SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION
LICENSING TOPICAL REPORT WCAP-17079-P FOR BWRS 2-6
"SUPPLEMENT 3 TO BISON TOPICAL REPORT RPA 90-90-P-A SAFIR CONTROL SYSTEM SIMULATOR,"
WESTINGHOUSE ELECTRIC COMPANY
PROJECT NO. 700

1.0 Introduction

Westinghouse Electric Company (Westinghouse) submitted WCAP-17079-P, "Supplement 3 to BISON Topical Report RPA 90-90-P-A SAFIR Control System Simulator," (hereafter Supplement 3) (Ref. 1) for U.S. Nuclear Regulatory Commission (NRC) review and approval by letter dated October 13, 2009 (Ref. 2). Supplement 3 is an additional supplement to the BISON licensing topical report (LTR). BISON is a one-dimensional, two-phase thermal-hydraulic code with a two-group, one-dimensional neutron kinetics model. BISON was first approved by the NRC staff in 1989 (Ref. 3).

ASEA Brown Boveri/Combustion Engineering (ABB/CE) supplemented the original BISON LTR in 1994 with CENPD-292-P, "BISON—One Dimensional Dynamic Analysis Code for Boiling Water Reactors: Supplement 1 to Code Description and Qualification," for staff review and approval (Ref. 4). The purpose of Topical Report CENPD-292-P was to update the code package to enable analysis of cores containing SVEA-96 fuels. The proposed changes and upgrades include (1) implementation of ABB's critical power ratio correlation XL-S96 for SVEA-96 fuel, (2) implementation of recirculation loop dynamics for each loop, enabling explicit modeling of single-loop operation, (3) incorporation of steamline modeling, enabling modeling of separate steamlines, steam bypass lines, and steam cross flows between different steamlines, (4) implementation of core boiling and condensation based on the Electric Power Research Institute model, (5) use of the fuel rod thermal data derived by fuel performance code STAV6.2, and (6) geometric representation of the steam separator length-over-area ratio rather than an effective length over area. The staff approved this supplement in 1995 (Ref. 4).

Westinghouse submitted WCAP-16606-P, "Supplement 2 to BISON Topical Report RPA 90-90-P," for NRC review in 2006 (Ref. 5). The purpose of Supplement 2 is to extend the applicability of the BISON analysis methodology to analyze anticipated transients without scram (ATWS) beyond the time of peak pressure so as to calculate the mass and energy release to containment during the boron injection phase of an ATWS. The staff approved Supplement 2 in 2007 (Ref. 5).

In its review of the original BISON LTR, the staff imposed a series of conditions. In particular, Condition 6 from the staff's safety evaluation (SE) for the BISON LTR states that, when a control system simulation is required, such simulations must be performed using a staff-approved model (Ref. 3). Westinghouse intends to use the SAFIR (Logics and control component tool box) control system simulator methodology to satisfy Condition 6 in the staff's SE for the BISON LTR.

Although Supplement 3 has been provided as a supplement to the BISON LTR, SAFIR is a generic control system simulator methodology that may be used within any NRC-approved transient analysis methodology. For example, POLCA-T is a systems analysis code with a three-dimensional core model. POLCA-T was submitted for NRC review and approval in 2007 to analyze control rod drop accidents and to perform stability assessments. The POLCA-T code has an optional capability to use the SAFIR control system simulator methodology (Ref. 6). This part of the safety evaluation report (Enclosure 1) is applicable for boiling-water-reactor (BWRs) 2–6 only. Enclosure 2 gives the NRC staff's evaluation of SAFIR for advanced boiling-water-reactor (ABWR) applicability.

2.0 Regulatory Evaluation

Title 10 of the *Code of Federal Regulations* (10 CFR) 50.34, "Contents of Applications; Technical Information," requires that the licensee (or vendors) provide safety analysis reports to the NRC detailing the performance of systems, structures, and components provided for the prevention or mitigation of potential accidents.

General Design Criterion (GDC) 10, "Reactor Design," of Appendix A, "General Design Criteria for Nuclear Power Plants," to 10 CFR Part 50, "Domestic Licensing of Production and Utilization Facilities," requires that the reactor core and associated coolant, control, and protection systems shall be designed with appropriate margin to assure that specified acceptable fuel design limits are not exceeded during any condition of normal operation, including the effects of anticipated operational occurrences.

The regulation at 10 CFR 50.62, "Requirements for Reduction of Risk from Anticipated Transients without Scram (ATWS) Events for Light-Water-Cooled Nuclear Power Plants," gives provisions for mitigating the consequences of potential ATWS events. The staff considered Section 15.8, "Anticipated Transients without SCRAM," of NUREG-0800, "Standard Review Plan for the Review of Safety Analysis Reports: LWR Edition" (hereafter SRP), insofar as it provides guidance on the use of analyses to demonstrate compliance with GDC 38, "Containment Heat Removal," and GDC 50, "Containment Design Basis" (Ref. 7).

The intent of the current application is to use the SAFIR control system simulator methodology in conjunction with approved neutronic and thermal-hydraulic transient analysis codes to analyze transients to demonstrate compliance with the Commission's regulations. Supplement 3 specifically details the coupling of the SAFIR method with BISON. BISON is used to analyze transients such as anticipated operational occurrences (AOOs) and ATWS events. Supplement 3 also states that SAFIR may be used in conjunction with other NRC-approved codes to model control systems.

Analysis methods used to perform safety analyses, such as BISON and SAFIR, must be maintained under a quality assurance program that meets the requirements of Appendix B, "Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants," to 10 CFR Part 50. As a minimum, this program must address design control, document control, software configuration control and testing, and corrective actions.

The staff used the review guidance in SRP Section 15.0.2, "Review of Transient and Accident Analysis Methods" (SRP Section 15.0.2), (Ref. 7), in conducting its review of Supplement 3. The review covered the areas of (1) documentation, (2) evaluation model, (3) accident scenario identification process, (4) code assessment, (5) uncertainty analysis, and (6) quality assurance plan.

3.0 Technical Evaluation

3.1 Documentation

The staff reviewed Supplement 3 to determine the adequacy of the documentation relative to the review guidance provided in SRP Section 15.0.2, Section 3 of Supplement 3 provides a basic description of the SAIFR methodology. This section clearly describes the parts of the evaluation model (namely, the components in a control system model) and how the components are assembled into either macros or complex control system representations. The staff finds that this description is acceptably clear and complete for the evaluation model.

As a control system simulator, SAFIR is intended for use in a variety of transient analyses. In the subject review, SAFIR is applied to transient analyses performed using BISON. However, Supplement 3 does not specifically limit the application of SAFIR to only those transient analyses performed by BISON. Generally, the accident scenarios to which SAFIR may be applied are dictated by the approval of associated, compatible transient analysis methods. To this end, BISON serves as an example of how SAFIR is integrated into an approved transient analysis method. BISON has been approved for application to AOOs and ATWS events. Therefore, this example demonstrates how scenario identification and associated review is relegated to the review and approval of transient thermal-hydraulic and neutronic methods to perform particular analyses. Therefore, a specific scenario identification process is not required for SAFIR.

Sections 4 and 5 describe the verification and validation (V&V) processes for SAFIR components and models, respectively. Section 6 of Supplement 3 provides the results of V&V of SAFIR models against plant data collected at a Swedish BWR [[ ]] during a load rejection test in 2001 and against startup tests performed at an ABWR (Hamaoka Unit 5, hereafter Hamaoka 5) in Japan in 2005. The [[ ]] model includes a complex control system model comprising three SAFIR submodels: (1) a turbine control model, (2) a valve process model, and (3) a turbine model. The Hamaoka 5 model includes (1) a recirculation flow control system model, (2) a turbine control system model, and (3) a feedwater control system model. The [[ ]] and Hamaoka 5 model validations provide a comprehensive validation of the SAFIR components used to simulate complex control systems and to compare the predictive capability of the code against plant data. Section 6 of Supplement 3 provided model diagrams for the various control system models. The NRC staff requested additional information about success criteria in Request for Additional Information (RAI) 2. The response to RAI 2 (Ref. 8) stated that the approved process described by CENPD-300-P-A, “Reference Safety Report for Boiling Water Reactor Fuel,” issued July 1996 (hereafter RSR) (Ref. 9), is used for SAFIR. The staff finds this to be acceptable. The staff finds that these V&V examples provide sufficient documentation of the code assessment for the intended purpose.

Section 1 of Supplement 3 states that the SAFIR methodology is capable of modeling control systems consistent with the provisions of the RSR (Ref. 9). The staff requested additional clarification of this statement in RAI 1. The response to RAI 1 confirms the staff’s interpretation (Ref. 8). The RSR generically describes acceptable means for performing uncertainty analyses. For example, Section 7.3.3 of the RSR describes the processes for incorporating analysis uncertainties into operating limits for AOO analyses. Therefore, specific documentation of the uncertainty analysis for SAFIR is not required. To help the staff understand the use of SAFIR within the context of the RSR, the staff requested additional information in RAI 3.

Specifically, the staff asked Westinghouse to provide a sample calculation to demonstrate the uncertainty analysis process. This approach is consistent with Section II.1.D of SRP Section 5.0.2. The response to RAI 3 demonstrated how the RSR uncertainty analysis process is applied for control systems simulated using SAFIR (Ref. 10). The staff finds that sufficient information has been provided in the response to RAI 3 to illustrate how the RSR uncertainty analysis processes are applied to SAFIR.

Section 3.10 of Supplement 3 provides a list of the available components currently coded in SAFIR. These component descriptions provide the transfer function and the time-dependent solutions for various component types. These equations provide the basis for the larger macros and models that are made of several components. In RAI 4, the staff requested additional information about the solution technique. The response to RAI 4 describes the numerical solution technique (Ref. 11). The staff finds that the solution technique and model equations have been adequately described in the LTR documentation and RAI 4 response. This information is consistent with the definition of a theory manual provided in SRP Section 15.0.2.

In RAI 5, the staff asked Westinghouse to provide the SAFIR user manual in accordance with SRP Section 15.0.2. The staff reviewed the user manual to ensure that the manual provides (1) detailed instructions about how the code is used, (2) a description of how to choose model input parameters and appropriate code options, (3) guidance about the code limitations and options that must be avoided on an analysis-specific basis, and (4) documentation of procedures for ensuring complete and accurate transfer of information between different elements of the evaluation model.

The response to RAI 5 stated that the SAFIR user manual is part of the BISON code documentation and is not maintained separately. The response further stated that the documentation has been made available for staff audit (Ref. 8). The NRR staff conducted an audit of the user manual and confirmed that it meets the applicable criteria in SRP Section 15.0.2.

Section 3.8 of Supplement 3 refers to the standard code update procedures. Sections 4 and 5 provide descriptions of the development, verification, and validation processes for SAFIR components and models. In RAI 6, the staff requested additional details about the quality assurance process. The response to RAI 6 confirms that the code is maintained under an approved quality assurance process (Ref. 8). As part of a separate review, the staff conducted an audit of this process and found it to be acceptable. (For additional details about the staff's review, see Ref. 12.) The staff finds that this information is sufficiently complete to address the procedures and controls under which the code is developed and assessed as well as the corrective action procedures.

3.2 Evaluation Model

The SAFIR methodology is used to construct models of BWR control systems. These models are built from predefined component models. The individual component models calculate control system response to input signals based on simple operators, such as transfer functions, filters, or Boolean operators.

Components are the building blocks for complex control systems in which, typically, several components are strung together via their input and output signals to generate a cascade of components that simulate control system signals based on plant instrumentation signals.

Section 3.10 of Supplement 3 provides a description of the components available in SAFIR. These components provide a means for flexible control system modeling and encompass a variety of standard control system components. Each component is characterized by inputs to the component and parameters that may be specified for a unique component. Several components are characterized by transfer functions common in control system servo analysis, such as the integrator component. Other components may (1) perform simple mathematical operations, (2) perform Boolean operations, or (3) filter signals. Table 3-2 provides a comprehensive summary of the available components, the input specifications, and the expressions used to determine the component signal output. Supplement 3 describes a process for adding new component models to SAFIR after the NRC approval of Supplement 3. The staff review the process for developing and implementing new component models is discussed in Section 3.4.5 of this SE.

As noted above, the staff requested additional information about the solution technique in RAI 4. Specifically, the staff asked Westinghouse to clarify how SAFIR performs its calculations for the standard components. The response to RAI 4 describes the numerical solution technique and confirms that the solution technique is based on time-dependent functions (Ref. 11).

The time-dependent output functions are provided in Table 3-2 of Supplement 3 and are based on the component sampling time. The staff performed confirmatory calculations for several of the component transfer functions to independently verify the time-dependent solution. Appendix A to this SE includes the results of the staff confirmatory calculations to verify the numerical solutions against analytical solutions. In all cases, the staff found that the time-dependent functions accurately reproduced the analytical solutions.

The time-dependent output functions provided in Section 3.10 are consistent with numerical servo analysis and the definitions for the sampling time. Section 3.9 of Supplement 3 provides details of the time sampling for digital and analog control systems. This section states that, for a digital control system, the component sampling time shall be the same as that for the real plant component. For analog control system components, the sampling time shall not be longer than the transient code time step. The staff requested additional information about the coupling between SAFIR and BISON in RAI 7. The staff requested information about the frequency with which the two codes share information to clarify the information presented in Section 3.9 of Supplement 3.

The response to RAI 7 stated that the transient code will make a call to SAFIR [[

]], the staff finds that the methodology to account for the sampling time is acceptable.

SAFIR is used in conjunction with transient codes such as BISON. To couple these codes, SAFIR must be compiled and loaded as part of the transient code itself. The linkage between the transient code and SAFIR is dictated by a matrix of input/output interfaces. Table 3-1 of Supplement 3 provides these output/input interfaces for BISON. These parameters describe the parameters required for normalization, time control, initialization, and flows or flow areas that are controlled by SAFIR-modeled control systems. For any coupled transient code, such a table must be constructed. In RAI 8, the staff asked Westinghouse to provide additional information about the generation of such a table for alternative transient analysis codes.

The response to RAI 8 describes the process for SAFIR-to-transient-code coupling by way of example (Ref. 8). An interface between alternative transient analysis codes (i.e., POLCA-T) and SAFIR is developed in which the signals are specified and translated into the corresponding alternative transient analysis code signals. In effect, an equivalent table to Table 3-1 is generated by translating the BISON signals into the alternative transient analysis code signals. The staff finds that this translation approach is acceptable.

Section 3.11 of Supplement 3 specifies the limitations to SAFIR. Three general limitations are listed: (1) a signal can only be connected to one single output, (2) a model must have at least one input signal, and (3) an instance of a component must have a unique name within a model. In RAI 9, the staff requested additional information about the first limitation.

The response to RAI 9 states that the signal flow is from an output connection to one or several input connections. The uniqueness of the output signal is maintained if the output signal is connected in this way. A connection of more than one component to a single input connection would destroy the uniqueness of the input signal (Ref. 8). The staff finds this description of configurations that utilize a single input signal for several control systems in SAFIR to be acceptable.

The staff asked Westinghouse to describe how configurations that use a single input signal for several control systems are modeled in SAFIR. In RAI 10, the staff requested additional information about the third limitation. The staff asked Westinghouse to specify the limit to the number of component names that may be input in a model in order to clarify if this limitation presents a secondary limitation on the number of components that may be modeled within a single control system model.

The response to RAI 10 stated that a component may be named using any combination of 72 characters (Ref. 8). This allows for 72 factorial (72!) names. The staff finds this to be more than adequate.

3.3 Accident Scenario Identification Process

SAFIR is intended for use with NRC-approved transient methods for transient and accident analysis. The accident scenario identification process is relegated to the approval of the associated transient methods for specific accident and transient analyses. In the subject review, Westinghouse presented detailed information about the coupling of SAFIR with BISON. BISON is approved to analyze AOOs, overpressure transients, and ATWS events. In the case of BISON, the accident scenario identification process has been previously established.

When SAFIR is used with other transient analysis codes, these codes are employed within the framework of the RSR (Ref. 9). The RSR specifies the types of safety analyses and supporting analyses (such as uncertainty analyses that must be performed) to support fuel reload licensing. The RSR approves methods to analyze specific scenarios described in the RSR. Supplement 3 states that SAFIR will be used consistent with the provisions of the RSR. Therefore, the accident scenario identification process for alternative analysis methods is addressed by the previous approval of the thermal-hydraulic and neutron methods themselves.

The staff finds that the scenario identification process is acceptable on the basis of the previous approval of the transient methods and the assurance that SAFIR is applied within the provisions of the previously approved RSR.

3.4 Code Assessment

3.4.1 Verification and Validation for Components

The SAFIR method relies on developing macros and models from combinations of simpler components. Section 4 of Supplement 3 describes the V&V process for components within SAFIR. The V&V process for components is performed within the Westinghouse standard quality assurance process. The staff review of the quality assurance process is documented in Section 3.6 of this SE.

Generally, components are verified using a set of verifications commensurate with the complexity of the component itself. For very simple components, such as AND gates or the SUM component, only a limited set of verifications are required to confirm the functionality of the component consistent with the requirements. The staff finds that this approach is reasonable and therefore acceptable.

For more complex components, the verification set is expanded. Potential verifications include comparison of the component model to theoretical solutions, code-to-code comparisons, or other methods of solution. For the vast majority of control system components, the components are described by relatively simple transfer functions for which analytical solutions are available. The testing of the SAFIR component models against these analytical solutions provides a viable basis for verification. Therefore, the staff finds that the verification process is acceptable.

The validation process generally requires comparison of the SAFIR component model against measurement data. Since many components are composed of simple transfer functions, the staff agrees that, for many cases, verification against analytical solutions is sufficient to confirm the adequacy of the model. However, certain SAFIR components may be empirical and are designed to fit measurement data. For these cases, Supplement 3 specifies that validation must be performed using comparisons to measurement data. The rigor of the validation process is commensurate with the complexity of the component models; therefore, the staff finds the validation approach to be reasonable.

For cases in which the models are empirical in nature, the validation process requires validation against measurement data. The staff finds that this requirement is appropriate and necessary for this subset of component models.

Section 3.4.5 of this SE discusses the staff's review of the introduction of new components into the SAFIR method.

Section 4.4 of Supplement 3 provides an example V&V for the Proportional Integrating (PI) component. The verification ensures that all relevant aspects of the component were tested and assured to be accurate. The verification cases were sufficient to test all of the requirements for the PI component functions. The results of the SAFIR calculations demonstrate excellent agreement with the analytical solution. Figure 4-8 of Supplement 3 provides a direct comparison of the SAFIR and analytical solutions. The staff agrees that the verification process addresses the functions of the components and has, in the case of the PI component, ensured adequate performance of the SAFIR solution methodology.

The staff finds that the requirements and elements of the V&V process for components are acceptable in terms of scope, quality assurance, and rigor. The example provided for the PI component demonstrates acceptable performance by SAFIR and confirms that the V&V process for components is sufficiently robust to test all functions of the components. Therefore, the staff finds the component V&V process to be acceptable.

3.4.2 Development, Verification, and Validation for Models

The development process for SAFIR models is divided into three steps: (1) requirements, (2) design, and (3) implementation. The requirements step requires each model to specify (1) desired functionality, (2) limitations and assumptions, (3) communications with adjacent systems, and (4) communication with the transient code.

The staff reviewed these requirements and found that these specifications are sufficient to allow for the next design step. Further, the model requirements explicitly ensure that the models are applied appropriately within the greater code hierarchy in terms of communication and are implemented within specific constraints specified by the limitations of the model. Therefore, the staff finds that the requirements step in the model development process is acceptable. The design and implementation are straightforward steps in the development process.

Development of a SAFIR model requires subsequent V&V. The V&V process for SAFIR models is largely akin to the V&V process for SAFIR components. One difference discussed in Supplement 3 is that SAFIR models are constructed from the available SAFIR components, and that new model development does not require software upgrades to implement any new features within SAFIR.

The verification process requires testing of the SAFIR model to ensure that functionality of the model. Section 6.1.4 of Supplement 3 provides an example verification for the SAFIR control system model for a turbine controller model for [[ ]]. To verify the model, several perturbations were applied to the control system model and the SAFIR output was simulated. The verification confirmed that the model behavior was consistent with expectations based on the specific perturbations applied. The staff finds the scope of the perturbations consistent with the model functionality and finds the results to be acceptable.

Validation of the model requires that the model behavior be compared with reference data. Two approaches may be taken here. In the first approach, the model is validated against recorded plant data collected during startup tests or during operational occurrences. When these data are available, they are used in the validation process. For instances in which recorded plant data are unavailable, Westinghouse relies on code-to-code comparisons. In particular, the final safety analysis report is referenced as a source of data for validation comparisons.

The staff finds that it is acceptable to use plant data whenever available to validate the SAFIR model. Supplement 3 provides two example cases of validation of SAFIR models against recorded plant data. The staff review of these validation cases is documented in Sections 3.4.3 and 3.4.4 of this SE.

3.4.3 Swedish BWR [[ ]] Load Rejection Test

Section 6.1.5 of Supplement 3 provides the results of validation of the [[ ]] pressure control system model. The pressure control system model is a complex SAFIR control system model with several subsystems. The pressure control model is composed of a turbine controller; valve process models for high-pressure valves, bypass valves, reheater valves, and a capacity trimming valve; and one simple turbine model. Section 6.1.3.1 of Supplement 3 provides a detailed description of the pressure control system model, including flow diagrams that depict the various subsystems in the SAFIR model. The staff finds that the pressure control system model is complex and involves many of the SAFIR component models. Therefore, the staff accepts validation against the [[ ]] test data as a reasonable demonstration of the sufficiency and capability of the SAFIR control system simulator.

Additionally, the validation case presented serves as a prototypic example of the V&V process and illustrates the exercise of the model development and V&V processes for a typical plant control system.

The pressure control system model was validated against data collected during the generator load-rejection test performed in 2001. The load rejection was initiated by switching off the plant breaker. The validation case considers the plant response after the first 59 seconds (which were excluded). The calculated and measured control system responses provided in Figures 6-78 through 6-87 indicate excellent agreement between measurements and prediction. Some subtle differences were observed, [[ ]]. Therefore, small differences of this order are expected. However, plant response and code performance indicate a high degree of agreement overall.

The pressure control system validation provides reasonable assurance of SAFIR's ability to simulate large, complex, realistic BWR plant control systems. The specific validation results indicate that the V&V process ensures that the SAFIR models produce highly accurate results when compared to full-scale measurement plant data for transient conditions. Therefore, the staff finds the results to be acceptable.

3.4.4 Hamaoka 5 Startup Testing

Validation was also performed for various plant control systems against data collected at Hamaoka 5 (an ABWR) in Japan. The staff considered these validation data in the context of (1) demonstration of the capabilities and accuracy of the SAFIR method and (2) demonstration of the robustness of the general validation process described in Section 5 of the Supplement 3 LTR. The staff did not consider these validation data within the context of the approval of SAFIR for application to ABWRs.

The startup testing exercised several plant systems. The specific tests considered as part of the SAFIR validation included (1) a pressure control system step change, (2) a feedwater control system step change, and (3) a recirculation flow control system ramp change. These test data allow validation of the pressure control system, the feedwater control system, and the recirculation flow control system against full-scale recorded plant data.

These control systems are complex and are composed of several subsystems. Section 6.2.2.1 of Supplement 3 provides the details of the control system models and the subsystems. The staff finds that these systems are likewise complex and provide a robust basis for the validation of the capability of SAFIR to accurately predict plant control system behavior.

Figures 6-92 through 6-97 illustrate comparison between the SAFIR/BISON-predicted plant behavior and the measurement data. In all cases, the measurements and calculations indicate excellent agreement. Within the context of the staff review, these validation comparisons indicate that SAFIR/BISON code performance is very accurate in the prediction of plant system behavior. There are only minor differences between measurements and calculations. The staff also finds that validation activities provide an acceptable means for demonstrating the adequacy and robustness of a plant-specific SAFIR control system model. Therefore, the staff finds these validation studies to be acceptable.

3.4.5 Development and Implementation of New Components

Section 4 of Supplement 3 states that additional component models may be integrated within SAFIR using the Westinghouse code update process and associated procedures. The staff agrees that, although SAFIR includes a large number of components and the performance of SAFIR using these pre-existing components indicates high degrees of agreement with validation data, it is advantageous to maintain a capability to include additional component models in SAFIR to ensure continued applicability to control systems for a wide variety of plant configurations. Therefore, the staff reviewed the process detailed in Supplement 3 for the potential addition of new SAFIR components within the SAFIR methodology.

Supplement 3 states that new components added to SAFIR must comply with the V&V processes and the standard Westinghouse quality assurance processes. The staff has reviewed the V&V process for components and has found this process to be flexible, robust, and acceptable. The example provided for the PI component verification indicates that the process is thorough and that high accuracy may be maintained in the SAFIR simulation when compared against analytical solutions.

However, the NRC staff requested additional information about this process in several RAIs.

In RAI 2, the staff asked Westinghouse to provide a greater level of detail in terms of acceptance or success criteria in the V&V process to ensure that components added to the SAFIR method subsequent to the staff approval ensure that the accuracy of SAFIR is not compromised by subsequent modification.

[[

]]. The staff finds this approach to be acceptable.

In RAI 11, the staff asked Westinghouse to clarify the quality assurance requirements and confirm that the software update documentation is maintained under a program that adheres to Appendix B to 10 CFR Part 50 and that the documentation is auditable.

According to the response to RAI 11, Westinghouse software is developed and maintained in accordance with the Westinghouse quality management system (QMS) (Ref. 8). The QMS meets the applicable requirements of Appendix B to 10 CFR Part 50 and American Society of Mechanical Engineers (ASME) NQA-1-1994, "Quality Assurance Program for Nuclear Facilities," Part 1, Supplement 11S-2, and Part II, Subpart 2.7. The Westinghouse QMS has been reviewed and approved by the NRC and meets all requirements of Appendix B to 10 CFR Part 50 as well as International Organization for Standardization (ISO) 9001, "Quality Management Systems—Requirements." All analysis and internal calculations, or in the case of the addition of new input or output connectors, must be done in accordance with the Westinghouse QMS. The staff finds this approach to be acceptable.

In RAI 12, the staff asked Westinghouse to clarify what is meant by "simple" transfer functions.

According to the response to RAI 12, a "simple" function is one that can be described by an equation that has an analytic solution or has a representation in terms of standard mathematical functions (Ref. 13). The staff finds the clarification to be acceptable.

Supplement 3 states that components added to SAFIR through the prescribed process must [[

]].

In RAI 13, the staff asked Westinghouse to provide specific details of the process for verifying and validating an empirical component model—including details about the definition of the assumptions and limitations associated with such a model and how these limitations are tracked in the analysis procedures.

According to the response to RAI 13, Westinghouse will, if necessary, incorporate new components [[ ]]. New components that cannot be classified as [[

]] (Ref. 13). The assumptions, validation range, and limitations of such a component depend on the nature of the function. The verification and validation process, including documentation for such components, is identical to the process to verify and validate a SAFIR model as described in Section 5 of Supplement 3. The staff finds this to be acceptable.

In RAI 14, the staff asked Westinghouse to confirm that cycle-specific reload safety analyses include sufficient information for licensees to verify that component models included in SAFIR have adhered to the approved V&V process.

The response to RAI 14 clarifies that CENPD-300-P-A for BWRs (Ref. 9)) does not contain the level of detail that is necessary to address the addition of new control system components.

However, the addition of new components is reviewed and approved in accordance with the Westinghouse QMS (Ref. 13). The staff has approved the QMS and finds this to be adequate.

3.5 Uncertainty Analysis

To assist the staff in understanding the use of SAFIR within the context of the RSR (Ref, 9), the staff requested additional information in RAI 3. In particular, the staff requested that a sample calculation be provided to demonstrate the uncertainty analysis process. This approach is consistent with Section II.1.D of SRP Section 15.0.2.

The purpose of referring to CENPD-300-P-A (Ref. 9) is to clarify that the control system model will be developed in the same way as the model of any other plant system important to the transient analysis, and that SAFIR will be used to apply control system inputs to plant models in accordance with the provisions of the NRC-approved methodology; for example, in the RSR (CENPD-300-P-A). Therefore, the uncertainties and justification of the models will be treated in the same way as any other plant model that is input to the licensing analysis according to current licensing methodology (see the response to RAI 16 (Ref. 11)).

In the safety analysis method for AOOs, the model uncertainty is typically accounted for

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Uncertainties in SAFIR modeling parameters can be estimated from the comparison between SET data and SAFIR simulation of such SETs. The comparison between measurements and code predictions for the relevant modeling parameters yields either the distribution function of differences or the mean bias and the standard deviation of the bias.

For example, validation results against the plant data (SET) for the pressure controller of a specific plant are shown in Figures 6-78 through 6-81 in the topical report. [[

]]. Comparison of the model output parameters (BAFR, BATT, and APRM-Filter) yields the following probabilistic data:

- [[ ]]
- [[ ]]
- [[ ]]

It should be noted that the examples in the V&V presented in Supplement 3 were aimed to show the capability of SAFIR to model plant systems, and that comparisons were made against expected behavior and measurement data. In licensing applications, conservative plant responses are modeled by altering the system response in a conservative manner; i.e., by changing setpoints or the performance of critical functions in the model.

Currently, the NRC-approved Uncertainty Method A from Section 7.3.3 in CENPD-300-P-A (Ref. 9) is used in licensing applications. [[ ]]. SAFIR modeling uncertainties will be addressed consistent with the approved methodology for AOO uncertainty evaluation.

3.6 Quality Assurance Plan

In RAI 6, the staff requested additional information about details of the quality assurance process.

The response to RAI 6 stated that the Westinghouse QMS has been reviewed and approved by the NRC (WCAP-12308) and meets all requirements of Appendix B to 10 CFR Part 50 and ISO 9001. All analyses and internal calculations with regard to the addition of a new component must be done in accordance with the Westinghouse QMS (Ref. 8). The staff has previously reviewed the QMS and found it to be acceptable (see Ref. 12). Therefore, the QMS meets the criteria specified in SRP Section 15.0.2 for quality assurance.

4.0 Conditions And Limitations

Conditions and limitations for the SAFIR control system simulator method have been identified throughout Supplement 3. On the basis of the staff review, the staff finds that those conditions and limitations specified within the Supplement 3 LTR are sufficient and complete. This section provides a summary of the Supplement 3 list. The staff finds these to be acceptable and, therefore, has not imposed any new conditions or limitations.

1. Approval of SAFIR is limited to use in combination with NRC-approved transient analysis codes (from the Supplement 3 Abstract).

2. SAFIR shall model control systems consistent with the provisions of CENPD-300-P-A (from Supplement 3, Section 1).

3. If a new input or output connector is requested, this will be added to the code using the standard code update procedures (from Supplement 3, Section 3.8).

4. For a digital control system, the requirement on individual component sampling time shall be that of the real plant component (from Supplement 3, Section 3.9.1).

5. For an analog control system, the sampling time shall not be longer than the transient code time step (from Supplement 3, Section 3.9.1).

6. A signal can only be connected to one single output (from Supplement 3, Section 3.11).

7. A model must have at least one input signal (from Supplement 3, Section 3.11).

8. An instance of a component must have a unique name within a model (from Supplement 3, Section 3.11).

9. The addition of a component to SAFIR follows the Westinghouse standard quality assurance processes for both the implementation verification and validation when required. Components that may be added by the described procedure shall [[ ]] (from Supplement 3, Section 4.1).

10. Validation of complex components will be performed using comparisons to measurement data (from Supplement 3, Section 4.3).

11. Validation of models is performed against available data and code-to-code comparison. Plant data recorded during startup tests or operational occurrences are used when available (from Supplement 3, Section 5.4).

5.0 Conclusions

On the basis of the descriptions of the methodology and the analytical methods associated with the SAFIR control system simulator as presented in Supplement 3 to BISON Topical Report RPA 90-90-P-A, the responses by Westinghouse to the NRC's RAIs, and a staff audit of the user manual, we find that SAFIR, in conjunction with an NRC-approved system code such as BISON, is acceptable for performing licensing-basis analyses for BWRs 2–6, subject to the conditions and limitations stated in Section 4 of this SE. This eliminates Condition 6 of the BISON topical report.

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6.0 References

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2. Westinghouse letter (LTR-NRC-09-49) from Maurer, B.F., to U.S. Nuclear Regulatory Commission, "Submittal of WCAP-17079-P/WCAP-17079-NP, 'Supplement 3 to BISON Topical Report RPA 90-90-P-A SAFIR Control System Simulator' (Proprietary/Non-Proprietary)," October 13, 2009 (ADAMS Accession No. ML093080098).

3. RPA 90-90-P-A, "BISON—A One Dimensional Dynamic Analysis Code for Boiling Water Reactors," ABB/CE, December 1991 (ADAMS Accession No. ML093130454).

4. CENPD-292-P-A, "BISON—One Dimensional Dynamic Analysis Code for Boiling Water Reactors: Supplement 1 to Code Description and Qualification," ABB/CE, July 1996.

5. WCAP-16606-P-A, "Supplement 2 to BISON Topical Report RPA 90-90-P-A," Westinghouse Electric Company, January 2008 (ADAMS Accession No. ML081280716).

6. WCAP-16747-P, "POLCA-T: System Analysis Code with Three-Dimensional Core Model," Westinghouse Electric Company, March 2007 (ADAMS Accession No. ML071380122).

7. NUREG-0800, "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants: LWR Edition," U.S. Nuclear Regulatory Commission, 2007.

8. South Texas Project Letter (U7-C-STP-NRC-100089) from Head, S., to U.S. Nuclear Regulatory Commission, "Response to Request for Additional Information," May 12, 2010 (ADAMS Accession No. ML101380351).

9. CENPD-300-P-A, "Reference Safety Report for Boiling Water Reactor Reload Fuel," ABB/CE, July 1996 (ADAMS Accession No. ML072250429).

10. South Texas Project letter (U7-C-STP-NRC-100127) from Head, S., to U.S. Nuclear Regulatory Commission, "Response to Request for Additional Information," June 8, 2010 (ADAMS Accession No. ML101620286).

11. South Texas Project Letter (U7-C-STP-NRC-100095) from Head, S., to U.S. Nuclear Regulatory Commission. "Response to Request for Additional Information," May 12, 2010 (ADAMS Accession No. ML101380349).

12. "Revised Final Safety Evaluation by the Office of Nuclear Reactor Regulation for Westinghouse Electric Company Topical Report WCAP-16747-P, 'POLCA-T: System Analysis Code with Three-Dimensional Code Model' (TAC No. MD5258)," U.S. Nuclear Regulatory Commission, June 1, 2010 (ADAMS Accession No. ML101460445).

13. South Texas Project letter (U7-C-STP-NRC-100078) from Head, S., to U.S. Nuclear Regulatory Commission, “Response to Request for Additional Information,” April 13, 2010 (ADAMS Accession No, ML101090145).