operation on demand, it is assumed that the test contributes to the overall system unavailability.

When applicable, the basic event code for each test is included in parentheses under the "Component Undergoing Test" column of Table B-2.

TABLE B-2

RCIC SYSTEM TEST REQUIREMENTS SUMMARY

COMPONENT UNDERGOING TEST	TYPE OF TEST	TEST PROCEDURE NUMBER	COMPONENTS ALIGNED AWAY FROM ENGINEERED SAFEGUARDS POSITION FOR TEST	EXPECTED TEST FREQUENCY	EXPECTED TEST OUTAGE TIME	REMARKS
Valve A Valve B	Turbine steam line high flow functional test and calibration	B-1	None (see remarks)	Once every month	2 hours	Power removed from both valves
Valve C	RCIC steam line space high temperature functional test and calibration	B-2	Valve C	Once every 3 months	--	Shut and tagged (only i instrument needs to be replaced)
RCIC System	Automatic actuation	A-1	Valve A* Valve B* Valve E	Once every operating cycle	Assume: 1 hour	Valves A,B,F,G, and H a repositioned to "normal' by test signal and procedure
RCIC Pump	Operability	A-2	Flow controller (manual)	Once every month	Assume: 10 minutes	System will not deliver design flow with controller in manual; repositioned when test complete
			Valve G (tripped)		(Repositioned when test complete)	

* Will reopen automatically if accident signal is present.

Maintenance: Upon reviewing the maintenance schedules, only one maintenance act was identified that was assumed to contribute to the overall RCIC system unavailability. The RCIC turbine oil is changed semiannually. This requires that the system be taken out of service for approximately 4 hours. It is assumed that the RCIC system will be unavailable for the total duration of the maintenance act.

Table B-3 is a summary of the RCIC system maintenance acts identified as a result of the review mentioned above.

2.4 TECHNICAL SPECIFICATION LIMITATIONS

1. The RCIC system must be operable prior to startup from a cold condition or whenever there is irradiated fuel in the reactor and the reactor vessel pressure is above (   ) psig.

   If the RCIC system is inoperable, the reactor may remain in operation for a period not to exceed (   ) days if the HPCI system is operable during such time. When it is determined that the RCIC system is inoperable, the HPCI system must be demonstrated to be operable immediately, and weekly thereafter.

   If these conditions are not met, an orderly shutdown of the reactor must be initiated, and the reactor depressurized to less than 122 psig within 24 hours.

TABLE B-3
RCIC SYSTEM MAINTENANCE ACTS SUMMARY

MAINTENANCE REQUIREMENT	INSTRUCTION NUMBER	FREQUENCY	DURATION	REMARKS
Sample RCIC turbine oil	1/2 day after A-1 and A-2	Once every 6 months	1 hour	Assumed: does not not take system out of service (drain 1 pint, add 1 pint)
Perform quarterly inspection of RCIC system	M-2	Once every 3 months	4 hours	Visual inspection only
Change RCIC turbine oil	1 day before A-1 and A-2	Once every 6 months	4 hours	Assumed: system out of service for 4 hours, per plant maintenance supervisor
Check movement of RCIC pedestal sliding foot	M-2	Once every year	--	Assumed: does not take system out of service

2. RCIC testing shall be performed as follows:

   a. Simulated automatic actuation test (A-1) once per operating cycle.

   b. Pump operability (A-2) once every month.

   c. Motor-operated valve operability (A-3) once every month.

   d. Flow rate at normal reactor vessel operating pressure (A-4 and A-5) once every 3 months.

   e. Flow rate at (   ) psig (A-4 and A-5 or B-4 and B-5) once per operating cycle.

   The RCIC pump shall deliver at (   ) gpm during each flow test.

3. When RCIC is required to be operable, the piping from the pump discharge to the last flow-blocking valve shall be filled. Water flow from the high point vent must be observed monthly.

2.1.3 System Operation

As discussed earlier, the RCIC system is designed to start and inject water into the reactor vessel without operator intervention. However, it is necessary to manually shift RCIC pump suction from the condensate storage tank to the suppression pool. It is also possible to manually start the system. Both automatic and manual operation of the RCIC system will be discussed below.

Automatic Operation: When reactor vessel level decreases to (   ) inches above vessel zero the RCIC logic circuitry sends an initiation signal to various RCIC components. Given a normal system lineup, as depicted in Figure B-2, the following actions will take place. The turbine steam supply valve, the cooling water supply valve the minimum-flow bypass valve, and the RCIC pump discharge valve will open. Since the trip throttle valve and the turbine governor valves are normally open, the turbine will begin to rotate. As the turbine increases speed, the RCIC pump discharge flow will also increase. When pump flow reaches ( ) gpm the minimum-flow bypass valve will close. The turbine will continue to accelerate until pump output reaches ( ) gpm. When this flow rate is obtained, the turbine governor will act to maintain a constant pump flow rate of ( ) gpm, regardless of steam inlet pressure to the turbine.

The turbine control system will maintain turbine speed to provide constant flow to the reactor vessel until a turbine trip signal or an isolation signal shuts the system down.

3.0 SYSTEM OPERATION

Manual Operation: The system is manually started by transferring the flow controller to "manual" and zeroing the controller. After verification of a normal valve lineup, the cooling water supply valve is opened. The barometric condenser vacuum pump and condensate pump are started. The minimum-flow valve is open and the turbine steam supply valve is opened. This will start and accelerate the turbine to approximately rpm. The flow controller is then adjusted as necessary to maintain reactor vessel level.

Whether the system is started automatically or manually, it is always necessary to manually shift the RCIC pump suction from the condensate storage tank to the suppression pool, if the need for transfer arises. The operator is alerted by either a high level alarm in the suppression pool or low level alarm in the CST. This is accomplished by opening the two motor-operated suppression pool suction valves. When both are full open, the CST suction valve should close automatically. If not, it will be necessary to close with the switch on the RCIC control panel. Otherwise, pump suction could be lost if the CST is pumped dry. However, for transients where the PCS is unavailable, it will not be necessary to shift RCIC suction to the suppression pool.

Recovery actions available to the operator in the event of RCIC failure include manual restart of the pumps (if pump failure is the cause of the failure), and/or remote manual operation of valves.

EP 1000 - "Loss of All AC Power"
EP 1001 - "Abnormal Suppression Pool Parameters"
EP 1002 - "Loss of RCIC"

4.0 PERFORMANCE DURING ACCIDENT CONDITIONS

The RCIC system is designed such that it is essentially a single-train system. Consequently, all major components of the system must operate when required for the system to fulfill its function.

The RCIC is considered to be successfully fulfilling its function if it delivers sufficient flow to the reactor vessel during transients where the power conversion system is unavailable. Sufficient flow is considered to be the design flow of ( ) gpm. Any flow less than this amount is considered insufficient for recovery and maintenance of vessel water level.

Faults in the minimum-flow bypass line downstream of the orifice are not considered to be failures of the RCIC. This is because the RCIC pump is designed to maintain a constant discharge flow of ( ) gpm. Since the minimum-flow bypass line taps off of the discharge line upstream of the discharge flow sensor, any flow diversion through the bypass line will be detected by the flow sensor, and the pump output will be adjusted to maintain the ( ) gpm flow setting. The orifice will tend to reduce flow diversion to a minimum.

The ability of the RCIC to perform its function can be impaired by certain conditions which may arise following some transient events. In particular, the failure of containment drywell heat removal could cause the backpressure to rise high enough to cause a RCIC pump trip on high backpressure. Any sudden changes in drywell pressure could also affect the suppression pool in such a way that pump cavitation could result. Therefore, any situation in which the integrity of the drywell is threatened should be treated immediately to ensure continued injection of coolant into the core via the RCIC system.

Failure of the RCIC to perform its function will result in a serious threat to the reactor core. Without supplying some other source of coolant to the core, uncovery of fuel will begin, followed by fuel damage and the potential for core melting.

5.0 LOCATION WITHIN THE PLANT

The locations of the key components of the RCIC system are contained in Table B-4. This table also indicates structures, pipes, etc., which are in close proximity.

TABLE B-4
RCIC EQUIPMENT LOCATION

COMPONENT	LOCATION	COMMENTS
Valve A	Room 1	Located within 2 feet of concrete wall. Located directly underneath high pressure pipe PP-101.
Valve B	Room 2	Circuitry for valve passes within 5 feet of lube oil reservoir.
Valve C ...etc.		
Turbine	Room 2	MCC 011 located 3 feet away. Circuitry for turbine control runs in raceway along north side of room. Passes next to high pressure pipe PP-102
ETC.		

6.0 OPERATING EXPERIENCE

Plant experience over the period 1975-1985 indicates that the RCIC system at the ( ) plant has operated relatively well when called upon. Comparisons with Nuclear Plant Experience records and other PRAs indicates a performance record that is comparable to similar systems in other plants.

Section 9 contains more details on system unavailability.

7.0 LOGIC MODELS

Figure B-4 is the RCIC system fault tree. Major assumptions about the system which were used in the construction of this tree are summarized below:

PART 1

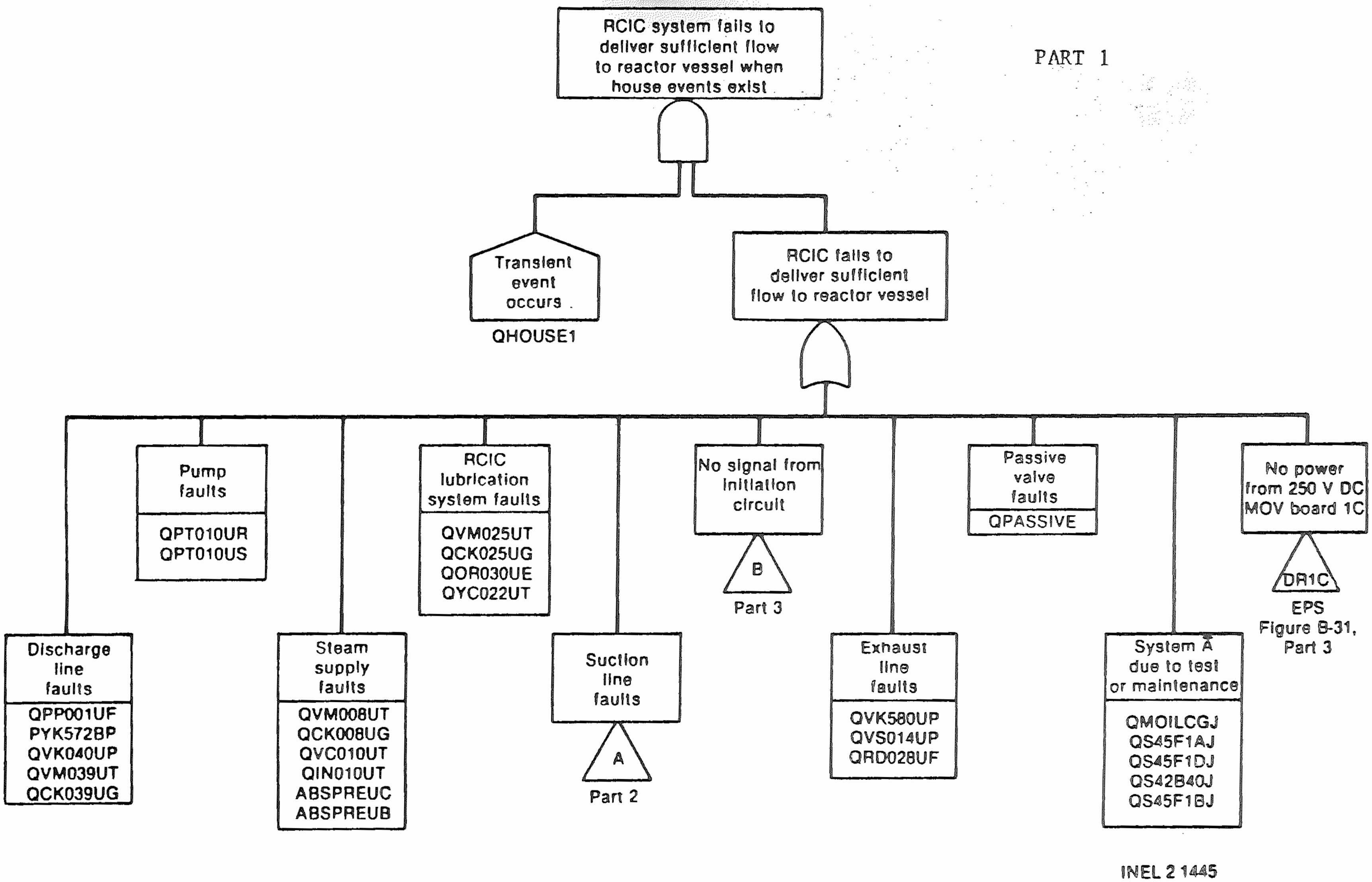
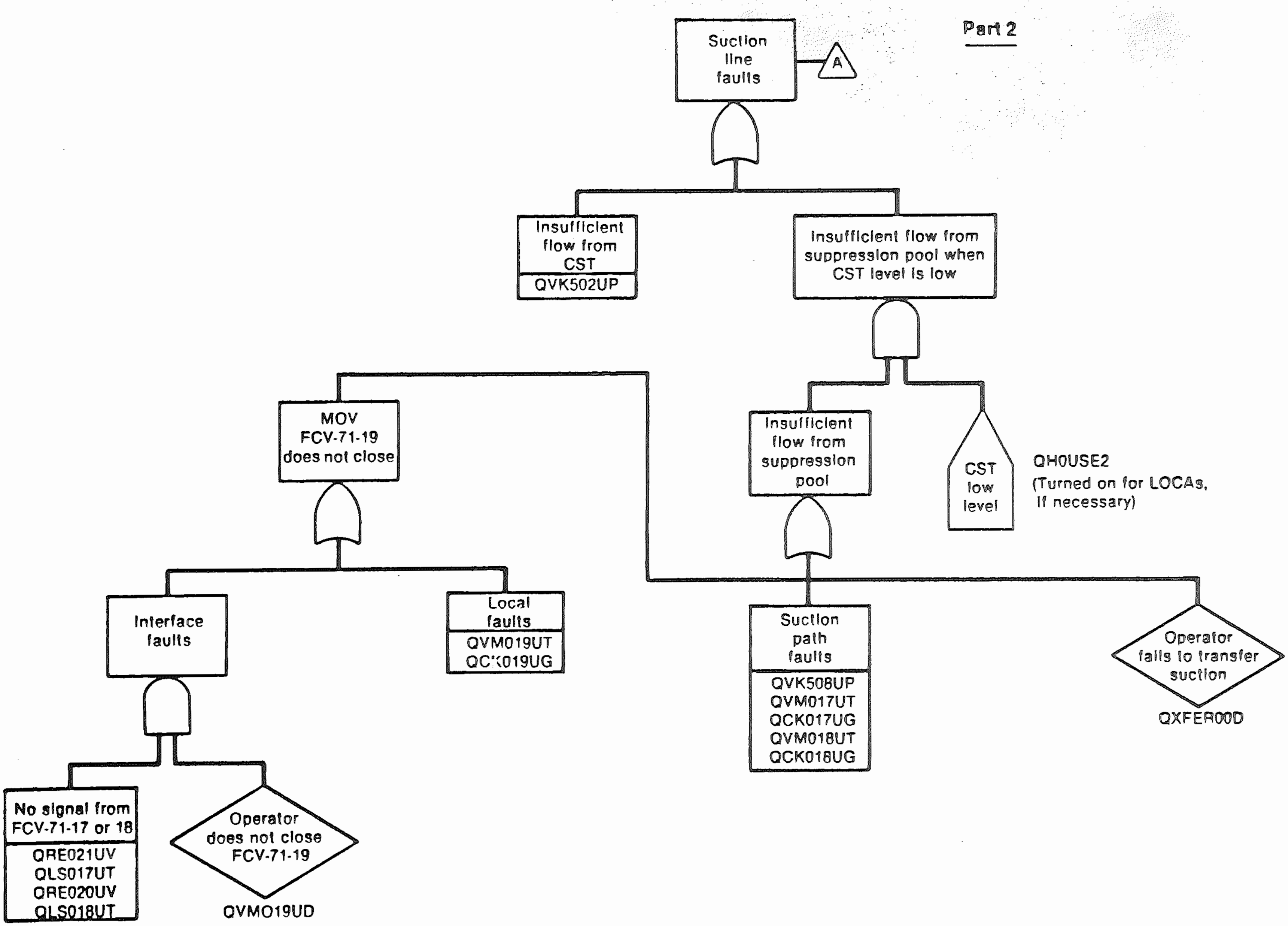


Figure B-4. RCIC fault tree.

Part 2



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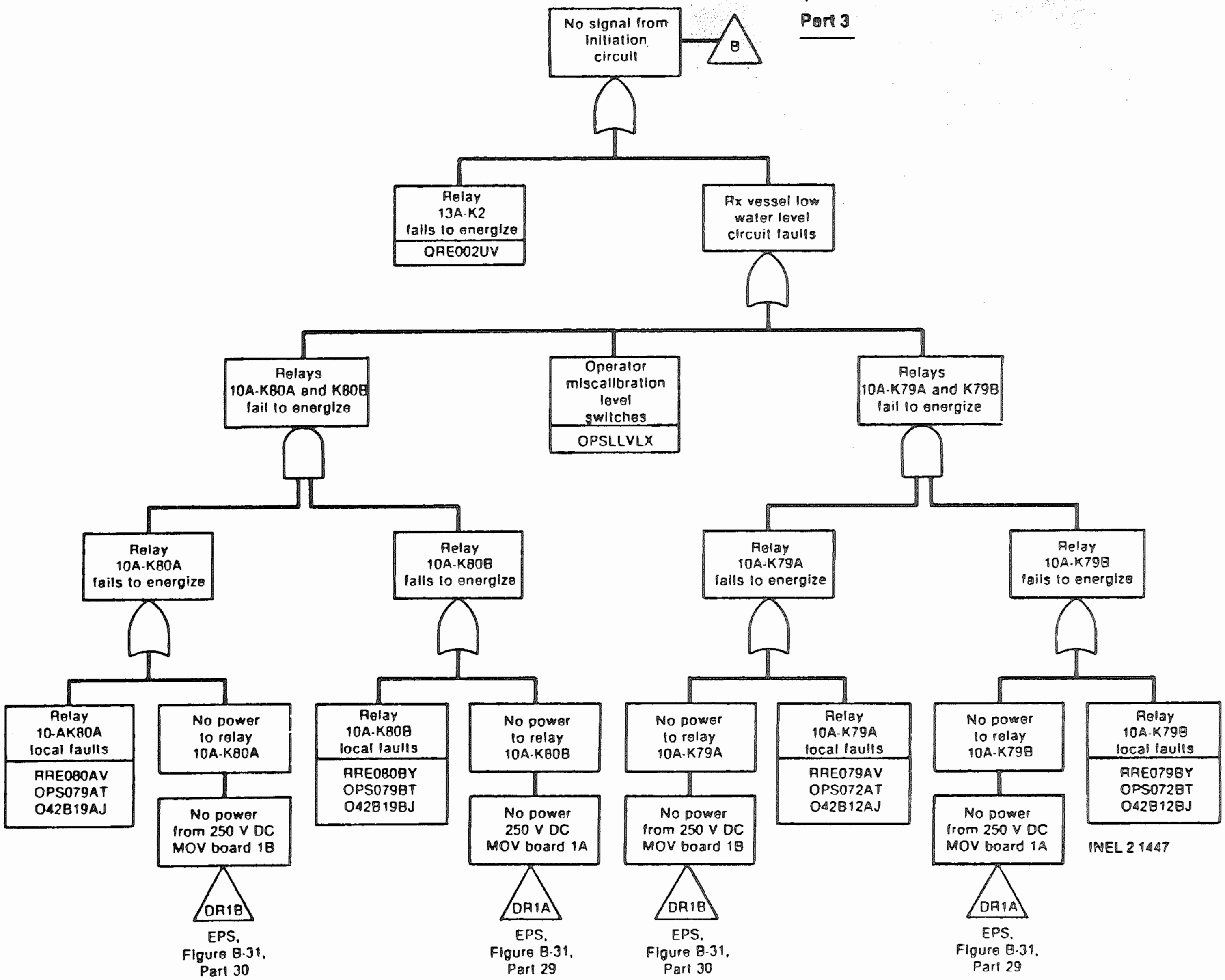

Figure B-4. (continued).

Major Assumptions: The following major assumptions were used in construction of the RCIC system fault tree:

1. The RCIC system will be required to perform the HPCI function for all transients where the PCS becomes unavailable.

2. The system is initially aligned as shown in Figure B-2. This implies, that to achieve successful injection to the vessel, the only valves required to change state, other than those required for turbine control, are: the steam supply valve; the pump discharge valve to the feedwater line; and the cooling water supply valve.

3. Faults in the minimum-flow bypass line downstream of the orifice are not considered in this tree. The RCIC pump is designed to maintain a constant discharge flow of (   ) gpm. Since the minimum-flow bypass line taps off of the discharge line upstream of the discharge flow sensor, any flow diversion through the bypass line will be detected by the flow sensor, and the pump output will be adjusted to maintain the 600 gpm flow setting. The orifice will tend to reduce flow diversion to a minimum. Ruptures in the minimum-flow bypass line were not considered due to the size of the piping (see Assumption 4) and the fact that the RCIC system is a constant-discharge flow system. It is further assumed that failure of the minimum-flow bypass to open will not significantly affect system operation unless a fault in the RCIC pump discharge path to the reactor vessel exists. However, if a discharge path fault causes a need for the minimum-flow bypass valve to be open, the flow blockage in the discharge path will cause the RCIC system to be unavailable, by definition, regardless of the position of the minimum-flow bypass valve.

4. Faults in pipes, valves, or system connections of a 2-inch diameter or less are considered to have an insignificant effect on system operation. One exception to this assumption is the lubricating oil system. Since many of the system components have a direct dependence on this system, it is assumed that lube oil supply and cooling faults

could significantly affect system operation. Therefore, these faults are considered in the fault model.

5. For transients where the PCS system is unavailable, it will not be necessary to shift RCIC suction to the suppression pool. In a transient or LOCA in which the decay heat removal systems fail, water makeup to the primary system can generally be maintained initially by injection from the CST. If the operators choose to maintain sufficient makeup to just compensate for decay heat boiloff, the CST will empty (___ gallons assumed injected) after about ( ) hours. The operators would then be expected to switch to injection of water from the suppression pool. Since stable hot shutdown is defined to be the termination point for the analysis, it was assumed that ( ) hours was a realistic time frame to achieve a stable hot shutdown condition. (see Appendix ( ), Section ( ) for further discussion of the ( ) hour time frame).

6. Any faults in the turbine exhaust piping that cause turbine exhaust piping overpressure are assumed to actuate the turbine exhaust line pressure switches. This action sends a signal to the turbine control circuitry that will initiate a turbine trip. Turbine exhaust line rupture disk leakage will cause a turbine isolation signal to be generated in the control circuitry, which also causes a turbine trip.

7. Faults in the condensate drain systems were analyzed and found to be insignificant relative to the dominant contributors to RCIC system unavailability. Essentially, in order for drain system faults to cause turbine damage, there must be either a flooded steam supply line or steam line drain system faults that would cause the condensate drain pots to fill. These faults must then be combined with condensate drain pot level switch failure in order for significant amounts of condensate to remain undetected in the steam supply line.

8. Passive failures of normally open valves that do not need to change state were considered if the passive failure could disable the entire system. There was nine valves for this system, three CST suction valves, two discharge valves, and four steam valves.

8.0 INITIATING EVENT REVIEW

Following a review of the system operation and the system fault tree, no initiating events due to failures of components in the system were identified.

9.0 QUANTIFICATION

Basic Events: The information associated with the various basic events listed in the fault tree are summarized in the RCIC fault summary short form, Table B-5. In addition, the failure data associated with these basic events is summarized in Table B-6. Table B-7 summarizes the dominant contributors to RCIC unavailability.

TABLE B-5
RCIC SYSTEM FAULT SUMMARY SHORT FORM

		PRIMARY FAILURES			
EVENT NAME	EVENT COMPONENT	FAILURE MODE	FAILURE RATE	FAULT DURATION (HR)	ERROR FACTOR
QPP001UF	RCIC pipe break (anywhere)	Leakage/ section	1E-10/H/ section	384	30
PVK572BP	Check Valve 3-572	Does not open	1E-4/D	--	3
QVK040UP	Testable check valve FCV-71-40	Does not open	1E-4/D	--	3
QVM039UT	Discharge valve FCV-71-39	Does not operate	1E-3/D	--	3
QCK039UG	FCV-71-39 control circuit	No output	3.2E-3/D	--	10
QPT010UR	RCIC pump	Does not start	3E-3/D	--	3
QPT010US	RCIC pump	Does not continue to run	3E-5/H	37	3
QVM008UT	Steam stop valve FCV-71-P	Does not operate	1E-3/D	--	3
QCK008UG	FCV-71-P control circuit	No output	3.2E-3/D	--	10
QVC010UT	Turbine govern control valve FCV-71-10	Does not operate	3E-4/D	--	3

TABLE B-6

RCIC SYSTEM FAILURE DATA SUMMARY

COMPONENT/ACTIVITY CODE	FAILURE MODE (CODE)	TIME TO DETECT (T_D)	TIME TO REPAIR (T_R)	FAULT DURATION TIME ($T = T_D + T_R$)	FAILURE PROBABILITY	UNAVAILABILITY (A)	REMARKS
Electrical bus (BS)	Open circuit (B)	0 hour	7 hours	7 hours	3E-8/hour	2.1E-7	T_D = 0, because fault will be detected immediately T_R, WASH-1400, Table III 5-2, (instrumentation) λ = IREP, Table 3B, wire data; decreased by order of magnitude because buses are much less likely to open than wires (engineering judgement)
Electrical bus (BS)	Short to ground (C)	0 hour	7 hours	7 hours	3E-7/hr	2.1E-6	T_D = T_R, same as above λ = IREP, Table 3B, wire data
Motor-operated valve control circuit (CK)	No output (G)	360 hours	7 hours	367 hours	7.7E-6/hr	3.2E-3	A- = 4.1E-4 + 7.7E-6T T_R--WASH-1400, Table III- 5-2 T_D = half test interval; based on pump operability test and stroke time test; once per month
Governor instrumentation (transmitter, amplifier, output devices) (IN)	Does not operate (T)	360 hours	7 hours	367 hours	1E-6/hr	3.7E-4	T_D--based on pump operability check; once per month T_R--WASH-1400, Table III 5-2

TABLE B-6 (Cont.)
RCIC SYSTEM FAILURE DATA SUMMARY

COMPONENT/ACTIVITY CODE	FAILURE MODE (CODE)	TIME TO DETECT (T_D)	TIME TO REPAIR (T_R)	FAULT DURATION TIME ($T = T_D + T_R$)	FAILURE PROBABILITY	UNAVAILABILITY (A)	REMARKS
Limit switch (LS)	Does not operate (T)	360 hours	24 hours	384 hours	1E-10/hr	3.8E-8	T_R = 24 hour, assumed time to shut down plant T_D--based on pump operability test; once per month
Orifice (OR)	Plugged (E)	--	--	--	3E-4/D	3E-4	--
Pipe (PP)	Leakage/ rupture (F)	360 hours	24 hours	384 hours	1E-10/hr	3.8E-8	T_R = 24 hour, assumed time to shut down plant T_D--based on pump operability test; once per month
Process switch (PS)	Does not operate (T)	--	--	--	1E-4/D	1E-4	--
RCIC pump (PT)	Does not start (R)	--	--	--	1E-3/D	1E-3	--
RCIC pump (PT)	Does not run (S)	0 hour	37 hours	8 hours	3E-5/hr	2.4E-4	T_R--WASH-1400, Table III 5-2
Rupture disk (RD)	Leakage/ rupture (F)	360 hours	12 hours	372 hours	5.7E-5/hr	2E-2	T_D--based on pump operability check; once per month T_R--plant-specific data λ--based on plant-specific data

TABLE B-7

RCIC SYSTEM CUT SETS

UNAVAILABILITY	IMPORTANCE (%)	CUT SETS	POTENTIALLY RECOVERABLE
2.0E-2	47.5	QRD028UF	No
3.2E-3	7.6	QCK039UG	No
3.2E-3	7.6	QCK025UG	No
3.2E-3	7.6	QCK008UG	No
3.0E-3	7.1	QPT010UR	No
1.9E-3	4.5	QS42B40J	No
1.0E-3	2.4	QVM039UT	No
1.0E-3	2.4	QVM025UT	No
1.0E-3	2.4	QVM008UT	No
Cumulative importance	89.1		

10. SUMMARY OF KEY FINDERS

The overall unavailability of the RCIC system, estimated using the fault tree and data supplied in this appendix, is approximately 3.8E-2/demand. Almost 50% of this is due to a rupture disk failure in the turbine exhaust line. This failure, along with the majority of the other which make up the total system unavailability, is non-recoverable.

11.0 SUMMARY OF KEY REVIEW COMMENTS

No major review comments were received

12.0 REFERENCES

A. "Plant Operating Procedures"

B. "Nuclear Power Experience," S.M. Stoeller Company

C. IEEE-500

D. "Plant Piping and Instrumentation Drawing"

E. "Plant Electrical Drawings"

F. "Plant Raceway Schedules"

G. ETC.