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NUCLEAR REGULATORY COMMISSION
OFFICE OF NUCLEAR REACTOR REGULATION
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September 30, 2002

**NRC REGULATORY ISSUE SUMMARY 2002-14, SUPPLEMENT 1
PROPOSED CHANGES TO THE SAFETY SYSTEM UNAVAILABILITY
PERFORMANCE INDICATORS**

ADDRESSEES

All holders of operating licenses for nuclear power reactors, except those who have permanently ceased operations and have certified that fuel has been permanently removed from the reactor vessel.

INTENT

The U. S. Nuclear Regulatory Commission (NRC) is issuing this supplement to Regulatory Issue Summary (RIS) 2002-14 to provide to the addressees revised versions of the three attachments to the RIS.

BACKGROUND

Regulatory Issue Summary 2002-14 informed addressees that the NRC was starting a 6-month pilot program on September 1, 2002, to evaluate changes to the safety system unavailability (SSU) performance indicators (PIs), and that the pilot program would be assessed midway through the test period to determine if more than six months were needed to obtain meaningful results. The RIS and its three attachments provided guidance to participating addressees for submitting PI data to the NRC and on the program success criteria.

Addressee participation in the pilot program is voluntary and participants were asked to conform to the guidance in the RIS for the voluntary submission of PI data. Addressees were also informed that updated guidance would be provided in the form of revisions to the attachments to the RIS, namely, Attachment 1, an excerpt from Draft NEI 99-02, Rev. 0, "Regulatory Assessment Performance Indicator Guideline," Section 2.2, "Mitigating System Performance Index," and Attachment 2, Draft NEI 99-02, Rev. 0, Appendix F, "Methodologies For Computing the Unavailability Index, the Unreliability Index and Determining Performance Index Validity."

SUMMARY OF ISSUE

Since the issuance of RIS 2002-14 on August 28, 2002, Attachments 1 and 2 have been updated and Attachment 3 has been revised. The revised attachments are attached to this RIS supplement.

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BACKFIT DISCUSSION

This RIS supplement requires no action or written response. Therefore, the staff did not perform a backfit analysis.

FEDERAL REGISTER NOTIFICATION

A notice of opportunity for public comment was not published in the *Federal Register* because this RIS supplement is informational.

PAPERWORK REDUCTION ACT STATEMENT

This RIS supplement does not request any information collections.

If there are any questions about this matter, please contact one of the persons listed below.

/Original signed by: TReis/

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Attachments:

1. Draft NEI 99-02, Rev. 0, "Regulatory Assessment Performance Indicator Guideline," Section 2.2, "Mitigating System Performance Index"
2. Draft NEI 99-02, Rev. 0, "Regulatory Assessment Performance Indicator Guideline," Appendix F, "Methodologies For Computing the Unavailability Index, the Unreliability Index, and Determining Performance Index Validity"
3. Mitigating System Performance Index Pilot Program Success Criteria
4. List of Recently Issued NRC Regulatory Issue Summaries

Draft NEI 99-02, Rev. 0, "Regulatory Assessment Performance Indicator Guideline,"
Section 2.2, "Mitigating System Performance Index"

1
2 **MITIGATING SYSTEM PERFORMANCE INDEX**

3 **Purpose**

4 The purpose of the mitigating system performance index is to monitor the performance of
5 selected systems based on their ability to perform risk-significant functions as defined herein. It
6 is comprised of two elements - system unavailability and system unreliability. The index is used
7 to determine the significance of performance issues for single demand failures and accumulated
8 unavailability. Due to the limitations of the index, the following conditions will rely upon the
9 inspection process for determining the significance of performance issues:

- 10
11 1. Multiple concurrent failures of components
12 2. Common cause failures
13 3. Conditions not capable of being discovered during normal surveillance tests
14 4. Failures of non-active components
15

16 **Indicator Definition**

17 *Mitigating System Performance Index (MSPI)* is the sum of changes in a simplified core damage
18 frequency evaluation resulting from changes in unavailability and unreliability relative to
19 baseline values.
20

21 *Unavailability* is the ratio of the hours the train/system was unavailable to perform its risk-
22 significant functions due to planned and unplanned maintenance or test on active and non-active
23 components during the previous 12 quarters while critical to the number of critical hours during
24 the previous 12 quarters. (Fault exposure hours are not included; unavailable hours are counted
25 only for the time required to recover the train's risk-significant functions.)
26

27 *Unreliability* is the probability that the system would not perform its risk-significant functions
28 when called upon during the previous 12 quarters.
29

30 *Baseline values* are the values for unavailability and unreliability against which current changes
31 in unavailability and unreliability are measured. See Appendix F for further details.
32

33 The MSPI is calculated separately for each of the following five systems for each reactor type.
34

35 **BWRs**

- 36 • emergency AC power system
37 • high pressure injection systems (high pressure coolant injection, high pressure core spray, or
38 feedwater coolant injection)
39 • heat removal systems (reactor core isolation cooling)
40 • residual heat removal system (or their equivalent function as described in the Additional
41 Guidance for Specific Systems section.)

- 1 • cooling water support system (includes risk significant direct cooling functions provided by
2 service water and component cooling water or their cooling water equivalents for the above
3 four monitored systems)

4
5 **PWRs**

- 6 • emergency AC power system
- 7 • high pressure safety injection system
- 8 • auxiliary feedwater system
- 9 • residual heat removal system (or their equivalent function as described in the Additional
10 Guidance for Specific Systems section.)
- 11 • cooling water support system (includes risk significant direct cooling functions provided by
12 service water and component cooling water or their cooling water equivalents for the above
13 four monitored systems)

14
15 **Data Reporting Elements**

16 The following data elements are reported for each system

- 17
- 18 • Unavailability Index (UAI) due to unavailability for each monitored system
- 19 • Unreliability Index (URI) due to unreliability for each monitored system

20
21 During the pilot, the additional data elements necessary to calculate UAI and URI will be
22 reported monthly for each system on an Excel spreadsheet. See Appendix F.

23
24
25 **Calculation**

26 The MSPI for each system is the sum of the UAI due to unavailability for the system plus URI
27 due to unreliability for the system during the previous twelve quarters.

28
29 $MSPI = UAI + URI.$

30
31 See Appendix F for the calculational methodology for UAI due to system unavailability and URI
32 due to system unreliability.

33
34 **Definition of Terms**

35 *A train* consists of a group of components that together provide the risk significant functions of
36 the system as explained in the additional guidance for specific mitigating systems. Fulfilling the
37 risk-significant function of the system may require one or more trains of a system to operate
38 simultaneously. The number of trains in a system is generally determined as follows:

- 39
- 40 • for systems that provide cooling of fluids, the number of trains is determined by the number
41 of parallel heat exchangers, or the number of parallel pumps, or the minimum number of
42 parallel flow paths, whichever is fewer.

- for emergency AC power systems the number of trains is the number of class 1E emergency (diesel, gas turbine, or hydroelectric) generators at the station that are installed to power shutdown loads in the event of a loss of off-site power. (This does not include the diesel generator dedicated to the BWR HPCS system, which is included in the scope of the HPCS system.)

Risk Significant Functions: those at power functions, described in the “Additional Guidance for Specific Systems,” that were determined to be risk-significant in accordance with NUMARC 93-01, or NRC approved equivalents (e.g., the STP exemption request.) The system functions described in the “Additional Guidance for Specific Systems” must be modeled in the plant’s PRA/PSA.

Risk-Significant Mission Times: The mission time modeled in the PRA for satisfying the risk-significant function of reaching a stable plant condition where normal shutdown cooling is sufficient. Note that PRA models typically analyze an event for 24 hours, which may exceed the time needed for the risk-significant function captured in the MSPI. However, other intervals as justified by analyses and modeled in the PRA may be used.

Success criteria are the plant specific values of parameters the train/system is required to achieve to perform its risk-significant function. Default values of those parameters are the plant’s design bases values unless other values are modeled in the PRA.

Clarifying Notes

Documentation

Each licensee will have the system boundaries, active components, risk-significant functions and success criteria readily available for NRC inspection on site. Additionally, plant-specific information used in Appendix F should also be readily available for inspection.

Success Criteria

Individual component capability must be evaluated against train/system level success criteria (e.g., a valve stroke time may exceed an ASME requirement, but if the valve still strokes in time to meet the PRA success criteria for the train/system, the component has not failed for the purposes of this indicator because the risk-significant train/system function is still satisfied). Important plant specific performance factors that can be used to identify the required capability of the train/system to meet the risk-significant functions include, but are not limited to:

- Actuation
 - Time
 - Auto/manual
 - Multiple or sequential
- Success requirements
 - Numbers of components or trains
 - Flows
 - Pressures

- 1 o Heat exchange rates
- 2 o Temperatures
- 3 o Tank water level
- 4 • Other mission requirements
- 5 o Run time
- 6 o State/configuration changes during mission
- 7 • Accident environment from internal events
- 8 o Pressure, temperature, humidity
- 9 • Operational factors
- 10 o Procedures
- 11 o Human actions
- 12 o Training
- 13 o Available externalities (e.g., power supplies, special equipment, etc.)

14
15
16
17 System/Component Interface Boundaries

18
19 For active components that are supported by other components from both monitored and
20 unmonitored systems, the following general rules apply:

- 21
22 • For control and motive power, only the last relay, breaker or contactor necessary to
23 power or control the component is included in the active component boundary. For
24 example, if an ESFAS signal actuates a MOV, only the relay that receives the ESFAS
25 signal in the control circuitry for the MOV is in the MOV boundary. No other portions
26 of the ESFAS are included.
- 27
28 • For water connections from systems that provide cooling water to an active component,
29 only the final active connecting valve is included in the boundary. For example, for
30 service water that provides cooling to support an AFW pump, only the final active valve
31 in the service water system that supplies the cooling water to the AFW system is
32 included in the AFW system scope. This same valve is not included in the cooling water
33 support system scope.

34
35 Water Sources and Inventory

36
37 Water tanks are not considered to be active components. As such, they do not contribute to URI.
38 However, periods of insufficient water inventory contribute to UAI if they result in loss of the
39 risk-significant train function for the required mission time. Water inventory can include
40 operator recovery actions for water make-up provided the actions can be taken in time to meet
41 the mission times and are modeled in the PRA. If additional water sources are required to satisfy
42 train mission times, only the connecting active valve from the additional water source is
43 considered as an active component for calculating URI. If there are valves in the primary water
44 source that must change state to permit use of the additional water source, these valves are
45 considered active and should be included in URI for the system.

1
2 Monitored Systems

3
4 Systems have been generically selected for this indicator based on their importance in preventing
5 reactor core damage. The systems include the principal systems needed for maintaining reactor
6 coolant inventory following a loss of coolant accident, for decay heat removal following a
7 reactor trip or loss of main feedwater, and for providing emergency AC power following a loss
8 of plant off-site power. One risk-significant support function (cooling water support system) is
9 also monitored. The cooling water support system monitors the risk significant cooling functions
10 provided by service water and component cooling water, or their direct cooling water
11 equivalents, for the four front-line monitored systems. No support systems are to be cascaded
12 onto the monitored systems, e.g., HVAC room coolers, DC power, instrument air, etc.
13

14 Diverse Systems

15
16 Except as specifically stated in the indicator definition and reporting guidance, no credit is given
17 for the achievement of a risk-significant function by an unmonitored system in determining
18 unavailability or unreliability of the monitored systems.
19

20 Common Components

21
22 Some components in a system may be common to more than one train or system, in which case
23 the unavailability/unreliability of a common component is included in all affected trains or
24 systems. (However, see “Additional Guidance for Specific Systems” for exceptions; for example,
25 the PWR High Pressure Safety Injection System.)
26

27 Short Duration Unavailability

28
29 Trains are generally considered to be available during periodic system or equipment
30 realignments to swap components or flow paths as part of normal operations. Evolutions or
31 surveillance tests that result in less than 15 minutes of unavailable hours per train at a time need
32 not be counted as unavailable hours. Licensees should compile a list of surveillances/evolutions
33 that meet this criterion and have it available for inspector review. In addition, equipment
34 misalignment or mispositioning which is corrected in less than 15 minutes need not be counted
35 as unavailable hours. The intent is to minimize unnecessary burden of data collection,
36 documentation, and verification because these short durations have insignificant risk impact.
37

38 If a licensee is required to take a component out of service for evaluation and corrective actions
39 for greater than 15 minutes (for example, related to a Part 21 Notification), the unavailable hours
40 must be included.
41

42 Treatment of Demand /Run Failures and Degraded Conditions

43
44 1. Treatment of Demand and Run Failures

45 Failures of active components (see Appendix F) on demand or failures to run, either
46 actual or test, while critical, are included in unreliability. Failures on demand or failures

1 to run at any other time must be evaluated to determine if the failure would have resulted
2 in the train not being able to perform its risk-significant at power functions, and must
3 therefore be included in unreliability. Unavailable hours are included only for the time
4 required to recover the train's risk-significant functions and only when the reactor is
5 critical.

6
7 2. Treatment of Degraded Conditions

8
9 a) Capable of Being Discovered By Normal Surveillance Tests

10 Normal surveillance tests are those tests that are performed at a frequency of a
11 refueling cycle or more frequently.

12
13 Degraded conditions, even if no actual demand existed, that render an active
14 component incapable of performing its risk-significant functions are included in
15 unreliability as a demand and a failure. The appropriate failure mode must be
16 accounted for. For example, for valves, a demand and a demand failure would be
17 assumed and included in URI. For pumps and diesels, if the degraded condition
18 would have prevented a successful start demand, a demand and a failure is
19 included in URI, but there would be no run time hours or run failures. If it was
20 determined that the pump/diesel would start and load run, but would fail
21 sometime during the 24 hour run test or its surveillance test equivalent, the
22 evaluated failure time would be included in run hours and a run failure would be
23 assumed. A start demand and start failure would not be included. If a running
24 component is secured from operation due to observed degraded performance, but
25 prior to failure, then a run failure shall be counted unless evaluation of the
26 condition shows that the component would have continued to operate for the risk-
27 significant mission time starting from the time the component was secured.
28 Unavailable hours are included for the time required to recover the risk-
29 significant function(s).

30
31 Degraded conditions, or actual unavailability due to mispositioning of non-active
32 components that render a train incapable of performing its risk-significant
33 functions are only included in unavailability for the time required to recover the
34 risk-significant function(s).

35
36 Loss of risk significant function(s) is assumed to have occurred if the established
37 success criteria has not been met. If subsequent analysis identifies additional
38 margin for the success criterion, future impacts on URI or UAI for degraded
39 conditions may be determined based on the new criterion. However, URI and
40 UAI must be based on the success criteria of record at the time the degraded
41 condition is discovered. If the degraded condition is not addressed by any of the
42 pre-defined success criteria, an engineering evaluation to determine the impact of
43 the degraded condition on the risk-significant function(s) should be completed
44 and documented. The use of component failure analysis, circuit analysis, or event
45 investigations is acceptable. Engineering judgment may be used in conjunction
46 with analytical techniques to determine the impact of the degraded condition on

1 the risk-significant function. The engineering evaluation should be completed as
2 soon as practicable. If it cannot be completed in time to support submission of the
3 PI report for the current quarter, the comment field shall note that an evaluation is
4 pending. The evaluation must be completed in time to accurately account for
5 unavailability/unreliability in the next quarterly report. Exceptions to this
6 guidance are expected to be rare and will be treated on a case-by-case basis.
7 Licensees should identify these situations to the resident inspector.

8
9 b) Not Capable of Being Discovered by Normal Surveillance Tests

10 These failures or conditions are usually of longer exposure time. Since these
11 failure modes have not been tested on a regular basis, it is inappropriate to include
12 them in the performance index statistics. These failures or conditions are subject
13 to evaluation through the inspection process. Examples of this type are failures
14 due to pressure locking/thermal binding of isolation valves, blockages in lines not
15 regularly tested, or inadequate component sizing/settings under accident
16 conditions (not under normal test conditions). While not included in the
17 calculation of the index, they should be reported in the comment field of the PI
18 data submittal.

19
20
21 Credit for Operator Recovery Actions to Restore the Risk-Significant Function

22
23 1. *During testing or operational alignment:*

24 Unavailability of a risk-significant function during testing or operational alignment need not
25 be included if the test configuration is automatically overridden by a valid starting signal, or
26 the function can be promptly restored either by an operator in the control room or by a
27 designated operator¹ stationed locally for that purpose. Restoration actions must be
28 contained in a written procedure², must be uncomplicated (*a single action or a few simple*
29 *actions*), must be capable of being restored in time to satisfy PRA success criteria and must
30 not require diagnosis or repair. Credit for a designated local operator can be taken only if
31 (s)he is positioned at the proper location throughout the duration of the test for the purpose of
32 restoration of the train should a valid demand occur. The intent of this paragraph is to allow
33 licensees to take credit for restoration actions that are virtually certain to be successful (i.e.,
34 probability nearly equal to 1) during accident conditions.

35
36 The individual performing the restoration function can be the person conducting the test and
37 must be in communication with the control room. Credit can also be taken for an operator in
38 the main control room provided (s)he is in close proximity to restore the equipment when
39 needed. Normal staffing for the test may satisfy the requirement for a dedicated operator,
40 depending on work assignments. In all cases, the staffing must be considered in advance and

¹ Operator in this circumstance refers to any plant personnel qualified and designated to perform the restoration function.

² Including restoration steps in an approved test procedure.

1 an operator identified to perform the restoration actions independent of other control room
2 actions that may be required.

3
4 Under stressful, chaotic conditions, otherwise simple multiple actions may not be
5 accomplished with the virtual certainty called for by the guidance (e.g., lifting test leads and
6 landing wires; or clearing tags). In addition, some manual operations of systems designed to
7 operate automatically, such as manually controlling HPCI turbine to establish and control
8 injection flow, are not virtually certain to be successful. These situations should be resolved
9 on a case-by-case basis through the FAQ process.

10
11 2. *During Maintenance*

12 Unavailability of a risk-significant function during maintenance need not be included if the
13 risk-significant function can be promptly restored either by an operator in the control room or
14 by a designated operator³ stationed locally for that purpose. Restoration actions must be
15 contained in a written procedure⁴, must be uncomplicated (*a single action or a few simple*
16 *actions*), must be capable of being restored in time to satisfy PRA success criteria and must
17 not require diagnosis or repair. Credit for a designated local operator can be taken only if
18 (s)he is positioned at a proper location throughout the duration of the maintenance activity
19 for the purpose of restoration of the train should a valid demand occur. The intent of this
20 paragraph is to allow licensees to take credit for restoration of risk-significant functions that
21 are virtually certain to be successful (i.e., probability nearly equal to 1). The individual
22 performing the restoration function can be the person performing the maintenance and must
23 be in communication with the control room. Credit can also be taken for an operator in the
24 main control room provided (s)he is in close proximity to restore the equipment when
25 needed. Under stressful chaotic conditions otherwise simple multiple actions may not be
26 accomplished with the virtual certainty called for by the guidance (e.g., lifting test leads and
27 landing wires, or clearing tags). These situations should be resolved on a case-by-case basis
28 through the FAQ process.

29
30 3. Satisfying Risk Significant Mission Times

31 Risk significant operator actions to satisfy pre-determined train/system risk-significant
32 mission times can only be credited if they are modeled in the PRA.

33
34 Swing trains and components shared between units

35
36 Swing trains/components are trains/components that can be aligned to any unit. To be credited
37 as such, their swing capability should be modeled in the PRA to provide an appropriate Fussell-
38 Vesely value.

39
40 Unit Cross Tie Capability

41

³ Operator in this circumstance refers to any plant personnel qualified and designated to perform the restoration function.

⁴ Including restoration steps in an approved test procedure.

1 Components that cross tie monitored systems between units should be considered active
2 components if they are modeled in the PRA and meet the active component criteria in Appendix
3 F. Such active components are counted in each unit's performance indicators.

4
5 Maintenance Trains and Installed Spares

6
7 Some power plants have systems with extra trains to allow preventive maintenance to be carried
8 out with the unit at power without impacting the risk-significant function of the system. That is,
9 one of the remaining trains may fail, but the system can still perform its risk significant function.
10 To be a maintenance train, a train must not be needed to perform the system's risk significant
11 function.

12
13 An "installed spare" is a component (or set of components) that is used as a replacement for other
14 equipment to allow for the removal of equipment from service for preventive or corrective
15 maintenance without impacting the risk-significant function of the system. To be an "installed
16 spare," a component must not be needed for the system to perform the risk significant function.

17
18
19 For unreliability, spare active components are included if they are modeled in the PRA.
20 Unavailability of the spare component/train is only counted in the index if the spare is substituted
21 for a primary train/component. Unavailability is not monitored for a component/train when that
22 component/train has been replaced by an installed spare or maintenance train.

23
24 Use of Plant-Specific PRA and SPAR Models

25
26 The MSPI is an approximation using some information from a plant's actual PRA and is
27 intended as an indicator of system performance. Plant-specific PRAs and SPAR models cannot
28 be used to question the outcome of the PIs computed in accordance with this guideline.

29
30 Maintenance Rule Performance Monitoring

31
32 It is the intent that NUMARC 93-01 be revised to require consistent unavailability and
33 unreliability data gathering as required by this guideline.

34
35 **ADDITIONAL GUIDANCE FOR SPECIFIC SYSTEMS**

36 This guidance provides typical system scopes. Individual plants should include those systems
37 employed at their plant that are necessary to satisfy the specific risk-significant functions
38 described below and reflected in their PRAs.

39 **Emergency AC Power Systems**

40 Scope

41 The function monitored for the emergency AC power system is the ability of the emergency
42 generators to provide AC power to the class 1E buses upon a loss of off-site power while the
43 reactor is critical, including post-accident conditions. The emergency AC power system is

1 typically comprised of two or more independent emergency generators that provide AC power to
2 class 1E buses following a loss of off-site power. The emergency generator dedicated to
3 providing AC power to the high pressure core spray system in BWRs is not within the scope of
4 emergency AC power.

5
6 The electrical circuit breaker(s) that connect(s) an emergency generator to the class 1E buses that
7 are normally served by that emergency generator are considered to be part of the emergency
8 generator train.

9
10 Emergency generators that are not safety grade, or that serve a backup role only (e.g., an
11 alternate AC power source), are not included in the performance reporting.

12 Train Determination

13
14 The number of emergency AC power system trains for a unit is equal to the number of class 1E
15 emergency generators that are available to power safe-shutdown loads in the event of a loss of
16 off-site power for that unit. There are three typical configurations for EDGs at a multi-unit
17 station:

- 18
19 1. EDGs dedicated to only one unit.
20 2. One or more EDGs are available to “swing” to either unit
21 3. All EDGs can supply all units

22
23 For configuration 1, the number of trains for a unit is equal to the number of EDGs dedicated to
24 the unit. For configuration 2, the number of trains for a unit is equal to the number of dedicated
25 EDGs for that unit plus the number of “swing” EDGs available to that unit (i.e., The “swing”
26 EDGs are included in the train count for each unit). For configuration 3, the number of trains is
27 equal to the number of EDGs.

28 Clarifying Notes

29
30 The emergency diesel generators are not considered to be available during the following portions
31 of periodic surveillance tests unless recovery from the test configuration during accident
32 conditions is virtually certain, as described in “Credit for operator recovery actions during
33 testing,” can be satisfied; or the duration of the condition is less than fifteen minutes per train at
34 one time:

- 35
36 • Load-run testing
37 • Barring

38
39 An EDG is not considered to have failed due to any of the following events:

- 40
41 • spurious operation of a trip that would be bypassed in a loss of offsite power event
42 • malfunction of equipment that is not required to operate during a loss of offsite power event
43 (e.g., circuitry used to synchronize the EDG with off-site power sources)

- 1 • failure to start because a redundant portion of the starting system was intentionally disabled
2 for test purposes, if followed by a successful start with the starting system in its normal
3 alignment

4 Air compressors are not part of the EDG boundary. However, air receivers that provide starting
5 air for the diesel are included in the EDG boundary.

6
7 If an EDG has a dedicated battery independent of the station's normal DC distribution system,
8 the dedicated battery is included in the EDG system boundary.

9
10 If the EDG day tank is not sufficient to meet the EDG mission time, the fuel transfer function
11 should be modeled in the PRA. However, the fuel transfer pumps are not considered to be an
12 active component in the EDG system because they are considered to be a support system.

13 14 15 16 **BWR High Pressure Injection Systems**

17 **(High Pressure Coolant Injection, High Pressure Core Spray, and Feedwater Coolant** 18 **Injection)**

19 20 Scope

21 These systems function at high pressure to maintain reactor coolant inventory and to remove
22 decay heat following a small-break Loss of Coolant Accident (LOCA) event or a loss of main
23 feedwater event.

24
25 The function monitored for the indicator is the ability of the monitored system to take suction
26 from the suppression pool (and from the condensate storage tank, if credited in the plant's
27 accident analysis) and inject into the reactor vessel.

28
29 Plants should monitor either the high-pressure coolant injection (HPCI), the high-pressure core
30 spray (HPCS), or the feedwater coolant injection (FWCI) system, whichever is installed. The
31 turbine and governor (or motor-driven FWCI pumps), and associated piping and valves for
32 turbine steam supply and exhaust are within the scope of these systems. Valves in the feedwater
33 line are not considered within the scope of these systems. The emergency generator dedicated to
34 providing AC power to the high-pressure core spray system is included in the scope of the
35 HPCS. The HPCS system typically includes a "water leg" pump to prevent water hammer in the
36 HPCS piping to the reactor vessel. The "water leg" pump and valves in the "water leg" pump
37 flow path are ancillary components and are not included in the scope of the HPCS system.

38 Unavailability is not included while critical if the system is below steam pressure specified in
39 technical specifications at which the system can be operated.

40 41 Train Determination

42 The HPCI and HPCS systems are considered single-train systems. The booster pump and other
43 small pumps are ancillary components not used in determining the number of trains. The effect

1 of these pumps on system performance is included in the system indicator to the extent their
2 failure detracts from the ability of the system to perform its risk-significant function. For the
3 FWCI system, the number of trains is determined by the number of feedwater pumps. The
4 number of condensate and feedwater booster pumps are not used to determine the number of
5 trains.

6
7 **BWR Heat Removal Systems**
8 **(Reactor Core Isolation Cooling or Isolation Condenser)**

9
10 **Scope**

11 This system functions at high pressure to remove decay heat following a loss of main feedwater
12 event. The RCIC system also functions to maintain reactor coolant inventory following a very
13 small LOCA event.

14
15 The function monitored for the indicator is the ability of the RCIC system to cool the reactor
16 vessel core and provide makeup water by taking a suction from either the condensate storage
17 tank or the suppression pool and injecting at rated pressure and flow into the reactor vessel.

18
19 The Reactor Core Isolation Cooling (RCIC) system turbine, governor, and associated piping and
20 valves for steam supply and exhaust are within the scope of the RCIC system. Valves in the
21 feedwater line are not considered within the scope of the RCIC system. The Isolation Condenser
22 and inlet valves are within the scope of Isolation Condenser system. Unavailability is not
23 included while critical if the system is below steam pressure specified in technical specifications
24 at which the system can be operated.

25
26
27 **Train Determination**

28 The RCIC system is considered a single-train system. The condensate and vacuum pumps are
29 ancillary components not used in determining the number of trains. The effect of these pumps on
30 RCIC performance is included in the system indicator to the extent that a component failure
31 results in an inability of the system to perform its risk-significant function.
32

33 **BWR Residual Heat Removal Systems**

34 **Scope**

35 The functions monitored for the BWR residual heat removal (RHR) system are the ability of the
36 RHR system to remove heat from the suppression pool, provide low pressure coolant injection,
37 and provide post-accident decay heat removal. The pumps, heat exchangers, and associated
38 piping and valves for those functions are included in the scope of the RHR system.
39

1 **Train Determination**

2 The number of trains in the RHR system is determined by the number of parallel RHR heat
3 exchangers.

4
5 **PWR High Pressure Safety Injection Systems**

6 **Scope**

7 These systems are used primarily to maintain reactor coolant inventory at high pressures
8 following a loss of reactor coolant. HPSI system operation following a small-break LOCA
9 involves transferring an initial supply of water from the refueling water storage tank (RWST) to
10 cold leg piping of the reactor coolant system. Once the RWST inventory is depleted,
11 recirculation of water from the reactor building emergency sump is required. The function
12 monitored for HPSI is the ability of a HPSI train to take a suction from the primary water source
13 (typically, a borated water tank), or from the containment emergency sump, and inject into the
14 reactor coolant system at rated flow and pressure.

15
16 The scope includes the pumps and associated piping and valves from both the refueling water
17 storage tank and from the containment sump to the pumps, and from the pumps into the reactor
18 coolant system piping. For plants where the high-pressure injection pump takes suction from the
19 residual heat removal pumps, the residual heat removal pump discharge header isolation valve to
20 the HPSI pump suction is included in the scope of HPSI system. Some components may be
21 included in the scope of more than one train. For example, cold-leg injection lines may be fed
22 from a common header that is supplied by both HPSI trains. In these cases, the effects of testing
23 or component failures in an injection line should be reported in both trains.

24
25 **Train Determination**

26
27 In general, the number of HPSI system trains is defined by the number of high head injection
28 paths that provide cold-leg and/or hot-leg injection capability, as applicable.

29
30 For Babcock and Wilcox (B&W) reactors, the design features centrifugal pumps used for high
31 pressure injection (about 2,500 psig) and no hot-leg injection path. Recirculation from the
32 containment sump requires operation of pumps in the residual heat removal system. They are
33 typically a two-train system, with an installed spare pump (depending on plant-specific design)
34 that can be aligned to either train.

35
36 For two-loop Westinghouse plants, the pumps operate at a lower pressure (about 1600 psig) and
37 there may be a hot-leg injection path in addition to a cold-leg injection path (both are included as
38 a part of the train).

39
40 For Combustion Engineering (CE) plants, the design features three centrifugal pumps that
41 operate at intermediate pressure (about 1300 psig) and provide flow to two cold-leg injection
42 paths or two hot-leg injection paths. In most designs, the HPSI pumps take suction directly from
43 the containment sump for recirculation. In these cases, the sump suction valves are included
44 within the scope of the HPSI system. This is a two-train system (two trains of combined cold-leg

1 and hot-leg injection capability). One of the three pumps is typically an installed spare that can
2 be aligned to either train or only to one of the trains (depending on plant-specific design).

3
4 For Westinghouse three-loop plants, the design features three centrifugal pumps that operate at
5 high pressure (about 2500 psig), a cold-leg injection path through the BIT (with two trains of
6 redundant valves), an alternate cold-leg injection path, and two hot-leg injection paths. One of
7 the pumps is considered an installed spare. Recirculation is provided by taking suction from the
8 RHR pump discharges. A train consists of a pump, the pump suction valves and boron injection
9 tank (BIT) injection line valves electrically associated with the pump, and the associated hot-leg
10 injection path. The alternate cold-leg injection path is required for recirculation, and should be
11 included in the train with which its isolation valve is electrically associated. This represents a
12 two-train HPSI system.

13
14 For Four-loop Westinghouse plants, the design features two centrifugal pumps that operate at
15 high pressure (about 2500 psig), two centrifugal pumps that operate at an intermediate pressure
16 (about 1600 psig), a BIT injection path (with two trains of injection valves), a cold-leg safety
17 injection path, and two hot-leg injection paths. Recirculation is provided by taking suction from
18 the RHR pump discharges. Each of two high pressure trains is comprised of a high pressure
19 centrifugal pump, the pump suction valves and BIT valves that are electrically associated with
20 the pump. Each of two intermediate pressure trains is comprised of the safety injection pump, the
21 suction valves and the hot-leg injection valves electrically associated with the pump. The cold-
22 leg safety injection path can be fed with either safety injection pump, thus it should be associated
23 with both intermediate pressure trains. This HPSI system is considered a four-train system for
24 monitoring purposes.

25 26 27 28 **PWR Auxiliary Feedwater Systems**

29 **Scope**

30 The AFW system provides decay heat removal via the steam generators to cool down and
31 depressurize the reactor coolant system following a reactor trip. The AFW system is assumed to
32 be required for an extended period of operation during which the initial supply of water from the
33 condensate storage tank is depleted and water from an alternative water source (e.g., the service
34 water system) is required. Therefore components in the flow paths from both of these water
35 sources are included; however, the alternative water source (e.g., service water system) is not
36 included.

37
38 The function monitored for the indicator is the ability of the AFW system to take a suction from
39 the primary water source (typically, the condensate storage tank) or, if required, from an
40 emergency source (typically, a lake or river via the service water system) and inject into at least
41 one steam generator at rated flow and pressure.

42
43 The scope of the auxiliary feedwater (AFW) or emergency feedwater (EFW) systems includes
44 the pumps and the components in the flow paths from the condensate storage tank and, if
45 required, the valve(s) that connect the alternative water source to the auxiliary feedwater system.
46 Startup feedwater pumps are not included in the scope of this indicator.

1

2 **Train Determination**

3 The number of trains is determined primarily by the number of parallel pumps. For example, a
4 system with three pumps is defined as a three-train system, whether it feeds two, three, or four
5 injection lines, and regardless of the flow capacity of the pumps. Some components may be
6 included in the scope of more than one train. For example, one set of flow regulating valves and
7 isolation valves in a three-pump, two-steam generator system are included in the motor-driven
8 pump train with which they are electrically associated, but they are also included (along with the
9 redundant set of valves) in the turbine-driven pump train. In these instances, the effects of testing
10 or failure of the valves should be reported in both affected trains. Similarly, when two trains
11 provide flow to a common header, the effect of isolation or flow regulating valve failures in
12 paths connected to the header should be considered in both trains.

13

14 **PWR Residual Heat Removal System**

15 **Scope**

16 The functions monitored for the PWR residual heat removal (RHR) system are those that are
17 required to be available when the reactor is critical. These typically include the low-pressure
18 injection function and the post-accident recirculation mode used to cool and recirculate water
19 from the containment sump following depletion of RWST inventory to provide post-accident
20 decay heat removal. The pumps, heat exchangers, and associated piping and valves for those
21 functions are included in the scope of the RHR system. Containment spray function should be
22 included if it is identified as a risk-significant post accident decay heat removal function.
23 Containment spray systems that only provide containment pressure control are not included.

24

25

26

27 **Train Determination**

28 The number of trains in the RHR system is determined by the number of parallel RHR heat
29 exchangers. Some components are used to provide more than one function of RHR. If a
30 component cannot perform as designed, rendering its associated train incapable of meeting one
31 of the risk-significant functions, then the train is considered to be failed. Unavailable hours
32 would be reported as a result of the component failure.

33 **Cooling Water Support System**

34 **Scope**

35 The function of the cooling water support system is to provide for direct cooling of the
36 components in the other monitored systems. It does not include indirect cooling provided by
37 room coolers or other HVAC features.

38

39 Systems that provide this function typically include service water and component cooling water
40 or their cooling water equivalents. Pumps, valves, heat exchangers and line segments that are
41 necessary to provide cooling to the other monitored systems are included in the system scope up
42 to, but not including, the last valve that connects the cooling water support system to the other
43 monitored systems. This last valve is included in the other monitored system boundary.

1
2 Valves in the cooling water support system that must close to ensure sufficient cooling to the
3 other monitored system components to meet risk significant functions are included in the system
4 boundary.
5
6
7

8 **Train Determination**

9 The number of trains in the Cooling Water Support System will vary considerably from plant to
10 plant. The way these functions are modeled in the plant-specific PRA will determine a logical
11 approach for train determination. For example, if the PRA modeled separate pump and line
12 segments, then the number of pumps and line segments would be the number of trains.
13

14 **Clarifying Notes**

15 Service water pump strainers and traveling screens are not considered to be active components
16 and are therefore not part of URI. However, clogging of strainers and screens due to expected or
17 routinely predictable environmental conditions that render the train unavailable to perform its
18 risk significant cooling function (which includes the risk-significant mission times) are included
19 in UAI.
20

21 Unpredictable extreme environmental conditions that render the train unavailable to perform its
22 risk significant cooling function should be addressed through the FAQ process to determine if
23 resulting unavailability should be included in UAI.
24

APPENDIX F

METHODOLOGIES FOR COMPUTING THE UNAVAILABILITY INDEX, THE UNRELIABILITY INDEX AND DETERMINING PERFORMANCE INDEX VALIDITY

This appendix provides the details of three calculations, calculation of the System Unavailability Index, the System Unreliability Index, and the criteria for determining when the Mitigating System Performance Index is unsuitable for use as a performance index.

System Unavailability Index (UAI) Due to Changes in Train Unavailability

Calculation of System UAI due to changes in train unavailability is as follows:

$$UAI = \sum_{j=1}^n UAI_j \tag{Eq. 1}$$

where the summation is over the number of trains (*n*) and *UAI_t* is the unavailability index for a train.

Calculation of *UAI_t* for each train due to changes in train unavailability is as follows:

$$UAI_t = CDF_p \left[\frac{FV_{UA_p}}{UA_p} \right]_{\max} (UA_t - UA_{BLt}), \tag{Eq. 2}$$

where:

CDF_p is the plant-specific, internal events, at power Core Damage Frequency,

FV_{UA_p} is the train-specific Fussell-Vesely value for unavailability,

UA_p is the plant-specific PRA value of unavailability for the train,

UA_t is the actual unavailability of train t, defined as:

$$UA_t = \frac{\text{Unavailable hours during the previous 12 quarters while critical}}{\text{Critical hours during the previous 12 quarters}}$$

and,

UA_{BLt} is the historical baseline unavailability value for the train determined as described below.

UA_{BLt} is the sum of two elements: planned and unplanned unavailability. Planned unavailability is the actual, plant-specific three-year total planned unavailability for the train for the years 1999 through 2001 (see clarifying notes for details).

This period is chosen as the most representative of how the plant intends to perform routine maintenance and surveillances at power. Unplanned unavailability is the historical industry average for unplanned unavailability for

1 the years 1999 through 2001. See Table 1 for historical train values for
 2 unplanned unavailability.

3 Calculation of the quantity inside the square bracket in equation 2 will be discussed at the
 4 end of the next section. See clarifying notes for calculation of UAI for cooling water
 5 support system.

6

7 **System Unreliability Index (URI) Due to Changes in Component Unreliability**

8 Unreliability is monitored at the component level and calculated at the system level.

9 Calculation of system URI due to changes in component unreliability is as follows:

10
$$URI = CDF_p \sum_{j=1}^m \left[\frac{FV_{URcj}}{UR_{pcj}} \right]_{\max} (UR_{Bcj} - UR_{BLcj}) \quad \text{Eq. 3}$$

11 Where the summation is over the number of active components (m) in the system, and:

12 CDF_p is the plant-specific internal events, at power, core damage frequency,

13 FV_{URc} is the component-specific Fussell-Vesely value for unreliability,

14 UR_{pc} is the plant-specific PRA value of component unreliability,

15 UR_{Bc} is the Bayesian corrected component unreliability for the previous 12
 16 quarters,

17 and

18 UR_{BLc} is the historical industry baseline calculated from unreliability mean values
 19 for each monitored component in the system. The calculation is performed in a
 20 manner similar to equation 4 below using the industry average values in Table 2.

21 Calculation of the quantity inside the square bracket in equation 3 will be discussed at the
 22 end of this section.

23 Component unreliability is calculated as follows.

24
$$UR_{Bc} = P_D + \lambda T_m \quad \text{Eq 4}$$

25 where:

26 P_D is the component failure on demand probability calculated based on data
 27 collected during the previous 12 quarters,

28 λ is the component failure rate (per hour) for failure to run calculated based on
 29 data collected during the previous 12 quarters,

30 and

31 T_m is the risk-significant mission time for the component based on plant specific
 32 PRA model assumptions.

1 NOTE:

2 For valves only the P_D term applies

3 For pumps $P_D + \lambda T_m$ applies

4 For diesels $P_{D \text{ start}} + P_{D \text{ load run}} + \lambda T_m$ applies

5

6 The first term on the right side of equation 4 is calculated as follows.¹

7
$$P_D = \frac{(N_d + a)}{(a + b + D)} \quad \text{Eq. 5}$$

8 where:

9 N_d is the total number of failures on demand during the previous 12 quarters,

10 D is the total number of demands during the previous 12 quarters (actual ESF
11 demands plus estimated test and estimated operational/alignment demands. An
12 update to the estimated demands is required if a change to the basis for the
13 estimated demands results in a >25% change in the estimate),

14 and

15 a and b are parameters of the industry prior, derived from industry experience (see
16 Table 2).

17 In the calculation of equation 5 the numbers of demands and failures is the sum of all
18 demands and failures for similar components within each system. Do not sum across
19 units for a multi-unit plant. For example, for a plant with two trains of Emergency Diesel
20 Generators, the demands and failures for both trains would be added together for one
21 evaluation of P_D which would be used for both trains of EDGs.

22 In the second term on the right side of equation 4, λ is calculated as follows.

23
$$\lambda = \frac{(N_r + a)}{(T_r + b)} \quad \text{Eq. 6}$$

24 where:

25 N_r is the total number of failures to run during the previous 12 quarters,

26 T_r is the total number of run hours during the previous 12 quarters (actual ESF run
27 hours plus estimated test and estimated operational/alignment run hours. An
28 update to the estimated run hours is required if a change to the basis for the
29 estimated hours results in a >25% change in the estimate).

30 and

¹ Atwood, Corwin L., Constrained noninformative priors in risk assessment, *Reliability Engineering and System Safety*, 53 (1996; 37-46)

1 a and b are parameters of the industry prior, derived from industry experience (see
2 Table 2).

3 In the calculation of equation 6 the numbers of demands and run hours is the sum of all
4 run hours and failures for similar components within each system. Do not sum across
5 units for a multi-unit plant. For example, a plant with two trains of Emergency Diesel
6 Generators, the run hours and failures for both trains would be added together for one
7 evaluation of λ which would be used for both trains of EDGs.

8 Fussell-Vesely, Unavailability and Unreliability

9 Equations 2 and 3 include a term that is the ratio of a Fussell-Vesely importance value
10 divided by the related unreliability or unavailability. Calculation of these quantities is
11 generally complex, but in the specific application used here, can be greatly simplified.

12 The simplifying feature of this application is that only those components (or the
13 associated basic events) that can fail a train are included in the performance index.
14 Components within a train that can each fail the train are logically equivalent and the
15 ratio FV/UR is a constant value for any basic event in that train. It can also be shown that
16 for a given component or train represented by multiple basic events, the ratio of the two
17 values for the component or train is equal to the ratio of values for any basic event within
18 the train. Or:

19
$$\frac{FV_{be}}{UR_{be}} = \frac{FV_{URc}}{UR_{Fc}} = \frac{FV_t}{UR_t} = \text{Constant}$$

20 and

21
$$\frac{FV_{be}}{UA_{be}} = \frac{FV_{UAp}}{UA_p} = \text{Constant}$$

22 Note that the constant value may be different for the unreliability ratio and the
23 unavailability ratio because the two types of events are frequently not logically
24 equivalent. For example recovery actions may be modeled in the PRA for one but not the
25 other.

26 Thus, the process for determining the value of this ratio for any component or train is to
27 identify a basic event that fails the component or train, determine the failure probability
28 or unavailability for the event, determine the associated FV value for the event and then
29 calculate the ratio. Use the basic event in the component or train with the largest failure
30 probability (hence the maximum notation on the bracket) to minimize the effects of
31 truncation on the calculation. Exclude common cause events, which are not within the
32 scope of this performance index

33 Some systems have multiple modes of operation, such as PWR HPSI systems that operate
34 in injection as well as recirculation modes. In these systems all active components are not
35 logically equivalent, unavailability of the pump fails all operating modes while
36 unavailability of the sump suction valves only fails the recirculation mode. In cases such

1 as these, if unavailability events exist separately for the components within a train, the
 2 appropriate ratio to use is the maximum.

3 **Determination of systems for which the performance index is not valid**

4 The performance index relies on the existing testing programs as the source of the data
 5 that is input to the calculations. Thus, the number of demands in the monitoring period is
 6 based on the frequency of testing required by the current test programs. In most cases this
 7 will provide a sufficient number of demands to result in a valid statistical result.
 8 However, in some cases, the number of demands will be insufficient to resolve the
 9 change in the performance index (1.0×10^{-6}) that corresponds to movement from a green
 10 performance to a white performance level. In these cases, one failure is the difference
 11 between baseline performance and performance in the white performance band. The
 12 performance index is not suitable for monitoring such systems and monitoring is
 13 performed through the inspection process.

14 This section will define the method to be used to identify systems for which the
 15 performance index is not valid, and will not be used.

16 The criteria to be used to identify an invalid performance index is:

17 If, for any failure mode for any component in a system, the risk increase
 18 (Δ CDF) associated with the change in unreliability resulting from single
 19 failure is larger than 1.0×10^{-6} , then the performance index will be
 20 considered invalid for that system.

21 The increase in risk associated with a component failure is the sum of the contribution
 22 from the decrease in calculated reliability as a result of the failure and the decrease in
 23 availability resulting from the time required to affect the repair of the failed component.
 24 The change in CDF that results from a demand type failure is given by:

25

$$\begin{aligned}
 MSPI = CDF_p \times \sum_{N \text{ similar comp}} \left\{ \frac{FV_{URc}}{UR_{pc}} \times \frac{1}{a + b + D} \right\} \\
 + CDF_p \times \frac{FV_{UAp}}{UA_p} \times \frac{T_{\text{Mean Repair}}}{T_{CR}}
 \end{aligned}
 \tag{Eq. 7}$$

27

28 Likewise, the change in CDF per run type failure is given by:

29

$$\begin{aligned}
 MSPI = CDF_p \times \sum_{N \text{ similar comp}} \left\{ \frac{FV_{URc}}{UR_{pc}} \times \frac{T_m}{b + T_r} \right\} \\
 + CDF_p \times \frac{FV_{UAp}}{UA_p} \times \frac{T_{\text{Mean Repair}}}{T_{CR}}
 \end{aligned}
 \tag{Eq. 8}$$

30

1 In these expressions, the variables are as defined earlier and additionally

2 T_{MR} is the mean time to repair for the component

3 and

4 T_{CR} is the number of critical hours in the monitoring period.

5 The summation in the equations is taken over all similar components within a system.

6 With multiple components of a given type in one system, the impact of the failure on

7 CDF is included in the increased unavailability of all components of that type due to

8 pooling the demand and failure data.

9 The mean time to repair can be estimate as one-half the Technical Specification Allowed

10 Outage Time for the component and the number of critical hours should correspond to the

11 1999 – 2001 actual number of critical hours.

12 These equations are be used for all failure modes for each component in a system. If the

13 resulting value of ΔCDF is greater than 1.0×10^{-6} for any failure mode of any component,

14 then the performance index for that system is not considered valid.

15

16 Definitions

17

18 *Train Unavailability:* Train unavailability is the ratio of the hours the train was
19 unavailable to perform its risk-significant functions due to planned or unplanned
20 maintenance or test during the previous 12 quarters while critical to the number of critical
21 hours during the previous 12 quarters. (Fault exposure hours are not included;
22 unavailable hours are counted only for the time required to recover the train's risk-
23 significant functions.)

24 *Train unavailable hours:* The hours the train was not able to perform its risk significant
25 function due to maintenance, testing, equipment modification, electively removed from
26 service, corrective maintenance, or the elapsed time between the discovery and the
27 restoration to service of an equipment failure or human error that makes the train
28 unavailable (such as a misalignment) while the reactor is critical.

29 *Fussell-Vesely (FV) Importance:*

30 The Fussell-Vesely importance for a feature (component, sub-system, train, etc.) of a
31 system is representative of the fractional contribution that feature makes to the to the total
32 risk of the system.

33 The Fussell-Vesely importance of a basic event or group of basic events that represent a
34 feature of a system is represented by:

35
$$FV = 1 - \frac{R_i}{R_0}$$

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1 Where:

2 R_0 is the base (reference) case overall model risk,

3 R_i is the decreased risk level with feature i completely reliable.

4 In this expression, the second term on the right represents the fraction of the reference
5 risk remaining assuming the feature of interest is perfect. Thus 1 minus the second term is
6 the fraction of the reference risk attributed to the feature of interest.

7 The Fussell-Vesely importance is calculated according to the following equation:

8
$$FV = 1 - \frac{\bigcup_{j=1,n} C_{i,j}}{\bigcup_{j=1,m} C_{0,j}}$$

9 where the denominator represents the union of m minimal cutsets C_0 generated with the
10 reference (baseline) model, and the numerator represents the union of n minimal cutsets
11 C_i generated assuming events related to the feature are perfectly reliable, or their failure
12 probability is False.

13 *Critical hours:* The number of hours the reactor was critical during a specified period of
14 time.

15 *Component Unreliability:* Component unreliability is the probability that the component
16 would not perform its risk-significant functions when called upon during the previous 12
17 quarters.

18 *Active Component:* A component whose failure to change state renders the train incapable
19 of performing its risk-significant functions. In addition, all pumps and diesels in the
20 monitored systems are included as active components. (See clarifying notes.)

21 *Manual Valve:* A valve that can only be operated by a person. An MOV or AOV that is
22 remotely operated by a person may be an active component.

23 *Start demand:* Any demand for the component to successfully start to perform its risk-
24 significant functions, actual or test. (Exclude post maintenance tests, unless in case of a
25 failure the cause of failure was independent of the maintenance performed.)

26 *Post maintenance tests:* Tests performed following maintenance but prior to declaring the
27 train/component operable, consistent with Maintenance Rule implementation.

28 *Run demand:* Any demand for the component, given that it has successfully started, to
29 run/operate for its mission time to perform its risk-significant functions. (Exclude post
30 maintenance tests, unless in case of a failure the cause of failure was independent of the
31 maintenance performed.)

32 *EDG failure to start:* A failure to start includes those failures up to the point the EDG has
33 achieved rated speed and voltage. (Exclude post maintenance tests, unless the cause of
34 failure was independent of the maintenance performed.)

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1 *EDG failure to load/run:* Given that it has successfully started, a failure of the EDG
2 output breaker to close, loads successfully sequence and to run/operate for one hour to
3 perform its risk-significant functions. This failure mode is treated as a demand failure for
4 calculation purposes. (Exclude post maintenance tests, unless the cause of failure was
5 independent of the maintenance performed.)

6 *EDG failure to run:* Given that it has successfully started and loaded and run for an hour,
7 a failure of an EDG to run/operate. (Exclude post maintenance tests, unless the cause of
8 failure was independent of the maintenance performed.)

9 *Pump failure on demand:* A failure to start and run for at least one hour is counted as
10 failure on demand. (Exclude post maintenance tests, unless the cause of failure was
11 independent of the maintenance performed.)

12 *Pump failure to run:* Given that it has successfully started and run for an hour, a failure of
13 a pump to run/operate. (Exclude post maintenance tests, unless the cause of failure was
14 independent of the maintenance performed.)

15 *Valve failure on demand:* A failure to open or close is counted as failure on demand.
16 (Exclude post maintenance tests, unless the cause of failure was independent of the
17 maintenance performed.)

18 **Clarifying Notes**

19 **Train Boundaries and Unavailable Hours**

20 Include all components that are required to satisfy the risk-significant function of the
21 train. For example, high-pressure injection may have both an injection mode with
22 suction from the refueling water storage tank and a recirculation mode with suction from
23 the containment sump. Some components may be included in the scope of more than one
24 train. For example, one set of flow regulating valves and isolation valves in a three-pump,
25 two-steam generator system are included in the motor-driven pump train with which they
26 are electrically associated, but they are also included (along with the redundant set of
27 valves) in the turbine-driven pump train. In these instances, the effects of unavailability
28 of the valves should be reported in both affected trains. Similarly, when two trains
29 provide flow to a common header, the effect of isolation or flow regulating valve failures
30 in paths connected to the header should be considered in both trains

31 **Cooling Water Support System Trains**

32 The number of trains in the Cooling Water Support System will vary considerably from
33 plant to plant. The way these functions are modeled in the plant-specific PRA will
34 determine a logical approach for train determination. For example, if the PRA modeled
35 separate pump and line segments, then the number of pumps and line segments would be
36 the number of trains. A separate value for UAI and URI will be calculated for each of the
37 systems in this indicator and then they will be added together to calculate the MSPI.

1

2 Active Components

3 For unreliability, use the following criteria for determining those components that should
4 be monitored:

- 5 • Components that are normally running or have to change state to achieve the risk
6 significant function will be included in the performance index. Active failures of
7 check valves and manual valves are excluded from the performance index and will be
8 evaluated in the NRC inspection program.
- 9 • Redundant valves within a train are not included in the performance index. Only
10 those valves whose failure alone can fail a train will be included. The PRA success
11 criteria are to be used to identify these valves.
- 12 • Redundant valves within a multi-train system, whether in series or parallel, where the
13 failure of both valves would prevent all trains in the system from performing a risk-
14 significant function are included. (See Figure F-5)
- 15 • All pumps and diesels are included in the performance index

16 Table 3 defines the boundaries of components, and Figures F-1, F-2, F-3 and F-4 provide
17 examples of typical component boundaries as described in Table 3. Each plant will
18 determine their system boundaries, active components, and support components, and
19 have them available for NRC inspection.

20 Failures of Non-Active Components

21 Failures of SSC's that are not included in the performance index will not be counted as a
22 failure or a demand. Failures of SSC's that cause an SSC within the scope of the
23 performance index to fail will not be counted as a failure or demand. An example could
24 be a manual suction isolation valve left closed which causes a pump to fail. This would
25 not be counted as a failure of the pump. Any mispositioning of the valve that caused the
26 train to be unavailable would be counted as unavailability from the time of discovery.
27 The significance of the mispositioned valve prior to discovery would be addressed
28 through the inspection process.

29

30 Baseline Values

31 The baseline values for unreliability are contained in Table 2 and remain fixed.

32 The baseline values for unavailability include both plant-specific planned unavailability
33 values and unplanned unavailability values. The unplanned unavailability values are
34 contained in Table 1 and remain fixed. They are based on ROP PI industry data from
35 1999 through 2001. (Most baseline data used in PIs come from the 1995-1997 time
36 period. However, in this case, the 1999-2001 ROP data are preferable, because the ROP
37 data breaks out systems separately (some of the industry 1995-1997 INPO data combine

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- 1 systems, such as HPCI and RCIC, and do not include PWR RHR). It is important to note
2 that the data for the two periods is very similar.)
- 3 Support cooling baseline data is based on plant specific maintenance rule unavailability
4 for years 1999 to 2001. (Maintenance rule data does not distinguish between planned and
5 unplanned unavailability. There is no ROP support cooling data.)
- 6 The baseline planned unavailability is based on actual plant-specific values for the period
7 1999 through 2001. These values are expected to remain fixed unless the plant
8 maintenance philosophy is substantially changed with respect to on-line maintenance or
9 preventive maintenance. In these cases, the planned unavailability baseline value can be
10 adjusted. A comment should be placed in the comment field of the quarterly report to
11 identify a substantial change in planned unavailability. To determine the planned
12 unavailability:
- 13 1. Record the total train unavailable hours reported under the Reactor Oversight Process
14 for 1999 through 2001.
 - 15 2. Subtract any fault exposure hours still included in the 1999-2001 period.
 - 16 3. Subtract unplanned unavailable hours
 - 17 4. Add any on-line overhaul hours and any other planned unavailability excluded in
18 accordance with NEI 99-02.²
 - 19 5. Add any planned unavailable hours for functions monitored under MSPI which were
20 not monitored under SSU in NEI 99-02.
 - 21 6. Subtract any unavailable hours reported when the reactor was not critical.
 - 22 7. Subtract hours cascaded onto monitored systems by support systems.
 - 23 8. Divide the hours derived from steps 1-6 above by the total critical hours during 1999-
24 2001. This is the baseline planned unavailability
- 25 Baseline unavailability is the sum of planned unavailability from step 7 and unplanned
26 unavailability from Table 1.
27

² Note: The plant-specific PRA should model significant on-line overhaul hours.

1
2
3
4

**Table 1. Historical Unplanned Maintenance Unavailability Train Values
(Based on ROP Industrywide Data for 1999 through 2001)**

SYSTEM	UNPLANNED UNAVAILABILITY/TRAIN
EAC	1.7 E-03
PWR HPSI	6.1 E-04
PWR AFW (TD)	9.1 E-04
PWR AFW (MD)	6.9 E-04
PWR AFW (DieselD)	7.6 E-04
PWR (except CE) RHR	4.2 E-04
CE RHR	1.1 E-03
BWR HPCI	3.3 E-03
BWR HPCS	5.4 E-04
BWR RCIC	2.9 E-03
BWR RHR	1.2 E-03
Support Cooling	Use plant specific Maintenance Rule data for 1999-2001

1
2
3

Table 2. Industry Priors and Parameters for Unreliability

Component	Failure Mode	a ^a	b ^a	Industry Mean Value ^b	Source(s)
Motor-operated valve	Fail to open (or close)	5.0E-1	2.4E+2	2.1E-3	NUREG/CR-5500, Vol. 4,7,8,9
Air-operated valve	Fail to open (or close)	5.0E-1	2.5E+2	2.0E-3	NUREG/CR-4550, Vol. 1
Motor-driven pump, standby	Fail to start	5.0E-1	2.4E+2	2.1E-3	NUREG/CR-5500, Vol. 1,8,9
	Fail to run	5.0E-1	5.0E+3h	1.0E-4/h	NUREG/CR-5500, Vol. 1,8,9
Motor-driven pump, running or alternating	Fail to start	4.9E-1	1.6E+2	3.0E-3	NUREG/CR-4550, Vol. 1
	Fail to run	5.0E-1	1.7E+4h	3.0E-5/h	NUREG/CR-4550, Vol. 1
Turbine-driven pump, AFWS	Fail to start	4.7E-1	2.4E+1	1.9E-2	NUREG/CR-5500, Vol. 1
	Fail to run	5.0E-1	3.1E+2	1.6E-3/h	NUREG/CR-5500, Vol. 1
Turbine-driven pump, HPCI or RCIC	Fail to start	4.6E-1	1.7E+1	2.7E-2	NUREG/CR-5500, Vol. 4,7
	Fail to run	5.0E-1	3.1E+2h	1.6E-3/h	NUREG/CR-5500, Vol. 1,4,7
Diesel-driven pump, AFWS	Fail to start	4.7E-1	2.4E+1	1.9E-2	NUREG/CR-5500, Vol. 1
	Fail to run	5.0E-1	6.3E+2h	8.0E-4/h	NUREG/CR-4550, Vol. 1
Emergency diesel generator	Fail to start	4.8E-1	4.3E+1	1.1E-2	NUREG/CR-5500, Vol. 5
	Fail to load/run	5.0E-1	2.9E+2	1.7E-3 ^c	NUREG/CR-5500, Vol. 5
	Fail to run	5.0E-1	2.2E+3h	2.3E-4/h	NUREG/CR-5500, Vol. 5

4

DRAFT NEI 99-02 MSPI Rev 0

1 a. A constrained, non-informative prior is assumed. For failure to run events, $a = 0.5$ and
2 $b = (a)/(\text{mean rate})$. For failure upon demand events, a is a function of the mean
3 probability:

4

5	<u>Mean Probability</u>	<u>a</u>
6	0.0 to 0.0025	0.50
7	>0.0025 to 0.010	0.49
8	>0.010 to 0.016	0.48
9	>0.016 to 0.023	0.47
10	>0.023 to 0.027	0.46

11

12 Then $b = (a)(1.0 - \text{mean probability})/(\text{mean probability})$.

13

14 b. Failure to run events occurring within the first hour of operation are included within
15 the fail to start failure mode. Failure to run events occurring after the first hour of
16 operation are included within the fail to run failure mode. Unless otherwise noted, the
17 mean failure probabilities and rates include the probability of non-recovery. Types of
18 allowable recovery are outlined in the clarifying notes, under "Credit for Recovery
19 Actions."

20

21 c. Fail to load and run for one hour was calculated from the failure to run data in the
22 report indicated. The failure rate for 0.0 to 0.5 hour ($3.3E-3/h$) multiplied by 0.5 hour,
23 was added to the failure rate for 0.5 to 14 hours ($2.3E-4/h$) multiplied by 0.5 hour.

Table 3. Component Boundary Definition

Component	Component boundary
Diesel Generators	The diesel generator boundary includes the generator body, generator actuator, lubrication system (local), fuel system (local), cooling components (local), startup air system receiver, exhaust and combustion air system, dedicated diesel battery (which is not part of the normal DC distribution system), individual diesel generator control system, circuit breaker for supply to safeguard buses and their associated local control circuit (coil, auxiliary contacts, wiring and control circuit contacts, and breaker closure interlocks) .
Motor-Driven Pumps	The pump boundary includes the pump body, motor/actuator, lubrication system cooling components of the pump seals, the voltage supply breaker, and its associated local control circuit (coil, auxiliary contacts, wiring and control circuit contacts).
Turbine-Driven Pumps	The turbine-driven pump boundary includes the pump body, turbine/actuator, lubrication system (including pump), extractions, turbo-pump seal, cooling components, and local turbine control system (speed).
Motor-Operated Valves	The valve boundary includes the valve body, motor/actuator, the voltage supply breaker (both motive and control power) and its associated local open/close circuit (open/close switches, auxiliary and switch contacts, and wiring and switch energization contacts).
Air-Operated Valves	The valve boundary includes the valve body, the air operator, associated solenoid-operated valve, the power supply breaker or fuse for the solenoid valve, and its associated control circuit (open/close switches and local auxiliary and switch contacts).

1

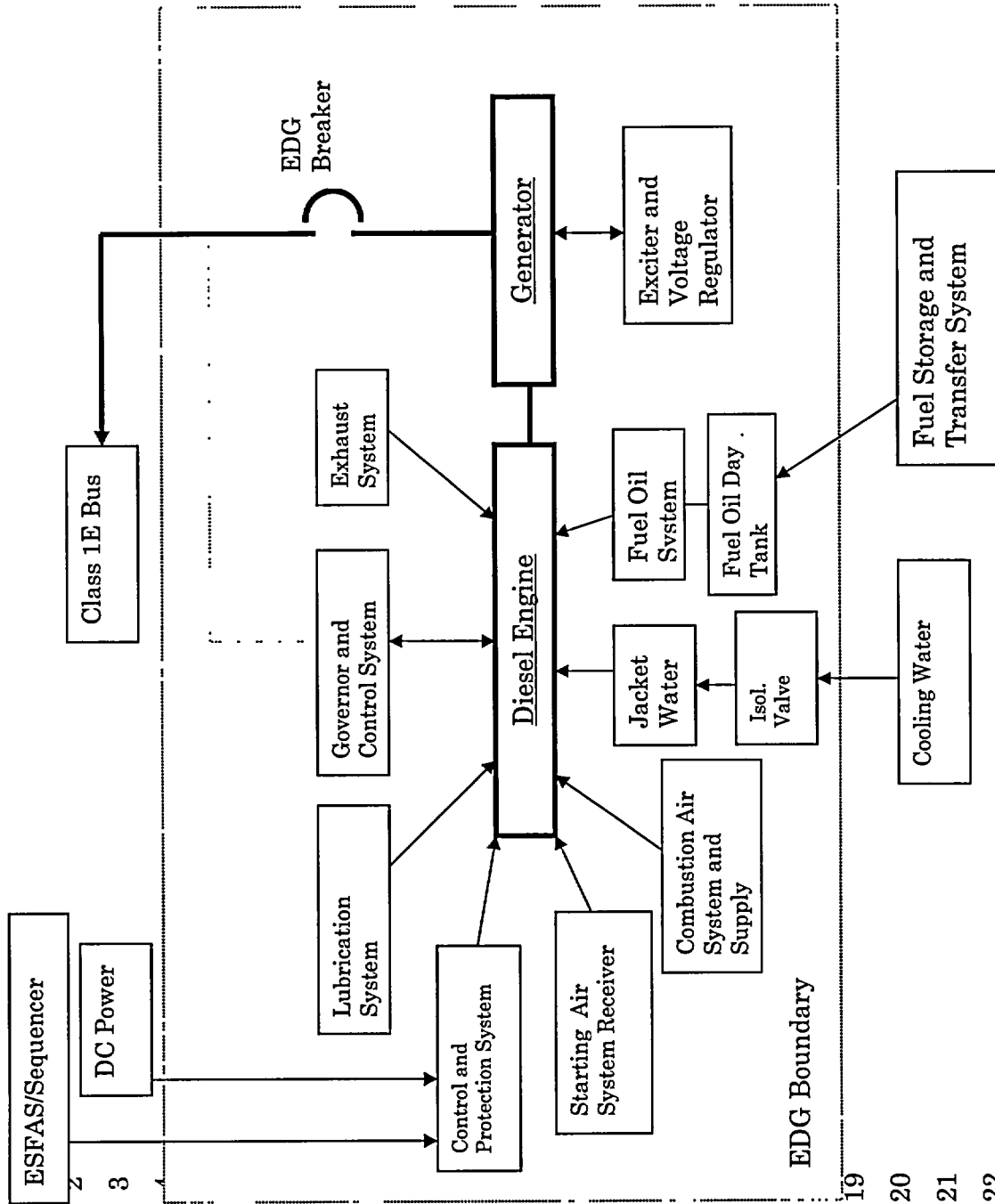
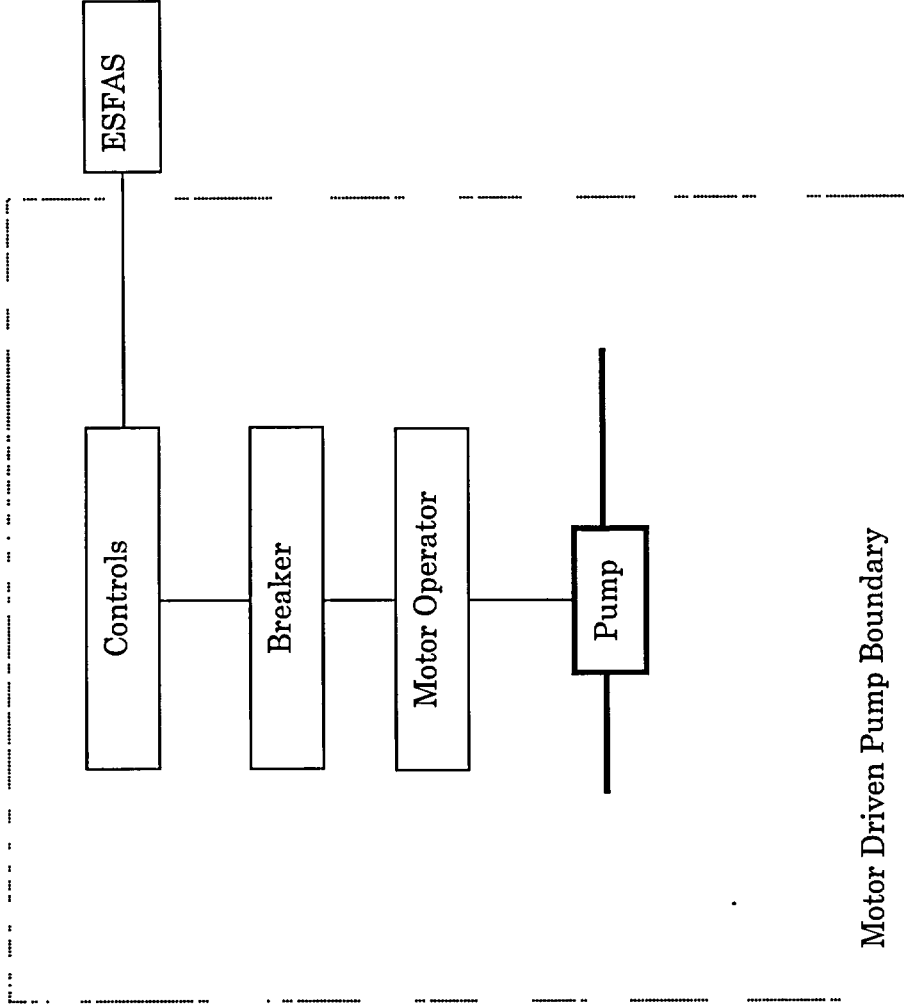


Figure F-1

1



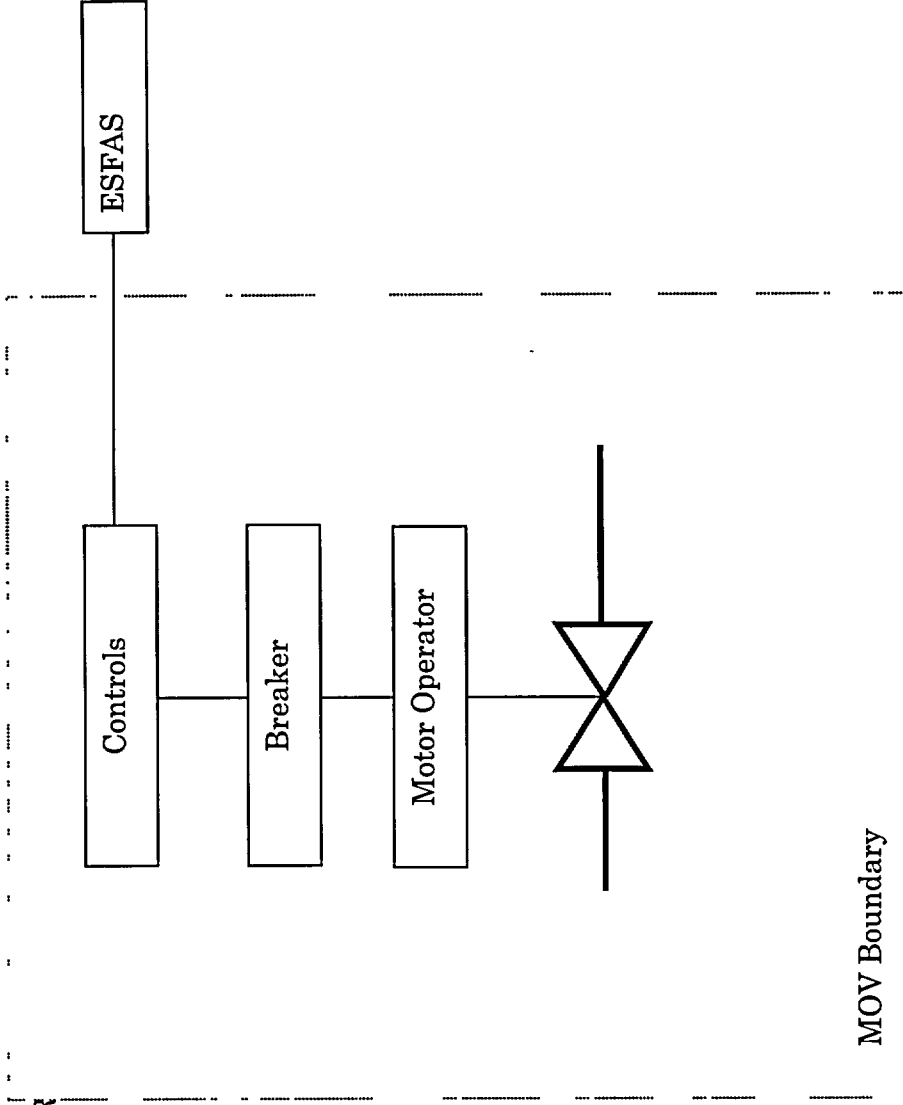
2

Figure F-2

3

4

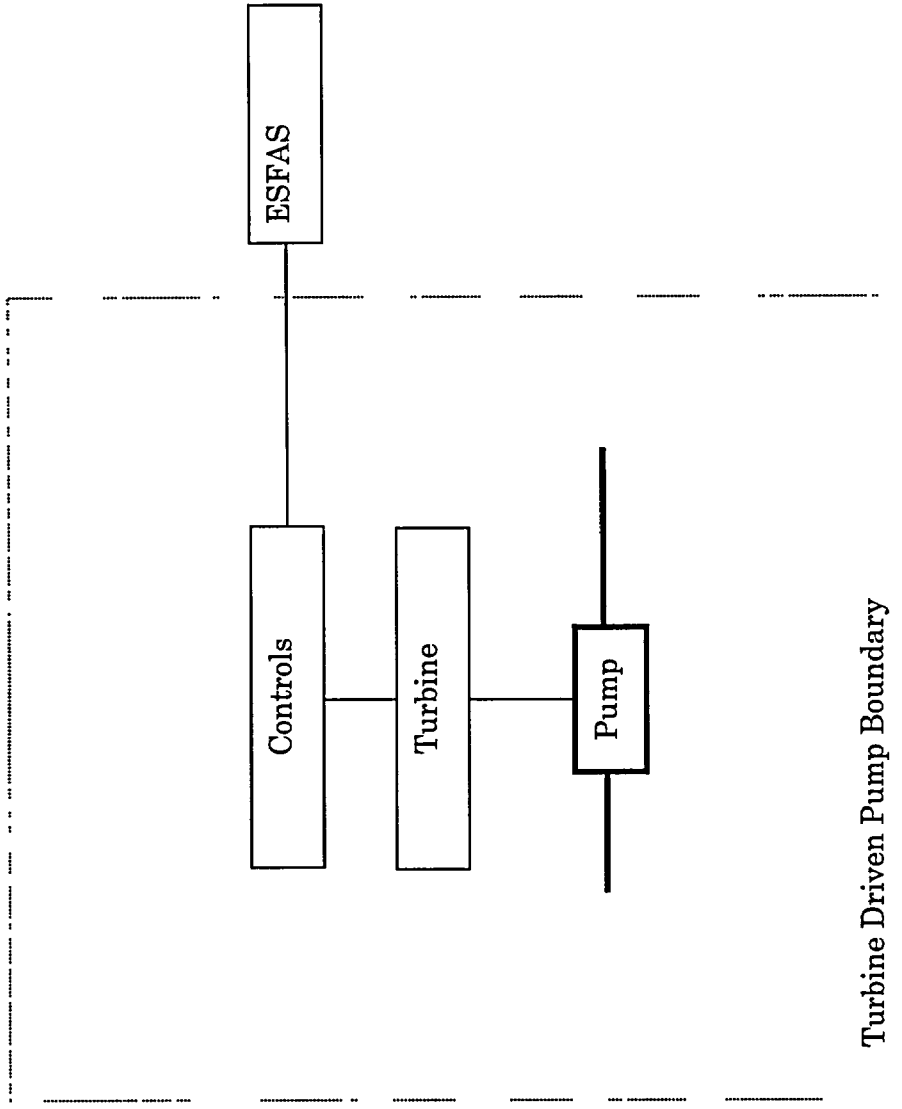
5



MOV Boundary

Figure F-3

1



2

3

Figure F-4

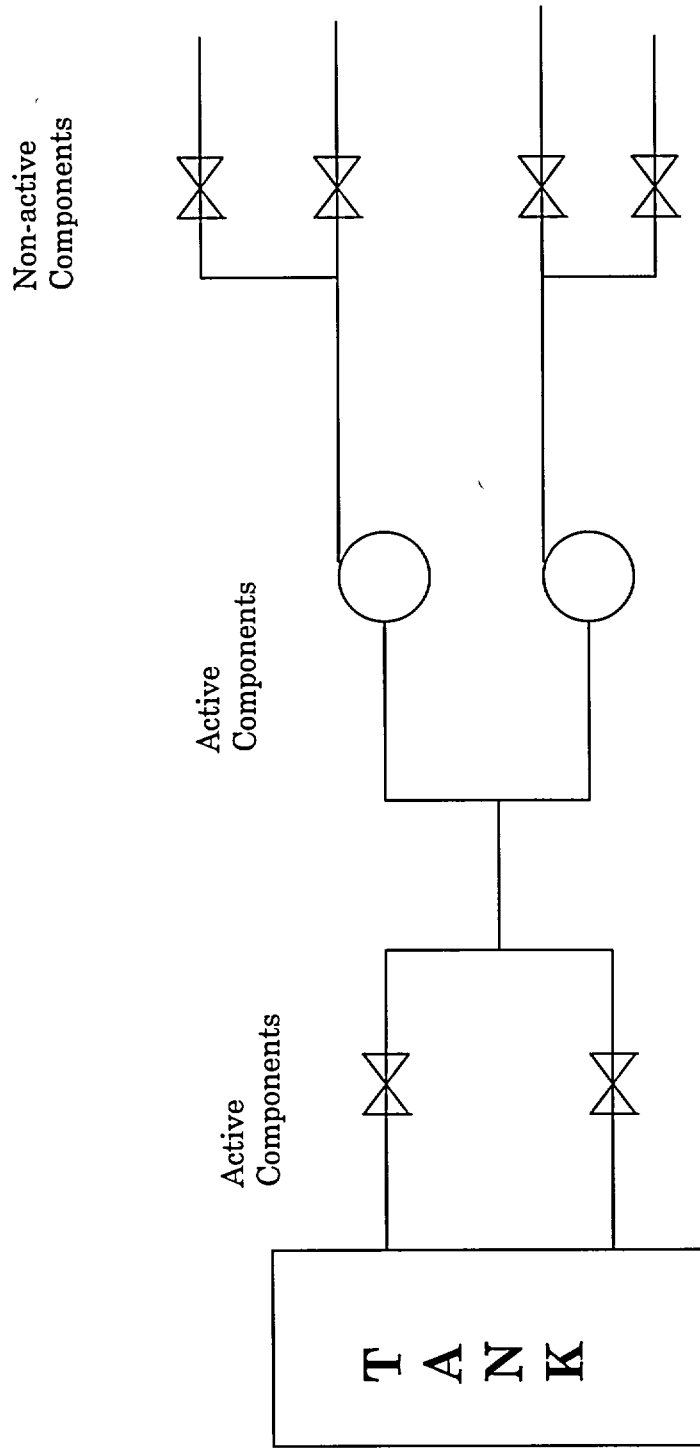


Figure F-5

Draft NEI 99-02, Rev. 0, Appendix F, "Methodologies For Computing the Unavailability Index, the Unreliability Index and Determining Performance Index Validity"

APPENDIX F

METHODOLOGIES FOR COMPUTING THE UNAVAILABILITY INDEX, THE UNRELIABILITY INDEX AND DETERMINING PERFORMANCE INDEX VALIDITY

This appendix provides the details of three calculations, calculation of the System Unavailability Index, the System Unreliability Index, and the criteria for determining when the Mitigating System Performance Index is unsuitable for use as a performance index.

System Unavailability Index (UAI) Due to Changes in Train Unavailability

Calculation of System UAI due to changes in train unavailability is as follows:

$$UAI = \sum_{j=1}^n UAI_{tj} \tag{Eq. 1}$$

where the summation is over the number of trains (*n*) and *UAI_t* is the unavailability index for a train.

Calculation of *UAI_t* for each train due to changes in train unavailability is as follows:

$$UAI_t = CDF_p \left[\frac{FV_{UAp}}{UA_p} \right]_{\max} (UA_t - UA_{BLt}), \tag{Eq. 2}$$

where:

CDF_p is the plant-specific, internal events, at power Core Damage Frequency,

FV_{UAp} is the train-specific Fussell-Vesely value for unavailability,

UA_p is the plant-specific PRA value of unavailability for the train,

UA_t is the actual unavailability of train *t*, defined as:

$$UA_t = \frac{\text{Unavailable hours during the previous 12 quarters while critical}}{\text{Critical hours during the previous 12 quarters}}$$

and,

UA_{BLt} is the historical baseline unavailability value for the train determined as described below.

UA_{BLt} is the sum of two elements: planned and unplanned unavailability. Planned unavailability is the actual, plant-specific three-year total planned unavailability for the train for the years 1999 through 2001 (see clarifying notes for details). This period is chosen as the most representative of how the plant intends to perform routine maintenance and surveillances at power. Unplanned unavailability is the historical industry average for unplanned unavailability for

1 the years 1999 through 2001. See Table 1 for historical train values for
 2 unplanned unavailability.

3 Calculation of the quantity inside the square bracket in equation 2 will be discussed at the
 4 end of the next section. See clarifying notes for calculation of UAI for cooling water
 5 support system.

6

7 **System Unreliability Index (URI) Due to Changes in Component Unreliability**

8 Unreliability is monitored at the component level and calculated at the system level.

9 Calculation of system URI due to changes in component unreliability is as follows:

10
$$URI = CDF_p \sum_{j=1}^m \left[\frac{FV_{URcj}}{UR_{pcj}} \right]_{\max} (UR_{Bcj} - UR_{BLcj}) \quad \text{Eq. 3}$$

11 Where the summation is over the number of active components (m) in the system, and:

12 CDF_p is the plant-specific internal events, at power, core damage frequency,

13 FV_{URc} is the component-specific Fussell-Vesely value for unreliability,

14 UR_{pc} is the plant-specific PRA value of component unreliability,

15 UR_{Bc} is the Bayesian corrected component unreliability for the previous 12
 16 quarters,

17 and

18 UR_{BLc} is the historical industry baseline calculated from unreliability mean values
 19 for each monitored component in the system. The calculation is performed in a
 20 manner similar to equation 4 below using the industry average values in Table 2.

21 Calculation of the quantity inside the square bracket in equation 3 will be discussed at the
 22 end of this section.

23 Component unreliability is calculated as follows.

24
$$UR_{Bc} = P_D + \lambda T_m \quad \text{Eq 4}$$

25 where:

26 P_D is the component failure on demand probability calculated based on data
 27 collected during the previous 12 quarters,

28 λ is the component failure rate (per hour) for failure to run calculated based on
 29 data collected during the previous 12 quarters,

30 and

31 T_m is the risk-significant mission time for the component based on plant specific
 32 PRA model assumptions.

1 NOTE:

2 For valves only the P_D term applies

3 For pumps $P_D + \lambda T_m$ applies

4 For diesels $P_{D \text{ start}} + P_{D \text{ load run}} + \lambda T_m$ applies

5

6 The first term on the right side of equation 4 is calculated as follows.¹

7
$$P_D = \frac{(N_d + a)}{(a + b + D)} \quad \text{Eq. 5}$$

8 where:

9 N_d is the total number of failures on demand during the previous 12 quarters,

10 D is the total number of demands during the previous 12 quarters (actual ESF
11 demands plus estimated test and estimated operational/alignment demands. An
12 update to the estimated demands is required if a change to the basis for the
13 estimated demands results in a >25% change in the estimate),

14 and

15 a and b are parameters of the industry prior, derived from industry experience (see
16 Table 2).

17 In the calculation of equation 5 the numbers of demands and failures is the sum of all
18 demands and failures for similar components within each system. Do not sum across
19 units for a multi-unit plant. For example, for a plant with two trains of Emergency Diesel
20 Generators, the demands and failures for both trains would be added together for one
21 evaluation of P_D which would be used for both trains of EDGs.

22 In the second term on the right side of equation 4, λ is calculated as follows.

23
$$\lambda = \frac{(N_r + a)}{(T_r + b)} \quad \text{Eq. 6}$$

24 where:

25 N_r is the total number of failures to run during the previous 12 quarters,

26 T_r is the total number of run hours during the previous 12 quarters (actual ESF run
27 hours plus estimated test and estimated operational/alignment run hours. An
28 update to the estimated run hours is required if a change to the basis for the
29 estimated hours results in a >25% change in the estimate).

30 and

¹ Atwood, Corwin L., Constrained noninformative priors in risk assessment, *Reliability Engineering and System Safety*, 53 (1996; 37-46)

1 a and b are parameters of the industry prior, derived from industry experience (see
2 Table 2).

3 In the calculation of equation 6 the numbers of demands and run hours is the sum of all
4 run hours and failures for similar components within each system. Do not sum across
5 units for a multi-unit plant. For example, a plant with two trains of Emergency Diesel
6 Generators, the run hours and failures for both trains would be added together for one
7 evaluation of λ which would be used for both trains of EDGs.

8 Fussell-Vesely, Unavailability and Unreliability

9 Equations 2 and 3 include a term that is the ratio of a Fussell-Vesely importance value
10 divided by the related unreliability or unavailability. Calculation of these quantities is
11 generally complex, but in the specific application used here, can be greatly simplified.

12 The simplifying feature of this application is that only those components (or the
13 associated basic events) that can fail a train are included in the performance index.
14 Components within a train that can each fail the train are logically equivalent and the
15 ratio FV/UR is a constant value for any basic event in that train. It can also be shown that
16 for a given component or train represented by multiple basic events, the ratio of the two
17 values for the component or train is equal to the ratio of values for any basic event within
18 the train. Or:

19
$$\frac{FV_{be}}{UR_{be}} = \frac{FV_{URc}}{UR_{Pc}} = \frac{FV_t}{UR_t} = \text{Constant}$$

20 and

21
$$\frac{FV_{be}}{UA_{be}} = \frac{FV_{UAp}}{UA_p} = \text{Constant}$$

22 Note that the constant value may be different for the unreliability ratio and the
23 unavailability ratio because the two types of events are frequently not logically
24 equivalent. For example recovery actions may be modeled in the PRA for one but not the
25 other.

26 Thus, the process for determining the value of this ratio for any component or train is to
27 identify a basic event that fails the component or train, determine the failure probability
28 or unavailability for the event, determine the associated FV value for the event and then
29 calculate the ratio. Use the basic event in the component or train with the largest failure
30 probability (hence the maximum notation on the bracket) to minimize the effects of
31 truncation on the calculation. Exclude common cause events, which are not within the
32 scope of this performance index

33 Some systems have multiple modes of operation, such as PWR HPSI systems that operate
34 in injection as well as recirculation modes. In these systems all active components are not
35 logically equivalent, unavailability of the pump fails all operating modes while
36 unavailability of the sump suction valves only fails the recirculation mode. In cases such

1 as these, if unavailability events exist separately for the components within a train, the
 2 appropriate ratio to use is the maximum.

3 **Determination of systems for which the performance index is not valid**

4 The performance index relies on the existing testing programs as the source of the data
 5 that is input to the calculations. Thus, the number of demands in the monitoring period is
 6 based on the frequency of testing required by the current test programs. In most cases this
 7 will provide a sufficient number of demands to result in a valid statistical result.

8 However, in some cases, the number of demands will be insufficient to resolve the
 9 change in the performance index (1.0×10^{-6}) that corresponds to movement from a green
 10 performance to a white performance level. In these cases, one failure is the difference
 11 between baseline performance and performance in the white performance band. The
 12 performance index is not suitable for monitoring such systems and monitoring is
 13 performed through the inspection process.

14 This section will define the method to be used to identify systems for which the
 15 performance index is not valid, and will not be used.

16 The criteria to be used to identify an invalid performance index is:

17 If, for any failure mode for any component in a system, the risk increase
 18 (Δ CDF) associated with the change in unreliability resulting from single
 19 failure is larger than 1.0×10^{-6} , then the performance index will be
 20 considered invalid for that system.

21 The increase in risk associated with a component failure is the sum of the contribution
 22 from the decrease in calculated reliability as a result of the failure and the decrease in
 23 availability resulting from the time required to affect the repair of the failed component.
 24 The change in CDF that results from a demand type failure is given by:

25

$$\begin{aligned}
 MSPI = CDF_p \times \sum_{N \text{ similar comp}} \left\{ \frac{FV_{URc}}{UR_{pc}} \times \frac{1}{a + b + D} \right\} \\
 + CDF_p \times \frac{FV_{UAp}}{UA_p} \times \frac{T_{Mean \text{ Repair}}}{T_{CR}}
 \end{aligned}
 \tag{Eq. 7}$$

27

28 Likewise, the change in CDF per run type failure is given by:

29

$$\begin{aligned}
 MSPI = CDF_p \times \sum_{N \text{ similar comp}} \left\{ \frac{FV_{URc}}{UR_{pc}} \times \frac{T_m}{b + T_r} \right\} \\
 + CDF_p \times \frac{FV_{UAp}}{UA_p} \times \frac{T_{Mean \text{ Repair}}}{T_{CR}}
 \end{aligned}
 \tag{Eq. 8}$$

30

1 In these expressions, the variables are as defined earlier and additionally

2 T_{MR} is the mean time to repair for the component

3 and

4 T_{CR} is the number of critical hours in the monitoring period.

5 The summation in the equations is taken over all similar components within a system.
6 With multiple components of a given type in one system, the impact of the failure on
7 CDF is included in the increased unavailability of all components of that type due to
8 pooling the demand and failure data.

9 The mean time to repair can be estimate as one-half the Technical Specification Allowed
10 Outage Time for the component and the number of critical hours should correspond to the
11 1999 – 2001 actual number of critical hours.

12 These equations are be used for all failure modes for each component in a system. If the
13 resulting value of ΔCDF is greater than 1.0×10^{-6} for any failure mode of any component,
14 then the performance index for that system is not considered valid.

15

16 **Definitions**

17

18 *Train Unavailability:* Train unavailability is the ratio of the hours the train was
19 unavailable to perform its risk-significant functions due to planned or unplanned
20 maintenance or test during the previous 12 quarters while critical to the number of critical
21 hours during the previous 12 quarters. (Fault exposure hours are not included;
22 unavailable hours are counted only for the time required to recover the train's risk-
23 significant functions.)

24 *Train unavailable hours:* The hours the train was not able to perform its risk significant
25 function due to maintenance, testing, equipment modification, electively removed from
26 service, corrective maintenance, or the elapsed time between the discovery and the
27 restoration to service of an equipment failure or human error that makes the train
28 unavailable (such as a misalignment) while the reactor is critical.

29 *Fussell-Vesely (FV) Importance:*

30 The Fussell-Vesely importance for a feature (component, sub-system, train, etc.) of a
31 system is representative of the fractional contribution that feature makes to the to the total
32 risk of the system.

33 The Fussell-Vesely importance of a basic event or group of basic events that represent a
34 feature of a system is represented by:

35
$$FV = 1 - \frac{R_i}{R_0}$$

1 Where:

2 R_0 is the base (reference) case overall model risk,

3 R_i is the decreased risk level with feature i completely reliable.

4 In this expression, the second term on the right represents the fraction of the reference
5 risk remaining assuming the feature of interest is perfect. Thus 1 minus the second term is
6 the fraction of the reference risk attributed to the feature of interest.

7 The Fussell-Vesely importance is calculated according to the following equation:

8
$$FV = 1 - \frac{\bigcup_{j=1,n} C_{i j}}{\bigcup_{j=1,m} C_{0 j}},$$

9 where the denominator represents the union of \underline{m} minimal cutsets C_0 generated with the
10 reference (baseline) model, and the numerator represents the union of \underline{n} minimal cutsets
11 C_i generated assuming events related to the feature are perfectly reliable, or their failure
12 probability is False.

13 *Critical hours:* The number of hours the reactor was critical during a specified period of
14 time.

15 *Component Unreliability:* Component unreliability is the probability that the component
16 would not perform its risk-significant functions when called upon during the previous 12
17 quarters.

18 *Active Component:* A component whose failure to change state renders the train incapable
19 of performing its risk-significant functions. In addition, all pumps and diesels in the
20 monitored systems are included as active components. (See clarifying notes.)

21 *Manual Valve:* A valve that can only be operated by a person. An MOV or AOV that is
22 remotely operated by a person may be an active component.

23 *Start demand:* Any demand for the component to successfully start to perform its risk-
24 significant functions, actual or test. (Exclude post maintenance tests, unless in case of a
25 failure the cause of failure was independent of the maintenance performed.)

26 *Post maintenance tests:* Tests performed following maintenance but prior to declaring the
27 train/component operable, consistent with Maintenance Rule implementation.

28 *Run demand:* Any demand for the component, given that it has successfully started, to
29 run/operate for its mission time to perform its risk-significant functions. (Exclude post
30 maintenance tests, unless in case of a failure the cause of failure was independent of the
31 maintenance performed.)

32 *EDG failure to start:* A failure to start includes those failures up to the point the EDG has
33 achieved rated speed and voltage. (Exclude post maintenance tests, unless the cause of
34 failure was independent of the maintenance performed.)

1 *EDG failure to load/run:* Given that it has successfully started, a failure of the EDG
2 output breaker to close, loads successfully sequence and to run/operate for one hour to
3 perform its risk-significant functions. This failure mode is treated as a demand failure for
4 calculation purposes. (Exclude post maintenance tests, unless the cause of failure was
5 independent of the maintenance performed.)

6 *EDG failure to run:* Given that it has successfully started and loaded and run for an hour,
7 a failure of an EDG to run/operate. (Exclude post maintenance tests, unless the cause of
8 failure was independent of the maintenance performed.)

9 *Pump failure on demand:* A failure to start and run for at least one hour is counted as
10 failure on demand. (Exclude post maintenance tests, unless the cause of failure was
11 independent of the maintenance performed.)

12 *Pump failure to run:* Given that it has successfully started and run for an hour, a failure of
13 a pump to run/operate. (Exclude post maintenance tests, unless the cause of failure was
14 independent of the maintenance performed.)

15 *Valve failure on demand:* A failure to open or close is counted as failure on demand.
16 (Exclude post maintenance tests, unless the cause of failure was independent of the
17 maintenance performed.)

18 **Clarifying Notes**

19 Train Boundaries and Unavailable Hours

20 Include all components that are required to satisfy the risk-significant function of the
21 train. For example, high-pressure injection may have both an injection mode with
22 suction from the refueling water storage tank and a recirculation mode with suction from
23 the containment sump. Some components may be included in the scope of more than one
24 train. For example, one set of flow regulating valves and isolation valves in a three-pump,
25 two-steam generator system are included in the motor-driven pump train with which they
26 are electrically associated, but they are also included (along with the redundant set of
27 valves) in the turbine-driven pump train. In these instances, the effects of unavailability
28 of the valves should be reported in both affected trains. Similarly, when two trains
29 provide flow to a common header, the effect of isolation or flow regulating valve failures
30 in paths connected to the header should be considered in both trains

31 Cooling Water Support System Trains

32 The number of trains in the Cooling Water Support System will vary considerably from
33 plant to plant. The way these functions are modeled in the plant-specific PRA will
34 determine a logical approach for train determination. For example, if the PRA modeled
35 separate pump and line segments, then the number of pumps and line segments would be
36 the number of trains. A separate value for UAI and URI will be calculated for each of the
37 systems in this indicator and then they will be added together to calculate the MSPI.

1

2 Active Components

3 For unreliability, use the following criteria for determining those components that should
4 be monitored:

- 5 • Components that are normally running or have to change state to achieve the risk
6 significant function will be included in the performance index. Active failures of
7 check valves and manual valves are excluded from the performance index and will be
8 evaluated in the NRC inspection program.
- 9 • Redundant valves within a train are not included in the performance index. Only
10 those valves whose failure alone can fail a train will be included. The PRA success
11 criteria are to be used to identify these valves.
- 12 • Redundant valves within a multi-train system, whether in series or parallel, where the
13 failure of both valves would prevent all trains in the system from performing a risk-
14 significant function are included. (See Figure F-5)
- 15 • All pumps and diesels are included in the performance index

16 Table 3 defines the boundaries of components, and Figures F-1, F-2, F-3 and F-4 provide
17 examples of typical component boundaries as described in Table 3. Each plant will
18 determine their system boundaries, active components, and support components, and
19 have them available for NRC inspection.

20 Failures of Non-Active Components

21 Failures of SSC's that are not included in the performance index will not be counted as a
22 failure or a demand. Failures of SSC's that cause an SSC within the scope of the
23 performance index to fail will not be counted as a failure or demand. An example could
24 be a manual suction isolation valve left closed which causes a pump to fail. This would
25 not be counted as a failure of the pump. Any mispositioning of the valve that caused the
26 train to be unavailable would be counted as unavailability from the time of discovery.
27 The significance of the mispositioned valve prior to discovery would be addressed
28 through the inspection process.

29

30 Baseline Values

31 The baseline values for unreliability are contained in Table 2 and remain fixed.

32 The baseline values for unavailability include both plant-specific planned unavailability
33 values and unplanned unavailability values. The unplanned unavailability values are
34 contained in Table 1 and remain fixed. They are based on ROP PI industry data from
35 1999 through 2001. (Most baseline data used in PIs come from the 1995-1997 time
36 period. However, in this case, the 1999-2001 ROP data are preferable, because the ROP
37 data breaks out systems separately (some of the industry 1995-1997 INPO data combine

1 systems, such as HPCI and RCIC, and do not include PWR RHR). It is important to note
2 that the data for the two periods is very similar.)

3 Support cooling baseline data is based on plant specific maintenance rule unavailability
4 for years 1999 to 2001. (Maintenance rule data does not distinguish between planned and
5 unplanned unavailability. There is no ROP support cooling data.)

6 The baseline planned unavailability is based on actual plant-specific values for the period
7 1999 through 2001. These values are expected to remain fixed unless the plant
8 maintenance philosophy is substantially changed with respect to on-line maintenance or
9 preventive maintenance. In these cases, the planned unavailability baseline value can be
10 adjusted. A comment should be placed in the comment field of the quarterly report to
11 identify a substantial change in planned unavailability. To determine the planned
12 unavailability:

- 13 1. Record the total train unavailable hours reported under the Reactor Oversight Process
14 for 1999 through 2001.
- 15 2. Subtract any fault exposure hours still included in the 1999-2001 period.
- 16 3. Subtract unplanned unavailable hours
- 17 4. Add any on-line overhaul hours and any other planned unavailability excluded in
18 accordance with NEI 99-02.²
- 19 5. Add any planned unavailable hours for functions monitored under MSPI which were
20 not monitored under SSU in NEI 99-02.
- 21 6. Subtract any unavailable hours reported when the reactor was not critical.
- 22 7. Subtract hours cascaded onto monitored systems by support systems.
- 23 8. Divide the hours derived from steps 1-6 above by the total critical hours during 1999-
24 2001. This is the baseline planned unavailability

25 Baseline unavailability is the sum of planned unavailability from step 7 and unplanned
26 unavailability from Table 1.

27

² Note: The plant-specific PRA should model significant on-line overhaul hours.

1 **Table 1. Historical Unplanned Maintenance Unavailability Train Values**
 2 **(Based on ROP Industrywide Data for 1999 through 2001)**
 3
 4

SYSTEM	UNPLANNED UNAVAILABILITY/TRAIN
EAC	1.7 E-03
PWR HPSI	6.1 E-04
PWR AFW (TD)	9.1 E-04
PWR AFW (MD)	6.9 E-04
PWR AFW (DieselD)	7.6 E-04
PWR (except CE) RHR	4.2 E-04
CE RHR	1.1 E-03
BWR HPCI	3.3 E-03
BWR HPCS	5.4 E-04
BWR RCIC	2.9 E-03
BWR RHR	1.2 E-03
Support Cooling	Use plant specific Maintenance Rule data for 1999-2001

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2
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Table 2. Industry Priors and Parameters for Unreliability

Component	Failure Mode	a^a	b^a	Industry Mean Value^b	Source(s)
Motor-operated valve	Fail to open (or close)	5.0E-1	2.4E+2	2.1E-3	NUREG/CR-5500, Vol. 4,7,8,9
Air-operated valve	Fail to open (or close)	5.0E-1	2.5E+2	2.0E-3	NUREG/CR-4550, Vol. 1
Motor-driven pump, standby	Fail to start	5.0E-1	2.4E+2	2.1E-3	NUREG/CR-5500, Vol. 1,8,9
	Fail to run	5.0E-1	5.0E+3h	1.0E-4/h	NUREG/CR-5500, Vol. 1,8,9
Motor-driven pump, running or alternating	Fail to start	4.9E-1	1.6E+2	3.0E-3	NUREG/CR-4550, Vol. 1
	Fail to run	5.0E-1	1.7E+4h	3.0E-5/h	NUREG/CR-4550, Vol. 1
Turbine-driven pump, AFWS	Fail to start	4.7E-1	2.4E+1	1.9E-2	NUREG/CR-5500, Vol. 1
	Fail to run	5.0E-1	3.1E+2	1.6E-3/h	NUREG/CR-5500, Vol. 1
Turbine-driven pump, HPCI or RCIC	Fail to start	4.6E-1	1.7E+1	2.7E-2	NUREG/CR-5500, Vol. 4,7
	Fail to run	5.0E-1	3.1E+2h	1.6E-3/h	NUREG/CR-5500, Vol. 1,4,7
Diesel-driven pump, AFWS	Fail to start	4.7E-1	2.4E+1	1.9E-2	NUREG/CR-5500, Vol. 1
	Fail to run	5.0E-1	6.3E+2h	8.0E-4/h	NUREG/CR-4550, Vol. 1
Emergency diesel generator	Fail to start	4.8E-1	4.3E+1	1.1E-2	NUREG/CR-5500, Vol. 5
	Fail to load/run	5.0E-1	2.9E+2	1.7E-3 ^c	NUREG/CR-5500, Vol. 5
	Fail to run	5.0E-1	2.2E+3h	2.3E-4/h	NUREG/CR-5500, Vol. 5

4

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1 a. A constrained, non-informative prior is assumed. For failure to run events, $a = 0.5$ and
2 $b = (a)/(\text{mean rate})$. For failure upon demand events, a is a function of the mean
3 probability:

4

5	<u>Mean Probability</u>	<u>a</u>
6	0.0 to 0.0025	0.50
7	>0.0025 to 0.010	0.49
8	>0.010 to 0.016	0.48
9	>0.016 to 0.023	0.47
10	>0.023 to 0.027	0.46

11

12 Then $b = (a)(1.0 - \text{mean probability})/(\text{mean probability})$.

13

14 b. Failure to run events occurring within the first hour of operation are included within
15 the fail to start failure mode. Failure to run events occurring after the first hour of
16 operation are included within the fail to run failure mode. Unless otherwise noted, the
17 mean failure probabilities and rates include the probability of non-recovery. Types of
18 allowable recovery are outlined in the clarifying notes, under "Credit for Recovery
19 Actions."

20

21 c. Fail to load and run for one hour was calculated from the failure to run data in the
22 report indicated. The failure rate for 0.0 to 0.5 hour ($3.3E-3/h$) multiplied by 0.5 hour,
23 was added to the failure rate for 0.5 to 14 hours ($2.3E-4/h$) multiplied by 0.5 hour.

Table 3. Component Boundary Definition

Component	Component boundary
Diesel Generators	The diesel generator boundary includes the generator body, generator actuator, lubrication system (local), fuel system (local), cooling components (local), startup air system receiver, exhaust and combustion air system, dedicated diesel battery (which is not part of the normal DC distribution system), individual diesel generator control system, circuit breaker for supply to safeguard buses and their associated local control circuit (coil, auxiliary contacts, wiring and control circuit contacts, and breaker closure interlocks) .
Motor-Driven Pumps	The pump boundary includes the pump body, motor/actuator, lubrication system cooling components of the pump seals, the voltage supply breaker, and its associated local control circuit (coil, auxiliary contacts, wiring and control circuit contacts).
Turbine-Driven Pumps	The turbine-driven pump boundary includes the pump body, turbine/actuator, lubrication system (including pump), extractions, turbo-pump seal, cooling components, and local turbine control system (speed).
Motor-Operated Valves	The valve boundary includes the valve body, motor/actuator, the voltage supply breaker (both motive and control power) and its associated local open/close circuit (open/close switches, auxiliary and switch contacts, and wiring and switch energization contacts).
Air-Operated Valves	The valve boundary includes the valve body, the air operator, associated solenoid-operated valve, the power supply breaker or fuse for the solenoid valve, and its associated control circuit (open/close switches and local auxiliary and switch contacts).

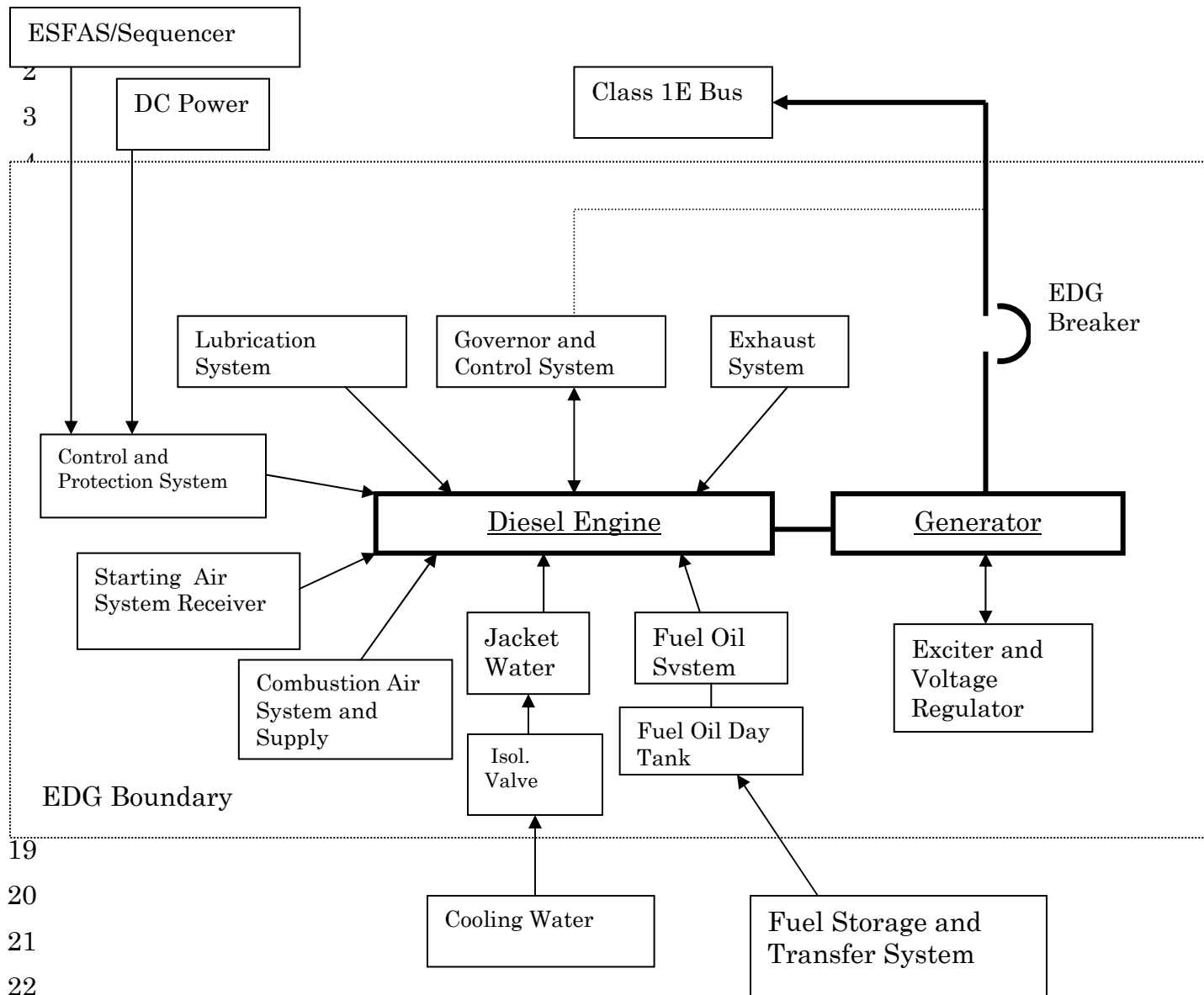
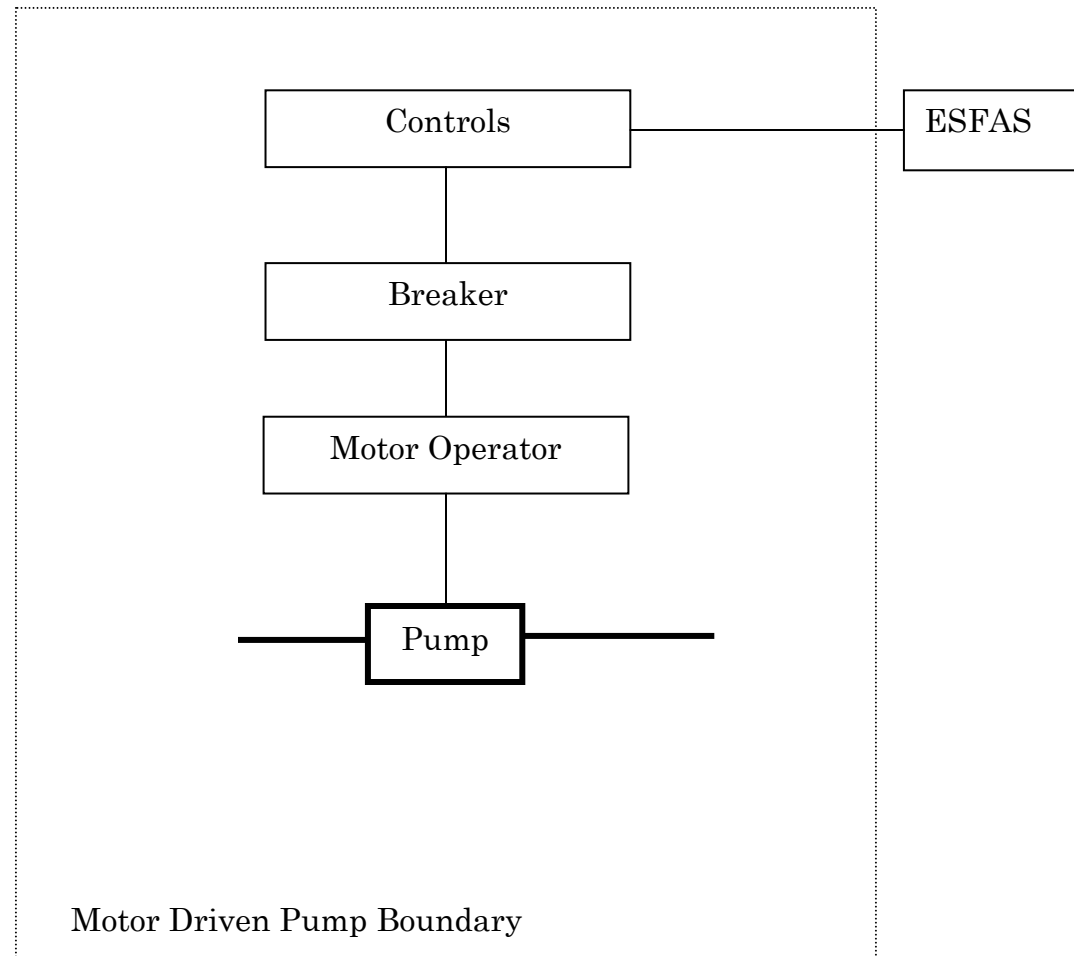


Figure F-1

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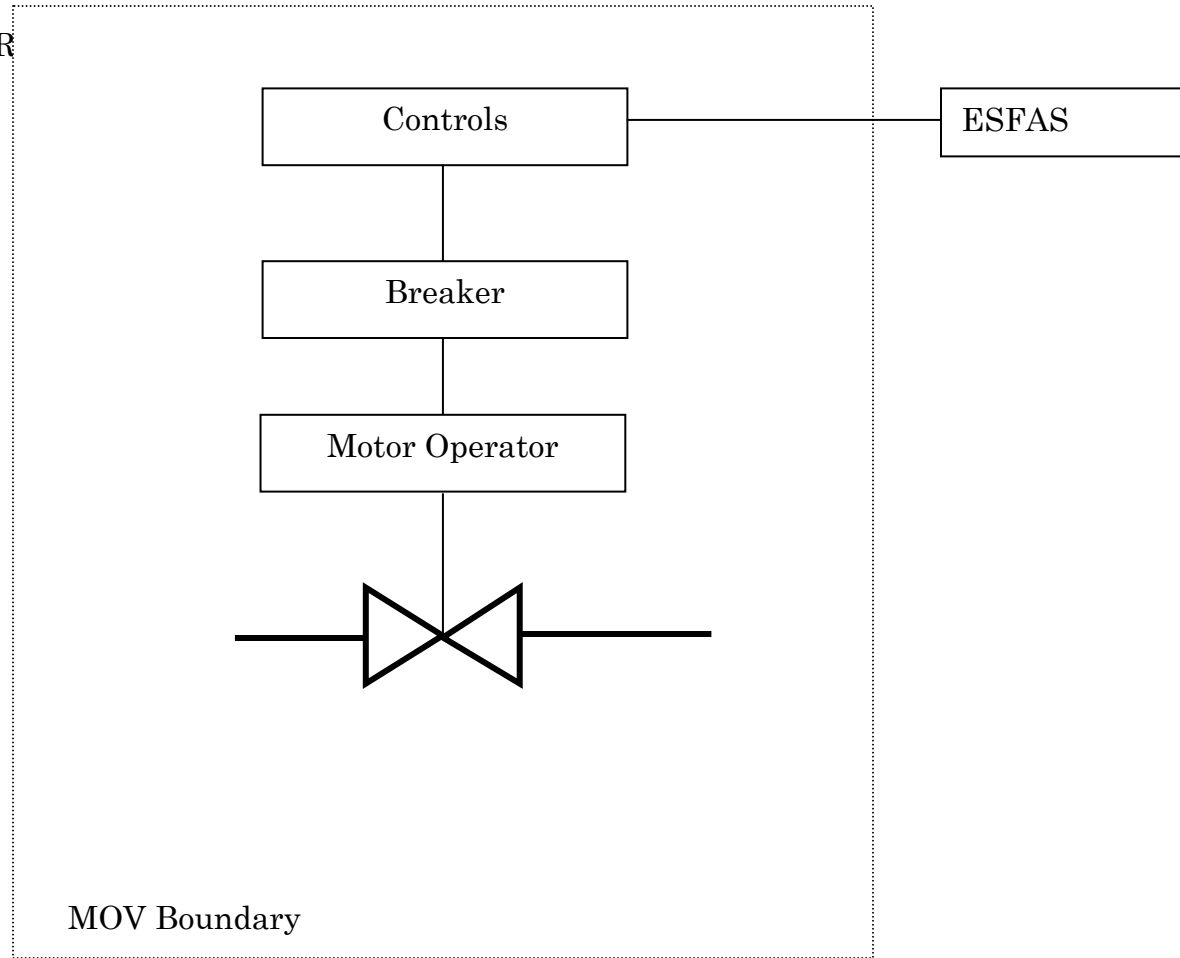
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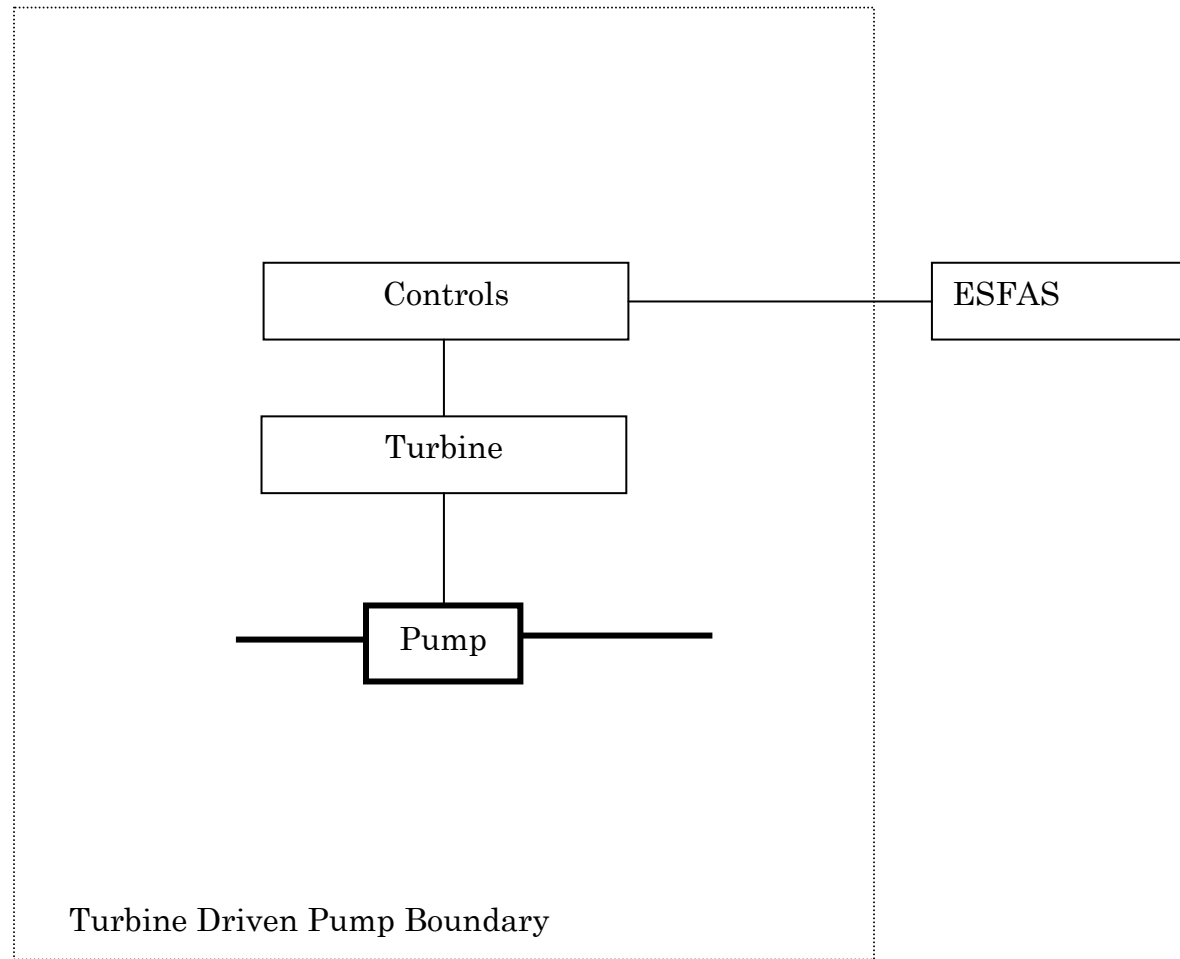
Figure F-2



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Figure F-3

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Figure F-4

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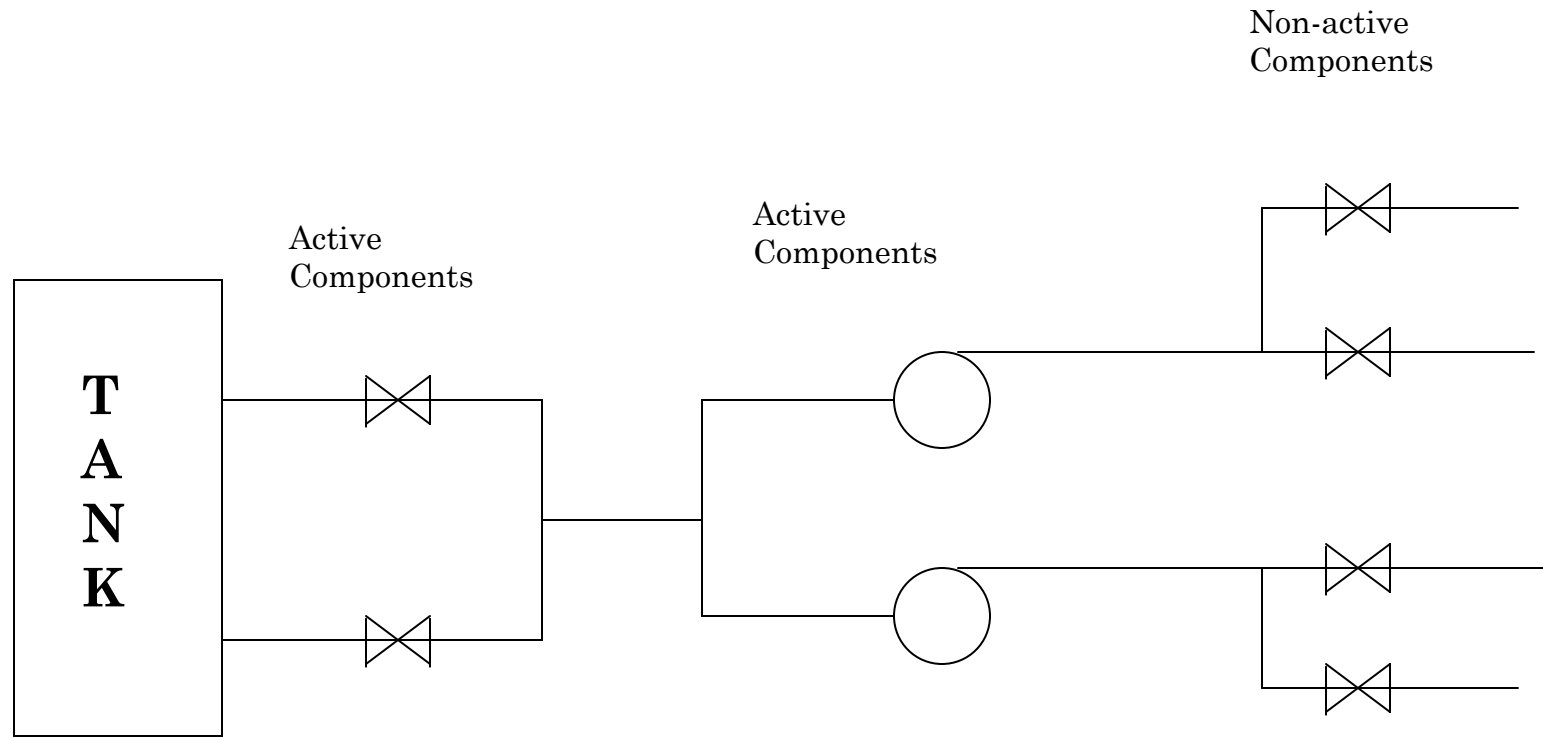


Figure F-5

Mitigating System Performance Index Pilot Program Success Criteria

The Mitigating System Performance Index (MSPI) success criteria listed below will be met if there is general agreement among internal and external stakeholders that the criteria have been met.

- a. The occurrence of a single failure of an MSPI monitored component by itself, absent any other failures or unavailabilities, should rarely exceed the green/white MSPI threshold as measured from the baseline value. The term "rare" is defined as minimizing the inconsistencies across plants, within plants, and within systems such that there is no undue burden on resources, and the objective of having consistent publicly displayed results can be achieved.
- b. False positive and false negative rates can be established for the chosen statistical method, and instances where the MSPI cannot meet the criteria are rare.
- c. Instances where the results from the MSPI calculational methodology are not consistent with the SPAR-3 models are rare and the differences are explainable.
- d. The MSPI pilot plant participants can identify and compile the risk significant functions for the monitored systems in a readily inspectable format and can compile a set of predetermined success criteria for those risk significant functions.
- e. The active components in the monitored systems are appropriate for inclusion in the MSPI and are a manageable number of components under the MSPI.
- f. By the end of the pilot, MSPI data can be accurately reported and quality checked.
- g. By the end of the pilot program, inspection procedures and MSPI pilot guidelines are sufficiently detailed to minimize MSPI Questions and NRC feedback forms.
- h. MSPI Questions and NRC feedback do not reveal any unresolvable issues.
- i. Data collection inconsistencies between the maintenance rule and the MSPI can be reconciled in order to eliminate or significantly reduce separate reporting.
- j. Differences between the linear approximation models generated by licensee probabilistic risk assessments and those generated by the NRC SPAR-3 models can be reconciled.
- k. The MSPI produces no new unintended consequences that cannot be resolved.

Upon the successful meeting of the success criteria, with a determination that the MSPI pilot is a valid and appropriate means of measuring risk for the monitored systems, the MSPI will suffice as the measure of assessment and not the significance determination process for single failures of the active components within the scope of the MSPI. Any significant problems will be resolved before full MSPI implementation.