

Enclosure 4

**Submittal of Comments on Draft Safety Evaluation for Westinghouse Electric Company WCAP-16260-P I
WCAP-16260-NP, Revision 2, "The Spatially Corrected Inverse Count Rate (SCICR) Method for
Subcritical Reactivity Measurement," Topical Report (EPID L-2017-TOP-0064)**

(Non-Proprietary)

March 2019

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U. S. NUCLEAR REGULATORY COMMISSION

OFFICE OF NUCLEAR REACTOR REGULATION

DRAFT SAFETY EVALUATION

FOR WESTINGHOUSE ELECTRIC COMPANY TOPICAL REPORT

WCAP-16260-P/WCAP-16260-NP, REVISION 2, "THE SPATIALLY CORRECTED INVERSE COUNT

RATE (SCICR) METHOD FOR SUBCRITICAL REACTIVITY MEASUREMENT"

EPID: L-2017-TOP-0064

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1.0 INTRODUCTION

Subcritical Physics
Testing (SPT) application
of the SCICR method

By letter dated December 14, 2017 (Ref. 1), Westinghouse Electric Company (Westinghouse) submitted Topical Report (TR) WCAP-16260-P/WCAP-16260-NP, Revision 2, "The Spatially Corrected Inverse Count Rate (SCICR) Method for Subcritical Reactivity Measurement" (Ref. 2) for U.S. Nuclear Regulatory Commission (NRC) review and approval. The NRC had previously reviewed and approved Revision 0 to WCAP-16260-P (Ref. 3); however, Westinghouse has made several fundamental changes to the application of subcritical physics testing (SPT) that is the subject of WCAP-16260-P, and hence stated that Revision 2 supersedes Revision 1 in its entirety. The basic theory of spatial correction, however, is retained from the previous revision. The NRC staff therefore reviewed the entire TR, but focused on the application changes.

By letters dated August 9, 2018 (Ref. 4), and September 24, 2018 (Ref. 5), the NRC staff from the Nuclear Performance and Code Review Branch (SNPB) and the Instrumentation and Controls Branch (EICB) issued request for additional information (RAI) questions to complete the review. Westinghouse provided RAI responses via letters dated September 13, 2018 (Ref. 6), and October 24, 2018 (Ref. 7), respectively. An additional supplement (Ref. 8) was provided by Westinghouse via letter dated January 8, 2019, to address issues discussed at a closed public meeting.

2.0 REGULATORY EVALUATION

The theory and methods described in WCAP-16260-P, Revision 2, describe a subset of startup physics tests that are performed at the beginning of a cycle in a pressurized water reactor (PWR) to ensure that core characteristics are maintained (e.g., shutdown margin) and the core is operating as designed. The following sections provide the applicable regulations contained in Title 10, "Energy," of the *Code of Federal Regulations*" (10 CFR), followed by a discussion of available regulatory guidance, and finally, a discussion of the way that SCICR is intended to satisfy the applicable requirements. The section concludes with a statement of the NRC staff review objective.

confirm

via measurement as a means to demonstrate that

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1 2.1 APPLICABLE REGULATORY REQUIREMENTS

2 Section 50.34, "Contents of Applications; Technical Information," of the 10 CFR requires that
 3 safety analysis reports be submitted that analyze the design and performance of structures,
 4 systems, and components provided for the prevention of accidents and the mitigation of the
 5 consequences of accidents. As part of the core-reload-design process, licensees or supporting
 6 vendors perform reload safety evaluations (SEs) to ensure the safety analyses remain
 7 applicable to the as-designed cycle. Testing provides further assurance that the cycle will
 8 operate in conformance with its design, and hence within the constraints of the safety analyses
 9 and supporting evaluations. (delete text)

10 The regulation at 10 CFR 50.36, "Technical specifications," requires reactor licenses to include
 11 technical specifications (TS), which must contain items in the following categories: safety limits
 12 (SLs), limiting safety system settings, and limiting control settings; limiting conditions for
 13 operation (LCOs); surveillance requirements (SRs); design features; and administrative
 14 controls. In particular, 10 CFR 50.36(c)(1) defines SLs as limits on important process
 15 parameters found necessary to protect the integrity of the physical barriers that guard against
 16 the uncontrolled release of radioactivity; 10 CFR 50.36(c)(2) defines LCOs as the lowest
 17 functional capability or performance level of equipment required for safe operation of the facility;
 18 and 10 CFR 50.36(c)(3) defines SRs as those requirements relating to test, calibration, or
 19 inspection to assure that the necessary quality of systems and components is maintained, that
 20 facility operation will be within SLs, and that the LCOs will be met. Plants are typically required
 21 to maintain a certain amount of shutdown margin and to maintain core reactivity close to
 22 predicted values - these are included, for example, in the Westinghouse Standard Technical
 23 Specifications (STS) documented in NUREG-1431, Revision 4, Volume 1 (Ref. 9), as LCO 3.1.1
 24 and LCO 3.1.2, respectively. While the SPT techniques described in WCAP-16260-P/
 25 WCAP-16260-NP, Revision 2, do not directly affect these LCOs, they will be used to perform
 26 the surveillances required by their associated SRs to ensure the LCOs are met.

27 Section XI, "Test Control," of 10 CFR Part 50 Appendix B, "Quality Assurance Criteria for
 28 Nuclear Power Plants and Fuel Reprocessing Plants," requires that a test program be
 29 established to ensure that structures, systems, and components will perform satisfactorily in
 30 service. All functions necessary to ensure that the specified design conditions are not exceeded
 31 during normal operation and anticipated operational occurrences must be tested. This testing is
 32 an integral part of the design, construction, and operation of the plant.

36 2.2 DISCUSSION AND REGULATORY GUIDANCE

37 Physics tests are the subject of discussion in the NRC's STS. NUREG-1431, Revision 4,
 38 Volume 1, "Standard Technical Specifications - Westinghouse Plants: Specifications," defines
 39 the physics tests as "those tests performed to measure the fundamental nuclear characteristics
 40 of the reactor core and related instrumentation." The tests are described in NUREG-1431,
 41 Revision 4, Volume 2, "Standard Technical Specifications - Westinghouse Plants: Bases," in
 42 the context of exceptions provided to certain TS requirements to allow for the completion of
 43 such tests. The description provides a succinct description of the purpose of the physics tests.
 44 The following is quoted from Page B 3.1.8-1 of NUREG-1431, Volume 2:

47 The key objectives of a test program are to:

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- 1 a. Ensure that the facility has been adequately designed,
 2 b. Validate the analytical models used in the design and analysis,
 3 c. Verify the assumptions used to predict unit response,
 4 d. Ensure that installation of equipment in the facility has been
 5 accomplished in accordance with the design, and
 6 e. Verify that the operating and emergency procedures are adequate.

7 [.] The PHYSICS TESTS requirements for reload fuel cycles ensure that
 8 the operating characteristics of the core are consistent with the design
 9 predictions and that the core can be operated as designed.
 10
 11

12 The STS BASES identify five physics tests required for reload fuel cycles in Mode 2: (1) critical
 13 boron concentration (CBC) with control rods withdrawn; (2) CBC with control rods inserted;
 14 (3) control rod worth; (4) isothermal temperature coefficient (ITC); and (5) neutron flux
 15 symmetry.
 16

17 Additionally, the STS BASES contain references to two other sources of guidance that may be
 18 considered relevant to physics test methods, although each has limitations. First, the STS
 19 BASES refer to NRC Regulatory Guide (RG) 1.68, Revision 2, "Initial Test Programs for
 20 Water-Cooled Nuclear Power Plants," dated August 1978. This RG is intended to be used in
 21 conjunction with planning an initial startup testing program, although portions of it describe
 22 physics testing requirements that would remain applicable for subsequent startups. Note that
 23 RG 1.68 has been revised twice since the publication of the 1978 version that is referenced in
 24 the STS. Second, the STS BASES refer to American National Standards Institute
 25 (ANSI)/American Nuclear Society (ANS) standard ANSI/ANS-19.6.1-1985, "Reload Startup
 26 Physics Tests for Pressurized Water Reactors." While this standard may provide guidance of
 27 direct relevance to the testing methods described in WCAP-16260-P/WCAP-16260-NP,
 28 Revision 2, a more recent revision was issued in 2011, and neither revision has been endorsed
 29 by the NRC.
 30

31 Given the limitations noted above, the NRC considered discussion contained in RG 1.68 and
 32 ANSI/ANS-19.6.1, as provided in the most recently issued revisions of both, and to the extent
 33 appropriate given the regulatory requirements identified above.
 34

35 2.3 REVIEW OBJECTIVES

36 The testing methods described in WCAP-16260 relate to SPT undertaken during reactor
 37 startup. The characteristics required to be confirmed during startup by ANSI/ANS-19.6.1-2011
 38 include the global reactivity balance, the capability to shutdown the core, the core power
 39 distribution¹, and measures for reactivity control. The bases for TS 3.1.8, "PHYSICS TEST
 40 Exceptions – MODE 2" provided in NUREG-1431, Revision 4, Volume 2, "Standard Technical

¹ Though a flux map is typically performed at higher powers to get a better indication of the core power distribution, control rod worth measurements in the low power or startup configuration provides a preliminary indication of the core power distribution.

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1 Specifications - Westinghouse Plants: Bases" (Ref. 10) also discusses the need to confirm
2 certain low-power physics test parameters, including critical boron concentration (CBC) at hot
3 zero power (HZP) conditions with all control rods out of the core, CBC at HZP conditions with
4 control rods inserted, control rod worth, ITC, and flux symmetry (which may be performed at up
5 to 30 percent power and is therefore not necessarily a MODE 2 test).
6

7 A key distinction between the SCICR method described in the TR and low-power physics testing
8 (LPPT) as described in the STS BASES is that the SCICR-based testing can be performed
9 before criticality is achieved. According to Westinghouse, this "inherently enhances plant safety
10 and reactivity management" and the []
11 "improves test reliability and human performance." However, it is noteworthy that there is no
12 direct correspondence between the SPT parameters and the LPPT parameters, though they
13 validate the same core characteristics. Table 1-1 of WCAP-16260 provides a mapping between
14 the typical LPPT parameters and the SPT parameters that accomplish the same goal. Because
15 this table does not discuss the need to test for CBC with rods inserted, and how its equivalent
16 will be accomplished by SPT, the NRC asked Westinghouse in SNPB RAI 1 to investigate this
17 omission. Westinghouse responded that the requirement for HZP CBC with rods inserted was
18 removed in the 1997 revision of ANSI/ANS-19.6.1 and was only used to confirm reactivity
19 computer performance for the rod swap and sequential dilution LPPT programs; therefore, it is
20 not needed for more advanced LPPT programs, such as dynamic rod worth measurement
21 (DRWM), and the SPT program under evaluation in this SE. Of the characteristics and tests
22 from ANSI/ANS-19.6.1-2011 and NUREG-1431, Revision 4, Volume 2, discussed above, all are
23 therefore covered by SPT parameters except for the ITC and flux symmetry, which must still be
24 performed by traditional LPPT techniques.
25

26 The NRC staff thus performed its review of WCAP-16260-P/WCAP-16260-NP, Revision 2, to
27 ensure that the testing methods and procedural guidance described therein provide a reliable
28 means to satisfy the startup physics testing requirements established in the STS, which are
29 identified as within the scope of SCICR. This review establishes that SCICR is an acceptable
30 means to satisfy the requirements set forth in 10 CFR 50.34, and in 10 CFR Part 50,
31 Appendix B, Criterion XI, insofar as those requirements pertain to core physics testing for
32 verification of the relevant design and analyses.
33

34 **3.0 TECHNICAL EVALUATION**

35 **3.1 BASIC THEORY**

36 The SCICR methods rely on a quantity known as the inverse count rate ratio (ICRR). A
37 fundamental tenet of the theory behind SCICR is that, [
38
39
40]
41

42 A series of [] are defined in order to apply the ICRR theory to an actual, subcritical
43 core. These are [
44
45]
46

47 The [] measures [
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the Dynamic Rod Worth
Measurement (DRWM™)
technique

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] Westinghouse elaborated on the TR discussion in the response to SNPB RAI 2, which provided more detailed information on the process used to determine [] The process is fundamentally similar to that applied in the NRC-approved methodology for rod worth measurements discussed in WCAP-13360-P-A, "Westinghouse Dynamic Rod Worth Measurement Technique" (Ref. 11) for calculating []

Include new prop brackets

The NRC staff were initially concerned that the calculation of [] would potentially introduce calculational errors or biases. However, the introduction of biases is not an issue because of [] used in determining the ICRR. Based on the discussion provided in Section 2.3 of WCAP-16260-P/WCAP-16260-NP, Revision 2, the ICRR is calculated by []

[], and as a result persistent biases in the [] are negated. Additionally, because the predicted [] is always [] and the measured [] is always [] code uncertainties are not mixed with experimental uncertainties. Therefore, even if the [] calculation were to introduce additional uncertainty, it would only contribute to an overall higher uncertainty as compared to the ICRR measurements, which would be reflected in [] (as will be discussed later in this SE).

Move prop. bracket to end of the sentence, which ends on line 32.

The [] measures [] Mathematically, it is []

] Because, in power operations, the [] contribute a negligible amount² of reactivity compared to the remainder of the core, they are typically omitted from core design codes. However, [] can be included for the purposes of []

In response to SNPB RAI 3, Westinghouse provided a discussion of how [] were included in the standard set of Westinghouse nuclear design codes (ALPHA/PHOENIX-P/ANC). In 2005, with the initial introduction of the SCICR methodology following NRC approval of WCAP-16260-P, Revision 0, the codes were updated to include []

] Westinghouse noted that appropriate

toward the overall neutron flux distribution

² As discussed in Westinghouse's response to SNPB RAI 3, []

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1 quality assurance processes³ were followed to ensure that the inclusion of extraneous sources
 2 was adequately implemented and did not affect the licensed uses of the codes. Additional
 3 validation of the extraneous source implementation was provided through the demonstration
 4 calculations discussed in Section 4 of the TR, which will be discussed later in this SE. By
 5 reviewing a sample of Westinghouse nuclear design code TRs, the NRC staff additionally
 6 verified that the codes were qualified for performing physics calculations in subcritical conditions
 7 by simulating subcritical and low-power physics tests with acceptable agreement between
 8 predicted and measured parameters.

9
 10 The [] is the product of []

11] If []

12
 13] can be realized for an actual core.

14 The derivation and implementation of [] is the second fundamental
 15 tenet of the theory underpinning SCICR, and its practical applicability. Based on the review
 16 described above, which established that the Westinghouse methods for determining
 17 [] is valid and produces acceptable results, and on the consideration that
 18 the NRC staff has previously approved the SCICR theory, the NRC staff finds presently that the
 19 theoretical basis, as described in Sections 2.1 and 2.2 of WCAP-16260-P, Revision 2, is
 20 acceptable.

21
 22 3.2 PRIOR METHODOLOGICAL ISSUES

23 In the prior revision of WCAP-16260-P, the successful execution of the SCICR methods

24 []

25 However, in the original SCICR implementation, the computationally-determined []

26
 27] Westinghouse
 28 issued a Technical Bulletin in 2012 describing this issue in detail, and suspending the use of the
 29 SCICR methodology (Ref. 12).

30
 31 Although the present construction of the SCICR methodology relies on the same theoretical
 32 foundation, the application approach has been revised to compare []

33
 34
 35] This approach results in []

36
 37
 38] While the present review is not intended to revisit
 39 issues with the prior versions of the methodology, which Westinghouse has stated throughout
 40 the TR are superseded in their entirety with Revision 2, the NRC staff nonetheless concluded
 41 that [] count rate data produces a more meaningful
 42 comparison to determine whether there are significant differences between the as-designed and
 43 as-loaded cores.

44
³ The procedure followed is documented in []

]

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1 The new, comparative approach is described in detail in Section 2.3 of the TR, but the
2 description and evaluation continues in the following sections of this SE, alongside an
3 evaluation of the demonstration applications for fuller context.
4

5 3.3 PROPOSED SCICR APPLICATIONS AND PROCESS

6 Sections 1.6 and 3.1 of WCAP-16260-P/WCAP-16260-NP, Revision 2, explain how SCICR is
7 applied on a plant. Section 1.6 describes four applications of SCICR, and Section 3.1 provides
8 a succinct overview of how the SCICR method is applied at a plant. The four applications
9 described in Section 1.6 are as follows:

- 10 1. [
- 11
- 12
- 13]
- 14 2. [
- 15]
- 16 3. [
- 17]
- 18 4. [
- 19]

20 These applications are also presented within the process overview in Section 3.1 of the TR.
21 [

22
23
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35]

37 Section 3.1 presents the process steps in a sequential order, meaning that the statepoint
38 evolution is known at the time [] in Step 2. However, Step 5 was
39 written in such a way that it appeared to the NRC staff to allow deviation from the Step 2
40 [] Westinghouse's response to SNPB RAI 4 clarified that in Step 5, it is
41 expected that the reactor will progress through [] with minor
42 deviations allowed. Predicted ICRR is a function of []
43] Each statepoint in the predicted data set is defined by 44 []
45] If the []

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1
2 Implementation of the SCICR methodology at a site must be consistent with these processes
3 and procedures, as well as the site licensee and Westinghouse quality assurance programs as
4 required by Appendix B to 10 CFR Part 50.

5
6 Given that Westinghouse provided sufficient information concerning the instrumentation
7 requirements, that adequate processes and procedures exist to implement the SCICR
8 methodology, and that Westinghouse and any implementing licensees must continue to follow
9 quality assurance plans in implementing the SCICR methodology, the NRC staff found the
10 measurement controls for SCICR to be acceptable.

11
12 3.5 SCICR RESULTS AND EVALUATION

13 The SCICR methodology application is demonstrated in Chapter 4 of WCAP-16260-P/
14 WCAP-16260-NP, Revision 2, and the acceptance criteria are discussed and evaluated in
15 Chapter 5.

16
17 3.5.1 Regression Analysis

18 Once the ICRR data are gathered, [
19]. The [
20] are examined. Ideally, measured
21 and predicted [] values [
22] In reality, after [
23
24]. Because the core physics calculations are generally highly accurate, it is
25 reasonable to expect []

26
27 In SCICR, [] is the independent
28 variable and [] is the dependent variable. A []
29 assumes that differences between the dependent and independent variables are the result of
30 random error in the dependent variable. However, in reality, there is an uncertainty in both the
31 measured [] (resulting from the instrumentation system used to take the []
32 measurement and transient fluctuations in the system parameters) and an uncertainty in the
33 predicted [] (resulting from the use of analytical methodologies, including []
34

35] The NRC therefore issued SNPB RAI 6 to interrogate the potential for these
36 uncertainties to introduce error in the predicted ICRR values that undermines the results of []
37]
38

39 In response, Westinghouse stated that the comparison between measured and predicted
40 startup physics test parameters is used to confirm the consistency of core behavior with design
41 predictions prior to establishing power operations. Measurement and prediction must agree
42 within a certain pre-established tolerance. If this tolerance is exceeded, the consistency of the
43 core with the design is called into question, resulting in further actions to confirm or refute the
44 deviation. Westinghouse then further stated that []
45

46] Considering all of this, the NRC staff concluded that the use of []
47] to assess the deviation between measurement and prediction is adequate provided
48 (a) that the tolerances are established such that true, significant deviations will be appropriately

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1 recognized and (b) that the actions taken in response to an indicated deviation will adequately
2 address true, significant deviations. These factors will be discussed in Sections 3.5.3 and 3.5.5
3 of this SE, respectively.
4

5 3.5.2 Criticality Prediction

6 During [], the global reactivity bias is estimated by [

7
8] The reactivity bias adjustment that [

9] is termed [

10], which is an estimate of the true global reactivity bias. The [] serves to
11 obtain a better projection of the estimated point of criticality. Once the core reaches a critical
12 condition, the true core reactivity bias (i.e., the difference between measured and predicted
13 critical conditions) can be determined and is denoted ACC.
14

15 In SNPB RAI 7, the NRC staff asked for additional detail on the codes and methods used to
16 determine [] and a demonstration calculation. Westinghouse's response clarified that
17 the codes used for [] To
18 calculate [

19
20] This results in changes to [

21
22
23
24
25
26
27]

28 As shown in Sections 4 and 5.2.1.1 of WCAP-16260-P/WCAP-16260-NP, Revision 2, and
29 particularly in Table 5-2, [] provide an accurate
30 estimate of the actual critical conditions. Therefore, because the method defined by
31 Westinghouse for calculating [] is consistent with the rest of the SCICR approach
32 ([]), and because it has been demonstrated
33 to provide an accurate estimate of the actual critical conditions, the NRC staff found the use of
34 the SCICR for criticality prediction to be acceptable.
35

36 3.5.3 Test Results and Acceptance Criteria

37 As shown in the demonstration results in Chapter 4, and as discussed in greater detail in
38 Chapter 5, the results of SCICR are tabulated [

39
40
41] Once the true core reactivity bias is determined, [

42
43]

44
45 The application review criteria are provided in Table 5-5 of WCAP-16260-P, Revision 2. These
46 criteria establish limits on the values of [

47
48

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1] Failure of any of these criteria would require a more thorough review
2 of measurement results and deliberate continuation of startup.

3
4 SPT application acceptance criteria, in contrast to the review criteria, have direct links to safety
5 analysis assumptions and TS requirements. Such criteria are specified for [] which
6 serves as a measure of rod worth uncertainty, and [] which serves as a measure of
7 reactivity balance. As Westinghouse explained the bases for these values, the NRC staff
8 determined that the acceptance criteria are appropriate and acceptable. As noted in the TR,
9 failure to meet the acceptance criteria would prohibit entry into MODE 1 operation prior to
10 resolution. Since these criteria relate directly to shutdown margin and ~~rod worth~~ requirements,
11 the NRC staff agrees that failure to meet the application acceptance criteria appropriately
12 preclude entry into MODE 1.

13
14] reactivity balance

14 3.5.4 Comparison to Prior Low-Power Physics Testing Methods

15 To demonstrate the viability of the SPT methods, Westinghouse provided Table 4-8 to compare
16 the results obtained from SPT to those obtained using the more traditional, low-power physics
17 testing. The table showed reasonable agreement between [] and total bank worth
18 measurements from LPPT. The table also showed close agreement between [] and
19 the BEP measured-to-predicted comparison. The generally good agreement between these
20 parameters provides an additional indication that the proposed testing methods provide an
21 adequate replacement for the more traditional methods.

22
23 3.5.5 Detectability of Anomalies

24 The comparison between [

25
26
27
28]

29
30 Westinghouse illustrated the detectability of local anomalies by []
31] as well as [] Both of these types
32 of errors resulted in significant deviations between the predicted and measured [] {
33] An inspection of the errors reveals that such errors
34 would result in anomalous []

35
36 In Section 5.3, along with the review and acceptance criteria, guidance is provided to assist in
37 the identification of potential causes of anomalous results from application of the SCICR
38 method. The NRC staff reviewed this issue resolution process and determined that it provides a
39 reasonable means to disposition results that do not meet the review or acceptance criteria, and
40 appropriate cautions not to proceed to MODE 1 when the testing results suggest that there is an
41 unexplained discrepancy between the core design and its operating characteristics.

42
43 3.6 APPLICABILITY OF SCICR

44 As discussed in Section 6.4 of the TR, Westinghouse proposed limitations on the applicability of
45 WCAP-16260-P/WCAP-16260-NP, Revision 2. Westinghouse considers the SCICR
46 methodology and applications to be applicable to [

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1] The method is also specified to
2 only be applicable to [
3] since all demonstration cases were performed under these conditions.
4 These limitations on the applicability of SCICR will be considered in the following sections of this
5 SE.

6
7 3.6.1 [] NSSS Plants Move prop. bracket from here...
8 ...to here.

8 Demonstrations of the SCICR method and applications were provided for [
9] in Section 4.1 of the TR. These demonstrations showed that the measured and
10 predicted []

11] Aside from one instance in which [
12] the results
13 were well within the SPT application review criteria discussed in Table 5-5 of the TR and
14 Section 3.5.3 of this SE. This is expected, since [
15]. The design method controls discussed in Section 5.2 of the TR includes [
16] cases showing that the review and acceptance criteria, when applied at
17 [] are capable of detecting core anomalies. Thus the NRC staff
18 finds that SCICR is acceptable for use at [] based on the analyses
19 and demonstrations provided in the TR, with no additional work required.

20
21 3.6.2 [] NSSS Plants

22 More limited information was provided to justify applicability to [
23] Earlier revisions of the SCICR TR included data from plants of these types;
24 this data was reevaluated under the updated SCICR methodology and applications, and was
25 presented in Section 4.3 of the TR. As discussed in Section 4.3.4, the data for these
26 demonstrations were taken under conditions [

27
28]
29 Additionally, [] applied in Revision 2 of the TR were not in
30 place when the data were collected.

31
32 The results for the plants in question ([
33] labeled Plant E through G in the TR, respectively) were relatively good. All displayed the
34 expected [] behavior. However, [

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44] The NRC staff agrees with Westinghouse's assessment of
45 the issues with these measurements and how they could be mitigated [
46]
47

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1 The NRC staff finds, therefore, that these demonstration cases for the [
2] plants validate that the SCICR methodology is generally applicable to these types of
3 plants, in that it produces measured and predicted []
4] However, given that SCICR is used to detect core
5 anomalies prior to startup, appropriate review and acceptance criteria must be established for
6 these plant types. Because the demonstration cases for the [
7] it is not
8 possible to determine whether the review criteria provided in Table 5-5 of the TR provide the
9 appropriate level of detection for these plant types based on these sample analyses. Therefore,
10 while the NRC staff generally determined that SCICR is applicable to [
11] plants, application of SCICR at these plant
12 types is contingent on verification that the review and acceptance criteria are appropriate for
13 these plants. Thus, as will be discussed in Section 4.0 of this SE, appropriate limitations and
14 conditions will be applied to the use of SCICR at []
15 plants.
16

17 3.6.3 Extension to Other Plant Types

18 In the limitations and conditions Westinghouse proposed in Section 6.4 of the TR,
19 Westinghouse suggested that application of SCICR to plants other than [
20] plants would require a side-by-side comparison to physics test results
21 obtained using a different method during the same startup. The process was discussed in
22 further detail in Appendix C of the TR, which specifies that the results of this side-by-side
23 demonstration, [
24] would be formally documented and made available for NRC audit purposes. The NRC
25 staff finds this approach to be acceptable, since it will confirm that SCICR and the associated
26 review and acceptance criteria are applicable to the plant type before it may be used without
27 also applying other startup physics testing techniques.
28

29 3.6.4 Extension to Other Nuclear Design Codes and Utility Self-Performance

30 In the limitations and conditions Westinghouse proposed in Section 6.4 of the WCAP-16260-P/
31 WCAP-16260-NP, Revision 2, Westinghouse suggested that the SCICR methodology could be
32 extended beyond the Westinghouse nuclear design codes or could be used by non-
33 Westinghouse core designers, with appropriate benchmarking and comparison as discussed in
34 Appendix D of the TR. Appendix D specifies that the nuclear design codes to be used for
35 SCICR must have received prior NRC review and approval, must be applied in a manner
36 consistent with the process provided by Westinghouse, and must be qualified for subcritical
37 physics calculations by comparison to existing subcritical physics calculations (Criteria 1, 2,
38 and 4). A utility that wishes to self-perform core design calculations and use SCICR must also
39 ensure that utility personnel are qualified with an accredited technical training program
40 (Criterion 3) and that SCICR calculations are conducted under a 10 CFR Part 50, Appendix B
41 compliant quality assurance program (Criterion 5). The first application of SCICR at a plant
42 must be performed by Westinghouse, and the comparison required in Criterion 4 must include a
43 comparison to that SCICR application. Also, a notification of compliance with the criteria is
44 required at least 3 months before the utility's use of the SCICR methodology.
45

46 The NRC staff finds that the five criteria provided in Appendix D to WCAP-16260-P/
47 WCAP-16260-NP, Revision 2, are sufficient to ensure that the SCICR methodology may be
48 safely extended to other nuclear design codes and to utility self-performed SCICR calculations.

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1 This is because the criteria require the use of NRC-approved core physics codes, require
2 demonstration of adequate technical performance, and require appropriate controls on the utility
3 personnel, processes, and procedures.
4

5 **4.0 LIMITATIONS AND CONDITIONS**

6 Westinghouse proposed several limitations and conditions as applicable to WCAP-16260-P/
7 WCAP-16260-NP, Revision 2, in Section 6.4 of the TR. The NRC staff generally concur with
8 these limitations and conditions, as largely discussed in Section 3.6 of this SE. The following
9 conditions and limitations, which represent the TR Section 6.4 limitations and conditions with
10 some minor editorial changes, are therefore applied to the use of WCAP-16260-P/
11 WCAP-16260-NP, Revision 2:
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5.0 CONCLUSION

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Based on the review described above and subject to the conclusions and limitations delineated in Chapter 5 of this SE, the NRC staff has determined that WCAP-16260-P/WCAP-16260-NP, Revision 2, is acceptable. The NRC staff based its conclusion on the following considerations:

- The theory described in Sections 2.1 and 2.2 of the TR is consistent with that previously approved, and leads to a meaningful comparison of measured to predicted data, which can be taken from a core in a subcritical configuration and used to verify that the as-installed core is operating consistently with the as-designed core.
- By [] provides more meaningful results []. This [] . This
- The SCICR process and applications represent a valid and meaningful application of the theory described in the TR.
- The demonstration results and sensitivity studies demonstrate that the method works reasonably well, insofar that it is capable of identifying core design anomalies, given the testing review and acceptance criteria provided in Chapter 5.
- Comparisons using prior core startup physics testing data and the results of different testing methods demonstrates consistent performance between SCICR and the prior methods.

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1 Because Westinghouse has shown that the method provides an acceptable means to detect
 2 potential differences between the as-designed and as-installed core, based on comparisons
 3 between [] the
 4 NRC staff determined that the proposed testing method is consistent with the objective stated
 5 for the PHYSICS TESTS in the STS BASES, as well as the requirements of 10 CFR 50.34 and
 6 10 CFR 50.36. Based on this consideration, the NRC staff further determined that the proposed
 7 testing program adheres to Criterion XI of 10 CFR Part 50 Appendix B. confirm

8
 9 Therefore, the NRC staff concludes that WCAP-16260-P, Revision 2, is acceptable for use as a
 10 method for performing PWR startup physics tests to ensure that certain core characteristics
 11 (e.g., shutdown margin) are maintained within their TS limits and the core is operating as
 12 designed.

13
 14 **6.0 REFERENCES**

via measurement as a means to demonstrate that

1. J. Gresham, Westinghouse Electric Company, letter to Document Control Desk, U.S. Nuclear Regulatory Commission, "Submittal of the Topical Report WCAP-16260-P/WCAP-16260-NP, Revision 2, "The Spatially Corrected Inverse Count Rate (SCICR) Method for Subcritical Reactivity Measurement" (Proprietary/Non-proprietary)," December 14, 2017, ADAMS Accession No. ML17348B293.
2. P.J. Sebastiani and J.L. Diorio, Westinghouse Electric Company, "The Spatially Corrected Inverse Count Rate (SCICR) Method for Subcritical Reactivity Measurement," WCAP-16260-P/NP, Revision 2, December 2017, ADAMS Accession No. ML17348B295 (publicly available) / ML17348B311 (non-publicly available).
3. Y.A. Chao, et al., Westinghouse Electric Company, "The Spatially Corrected Inverse Count Rate (SCICR) Method for Subcritical Reactivity Measurement," WCAP-16260-P-A, Rev. 0, September 2005, ADAMS Accession No. ML052640396 (non-publicly available) / ML052640402 (publicly available).
4. E. Lenning, US NRC, letter to J. Gresham, Westinghouse Electric Company, "Request for Additional Information Re: Westinghouse Electric Company WCAP-16260-P/WCAP-16260-NP, Revision 2, "The Spatially Corrected Inverse Count Rate Method for Subcritical Reactivity Measurement" Topical Report (EPID-L-2017-TOP-0064)," August 9, 2018, ADAMS Accession No. ML18207A226.
5. E. Lenning, US Nuclear Regulatory Commission, letter to J.A. Gresham, Westinghouse Electric Company, "Request for Additional Information Re: Westinghouse Electric Company WCAP-16260-P/WCAP-16260-NP, Revision 2, 'The Spatially Corrected Inverse Count Rate (SCICR) Method for Subcritical Reactivity Measurement' Topical Report - Second Round," September 24, 2018, ADAMS Accession No. ML18263A197.
6. E.J. Mercier, Westinghouse Electric Company, letter to Document Control Desk, U.S. Nuclear Regulatory Commission, "Response to Request for Additional Information RE: Westinghouse Electric Company WCAP-16260-P/WCAP-16260-NP, Revision 2, "The Spatially Corrected Inverse Count Rate (SCICR) Method for Subcritical Reactivity Measurement" Topical Report," September 13, 2018, ADAMS Accession No. ML18257A062.
7. K.L. Hosack, Westinghouse Electric Company, letter to Document Control Desk, US Nuclear Regulatory Commission, "Submittal of Response to Request for Additional Information - Second Set - RE: Westinghouse Electric Company WCAP-16260-P/

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WCAP-16260-NP, Revision 2, "The Spatially Corrected Inverse Count Rate (SCICR) Method for Subcritical Reactivity Measurement" Topical Report," October 24, 2018, ADAMS Accession No. ML18299A090.

- 8. K.L. Hosack, Westinghouse Electric Company, letter to Document Control Desk, U.S. Nuclear Regulatory Commission, "Submittal of Additional Information - Public Meeting - RE: Westinghouse Electric Company WCAP-16260-P/WCAP-16260-NP, Revision 2, "The Spatially Corrected Inverse Count Rate (SCICR) Method for Subcritical Reactivity Measurement" Topical Report," January 8, 2019, ADAMS Accession No. ML19011A352.
- 9. U.S. Nuclear Regulatory Commission, NUREG-1431, Volume 1, "Standard Technical Specifications - Westinghouse Plants: Specifications," Revision 4, April 2012, ADAMS Accession No. ML12100A222.
- 10. U.S. Nuclear Regulatory Commission, NUREG-1431, Volume 2, "Standard Technical Specifications - Westinghouse Plants: Bases," Revision 4, April 2012, ADAMS Accession No. ML12100A228.
- 11. Westinghouse Electric Company, "Westinghouse Dynamic Rod Worth Measurement Technique," WCAP-13360-P-A, Revision 1, October 1998, ADAMS Accession No. ML063410295.
- 12. Westinghouse Electric Company LLC, "Technical Bulletin: Subcritical Rod Worth Measurement Methodology," TB-12-3, February 17, 2012, ADAMS Accession No. **ML121010060**.

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Principal Contributors: Benjamin T. Parks, NRR/DSS
Reed A. Anzalone, NRR/DSS

Westinghouse was not able to locate this on ADAMS.

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Item No.	Page	Line(s)	Suggested Edit	Notes	NRC Response
1	1	22	...changes to the application of subcritical physics testing (SPT)- Subcritical Physics Testing application of the SCICR method...	Westinghouse requests this change to clarify that SPT is one of the applications of the SCICR methodology.	
2	1	38-39	...to ensure that confirm core characteristics are maintained (e.g., shutdown margin) and via measurement as a means to demonstrate that the core is operating as designed.	Westinghouse requests this change to clarify the purpose of testing to compare key core characteristics to measurements in order to demonstrate that the core is operating as designed.	
3	2	11	The regulation at 10 CFR 50.36...	Editorial correction	
4	2	38	...Technical Specifications – Westinghouse Pants- Plants ...	Editorial correction	

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Item No.	Page	Line(s)	Suggested Edit	Notes	NRC Response
5	4	20-21	<p>...such as dynamic rod-worth measurement the Dynamic Rod Worth Measurement (DRWM™) technique...</p> <p>(New Footnote on page 4) DRWM is a trademark of Westinghouse Electric Company LLC, its affiliates and/or its subsidiaries in the United States of America and may be trademarked or registered in other countries throughout the world. All rights reserved. Unauthorized use is strictly prohibited. Other names may be trademarks of their respective owners.</p>	<p>Westinghouse requests using trademark identification on first usage.</p> <p>Use of the trademark also requires insertion of a footnote on the page of first usage.</p>	

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Item No.	Page	Line(s)	Suggested Edit	Notes	NRC Response
9	5	34-35	... contribute a negligible amount ² of reactivity compared to the remainder of the core- toward the overall neutron flux distribution , they are typically	Requested changes for technical accuracy.	

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Item No.	Page	Line(s)	Suggested Edit	Notes	NRC Response

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Item No.	Page	Line(s)	Suggested Edit	Notes	NRC Response
19	11	10	...directly to shutdown margin and rod worth reactivity balance requirements...	Westinghouse requests this change for technical accuracy. Reactivity balance is needed before MODE 1 entry, and is an explicit surveillance requirement. Rod worth is a part of the SDM assumptions/calculation, but its explicit measurement is not defined in TS.	

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Item No.	Page	Line(s)	Suggested Edit	Notes	NRC Response
23	15	20	In Chapter 5 Chapter 4 of this SE...	The conclusions and limitations are provided in Chapter 4 of the SE.	
24	16	10-12	...to ensure that certain confirm core characteristics (e.g., shutdown margin) are maintained within their TS limits and via measurement as a means to demonstrate that the core is operating as designed.	Westinghouse requests this change to clarify the purpose of testing (to compare key core characteristics to measurements in order to demonstrate that the core is operating as designed).	
25	17	(Ref. 12)	Not an edit, but a question regarding the reference as listed currently	Westinghouse was unable to locate the ML number on ADAMS.	

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