ArevaEPRDCPEm Resource

From: WELLS Russell D (AREVA NP INC) [Russell.Wells@areva.com]
Sent: Monday, October 26, 2009 4:36 PM
To: Tesfaye, Getachew
Cc: Pederson Ronda M (AREVA NP INC); BENNETT Kathy A (OFR) (AREVA NP INC); DELANO Karen V (AREVA NP INC)
Subject: Response to U.S. EPR Design Certification Application RAI No. 238, FSAR Ch 10, Supplement 1
Attachments: RAI 238 Supplement 1 Response US EPR DC.pdf

Getachew,

AREVA NP Inc. provided a response to the one question of RAI No. 238 on July 8, 2009. Subsequent to submitting this response, the NRC technical staff requested that AREVA NP revise this response to support finalizing the Safety Evaluation Report for the U.S. EPR Final Safety Analysis Report Chapter 10. AREVA NP provided DRAFT marked-up pages from FSAR Section 10.4.9 on September 23, 2009, which capture pertinent information from our response.

The attached file, "RAI 238 Supplement 1 Response US EPR DC.pdf" provides a technically correct and complete response to this question, as committed.

Appended to this file are affected pages of the U.S. EPR Final Safety Analysis Report in redline-strikeout format which support the response to RAI 238 Question 10.04.09-12.

The following table indicates the respective pages in the response document, "RAI 238 Supplement 1 Response US EPR DC.pdf," that contain AREVA NP's response to the subject question.

Question #	Start Page	End Page
RAI 238 — 10.04.09-12	2	11

This concludes the formal AREVA NP response to RAI 238, and there are no questions from this RAI for which AREVA NP has not provided responses.

Sincerely,

(Russ Wells on behalf of)
Ronda Pederson
ronda.pederson@areva.com
Licensing Manager, U.S. EPR Design Certification
New Plants Deployment
AREVA NP, Inc.
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3315 Old Forest Road
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From: Pederson Ronda M (AREVA NP INC)
Sent: Wednesday, September 23, 2009 7:57 PM
To: 'Tesfaye, Getachew'
Cc: HAMMOND Philip R (AREVA NP INC); KOWALSKI David J (AREVA NP INC)
Subject: DRAFT Response to U.S. EPR Design Certification Application RAI No. 238, FSARCh. 10, Supplement

Getachew,

NRC's technical staff requested that AREVA NP provide draft mark-ups for their review to support finalizing the Chapter 10 SE.

Attached are DRAFT marked-up pages from FSAR Section 10.4.9, including two inserts, to capture pertinent information from our response to RAI 238.

AREVA NP requests a conference call be arranged to receive NRC's feedback.
AREVA NP can support a telecon anytime on Tuesday or Wednesday, September 29 or 30.

Thank you,

Ronda Pederson
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From: Pederson Ronda M (AREVA NP INC)
Sent: Wednesday, July 08, 2009 6:31 PM
To: 'Getachew Tesfaye'
Cc: BENNETT Kathy A (OFR) (AREVA NP INC); DELANO Karen V (AREVA NP INC); KOWALSKI David J (AREVA NP INC)
Subject: Response to U.S. EPR Design Certification Application RAI No. 238, FSARCh. 10

Getachew,

Attached please find AREVA NP Inc.'s response to the subject request for additional information (RAI). The attached file, "RAI 238 Response US EPR DC.pdf" provides a technically correct and complete response to the question.

Appended to this file are affected pages of the U.S. EPR Final Safety Analysis Report in redline-strikeout format which support the response to RAI 238 Question 10.04.09-12.

The following table indicates the pages in the response document, "RAI 238 Response US EPR DC.pdf," that contain AREVA NP's response to the subject question.

Question #	Start Page	End Page
RAI 238 — 10.04.09-12	2	11

This concludes the formal AREVA NP response to RAI 238, and there are no questions from this RAI for which AREVA NP has not provided responses.

Sincerely,

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From: Getachew Tesfaye [mailto:Getachew.Tesfaye@nrc.gov]
Sent: Friday, June 05, 2009 5:51 PM
To: ZZ-DL-A-USEPR-DL
Cc: Angelo Stubbs; John Segala; Steven Bloom; Peter Hearn; Joseph Colaccino; ArevaEPRDCPEm Resource
Subject: U.S. EPR Design Certification Application RAI No. 238 (2881), FSARCh. 10

Attached please find the subject requests for additional information (RAI). A draft of the RAI was provided to you on May 21, 2009, and on May 28, 2009, you informed us that the RAI is clear and no further clarification is needed. As a result, no change is made to the draft RAI. The schedule we have established for review of your application assumes technically correct and complete responses within 30 days of receipt of RAIs. For any RAIs that cannot be answered within 30 days, it is expected that a date for receipt of this information will be provided to the staff within the 30 day period so that the staff can assess how this information will impact the published schedule.

Thanks,
Getachew Tesfaye
Sr. Project Manager
NRO/DNRL/NARP
(301) 415-3361

Hearing Identifier: AREVA_EPR_DC_RAIs
Email Number: 911

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Subject: Response to U.S. EPR Design Certification Application RAI No. 238, FSAR Ch 10, Supplement 1
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From: WELLS Russell D (AREVA NP INC)

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Response to

Request for Additional Information No. 238, Supplement 1

6/05/2009

U. S. EPR Standard Design Certification
AREVA NP Inc.
Docket No. 52-020
SRP Section: 10.04.09 - Auxiliary Feedwater System (PWR)
Application Section: 10.4.9

QUESTIONS for Balance of Plant Branch 1 (AP1000/EPR Projects) (SBPA)

Question 10.04.09-12:

Follow Up to RAI 10.4.9–4

SRP 10.4.9, "Auxiliary Feedwater System (PWR)," states, in part, that the system design should conform to the guidance of BTP 10-1, "Design Guidelines for Auxiliary Feedwater System Pump Drive and Power Supply Diversity for Pressurized Water Reactor Plants", as it relates to auxiliary feedwater pump drive and power supply diversity. SRP 10.4.9 also indicates that diversity in pump motive power sources (e.g. electric motor-driven, steam driven, direct-drive diesel, etc), and essential instrumentation should be provided, and that the diverse system including pump(s), controls and valves should be independent of offsite and onsite AC power sources in accordance with BTP 10-1. In Section 10.4.9.3 of the FSAR the applicant indicates that the design of the emergency feedwater system (EFWS) is consistent with BTP 10-1, except that the power sources are redundant but not diverse. FSAR section 10.4.9.3 also states that incorporating non-electric EFWS pumps into the EPR plant design for diversity is not expected to significantly improve EFWS reliability and plant core damage frequency.

The staff previously issued RAI 10.4.9-4 requesting that Areva to provide additional information to demonstrate compliance of the EPR with BTP 10-1. In the response to question 10.04.09-4 (RAI 83), Areva provide information on diversity of the EFW power supply, but did not provide justification for the exception taken in the FSAR to the recommendation to have diversity in the EFW pump motive power source, nor did they provide information to support their conclusion that incorporating non-electric EFWS pumps into the EPR plant design for diversity will not significantly improve EFWS reliability and plant core damage frequency.

In addition to the SRP 10.4.9 and BTP 10-1 recommending that the that the diverse system including pump(s), controls and valves should be independent of offsite and onsite AC power sources, SRP 10.4.9 Section III, Item 3, states that the EFWS design should have features to meet the generic recommendations of NUREG-0611, "Generic Evaluation of Feedwater Transients and Small Break Loss-of-Coolant Accidents in Westinghouse-Designed Operating Plants," January 1980, and NUREG-0635, "Generic Evaluation of Feedwater Transients and Small Break Loss-of-Coolant Accident in Combustion Engineering – Designed Operating Plants," January 1980," Generic Long Term Recommendation No. 3 (GL-3) recommends that at least one EFW system pump and its associated flow path and essential instrumentation should automatically initiate AFW system flow and be capable of being operated independently of any AC power source for at least two hours. Also, Generic Short Term Recommendation No. 5 (GS-5) recommends that plants be capable of providing required EFW flow for at least two hours from one EFW pump train independent of any ac power. The EPR FSAR claims compliance with NUREG-0611 and NUREG-0635 without exception.

1. EFWS, designed using a defense-in-depth design philosophy generally provide diverse and independent means of delivering feedwater to the steam generators, with one of the means being independent of AC power availability. This arrangement allows for timely initiation and operation of the EFWS following a loss of all AC power. Recommendations related to this are contained in BTP 10-1, NUREG-0611 and NUREG-0635 (Recommendations GL-3, and GS-5).

    a) Provide the provisions for the diversity in pump motive power sources and essential instrumentation and control power sources in the EPR design.

b) The guidelines of BTP 10-1 recommend that the diverse system including pumps(s), controls and valves should be independent of offsite and onsite AC power sources, address this recommendation in the EPR design or demonstrate that the EPR design provides equivalent reliability to the BTP 10-1 guidelines..

c) Demonstrate that the EFWS design meets GS-5 and GL-3 listed in NUREG-0611 and NUREG-0635.

d) Explain the case of a lost of all AC power for the establishment of the EFWS flow to the steam generators in a timely manor. If automatic actuation of the EFWS is not assumed, describe required operator action needed to manually start the EFWS, and discuss the time required for the actions and the time required for the steam generator to dryout.

2. In response to Question 10.04.09-1 (RAI 83), the EFWS design was changed to maintain the supply header isolation valves normally closed. The response to Question 19-274 (RAI 197) showed an increase in overall core damage frequency (CDF) as a result of this design change, which indicates that the EFWS system reliability decreases. Provide a revision to Table 10.4.9-4 that reflects the new EFWS system reliability.

3. In Section 10.4.9.3 of the FSAR the applicant indicates that the design of the EFWS is consistent with BTP 10-1, except that the power sources are redundant but not diverse. FSAR section 10.4.9.3 also states that incorporating non-electric EFWS pumps into the EPR plant design for diversity is not expected to significantly improve EFWS reliability and plant core damage frequency. Discuss, with support from sensitivity studies as needed, the benefit in EFWS reliability that could be obtained if diverse EFWS pumps were included in the U.S. EPR design.

Describe the process for evaluating the risk reduction of proposed design changes and balancing them with operational considerations (e.g., increased maintenance). The staff observes that this design change appears not to have been evaluated as a PRA sensitivity study, as described in FSAR Table 19.1-15 and the response to Question 19-45 (RAI 2), although FSAR page 19.1-58 indicates that another design change resulting in a 7-percent CDF improvement may be considered in the future.

Response to Question 10.04.09-12:

This response supersedes in its entirety the Response to RAI 238, Question 10.04.09-12.

1.a) Question 1.a addresses two areas of diversity: (1) pump motive power sources, and (2) essential instrumentation and control (I&C) power sources. The U.S. EPR design includes diversity in power sources for essential I&C comprised of safety-related alternating current (AC) power, safety-related direct current (DC) power, and non-safety-related back-up power. The following discussion focuses on the diversity of pump motive power sources.

The U.S. EPR design complies with all regulatory requirements relevant to the emergency feedwater system (EFWS) and the alternate AC source of power, including GDC 34 related to EFWS redundancy; 10CFR 50.34(f)(1)(ii) related to EFWS reliability; and 10CFR50.63 related to station blackout (SBO) mitigation. With regards to the regulatory guidance in SRP 10.4.9 and BTP 10-1, this response demonstrates that the U.S. EPR design provides an appropriate level of safety and reliability without fully

implementing the prescriptive diversity recommendations given in the NRC guidance documents. This approach enhances plant safety and is consistent with the Commission's Policy Statement on the Regulation of Advanced Reactors [73 FR 60612; October 14, 2008].

SRP 10.4.9 Acceptance Criteria 5 calls for "system design conforming to the guidance of BTP 10-1 as it relates to AFW pump drive and power supply diversity." The Background Section of BTP 10-1 states:

> "The AFWS functions as an engineered safety system because it is the only source of makeup water to the steam generators (SG) for decay heat removal when the main feedwater system becomes inoperable. It must, therefore, be designed to operate when needed under the principles of redundancy and diversity so it can function under postulated accident conditions.
>
> Most current systems are powered by electrical or steam-driven sources. Operating experience demonstrates that each type of motive power can be subject to a failure of the driving component itself, its source of energy, or its control system. The effects of such failures can be minimized by diverse systems with energy sources of at least two different and distinct types."

The SRP does not provide a technical rationale for conformance to the BTP 10-1 guidance relative to AFW pump drive and power supply diversity. However, Attachment 2 of SECY 05-0138 provides the following explanation:

> "From lessons learned following the TMI accident, the requirements and guidance for AFW systems were enhanced beyond the SFC concept to ensure increased reliability and defense against common-mode failure. Section 10.4.9 of the SRP addresses these extensions. In addition to a system being able to perform its function assuming a single active failure, it must have diverse 'motive power sources' and must undergo a reliability analysis in accordance with the criteria in NUREG-0737 [USNRC, 1980]."

Based on the above, the rationale for the BTP 10-1 recommendation to have an EFWS train "powered wholly by steam and direct current electric power" was to minimize the effects of a common cause failure (CCF) on the EFWS. At that time (circa 1980), the guidance was published based on two basic premises:

1) CCFs are likely and can directly lead to core melt scenarios.
2) Quantitative methods to assess the effects of EFWS reliability on core melt probability are not well known.

Accordingly, the staff concluded that deterministically treating the CCFs of the EFWS pump drives would provide a reasonable surrogate to ensure plant safety. Since that time (early 1980s), significant advancements in equipment reliability and probabilistic risk assessment (PRA) methods have occurred that obviate the need to impose surrogate methods. CCFs are more appropriately addressed as part of a reliability analysis due to the many factors and dependencies involved.

Data from NUREG/CR-6819 shows that the occurrence of CCFs for the majority of EFWS and associated power supply active components (pumps, motor-operated valves (MOV), emergency diesel generators (EDG), and circuit breakers) has significantly decreased (approximately 85 percent on average) since the early 1980s when the BTP 10-1 guidance was issued. This decrease was attributed to increased maintenance focus and emphasis on equipment reliability from initiatives throughout the industry (NRC, utilities, INPO, and EPRI). The small percentage of CCFs analyzed in this NUREG that resulted in the loss of safety function is also of note.

Based on this decrease in the occurrence of CCFs of pumps, EDGs, MOVs, and circuit breakers and the efforts taken to address CCFs in controls systems, the likelihood of a CCF preventing the EFWS from performing its safety function has significantly decreased since the BTP 10-1 guidelines were issued. Also, the diversities provided between the alternate AC power supply and EDGs, the greater than two hour allowable time for EFW recovery, and feed and bleed capability decrease the possible effects of potential EFWS related CCFs.

Table 10.4.9-12-2 and Table 10.4.9-12-3 provide the results of the sensitivity cases of EFWS reliability and core damage frequency (CDF) risk for four motor-driven pumps compared to two turbine-driven and two motor-driven pumps. There is no significant increase in the reliability; however, the addition of turbine-driven pumps increases CDF risk.

A turbine-driven EFWS pump was not incorporated into the U.S. EPR design due to their lower reliability, the extra maintenance they require, and the high energy piping and ambient environment issues that would be introduced to the building(s) housing the pump/drive. The use of the four AC powered EFW trains, four EDGs, and alternate AC supply of power (consisting of the two SBO diesels) was selected based on years of experience with this equipment, higher reliability, compatibility with the plant design, and adequate diversity to address loss of normal AC power while decreasing the risk of CCFs. The alternate AC power supply diesels have the capability and quality requirements to support their use to address beyond design basis SBO and CCF events. Adding turbine-driven pump(s) to the U.S. EPR EFWS would require major mechanical, structural, electrical, I&C, and plant layout design changes. These changes are not warranted since (1) the U.S. EPR design complies with all regulatory requirements for EFWS, and (2) inclusion of turbine-driven EFWS pumps results in equivalent EFWS reliability, but results in an increase in plant CDF.

1.b) As discussed in Question 2 (below), Table 10.4.9-12-2 provides the results of the sensitivity cases analyzed that demonstrate that the reliability of the as-designed U.S. EPR EFWS is equivalent to the reliability if trains 1 and 4 were changed to turbine-driven pumps and DC controls. Also, as shown in Table 10.4.9-12-3, the addition of the turbine-driven pumps results in an increase in CDF.

1.c) In the unlikely event that the EFWS is unavailable due to a CCF, the large water inventory in the SGs provides approximately one and one-half hours before dry-out. The U.S. EPR EFWS design does not meet the guidelines of GS-5 and GL-3 listed in NUREG-0611 and NUREG-0635 to provide the capability of EFW flow for two hours without AC power. However, the U.S. EPR design includes the safety-related capability of removing decay heat by feed and bleed as described in U.S. EPR FSAR, Tier 2,

Sections 5.1.1, 7.8.1.2.16, and Section 19. Greater than two hours would be available for recovery of EFW capability prior to the need to initiate feed and bleed.

Equivalent protection is provided by the alternate AC source of power (two SBO diesels) which can provide EFWS trains 1 and 4 power at 30 minutes and support EFWS operation for greater than two hours. The response to Part 1.a provides a discussion supporting the acceptability of the U.S. EPR design.

1.d) A timeline of activities, including the manual actuation of the EFWS, following the loss of all AC power (SBO), is described in U.S. EPR FSAR, Tier 2, Section 8.4.6.2. Two EFW pumps are manually actuated and aligned to provide flow to all four SGs at 30 minutes. The SG levels will be at approximately 45 percent of wide range when the pumps are actuated. The large water inventory of the U.S EPR SGs provides approximately one and one-half hours to dry-out.

2. Table 10.4.9-12-1 provides the EFW reliability results comparing the supply cross connect valves, maintained normally opened to closed. The closure of EFW supply cross connect valves results in negligible changes in the EFW reliability due to various losses of MFW; however, this change significantly improves the EFW system performance for challenges presented by some internal hazards (internal flooding due to breaks in EFW piping) and external hazards (airplane crashes).

3. A sensitivity study was performed to evaluate the reliability and risk impact if a turbine-driven pump was incorporated into the U.S. EPR EFW design. The process employed was (a) to identify a conceptual design, (b) to construct a sensitivity model reflecting the conceptual design, and (c) to evaluate the change to EFW system reliability and to the U.S. EPR CDF. No attempt was made to estimate the increased maintenance workload that may be associated with maintaining turbine-driven pumps, nor was the risk impact of high-energy line break (associated with the steam lines to the turbine-driven pumps) evaluated. These could be additional qualitative factors to consider in addition to the reliability results.

<u>Sensitivity Study Process and Assumptions:</u>

Evaluating the reliability impact requires that a conceptual design be identified. For the purposes of the EFW reliability sensitivity study, the following design assumptions were made:

- It is assumed that the motor-driven pumps in EFW trains 1 and 4 are replaced with a turbine-driven pump design. Trains 1 and 4 were chosen because main steam lines (MSL) are located on top of Safeguards Buildings (SB) 1 and 4. The impact of adding the turbine-driven pumps to these buildings was not considered in this study.
- It is assumed that the turbine-driven pumps have a long term dependency on DC power (31BUC and 34BUC for trains 1 and 4, respectively). This is consistent with assumptions made in industry studies. For example NUREG\CR-6890 Volume 2 states that “Given SBO conditions, only the turbine-driven pump or diesel-driven pump is operable. However, these components often require DC power for control, so when the DC batteries deplete, these components are typically assumed to fail if AC power has not been recovered by that time.”

- In order for the turbine-driven pump trains to function during an SBO event, the corresponding discharge flow control valves and level control valves are assumed to be powered from 31BRA and 34BRA, respectively (which are powered by an uninterruptible power supply).
- Offsite power recovery is not credited after the time of battery depletion. This is consistent with the PRA assumption that a loss-of-offsite power (LOOP) initiating event with failure of all four batteries results directly in core damage.
- A single steam line supply is assumed to go to each turbine-driven pump from the corresponding MSL, 1 or 4, upstream from the main steam isolation valve.
- The PRA model included a 1E-3 failure probability for the steam admission valves (based on NUREG\CR-5500 Volume 1 Table 2).
- The turbine-driven pump fail to start probability was estimated as 5.86E-3, per demand, and the first hour turbine-driven pump fail-to-run failure rate was estimated as 1.65E-2/hr. Both values were based on the Centralized Reliability and Events Database (ZEDB), as defined in U.S. EPR FSAR, Tier 2, Section 19.1.4.1.1.4.
- The turbine-driven pump fail to run rate after the first hour was assumed the same as for the motor-driven pump (5.1E-4 failures/ hr).

Table 10.4.9-12-2 shows that the introduction of the two turbine-driven pumps results in an improvement in EFW system performance for loss of main feedwater (LOMFW) events due to the elimination of the CCF to start on demand of all four pumps. However, the EFWS reliability for LOOP events is decreased due to the reduced reliability of the turbine-driven pumps, relative to the motor-driven pumps, because the individual pump failure events become much more important for the LOOP events (e.g. the Fussel-Vesely of the turbine-driven driver failure to run basic events are 18 percent in the LOOP case versus only eight percent for the LOMFW case). Since LOOP is a large contributor to CDF and LOMFW is a relatively minor contributor, the net impact is a decrease in plant safety.

Table 10.4.9-12-3 shows that the introduction of the two turbine-driven pumps results in approximately a six percent increase in CDF risk. The increase in CDF occurs for the following reasons:

- The U.S. EPR design incorporates the ability to mitigate the station-blackout event with the inclusion of two station-blackout diesel generators. The SBO diesel generators are still required to support long-term turbine-driven pump operation (control power and HVAC to control power), therefore the inclusion of a turbine-driven pump does not significantly improve the ability to mitigate a SBO event.
- Since motor-driven pumps are significantly more reliable than turbine-driven pumps based on NUREG/CR-6928 data (and since extended operation of the turbine-driven pumps or the motor-driven pumps require the availability of AC power), the motor-driven pumps are preferable.
- The U.S. EPR design has a long SG dry-out time relative to typical nuclear power plants. .Therefore a complete loss of station AC (e.g., a LOOP initiating event and failure of all six diesels) can still be mitigated if offsite power is recovered within two hours. Since the U.S. EPR design battery capacity is also two hours, both cases (the turbine-driven pump case and the base U.S. EPR EFW design) require power

recovery within two hours to allow for successful event mitigation (power recovery is not credited subsequent to the time of battery depletion).

U.S. EPR FSAR, Tier 2, Section 10.4.9.3 and Table 10.4.9-4—EFWS Unreliability Results will be revised to reflect this information.

FSAR Impact:

U.S. EPR FSAR, Tier 2, Section 10.4.9.3 and Table 10.4.9-4 will be revised as described in the response and indicated on the enclosed markup.

Table 10.4.9-12-1—Results of EFWS Unreliability Comparison (with Supply Cross Connect Valves Open or Closed)

Initiating Event	Secondary Cooling Systems Credited	Probability that the credited systems fail to provide adequate SG flow	
		EFW Supply Header Isolation Valves Position	
		Open	Closed
General Transient	MFW, SSS, and EFWS	3.58E-07*	3.55E-07
Loss of Main Feedwater	EFWS	3.84E-05	3.89E-05
Loss of Main Feedwater	EFWS and SSS	1.13E-05	1.14E-05
Loss of Offsite Power	EFWS (without power recovery)	1.03E-04	1.01E-04
Loss of Offsite Power	EFWS (offsite power recovery considered)	7.43E-05	7.15E-05
Loss of Offsite Power	EFWS and SSS (offsite power recovery considered)	5.85E-05	5.68E-05

* Value varies from U.S. EPR FSAR Tier 2, Table 10.4.9-4 because this evaluation used a relative truncation of 1E-06, whereas the original study used a 1E-10 absolute truncation

Table 10.4.9-12-2—Results of EFWS Unreliability Sensitivity Cases

Initiating Event	Secondary Cooling Systems Credited	Probability that the credited systems fail to provide adequate SG flow	
		4 Motor-Driven Pumps	2 Motor and 2 Turbine Pumps
General Transient	MFW, SSS, and EFWS	3.55E-07	4.00E-07
Loss of Main Feedwater	EFWS	3.89E-05	2.90E-05
Loss of Main Feedwater	EFWS and SSS	1.14E-05	8.35E-06
Loss of Offsite Power	EFWS (without power recovery)	1.01E-04	1.37E-04
Loss of Offsite Power	EFWS (offsite power recovery considered)	7.15E-05	8.62E-05
Loss of Offsite Power	EFWS and SSS (offsite power recovery considered)	5.68E-05	7.50E-05
Loss of Offsite Power	EFWS (SBO conditions)	2.20E-2	2.95E-2

Table 10.4.9-12-3—Results of CDF Sensitivity Cases

Risk Measure	PRA Results with 4 MD EFW Pumps	Sensitivity PRA Results with 2 MD & 2TD EFW Pumps
Total CDF [1/yr]	5.3E-07	5.6E-07
LOOP CDF [1/yr]	1.5E-07	1.7E-07
SBO CDF [1/yr]	3.1E-08	3.9E-08

Note: Tables 10.4.9-12-2 and 10.4.9-12-3 reflect results with the supply cross connect valves normally closed.

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- The EFWS automatically initiates upon a system actuation signal. The EFWS also satisfies the recommendations of RG 1.62 regarding the capability of manual initiation of protective actions.

- The EFWS meets the applicable recommendations of NUREG-0611 (Reference 2) and NUREG-0635 (Reference 3) with the exception to GS-5 and GL-3. ~~TMI Action Plan item II.E.1.1 of NUREG 0737 (Reference 4) and 10 CFR 50.34(f)(1)(ii) for applicants subject to 10 CFR 50.34(f) require an AFWS reliability analysis. An acceptable AFWS should have unreliability in the range of 10^{-4} to 10^{-5} per demand exclusive of station blackout scenarios. The results of the EFWS reliability analysis is provided in Table 10.4.9-4—EFWS Unreliability Results.~~

~~The design of the EFWS is consistent with BTP 10-1, except that the power sources are redundant but not diverse. Incorporating a non-electric EFWS pump into the U.S. EPR plant design for diversity is not expected to significantly improve the EFWS reliability or the plant core damage frequency (CDF). The following EFWS design features provide a highly reliable means of cooling the RCS~~

From a reliability perspective, the EFWS design satisfies the requirements of the TMI Action Plan item II.E.1.1 of NUREG 0737 (Reference 4) and 10 CFR 50.34(f)(1)(ii) for applicants subject to 10 CFR 50.34(f). An acceptable AFWS should have unreliability in the range of 10-4 to 10-5 per demand exclusive of station blackout scenarios. The EFWS achieves this reliability target, as described in Table 10.4.9-4—EFWS Unreliability Results, through a combination of redundancy and diversity.

10.04.09-12

- There are four complete trains, each normally aligned to a separate SG. The supply and discharge headers can be configured to allow the pumps to feed any combination of SGs.

- Each EFWS train receives power from a separate Class 1E emergency power system. In the event of loss of normal onsite and offsite power, power is supplied by the EDGs. The level control valves, SG isolation valves, and discharge header cross-connect valves are also provided uninterruptible vital battery power.

- The system has suitable redundancy, as demonstrated by a single active failure analysis to withstand a single active failure and still perform its safety functions. Refer to Table 10.4.9-2 for a summary of the evaluation.

- The EFWS is not required to operate following a normal loss of the MFWS, as the SSS pump is actuated automatically. The SSS actuation reduces the frequency of EFWS actuation and increases the reliability of the plant overall decay heat removal capability.

- EFWS trains 1 and 4, including pump room cooling, are powered from the two non-Class 1E SBODGs. ~~Station blackout is addressed in Section 8.4.~~

- Critical EFWS valves and instrumentation are provided with uninterruptible emergency power.

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From a diversity perspective, the design of the EFWS and its power supplies consists of four AC motor-driven, centrifugal EFW pumps. Each pump is located in a separate Safeguard Building with separate heating, ventilation, and air conditioning (HVAC), and is provided emergency power from a separate emergency diesel generator (EDG). Two EFW pumps and associated room cooling can also be powered from an alternate AC source of power consisting of two, diverse station blackout diesel generators (SBODG). The SBODGs and the SBO Building Ventilation System are included in the Reliability Assurance Program discussed in Section 17.4.1. The alternate AC power supply diesels have the capability and quality requirements to support use to address beyond design basis common cause failure events.

- The following U.S. EPR design features enhance the plant's ability to address common cause failures of the EFWS:
  - The EDGs are housed in two separate buildings, with two units per building, each in a different fire area. The buildings do not share control power, HVAC, or engine cooling.
  - Diversity exists between the EDGs and the SBODGs, including the difference in nominal size and models; location in separate areas; and exclusion of shared control power, HVAC, engine cooling, or fuel systems. The cooling system for the EDG transfers heat utilizing a water-to-water heat exchanger, while the corresponding system for the SBODG transfers heat from water-to-air. There are no environment-related events or single active failures than can simultaneously disable both the SBODGs and EDGs.
  - Diversity in maintenance and testing of the EFWS and support systems will be provided through several methods, such as using different crews or varying schedules (staggered vs. sequential).
  - The EFWS normal and makeup water supplies are clean water stored in tanks or pools that are not susceptible to common-mode failures caused by blockage.
  - Detailed equipment specifications, vendor quality assurance (QA) of equipment manufacturing, owner oversight of manufacturing activities, shop testing, and pre-service and in-service inspection will reduce the risk of hardware-related common-cause factors. QA and testing programs will be established for the EFWS-related hardware.
- In the unlikely event that the emergency feedwater capability is lost due to a common cause failure, the effects are reduced by the plant's large primary and secondary water inventories. Analysis of a postulated loss of the EFWS without taking mitigating actions shows that the time to steam generator dry-out is greater than 1.5 hours, and that the core remains covered with sub-cooled water for greater than 2 hours. The analysis of this beyond design basis event assumed:
  - A LOOP with the plant running at full-load steady state power.
  - Normal operating steam generator and pressurizer levels.

- Best estimate decay heat curve.
- Primary and secondary temperature and pressure conditions, and latent heat as calculated by S-RELAP5.

This extended coping time provides time for compensatory actions to initiate decay heat removal. For example, following a loss of normal and emergency AC power, two EFW pumps can be energized from the alternate source of AC power and the pumps started from the control room within 30 minutes of the initiating event. The SBO timeline is further described in Section 8.4.2.6.2.

Depending on the initiating event, other compensatory measures that may be used for decay heat removal include:

- Removing core decay heat using the plant's safety-related feed and bleed capability.
- Removing core decay heat using the plant's non-safety-related Startup Feedwater system or the plant's non-safety-related Main Feedwater system.

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The design of the EFWS satisfies GDC 45 as is relates to provisions for periodic inservice inspection of system components and equipment as described in Section 10.4.9.4.

The design of the EFWS satisfies GDC 46 regarding provisions made to permit appropriate functional testing of the system and components, as described in Section 10.4.9.4.

The design satisfies 10 CFR 50.62 regarding provisions for automatic initiation in an ATWS. A diverse low SG level EFWS actuation signal is provided for ATWS mitigation.

The design of the EFWS satisfies 10 CFR 50.63 regarding the capability for responding to a SBO. Station blackout is addressed in Section 8.4.

- Trains 1 and 4 of the EFWS are powered from the SBODGs, including the air recirculation fans of the room coolers for these EFWS pumps. The cooling medium for these coolers is supplied by the safety chilled water system (SCWS), which is also powered by the SBODGs.
- The EFWS water inventory required to meet SBO requirements is 166,000 gallons. This is based on the EFWS providing the necessary flow for decay heat removal while remaining in the hot standby conditions for eight hours. ~~Section 8.4 describes the SBO event.~~

Table 10.4.9-4—EFWS Unreliability Results

Initiating Event	Secondary Cooling Systems Credited	Probability that the Credited Systems Fail to Provide Adequate Steam Generator Flow
General Transient	MFW, SSS, and EFWS	~~2.99~~3.55E-07
Loss of Main Feedwater	EFWS	~~3.83~~3.89E-05
Loss of Main Feedwater	EFWS and SSS	~~1.12~~1.14E-05
Loss of Offsite Power	EFWS (without power recovery)	~~1.03~~1.01E-04
Loss of Offsite Power	EFWS (offsite power recovery considered)	~~7.23~~7.15E-05
Loss of Offsite Power	EFWS and SSS (offsite power recovery considered)	~~5.81~~5.68E-05

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