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

Response to U.S. EPR Design Certification Application RAI No. 389, Supplement 10

In Reference 1, the NRC provided a request for additional information (RAI) regarding the U.S. EPR design certification application. Reference 2 provided a schedule for a technically correct and complete response to RAI No. 389. Reference 3 and Reference 4 provided revised schedules for a technically correct and complete response to RAI No. 389. Reference 5 provided Supplement 3 response to RAI No. 389 with a technically correct and complete response to one of the five questions. Reference 6, Reference 7, Reference 8 and Reference 9 provided revised response schedules. Reference 10 provided Supplement 8 response to RAI No. 389 with a technically correct and complete response to one of the four remaining questions. Reference 11 provided a revised response schedule for the three remaining questions.

The enclosure to this letter provides technically correct and complete final responses to Question 06.02.02-47 and Question 06.02.02-51. AREVA NP considers some of the material contained in the attached response to be proprietary. As required by 10 CFR 2.390(b), an affidavit is enclosed to support the withholding of the information from public disclosure. Proprietary and non-proprietary versions of the enclosure to this letter are provided.

The following table indicates the respective pages in the enclosure that contain AREVA NP's final response to the subject questions.

Question #	Start Page	End Page
RAI 389 — 06.02.02-47	2	30
RAI 389 — 06.02.02-51	31	31

A complete response is not provided for the one remaining question. The schedule for a technically correct and complete response is changed and is provided below.

Question #	Response Date
RAI 389 — 06.02.02-50	July 27, 2011

D077
NRO

If you have any questions related to this submittal, please contact me by telephone at 434-832-2369 or by e-mail to sandra.sloan@areva.com.

Sincerely,

Sandra M. Sloan

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

Enclosures

cc: G. Tesfaye
Docket No. 52-020

References

Ref. 1: E-mail, Getachew Tesfaye (NRC) to Martin C. Bryan (AREVA NP Inc.), "U.S. EPR Design Certification Application RAI No. 389 (4615) FSAR Ch. 6," June 2, 2010.

Ref. 2: E-mail, Martin C. Bryan (AREVA NP Inc.) to Getachew Tesfaye (NRC), "Response to U.S. EPR Design Certification Application RAI No. 389, FSAR Ch. 6," June 30, 2010.

Ref. 3: E-mail, Martin C. Bryan (AREVA NP Inc.) to Getachew Tesfaye (NRC), "Response to U.S. EPR Design Certification Application RAI No. 389, FSAR Ch. 6, Supplement 1," August 4, 2010.

Ref. 4: E-mail, Martin C. Bryan (AREVA NP Inc.) to Getachew Tesfaye (NRC), "Response to U.S. EPR Design Certification Application RAI No. 389, FSAR Ch. 6, Supplement 2," September 1, 2010.

Ref. 5: E-mail, Martin C. Bryan (AREVA NP Inc.) to Getachew Tesfaye (NRC), "Response to U.S. EPR Design Certification Application RAI No. 389, FSAR Ch. 6, Supplement 3," October 6, 2010.

Ref. 6: E-mail, Martin C. Bryan (AREVA NP Inc.) to Getachew Tesfaye (NRC), "Response to U.S. EPR Design Certification Application RAI No. 389, FSAR Ch. 6, Supplement 4," October 13, 2010.

Ref. 7: E-mail, Martin C. Bryan (AREVA NP Inc.) to Getachew Tesfaye (NRC), "Response to U.S. EPR Design Certification Application RAI No. 389, FSAR Ch. 6, Supplement 5," November 17, 2010.

Ref. 8: E-mail, Martin C. Bryan (AREVA NP Inc.) to Getachew Tesfaye (NRC), "Response to U.S. EPR Design Certification Application RAI No. 389, FSAR Ch. 6, Supplement 6," February 9, 2011.

Ref. 9: E-mail, Martin C. Bryan (AREVA NP Inc.) to Getachew Tesfaye (NRC), "Response to U.S. EPR Design Certification Application RAI No. 389, FSAR Ch. 6, Supplement 7," March 8, 2011.

Ref. 10: E-mail, Martin C. Bryan (AREVA NP Inc.) to Getachew Tesfaye (NRC), "Response to U.S. EPR Design Certification Application RAI No. 389, FSAR Ch. 6, Supplement 8," March 31, 2011.

Ref. 11: E-mail, Martin C. Bryan (AREVA NP Inc.) to Getachew Tesfaye (NRC), "Response to U.S. EPR Design Certification Application RAI No. 389, FSAR Ch. 6, Supplement 9," April 19, 2011.

AFFIDAVIT

COMMONWEALTH OF VIRGINIA)
) ss.
COUNTY OF CAMPBELL)

1. My name is Sandra M. Sloan. I am Manager, Regulatory Affairs for New Plants, 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. 389, Supplement 10" 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 1st

day of June, 2011.

Kathleen A. Bennett

Kathleen A. Bennett
NOTARY PUBLIC, COMMONWEALTH OF VIRGINIA
MY COMMISSION EXPIRES: 8/31/2011
Reg. #110864

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

Response to

Request for Additional Information No. 389(4615), Revision 1, Supplement 10

6/2/2010

U. S. EPR Standard Design Certification
AREVA NP Inc.
Docket No. 52-020
SRP Section: 06.02.02 - Containment Heat Removal Systems
Application Section: FSAR Chapter 6

QUESTIONS for Containment and Ventilation Branch 1 (AP1000/EPR Projects) (SPCV)

Question 06.02.02-47:

In the revised GOTHIC model the fluid entering the core is limited to that which is boiled away by decay heat plus 5% of the total ECCS flow. The 5% of ECCS fraction is assumed to be carried out of the core as liquid. One quarter of this liquid flow is assumed to be turned to steam as the remaining sensible heat is removed from the reactor system metal above the reactor vessel nozzles and from the broken loop steam generator metal and fluid. This steam flows into the containment building and acts to pressurize the containment. The remaining three quarters of the liquid flow is assigned to the intact loops where any steam produced is condensed by the ECCS water injected in the cold legs. The NRC staff requested additional justification for the 5% of total ECCS flow entrainment assumption. See RAI 221 06.02.01-35a. The NRC staff questioned the validity of the assumed equal flow split. See RAI 221 06.02.01-35b.

AREVA responded to these RAIs by comparing the integrated heat flow to the steam and to the liquid in the reactor system between the GOTHIC reactor system model and that calculated by RELAP5/MOD2-BW. The RELAP5/MOD2-BW analysis does not assume the loop seals to be blocked and calculates its own liquid entrainment and flow split. The staff has not accepted the M&E results from RELAP5/MOD2-BW beyond the time when AREVA assumes that the intact loop seals could be blocked in ANP-100299P Rev. 2. This is because RELAP5/MOD2-BW may calculate the steam source to the containment to be too low because of non-conservative assumptions for steam condensation in the cold legs beyond the time when the intact loop seals could be blocked.

The staff therefore requests that AREVA calculate the M&E source for cold leg breaks using phenomenological considerations for two phase level swell in the core and to assume that all steam and water carried out of the reactor vessel travels out of the broken loop after the time when the loop seals in the intact cold legs are blocked. With the revised M&E source, calculate the containment pressure for cold leg breaks using AREVA's multi-noded GOTHIC containment model.

Response to Question 06.02.02-47:

(Acronyms used in the response to this question are defined in Table 06.02.02-47-1.)

A quasi-steady, static balance, modeling approach is used to assess the mass and energy (M&E) source for cold leg pump suction breaks. The modeling includes phenomenological considerations for two-phase level swell in the core. The level swell can extend into the steam generators (SGs), where water is available for evaporation. The assessment also includes a physically based criterion for intact loop-seal venting and blocking.

The modeling approach is adapted from the Response to RAI 403, Question 15.06.05-69 to Question 15.06.05-78.

Considering the evaporation of water in the SGs, the analysis shows that the current GOTHIC methodology provides an adequately conservative estimate of steam flow to containment.

Analytical Methodology:

Figures 06.02.02-47-1 through 06.02.02-47-3 illustrate the modeling for the approach of this assessment, which is based on static balance concepts applied to the reactor system. Figures

06.02.02-47-1 through 06.02.02-47-3 show direct steam discharge from the broken loop SG to the break. The vented intact loops flow to the downcomer, where they combine and flow to the break. The vented intact loop steam flow to containment is reduced by condensation from subcooled water from the safety injection (SI). Non-vented (blocked) loop seals do not allow steam flow.

The static balance concept used for this assessment is based on the following:

1. The primary system is assumed to have reached a quiescent state without significant fluid dynamic effects. For those conditions, a set of steady-state pressure drop equations can be created based on hydrostatics and steam flow resistance. Together with steady-state mass and energy equations, this equation set can be solved for the collapsed liquid level in the reactor vessel (RV), steam flow rates, and pressures at a selected decay power. [

   ] The two-phase mixture can extend into the SGs, where water can evaporate and add to the loop steam flow. The total steam flow to containment depends on the added evaporation in the SGs, the number of vented loops, and the condensation of steam flowing in the vented intact loops by subcooled SI water. By following a decay heat table, the steady-state solutions are a function of time from reactor shutdown.
2. Figure 06.02.02-47-1 through Figure 06.02.02-47-3 show modeling concepts specific to the cold leg suction break:

[

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[ ]

3. The broken loop is always vented for a suction break, while the intact loops can either be vented or non-vented. A loop seal fills by countercurrent backflow of subcooled water from SI in the discharge piping through the pump. A loop seal of an intact loop, without SI, could also fill by countercurrent backflow from a sufficient head of water in the downcomer. Based on countercurrent flow limiting (CCFL) considerations, a loop seal is flooded with the availability of SI water as decay heat steaming is reduced during post-reflood. The steam in a vented intact loop flows from the upper plenum to its respective cold leg. A non-vented intact loop has no steam flow because the loop seal has filled with water and blocks the steam flow.
4. Vented and non-vented intact loops can coexist because there are two pressure drop solutions. Figure 06.02.02-47-2 shows Z_1 above the loop seal and in balance with the loop seal water level Z_{3LS} and other aspects of pressure drop for a vented loop. Figure 06.02.02-47-3 shows the same Z_1 in a non-vented loop (zero steam flow), where Z_1 is in simple hydrostatic balance with water level Z_3 that is above the loop seal on the SG side. Depression of Z_3 below the top of the loop seal allows vapor to enter the loop seal. Vapor entry into the vertical section under the pump reduces the liquid hydrostatic head. The resulting pressure imbalance drains the loop seal like a "plumbing trap" and allows loop venting. [ ] While a higher or lower value could be selected, this value was chosen because water depression to that level is the start of significant vapor flow in a loop seal. See the Response to RAI 403, Question 15.06.05-73 for more information.
5. Liquid flow at the core inlet consists of two components. The first component is the makeup water needed to support boil off in the core from decay power. The second component is the water that will be evaporated in the SG(s) if the two-phase mixture level Z_2 extends into the SG tubes. Both water components contribute to the total steam flow in the loops.
6. Water evaporation by heat transfer from primary system structures is comparatively small to water evaporation in the SGs.
7. Two trains of low head safety injection (LHSI) and medium head safety injection (MHSI) are operational. They inject more than adequate water to maintain the postulated water levels. LHSI water is subcooled by the residual heat removal (RHR) heat exchanger. MHSI water is not subcooled by the RHR heat exchanger. Its temperature is defined by containment modeling. With adequate water inventory in the in-reactor water storage tank (IRWST),

LHSI and MHSI injection continuously delivers water to the primary system for the required time.

8. Mixing of subcooled SI water with intact loop steam provides condensation benefits as follows:
   A. SI into a vented intact loop mixes subcooled water with steam at the injection point.
   B. SI into a non-vented (blocked) intact loop flows to the upper downcomer where it mixes with steam from other vented loop(s) en route to the break.
   C. SI of subcooled water into the broken loop mixes with the steam from the intact loops as it passes the broken loop injection point.
   D. The suction break is unique because the broken loop steam flow discharges directly to containment. Subcooled water flowing to the break from the RV side could condense some broken loop steam, depending on the nature of the break. This condensation benefit is not included.
   E. Two trains of SI are available for steam condensation from the intact loops. All or part of the steam is condensed, depending on the steam flow rates and the SI flow rates and temperature.
9. This assessment considers the time from the end of reflood (1200 seconds) to the time of hot leg injection (3600 seconds). Hot leg injection suppresses core steaming and effectively ends the steam load to containment as described in Reference 1, Section 8.3.1 and Section 8.3.2. Hot leg injection is not included in this assessment.

Static Balance Equation Summary

Six equations exist in the static balance model used for this assessment.

Path 1, Bypass

The pressure drop is based on steam flow resistance. A maximum flow resistance coefficient is selected to minimize the steam flow in this path.

$$P_{UP} - P_{CL} = \frac{1}{2g_c\rho_g}\left(\frac{K}{A^2}\right)_{BYP}\left|w_{gBYP}\right|w_{gBYP}$$

Path 2, Vented Intact Loop(s)

The intact vented loops are identical. The pressure drop is based on steam flow resistance and a two-phase mixture gravity head in the vertical leg below the RCP. The flow resistance is defined for the loop and the RCP.

$$P_{UP} - P_{CL} = \rho_f\left(1-\overline{\alpha}\right)\left(Z_{CL} - Z_{3LS}\right)\frac{g}{g_c}$$
$$+\frac{1}{2g_c\rho_g}\left(\frac{1}{\overline{\alpha}^2}\left(\frac{K}{A^2}\right)_{Pump} + \left(\frac{K}{A^2}\right)_{ILoop}\right)\left|w_{gILoop}\right|w_{gILoop} \quad w_{gILoop} > 0, \overline{\alpha} > 0$$

Path 3, Downcomer to Upper Plenum via Core

The pressure drop is defined by gravity heads in downcomer and core, and by a small frictional resistance at the core inlet. The gravity head difference creates the pressure difference that drives flow through the core and loops. Both the downcomer and core liquid densities are taken at saturated liquid density.

$$P_{UP} - P_{CL} = \rho_f\left(Z_{CL} - Z_1\right)\frac{g}{g_c} - \frac{1}{2g_c\rho_f}\left(\frac{K}{A^2}\right)_{Inlet}\left|w_{in}\right|w_{in}$$

Path 4, Upper Plenum to Break

The pressure drop is defined by steam flow resistance along the path from the upper plenum, through the SG, and to the break. No elevation components are included in this steam flow path.

$$P_{UP} - P_{Brk} = \frac{1}{2g_c\rho_g}\left(\frac{K}{A^2}\right)_{SGBL}\left|w_{gBLoop}\right|w_{gBLoop}$$

Path 5, Downcomer/Cold Leg to Break

The pressure drop is defined by flow resistance and a gravity head. The flow resistance includes the frictional resistance in the piping from the RV to the break and through the RCP. The gravity head terms defines the contribution of the elevation difference between the cold leg and the break. The break elevation can range from the loop seal to the outlet of the SG. It affects the number of vented loop seals and the steam flow split to containment through the broken and intact loops.

The intact loop flow rates are combined and mixed with subcooled SI to define the total flow rate to containment from the RV side of the break. The flow rate is assumed to be liquid because of the expected condensation of intact loop steam.

$$P_{CL} - P_{Brk} = \rho_f\left(Z_{Brk} - Z_{CL}\right)\frac{g}{g_c} + \frac{1}{2g_c\rho_f}\left(\left(\frac{K}{A^2}\right)_{Pump} + \left(\frac{K}{A^2}\right)_{RVBL}\right)\left|w_{ILCon}\right|w_{ILCon}$$

Core Upper Plenum Mass Balance

The core steaming rate is divided into paths through the broken loop, intact loop(s), and the bypass.

$$w_g = w_{gBL} + (N_V - 1)w_{gIL} + w_{gBYP}$$

These six equations are from the static balance model. They are nonlinear and solved in matrix form using a Newton iteration process.

Two-phase Level Swell

The two-phase level swell solution is superimposed on the static balance solution. This calculation determines the height of the two-phase mixture that produces a gravity head consistent with the collapsed level, Z_1. The collapsed level is defined mathematically as:

$$Z_1 = \int_0^{Z_2} (1 - \alpha(z))dz$$

[

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The integration to determine the two-phase mixture level, Z_2, is done numerically using the nodal arrangement shown in Figure 06.02.02-47-4. Multiple nodes exist in the core to account for non-uniform axial power. Nodes are added above Z_{CORE} to determine Z_2.

The equations are solved by using a Newton iteration process to determine the start of boiling, Z_0, two-phase mixture level, Z_2, and the core steaming rate, w_g. Input to the computation includes:

1. Collapsed level Z_1.
2. Linear heat rate.
3. Broken and intact steaming rates.
4. Bypass steam flow.
5. Broken and intact loop water flow rates to be evaporated in the SGs.

The broken and intact loop two-phase mixture levels share a common collapsed level, Z_1. A check calculation confirms that the broken and intact loop two-phase mixture level solution correctly produce the same Z_1.

Assessment of Steam Flow to Containment

Several modeling approaches are discussed, which estimate steam flow to containment. The entrained water evaporation in the SG is a critical results factor. The following cases are considered:

- Level Swell with No Evaporation.
- Level Swell with Full Evaporation.
- Level Swell with Evaporation Estimate from RELAP5/MOD2-BW.

Table 06.02.02-47-2 presents an input summary.

Level Swell with No Evaporation

Figure 06.02.02-47-5 shows the broken loop steam flow rates to containment for the low and high elevation breaks. The steam flow rate for the high elevation break is identical to the core steaming rate because the broken loop is the only vented loop. The intact loops have blocked loop seals.

The steam flow rate from the broken loop for the low elevation break is less than the core steaming rate. The core steaming rate balance flows into the vented intact loop, and is condensed by subcooled SI flow en route to the break.

The liquid gravity head in the piping from the RV to the break causes reduced flow rate in the broken loop. That gravity head reduces the cold leg and upper plenum pressure relative to the break and reduces the steam flow. The liquid gravity head "siphons" water from the RV.

Figure 06.02.02-47-6 shows the collapsed level, Z_1, and the two-phase mixture levels, Z_2, for the low elevation suction break. The collapsed level is just above the loop seal and is constant. The intact loops are vented as the water elevations on the SG side of the loop seals are sufficiently depressed to allow vapor flow. The two-phase level swell is initially large and decreases with decay power. The inlet to the SG tubes is Elevation 32.24 feet. The broken loop mixture level drops below that elevation around 2800 seconds, and water is unavailable for evaporation. The intact loop mixture level is above tube inlet elevation throughout the required time.

The collapsed level for the high elevation suction break is above the loop seals elevation because of the added pressure imposed by the head of water in the broken loop on the RV side of the break. The broken loop from the SG is the only vented loop. The intact loop seals are blocked.

Both the low and high elevation breaks results for this case show that water is available for evaporation in the SGs.

Level Swell with Full Evaporation

The previous case shows that the core steaming rate can produce two-phase mixture levels extending into the SGs. Water evaporation in the SG tubes reduces the two-phase mixture elevation component needed to balance with the collapsed level, Z_1. The liquid flow rate to the SG must increase. Assuming that the water evaporates during entry to the SG, there is a flow rate where the two-phase level can be brought to the elevation at the start of the SG tubes. This assumption produces maximum evaporation in the SGs without considering the more realistic details of the heat transfer rate processes.

An iterative process is used to compute the liquid flow rates to be evaporated in the broken and intact loop SGs. Those flow rates are also included in the core inlet flow rate. They are used as liquid flow boundary conditions at the hot legs for the computation of the two-phase mixture levels in the broken and intact loop SGs.

Low Elevation Break

Table 06.02.02-47-3 presents the steam flow rates and added liquid flow rates to the broken and intact loop SGs for the low elevation break. Until approximately 2000 seconds, the added liquid flow rates for evaporation are larger than those from the core steaming rate. Table 06.02.02-47-3 also shows the vented loop count. The four loops are venting initially, followed by a transition to three loops and then to two loops.

Figure 06.02.02-47-7 shows the steam flow rate to containment for the low elevation break. The steam flow rate from the SG side of the broken loop (wg_BLCon) is less than the core steaming rate, even though there is full evaporation of water reaching in the SG. The flow rate is lower because of the reduced pressure in the cold leg and upper plenum caused by the liquid gravity head term in the leg from the RV to the low elevation break.

The intact loop flow rate (wg_ILCon) is not completely condensed until approximately 2400 sec. The presence of intact loop steam produces a gravity head less than the liquid gravity head assumption for a relatively short time, prior to 2400 seconds. Beyond 2400 seconds, the intact loop steam is condensed and the steam flow rate decreases to zero as the vented loop count decreases.

High Elevation Break

Table 06.02.02-47-4 presents the steam flow rates and added liquid flow rates for the broken and intact loop SGs for the high elevation break. The added evaporation rates from liquid entrainment are also larger than those from the core steaming rate. The added liquid flow rate for the broken loop, wf_BL, is larger because of the required large depression of the collapsed level, Z_1, needed to balance the pressure drops.

The level depression is important to loop venting. Table 06.02.02-47-4 shows that the four loops are venting initially, followed by a transition to three loops and then to two loops.

Figure 06.02.02-47-8 shows the steam flow rate to containment for the high elevation break. The steam flow rate from the SG side of the broken loop (wg_BLCon) is higher than the core steaming rate because of the high added water evaporation rate in the SG. The steam flow rate is higher because of the higher upper plenum pressure caused by the liquid gravity head term in the leg from the RV to the high elevation break. That gravity head increases the cold leg, and the upper plenum pressure follows. The intact loop steam flow to containment (wg_ILCon) is not fully condensed until about 2000 seconds. Beyond that time, the steam flow decreases to zero.

Level Swell with Evaporation Estimate from RELAP5/MOD2-BW

The two cases described show the extremes between no evaporation and full evaporation of water reaching into the SGs. The full evaporation case is unrealistic because the FLECHT-SEASET experiments show that a fraction of entrained water survives the evaporation process.

Though the FLECHT-SEASET experiments for the SG appear to be steady-state experiments, they are actually transient experiments because of the space and time behavior of quench fronts and other phenomena. The test documentation in the "Steam Generator Separate Effect Task Data Report" (Reference 2) only provides data suitable for validation of computer codes.

Derived heat transfer coefficients are excluded from the reported data. Direct extension of the data is impossible because of the scaling and time differences between the experiments and the U.S. EPR SGs. FLECHT-SEASET heat transfer information does not directly apply to this assessment.

An alternate approach uses RELAP5/MOD2-BW to estimate heat transfer to the primary side of the SGs. RELAP5/MOD2-BW is validated against the FLECHT-SEASET experimental data as reported in "Applicability of AREVA NP Containment Response Evaluation Methodology to the U.S. EPR for Large Break LOCA Analysis Technical Report" (Reference 1), Section 6.1.3. RELAP5/MOD2-BW includes the complexities of SG heat transfer, such as heat transfer rate processes, thermal non-equilibrium, quench front phenomena, secondary side fluid inventory, fluid velocities, vapor fraction, and heat transfer modes. Using RELAP5/MOD2-BW in this context provides estimates of the heat transfer to the primary side of the SGs. RELAP5/MOD2-BW is only used to display SG heat transfer related phenomena for this discussion.

The RELAP5/MOD2-BW, U.S. EPR modeling uses a single loop to represent the broken loop and a second loop to model the remaining three loops (triple loop). Although the modeling does not examine loop seal blockages details, or venting, RELAP5/MOD2-BW computations can provide a credible estimate of heat transfer for the evaporation of entrained water in the SGs.

The current suction break of record is the low elevation suction break at the loop seal. That case is rerun to 3600 seconds. A new case with the suction break located at the exit of the SG is run to 3600 seconds. The following sections discuss the results of the RELAP5/MOD2-BW computations of SG heat transfer to primary.

RELAP5/MOD2-BW Low Elevation Suction Break

This break is located at the pipe centerline elevation at the bottom of the loop seal.

Figure 06.02.02-47-9 shows the vapor flow rate at the inlet and exit of the broken loop SG. The figure shows that the inlet and exit mass flow rates are approximately the same. The data indicate that the exit flow rate is larger, which shows some water evaporation in the SG. The magnitude of the flow rate is similar to the static balance result in Figure 06.02.02-47-7. Also, the flow rate is significantly less than the core steaming rate.

Figure 06.02.02-47-10 shows the vapor flow rate at the inlet and exit of the intact (triple) loop SG. The figure shows that the exit steam flow rate is larger than at the inlet, and the difference decreases with time. The sum of the flow rates in Figure 06.02.02-47-9 and Figure 06.02.02-47-10 is above the core steaming rate (see Figure 06.02.02-47-5 for an example).

Figure 06.02.02-47-11 shows the vapor flow rate to containment from the broken and intact (triple) loops. This sum is below the core steaming rate (see Figure 06.02.02-47-5 for an example). The flow rate from the intact loop decreases to zero at about 2200 seconds, with a noisy flow rate prior. The steam flow to containment is similar to the static balance result in Figure 06.02.02-47-7.

Figure 06.02.02-47-12 shows the heat transfer "from" the broken loop SG, indicated by the negative sign. The heat transfer rate is modest, starting at approximately 6 MW and decreasing to zero at approximately 2400 seconds. This is consistent with the observed slight difference between the inlet and exit steam flow rates in Figure 06.02.02-47-9.

Figure 06.02.02-47-13 shows the heat transfer "from" the intact (triple) loop SG, indicated by the negative sign. The heat transfer rate is larger than in the broken loop. It starts at approximately 40 MW and decreasing toward zero with time. This is consistent with the observed larger difference between the inlet and exit steam flow rates that decreases with time in Figure 06.02.02-47-10.

The steam flow rates to containment are similar between RELAP5/MOD2-BW and the static balance model with full SG evaporation shown in Figure 06.02.02-47-7. The steam flow rates to containment are less than the core steaming rate for both the static balance model and the RELAP5/MOD2-BW model.

<u>RELAP5/MOD2-BW High Elevation Suction Break</u>

The break occurs at the SG exit.

Figure 06.02.02-47-14 shows the vapor flow rate at the inlet and exit of the broken loop SG. The figure shows that the exit flow rate is larger, which indicates some water evaporation in the SG. The flow rate is less than the core steaming rate.

Figure 06.02.02-47-15 shows the vapor flow rate at the inlet and exit of the intact (triple) loop SG. The figure shows that the exit mass flow rate is larger than at the inlet. The flow rates go to zero at approximately 2400 seconds, followed by some flow "spikes." The sum of the flow rates in Figure 06.02.02-47-14 and Figure 06.02.02-47-15 is above the core steaming rate (see Figure 06.02.02-47-5 for an example).

Figure 06.02.02-47-16 shows the vapor flow rate to containment from the broken and intact (triple) loops. The steam flow rate from the intact (triple) loop is zero. The flow rate from the broken loop to containment is the same as in Figure 06.02.02-47-14. It is less than the core steaming rate.

The flow behavior is different from the static balance model with 100 percent evaporation. The static balance model produces a higher broken loop steam flow rate with 100 percent evaporation.

Figure 06.02.02-47-17 shows the vapor fraction in the broken loop SG. The exit void fraction is higher than the inlet void fraction, indicating some evaporation. The void fraction throughout the SG is below 1.0 and near 0.9. A significant amount of water is flowing in the SG, which adds a gravitational component to the pressure drop in that path. The static balance model is based on steam flow only through the SG, and it does not include gravity head components in the pressure drop equations.

Figure 06.02.02-47-18 shows the heat transfer "from" the broken loop SG, indicated by the negative sign. The heat transfer rate is modest, starting at approximately 6 MW and decreases toward zero at approximately 3600 seconds. This is consistent with the observed small difference between the inlet and exit steam flow rates in Figure 06.02.02-47-14.

Figure 06.02.02-47-19 shows the heat transfer "from" the intact (triple) loop SG, indicated by the negative sign. The heat transfer rate is initially higher than in the broken loop. It starts at approximately 40 MW and decreases to zero at approximately 2000 seconds, with some following "spikes". This is consistent with the observed larger difference between the inlet and exit steam flow rates that decreases with time in Figure 06.02.02-47-15.

Estimate of Steam Generator Heat Transfer from RELAP5/MOD2-BW

Figure 06.02.02-47-20 and Figure 06.02.02-47-21 show the RELAP5/MOD2-BW computed total heat transfer to the single (broken) loop SG and to the triple loop SG for both the low and high elevation break. The data are smoothed, extracted from the plot file, and imported to Excel. Linear trend lines through the RELAP5/MOD2-BW results provide the basis for the indicated bounds.

The bounding lines are the most limiting trend lines multiplied by a factor of two to add conservatism to the heat transfer estimate. The bounding lines capture the RELAP5/MOD2-BW heat transfer values, except for some oscillatory "spikes." The bound line for the triple loop is divided by three to get the heat transfer per SG for the intact loops.

Static Balance Results using Heat Transfer Estimate from RELAP5/MOD2-BW

The bounding heat transfer estimates from RELAP5/MOD2-BW are used in the static balance model to define the evaporation rates. The vaporization rate is the heat transfer to the primary side of the SG divided by the heat of vaporization. Figure 06.02.02-47-22 shows the steam flow rates to containment for the low and high elevation suction breaks.

The only flow rate to containment for the high elevation break is from the SG side of the broken loop. It is the core steaming rate plus the added evaporation of entrained water. The intact loops are blocked.

The flow rates to containment for the low elevation break are from the broken loop and from the intact loops at 1200 seconds, where three intact loops are venting. The steam discharge from the SG side of the broken loop is less than the core steaming rate. The balance of the core steaming rate flows in the intact loops. At two or less vented intact loops, the intact loop steam is condensed, and the total steam discharge to containment is less than the core steaming rate.

Figure 06.02.02-47-22 shows the core steaming rate and the GOTHIC assumption, where one fourth of the five percent emergency core cooling system (ECCS) flow rate (784 lbm/sec) is added to the core steaming rate. The broken loop steam flow rate for the limiting high elevation break follows under the GOTHIC assumed steam flow rate to containment.

Conclusion

The quasi-steady static balance model, applied to the suction break, shows different water evaporation rates that can increase the steam flow rates to containment. Heat transfer to the entrained water on the primary side of the SG defines the added evaporation rate. Full evaporation of entrained water is unrealistic based on observations from the FLECHT-SEASET experiments. RELAP5/MOD2-BW is validated against the FLECHT-SEASET experiments, and RELAP5/MOD2-BW is used to provide an estimate of the heat transfer to the SG primary side entrained water for low and high elevation suction breaks. Using conservative bounds of that heat transfer in the static-balance model provides a conservative estimate of the steam flow to containment.

Suction break elevation critically affects the steam flow rate to containment. The most limiting case is a high elevation suction break where the intact loop seals are blocked and the broken loop vents the steam to containment. The estimated steam flow rate to containment is less than that used in the GOTHIC methodology. Based on these results, the GOTHIC methodology is conservative and the M&E calculation does not need to be repeated for the suction break analysis of record.

References for Question 06.02.02-47:

1. ANP-10299P, Revision 2, "Applicability of AREVA NP Containment Response Evaluation Methodology to the U.S. EPR for Large Break LOCA Analysis Technical Report," AREVA NP Inc., December 2009.
2. PWR FLECHT-SEASET, "Steam Generator Separate Effect Task Data Report," Westinghouse Electric Corporation, July 1980 (Available as AREVA NP Document, 38-9089728-000).

FSAR Impact:

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

Table 06.02.02-47-1—Acronyms
(2 Sheets)

Variable	Definition
A_{CORE}	Flow area of active core, ft^2
A_{HL}	Flow area of hot leg pipe (same as cold leg pipe), ft^2
A_{SGPL}	Flow area of steam generator inlet plenum, ft^2
A_{SGT}	Flow area of steam generator tubes, ft^2
A_{UP}	Flow area of upper plenum, ft^2
D	Diameter, ft
g	Acceleration of gravity (32.2 ft/sec^2)
g_c	Gravity constant, (32.2 lbm/lbf)(ft/sec^2)
(K/A^2)	Hydraulic loss coefficient, ft^{-4}
N_0	Number of nodes in core subcooled region
N_2	Number of nodes in core two-phase region
N_S	Number of nodes in core steam region
N_V	Number of vented loop seals
P_{UP}	Upper plenum pressure relative to break, lbf/ft^2
P_{CL}	Cold leg/Downcomer pressure relative to break, lbf/ft^2
P_{Brk}	Break pressure, lbf/ft^2
w_{gBYP}	Steam flow rate through bypass, lbm/sec
w_{in}	Core inlet flow rate, lbm/sec
w_{fBL}	Water flow rate evaporated in broken loop steam generator, lbm/sec
w_{fIL}	Water flow rate evaporated in intact loop steam generators, lbm/sec
w_{gBL}	Steam flow rate from core to broken loop steam generator, lbm/sec

Table 06.02.02-47-1—Acronyms
(2 Sheets)

Variable	Definition
w_{gIL}	Steam flow rate from core to intact loop steam generator, lbm/sec
w_g	Steam flow rate generated in core, lbm/sec
w_{gBLoop}	Steam flow rate in broken loop, lbm/sec
w_{gILoop}	Steam flow rate in intact loop, lbm/sec
w_{gBLCon}	Steam flow rate to containment from broken loop, lbm/sec
w_{gILCon}	Steam flow rate to containment from intact loop, lbm/sec
w_{ILCon}	Total flow rate to containment from reactor vessel side of break, lbm/sec
z	Distance from core inlet, ft
Z_0	Elevation at start of boiling, ft
Z_1	System collapsed liquid level (collapsed level) for static-balance, ft
Z_2	Two-phase mixture elevation, ft
Z_{2BL}	Two-phase mixture elevation in broken loop steam generator, ft
Z_{2IL}	Two-phase mixture elevation in intact loop steam generator, ft
Z_3	Water level elevation on steam generator side of blocked loop seal, ft
Z_{3LS}	Water level elevation in vented loop seal, ft
Z_{CORE}	Elevation at top of active fuel, ft
Z_{CL}	Elevation of water in cold leg, ft
Z_{Break}	Elevation of suction break, ft
Z_{LS}	Elevation at top of cross-over pipe U-bend loop seal, ft
Z_{LSCen}	Elevation at center of cross-over pipe U-bend loop seal, ft
Z_{SGPL}	Elevation at inlet to steam generator plenum, ft
Z_{SGT}	Elevation at start of active steam generator tubes, ft
Z_{SGTS}	Elevation at bottom to steam generator tube sheet, ft
α	Void fraction
ρ_f	Saturated water density, lbm/ft^3
ρ_g	Saturated steam density, lbm/ft^3

Table 06.02.02-47-2—Common Input Summary

Table 06.02.02-47-3—SG Flow Rates for Full Evaporation, Low Elevation Break

Z_Brk = ZLS_cen (low), 100% SG Evaporation								
Time	wg	wg_BL	wf_BL	wg_IL	wf_IL	wg_byp	NV	Z1
sec	lbm/s	lbm/s	lbm/s	lbm/s	lbm/s	lbm/s		ft
1200	116.94	28.77	54.54	28.72	37.53	2.01	4	11.85
1600	106.01	26.04	42.63	26.02	36.42	1.92	4	12.62
2000	95.08	23.29	25.39	23.32	34.95	1.82	4	13.42
2400	90.41	29.50	19.55	29.53	29.66	1.85	3	13.25
2800	85.75	41.92	15.69	41.94	18.98	1.89	2	12.92
3200	81.85	39.99	10.00	40.02	19.35	1.85	2	13.22
3600	78.73	38.43	4.33	38.48	19.59	1.82	2	13.46

Table 06.02.02-47-4—SG Flow Rates for Full Evaporation, High Elevation Break

Z_Brk = Z_SGPL (high), 100% SG Evaporation								
Time	**wg**	**wg_BL**	**wf_BL**	**wg_IL**	**wf_IL**	**wg_byp**	**NV**	**Z1**
sec	lbm/s	lbm/s	lbm/s	lbm/s	lbm/s	lbm/s		ft
1200	116.94	29.11	187.96	28.61	37.37	2.00	4	11.91
1600	106.01	26.39	185.01	25.90	36.22	1.91	4	12.68
2000	95.08	31.39	176.61	30.90	29.85	1.88	3	12.95
2400	90.41	29.85	175.46	29.36	29.44	1.84	3	13.32
2800	85.75	42.18	165.54	41.69	18.86	1.88	2	12.99
3200	81.85	40.25	165.30	39.76	19.21	1.84	2	13.29
3600	78.73	38.71	165.05	38.22	19.43	1.81	2	13.54

Figure 06.02.02-47-1—Modeling Sketch for Suction Break

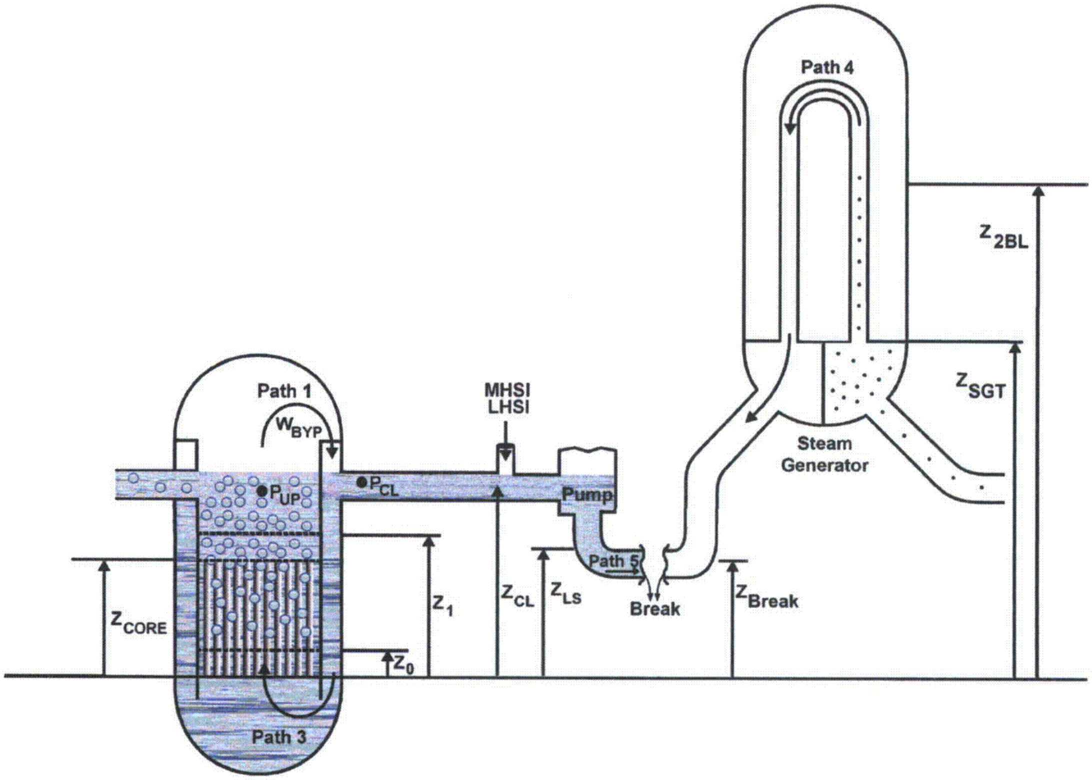


Figure 06.02.02-47-2—Modeling Sketch for Vented Intact Loop Seal

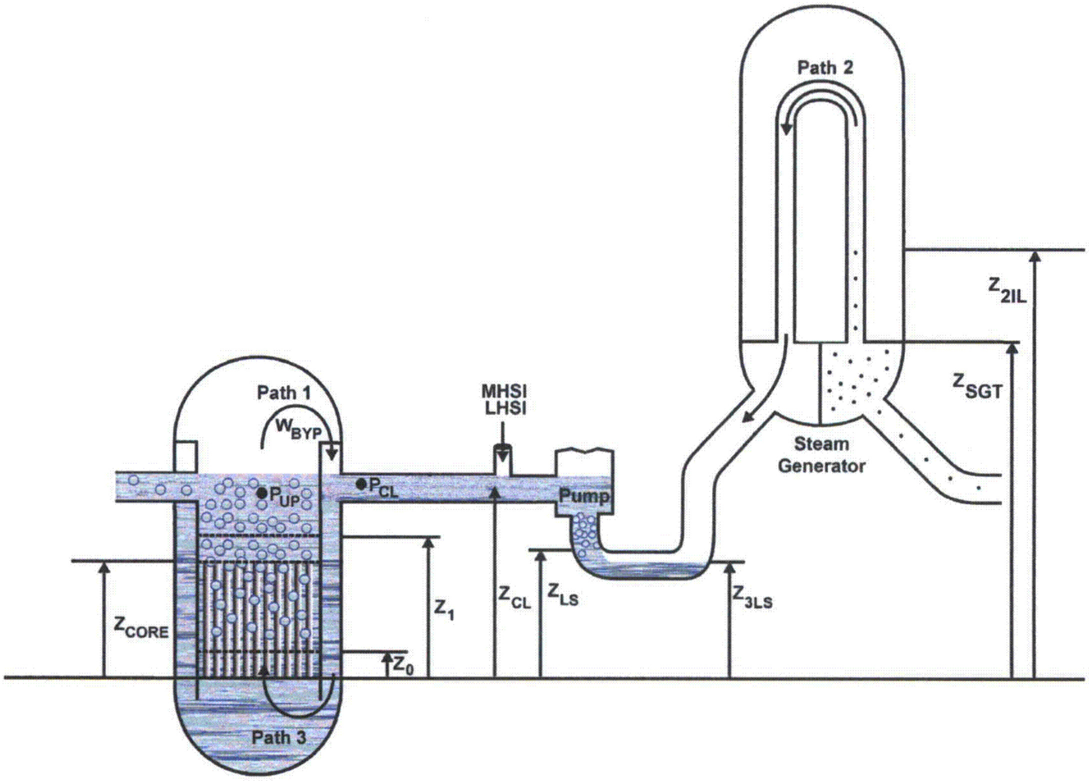


Figure 06.02.02-47-3—Modeling Sketch for Non-Vented Intact Loop Seal

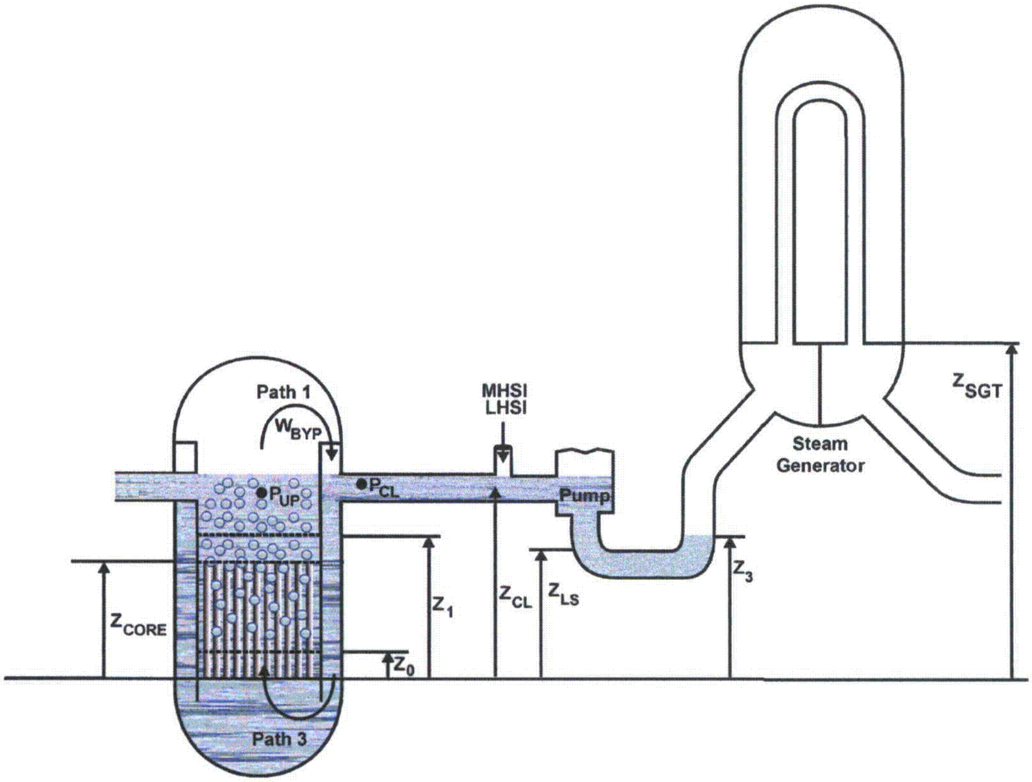


Figure 06.02.02-47-4—Nodal Arrangement Level Swell Computation

Figure 06.02.02-47-5—Steam Flow to Containment, No SG Evaporation

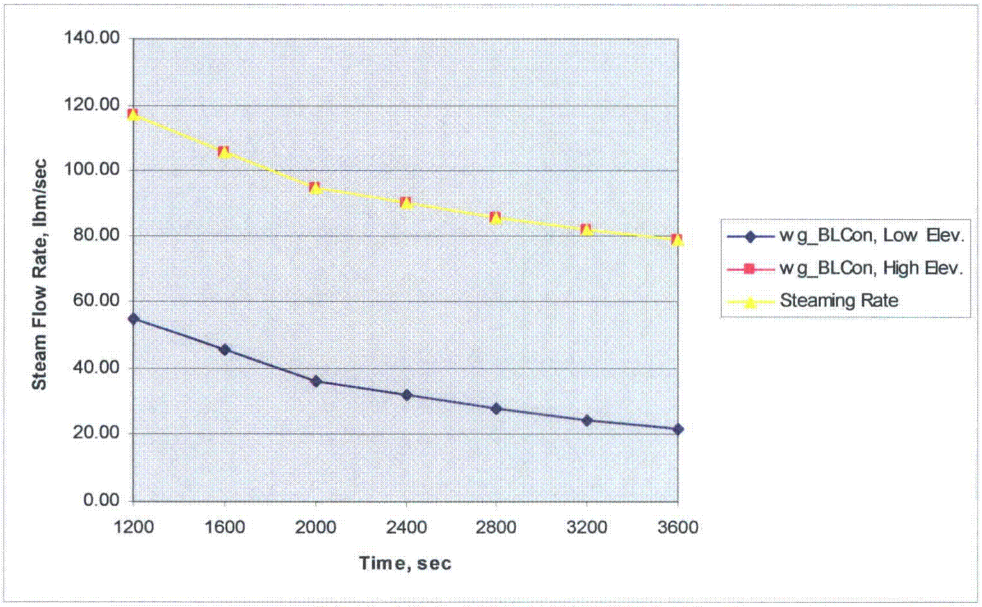


Figure 06.02.02-47-6—Two-Phase Mixture and Collapsed Levels, No SG Evaporation

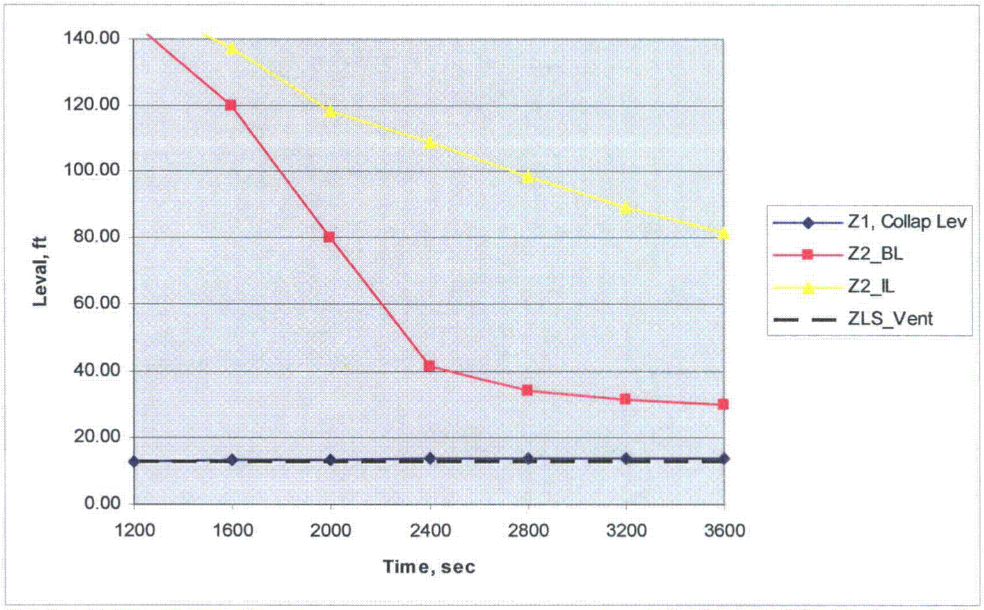


Figure 06.02.02-47-7—Steam Flow to Containment, Low Elevation Break, Full SG Evaporation

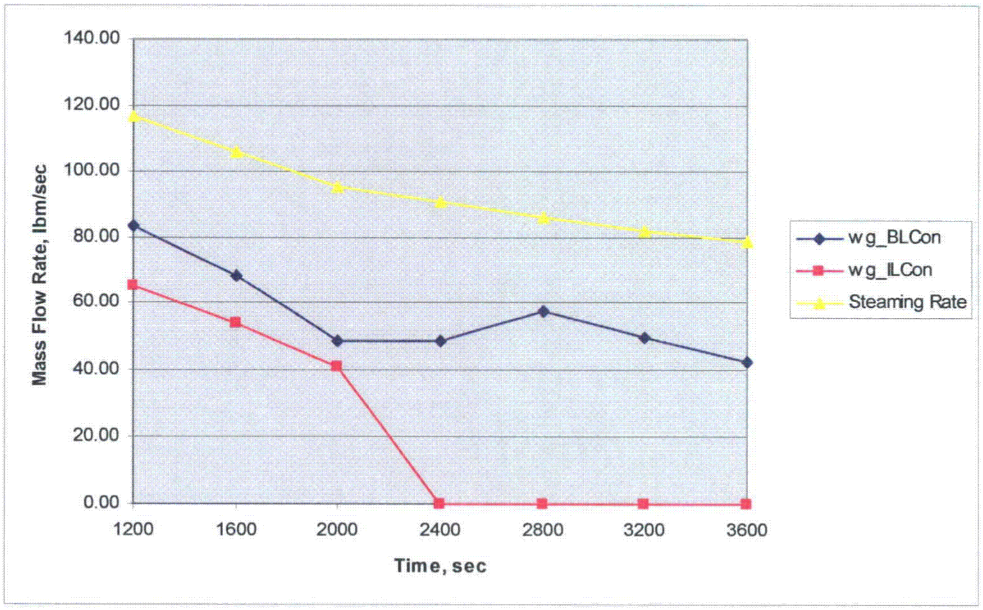


Figure 06.02.02-47-8—Steam Flow to Containment, High Elevation Break, Full SG Evaporation

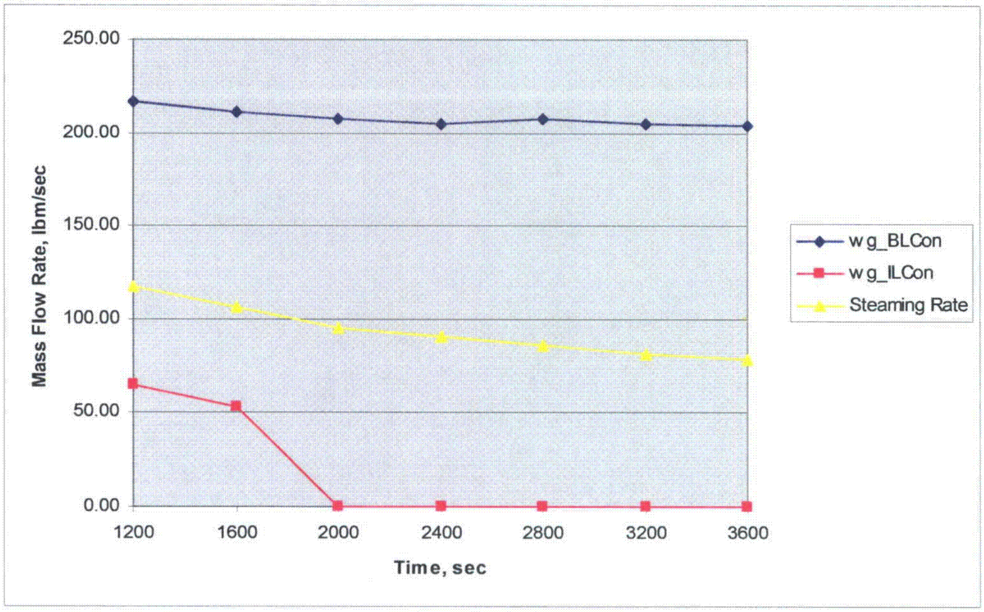
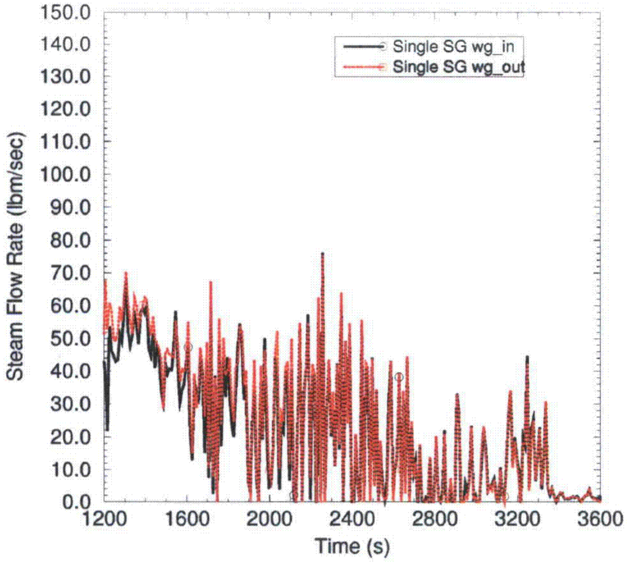
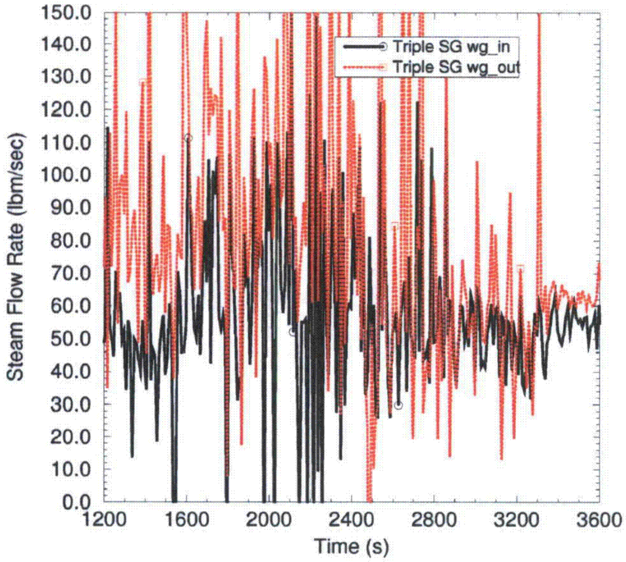


Figure 06.02.02-47-9—RELAP5/MOD2-BW, Single Loop SG Steam Flow, Low Elevation Break



TYOO

Figure 06.02.02-47-10—RELAP5/MOD2-BW, Triple Loop SG Steam Flow, Low Elevation Break



TYOO

Figure 06.02.02-47-11—RELAP5/MOD2-BW, Steam Flow to Containment, Low Elevation Break

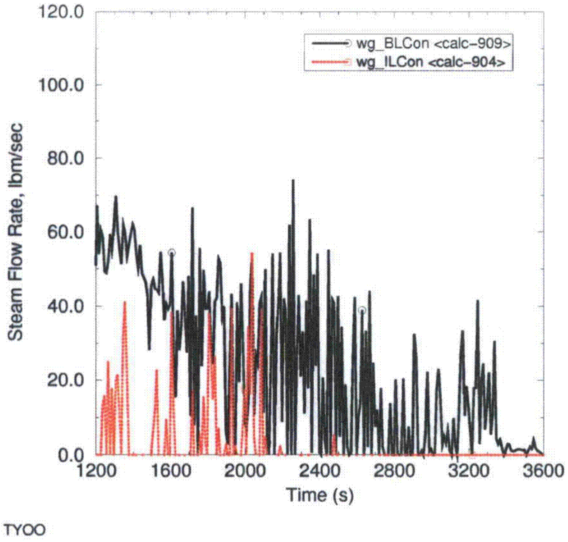


Figure 06.02.02-47-12—RELAP5/MOD2-BW, Single Loop SG Heat Transfer, Low Elevation Break

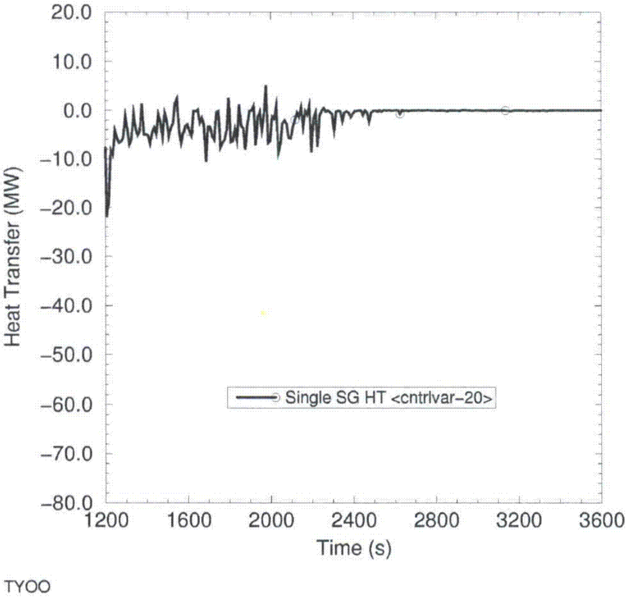
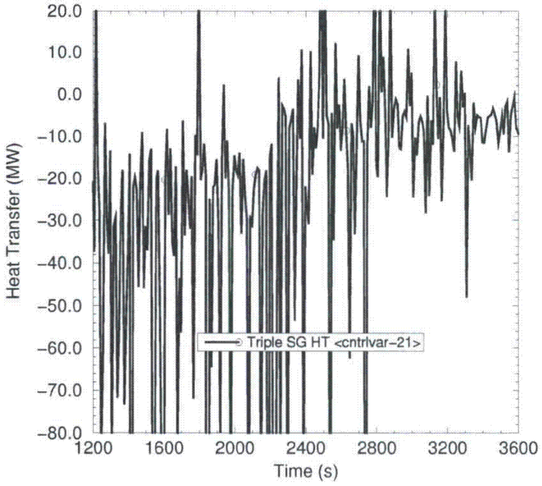
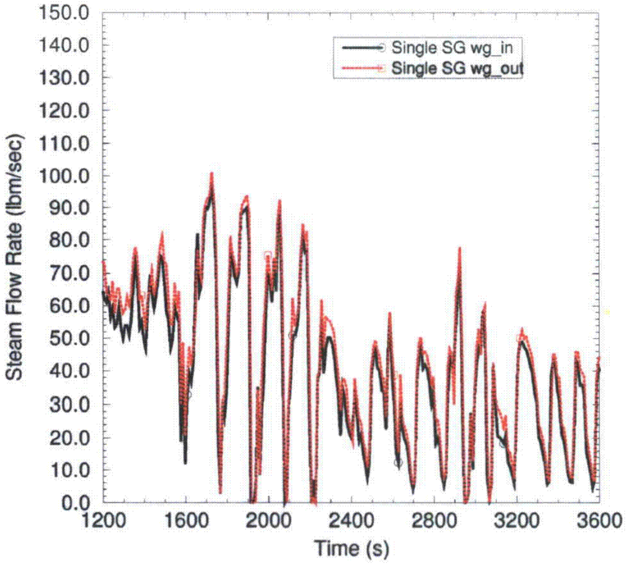


Figure 06.02.02-47-13—RELAP5/MOD2-BW, Triple Loop SG Heat Transfer, Low Elevation Break



TYOO

Figure 06.02.02-47-14—RELAP5/MOD2-BW, Broken Loop SG Steam Flow, High Elevation Break



UEIK

Figure 06.02.02-47-15—RELAP5/MOD2-BW, Triple Loop SG Steam Flow, High Elevation Break

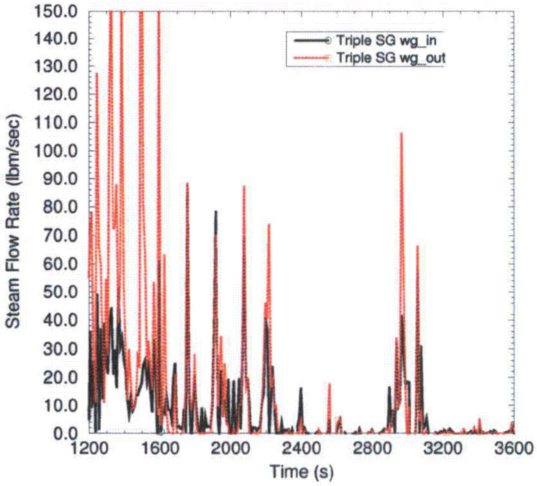


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Figure 06.02.02-47-16—RELAP5/MOD2-BW, Steam Flow to Containment, High Elevation Break

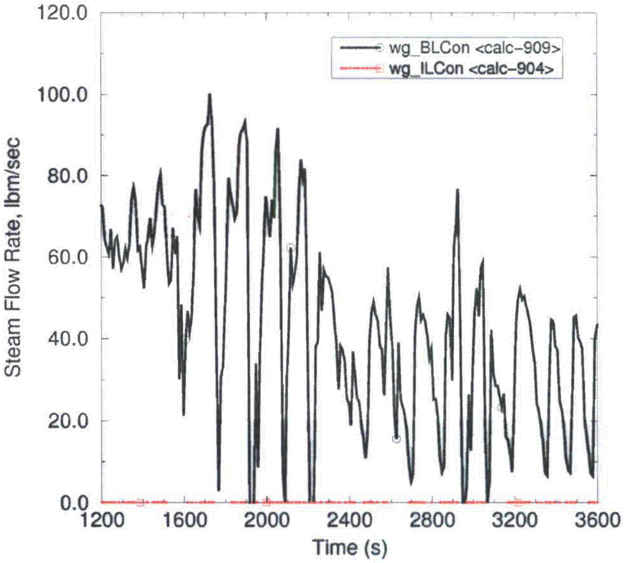

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Figure 06.02.02-47-17—RELAP5/MOD2-BW, Single Loop SG Vapor Fractions, High Elevation Break

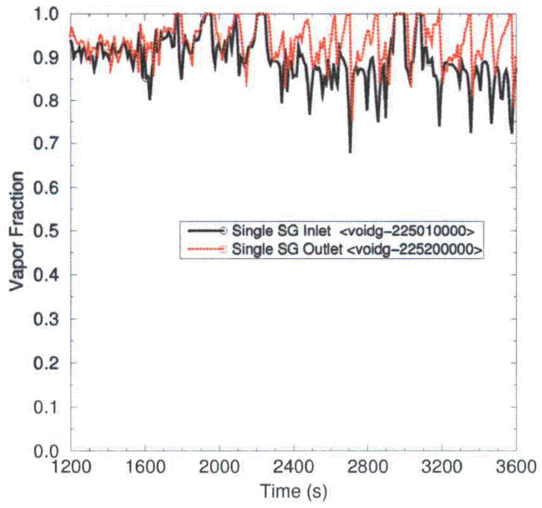

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Figure 06.02.02-47-18—RELAP5/MOD2-BW, Single Loop SG Heat Transfer, High Elevation Break

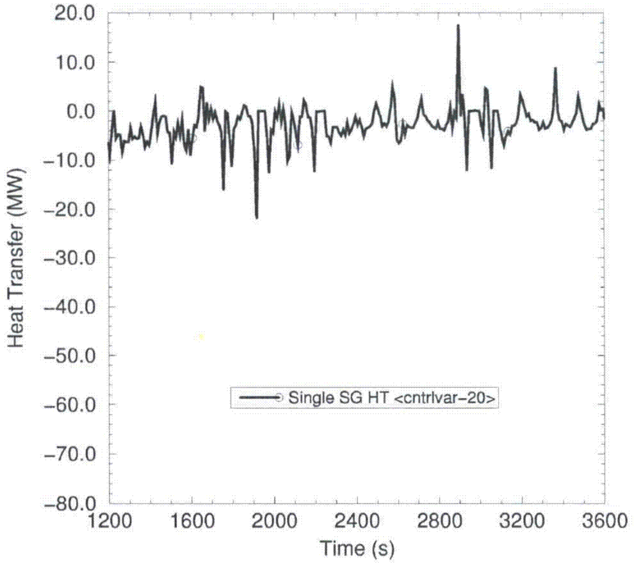

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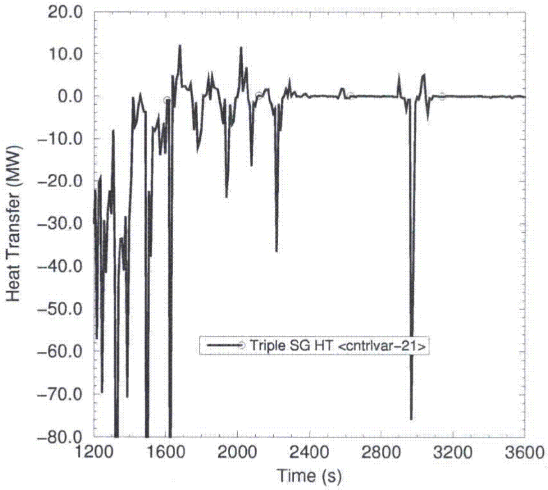
Figure 06.02.02-47-19—RELAP5/MOD2-BW Triple Loop SG Heat Transfer, High Elevation Break



UEIK

Figure 06.02.02-47-20—Heat Transfer Defined by RELAP5/MOD2-BW for Broken Loop SG

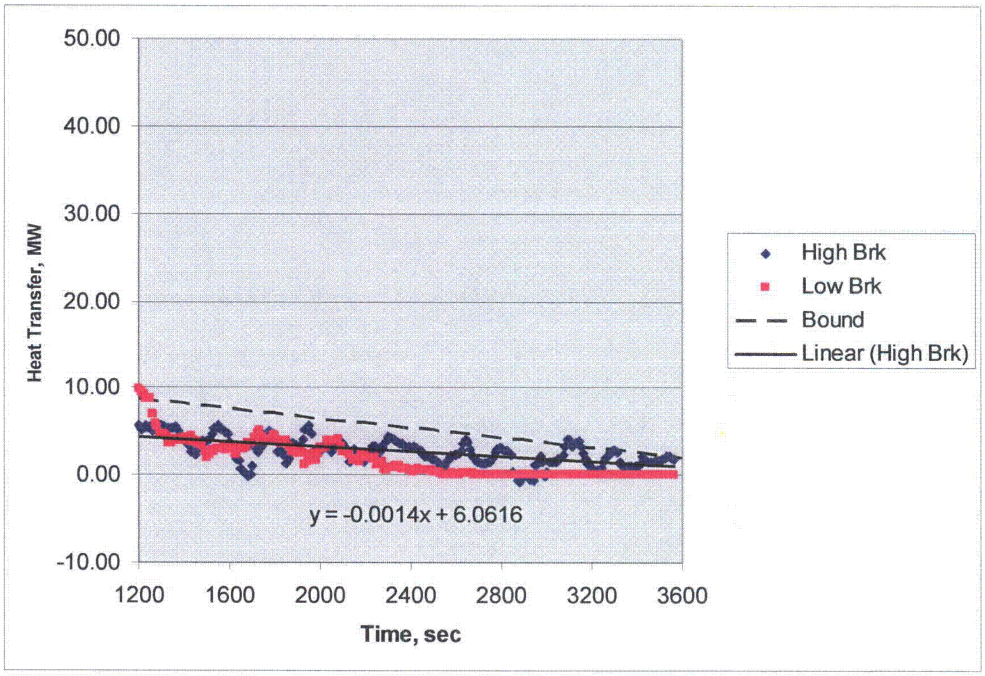


Figure 06.02.02-47-21—Heat Transfer Defined by RELAP5/MOD2-BW for Triple Loop SG

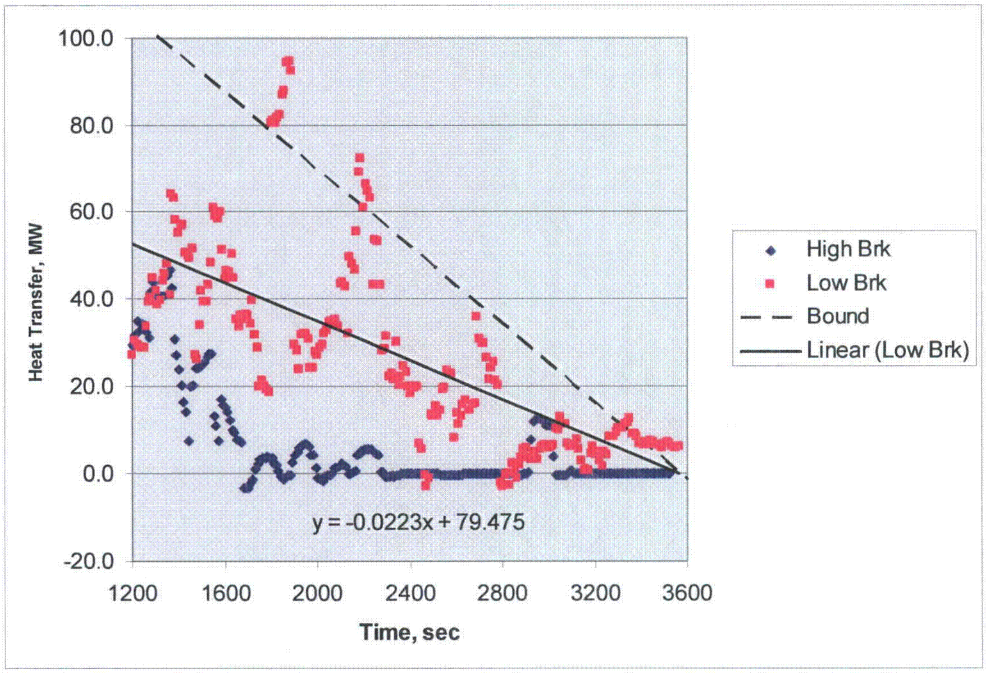
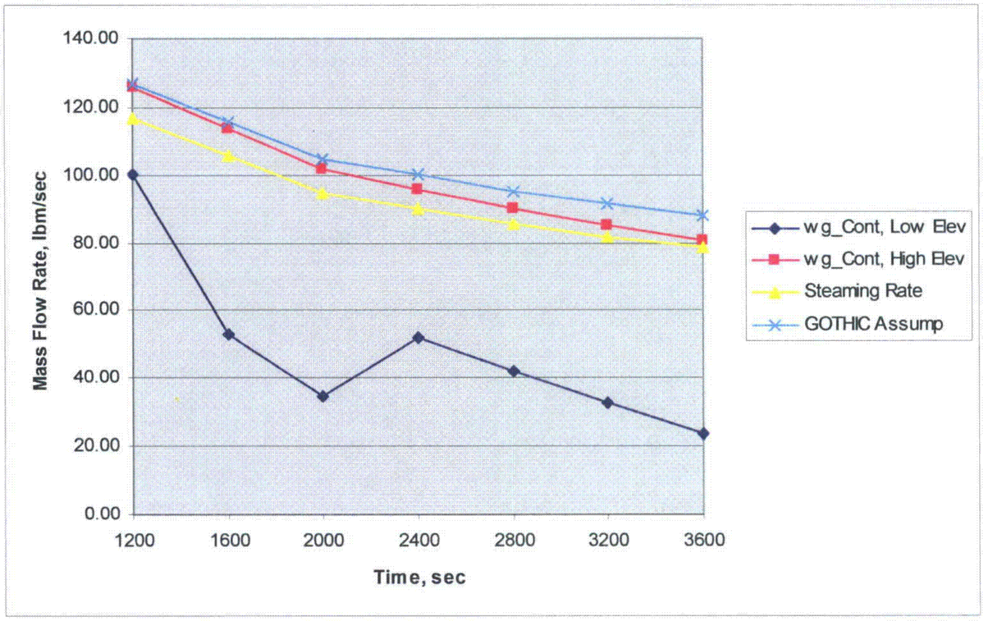


Figure 06.02.02-47-22—Steam Flow to Containment, RELAP5/MOD2-BW Estimate of SG Heat Transfer



Question 06.02.02-51

Interim FSAR Revision 2 Table 6.2.1-25, "MSLB Reactor Trip and Isolation Signal Summary" includes steam generator isolation on high containment pressure to mitigate small steam line breaks. Include this signal in the steam generator isolation discussions of FSAR Chapter 7.3 "Engineered Safety Features Systems".

Response to 06.02.02-51:

U.S. EPR FSAR Tier 2, Table 6.2.1-25, "MSLB Reactor Trip and Isolation Signal Summary" includes main steam isolation and main feedwater (MFW) isolation on high containment pressure, but not a steam generator (SG) isolation signal. Containment isolation and a reactor trip (RT) also occur on a high containment pressure signal (Containment Equipment Compartment Pressure > Max1p and Containment Service Compartment Pressure (NR) > Max2p). U.S. EPR FSAR Tier 2, Section 7.3.1.2.7 and Section 7.3.1.2.8 will be revised to include main steam isolation and MFW isolation on high containment pressure, respectively. Associated changes will be made to U.S. EPR FSAR Tier 2, Table 7.3-1, Figure 7.3-14, Figure 7.3-15 and Figure 7.3-17. U.S. EPR FSAR Tier 1 Table 2.4.1-3 will be revised to include additional main steam isolation signal input variables.

FSAR Impact:

U.S. EPR FSAR Tier 1, Table 2.4.1-3 and U.S. EPR FSAR Tier 2, Section 7.3 will be revised as described in the response and indicated on the enclosed markup.

U.S. EPR Final Safety Analysis Report Markups

Table 2.4.1-3—Protection System Automatic Engineered Safety Feature Signals and Input Variables (2 Sheets)

Engineered Safety Feature Signal	Input Variable
Safety Injection System Actuation	Pressurizer Pressure (NR)
	Hot Leg Pressure (WR)
	Hot Leg Temperature (WR)
	RCS Loop Level
Emergency Feedwater System Actuation	SG Level (WR)
	LOOP Signal
	SIS Actuation signal
Emergency Feedwater System Isolation	SG Level (WR)
	SG Isolation Signal
Partial Cooldown Actuation	SIS Actuation signal
Main Steam Relief Train (MSRT) Opening	SG Pressure
MSRT Isolation	SG Pressure
Main Steam Isolation	SG Pressure
	SG Isolation Signal
06.02.02-51	Containment Equipment Compartment Pressure
	Containment Service Compartment Pressure (NR)
Main Feedwater Isolation	SG Level (NR)
	SG Pressure
	RT Breaker Position
	SG Isolation Signal
Containment Isolation Stage 1	Containment Service Compartment Pressure (NR)
	Containment Service Compartment Pressure (WR)
	Containment Equipment Compartment Pressure
	Containment High Range Activity
	SIS Actuation Signal
Containment Isolation Stage 2	Containment Service Compartment Pressure (WR)
CVCS Charging Isolation	Pressurizer Level (NR)
CVCS Isolation for Anti-Dilution	Boron Concentration

- SG pressure drop.
- SG pressure < Min1p.
- SG isolation signal (Section 7.3.1.2.14).
- Containment equipment compartment pressure > Max1p.
- Containment service compartment pressure (NR) > Max2p.

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An actuation order is generated for main steam isolation when two-out-of-four SG pressure measurements on any one SG decrease faster than the specified allowable rate. When this condition occurs in any one SG, all four main steam trains are isolated. A SG pressure drop is detected by using a variable low setpoint equal to the actual SG pressure minus a fixed value, with a limitation placed on the rate of decrease of the setpoint. The maximum value of the setpoint is also limited in order to avoid MSIV closure during a SG pressure decrease following RT and turbine trip, which could result in a SG over-pressure condition.

There are no permissive conditions associated with main steam isolation due to SG pressure drop; this initiation parameter is used in all plant operating conditions.

An actuation order is also generated for main steam isolation when two-out-of-four SG pressure measurements on any one SG are below the fixed Min1p setpoint. When this condition occurs in any one SG, all four main steam trains are isolated. Main steam isolation due to low SG pressure is bypassed when RCS pressure is below the P12 permissive setpoint. The bypass is automatically removed above the P12 setpoint. Generation of the P12 permissive signal is discussed in Section 7.2.1.3.

An actuation order is generated for main steam isolation when two-out-of-four PS divisions detect high containment pressure. Either two-out-of-four equipment compartment pressure measurements exceeding the Max1p setpoint, or two-out-of-four NR service compartment pressure measurements exceeding the Max2p setpoint results in main steam isolation. There are no operating bypasses associated with main steam isolation on high containment pressure.

The capability for manual system-level actuation of main steam isolation is provided on the SICS in the MCR. This manual system-level initiation closes all four MSIVs. Four manual system-level initiation controls are provided, any two of which will actuate the main steam isolation.

The capability for component-level control of the MSIVs is available to the operator on both the PICS and the SICS in the MCR. For small main steam line breaks (MSLB) and FWLB, manual initiation from the SICS is credited with closing the MSIVs when operating below P12 permissive setpoint. Operator actions credited in mitigating accidents are addressed in Section 15.0.0.3.7.

The sense and command output for main steam isolation can be reset manually from ~~both~~ the ~~PICS and~~ SICS in the MCR. Reset of the sense and command output does not result in opening of the associated valves; it allows the operator to take further manual actions to open the valves.

The functional logic for automatic main steam isolation is shown in Figure 7.3-14—MSIV Isolation (Div. 1&2) and Figure 7.3-15—MSIV Isolation (Div. 3&4).

7.3.1.2.8 Main Feedwater Isolation

To protect against a loss of SG level control arising from a SGTR, pipe fault, or level control malfunction, and to prevent overcooling of the RCS following a RT, isolation of the main feedwater (MFW) system is performed. The MFW isolation is actuated in two steps, full load isolation or startup and shutdown system (SSS) isolation, depending upon the severity of the SG level deviation. The SSS isolation includes the closure of the main MFW isolation valve, which prevents flow via the full load path as well as SSS.

Operation of the MFW system is described in Section 10.4.

The U.S. EPR design uses the following initiating conditions to actuate MFW isolation:

- ~~Confirmation~~Initiation of RT (full load isolation).
- SG level NR > Max1p (full load isolation).
- SG level NR > Max0p for a period of time following RT (SSS isolation).
- SG pressure drop > Max2p (SSS isolation).
- SG pressure < Min2p (SSS isolation).
- SG isolation signal (Section 7.3.1.2.14).
- Containment equipment compartment pressure > Max1p.
- Containment service compartment pressure (NR) > Max2p.

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Following RT, a MFW full load isolation of all four SG is required in order to avoid RCS overcooling, which could result in a return to critical conditions with a potential power excursion. ~~The confirmation of RT signal is generated when two out of four RT breakers are in the open position.~~ This MFW isolation secures the full load flow path and allows for SG level control from the low load valves, in the absence of close commands for the low load valves.

Table 7.3-1—ESF Actuation Variables

06.02.02-51

Protective Function	Variables To Be Monitored	Range of Variables
Safety Injection System Actuation	Pressurizer Pressure (NR)	1615-2515 psia
	Hot Leg Pressure (WR)	15-3015 psia
	Hot Leg Temperature (WR)	32-662°F
	RCS Loop Level	0-30.71 in.
Reactor Coolant Pump Trip	RCP differential pressure	0-120% nominal
Emergency Feedwater Actuation	SG Level (WR)	0-100% MR
Emergency Feedwater Isolation	SG Level (WR)	0-100% MR
SG Isolation	Main Steam Line Activity	$1x10^{-1} – 1x10^{4}$ counts/ sec.
	SG Level (NR)	0-100% MR
Main Steam Relief Train Actuation	SG Pressure	15-1615 psia
Main Steam Relief Train Isolation	SG Pressure	15-1615 psia
Main Steam Isolation	SG Pressure	15-1615 psia
	Cont. Equipment Compartment Pressure	-3 to +7 psig
	Cont. Service Compartment Pressure	-3 to +7 psig
Main Feedwater Isolation	SG Level (NR)	0-100% MR
	SG Pressure	15-1615 psia
	RT Breaker Position	Open/Closed
	Cont. Equipment Compartment Pressure	-3 to +7 psig
	Cont. Service Compartment Pressure	-3 to +7 psig
Containment Isolation	Cont. Service Compartment Pressure (NR)	-3 to +7 psig
	Cont. Service Compartment Pressure (WR)	-5 to +220 psig
	Cont. Equipment Compartment Pressure	-3 to +7 psig
	Containment High Range Activity	$1x10^{-1} – 1x10^{7}$ Rad/hr
Emergency Diesel Generator Actuation	6.9 kV Bus Voltage	0-8.625 kV
PSRV Opening	Hot Leg Pressure (NR)	0-870 psia
CVCS Charging Isolation	Pressurizer Level (NR)	0-100% MR
CVCS Isolation for Anti-Dilution	Boron Concentration	0-5000 ppm
	Boron Temperature	32-212°F
	CVCS Charging Flow	0-320,000 lb/hr
	Cold Leg Temperature (WR)	32-662°F

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Figure 7.3-14—MSIV Isolation (Div. 1&2)

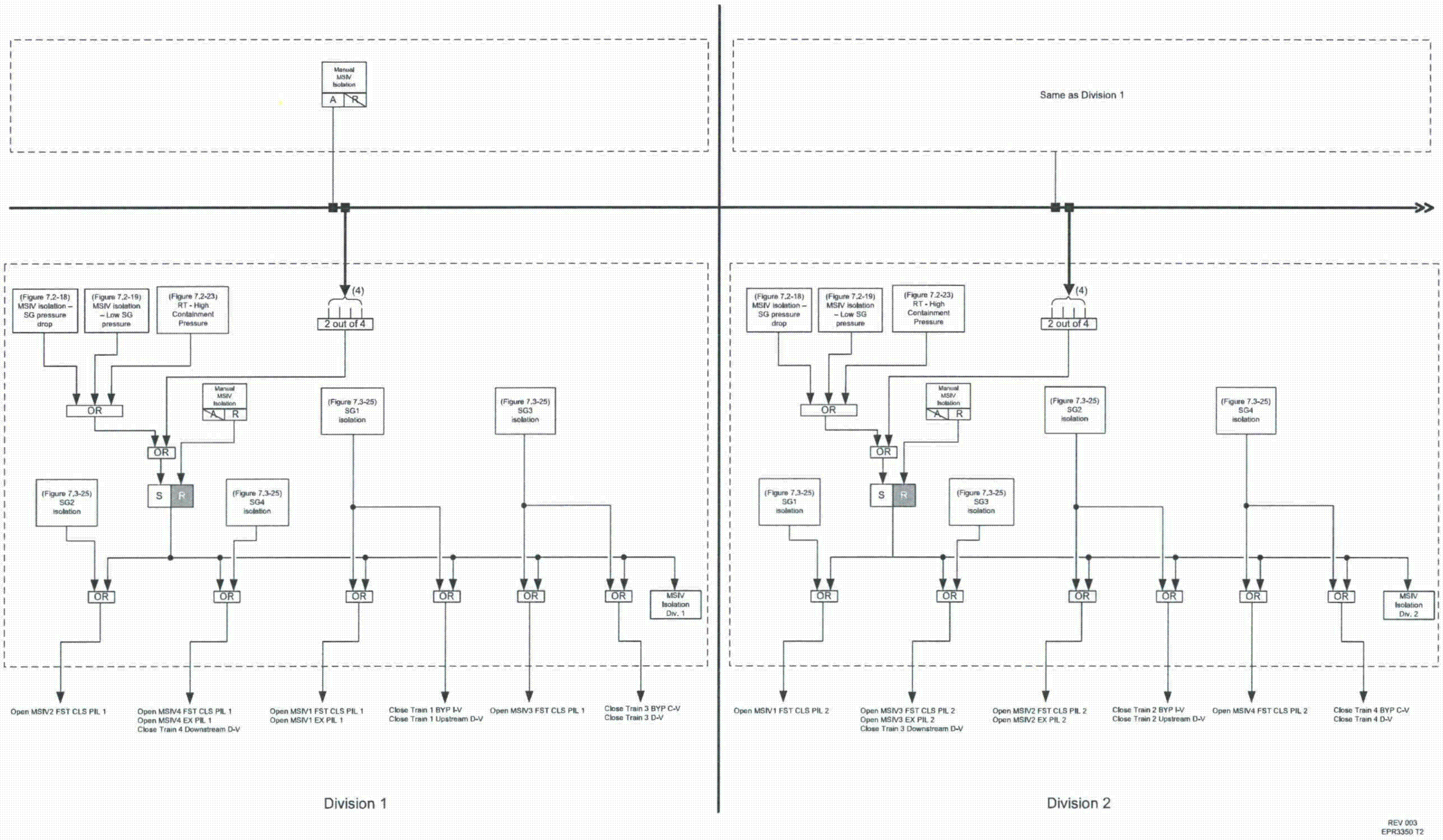

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Figure 7.3-15—MSIV Isolation (Div. 3&4)

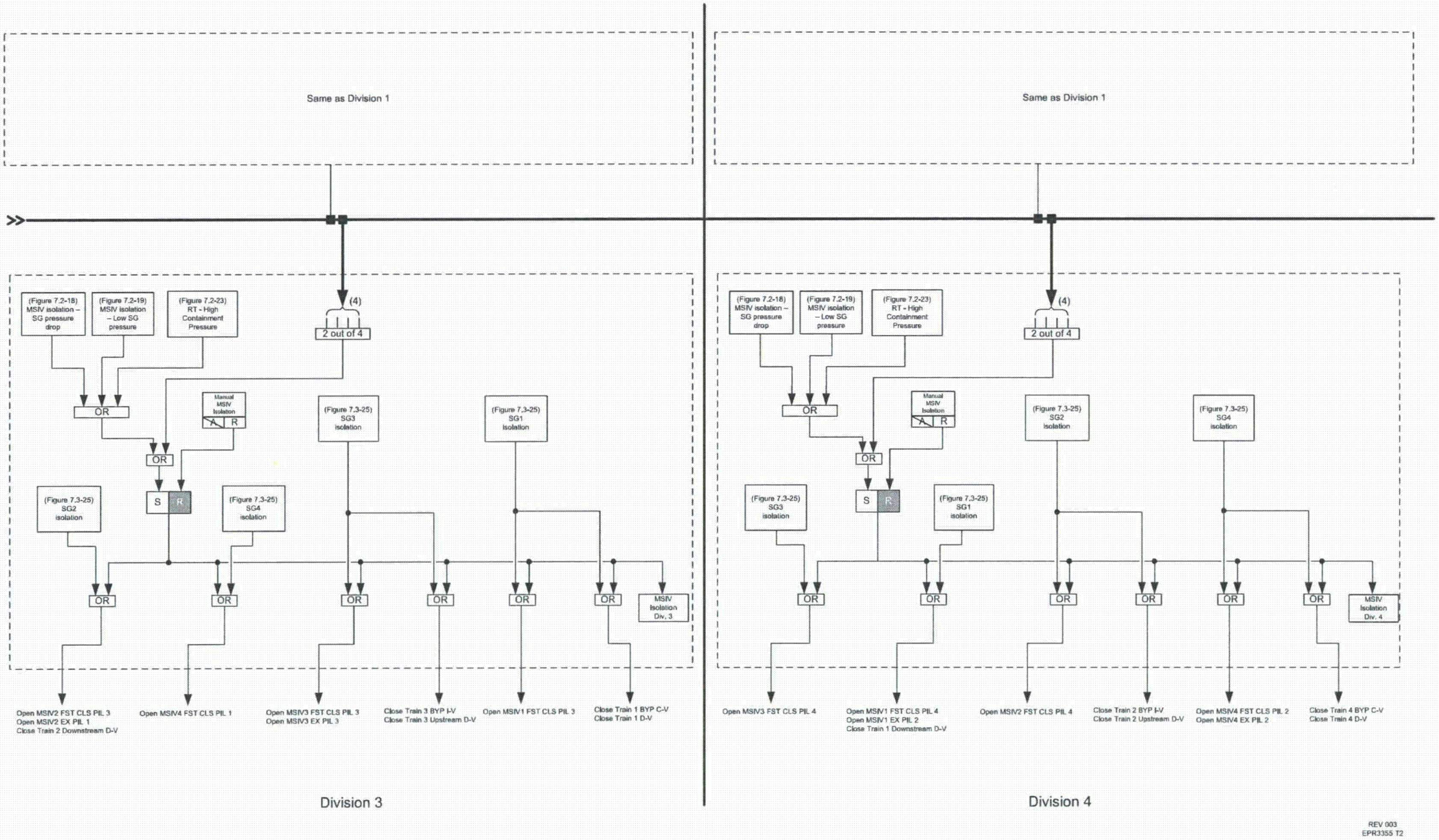

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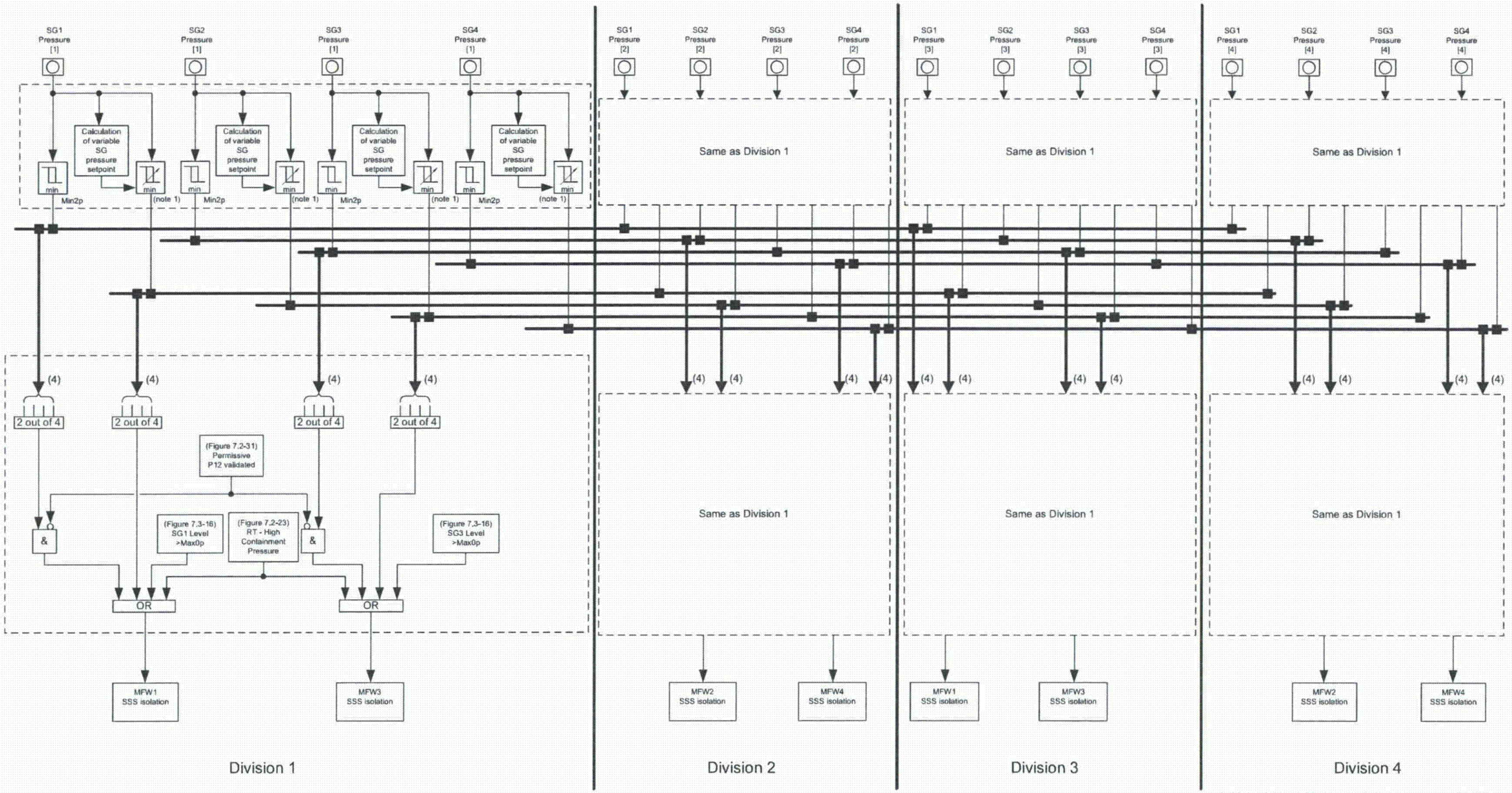
Figure 7.3-17—MFWS Isolation - SSS



Note 1: The condition to be detected is a SG pressure drop > Max 2p. This is implemented with a variable "Min" setpoint that decreases in a rate-limited manner.

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