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APPENDIX 10.4.9B

EMERGENCY FEEDWATER SYSTEM

RELIABILITY ANALYSIS

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APPENDIX 10.4.9B

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10.4.9B.1 Introduction

This report summarizes the results of a reliability study for the Waterford 3 EFS required by the NRC in Reference 1. The primary purpose of this study is to assess the system availability to function on demand and identify any areas where changes in design, operating procedures and/or system testing/maintenance practice could result in significant availability improvements. The steps in this study were:

- SYSTEM DEFINITION: The objectives of the study and its scope and limitations are clearly defined.
- SYSTEM MODEL CONSTRUCTION: A Failure Modes and Effects Analysis for each component and Common Cause Analysis are performed and used to construct a system fault tree for each condition to be analyzed.
- SYSTEM MODEL QUALITATIVE ANALYSIS: The system model is examined to determine the combination of events (minimal cut sets) which can lead to system unavailability on demand.
- SYSTEM MODEL QUANTITATIVE ANALYSIS: Probabilities of occurrence are determined for the basic events in the fault tree, and are used to calculate the overall system availability and to weigh the relative importance of the events and event combinations as failure contributors.
- ANALYSIS OF RESULTS: The results of the qualitative analysis are reviewed to determine if any changes in design, operating procedures and/or system testing/maintenance practice could result in significant availability improvements.

The details of the actual study are described herein.

10.4.9B.2 System Definition

10.4.9B.2.1 Top Event

The purpose of the analysis is to determine the availability of the EFS to maintain the Reactor Coolant System in the hot standby condition on a demand produced by a Loss of Main Feedwater (LMFW), LMFW with Loss of Offsite Power (LOOP), and LMFW with Station Blackout (SB). Operation under main steam or feedwater line break or LOCA conditions were not considered.

The EFS flow requirement for each condition is described below:

LMFW: It is assumed that the operator will trip the Reactor Coolant Pumps (RCPS) 30 minutes after the reactor trip brought on by the LMFW, if only one motor driven EFW pump is available for operating. This is a required operating procedure action intended to reduce the heat load on the primary system.

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If both steam generators (SGs) are available, 450 gpm of EFS flow (225 per SG)* is needed to maintain the level required for the SGs to be adequate heat sinks. If only one SG is available, 400 gpm to that SG is adequate to maintain the level required for the SG to be an adequate heat sink (required EFS flow when one SG is available is less than for two SGs because of the RCS energy dissipated as the unfed SG boils away its inventory). To simplify the system logic model, it will be assumed that 450 gpm EFS flow, either split between two SGs or all delivered to one SG, is required for the LMFW condition.

LMFW & LOOP: The EFW flow requirement for this condition is less than for the LMFW condition, since the RCPs will stop immediately upon the LOOP. However, to simplify the logic model, the same EFS flow requirement for the LMFW (450 gpm) is conservatively used for this case as well.

LMFW & SB Same as LMFW & LOOP.

Thus, it is conservatively assumed that the EFS minimum function (i.e., to deliver a total of at least 450 gpm to the steam generator(s)), and therefore the top event, is the same for all three conditions regardless of the number of SGs available.

It is known that the basic failure events to be considered have small probabilities. Thus, to minimize round-off error in numerical calculations, the system model will be constructed in fault tree as opposed to success tree fashion. The top event will then be failure to deliver at least 450 gpm EFS flow to the steam generator(s), or "< 450 gpm EFS flow to SG's."

The scope of the top event spans only the availability of the system to start on demand for the transients under consideration and does not include the reliability of the system to carry out this mission through the required duration (several hours), consistent with the NRC request in Reference 1. However, it is believed that for the events analyzed, the system undependability is dominated by the unavailability to start on demand.

10.4.9B.2.2 System Boundaries

The EFS simplified flow diagram is shown on Figure 10.4.9B-1. For this analysis, the system consists of the EFS flow path from the Condensate Storage Pool (CSP) to the normal flow connections with the Main Feedwater System (MFWS), inclusive of interconnections with other systems. Support systems/components considered in the analysis not shown on the figure are pump and valve control circuits, power supplies and ESFAS logic. More detail on the types of failures considered is given in Subsection 10.4.9B.2.3.

*It should be noted that this is not inconsistent with the conservative licensing design basis EFS flow rate of 575 gpm. The analytical bases for the 575 gpm flow requirement contain conservatisms which are not appropriate for a realistic reliability study.

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10.4.9B.2.3 Basic Events Considered

The types of events considered in the FMEA and their possible causes are listed by component as follows. It should be noted that in some cases events which obviously were not failure events were not fully developed in the FMEA. Also, not all the possible causes listed under each component type are applicable to each event for the component. This Appendix is a stand-alone study. The following is in addition to the study and is included for clarification purposes:

In performing the system reliability study contained in this Appendix, the failure of check valves to operate properly was evaluated. However, failures of check valves EFW 2191A, B are not considered credible failures.

MANUAL VALVE

- Events:
  - Open (able to pass flow)
  - Closed (unable to pass flow)
- Possible Causes:
  - Plugging (flow path blocked)
  - In wrong position due to test or maintenance on another component at the time of demand
  - Normal or proper position

CHECK-VALVE

- Events:
  - Open against forward current
  - Open against reverse current
  - Closed against forward current
  - Closed against reverse current
- Possible Causes:
  - Frozen in wrong position due to mechanical binding
  - In test or maintenance
  - Proper position

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POWER OPERATED VALVE

- Events:

  - Remains OPEN on demand close signal
  - Remains CLOSED on demand open signal
  - CLOSED and receives no automatic signal
  - OPEN and receives no automatic signal

- Possible Causes:

  - Mechanical binding
  - Control circuit failure
  - Actuating signal failure
  - Motive force failure
  - Left in wrong position (if valves receives no confirmatory automatic signal) after test or maintenance action
  - In test or maintenance

PUMP

Events:

- Fails to deliver the required flow

Possible Causes:

- Mechanical binding
- Control circuit failure
- Actuating signal failure
- Motive force failure

ACTUATING LOGIC

Events:

- Signal not generated when required

Possible Causes:

- Unspecified electronics failure
- In test or maintenance

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4 kV POWER SUPPLY (DG's)

Events:

- Does not supply power Possible Causes:
- DG failure to start
- DG in test or maintenance

The following events were not considered:

- Passive fluid boundary failures or valve disc-stem separations.
- Spurious control circuit or actuation circuit logic commands.

Common cause failures considered as basic events are discussed in Subsection 10.4.9B.3.2. Common cause failures not considered were sabotage or those of a physical layout nature, such as non-seismic systems falling on EFS components, high energy line breaks in other systems affecting the EFS, etc. This is not to say that such possibilities exist in the Waterford 3 design; it was simply not within the scope of this study to investigate this.

10.4.9B.3 System Model Construction

10.4.9B.3.1 Failure Modes and Effects Analysis

A Failure Modes and Effects Analysis (FMEA) was developed as a first step in the system model construction to identify the effects that individual component actions have on subsystem and overall system operation. The FMEA describes the effect on the system of every component action regardless of whether or not the action contributed to system failure, and is a necessary complement to the fault tree for this reason.

The system was broken up into the functional blocks (shown by the dashed lines and roman numerals on Figure 10.4.9B-1) for generation of the FMEA, with the breakdown for these blocks chosen with an eye towards facilitating construction of the fault tree. The structure and rationale behind the details of the FMEA is discussed below. The FMEA is given in Table 10.4.9B-2.

10.4.9B.3.1.1 Component

Each component selected in accordance with the criteria of Subsections 10.4.9B.2.2 and 10.4.9B.2.3 appears in the FMEA, with the exception of vent and drain valves. These were not included because the system is kept continually full of water by the CSP/MFWS, so it is not considered credible that a vent or drain valve could be left open without being quickly noticed and corrected.

For simplicity in this study, each component considered was assigned to a two digit identification (ID) number. A list of all components considered, along with a description of the component, it's two digit ID number, actual ID number and FMEA blocks in which it appears is given in Table 10.4.9B-1.

10.4.9B.3.1.2 Component State

Each component was considered in it's extreme states within the limitations of Subsection 10.4.9B.2.3 for the purpose of analyzing it's effects. For example, valves were considered in both the open and closed

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state. Actuation signals were analyzed only for failure to be generated when required, but not for spurious generation.

10.4.9B.3.1.3 Effect

The effect of the component being in the state under study on the functional block, of which it is a part, is analyzed. The following general guidelines were used in analyzing the effect of the component states:

a) Valves: can impair system operation in the closed position by blocking flow where flow is desired, or in the open position by diverting flow or permitting flow where not desirable.

b) Pumps: can impair system operation by not pumping fluid as required and by providing a possible flow diversion path for parallel pumps.

c) Valve/Pump Control Circuits: can cause a pump not to start or valve to not change position when required, leading to the same system impairments discussed under Pump and Valves above.

d) Actuating Logic: can fail to issue a command to the pump or valve control circuits, leading to the same system impairments discussed above.

e) Power Supplies: can fail to provide motive force to pumps or valves, leading to the same system impairments discussed above.

10.4.9B.3.1.4 Inherent Compensation

Any inherent provisions in the system which compensate for the degradation brought about by the component state under study is listed to assist in the fault tree construction.

10.4.9B.3.2 Common Cause Failure Consideration

Several events were assessed for their potential to induce common cause failures in the EFS, as discussed below.

a) LOSS OF INSTRUMENT AIR: All air-operated valves in the EFS require instrument air to go away from their operational state (i.e., to close). A loss of instrument air would have no immediate effect on the system as the valves have air accumulators sized for several open-close cycles, but would prevent the operator from reclosing the air operated valves once the accumulators are exhausted. This has no adverse affect on system operation for the transients under consideration.

b) LOSS OF COMPONENT COOLING WATER: The EFS does not rely on Component Cooling Water. The EFS pumps, unlike the ECCS pumps, handle a relatively cool fluid which is itself sufficient for pump cooling, so no CCW is required.

c) LOSS OF AC POWER: The EFS Turbine Driven Pump (TDP) and all power operated valves associated with its flow and steam supply paths, are independent of ac power except normally open, fail as is, Valve 74 (Turbine Trip and Throttle Valve), whose operation (closure) is equipment protective and not required for system functioning. No TDP auxiliary functions, including lubrication, are dependent upon ac power.

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Extended operation of the TDP is indirectly reliant on ac power by the ventilation system serving the pump cubicle. Without ventilation for several hours when the pump is running, temperature in the pump area would become high enough to affect the pump controls, possibly in an adverse manner. This would not be an immediate failure however, and time would be available to restore some ac power. As such, this failure mechanism was not factored into the fault tree.

d) POOR WATER QUALITY CONTROL: If very low quality water were used for extended periods in the EFS, it could conceivably cause corrosion/ particle deposition in the system, perhaps binding the moving parts of the pumps and valves. However, it is not credible that this would occur to any extent in the EFS for the following reasons:

1) Only condensate or demineralized quality water is used in the EFS.

→(EC-34060, R306)

2) The system is periodically treated with a pH control agent and Hydrazine as necessary to control water chemistry.

←(EC-34060, R306)

3) The system is periodically flow tested, which not only provides some system flushing, but assures that water quality has not affected the pumps.

4) The valves are periodically stroke tested, which would detect any loss of function due to corrosion or particle deposition.

e) TESTING: As discussed in Subsection 10.4.9B.5.1.1, system testing has no potential for causing common mode failures.

f) MAINTENANCE: As discussed in Subsection 10.4.9B.5.1.1, only one maintenance operation (Condensate and Feedwater Systems Pre-Startup Cleaning) has potential for causing a system common mode failure. This has been added to the fault tree as common cause failure basic event ME1.

g) CONDENSATE STORAGE POOL PROBLEMS: The CSP is the only dedicated source of water to the EFS, so it is assessed for it's potential to cause EFS failure.

1) Tank Vent Clogging: The CSP (essentially a stainless steel lined concrete room) is equipped with an 8 in. Schedule 40 (nominal wall thickness = 3/8 in.) vent line which penetrates the pool ceiling and terminates in the above room (CCW pump cubicle) six feet above the floor.

There is no isolation valve on the line, and there is no known sources of debris in the area which could clog such a large diameter pipe. Also, the pipe ends with a "U"-bend, with the open end turned downwards. Accidental crimping of the thick walled pipe is not considered credible since the pipe is not within the travel path of any cranes, and is located in a congested area behind an instrument cabinet, out of the path of any fork lifts. As such, failure of the pool due to a restricted vent line is not considered credible.

→(DRN M9900828, R11)

2) Low Tank Level: The CSP is used mainly as a water supply for the EFS. The only exception is its use as a makeup source for CCW makeup, which places a minimal demand on the pool. The pool is equipped with redundant, safety grade level indicators and the operators are required to verify that tank level is within allowable limits every 12 hours. As such, it is not considered credible that tank level would be out of limits when a system demand occurred.

←(DRN M9900828, R11; EC-33720, R307)

➔(EC-33720, R307)

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3) Pump Suction Flashing: The CSP water remains at RAB ambient temperatures, usually below 90°F. There are no lines from hot, interfacing system which connect to the lines between the CSP and pump suction, as in some other plants. Thus, flashing of the pump suction source is not considered a credible common cause failure mechanism.

10.4.9B.3.3 Fault Tree

The fault tree was constructed from the FMEA (independent failure analysis) and the common cause failure analysis, using the same functional blocks as in the FMEA. The failures and combinations of failures that could defeat operation of the functional block (including failures from other blocks) were combined using conventional AND and OR gates. Then the blocks were arranged through logic which related them to the "top event" specified in Subsection 10.4.9B.2.1. The last step was particularly complex for the EFS due to its extensive interconnection of redundant trains and the multiple ways in which it can successfully perform its function.

To simplify the fault tree, only the (failure contributing component states (or events) from the FMEA, and not all possible causes of the state were incorporated into the fault tree. For example, if a valve being closed (unable to pass fluid) was a contributor in the fault tree, "VALVE XX CLOSED" was included as the event in the fault tree rather than placing an OR gate in the tree with event inputs such as "VALVE XX CLOSED DUE TO MAINT", "VALVE XX CLOSED DUE TO ERROR", "VALVE XX PLUGGED WITH DEBRIS," etc. The latter would generate an unmanageable number of cut sets, and would produce a computer analysis output which focused on causes of concern as opposed to component of concern, which is more useful. A complete listing of the causes and probabilities of each event along with the rationale for their selection is given in Subsection 10.4.9B.5.1.

The fault tree was not constructed to take advantage of "fortuitous failures," e.g , where a failed or misoperated components negates the effect of another failure or misoperation. This does result in some physically unrealistic failure combinations, but constructing the fault tree to eliminate them would unduly complicate the fault tree without significant improvement in predicted system reliability.

As noted in the FMEA, certain components can contribute to system failure by being in one state (e.g., valve open) under certain conditions and by being in the opposite state (valve closed) under different conditions. The fault tree could have been constructed to prevent the possible generation of cut sets including such mutually exclusive conditions by using NOT and AND gate combinations. However, this could not be done because the computer program used in the fault tree analysis will not accept a NOT gate, so such cases were handled by manually culling the cut sets of such combinations, as discussed in Subsection 10.4.9B.4.

Any failure which could affect more than one component, including common mode failures, were factored into the fault tree at the level at which the effect is seen, as opposed to being factored in a failure mode to each individual component. For example, the EFAS1 "A" logic failure, which could incapacitate both SG1 flow paths by not opening a valve on each path, was not entered as a failure to each valve individually, but rather was entered in an OR gate along with other events/event combinations which would incapacitate both SG1 flow paths. This approach was used because it permits use of the fault tree as a visual tool to readily identify the system level effects of certain failures.

🡐EC-33720, R307)

→(EC-33720, R307)

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A single fault tree including all components considered in the study was first generated. This fault tree represented the system under CASE 2 - LMFW/LOOP, and is shown on Figure 10.4.9B-3. For the other cases, the CASE 2 fault tree was reviewed to eliminate components which could not play a role due to differing initial condition assumptions. The resultant CASE 1 - LMFW and CASE 3 - LMFW/SB fault trees are shown respectively on Figures 10.4.9B-2 and 10.4.9B-4.

It was assumed that the operator did not correct component failures with one exception. The operator is assumed to be available to back up the automatic actuation of the system. This is considered reasonable, because the operating guidelines for plant transients call for the operator to confirm emergency feedwater actuation (immediately after confirming reactor trip), and to take action to restore emergency feedwater if it is not functioning. Both system and component level controls are available to the operator in the main control room. Failure of the operator to back up system level actuation signals has been factored into the fault tree as event OEI.

10.4.9B.4 System Model Qualitative Analysis

The purpose of the system qualitative analysis is to determine the "minimal cut sets," or minimum combinations of events which can lead to the top event. Since it was expected that most of the failure events were of relatively low probability (10 or less), it was decided that only the minimal cut sets containing three or less events would be of interest. Events containing more than three events would be of such low probability that it would not be meaningful to pursue them.

The PREP Code was chosen to perform the qualitative analysis because its combinational (trial and error) method of fault tree analysis is generally efficient when three event minimal cut sets are desired.

Each fault tree was individually analyzed to determine its three-or-less event minimal cut sets. The cut sets for each case are listed on Tables 10.4.9B-3 through 10-4.9B-5.

As discussed in Subsection 10.4.9B.3.3 some components (check valves 34, 35 & 36) enter the fault tree twice, in different states. Since the computer logic model could not be constructed to eliminate the possible generation of cut sets containing the same component in two different states, the output of the PREP Code was manually culled to find and eliminate such cut sets.

10.4.9B.5 System Model Quantatative Analysis

10.4.9B.5.1 Events Causes and Probabilities

To determine overall system unavailability, a probability of occurrence had to be established for each of the basic events on the fault tree. This was accomplished by identifying the applicable causes (from Subsection 10.4.9B.2.3) of each event, assigning probabilities to each cause, and summing the cause probabilities to obtain the event probability. Simple arithmetic summing of the cause probabilities was used because the "bracketing" correction terms would be insignificant because of the small numbers involved. The causes and probabilities of each event entering into the fault tree are given in Table 10.4.9B-6.

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→(EC-33720, R307)

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With the exception of testing and maintenance, selection of applicable causes for each event was straightforward. Applicability of test/maintenance causes to each event was determined on a case by case basis through a review of anticipated plant test and maintenance actions. This review is described in detail in Subsection 10.4.9B.5.1.1.

It should be noted that some of the causes of certain events are not expected to occur simultaneously, with some causes of other events appearing in the same cut sets. For example, if the "A" MDP was in maintenance during power operation, the Technical Specifications would not allow TDP maintenace without a plant shutdown. Performing the analysis to account for this would have unduly complicated the analysis without significantly improving the predicted overall system reliability, so this was conservatively ignored.

10.4.9B.5.1.1 Unavailability Due to Testing and Maintenance

System testing/maintenance can contribute to unavailability by two means:

-OUTAGE: Components/system are being tested/maintained in an inoperable state at the time operation is demanded.

-ERROR: Components realigned for the test/maintenance operation were not restored to their proper state following the operation by the test/maintenance crew.

A review of the Technical Specifications, ASME Section XI, equipment vendor maintenance manuals, system operating procedures, etc. was conducted to identify testing/maintenance operations, their expected frequency and their potential for unavailability contribution from either outage or error. The sections herein on testing and maintenance summarize this review. Table 10.4.9B-8 lists by component those maintenance/testing acts which were determined to contribute to unavailability.

SYSTEM TESTING

A review of system tests revealed that there is no unavailability contribution due to testing, primarily because:

a) All tests involve putting the component in its operational state, so that it is ready if system response is demanded during the test.

b) No realignment of manual valves is required for any system tests.

A discussion of system tests and their potential for unavailability contributions is given below:

PUMPS: The motor-driven and turbine-driven pumps must be tested in accordance with ASME Section XI Subsection IWP, which requires a monthly test for speed, inlet pressure, Δp, flow rate, vibration and bearing temperature. The Technical Specification 4.7.1.2.b requirement to measure pump discharge pressure every 92 days is enveloped by the Section XI tests.

←EC-33720, R307)

→(EC-33720, R307)

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To perform these tests, the pump is started (by turning the control switch to start) and allowed to deliver flow back to the CSP through the minimum flow recirculation line. This is carried out in normal system alignment, and none of the measurements to be taken affect pump operation. If a system demand occurred during the test, the motor-driven pumps would continue running if offsite power were available, or would be tripped and restarted by the diesel generator load sequencer if offsite power were unavailable. The turbine driven pump would continue running in any case. As such, the quarterly tests are not deemed to contribute to unavailability either by outage or error done.

The Technical Specifications also require that the pumps be verified to start on an EFAS every 18 months (i.e., during a refueling shutdown). This test will be performed by depressing the manual EFAS button(s) and observing that the appropriate pumps start. No system valve realignment or temporary wiring arrangements are required. The test is terminated by clearing the EFAS manual trip and turning the control switch to off. Since the test is performed during plant shutdown and with no system realignment, there is no potential for unavailability from the test either due to outage or error.

VALVES: The valves that are subject to testing under ASME Section XI, Subsection IWV, are listed in Table 10.4.9B-7.

Subsection IWV requires that these valves be exercised to the position required to fulfill their function every three months. For power operated valves, this includes timing the stroke to assure that valve closure time is within acceptable limits.

For the power operated valves, the test involves opening the valve by turning the control switch to "open" and measuring the time the valve requires to open as observed by the valve position indicator. The valve is returned to its original position by turning the control switch to "close." If a system demand occurs while the valve is open or being opened, there is no effect on the system, since the valve is already in or nearing its operational state. If a system demand occurs while the valve is being closed, the valve would reverse itself and go to the operational state. Thus, exercise testing of the power operated valves does not contribute to system unavailability.

Each check valve subject to testing can be tested during the testing of the pumps and power operated valves. If a system demand were to occur either during or after testing, the check valve would be returned to its proper position by the fluid forces of system operation. Thus, testing of the check valves does not contribute to unavailability either by outage or errors.

CONTROL: CIRCUITS The Section XI test for pumps and power operated valves is also a control circuit test. This is a monthly test for pumps and quarterly test for valves. As with the pump and valve tests, there is no contribution to system unavailability.

←EC-33720, R307)

→(EC-33720, R307)

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ACTUATING: LOGIC — Details of the testing of the EFAS logic are given in FSAR Section 7.3. As demonstrated there, these tests do not affect generation of the EFAS on demand and thus do not contribute to EFS unavailability.

DIESEL: GENERATORS — Details of the standby diesel generator testing are given in FSAR Section 8.3. As demonstrated there, tests do not affect the ability of the diesel generators to respond on demand, and thus do not contribute to EFS unavailability.

SYSTEM MAINTENANCE

There is little or no incapacitating maintenance planned during plant operation on the components under consideration. In general, the only time such maintenance would be performed during operation would be if the component failed to function during a periodic test. Unavailability due to this is normally given by the mean time to repair divided by the mean time between failure for the component. However, the plant Technical Specifications place an upper bound on how long the plant can be operated with the component in repair, so it is appropriate to use a mean time to repair based only on those repairs which take less time than the Technical Specifications LCO for that component. In addition, certain components cannot be repaired during plant operation, so maintenance on these components has no potential for causing unavailability. Details of how maintenance contributes to unavailability for each component is discussed below. A summary listing of maintenance actions affecting each component is given in Table 10.4.9B-8.

PUMP: MAINTENANCE — All planned maintenance for the pumps is to be performed during shutdown. The only time pump maintenance would be performed during operation would be if the pump failed to start during a routine Section XI test (discussed in the testing section). This is expected to contribute an outage contribution for the pumps only on the order of 10^{-4} which is an insignificant addition to the pump probability of failure to start on demand of 5×10^{-3} (including the control circuit). This is believed to be a realistic estimate, but for consistency with Reference 1 (p. III-16) the following method was used:

$$Q_{MAINT} = \frac{(0.22 \text{ maint. act/mo.})\ (7 \text{ hr./maint. act})}{(720 \text{ hr/mo.})}$$

$$= 2.1 \times 10^{-3}$$

Major pump maintenance would require closing the pump discharge and suction isolation valves to permit draining of the pump casing, introducing possible unavailability due to maintenance error. However, the position of these valves is rechecked at least every 31 days in accordance with the Technical Specifications. In addition, the position of these valves is monitored by the plant computer. As such, the probability of the pump suction/discharge isolation valves being left closed after pump maintenance is considered insignificant.

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→(EC-33720, R307)

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In addition, any such work done on the TDP would require isolation of the steam supply by closing manual valve 18. However, since the pump is to be tested after maintenance, the chance of the valve being left closed unnoticed is not considered credible.

VALVE: MAINTENANCE Certain EFS valves are not accessible for maintenance during plant operation plant operation because they directly interface with pressurized systems. Afault in such valves might require a plant shutdown in accordance with the LCO's which, while undesirable from an operations standpoint, virtually precludes the chance of maintenance on these valves from contributing to unavailability. These valves are: 64, 65, 66, 67, 68, 69, 70 and 71, (EFW isolation valves) and 72, 73, 39, and 40 (TDP steam supply valves).

The only remaining EFS active valves on the fault tree are the check valves at the pump discharges (valve 34, 35 and 36). There is no planned maintenance for these valves during planned operation, so the only time valve maintenance would be performed during operation would be if the valve failed to function during a routine Section XI test (discussed in the testing section). However, for consistency with Reference 1 (p. III-16), the following method was used:

$$Q_{MAINT} = \frac{(0.22 \text{ maint. act/mo.})\ (7 \text{ hr./maint. act})}{(720 \text{ hr/mo.})}$$

$$= 2.1 \times 10^{-3}$$

Repair on a pump discharge check valve would require closing the pump discharge and suction isolation valves to permit drainage of the piping section prior to disassembly if the valves. However, as with the pump repair, the probability of these valves being left closed after the check valve repair is negligible.

OTHER: MAINTENANCE There are two general plant maintenance activities which involve the EFS: the EFS: Water Treatment of the EFS and the Condensate and Feedwater Systems Pre-Startup Cleaning Operation. The potential for these activities affecting EFS availability is discussed below.

→(EC-34060, R306)

a) EFS Water Treatment - This operation injects chemicals (pH control agent and hydrazine) into the normally stagnant EFS as necessary to maintain water quality, and may be conducted during plant operation. It is performed by opening Valves 6CF-V605 and V607 (on the EFS suction header), Valves 64 and 70 (the inboard isolation valve on EFW flow path 1 to each SG) and Valves 20 and 21 (on the water treatment recirculation lines). This operation has no potential for contributing to unavailability either by outage or error, as discussed below. The two EFW isolation valves are placed in their operational state, so they would be ready if a system demand occurred during the operation. Similarly, even if they were erroneously left open by the maintenance crew, they would be in their operational state.

←(EC-34060, R306; EC-33720, R307)

➔(EC-33720, R307)

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➔(DRN 00-786, R11-A)

The chemical injection lines to the EFS suction header have check valves, which would prevent any backflow through these lines if a demand were to occur during the operation or following the operation and the maintenance crew erroneously left the isolation valves open. However, the line is only 1 in. in diameter compared to 6 in. for the header, so there would be no significant loss of suction to the EFS pumps via these lines even if the isolation valves were left open and the check valves stuck open.

🡐(DRN 00-786, R11-A)

The water treatment recirculation lines are only 1 in. and have flow restrictors. Thus, even if the isolation valves in these lines were erroneously left open by the maintenance crew, no significant diversion of EFS flow would occur.

b) Condensate and Feedwater Systems Pre-Startup Cleaning Operation: In this operation, the condensate and feedwater systems are flushed to the main condenser and via a portion of the EFS. The Main Feedwater Isolation Valves are closed and the main feedwater flow path is diverted to the EFS by opening either Valve 62 or 63 (the valves are interlocked so that only one at a time may be opened).

The flow path to the main condenser is established by opening either Valve 60 or 61 (also interlocked). Since this operation is performed only during shutdown, there is no unavailability contribution due to outage, but there is a contribution from error as discussed below.

If Valve 62 or 63 was erroneously left open after the operation by the maintenance crew, the series check valve (37 or 38) would prevent any diversion of EFS flow to the Main Feedwater System. However, as long as the MFWS remains intact and water solid, as it is assumed to be for the transients being analyzed, there is no potential for flow diversion by these lines even if the check valves were frozen open and the motor operated valves were open. There is thus no unavailability contribution due to the valves on the lines connecting the EFS to the MFWS upstream of the MFIV's.

If Valve 60 or 61 was erroneously left open, as much as 700 gpm of EFS flow could be diverted from the SG's to the Main Condenser. However, one of the valves must be left open AND the turbine-driven pump must fail for this to cause system failure. Hand calculations showed this to be an insignificant failure contributing mechanism, so it was not modeled into the fault tree.

Manual Valves 13, 15, 16, and 17, which are used to isolate the EFS header for this operation, could conceivably be left closed after the flushing operation leaving the EFS inoperable. A single valve or pair of valves could be left closed as well, but failure to leave all the valves closed is the most significant error since it is a system incapacitating common mode failure.

There are three major checkpoints at which this condition would be detected prior to plant startup. These, along with their probability to fail to be properly executed, are as follows:

🡐EC-33720, R307)

➔(EC-33720, R307)

CONTINUED HISTORICAL INFORMATION

1. System realignment: The operators/maintenance crew must fail to carry out the system realignment specified in the procedure for the prestartup condensate and feedwater cleanup operation. This is a failure to use a valve restoration list, and is assigned a probability of 0.01 from Reference 2, p-15-9.

2. EFS flow path verification: The operators must fail to carry out the EFS flow path verification test (NUREG-0635 Recommendation GS-6; see Appendix 10.4.9A) which, if performed, would readily detect the valve mispositioning. This is a failure to carry a plant policy, and is assigned a probability of 0.01 from Reference 2, p. 15-9.

3. EFS status monitoring: The control room operators must fail to notice the EFS annunciator on the ESF bypassed and inoperable status indication insert, which would be lighted in response to the position indicators on the valves. This is a failure to detect a deviant status light, and is assigned a probability of 0.01 from Reference 2, p. 11-17.

Assuming that the three check points are independent, the probability of all three failing to be carried out is 1×10^{-6} . However, recognizing that the checkpoints are not totally independent (they are all carried out by the same plant operating staff), the probability of ME1 is raised judgementally to 5×10^{-6}.

10.4.9B.5.2 System Failure Probability Analysis

The overall system failure probability was determined from the minimal cut sets and individual event probabilities using an option of the KITT 1 Code. In essence, the probability of each cut set is determined by multiplying the probability of each event in the cut set, and the system failure probability is determined by adding the probability of each cut set. No corrections for simultaneous occurrence (i.e., bracketing) were made, as the numbers involved are quite small. The results are as follows:

TRANSIENT	$\overline{a}$
CASE 1	1.42×10^{-5}
CASE 2	3.97×10^{-5}
CASE 3	2.63×10^{-2}

🡐EC-33720, R307)

→(EC-33720, R307)

CONTINUED HISTORICAL INFORMATION

10.4.9B.6 Discussion of Results

CASE 1

The dominant cut sets for Case 1 and their relative contributions to system failure are given on Table 10.4.9B-9. The dominant cut sets fall into four basic system failure modes:

a) Maintenance errors, specifically MEI, which is discussed in detail in Subsection 10.4.9B.5.1.1 (cut set 1). This contributes 35.2 percent of total system failure probability.

b) Failure of one of the pumps to start coupled with its discharge check valve sticking open, which diverts the other pumps flow from the SGs to recirculate through the idle pump loop (cut sets 4, 9, 10, 11, 12 & 15). These failure types contribute 26.4 percent of total system failure probability.

c) Failure of both automatic and operator backup actuation of the system (cut sets 17, 18, 19 & 20). These failure types contribute 14.0 percent of total system failure probability.

d) Failure of both motor driven pumps coupled with failures in the turbine driven pump steam supply system (cut sets 76, 80 & 84). These failure types contribute 7.3 percent of total system failure probability.

The above failure modes account for 82.9 percent of total system failure probability. The remaining 17.1 percent is from over 193 cut sets of lesser importance.

The absolute value of the Waterford 3 EFS unavailability for Case 1 of 1.42×10^{-5} is in the high reliability range of Reference 1 (unavailability between 10^{-4} and 10^{-5}.

CASE 2

The dominant cut sets for Case 2 and their relative contributions to system failure are given in Table 10.4.9B-10. The dominant cut sets fall into the same four basic system failure modes as Case 1:

a) Maintenance errors (cut set 1) - 12.6 percent of total system failure probability.

b) Failure of one pump to start coupled with its discharge check valve sticking open (cut sets 4, 5, 10, 11, 12, 16 & 17) - 27.2 percent of total system failure probability.

c) Failure of both automatic and operator backup actuation of the system (cut sets 19, 20, 21 & 22) - 4.8 percent of total system failure probability.

d) Failure of both motor driven pumps coupled with failures in the turbine driven pump or its steam supply system (cut sets 92, 97, 102, 107, 137, 142, 147 & 152) - 30.6 percent of total system failure probability.

←EC-33720, R307)

→(EC-33720, R307)

CONTINUED HISTORICAL INFORMATION

The above failure modes account for 75.2 percent of total system failure probability. The remaining 24.8 percent is from over 274 cut sets of lesser importance. The difference between Case I and Case 2 was due to the fact that a motor driven pump failure can be caused either by a direct pump failure or by failure of its associated diesel generator.

The absolute value of the Waterford 3 EFS unavailability for Case 2 of 3.97×10^{-5} is in the high reliability range of Reference 1 (unavailability between 10^{-4} and 10^{-5}.

CASE 3

The dominant cut sets for Case 3 and their relative contributions to system failure are given on Table 10.4.9B-11. As expected, there are a number of one event cut sets, since the motor-driven pumps are deemed inoperable by the initial condition of Station Blackout for this case. The dominant contributions to system failure potential for this case are the turbine-driven pump and its governor valve, speed controller and overspeed protection, which comprise roughly 90 percent of the total causes.

The absolute value of EFS reliability for Case 3 is in the medium range of Reference 1 (unavailability between 10^{-1} and 10^{-2}.

10.4.9B.7 Conclusions

No acceptance criteria for this study were given, but as noted in the previous section the results were good when compared to the other plants studied in Reference 1. The main reasons that favorable results were achieved are:

a) The active components and flow paths are redundant, so there are no single point vulnerabilities.

b) The system is automatically actuated, so no human action is required.

c) System design is such that all routine testing can be done with no incapacitating realignments or locking out of components.

d) All anticipated maintenance is performed during plant shutdown.

e) There are few interconnections with other systems, minimizing the potential for adverse interactions with other systems.

f) Position of most of the manual valves in the system are monitored by the plant computer, minimizing the potential that these valves are mispositioned.

Other than ME1, the analysis did not uncover any areas where minor changes could result in major reliability improvements. Reliability has always been a subjective consideration in the design and intended operating/maintenance practices for this system, and this quantitative reliability analysis confirmed that.

←EC-33720, R307)

→(EC-33720, R307)
CONTINUED HISTORICAL INFORMATION

Regarding ME1, the potential for error could be eliminated by not closing Valves 13, 14, 16 & 17 during the prestartup condensate and feedwater cleanup operation, i.e., rely on the pump discharge check valves to prevent backflow to the CSP during the operation. This will be investigated and will be incorporated into the procedure if feasible. This would improve system reliability beyond the values given in this report if incorporated.

This study was useful in demonstrating that the Waterford 3 EFS is of high reliability, and that there were no major faults in the system design. However, care should be taken in applying the numerical results too literally. In particular, the unavailability reported for Case 1 begins to approach a judgemental lower bound on achievable unavailability for any system due to unidentified common cause failures. For this reason, there is probably little actual system reliability improvements to be gained even by major changes such as adding more pumps.

References:

1. Letter from D. Ross to all Westinghouse and Combustion Engineering Operating License Applicants, dated March 10, 1980.

2. NUREG/CR-1278, "Handbook of Human Reliability Analysis with Emphasis on Nuclear Power Plant Applications," October 1980.

END OF HISTORICAL INFORMATION
←(EC-33720, R307)

TABLE 10.4.9B-1 (Sheet 1 of 5) Revision 307 (07/13)

→(EC-33720, R307)
START OF HISTORICAL INFORMATION

COMPONENT LIST

MANUAL VALVES

VALVE NUMBER	DESCRIPTION	FMEA SEGMENT
* 1:EFW-102B/3CD-V111B	Isolation valve on CSP suction line "B"	I
* 2:EFW-102A/3CD-VIIOA	Isolation valve on CSP suction line "A"	I
3:3CC-V211B	Isolation valve on line to alternate water source for suction line "B"	I
4:3CC-V201A	Isolation valve on line to alternate water source for suction line "A"	I
* 5:EFW-103A/3CD-V145A/B	Isolation valve on suction header between "A" MDP and TDP	I
* 6:EFW-103B/3CD-V146A/B	Isolation valve on suction header between TDP and "B" MDP	I
* 7:EFW-106A/3CD-V112A	Isolation valve on "A" MDP suction	I
* 8:EFW-106A/B/3CD-V114A/B	Isolation valve on TDP suction	I
* 9:EFW-106B/3CD-V113B	Isolation valve on "B" MDP suction	I
10:EFW-201A/3FW-V15O5-16	Isolation valve on "A" MDP mini-flow recirc line	I.A
11:EFW-201A/B/3FW-V1503-7	Isolation valve on TDP mini-flow recirc line	II.T.2
12:EFW-201B/3FW-1505-17	Isolation valve on "B" MDP mini-flow recirc line	II.B
* 13:EFW-211A/3FW-604A	Isolation valve on "A" MDP discharge	II.A
* 14:EFW-211A/B/3FV-606A/B	Isolation valve on TDP discharge	II.T.2
* 15:EFW-211B/3FW-V605B	Isolation'valve on "B" MDP discharge	II.B
* 16:EFW-215A/3FW-V608	Isolation valve on discharge header between	III.I "A" MDP and TDP
* 17:EFW-215B/3FW-V609	Isolation valve on discharge header between	III TDP and "B" MDP
18:MS-415/3MS-678A/B	Isolation valve on TDP steam supply line	III.T.1
* 19:FW-205/3FW-V619A/B	Isolation valve on mini-flow recirculation	- line CSP

*Valve is position monitored by the plant computer

←EC-33720, R307)

→(EC-33720, R307)

CONTINUED HISTORICAL INFORMATION

COMPONENT LIST

MANUAL VALVES

VALVE NUMBER	DESCRIPTION	FMEA SEGMENT
20:EFW-22SA/2FW-VI501-1	Isolation valve on water treatment recirculation line serving SGI branch	III.1
21:EFW-227B/2FW-VI501-2	Isolation valve on water treatment recirculation line serving SG2 branch	III.2
22:3MS-V753	Isolation valve on TDP steam supply line drip pot flush line	II.T.1
23:MS-409/5MS-V649-7	Isolation valve on TDP steam supply line drip pot normal drain line	II.T.1
24:MS-408/SMS-V649-8	Isolation valve on TDP steam supply line drip pot comon drain line	II.T.1
25:CF-114/6CF-V605	Isolation valve on line from hydrazine pump (for chemical treatment)	I
26:CF-212/6CF-V607	Isolation valve on line from ammonia line (for chemical treatment)	I

CHECK VALVES

VALVE NUMBER	DESCRIPTION	FEMA SEGMENT
31:EFW-204A/3FW-VI507-2	"A" MDP mini-flow recirculation line	II.A
32:EFW-204A/B3FW-VI517	TDP mini-flow recirculation line	II.T.2
33:EFW-204B/3FW-VI507-1	"B" MDP mini-flow recirculation line	II.B
34:EFW-207A/3FW-V601A	"A" MDP discharge line	II.A
35:EFW-207A/B/3FW-V603A/B	TDP discharge line	II.T.2
36:EFW-207B/3FW-V602B	"B" MDP discharge line	II.B
37:FW-18OA/3FW-V837A	Prestartup cleanup line from MFW serving SGI branch	III.1
38:FW-18OB/3FW-V838B	Pre-startup cleaning line from MFW serving SG2 branch	III.2

←EC-33720, R307)

→(EC-33720, R307)
CONTINUED HISTORICAL INFORMATION

COMPONENT LIST

CHECK VALVES

VALVE NUMBER	DESCRIPTION	FEMA SEGMENT
39:MS-402A/3MS-V676A	TDP steam supply line from SG1	II.T.1
40:MS-402B/3MS--V677B	TDP steam supply line from SG2	II.T.1
41:5MS-V722	TDP steam supply line drip pot common drain line	II.T.1
42:EFW-2191A/3FW-V1541A	TDP & MDP discharge header line to SGI	III.1
43:EFW-2191B/3FW-V1541B	TDP & MDP discharge header line to SG2	III.2
	POWER OPERATED VALVES (including control circuits)	
→(EC-3926, R304)		
+60:EFW-22OA/3FW-V607A	Pre-startup cleanup line to SG blowdown serving SGI branch	III.1
+61:EFW-22OB/3FW-V61OB	Pre-Startup cleanup line to SG blowdown serving SG2 branch	III.2
+62:FW-179A/3FW-V839A	Pre-startup cleanup line from MFW serving SG1 branch	III.1
+63:FV-179B/3FW-V84OB	Pre-startup cleanup line from MEV serving SG2 branch	III.2
←(EC-3926, R304)		
64:EFW-224A/2FW-V85IB(Air)	Inboard isolation on SG1 EFW Path 1	III.1
**65:EFW-22BA/2FW-V848A(Air)	Outboard isolation on SG1 EFV Path 1	III.1
66:EFW-223A/2FW-V852A(Air)	Inboard isolation on SG1 EFV Path 2	III.1
**67:EFW-229A/2FW-V847B(Air)	Outboard isolation on SG1 EFV Path 2	III.1
68:EFW-223B/2FW-VB54B(Air)	Inboard isolation on SG2 EFV Path 2	III.2
**69:EFW-229B/2FW-V849A(Air)	Outboard isolation on SG2 EFW Path 2	III.2
70:EFW-224B/2FW-V853A(Air)	Inboard isolation on SG2 EFW Path 1	III.2
**71:EFW-228B/2FW-V85OB(Air)	Outboard isolation on SG2 EFW Path 1	III.2
**72:2MS-V611A(Motor)	TDP steam supply line from SG1	II.T.1

**Valve has position indication in control room.
+Motor Operator Abandoned in Place

←EC-33720, R307)

TABLE 10.4.9B-1 (Sheet 4 of 5) Revision 307 (07/13)

➔(EC-33720, R307)

CONTINUED HISTORICAL INFORMATION

COMPONENT LIST
PUMPS

PUMP	CAPACITY	FEMA SEGMENT
**73:2MS-V612B(Motor)	TDP steam supply line form SG2	II.T.1
**74:MS-416(Motor)	TDP trip and throttle valve	II.T.1
75:MS-417(Hydr)	TDP governor valve	II.T.1
**76:MS-412/3MS-V684(Motor)	TDP steam supply line drip pot normal drain Line	II.T.1
**77:MS-407 (Air)	EFW PT MS supply drip pot normal drain bypass	II.T.1
78:MS-410/MS-V716(Air)	TDP steam supply line drip pot drain to EDS	II.T.1
85:"A" MOTOR DRIVEN*	450 gpm + 45 gpm recirc. @ SG Pres = 1050 psi	II.A
86:TURBINE DRIVEN	700 gpm + 80 gpm recirc.	II.T.2
87:"B" MOTOR DRIVEN*	450 gpm + 45 gpm recirc. @ SG Pres = 1050 psi	II.B

🡐EC-33720, R307)

TABLE 10.4.9B-1 (Sheet 5 of 5) Revision 307 (07/13)

➔(EC-33720, R307)
CONTINUED HISTORICAL INFORMATION

COMPONENT LIST

ACTUATING LOGIC

SIGNAL	PURPOSE	FEMA SEGMENT(S)
90:EFAS 1"A"	Indicates that SGI is intact and is in need of EFW; ACTUATES "A" MDP and Valves 65, 66 & 72 (TDP)	II.A; II.T.1; III.1
91:EFAS 2"A"	Indicates that SG2 is intact and is in need of EF'W; ACTUATES "A" MDP and Valves 69, 70, & 73 (TDP)	II.A; II.T.1; III.2
92:EFAS 1"B"	Indicates that SGI is intact and is in need of EFW; actuates "B" MDP and Valves 64, 67 & 72 (TDP)	II.B; II.T.1; III.1
93:EFAS 2"B"	Indicates that SG2 is intact and is in need of EFW; acutates "B" MDP and Valves 68, 71 & 73 (TDP)	III.B; II.T.1; III.2
94:TDP Overspeed	Indicates failure of TDP speed control; closes TDP steam stop valve (Valve 74)	II.T.1
95:TDP Speed Control	Regulates TDP governor valve (Valve 75) as necessary to maintain pump speed	II.T.1

POWER SUPPLIES

SYSTEM	SERVICES COMPONENTS	FMEA SEGMENT
80:SA ac-4kV & 480V	"A" MDP	II.A
81:SB ac-4kV & 480V	"B" MDP	II.B

*Includes control circuit

END OF HISTORICAL INFORMATION
🡐(EC-33720, R307)

TABLE 10.4.9B-2 (Sheet 1 of 9) Revision 307 (07/13)

→(EC-33720, R307)

START OF HISTORICAL INFORMATION

EFS FAILURE MODES AND EFFECTS ANALYSIS

COMPONENT	COMPONENT STATE	EFFECT	INHERENT COMPENSATION
I. CONDENSATE SUPPLY (SUCTION TO EFS PUMPS)			
- Manual Valve 1 EFW-102B/CD-V111B	- Open	Normal State	---
	- Closed	Loss of CSP Suction Line "B" to all EFW pumps	CSP Suction Lines "A" available to all EFW pumps
- Manual Valve 2 EFW-102A/3CD-V110A	- Open	Normal State	---
	- Closed	Loss of CSP Suction Line "A" to all EFW pumps	CSP Suction Line "B" available to all EFW pumps
- Manual Valve 3 3CC-V211B	- Open	Potential for CSP draining to Wet Cooling Tower Basin	None, but there is a manual butterfly valve (3CC-B306B) which is locked closed upstream of 3CC-V211B
	- Closed	---	---
- Manual Valve 4 3CC-V210A	- Open	Potential for CSP draining to WCT Basin	None, but there is a manual butterfly valve (3CC-B305B) which is locked closed upstream of 3CC-V212A
- Manual Valve 5 3CD-V145A/B; EFW-103A	- Open	Normal State	---
	- Closed	Loss of CSP Suction Line "A" to TDP and "B" MDP and loss of CSP Suction Line "B" to "A" MDP	CSP Suction Line "B" available to TDP and "B" MDP and VSP Suction Line "A" available to "A" MDP
- Manual Valve 6 3CD-V146A/B; EFW-103B	- Open	Normal State	---
	- Closed	Loss of CSP Suction Line "B" to TDP and "A" MDP and loss of CSP Suction Line "A" to "B" MDP	CSP Suction Line "A" available to TDP and "A" MDP and CSP Suction Line "B" available to "B" MDP
- Manual Valve 7 3CD-V112A; EFW-106A	- Open	Normal State	---
	- Closed	Loss of all suction sources to "A" MDP	None, but TDP and "B" MDP not affected.
- Manual Valve 8 3CD-V114A/B; EFW-106A/B	- Open	Normal State	---
	- Closed	Loss of all suction sources to TDP	None, but "A" MDP and "B" MDP not affected

←(EC-33720, R307)

TABLE 10.4.9B-2 (Sheet 2 of 9) Revision 307 (07/13)

→(EC-33720, R307)

CONTINUED HISTORICAL INFORMATION

COMPONENT	COMPONENT STATE	EFFECT	INHERENT COMPENSATION
- Manual Valve 9 3CD-V113B; EFW-106B	- Open - Closed	Normal State Loss of all suction sources	None, but TDP and "A" MDP not affected to "B" MDP
- Manual Valve 19 3FW-619A/B; FW-205	- Open - Closed	Normal State Loss of mini-flow recirculation; no immediate effect, but possible pump damage when SG isolation valves cycle closed	None, but system initial start not affected
Manual Valve 25 CF-114/6CF-V605	- Open Closed	Insignificant - see Subsection 10.4.9B.5.1.1.a Normal State	--- ---
Manual Valve 26 CF-212/6CF-V607	Open - Closed	Insignificant - see Subsection 10.4.9B.5.1.1.a Normal State	--- ---
II.A "A" MOTOR DRIVEN PUMP BLOCK			
- Pump/Motor	- Fails to start	Fluid not delivered towards header	None, but TDP and "B" MDP not affected
- SA ac Power (4kV & 480V)	- Fails to energize pump motor	Fluid not delivered towards header	None, but TDP and "B" MDP not affected
- EFAS 1 "A" Logic	- Signal not generated	Loss of one of two automatic start signals to pump	EFAS 2 "A" starts pump; Operator could start pump
- EFAS 2 "A" Logic	- Signal not generated	Loss of one of two automatic start signals to pump	EFAS 1 "A" starts pump; Operator could start pump
- Manual Valve 10 EFW-201A/3FW-V1505-16	- Open - Closed	Normal State Loss of "A" MDP mini-flow recirculation no immediate effect, but possible pump damage when SG isolation valves cycle closed	None, but TDP and "B" MDP not affected; "A" MDP initial response not affected
- Check Valve 31 EFW-204A/3FW-V1507-2	- Open (against forward current)	Proper State	---
	- Closed (against reverse current)		
	- Open (against reverse current)	TDP and "B" MDP partial mini-flow recirculation through idle "A" MDP loop; No problem	---
	- Closed (against forward current)	Loss of "A" MDP mini-flow recirculation; no immediate effect, but possible pump damage when SG isolation valves cycle closed	None, but TDP and "B" MDP not affected; "A" MDP initial start not affected

←(EC-33720, R307)

→(EC-33720, R307)

CONTINUED HISTORICAL INFORMATION

COMPONENT	COMPONENT STATE	EFFECT	INHERENT COMPENSATION
- Check Valve 34 EFW-207A/3FW-V601A	- Open (against forward current)	Proper State	---
	- Closed (against reverse current)	Proper State	---
	- Open (against reverse current)	Most TDP and "B" MDP flow diverted from SGs to recir through idle "A" MDP loop; negation of system function	None, unless Valve 7 or 13 mispositioned closed (fortuitous failure)
	- Closed (against forward current)	Fluid not delivered towards header	None, but TDP and "B" MDP not affected
- Manual Valve 13 EFW-211A/3FW-V604A	- Open	Normal State	---
	- Closed	Fluid not delivered towards header	None, but TDP and "B" MDP not affected
II.T.1 TURBINE DRIVEN PUMP STEAM SUPPLY			
- Motor Op. Valve 72 2MS-611A	- Open	Proper Operation	---
	- Closed	Loss of SG1 steam supply to TDP	SG2 steam supply not affected
- Check Valve 39 MS-402A/3MS-V676A	- Open (against forward current)	Proper Operation	---
	- Closed (against forward current)	Loss of SG1 steam supply to TDP	SG2 steam supply not affected
	(Reverse current will not occur under the conditions analyzed)		
- Motor Op. Valve 73 2MS-V612B	- Open	Proper Operation	---
	- Closed	Loss of SG2 steam supply to TDP	SG1 steam supply not affected
- Check Valve 40 MS402B/3MS-V677B	- Open (against forward current)	Proper State	
	- Closed (against forward current)	Loss of SG2 steam supply to TDP	- SG1 steam supply available (Reverse current will not occur under the conditions analyzed).
- Manual Valve 18 MS415/3MS-V678A/B	- Open	Normal State	
	- Closed	Loss of all steam supply to TDP	None, but "A" and "B" MDPs not affected

←(EC-33720, R307)

TABLE 10.4.9B-2 (Sheet 4 of 9) Revision 307 (07/13)

→(EC-33720, R307)

CONTINUED HISTORICAL INFORMATION

COMPONENT	COMPONENT STATE	EFFECT	INHERENT COMPENSATION
- Motor Op. Valve 74 MS416	- Open - Closed	Normal State Loss of all steam supply to TDP	--- None, but "A" and "B" MDPs not affected
- Hyd. Op. Valve 75 MS417	- Open - Closed	Normal State Loss of all steam supply to TDP	--- None, but "A" and "B" MDPs not affected
- EFAS1 "A" Logic	Failure to be generated	Loss of one group of automatic open signals to Valve 72	EFAS1 "B" Opens Valve 72
- EFAS1 "B" Logic	Failure to be generated	Loss of one group of automatic open signals to Valve 72	EFAS1 "A" Opens Valve 72
- EFAS2 "A" Logic	Failure to be generated	Loss of one group of automatic open signals to Valve 73	EFAS2 "B" Opens Valve 73
- EFAS2 "B" Logic	Failure to be generated	Loss of one group of automatic opens signals to Valve 73	EFAS2 "A" Opens Valve 73
- Valves 22,23,24 41,76,77 & 78	These valves are on drain lines serving the TDP steam supply line drip pot, and as such, must be evaluated for their potential to divert steam from the TDP. Because of their small size (1 in. - 2 in.) they are not considered to be capable of diverting any significant quantity of steam.		
II.T.2 TURBINE DRIVEN PUMP BLOCK			
- Pump/Turbine	Fails to start	Fluid not delivered towards header	None, but "A" and "B" MDPs not affected
- Manual Valve 11 EFW-201A/B/3FW-V1503-7	- Open - Closed	Normal State Loss of TDP mini-flow recirculation; no immediate effect, but possible pump damage when SG isolation valves cycle closed	--- None, but "A" and "B" MDPs not affected; TDP initial start not affected
Check Valve 32 EFW-204A/B3FW-V5I7	- Open (against forward current) - Closed (against reverse current)	Proper State	---

←(EC-33720, R307)

→(EC-33720, R307)

CONTINUED HISTORICAL INFORMATION

COMPONENT	COMPONENT STATE	EFFECT	INHERENT COMPENSATION
- Check Valve 32 EFW-204A/B3FW-V517 (cont'd)	- Open (against reverse current)	"A" and "B" MDP partial mini-flow recirculation through idle TDP loop; No problem	---
	- Closed (against forward current)	Loss of TDP mini-flow recirculation; no immediate effect, but possible pump damage when SG isolation valves cycle closed	None, but "A" and "B" MDPs not affected; TDP initial start not affected
- Check Valve 35 EFW-207A/B3FW-V603 A/B	- Open (against forward current)	Proper Operation	---
	- Closed (against reverse current)	Proper Operation	
	- Closed (against forward current)	Fluid not delivered towards header	None, but "A" and "B" MDPs not affected
	- Open (against reverse current)	Most "A" and "B" MDP flow diverted from SG's to recirculation through idle TDP loop; negation of system function	None, unless Valve 8 or 14 mispositioned closed (fortuitous failure)
- Manual Valve 14 EFW-211A/B/3FW-V606 A/B	- Open	Normal State	---
	- Closed	Pump doesn't deliver fluid towards header	None, but "A" and "B" MDPs not affected
II.B "B" MOTOR DRIVEN PUMP BLOCK			
- Pump/Motor	Fails to start	Fluid not delivered towards header	None, but "A" MDP and TDP not affected
- SB ac Power (4kV & 480V)	Fails to energize pump motor	Fluid not delivered towards header	None, but "A" MDP and TDP not affected
- EFAS 1 "B" Logic	Signal not generated	Loss of one of two auto start signals to pump	EFAS 2 "B" or Operator starts pump
- EFAS 2 "B" Logic	Signal not generated	Loss of one of two auto start signals to pump	EFAS 2 "B" or Operator starts Pump
- Manual Valve 12 EFW-201B/3FW-V1505-17	- Open	Normal State	---
	- Closed	Loss of "B" MDP mini-flow recirculation; no immediate effect, but possible pump damage when SG isolation valves cycle closed	None, but "A" MDP and TDP not affected; "B" MDP initial response not affected

←(EC-33720, R307)

→(EC-33720, R307)

CONTINUED HISTORICAL INFORMATION

COMPONENT	COMPONENT STATE	EFFECT	INHERENT COMPENSATION
Check Valve 33 EFW-204B/3FW-V1507-1	- Open (against forward current)	Proper State	---
	- Closed (against reverse current)	Proper State	---
	- Open (against reverse current)	"A" MDP and TDP partial mini-flow recirculation through idle "B" MDP loop; no problem	---
	- Closed (against forward current)	Loss of "B" MDP mini-flow recirculation; no immediate effect, but possible pump damage when SG isolation valves cycle closed	None, but "A" MDP and TDP, MDP not affected; "B" MDP initial start not affected
- Check Valve 36 EFW-207B/3FW-V602B	- Open (against forward current)	Proper State	---
	- Closed (against reverse current)	Proper State	---
	- Open (against reverse current)	Most "A" MDP and TDP flow diverted from SGs to recirc through idle "B" MDP loop; negation of system function	None, unless Valve 9 or 15 mispositioned closed (fortuitous failure)
	- Closed (against forward current)	Fluid not delivered towards header	None, but "A" MDP and TDP not affected
- Manual Valve 15 EFW-211B/3FW-V605B	- Open	Normal State	---
	- Closed	Fluid not delivered towards header	None, but "A" MDP and TDP not affected
III.1 SG1 FLOW PATH			
- Manual Valve 16 EFW-215A/3FW-V608	- Open	Normal State	---
	- Closed	"A" MDP can't feed SG2; TDP & "B" MDP can't feed SG1	TDP & "B" MDP can feed SG2; "A" MDP can feed SG1
→(EC-3926, R304) - Manual Valve 60 FW-220A/3FW-V607A	- Closed	Normal State	---
	- Open	Diversion of up to 700 gpm EFW flow from SGs to Main Condenser	At least 700 gpm EFW flow available to SGs

←(EC-3926, R304; EC-33720, R307)

➔(EC-33720, R307)

CONTINUED HISTORICAL INFORMATION

COMPONENT	COMPONENT STATE	EFFECT	INHERENT COMPENSATION
- Check Valve 37 FW-180A/3FW-V837A	- Closed (against reverse current)	Proper State	---
	- Open (against reverse current)	Possible diversion EFS flow from SGs to MFW	Series Valve 62 closed. Also, MFW System intact and solid for transients under consideration
	(Forward current not deleterious to operation)		
Check Valve 42 3FW-V1541A	- Open (against forward current)	Proper State	---
	- Closed (against reverse current)	Proper State	---
	- Open (against reverse current)	Fluid not delivered towards SG1	SG2 flow path not affected
	- Closed (against forward current)	Fluid not delivered towards SG1	SG2 flow path not affected
➔(EC-3926, R304)			
- Manual Valve 62 FW-179A/3FW-839A	- Closed	Normal State	---
	- Open	Possible diversion of EFS flow from SGs to MFW if check valves 37 open against reverse current	Series Check Valve 37 closed. Also, MFW System Intake and solid for transients under consideration
🡐(EC-3926, R304)			
- Air Op. Valve 64 EFW-224A/2FW-851B	- Open	Proper Operation	---
	- Closed	Loss of SG1 EFW path 1	SG1 EFW path 2 not affected
- Manual Valve 20 EFW-225A/2FW-V1501-1	- Closed	Normal State	---
	- Open	None; 1 in. line with flow restrictor will not divert any significant EFW flow	---
- Air Op. Valve 65 EFW-228A/2FW-V848A	- Open	Proper Operation	---
	- Closed	Loss of SG1 EFW Path 1	SG1 EFW path 2 unaffected
- Air Op. Valve 66 EFW-223A/2FW-V852A	- Open	Proper Operation	---
	- Closed	Loss of SG1 EFW path 2	SG1 EFW path 1 unaffected

🡐(EC-33720, R307)

→(EC-33720, R307)

CONTINUED HISTORICAL INFORMATION

COMPONENT	COMPONENT STATE	EFFECT	INHERENT COMPENSATION
- Air Op. Valve 67 EFW-229A/2FW-B847B	- Open	Proper Operation	---
	- Closed	Loss of SG1 EFW path 2	SG1 EFW path 1 unaffected
- EFAS 1 "A" Logic	- Signal not generated	Valves 65 & 66 do not open; Both SG1 paths lost	SG2 EFW paths unaffected; Operator can open valves
- EFAS 1 "B" Logic	- Signal not generated	Valves 64 & 67 do not open; Both SG1 paths lost	SG2 EFW paths unaffected; Operator can open valves
III.2 SG2 FLOW PATH			
- Manual Valve 17 EFW-215B/3FW-V609	- Open	Normal State	---
	- Closed	"A" MDP and TDP can't feed SG2; "B" MDP can't feed SG1	"B" MDP can feed SG2; "A" MDP & TDP can feed SG1
→(EC-3926, R304)			
- Manual Valve 61 EFW-220B/3FW-V601B	- Closed	Normal State	---
	- Open	Diversion of up to 350 gpm EFW flow from SGs to Main Condenser	At least 1050 gpm EFW flow available to SGs
←(EC-3926, R304)			
- Check Valve 38 FW-180B/3FW-V838B	- Closed (against reverse current)	Proper State	---
	- Open (against reverse current)	Possible diversion EFS flow from SGs to MFW	Series Valve 63 closed. Also, MFW intact and solid for transients under consideration
	(Forward current not deleterious to operation)		
- Check Valve 43 3FW-V1542B	- Open (against forward current)	Proper State	---
	- Closed (against reverse current)	Proper State	---
	- Open (against reverse current)	Fluid not delivered towards SG2	SG1 flow path not affected
	- Closed (against forward current)	Fluid not delivered towards SG2	SG1 flow path not affected

←(EC-33720, R307)

→(EC-33720, R307)

CONTINUED HISTORICAL INFORMATION

COMPONENT	COMPONENT STATE	EFFECT	INHERENT COMPENSATION
→(EC-3926, R304)			
- Manual Valve 63 FW-179B/3FW-V840B	- Closed	Normal State	---
	- Open	Possible diversion of EFS flow from SGs to MFW if check valve 38 open against reverse current	Series Check Valve 38 closed. Also, MFW System intact and solid for transients under consideration
←(EC-3926, R304)			
- Air Op. Valve 68 EFW-223B/2FW-V854B	- Open	Proper Operation	---
	- Closed	Loss of SG2 EFW path 2	SG2 EFW path 1 unaffected
- Air Op. Valve 69 EFW-229B/2FW-V849A	- Open	Proper Operation	---
	- Closed	Loss of SG2 EFW path 2	SG2 EFW path 1 unaffected
- Air Op. Valve 70 EFW-224B/2FW-V853A	- Open	Proper Operation	---
	- Closed	Loss of SG2 EFW path 1	SG2 EFW path 2 unaffected
- Manual Valve 21 EFW-227B/2FW-V1530-2	- Closed	Normal State	---
	- Open	None; 1 in. line with flow restrictor will not divert any significant EFW flow	---
- Air Op. Valve 71 EFW-228B/2FW-V850B	- Open Closed	Proper Operation Loss of SG2 EFW path 1	--- SG2 EFW path 2 unaffected
- EFAS 2 "A" Logic	- Signal not generated	Valves 69 & 70 do not open; Both SG2 EFW paths lost	SG1 EFW paths unaffected; Operator can open valve
- EFAS 2 "B" Logic	- Signal not generated	Valves 68 & 71 do not open; Both SG2 EFW paths lost	SG1 EFW paths unaffected; Operator can open valves

IV. OVERALL SYSTEM FUNCTION

→(DRN 00-786, R11-A)

As noted in Subsection 10.4.9B.2.1 system minimum function is fulfilled when a total of 450 gpm is delivered to the steam generator(s). This can be accomplished if any one of the pumps is able to deliver fluid to any one steam generator(s). Thus, using DeMorgans theorem, system function is not fulfilled if all of the pumps are unable to deliver fluid to both steam generators, i.e. "A" MDP can't deliver to SG1 and "A" MDP can't deliver to SG2 and "B" MDP can't deliver to SG1 and "B" MDP can't deliver to SG1 and "B" MDP can't deliver to SG2 and TDP can't deliver to SG1 and TDP can't deliver to SG2.

←(DRN 00-786, R11-A)

These failure conditions effectively relate failures of the system blocks to overall system function.

END OF HISTORICAL INFORMATION

←(EC-33720, R307)

TABLE 10.4.9B-3 (Sheet 1 of 4) Revision 307 (07/13)

→(EC-33720, R307)

START OF HISTORICAL INFORMATION

MINIMAL CUT SETS - CASE 1

ME1

1	2	
42	43	
36B	9	
36B	87	
36B	36A	
36B	15	
35B	8	
35B	18	
35B	74	
35B	75	
35B	94	
35B	95	
35B	86	
35B	35A	
35B	14	
34B	7	
34B	85	
34B	34A	
34B	13	
92	OEI	93
92	91	OE1
92	OE1	93
90	OE1	93
90	91	OE1
9	6	2
7	1	5
7	8	9
87	6	2
87	7	8
36A	6	2
36A	7	8
15	6	2
15	7	8
18	7	9
18	87	7
18	36A	7
18	15	7
74	7	9
74	87	7
74	36A	7
74	15	7
75	7	9
75	87	7
75	36A	7
75	15	7
94	7	9
94	87	7
94	36A	7
94	15	7
95	7	9
95	87	7
95	36A	7

←(EC-33720, R307)

→(EC-33720, R307)

CONTINUED HISTORICAL INFORMATION

MINIMAL CUT SETS-CASE 1

95	15	7	85	75	87
86	7	9	85	75	36A
86	87	7	85	75	15
86	36A	7	85	94	9
86	15	7	85	94	87
35A	7	9	85	94	36A
35A	87	7	85	94	15
35A	36A	7	85	95	9
35A	15	7	85	95	87
14	7	9	85	95	36A
14	87	7	85	95	15
14	36A	7	85	86	9
14	15	7	85	86	87
85	1	5	85	86	36A
85	8	9	85	86	15
85	87	8	85	35A	9
85	36A	8	85	35A	87
85	15	8	85	35A	36A
85	18	9	85	35A	15
85	18	87	85	14	9
85	18	36A	85	14	87
85	18	15	85	14	36A
85	74	9	85	14	15
85	74	87	34A	1	5
85	74	36A	34A	8	9
85	74	15	34A	87	8
85	75	9	34A	36A	8

←(EC-33720, R307)

➔(EC-33720, R307)

CONTINUED HISTORICAL INFORMATION

MINIMAL CUT SETS-CASE 1

34A	15	8	34A	35A	36A
34A	18	9	34A	35A	15
34A	18	87	34A	14	9
34A	18	36A	34A	14	87
34A	18	15	34A	14	36A
34A	74	9	34A	14	15
34A	74	87	13	1	5
34A	74	36A	13	8	9
34A	74	15	13	87	8
34A	75	9	13	36A	8
34A	75	87	13	15	8
34A	75	36A	13	18	9
34A	75	15	13	18	87
34A	94	9	13	18	36A
34A	94	87	13	18	15
34A	94	36A	13	74	9
34A	94	15	13	74	87
34A	95	9	13	74	36A
34A	95	87	13	74	15
34A	95	36A	13	75	9
34A	95	15	13	75	87
34A	86	9	13	75	36A
34A	86	87	13	75	15
34A	86	36A	13	94	9
34A	86	15	13	94	87
34A	35A	9	13	94	36A
34A	35A	87	13	94	15

←(EC-33720, R307)

→(EC-33720, R307)

CONTINUED HISTORICAL INFORMATION

MINIMAL CUT SETS-CASE 1

13	95	9
13	95	87
13	95	36A
13	95	15
13	86	9
13	86	87
13	86	36A
13	86	15
13	35A	9
13	35A	87
13	35A	36A
13	35A	15
13	14	9
13	14	87
13	14	36A
13	14	15
43	92	OE1
43	90	OEI
43	64	66
43	64	67
43	65	66
43	65	67
42	OEI	93
42	91	OE1
42	68	70
42	68	71
42	69	70
42	69	71
17	42	9
17	42	87
17	42	36A
17	42	15
16	43	7
16	43	85
16	43	34A
16	43	13
36B	1	5
36B	1	6
35B	6	2
35B	6	5
35B	1	5
35B	72	73
35B	72	40
35B	39	73
35B	39	40
34B	5	2
34B	6	2

END OF HISTORICAL INFORMATION

←(EC-33720, R307)

TABLE 10.4.9B-4 (Sheet 1 of 5) Revision 307 (07/13)

→(EC-33720, R307)

START OF HISTORICAL INFORMATION

MINIMAL CUT SETS CASE 2

ME1

1	2		87	6	2
42	43		87	7	8
36B	9		81	6	2
36B	87		81	7	8
36B	81		36A	6	2
36B	36A		36A	7	8
36B	15		15	6	2
35B	8		157	8	
35B	18		18	7	9
35B	74		18	87	7
35B	75		18	81	7
35B	94		18	36A	7
35B	95		18	15	7
35B	86		74	7	9
35B	35A		74	87	7
35B	14		74	81	7
34B	7		74	36A	7
34B	85		74	15	7
34B	80		75	7	9
34B	34A		75	87	7
34B	13		75	81	7
92	OE1	93	75	36A	7
92	91	OE1	75	15	7
90	OE1	93	94	7	9
90	91	OE1	94	87	7
9	6	2	94	81	7
7	1	5	94	36A	7
7	8	9	94	15	7

←(EC-33720, R307)

→(EC-33720, R307)

CONTINUED HISTORICAL INFORMATION

MINIMAL CUT SETS - CASE 2

95	7	9
95	87	7
95	81	7
95	36A	7
95	15	7
86	7	9
86	87	7
86	81	7
86	36A	7
86	15	7
35A	7	9
35A	87	7
35A	81	7
35A	36A	7
35A	15	7
14	7	9
14	87	7
14	81	7
14	36A	7
14	15	7
85	1	5
85	8	9
85	87	8
85	81	8
85	36A	8
85	15	8
85	18	9
85	18	87
85	18	81
85	18	36A
85	18	15
85	74	9
85	74	87
85	74	81
85	74	36A
85	74	15
85	75	9
85	75	87
85	75	81
85	75	36A
85	75	15
85	94	9
85	94	87
85	94	81
85	94	36A
85	94	15
85	95	9
85	95	87
85	95	81
85	95	36A
85	95	15
85	86	9
85	86	87
85	86	81
85	86	36A
85	86	15
85	35A	9
85	35A	87
85	35A	81
85	35A	36A
85	35A	15
85	14	9
85	14	87
85	14	81
85	14	36A
85	14	15
80	1	5
80	8	9
80	87	8
80	36A	8
80	15	8
80	18	9
80	18	87
80	18	36A
80	18	15
80	74	9
80	74	87
80	74	36A
80	74	15
80	75	9
80	75	87

←(EC-33720, R307)

→(EC-33720, R307)

CONTINUED HISTORICAL INFORMATION

MINIMAL CUT SETS - CASE 2

80	75	36A
80	75	15
80	94	9
80	94	87
80	94	36A
80	94	15
80	95	9
80	95	87
80	95	36A
80	95	15
80	86	9
80	86	87
80	86	36A
80	86	15
80	35A	9
80	35A	87
80	35A	36A
80	35A	15
80	14	9
80	14	87
80	14	36A
80	14	15
34A	1	5
34A	8	9
34A	87	8
34A	81	8
34A	36A	8
34A	15	8
34A	18	9
34A	18	87
34A	18	81
34A	18	36A
34A	18	15
34A	74	9
34A	74	87
34A	74	81
34A	74	36A
34A	74	15
34A	75	9
34A	75	87
34A	75	81
34A	75	36A
34A	75	15
34A	94	9
34A	94	87
34A	94	81
34A	94	36A
34A	94	15
34A	95	9
34A	95	87
34A	95	81
34A	95	36A
34A	95	15
34A	86	9
34A	86	87
34A	86	81
34A	86	36A
34A	86	15
34A	35A	9
34A	35A	87
34A	35A	81
34A	35A	36A
34A	35A	15
34A	14	9
34A	14	87
34A	14	81
34A	14	36A
34A	14	15
13	1	5
13	8	9
13	87	8
13	81	8
13	36A	8
13	15	8
13	18	9
13	18	87
13	18	81
13	18	36A

←(EC-33720, R307)

→(EC-33720, R307)

CONTINUED HISTORICAL INFORMATION

MINIMAL CUT SETS - CASE 2

13	18	15
13	74	9
13	74	87
13	74	81
13	74	36A
13	74	15
13	75	9
13	75	87
13	75	81
13	75	36A
13	75	15
13	94	9
13	94	87
13	94	81
13	94	36A
13	94	15
13	95	9
13	95	87
13	95	81
13	95	36A
13	95	15
13	86	9
13	86	87
13	86	81
13	86	36A
13	86	15
13	35A	9
13	35A	87

13	35A	81
13	35A	36A
13	35A	15
13	14	9
13	14	87
13	14	81
13	14	36A
13	14	15
43	92	OE1
43	90	OE1
43	64	66
43	64	67
43	65	66
43	65	67
42	OE1	93
42	91	OE1
42	68	70
42	68	71
42	69	70
42	69	71
17	42	9
17	42	87
17	42	36A
17	42	15
17	42	81
16	43	7
16	43	85
16	43	34A
16	43	13
16	43	80
36B	1	5
36B	1	6
35B	6	2
35B	6	5
35B	1	5
35B	72	73
35B	72	40
35B	39	73
35B	39	40
34B	5	2
34B	6	2

←(EC-33720, R307)

→(EC-33720, R307)

CONTINUED HISTORICAL INFORMATION

MINIMAL CUT SETS - CASE 2

34B		
36B		
8		
18		
74		
75		
94		
95		
86		
35A		
14		
ME1		
2	1	
2	6	
5	1	
5	6	
72	73	
72	40	
39	73	
39	40	
42	43	
17	42	
16	43	
16	17	
92	OE1	93
92	91	OE1
90	OE1	93
90	91	OE1
43	92	OE1
43	90	OE1
43	64	66
43	64	67
43	65	66
43	65	67
42	OE1	93
42	91	OEI
42	68	70
42	68	71
42	69	70
42	69	71
17	92	OE1
17	90	OE1
17	64	66
17	64	67
17	65	66
17	65	67
16	OE1	93
16	91	OE1
16	68	70
16	68	71
16	69	70
16	69	71

END OF HISTORICAL INFORMATION

←(EC-33720, R307)

➔(EC-33720, R307)

<u>START OF HISTORICAL INFORMATION</u>

TABLE 10.4.9B-5 HAS BEEN DELETED.

<u>END OF HISTORICAL INFORMATION</u>

🡐(EC-33720, R307)

→(EC-33720, R307)

START OF HISTORICAL INFORMATION

BASIC EVENT CAUSES AND PROBABILITIES

Basic Event	Description	Cause	Probability On Demand (Ref)
1.	Manual Valve 1 Closed	Plugging	1×10^{-4} (1)
		Random Operator Error	3.8×10^{-4} (2)
		Total	4.8×10^{-4}
2.	Manual Valve 2 Closed	Plugging	1×10^{-4} (1)
		Random Operator Error	3.8×10^{-4} (2)
		Total	4.8×10^{-4}
5.	Manual Valve 5 Closed	Plugging	1×10^{-4} (1)
		Total	1.0×10^{-4}
6.	Manual Valve 6 Closed	Plugging	1×10^{-4} (1)
		Total	1.0×10^{-4}
7.	Manual Valve 7 Closed	Plugging	1×10^{-4} (1)
		Total	1.0×10^{-4}
8.	Manual Valve 8 Closed	Plugging	1×10^{-4} (1)
		Total	1.0×10^{-4}
9.	Manual Valve 9 Closed	Plugging	1×10^{-4} (1)
		Total	1.0×10^{-4}
13.	Manual Valve 13 Closed	Plugging (see also ME1)	1×10^{-4} (1)
		Total	1×10^{-4}

←(EC-33720, R307)

→(EC-33720, R307)

CONTINUED HISTORICAL INFORMATION

BASIC EVENT CAUSES AND PROBABILITIES

Basic Event	Description	Cause		Probability On Demand (Ref)
14.	Manual Valve 14 Closed	Plugging		1×10^{-4} (1)
			Total	1×10^{-4}
15.	Manual Valve 15 Closed	Plugging (see also ME1)		1×10^{-4} (1)
			Total	1×10^{-4}
16.	Manual Valve 16 Closed	Plugging (see also ME1)		1×10^{-4} (1) -
			Total	1×10^{-4}
17.	Manual Valve 17 Closed	Plugging (see also ME1)		1×10^{-4} (1) -
			Total	1×10^{-4}
18.	Manual Valve 18 Closed	Plugging		1×10^{-4} (1)
			Total	1×10^{-4}
34A.	Check Valve 34 Closed	Mechanical Binding In Repair		1×10^{-4} (1) 2.1×10^{-3} (2)
			Total	2.2×10^{-3}
34B.	Check Valve 34 Open	Mechanical Binding		1×10^{-4} (1)
35A.	Check Valve 35 Closed	Mechanical Binding In Repair		1×10^{-4} (1) 2.1×10^{-3} (2)
			Total	2.2×10^{-3}

←(EC-33720, R307)

→(EC-33720, R307)

CONTINUED HISTORICAL INFORMATION

BASIC EVENT CAUSES AND PROBABILITIES

Basic Event	Description	Cause	Probability On Demand (Ref)
35B.	Check Valve 35 Open	Mechanical Binding	1×10^{-4} (1)
36A.	Check Valve 36 Closed	Mechanical Binding	1×10^{-4} (1)
		In Repair	2.1×10^{-3}
		Total	2.2×10^{-3}
36B.	Check Valve 36 Open	Mechanical Binding	1×10^{-4} (1)
39.	Check Valve 39 Closed	Mechanical Binding	1×10^{-4} 1)
40.	Check Valve 40 Closed	Mechanical Binding	1×10^{-4} (1)
42.	Check Valve 42 Closed	Mechanical Binding	1×10^{-4} (1)
43.	Check Valve 43 Closed	Mechanical Binding	1×10^{-4} (1)
64.	Air Op Valve 64 Closed	Mechanical Binding	3×10^{-4} (1)
		Control Circuit Fault	ε (1)
		Total	3×10^{-4}
65.	Air Op Valve 65 Closed	Mechanical Binding	3×10^{-4} (1)
		Control Circuit Fault	ε (1)
		Total	3×10^{-4}
66.	Air Op Valve 66 Closed	Mechanical Binding	3×10^{-4} (1)
		Control Circuit Failure	ε (1)
		Total	3×10^{-4}
67.	Air Op Valve 67 Closed	Mechanical Binding	3×10^{-4} (1)
		Control Circuit Failure	ε (1)
		Total	3×10^{-4}
68.	Air Op Valve 68 Closed	Mechanical Binding	3×10^{-4} (1)
		Control Circuit Failure	ε (1)
		Total	3×10^{-4} (1)

←(EC-33720, R307)

→(EC-33720, R307)

CONTINUED HISTORICAL INFORMATION

BASIC EVENT CAUSES AND PROBABILITIES

Basic Event	Description	Cause	Probability On Demand (Ref)
69.	Air Op Valve 69 Closed	Mechanical Binding	3×10^{-4} (1)
		Control Circuit Failure	ε (1)
		Total	3×10^{-4}
70.	Air Op Valve 70 Closed	Mechanical Binding	3×10^{-4} (1)
		Control Circuit Failure	ε (1)
		Total	3×10^{-4}
71.	Air Op Valve 71 Closed	Mechanical Binding	3×10^{-4} (1)
		Control Circuit Failure	ε (1)
		Total	3×10^{-4}
72.	Motor Op Valve 72 Closed	Mechanical Binding	1×10^{-3} (1)
		Plugging Contribution	1×10^{-4} (1)
		Control Circuit Failure	2×10^{-3} (1)
		Total	3.1×10^{-3}
73.	Motor Op Valve 73 Closed	Mechanical Binding	1×10^{-3} (1)
		Plugging Contribution	1×10^{-4} (1)
		Control Circuit Failure	2×10^{-3} (1)
		Total	3.1×10^{-3}
74.	Motor Op TDP Steam Stop Valve Closed	Random Operator Error	5×10^{-4} (2)
75.	Hydr Op TDP Governor Valve Closed	Mechanical Binding	3×10^{-4} (1)
		Control Circuit Failure	6×10^{-3} (1)
		Total	6.3×10^{-3}
80.	"A" 4 kV Power Supply Failure	"A" DG Start Failure	3×10^{-2} (3)
		"A" DG in Repair	0.64×10^{-2} (1)
		Total	3.64×10^{-2}

←(EC-33720, R307)

→(EC-33720, R307)

CONTINUED HISTORICAL INFORMATION

BASIC EVENT CAUSES AND PROBABILITIES

Basic Event	Description	Cause	Probability On Demand (Ref)
81.	"B" 4 kV Power Supply Failure	"B" DG Start Failure "B" DG in Repair	3×10^{-2} (3) 0.64×10^{-2} (1)
		Total	3.64×10^{-2}
85.	"A" MDP Failure to Start	Mechanical Fault Control Circuit Fault Pump in Repair	1×10^{-3} (1) 4×10^{-3} (1) 2.1×10^{-3} (2)
		Total	7.1×10^{-3}
86.	TDP Failure To Start	Mechanical Fault Pump Repair	1×10^{-3} (1) 2.1×10^{-3} (2)
		Total	3.1×10^{-3}
87.	"B" MDP Failure To Start	Mechanical Fault Control Circuit Fault Pump In Repair	1×10^{-3} (1) 4×10^{-3} (1) 2.1×10^{-3}
		Total	7.1×10^{-3}
90.	EFAS 1 "A" Not Generated	(Not Specified)	7×10^{-3} (1)
91.	EFAS 2 "A" Not Generated	(Not Specified)	7×10^{-3} (1)
92.	EFAS 1 "B" Not Generated	(Not Specified)	7×10^{-3} (1)
93.	EFAS 1 "B" Not Generated	(Not Specified)	7×10^{-3} (1)
94.	Spurious TDP Overspeed Signal	(Not Specified)	7×10^{-3} (1)
95.	TDP Speed Controller Failure	(Not Specified)	7×10^{-3} (1)
ME1	See Subsection 10.4.9B.5.1.1	Maintenance Error	5×10^{-6} (1) (2)
OEI	Operator failure to back up automatic EFW actuation	Operator Error	1×10^{-2} (1)

←(EC-33720, R307)

→(EC-33720, R307)

CONTINUED HISTORICAL INFORMATION

BASIC EVENT CAUSES AND PROBABILITIES

NOTES:

(1) Letter, D Ross (NRC) to All Pending OL Applicants of W and CE NSSS Designs, dated 3/10/80.

(2) Subsection 10.4.9B.5.1.1.

(3) WASH-1400

END OF HISTORICAL INFORMATION

←(EC-33720, R307)

TABLE 10.4.9B-7 Revision 307 (07/13)

→(EC-33720, R307)

START OF HISTORICAL INFORMATION

EFS VALVES SUBJECT TO ASME SECTION XI TESTING

POWER OPERATED VALVES

LP&L UNID NO. / EBASCO NO.

64	EFW-224A/2FW-V851B	
65	EFW-228A/2FW-V848A	
66	EFW-223A/2FW-V852A	
67	EFW-229A/2FW-V847A	
68	EFW-223B/2FW-V854B	
69	EFW-229B/2FW-V849A	
70	EFW-224B/2FW-V853A	
71	EFW-228B/2FW-V850B	
72	MS-401A/2MS-V611A	
73	MS-40lB/2MS-V612B	
74	MS-416	*
75	MS-417	*

CHECK VALVES

31	EFW-204A/3FW-Vl507-2
32	EFW-204A/B/3FW-Vl517
33	EFW-204B/3FW-Vl507-1
34	EFW-207A/3FW-V601A
35	EFW-207A/B/3FW-V603A/B
36	EFW-207B/3FW-V602B
39	MS-402A/3MS-V676A
40	MS-402B/3MS-V677B
42	EFW-2191A/3FW-Vl541A
43	EFW-219lB/3FW-Vl542B

* For the Reliability Study, the purpose of assuming a quarterly test is to ensure that the valves are operable (or in the correct position) at least quarterly. These valves are exempt from ASME Section XI testing, however, they are verified operable monthly during the EFW pump test. Therefore, the Reliability Study was conservative.

END OF HISTORICAL INFORMATION

←(EC-33720, R307)

TABLE 10.4.9B-8 (Sheet 1 of 5) Revision 307 (07/13)

→(EC-33720, R307)

START OF HISTORICAL INFORMATION

SUMMARY OF TEST AND MAINTENANCE CONTRIBUTIONS
TO COMPONENT AVAILABILITY

	Component	Testing of Component		Maintenance on Component		Other Tests Involving Components Which Contribute To Unavailability	Other Maintenance Acts Involving Components Which Contribute To Unavailability
		Frequency	Unavailabitity From Test	Frequency	Unavailability From Maint.		
1.	Valve 1 - Manual EFW-102B/3CO-V111B2.	-	-	-	-	None	None planned or anticipated
2.	Valve 2 - Manual EFW-102A/3CO-V110A	-	-	-	-	None	None plained or anticipated
5.	Valve 5 - Manual 3CC-V211B	-	-	-	-	None	None planned or anticipated
6.	Valve 6 - Manual 3CC-V210A	-	-	-	-	None	None planned or anticipated
7.	Valve 7 - Manual EFW-106A/3CD-V112A	-	-	-	-	None	"A MDP maintenance; Valve 34 maintenance
8.	Valve 8 - Manual EFW-106A/B/3CD-V114 A/B	-	-	-	-	None	TDP maintenance; Valve 35 Maintenance
9.	Valve 9 - Manual EFW-106B/3CD-V113B	-	-	-	-	None	"B" MDP mintenance; valve 36 maintenance
13.	Valve 13 - Manual EFW-211A/3FW-604A	-	-	-	-	None	"A" MDP maintenance; Valve 34 maintenance Prestart-up Feedwater Cleaning
14.	Valve 14 - Manual EFW-211A/B/3FW-606A/B	-	-	-	-	None	TDP mintenance; Valve 35 maintenance
15.	Valve 15 - Manual EFw-211B/3FW-V605B	-	-	-	-	None	"B" MPD maintenance; Valve 36 Prestart-up Feedwater Cleaning
16.	Valve 16 - Manual EFW-215A/3FW-V608	-	-	-	-	None	Prestart-up Feedwater Cleaning

←(EC-33720, R307)

TABLE 10.4.9B-8 (Sheet 2 of 5) Revision 307 (07/13)

→(EC-33720, R307)

CONTINUED HISTORICAL INFORMATION

SUMMARY OF TEST AND MAINTENANCE CONTRIBUTIONS

TO COMPONENT AVAILABILITY

	Component	Testing of Component		Maintenance of Component		Other Tests Involving Components Which COntribute to Unavailability	Other Maintenance Acts Involving Components Which Contribute to Unavailability
		Frequency	Unavailability From Test	Frequency	Unavailability From Maint.		
17.	Valve 17 - Manual EFW-215B/3FW-V609	-	-	-	-	None	Prestartup Feedwater Cleaning
18.	Valve 18 - Manual	-	-	-	-	None	TDP maintenance; Valve 35 maintenance
34.	Valve 34 Check EFW-207A/3FW-601A	quarterly	0	Note 2	-	Not Applicable	Not Applicable
35.	Valve 35 - Check EFW-207A/B/3FW-603A/B	quarterly	0	Note 2	-	Not Applicable	Not Applicable
36.	Valve 36 - Check EFW-207A/3FW-602B	quarterly	0	Note 2	-	Not Applicable	Not Applicable
39.	Valve 39 -Check	quarterly	0	Note 1	-	Not Applicable	Not Applicable
40.	Valve 40 - Check	quarterly	0	Note 1	-	Not Applicable	Not Applicable
42.	Valve 42 - Check EFW-VI541A	quarterly	0	Note 1	-	Not Applicable	Not Applicable
43.	Valve 43 - Check EFW-VI542B	quarterly	0	Note 1	-	Not Applicable	Not Applicable
64.	Valve 64 - Air EFW-224A/2FW-V851B	quarterly	0	Note 1	0	None	-
65.	Valve 65 - Air EFW-22BA/2FW-V848A	quarterly	0	Note 1	0	None	-
66.	Valve 66 - Air EFW-223A/2FW-V852A	quarterly	0	Note 1	0	None	-
67.	Valve 67 - Air EFW-229A/2FW-V847B	quarterly	0	Note 1	0	None	-
68.	Valve 68 - Air EFW-223B/2FW-V8540	quarterly	0	Note 1	0	None	-

←(EC-33720, R307)

TABLE 10.4.9B-8 (Sheet 3 of 5) Revision 307 (07/13)

→(EC-33720, R307)

CONTINUED HISTORICAL INFORMATION

SUMMARY OF TEST AND MAINTENANCE CONTRIBUTIONS
TO COMPONENT AVAILABILITY

	Component	Testing of Component Frequency	Unavailability From Test	Maintenance of Component Frequency	Unavailability From Maint.	Other Tests Involving Components Which COntribute to Unavailability	Other Maintenance Acts Involving Components Which Contribute to Unavailability
69.	Valve 69 - Air EFW-220B/2FW-V849A	quarterly	0	Note 1	0	None	-
70.	Valve 70 - Air EFW-224B/2FW-V853A	quarterly	0	Note 4	0	None	-
71.	Valve 71 - Air EFW-228B/2FW-850B	quarterly	0	Note 1	0	None	-
72.	Valve 72 - Motor 2MS-V611A	quarterly	0	Note 1	0	None	-
73.	Valve 73 - Motor 2MS-V612B	quarterly	0	Note 1	0	None	-
74.	Valve 74 - Motor	quarterly	0	Note 2	Section 10.4.9B.5.1.1	None	- *
75.	Valve 75 - Hydraulic	quarterly	0	Note 2	Section 10.4.9B.5.1.1	None	None *
80.	"A" 4kV Power (SA-DG)	monthly	0	Note 2	Section 10.4.9B.5.1.1	None	None
81.	"B" 4kV Power (SA-DG)	monthly	0	Note 2	Section 10.4.9B.5.1.1.	None	None
85.	"A" MDP	monthly	0	Note 2	Section 10.4.9B.5.1.1.	None	None
86.	TDP	monthly	0	Note 2	Section 10.4.9B.5.1.1	None	None
87.	"B" MDP	monthly	0	Note 2	Section 10.4.9B.5.1.1	None	None
90.	EFAS 1 "A" Logic	monthly	0	Note 2	Note 3	None	None

→(DRN 00-786, R11-A)

* For the Reliability Study, the purpose of assuming a quarterly test is to ensure that the valves are operable (or in the correct position) at least quarterly. These valves are exempt frm ASME Sectim Xi testing, however, they are verified operable monthly during the EFW pump test. Therefore, the Reliability Study was conservative.

←(DRN 00-786, R11-A ; EC-33720, R307)

→(EC-33720, R307)

CONTINUED HISTORICAL INFORMATION

SUMMARY OF TEST AND MAINTENANCE CONTRIBUTIONS

TO COMPONENT AVAILABILITY

Component	Testing of Component Frequency	Unavailability From Test	Maintenance of Component Frequency	Unavailability From Maint.	Other Tests Involving Components Which COntribute to Unavailability	Other Maintenance Acts Involving Components Which Contribute to Unavailability
91. EFAS 2 "A" Logic	monthly	0	Note 2	Note 3	None	None
92. EFAS 1 "B" Logic	monthly	0	Note 2	Note 3	None	None
93. EFAS 2 "B" Logic	monthly	0	Note 2	Note 3	None	None
94. TDP Overspeed Trip	See 86	0	Note 2	Note 3	None	None
95. TDP Speed Control	See 86	0	Note 2	Note 3	None	None

←(EC-33720, R307)

TABLE 10.4.9B-8 (Sheet 5 of 5) Revision 307 (07/13)

→(EC-33720, R307)

CONTINUED HISTORICAL INFORMATION

SUMMARY OF TEST AND MAINTENANCE CONTRIBUTIONS
TO COMPONENT AVAILABILITY

NOTES:

1. Valve cannot be maintained during power operation due to connection with pressurized system.

2. Component maintained during power operation only if results of periodic test unsatisfactory.

3. Maintenance on single channel EFAS Logic does not render Logic inoperable.

END OF HISTORICAL INFORMATION

←(EC-33720, R307)

TABLE 10.4.9B-9 Revision 307 (07/13)

→(EC-33720, R307)

START OF HISTORICAL INFORMATION

DOMINANT CUT SETS - CASE 1

$\bar{a} = 1.42 \times 10^{-5}$

Cut Set	Events			$\bar{a}_i$	$\frac{\bar{a}_i}{\bar{a}}$	
1	ME1			5×10^{-6}	35.2%	
5	36B	87		7.1×10^{-7}	5.0	
11	35B	75		6.3×10^{-7}	4.4	
12	35B	94		7.0×10^{-7}	4.9	26.4
13	35B	95		7.0×10^{-7}	4.9	
14	35B	86		3.1×10^{-7}	2.2	
18	34B	85		7.1×10^{-7}	5.0	
21	92	93	ϕE1	4.9×10^{-7}	3.5	
22	91	92	ϕE1	4.9×10^{-7}	3.5	14.0
23	90	93	ϕE1	4.9×10^{-7}	3.5	
24	90	91	ϕE1	4.9×10^{-7}	3.5	
80	85	75	87	3.2×10^{-7}	2.3	7.3
84	85	94	87	3.5×10^{-7}	2.5	
88	85	95	87	3.5×10^{-7}	2.5	
				TOTAL	82.9%	

END OF HISTORICAL INFORMATION

←(EC-33720, R307)

TABLE 10.4.9B-10 Revision 307 (07/13)

→(EC-33720, R307)

START OF HISTORICAL INFORMATION

DOMINANT CUT SETS - CASE 2

$\bar{a} = 3.97$ x 10^{-5}

Cut Set	Events			$\bar{a}_i$	$\frac{\bar{a}_i}{\bar{a}}$	
1	ME1			5.0x10^{-6}	12.6%	
5	36B	87		7.1x10^{-7}	1.8	
8	36B	81		3.64x10^{-6}	9.2	
12	35B	75		6.30x10^{-7}	1.6	
13	35B	94		7.0x10^{-7}	1.8	27.2
14	35B	95		7.0x10^{-7}	1.8	
19	34B	85		7.1xl0^{-7}	1.8	
22	34B	80		3.64x10^{-6}	9.2	
23	92	93	ϕE1	4.9x10^{-7}	1.2	
24	91	92	ϕE1	4.9x10^{-7}	1.2	4.8
25	90	93	ϕE1	4.9x10^{-7}	1.2	
26	90	91	ϕE1	4.9x10^{-7}	1.2	
98	85	75	81	1.63x10^{-6}	4.1	
103	85	94	81	1.81x10^{-6}	4.6	
108	85	95	81	1.81x10^{-6}	4.6	
113	85	86	81	8.01x10^{-7}	2.0	30.6
233	80	75	87	1.63x10^{-6}	4.1	
238	80	94	87	1.81x10^{-6}	4.6	
243	80	95	87	1.81x10^{-6}	4.6	
248	80	86	87	8.01x10^{-7}	2.0	
				TOTAL	75.2%	

END OF HISTORICAL INFORMATION

←(EC-33720, R307)

TABLE 10.4.9B-11 Revision 307 (07/13)

→(EC-33720, R307)

START OF HISTORICAL INFORMATION

DOMINANT CUT SETS - CASE 3

$\overline{a} = 2.63 \times 10^{-2}$

Cut Set	Events	$\overline{a}_i$	$\frac{\overline{a}_i}{\overline{a}}$
6	75	6.3×10^{-3}	24.0%
7	94	7.0×10^{-3}	26.6
8	95	7.0×10^{-3}	26.6
9	86	3.1×10^{-3}	11.8
10	35A	2.2×10^{-3}	8.4
		TOTAL	97.4%

END OF HISTORICAL INFORMATION

←(EC-33720, R307)