Calvert Cliffs Nuclear Power Plant

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Lusby, Maryland 20657

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CALVERT CLIFFS
NUCLEAR POWER PLANT

July 25, 2012

U. S. Nuclear Regulatory Commission
Washington, DC 20555

ATTENTION: Document Control Desk

SUBJECT: Calvert Cliffs Nuclear Power Plant
Unit Nos. 1 & 2; Docket Nos. 50-317 & 50-318
Response to Request for Additional Information Regarding Realistic Large Break Loss-of-Coolant Accident Analysis

REFERENCES:

(a) Letter from J. J. Stanley (CCNPP) to Document Control Desk (NRC), dated December 1, 2011, Review of Realistic Large Break LOCA Analysis

(b) Letter from J. J. Stanley (CCNPP) to Document Control Desk (NRC), dated January 17, 2012, Review of Realistic Large Break LOCA Analysis – Supplemental Information

(c) Letter from N. S. Morgan (NRC) to G. H. Gellrich (CCNPP), dated June 21, 2012, Calvert Cliffs Nuclear Power Plant, Unit Nos. 1 and 2 - Request for Additional Information Regarding Realistic Large Break Loss-of-Coolant Accident Analysis (TAC Nos. ME7672 and ME7673)

In References (a) and (b), Calvert Cliffs Nuclear Power Plant, LLC (Calvert Cliffs) requested approval of the realistic large break loss-of-coolant accident analysis for the second, and subsequent, cycles of operation with AREVA fuel in Calvert Cliffs Units 1 and 2 to comply with a license condition. Review of the request by the Nuclear Regulatory Commission (NRC) has resulted in a request for additional information (Reference c). A phone call was held with the NRC staff on June 13, 2012 to ensure understanding of the information requested. The response has been modified based on that phone call. Attachment (1) contains our response to the requested information.

Note that Attachment (1) contains proprietary information. Since this Attachment contains information that is proprietary to AREVA, it is accompanied by an affidavit signed by AREVA, the owner of the information (Attachment 2). The affidavit sets forth the basis on which the information may be withheld from public disclosure by the Commission, and addresses, with specificity, the considerations listed in 10 CFR 2.390(a)(4). Accordingly, it is requested that the information that is proprietary to AREVA be

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withheld from public disclosure. The non-proprietary version of the response is included as Attachment (3) for public disclosure.

There are no regulatory commitments contained in this letter.

Should you have questions regarding this matter, please contact Mr. Douglas E. Lauver at (410) 495-5219.

Very truly yours,

James J. Stanley
Manager – Engineering Services

JJS/PSF/bjd

Attachments: (1) Proprietary Response to Request for Additional Information
(2) Proprietary Affidavit
(3) Non-Proprietary Response to Request for Additional Information

cc: **(Without Attachments)**
N. S. Morgan, NRC
W. M. Dean, NRC
Resident Inspector, NRC
S. Gray, DNR

ATTACHMENT (2)

PROPRIETARY AFFIDAVIT

Calvert Cliffs Nuclear Power Plant, LLC
July 25, 2012

AFFIDAVIT

STATE OF WASHINGTON)
) ss.
COUNTY OF BENTON)

1. My name is Alan B. Meginnis. I am Manager, Product Licensing, for AREVA NP Inc. and as such I am authorized to execute this Affidavit.

2. I am familiar with the criteria applied by AREVA NP to determine whether certain AREVA NP information is proprietary. I am familiar with the policies established by AREVA NP to ensure the proper application of these criteria.

3. I am familiar with the AREVA NP information contained in the attachment to the letter from J. Stanley (Calvert Cliffs Nuclear Power Plant) to the Document Control Desk (NRC) entitled "Response to Request for Additional Information Regarding Realistic Large Break Loss-of-Coolant Accident Analysis," numbered NRC 12-047 and referred to herein as "Document." Information contained in this Document has been classified by AREVA NP as proprietary in accordance with the policies established by AREVA NP for the control and protection of proprietary and confidential information.

4. This Document contains information of a proprietary and confidential nature and is of the type customarily held in confidence by AREVA NP and not made available to the public. Based on my experience, I am aware that other companies regard information of the kind contained in this Document as proprietary and confidential.

5. This Document has been made available to the U.S. Nuclear Regulatory Commission in confidence with the request that the information contained in this Document be withheld from public disclosure. The request for withholding of proprietary information is made

in accordance with 10 CFR 2.390. The information for which withholding from disclosure is requested qualifies under 10 CFR 2.390(a)(4) "Trade secrets and commercial or financial information."

6. The following criteria are customarily applied by AREVA NP to determine whether information should be classified as proprietary:

(a) The information reveals details of AREVA NP's research and development plans and programs or their results.

(b) Use of the information by a competitor would permit the competitor to significantly reduce its expenditures, in time or resources, to design, produce, or market a similar product or service.

(c) The information includes test data or analytical techniques concerning a process, methodology, or component, the application of which results in a competitive advantage for AREVA NP.

(d) The information reveals certain distinguishing aspects of a process, methodology, or component, the exclusive use of which provides a competitive advantage for AREVA NP in product optimization or marketability.

(e) The information is vital to a competitive advantage held by AREVA NP, would be helpful to competitors to AREVA NP, and would likely cause substantial harm to the competitive position of AREVA NP.

The information in the Document is considered proprietary for the reasons set forth in paragraphs 6(b), 6(d) and 6(e) above.

7. In accordance with AREVA NP's policies governing the protection and control of information, proprietary information contained in this Document have been made available, on a limited basis, to others outside AREVA NP only as required and under suitable agreement providing for nondisclosure and limited use of the information.

8. AREVA NP policy requires that proprietary information be kept in a secured file or area and distributed on a need-to-know basis.

9. The foregoing statements are true and correct to the best of my knowledge, information, and belief.

SUBSCRIBED before me this 19th

day of July, 2012.

Susan K. McCoy
NOTARY PUBLIC, STATE OF WASHINGTON
MY COMMISSION EXPIRES: 1/14/2016

SUSAN K. MCCOY
NOTARY
PUBLIC
STATE OF WASHINGTON

ATTACHMENT (3)

NON-PROPRIETARY RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

In References (1) and (2), Calvert Cliffs Nuclear Power Plant, LLC requested approval of the realistic large break loss-of-coolant-accident (RLBLOCA) analysis for the second, and subsequent, cycles of AREVA fuel in Calvert Cliffs Nuclear Power Plant, Unit Nos. 1 and 2 (Calvert Cliffs).

In order to complete the review, the Nuclear Regulatory Commission (NRC) staff requested additional information in Reference (3). The responses to that request are given below.

NRC RAI QUESTION 1:

1. *Please show the results for the limiting downcomer boiling case for Calvert Cliffs. Please identify the limiting parameters for this case in a data table. See the requested list of data parameters for all of the LBLOCA case runs.*

CCNPP RAI RESPONSE 1:

The limiting downcomer boiling case was defined as the case which has the following characteristics during the period following Safety Injection Tank (SIT) injection:

- the highest overall peak clad temperature (PCT) trend,
- the slowest cooldown rate, and
- downcomer temperatures at or near saturation.

Note that the maximum PCT from the full transient obtained in all 59 cases occurred prior to the transient period defined for the limiting downcomer boiling case.

During the later reflood phase, downcomer boiling can occur as a result of the large step reduction in coolant flow from the Emergency Core Cooling Systems after the SIT flow is terminated. To maximize the potential for downcomer boiling, the AREVA RLBLOCA method applies large steam and liquid condensation heat transfer correlation (HTC) multipliers to bring the fluid temperature of the intact cold legs at or near saturation before it enters the downcomer (see Section 1 of Attachment 1 of Reference 2).
[

] As such, the time period of interest for the limiting downcomer boiling case starts when the large HTC condensation multipliers are applied. Downcomer boiling is expected to be maximized between this time and core quench. The large HTC condensation multipliers are fixed values (not sampled) implemented in all 59 cases. Therefore, the potential for downcomer boiling between the time of the multiplier application and the time of core quench is maximized for all cases.

Among the 59 cases, Case 15 exhibited the highest overall PCT trend, the slowest core cooling, and the highest downcomer fluid temperature during the period of interest following the end of SIT injection until core quench. The maximum PCT for Case 15 during this period is 1373°F, which is reached at 126 seconds. Table 1-1 shows the limiting parameters for this case. Figure 1-3 through Figure 1-14 provide a general depiction of system behavior in terms of the main phases of the LOCA event for Case 15.

Figure 1-1 shows the PCT trace, independent of elevation, for Case 15. The two vertical lines in the plot mark the beginning of reflood and the initiation of the large HTC multiplier implementation.

Figure 1-2 shows the average fluid temperature of the downcomer azimuthal sectors at two axial locations: bottom and top (below the cold leg nozzle); the saturation temperature of the downcomer fluid (top); and the fluid temperature of one of the intact cold legs (Loop 2) in the node adjacent to the

downcomer inlet. The differences between the saturation temperature throughout the downcomer and the cold legs are negligible.

Following the end of SIT injection, the downcomer collapsed level (Figure 1-8) begins to decrease. It reaches a minimum level near 120 seconds; thereafter, the level begins to increase at a slow rate until the core quenches at 282 seconds.

With the termination of the SIT flow, the temperature near the top of the downcomer increases quickly while the temperature at the bottom begins to increase as heat is released and the warmer fluid mixes. The HTC multiples are applied at 117 seconds [ ], causing a rapid increase to the cold leg temperatures. As the transient proceeds, both the top and bottom elevations of the downcomer reach a nearly saturated state by the time the core is quenched (Figure 1-2).

After 150 seconds, three small core heatups can be observed with decreasing magnitudes at 200 sec, 260 sec and 280 sec (Figure 1-1). These peaks along with the overall slow cool down of the core are indicators of the effects of the nearly saturated condition in the downcomer. At around 150 seconds the core inventory is sufficiently high to inhibit bulk boiling in the downcomer; therefore no significant reduction in the downcomer hydraulic head takes place and consequently no major core heatup occurs.

Table 1-1: Limiting Parameters for Limiting Downcomer Boiling Case

Figure 1-1, PCT Trace (Independent of Elevation) for Case 15

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Figure 1-2, Downcomer and Cold Leg Fluid Temperatures for Case 15

Figure 1-3, Core Inlet Mass Flux for Case 15

Figure 1-4, Core Outlet Mass Flux for Case 15

Figure 1-5, Pump Void Fraction for Case 15

[ ]

Figure 1-6, ECCS Flows for Case 15

[ ]

Figure 1-7, Upper Plenum Pressure for Case 15

Figure 1-8, Downcomer Liquid Level for Case 15

Figure 1-9, Lower Vessel Liquid Level for Case 15

Figure 1-10, Core Liquid Level for Case 15

Figure 1-11, Containment and Loop Pressures for Case 15

Figure 1-12, Break Flow for Case 15

Figure 1-13, Total Primary Mass for Case 15

[ ]

Figure 1-14, Total RV Mass for Case 15

NRC RAI QUESTION 2:

2. *Figure 3-19 shows a decreasing downcomer liquid level, while the core levels are increasing after about 325 seconds.*
   a. *Please explain why the core levels are increasing while the downcomer levels show a dramatic decrease.*
   b. *The average trends of the core and downcomer liquid levels show a decreasing average inventory over the last 150 seconds. Provide results of this limiting break beyond 300 sec until the levels show a steadily increasing trend.*

CCNPP RAI RESPONSE 2:

The decrease in downcomer level and the increase in core level towards the end of the transient, observed in Figure 3-19 and Figure 3-21, respectively, of Attachment 1 of Reference (2) are caused by the effects of core quenching. Starting around 260 seconds, the average trend of the downcomer collapsed level oscillates until the end of the transient (340 seconds). The start of these oscillations coincides, approximately, with the time that the core quenches (about 240 seconds).

Following core quench, the steam production in the core is reduced. The downcomer level is reduced and the core level increases. As water levels rise into the upper plenum, entrainment into the hot legs and steam generators occurs. This results in pressure increases on the hot side, which then depresses the level in the core and forces water back out the downcomer. The downcomer level increases and liquid flows out of the break. This is a cyclic process which is evidenced in the downcomer level, core level, upper plenum and steam generator outlet (primary side) pressures, and break flow plots (Figures 1-16, 1-17, 1-18 and 1-19, respectively). The original transient terminated at 340 seconds at a point in this cycle where the downcomer level was reduced. The transient run for the limiting case in Attachment 1 of Reference 2 was extended and the plots now show the system behavior to 600 seconds. Figure 1-15 confirms that there is no PCT heatup. Additionally, the reactor vessel mass and primary system mass plots (Figure 1-20 and 1-21) confirm a stable cooling inventory from 340 seconds until the end of the extended transient.

Figure 1-15, PCT Trace Independent of Elevation Extended Transient

Figure 1-16, Downcomer Liquid Level Extended Transient

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Figure 1-17, Core Liquid Level Extended Transient

Figure 1-18, Containment and Loop Pressure Extended Transient

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Figure 1-19, Break Flows Extended Transient

Figure 1-20, Reactor Vessel Liquid Mass Extended Transient

Figure 1-21, Primary System Liquid Mass Extended Transient

NRC RAI QUESTION 3:

3. *Fig. 3-3 shows only four azimuthal sectors for a four loop plant. NRC staff calculations for a combustion engineering plant showed that use of 8 azimuthal sectors in the downcomer (an azimuthal downcomer volume in between each cell connected to each cold leg) increase peak cladding temperature (PCT) by as much as 400 degrees Fahrenheit (°F). While the four azimuthal sectors may be converged as stated in section 4.5.2.1, the additional azimuthal sectors have been shown to produce more downcomer boiling, since the injected emergency core coolant (ECC) is no longer averaged over the entirety of only four cells, thereby reducing the driving head and increasing PCT. If the refueling water storage tank (RWST) temperature is at a maximum with the increased nodalization, PCT is expected to show an increase relative to the crude downcomer nodalization scheme.*

   a. *Show the results of the more detailed downcomer on ECC response for Calvert Cliffs.*

b. *What RWST/safety injection tank (SIT) temperatures, decay heat multiplier, and planar linear heat generation rate (PLHGR) were used in the 3-loop sensitivity study?*

CCNPP RAI RESPONSE 3:

As discussed in a phone call with the NRC on June 13, 2012, the refinement of the downcomer model for the Calvert Cliffs RLBLOCA analysis is not necessary for the reasons explained below.

A downcomer azimuthal sensitivity study was performed by AREVA and is reported in Section 4.5.2.1 of Attachment 1 of Reference 2. The study was transmitted to NRC in Reference 4. The study on azimuthal nodalization was Study #4, which consisted of four calculations examining clad temperature sensitivity to downcomer nodalization. The calculations were derived from one of two base cases, each with a different set of conditions. The conditions of these base cases, including Refueling Water Storage Tank (RWST)/SIT temperatures, decay heat multipliers, and linear heat generation rate used in the 3-loop sensitivity study are listed in Table 1-2. The study showed no sensitivity to the refinement of downcomer azimuthal sectors.

In addition to azimuthal nodalization studies, the wall heat release model has been validated through an exact solution comparison to show that S-RELAP5 properly calculates the wall heat release rate (Section 4.5.1 of Attachment 1 of Reference 2). The validated downcomer nodalization and wall heat release model are used in the Calvert Cliffs analysis.

Furthermore, to assure that cold leg condensation would not be under predicted, the AREVA RLBLOCA method applies large steam and liquid HTC condensation multipliers after SIT injection is terminated to approximately saturate the cold leg fluid prior to entering the downcomer. The modification is implemented for all 59 cases. As such, the nearly saturated water in the downcomer absorbs the heat released from the downcomer wall, increasing downcomer boiling and reducing the downcomer driving head (see Section 1 of Attachment 1 of Reference 2). Therefore, for all plants, the AREVA RLBLOCA methodology results in the maximum possible vapor generation from the walls of the downcomer.

Table 1-2: 3-Loop Sensitivity Study – Key Parameters

NRC RAI QUESTION 4:

4. *Tabulate the statistically sampled conditions, input data, etc. for the following parameters for all of the sampled break sizes. A data file is preferred for transmitting the data.*

Case number
PCT (F)
Case end time
PCT elevation
Hot rod
Assembly burnup

Core power (Mwt)
PLHGR (kw/ft)
Axial skew
Axial shape index
Break type
One sided break size (ft^2)
T_{min} (°F)
Initial stored energy (°F)
Decay heat multiplier
Film boiling heat transfer coefficient (HTC) ($btu/hr/ft^2/°F$)
Dispersed flow film boiling HTC
Condensation interphase HTC
Initial reactor coolant system
Flow rate (Mlbs/hr)
Initial T_{cold} (°F)
Pressurizer pressure (psia)
Pressurizer level (ft)
SIT temp (°F)
SIT pressure (psia)
SIT liquid volume (ft^3)
Start of broken loop SIT injection (seconds)
Start of intact loop SIT injection (seconds)
Broken loop SIT empty time
Intact loop SIT empty time
Start of high pressure safety injection flow
Start of low pressure safety injection flow
Beginning of refill time
End of refill time/start of reflood
Beginning of bypass time
Time of annulus downflow/end of bypass
Reflood rate up to time of PCT
Containment pressure at time of PCT
Containment volume (ft^3)
RWST temp (°F)

CCNPP RAI RESPONSE 4:

All of the requested parameter values, except for "reflood rate up to time of PCT," for all 59 sampled cases are listed in Tables 1-3 and 1-4.

The core effective flooding rate was not calculated in the Calvert Cliffs RLBLOCA analysis in Attachment 1 of Reference 2, therefore, it is not provided. The core collapsed liquid level and reactor vessel liquid mass plots provide sufficient detail. These are provided in the response to NRC RAI Question 1 for the limiting downcomer boiling case and in the response to NRC RAI Question 2 for the extended transient of the limiting peak clad temperature case.

Table 1-3: Key Input and Output Parameters for all 59 Cases

Table 1-4: Key Input and Output Parameters for all 59 Cases

3.0 REFERENCES

1. Letter from J. J. Stanley (CCNPP) to Document Control Desk (NRC), dated December 1, 2011, Review of Realistic Large Break LOCA Analysis
2. Letter from J. J. Stanley (CCNPP) to Document Control Desk (NRC), dated January 17, 2012, Review of Realistic Large Break LOCA Analysis – Supplemental Information
3. Letter from N. S. Morgan (NRC) to G. H. Gellrich (CCNPP), dated June 21, 2012, Request for Additional Information Regarding Realistic Large Break Loss-of-Coolant Accident
4. Letter from James Malay (AREVA) to Document Control Desk (NRC), dated April 4, 2003, AREVA NP Letter NRC:03:011 Rev. 1, Downcomer Boiling in Framatome ANP ECCS Evaluation Models, NRC ML030980074