14 INITIAL TEST PROGRAM

The U.S. Nuclear Regulatory Commission (NRC) staff reviewed Chapter 14, "Initial Test Program," of the Tennessee Valley Authority (hereinafter referred to as TVA or the applicant), Construction Permit Application (CPA) Preliminary Safety Analysis Report (PSAR), as supplemented, against applicable regulatory requirements using regulatory guidance and standards to assess the sufficiency of the preliminary information on the Initial Test Program (ITP) for the issuance of a construction permit (CP) in accordance with Title 10 of the *Code of Federal Regulations* (10 CFR) Part 50 (TN249), "Domestic Licensing of Production and Utilization Facilities." As part of this review, the NRC staff evaluated information on the ITP, with special attention given to design and operating characteristics, unusual or novel design features, and principal safety considerations. The NRC staff evaluated the preliminary design of the ITP to ensure that the design criteria, design bases, and information relative to construction were sufficient to provide reasonable assurance that the final design will conform to the design-basis.

The NRC staff's reviews and evaluations for areas relevant to PSAR Chapter 14, including regulations and guidance used, a summary of the application information reviewed, and evaluation findings and conclusions, are discussed in the sections below for each specific review area. A summary and overall conclusions on the staff's technical evaluation of the initial test program are provided in Section 14.1.4, "Conclusion."

14.1 Safety Analysis Report Content

14.1.1 Introduction

Clinch River Nuclear Unit 1 (CRN-1) is a one-unit BWRX-300 SMR (hereinafter referred to as CRN-1) designed by GE-Vernova Hitachi Nuclear Energy. CRN-1 PSAR Chapter 14, Initial Test Program," describes the ITP that is performed during the first startup of CRN-1. The ITP establishes the manner in which the testing is performed, controlled, and documented for the testing phases of CRN-1. Chapter 14 of the CRN-1 PSAR describes:

1. the scope of the test program;
2. plant design features that are specific, unique, or first-of-a-kind (FOAK);
3. conformance of test programs with NRC Regulatory Guides (RGs);
4. the utilization of plant operating and testing experience at other reactor facilities;
5. the test program schedule;
6. trial use of plant operating and emergency procedures; and
7. the augmentation of plant staff during the test program.

14.1.2 Regulatory Evaluation

The NRC's regulations in 10 CFR 50.34 (TN249), "Contents of applications; technical information," paragraph (a), "Preliminary safety evaluation report," require CP applicants to submit a PSAR to the NRC for review which must describe specific aspects of the proposed nuclear power plant. Paragraph (3) of 10 CFR 50.34(a) requires that the PSAR include principal design criteria for the facility and notes that 10 CFR 50, Appendix A, General Design Criterion 1,

establishes minimum requirements for principal design criteria needed for testing of SSCs important to safety. Paragraph (6) in 10 CFR 50.34(a) requires that the PSAR include a preliminary plan for the applicant's organization, personnel training, and conduct of operations. Paragraph (7) of 10 CFR 50.34(a) requires that the PSAR contain a description of the quality assurance program to be applied to the testing of the structures, systems, and components of the facility.

In RG 1.70 (NRC 1978-TN12879), Revision 3, "Standard Format and Content of Safety Analysis Reports for Nuclear Power Plants, LWR Edition," the NRC provides guidance for preparation of a PSAR pursuant to 10 CFR 50.34. In Chapter 14, "Initial Test Program," of RG 1.70, the NRC states that the PSAR should provide information on the ITP for SSCs and design features for both the nuclear portion of the plant and the balance of plant. In particular, the information provided should address major phases of the ITP, including preoperational tests, initial fuel loading and initial criticality, low-power tests, and power-ascension tests. The PSAR should also describe the scope of the ITP and general plans for accomplishing the ITP in sufficient detail to demonstrate that due consideration has been given to matters that normally require advance planning. In RG 1.70, Section 14.1, "Specific Information to be included in Preliminary Safety Analysis Reports," the NRC staff provides guidance for describing:

1. the scope of the test program;
2. plant design features that are special, unique, or FOAK;
3. RGs;
4. utilization of plant operating and testing experiences at other reactor facilities;
5. the test program schedule;
6. trial use of plant operating and emergency procedures; and
7. augmentation of the applicant's staff during the test program.

In its review, the NRC staff evaluated whether the applicant complied with the NRC's regulatory requirements in 10 CFR 50.34(a) and satisfied the NRC's guidance in RG 1.70 in describing the ITP for CRN-1. The NRC staff's technical evaluation of Chapter 14 of the CRN-1 CPA PSAR, with respect to the applicable regulatory requirements and guidance for the ITP, is described in the following section of this SE.

14.1.3 Technical Evaluation

The NRC's regulations in 10 CFR 50.34(a) (TN249) require CP applicants to submit a PSAR to the NRC for review which must describe specific aspects of the proposed nuclear power plant. Chapter 14 of RG 1.70 (NRC 1978-TN12879) provides guidance for CP applicants to describe their plans for preoperational testing and initial operations of the proposed nuclear power plant in the PSAR. The NRC staff reviewed the individual subsections of Section 14.1, "Preliminary Safety Analysis Report Content," of the CRN-1 PSAR for compliance with 10 CFR 50.34(a) and for consistency with the NRC's guidance in RG 1.70. In addition to reviewing the CRN-1 PSAR, the NRC staff conducted an audit of information provided in the applicant's electronic reading room and discussed the ITP plans for CRN-1 with applicant personnel. The NRC staff describes its technical review of the planned ITP in this section of the SE.

Section 14.1.1, "Scope of Test Program," in RG 1.70 states that the PSAR should describe the major phases of the ITP and the overall test objectives and general prerequisites for each major phase. The NRC staff reviewed the information provided in CRN-1 PSAR Section 14.1.1,

"Scope of Test Program," and compared it to the guidance provided in Section 14.1.1 of RG 1.70. As described in the CRN-1 PSAR Section 14.1.1, the ITP is composed of three tests categorized as construction, preoperational, and initial startup. Construction tests will serve as prerequisites for preoperational tests at CRN-1. Preoperational tests will be conducted prior to fuel loading and will demonstrate the capability of plant systems to meet their performance requirements. Initial startup tests will begin with fuel loading and will include precritical tests, initial criticality, low-power testing, and power-ascension tests. Initial startup tests at CRN-1 will demonstrate the capability of the integrated plant to meet its performance requirements.

CRN-1 PSAR Section 14.1.1, "Summary of Test Program and Objectives," states that the ITP is applied to Safety Class 1 (SC1), Safety Class 2 (SC2), and Safety Class 3 (SC3) SSCs, and notes that a preliminary list of SSC classification is provided in CRN-1 PSAR Table 3A-1, "Preliminary BWRX-300 Component Classification List." GE-Hitachi Nuclear Energy Licensing Topical Report NEDO-33934, Revision 2, "BWRX-300 Safety Strategy – Non-Proprietary Information" (GE Hitachi 2026-TN13283) Table 4-1, "Functional Safety Category Assignment," and Table 5-1, "Safety Class and Safety Category Mapping to USNRC Regulatory Requirements and Guidance," indicate that SC1 includes safety-related and important to safety SSCs that support DL3 functions, and SC 2 and 3 supports non safety-related but important to safety and regulatory treatment of non-safety systems (RTNSS) functions associated with DL2, 4a, and 4b functions. The BWRX-300 safety classifications, Defense Lines 2, 3, 4a and 4b functions, stem from the aforementioned technical report. Table 5-1 explains how the BWRX-300 safety classifications map to the NRC's regulatory requirements. The NRC staff finds the preliminary information in PSAR Table 3A-1 to be acceptable for the CPA for the CRN-1 site. As part of the future review of the Operating License (OL) application for the CRN-1 site, the NRC staff will evaluate any SSCs in the CRN-1 BWRX-300 design that are of sufficient safety significance to be included in the ITP. CRN-1 PSAR Section 14.1.1 states that the ITP addresses SSCs and design features for both the nuclear portion of the facility as well as the balance-of-plant for the CRN-1 site.

As stated in PSAR Section 14.1.1, the overall objectives of the ITP at the CRN-1 site are to:

1. demonstrate that construction is complete and acceptable, including required testing;

2. ensure that the capability of SSCs meet their design performance requirements;

3. provide additional assurance that the facility has been adequately designed;

4. achieve fuel loading in a safe manner;

5. demonstrate, where practical, that the plant is capable of withstanding anticipated transients and postulated accidents;

6. validate, to the extent practical, that operating procedures and operator training are adequate to operate the facility in a safe manner; and

7. bring the plant to rated capacity and sustained power operation.

CRN-1 PSAR Section 14.1.1 provides a high-level description of the types of testing to be conducted under the ITP. In particular, PSAR Section 14.1.1 describes the planned construction tests, preoperational tests, and initial startup tests, as well as their objectives, at the CRN-1 site. In addition, PSAR Section 14.1.1 references the Quality Assurance Program

Description in PSAR Section 17.5, “Quality Assurance Program Description – Design Certification, Early Site Permit, and New License Applicants,” for the organization responsible for design, construction, and operations of CRN-1. PSAR Section 14.1.1 describes the startup administrative manual that will provide high-level organization and administrative guidance to establish bounding requirements and an administrative framework for the preoperational and initial startup tests for CRN-1. PSAR Section 14.1.1 specifies that testing will be conducted using detailed, step-by-step written procedures to control the conduct of each test. PSAR Section 14.1.1 specifies that the ITP group, which is comprised of applicant personnel assigned to perform the testing, will conduct testing in accordance with the startup administrative manual. PSAR Section 14.1.1 states that test results will be evaluated, reviewed, and approved by an ITP supervisor.

Consistent with 10 CFR Part 50, Appendix A, General Design Criterion 1, important to safety SSCs are tested commensurate with the importance of their safety functions. CRN-1 PSAR Section 14.1.1 states that one objective of the ITP is to demonstrate that construction is complete and acceptable, including required testing, and that the ITP is applied to SC 1, 2, and 3 SSCs that are important to safety. Therefore, the NRC staff finds the preliminary information in PSAR Section 14.1.1 to be acceptable to support the issuance of the CP for CRN-1.

As part of the review of the OL application for CRN-1, the NRC staff will evaluate the ITP requirements (such as installed valve post-installation qualification testing requirements, individual valve opening and closing capability demonstration, leak-tight testability of individual valves, and testing accessibility for ITP components) consistent with the design and construction of CRN-1.

Based on its review, the NRC staff finds that CRN-1 PSAR Section 14.1.1 provides acceptable information related to the major phases of the ITP, as well as the overall test objectives and general prerequisites for each major phase, and is consistent with the guidance set forth in RG 1.70 for a construction permit application.

Section 14.1.2, “Plant Design Features that are Special, Unique, or First of a Kind,” in RG 1.70 states that the CPA should provide a summary description in the PSAR of the preoperational and initial startup tests planned for each unique or FOAK feature of the nuclear power plant. The NRC staff reviewed CRN-1 PSAR Section 14.1.2, “Plant Design Features that are Specific, Unique, or First-of-a-Kind,” in comparison with the guidance provided in Section 14.1.2 of RG 1.70. CRN-1 PSAR Section 14.1.2 states that the BWRX-300 reactor contains design features that are new and have not been tested previously; therefore, these new features will be treated as FOAK. Table 14.1-1, “Objectives of First-of-a-Kind Testing,” in PSAR Section 14.1.2 lists the FOAK tests anticipated for the BWRX-300 reactor based on its current design maturity for the Isolation Condenser System (ICS) and ICS Condensate Return to the Chimney. PSAR Section 14.1.2 states that preoperational and initial startup tests may be added to the list in Table 14.1-1 as testing plans are developed in preparation for the OL application for CRN-1.

Table 14.1-1 provides the following information for the ICS and the ICS Condensate Return to the Chimney, which Table 14.1-1 identifies as two FOAK features for the CRN-1 BWRX-300 design:

1. Isolation Condenser System (ICS)

   - *System Design*: The ICS consists of three independent trains, each containing a heat exchanger or isolation condenser that is submerged in a pool of water and is connected to the reactor vessel by steam supply and condensate return piping. When in operation,

the ICS removes heat from the reactor coolant and rejects it to the environment. This provides overpressure protection by maintaining the reactor vessel below design limits. The use of ICS for overpressure protection instead of traditional safety or relief valves is a new design feature that has not been previously demonstrated in an operating nuclear station.

- *Test Objective*: Full-scale prototype testing has been accomplished for the heat exchanger and return to the reactor vessel. During the startup phase, a FOAK test places the ICS in service and determines heat exchange capacity and confirms prototype testing results, within the limitations of the test program and site conditions.

2. ICS Condensate Return to the Chimney

- *Design Description*: When the ICS is in operation, the condensate return line to the reactor vessel is open. The subcooled condensate that is stored in the ICS during the standby state enters the reactor vessel chimney providing additional inventory while also condensing steam and increasing the fluid density in the chimney. Placement of the ICS condensate returns in the chimney above the core, instead of in the downcomer as in previous designs, has thermal-hydraulic benefits and is a new design feature.
- *Test Objective*: The return line to the reactor vessel chimney region was modeled and analyzed using Computational Fluid Dynamics and Transient Reactor Analysis Code General Electric (TRACG). Scaled testing with steam/water at reactor conditions at the Hitachi Utility Steam Test Leading facility was used to benchmark the following key aspects of the Computational Fluid Dynamics and TRACG modeling of ICS condensate return to the chimney:

  – interfacial shear characteristics between steam and liquid phases
  – steady-state flow patterns of two-phase flows

  During the startup phase, a FOAK test confirms the accuracy of the predictions of the BWRX-300 core flow when the ICS is operating based on the measured temperatures at the core inlet.

During the audit, the NRC staff discussed the applicant's plans, in demonstrating the performance of the ICS and ICS Condensate Return to the Chimney, to correlate the CRN-1 ITP results for these components to the testing that will be performed to satisfy 10 CFR 50.43, "Additional standards and provisions affecting class 103 licenses and certifications for commercial power," paragraph (e), and to the testing that will be performed to satisfy the provisions in American Society of Mechanical Engineers (ASME) QME-1, "Qualification of Active Mechanical Equipment Used in Nuclear Facilities," as referenced in the CRN-1 PSAR. The applicant is in the process of completing design aspects and procedures related to the ICS and ICS Condensate Return to the Chimney for the BWRX-300 reactor and will coordinate the testing activities performed for the 10 CFR 50.43(e) design demonstration, ASME QME-1 qualification, and ITP for these components at CRN-1. The NRC staff will review the completion of those activities as part of the review of the OL application for CRN-1.

Regulatory Guide 1.70, Section 14.1.2, "Plant Design Features That Are Special, Unique, or First of a Kind," states that the CP applicant should provide a summary description of the preoperational and/or startup testing planned for each unique or FOAK feature in the PSAR. In addition to the ICS and ICS Condensate Return to the Chimney, the CRN-1 BWRX-300 design includes components with new features that are different from light-water reactor nuclear power

plants currently licensed under 10 CFR Part 50, such as the BWRX-300 Reactor Pressure Vessel Reactor Isolation Valves. During the audit, the NRC staff discussed the applicant's plans to perform ITP testing for components (other than the ICS and ICS Condensate Return to the Chimney) to correlate with the results of the 10 CFR 50.43(e) design demonstration and ASME QME-1 qualification testing. The applicant is in the process of completing design aspects and procedures for the CRN-1 BWRX-300 reactor and may identify, during the preparation for the OL application, additional components that need to be addressed under 10 CFR 50.43(e) with associated ITP activities.

Based on its review, the NRC staff finds that CRN-1 PSAR Section 14.1.2 provides acceptable information related to the ICS and ICS Condensate Return to the Chimney, which are FOAK design features, in support of the planned ITP and is consistent with the guidance set forth in RG 1.70. The NRC staff will review the completion of activities related to other potential FOAK design features as part of the staff's review of the OL application for CRN-1.

Section 14.1.3, "Regulatory Guides," in RG 1.70 states that the PSAR should describe the applicant's plans for using guidance in applicable RGs in the development and conduct of the ITP. The NRC staff reviewed CRN-1 PSAR Section 14.1.3, "Conformance of Test Programs with Regulatory Guides," in comparison with the guidance provided in Section 14.1.3 of RG 1.70. CRN-1 PSAR Section 14.1.3 states that the development of the ITP will conform to RG 1.68, "Initial Test Program for Water-Cooled Nuclear Power Plants," and lists additional RGs to which the development of the ITP will conform. The applicant plans to address conformance to the additional RGs in the final safety analysis report when associated system test descriptions have been developed. The NRC staff finds that CRN-1 PSAR Section 14.1.3 provides acceptable information related to applicable RGs in support of the planned ITP and is consistent with the guidance in RG 1.70.

Section 14.1.4, "Utilization of Plant Operating and Testing Experiences at Other Reactor Facilities," in RG 1.70 states that the PSAR should describe the applicant's plans for using available information on reactor plant operating experience to establish where emphasis may be warranted in the ITP. RG 1.70 indicates that the PSAR should describe a schedule, relative to the fuel loading date, for conducting a study or implementing a program for using available information on reactor plant operating experience in the ITP. The NRC staff reviewed the CRN-1 PSAR Section 14.1.4, "Utilization of Plant Operating and Testing Experiences at Other Reactor Facilities," in comparison with the guidance provided in Section 14.1.4 of RG 1.70. CRN-1 PSAR Section 14.1.4 notes that TVA has experience in constructing, testing, and operating nuclear reactors, and has reviewed lessons learned from nuclear industry experience. PSAR Section 14.1.4 also states that lessons learned from design, construction, testing, and operation of other nuclear power plants will be incorporated into test specification development and test procedures as part of the ITP for CRN-1. PSAR Section 14.1.4 further indicates that a program will be developed and implemented to obtain construction and operating experience from other BWRX-300 nuclear power plants prior to submittal of the final safety analysis report as part of the OL application for CRN-1. The NRC staff finds that the CRN-1 PSAR Section 14.1.4 provides acceptable information related to the use of plant operating and testing experience from other reactor facilities in support of the planned ITP and is consistent with the guidance in RG 1.70.

Section 14.1.5, "Test Program Schedule," in RG 1.70 states that the PSAR should provide a summary description of the overall schedule, relative to the expected fuel loading date, for developing and conducting the major phases of the ITP. RG 1.70 notes that the information should establish the scheduled time period for developing detailed test procedures and

conducting the tests for each major phase. The NRC staff reviewed the CRN-1 PSAR Section 14.1.5, “Test Program Schedule,” in comparison with the guidance provided in Section 14.1.5 of RG 1.70. CRN-1 PSAR Section 14.1.5 states that the specific test schedule is currently under development. To allow for NRC inspection, PSAR Section 14.1.5 states that test procedure preparation is scheduled such that the approved procedures will be available to the NRC staff approximately 60 days prior to their intended use. PSAR Section 14.1.5 further states that implementation milestones for development of plant operating and emergency procedures are provided in Chapter 13, “Conduct of Operations,” of the PSAR. The NRC staff finds that the CRN-1 PSAR Section 14.1.5 provides acceptable information related to the overall schedule, relative to the expected fuel loading date, for developing and conducting the major phases of the ITP and is consistent with the guidance in RG 1.70 for the CPA for CRN-1.

Section 14.1.6, “Trial Use of Plant Operating and Emergency Procedures,” in RG 1.70 states that the PSAR should describe the applicant’s plans pertaining to the trial use of plant operating and emergency procedures during the ITP. The NRC staff reviewed the CRN-1 PSAR Section 14.1.6, “Trial Use of Plant Operating and Emergency Procedures,” in comparison with the guidance provided in Section 14.1.6 of RG 1.70. CRN-1 PSAR Section 14.1.6 states that procedures developed for operating, surveillance, emergency, and abnormal conditions will be used, to the extent practicable, throughout the preoperational and initial startup test phases, where applicable. PSAR Section 14.1.6 states that the use of these procedures will: (1) prove the specific procedure or illustrate changes which may be required; (2) train plant personnel in the use of these procedures; and (3) increase the level of knowledge of plant personnel on the systems being tested. PSAR Section 14.1.6 indicates that a test procedure used during the ITP might consist of a combination of references to procedures pertaining to operating, surveillance, emergency, or abnormal conditions, or repeat a series of steps from a procedure to accomplish the test’s goals while also efficiently performing the specified testing. The NRC staff finds that CRN-1 PSAR Section 14.1.6 provides acceptable information related to the trial use of plant operating and emergency procedures in support of the planned ITP and is consistent with the guidance in RG 1.70.

Section 14.1.7, “Augmenting Applicant’s Staff During Test Program,” in RG 1.70 states that the PSAR should describe the applicant’s general plans for the assignments of additional personnel to supplement the plant’s operating and technical staff during each major phase of the ITP. RG 1.70 also states that the PSAR should provide a description of the general responsibilities of the various augmenting organizations, a summary of the interrelationships and interfaces of the various organizations that will participate in the ITP, the general qualifications of participating organizations, and the approximate schedule, relative to the fuel loading date, for augmenting the applicant’s staff. The NRC staff reviewed the CRN-1 PSAR Section 14.1.7, “Augmenting Staff During the Test Program,” in comparison with the guidance provided in Section 14.1.7 of RG 1.70. CRN-1 PSAR Section 14.1.7 indicates that ITP technical staff and plant operating staff will be trained and in place to implement the ITP at CRN-1. PSAR Section 14.1.7 states that subject matter experts from outside organizations, such as from various equipment suppliers and vendors, will be contracted by TVA, as needed, to support the ITP at CRN-1. Further, PSAR Section 14.1.7 indicates that augmenting the CRN-1 staff with personnel from the current fleet of operating TVA nuclear power plants to support preoperational and initial startup tests at CRN-1 will be considered, as necessary. The NRC staff finds that CRN-1 PSAR Section 14.1.7 provides acceptable information related to the plans to augment plant staff, as needed, in support of the planned ITP and is consistent with the guidance in RG 1.70.

14.1.4 Conclusion

Based on its review of Chapter 14 of the CRN-1 PSAR, the NRC staff concludes that the information provided by the applicant for the planned ITP complies with the regulatory requirements specified in 10 CFR 50.34(a) and further satisfies the NRC guidance in RG 1.70 to support issuance of a CP pursuant to the regulations in 10 CFR 50.35. When the final design and procedures are established for the BWRX-300 reactor, the NRC staff will review the ITP described by the applicant in its final safety analysis report using guidance in RG 1.70 to verify that the regulatory requirements in 10 CFR 50.34(b), “Final safety analysis report,” have been met for the OL application for CRN-1.