August 31, 2009
NRC:09:093

Document Control Desk
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555-0001

Response to U.S. EPR Design Certification Application RAI No. 262

Ref. 1: E-mail, Getachew Tesfaye (NRC) to Ronda Pederson, et al (AREVA NP Inc.), "U.S. EPR Design Certification Application RAI No. 262 (3292), FSAR Ch. 19," July 30, 2009, (Accession No. ML092110814).

In Reference 1, the NRC provided a request for additional information (RAI) regarding the U.S. EPR design certification application (i.e., RAI No. 262). Technically correct and accurate responses to 2 of the 7 questions and a partial response to 1 of the 7 questions are enclosed with this letter.

The following table indicates the respective page(s) in the enclosure that contains AREVA NP's response to the subject questions.

Question #	Start Page	End Page
RAI 160—03.09.02-25	2	4
RAI 160—03.09.02-26	5	5

A complete answer is not provided for 5 of the 7 questions. The schedule for a technically correct and complete response to these questions is provided below.

Question #	Response Date
RAI 262 — 19-319	October 16, 2009
RAI 262 — 19-320	October 16, 2009
RAI 262 — 19-321	September 30, 2009
RAI 262 — 19-322 (Parts a, b, c)	October 16, 2009
RAI 262 — 19-323	September 30, 2009
RAI 262 — 19-324	September 30, 2009

AREVA NP considers some of the material contained in the enclosure to be proprietary. As required by 10 CFR 2.390(b), an affidavit is enclosed to support the withholding of the

D077
NRO

AREVA NP INC.
An AREVA and Siemens company

3315 Old Forest Road, P.O. Box 10935, Lynchburg, VA 24506-0935
Tel.: (434) 832-3000 Fax: (434) 832-3840

information from public disclosure. Proprietary and non-proprietary versions of the enclosure to this letter are provided. If you have any questions related to this submittal, please contact me. I may be reached by telephone at 434-832-2369 or by e-mail at sandra.sloan@areva.com.

Sincerely,

Sandra M. Sloan

Sandra M. Sloan, Manager
New Plants Regulatory Affairs
AREVA NP Inc.

Enclosures

cc: G. Tesfaye
Docket 52-020

AFFIDAVIT

COMMONWEALTH OF VIRGINIA)
) ss.
COUNTY OF CAMPBELL)

1. My name is Sandra M. Sloan. I am Manager, New Plant Regulatory Affairs 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 "Response to U.S. EPR Design Certification Application RAI No. 262" 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) and 6(c) above.

7. In accordance with AREVA NP's policies governing the protection and control of information, proprietary information contained in this Document has 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.

Sandra M. Sloan

SUBSCRIBED before me this 31st

day of August, 2009.

Kathleen A. Bennett

Kathleen A. Bennett
NOTARY PUBLIC, COMMONWEALTH OF VIRGINIA
MY COMMISSION EXPIRES: 8/31/2011

KATHLEEN ANN BENNETT
Notary Public
Commonwealth of Virginia
110864
My Commission Expires Aug 31, 2011

Response to

Request for Additional Information No. 262 (3292), Revision 0

7/30/2009

U. S. EPR Standard Design Certification
AREVA NP Inc.
Docket No. 52-020
SRP Section: 19 - Probabilistic Risk Assessment and Severe Accident Evaluation
Application Section: 19.2

QUESTIONS for PRA Licensing, Operations Support and Maintenance Branch 2 (ESBWR/ABWR Projects) (SPLB)

Question 19-319:

It appears from the MAAP parameter file "us_epr_407.par" that there is no unconditionally open drainage path from the lower annular rooms (compartments 15 and 16) to points at lower elevations, suggesting that condensate may accumulate in these compartments unless or until a mixing damper may be opened due to water build-up (hydrostatic head of the pool).If there are any ducts, channels, or drains in the U.S. EPR containment compartments that direct liquid condensate from upper regions of the containment into the IRWST or other locations, please describe their features, including:

a. The beginning and ending locations (i.e., compartments) of the drainage paths.
b. The beginning and ending elevations of the drainage paths.
c. The effective cross-sectional dimensions and flow area of the drainage paths.
d. The lengths of the drainage paths.
e. Whether the paths are normally open or closed during plant operation, and what other conditions (if any) may result in their being closed.

Response to Question 19-319:

A response to this question will be provided by October 16, 2009.

Question 19-320:

If any openings exist for overflow from the IRWST, should the water level in the IRWST increase above its nominal value, please supply the following information about each opening:

a) The elevations of the bottom of the overflow paths relative to the nominal IRWST level;

b) The volume of water that must be added beyond the IRWST nominal inventory in order to reach the bottom of the overflow paths;

c) The beginning and end locations (i.e., compartments) of the overflow paths;

d) The beginning and end elevations (for the bottom of the openings) of the overflow paths;

e) Are the overflow paths normally open or closed during plant operation?

f) What conditions might result in these paths opening or closing, either during normal operation or during an accident?

g) If physically reasonable amounts of added IRWST inventory (i.e., RCS and accumulator volumes) were to spill over into other compartments as a result of these overflows, could this water reach the spreading compartment prior to initiation of SAHRS passive flooding?

Response to Question 19-320:

A response to this question will be provided by October 16, 2009.

Question 19-321:

Please provide the following information regarding data in the MAAP parameter file "us_epr_407.par":

a) Many of the flow junctions in the containment are of the "Failure" junction type, which normally open in response to a specified value of pressure differential. Please specify for each such junction any other accident conditions under which it might be assumed to open (e.g., in response to loss of offsite power).

b) A list of any changes made to the base parameter file since the last version of the file was provided to NRC, including new values of the updated or added parameters. Please include the file "fchf.inc", which was not included with the base parameter file, and the basis for the development of the functions included therein.

c) Please provide the following information regarding the melting of portions of the heavy reflector and their incorporation into the molten/core debris:

   i. Input parameters, models, and input assumptions that govern the potential relocation of large parts of the heavy reflector and their incorporation into the molten/core debris;

   ii. For calculations performed using this parameter file as part of the Level-2 PRA (FSAR Chapter 19), provide the fraction of the heavy reflector that typically melts and is incorporated in this way, and justification for this amount (if not self-explanatory given the response to (i)).

   iii. Describe the potential impacts on severe accident progression during in- and ex-vessel phases if the majority of the reflector were to relocate.

d) Please describe the model and any other governing parameters used to calculate the extent of in-vessel oxidation, and the extent to which any aspects of the in- and ex-vessel progression might be affected by reasonable variations in these parameters due to uncertainty.

Response to Question 19-321:

A response to this question will be provided by September 30, 2009.

Question 19-322:

Please provide the following information regarding the MAAP source term calculations "st1_1_5bar", "st1.5", and "st1_10a" performed as part of the Level-2 PRA (FSAR Chapter 19):

a) What is the time of scram relative to accident initiation? If not equal to time zero (i.e., accident initiation time), what is the proximate cause of scram?

b) For the seal LOCAs (in "st1_1_5bar" and "st1.5"), what assumptions were used regarding the break flow rates, either in terms of the area, dimensions, and discharge coefficient, or in terms of any tabular data of mass and energy flow rates out the break?

c) What is the total release fraction to the environment of cesium in each chemical form, (e.g., CsI, CsOH, etc.)? Alternately, please provide the mass released to the environment of each chemical form of cesium together with the pre-accident mass of elemental cesium in the reactor core.

d) Please provide the details and any sources of information for the heat transfer rate modeled between the debris and overlying water in the spreading compartment for those scenarios involving SAHRS passive flooding (if not already included in 3(b), above). This should include the time-dependent rate of steam and (any) hydrogen production during the cooling period.

e) Please provide the mass and energy flow rate out the break that was used in MAAP calculation of the containment transient following a main steam line break.

Response to Question 19-322:

Response to Question 19-322, Part a:

A response to this question will be provided by October 16, 2009.

Response to Question 19-322, Part b:

A response to this question will be provided by October 16, 2009.

Response to Question 19-322, Part c:

A response to this question will be provided by October 16, 2009.

Response to Question 19-322, Part d:

A special process model was developed for U.S. EPR severe accident analysis using the modular accident analysis program (MAAP) 4.0.7 code to describe the heat transfer and subsequent steam generation from a core melt residing in the core spreading area to the developing water pool above the melt during passive flooding. The model was implemented using MAAP4's "include file feature" to modify the flat plate critical heat flux Kutateladze number (FCHF) parameter.

Phenomenological Description and Experimental Basis

Following the melt retention and conditioning period, characterized by molten-core concrete interactions (MCCI) in the reactor cavity, the corium and concrete mixture flows into the core spreading area via a discharge channel. A consequence of the expected stratification of the melt during and after MCCI is that the water, which pours onto the surface of the melt, will make contact with the oxidic melt fraction.

The flooding and quenching of oxidic melts, including prototypic corium, has been studied in the frame of the MACE project (Reference 1 through Reference 3). The results demonstrate that water will spread on the molten surface smoothly, without any energetic interaction. Further, these tests indicate substantial superficial fragmentation and improved coolability at the surface, promoted by the ongoing interaction with the concrete and the mixing provided by the released gas. The fast formation of an oxidic crust limits the contact time between melt and water.

At the time flooding starts, the melt is subject to an intense convective mixing, driven by concrete decomposition gases. This causes a steady introduction of hot material to the surface and a high convective heat flux at the interface with the water. As a result, the surface temperature remains high so that film boiling will remain the dominant heat transfer mode.

In the film boiling regime, efficient heat transfer is anticipated because of conduction and radiation across the agitated (i.e., area enhanced) melt-water interface. In addition, melt droplets will be entrained into the water overlayer by sparging gas. The resulting heat fluxes, as measured in the MACE program, are >2 MW/m^2.

Transferred to the U.S. EPR spreading area of 170 m^2, this compares to a total equivalent heat load of >350 MW. With an average flooding rate of approximately 100kg/s and a specific heat of 2.2MJ/kg, the heat needed to evaporate the incoming water is 220MW. Therefore, there is sufficient heat transfer area to evaporate the incoming water.

With proceeding cool-down, the melt will enter a transient bulk-freezing phase. Because solid oxidic corium has a higher density than the liquid, fragments of frozen material (formed at the surface) will re-mix into the molten pool and cause an overall decrease in temperature. This process leads to a collapse of the gas film and eventually to the formation of a slurry-type, viscous oxidic melt. The drop in surface temperature, which results from the switch to gas-enhanced, nucleate boiling is accompanied by the formation of a surface crust.

The late bulk-freezing phase is characterized by a strong decline in superficial heat flux to almost zero. In this state, the melt becomes thermally insulated from the water. As a consequence, the bulk temperature starts to rise (due to decay heating) and convection is reestablished. The temperature of the melt and the thickness of the crust then approach steady-state, governed by the level of internal decay heat generation.

The forming crust provides support for melt particles and droplets that are drained through cracks and holes into the water by the flow of concrete decomposition gas. Such melt ejections through volcano-like structures have been observed in experiments with stimulant and prototypic material. The created particle bed transfers its internal decay heat directly to the water. Effective cooling is also achieved within porous regions of the crust potentially created by thermal cracking. There are large uncertainties associated with this process. However, a best-estimate value for the coolable melt fraction of 20 wt percent (engineering judgment supported by Reference 1 through Reference 3) has been assumed for analytical models used for U.S. EPR studies.

Based on the described phenomenology, the assumptions given in this response determine the heat transfer during the individual phases of quenching.

Initial flooding of the melt

]

[ ]

References for Question 19.322, Part d:

1. M.T. Farmer, et al., *MACE Test M3b, Data Report*, MACE-TR-D13, Vol. 1/2; Argonne Nat. Lab., Nov. 1997.
2. M. T. Farmer, et al., *MACE Test M1B - Data Report*, ACE-TR-D6, Argonne Nat. Lab., Sept. 1992.
3. M.T. Farmer, et al., *MACE Test M4, Data Report*, MACE-TR-D16; Argonne Nat. Lab., Aug. 1999.

FSAR Impact:

The U.S. EPR FSAR will not be changed as a result of this question.

Table 19-322d-1—Relevant Data for Heat Transfer Calculations

[ ]

Table 19-322d-2—Derived Results

[ ]

Response to Question 19-322, Part e:

The question refers to MAAP source term calculations st1_1_5bar, st1.5, and st1_10a performed to support the Level-2 probabilistic risk assessment (PRA). However, none of these calculations contain a main steam line break (MSLB) inside containment. An analysis of a MSLB inside containment was provided in the Response to RAI 22, Supplement 3, Question 19-160. The mass and energy releases (MERs) calculated by the MAAP simulation in the Response to RAI 22, Supplement 3, Question 19-160 are also used in this response.

The MAAP model used in the representation of the MSLB within containment provides two sets of data. The first set is for the releases from the "broken steam generator (SG)" representation, which models one SG, one reactor coolant pump (RCP), and the associated piping. The second set of releases is from the "unbroken SG" representation, which models three SGs, three RCPs, and associated piping. In a typical MAAP analysis, releases will only occur from the "broken SG" set; however, to maximize containment pressurization, a break was assumed in both sets of representations.

For each SG representation set, four variables are used in delineating the MERs. These variables represent the mass flow rate for the water and steam (kg/s) and the associated energy release rate (W). The mass flow rate that the MAAP model provides is the average flow rate over multiple plot time steps. This average value provides a better representation of the total flow rate instead of the instantaneous value in which a spike may have been missed.

Figure 19-322e-1 through Figure 19-322e-8 provides the MERs for the two sets of SG representations. Figure 19-322e-1 and Figure 19-322e-5 show that the water mass flow rate peaks at around 10 seconds and then drops to near zero after approximately 20 seconds after the start of the accident. The steam MERs are divided among three plots: Figure 19-322e-2 to Figure 19-322e-4 for the "broken SG" and Figure 19-322e-6 to Figure 19-322e-8 for the "unbroken SG."

FSAR Impact:

The U.S. EPR FSAR will not be changed as a result of this question.

Figure 19-322e-1—Water Mass Flow Rate and Energy from Broken Steam Generator

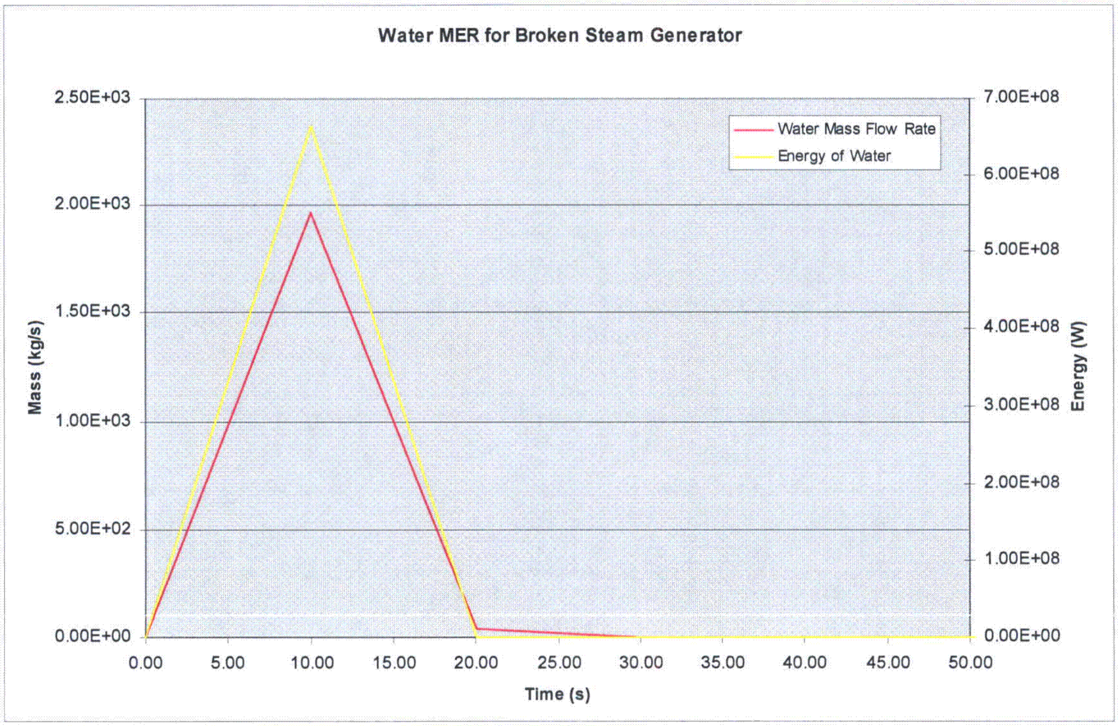


Figure 19-322e-2—Steam Mass Flow Rate and Energy from Broken Steam Generator During first 100 S

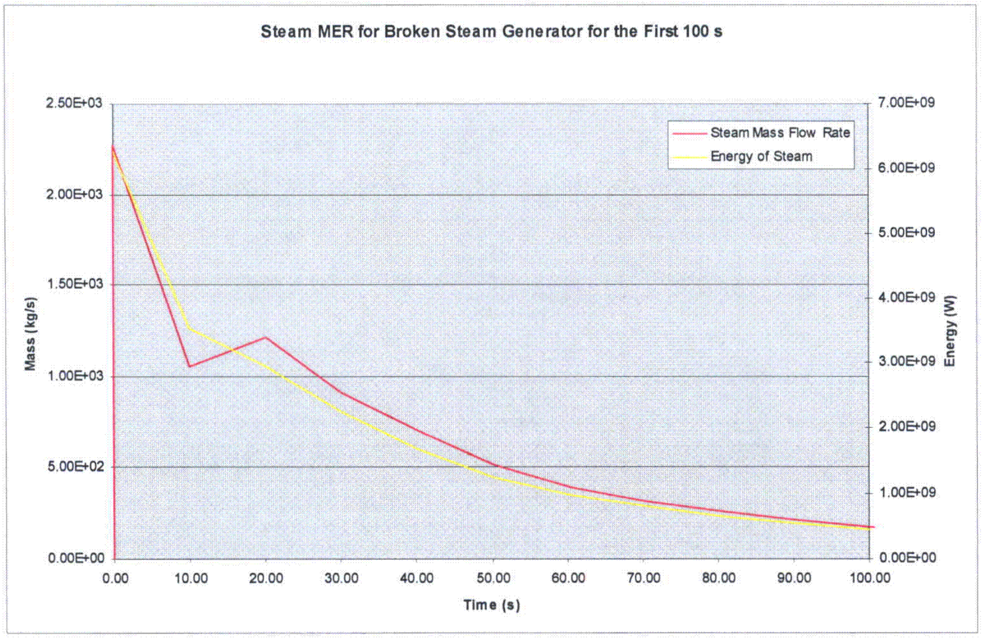


Figure 19-322e-3—Steam Mass Flow Rate and Energy from Broken Steam Generator for 100 to 1,000s from the Start of the Accident

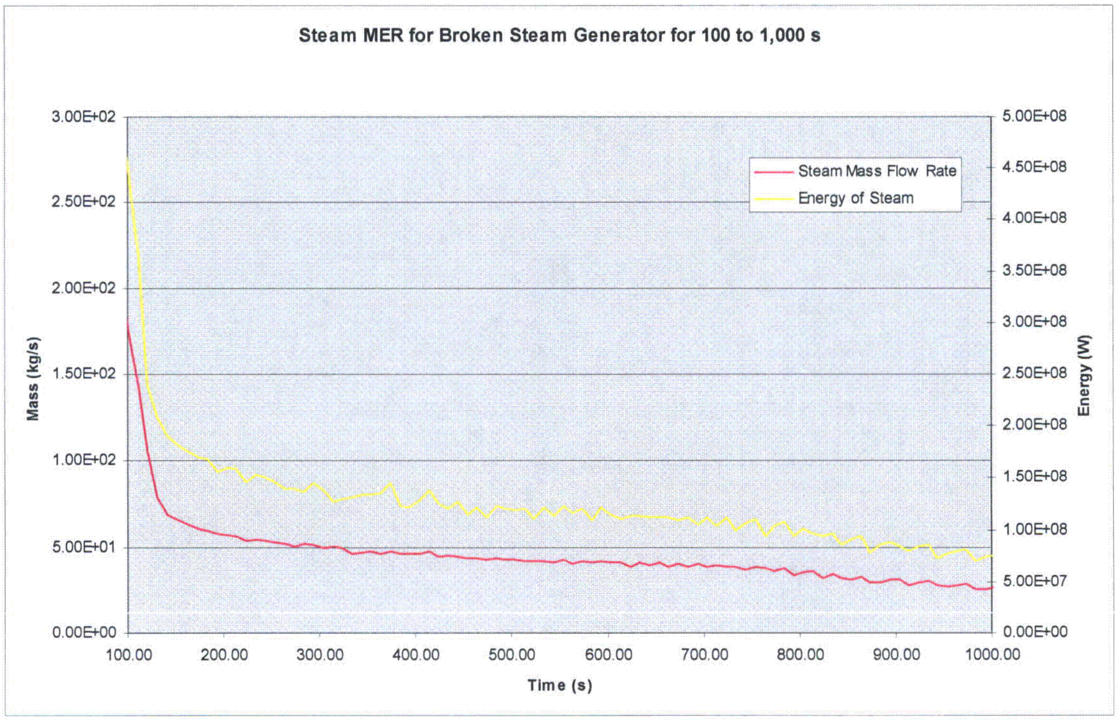


Figure 19-322e-4—Steam Mass Flow Rate and Energy from Broken Steam Generator from 1,000s after the Start of the Accident

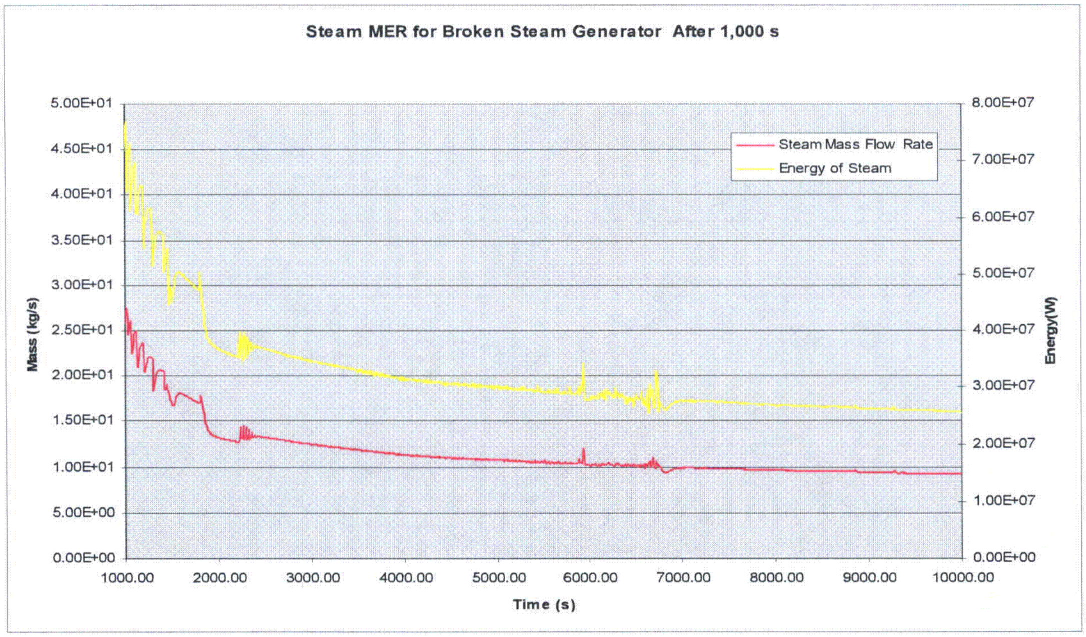


Figure 19-322e-5—Water Mass Flow Rate and Energy from Unbroken Steam Generator

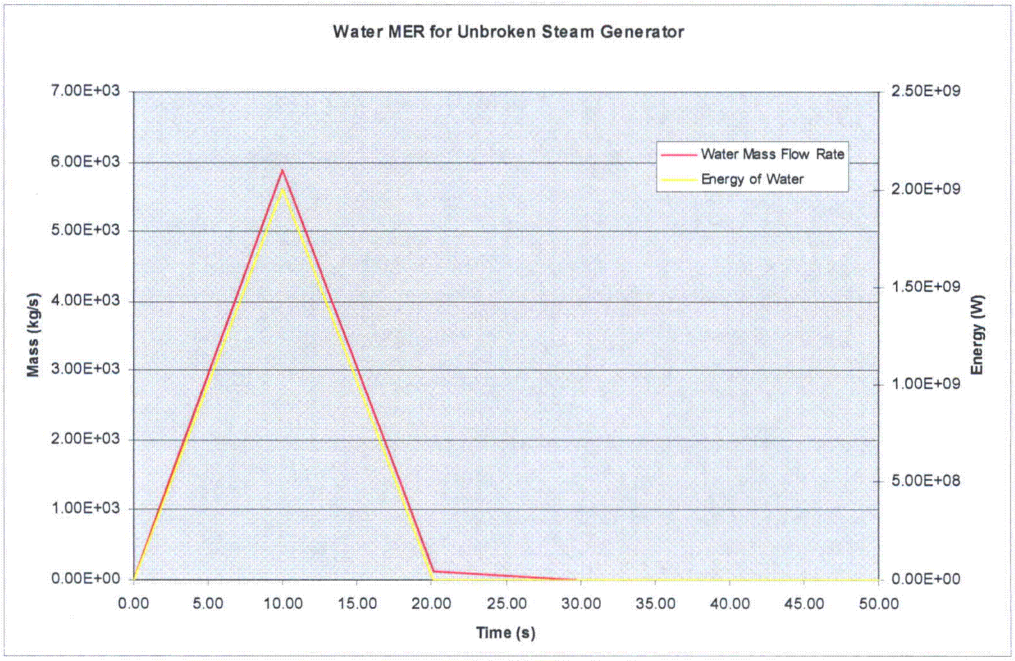


Figure 19-322e-6—Steam Mass Flow Rate and Energy from Unbroken Steam Generator During first 100 S

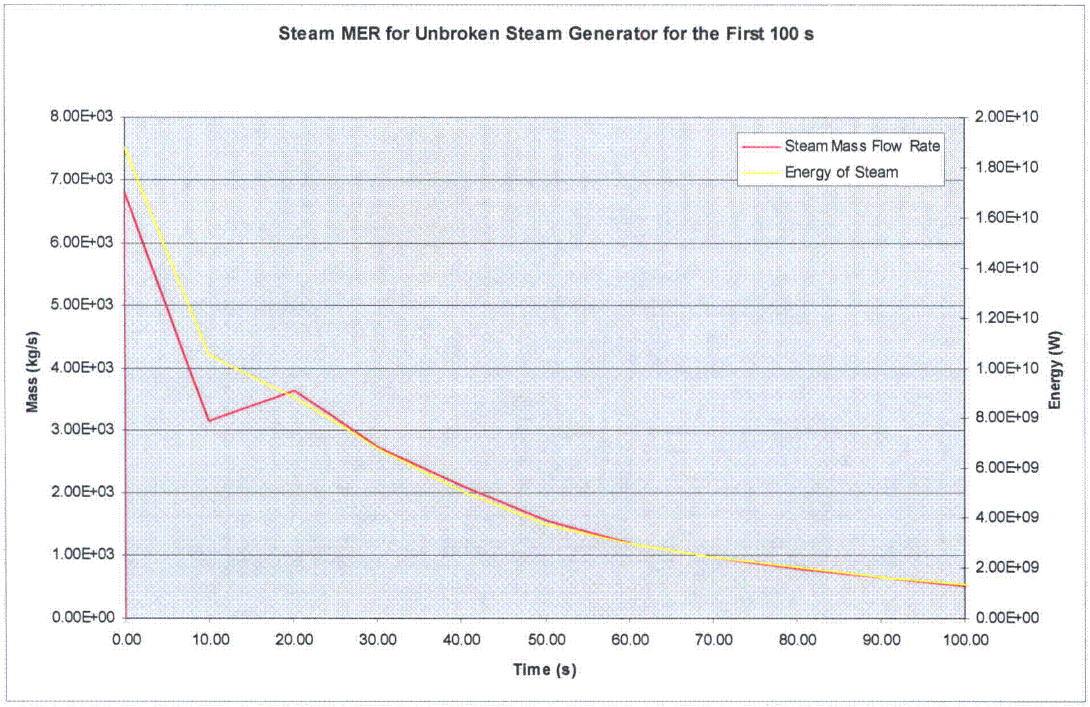


Figure 19-322e-7—Steam Mass Flow Rate and Energy from Unbroken Steam Generator for 100 to 1,000s from the Start of the Accident

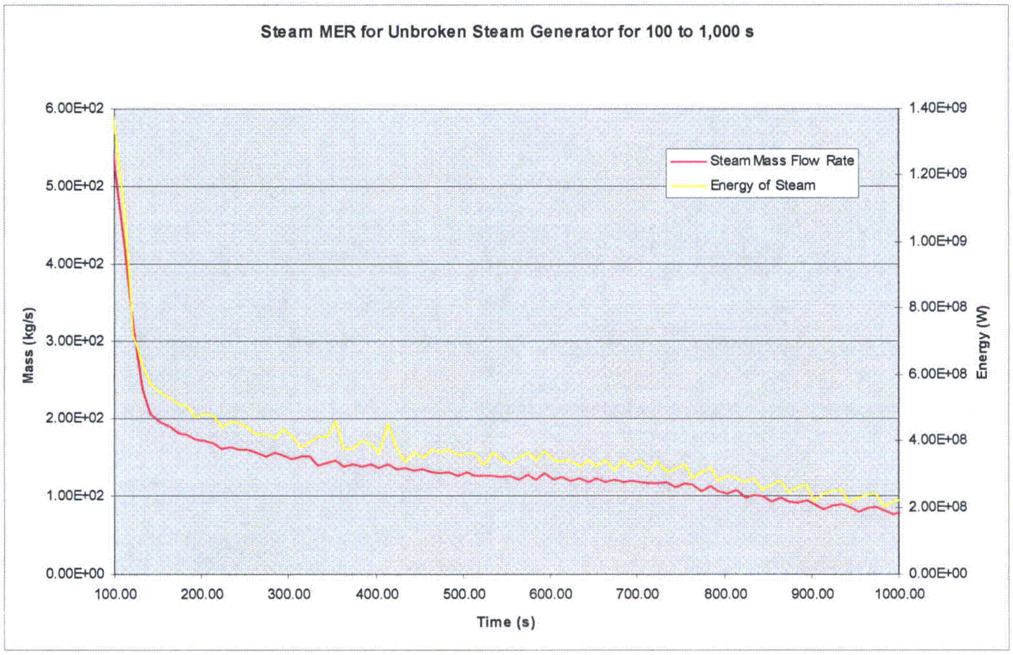
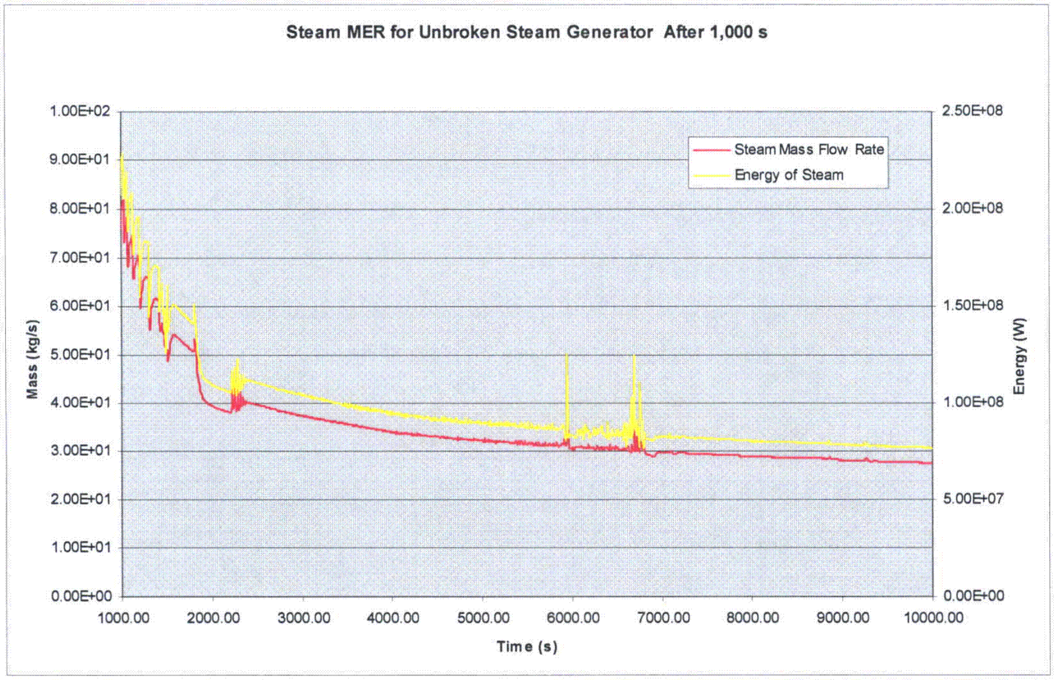


Figure 19-322e-8—Steam Mass Flow Rate and Energy from Unbroken Steam Generator from 1,000s after the Start of the Accident



Question 19-323:

In MAAP scenario st1_10a, hydrogen generation in the ex-vessel phase ceases at 20 hours at a peak value of about 1200 kg, indicating complete oxidation of the available previously unoxidized metal. Please provide an inventory of the amounts of metal in the corium outside the vessel at the various stages prior to this point, i.e., before and after vessel failure and before and after failure of the melt plug gate. This will help in understanding the MELCOR results which show the oxidation continuing unabated.

Response to Question 19-323:

A response to this question will be provided by September 30, 2009.

Question 19-324:

In several instances, the MAAP results have been "influenced to the conservative side" by the judgmental use of selected model and parameters. This appears in such areas as in-vessel hydrogen generation, melt temperature at vessel breach, water/steam discharge from the reactor coolant system into the containment, MCCI, and containment pressurization, among others. Please provide a discussion of significant input parameters of this nature, especially, as related to the above listed figures-of-merit.

Response to Question 19-324:

A response to this question will be provided by September 30, 2009.

Question 19-325:

Please provide the view factors and surface emissivity values used in the MAAP calculation of radiation heat transfer from the core debris to various heat sinks/surfaces inside the reactor pit.

Response to Question 19-325:

Table 19-325-1 contains the view factors between surfaces in the reactor pit used in the modular accident analysis program (MAAP) calculation. The surfaces are defined as follows:

- Surface 1 represents the corium pool upper crust.
- Surface 2 represents the reactor pit upper wall.
- Surface 3 through Surface 7 represent the outer surfaces reactor vessel lower plenum axial nodes 1 through 5.

Table 19-325-2 contains the surface emissivity values used in the MAAP calculation.

FSAR Impact:

The U.S. EPR FSAR will not be changed as a result of this question.

Table 19-325-1—View Factors

Surface	1	2	3	4	5	6	7
1	0.000000	0.379958	0.0776191	0.125786	0.158479	0.150624	0.107534
2	0.375803	0.132483	0.00144021	0.0242712	0.0639426	0.143717	0.258342
3	0.981586	0.0184145	0.000000	0.000000	0.000000	0.000000	0.000000
4	0.836757	0.163243	0.000000	0.000000	0.000000	0.000000	0.000000
5	0.710258	0.289742	0.000000	0.000000	0.000000	0.000000	0.000000
6	0.508984	0.491016	0.000000	0.000000	0.000000	0.000000	0.000000
7	0.291631	0.708369	0.000000	0.000000	0.000000	0.000000	0.000000

Table 19-325-2—Surface Emissivity Values

Description	Value
Emissivity of Water	0.9
Emissivity of Walls	0.85
Emissivity of Hot Leg Walls	0.65
Emissivity of Corium Surfaces	0.85
Emissivity of Equipment	0.85
Emissivity of Gas	0.65
Emissivity of Steam	0.1

Question 19-326:

RAI 19-161 follow-up: It was pointed out by AREVA in the audit meeting on 6/25/2009 that several of the tables of MAAP results reported in response to RAI 19-161 contain transcription errors. Please provide the corrected tables.

Response to Question 19-326:

The corrected MAAP results tables have been submitted in the Response to RAI 22, Supplement 4, Question 19-161.

FSAR Impact:

The U.S. EPR FSAR will not be changed as a result of this question.