ArevaEPRDCPEm Resource

From:	Pederson Ronda M (AREVA NP INC) [Ronda.Pederson@areva.com]
Sent:	Wednesday, July 08, 2009 6:31 PM
To:	Tesfaye, Getachew
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
Attachments:	RAI 238 Response US EPR DC.pdf

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,

Ronda Pederson
ronda.pederson@areva.com
Licensing Manager, U.S. EPR Design Certification
AREVA NP Inc.
An AREVA and Siemens company
3315 Old Forest Road
Lynchburg, VA 24506-0935
Phone: 434-832-3694
Cell: 434-841-8788

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
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Created By: Ronda.Pederson@areva.com

Recipients:
"BENNETT Kathy A (OFR) (AREVA NP INC)" <Kathy.Bennett@areva.com>
Tracking Status: None
"DELANO Karen V (AREVA NP INC)" <Karen.Delano@areva.com>
Tracking Status: None
"KOWALSKI David J (AREVA NP INC)" <David.Kowalski@areva.com>
Tracking Status: None
"Tesfaye, Getachew" <Getachew.Tesfaye@nrc.gov>
Tracking Status: None

Post Office: AUSLYNCMX02.adom.ad.corp

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Response to

Request for Additional Information No. 238

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:

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 (versus strict compliance with NRC guidance), and is fully consistent with the Commission's Policy Statement on the Regulation of Advanced Reactors.

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 staff 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% 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). Also of note, is the small percentage of CCFs analyzed in this NUREG that resulted in the loss of safety function.

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 global 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) 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, in the unlikely event that the EFWS was 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 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 core damage frequency. 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 are located on top of Safeguards Buildings (SB) 1 and 4. The impacts 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 typically are assumed to fail if ac power has not been recovered by that time."
- In order for the turbine-driven pump trains to function during a 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 each turbine-driven pump, from the corresponding MS line 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 Section 19.1.4.1.1.4 of the FSAR.
- 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 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 8 percent for the LMFW case). Since LOOP is a large contributor to core damage frequency 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 6 percent increase in CDF risk. The increase in CDF occurs for the following reasons:

- The 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, Table 10.4.9-4—EFWS Unreliability Results has been revised to reflect updated reliability values.

FSAR Impact:

U.S. EPR FSAR Tier 2, 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 FSAR 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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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

10.04.09-12

Next File