H. B. ROBINSON UNIT 2 SUPPORT SYSTEM INTERACTION ANALYSIS IN SUPPORT OF THE ORNL PRESSURIZED THERMAL SHOCK PROGRAM

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1.0 INTRODUCTION

An analysis of the H. B. Robinson Unit 2 nuclear power plant is being performed by the Oak Ridge National Laboratory (ORNL) to assess the potential risk due to Pressurized Thermal Shock (PTS). The PTS analysis consists of identifying and estimating the frequency of sequences of events leading to low temperature, high pressure conditions at the reactor vessel wall, estimating the response of the reactor vessel wall to these conditions, and calculating the conditional probability of a through wall crack for sequences of interest. These analysis elements are combined to assess the overall risk due to PTS.

This report describes the response of key plant systems identified in PTS sequences to failures of required support systems. Support system failures can be important since single support system failures can result in multiple failures of the systems comprising the PTS event sequences. The electric power, instrument air, service water and component cooling water systems were identified as the support systems that could impact the systems and associated control instrumentation comprising the H. B. Robinson PTS event tree sequences.

In addition to these support systems, the necessity of the plant's heating, ventilating and air conditioning (HVAC) systems for continued plant operation was recognized. However, the effect of HVAC failures on equipment performance is expected to be long term with respect to the effects of failures of the other identified support systems. In general, the effects of HVAC failures and severe equipment operating environments is considered to be beyond the scope of this analysis.

The major results of the support system failure analysis are summarized in Section 2. In Section 3, the methodology used to identify and analyze the response of plant systems and components to support systems failures is described. Section 4 provides a brief description of the support systems considered in the analysis. Section 5 details the data base of components considered in the analysis and their failure modes in response to support system failures. The response of the key plant systems and components

comprising PTS event sequences to postulated support system failures is provided in Section 6.

The identification of support system failures which could lead to adverse PTS sequences is the first step in evaluating their impact. Although not assessed in this analysis, the frequency of each support system failure and associated events (including the effects of operator intervention) must be calculated and compared to the frequencies of equivalent sequences occurring independently to evaluate the overall impact of support system failures on the PTS sequences. This is done in Chapter 3 of the main report.

2.0 SUMMARY OF RESULTS

The H. B. Robinson Unit 2 systems and components identified in the PTS event trees have been analyzed to determine the effects of postulated failures of the electric power, instrument air, component cooling water, and service water systems. Plant responses from 12 of the 36 support system failures postulated were initially considered to warrant further study to assess their potential concern to PTS sequences. The 12 failures included loss of instrument air, loss of component cooling water, loss of service water and several electrical bus failures. Plant responses from all failures postulated can be found in Tables 3 and 4 and the plant responses to the selected 12 failures are summarized in Table 5 in Section 6.

The only significant plant responses found that could be of concern from a PTS standpoint were auxiliary feedwater (AFW) and charging flow overfeed on loss of instrument air, electric bus failures that would result in isolation of main feedwater with AFW still operable (and thus subject to potential overfeed), and reactor trip with AFW still operable. The AFW and charging flow overfeed result from loss of pump speed control on the charging pumps and on the steam driven AFW pump. Charging pump control can be switched to the manual mode and operated in a start-and-stop-mode to gain flow control. Loss of service water can fail the instrument air system compressors and over a longer term, similarly lead to the charging flow overfeed. A double bus failure on 4KV Buses 2 and 3 (including their diesels) will fail all charging pumps and could lead to a potential RCP seal failure.

The steam dump valves, primary and secondary side PORV's, and MSIV's all assume closed positions on support system failures. No main feedwater overfeed results from support system failures; in all cases investigated feedwater isolates.

Some electric bus failures would actuate AFW and SI, but this would not impact PTS sequences since AFW is typically demanded anyway in the sequences and the SI pumps could not deliver flow to the reactor coolant

system (RCS) unless RCS pressure were reduced. These failures include the three bus failures that involve vital instrument buses tied to 4KV Bus 3 for maintenance, failure of DC Bus A, and failure of DC Bus B. However, the coincident feedwater isolation with AFW still operable is a potential initiator in sequences involving AFW overfeed.

Loss of component cooling water results in loss of seal flow to the charging pumps. This could lead to a reactor coolant pump (RCP) seal failure over a long period of time due to eventual loss of the charging pumps if no remedial action is taken. However, many recovery actions are available to prevent the RCP seal failure, including alternating use of the three charging pumps and tripping the RCP's.

Electric bus failures involving the loss of the 480 VAC E2 bus would result in charging flow runback due to loss of signal from the pressurizer level controller. However, the charging pumps are each equipped with a variable control stop which will not permit pump flow lower than a minimum specified to ensure that RCP seal water and minimum charging flow requirements are met. It has been assumed in this analysis that this minimum flow stop is set to ensure adequate seal flow.

Other electrical bus failures involving 4KV Bus 3 fail the pressurizer PORV block valves open while at least one of the PORV's is operable. Thus, the likelihood of small break LOCA isolation may be impacted for certain PTS sequences involving PORV failures.

Loss of power or both DC Buses A and B will fail circuit breakers on the pressurizer heaters and the RCP pumps so that these components cannot be tripped off. Loss of both DC buses would also cause turbine trip failure of 3 of the 4 turbine trip systems. If loss of DC power also fails the solenoid trip valves associated with the fourth turbine trip system, the Turbine Redundant Overspeed Trip System (TROTS),* the turbine can only trip by mechanical overspeed actuation of the auto-stop trip system. However, the DC power failure also results in the MSIV's closing and other equipment responses that would preclude excessive heat removal from the secondary side.

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*The power supply configuration for the TROTS solenoids has not been determined at this time.

The support system failures postulated are typically low probability events. The frequency of each potentially significant support system failure and subsequent possible sequences is developed in Chapter 3 of the main report.

3.0 METHODOLOGY

The objective of this study is to identify common cause failures which result from failures in the electric power, instrument air, component cooling water or service water systems and affect PTS sequence quantification.

The methodology used in this study is outlined below:

1. Identify plant systems and components potentially affecting the PTS event sequences.
2. Identify support system components, including controls, potentially affecting the plant system components.
3. Identify the specific failure modes of individual systems and components in response to electric power, instrument air, component cooling water, and service water system failures.
4. Determine the combined impact on the systems and components potentially affecting PTS, from postulated failures of the support systems.
5. Identify the failures which could be "PTS adverse" (i.e., make the pressure-temperature response of the reactor coolant system more severe from a PTS standpoint).
6. Determine which support system failures (from Step 5) could initiate PTS sequences of concern.

Using the methodology outlined above, the effects of support systems failure on PTS sequences can be evaluated. It should be noted that the results are not necessarily applicable to non-PTS accident sequences and have not considered the effects of common cause initiators such as operator errors, severe operating environments, severe natural phenomena or sabotage.

4.0. SUPPORT SYSTEM DESCRIPTIONS

This section provides a brief description of the support systems considered in this study. The plant-level systems and components that impact PTS sequences are described in detail in Chapter 2 of the main report and are described in terms of their pertinent failure modes in Section 5 of this report.

4.1. Electric Power Distribution System

The H. B. Robinson Unit 2 AC-DC electric power distribution is shown in a simplified schematic diagram, Figure 1. The unit generator and the 115 KV switchyard are the primary sources of electrical power during on-line operation of the plant. Power from the unit generator is supplied to plant systems through the 22/4.16 KV unit auxiliary transformer (UAT). Electric power is supplied from the 115 KV switchyard via the 115/4.16 KV startup transformer (SUT).

The 4160V buses supply the 480V buses through 4160/480V station service transformers. In particular, 4160V Bus 1 supplies 480V Buses 2A and 2B; 4160V Bus 2 supplies 480V Buses 1 and E1; 4160V Bus 3 supplies 480V Buses 3, E2, and DS; and 4160V Bus 4 supplies 480V Bus 4. Tie breakers are provided between 480V Buses 1, and 2A, 2B and 3, and E1 and E2. Buses E1 and E2 can also be supplied from emergency diesel generators A and B, respectively. The designated shutdown (DS) diesel generator can supply power to the 480V DS Bus.

The 480V buses supply the 12 motor control centers (MCC's). Figure 2.10 details which 480V buses supply the individual MCC's. In addition, MCC-5 has an alternate feed from 480V Bus DS.

Plant DC loads are supplied by 125 VDC buses A and B. Each DC bus is fed by its associated battery charger. The two 125 VDC battery chargers, A and B, are fed by 480 VAC MCC-5 and MCC-6 respectively.

The 120V instrument power supply is split into 8 buses. Buses 1, 2, 3, and 4 each have a normal and an alternate power supply. Instrument buses

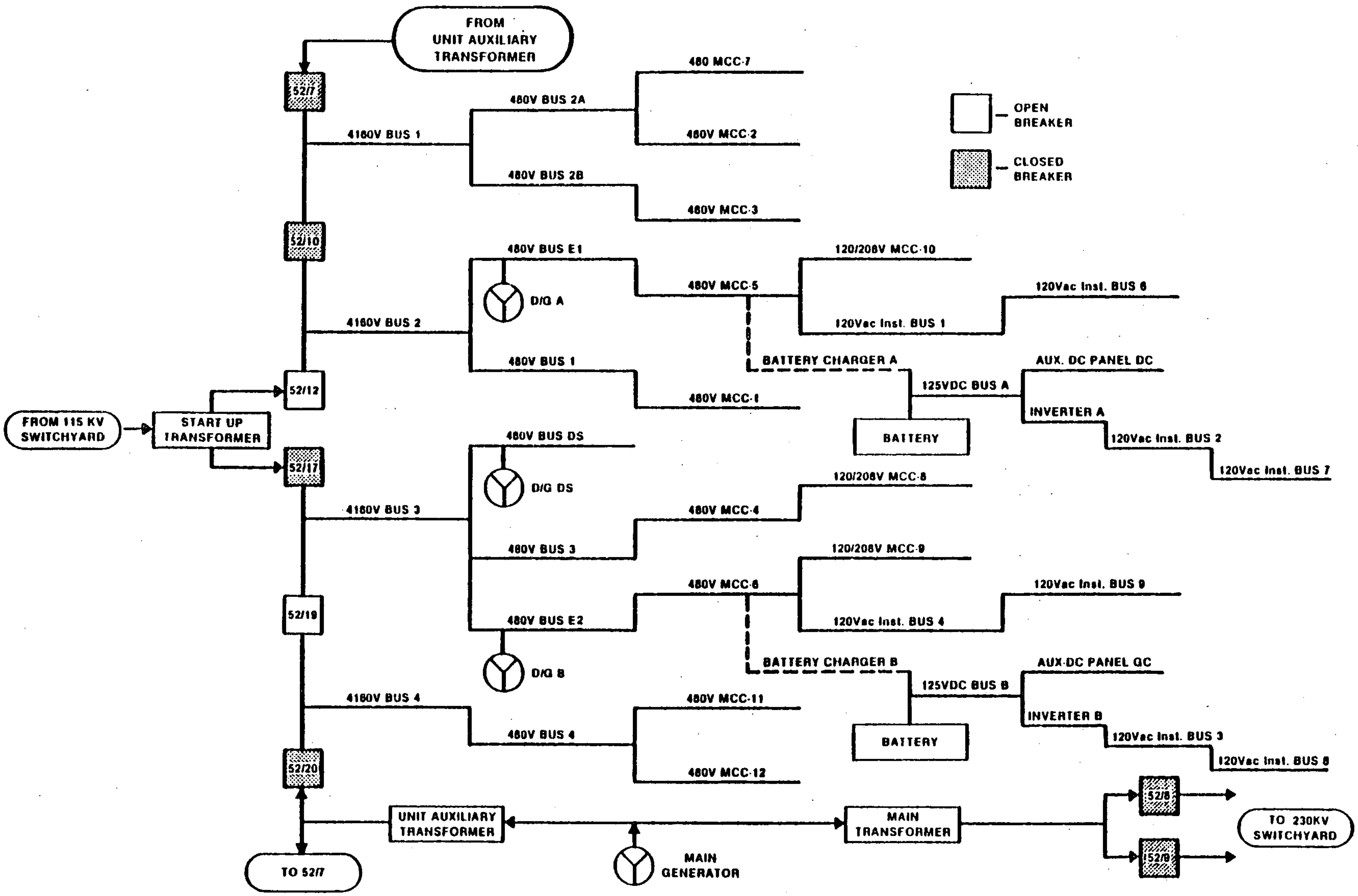

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FIGURE 1 SIMPLIFIED SCHEMATIC OF H.B. ROBINSON UNIT 2 AC/DC POWER DISTRIBUTION

2 and 3 are normally fed from 125 volt DC Bus A and Bus B, respectively, via inverters. Instrument buses 1 and 4 are normally fed from 480V MCC-5 and MCC-6, respectively. The alternate power supply for instrument buses 1, 2, 3, and 4 is 120/208V MCC-8. Instrument buses 6, 7, 8, and 9 are fed from instrument buses 1, 2, 3, and 4, respectively.

Instrument Buses 1, 2, 3, and 4 supply control power to process instrumentation via the Analog Instrument Racks. Some of this instrumentation includes pressurizer pressure transmitters, turbine overspeed channels (TROTS), steam dump instrumentation, pressurizer level control, charging line flow control, RHR flow control, feedwater flow control, and bistables for safety injection and AFW initiation.

4.2. Instrument Air System

The H. B. Robinson Unit 2 instrument air system consists of multiple trains of air compressors, aftercoolers, dryers and air receivers which provide air to the instrument air headers. Instrument air headers are located in the Turbine Building, Reactor Containment Building, Reactor Auxiliary Building, Corridor and Fuel Handling Area.

Nominal instrument air header conditions are 100-110 psig and 85°F. Air flow demands may fluctuate with peak demands between 200 and 400 scfm. A 516 scfm primary air compressor normally supplies the instrument air requirements throughout the plant. The compressor controller regulates the compressor cylinder load to maintain pressure in its 427 cubic foot air receiver.

Two 200 scfm instrument air compressors, A and B, normally provide intermittent air flow to meet peak air flow demands. These instrument air trains are in parallel and are normally auto-aligned to provide an on-line backup to the primary air train. Aligned in the auto-mode, the compressors automatically start and stop to maintain pressure in a single shared 150 cubic foot air receiver.

In addition, a 400 scfm station air compressor is used as a manual backup instrument air supply when the primary air and instrument air systems

are unavailable. This compressor is normally not operating and must be manually started and valved in when needed. The station air is not of instrument air quality, but is available if required.

Power to the primary air compressor is supplied from 480V bus 2A; instrument air compressors A and B are supplied from 480V MCC-5 and MCC-6, respectively. The compressors are cooled by the Service Water System.

Instrument air is required by the following components: pressurizer relief valves, MSIV's, steam side PORV's, feedwater control and bypass valves, charging pump and AFW pump lube oil cooling valves, letdown isolation and charging flow control valves, charging pump and AFW turbine pump speed control and RHR system valves.

4.3. Component Cooling Water System

The component cooling water (CCW) system is a closed loop system with three centrifugal CCW pumps and two CCW heat exchangers; which are cooled by service water. The three CCW pumps discharge into a common header which feeds the heat exchangers. The heat exchangers discharge into another common header and out to the various plant loads. Normally, one pump and one heat exchanger have sufficient capacity to remove the heat loads during full power operation. During normal operation the CCW system provides cooling water to the reactor coolant and charging pumps. Two CCW pumps and heat exchangers are utilized for removing residual heat and pump heat during normal plant shutdown.

Power to CCW pumps A, B, and C is supplied from 480V buses DS, E1, and E2, respectively. CCW pumps B and C are actuated by SI trains A and B, respectively. The pump motor circuit breakers have undervoltage trips which open upon loss of power.

4.4 Service Water System

The service water system (SWS) is an open loop system taking its suction from Lake Robinson. The SWS is a two train system with each train supplying cooling water to one of two or three redundant items of plant equipment.

There are four service water pumps with three pumps normally operating. Complete train separation is possible at the discharge header from the four pumps, which then discharge into the two 30-inch train headers.

The service water system provides heat removal from the following components: main feedwater pumps; motor and steam driven auxiliary feedwater pumps; CCW heat exchangers; primary, station, and instrument air compressors, isolated phase bus heat exchanger; and the safety injection pumps.

The service water pumps are supplied motive power from the following 480V buses: pump A and B from 480V bus E1, and pump C and D from 480V bus E2.

5.0 SYSTEMS AND COMPONENTS AFFECTING PTS SEQUENCES

In this analysis, a data base associated with the plant components important in determining potential impacts on PTS sequences was developed. The data base identifies the systems and components considered, their interfaces with support systems, and their failure modes in response to failure of required support systems. With this information the effect of postulated support system failures on aspects of the plant state, potentially important to PTS sequences could be assessed. That assessment is provided in Section 6. This section describes the data base developed and Attachment 1 contains the bulk of the actual data.

5.1 Selection of Systems and Components

Identification of the plant systems and components that could impact PTS sequences is the first step in performing the PTS support system interaction analysis. The specific purpose of performing the support system interaction analysis is to determine whether one or more individual "branch events" of the PTS event sequences many occur due to a failure of the support systems. The principal sources of information to select the systems and components affecting PTS sequences are the PTS event trees and the branch failure modes.

The systems and components identified from the PTS sequences, and potentially important failure modes, are listed in Table 1. Each of the key components was evaluated to determine whether a potential failure due to a support system failure was possible.

For those key systems and components that could be impacted by support system failures, additional components that would be required for proper functioning were identified. For example, the additional components for the AFW pumps included specific pump discharge and control valves, the flow controllers for the turbine driven pump and motor driven pump trains, the turbine pump steam supply valves, and the steam generator bistables that can initiate AFW. Support system components required for proper functioning of plant-level or "front-line" components were then similarly identified. Table 1-1 in Attachment 1 provides a complete list of the front-line

Table 1. Summary of Potential Support System Impact on Key PTS Event Tree Systems and Components

Key Systems and Components	Failure Modes of Interest	Component Response Impacted by Support System Failures
1) Reactor Coolant System		
a) Pressurizer Relief Valves	Inadvertantly open or fail to close on demand	Yes
b) Safety Valves	Fail to close on demand	No
c) Reactor Coolant Pumps	Seal Failure (LOCA)	Yes
d) Piping	Piping Failure (LOCA)	No
e) Steam Generator Tubes	Tube Rupture (LOCA)	No
2) Main Steam System		
a) Turbine Trip Systems	Fail to trip on demand	Yes
b) Steam Side Power Operated Relief Valves	Inadvertantly open or fail to close on demand	Yes
c) Steam Dump Valves	Inadvertantly open or fail to close on demand	Yes
d) Main Steam Isolation Valves	Fail to close on demand	Yes
e) Main Steam Bypass Valves	Inadvertantly open or fail to close on demand	Yes
f) Main Safety Valves	Inadvertantly open or fail to close on demand	No
g) Piping	Steam line breaks	No
3) Main Feedwater System		
a) Feedwater Pumps	Overfeed or fail to isolate	Yes
b) Feedwater Control Valves	Overfeed or fail to runback	Yes
c) Feedwater Isolation Valves	Fail to isolate	Yes
d) Feedwater Bypass Valves	Inadvertantly open or fail to close on demand	Yes
4) Chemical Volume and Control System		
a) Charging Pumps	Overfeed or loss of flow	Yes
b) Letdown Isolation Valves	Fail to isolate on demand	Yes
5) Emergency Core Cooling System		
a) Safeguards Actuation System	Inadvertant actuation or fails to actuate	Yes
b) High Pressure Safety Injection	Inadvertant overfeed or failure	Yes
c) Low Pressure Safety Injection	Fails on demand	Yes
6) Auxiliary Feedwater System		
a) AFW Electric Motor Driven Pumps	Inadvertant actuation or failure to actuate	Yes
b) AFW Steam Driven Pump	Inadvertant actuation, overfeed or failure	Yes
c) AFW Valves	Fail to close on demand	Yes
7) Reactor Protection System	Reactor Trip	Yes

and support system components selected and subsequently considered in this analysis.

5.2 Support System Interfaces

The support system interfaces for the component's considered in the analysis were established. (See Table 1-1 for a listing of these components.) A complete summary of the interfaces between these components and the instrument air, CCW, SWS, and electric power system is provided in Table 2. The table lists all components considered in the study according to which support systems they require.

5.3 Description of System and Component Failure Modes in Response to Support System Failures

Once the systems and components that could impact PTS sequences were identified, their failure modes were determined. This was done based on available design documentation and from specific information provided by Carolina Power & Light. Failure modes on loss of electric power, instrument air, CCW, and service water were determined for each component requiring these support systems.

Failure modes determined for applicable components on loss of instrument air, CCW, and service water are provided in Table 1-2 (Attachment 1). Component failure modes that would occur on loss of electric power supply are included in Table 1-3 (Attachment 1) for the components requiring motive power and/or control power. Also included in the table is the source of motive and/or control power for the components.

Tables 1-2 and 1-3 complete the data base required to assess the impact of postulated support system failures on aspects of the plant state potentially important to PTS sequences.

The component failure modes determined are discussed further, by key system and/or component, in Sections 5.3.1 through 5.3.15.

Table 2. Summary of Interfaces Between Components and Support Systems Considered (Continued)

Systems	Components Requiring Instrument Air	Components Requiring CCW	Components Requiring SWS	Components Requiring Electric Power
Front Line Systems (Cont.)				
7. SI System	o N_2 Supply Valve to Accumulators SI-855 o Accumulator Drain and Vent Valves	o SI pumps (seal water heat exchanger)	o SI pumps (thrust bearing cooling)	o SI Pumps o N_2 Supply Valve to Accumulators SI-855 o Accumulator Drain and Vent Valves o Accumulator Discharge Valves o Cold Leg Injection Valves SI-870A&B o Boron Injection Tank Inlet Valves SI-867A&B o RWST Outlet Valves SI-864A & B o Hot Leg Injection Valves SI-869, 866A & B o Low PZR Pressure Bistables PC-455E, 456D, 457D
8. RHR System	o Discharge Valves FCV-605 HCV-758	o RHR pump (seal water heat exchanger)		o RHR Pumps o Pump Suction Valves from RWST SI-862A & B o Cold Leg Inlet Valves RHR-744A & B o RHR Discharge Valve FCV-605
9. Safeguards Systems				o Safeguards Trains A & B o Pressurizer Pressure Instrument Strings PC-455E, 456D & 457D
10. Reactor Protection System				o Control Rod Drive Motor Generator Sets A & B o RCP Under Voltage Relays UV-1,2,&3 o Reactor Protection Trains A & B
Support Systems				
11. Component Cooling Water System	o CCW Discharge Valves from Charging Pumps TCV-659A, B, & C		o CCW heat exchangers A & B	o CCW Pumps o RCP Supply Valves CC-716A & B o RCP Lube Oil Coolers CCW Valve CC-730 o RCP Thermal Barrier Cooling Coils CCW Valve FCV-626
12. Service Water System	o Suction Control Valves to AFW Pumps A, B, & Turbine TCV-1902 TCV-1903A TCV-1903B o Discharge Control Valves from Air Compressors A & B TCV-1629A & B			o SW Pumps o SW Discharge Cross-Tie Valves V6-12B & C o SW Supply Train Isolation Valves V6-16A & B o SW Control Valve to AFW Turbine Driven Pump TCV-1092 o SW Control Valve to AFW Motor Driven Pumps TCV-1903A & B
13. Instrument Air System			o Primary Air Compressor o Instrument Air Compressors A & B	o Primary Air Compressor o Instrument Air Compressors A & B
14. Electric Power System			o Diesel generator cooling	o Diesel Generators A & B

Table 2. Summary of Interfaces Between Components and Support Systems Considered

Systems	Components Requiring Instrument Air	Components Requiring CCW	Components Requiring SWS	Components Requiring Electric Power
Front Line Systems				
1. RCS	o PORVs RC-456 RC-455C	o RCP (bearings and thermal barrier cooling coil)		o RCPs A, B, & C o PZR Heaters o PZR Pressure transmitters o PZR PORVs o PORV Block Valves
2. Turbine Protection System				o Turbine Auto Stop Trip System & Solenoid 20-AST o Turbine Emergency Trip System & Solenoid 20-ET o Gov/Intercept Trip System & Solenoids 20-1, 20-2 o Governor Control Cabinet o EH System o EH Oil Pumps o TROTS
3. Main Steam System	o MSIVs o Steam Side PORVs			o MSIVs o Steam Dump Valves o Steam Side PORVs o Steam Dump Controllers o Main Steam Bypass Valves
4. Main Feedwater System	o Feedwater Control Valves o Feedwater Bypass Valves		o Feedwater Pumps A & B (seal water)	o Feedwater Pumps o Feedwater Control Valves o Feedwater Bypass Valves o Feedwater Isolation Valves o Feedwater Valve Controllers
5. Auxiliary Feedwater	o Turbine Driven Pump Speed Control		o Motor driven and turbine driven AFW pumps (bearings)	o Motor Driven AFW Pumps o Turbine Driven AFW Pump Controller o Motor Driven Pump Train Controllers o Motor Driven AFW Pump Discharge Valves V2-16A,B,&C o Motor Driven AFW Pump Control Valves 45 & 46 o Turbine Driven AFW Pump Discharge Valves V2-14A,B,&C o Turbine Driven AFW Steam Supply Valves V1-8A,B,&C o Steam Generator Low-Low Level Instr. Strings SG1 LC-474A, 475A, 476A SG2 LC-484A, 485A, 486A SG3 LC-494A, 495A, 496A
6. Chemical and Volume Control System	o Isolation Valves to RCS: CVC-310A, B CVC-311 o Charging Line FCV o Letdown Icolation Valves o Pump Suction Valve from RWST o Charging Pump Speed Control	o Charging pumps (lube oil cooling)		o Charging Pumps o Pumps Suction Valves LCV-115C, LCV-115B, MOV-350 o Isolation Valves to RCS CVC-310A & B, CVC-311 o Charging Line FCV, HCV-121 o Letdown Isolation Valves LCV-460A& B o Letdown Orifice Valves CVC-200A, B & C o Letdown Isolation Stops CVC-204A & B o PZR Level Controller, LC-459F

5.3.1 Reactor Coolant Pumps

The three reactor coolant pumps (RCP's) require 4160 VAC motive power and 125 VDC breaker control power to operate. Seal injection water is supplied to the RCP's from the charging pumps and cooling water for the bearing lube oil coolers and thermal barrier cooling coil is supplied from the CCW system.

Loss of DC control power to the RCP breakers will prevent operating pumps from being tripped. Loss of charging flow could lead to RCP seal failure unless the pumps are tripped.

5.3.2 Pressurizer Power Operated Relief Valves

The two pressurizer PORV's are designed to open on high pressurizer pressure to prevent or minimize the lifting of pressurizer code safety valves. The two PORV's are opened by energizing solenoid valves powered from 125 VDC auxiliary panels DC and GC. The solenoids supply opening air to the PORV's. The pressurizer pressure transmitters, PT-445 and 444, which are powered from instrument buses 3 and 4, respectively, open the PORV's on high pressure.

Loss of instrument air, failure of the 125 VDC auxiliary panels or loss of power on the respective instrument buses will result in the PORV's closing or remaining closed.

5.3.3 Turbine Protection System

Turbine protection by turbine trip is accomplished by depressurizing the hydraulic fluid system which normally holds the governor, reheat, intercept, and stop valves to the turbine open. Hydraulic pressure release is accomplished by opening any of 3 solenoid operated valves (20-ET, 20-1, and 20-2) or by opening the mechanically activated auto-stop trip valve maintained closed by the auto-stop lube oil pressure. A fourth solenoid operated valve, 20-AST, can also open the mechanical auto-stop trip valve.

All four solenoid operated valves require electrical power to open (to actuate turbine trip). The non-mechanical auto-stop turbine trip will

not occur if the 125 VDC Bus A is de-energized due to the lack of power availability to the solenoid of 20-AST. This is also true for the Turbine Emergency Trip (20-ET), except that the power is supplied from 125 VDC Bus B. Loss of power from DC Bus B, also fails solenoids 20-1 and 20-2, preventing a Governor/Intercept Trip.

Additional and diverse turbine protection is provided by the Turbine Redundant Overspeed Trip System (TROTS) which operates under a 2 out of 3 logic scheme. Loss of power to two of the three TROTS control channels powered from 120 VAC Instrument Buses 6, 7 and 8 will initiate turbine trip. Actuation of additional solenoids* is required to implement this turbine trip.

5.3.4 Steam Dump System

Three steam side PORV's and five steam dump valves are provided to relieve steam from the main steam lines to the atmosphere and condenser when required. These valves are pneumatically operated and designed to fail closed upon loss of pneumatic pressure.

The steam side PORV's and steam dump valves open by energizing solenoid valves to open, (powered by 125 VDC auxiliary panels DC and GC) which results in pressurization of the PORV's with air and the steam dump valves with nitrogen. Additionally, the steam dump valves require the nitrogen supply to be armed (supply valves open), which requires that an arming signal exist.

The steam dump valves normally operate under the T_{ave} steam dump control system but can be operated under the steam dump pressure control system for plant cooldown. This analysis assumes the T_{ave} control configuration. Control of the steam side PORV's, which is normally from independent pressure controllers, switches to the T_{ave} steam dump control when a sudden

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*The power supply to these solenoids has not been determined at this time but is assumed to be from DC Bus A and DC Bus B to redundant solenoids. Failure of both DC buses would then be required to fail the TROTS turbine trip.

loss of load occurs. Loss of power to PM-447, the loss-of-load signal generator, precludes control of the steam side PORV's by the T_{ave} control system. The loss-of-load signal from PM-447 also provides the arming signal to the steam dump valves. When T_{ave} falls below a certain setpoint, the arming signal is removed. The signals required for automatic opening of the steam dump valves and PORV's under T_{ave} control (high T_{ave} and sudden of loss-of-load signals) require 120V AC power from instrument buses 1 and 4.

5.3.5 <u>Main Steam Isolation Valves (MSIV's)</u>

Each of the three main steam lines has an air operated swing disk MSIV. The MSIV's (V1-3A, B, and C) are designed to isolate the containment and limit the release of steam from the steam generators following main steam line break accidents. The MSIV's are located in the steam lines downstream of the main steam safety valves and the steam-side PORV's, and outside the containment.

Each MSIV has two 3-way solenoids, in series, which when energized supply instrument air pressure to the MSIV bottom chamber and hold the MSIV open. These two solenoids are supplied 125V DC power from auxiliary DC panels DC and GC, respectively. Loss of power supply to either solenoid or loss of instrument air to the bottom chamber will cause the valve to close with spring assist. The MSIV's also close on any of the following signals: high steam flow coincident with either low steam line pressure or low T_{ave}; high-high containment pressure; or manual actuation.

Each steam line has a motor operated bypass valve to equalize upstream and downstream pressures to permit MSIV reopening after closure. All three bypass valves are normally closed and fail as is on loss of their power supply (120/208 VAC MCC-8). The bypass valves must be manually actuated.

5.3.6 <u>Main Feedwater Pumps</u>

Safety injection or high steam generator level signals will trip the main feedwater pumps. Switchgear for feedwater pumps A and B is powered from 125 VDC buses A and B, respectively. Failure of the 125 VDC power

supply will prevent tripping of operating pumps. The pumps will trip from undervoltage on their respective motive power supply (4KV Buses 1 and 4). In the long term, the pumps will fail if service water cooling to the pump lube oil coolers is lost.

5.3.7 Main Feedwater Control Valves

The main feedwater flowrate to each steam generator is controlled by a pneumatically operated control valve in response to feedwater demand signals. Flow to steam generators 1, 2, and 3 is controlled by control valves FCV-478, 488, and 498, respectively. The feedwater demand signal for each control valve is developed based on steam generator steam flow, feedwater flowrate and steam generator water level. The normal demand signals are overridden by low T_{ave} coincident with reactor trip , high steam generator water level or safety injection signals, which close all control valves.

The FW control valves are designed to close on loss of instrument air or control power. The instrument air supply to the control valves from the positioners is isolated by solenoid valves upon loss of power to the solenoids or loss of power to the FW loop control instrumentation. The control instrumentation which positions the FW valves is powered through 120 VAC instrument buses 1, 2, and 3 for valves FCV-478, 488, and 498, respectively.

Each control valve has two solenoid valves, in series, which supply air to the valve. These solenoids are powered from auxiliary DC panels DC and GC, respectively. Loss of power to either solenoid results in the control valve closing.

5.3.8 Main Feedwater Isolation Valves

Main feedwater isolation valves V2-6A, B, and C are designed to close and isolate feedwater pump discharge flow to the steam generators. The isolation valves automatically close on a safety injection signal or may be manually closed by the operator.

The valve motors for V2-6A, B and C and associated switchgear are powered from 120/208 VAC MCC-10, 9, and 9, respectively. During normal operation the isolation valves are open. Failure of the associated MCC will result in the valve remaining open.

5.3.9 Main Feedwater Bypass Valves

Feedwater bypass valves FCV-479, 489, 499 are designed to regulate the feedwater flow to steam generators 1, 2, and 3, respectively, at low power conditions. During power operation the bypass valves are normally closed. At low power conditions, the operator normally will manually position the bypass valves to regulate steam generator level. The opening of the bypass valves is prevented in the presence of either safety injection or high steam generator level signal. As a part of the reactor trip runback sequence, this valve is manually opened to a pre-determined setpoint based on feedwater flow required to maintain steam generator level. The bypass valves can allow a maximum flow rate of about 15% of nominal feedwater flow.

Each bypass valve has two solenoid valves, in series, which supply opening air to the valve. These solenoids are powered from auxiliary DC panels DC and GC, respectively. Loss of power or instrument air to either solenoid results in the bypass valve remaining closed or closing.

5.3.10 Auxiliary Feedwater System

The auxiliary feedwater system is designed to provide feedwater to the steam generators if the main feedwater system is incapable of maintaining a minimum steam generator level.

The auxiliary feedwater system consists of two motor driven pumps, A and B, and one steam turbine driven pump. The motor operated isolation valves on the pump discharge lines to the steam generator open when their respective pumps are actuated. These valves can be manually closed from the control room to isolate flow to any of the steam generators. A low level signal in any two steam generators or a direct signal of loss of power to the main feedwater pumps will automatically start the steam driven AFW pump by

opening steam admission valves and the auxiliary feedwater discharge valves to individual steam generators. The signals for starting the motor driven AFW pumps and opening the associated discharge valves are both feedwater pump breakers open, low level in any steam generator, or a safeguards actuation signal.

Control of AFW flow is based on a constant, predetermined flow rate to each steam generator and may be manually controlled via the discharge valves to the individual steam generators.

The motor operated isolation valves and turbine pump steam supply valves will fail as is on loss of power. These valves are normally closed. The turbine pump speed controller requires instrument air and will fail at full speed on loss of instrument air.

All three auxiliary feedwater pumps require service water to cool their motor bearings. Loss of service water can fail these pumps in the long term.

5.3.11 Chemical and Volume Control System

The Chemical and Volume Control System (CVCS) is designed to remove, purify and replace reactor coolant at a controlled flowrate to maintain pressurizer level during reactor operation. The system provides chemicals to the RCS to control reactor coolant chemistry and seal water to the RCP seals. Letdown flow is controlled by the letdown orifices and isolation valves, CVC-200 A, B, and C.

Reactor coolant is delivered to the RCS by one or more of the positive displacement charging pumps. When in automatic control, the pressurizer level controller will automatically vary the speed of the operating charging pumps to control pressurizer level. One pump is normally in use with the second and third pump on standby with manual start and optional automatic control.

The CVCS requires instrument air and control power for valve positioning and motive power for charging pumps and motor operated valves to function.

Loss of instrument air results in closure of the letdown stop valves, resulting in letdown isolation. Loss of air to the charging pump speed controllers results in full speed pump operation.

Loss of power to the pressurizer level controller from 120 VAC instrument bus 4 results in letdown isolation and runback of the charging pump speed to a present minimum speed designed to ensure that sufficient seal water and minimum charging flow requirements are met. Flow can be restored by operating the pumps in the manual, rather than automatic mode.

In addition to electric power, the charging pumps require cooling water from the CCW system for their lube oil coolers. Loss of CCW can lead to eventual pump failure in the long term.

5.3.12 Safeguards Actuation System

The Safeguards Actuation System consists of two trains, A and B. Safeguards Trains A and B can be actuated by low pressurizer pressure, high containment pressure, high steam line differential pressure, or high steam flow coincident with either low steam line differential pressure or with low T_{ave}. The actuation of both trains causes the two low pressure injection pumps (RHR pumps) and the three high pressure injection (SI) pumps to start. In addition, the SI discharge valves open, the reactor will trip, main feedwater isolates, all service water pumps and component cooling water pumps are started, and AFW is initiated.

Safeguards Trains A and B are powered from 125 VDC Buses A and B, respectively. If power is lost on DC bus B, train A safeguards system components can still actuate on demand, but train B components cannot, (and visa versa).

The three strings of pressurizer pressure instrumentation, that are each powered from separate instrument buses produce a low signal on loss of their power supply. Loss of power to any two of these generates the low pressure signal, which initiates safety injection. Other instrumentation signals that initiate SI will not do so on loss of their power supplies

since these others require a high signal to initiate SI and the power loss results in low signals.

5.3.13 Safety Injection System

The safety injection system (SI) is designed to supply borated water to the reactor core in the event of a loss of coolant accident. The SI system discussed here is the high pressure injection portion of the system. The system consists of three SI pumps, associated injection valves, as well as three pressurized accumulators that can passively deliver borated water to the RCS at lower RCS pressure. The three SI pumps take suction from the RWST and feed a common header which supplies the three cold legs through the Boron Injection Tank (BIT) and also feeds two RCS hot legs. Hot leg injection is manually actuated, while cold leg injection is actuated on an SI signal.

The SI electric power supply is divided into two trains, A and B, each providing 480 and 120 VAC power. Train A (480 VAC Bus E1 and 480 VAC MCC-5) powers SI pump A, cold leg injection valve SI-870A, and the RCS Loop 2 hot leg injection valve. Train B (480 VAC Bus E2 and 480 VAC MCC-6) powers SI pumps B and C, cold leg injection valve SI-870B, and the RCS loop 3 hot leg injection valve. The SI pump circuit breakers require power from 125 VDC Bus A for Train A pumps and 125 VDC Bus B for Train B pumps.

The cold leg injection valves are arranged in parallel, so that either valve can deliver SI flow to the three cold legs. The hot and cold leg injection valves are motor operated and normally closed. These will fail as is upon loss of power.

In addition to electric power, the pumps require cooling water from the CCW and SW systems. Cooling water for the pumps' bearing and seal coolers is provided from the Service Water and CCW systems, respectively. Loss of cooling water can lead to eventual pump failure.

5.3.14 Residual Heat Removal System (RHR)

The RHR System provides low pressure injection (LPI) which is actuated on an SI signal and decay heat removal during shutdown. The system utilizes two pumps which take suction from the RWST during LPI. Flow from these pumps is controlled by two air operated control valves and passes through two motor operated isolation valves before discharging into the RCS cold legs.

The system power supply is divided into two trains, A and B, each providing 480 and 120 VAC power. RHR pump A and isolation valve RHR-744A are supplied train A power from 480 VAC Bus E1 and 480 VAC MCC-5, respectively. RHR pump B and isolation valve RHR-744B are supplied train B power from Bus E2 and MCC-6, respectively. The RHR pump circuit breakers require power from the associated 125 VDC Bus A for Pump A and 125 VDC Bus B for Pump B.

The RHR motor operated isolation valves are normally closed and will fail as is on loss of power. The air operated control valves are normally open and fail closed on loss of air. There is a locked open bypass valve around one of the control valves that ensures flow to the isolation valves. The isolation valves automatically open on an SI signal.

In addition to electric power, the RHR pumps require CCW for the pump seal water heat exchangers. Loss of cooling water can lead to eventual pump failure in the long term.

5.3.15 Reactor Protection System

The reactor protection system consists essentially of control/logic cabinets which cause the control rods to drop into the core on the detection of a variety of unfavorable plant states. Reactor trip (rod drop) will occur on: loss of power to both motor generator sets powered from the 480V Buses 2B and 3; or loss of 125 VDC power from Buses A or B to either reactor protection train or to the reactor trip circuit breakers. Reactor trip will also occur upon undervoltage detection on 2/3 of the 4KV buses 1, 2 or 4. Failure of any one of the 120 VAC instrument buses, which power the separate reactor trip channels transmitting process signals, will not

directly cause a reactor trip due to the 2 out of 3 logic arrangement that prevails in the reactor protection system.

6.0 IMPACT OF SUPPORT SYSTEM FAILURES

In this chapter the effects of postulated support system failures on aspects of the plant state potentially important to PTS sequences are assessed. The impact of each support system failure postulated is described in Section 6.1 and the potential impact of the plant responses on PTS sequences is assessed. Section 6.2 summarizes the support system failures that are considered of potential concern to PTS sequences.

6.1 Impact of Postulated Failures

In this section the change in plant systems and components in response to postulated support system failures is described. Thirty-six support system failures were postulated including 33 cases involving failure of electrical buses (loss of voltage on the bus), failure of the instrument air system (loss of instrument air pressure), and failure of the CCW and SW systems (loss of system flow).

Many of the failures postulated are low probability events. In addition, the operator may be able to take remedial action or manual control to restore operability in many cases.

The initial conditions assumed for the analysis are that the plant is in a normal automatic control mode and the on-site electrical system is configured as shown in Figure 1. Immediate effects due to support system failures have been noted. In addition, certain failures leading to long term effects, such as the potential loss of RCP seals due to the unavailability of seal water, have been noted.

6.1.1 Electrical Bus Failures

Electric bus failures can occur for a variety of reasons including isolation or failure of feeder buses, equipment faults not cleared by local breakers, or faults that could occur during maintenance. For purposes of this analysis, single unspecified failures were postulated at various points in the power distribution circuitry. A bus failure was assumed to de-energize the directly affected bus and buses fed from the failed bus. The batteries

supplying DC Buses A and B were considered to be fully charged and the diesel generators were assumed to be unavailable.

The impact of single bus failures was assessed first. The buses considered included the 4KV buses, the 480V buses, the 480V and 120/208V MCC's, the 125V DC buses, and DC Auxiliary Panels "DC" and "GC". In addition, certain double bus failures were postulated. Those considered two failed 4KV buses at a time and failure of both DC Buses A and B. Lastly, the existence of maintenance ties was considered by postulating failure of the vital instrument buses tied to MCC-8 on 4KV Bus 3. The 125V DC buses have multiple power supplies and have no maintenance ties.

The response of the systems and components to the postulated electric power failures are summarized in Table 3. The table also includes an assessment of whether or not the plant response is of potential concern to PTS sequences and warrants further consideration. The assessment is based on eliminating those sequences that were clearly not of PTS concern.

Loss of any one of the 4KV Buses 1, 2 (and associated Bus E1 diesel) or 4 would be expected to have little or no impact from a PTS standpoint; although a reactor and turbine trip would be expected due to loss of RCP's. However, loss of 4KV Bus 3 would result in the following simultaneous effects: turbine trip, and subsequent reactor trip, letdown isolation, one pressurizer relief valve would fail closed, all steam dump valves would fail closed, charging flow (assumed in the auto mode) would runback to a minimum level and only one SI pump would be available. The pressurizer relief block valves would not be operable if required to close. Loss of 4KV Bus 2 would result in isolation of one main feedwater loop and failure of all five steam dump valves in the closed position.

Loss of power to the 125 VDC buses results in multiple effects. Loss of DC Bus A produces a reactor trip signal, which initiates a turbine trip and transfer of the 4KV buses from the unit auxiliary transformer to the startup transformer; however, the transfer cannot be completed without power from DC Bus A and thus, power is also lost on 4KV Buses 1 and 2. This sequence does not occur on the loss of DC Bus B; or on the simultaneous

Table 3. Impact of Electric Power Failures on Systems and Components Important to PTS Sequences

Postulated Failures	System/Component Response	Response of Potential Concern to PTS Sequences
<u>Single Bus Failures</u>		
1. Loss of 4 KV Bus 1	o FW Pump A off o RCP A off (reactor trip due to resulting transient)	No
2. Loss of 4 KV Bus 2	o FW Loop 1 isolation o STM dump valves fail closed o RCP C off (reactor trip due to resulting transient)	No
3. Loss of 4 KV Bus 3 (and associated 480 V diesel generator)	o PORV RC-455C stays closed o PORV block valves failed open o STM dump valves fail closed o STM PORV's fail closed if load reject signal PM-447 exists o Turbine Trip (and RT by logic) o Letdown isolation o Minimum auto charging pump flow (manual recovery may be required) o Loss of all SI pumps except A	No
4. Loss of 4 KV Bus 4	o FW Pump B off o RCP B off (reactor trip due to resulting transient)	No
5. Loss of 125 VDC Panel A (which through logic, also results in loss of 4 KV Buses 1 and 2)	o All PZR heaters off o PZR aux-spray valve fail closed o Reactor Trip o Turbine Trip (from 2/3 TROTS channels) o SI Train B actuated (from 2/3 PZR low pressure) o RCP A and C off o MSIV's close (given spring assist operates) o AFW actuates o PORV RC-456 stays closed o All STM dump valves and STM-side PORV's fail close o FW isolation o Letdown isolation	Yes

Table 3. Impact of Electric Power Failures on Systems and Components Important to PTS Sequences (Continued)

Postulated Failures	System/Component Response	Response of Potential Concern to PTS Sequences
Single Bus Failures (Cont.)		
	o Instrument air capacity marginal (compressor B only) o Charging line to Loop 2 cold leg failed open, but no change in charging flow	
6. Loss of 125 VDC Panel B	o Reactor Trip (and TT by logic) o SI Train B actuated (from 2/3 PZR low pressure) o 2 STM Dump Valves fail closed (A-2 and B-3) o FW isolation o Letdown isolation o Both pressurizer PORV's fail closed o PZR control heaters on o AFW actuates with only MAFW pump A available o MSIV's close (given spring assist operates)	Yes
7. Loss of 125 VDC Aux. Panel "DC"	o PZR aux-spray valve fails closed o PORV RC-456 fails closed o STM side PORV's fail closed o 3 STM dump valves fail closed (A-1, B-1, B-2) o MSIV's close (given spring assist operates) o FW isolation (control and bypass valves closed) o Letdown isolated o Charging line to Loop 2 cold leg failed open, but no change in charging flow	Yes
8. Loss of 125 VDC Aux. Panel "GC"	o PORV RC-455C fails closed o 2 STM dump valves closed (A-2, B-3) o MSIV's close (given spring assist operates) o FW isolation o Letdown isolated o Charging line to Loop 1 cold leg failed open, but no change in charging flow	No

Table 3. Impact of Electric Power Failures on Systems and Components Important to PTS Sequences (Continued)

Postulated Failures	System/Component Response	Response of Potential Concern to PTS Sequences
Single Bus Failures (Cont.)		
9. Loss of 480 V Bus 1	o None	No
10. Loss of 480 V Bus 2A	o Primary Air Compressor failed o Delayed Turbine Trip (due to eventual EH system depressurization)	No
11. Loss of 480 V Bus 2B	o None	No
12. Loss of 480 V Bus 3	o Delayed Turbine Trip (eventual EH system depressurization) o Turbine Trip (RT by logic)	No
13. Loss of 480 V Bus E1	o STM dump valves fail closed o Loop 1 FW isolated	No
14. Loss of 480 V Bus E2	o PORV RC-455C fails closed o STM dump valves fail closed o STM PORV's fail closed if load reject signal PM-447 exists o Minimum auto charging pump flow (manual recovery may be required) o Letdown Isolated o 2/3 SI pumps off (B and C)	No
15. Loss of 480 V Bus DS	o One charging pump and one CCW pump failed	No
16. Loss of 480 V MCC-2	o Delayed TT (due to eventual EH system depressurization)	No
17. Loss of 480 V MCC-3	o None	No
18. Loss of 480 V MCC-4	o TT (Reactor trip by logic) o Delayed TT (due to eventual EH system depressurization) o MSIV bypass valves fail closed	No
19. Loss of 480 V MCC-5	o Loop 1 FW isolated o STM dump valves fail closed	No
20. Loss of 480 V MCC-6	o PORV RC-455C fails closed o STM dump valves fail closed o STM PORV's fail closed if load reject signal PM-447 exists o Minimum auto charging flow (manual recovery may be required)	No

Table 3. Impact of Electric Power Failures on Systems and Components Important to PTS Sequences (Continued)

Postulated Failures	System/Component Response	Response of Potential Concern to PTS Sequences
<u>Single Bus Failures (Cont.)</u>		
21. Loss of 480 V MCC-8	o TT (Reactor Trip by logic) o Delayed TT (due to eventual EH system depressurization) o MSIV bypass valves fail closed	No
22. Loss of 480 V MCC-9	o None	No
23. Loss of 480 V MCC-10	o None	No
<u>Multiple Bus Failures</u>		
1. Loss of 4 KV Bus 2 and 3 (and associated 480 V diesel generators)	o TT (RT by logic) o PORV RC-455C fails closed o PORV block valves failed open o RCP C off o Steam dump valves fail closed o FW Loop 1 isolation o Charging pumps off o Letdown isolated (loss of PZR level control) o HPI not operable o AFW not operable o RHR not operable o Component cooling pumps lost* o Service water pumps off* (resulting in loss of instr. air) MSIV closure (given spring exist operates) Primary and secondary PORV closure FW isolation	Yes
2. Loss of 4 KV Buses 1 and 2 (and associated 480 V diesel generator)	o RCP's A and C off (reactor trip due to resulting transient) o PZR heaters off o Delayed TT and immediate TT by logic o Reactor trip o STM dump valves fail closed o Only inst. air compressor B is left o FW Loop 1 isolated o Charging flow can't be throttled by valve (level control on pump speed is operable)	Yes

*See Table 4 for additional effects

Table 3. Impact of Electric Power Failures on Systems and Components Important to PTS Sequences (Continued)

Postulated Failures	System/Component Response	Response of Potential Concern to PTS Sequences
Multiple Bus Failures (Cont.)		
3. Loss of 4 KV Buses 1 and 4	o Reactor trip o TT (by logic) o RCPs A and B off o FW isolation o AFW actuated by logic (Turbine pump only)	No
4. Loss of 4 KV Buses 1 and 3 (and associated 480 V diesel generators)	o PORV RC-455C stays closed o PORV block valves failed open o Delayed TT (eventual EH system depressurization) o RCP A is off o Reactor trip o Instr. air compressor A left only o Minimum auto charging pump flow (manual recovery may be required) o Letdown isolation o STM dump valves fail closed o STM PORV's fail closed if load reject signal PM-447 exists o SI available with Pump A only	No
5. Loss of 4 KV Buses 2 and 4 (and associated 480 V diesel generator)	o Reactor trip o TT (by logic) o RCP's B and C off o STM dump valves fail closed o FW isolated to Loop 1 via contol valve closure	No
6. Loss of 4 KV Buses 3 and 4 (and associated 480 V diesel generators)	o PORV RC-455C stays closed o PORV block valves failed open o Delayed TT (eventual EH system depressurization) o Immediate Turbine Trip from Governor Control Cabinet (RT by logic) o RCP B is off o Minimum auto charging pump flow (manual recovery may be required) o Letdown isolation o STM dump valves fail closed o STM PORV's fail closed if load reject signal PM-447 exists o SI available with pump A only	No

Table 3. Impact of Electric Power Failures on Systems and Components Important to PTS Sequences (Continued)

Postulated Failures	System/Component Response	Response of Potential Concern to PTS Sequences
Multiple Bus Failures (Cont.)		
7. DC Panel A and B	o Reactor trip o PZR aux-spray valve failed closed o Both primary PORV's closed o TT failure (if TROTS also fails on loss of DC power) o STM dump valves and STM PORV's fail closed o MSIV's closed (given spring assist operates) o FW isolated o Letdown isolated o Charging flow continues to cold legs 1 and 2 from Pump A only. Operator can shut off pump A. o All RCP's on and cannot be tripped o All PZR heaters on and cannot be tripped o SI not operable o AFW not operable o RHR not operable	Yes
Bus Failures with Maintenance Ties		
1. Loss of 4 KV Bus 3* with Instrument Bus 2 tied to 120/208V MCC-8 (Instrument Bus 1 also incurs a temporary voltage reduction due to the 4 KV transfer that is initiated by TT)	o Turbine trip (RT by logic) o PORV RC-455C stays closed o PORV block valves fail open o Steam dump valves fail closed o STM PORV's fail closed if load reject signal PM-477 exists o FW Loop 2 isolates o Minimum auto charging flow (manual recovery may be required) o SI actuated (one SI pump available) o AFW actuated o Letdown isolated	Yes

*Also assumes loss of associated 480 V diesel generators.

Table 3. Impact of Electric Power Failures on Systems and Components Important to PTS Sequences (Continued)

Postulated Failures	System/Component Response	Response of Potential Concern to PTS Sequences
Bus Failures with Maintenance Ties (Cont.)		
2. Loss of 4 KV Bus 3* with Instrument Bus 3 tied to 120/208V, MCC-8 (Instrument Bus 1 also incurs a temporary voltage reduction due to the 4 KV transfer that is initiated by TT)	o Turbine trip (RT by logic) o PORV's RC-455C and RC-456 stay closed o Steam dump valves fail closed o STM PORV's fail closed if load reject signal PM-447 exists o FW loop 3 isolates o Minimum auto charging flow (manual recovery may be required) o SI actuated (one SI pump available) o AFW actuated o Letdown isolated	Yes
3. Loss of 4 KV Bus 3* with Instrument Buses 2 and 3 tied to 120/208V, MCC-8 (Instrument Bus 1 also incurs a temporary voltage reduction due to the 4 KV transfer that is initiated by TT)	o Turbine trip (RT by logic) o PORV's RC-456 and RC-455C stay closed o Steam dump valves fail closed o STM PORV's fail closed if load reject signal PM-447 exists o FW loops 2 and 3 isolate o Minimum auto charging flow (manual recovery may be required) o SI actuated (one SI pump available) o AFW actuated o Letdown isolated	Yes

*Also assumes loss of associated 480 V diesel generators.

loss of both DC buses. When power is lost on both DC buses the 4KV buses are backfed from the 230 KV switchyard. With the loss of DC Bus A and the consequential loss of 4KV Buses 1 and 2, AFW and SI are initiated and the secondary side is isolated. With loss of power on DC Bus B the pressurizer heaters are failed on with both pressurizer relief valves failed closed and the turbine trips, initiating transfer of the 4 KV transfer to the SUT. This induces a momentary power loss on instrument bus 1, which coupled with the loss of instrument bus 3 from DC Bus B, results in SI actuation on a two of three low pressurizer pressure channel logic. See Table 3 for other components impacted by single 125 VDC bus failures.

With loss of power on both 125V DC Buses A and B, a reactor trip is initiated, but at least 3 out of 4 turbine trip systems are failed, due to loss of power to the trip solenoids. The fourth trip system (TROTS) will also fail if DC buses A and B power its trip solenoids as well.* Also, AFW, SI, and low pressure safety injection (RHR) are failed on loss of DC Buses A and B, and all RCP's and pressurizer heaters are failed on and cannot be tripped.

All combinations of double 4KV bus failures were postulated and analyzed (i.e., all double failure combinations of the 4 buses). The postulated failure of 4KV Buses 2 and 3 (including loss of associated diesel generators on Bus E1 and E2) had the greatest impact. The other combinations involving failure of 4KV bus 3 (Bus 3 & 1 and 3 & 4) had lesser impacts. These combinations result in all steam dump valves failing closed, and runback of charging pump flow (although flow could be restored manually). With failure of 4KV Buses 2 and 3 all SI pumps and charging pumps would be inoperable, as would all AFW, component cooling water and service water pumps. Loss of seal flow to the RCP's due to the charging pump failure could potentially lead to RCP seal failure. And in addition, although the

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*The power supply configuration for the TROTS solenoids has not been determined at this time.

lag time would be greater, loss of service water could fail all instrument air compressors, which would eventually cause feedwater isolation, MSIV closure, and primary and secondary side PORV closure.

Failure of 4KV Buses 1 & 2, 1 & 4, and 2 & 4 are similar; except the 1 & 4 combination results in actuation of AFW, and the 1 & 2 combination results in the pressurizer heaters failing off and all instrument air compressors except B failing. These failed bus combinations would all result in reactor trip, turbine trip, two RCP's off, and at least partial feedwater isolation.

The postulated failure of 4KV Bus 3 with maintenance ties to 120V instrument buses 2 or 3 through MCC-8 maintenance tie led to evaluation of three additional failure modes. Failure of 4KV Bus 3 will initiate a transfer of the 4KV buses to the SUT. The transfer of 4KV Bus 1 to the SUT will induce a momentary power loss on Instrument Bus 1. This momentary loss, coupled with the loss of either Instrument Bus 2 or 3 will actuate SI on a two of three low pressurizer pressure channel logic.

In addition to the conditions that failure of 4KV Bus 3 would initiate, loss of Instrument Bus 2 or Instrument Bus 3 in combination with the momentary loss of Instrument Bus 1 will result in SI and AFW actuation, main feedwater isolation (due to SI), and PORV RC-456 unavailability (Instrument Bus 3 only).

6.1.2 Instrument Air System Failures

Instrument air system failure (low pneumatic supply pressure) can be caused by a passive failure of the instrument air headers or loss of motive or control power to the instrument air compressors. Normal plant instrument air requirements can be satisfied by either the primary air compressor or either instrument air compressor A or B. Thus, failure of one or two of the compressors will not result in system failure. No single or double bus failures will directly result in loss of all three compressors. Loss of service water to the compressors would lead, ultimately, to failure of the three instrument air compressors as well as the station air compressor. A double bus failure of 4KV Buses 2 & 3 will fail service water. The time

required for the compressors to fail following a loss of service water is unknown; however, the operator is expected to trip the compressors rather than allow them to run to failure. Following loss of the compressors, the instrument air system is expected to depressurize over a period of minutes, perhaps longer, depending on the air requirements during the particular transient.

The effects of instrument air failure on the systems and components important to PTS are provided in Table 4. The primary and secondary side PORV's would fail closed, as would the MSIV's, feedwater control and bypass valves (if open), letdown isolation valves, and RHR supply valves to the RCS. This would isolate feedwater and letdown flow but would not fail low-pressure injection since a locked open bypass exists around one of the air operated RHR valves. The steam dump valves, which require N_2 for actuation, are not impacted by loss of instrument air, but fail closed on loss of N_2. Loss of air to the speed controllers on the AFW turbine pump and the charging pumps would result in pump operation at full speed. In addition, charging flow supply and control valves would fail open. Thus, charging pumps would have to be manually controlled (turned off and on) to control charging flow.

6.1.3 Cooling Water System Failures

Failure of the component cooling water system and service water system can be caused by loss of power to the respective supply pumps or by mechanical pump failures. Supply valves in the systems are normally open. The air-operated valves normally fail open and the motor-operated valves fail as is.

All three CCW pumps must be inoperable in order to fail CCW. Loss of motive power on the 480V Buses DS, E1, and E2 or loss of motive power on the 480V Bus DS and control power on DC Buses A and B would fail the CCW pumps. If diesel generators were unavailable, faults on 4KV Buses 2 and 3 would also fail CCW.

Normally two of the four service water pumps are required for the service water system to be operable during transient conditions. Loss of motive

Table 4. Impact of Loss of Instrument Air, Component Cooling Water, and Service Water on Systems and Components Important to PTS Sequences

Postulated Failures	System/Component Response	Response of Potential Concern to PTS Sequences
Loss of Instrument Air	o Primary PORV's fail closed o STM PORV's fail closed o MSIV's fail closed (given spring assist operates) o FW isolation (control and bypass valves closed) o Auto throttling of charging flow is failed (control valves failed open and charging pump speed control is lost) o Letdown isolated and charging pump speed control is lost, failing pump full speed o AFW turbine pump full speed, if pump is operating (due to failure of speed controller)	Yes
Loss of CCW	o Charging Pump failure (due to loss of lube oil cooling) o Potential RCP seal failure (due to loss of RCP thermal barrier coil cooling and seal injection from charging pumps) o SI pump seal failure o RHR pump seal failure	Yes
Loss of SWS	o Loss of FW pumps (FW isolation) o Loss of AFW (pumps) o SI (pump) failure o Loss of IA (primary and Inst. air compressors) MSIV's close (given spring assist operates) PORV's fail closed STM PORV's closed Letdown isolated Auto throttling of charging flow failed Loss of RHR o Slow loss of CCW (loss of heat sink from HX's) o Potential RCP bearing failure	Yes

power on both 480V E1 and E2 buses would fail the four service water pumps. Depending on which pumps were operating, loss of control power from either DC Panel (A or B) could prevent standby pumps from being started, if required. In addition, loss of service water to the CCW heat exchangers would result in a slow degradation of the CCW system due to loss of heat removal.

The effects of cooling water system failures on the systems and components important to PTS are provided in Table 7 with the effects of instrument air failures. Loss of CCW could lead to eventual seal degradation or failure of the charging pumps, the SI pumps, and the RHR pumps. Loss of the charging pumps would fail seal water to the RCP's which could lead to RCP seal failure and a small break LOCA. However, this would be a very long term sequence and operator recovery is expected to occur before seal failure occurs. CCW also cools the RCP bearings and the thermal barrier cooling coil.

Loss of service water would result in loss of all three instrument air compressors and subsequent unavailability of the instrument air system. AFW pumps, feedwater pumps, and SI pumps also require service water. The system level effects of a service water system failure including the subsequent loss of instrument air would include: feedwater and letdown isolation; inoperability of AFW, SI, RHR, and charging flow auto control; and closure of MSIV's, and primary and secondary side PORV's.

6.2 Support System Failures Considered to be of Potential Concern to PTS Sequences

Plant responses from 12 of the 36 support system failures postulated were considered to be of potential concern to PTS sequences. These included loss of instrument air, loss of component cooling water, loss of service water, and nine cases involving electrical bus failures. The plant responses to these support system failures are summarized in Table 5.

Table 5. Selected Postulated Support System Failures and Responses Considered to be of Potential Concern to PTS Sequences

Postulated Failure	System/Component Response												
	Reactor Trip	Turbine Trip	RC Pumps	Pressurizer and Primary PORVs	STM Dump Valves	Steam Side PORVs	MSIVs	Feedwater Isolation	Feedwater Runback	AFW	Safety Injection[a]	Charging Pump Flow	Letdown Flow
Electrical System Failures													
1. 125 VDC Panel A (and associated 4 KV Buses 1 & 2)	Reactor Trip	Turbine Trip	RCP A and C off	PZR heaters off, aux-spray valve closed, RC-456 stays closed	Closed	Closed	Closed	Isolated	N/A	Actuates	Train B actuates	Operable	Isolated
2. 125 VDC Panel B	Reactor Trip	Turbine Trip	Operable	PORVs failed closed, control heaters on	A-2 and B-3 closed	Operable	Closed	Isolated	N/A	Actuates (only 1 motor driven pump available)	Train A actuates	Operable	Isolated
3. 125 VDC Aux Panel "DC"	Operable	Operable	Operable	RC-456 closed, aux-spray valve closed	A-1, B-1, B-2, closed	Closed	Closed	Isolated	N/A	Operable	Operable	Operable	Isolated
4. DC Buses A & B	Reactor Trip	Immediate turbine trip fails	Cannot be tripped off	PORVs closed, aux spray valve closed, PZR heaters failed on	Closed	Closed	Closed	Isolated	N/A	Not operable	HPI and LPI not operable	Operable	Operable
5. 4 KV Buses 2 & 3 (and associated D/G's)	Reactor Trip	Turbine Trip	RCP C off, Potential seal failure	RC-455C closed, block valves failed open, and RC-456 eventually closed[d]	Closed	Eventual[d] closure	Eventual[d] closure	Loop 1 isolated, and eventual isolation of other FW loops[d]	Operable	Not operable	HPI and LPI not operable	No flow, pumps failed	Isolated
6. 4 KV Buses 1 & 2 (and associated	Reactor Trip	Turbine Trip	RCP A & C off	PZR heaters off	Closed	Operable	Operable	Loop 1 Isolated	Operable	Operable	Operable	Operable, but discharge throttle valve fails open	Operable

Table 5. Selected Postulated Support System Failures and Responses Considered to be of Potential Concern to PTS Sequences (Con't)

Postulated Failure	System/Component Response												
	Reactor Trip	Turbine Trip	RC Pumps	Pressurizer and Primary PORVs	STM Dump Valves	Steam Side PORVs	MSIVs	Feedwater Isolation	Feedwater Runback	AFW	Safety[a] Injection	Charging Pump Flow	Letdown Flow
7. 4 KV Bus 3 with maintenance tie to instr. bus 2	Reactor Trip	Turbine Trip	Operable	RC-455C closed, block valves failed open	Closed	Closed[b]	Operable	Loop 2 isolated	Operable	Actuated	Actuated (only 1 SI pump available)	Low flow[c]	Isolated
8. 4 KV Bus 3 with maintenance tie to instr. bus 3	Reactor Trip	Turbine Trip	Operable	PORVs closed	Closed	Closed[b]	Operable	Loop 3 isolated	Operable	Actuated	Actuated (only 1 SI pump available)	Low flow[c]	Isolated
9. 4 KV Bus 3 with maintenance tie to instr. bus 2 & 3	Reactor Trip	Turbine Trip	Operable	PORVs closed	Closed	Closed[b]	Operable	Loop 2 & 3 isolated	Operable	Actuated	Actuated (only 1 SI pump available)	Low flow[c]	Isolated
<u>Instrument Air System Failures</u>													
10. Loss of Instr. Air	Operable	Operable	Operable	PORVs closed	Operable	Closed	Closed	Isolated	N/A	Overfeed if turbine pump is actuated	RHR inoperable	Overfeed (loss of speed control and throttle valve open)	Isolated
<u>Component Cooling Water System Failures</u>													
11. Loss of CCW	Operable	Operable	Potential RCP seal failure	Operable	Operable	Operable	Operable	Operable	Operable	Operable	RHR and SI pump seal failure	Pump seal failure	Operable
<u>Service Water System Failures</u>													
12. Loss of SWS	Operable	Operable	Potential RCP bearing failure	PORVs closed[d]	Operable	Eventual[d] closure	Eventual[d] closure	Isolated	N/A	Inoperable	SI pumps inoperable RHR inoperable	Overfeed[d] (loss of speed control and throttle valve open)	Isolated[d]

[a]Accumulator injection remains operable under all failures postulated.

[b]Steam-side PORVs only failed closed if load reject signal from PM-447 exists.

[c]Manual recovery may be required.

[d]Failure results in loss of SWS, which can fail the instrument air compressors.

6.2.1 Electric System Failures

Three postulated electric system failures would directly result in feedwater isolation with AFW operable, and so, could potentially initiate certain PTS sequences. Three additional failures would initiate SI directly which would then subsequently isolate main feedwater. These three also do not impact AFW operability and could initiate certain PTS sequences involving potential AFW overfeed.

Two of the electrical system failures (loss of both DC buses A & B and loss of 4KV Buses 2, 3, & their diesel generators) result in reactor trip, AFW and SI inoperability, and secondary side isolation. The 4KV bus failure also results in loss of RCP seal water flow. These may not be of direct PTS concern, since overcooling and pressurization do not occur directly, but upon recovery from the bus failures system responses may be PTS adverse. Subsequent failures on recovery of the buses may also be adverse to PTS sequences but have not been addressed in this study.

Loss of 4KV Buses 1, 2 and their diesel generator result in a reactor trip, with AFW and HPI operable and with steam side PORV's and MSIV's operable. The expected frequency of the failure is lower than that of an unspecified reactor trip, but the failure could still initiate sequences adverse to PTS.

6.2.2 Loss of Instrument Air

The loss of instrument air results in secondary side isolation but potential overfeed of AFW and charging flow if operator recovery does not occur. The feedwater isolation forced by the failure could initiate PTS sequences of concern.

6.2.3 Loss of Component Cooling Water

The loss of CCW could initiate an RCP seal failure LOCA and subsequent PTS sequences of concern due to loss of seal flow to the charging pumps. However, many recovery actions are available to prevent the RCP seal

failure, including alternating use of the three charging pumps and tripping of the RCP's.

6.2.4 Loss of Service Water

The loss of the SWS could fail the instrument air compressors or force them to be tripped. The failure could then initiate some PTS sequences similar to those initiated by loss of instrument air. Feedwater isolation would also be forced by a SWS failure, due to pumps cooling requirements, and AFW would be similarly failed due to AFW pump cooling requirements.

7.0 REFERENCES

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3. Discussions with R. Anoba and J. Phillips (Carolina Power & Light) 6/21/84, 7/2/84, 7/5/84, & 7/25/84.

4. H.B. Robinson Unit 2, Abnormal Procedures, AP-1 Rev. 4, Loss of Instrument Air.

5. H.B. Robinson Unit 2, Instrument Air System Reliability Study, by EDS Nuclear Inc., Report No. 03-1320-1035, Rev. A, November 1982.

6. H.B. Robinson Unit 2, Instruction Book For Control and Protection Instrumentation System, Volume 1 - System Description and Installation, prepared by Westinghouse Electric Corporation.

7. H.B. Robinson Unit 2, Logic Diagrams, Sheets 1-18.

8. H.B. Robinson Unit 2, Flow Diagrams - Service and Cooling Water System, Instrument and Service Air System, and Component Cooling Water System, Drawing No's G-190199, G-190200, and 5379-376.

9. H.B. Robinson Unit 2, Control Wiring Diagrams, Drawing No. B-109628, Sheet No's 119, 141, 144, 147, 642, 701, 703, 704, 705, 710, and 711.

10. H.B. Robinson Unit 2, Safeguards System, Drawing No. CP-380-5379-3227, Rev. 16.

11. H.B. Robinson Unit 2, Reactor Protection System, Drawing No. CP-380-5379-3239, Rev. 10.

12. H.B. Robinson Unit 2, Student Handouts for Operators.

ATTACHMENT 1. PTS COMPONENT DATA BASE

Table 1-1. Components Considered in PTS Interaction Study by System

Systems	Components
Front Line Systems	
1. RCS	o RCP A o RCP B o RCP C o PZR Control Heaters o PZR Backup Heaters A o PZR Backup Heaters B o PZR Pressure Transmitter PT-445 o PZR Pressure Transmitter PT-444 o PORV RC-456 o PORV RC-455C o PORV Block Valve RC-535 o PORV Block Valve RC-536
2. Turbine Protection System	o Turbine Auto Trip Logic and Solenoid (20-AST) o Turbine Emergency Trip Logic and Solenoid (20-ET) o Governor/Intercept Trip Logic and Solenoids (20-1, 20-2) o Governor Control Cabinet o EH System Logic o EH Oil Pump A o EH Oil Pump B o TROTS Channel 1 o TROTS Channel 2 o TROTS Channel 3
3. Main Steam System	o Steam Side PORV RV1 o Steam Side PORV RV2 o Steam Side PORV RV3 o Steam Dump PORV 1324A-1 o Steam Dump PORV 1324B-1 o Steam Dump PORV 1324B-2 o Steam Dump PORV 1324A-2 o Steam Dump PORV 1324B-3 o Steam Dump Controller T-408 o Steam Dump Pressure Controller P-464 o High Tavg Output Logic o Steam Dump Loss-Load Pressure Monitor PM-447 o MSIV V1-3A o MSIV V1-3B o MSIV V1-3C o V1-3A Bypass Valve o V1-3B Bypass Valve o V1-3C Bypass Valve

*See Table 2 for a summary of the interfaces between these components and the support systems.

Table 1-1. Components Considered in PTS Interaction Study by System (Continued)

Systems	Components
Front Line Systems (Cont.)	
4. Main Feedwater System	o FW Pump A o FW Pump B o MFIV V2-6A o MFIV V2-6B o MFIV V2-6C o FW Control Valve FCV-478 o FW Control Valve FCV-488 o FW Control Valve FCV-498 o FW Bypass Valve FCV-479 o FW Bypass Valve FCV-489 o FW Bypass Valve FCV-499 o FW Valve Controller Loop 1 o FW Valve Controller Loop 2 o FW Valve Controller Loop 3
5. Auxiliary Feedwater System	o Motor driven AFW Pump A o Motor driven AFW Pump B o Steam driven AFW Pump Controller o Pump A Train Controller o Pump B Train Controller o Pump Train A Control Valve, 45 o Pump Train B Control Valve, 46 o MAFW Disch VLV V2-16A o MAFW Disch VLV V2-16B o MAFW Disch VLV V2-16C o SAFW Disch VLV V2-14A o SAFW Disch VLV V2-14B o SAFW Disch VLV V2-14C o SAFW Supply VLV V1-8A o SAFW Supply VLV V1-8B o SAFW Supply VLV V1-8C o S/G 1 Level LC-474A String o S/G 1 Level LC-475A String o S/G 1 Level LC-476A String o S/G 2 Level LC-484A String o S/G 2 Level LC-485A String o S/G 2 Level LC-486A String o S/G 3 Level LC-494A String o S/G 3 Level LC-495A String o S/G 3 Level LC-496A String

Table 1-1. Components Considered in PTS Interaction Study by System (Continued)

Systems	Components
Front Line Systems (Cont.)	
6. Chemical and Volume Control System	o Charging Pump A o Charging Pump B o Charging Pump C o PZR Level Controller LC-459F o Charging Pump Suction Valve LCV-115C o Charging Pump Suction Valve LCV-115B o Boric Acid Valve MOV-350 o Loop 1 Cold Leg Inlet Valve CVC-310A o Loop 2 Cold Leg Inlet Valve CVC-310B o Aux Spray Valve CVC-311 o Letdown Stop Valve LCV-460A o Letdown Stop Valve LCV-460B o Letdown Isolation Valve CVC-200A o Letdown Isolation Valve CVC-200B o Letdown Isolation Valve CVC-200C o Letdown Isolation Valve CVC-204A o Letdown Isolation Valve CVC-204B o Charging Line FCV HCV-121
7. Safety Injection System	o SI Pump A o SI Pump B o SI Pump C o ACC Nitrogen Supply SI-855 o ACC Drain Valve SI-852A o ACC Drain Valve SI-852B o ACC Drain Valve SI-852C o ACC Vent Valve SI-853A o ACC Vent Valve SI-853B o ACC Vent Valve SI-853C o ACC Disch Valve SI-865A o ACC Disch Valve SI-865B o ACC Disch Valve SI-865C o Cold Leg Injection VLV SI-870A o Cold Leg Injection VLV SI-870B o BIT Inlet VLV SI-867A o BIT Inlet VLV SI-867B o Inlet Valve to Loop 3 Hot Leg SI-866A o Inlet Valve to Loop 2 Hot Leg SI-866B o Isolation Valve to Hot Legs SI-869

Table 1-1. Components Considered in PTS Interaction Study by System (Continued)

Systems	Components
Front Line Systems (Cont.)	
8. RHR	o RHR Pump A
	o RHR Pump B
	o RHR Suction Valve SI-862A
	o RHR Suction Valve SI-862B
	o RHR Disch Valve HCV-758
	o RHR Disch Valve FCV-605
	o Cold Leg Injection Valve RHR-744A
	o Cold Leg Injection Valve RHR-744B
9. Safeguards System	o Safeguards Train A Logic
	o Safeguards Train B Logic
	o PZR Pressure PC-455E String
	o PZR Pressure PC-456D String
	o PZR Pressure PC-457D String
10. Reactor Protection System	o Control Rod Drive MG Set A
	o Control Rod Drive MG Set B
	o RCP Undervoltage TRP Relay UV-1
	o RCP Undervoltage TRP Relay UV-2
	o RCP Undervoltage TRP Relay UV-3
	o Reactor Protection Train A Logic
	o Reactor Protection Train B Logic
Support Systems	
11. Component Cooling Water System	o Component Cooling Pump A
	o Component Cooling Pump B
	o Component Cooling Pump C
	o Component Cooling Heat Exchangers
	o CCW Disch Valve TCV-659A from Charging Pump
	o CCW Disch Valve TCV-659B from Charging Pump
	o CCW Disch Valve TCV-659C from Charging Pump
	o Header Supply Valve To RCP CC-716A
	o Header Supply Valve To RCP C-716B
	o RCP Motor Oil Cooler Valve CC-730
	o RCP Thermal Barrier Cooling Coil Valve FCV-626

Table 1-1. Components Considered in PTS Interaction Study by System (Continued)

Systems	Components
<u>Support Systems</u>	
12. Service Water System	o Service Water Pump A o Service Water Pump B o Service Water Pump C o Service Water Pump D o SW Disch Valve V6-12B o SW Disch Valve V6-12C o SW Isolation Valve V6-16A o SW Isolation Valve V6-16B o Steam Driven AFW Pump SW Valve TCV-1902 o Motor Driven AFW Pump SW Valve TCV-1903A o Motor Driven AFW Pump SW Valve TCV-1903B o SW Disch Valve TCV-1629A from IA Compressor A o SW Disch Valve TCV-1629B from IA Compressor B
13. Instrument Air System	o Primary Air Compressor o Instrument Air Compressor A o Instrument Air Compressor B
14. Electric Power System	o Diesel Generators A, B & DS o Startup Transformer o Unit Auxiliary Transformer o 125 VDC buses o 4160 VAC buses o 480 VAC buses o 120/208 VAC buses

Table 1-2. Component Failure Modes on Loss of Instrument Air, Component Cooling Water and Service Water

Component Requiring Support System	Normal Position/Mode	Failure Mode on Loss of Space: Instrument Air	CCW	SWS
Front Line Systems				
1. Reactor Coolant System				
RCP's A, B, & C	Operating	N/A	Eventual failure due to bearing failure or thermal barrier cooling coil failure, unless tripped. Seal injection degraded by loss of CCW to charging pumps.	N/A
PORV's RC-456 RC-455C	Closed	Closed	N/A	N/A
2. Turbine Protection System	Operable	N/A	N/A	N/A
3. Main Steam System				
Steam Side PORV's RV1 RV2 RV3	Closed	Closed	N/A	N/A
MSIV's	Open	Closed	N/A	N/A
4. Main Feedwater System				
FW Pumps A & B	Operating	N/A	N/A	Eventual failure, unless tripped.
FW Control Valves	Open	Closed	N/A	N/A
FW Bypass Valves	Closed	Closed	N/A	N/A

Table 1-2. Component Failure Modes on Loss of Instrument Air, Component Cooling Water and Service Water (Continued)

Component Requiring Support System	Normal Position/Mode	Failure Mode on Loss of Instrument Air	CCW	SWS
5. <u>Auxiliary Feedwater System</u>				
Motor Driven AFW Pumps A & B	Standby	N/A	N/A	Pumps fail (bearing failure)
Steam Driven AFW Pump	Standby	Full Speed	N/A	Pumps fail (bearing failure).
6. <u>Chemical And Volume Control System</u>				
Charging Pumps	Operating (1 pump on auto-control, 2 on standby)	Full Speed	Pumps fail (loss of lube oil cooling).	N/A
Charging Line Isolation Valves CVC-310A	Closed	Open	N/A	N/A
CVC-310B	Open	Open	N/A	N/A
Auxiliary Spray Isolation Valves CVC-311	Closed	Closed	N/A	N/A
Charging Line FCV HCV-121	Open	Open	N/A	N/A
Letdown Stop Valves LCV-460A	Open	Closed	N/A	N/A
LCV-460B	Open	Closed	N/A	N/A
Letdown Orifice Isolation Valves CVC-200A	Closed	Closed	N/A	N/A
CVC-200B	Closed	Closed	N/A	N/A
CVC-200C	Open	Closed	N/A	N/A

Table 1-2. Component Failure Modes on Loss of Instrument Air, Component Cooling Water and Service Water (Continued)

Component Requiring Support System	Normal Position/Mode	Failure Mode on Loss of Instrument Air	CCW	SWS
6. Chemical And Volume Control System (Cont.)				
Letdown Isolation Stop Valves				
CVC-204A	Open	Closed	N/A	N/A
CVC-204B	Open	Closed	N/A	N/A
Charging Pump Suction Valve from RWST LCV-115B	Closed	Closed	N/A	N/A
7. SI System				
SI Pumps A, B, & C	Operable	N/A	Eventual failure of pump seals.	Eventual bearing failure.
N_2 Supply Valve to Accumulators SI-855	Closed	Closed	N/A	N/A
Accumulator Drain Valves SI-852 A, B, & C	Closed	Closed	N/A	N/A
Accumulator Vent Valves SI-853 A, B, & C	Closed	Closed	N/A	N/A

Table 1-2. Component Failure Modes on Loss of Instrument Air, Component Cooling Water and Service Water (Continued)

Component Requiring Support System	Normal Position/Mode	Failure Mode on Loss of Instrument Air	CCW	SWS
8. RHR System				
RHR Pumps A & B	Standby	N/A	Eventual pump seal failure.	N/A
RHR Discharge Valves				
FCV-605	Closed	Closed	N/A	N/A
HCV-758	Closed	Closed	N/A	N/A
9. Safeguards Systems	Standby	N/A	N/A	N/A
10. Reactor Protection System	Standby	N/A	N/A	N/A
Support Systems				
11. Component Cooling Water System				
Charging Pump Discharge Valves TCV-659 A, B, & C	Open	Open	N/A	N/A
CCW Heat Exchangers	Operating	N/A	N/A	Loss of cooling capacity.
12. Service Water System				
SWS Control Valves to AFW Pumps A & B and Turbine Pump				
TCV-1902	Closed (open on pump start)	Open	N/A	N/A
TCV-1903A	Closed (open on pump start)	Open	N/A	N/A
TCV-1903B	Closed (open on pump start)	Open	N/A	N/A

Table 1-2. Component Failure Modes on Loss of Instrument Air, Component Cooling Water and Service Water (Continued)

Component Requiring Support System	Normal Position/Mode	Failure Mode on Loss of Instrument Air	CCW	SWS
12. <u>Service Water System (Cont.)</u>				
SWS Control Valves from Instrument Air Compressors TCV-1629 A & B	Open	Open	N/A	N/A
13. <u>Instrument Air System</u>				
Primary Air Compressor	Operating	N/A	N/A	Eventual failure, unless tripped.
Instrument Air Compressor A & B	Intermittent Operation	N/A	N/A	Eventual failure, unless tripped.

TABLE 1-3. COMPONENT POWER SUPPLIES AND ASSOCIATED FAILURE MODES

Component	Control Power Source	Supply Power Source	Failure Mode
<u>Front Line Systems</u>			
1. <u>Reactor Coolant System</u>			
RCP A	DC PNL. A, CKT. 2	4160 V Bus 1	Pump fails on loss of supply power. Pump fails to trip on loss of control power.
RCP B	DC PNL. B, CKT. 2	4160 V Bus 4	Pump fails on loss of supply power. Pump fails to trip on loss of control power.
RCP C	DC PNL. A, CKT. 2	4160 V Bus 2	Pump fails on loss of supply power. Pump fails to trip on loss of control power.
PZR Control Heaters	DC PNL. B, CKT. 4	480 V Bus 2B (4160 Bus 1)	Heaters fail on loss of supply power. Heaters fail to trip on loss of control power.
PZR Backup Heaters "A"	DC PNL. A, CKT. 4	480 V Bus 1 (4160 Bus 2)	Heaters fail on loss of supply power. Heaters fail to trip on loss of control power.

TABLE 1-3. COMPONENT POWER SUPPLIES AND ASSOCIATED FAILURE MODES (Continued)

Component	Control Power Source	Supply Power Source	Failure Mode
PZR Backup Heaters "B"	DC PNL. A, CKT. 4	480 V Bus 2A (4160 Bus 1)	Heaters fail on loss of supply power. Heaters fail to trip on loss of control power.
PZR Pressure Transmitters			
PT-445		Instrument Bus 3 (Inverter B)	PORV-456 fails closed.
PT-444		Instrument Bus 4 (4160 V Bus 3)	PORV-455C fails closed.
PORVs			
RC-456	DC Aux. Pnl. DC CKT. 27		Valve fails closed on loss of control power.
RC-455C	DC Aux. Pnl. GC CKT. 23		Valve fails closed on loss of control power.
PORV Shutoff Valves			
RC-535	120 VAC from 480 V MCC-6	480 V MCC-6 (4160 V Bus 3)	Valve fails as is (open).
RC-536	120 VAC from 480 V MCC-6	480 V MCC-6 (4160 V Bus 3)	Valve fails as is (open).

TABLE 1-3. COMPONENT POWER SUPPLIES AND ASSOCIATED FAILURE MODES (Continued)

Component	Control Power Source	Supply Power Source	Failure Mode
2. Turbine Protection System			
Turbine Auto Stop Trip Logic and Solenoid (20-AST)	DC PNL. A, CKT. 22		No turbine auto stop trip on loss of control power.
Turbine Emergency Trip Logic and Solenoid (20-ET)	DC PNL. B, CKT. 13		No turbine emergency trip on loss of control power.
Gov./Intercept Trip Logic and Solenoids (20-1, 20-2)	DC PNL. B, CKT. 13		No Gov./Intercept valve trip on loss of control power.
Governor Control Cabinet		PP-21 off MCC-8 (4160 V Bus 3)	Turbine trips on loss of power to cabinet.
EH System Logic	120 VAC LP27, CKT. 2 (4160 V Bus 1)		Turbine trip over long term due to EH depressurization.
EH Oil Pump "A"	PP-21 from MCC 8 (4160 V Bus 3)	480 V MCC 4 (4160 V Bus 3)	Failure of Pumps "A" and "B" will cause turbine trip over long term. Loss of PP-21 will fail both pumps.

TABLE 1-3. COMPONENT POWER SUPPLIES AND ASSOCIATED FAILURE MODES (Continued)

Component	Control Power Source	Supply Power Source	Failure Mode
EH Oil Pump "B"	PP-21 from MCC 8 (4160 V Bus 3)	480 V MCC 3 (4160 V Bus 1)	Failure of Pumps "A" and "B" will cause turbine trip over long term. Loss of PP-21 will fail both pumps.
Turbine Overspeed Protection (TROTS) Channel 1	Instr. Bus 6, CKT. 23 4160 V Bus 3		Turbine trip on loss of power to 2/3 channels.
Turbine Overspeed Protection (TROTS) Channel 2	Instr. Bus 7, CKT. 23 Inverter A		Turbine trip on loss of power to 2/3 channels.
Turbine Overspeed Protection (TROTS) Channel 3	Instr. Bus 8, CKT. 23 Inverter B	DC Panel "A" and "B"	Turbine trip on loss of power to 2/3 channels.
TROTS Logic	DC Panel A and B		No TROTS turbine trip.

TABLE 1-3. COMPONENT POWER SUPPLIES AND ASSOCIATED FAILURE MODES (Continued)

Component	Control Power Source	Supply Power Source	Failure Mode
3. <u>Main Steam System</u>			
Steam Side PORVs			
RV1	Aux. Pnl. DC, CKT. 40 for solenoids (PIC-477 controller self contained)		Valve fails closed on loss of control power.
RV2	Aux. Pnl. DC, CKT. 41 for solenoids (PIC-487 controller self contained)		Valve fails closed on loss of control power.
RV3	Aux. Pnl. DC, CKT. 42 for solenoids (PIC-497 controller self contained)		Valve fails closed on loss of control power.
Steam Dump Valves			
PRV 1324 A-1	Aux. DC Pnl. DC, CKT. 38		Fails closed on loss of control power.
PRV 1324 B-1	Aux. DC Pnl. DC, CKT. 38		Fails closed on loss of control power.
PRV 1324 B-2	Aux. DC Pnl. DC, CKT. 38		Fails closed on loss of control power.
PRV 1324 A-2	Aux. DC Pnl. GC, CKT. 38		Fails closed on loss of control power.

TABLE 1-3. COMPONENT POWER SUPPLIES AND ASSOCIATED FAILURE MODES (Continued)

Component	Control Power Source	Supply Power Source	Failure Mode
PRV 1324 B-3	Aux. DC Pnl. GC, CKT. 38		Fails closed on loss of control power.
Steam Dump Control System			
T-408 (Temperature Controller)		Inst. Bus 4 (4160 V Bus 3)	Dump valves fail closed and steam side PORVs fail closed if load reject signal from PM-447 exists.
P-464 (Pressure Controller)		Inst. Bus 4 (4160 V Bus 3)	Not normal control mode.
High Tavg Logic	Instrument Bus 4 (4160 V Bus 3)		Dump valves fail closed.
PM-447 (Loss of Load Pressure Monitor)	Instrument Bus 1 (4160 V Bus 2)		Dump valves fail closed.
MSIVs			
V1-3A ISO	DC Aux. Pnl. DC, CKT. 1 or DC Aux. Pnl. GC, CKT. 40		Fails closed on loss of power to either redundant 3-way solenoid.
V1-3B ISO	DC Aux. Pnl. GC, CKT. 1 or DC Aux. Pnl. DC, CKT. 43		Fails closed on loss of power to either redundant 3-way solenoid.

TABLE 1-3. COMPONENT POWER SUPPLIES AND ASSOCIATED FAILURE MODES (Continued)

Component	Control Power Source	Supply Power Source	Failure Mode
V1-3C ISO	DC Aux. Pnl. GC, CKT. 2 or DC Aux. Pnl. DC, CKT. 44		Fails closed on loss of power to either redundant 3-way solenoid.
V1-3A BYP	120 V MCC 8	208 V MCC-8 (4160 V Bus 3)	Fails as is on loss of supply power (closed).
V1-3B BYP	120 V MCC 8	208 V MCC-8 (4160 V Bus 3)	Fails as is on loss of supply power (closed).
V1-3C BYP	120 V MCC 8	208 V MCC-8 (4160 V Bus 3)	Fails as is on loss of supply power (closed).
4. <u>Main Feedwater System</u>			
FW Pump A	Circuit breaker 52/3, DC Pnl. A, CKT. 2	4160 V Bus 1	Pump fails on loss of supply power. Pump fails to trip on loss of control power.
FW Pump B	Circuit breaker 52/26, DC Pnl. B, CKT. 2	4160 V Bus 4	Pump fails on loss of supply power. Pump fails to trip on loss of control power.
MFW Isolation Valves			
V2-6A	208 V MCC 10	208 V MCC-10 (4160 V Bus 2)	Fail as is on loss of supply power (open).

TABLE 1-3. COMPONENT POWER SUPPLIES AND ASSOCIATED FAILURE MODES (Continued)

Component	Control Power Source	Supply Power Source	Failure Mode
V2-6B	208 V MCC 9	208 V MCC-9 (4160 V Bus 3)	Fail as is on loss of supply power (open).
V2-6C	208 V MCC 9	208 V MCC-9 (4160 V Bus 3)	Fail as is on loss of supply power (open).
MFW Control Valves			
FCV-478			
Sol. A	DC Aux. Pnl. DC, CKT. 47		Valve closes on loss of
Sol. B	DC Aux. Pnl. GC, CKT. 43		power to either solenoid.
FCV-488			
Sol. A	DC Aux. Pnl. DC, CKT. 47		Valve closes on loss of
Sol. B	DC Aux. Pnl. GC, CKT. 43		power to either solenoid.
FCV-498			
Sol. A	DC Aux. Pnl. DC, CKT. 47		Valve closes on loss of
Sol. B	DC Aux. Pnl. GC, CKT. 43		power to either solenoid.
MFW Bypass Valves			
FCV-479			
Sol. A	DC Aux. Pnl. DC, CKT. 46		Valve closes on loss of
Sol. B	DC Aux. Pnl. GC, CKT. 42		power to either solenoid.
FCV-489			
Sol. A	DC Aux. Pnl. DC, CKT. 46		Valve closes on loss of
Sol. B	DC Aux. Pnl. GC, CKT. 42		power to either solenoid.

TABLE 1-3. COMPONENT POWER SUPPLIES AND ASSOCIATED FAILURE MODES (Continued)

Component	Control Power Source	Supply Power Source	Failure Mode
FCV-499			
Sol. A	DC Aux. Pnl. DC, CKT. 46		Valve closes on loss of power to either solenoid.
Sol. B	DC Aux. Pnl. GC, CKT. 42		
FW Valve Controllers			
Loop 1	Inst. Bus #1 (4160 V Bus 2)		FW control valves fail closed.
Loop 2	Inst. Bus #2 (Inverter A)		FW control valves fail closed.
Loop 3	Inst. Bus #3 (Inverter B)		FW control valves fail closed.
5. Aux. Feedwater System			
Motor Driven AFW Pump A	DC PNL. A, CKT. 1	480 V Bus E1 (4160 V Bus 2)	Pump fails as is (normally off) on loss of control power. Pump fails on loss of supply power.
Motor Driven AFW Pump B	DC PNL. B, CKT. 1	480 V Bus E2 (4160 V Bus 3)	Pump fails as is (normally off) on loss of control power. Pump fails on loss of supply power.
Steam Driven AFW Pump Controller	DC PNL. B, CKT. 23 or Aux. Pnl. DC, CKT. 35 for relay "OX"		Pump fails to start on loss of control power.

TABLE 1-3. COMPONENT POWER SUPPLIES AND ASSOCIATED FAILURE MODES (Continued)

Component	Control Power Source	Supply Power Source	Failure Mode
Motor Driven AFW Pump Disch. Valves			
V2-16A	208 V MCC-10 or 208 V MCC-9	NORM: 208 V MCC-10 (4160 V Bus 2) ALT: 208 V MCC-9 (4160 V Bus 3)*	Fails as is (normally closed) on loss of supply power.
V2-16B	208 V MCC-10	208 V MCC-10 (4160 V Bus 2)	Fails as is (normally closed) on loss of supply power.
V2-16C	208 V MCC-9	208 V MCC-9 (4160 V Bus 3)	Fails as is (normally closed) on loss of supply power.
Steam Driven AFW Pump Disch. Valves			
V2-14A	208 V MCC-10	208 V MCC-10 (4160 V Bus 2)	Fails as is (closed) on loss of supply power.
V2-14B	208 V MCC-9	208 V MCC-9 (4160 V Bus 3)	Fails as is (closed) on loss of supply power.
V2-14C	208 V MCC-10	208 V MCC-10 (4160 V Bus 2)	Fails as is (closed) on loss of supply power.

*Alternate supply was assumed in the study.

TABLE 1-3. COMPONENT POWER SUPPLIES AND ASSOCIATED FAILURE MODES (Continued)

Component	Control Power Source	Supply Power Source	Failure Mode
Steam Driven AFW Pump Steam Supply Valves			
V1-8A	120 V MCC-5	480 V MCC-5 (4160 V Bus 2)	Fails as is (closed) on loss of supply power.
V1-8B	120 V MCC-6	480 V MCC-6 (4160 V Bus 3)	Fails as is (closed) on loss of supply power.
V1-8C	120 V MCC-6	480 V MCC-6 (4160 V Bus 3)	Fails as is (closed) on loss of supply power.
SG Low Low Level Instrument Strings			
SG1-LC-474A		Inst. Bus 1 (4160 V Bus 2)	AFW actuates if 2/3 channels de-energize.
SG1-LC-475A		Inst. Bus 2 (Inverter A)	AFW actuates if 2/3 channels de-energize.
SG1-LC-476A		Inst. Bus 3 (Inverter B)	AFW actuates if 2/3 channels de-energize.
SG2-LC-484A		Inst. Bus 1 (4160 V Bus 2)	AFW actuates if 2/3 channels de-energize.
SG2-LC-485A		Inst. Bus 2 (Inverter A)	AFW actuates if 2/3 channels de-energize.

TABLE 1-3. COMPONENT POWER SUPPLIES AND ASSOCIATED FAILURE MODES (Continued)

Component	Control Power Source	Supply Power Source	Failure Mode
SG2-LC-486A		Inst. Bus 3 (Inverter B)	AFW actuates if 2/3 channels de-energize.
SG3-LC-494A		Inst. Bus 1 (4160 V Bus 2)	AFW actuates if 2/3 channels de-energize.
SG3-LC-495A		Inst. Bus 2 (Inverter A)	AFW actuates if 2/3 channels de-energize.
SG3-LC-496A		Inst. Bus 3 (Inverter B)	AFW actuates if 2/3 channels de-energize.
6. CVC System			
Charging Pumps			
A	120 VAC from 480 V Bus DS	480 V Bus DS (4160 V Bus 3)	Pump fails off on loss of 480 V Bus DS.
B	DC PNL. A, CKT. 1	480 V Bus E1 (4160 V Bus 2)	Pump fails as is (off) on loss of control power. Pump fails off on loss of supply power.
C	DC PNL. B, CKT. 1	480 V Bus E2 (4160 V Bus 3)	Pump fails as is (off) on loss of control power. Pump fails off on loss of supply power.

TABLE 1-3. COMPONENT POWER SUPPLIES AND ASSOCIATED FAILURE MODES (Continued)

Component	Control Power Source	Supply Power Source	Failure Mode
Charging Pump Suction Valves			
VCT LCV-115C	120 VAC from 480 V MCC-6	480 V MCC-6 (4160 V Bus 3)	Fails as is (normally open).
RWST LCV-115B	DC Aux. Pnl. DC, CKT. 31		Fails closed on loss of control power.
Boric Acid Valve MOV-350		480 V MCC-5 (4160 V Bus 2)	Fails as is on loss of supply power (normally closed).
Charging Line Valves			
CVC-310A	DC Aux. Pnl. GC, CKT. 15		Fails open on loss of control power (normally closed).
CVC-310B	DC Aux. Pnl. DC, CKT. 22		Fails open on loss of control power (normally open).
Aux. Spray CVC-311	DC Aux. Pnl. DC, CKT. 23		Fails closed on loss of control power (normally closed).

TABLE 1-3. COMPONENT POWER SUPPLIES AND ASSOCIATED FAILURE MODES (Continued)

Component	Control Power Source	Supply Power Source	Failure Mode
Letdown Stop Valves			
LCV-460A	DC Aux. Pnl., CKT. 13		Fails closed on loss of control power to valve and to PZR level controller LC-459F.
LCV-460B	DC Aux. Pnl., CKT. 13		Fails closed on loss of control power to valve and to PZR level controller LC-459F.
PZR Level Controller LC-459F	Instrument Bus 4 & 9 (4160 V Bus 3)		LCV-460 A&B fail closed on loss of controller power and charging pump in "auto" goes to minimum speed.
Letdown Orifice Isolation Valves			
CVC-200A	DC Aux. Pnl. DC, CKT. 18		Fails closed on loss of control power.
CVC-200B	DC Aux. Pnl. GC, CKT. 13		Fails closed on loss of control power.

TABLE 1-3. COMPONENT POWER SUPPLIES AND ASSOCIATED FAILURE MODES (Continued)

Component	Control Power Source	Supply Power Source	Failure Mode
CVC-200C	DC Aux. Pnl. DC, CKT. 2		Fails closed on loss of control power.
Letdown Isolation Stop Valves			
CVC-204A	DC Aux. Pnl. DC, CKT. 3		Fails closed on loss of control power.
CVC-204B	DC Aux. Pnl. GC, CKT. 3		Fails closed on loss of control power.
Charging Line FCV, HCV-121	Instrument Bus 1 & 6 (4160 V Bus 2)		Fails open on loss of control power. Normally open.
7. <u>Safety Injection System</u>			
SI Pumps			
A	DC PNL. A, CKT. 1	480 V Bus E1 (4160 V Bus 2)	Pump fails to start on loss of control power. Fails off on loss of supply power.
B	DC PNL. B, CKT. 1 and DC PNL. A, CKT. 1	480 V Bus E2 (4160 V Bus 3)	Pump fails to start on loss of both sources of control power. Fails off on loss of supply power.

TABLE 1-3. COMPONENT POWER SUPPLIES AND ASSOCIATED FAILURE MODES (Continued)

Component	Control Power Source	Supply Power Source	Failure Mode
C	DC PNL. B, CKT. 1	480 V Bus E2 (4160 V Bus 3)	Pump fails to start on loss of control power. Fails off on loss of supply power.
Accumulators A, B, C			
Acc. N_2 Supply Valve SI-855	DC Aux. Pnl. DC, CKT. 17		Fails closed on loss of control power (normally closed).
Acc. Drain Valves			
SI-852A	DC Aux. Pnl. DC, CKT. 8		Fails closed on loss of control power.
SI-852B	DC Aux. Pnl. GC, CKT. 8		Fails closed on loss of control power.
SI-852C	DC Aux. Pnl. GC, CKT. 9		Fails closed on loss of control power.
Acc. Vent Valves			
SI-853A	DC Aux. Pnl. DC, CKT. 9		Fails as is on loss of control power (closed).
SI-853B	DC Aux. Pnl. GC, CKT. 10		Fails as is on loss of control power (closed).

TABLE 1-3. COMPONENT POWER SUPPLIES AND ASSOCIATED FAILURE MODES (Continued)

Component	Control Power Source	Supply Power Source	Failure Mode
SI-853C	DC Aux. Pnl. GC, CKT. 11		Fails as is on loss of control power (closed).
Acc. Discharge Valves			
SI-865A	120 VAC from 480 V MCC-5	480 V MCC-5 (4160 V Bus 2)	Fails as is (normally open).
SI-865B	120 VAC from 480 V MCC-6	480 V MCC-6 (4160 V Bus 3)	Fails as is (normally open).
SI-865C	120 VAC from 480 V MCC-5	480 V MCC-5 (4160 V Bus 2)	Fails as is (normally open).
Cold Leg Injection Valves			
SI-870A	120 VAC from 480 V MCC-5	480 V MCC-5 (4160 V Bus 2)	Fails as is on loss of supply power (closed).
SI-870B	120 VAC from 480 V MCC-6	480 V MCC-6 (4160 V Bus 3)	Fails as is on loss of supply power (closed).
Boron Inj. Tank Inlet Valves			
SI-867A	120 VAC from 480 V MCC-5	480 V MCC-5 (4160 V Bus 2)	Fails as is on loss of supply power (closed).

TABLE 1-3. COMPONENT POWER SUPPLIES AND ASSOCIATED FAILURE MODES (Continued)

Component	Control Power Source	Supply Power Source	Failure Mode
SI-867B	120 VAC from 480 V MCC-6	480 V MCC-6 (4160 V Bus 3)	Fails as is on loss of supply power (closed).
RWST Outlet Valves			
SI-864A	120 VAC from 480 V MCC-5	480 V MCC-5 (4160 V Bus 2)	Fails as is on loss of supply power (open).
SI-864B	120 VAC from 480 V MCC-6	480 V MCC-6 (4160 V Bus 3)	Fails as is on loss of supply power (open).
SI Valves to Hot Legs			
SI-866A	120 VAC from 480 V MCC-6	480 V MCC-6 (4160 V Bus 3)	Fails as is on loss of supply power (closed).
SI-866B	120 VAC from 480 V MCC-5	480 V MCC-5 (4160 V Bus 2)	Fails as is on loss of supply power (closed).
SI-869	120 VAC from 480 V MCC-5	480 V MCC-5 (4160 V Bus 2)	Fails as is on loss of supply power (open).
Pressurizer Pressure Instrument Strings			
PC-455E		Inst. Bus 1 (4160 V Bus 2)	SI signal if 2/3 channels de-energize.

TABLE 1-3. COMPONENT POWER SUPPLIES AND ASSOCIATED FAILURE MODES (Continued)

Component	Control Power Source	Supply Power Source	Failure Mode
PC-456D		Inst. Bus 2 (Inverter A)	SI signal if 2/3 channels de-energize.
PC-457D		Inst. Bus 3 (Inverter B)	SI signal if 2/3 channels de-energize.
8. <u>RHR System</u>			
RHR Pump A	DC Pnl. A, CKT 1	480 V Bus E1 (4160 V Bus 2)	Fails on loss of supply power. Fails as is (off) on loss of control power.
RHR Pump B	DC Pnl. B, CKT 1	480 V Bus E2 (4160 V Bus 3)	Fails on loss of supply power. Fails as is (off) on loss of control power.
Pump Suction Valves from RWST			
SI-862A	120 VAC from 480 V MCC-5	480 V MCC-5 (4160 V Bus 2)	Fails as is on loss of supply power (open).
SI-862B	120 VAC from 480 V MCC-6	480 V MCC-6 (4160 V Bus 3)	Fails as is on loss of supply power (open).
RHR Pump Disch. Valve FCV-605	Inst. Bus 4 & 9 (4160 V Bus 3)		Fails closed on loss of supply power.

TABLE 1-3. COMPONENT POWER SUPPLIES AND ASSOCIATED FAILURE MODES (Continued)

Component	Control Power Source	Supply Power Source	Failure Mode
Cold Leg Inlet Valves			
RHR-744A	120 VAC from 480 V MCC-5	480 V MCC-5 (4160 V Bus 2)	Fails as is on loss of supply power (closed).
RHR-744B	120 VAC from 480 V MCC-6	480 V MCC-6 (4160 V Bus 3)	Fails as is on loss of supply power (closed).
9. Safeguards System			
Safeguards Train "A" (DC Logic Rack A)		DC Panel A	Loss of safeguards. Train A.
Safeguards Train "B" (DC Logic Rack B)		DC Panel B	Loss of safeguards. Train B.
10. Reactor Protection System			
Control Rod Drive Motor Generator Set A	DC Pnl. A	480 V Bus 2B (4160 V Bus 1)	Reactor trips on loss of supply power to both motor generator sets.
Control Rod Drive Motor Generator Set B	DC Pnl. B	480 V Bus 3 (4160 V Bus 3)	Reactor trips on loss of supply power to both motor generator sets.

TABLE 1-3. COMPONENT POWER SUPPLIES AND ASSOCIATED FAILURE MODES (Continued)

Component	Control Power Source	Supply Power Source	Failure Mode
RCP Undervoltage Trip Relays			
UV-1		4 KV Bus 1	RT on trip of 2/3 relays.
UV-2		4 KV Bus 2	RT on trip of 2/3 relays.
UV-3		4 KV Bus 4	RT on trip of 2/3 relays.
Reactor Protection Train "A" Logic		DC Panel A	RT on de-energizing of undervoltage trip coils which occurs on loss of power to Logic Rack.
Reactor Protection Train "B" Logic		DC Panel B	RT on de-energizing of undervoltage trip coils which occurs on loss of power to Logic Rack.
<u>Support Systems</u>			
11. <u>Component Cooling Water</u>			
CCW Pump A		480 V Bus DS (4160 V Bus 3)	Pump fails off on loss of supply power.
CCW Pump B	DC Pnl. A, CKT. 1	480 V Bus E1 (4160 V Bus 2)	Pump fails as is (normally off) on loss of control power. Pump fails on loss of supply power.

TABLE 1-3. COMPONENT POWER SUPPLIES AND ASSOCIATED FAILURE MODES (Continued)

Component	Control Power Source	Supply Power Source	Failure Mode
CCW Pump C	DC Pnl. B, CKT. 1	480 V Bus E2 (4160 V Bus 3)	Pump fails as is (normally off) on loss of control power. Pump fails on loss of supply power.
Header Supply Valves to RCPs			
CC-716A	120 V from 480 V MCC-5	480 V MCC-5 (4160 V Bus 2)	Fails as is on loss of supply power (open).
CC-716B	120 V from 480 V MCC-6	480 V MCC-6 (4160 V Bus 3)	Fails as is on loss of supply power (open).
CCW Return Valve from RCP Lube Oil Coolers, CC-730	120 V from 480 V MCC-6	480 V MCC-6 (4160 V Bus 3)	Fails as is on loss of supply power (open).
CCW Return Valve from RCP Thermal Barrier Cooling Coils, FCV-626	120 V from 480 V MCC-6	480 V MCC-6 (4160 V Bus 3)	Fails as is on loss of supply power (open).

TABLE 1-3. COMPONENT POWER SUPPLIES AND ASSOCIATED FAILURE MODES (Continued)

Component	Control Power Source	Supply Power Source	Failure Mode
12. Service Water System			
SW Pump A	DC Pnl. A, CKT. 1	480 V Bus E1 (4160 V Bus 2)	Pump fails as is on loss of control power. Pump fails off on loss of supply power.
SW Pump B	DC Pnl. A, CKT. 1	480 V Bus E1 (4160 V Bus 2)	Pump fails as is on loss of control power. Pump fails off on loss of supply power.
SW Pump C	DC Pnl. B, CKT. 2	480 V Bus E2 (4160 V Bus 3)	Pump fails as is on loss of control power. Pump fails off on loss of supply power.
SW Pump D	DC Pnl. B, CKT. 2	480 V Bus E2 (4160 V Bus 3)	Pump fails as is on loss of control power. Pump fails off on loss of supply power.
SW Disch. Cross-Tie Valves			
V6-12B	120 V from 480 V MCC-5	480 V MCC-5 (4160 V Bus 2)	Fails as is on loss of supply power (open).
V6-12C	120 V from 480 V MCC-6	480 V MCC-6 (4160 V Bus 3)	Fails as is on loss of supply power (open).

TABLE 1-3. COMPONENT POWER SUPPLIES AND ASSOCIATED FAILURE MODES (Continued)

Component	Control Power Source	Supply Power Source	Failure Mode
SW Train Isolation Valves			
V6-16A	208 V MCC-9	208 MCC-9 (4160 V Bus 3)	Fails as is on loss of supply power (open).
V6-16B	208 V MCC-10	208 MCC-10 (4160 V Bus 3)	Fails as is on loss of supply power (open).
SW Suction Control Valve to AFW Turbine Driven Pump			
TCV-1902	120 V PP-21, CKT 15 (4160 V Bus 3)		Fails open on loss of control power.
SW Suction Control Valves from AFW Motor Pump Lube Oil Coolers			
TCV-1903A	120 V PP-21, CKT. 15 (4160 V Bus 3)		Fails open on loss of control power.
TCV-1903B	120 V PP-21, CKT. 15 (4160 V Bus 3)		Fails open on loss of control power.

TABLE 1-3. COMPONENT POWER SUPPLIES AND ASSOCIATED FAILURE MODES (Continued)

Component	Control Power Source	Supply Power Source	Failure Mode
13. Instrument Air System			
Primary Air Compressor		480 V Bus 2A (4160 V Bus 1)	Compressor fails on loss of supply power.
Instrument Air Compressors			
A		480 V MCC-5 (4160 V Bus 2)	Compressor fails on loss of supply power.
B		480 V MCC-6 (4160 V Bus 3)	Compressor fails on loss of supply power.
14. Electric Power System			
Diesel Generator A Circuit Breaker (52/17B)	DC PNL. A		D/G A fails to close onto 480 V bus E1.
Diesel Generator B Circuit Breaker (52/27B)	DC PNL. B		D/G B fails to close onto 480 V bus E2.

ATTACHMENT 2. COMPUTERIZED DATA BASE SORTS FOR POSTULATED ELECTRIC BUS FAILURES

The data base for the selected components* requiring electric power was computerized to facilitate the analysis of numerous postulated electric bus failures.

The computerized data base includes components, power supplies, component failure modes, and the normal component operating modes. The components were sorted by their power supplies for each power supply failure combination postulated. The sorts included components directly powered from the failed bus(es), components powered from buses fed by the failed bus(es), and components that could be fed by diesel generators associated with the failed bus(es).

Examples of a few of the sorts done are provided in this section.

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*See section 5.1 and Table 1-1 in Attachment 1.

COMPONENT RESPONSE TO 4160V BUS 1 FAILURE

COMPONENT	FAILURE MODE	NORMAL POSITION
RCP A	OFF	ON
PZR CONTROL HEATERS	OFF	ON
PZR BACKUP HEATERS B	OFF	AUTO
EH SYSTEM	SLOW TT PMP A&B FAIL	
EH OIL PUMP B	SLOW TT ON PUMPS A&B	
FW PUMP A	OFF	ON
PRIMARY AIR COMPRESSOR	OFF	ON
CNTRL ROD DRIVE MG SET A	RT ON MG A&B FAILURE	
RCP UNDERVOLTAGE TRP UV-1	RT ON 2/3 TRIP RELAY	

COMPONENT RESPONSE TO 4160V BUS 2 FAILURE

COMPONENT	FAILURE MODE	NORMAL POSITION
RCP C	OFF	ON
PZR BACKUP HEATERS A	OFF	AUTO
C-TROTS CHANNEL 1	TT ON 2/3 CHANNELS	
STM DMP LOSS-LOAD PM-447	DMP VLVS FAIL CLOSED	
MFIV V2-6A	AS IS	OPEN
FW VALVE CONTROL LOOP 1	CONTROL VALVE CLOSED	CONTROL VALVE OPEN
CHARGING PUMP B	OFF	OFF
BORIC ACID VLV MOV-350	AS IS	CLOSED
CHG LINE FCV HCV-121	OPEN	THROTTLED
SI PUMP A	OFF	OFF
ACC DISCH VLV SI-865A	AS IS	OPEN
ACC DISCH VLV SI-865C	AS IS	OPEN
COLD LEG INJ SI-870A	AS IS	CLOSED
BIT INLET SI-867A	AS IS	CLOSED
RWST OUTLET SI-864A	AS IS	OPEN
TO HOT LEGS SI-866B	AS IS	CLOSED
TO HOT LEGS SI-869	AS IS	OPEN
MOTOR AFW PUMP A	OFF	OFF
MAFW DISCH V2-16B	AS IS	CLOSED
SAFW DISCH V2-14A	AS IS	CLOSED
SAFW DISCH V2-14C	AS IS	CLOSED
SAFW SUPPLY V1-8A	AS IS	CLOSED
RHR PUMP A	OFF	OFF
RHR SUCTION SI-862A	AS IS	OPEN
COLD LEG IN RHR-744A	AS IS	CLOSED
COMP COOLING PUMP B	OFF	OFF
HEADER TO RCP CC-716A	AS IS	OPEN
SERV WATER PUMP A	OFF	ON
SERV WATER PUMP B	OFF	ON
SW DISCH VLV V6-12B	AS IS	OPEN
SW ISO VLV V6-16B	AS IS	OPEN
INST AIR COMPRESSOR A	OFF	AUTO
PZR PRESSURE PC-455E	LOW SIGNAL, 2/3 SI	
S/G 1 LEVEL LC-474A	LOW SIGNAL, 2/3 AFW	
S/G 2 LEVEL LC-484A	LOW SIGNAL, 2/3 AFW	
S/G 3 LEVEL LC-494A	LOW SIGNAL, 2/3 AFW	
RCP UNDERVOLTAGE TRP UV-2	RT ON 2/3 TRIP RELAY	

COMPONENT RESPONSE TO 4160V BUS 3 FAILURE

COMPONENT	FAILURE MODE	NORMAL POSITION
PZR PRES TRAN PT-444	PORV455C STAYS CLOSE	
PORV SHUTOFF RC-535	AS IS	OPEN
PORV SHUTOFF RC-536	AS IS	OPEN
GOVERNOR CONTROL CABINENT	TURBINE TRIP	
EH OIL PUMP A	SLOW TT ON PUMPS A&B	
STEAM DUMP CONTROL T-408	DMP VLVS FAIL CLOSED	
STEAM DUMP CONTROL T-408	PORV FC IF LR EXISTS	
STM DUMP PRESS CTL P-464	NOT NORMAL CNTL MODE	
HIGH Tavg	DMP VLVS FAIL CLOSED	
V1-3A BYPASS	AS IS	CLOSED
V1-3B BYPASS	AS IS	CLOSED
V1-3C BYPASS	AS IS	CLOSED
MFIV V2-6B	AS IS	OPEN
MFIV V2-6C	AS IS	OPEN
CHARGING PUMP A	OFF	ON
CHARGING PUMP C	OFF	OFF
PZR LEVEL CONTROL LC-459F	MINIMUM CH PMP SPEED	AUTO-CONTROL
CHG PMP SUC LCV-115C	AS IS	OPEN
SI PUMP B	OFF	OFF
SI PUMP C	OFF	OFF
ACC DISCH VLV SI-865B	AS IS	OPEN
COLD LEG INJ SI-870B	AS IS	CLOSED
BIT INLET SI-867B	AS IS	CLOSED
RWST OUTLET SI-864B	AS IS	OPEN
TO HOT LEGS SI-866A	AS IS	CLOSED
MOTOR AFW PUMP B	OFF	OFF
MAFW DISCH V2-16A	AS IS	CLOSED
MAFW DISCH V2-16C	AS IS	CLOSED
SAFW DISCH V2-14B	AS IS	CLOSED
SAFW SUPPLY V1-8B	AS IS	CLOSED
SAFW SUPPLY V1-8C	AS IS	CLOSED
RHR PUMP B	OFF	OFF
RHR SUCTION SI-862B	AS IS	OPEN
RHR DISCH FCV-605	CLOSED	CLOSED
COLD LEG IN RHR-744B	AS IS	CLOSED
COMP COOLING PUMP A	OFF	ON
COMP COOLING PUMP C	OFF	OFF
HEADER TO RCP CC-716B	AS IS	OPEN
RCP OIL COOLER CC-730	AS IS	OPEN
RCP COOLING COIL FCV-626	AS IS	OPEN
SERV WATER PUMP C	OFF	OFF
SERV WATER PUMP D	OFF	OFF
SW DISCH VLV V6-12C	AS IS	OPEN
SDAFW PMP SW VLV TCV-1902	OPEN	CLOSED
MAFW PMP SW VLV TCV-1903A	OPEN	CLOSED
MAFW PMP SW VLV TCV-1903B	OPEN	CLOSED
SW ISO VLV V6-16A	AS IS	OPEN
INST AIR COMPRESSOR B	OFF	AUTO
CNTRL ROD DRIVE MG SET B	RT ON MG A&B FAILURE	

COMPONENT RESPONSE TO 4160V BUS 4 FAILURE

COMPONENT	FAILURE MODE	NORMAL POSITION
RCP B	OFF	ON
FW PUMP B	OFF	ON
RCP UNDERVOLTAGE TRP UV-3	RT ON 2/3 TRIP RELAY	

COMPONENT RESPONSE TO 125VDC BUS A & B FAILURE

COMPONENT	FAILURE MODE	NORMAL POSITION
PZR PRES TRAN PT-445	PORV456 STAYS CLOSED	
PORV RC-456	CLOSED	CLOSED
PORV RC-455C	CLOSED	CLOSED
TURBINE AUTO TRIP 20-AST	NO TURBINE AUTO TRIP	
TURB EMERGENCY TRIP 20-ET	NO TURB EMERG TRIP	
GOV/INTCPT TRIP 20-1,20-2	NO GOV/INTCPT TRIP	
TROTS LOGIC TRAIN A	NO TROTS TT W/O DC B	
TROTS LOGIC TRAIN B	NO TROTS TT W/O DC A	
C-TROTS CHANNEL 2 *	TT ON 2/3 CHANNELS	
C-TROTS CHANNEL 3 *	TT ON 2/3 CHANNELS	
STEAM SIDE PORV RV1	CLOSED	CLOSED
STEAM SIDE PORV RV2	CLOSED	CLOSED
STEAM SIDE PORV RV3	CLOSED	CLOSED
STM DUMP PRV 1324A-1	CLOSED	CLOSED
STM DUMP PRV 1324B-1	CLOSED	CLOSED
STM DUMP PRV 1324B-2	CLOSED	CLOSED
STM DUMP PRV 1324A-2	CLOSED	CLOSED
STM DUMP PRV 1324B-3	CLOSED	CLOSED
MSIV V1-3A ISO	CLOSED	OPEN
MSIV V1-3A ISO	CLOSED	OPEN
MSIV V1-3B ISO	CLOSED	OPEN
MSIV V1-3B ISO	CLOSED	OPEN
MSIV V1-3C ISO	CLOSED	OPEN
MSIV V1-3C ISO	CLOSED	OPEN
FW CTRL VLV FCV-478 SOL-A	CLOSED	OPEN
FW CTRL VLV FCV-478 SOL-B	CLOSED	OPEN
FW CTRL VLV FCV-488 SOL-A	CLOSED	OPEN
FW CTRL VLV FCV-488 SOL-B	CLOSED	OPEN
FW CTRL VLV FCV-498 SOL-A	CLOSED	OPEN
FW CTRL VLV FCV-498 SOL-B	CLOSED	OPEN
FW BYP FCV-479 SOL-A	CLOSED	CLOSED
FW BYP FCV-479 SOL-B	CLOSED	CLOSED
FW BYP FCV-489 SOL-A	CLOSED	CLOSED
FW BYP FCV-489 SOL-B	CLOSED	CLOSED
FW BYP FCV-499 SOL-A	CLOSED	CLOSED
FW BYP FCV-499 SOL-B	CLOSED	CLOSED
FW VALVE CONTROL LOOP 2	CONTROL VALVE CLOSED	CONTROL VALVE OPEN
FW VALVE CONTROL LOOP 3	CONTROL VALVE CLOSED	CONTROL VALVE OPEN
C-FW PUMP A *	ON-FWP TRIP FAILS	ON
C-FW PUMP B *	ON-FWP TRIP FAILS	ON
CHG PMP SUC LCV-115B	CLOSED	CLOSED
CH ISO CVC-310A LOOP1 C L	OPEN	CLOSED
CH ISO CVC-310B LOOP2 C L	OPEN	OPEN
AUX SPRAY CVC-311	CLOSED	CLOSED
LETDOWN VLV LCV-460A	CLOSED	OPEN
LETDOWN VLV LCV-460B	CLOSED	OPEN
LETDOWN ISO CVC-200A	CLOSED	CLOSED
LETDOWN ISO CVC-200B	CLOSED	CLOSED
LETDOWN ISO CVC-200C	CLOSED	OPEN
LETDOWN ISO CVC-204A	CLOSED	OPEN

*"C-" indicates circuit breaker or control for components.

COMPONENT RESPONSE TO 125VDC BUS A & B FAILURE

COMPONENT	FAILURE MODE	NORMAL POSITION
LETDOWN ISO CVC-204B	CLOSED	OPEN
ACC NITRGEN SUPPLY SI-855	CLOSED	CLOSED
ACC DRN VLV SI-852A	CLOSED	CLOSED
ACC DRN VLV SI-852B	CLOSED	CLOSED
ACC DRN VLV SI-852C	CLOSED	CLOSED
ACC VENT VLV SI-853A	AS IS	CLOSED
ACC VENT VLV SI-853B	AS IS	CLOSED
ACC VENT VLV SI-853C	AS IS	CLOSED
STEAM AFW PUMP CNTRL	OFF	OFF
C-RCP A	RCP TRIP FAIL	RCP ON
C-RCP B	RCP TRIP FAIL	RCP ON
C-RCP C	RCP TRIP FAIL	RCP ON
C-PZR CNTL HEATERS	ON	AUTO
C-PZR B-UP HEATERS A	OFF	AUTO
C-PZR B-UP HEATERS B	OFF	AUTO
C-CHARGING PUMP B	AS IS	OFF
C-CHARGING PUMP C	AS IS	OFF
C-SI PUMP A	AS IS	OFF
C-SI PUMP B	AS IS	OFF
C-SI PUMP C	AS IS	OFF
C-MAFW PUMP A	AS IS	OFF
C-MAFW PUMP B	AS IS	OFF
C-RHR PUMP A	AS IS	OFF
C-RHR PUMP B	AS IS	OFF
C-COMP COOL PUMP B	AS IS	OFF
C-COMP COOL PUMP C	AS IS	OFF
C-SW PUMP A	AS IS	ON
C-SW PUMP B	AS IS	ON
C-SW PUMP C	AS IS	OFF
C-SW PUMP D	AS IS	OFF
PZR PRESSURE PC-456D	LOW SIGNAL, 2/3 SI	
PZR PRESSURE PC-457D	LOW SIGNAL, 2/3 SI	
S/G 1 LEVEL LC-475A	LOW SIGNAL, 2/3 AFW	
S/G 1 LEVEL LC-476A	LOW SIGNAL, 2/3 AFW	
S/G 2 LEVEL LC-485A	LOW SIGNAL, 2/3 AFW	
S/G 2 LEVEL LC-486A	LOW SIGNAL, 2/3 AFW	
S/G 3 LEVEL LC-495A	LOW SIGNAL, 2/3 AFW	
S/G 3 LEVEL LC-496A	LOW SIGNAL, 2/3 AFW	
SAFEGUARDS TRAIN A LOGIC	NO SI ON TRAIN A	
SAFEGUARDS TRAIN B LOGIC	NO SI ON TRAIN B	
DIESEL GENERATOR A	FAILS TO ENERGIZE E1	OFF
DIESEL GENERATOR B	FAILS TO ENERGIZE E2	OFF
C-CTRL ROD DRIVE MG SET A	RT ON MG A&B FAILURE	
C-CTRL ROD DRIVE MG SET B	RT ON MG A&B FAILURE	
REACTOR PROTECT. TRAIN A	REACTOR TRIP	
REACTOR PROTECT. TRAIN B	REACTOR TRIP	

COMPONENT R[illegible]PONSE TO DC BUS "A" AND 4KV BU[illegible] & 2 FAILURE

COMPONENT	FAILURE MODE	NORMAL POSITION
RCP A	OFF	ON
RCP C	OFF	ON
PZR CONTROL HEATERS	OFF	ON
PZR BACKUP HEATERS A	OFF	AUTO
PZR BACKUP HEATERS B	OFF	AUTO
PORV RC-456	CLOSED	CLOSED
TURBINE AUTO TRIP 20-AST	NO TURBINE AUTO TRIP	
EH SYSTEM	SLOW TT PMP A&B FAIL	
EH OIL PUMP B	SLOW TT ON PUMPS A&B	
TROTS LOGIC TRAIN A	NO TROTS TT W/O DC B	
C-TROTS CHANNEL 1	TT ON 2/3 CHANNELS	
C-TROTS CHANNEL 2	TT ON 2/3 CHANNELS	
STEAM SIDE PORV RV1	CLOSED	CLOSED
STEAM SIDE PORV RV2	CLOSED	CLOSED
STEAM SIDE PORV RV3	CLOSED	CLOSED
STM DUMP PRV 1324A-1	CLOSED	CLOSED
STM DUMP PRV 1324B-1	CLOSED	CLOSED
STM DUMP PRV 1324B-2	CLOSED	CLOSED
STM DMP LOSS-LOAD PM-447	DMP VLVS FAIL CLOSED	
MSIV V1-3A ISO	CLOSED	OPEN
MSIV V1-3B ISO	CLOSED	OPEN
MSIV V1-3C ISO	CLOSED	OPEN
FW PUMP A	OFF	ON
MFIV V2-6A	AS IS	OPEN
FW CTRL VLV FCV-478 SOL-A	CLOSED	OPEN
FW CTRL VLV FCV-488 SOL-A	CLOSED	OPEN
FW CTRL VLV FCV-498 SOL-A	CLOSED	OPEN
FW BYP FCV-479 SOL-A	CLOSED	CLOSED
FW BYP FCV-489 SOL-A	CLOSED	CLOSED
FW BYP FCV-499 SOL-A	CLOSED	CLOSED
FW VALVE CONTROL LOOP 1	CONTROL VALVE CLOSED	CONTROL VALVE OPEN
FW VALVE CONTROL LOOP 2	CONTROL VALVE CLOSED	CONTROL VALVE OPEN
C-FW PUMP A	ON-FWP TRIP FAILS	ON
CHARGING PUMP B	OFF	OFF
CHG PMP SUC LCV-115B	CLOSED	CLOSED
BORIC ACID VLV MOV-350	AS IS	CLOSED
CH ISO CVC-310B LOOP2 C L	OPEN	OPEN
AUX SPRAY CVC-311	CLOSED	CLOSED
LETDOWN VLV LCV-460A	CLOSED	OPEN
LETDOWN VLV LCV-460B	CLOSED	OPEN
LETDOWN ISO CVC-200A	CLOSED	CLOSED
LETDOWN ISO CVC-200C	CLOSED	OPEN
LETDOWN ISO CVC-204A	CLOSED	OPEN
CHG LINE FCV HCV-121	OPEN	THROTTLED
SI PUMP A	OFF	OFF
ACC NITRGEN SUPPLY SI-855	CLOSED	CLOSED
ACC DRN VLV SI-852A	CLOSED	CLOSED
ACC VENT VLV SI-853A	AS IS	CLOSED
ACC DISCH VLV SI-865A	AS IS	OPEN
ACC DISCH VLV SI-865C	AS IS	OPEN

COMPONENT RESPONSE TO DC BUS "A" AND 4KV BUS 1 & 2 FAILURE

COMPONENT	FAILURE MODE	NORMAL POSITION
COLD LEG INJ SI-870A	AS IS	CLOSED
BIT INLET SI-867A	AS IS	CLOSED
RWST OUTLET SI-864A	AS IS	OPEN
TO HOT LEGS SI-866B	AS IS	CLOSED
TO HOT LEGS SI-869	AS IS	OPEN
MOTOR AFW PUMP A	OFF	OFF
MAFW DISCH V2-16B	AS IS	CLOSED
SAFW DISCH V2-14A	AS IS	CLOSED
SAFW DISCH V2-14C	AS IS	CLOSED
SAFW SUPPLY V1-8A	AS IS	CLOSED
RHR PUMP A	OFF	OFF
RHR SUCTION SI-862A	AS IS	OPEN
COLD LEG IN RHR-744A	AS IS	CLOSED
COMP COOLING PUMP B	OFF	OFF
HEADER TO RCP CC-716A	AS IS	OPEN
SERV WATER PUMP A	OFF	ON
SERV WATER PUMP B	OFF	ON
SW DISCH VLV V6-12B	AS IS	OPEN
SW ISO VLV V6-16B	AS IS	OPEN
PRIMARY AIR COMPRESSOR	OFF	ON
INST AIR COMPRESSOR A	OFF	AUTO
C-RCP A	RCP TRIP FAIL	RCP ON
C-RCP C	RCP TRIP FAIL	RCP ON
C-PZR B-UP HEATERS A	OFF	AUTO
C-PZR B-UP HEATERS B	OFF	AUTO
C-CHARGING PUMP B	AS IS	OFF
C-SI PUMP A	AS IS	OFF
C-MAFW PUMP A	AS IS	OFF
C-RHR PUMP A	AS IS	OFF
C-COMP COOL PUMP B	AS IS	OFF
C-SW PUMP A	AS IS	ON
C-SW PUMP B	AS IS	ON
PZR PRESSURE PC-455E	LOW SIGNAL, 2/3 SI	
PZR PRESSURE PC-456D	LOW SIGNAL, 2/3 SI	
S/G 1 LEVEL LC-474A	LOW SIGNAL, 2/3 AFW	
S/G 1 LEVEL LC-475A	LOW SIGNAL, 2/3 AFW	
S/G 2 LEVEL LC-484A	LOW SIGNAL, 2/3 AFW	
S/G 2 LEVEL LC-485A	LOW SIGNAL, 2/3 AFW	
S/G 3 LEVEL LC-494A	LOW SIGNAL, 2/3 AFW	
S/G 3 LEVEL LC-495A	LOW SIGNAL, 2/3 AFW	
SAFEGUARDS TRAIN A LOGIC	NO SI ON TRAIN A	
DIESEL GENERATOR A	FAILS TO ENERGIZE E1	OFF
CNTRL ROD DRIVE MG SET A	RT ON MG A&B FAILURE	
C-CTRL ROD DRIVE MG SET A	RT ON MG A&B FAILURE	
RCP UNDERVOLTAGE TRP UV-1	RT ON 2/3 TRIP RELAY	
RCP UNDERVOLTAGE TRP UV-2	RT ON 2/3 TRIP RELAY	
REACTOR PROTECT. TRAIN A	REACTOR TRIP	

COMPONENT RESPONSE TO 480V BUS 3 FAILURE

COMPONENT	FAILURE MODE	NORMAL POSITION
GOVERNOR CONTROL CABINENT	TURBINE TRIP	
EH OIL PUMP A	SLOW TT ON PUMPS A&B	
V1-3A BYPASS	AS IS	CLOSED
V1-3B BYPASS	AS IS	CLOSED
V1-3C BYPASS	AS IS	CLOSED
SDAFW PMP SW VLV TCV-1902	OPEN	CLOSED
MAFW PMP SW VLV TCV-1903A	OPEN	CLOSED
MAFW PMP SW VLV TCV-1903B	OPEN	CLOSED
CNTRL ROD DRIVE MG SET B	RT ON MG A&B FAILURE	

COMPONENT RESPONSE TO 480V MCC 4 FAILURE

COMPONENT	FAILURE MODE	NORMAL POSITION
GOVERNOR CONTROL CABINENT	TURBINE TRIP	
EH OIL PUMP A	SLOW TT ON PUMPS A&B	
V1-3A BYPASS	AS IS	CLOSED
V1-3B BYPASS	AS IS	CLOSED
V1-3C BYPASS	AS IS	CLOSED
SDAFW PMP SW VLV TCV-1902	OPEN	CLOSED
MAFW PMP SW VLV TCV-1903A	OPEN	CLOSED
MAFW PMP SW VLV TCV-1903B	OPEN	CLOSED

COMPONENT RESPONSE TO INSTRUMENT BUS 1 FAILURE

COMPONENT	FAILURE MODE	NORMAL POSITION
C-TROTS CHANNEL 1	TT ON 2/3 CHANNELS	
STM DMP LOSS-LOAD PM-447	DMP VLVS FAIL CLOSED	
FW VALVE CONTROL LOOP 1	CONTROL VALVE CLOSED	CONTROL VALVE OPEN
CHG LINE FCV HCV-121	OPEN	THROTTLED
PZR PRESSURE PC-455E	LOW SIGNAL, 2/3 SI	
S/G 1 LEVEL LC-474A	LOW SIGNAL, 2/3 AFW	
S/G 2 LEVEL LC-484A	LOW SIGNAL, 2/3 AFW	
S/G 3 LEVEL LC-494A	LOW SIGNAL, 2/3 AFW	