Surry Power Station
Updated Final Safety Analysis Report

Chapter 13

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CHAPTER 13 INITIAL TESTS AND OPERATION

The following information is HISTORICAL and is not intended or expected to be updated for the life of the plant.

13.1 TESTS PRIOR TO INITIAL REACTOR FUELING

The comprehensive testing program ensured that equipment and systems performed in accordance with design criteria prior to fuel loading. As the installation of individual components and systems was completed, they were tested and evaluated according to predetermined and approved written testing techniques, procedures, or check-off lists. Field and engineering analyses of test results were made to verify that systems and components were performing satisfactorily and to recommend corrective action, if necessary.

The program included tests, adjustments, calibrations, and system operations necessary to ensure that initial fuel loading and subsequent power operation could be safely undertaken. In general, the types of tests are classified as hydrostatic, functional, electrical, and operational. Functional tests verified that the system or equipment was capable of performing the function for which it was designed. Operational tests involved actually operating the system and equipment under design or simulated design conditions.

Whenever possible, these tests were performed under the same conditions as experienced under subsequent station operations. During systems tests for which unit parameters were not available and could not be simulated, the systems were operationally tested as far as possible without these parameters.

The remainder of the tests were performed when the parameters were available. Abnormal unit conditions were simulated during testing when such conditions did not endanger personnel or equipment, or contaminate clean systems. The detailed procedure took into account the predicted emergency or abnormal conditions involved in the test program, and appropriate measures were included in the procedure.

During the preoperational tests, piping systems were checked to ensure correct and satisfactory performance under normal operating conditions, including expected routine transients. Any abnormal conditions, such as water hammer, excessive vibration, or displacement were noted and referred to the start-up engineer for investigation. If no abnormal conditions were observed, the system was deemed to be satisfactory and no other action taken. Completed preoperational test procedures are maintained on file at the plant site.

For purpose of illustration, a listing of representative tests required prior to initial reactor fueling is contained in Table 13.1-1. Additional information on the preoperational testing of specific components and systems is contained in the inspection and tests subsections of Chapters 3 through 11. The quality assurance section (15.4.6) contains supplemental information concerning procedural and organizational matters during construction and start-up activities. The operational quality assurance program is discussed in Chapter 17.

Individual systems have system descriptions in which individual equipment tests are listed.

The following information is HISTORICAL and is not intended or expected to be updated for the life of the plant.

Table 13.1-1
OBJECTIVES OF SYSTEM TESTS PRIOR TO INITIAL REACTOR FUELING

System Tested	Test Objective
1. Electrical system	To ensure continuity, circuit integrity, and the correct and reliable functioning of electrical apparatus. Electrical tests were performed on transformers, switchgear, turbine generators, motors, cables, control circuits, excitation switchgear, dc systems, annunciator systems, lighting distribution switchboards, communication systems, and miscellaneous equipment. Special attention was directed to the following tests: a. High-voltage switchgear breaker interlock test. b. Station loss of voltage autotransfer test. c. Emergency power transfer test. d. Tests of protective devices. e. Equipment automatic start tests. f. Excitor check for proper voltage buildup. g. Insulation tests.
2. Voice communication system	To verify proper communication between all local stations, for interconnection to commercial phone service, and to balance and adjust amplifiers and speakers.
3. Service water system	To verify, prior to critical operation, the design head-capacity characteristics of the service water system, that the system would supply design flow rate through all heat exchangers, and would meet the specified requirements when operated in the safeguards mode.
4. Fire protection system	To verify proper operation of the system by ensuring that the design intent was met for the fire pumps, to verify that automatic start functions operated as designed, and to verify that level and pressure controls met specifications.
5. Compressed air system	To verify leaktightness of the system, proper operation of all compressors, the manual and automatic operation of controls at design setpoints, design air dryer cycle time and moisture content of discharge air, and proper air pressure to each controller served by the system.

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Table 13.1-1 (CONTINUED)
OBJECTIVES OF SYSTEM TESTS PRIOR TO INITIAL REACTOR FUELING

System Tested	Test Objective
6. Reactor coolant system cleaning	To flush and clean the reactor coolant and related primary systems to obtain the degree of cleanliness required for the intended service. Provisions to maintain cleanliness and protection from contaminated sources were made after system cleaning and acceptance. After systems were flushed clean of soluble and particulate matter, cleanliness of the system was maintained. Coolant was analyzed for chloride content, suspended solids, pH, and conductivity. Oxygen content was analyzed and brought to specifications before exceeding 200°F.
7. Ventilation system	To verify proper operability of fans, controls, and other components of the containment ventilation system and auxiliary ventilation system.
8. Condensate and system feedwater	To verify valve and control operability and set points. An inspection for completeness and integrity was made. Functional testing was performed when the main steam system was available. Flushing and hydrostatic tests were performed where applicable.
9. Auxiliary coolant systems	To verify component cooling flow to components, and to verify proper operation of instrumentation, controllers, and alarms. Specifically, each of the three systems (i.e., component cooling system, including the charging pump cooling system, residual heat removal system, and fuel pit cooling system) was tested to ensure that a. All manually and remotely operated valves were operable manually and/or remotely. b. All pumps performed their design functions satisfactorily. c. All temperature, flow, level, and pressure controllers functioned to control at the required setpoint when supplied with appropriate signals.

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Table 13.1-1 (CONTINUED)
OBJECTIVES OF SYSTEM TESTS PRIOR TO INITIAL REACTOR FUELING

System Tested	Test Objective
9. Auxiliary coolant systems (continued)	d. All temperature, flow, level, and pressure alarms provided alarms at the required locations when the alarm setpoint was reached, and cleared when the reset point was reached. e. Design flow rates were established through the principal heat exchangers.
10. Boron recovery system	To verify valve and control operability and setpoints, flushing and hydrostatic testing were performed as applicable, including inspection for completeness and integrity. Functional testing was performed when a steam supply was available.
11. Chemical and volume control system	To verify, prior to critical operation, that the chemical and volume control system functioned as specified in the system description and appropriate manufacturers' technical manuals. More specifically, that a. All manually and remotely operated valves were operable manually and/or remotely. b. All pumps performed to specifications. c. All temperature, flow, level, and pressure controllers functioned to control at the required setpoint when supplied with appropriate signal(s). d. All temperature, flow, level, and pressure alarms provided alarms at the required locations when the alarm setpoint was reached and cleared when the reset point was reached. e. The reactor makeup control regulated blending, dilution, and boration as designed. f. The design seal-water flow rates were attainable at each reactor coolant pump. g. Chemical addition subsystem functioned as specified.

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Table 13.1-1 (CONTINUED)
OBJECTIVES OF SYSTEM TESTS PRIOR TO INITIAL REACTOR FUELING

System Tested	Test Objective
12. Safety injection system	To verify, prior to critical operation, response to control signals and sequencing of the pumps, valves, and controllers of this system as specified in the system description and the manufacturers' technical manuals; and to check the time required to actuate the system after a safety injection signal was received. More specifically, that a. All manually and remotely operated valves were operable manually and/or remotely. b. For each pair of valves installed for redundant flow paths, disabling one of the valves did not impair operation of the other. c. All pumps performed their design functions satisfactorily. d. The proper sequencing of valves and pumps occurred on initiation of a safety injection signal. e. The fail position on loss of power for each remotely operated valve was as specified. f. Valves requiring initiating signals to operate did so when supplied with these signals. g. All level and pressure instruments were set at the specified points and provided appropriate alarms and resets. h. The time required to actuate the system was within the design specifications.
13. Containment spray system	To verify, prior to critical operation, response to control signals and sequencing of the pumps, valves, and controllers as specified in the system description and the manufacturers' technical manuals; and to check the time required to actuate the system after a containment high-pressure signal was received. More specifically, see the test objective listing for the safety injection system above.

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Table 13.1-1 (CONTINUED)
OBJECTIVES OF SYSTEM TESTS PRIOR TO INITIAL REACTOR FUELING

System Tested	Test Objective
14. Fuel handling system[a]	To show that the system design was capable of providing a safe and effective means of transporting and handling fuel from the time it reaches the station until it leaves the station. In particular, the tests were designed to verify that a. The major structures required for refueling, such as the reactor cavity, refueling canal, new-fuel and spent-fuel storage, and decontamination facilities were in accordance with the design intent. b. The major equipment required for refueling, such as the manipulator crane, fuel-handling tools, and spent-fuel transfer system, operated in accordance with the design specifications. c. All auxiliary equipment and instrumentation functioned properly.
15. Radiation monitoring systems	To verify the calibration, operability, and alarm setpoints of all area radiation monitors, air particulate monitors, gas monitors, and liquid monitors that were included in the process radiation monitor system and the area radiation monitor system.
16. Reactor control and protection system	To verify calibration, operability, and alarm settings of the reactor control and protection system; to test its operability in conjunction with other systems. As an example, the nuclear instrumentation system tests are detailed below.
17. Nuclear instrumentation system	To ensure that the instrumentation system was capable of monitoring the reactor leakage neutron flux from source range through 120% of full power and that protective functions were operating properly. In particular, tests were designed to verify that a. All system equipment, cabling, and interconnections were properly installed.

a. Tests were conducted with a dummy fuel element.

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Table 13.1-1 (CONTINUED)
OBJECTIVES OF SYSTEM TESTS PRIOR TO INITIAL REACTOR FUELING

System Tested	Test Objective
17. Nuclear instrumentation system (continued)	b. The source-range detector and associated instrumentation responded to neutron level changes and that the source-range protection (high-flux-level reactor trip), as well as alarm features and audible count rate, operated properly. c. The intermediate-range instrumentation operated properly; the reactor protective and control features, such as high-level reactor trip and high-level rod stop signals, operated properly; and the permissive signals for blocking source-range trip and source-range high-voltage-off operated properly. d. The power-range instrumentation operated properly; the protective features, such as the overpower trips, permissive, and dropped-rod functions, operated with the required redundancy and separation through the associated logic matrices; and the nuclear power signals to other systems were available and operating properly. e. All auxiliary equipment, such as the start-up rate channel, recorders, and indicators, operated properly. f. All instruments were properly calibrated and all setpoints and alarms were properly adjusted.
18. Radioactive waste system	To verify satisfactory flow characteristics through the equipment, to demonstrate satisfactory performance of pumps and instruments, to check for leak-tightness of piping and equipment, and to verify proper operation of monitors, alarms, and controls. More specifically, that a. All manual and automatic valves were operable. b. All instrument controllers operated to control the system at required values.

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Table 13.1-1 (CONTINUED)
OBJECTIVES OF SYSTEM TESTS PRIOR TO INITIAL REACTOR FUELING

System Tested	Test Objective
18. Radioactive waste system (continued)	c. All alarms were operable at required locations. d. All pumps performed their design functions satisfactorily. e. All pump indicators and controls were operable at required locations. f. All waste gas compressors and blowers operated as specified. g. The gas analyzers and recombiners operated as specified. h. The waste evaporator operated as specified.
19. Sampling system	To verify that a quantity of representative fluid could be obtained safely from each sampling point. In particular, the tests were designed to verify that a. All system piping and components were properly installed. b. All remotely and manually operated valving operated in accordance with the design specifications. c. All sample containers and quick-disconnect couplings functioned properly.
20. Emergency power system	To demonstrate that the system was capable of providing power for operation of vital equipment under power failure conditions. In particular, the tests were designed to verify that a. All system components were properly installed. b. Each emergency diesel functioned according to the design intent under emergency conditions. c. The emergency units were capable of supplying the power to vital equipment as required under emergency conditions. d. All redundant features of the system functioned according to design intent.

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Table 13.1-1 (CONTINUED)
OBJECTIVES OF SYSTEM TESTS PRIOR TO INITIAL REACTOR FUELING

System Tested	Test Objective
21. Hot functional tests	Using pump heat, the reactor coolant system was tested to check heatup and cooldown procedures to demonstrate satisfactory performance of components that were exposed to the reactor coolant temperature; to verify proper operating of instrumentation, controllers, and alarms; and to provide design operating conditions for checkout of auxiliary systems. The chemical and volume control system was tested to determine that water could be charged at rated flow against normal reactor coolant system pressure; to check letdown flow against design rate for each pressure reduction station; to determine the response of the system to changes in pressurizer level; to check procedures and components used in boric acid batching and transfer operations; to check operation of the reactor make-up control; to check operation of the excess letdown and seal-water flow path; and to verify proper operation of instrumentation controls and alarms. The sampling system was tested to determine that a specified quantity of representative fluid could be obtained safely and at design conditions from each sampling point. The component cooling system was tested to evaluate its ability to remove heat from systems containing radioactive fluid and other special equipment under varied service water conditions; to verify component cooling flow to all components; to verify that the charging pumps cooling water subsystem functioned as designed; and to verify proper operation of instrumentation, controllers, and alarms. Following this hot function test, the reactor internals were examined for evidence of vibration.

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Table 13.1-1 (CONTINUED)
OBJECTIVES OF SYSTEM TESTS PRIOR TO INITIAL REACTOR FUELING

System Tested	Test Objective
22. Pressurizer level control system	To ensure that the system was capable of monitoring the full range of pressurizer level and to verify alarms and setpoints. Also to verify that the system, in conjunction with the chemical and volume control system, controlled pressurizer level.
23. Rod position indication system	To check the system's response to test signals and to verify correct indicating and control functions. After fuel loading and after the position indication coils were installed, a calibration check and a complete operational check were performed by operating individual control rod drive mechanisms.
24. Reactor thermocouple instrumentation	To check and calibrate the system and compare thermocouple readings with other temperature instrumentation indications up to the maximum allowable temperature.
25. Auxiliary steam generator feedwater pumps.	To verify that all pumps performed their design functions satisfactorily.
26. Primary system safety and relief valves	To verify correct relief and lift pressures as necessary.
27. Cold hydrostatic tests	To verify the integrity and leaktightness of the reactor coolant system and auxiliary primary systems with the performance of a hydrostatic test at the specified test pressure.
28. Main steam trip valves	To verify that the valves would terminate steam flow to the turbine by testing at steam temperature and pressure associated with hot functional conditions.
29. Heat tracing check	To verify operations of the circuits and controls of the heat tracing system and safety-related equipment and to obtain a set of equilibrium data under static flowing and nonflowing conditions.

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Table 13.1-1 (CONTINUED)
OBJECTIVES OF SYSTEM TESTS PRIOR TO INITIAL REACTOR FUELING

System Tested	Test Objective
30. Pressurizer relief tank	To verify that the system responded accurately to low- and high-level and high-pressure setpoints; that the nitrogen cover gas system will maintain a nitrogen atmosphere at the required pressure; that the oxygen content of the gas space can be reduced and maintained within chemistry requirements; that the remotely operated valves for maintaining tank level operate correctly.
31. Residual heat removal system	To verify that the valve interlocks, flow controls, alarms, and indications operate properly.
32. Containment isolation valves test	To verify that the valves that provide containment isolation during accident conditions operate as designed.
33. Containment leakage test	To prepare the containment for the structural test and to provide a pre-operational containment leakage rate.
34. Containment personnel air lock and equipment hatch	To verify the leaktightness of the system.
35. CLS "Hi" and "Hi-Hi" system operation	To verify the proper operation of the systems. The test verified that all relays associated with the CLS "Hi" operated properly and that all signals were generated and all "logic" verified; the CLS "Hi-Hi" test verified the initiation of start signals to No. 2 and No. 3 EDGs and that the lockout circuitry to No. 3 EDG functioned properly.
36. Charging pump control circuit	To verify breaker interlocks, charging pump start signals, and breaker trip signals in the system.
37. Incore movable detector system	To provide an initial calibration of the upper and lower limit stop setpoints for the flux thimbles, and establish the slipping torque for the slip clutch.
38. Reactor coolant loop isolation valves	To verify that the interlocks associated with the reactor coolant isolation valves performed as designed.
39. Reactor coolant pump initial check	To verify reactor coolant pump operating valves and to establish a correlation between seal-water flow and the thermal barrier differential pressure

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Table 13.1-1 (CONTINUED)
OBJECTIVES OF SYSTEM TESTS PRIOR TO INITIAL REACTOR FUELING

System Tested	Test Objective
40. Reactor coolant system thermal expansion	To verify that all piping and components within the test boundary would expand freely and operate without interfering with other systems, components, and structures.
41. Operation from the auxiliary shutdown panel	To verify the capability of maintaining hot shutdown conditions from outside the control room at the auxiliary shutdown panel for a minimum of 4 hours.
42. Electric hydrogen recombiner	To demonstrate the performance of the electric hydrogen recombiner by running it at a set power and recording the temperatures reached and measuring the air flow through the recombiner.

13.2 FINAL STATION PREPARATION

Fuel loading began when all prerequisite system tests and operations were satisfactorily completed and the facility operating license was obtained. Upon completion of fuel loading, the reactor upper internals and pressure vessel head were installed, and additional mechanical and electrical tests were performed. The purpose of this phase of activities was to prepare the system for nuclear operation and to establish that all design requirements necessary for operation had been achieved. The core-loading and postloading tests are described below.

13.2.1 Core Loading

The overall responsibility and direction for the initial core loading was exercised by the Station Manager, assisted by the Superintendent - Station Operations.

The overall process of initial core loading was normally directed from the operating floor of the containment structure.

Standard procedures for the control of personnel and the maintenance of containment security were established prior to fuel loading.

Westinghouse provided technical advisors to assist during the initial core-loading operation.

The as-loaded core configuration was specified as part of the core design studies conducted in advance of station start-up, and as such was not subject to change at start-up.

The core was assembled in the reactor vessel, submerged in water containing enough dissolved boric acid (at least 1500 ppm boron) to maintain a core effective multiplication factor (K_{eff}) of 0.90 or lower.

The refueling cavity was dry during initial core loading.

Core moderator chemistry conditions (particularly boron concentration) were prescribed in the core-loading procedure document and were verified periodically by chemical analysis of moderator samples taken before and during core loading.

Core-loading instrumentation consisted of two permanently installed source range (pulse type) nuclear channels, two temporary incore source range channels, and a third temporary channel that could be used as a spare.

The permanent channels were monitored in the control room by licensed station operators; the temporary channels were installed in the containment structure and monitored by reactor engineering personnel.

At least one channel and one temporary channel were equipped with audible count range indicators. Both channels and both regular temporary channels displayed neutron count rates on count-rate meters and strip-chart recorders.

Minimum count rates of two counts per sec, attributable to core neutrons, were required on at least two of the four available nuclear channels at all times during core-loading operations.

Two artificial neutron sources were introduced into the core at appropriate specified points in the core-loading program to ensure a neutron population large enough for adequately monitoring the core.

Fuel assemblies, together with inserted components (control rod assemblies, burnable poison inserts, source spider, or thimble plugging devices), were placed in the reactor vessel one at a time according to a previously established and approved sequence that was developed to provide reliable core monitoring with minimum possibility of core mechanical damage.

The core-loading procedure documents included a detailed tabular check sheet that prescribed and verified the successive movements of each fuel assembly and its specified inserts from its initial position in the storage racks to its final position in the core.

Multiple checks were made of component serial numbers and types at successive transfer points to guard against possible inadvertent exchanges or substitutions of components.

An initial nucleus of eight fuel assemblies, the first of which contained an activated neutron source, was the minimum source-fuel nucleus that would permit subsequent meaningful inverse count-rate monitoring. This initial nucleus was determined by calculation and previous experience to be markedly subcritical ($K_{eff} = 0.90$) under the required conditions of loading.

Each subsequent fuel addition was accompanied by detailed neutron count-rate monitoring to determine that the just-loaded fuel assembly had not excessively increased the count rate and that the extrapolated inverse count-rate ratio was not decreasing for unexplained reasons.

The results of each loading step were evaluated by Vepco before the next prescribed step was started.

Criteria for safe loading required that loading operations stop immediately if:

1. The neutron count rates on all responding nuclear channels doubled during any single loading step after the initial nucleus of eight fuel assemblies had been loaded.
2. The neutron count rate on any individual nuclear channel increased by a factor of five during any single loading step.

An alarm in the containment and main control room was coupled to the source range channels with a setpoint at five times the current count rate. This alarm would have automatically alerted the loading operation to an indication of high count rate and would have required an immediate stop of all operations until the incident was evaluated by Vepco and by technical advisors.

If the licensed station operation in the control room had determined that an unacceptable increase in count rate was being observed in any or all responding nuclear channels, he would have executed one or a combination of the prepared special procedures that involved withdrawing fuel from the core, manually actuating the containment evacuation alarm, or charging concentrated boric acid into the moderator. In actuality, no difficulties were encountered on either Unit 1 or Unit 2, and core loading was satisfactorily completed in accordance with applicable procedures.

Core-loading procedures specified alignment of fluid systems to prevent inadvertent dilution of the reactor coolant, restricted the movement of fuel to preclude the possibility of mechanical damage, prescribed the conditions under which loading could proceed, identified chains of responsibility and authority, and provided for continuous and complete fuel and core component accountability.

13.2.2 Postloading Tests

Upon completion of core loading, the reactor upper internals and the pressure vessel head were installed and additional mechanical and electrical tests were performed prior to initial criticality.

The final hydrostatic tests were conducted after filling and venting were completed.

Mechanical and electrical tests were performed on the control rod drive mechanisms under both cold and hot conditions. These tests included a complete operational checkout of the mechanisms.

Checks were made to ensure that the control rod assembly position indicator coil stacks were connected to their position indicators. Similar checks were made on control rod drive mechanism coils.

Tests were performed on the reactor trip circuits to test manual trip operation, and actual control rod assembly drop times were measured for each control rod assembly.

By use of dummy signals, the reactor control and protection system was made to produce trip signals for the various unit abnormalities that required tripping.

At all times that the control rod drive mechanisms were being tested, the boron concentration in the coolant-moderator was large enough (approximately 1500 ppm boron) that criticality could not be achieved with all control rod assemblies out.

Furthermore, the number of control rod assemblies operated at any one time was restricted to no more than approximately half the total number of assemblies.

A complete functional electrical and mechanical check was made of the incore nuclear flux mapping system at the operating temperature and pressure.

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13.3 INITIAL TESTING IN THE OPERATING REACTOR

After satisfactory completion of fuel loading and final station tests, nuclear operation of the reactor was begun. The final phase of start-up and testing included initial criticality, initial unit verification testing, zero power testing, and power level escalation. The purpose of these tests was to establish the operational characteristics of the unit and core, to verify design predictions, to demonstrate that license requirements had been met, and to ensure that the next prescribed step in the test sequence could be safely undertaken. A brief description of the testing is presented in the following sections. Table 13.3-1 summarizes the tests that were performed from the initial core loading to rated power.

13.3.1 Initial Criticality

Initial criticality was established by sequentially withdrawing the shutdown and control groups of control rod assemblies from the core, leaving the last withdrawn control group inserted far enough in the core to provide effective control when criticality was achieved, and then slowly and continuously diluting the heavily borated reactor coolant until the chain reaction was self-sustaining.

Successive stages of control rod assembly group withdrawal and of boron concentration reduction were monitored by observing changes in neutron count rate, as indicated by the regular source range nuclear instrumentation, as functions of control rod assembly group position and, subsequently, of primary-water addition to the reactor coolant system during dilution.

Primary safety reliance was based on inverse count-rate ratio monitoring as an indication of the nearness and rate of approach to criticality of the core during control rod assembly group withdrawal and during reactor coolant boron dilution. The rate of approach was reduced as the reactor approached extrapolated criticality to ensure that effective control was maintained at all times.

Written procedures specified alignment of fluid systems to allow controlled start and stop and adjustment of the rate at which the approach to criticality could proceed, indicated values of core conditions under which criticality was expected, specified allowed deviations in expected values, and identified chains of responsibility and authority during reactor operations.

13.3.2 Initial Unit Verification Tests

Upon establishment of criticality, a series of tests was initiated to determine the overall unit behavior and to check out the system under operating conditions. The initial tests consisted of selected zero-power physics measurements and power escalation tests to ensure safe reactor operation while performing the overall unit checkout.

The selected zero-power measurements were made at or near operating temperature and pressure, and consisted of measurements of control rod assembly group reactivity worth, boron concentration reactivity worth, isothermal temperature coefficient, and the boron concentration and power distribution with all control rod assemblies out. Concurrent tests were conducted on the unit instrumentation, including the source and intermediate range nuclear channels. Control rod assembly operation and the behavior of the associated control and indicating circuits were demonstrated under zero-power operating conditions. The results of these tests and measurements were compared to the expected design behavior and the results were reported for each unit as an appendix to each start-up test report (References 1 & 2). The remainder of the initial station verification tests were performed during power escalation to no more than 40% of full power.

The purpose of the above nuclear tests was to survey overall station performance and to determine the adequacy of the design and the integrity of the systems used.

Detailed procedures specified the sequence of tests and measurements conducted and the conditions under which each was performed. If deviations from design predictions had existed or if apparent anomalies had developed, the testing would have been suspended and, prior to resumption of testing, the situation would have been reviewed by Vepco to determine whether a question of safety was involved. In actuality, no difficulties were encountered on either Unit 1 or Unit 2, and initial unit verification was satisfactorily completed in accordance with applicable procedures.

13.3.3 Zero-Power Testing

A prescribed program of reactor physics measurements was undertaken to verify that the basic static and kinetic characteristics of the core were as expected and that the values of the kinetic coefficients assumed in the safeguards analysis were indeed conservative.

The measurements were made at zero power and primarily at or near operating temperature and pressure. The measurements included verification of calculated values of control rod assembly group and unit reactivity worths, of isothermal temperature coefficient under various core conditions, of differential boron concentration reactivity worth, and of critical boron concentrations as functions of control rod assembly group configuration. Relative power distribution checks were made in normal and abnormal control rod assembly configurations.

Detailed procedures were prepared to specify the sequence of tests and measurements to be conducted and the conditions under which each was to be performed to ensure both safety of operation and the relevance and consistency of the results obtained.

13.3.4 Power Level Escalation

When the operating characteristics of the reactor and unit were verified by the preliminary zero-power tests, a program of power level escalation in successive stages brought the unit to its full rated power level. Both reactor and unit operational characteristics were closely examined at each stage and the relevance of the safeguards analysis was verified before escalation to the next programmed level was effected.

Reactor physics measurements were made to determine the magnitudes of reactivity effects, of control rod assembly group differential reactivity effects, of control rod assembly group differential reactivity worth, and of relative power distribution in the core as functions of power level and control rod assembly group position.

Concurrent determinations of primary and secondary heat balances ensured that the several indications of power level were consistent and provided bases for calibration of the power range nuclear channels. The ability of the reactor control and protection system to respond effectively to signals from primary and secondary instrumentation under a variety of conditions encountered in normal operations was verified.

At prescribed power levels the response characteristics of the reactor coolant and steam systems to dynamic stimuli were evaluated. The responses of system components were measured for 10% loss of load and recovery, 50% loss of load and recovery, turbine trip, and the trip of a single control rod assembly.

After the rated power level was achieved, a series of load follow tests was performed at selected power level escalation steps. The results of these tests gave actual reactor and unit behavior under operating conditions and were used to verify predicted load-follow capabilities.

Adequacy of radiation shielding was verified by gamma and neutron radiation surveys inside the containment and the outside area immediately adjacent to the containment.

The sequence of tests, measurements, and intervening operations was prescribed in the power escalation procedures, together with specific details relating to the conduct of the several tests and measurements. The measurement and test operations during power escalation were similar to normal operations.

13.3.5 Poststart-Up Surveillance and Testing Requirements

Poststart-up surveillance and testing requirements are designed to provide assurance that essential systems, including equipment components and instrument channels, are always capable of functioning in accordance with their original design criteria. These requirements can be separated into two categories:

1. The system must be capable of performing its function, i.e., pumps deliver at design flow and head, and instrument channels respond to initiating signals within design calibration and time responses.
2. Reliability is maintained at levels comparable to those established in the design criteria and during early station life.

The testing requirements, as described in the Technical Specifications, establishing this reliability and, in addition, provide the means by which this reliability is continually reconfirmed. Verification of operation of complete systems is checked at refueling intervals. Individual checks of components and instrumentation are made at more frequent intervals, as outlined in the Technical Specifications.

The techniques used for the testing of instrument channels included a preoperational calibration that confirmed values obtained during factory test programs. These reconfirmed calibration values became the reference for recalibration maintenance at refueling intervals during station life. Periodic testing, as defined in the Technical Specifications, includes the insertion of a predetermined signal that will trip the channel bi-stable. Indication of the operation is confirmed and recorded.

Testing of components is initiated through manual actuation. If response times are important, they are measured and recorded. The capability to deliver design output is checked by instrumentation and compared against design data. Allowable discrepancies are established in the Technical Specifications. The component is operated sufficiently long to allow the equalization of operating temperatures in bearings, seals, and motors. Checks are made on these parameters. The component is surveyed for excessive vibration. Readings are recorded.

It is believed that testing in accordance with the above described program provides a realistic basis for determining maintenance requirements, and, as such, ensures continued system capabilities, including reliability equal to that established in the original criteria.

13.3 REFERENCES

1. Virginia Electric and Power Company, *Unit No. 1 Start-Up Test Report*, Docket No. 50-280, May 1, 1973.
2. Virginia Electric and Power Company, *Unit No. 2 Start-Up Test Report*, Docket No. 50-281, July 31, 1973.

Table 13.3-1
INITIAL TESTING SUMMARY

Tests	Conditions	Objectives	Acceptance Criteria
Control rod assembly drop tests	a. Cold shutdown b. Hot shutdown	To measure the drop time of control rod assemblies under full-flow and no-flow conditions	Drop time less than value in Technical Specifications
Thermocouple/ RTD inter-calibration	Various temperatures during system heatup at zero power	To determine in-place isothermal correction constants for all core exit thermocouples and reactor coolant RTDs	Sensors showing excessive deviations from average were removed from service or replaced
Nuclear design check tests	All two-dimensional control rod assembly group configurations at hot zero power	To verify that nuclear design predictions for endpoint boron concentrations, isothermal temperature coefficients, and power distributions were valid	Within limits established in FSAR for $\delta\rho/\Delta T$ and $F_{\Delta H}$
Control rod assembly group worth	All control rod assembly groups at hot zero power	To verify that nuclear design predictions for control rod assembly group differential worths with and without partial length control rod assemblies were valid	Within limits established in FSAR for $\Delta p/\Delta h$, p/h, $\delta/\Delta h$, and $\Delta p/h$
Power and Doppler coefficient measurement	0 to 92% of rated power	To verify that nuclear design predictions for differential power coefficients and Doppler reactivity coefficients were valid	Technical Specification limiting values
Power and Doppler reactivity defects	0 to 92% of rated power	To verify that nuclear design predictions for power and Doppler reactivity defects were valid	Technical Specifications limiting values

Table 13.3-1 (CONTINUED)
INITIAL TESTING SUMMARY

Tests	Conditions	Objectives	Acceptance Criteria
Automatic control system	Approximately 30% of rated power	To verify control system response characteristics for: 1) Steam generator level control system 2) Control rod assembly automatic control system 3) Turbine control system	Applicable FSAR criteria
Load swing test	10% steps at 35, 75, and 100% of rated power	To verify reactor control performance	Applicable unit performance criteria
Station trip	Full-load rejection from 50 and 100% of rated power	To verify reactor control performance	Applicable unit performance criteria
Pressurizer spray effectiveness test	Hot shutdown	To verify that pressurizer pressure is reduced at the required rate by pressurizer spray actuation	Applicable unit performance criteria
Minimum shutdown verification	Hot zero power	To verify the nuclear design prediction of the minimum shutdown boron concentration with one stuck control rod assembly	Stuck control rod assembly shutdown criteria
Static rod insertion and rods-out-of-position test	50% of rated power	To verify that a single control rod assembly inserted fully or part-way below the control bank is detected by ex-core nuclear instrumentation, core exit thermocouples under typical operating conditions, and to provide bases for adjustment of protection system setpoints	Inserted control rod assembly detectable with station instrumentation

Table 13.3-1 (CONTINUED)
INITIAL TESTING SUMMARY

Tests	Conditions	Objectives	Acceptance Criteria
Step load reduction test	Reduction from 75% to 25% of rated power Reduction from 100% to 50% of rated power	To verify operation of reactor control system	Applicable unit performance report criteria
Dynamic control rod assembly drop test	45% of rated power	To verify automatic detection of dropped control rod stop and turbine cutback	Required power reduction and control rod assembly withdrawal block accomplishment
Turbine-generator start-up tests	Pre- and postsynchronization	To verify that the turbine-generator unit and associated controls and trips were in good working order and ready for service	Successful completion of all mechanical, electrical, and control functional checks
Turbine generator	0 to 75% of rated power	To verify normal trouble-free performance of the turbine generator at low power	Performance within manufacturer's limitations
Acceptance run	100 hr at rated power	To verify reliable steady-state full-power capability	100 hr equilibrium operation at full power
Station blackout test (loss of offsite power only)	Unit 1: 10% of rated power Unit 2: 37% of rated power	To verify the ability of the station control and protection systems to bring the plant safely to the hot shutdown condition following the loss of power to the 4160-V emergency buses	Emergency diesel generators start and restore power to emergency buses; both reactor and turbine are tripped; relays and breakers respond properly to de-energize the emergency buses on under-voltage and re-energize them from the diesel generators

Table 13.3-1 (CONTINUED)
INITIAL TESTING SUMMARY

Tests	Conditions	Objectives	Acceptance Criteria
Steam generator moisture carryover	Unit 1: 90%/100% of rated power Unit 2: 90, 95, and 100% of rated power	To verify that moisture carryover (averaged over all three steam generators) is less than 0.25%	Less than 0.25% moisture carryover (averaged over all three steam generators)
Rod drive mechanism stepping test	a. Cold shutdown b. Hot shutdown	To verify that each individual rod could be properly stepped from one position to another	Rod speeds and movement within Technical Specification limits
Part-length rod mechanism brake test	Shutdown	To ensure engagement of brake mechanism on application of current	Smooth operation of the engagement and disengagement of the part-length rod brake mechanism
Rod control system	Shutdown	To verify that the full-length rod control system performed properly	Smooth operation with rod position indicators and step counters verifying proper rod motion when in both “bank select” and “manual” mode of operation
Reactor coolant system flow measurement	Shutdown	To verify that the actual flow rates were equal to or greater than design flow rates	Applicable flow rate criteria
RTD bypass loop flow verification	Hot shutdown	To verify adequate flows through the RTD bypass loops	Applicable flow rate criteria
Containment shielding test	Hot zero power, 30, 50, 75, and 92%	Obtain actual radiation levels at specified locations and power levels	Levels are within design criteria

Table 13.3-1 (CONTINUED)
INITIAL TESTING SUMMARY

Tests	Conditions	Objectives	Acceptance Criteria
Ex-core detector behavior	Various power levels	To develop curves of incore/ex-core axial offsets for each ex-core detector and to develop plots of the sum of top and bottom detector currents versus power and full-power normalized detector currents versus axial offset	Within design specifications
Overpower and overtemperature delta T calibration	Hot shutdown, start-up, 75 and 92%	To ensure protection against excessive power levels and to protect the core against DNB	System calibrated to Technical Specifications
Delta flux calibration	Shutdown	To calibrate the reactor core power axial offset contribution to overpower and overtemperature delta T setpoints	Set to Technical Specification limits
Static rod drop measurement	48% power	To determine effect of the dropping of a full-length control rod assembly on the hot-channel factors	Within design limits
Rod ejection measurements	Hot, zero power, 32% Unit 1, 50% Unit 2	To confirm that the control rod insertion limits are satisfactory	Within design limits
Power distribution measurements	Hot, zero power, 75%	To obtain the core power distribution and flux maps	Within design criteria
Flow coastdown	Hot shutdown	To obtain reactor coolant flow coastdown rates	Within limits specified in FSAR
Nuclear design check	Hot shutdown	Determine differential and integral worth of the controlling RCC bank and differential boron worth over the range of controlling RCC bank	Applicable design criteria

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13.4 OPERATING RESTRICTIONS

13.4.1 Safety Precautions

The measurements and test operations during zero power and power escalation were similar to normal station operations at power, so that normal safety precautions were adequate.

13.4.2 Initial Operation Responsibilities

Vepco had overall responsibility for supervising and directing all phases of testing. Technical responsibility for each individual phase of actual start-up resided with the functional group most directly concerned with the results of the phase. Stone & Webster and Westinghouse had onsite representatives of supporting functional groups to provide technical advice, provide recommendations and assistance in planning, and execute the respective phases of unit start-up. Specific responsibilities during each phase of testing are discussed in preceding sections.

All system operations in the testing program were performed by station operators in accordance with the approved written procedures. These procedures included such items as the delineation of administrative procedures and test responsibilities, equipment clearance procedures, test purpose, conditions, precautions, limitations, and sequence of operations.

The methodology used in the preparation, review, approval, and revision of initial operating procedures is briefly described below.

The initial draft of each operating procedure was written by a member of the station staff knowledgeable in the operation of the system under consideration. After review by the Superintendent - Station Operations, the Operating Supervisor, or the Supervisor - Engineering Services, the procedure was submitted to the Station Nuclear Safety and Operating Committee for review and approval. The purpose of this was to ensure that the procedure was in accordance with other established procedures, clear in content, met the design criteria specified, and met the safety requirements for sound operating practices. If a procedure was found to be unsatisfactory by the committee, the necessary correction was made by the individual(s) originally preparing the procedure wherever possible, to provide continuity. All procedures approved by the committee were signed and dated by the committee chairman before implementation by the Operating Department.

Any minor procedural change found necessary after initial committee approval was obtained was to be forwarded through the Operating Supervisor and Superintendent - Station Operations for comment. Further review and approval was to be obtained from the Station Manager before the minor procedural change was implemented.

Any significant change was to be handled in the same manner as the approval required for the initial operating procedure.

Test procedures stating the test purpose, conditions, precautions, limitations, and criteria for acceptance were prepared for each test by station personnel with assistance from Westinghouse and Stone & Webster technical advisors. Before implementation, all such procedures were reviewed and approved by Vepco's senior personnel in accordance with approved standard administrative procedures.

As part of the precautions, all licensed senior reactor operators and manufacturer's representatives whose equipment was being tested were instructed to stop a test or a portion of a test if the test was not being performed safely or in accordance with the written test procedure. The test procedure was reviewed and approved by the Station Manager or his representative. If substantial revision was required, however, the Station Manager reviewed the change, using the same approach as that used for a new test procedure, before approving continuation.

If the results of preoperational tests, fuel loading, post-fuel-loading tests, or initial operation indicated that system modifications and/or procedural changes were required, the proposed changes were discussed with the Vepco engineering staff at the General Office in Richmond, Virginia. The station staff normally made recommendations or offered solutions before this time, and these accompanied the request for the change as an Engineering Deficiency Report.

Any changes that could alter the operation of the station were to be handled under the following three categories:

1. Changes not affecting the approved design or operation of the station, but considered primarily for convenience or improvement to operations, could be handled at the station level with the approval of the Station Manager. A report of all such changes was to be forwarded to the Superintendent - Production Operations and the Supervisor - Nuclear Design.
2. Changes that could alter the arrangement or function of a system from the intended approved design were to be reviewed by the Station Nuclear Safety Committee. If approved by the committee, the recommendation was forwarded to the System Nuclear Safety Committee for final approval. If there was no requirement to amend the FSAR, the proposed change was implemented through the Director of Power Station Design.
3. Design changes that would incorporate changes to approved design prints and would affect the operation of the station as described in the FSAR, either by description or drawings, were to be approved by the Station Nuclear Safety Committee and the System Nuclear Safety Committee. The recommended change was forwarded to the Manager of Power Production and the Vice President - Power, respectively. If approved, the Vice President - Power informed the Atomic Energy Commission (AEC) of the requested change. When changes of this type were considered, a full review of the Technical Specifications was conducted, and appropriate approved changes were handled as above through amendments to the Technical Specifications.

Vepco had overall responsibility during plant start-up, including precriticality tests, approach to criticality, and postcriticality operation. The station staff was assisted by the supplier of the nuclear steam supply system, Westinghouse Electric Corporation. Experienced Westinghouse reactor engineers were assigned to the station from fuel loading, through power ascension, until completion of the 100-hr full-load test. These reactor engineers had previously participated in reactor start-ups of similar units and were qualified and knowledgeable in reactor operations. At least one reactor engineer was at the site during all shifts when the reactor was operating. The responsible shift reactor engineer reported directly to the Shift Supervisor and received instructions from him. The reactor engineer acted in an advisory capacity only; Vepco retained responsibility and control of the unit. Reactor specialists (e.g., control engineers) were available and utilized as required.

The results of preoperational and start-up testing were reported to the Atomic Energy Commission in reports dated May 1, 1973 (Unit 1 Start-up Test Report), July 31, 1973 (Unit 2 Start-up Test Report), and July 1, 1976 (Supplement to Surry Units 1 and 2 Start-up Reports).

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The following information is HISTORICAL and is not intended or expected to be updated for the life of the plant.

13.5 STEAM GENERATOR POSTREPAIR START-UP TEST PROGRAM

An extensive steam generator repair program was completed in 1979 for Surry Unit 2 and in 1981 for Surry Unit 1. In both cases, a postrepair integrated start-up test program was performed as described below. Refer to Section 10.3.1 for further details on the steam generator repair program.

The subject test program consisted of three phases: construction tests, preoperational tests, and start-up tests. The format of the program followed the intent of Regulatory Guide 1.68, Revision 2 (Reference 1).

The tests in the construction test phase were designed to provide assurance that the construction and installation of new, modified, or replaced equipment in the station were accomplished properly and in accordance with requirements.

The tests in the preoperational test phase were designed to provide assurance that the components and subsystems of new, modified, and original systems function safely within established design criteria. The preoperational tests on new or modified systems were conducted after the successful completion of construction tests and before fuel loading. This test phase also allowed the plant operating staff to become familiar with the operation of a new or modified system and to verify by trial use, to the extent practical, that the operating procedures were adequate.

The tests in the start-up test phase were designed to provide assurance that systems previously demonstrated as functioning safely, and new or modified systems, will function to (1) provide for safe normal operation and high tolerance for system malfunctions and transients; (2) ensure that, in the event of errors, malfunctions, and abnormal conditions, the reactor protection systems and other design features will arrest the event or limit its consequences to defined and acceptable levels; and (3) ensure that adequate safety margins exist for events of extremely low probability or for arbitrarily postulated hypothetical events without substantial reduction in the safety margin for the protection of public health and safety. The start-up tests were performed during and after fuel loading to confirm the design basis and demonstrate that the plant will continue to operate in accordance with design.

Per Criterion 1 of Appendix A to 10 CFR 50, all structures, systems, and components were tested or demonstrated operable to levels commensurate with the importance of their safety function. In addition, the extent of testing varied directly with the amount of construction done to and around the particular equipment or system. The sequence of tests was conducted so that the safety of the plant was never totally dependent on the performance of untested structures, systems, or components.

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13.5.1 Test Phases

Each phase of the integrated start-up test program was composed of a series of tests, as described below.

13.5.1.1 Construction Test Phase

The construction test phase consisted of nondynamic instrument, electrical, and mechanical tests included in design change packages for new or modified systems or components.

The installed components and systems were tested and evaluated according to approved design change test procedures. Construction tests were performed to ensure the quality implementation of the design change.

This phase also included the testing of any rework associated with deficiencies found by testing or quality control in the construction test, preoperational test, or start-up test phases.

All safety-related equipment or systems removed for maintenance work underwent instrument, electrical, and mechanical tests included in the maintenance procedure, as applicable. All maintenance tests were conducted by station personnel.

13.5.1.2 Preoperational Test Phase

The preoperational test phase consisted of functional tests on new, modified, and affected original equipment and systems. This phase included tests, adjustments, calibrations, and system operations necessary to ensure that the subsequent testing would be safely undertaken. This phase also included a walkdown of systems adjacent to construction work. Any repairs and subsequent testing of equipment were accomplished by a field change to the design change.

Preoperational tests are listed in Table 13.5-1. The actual sequence of individual tests was formulated before the performance of the tests, considering equipment and system availability, and was maintained on an integrated start-up test schedule.

In instances where the performance of components or systems deviated from predicted results, further engineering evaluations, rework, and/or retesting were performed to resolve the discrepancies before the test was considered satisfactory. Systems that had to be modified as a result of the preoperational tests were retested to verify acceptable performance. Components and systems were tested and evaluated according to approved testing procedures. Preoperational tests were performed to verify as nearly as possible the performance of the system under actual operating conditions. Where required, simulated signals or inputs were used to verify the full operating range of the system and to calibrate and align the systems and instruments at these conditions.

13.5.1.3 Start-Up Test Phase

The major testing milestones during the start-up test phase are identified and discussed below. Major start-up tests are listed in Table 13.5-2.

The following information is HISTORICAL and is not intended or expected to be updated for the life of the plant.

13.5.1.3.1 Post-Fuel-Loading Tests

Systems that are not used during normal plant operation but must be in a state of readiness to perform safety functions were tested or demonstrated operable before plant conditions required them to be available, as defined in the Technical Specifications. Abnormal unit conditions were simulated during testing as required and when such conditions did not endanger personnel or equipment, or contaminate systems whose cleanliness had been established. Fuel loading began when all prerequisite system tests and operations were satisfactorily completed. Upon completion of fuel loading, the reactor upper internals and pressure vessel head were installed. Additional mechanical and electrical tests were performed on the rod control system, rod position indication system, and incore movable detection system. The purpose of this segment of the start-up test phase was to prepare the system for nuclear operation and to establish that all design requirements necessary for operation were achieved.

13.5.1.3.2 Hot Functional Tests

Before initial criticality, the following hot functional tests were performed: heatup of the primary system, thermal expansion testing of affected systems, vibration testing of construction-affected equipment, reactor coolant pump coastdown time check, and steam generator water-hammer testing (auxiliary feed). The final pressure test was conducted in accordance with the Technical Specifications.

13.5.1.3.3 Criticality and Low-Power Physics Tests

On completion of hot functional tests, nuclear operation of the reactor was begun. These final segments of start-up testing included criticality and low-power physics testing. The purpose of these tests was to verify the operational characteristics of the unit and core, to acquire data for the proper calibration of setpoints, and to ensure that operation was within license requirements. The actual sequence of tests was formulated by station engineering and operating personnel, considering test requirements and equipment availability.

Procedures were prepared to specify the sequence of tests and measurements conducted and the conditions under which each was to be performed to ensure safety of operation and consistency of the results obtained. If significant deviations from design calculations existed, or if unacceptable behavior was revealed, or if apparent anomalies developed, the testing was suspended and the situation was reviewed to determine whether a question of safety was involved before the resumption of testing.

13.5.1.3.4 Power Level Escalation Testing

When the operating characteristics of the reactor and unit were verified by low-power physics testing, a program of power level escalation in successive stages was used to bring the unit to its full rated power level. Both reactor and unit operational characteristics were examined at each stage of the power escalation program.

The following information is HISTORICAL and is not intended or expected to be updated for the life of the plant.

13.5.1.3.5 At-Power Testing

On completion of power level escalation testing, the following at-power tests were performed: final steam generator carryover testing, final recirculation ratio testing, secondary plant heat balance determination, condensate-polishing chemistry performance testing, and load rejection testing with the condensate polisher.

13.5.2 Extent of Testing

Because of the various amounts of construction done to and around each system, a graded approach for the extent of testing was employed. The tests required for individual components within a system were developed by the Start-up Group and listed on a test matrix for that system.

In areas such as containment, where extensive work had been performed, all equipment and systems were checked during the construction testing, preoperational testing, or start-up testing phase. In areas such as the auxiliary building, where little work had been performed, selected system walkdowns were employed in conjunction with normal station start-up procedures to verify the operability of the equipment.

Systems that were new or had undergone major design-basis changes were subjected to complete component testing and performance testing to verify design and installation.

13.5 REFERENCES

1. U.S. Nuclear Regulatory Commission, *Preoperational and Initial Start-up Test Programs for Water-Cooled Power Reactors*, Regulatory Guide 1.68, Revision 2, August 1978.

The following information is HISTORICAL and is not intended or expected to be updated for the life of the plant.

Table 13.5-1

POST-STEAM-GENERATOR REPAIR, LIST OF PREOPERATIONAL TESTS AND CHECKS

Test or Check	Plant Condition/Prerequisite	Test Objective
	I. PLANT INSTRUMENTATION	
1. Nuclear instrumentation	Before core loading	Nuclear instruments were aligned and source range detector response to a neutron source checked as the primary source was loaded.
2. Process instrumentation	Ambient and/or at temperature	Required equipment was aligned per station procedures.
	II. REACTOR COOLANT SYSTEM	
1. Pressure boundary integrity		
a. Hydrostatic test	Below 200°F (after verification of cleanliness and fill of system)	Cold hydrostatic testing of each reactor coolant system loop was performed at test pressures as specified by ASME standards for the system. Before pressurization, the affected portions of the system were heated above the minimum temperature for pressurization. The pressure was then increased in increments, and at each increment inspections were made for leakage. Leaky valves or mechanical joints were not a basis for rejecting the test. Overpressure protection was provided during testing.
b. Baseline data for inservice inspection	During preoperational testing	Systems and components that require inspection in accordance with Section XI of the ASME Code were examined for baseline data. Data from these inspections provide baseline data for subsequent inservice inspections.
2. Component tests		
a. Pressurizer safety valve	Ambient pressure	The setpoints of the safety valves were verified using existing station procedures.

The following information is HISTORICAL and is not intended or expected to be updated for the life of the plant.

Table 13.5-1 (CONTINUED)

POST-STEAM-GENERATOR REPAIR, LIST OF PREOPERATIONAL TESTS AND CHECKS

Test or Check	Plant Condition/Prerequisite	Test Objective
	III. REACTIVITY CONTROL SYSTEM	
1. Automatic reactor power control test systems	Preoperational testing	The system alignment was verified at pre-operational operational conditions to demonstrate response of the system to simulated inputs. These tests were performed to verify that the systems would operate satisfactorily at power.
	IV. REACTOR PROTECTION SYSTEMS	
1. Reactor protection system	Before core loading	Before core loading, the reactor protection system was tested to demonstrate operability, proper logic, redundancy, and coincidence. The protection channels were verified through to tripping of the reactor trip breakers.
2. Engineered safety features	Before core loading	Before core loading, the engineered safety features logic systems were tested to demonstrate operability, proper logic, redundancy, and coincidence.
	V. POWER CONVERSION SYSTEM	
	Done under startup testing	

The following information is HISTORICAL and is not intended or expected to be updated for the life of the plant.

Table 13.5-1 (CONTINUED)

POST-STEAM-GENERATOR REPAIR, LIST OF PREOPERATIONAL TESTS AND CHECKS

Test or Check	Plant Condition/Prerequisite	Test Objective
	VI. AUXILIARY SYSTEMS	
1. Residual heat removal system	Before core loading	This system was tested by verifying pressure and flow characteristics of the pumps and operation of the isolation valves.
2. Containment instrument air system	Before core loading	The instrument air system, including air receivers and compressors, was tested to verify proper operation.
3. Neutron shield tank cooling system	Before core loading	The system was operationally checked out to verify heat-exchanger operability.
4. Leak detection system	Before and during pre-operational tests	Temperature detectors in the drain lines from pressurizer safety valves and the reactor vessel head seal and their alarm functions were checked. Pressurizer relief tank level and temperature sensors were calibrated, and the associated alarms were checked.
	VII. ELECTRICAL SYSTEM	
1. Emergency power systems	Before core loading	The automatic starting and loading of the diesel generators was demonstrated under loss of emergency bus ac power.

The following information is HISTORICAL and is not intended or expected to be updated for the life of the plant.

Table 13.5-1 (CONTINUED)

POST-STEAM-GENERATOR REPAIR, LIST OF PREOPERATIONAL TESTS AND CHECKS

Test or Check	Plant Condition/Prerequisite	Test Objective
	VIII. CONTAINMENT SYSTEMS	
1. Reactor containment	Before core loading	Containment type A leakage tests were performed in accordance with an NRC-approved topical report,[a] which provides for a reduced-duration test. Containment type B and C leakage tests were performed in accordance with Appendix J to 10 CFR 50.
2. Containment isolation	Before core loading	The operation of actuation systems and components used for containment isolation was verified.
	IX. GASEOUS RADIOACTIVITY REMOVAL SYSTEMS	
	Done under start-up testing	
	X. EMERGENCY CORE COOLING SYSTEM	
1. High-pressure safety injection	Before core loading	This system was operationally tested to verify pressure/flow values. Tests were also conducted to check pump operating characteristics. More specifically, the tests checked that a. Valves installed for redundant flow paths operated as designed. b. Pump operating characteristics were verified.

a. BN-TOP-l, Revision J.

The following information is HISTORICAL and is not intended or expected to be updated for the life of the plant.

Table 13.5-1 (CONTINUED)

POST-STEAM-GENERATOR REPAIR, LIST OF PREOPERATIONAL TESTS AND CHECKS

Test or Check	Plant Condition/Prerequisite	Test Objective
X. EMERGENCY CORE COOLING SYSTEM (continued)		
1. High-pressure safety injection (continued)		c. Valves and pumps operated on operator initiation and/or automatically on initiation of a safety injection signal. d. Level and pressure instruments were properly calibrated.
2. Low-pressure safety injection	Before core loading	The low-head safety injection system was checked to verify design flow, flow paths, and pump operating characteristics. More specifically, the system was checked to ensure that a. Valves installed for redundant flow paths operated as designed. b. Pump operating characteristics were verified with the reactor coolant system at ambient conditions. c. Valves and motors operated on operator initiation and/or automatically on initiation of a safety injection signal. d. Level and pressure instruments were properly calibrated. In addition a 100-hr endurance test was performed, and the pump was disassembled and inspected.

The following information is HISTORICAL and is not intended or expected to be updated for the life of the plant.

Table 13.5-1 (CONTINUED)

POST-STEAM-GENERATOR REPAIR, LIST OF PREOPERATIONAL TESTS AND CHECKS

Test or Check	Plant Condition/Prerequisite	Test Objective
	XI. FUEL STORAGE AND HANDLING SYSTEM	
1. Refueling equipment (hand tools and power equipment, including protective interlocks)	Before core loading	Tests were performed before core loading to demonstrate the functioning of the fuel transfer system.
	XII. REACTOR COMPONENTS HANDLING SYSTEM	
	Done during start-up	
	XIII. RADIATION PROTECTION SYSTEM	
1. Criticality and area monitors	Before core loading	The radiation alarms associated with core loading were checked out and the alarm setpoints verified.

The following information is HISTORICAL and is not intended or expected to be updated for the life of the plant.

Table 13.5-2

LIST OF START-UP TESTS AND CHECKS

Test or Check	Plant Condition/Prerequisite	Test Objective
I. PLANT INSTRUMENTATION		
1. Nuclear instrumentation (out of core)	Before criticality	Just before criticality, all channels were checked to verify high-level trip functions, alarm setpoints, audible count rates where applicable, operation of strip-chart recorders, and any auxiliary equipment.
2. Process instrumentation (temperature, pressure, level, and flow instruments)	Ambient and/or at temperature	Equipment was aligned per station procedures.
II. REACTOR COOLANT SYSTEM		
1. Vibration and amplitude	After fuel loading	Vibration sensors were placed on the main coolant pumps and main coolant piping in order to check for excessive vibration while starting and stopping the pumps.
2. Expansion and restraint	During plant heatup	During the heatup to operating temperature, selected points on components and piping of the reactor coolant system were checked at various temperatures to verify unrestricted expansion. Points of interference detected during the heatup were corrected before increasing the temperature.

The following information is HISTORICAL and is not intended or expected to be updated for the life of the plant.

Table 13.5-2 (CONTINUED)

LIST OF START-UP TESTS AND CHECKS

Test or Check	Plant Condition/Prerequisite	Test Objective
II. REACTOR COOLANT SYSTEM (continued)		
3. Integrated hot functional	Heatup and at-temperature hydrostatic testing has been satisfactorily completed and reactor coolant system instruments are aligned and operational. Associated auxiliary systems shall be operational to the extent required to support hot functional testing.	The reactor coolant system was tested using tests pump heat to reverify heatup procedures to demonstrate satisfactory performance of components and systems exposed to reactor coolant system temperature. Proper operation of instrumentation, controllers, and alarms was checked against design operating conditions of auxiliary systems, and setpoints were verified. Among the demonstrations performed were a. To check that water could be charged by the chemical and volume control system at rated flow against normal reactor coolant pressures. b. To check letdown design flow rate for each operating mode. c. To check response of system to a change in pressurizer level. d. To check operation of the excess letdown and seal-water flow paths. e. To check steam generator level instrumentation response to level changes.

The following information is HISTORICAL and is not intended or expected to be updated for the life of the plant.

Table 13.5-2 (CONTINUED)

LIST OF START-UP TESTS AND CHECKS

Test or Check	Plant Condition/Prerequisite	Test Objective
II. REACTOR COOLANT SYSTEM (continued)		
3. Integrated hot functional tests (continued)		f. To check thermal expansion of selected system components and piping. g. To perform isothermal calibration of resistance temperature detectors and incore thermocouples. h. To operationally check out the residual heat removal system.
4. Component tests		
a. Pressurizer	At operating temperature	During the hot functional testing, the pressure-controlling capability of the pressurizer was demonstrated to be within the controlling band. With reactor coolant pumps operating and with full spray, the pressure-reducing capability of the pressurizer was verified. With the spray secured and all heaters energized, the pressure-increasing capability of the pressurizer was verified. Pressurizer relief valves were functionally checked.
b. Reactor coolant pumps and motors	At ambient conditions and during heatup and at temperature	As the pumps and motors were placed in operation, they were checked for a. Direction of rotation (initial start only). b. Vibration. c. Power requirements. d. Lubrication. e. Cooling. f. Megger and hi-pot test (as applicable).

The following information is HISTORICAL and is not intended or expected to be updated for the life of the plant.

Table 13.5-2 (CONTINUED)
LIST OF START-UP TESTS AND CHECKS

Test or Check	Plant Condition/Prerequisite	Test Objective
	II. REACTOR COOLANT SYSTEM (continued)	
		g. Overload protection.
		h. Correct power supply voltage.
c. Steam generators	At ambient conditions and during heatup and at temperature	The proper operation of instrumentation and control systems of steam generators were checked during heatup and at temperature. The heat transfer capability of the steam generators was demonstrated. The functioning of the blowdown system was checked.
5. Pressure test of reactor coolant system	Before criticality	After core loading and installation of the reactor vessel head and torquing of the reactor vessel head studs, pressure testing was performed in accordance with Technical Specifications.

The following information is HISTORICAL and is not intended or expected to be updated for the life of the plant.

Table 13.5-2 (CONTINUED)
LIST OF START-UP TESTS AND CHECKS

Test or Check	Plant Condition/Prerequisite	Test Objective
II. REACTOR COOLANT SYSTEM (continued)		
6. Chemical tests (to establish water quality)	Before heatup during start-up test	Water for reactor coolant system fill and makeup was analyzed for chloride content, conductivity, total suspended solids, pH, clarity, and fluorides to requirements specified by the chemistry manual for the nuclear steam supply system. After core loading and before exceeding 250°F, hydrazine was added to scavenge oxygen before critical operation. Before criticality, at criticality, and during power escalation, chemical analysis was performed to verify requirements.
7. Reactor coolant flow test	Before criticality	After core loading, measurements were made of elbow tap differential pressures to make a relative comparison. At hot shutdown conditions after core loading, measurements of loop elbow differential pressure drops were made. Using these data with the reactor coolant pump performance curve, the calculated flow was verified to the design flow. Flow coastdown and transients after reactor coolant pump stoppages were also determined at shutdown conditions after core loading.

The following information is HISTORICAL and is not intended or expected to be updated for the life of the plant.

Table 13.5-2 (CONTINUED)

LIST OF START-UP TESTS AND CHECKS

Test or Check	Plant Condition/Prerequisite	Test Objective
III. REACTIVITY CONTROL SYSTEMS		
1. Chemical and volume control system	At ambient and/or at operating conditions; system components are operationally checked out	Makeup and letdown operations were conducted with the chemical and volume control system to check out the different modes of dilution and boration and to verify flows in the different modes. The adequacy of heat tracing to maintain the required boric acid concentration in solution was verified. The ability to adequately sample was demonstrated.
2. Emergency boration system	During hot functional testing	The pressure/ flow characteristics of the emergency boration system were verified by pumping into the reactor coolant system.
3. Incore monitor system		
a. Incore thermocouples	During heatup and at temperature	During heatup and at temperature, the incore thermocouples were calibrated to the average of the reactor coolant system resistance temperature detectors. All readout and temperature-compensating equipment was checked during the calibration, and isothermal corrections for the operative thermocouples were determined.
b. Movable detector system	At ambient conditions after core loading and critical testing	After core loading, the installation checkout of the movable detector system was completed.

The following information is HISTORICAL and is not intended or expected to be updated for the life of the plant.

Table 13.5-2 (CONTINUED)

LIST OF START-UP TESTS AND CHECKS

Test or Check	Plant Condition/Prerequisite	Test Objective
III. REACTIVITY CONTROL SYSTEMS (continued)		
4. Control rod system		
a. Rod control system	Ambient conditions after core loading and critical testing	During the installation check of this system, it was energized and operationally checked out with mechanisms connected to each power supply. The ability of the system to stop the mechanism was verified, the alarm and inhibit functions were checked out, and the values of system parameters were adjusted to specified values. After core loading, the operation of each rod over its full range of travel was demonstrated.
b. Rod drop	Cold and hot plant conditions after core loading	At cold and hot plant conditions after core loading, the drop times of the full-length rods were measured. The drop time is measured from the release of the rod until the rod enters the top of the dashpot. This time was verified to be less than the maximum value specified in the Technical Specifications.
c. Rod position indication	At ambient conditions and at temperature after core loading	During rod control system tests, the position indication system was aligned to provide rod movement indication. Rod bottom setpoints were adjusted during these tests. After plant heatup, individual rod positions were calibrated to within tolerances specified by the test procedure.
IV. REACTOR PROTECTION SYSTEM		
	Done during preoperational testing	

The following information is HISTORICAL and is not intended or expected to be updated for the life of the plant.

Table 13.5-2 (CONTINUED)

LIST OF START-UP TESTS AND CHECKS

Test or Check	Plant Condition/Prerequisite	Test Objective
V. POWER CONVERSION SYSTEM		
1. System tests		
a. Vibration frequency and amplitude	Hot functional testing and/or plant heatup after criticality	When the main turbine was rolled, vibration readings were monitored. (Turbine vibrations were also monitored throughout the power escalation program.) Major equipment (e.g., feedwater pumps and condensate pumps) was operated as it became available and was observed for indications of excessive vibration.
b. Expansion and restraint	During heatup and at temperature	During heatup to operating temperature, selected points on the components and piping of the systems were checked at various temperatures to verify that they could expand unrestricted.
2. Components and individual systems		
a. Steam generator pressure relief and safety valves	Pressure conditions	The setpoint of safety valves was verified by in-plant tests at pressure and temperature conditions when the unit was shut down. Setpoints were checked by using a pressure-assist device that adds to the force due to pressure. Once the valve left the seated position, the assist device was vented, allowing the valve to reset immediately. Steam relief valve setpoints were checked during instrument alignment.

The following information is HISTORICAL and is not intended or expected to be updated for the life of the plant.

Table 13.5-2 (CONTINUED)

LIST OF START-UP TESTS AND CHECKS

Test or Check	Plant Condition/Prerequisite	Test Objective
V. POWER CONVERSION SYSTEM (continued)		
2. Components and individual systems (continued)		
b. Auxiliary feedwater system	Before criticality	During hot functional testing before criticality, the auxiliary feedwater system was checked out to verify its ability to feed the steam generators. Automatic starting was checked during the safeguards logic system tests.
c. Turbine control and bypass valve	Hot functional testing and/or power operation after criticality	During hot functional testing, the turbine control system was demonstrated by turbine operation up to and including a period of operation at synchronous speed. The turbine bypass valves to the condenser and their associated control systems were operationally checked out during hot functional testing.
d. Feedwater and feedwater control system	Hot functional testing and at power	The feedwater and condensate pumps were operationally checked out during hot functional testing. During power escalation the power was increased and the ability of the feedwater pumps and control system to maintain level in the steam generators was verified.
e. Condenser circulating water	Before hot functional testing	Before hot functional testing, the main circulating water system valves were tested to verify operability.

The following information is HISTORICAL and is not intended or expected to be updated for the life of the plant.

Table 13.5-2 (CONTINUED)

LIST OF START-UP TESTS AND CHECKS

Test or Check	Plant Condition/Prerequisite	Test Objective
V. POWER CONVERSION SYSTEM (continued)		
2. Components and individual systems (continued)		
f. Makeup water and chemical treatment system	During steam generator fill, hot functional testing, and start-up testing	The makeup system to the system generators was checked out during hot functional testing and at power. The chemical treatment system was checked out when chemicals were added to the steam generators at heatup to steaming conditions.
VI. AUXILIARY SYSTEMS		
1. Reactor coolant system makeup test (CVCS)		See Section III, Item 1.
2. Seal and pump cooling water test (CVCS)	Before heatup and at temperature	Before reactor coolant pump operation and with the system pressurized, flow to the pump seals and cooling water was set, and flow was adjusted to specified values using installed instruments. During hot functional testing when at operating temperature and pressure, seals and cooling flows and temperatures were checked.
3. Secondary vent and drain system	During hot functional testing	During hot functional testing after core loading, the secondary system was vented while pressurizing the secondary system. Secondary drains were tested for unrestricted flow in accordance with operating procedures.
4. Component cooling system	Ambient and/or hot plant conditions	Component cooling flow to the various components in the affected systems was adjusted, the system operationally checked out, and setpoints verified.
5. Residual heat removal system	Before and during hot functional testing	Heat removal capability was demonstrated.

The following information is HISTORICAL and is not intended or expected to be updated for the life of the plant.

Table 13.5-2 (CONTINUED)

LIST OF START-UP TESTS AND CHECKS

Test or Check	Plant Condition/Prerequisite	Test Objective
VI. AUXILIARY SYSTEMS (continued)		
6. Service water system	Before hot functional testing	The system was operationally checked out to verify pressure and flow. Service water flow to components in the system was verified.
7. Control rod drive mechanism and rod position indication coil cooling system	Before and/or during hot functional testing	The system was operationally checked out to verify air flow, temperatures, and motor current.
8. Primary sampling system	Before and/or during hot functional testing	Operations were performed to a. Demonstrate that liquid and gas samples could be obtained from sample points. b. Demonstrate that valves, instruments, and controls functioned properly. c. Verify proper functioning of the sample cooler.
9. Primary pressure relief system	Before hot functional testing and at pressure conditions	The pressurizer relief tanks, associated valves, and instrumentation were checked out to verify performance of design functions. For testing of pressurizer relief and safety valves see Section II.
VII. ELECTRICAL SYSTEM TESTS		
	Done during preoperational testing	

The following information is HISTORICAL and is not intended or expected to be updated for the life of the plant.

Table 13.5-2 (CONTINUED)

LIST OF START-UP TESTS AND CHECKS

Test or Check	Plant Condition/Prerequisite	Test Objective
VIII. CONTAINMENT SYSTEMS		
1. Containment ventilation system	Before and/or during hot functional testing	The system was operated to balance air flows and to verify the ability to maintain temperatures below maximum allowable limits.
2. Postaccident heat removal system (containment sprays)	Before criticality	Tests were performed to verify pump operating characteristics, response to control signals, and sequencing of the pumps, valves, and controller (and to ensure that spray nozzles were unobstructed).
IX. GASEOUS RADIOACTIVITY REMOVAL SYSTEMS		
	Done during preoperational testing	
X. EMERGENCY CORE COOLING SYSTEM		
1. Accumulator	During hot functional testing	Flow through the accumulator lines was initiated to demonstrate that the check valves were free to open. Tests were also made to verify that accumulator pressure could be maintained.
XI. FUEL STORAGE AND HANDLING SYSTEM		
1. Spent-fuel storage radiation monitoring equipment	Before plant start-up	Refer to Table 13.5-1, Section XIII, Item 1.
XII. REACTOR COMPONENT HANDLING SYSTEM		
1. Reactor component handling system (polar crane)	Before use for installation of components within the containment	Testing was conducted on the polar crane in accordance with standard crane testing procedures during steam generator replacement.
XIII. RADIATION PROTECTION SYSTEM		
	Done during preoperational testing	

The following information is HISTORICAL and is not intended or expected to be updated for the life of the plant.

Table 13.5-2 (CONTINUED)

LIST OF START-UP TESTS AND CHECKS

Test or Check	Plant Condition/Prerequisite	Test Objective
XIV. INITIAL CRITICALITY AND LOW-POWER TESTS		
1. Initial criticality	Plant at hot shutdown	The objective was to bring the reactor critical from the plant conditions specified. Before the start of rod withdrawal, the nuclear instrumentation had been aligned, checke0d, and conservative reactor trip setpoints made per procedures. At preselected points in rod withdrawal, data were taken and inverse count rate plots made to enable extrapolating to the expected critical rod position. In addition, the following tests associated with modified systems were performed: steam generator water-hammer test, blowdown system capability test, and thermal expansion monitoring.
XV. POWER ASCENSION		
1. Power ascension	Criticality	Normal postrefueling testing applied for power ascension. In addition, the following design tests associated with modified systems were performed: a. Steam generator carryover tests. b. Steam generator recirculation ratio test. c. Steam generator thermal and hydraulic performance verification. d. Steam generator water level stability and control demonstration. e. Condensate polishing performance testing. f. Load-rejection testing with condensate polisher.

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