U. S. NUCLEAR REGULATORY COMMISSION

OFFICE OF NUCLEAR REACTOR REGULATION

FINAL 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

1.0 Introduction

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 the 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 of Subcritical Physics Testing (SPT) application of the SCICR method 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 confirm core characteristics via measurement as a means to demonstrate that 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.

2.1 Applicable regulatory requirements

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

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

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

2.2 Discussion and Regulatory Guidance

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

> The key objectives of a test program are to:
>
> a. Ensure that the facility has been adequately designed,
>
> b. Validate the analytical models used in the design and analysis,

c. Verify the assumptions used to predict unit response,

d. Ensure that installation of equipment in the facility has been accomplished in accordance with the design, and

e. Verify that the operating and emergency procedures are adequate.

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

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

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

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

2.3 Review Objectives

The testing methods described in WCAP-16260 relate to SPT undertaken during reactor startup. The characteristics required to be confirmed during startup by ANSI/ANS-19.6.1-2011 include the global reactivity balance, the capability to shutdown the core, the core power distribution[1], and measures for reactivity control. The bases for TS 3.1.8, "PHYSICS TEST Exceptions – MODE 2" provided in NUREG-1431, Revision 4, Volume 2, "Standard Technical Specifications – Westinghouse Plants: Bases" (Ref. ***10***) also discusses the need to confirm certain low-power physics test parameters, including critical boron concentration (CBC) at hot zero power (HZP) conditions with all control rods out of the core, CBC at HZP conditions with control rods inserted, control rod worth, ITC, and flux symmetry (which may be performed at up to 30 percent power and is therefore not necessarily a MODE 2 test).

---

[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.

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

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

3.0 Technical Evaluation

3.1 Basic Theory

The SCICR methods rely on a quantity known as the inverse count rate ratio (ICRR). A fundamental tenet of the theory behind SCICR is that, **[**

]

A series of **[ ]** are defined in order to apply the ICRR theory to an actual, subcritical core. These are **[**

]

The [ ] measures [ ] 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 [ ]

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 [ ] measurements, which would be reflected in [ ] (as will be discussed later in this SE).

The [ ] measures [ ] Mathematically, it is [ ] Because, in power operations, the [ ] contribute a negligible amount[2] toward the overall neutron flux distribution, 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

---

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

of WCAP-16260-P, Revision 0, the codes were updated to include **[**

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

The **[** **]** is the product of **[** **]** If **[** **]** can be realized for an actual core. The derivation and implementation of **[** **]** is the second fundamental tenet of the theory underpinning SCICR, and its practical applicability. Based on the review described above, which established that the Westinghouse methods for determining **[** **]** is valid and produces acceptable results, and on the consideration that the NRC staff has previously approved the SCICR theory, the NRC staff finds presently that the theoretical basis, as described in Sections 2.1 and 2.2 of WCAP-16260-P, Revision 2, is acceptable.

3.2 Prior Methodological Issues

In the prior revision of WCAP-16260-P, the successful execution of the SCICR methods **[** **]** However, in the original SCICR implementation, the computationally-determined **[** **]** Westinghouse issued a Technical Bulletin in 2012 describing this issue in detail, and suspending the use of the SCICR methodology (Ref. ***12***).

Although the present construction of the SCICR methodology relies on the same theoretical foundation, the application approach has been revised to compare **[** **]** This approach results in **[** **]** While the present review is not intended to revisit issues with the prior versions of the methodology, which Westinghouse has stated throughout the TR are superseded in their entirety with Revision 2, the NRC staff nonetheless concluded that **[** **]** count rate data produces a more meaningful comparison

[3] The procedure followed is documented in **[** **]**

to determine whether there are significant differences between the as-designed and as-loaded cores.

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

3.3 Proposed SCICR Applications and Process

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

1. **[** **]**
2. **[** **]**
3. **[** **]**
4. **[** **]**

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

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

[ ] If the [ ] differs from the expected statepoint, [ ] Similarly, if [ ] differs from predicted values, [ ] The corrected [ ] are then used to calculate [ ] based on the true core state at the time of measurement. The NRC staff finds this process to be acceptable, since it will adequately compensate for deviations between the nominal predictions and the true state of the core.

The NRC staff also noted, in reviewing the demonstration applications discussed in Chapter 4, that the [ ] The NRC staff therefore requested additional information (SNPB RAI 5) about this normalization to ensure that it does not introduce a potential to [ ] Westinghouse's response to SNPB RAI 5 clarified that [ ] The NRC staff found this response adequate to verify that [ ]

The NRC staff considered the SCICR applications and process overview insofar as they support the application of the SCICR theory, and determined that these aspects of the method are acceptable because they are generally consistent with the theory described in Section 2 of the TR and with the demonstration applications provided in Section 4. The following SE sections provide additional NRC staff review for certain aspects of the application process, including the SCICR measurement controls and how the SCICR results are interpreted and evaluated.

3.4 SCICR Measurement Controls

Section 5.1 of WCAP-16260-P/WCAP-16260-NP, Revision 2, provides an overview of the measurement controls used in implementation of the SCICR method at a site. These controls focus on ensuring that: 1) detectors are capable of making the required measurements without interfering with safety related signals, 2) signal quality is adequate, 3) signal errors are compensated for, 4) signal noise is appropriately characterized and aligned with expectations, and 5) measurements are taken at steady conditions.

Limited information was provided on the measurement controls. As discussed throughout the responses to the EICB RAIs (Ref. ***7***), this is because numerous potentially suitable approaches exist for signal acquisition and evaluation. The NRC staff notes that the level of detail provided in WCAP-16260-P/WCAP-16260-NP, Revision 2 is consistent with that submitted in previous NRC-approved methodologies for startup physics testing (e.g., the Dynamic Rod Worth Measurement methodology documented in WCAP-13660-P-A, Rev. 1 (Reference ***11***)). Though the responses to various EICB RAIs provided examples of methods that could be used, Westinghouse committed to work with licensees implementing the SCICR methodology to find the best set of methods for the instrumentation and intended applications at each plant utilizing SCICR.

In a submittal dated January 8, 2019 (Ref. ***8***), Westinghouse provided a summary table laying out the procedures associated with each of the SCICR measurement controls. Documents described in this table discuss **[** **]** Implementation of the SCICR methodology at a site must be consistent with these processes and procedures, as well as the site licensee and Westinghouse quality assurance programs as required by Appendix B to 10 CFR Part 50.

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

3.5 SCICR Results and Evaluation

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

3.5.1 **[** **]**

Once the **[** **]** data are gathered, **[** **]** The **[** **]** are examined. Ideally, measured and predicted **[** **]** values **[** **]** In reality, after **[** **]** Because the core physics calculations are generally highly accurate, it is reasonable to expect **[** **]**

In SCICR, **[** **]** is the independent variable and **[** **]** is the dependent variable. A **[** **]** assumes that differences between the dependent and independent variables are the result of random error in the dependent variable. However, in reality, there is an uncertainty in both the measured **[** **]** (resulting from the instrumentation system used to take the ICRR measurement and transient fluctuations in the system parameters) and an uncertainty in the predicted ICRR (resulting from the use of analytical methodologies, including **[** **]** The NRC therefore issued SNPB RAI 6 to interrogate the potential for these uncertainties to introduce error in the predicted **[** **]** values that undermines the results of **[** **]**

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

] Considering all of this, the NRC staff concluded that the use of **[** **]** to assess the deviation between measurement and prediction is adequate provided (a) that the tolerances are established such that true, significant deviations will be appropriately recognized and (b) that the actions taken in response to an indicated deviation will adequately address true, significant deviations. These factors will be discussed in Sections 3.5.3 and 3.5.5 of this SE, respectively.

3.5.2 Criticality Prediction

During **[** **]** the global reactivity bias is estimated by **[**

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

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

] This results in changes to **[**

]

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

3.5.3 Test Results and Acceptance Criteria

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

] Once the true core reactivity bias is determined, **[**

]

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

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

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

3.5.4 Comparison to Prior Low-Power Physics Testing Methods

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

3.5.5 Detectability of Anomalies

The comparison between **[**

]

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

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

3.6 Applicability of SCICR

As discussed in Section 6.4 of the TR, Westinghouse proposed limitations on the applicability of WCAP-16260-P/WCAP-16260-NP, Revision 2. Westinghouse considers the SCICR methodology and applications to be applicable to **[ ]** The method is also specified to only be applicable to **[ ]** since all demonstration cases were performed under these conditions. These limitations on the applicability of SCICR will be considered in the following sections of this SE.

3.6.1 **[ ]** NSSS Plants

Demonstrations of the SCICR method and applications were provided for **[ ]** in Section 4.1 of the TR. These demonstrations showed that the measured and predicted **[ ]** Aside from one instance in which **[ ]** the results were well within the SPT application review criteria discussed in Table 5-5 of the TR and Section 3.5.3 of this SE. This is expected, since **[ ]** The design method controls discussed in Section 5.2 of the TR includes **[ ]** cases showing that the review and acceptance criteria, when applied at **[ ]** are capable of detecting core anomalies. Thus the NRC staff finds that SCICR is acceptable for use at **[ ]** based on the analyses and demonstrations provided in the TR, with no additional work required.

3.6.2 **[ ]** NSSS Plants

More limited information was provided to justify applicability to **[ ]** Earlier revisions of the SCICR TR included data from plants of these types; this data was reevaluated under the updated SCICR methodology and applications, and was presented in Section 4.3 of the TR. As discussed in Section 4.3.4, the data for these demonstrations were taken under conditions **[ ]** Additionally, **[ ]** applied in Revision 2 of the TR were not in place when the data were collected.

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

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

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

3.6.3 Extension to Other Plant Types

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

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

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

The NRC staff finds that the five criteria provided in Appendix D to WCAP-16260-P/ WCAP-16260-NP, Revision 2, are sufficient to ensure that the SCICR methodology may be safely extended to other nuclear design codes and to utility self-performed SCICR calculations. This is because the criteria require the use of NRC-approved core physics codes, require demonstration of adequate technical performance, and require appropriate controls on the utility personnel, processes, and procedures.

4.0 Limitations and conditions

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

1. [

]

[

]

2. [

]

3. **[**

]

4. [

]

5.0 Conclusion

Based on the review described above and subject to the conclusions and limitations delineated in Section 4 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 [ ] This provides more meaningful results [ ]

- 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.

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

Therefore, the NRC staff concludes that WCAP-16260-P/WCAP-16260-NP, Revision 2, “The Spatially Corrected Inverse Count Rate (SCICR) Method for Subcritical Reactivity Measurement,” is acceptable for use as a method for performing PWR startup physics tests to confirm core characteristics via measurement as a means to demonstrate that the core is operating as designed.

6.0 References

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/ 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: Wesitnghouse 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.

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

Date: April 12, 2019