

**Information to Satisfy the FULL SPECTRUM LOCA (FSLOCA) Evaluation
Methodology Plant Type Limitations and Conditions for 4-loop Westinghouse
Pressurized Water Reactors (PWRs)**

(Non-Proprietary)

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1.0 Introduction and Purpose

The United States Nuclear Regulatory Commission (US NRC) review of the **FULL SPECTRUM™** LOCA (**FSLOCA™**) evaluation model (EM) (WCAP-16996-P-A/WCAP-16996-NP-A, Revision 1 [1]) determined that it is applicable to performing best-estimate analyses for the entire spectrum of LOCAs, including small-break LOCA (SBLOCA), intermediate-break LOCA (IBLOCA), and large-break LOCA (LBLOCA) scenarios in Westinghouse designed 3- and 4-loop pressurized water reactors (PWRs) with cold leg injection (Section 1.2.3 of the safety evaluation (SE) [2]).

Limitation and condition 2 in the SE states that the approved FSLOCA EM is applicable for performing PWR LOCA analyses for Westinghouse designed 3- and 4-loop PWR plants only. Plant type-specific limitations and conditions applicable to 4-loop PWRs are also included in the SE, which require action in conjunction with the first application to a 4-loop PWR. The purpose of this letter is to address the plant type related limitations and conditions for Westinghouse 4-loop PWRs.

2.0 Identification of Westinghouse 4-loop PWR Limitations and Conditions

For application of the FSLOCA EM to Westinghouse 4-loop PWRs, the plant type-specific limitations and conditions must be addressed. The following items are identified in Table 22 of the SE:

- Limitation and condition 9: Effect of Bias in FSLOCA EM Applications for Region I
- Limitation and condition 10: Boundary Between FSLOCA EM Region I and Region II Breaks

3.0 Effect of Bias in FSLOCA EM Applications for Region I

The FSLOCA EM limitation and condition number 9 is as follows:

In PWR plant type-specific applications of the FSLOCA EM for designs which are not Westinghouse 3-loop PWRs, a confirmatory evaluation will be performed for Region I analyses to assess the effect associated with the [

] ^{a,c}. This confirmatory evaluation will be performed once for each PWR plant type (e.g., Westinghouse design four-loop PWR plant) analyzed with the FSLOCA EM and referenced in subsequent plant-specific FSLOCA analyses of the same PWR plant type.

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Individual 3-loop plant type sensitivity studies on [

] ^{a,c}

The effect of the Region I uncertainty biasing on peak cladding temperature (PCT) as function of break size is shown in Figure 3-1a through Figure 3-1c for Diablo Canyon Units 1 and 2 and the representative SNUPPS plant. The core uncover and cladding heatup in the 2.5-to-5.0 inch break diameter range is [

] ^{a,c}

[

I^{a,c}



Figure 3-1a: [

]^{a,c}

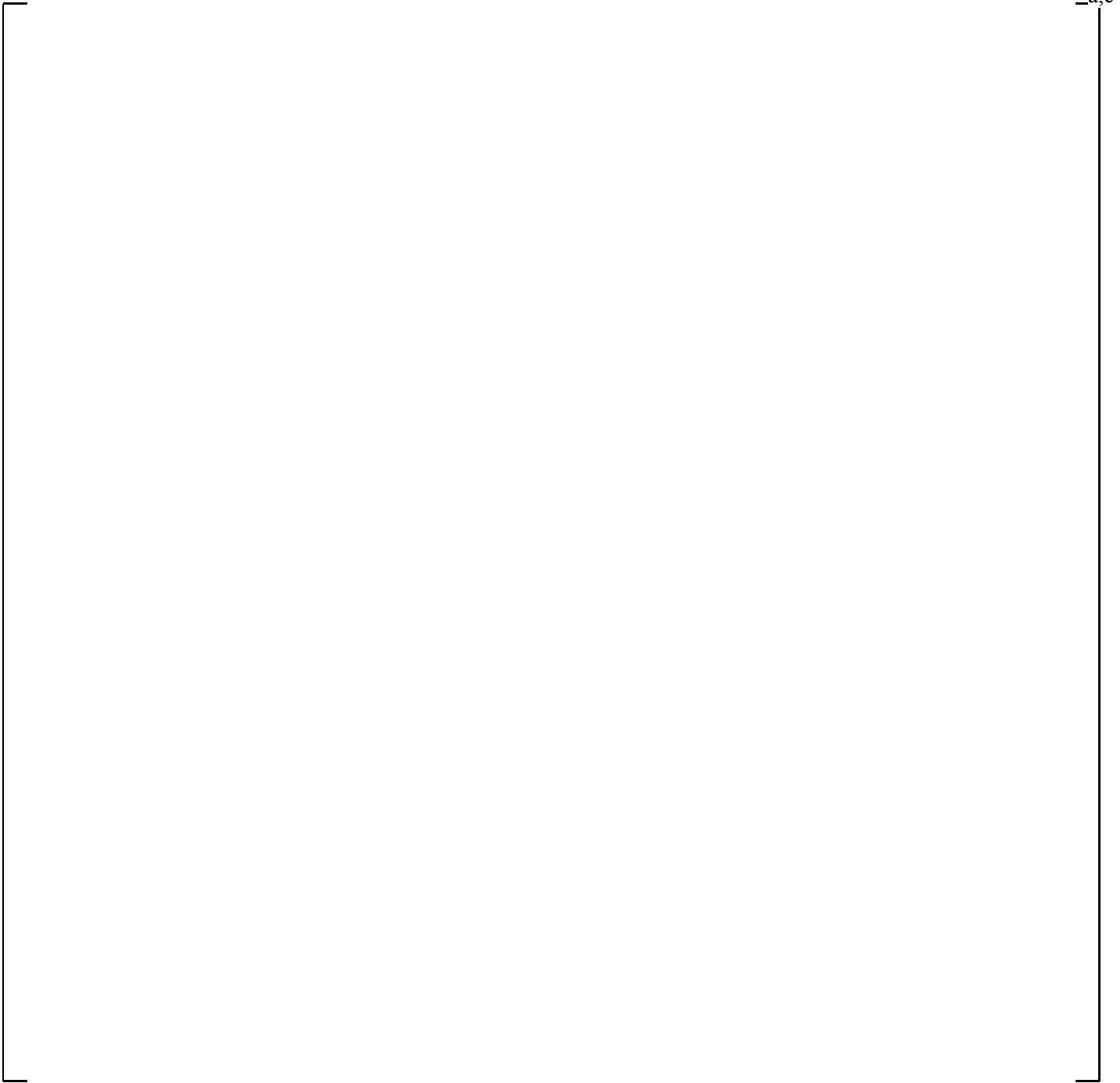


Figure 3-1b: [

]^{a,c}



Figure 3-1c: [

]^{a,c}

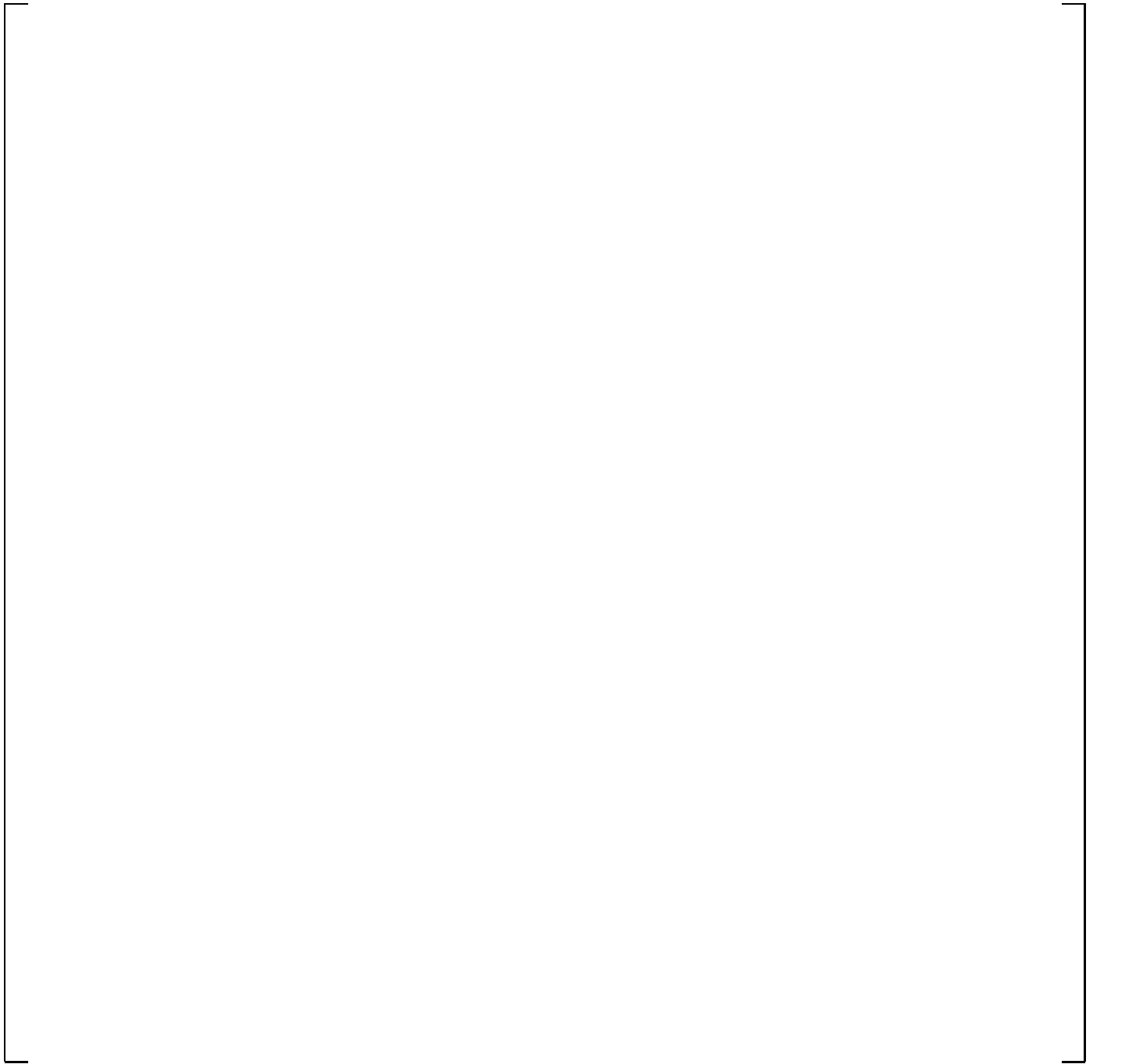


Figure 3-2: [

] ^{a,c}

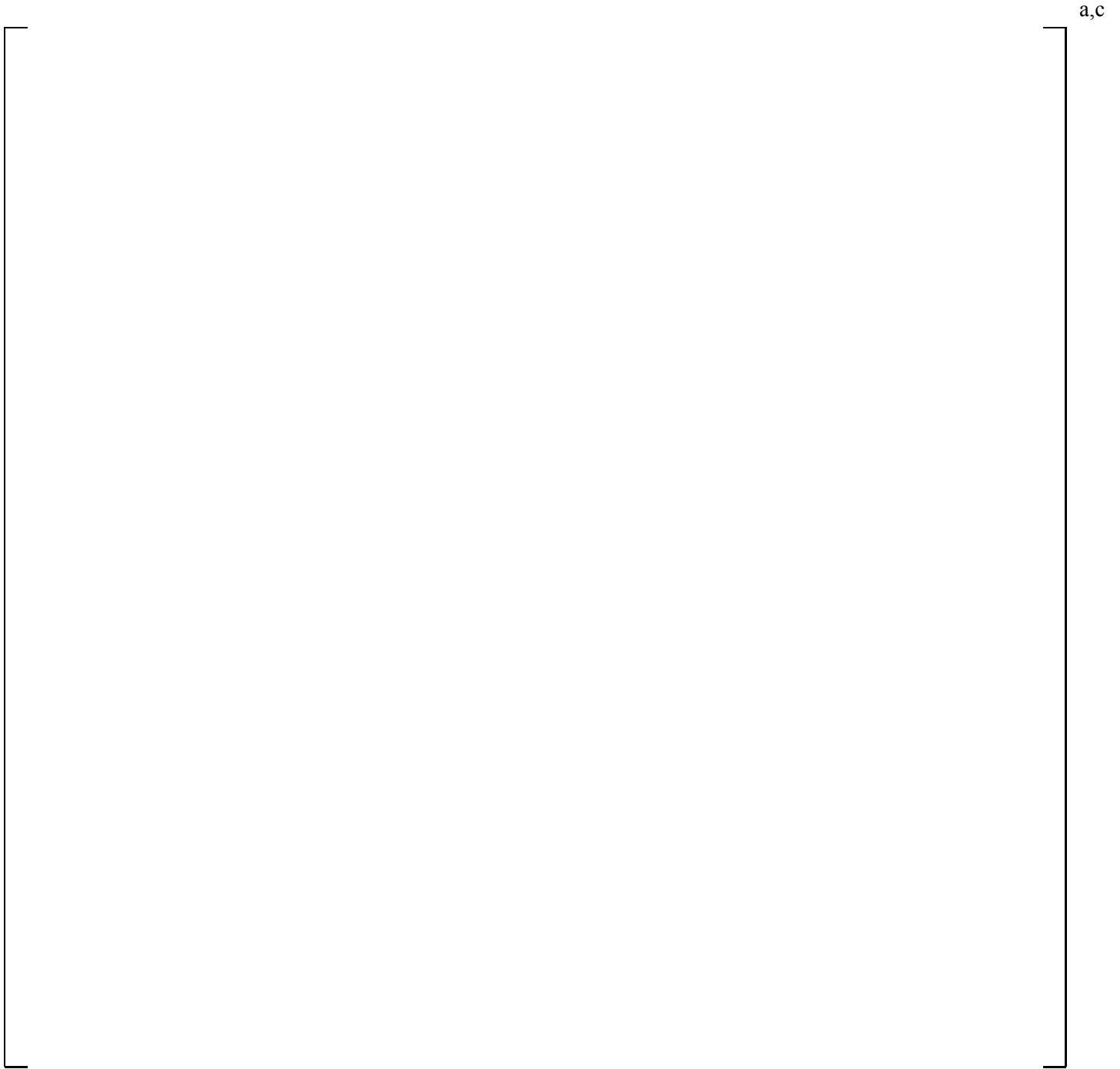


Figure 3-3: [

]^{a,c}

a,c

Figure 3-4: [

]^{a,c}

a,c

Figure 3-5: [

]^{a,c}

a,c

Figure 3-6: [

]^{a,c}

4.0 Boundary Between FSLOCA EM Region I and Region II Breaks

The FSLOCA EM limitation and condition number 10 is as follows:

In PWR plant type-specific application of the FSLOCA EM for designs which are not Westinghouse 3-loop PWRs, a confirmatory evaluation will be performed to demonstrate that the applied break size boundary between Region I and Region II serves the intended goal of [

] ^{a,c}

As of part this evaluation, it will be demonstrated that no unexplained behavior in the predicted safety criteria, including PCT, occurs across the boundary between Region I and Region II. In addition, it will be confirmed that [

] ^{a,c} In addition, it is important to also assure that the limiting small break between about 2- and 4-inch in an equivalent break diameter is properly captured by the robust Region I analysis approach. Plants with larger RCS fluid volumes than the Beaver Valley plant test example in WCAP-16996-P/WCAP-16996-NP, Revision 1, should cover the same 2- to 4-inch range using break area to RCS volume scaling to assure that the 2- to 4-inch break range is preserved and not artificially truncated. This confirmatory evaluation will be performed once for each PWR plant type (e.g., Westinghouse design four-loop PWR plant) analyzed with the FSLOCA EM and referenced in subsequent plant-specific FSLOCA analyses of the same PWR plant type. The WCOBRA/TRAC-TF2 code is applicable for analysis over the entire break spectrum of LOCA transients. However, for the purpose of the Region II analysis, the minimum of the break area sampling should extend only to 1.0 ft² consistent with the ASTRUM LBLOCA EM (WCAP-16009-P-A, “Realistic Large-Break LOCA Evaluation Methodology Using the Automated Statistical Treatment of Uncertainty Method (ASTRUM),” Revision 0) in lieu of the Region I/II boundary.

The FSLOCA EM analysis approach was demonstrated for a Westinghouse 3-loop PWR as described in Section 31.2 of WCAP-16996-P-A/WCAP-16996-NP-A, Revision 1. [

] ^{a,c}

The general emergency core cooling system (ECCS) layout is different for 4- and 3-loop plants. The typical 3-loop plant layout is such that the SI line connects to the cold leg separate from the accumulator line. The typical 4-loop plant layout is such that the high head SI line connects directly to the cold leg and the low head SI and intermediate head SI lines connect to the accumulator line, which then connects to the cold leg. Typical 4-loop plant high head SI cold leg connecting lines are less than 2.0 inches and typical accumulator connecting lines are 8.75 inches (inner diameter). For 3-loop plants, [

] ^{a,c} This is illustrated by Figures 4-1 and 4-2 of LTR-NRC-14-29.

The FSLOCA EM limitation and condition 10 states that the intended goal of the Region I/II boundary []^{a,c} should be demonstrated for PWR plant type-specific application of the FSLOCA EM. As part of this demonstration, no unexplained behavior in the predicted safety criteria, including PCT, across the boundary between Region I and Region II should occur. In addition, the limitation and condition []

[]^{a,c}. The limitation and condition does clarify that plants with larger reactor coolant system (RCS) fluid volumes than the Beaver Valley plant test example in WCAP-16996-P-A/WCAP-16996-NP-A, Revision 1 should cover the same 2-to-4 inch range using break area to RCS volume scaling to assure that the 2-to-4 inch break range is preserved and not artificially truncated. Applying []

[]^{a,c}.

The applicability of the FSLOCA EM analysis approach described in Section 31.2 of WCAP-16996-P-A/WCAP-16996-NP-A, Revision 1 and adherence to limitation and condition 10 is investigated here based on the break spectrum study performed for Diablo Canyon Unit 2. The PCT results from the break size sensitivity study are shown in Figure 4-1. []

[]^{a,c} Finally, it is noted that PCT is used as a surrogate for all safety criteria as no significant oxidation accrues at the predicted temperatures.

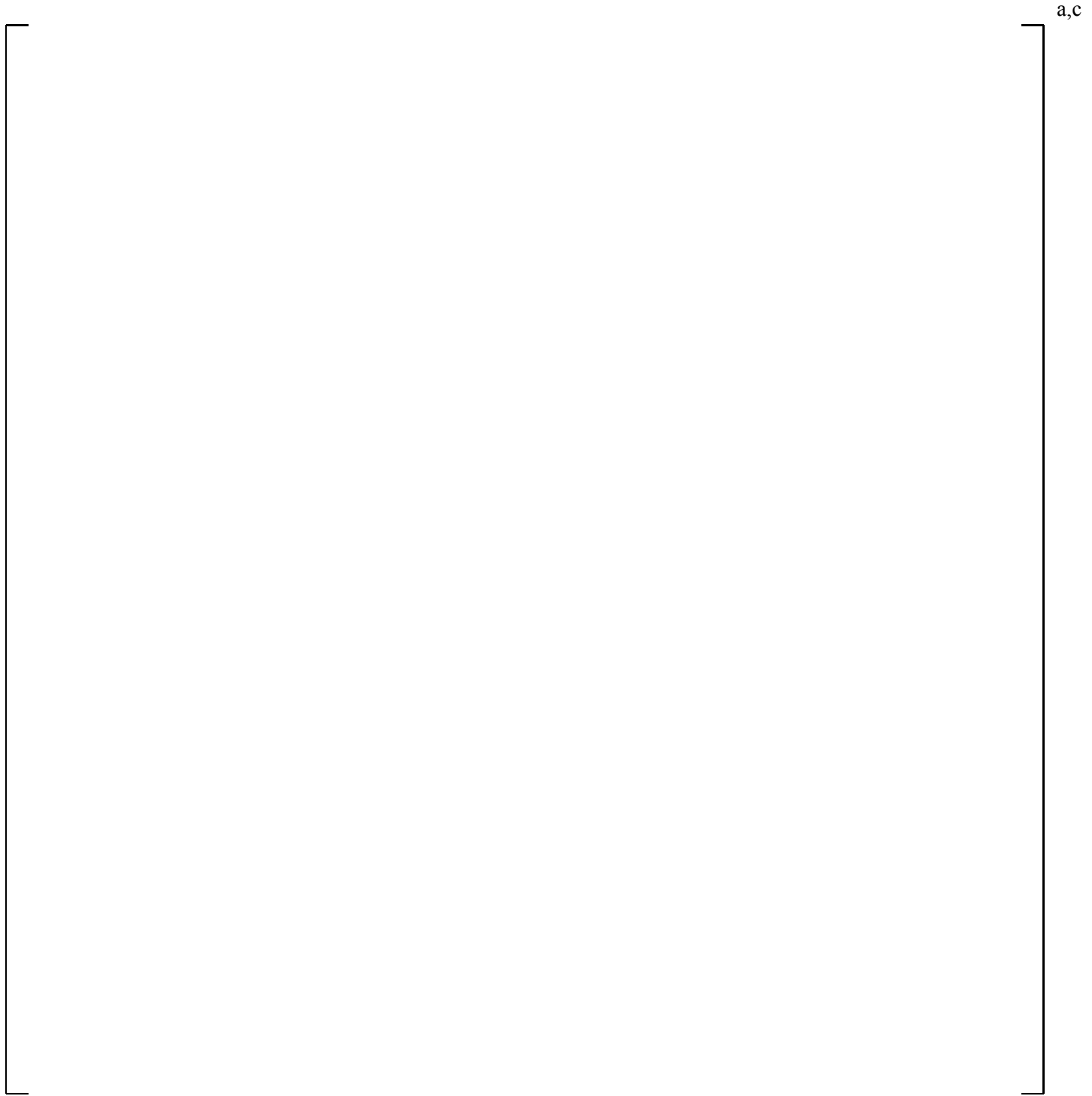
Based on these studies, it is evident that []

[]^{a,c}

[

] ^{a,c}

It is noted that the Region II analysis considers a minimum break area of 1.0 ft² consistent with the ASTRUM LBLOCA EM and the FSLOCA EM limitation and condition 10.



a,c

Figure 4-1: [

]^{a,c}

a,c

Figure 4-2: Effect of Increased SI Flow on SBLOCA PCT Behavior

a,c

Figure 4-3: Effect of Increased SI Flow on IBLOCA PCT Behavior



Figure 4-4: Illustrative Example of Pressure Behavior in SBLOCA and IBLOCA Cases

a,c

Figure 4-5: Illustrative Example of PCT Behavior in SBLOCA, IBLOCA, and LBLOCA Cases

5.0 Overview of the Application of the FSLOCA EM to Westinghouse 4-loop PWRs

In summary, the FSLOCA EM biasing approach from Sections 29 and 31 of WCAP-16996-P-A/WCAP-16996-NP-A, Revision 1 is applicable to Westinghouse 4-loop PWRs. The effect of applying the biasing approach for [

] ^{a,c}

The FSLOCA EM analysis approach demonstrated for a Westinghouse 3-loop PWR as described in Section 31.2 of WCAP-16996-P-A/WCAP-16996-NP-A, Revision 1 is applicable to Westinghouse 4-loop PWRs. The 4-loop PWR Region I [

] ^{a,c}

Following this approach addresses the FSLOCA EM limitations and conditions 9 and 10 relative to application of the methodology to 4-loop PWRs.

6.0 References

- 1) WCAP-16996-P-A / WCAP-16996-NP-A, Revision 1, “Realistic LOCA Evaluation Methodology Applied to the Full Spectrum of Break Sizes (FULL SPECTRUM LOCA Methodology),” November 2016.
- 2) NRC Letter, “Revised Final Safety Evaluation for Westinghouse Electric Company Topical Report WCAP-16996-P/WCAP-16996-NP, Volumes I, II, and III, Revision 1, ‘Realistic Loss-of-Coolant Accident Evaluation Methodology Applied to the Full Spectrum of Break Sizes’ (TAC No. ME5244),” September 12, 2017. (ADAMS Accession Nos.: Pkg: ML17207A124; Cover letter: ML17226A225; Enc. 1: ML17226A309; Enc. 2: ML17213A252; Att. 1: ML17226A216; Att. 2: ML17226A218)
- 3) LTR-NRC-13-70, “Summary of July 2013 NRC Code Workshop and August 2013 NRC Audit of the FULL SPECTRUM LOCA (FSLOCA) Evaluation Model (Proprietary/Non-Proprietary),” October 2013.
- 4) LTR-NRC-15-102, Revision 2, “Summary of November 2015, December 2015 and January 2016 Discussions on Draft Limitations and Conditions and Supplemental Information for the FULL SPECTRUM LOCA (FSLOCA) Evaluation Model (Proprietary/Non-Proprietary),” January 2016.
- 5) LTR-NRC-14-29, “Summary of May 2014 NRC Audit of the FULL SPECTRUM LOCA (FSLOCA) Evaluation Model (Proprietary/Non-Proprietary), Project 700, TAC No. ME5244,” June 2014.