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The Spatially Corrected Inverse Count Rate (SCICR) Method for Subcritical Reactivity Measurement

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* Revision 2 supersedes and replaces all previous versions of this topical report.

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ABSTRACT

This topical report describes the Spatially Corrected Inverse Count Rate (SCICR) method for subcritical reactivity measurement and the process for its application. While the original SCICR method was largely retained from Revision 1, the method application was revised to **[** **]** $^{a, c}$ Revision 2 of this topical report supersedes Revision 1 entirely and is being submitted for review and approval by the United States Nuclear Regulatory Commission to allow for future generic commercial application.

Application of the SCICR method requires neutron detector measurements and corresponding core condition predictions that account for the subcritical neutron flux distribution. The basic uses of the SCICR method are to monitor and project the subcritical state of the core. Associated applications include monitoring of negative reactivity conditions or shutdown margin, and forecasting of estimated critical conditions prior to plant startup. The advanced SCICR application is Subcritical Physics Testing (SPT), which integrates the monitoring and forecasting functions to ultimately execute a series of measured-to-predicted (M−P) comparisons to confirm the as-built core is operating consistent with design following refueling.

[**]** $^{a, c}$ In order to correct deficiencies in the original implementation, for this revision, data from four new demonstrations were obtained to support two key application improvements; **[** **]** $^{a, c}$ Detectability analyses using 3D core simulations were performed for the four new demonstrations, **[** **]** $^{a, c}$ It is concluded that the revised SPT program will provide plants with a robust process to evaluate whether or not the reactor responds as expected during initial plant startup following refueling.

Section 1 of this topical report contains background information, as well as a content comparison to the previous revision. Section 2 contains the subcritical core condition simulation (retained for this revision), along with **[** **]** $^{a, c}$ The revised application process overview is presented in Section 3, which includes an introduction to the SPT measurement parameters **[** **]** $^{a, c}$ Section 4 presents demonstration data using the revised approach. Section 5 discusses process controls, both for measurement and for the design method. Measurement process controls are defined to ensure high quality measurements are obtained. Design method controls are established **[** **]** $^{a, c}$ Section 5 concludes with the proposed results evaluation criteria for the revised SPT application. Section 6 includes various regulatory considerations, including the proposed limitations and conditions.

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1 INTRODUCTION

1.1 PURPOSE

A key piece of information needed for the safe and efficient operation of a subcritical reactor core is the negative reactivity of the core; that is, the amount that the core is subcritical. Prior to development of the methodology described herein, this information has only been inferred, and not directly measured. This topical report describes, and applies for the licensing of, revised application of the Spatially Corrected Inverse Count Rate (SCICR) methodology for subcritical reactivity measurement.

As was the case in prior revisions of this topical report (References 1 and 2), the basic uses of the SCICR method are to project and monitor the negative reactivity of a subcritical core for any static configuration of interest **[** **]** $^{a, c}$ via the use of neutron detector signal measurements and advanced subcritical core condition predictions. A series of subcritical measured-to-predicted (M−P) comparisons during plant startup **[** **]** $^{a, c}$, which is termed Subcritical Physics Testing (SPT).

SPT is performed at static and subcritical conditions (vs. dynamic and critical conditions for traditional low power physics testing, LPPT). In this respect, SPT is revolutionary as the technique is not the latest evolution of LPPT. However, the same objective as LPPT is achieved; following refueling and prior to returning to normal operation, testing is performed to determine if the operating characteristics of the core are consistent with design predictions as a means to ensure the core can be operated as designed.

While achieving the same objective as LPPT, performing SPT yields inherent safety, human performance, and test performance benefits over LPPT. Performing measurements at static and subcritical conditions inherently enhances plant safety and reactivity management. **[** **]** $^{a, c}$ which improves test reliability and human performance. Therefore, SPT-based core design verification offers broad benefits for essentially any plant type.

While much of the original approved SCICR methodology has been retained, Revision 2 of this topical report supersedes Revision 1 entirely and is being submitted for review and approval by the United States (U.S.) Nuclear Regulatory Commission (NRC) to allow for future generic commercial application.

1.2 BACKGROUND

The existence of neutron flux in a subcritical core is maintained by the embedded extraneous neutron sources, which consist of any implanted primary or secondary neutron source(s) and the spontaneous fission source due to certain isotopes generated in the process of fuel burnup. For a point core model, the inverse of the core flux level varies linearly with the magnitude of subcriticality of the core. **[**

] $^{a, c}$

The lack of a method to determine the expected subcritical core ICRR behavior that accounts for the influences of the extraneous source spatial distribution prevents the proper interpretation of the measured ICRR and, subsequently, also precludes measurement of core subcriticality.

Westinghouse nuclear design code packages (References 3 through 8) can calculate the extraneous neutron source distribution in a core and perform subcritical diffusion calculations in the presence of the extraneous neutron sources, and can also simulate the corresponding relative change in neutron detector signals. Equivalently, the source calculations and subcritical simulations can be performed with a Westinghouse on-line power distribution monitoring system (References 9 through 13). The requirements of Appendix D apply in order to extend the SCICR methodology to other nuclear codes, or to non-Westinghouse designers (e.g., technology transfer to utility designers). **[**

] $^{a, c}$ Consequently, it becomes possible to apply the SCICR methodology.

Field deployment of SPT with the Subcritical Rod Worth Measurement (SRWM) application began following NRC approval of Revision 0 of this topical report (Reference 1). SPT with the SRWM application was conducted 50 times at 10 different stations and 16 different units between October 2005 and November 2011. **[**

] $^{a, c}$

While the SRWM application was in use, no cores experienced significant discrepancies between the as-loaded core and the as-modeled core design. **[**

] $^{a, c}$

1.3 ISSUE RESOLUTION

[

] $^{a, c}$

[

] $^{a, c}$ Hence, supplemental information was gathered to provide those plants with the necessary reasonable assurance that the core was operating as designed. **[**

] $^{a, c}$

As mentioned previously, the SRWM application required **[**

] $^{a, c}$ see Figure 1-1 as an example. **[**

] $^{a, c}$

The neutron detector response in its “raw” **[** **]** $^{a, c}$ form is the most basic measurement result **[**

] $^{a, c}$

[

] $^{a, c}$

Figure 1-2 is an example of the revised approach, **[**

] $^{a, c}$

[

] $^{a, c}$ Therefore, the original NRC-approved SCICR methodology from previous revisions of this topical report was retained (with only minor editorial changes and clarifying additions for this revision). See Sections 2.1 and 2.2 for the fundamental SCICR method.
[
] $^{a, c}$

a, b, c

[ ]

Figure 1-1: SRWM Application Process Example

a, b, c

[ ]

Figure 1-2: Revised SPT Application Process Example

1.4 RECONSTRUCTION OF THE SPT PROGRAM

[

] $^{a, c}$ This revised approach warranted definition of new measurement parameters and associated criteria to confirm the operating characteristics of the core are consistent with design predictions.

A revised step-by-step application process was defined to obtain the necessary measurement data; details are provided in Section 3.1. [

] $^{a, c}$

The process described in the previous paragraph is performed at MODE 3 (Hot Shutdown) conditions, [

] $^{a, c}$

Once the plant reaches stable critical conditions, the true core reactivity bias can be determined. [

] $^{a, c}$ The final SPT results are presented at this point, and after confirming all results are acceptable, the plant can proceed to MODE 1.

In total, the revised application achieves the same objective as traditional LPPT, but in a unique way and via non-traditional measurements. [

] $^{a, c}$

Plant demonstrations were conducted in-line with the revised application process (Section 4.1). The successful plant demonstrations confirmed the feasibility of the application process and established normal variability in the new measurement parameters. The final step was conduct of studies [

] $^{a, c}$

a, b, c

Figure 1-3: ICRR M−P Evaluation Example

a, b, c

Figure 1-4: ICRR Line Evaluation Example

Table 1-1: Comparison of SRWM and Revised SPT Programs

a, c

[

]

1.5 REPORT ORGANIZATION

This topical report is structured as described in the following paragraphs. For convenience, Table 1-2 contains a comparison of the contents to previous revisions. Section 1 contains background information on the SCICR method, a summary of the issues experienced with the SRWM application, a summary of the reconstructed SPT application, and explanation of the SCICR applications. Section 2 explains the subcritical core condition simulation (primarily based on the method described in previous revisions and retained in Sections 2.1 and 2.2), **[**
] ^{a,c} The revised application process overview is presented in Section 3, which includes an introduction to the associated measurement parameters,
[
] ^{a,c} Section 4 presents demonstration data using the revised approach.

Section 5 discusses process controls, both for measurement and for the design method. Measurement process controls are defined to ensure high quality measurements are obtained. Design method controls are established **[**
] ^{a,c} Section 5 concludes with the proposed results evaluation criteria for the revised SPT application. Section 6 includes various regulatory considerations, including the proposed limitations and conditions.

Appendices contain the following support information. Appendix A provides guideline instructions on how to execute the SPT application. Appendix B **[**

] $^{a, c}$ Appendix C describes requirements to be completed if the SCICR applications are applied outside of the current experience base. Appendix D describes requirements to be completed if the SCICR method and applications are extended to non-Westinghouse nuclear design codes and/or non-Westinghouse nuclear designers. Finally, Appendix E links previous technical queries to information presented in this revision of the topical report (e.g., Revision 0 Requests for Additional Information).

Table 1-2: Content Comparison between SCICR Topical Report Revisions

a, c

Table 1-2: Content Comparison between SCICR Topical Report Revisions

a, c

Table 1-2: Content Comparison between SCICR Topical Report Revisions

a, c

Table 1-2: Content Comparison between SCICR Topical Report Revisions

a, c

Table 1-2: Content Comparison between SCICR Topical Report Revisions

a, c

1.6 SCICR APPLICATIONS

The SCICR methodology has multiple applications as described below. The first application is requisite and complementary to all other uses. The second and third applications can be utilized separately or jointly to support shutdown and startup activities throughout the course of an operating cycle. The fourth application integrates aspects of each of the other applications specifically for the purposes of core design validation during initial startup for an operating cycle. See Section 6.4 for the associated limitations and conditions.

Application 1 – [

] $^{a, c}$

Application 2 – [

] $^{a, c}$

Application 3 – [

] $^{a, c}$

Application 4 – [

] $^{a, c}$

2 THEORY

2.1 SPATIAL CORRECTION TO ICRR

[

]^{a,c}

[ ]^{a,c} **(2-1)**

[

]^{a,c}

[ ]^{a,c} **(2-2)**

[

]^{a,c}

[

]^{a,c}

[ ]^{a,c} **(2-3)**

[

]^{a,c}

[

]^{a,c}

[ ]^{a,c} **(2-4)**

[

] $^{a, c}$

[**]** $^{a, c}$ Equation (2-4) can be written as,

[ ] $^{a, c}$ **(2-5)**

[ ] $^{a, c}$ **(2-6)**

[

] $^{a, c}$

[

] $^{a, c}$

[ ] $^{a, c}$ **(2-7)**

This factor is always less than 1.0. Using this factor, we can relate the total source to the extraneous sources through Equation (2-1) as

[ ] $^{a, c}$ **(2-8)**

Substituting Equations (2-6) and (2-8) into Equation (2-5), we obtain

[ ] $^{a, c}$ **(2-9)**

[

] $^{a, c}$

[**]** $^{a, c}$ Equation (2-9) can be written as

[ ] $^{a, c}$ **(2-10)**

[ ] $^{a, c}$ **(2-11)**

[

] $^{a, c}$

[

] $^{a, c}$

[ ] $^{a, c}$ **(2-12)**

[ ] $^{a, c}$ **(2-13)**

Substituting Equations (2-12) and (2-13) into Equation (2-10) **[** **]** $^{a, c}$ we get the following relation,

[ ] $^{a, c}$ **(2-14)**

[

] $^{a, c}$

[

] $^{a, c}$ The following equation is a more accurate form of Equation (2-6),

[ ] $^{a, c}$ **(2-15)**

[

] $^{a, c}$

2.2 CAUSES FOR SUBCRITICAL SPATIAL REDISTRIBUTION

When a core is not generating power, there are no reactivity feedback effects that can cause spatial flux redistribution. For a subcritical core, there are basically two causes for spatial redistribution; the (negative) reactivity-induced spatial redistribution and the configuration-induced spatial redistribution.

The reactivity-induced redistribution is due to the difference between the distribution shape of the extraneous neutron sources and the fundamental mode of the core. This difference increases with the magnitude of the core subcriticality, and disappears if the core is very close to criticality.

The configuration-induced redistribution is due to the core configuration change that alters the fundamental mode of the core. This redistribution effect is more pronounced as the core is close to criticality where the fundamental mode dominates the flux distribution. For a very subcritical core, this effect is relatively much smaller.

The two kinds of redistribution can often happen at the same time. Examples of purely reactivity induced redistribution are changes in boron concentration or the isothermal change in core temperature. The configuration induced redistribution is mostly due to control rod movement. However, control rod movement changes the core reactivity also, and thus a reactivity-induced redistribution as well, unless the core is very close to criticality.

The configuration induced redistribution is more familiar and not a unique feature for a subcritical core. The reactivity induced redistribution, however, is less familiar and unique to a subcritical core. Figure 2-1 shows an example of the reactivity induced redistribution. **[**

] $^{a, c}$

[

]$^{a, c}$ This effect is greatly and rapidly amplified as the core goes more subcritical.

a,
b,
c

Figure 2-1: Comparison of Power Distributions in a Quarter of a 4-Loop Core Modeled with and without Extraneous Neutron Sources
(Critical and 100 ppm Subcritical cases)

2.3 SPT APPLICATION THEORY

Recognizing that (1/*M*) theory is practically represented by monitoring changes in measured neutron detector count rates from a baseline or reference condition, **[**
] $^{a, c}$

[ ] $^{a, c}$ **(2-16)**

M_R and M_i are count rates at the reference state point condition *R* and a subsequent state point condition *i*, respectively. **[**
] $^{a, c}$ re-arrangement of terms yields the following equation,

[ ] $^{a, c}$ **(2-17)**

[
] $^{a, c}$ Further re-arrangement results in the following equation,

[ ] $^{a, c}$ **(2-18)**

[
] $^{a, c}$ In simplified form,

[ ] $^{a, c}$ **(2-19)**

The true regression of Equation (2-19) can be written as,

[ ] $^{a, c}$ **(2-20)**

[
] $^{a, c}$ To apply the SCICR method, neutron detector measurements will be collected at various state points, **[**
] $^{a, c}$ The resultant estimate of the true regression, Equation (2-21), serves as the basis for the SPT results evaluation.

[ ] $^{a, c}$ **(2-21)**

[

] a, c

[ ] a, c **(2-22)**

[

] a, c

[ ] a, c **(2-23)**

[

] a, c

[ ] a, c **(2-24)**

[

] a, c

[

] a, c

[ ] a, c **(2-25)**

[

] a, c

3 METHOD APPLICATION

3.1 PROCESS OVERVIEW

[

] a, c

3.2 PROCESS IMPLEMENTATION PHILOSOPHY

3.2.1 Merging SPT into Existing Plant Processes

Sample guidelines for the overall SPT process are provided in Appendix A. **[**

] $^{a, c}$

[

] $^{a, c}$

[

] $^{a, c}$

3.2.2 Pre-MODE 1 Core Design Validation

Table 3-1 lists key core characteristics that are validated as part of any comprehensive reload startup physics testing. While these characteristics were developed based on many years of critical-based LPPT, the characteristics are carried over to SPT-based core design validation. It is clear that the SPT parameters assigned to demonstrate the key characteristics are much different than the parameters measured as part of traditional LPPT. It is important to note that the SPT parameters are not direct replacements for the LPPT parameters; rather, the SPT parameters provide equivalent means to demonstrate the key core characteristics.

In addition to negative reactivity/ICRR monitoring during state point data collection, the results obtained **[** **]**$^{a, c}$ will enhance the approach to critical in terms of improved Reactivity Management; **[**

]$^{a, c}$

[

]$^{a, c}$

[

]$^{a, c}$ While the new SPT application measurement parameters are non-traditional in comparison to previous LPPT methodologies, the same "prime directive" is achieved; measurement-based confirmation that the as-built core is operating as designed prior to power operation.

Table 3-1: SPT Parameters for Pre-MODE 1 Core Design Validation

a, c

4 APPLICATION DEMONSTRATION

Four new demonstrations were conducted for this revision to validate the revised SPT application. Each demonstration generally followed the process presented in Section 3.1 of this topical report. Details and differences between demonstrations are explained throughout Section 4.1. Section 4.2 presents the variation in the most-recent demonstration results, **[**

] $^{a, c}$ However, as will be explained in Section 4.3, the SPT application is not limited to plants of this specific design type.

4.1 DEMONSTRATION DETAILS AND RESULTS

4.1.1 Plant A Demonstration

Demonstration data was collected during Cycle 18 startup. **[**

] $^{a, c}$ The initial SPT results, **[**

] $^{a, c}$ are presented in Table 4-1.

[

] $^{a, c}$

The final SPT results, **[** **]** $^{a, c}$ are presented in Table 4-1. The final ICRR line results are presented in Figure 4-1.

4.1.2 Plant B Demonstration

Demonstration data was collected during Cycle 21 startup. **[**

] $^{a, c}$ The initial SPT results, **[**

] $^{a, c}$ are presented in Table 4-2.

[

] $^{a, c}$

The final SPT results, **[** **]** $^{a, c}$ are presented in Table 4-2. The final ICRR line results are presented in Figure 4-2.

Table 4-1: Plant A SPT Results

a, b, c

a, b, c

Figure 4-1: Plant A Final ICRR Line Results

Table 4-2: Plant B SPT Results

a, b, c

a, b, c

Figure 4-2: Plant B Final ICRR Line Results

4.1.3 Plant C Demonstration

Demonstration data was collected during Cycle 27 startup. **[**

] $^{a, c}$ The initial SPT results,
[
] $^{a, c}$ are presented in Table 4-3.

[

] $^{a, c}$ The initial SPT results, **[** **]** $^{a, c}$ are presented in Table 4-4.

[

] $^{a, c}$ The final SPT results, **[**
] $^{a, c}$ are presented in Table 4-3 and Table 4-4 **[**
] $^{a, c}$ Likewise, the final ICRR line results are presented in Figure 4-3 and Figure 4-4.

4.1.4 Plant D Demonstration

Demonstration data was collected during Cycle 20 startup. **[**

] $^{a, c}$ The initial SPT results,
[
] $^{a, c}$ are presented in Table 4-5.

[

] $^{a, c}$ The initial SPT results,
[
] $^{a, c}$ are presented in Table 4-6.

[
] $^{a, c}$ The final SPT results, **[**
] $^{a, c}$ are presented in Table 4-5 and Table 4-6 **[**
] $^{a, c}$ Likewise, the final ICRR line results are presented in Figure 4-5 and Figure 4-6.

Table 4-3: Plant C SPT Results [ ]$^{a, c}$

a, b, c

[ ]

a, b, c

[ ]

Figure 4-3: Plant C Final ICRR Line Results [ ]$^{a, c}$

Table 4-4: Plant C SPT Results [ ] a, c

a, b, c

[ ]

a, b, c

[ ]

Figure 4-4: Plant C Final ICRR Line Results [ ] a, c

Table 4-5: Plant D SPT Results [ ] a, c

a, b, c

[ ]

a, b, c

[ ]

Figure 4-5: Plant D Final ICRR Line Results [ ] a, c

Table 4-6: Plant D SPT Results [ ]$^{a, c}$

a, b, c

[ ]

a, b, c

[ ]

Figure 4-6: Plant D Final ICRR Line Results [ ]$^{a, c}$

4.2 RESULTS VARIATION AND COMPARISON TO LPPT

Table 4-7 contains the minimum and maximum observed final results for each SPT parameter over the four most-recent demonstrations. **[**

] a, c

Table 4-7: SPT Results Range (Most Recent Demonstrations)

a, b, c

[ ]

Section 3.2.2 of this topical report introduced how the new SPT application accomplishes core design validation in line with the longstanding key core characteristics validated as part of reload startup physics testing: **[**

] a, c

[

] a, c

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While exact agreement is not expected due to fundamental differences (e.g., methodology, nuclear instrumentation, data collection equipment, plant conditions), **[**

] $^{a, c}$

Table 4-8: SPT vs. LPPT Results Comparison

a, b, c

[ ]

4.3 DEMONSTRATION FOR PREVIOUSLY-APPROVED PLANT TYPES

Data from thirteen operating cycles of eight plants were analyzed and presented in earlier revisions of this topical report (References 1 and 2). The experience base at that time included Westinghouse 2-, 3-, and 4-Loop NSSS design plants and Combustion Engineering (CE) 217-assembly type plants. **[**

] $^{a, c}$

[

] $^{a, c}$ past topical report demonstration data can be re-analyzed to observe whether or not fundamental agreement exists between **[**

] $^{a, c}$

4.3.1 Plant E Demonstration

Demonstration data **[** **]** $^{a, c}$ during Plant E Cycle 25 startup (identified as Plant 7 in References 1 and 2). **[** **]** $^{a, c}$

The ICRR line statistics and plot **[** **]** $^{a, c}$ are presented in Table 4-9 and Figure 4-7, respectively. **[** **]** $^{a, c}$

[**]** $^{a, c}$

4.3.2 Plant F Demonstration

[**]** $^{a, c}$ Therefore, that data was replaced with data **[** **]** $^{a, c}$ during Plant F Cycle 22 startup. **[** **]** $^{a, c}$

The ICRR line statistics and plot are presented in Table 4-10 and Figure 4-8, respectively. **[** **]** $^{a, c}$

[**]** $^{a, c}$

Table 4-9: Plant E Cycle 25 ICRR Line Statistics

a, b, c

[ ]

a, b, c

[ ]

Figure 4-7: Plant E Cycle 25 ICRR Line Plot

Table 4-10: Plant F Cycle 22 ICRR Line Statistics

a, b, c

a, b, c

Figure 4-8: Plant F Cycle 22 ICRR Line Plot

4.3.3 Plant G Demonstration

Demonstration data **[** **]** $^{a, c}$ during Plant G Cycle 16 startup (identified as Plant 8 in References 1 and 2). **[** **]** $^{a, c}$

[**]** $^{a, c}$

[**]** $^{a, c}$

Table 4-11: Plant G Cycle 16 ICRR Line Statistics

a, b, c

a, b, c

Figure 4-9: Plant G Cycle 16 ICRR Line Plot

4.3.4 Previous Demonstration Conclusions

[

] a, c

[

] a, c

[

] a, c

[

] a, c

5 PROCESS CONTROLS

5.1 MEASUREMENT CONTROLS

5.1.1 Signal Source

To use the SCICR method with plant data, at least one indication of neutron flux level is required as an input. Typical Westinghouse nuclear instrumentation systems (NIS) provide a means to acquire such a flux signal, isolated from protection system channels, at two distinct stages of processing: **[**

] $^{a, c}$

SCICR measurement functionality extends to simultaneous acquisition of the flux signal at either or both of the two signal processing stages, for at least two detector instrumentation channels.

Signal acquisition methods minimize NIS electrical loading by appropriate selection of interfacing hardware. **[** **]** $^{a, c}$ In this manner, interference with a safety related signal is completely precluded.

5.1.2 Signal Quality

Since the SCICR method generally places demands on the plant NIS that are beyond those of traditional NIS employment, additional measures are required to confirm the suitability of the NIS output for the SPT application.

Thus, it serves to note that the disqualification of a detector signal from SCICR-based physics testing does not necessarily render the channel “inoperable” for any safety functions.

It should also be noted that for purposes of SPT, the term *signal quality* refers strictly to fidelity of the instrumentation channel output to the respective detector output, and does not include process-related aspects.

[

] $^{a, c}$

[

] $^{a, c}$

5.1.3 Signal Conditioning

SRNI signal errors can consist of fixed biases as well as gain errors. Gain errors, when relatively small in magnitude, are of lesser concern than are biases in the employment of the SCICR methodology, as gains, or multiplicative scalars, are mathematically canceled out when employed in a count rate ratio.

Because of the traditional employment of the SRNI (see Section 2.2 of Reference 16) as an input to the plant protective system, it is conceivable that a conservative bias could be inserted during the calibration process. In addition, it is likely that due to instrumentation limitations, some amplification non-linearity could remain after reasonable attempts to calibrate isolation amplifiers.

In order to address these effects, as well as other sources of measurement system biases, the SCICR measurement/testing system (or simply "SCICR system") functionality includes methodology **[**

] $^{a, c}$

5.1.4 Signal Noise

Signal noise is characterized by observing the statistical variance of a series of sample measurements. The SCICR system functionality includes the collection of count rate data and evaluation of sample variance with respect to expected system variances. Where sample variance exceeds expectation, an action (e.g., recording additional data, investigation of possible instrument issues, etc.) would be required. Detection methods described in Reference 17 are considered for employment where appropriate.

5.1.5 Signal Path Failure

Although the SCICR methodology benefits from the use of multiple data channels and paths, only one path is required in order to fulfill the objectives of the testing. **[**

] $^{a, c}$

5.1.6 Dwell Time

A certain dwell time is required after rod motion ceases at each data acquisition point, in order to allow process and measurement system transients to subside. The required dwell time is derived from the more limiting of (1) electronics settling time and (2) process equilibrium time. The former, depending on the design of the SRNI and the signal path chosen, is typically on the order of about 10 seconds, whereas the latter, which increases with proximity to criticality, can be on the order of a minute.

[

] $^{a, c}$

5.1.7 Procedural Controls

The SCICR system functionality includes procedural controls, enforced by work instructions or software coding, that ensure:

- **[**

  ] a, c

5.1.8 Controls Summary

The SCICR system employs a variety of controls in order to accomplish design objectives with respect to signal validation. The following table provides a summary of the signal validity goals and their associated controls.

Table 5-1: Measurement Process Controls Summary

a, c

[

]

5.2 DESIGN METHOD CONTROLS

The core design processes are unchanged for this revision, **[**

] $^{a, c}$ analyses using 3D core simulations were performed for the four most-recent demonstrations, **[**

] $^{a, c}$

5.2.1 Global Bias Detectability

[**]** $^{a, c}$ This section will demonstrate that **[** **]** $^{a, c}$ the SPT program to be very effective in detecting global biases. **[**

] $^{a, c}$

5.2.1.1 Core Reactivity Changes

[

] $^{a, c}$ A similar study was conducted for this revision to demonstrate that global reactivity biases can be detected and accurately quantified with the revised application.

[

] $^{a, c}$

[

] $^{a, c}$ The ability to project biases of this amount is highly valuable to plants in terms of Reactivity Management **[** **]** $^{a, c}$

[

] $^{a, c}$ These results further demonstrate not only the ability to detect, but also to project, global reactivity bias with good accuracy **[** **]** $^{a, c}$

Table 5-2: Reactivity Bias Detection via [ ] $^{\mathbf{a, c}}$

a, b, c

[ ]

[

] $^{a, c}$

The biases were imparted by manually changing the boron concentration values (obtained from Plant Chemistry sampling) recorded during the demonstrations presented in Section 4.1. **[**

] $^{a, c}$

[

] $^{a, c}$

a, b, c

[ ]

Figure 5-1: Change in Slope for Varying Boron Biases

5.2.1.2 Control Rod Worth Changes

[ ] a, c The key difference from past practice is that alternate parameters must detect the issue since [ ] a, c

[

] $^{a, c}$

As shown on Figure 5-2, and similar to the core reactivity bias study, slope is clearly affected by rod worth bias. **[**

] $^{a, c}$

Figure 5-3 presents the change **[** **]** $^{a, c}$ for varying changes in predicted total bank worth. **[**

] $^{a, c}$

These results provide confidence that revised methodology can support the use of reduced uncertainty in rod worth predictions and use for any Rod Cluster Control Assembly (RCCA) design (including the type described in Reference 18 – see Section 6.3.1.1 for additional discussion). **[**

] $^{a, c}$

5.2.1.3 Competing Bias Situations

[

] $^{a, c}$

a, b, c

Figure 5-2: Change in Slope for Varying Rod Worth Biases

a, b, c

[ ]

Figure 5-3: Change in [ ] $^{a, c}$ for Varying Rod Worth Biases

5.2.2 Local Issue Detectability

This section demonstrates how localized errors are detected, **[**

] $^{a, c}$

5.2.2.1 Rod Withdrawal Sequence Changes

[

] $^{a, c}$ While this situation is easily preventable by use of Human Performance tools during design development and test execution, simulation of such an error can demonstrate detectability of localized issues. An error of this type is considered localized **[**

] $^{a, c}$

[

] $^{a, c}$ see Table 5-3 for the complete scope. Very large perturbations are easily observed by inspection **[**

] $^{a, c}$

[

] $^{a, c}$ Figures 5-4 through 5-11 show the ICRR M−P behavior for each of the sequence changes, **[**

] $^{a, c}$ Based on the results, review (non-safety) criteria **[**

] $^{a, c}$ prior to proceeding to MODE 1 entry.

Table 5-3: Change in SPT Parameters for Rod Withdrawal Sequence Changes

a, b, c

[

]

a, b, c

Figure 5-4: ICRR M−P Behavior for Sequence Modification 1

a, b, c

Figure 5-5: ICRR M−P Behavior for Sequence Modification 2

a, b, c

Figure 5-6: ICRR M−P Behavior for Sequence Modification 3

a, b, c

Figure 5-7: ICRR M−P Behavior for Sequence Modification 4

a, b, c

[ ]

Figure 5-8: ICRR M−P Behavior for Sequence Modification 5

a, b, c

[ ]

Figure 5-9: ICRR M−P Behavior for Sequence Modification 6

a, b, c

Figure 5-10: ICRR M−P Behavior for Sequence Modification 7

a, b, c

Figure 5-11: ICRR M−P Behavior for Sequence Modification 8

5.2.2.2 Neutron Source Changes

As discussed earlier, the presence of a secondary neutron source will have a significant impact on core power distribution while the core is subcritical and not near criticality. Therefore, it is important to understand how the SPT application parameters are affected by source modifications; **[**
] $^{a, c}$

It is possible that the source strength could be modelled incorrectly **[**
] $^{a, c}$ These issues are generally prevented as part of the nuclear design control processes prior to plant startup. It is also possible, but much less likely, that a secondary source would be installed in the wrong core location or not installed in the core (e.g., left in the spent fuel pool). Fuel load verification generally prevents an error of this type. In any case, simulation of secondary source perturbations can demonstrate detectability of source modelling issues. Therefore, analyses were performed with the following variations **[**

] $^{a, c}$

See Table 5-4 and Figures 5-12 through 5-15 for detailed results. **[**

] $^{a, c}$ For each source modification case, at least one parameter indicates an observable change from the base case. Therefore, errors in secondary source modeling are considered detectable **[**
] $^{a, c}$

Table 5-4: Change in SPT Parameters for Secondary Source Changes

a, b, c

[

]

a, b, c

Figure 5-12: ICRR M−P Behavior for Source Modification 1

a, b, c

Figure 5-13: ICRR M−P Behavior for Source Modification 2

a, b, c

Figure 5-14: ICRR M−P Behavior for Source Modification 3

a, b, c

Figure 5-15: ICRR M−P Behavior for Source Modification 4

5.3 RESULTS EVALUATION CRITERIA

5.3.1 Review Criteria

Review Criteria, by definition, have no direct safety significance. These criteria are based on design tolerances and measurement experiences, and are used as indicators of measurement or non-critical design errors. The design tolerance values are developed based upon the designer's accuracy of predictions. The measurement experience values are based upon the measurement track record, and are primarily used by the test engineer as a means of process validation. Failure of any Review Criterion does not warrant stopping the testing process or power ascension unless a specific procedure or process does so. Failure of a Review Criterion should initiate a careful review of the specific measurement result, other related measurement results, and a review of the overall measurement process. If nothing is discovered in this review, then the designer should be notified for information. Westinghouse believes that it is prudent to address Review Criteria as part of a continuing evaluation of the design and measurement processes. Multiple Review Criteria failures at a particular testing plateau are indicative of potentially more severe problems that would require resolution as if an Acceptance Criterion has been exceeded.

Based on the plant demonstrations and detectability studies, the SPT Review Criteria are presented in Table 5-5. It is important to note that the Review Criteria presented here are subject to change as a larger database of results is obtained.

Table 5-5: SPT Application Review Criteria

a, b, c

5.3.2 Acceptance Criteria

Acceptance Criteria have a direct link to Safety Analysis assumptions and they may also be defined in TS. These criteria are constructed from Safety Analysis or related assumptions. Failure of these criteria should not prevent further testing at the current plateau for supporting information, but should prevent power ascension until resolution is completed, often performed under established procedures (e.g., TS Action statements, Safety Evaluation Report Requirements). The established procedures typically stipulate the power ascension requirements. For reload startup physics testing, failure of Acceptance Criteria typically prohibits entry into MODE 1 operation prior to resolution.

The SPT application acceptance criteria are presented in Table 5-6. **[**

] $^{a, c}$

Table 5-6: SPT Application Acceptance Criteria

a, b, c

[ ]

5.3.3 Issue Resolution Process

There is a three step process for evaluating the failure of any Review or Acceptance Criterion:

1. Investigate and resolve the issue by determining if there is a measurement or design error.

2. Confirm or refute the failure by further measurement and/or considering related measurements.

3. If confirmed, implement mitigation steps, which could be establishment of operating limitations or conduct of supporting measurements, depending on the nature of the issue and the corresponding impact to plant safety.

The following paragraphs describe general steps that will be executed in the event of a SPT review or acceptance criteria failure.

5.3.3.1 ICRR M-P Differences and Line Statistics

- **[**

  ] a, c

- **[**

  ] a, c

- **[**

  ] a, c

5.3.3.2 [ ] a, c and ACC

- **[**

  ] a, c

- If the initial investigations do not identify the cause, the final approach to criticality should be conducted in a conservative and deliberate manner (e.g., dilution to critical).

- **[**

  ] a, c

- **[**

  ] $^{a, c}$

- If the ACC does not meet its Acceptance Criteria, **[** **]** $^{a, c}$

5.3.3.3 [ ] $^{a, c}$

- **[**

  ] $^{a, c}$

- After establishing stable critical conditions, if the **[** **]** $^{a, c}$ does not meet its Acceptance Criteria, the Nuclear Designer should be contacted immediately for potential Shutdown Margin impacts. **[**
  ] $^{a, c}$

6 REGULATORY CONSIDERATIONS

6.1 REGULATORY NEXUS

Section 50.34 of Title 10 of the *Code of Federal Regulations* (10 CFR), "Contents of applications; technical information," 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 vendors) perform reload safety evaluations to ensure that their safety analyses remain bounding for the design cycle. To confirm that the analyses remain bounding, licensees confirm that key inputs to the safety analyses (such as the critical power ratio) are conservative with respect to the current design cycle. If key safety analysis parameters are not bounded, a reanalysis or reevaluation of the affected transients or accidents is performed to ensure that the applicable acceptance criteria are satisfied.

6.2 REGULATORY HISTORY

Revision 0 of the SCICR topical report was transmitted to the NRC for review and approval in April 2004:

- Letter from J. A. Gresham (Westinghouse) to U.S. Nuclear Regulatory Commission – Document Control Desk, “WCAP-16260-P, ‘The Spatially Corrected Inverse Count Rate (SCICR) Method for Subcritical Reactivity Measurement’ (Proprietary),” LTR-NRC-04-26, April 30, 2004.

[

] $^{a, c}$

For convenience, Appendix E of this topical report provides a cross-reference of past RAIs to applicable content in this revision. Table E-1 contains the past query/technical topic identification information, the corresponding location(s) within this revision that is relevant to the original RAI, and clarifying notes. For simplification, the formal RAIs and responses have not been retained in this revision of the topical report.

Revision 0 of the SCICR topical report (Reference 1) was approved by the NRC in August 2005:

- Letter from H. N. Berkow (NRC) to J. A. Gresham (Westinghouse), “Final Safety Evaluation for Topical Report (TR) WCAP-16260-P, ‘The Spatially Corrected Inverse Count Rate (SCICR) Method for Subcritical Reactivity Measurement’ (TAC No. MC3065),” August 11, 2005.

After commercial application of SCICR applications, Westinghouse transmitted a compliance interpretation with respect to two other approved topical reports and their associated safety evaluation report (SER) approvals. Westinghouse requested that the NRC acknowledge the compliance interpretation as part of the letter transmittal in March 2006:

- Letter from B. F. Maurer (Westinghouse) to F. M. Akstulewicz (NRC), “WCAP-16260-P-A Compliance Interpretation, (Non-Proprietary),” LTR-NRC-06-15, March 28, 2006.

As communicated in the compliance interpretation letter, Westinghouse ultimately concluded that the SPT application (at the time termed the SRWM method) fully complied with the SER requirements contained in both WCAP-8846-A, “Hybrid B4C Absorber Control Rod Evaluation Report” (Reference 18 of this revision) and WCAP-13749-P-A, “Safety Evaluation Supporting the Conditional Exemption of the Most Negative EOL Moderator Temperature Coefficient Measurement” (Reference 19 of this revision). See Section 6.3 for affirmation that the revised SCICR application complies with the SER requirements of topical reports WCAP-8846-A and WCAP-13749-P-A.

The NRC concurred with Westinghouse’s conclusion that the SCICR methodology provides no contradictions to the methodologies and conditions provided in topical reports WCAP-8846-A and WCAP-13749-P-A. The concurrence was transmitted to Westinghouse in May 2006:

- Letter from J. D. Peralta (NRC) to J. A. Gresham (Westinghouse), “NRC Staff Interpretation of WCAP-16260-P-A With Respect To Two Previously Approved Topical Reports WCAP-8846-A, WCAP-13749-P-A and Their Associated Safety Evaluations,” May 23, 2006.

The NRC required that Westinghouse incorporate the original compliance interpretation and the NRC concurrence letter into a new revision of the SCICR topical report. Revision 1 of the SCICR topical report (Reference 2) was completed in July 2007, with no changes beyond inclusion of the compliance interpretation and NRC concurrence.

[

] $^{a, c}$

6.3 COMPLIANCE WITH OTHER APPROVED TOPICAL REPORTS

Section 3.2.2 of this topical report introduced how the new SPT application accomplishes pre-MODE 1 core design validation. Section 4.2 demonstrated how parameters specific to the SCICR application effectively validate key core characteristics. In combination, these discussions support the information in the following paragraphs in an effort to demonstrate compliance with two previous Westinghouse topical reports related to physics testing.

6.3.1.1 B_4C Control Rod Material Report Compliance

The SER for WCAP-8846-A, "Hybrid B4C Absorber Control Rod Evaluation Report" (Reference 18) stated:

> "*An acceptable program might include several rod reactivity checks during the first core cycle and worth measurements of all the rod banks at refueling outages thereafter.*"

[

] $^{a, c}$ Therefore, the SCICR methodology and application are in compliance with the SER requirements of WCAP-8846-A.

6.3.1.2 EOL MTC Measurement Conditional Exemption Compliance

Page 6 of the SER for WCAP-13749-P-A, "Safety Evaluation Supporting the Conditional Exemption of the Most Negative EOL Moderator Temperature Coefficient Measurement" (Reference 19) stated:

> *"The BOL MTC measurement is made at Hot-Zero-Power (HZP) conditions and is an accurate measurement characterized by relatively small uncertainties."*

and on page 8 stated,

> *"2) Changes in Core/Fuel Designs and the Measurement Data Base*
>
> *The predictive correction should be reevaluated if changes in core/fuel designs or the MTC calculation-to-measurement data base have a significant effect on the MTC predictive correction (Section-3)."*

[

] a, c

[

] a, c Therefore, the SCICR methodology and application are in compliance with the requirements of WCAP-13749-P-A, and are consistent with the established reload safety evaluation methodology.

6.4 PROPOSED LIMITATIONS AND CONDITIONS

The SCICR methodology and applications are subject to the following limitations and conditions:

1. **[**

] a, c

c. **[**

] $^{a, c}$

7 SUMMARY AND CONCLUSIONS

This topical report describes the SCICR methodology for subcritical reactivity measurement and its applications. While the original SCICR theory was retained from the previous revisions of this topical report, the SPT application was revised to correct deficiencies in the original SRWM application.

The revised SPT application can be utilized as a means to confirm that the as-built core is operating as designed. The SCICR method can also be applied to calculate and monitor shutdown margin, as well as to forecast estimated critical conditions during cycle operation. All applications are dependent on generation of predictive information corresponding to given static subcritical plant conditions.

[

] $^{a, c}$

Analyses using 3D core simulations were performed for the four new demonstrations, with their purpose **[**

] $^{a, c}$

- SPT can detect changes in predicted rod worth very effectively **[** **]** $^{a, c}$
- SPT can detect global reactivity biases **[** **]** $^{a, c}$
- Localized anomalies are identified by revised SPT parameters **[** **]** $^{a, c}$

It is concluded that the SPT program will provide plants with a robust process to evaluate whether or not the reactor responds as expected during initial plant startup following refueling, and will serve as a sound first step in the overall process of confirming that the as-built core operates as designed.

8 REFERENCES

1. Chao, Y. A. et. al., “The Spatially Corrected Inverse Count Rate (SCICR) Method for Subcritical Reactivity Measurement,” WCAP-16260-P-A, Revision 0, September 2005.

2. Chao, Y.A., et. al., “The Spatially Corrected Inverse Count Rate (SCICR) Method for Subcritical Reactivity Measurement,” WCAP-16260-P-A, Revision 1, July 2007.

3. Liu, Y.S., et. al., “ANC: A Westinghouse Advanced Nodal Computer Code,” WCAP-10965-P-A (Proprietary), and WCAP-10966-A (Nonproprietary), September 1986.

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6. Nguyen, T. Q., et. al., “Qualification of the PHOENIX-P/ANC Nuclear Design System for Pressurized Water Reactor Cores,” WCAP-11596-P-A (Proprietary), and WCAP-11597-A (Nonproprietary), June 1988.

7. Ouisloumen, M., et. al., “Qualification of the Two-Dimensional Transport Code PARAGON,” WCAP-16045-P-A (Proprietary), August 2004.

8. Zhang, B., et. al., “Qualification of the NEXUS Nuclear Data Methodology,” WCAP-16045-P-A Addendum 1-A (Proprietary) and WCAP-16045-NP-A Addendum 1-A (Nonproprietary), August 2007.

9. Beard, C. L. and Morita, T., “BEACON™ Core Monitoring and Operations Support System,” WCAP-12472-P-A, August 1994.

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12. Boyd, W. A., et. al., “BEACON Core Monitoring and Operation Support System,” WCAP-12472-P, Addendum 3-A (Proprietary), and WCAP-12472-NP, Addendum 3-A (Nonproprietary), June 2006.

13. Boyd, W. A. and Krieg, D. J., “BEACON Core Monitoring and Operation Support System,” WCAP-12472-P-A, Addendum 4 (Proprietary), and WCAP-12472-NP-A, Addendum 4 (Nonproprietary), September 2012.

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14. Chao, Y. A., et. al., “Westinghouse Dynamic Rod Worth Measurement Technique,” WCAP-13360-P-A (Proprietary), Revision 1, October 1998, and WCAP-13361-A (Nonproprietary), Revision 1, November 1998.

15. Camden T. M., et. al., “Rod Bank Worth Measurements Utilizing Bank Exchange,” WCAP-9863-P-A (Proprietary), May 1982.

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18. Skaritka, J., “Hybrid B4C Absorber Control Rod Evaluation Report,” WCAP-8846-A, October 1977.

19. Fetterman, R. J. and Slagle, W. H., “Safety Evaluation Supporting the Conditional Exemption of the Most Negative EOL Moderator Temperature Coefficient Measurement,” WCAP-13749-P-A, March 1997.

20. Gresham, J. A., “Subcritical Rod Worth Measurement (SRWM) Methodology Service Withdrawal,” LTR-NRC-12-41, April 2012.

APPENDIX A: SPT GUIDELINE INSTRUCTIONS

Note that the following guideline instructions to implement the SPT application are subject to change as measurement experience is gained, or based on station-specific procedures and requirements.

1.0 PURPOSE

1.1 To define the sequence of plant and equipment operations needed to apply the SCICR methodology to measure key reactivity parameters at subcritical reactor conditions

1.2 To demonstrate, by measurement of key parameters, that the nuclear design calculations accurately represent the reactor core

2.0 SCOPE

2.1 This procedure includes the steps necessary to complete SPT, which is executed following every refueling outage.

3.0 DEFINITIONS

Acronym/Item	**Definition**
ACC	True core reactivity bias (determined from actual critical conditions)
ARI	all rods inserted
ARO	all rods out (all rods withdrawn)
I&C	Instrumentation & Control (department)
ICRR	inverse count rate ratio
LPPT	Low Power Physics Testing
MODE 2	Startup mode of plant operation per Technical Specifications
MODE 3	Hot Standby mode of plant operation per Technical Specifications
[	**]** $^{a, c}$
PZR	Pressurizer
PPM	parts per million
RCS	Reactor Coolant System
SCICR	Spatially Corrected Inverse Count Rate (methodology)
SPT	Subcritical Physics Testing
State Point Configuration	a static and subcritical combination of control rod position, RCS temperature, and RCS boron concentration.
swd	steps withdrawn

4.0 REFERENCES

4.1 **[**

] $^{a, c}$

5.0 RESPONSIBILITY

5.1 The station will provide the following:

5.1.1 A test director from the Reactor Engineering department, for each shift, that is responsible for advising licensed Reactor Operators in regards to performance of this procedure, verifying that plant conditions are in accordance with this procedure, and reviewing test results

5.1.2 Other support groups including Plant Chemistry (boron sampling) and I&C (equipment connection and disconnection)

5.2 Westinghouse will provide the following:

5.2.1 A test engineer, for each shift, that is responsible for advising the test director in regards to performance of this procedure, verifying that plant conditions support accurate data collection, and collecting/analyzing/evaluating test data

5.2.2 SPT equipment

6.0 GENERAL

6.1 **[**

] $^{a, c}$

7.0 PREREQUISITES AND INITIAL CONDITIONS

7.1 **[**

] $^{a, c}$

8.0 PRECAUTIONS

8.1 **[**

] $^{a, c}$

9.0 PROCEDURE

9.1 **[**

] $^{a, c}$

9.3 **[**

] $^{a, c}$

9.5 **[**

] a, c

---

[1] Not explicitly included in this Appendix; refer to Sections 5.3.1 and 5.3.2 of this topical report

[2] Not explicitly included in this Appendix; refer to Section 5.3.3 of this topical report

DATA SHEET 1
BORON CONCENTRATION LOG

Unit: _____ Cycle: _____

a,
c

[

]

Completed by: ________________________________ Date: _______________

Reviewed by: _________________________________ Date: _______________

Sheet ______of ______

(Mark unused portion of table as N/A.)

DATA SHEET 2
STATE POINT CONFIGURATIONS

Unit: _____ Cycle: _____

a,
c

Completed by: ______________________________ Date: ______________

Reviewed by: ______________________________ Date: ______________

Sheet ______of ______

(Mark unused portion of table as N/A.)

DATA SHEET 3
SPT RESULTS EVALUATION

Unit: _____ Cycle: _____

a, c

[ ]

Completed by: ________________________________ Date: _______________

Reviewed by: ________________________________ Date: _______________

APPENDIX B: [ ] $^{a, c}$ ENHANCEMENT

Figure B-1 shows a typical RCCA rod pattern in relation to an ex-core source range (SR) neutron detector **[** **]** $^{a, c}$ The conventional MODE 3 bank withdrawal for testing or pre-startup purposes is initiated with shutdown bank withdrawal (shutdown bank SA, followed by SB, SC, etc. until all shutdown banks have been withdrawn). Conventionally, the control banks are withdrawn next, with the banks in their normal overlap sequence (control bank A, eventually with B, with C, and finally with D) until reaching the ARO condition.

[**]** $^{a, c}$

[**]** $^{a, c}$

Figure B-2 shows the typical impact on the neutron detector response **[** **]** $^{a, c}$

[**]** $^{a, c}$

[**]** $^{a, c}$

a, c

Figure B-1: Typical RCCA Pattern (Half Core Top View)

a, b, c

[

Figure B-2: Illustration of Improved [ ] a, c

APPENDIX C: IMPLEMENTATION OUTSIDE OF EXPERIENCE BASE

Per the Limitations and Conditions of Section 6.4, and consistent with the original SCICR topical report approval, Westinghouse proposes to implement SCICR applications **[**

] $^{a, c}$

For new applications at plants licensed to operate in the U.S., but outside of the current experience base **[** **]** $^{a, c}$ Westinghouse will conduct a "side-by-side" demonstration and comparison to physics test results obtained from a different method during the same startup. **[** **]** $^{a, c}$ Prior to formal implementation, the results of these analyses will be formally documented and available for U.S. NRC audit purposes. Table C-1 summarizes the various scenarios regarding applicability and future implementation.

For application to a plant outside the current experience base, the neutronics code(s) must be licensed for general design application at that plant; if not, or if the code to be used for SCICR application does not have subcritical neutronics ability, the process described in Appendix D would also apply prior to formal implementation at that plant.

[

] $^{a, c}$

Table C-1: SCICR Applicability and Implementation Summary

a, c

[

]

APPENDIX D: EXTENSION TO OTHER CODES OR DESIGNERS

In order for a utility to perform their own nuclear physics calculations to support the use of the SCICR applications, the following five criteria must be met. Compliance with the criteria demonstrates a utility's qualification and constitutes inherent NRC approval to use the SCICR applications described in this topical. To document its qualification, the utility shall send the NRC a notification of compliance with the criteria and the intended date of the SCICR nuclear design constants generation at least three months before the intended first application. Any voluntary limitations or restrictions of the utility's use of the SCICR methodology must also be addressed in the notification. The NRC may, at their discretion, audit the application of the utility's SCICR nuclear design calculations program to ensure compliance.

The process described here is also applicable to a new physics code. Comparisons of the new code to existing SCICR application results (Criterion 4) demonstrate acceptable subcritical physics performance. Comparative results for any plant type shall be generated (Criterion 4) prior to SCICR application of the new code at that plant type. Appendix C of this topical report shall apply for SCICR application at a plant type outside of the current experience base.

Criterion 1: Eligibility of Codes for SCICR Computations

> Only lattice physics codes and methods which have received prior NRC review and approval for general nuclear design application and subcritical neutron detector response prediction capability are eligible to be used in determining the physics constants for SCICR applications. The NRC review ensures that the codes being used for the SCICR computations were developed under a qualified Quality Assurance (QA) program and were properly benchmarked and verified.
>
> Qualification of subcritical physics performance is provided by comparisons to an existing qualified code and results (Criterion 4).

Criterion 2: Application of Procedures to SCICR Computations

> In a manner consistent with the process obtained from Westinghouse, the utility analyses shall be performed in conformance with in-house application procedures which ensure that the use of the method is consistent with the Westinghouse approved application of the SCICR methodology.

Criterion 3: Training and Qualification of Utility Personnel

> The first SCICR application for a utility Customer shall be performed by Westinghouse. This will ensure that the SCICR methodology is applicable to the specific plant, provide utility personnel with training in the application technique, and will be used to meet Criterion 4 in this appendix.
>
> Under an accredited technical training program, utilities shall establish and implement a curriculum or qualification process to ensure that each qualified user of the SCICR methodology has a good working knowledge of the codes and methods used for SCICR calculations. This training shall include the ability to set up input decks, understand and interpret output results, understand applications and limitations, and perform analyses in compliance with the process provided by Westinghouse.

The first SCICR application for a utility Customer will be performed by Westinghouse, and the application will then be applicable for all of the remaining units of the same plant type operated by that utility. Utility responsibility may extend to any other plant type in its fleet for which Westinghouse has implementation experience. In situations where this is not the case, Appendix C shall apply, and Westinghouse shall have responsibility for the first application. If the fuel vendor should change subsequent to the first application, a second application by Westinghouse is not required.

Criterion 4: Comparison Calculations for the SCICR Method

Prior to the first application by a utility using their own physics codes and procedures to perform physics calculations in support of SCICR applications, the utility will demonstrate its ability to use the methods supplied by Westinghouse by comparing its calculated results with the analyses and results obtained by Westinghouse during the first, or subsequent, SCICR application(s) at the utility's nuclear units. These comparisons must be documented in a report which is part of the utility's QA records. As a minimum, the following parameters should be compared to the Westinghouse-supplied SCICR methodology calculations. Agreement should be within the given acceptable deviation listed in Table D-1; any significant differences between the calculations and the comparison data must be discussed in the report. The utility shall also document Appendix C requirements if applicable.

Table D-1: Comparison Calculation Criteria

a, b, c

[ ]

Criterion 5: Quality Assurance and Change Control

All SCICR calculations performed by a utility using the Westinghouse approved methodology shall be conducted under the control of a quality assurance program which meets the requirements of 10 CFR 50, Appendix B. The utility QA program shall include the following:

a) A provision for implementing changes in the SCICR applications and procedures being used.

b) A provision for informing Westinghouse of any problems or errors discovered while using the SCICR applications or procedures.[1]

---

[1] Westinghouse has a requirement to inform utilities that have agreed to Technology Transfer of the SCICR methodology of changes to the process as part of their QA procedures regarding Technology Transfer.

APPENDIX E: CORRESPONDENCE TO PREVIOUS REVISIONS

The purpose of this appendix is to cross-reference previous requests for information (RAIs) and technical interpretations regarding the SCICR theory, application, and related analyses to information in this topical report revision. Table E-1 contains the following information:

- The first column from the left (Ref.) lists the document reference containing the Revision 0 RAI response (see the Reference list immediately following Table E-1).

- The second column (RAI No.) lists the RAI identification number and/or descriptor from the Revision 0 RAI response.

- The third column lists the section(s) within Revision 2 that are most relevant in addressing the Revision 0 RAI.

- The fourth (right-most) column includes discussion regarding how the Revision 0 RAI has been addressed in the latest SCICR method and application.

Table E-1: Correspondence of Prior RAIs and Technical Topics to the Current Revision

a, c

Table E-1: Correspondence of Prior RAIs and Technical Topics to the Current Revision

a, c

Table E-1: Correspondence of Prior RAIs and Technical Topics to the Current Revision

a, c

Table E-1: Correspondence of Prior RAIs and Technical Topics to the Current Revision

a, c

Table E-1: Correspondence of Prior RAIs and Technical Topics to the Current Revision

a, c

[ ]

Table E-1: Correspondence of Prior RAIs and Technical Topics to the Current Revision

a, c

Table E-1 References:

1. J. A. Gresham (Westinghouse) to J. S. Wermiel (NRC), “Response to NRC Request for Additional Information on WCAP-16260-P, (Proprietary/Non-Proprietary),” LTR-NRC-05-3, January 20, 2005.

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