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REGULATORY GUIDE

DIRECTORATE OF REGULATORY STANDARDS

REGULATORY GUIDE 1.68

PREOPERATIONAL AND INITIAL STARTUP TEST PROGRAMS FOR WATER-COOLED POWER REACTORS

A. INTRODUCTION

Section 50.34, "Contents of Applications: Technical Information," of 10 CFR Part 50, "Licensing of Production and Utilization Facilities," requires that an applicant for a license to operate a production or utilization facility include plans for preoperational testing and initial operations in its final safety analysis report (FSAR). Section XI, "Test Control," of Appendix B, "Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants," to 10 CFR Part 50 requires that a test program be established to assure that all structures, systems, and components will satisfactorily perform their safety-related functions. This guide describes a method acceptable to the AEC Regulatory staff for complying with the Commission's regulations with regard to preoperational and initial startup testing programs for water-cooled nuclear power plants. The Advisory Committee on Reactor Safeguards has been consulted concerning this guide and has concurred in the Regulatory position.

B. DISCUSSION

The applicant is responsible for the development of suitable preoperational and initial startup test programs for its facility, the preparation of adequate procedures for carrying out the programs, the proper conduct of the test programs, and assuring the validity of the test results. The test programs should provide additional assurance that the plant has been properly designed and constructed and is ready to operate in a manner that will not endanger the health and safety of the public, that the procedures for operating the plant safely have been evaluated and demonstrated, and that the operating organization is knowledgeable about the plant and procedures and fully prepared to operate the facility in a safe manner.

The test programs should include simulation of equipment failures and control system malfunctions that could reasonably be expected to occur during the plant lifetime.

The test programs should also include testing for interactions such as the performance of interlock circuits in the reactor protection systems. It should be determined that proper permissive and prohibit functions are performed and that circuits normally active and supposedly unaffected by the position of the mode switch perform their function in each mode. Care should be taken to ensure that redundant channels of equipment are tested independently.[1]

Preoperational testing as used in this guide consists of those tests conducted prior to fuel loading to demonstrate the capability of structures, systems, and components to meet safety-related performance requirements.

Initial startup testing consists of such activities as precritical tests, low-power tests (including critical tests), and power-ascension tests performed after fuel loading and before commercial operation that confirm the design bases and demonstrate, where practical, that the plant is capable of withstanding the anticipated transients and postulated accidents.

This guide supersedes two existing guides, "Guide for the Planning of Preoperational Testing Programs" and "Guide for the Planning of Initial Startup Programs," dated December 1970.

[1] Regulatory Guide 1.41, "Preoperational Testing of Redundant On-Site Electric Power Systems to Verify Proper Load Group Assignments," may be used as general guidance for such testing.

C. REGULATORY POSITION

Each applicant should prepare and conduct preoperational and initial startup test programs including the provisions and applicable tests described in this section and in Appendix A of this guide, as well as other preoperational and initial startup tests that have been identified in the final safety analysis report.

Prior to issuance of the operating license, the applicant should perform preoperational tests of safety-related structures, systems, and components to provide assurance that these structures, systems, and components have been properly designed and constructed.

The overall preoperational test program should also include final verification tests to be performed prior to issuance of the operating license to demonstrate proper operation of interlocks, setpoints, and other protective features and equipment that will be required by the technical specifications.

Related information on inspections performed by the Directorate of Regulatory Operations to determine if satisfactory testing programs have been developed and implemented is provided in Appendix B of this guide.

Appendix C provides guidance on the preparation of procedures for conduct of the various test programs.

1. Test Program Description

A description of the test programs which discusses the preoperational testing, fuel loading, and startup testing and the schedules for these activities in relationship to the completion of construction, formal training programs, licensing of the facility, and licensing of the operators should be provided in the final safety analysis report. The description should discuss the assignment of responsibility for the preparation, review, and approval of test procedures; the performance of the tests; and the review and approval of test results. The description should specify the power levels at which startup tests will be performed and should contain sufficient information to show that the programs, when completed, will provide assurance that the plant will perform in accordance with safety and environmental requirements.

The applicant's description of its test program should give particular emphasis to (a) features of the plant that are not used during normal operation but which must be in constant readiness to perform safety functions during unusual circumstances and (b) tests that demonstrate satisfactory plant response to anticipated transients.

To the extent practicable, the applicant should complete preoperational tests before licensing and fuel loading. Certain tests or parts of tests may need to be deferred until after loading or even until early power operation. The deferred tests should be identified, the schedule for the deferred tests specified, and justification for deferring provided.[2] In any event, the applicant should identify those preoperational tests which require satisfactory execution before fuel loading and those which should be performed prior to initial criticality.

2. Discussion of Tests

a. **General.** The test programs should include sufficient tests to demonstrate, as nearly as can be simulated, the overall normal operation of the plant. Experience has shown that the interactions of one portion of the plant with another are not always as predicted and that the earlier such differences are determined, the more easily the necessary changes in procedures or equipment can be made.

Appendix A of this guide identifies components, systems, and tests which should be included in the preoperational, fuel loading, and initial startup programs. The manner in which the preoperational tests are listed is not intended to indicate their order of importance nor to suggest that every item listed is applicable to both boiling water reactors and pressurized water reactors.

b. **Objectives and Acceptance Criteria.** Each test should be discussed individually in the applicant's test program description and should include the safety precautions to be observed, specific identification of the test objectives, and a brief discussion of how the test will be performed. The performance specifications to be demonstrated may be described either by specific acceptance criteria or by a description of how the criteria will be determined from functional requirements. Acceptance criteria should be included to show conformance to the design requirements as well as proper installation.

c. **Prerequisites and Simulation.** The discussion of prerequisities should describe the conditions that should exist prior to the start of each test such as prior tests that should be completed, plant status, and the required environmental conditions. Justification for a proposed degree of simulation less than full simulation should be

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[2] Examples of tests that may need to be deferred are (1) the integrated hot functional test on boiling water reactors because nuclear heat is required to supply sufficient heat to keep the reactor coolant and auxiliary systems at rated temperature and (2) tests on control rod drives, with rod attached, in certain pressurized water reactors where the control rods cannot be tested until the fuel is loaded and the reactor vessel head is in place. In both of these cases sufficient cold tests should be performed to provide reasonable assurance that the hot tests will be successful. Both the cold and hot testing programs should be included in the discussion.

provided for tests where full simulation of process or environmental conditions is not provided, or where tests cannot demonstrate equipment response to the full range of the performance required under anticipated operating or accident conditions.

APPENDIX A

PREOPERATIONAL AND INITIAL STARTUP TESTS FOR WATER-COOLED POWER REACTORS

A. Preoperational Testing

Structures, systems, and components that should be included in the preoperational test program are listed in items 1 through 13 of this appendix. They are not identified as to reactor type. An applicant should include in its program only those items applicable to its facility. The testing should include prerequisite preparation such as instrument calibration; flushing and cleaning, if appropriate; functional demonstration of equipment in all modes throughout its full operating range; testing to verify that proper flow is delivered at the required pressure; and hydrostatic testing of all piping, vessels, and systems designed to contain pressurized or radioactive fluids.

1. **Reactor Coolant System.** The reactor coolant system includes all those pressure-containing components such as pressure vessels, piping, pumps, and valves within the reactor coolant pressure boundary as defined in 10 CFR §50.2(v).

a. **System Tests.** Expansion and restraint tests to confirm acceptability of clearances and displacements in the as-built system. Hot functional test with simultaneous operation of auxiliary systems.

b. **Component Tests.** Appropriate tests of reactor coolant system components:

(1) Pressurizer,
(2) Pumps and motors,
(3) Steam generators,
(4) Pressure relief valves,
(5) Safety valves,
(6) Main steam isolation valves,
(7) Other valves.

c. **Vibration Tests.** Vibration monitoring of reactor internals in accordance with Regulatory Guide 1.20 (Safety Guide 20), "Vibration Measurements on Reactor Internals," and other components such as piping systems, heat exchangers, and rotating machinery.

d. **Pressure Boundary Integrity Tests.** Hydrostatic tests. Obtain baseline data for subsequent inservice testing.

2. **Reactivity Control Systems**

a. **Chemical Control System Tests.** Verify proper blending of boron solution and water, uniform mixing, and adequacy of sampling and analytical techniques. Adequacy of heaters and heat tracing. Adequacy of rate of injection into and dilution from the primary system .

b. **Standby Liquid Control System Tests.** Demonstration of proper operation of the system with demineralized water. Mixing and sampling of boron solution in the solution tank. Operation of temperature controls and air sparger.

c. Automatic Reactor Power Control System Tests.

d. Incore Monitor System Tests.

e. **Control Rod Systems Tests.** Demonstration of normal operation and scram capability of the control rod system. Proper performance of control rod inhibit functions including demonstration of fail-safe features.

f. Auxiliary Startup Instrumentation Tests. Evaluation of special instrumentation used to monitor neutron multiplication during fuel loading. Determine response to a startup source.

3. **Protection System.** Verify response time of protection channels, proper logic, calibration, operability, and trip and alarm settings of the protection system. Test operability in conjunction with other systems. Demonstrate redundancy, coincidence, independence, and safe failure on power loss.

4. **Power Conversion System.** System expansion, restraint, and operability tests. Include appropriate tests on the following components and systems:

a. Steam and Feedwater Process Lines.
b. Steam Generator Pressure Relief and Safety Valves.
c. Emergency Feedwater Pump.
d. Turbine Control and Bypass Valves.
e. Feedwater Control.
f. Condenser Circulating Water System.
g. Main Steam Line Isolation Valves.
h. Makeup Water and Chemical Treatment Systems.

5. **Auxiliary Systems.** Include tests for the following systems:

a. **Reactor Coolant Makeup System.** Capability to adjust primary coolant volume. Demonstration of water injection for a loss-of-coolant accident.
b. Seal Water System.
c. Seal and Pump Cooling Water System.
d. Vent and Drain Systems.
e. Component Cooling System.
f. Decay Heat Removal System.
g. Purification System.
h. Fire Protection System.

i. **Service Water System.**

j. **Ventilation Systems.** Test for leaks and air flows in accordance with design.

k. **Compressed Gas Systems.** Include instrument "air" syst[illegible] and other compressed gas systems used for safety-re[illegible]ed functions.

l. **Emergency Condenser.**

m. **Reactor Core Isolation Cooling System.**

n. **Reactor Vessel Head Cooling.**

o. **Shield Cooling System.**

p. **Leak Detection System.** Demonstrate that system has sufficient sensitivity and accuracy to identify primary water leakage past reactor coolant system, auxiliary system, or emergency cooling system pressure boundaries.

q. **Primary Pressure Relief System.**

r. **Seismic Instrumentation**

6. **Electrical Systems**

a. **Normal Distribution Tests.** Test to ensure continuity, circuit integrity, and the correct and reliable functioning of transformers, breakers, motors, relays, cables, automatic transfer switches, and instrument power supplies. Verify channel and train separation and redundancy requirements.

b. **Vital Bus Tests.** Include a full-load test using all sources of power supplies to the bus.

c. **D-C System Tests.** Check and calibrate relays, instruments, breakers, interlocks, and other components. Verification of battery charger and battery discharge rate. Full-load and duration test.

d. **Communication System Tests.** Proper operation of the communication system and interconnection to commercial phone service. Demonstration that the evacuation signal can be heard from any location in the plant under all required conditions.

e. **Emergency Power Systems.** Under loss of all a-c voltage, demonstrate that the emergency power system can start, assume the required loads, and carry them for several hours. Check for proper safety-related bus stripping and separation of nonvital loads. Verify that redundant features function according to design specifications. Demonstrate proper voltage and frequency regulation under transient and steady-state conditions.

7. **Containment System**

a. **Containment Tests.** Include the following tests: integrated leak rate test, overpressure test, vacuum breaker operability and leak test, containment isolation valve tests, and containment penetration individual leak rate tests.

b. **Reactor Building Tests.** Demonstrate capability of blowers to maintain the required negative pressure in the reactor building (secondary containment for boiling water reactors).

c. **Ventilation System Tests.** Use the ventilation system for inerting and deinerting and determine gas composition.

d. **Postaccident Heat Removal System Tests.**

e. **Containment Isolation System Tests.**

f. **Hydrogen Removal System Tests.**

8. **Gaseous Radioactivity Removal Systems.** Radioactivity removal devices and systems, including cryogenic systems located in containment and auxiliary structures and used for postaccident cleanup and routine release of gaseous effluents.

9. **Emergency Core Cooling Systems**

a. **Systems Tests.** Expansion and restraint tests.

b. **High-Pressure Safety Injection Tests.** Demonstrate that specified flow at required pressure is delivered using normal and emergency power.

c. **Low-Pressure Safety Injection and Core Spray Tests.** Demonstrate that specified flow at required pressure is delivered using normal and emergency power.

d. **Automatic Depressurization System Tests.**

e. **Accumulator Tests.**

10. **Fuel Storage and Handling Systems**

a. **Spent Fuel Pit Cooling System Tests.**

b. **Refueling Equipment–Hand Tools and Power Equipment Including Protective Interlocks.**

c. **Operability and Leak Tests of Sectionalizing Devices in the Fuel Storage Pool and Refueling Canal.**

d. **Spent Fuel Storage Building Ventilation System.**

e. **Spent Fuel Storage Radiation Monitoring Equipment.**

11. **Reactor Components Handling System.** Includes equipment handling tests, including protective interlocks on cranes, hoists, and all reactor components that must be moved for refueling and for reactor vessel inspection.

12. **Radiation Protection System**

a. **Process, Criticality, and Area Monitor Tests.**

b. **Personnel Monitor and Survey Instrument Tests.**

c. **Laboratory Equipment Tests.**

13. **Radioactive Waste Systems.** Includes tests to demonstrate that samples of liquids and gases are

representative of releases, that design throughputs can be achieved, and that releases can be controlled and excessive releases prevented. Includes tests to determine the amount of plateout in sample system piping.

B. Precritical Tests—After Fuel Loading

After the core is fully loaded, open vessel tests should be completed and final checks should be performed before reactivity is inserted to approach initial criticality. Tests should be performed to assure that the reactor is in proper condition to start up. The startup tests below are identified by reactor type.

1. Tests Applicable to Pressurized Water Reactors

a. Mechanical and instrument tests on control rod drive and rod position indicators.

b. Reactor protection trip circuit and manual scram tests.

c. Rod drop time measurements: each rod, cold and hot, at rated recirculation flow and with no recirculation flow plus ten additional measurements for each of the fastest and slowest rods.

d. Final test of reactor coolant system to verify that the system is leaktight.

e. Chemical tests to establish water quality.

f. Calibration and neutron response check of source range monitors.

g. Mechanical and electrical tests of incore monitors, including traversing incore monitors, if installed.

h. Hot flow and loss-of-flow test to measure flow coastdown and to determine effects of core installation, flow characteristics, instrument response, and piping reactions.

i. Pressurizer effectiveness test (hot shutdown).

j. Vibration monitoring in accordance with Regulatory Guide 1.20 (Safety Guide 20).

2. Tests Applicable to Boiling Water Reactors

a. Chemical tests to establish water quality.

b. Vibration monitoring in accordance with Regulatory Guide 1.20 (Safety Guide 20).

c. Evaluation of control rod sequences to verify safety criteria and check operation of control rod inhibit functions during approach to critical.

d. Calibration and neutron response check of source range monitors.

e. Manual scram tests.

C. Low-Power Tests

After achieving initial criticality, reactor physics measurements should be performed as needed to verify that characteristics of the core coolant, shielding, and physics parameters are as expected and that the reactivity coefficients are as assumed in the safety analysis.

1. Tests Applicable to Pressurized Water Reactors

a. Neutron and gamma radiation surveys.

b. Determination of source and intermediate range overlap and verification of alarms and protective functions intended for operation and protection in the low-power test range.

c. Radiation monitors—verification of proper response to known source.

d. Moderator temperature reactivity coefficient measurement and defect measurement over the temperature range in which the reactor may be taken critical.

e. Control rod reactivity worth determinations including verification of rod insertion limits to assure adequate shutdown margin.

f. Boron reactivity worth measurements.

g. Determination of boron concentration at initial criticality and reactivity allocation.

h. Flux distribution measurement with normal rod patterns (this may be performed at a higher power, consistent with sensitivity of incore flux instrumentation.)

i. Chemical tests to demonstrate ability to analyze and control water quality.

j. Pseudo rod ejection test to verify reactivity worth used in safety analysis.

2. Tests Applicable to Boiling Water Reactors

a. Evaluation of control rod sequences to verify safety criteria and to verify operability of control rod inhibit functions up to the reactor power level at which the inhibit functions may be bypassed.

b. Neutron and gamma radiation surveys.

c. Chemical tests to demonstrate ability to analyze and control water quality.

d. Comparison of actual critical control rod configuration against predicted configuration.

e. Determination of source and intermediate-range neutron monitor overlap and calibration of intermediate range monitor with power.

f. Effluent radiation monitors – verification of response to known source.

g. Final leak test of reactor coolant system.

h. Confirmation that control rod calibrations are as predicted for standard rod patterns. (For nonstandard patterns differential and integral worths should be determined.)

i. Reactor vessel head cooling system functional test at operating temperature and pressure.

D. Power-Ascension Tests

1. Tests Applicable to Pressurized Water Reactors

a. Natural circulation tests to confirm sufficient cooling capacity. Comparison of adequate flow data with the performance of previously tested plants of like design may be substituted for this test (5%).[1]

b. Power reactivity coefficient evaluation (25%, 50%, 75%, 100%).

c. Plant response to load swings, including response to automatic dispatcher control, if applicable, (50%, 100%).

d. Automatic control system checkout—steam generator level control, automatic rod control, turbine control (25%).

e. Chemical analyses (25%, 50%, 75%, 100%).

f. Effluent monitoring systems—verification of calibration by laboratory analysis of samples (as early in power ascension as possible and repeated at major power plateaus).

g. Evaluation of core performance—including verification of calibration of flux and temperature instrumentation (25%, 50%, 75%, 100%).

h. Turbine trip (100%).

i. Trip of generator main breaker (100%).

j. Shutdown from outside the control room (≥10% generator output).

k. Loss of offsite power (≥10% generator output).

l. Radiation surveys to determine shielding effectiveness (50%, 100%).

m. Part-length rod insertion and removal—determination of effectiveness in controling xenon transient (75%).

n. Dropped rod—effectiveness of instrumentation in detecting a dropped rod and verification of associated automatic actions.

o. Evaluation of flux asymmetry with single rod assembly fully inserted and partially inserted below the control bank (50%) and evaluation of its effects on departure from nucleate boiling.

p. Vibration monitoring in accordance with Regulatory Guide 1.20 (Safety Guide 20).

q. Pseudo rod ejection test to verify safety analysis (≥10%, with full power rod configuration).

r. Process computer—comparison of safety-related predicted values with measured values (25%, 50%, 100%).

2. **Tests Applicable to Boiling Water Reactors**

a. High-pressure coolant injection system including injection (25%).

b. Control rod drive scram time and friction tests at rated pressure on all rods and on four rods with zero accumulator pressure.

c. Relief valve functional and capacity test.

d. Main steam line isolation.

e. Evaluation of performance of shutdown cooling system.

f. Recirculation flow instrument calibration and measurement (50%, 100%).

g. Chemical analyses of fluid systems (25%, 50%, 75%, 100%).

h. Radiation surveys to determine shielding effectiveness (50%, 100%).

i. Measurement of power control by flow variation and demonstration of flow control (50%, 75%, 100%).

j. Plant response to load swings, including response to automatic dispatcher control, if applicable. (50%, 100%).

k. Pressure regulator calibration and tests, including response to operation of a bypass valve (25%, 50%, 75%, 100%).

l. Emergency condenser performance (after shutdown from >25%).

m. Reactor core isolation cooling system performance (after shutdown from >25%).

n. Calibration of control rods to obtain relationship among rod motion, flux, and steam flow (25%, 50%, 75%, 100%).

o. Rod pattern exchange demonstration (at the maximum power that rod exchange will be permitted during operation).

p. Main steam isolation valve function tests (25%, 50%, 75%).

q. Main steam isolation valve closure and timing test (≤75%).

r. Single-pump trip and a two-pump trip (100%).

s. Turbine trip (100%).

t. Trip of generator main breaker (100%).

u. Shutdown from outside of control room (≥10% generator output).

v. Effluent monitoring systems—verification of calibration by laboratory analysis of samples (as early in power ascension as possible and repeated at major plateaus).

w. Feedwater pump tripout to check standby pump restart (100%).

x. Loss of offsite power (≤10% generator output).

y. Core performance evaluations, including instrument calibration and checks of calculated fuel element thermal design margins, e.g., local surface heat flux and minimum critical heat flux limits (100%).

z. Vibration monitoring in accordance with Regulatory Guide 1.20 (Safety Guide 20).

aa. Process computer—comparison of safety-related predicted values with measured values (25%, 50%, 100%).

[1] Parenthetical numbers following the tests indicate the approximate power levels for conducting the tests. If no number follows the test title, the test should be performed at the lowest practical power level.

APPENDIX B

INSPECTION BY THE DIRECTORATE OF REGULATORY OPERATIONS

The Directorate of Regulatory Operations conducts a series of inspections of the preoperational test and initial startup programs beginning before preoperational testing and continuing throughout startup. These inspections are intended to determine, on a selective basis, whether the applicant's programs as described in the FSAR are adequately implemented and whether the results of the tests demonstrate that the plant, procedures, and personnel are ready for safe operation. The Directorate effort focuses on the manner in which the applicant has fulfilled its responsibility for assuring that adequate programs have been developed and carried out, as exemplified by the methods it has used for establishing procedures and the results that it has produced.

To implement this inspection program, the applicant should make available to Regulatory Operations regional personnel for examination 30 days prior to the scheduled performance of the activity, but not less than 90 days prior to the scheduled fuel loading date, copies of procedures for conducting tests, fuel loading, initial startup, and operating activities. Drafts of these procedures should be made available as early as practical. Examination by Regulatory Operations personnel does not constitute approval of the procedures. The possession of such procedures by Regulatory Operations should not impede the revision, review, and refinement of the applicant's procedures.

The inspections by Regulatory Operations personnel will include the following:

1. An examination of methods being used for preparing, reviewing, and approving procedures; for controlling the performance of tests; for recording, evaluating, reviewing, approving, and retaining test data and results; and for identifying and correcting deficiencies noted in systems and procedures. For the most part, this examination will be carried out prior to the start of the formal test program and is intended to determine whether the applicant has established a set of administrative procedures that will assure that the programs are carried out in accordance with the methods described in the FSAR.

2. An examination of selected test procedures to ascertain whether the tests are designed to satisfy the test objectives, whether the tests meet the acceptance criteria, whether the procedures require the documentation of sufficient information to permit adequate evaluation of the results of the test, and whether baseline data for use during the life of the plant is required to be taken.

3. An examination of the fuel loading and startup procedures to ascertain whether prerequisites, prescribed operations, and limitations are appropriately included to control the operation and whether the applicant has implemented administrative controls identified in paragraph 1. of this appendix.

4. Confirmation that the applicant has evaluated the results of each test and has concluded that the results are satisfactory and meet the acceptance criteria.

5. Confirmation that the applicant has reviewed the results of fuel loading and initial operations.

6. An independent examination of the results of selected tests important to safety. This examination is intended primarily as an independent, selective audit to determine whether information is being appropriately documented and evaluated by the applicant and whether the applicant's technical conclusions appear valid.

7. Witnessing parts of fuel loading and startup, and the performance of portions of selected tests to determine whether they are being conducted in the manner described in the applicant's administrative and test procedures and whether they are being performed in a technically competent manner.

APPENDIX C

PREPARATION OF PROCEDURES

This appendix provides guidance regarding preparation and content of procedures for preoperational tests, fuel loading, startup to critical, and the initial ascension to rated power.

A. Preoperational Test Procedures

1. **Prerequisites.** Each test of the operation of a system normally requires that certain other activities be performed first, e.g., completion of construction, construction tests, and certain other preoperational tests or operations. The preoperational testing procedure should specify each of these or refer to specific prerequisite test procedures. For example, these could include:

a. Confirmation that construction activities associated with the system have been completed and documented. Field inspections should have been made to assure that the equipment is ready for operation, including inspection for proper fabrication and cleanness; checkout of wiring continuity and electrical protective devices; and adjustment of settings on torque-limiting devices, temperature controllers, and limit switches.

b. Confirmation that test equipment is operable and properly calibrated.

c. Tests of individual components or subsystems to demonstrate that they meet their functional requirements. Typical items to consider for common types of equipment are:

- Valves[1]
  - Leakage
  - Opening and closing times
  - Valve stroke
  - Position indication
  - Torque and travel limiting settings
  - Operability against pressure
- Pumps[1]
  - Direction of rotation
  - Vibration
  - Motor load
  - Seal or gland leakage
  - Seal cooling
  - Flow and pressure characteristics
  - Lubrication
- Motors
  - Direction of rotation
  - Vibration
  - Thermal overload protection
  - Lubrication
  - Megger or hi-pot tests
  - Supply voltage
- Piping and Vessels
  - Hydrostatic tests
  - Leaktightness
  - Cleaning, flushing, and layup
  - Clearance of obstructions
  - Support adjustments
  - Proper gasketing
  - Bolt torque
  - Insulation
  - Filling and venting
- Instrumentation and Control
  - Voltage
  - Circuit breaker operation
  - Bus transfers
  - Trip settings
  - Operation of interlock prohibits and permissives
  - Calibration

2. **Test Objectives.** Objectives of the test should be stated. Many system tests will be intended to demonstrate that each of several input signals will produce one or more desired actions. These input signals and the corresponding actions should be identified.

3. **System Initial Conditions.** Where appropriate, instructions should be given pertaining to the system configuration, the components which should or should not be operating, and other pertinent conditions that might affect the operation of this system.

4. **Environmental Conditions.** Most tests will be run at ambient conditions. However, suitable tests should be included to test the equipment under environmental conditions as close as practical to those it will experience in both normal and accident situations.

5. **Acceptance Criteria.** The criteria against which the success or failure of the test will be judged should be clearly identified. In some instances, these will be qualitative criteria—a given event does or does not occur. In other cases, quantitative values should be designated as acceptance criteria.

6. **Data Collection.** The test procedures should prescribe the data to be collected and the form in which it is to be recorded. Preplanned data forms should be provided.

[1] Subsections IWP and IWV of the Summer 1973 Addenda to Section XI of the ASME Boiler and Pressure Vessel Code provide requirements for inservice testing of pumps and valves in nuclear power plants. The applicant should examine these requirements for applicability to his preoperational test programs.

7. **Special Precautions.** Special precautions needed for safety of personnel or equipment or needed to assure a reliable test should be highlighted and clearly described in the test procedure.

8. **Detailed Procedures.** Detailed step-by-step procedures should be provided for each test. To the extent practical, the test procedures should utilize approved normal plant operating procedures to test these procedures and to provide an additional step in the training of operating personnel. The details of the procedures should require full response testing over the operating range under the most extreme anticipated system load changes. The procedures should require demonstration of correct performance of automatic systems and systems with automatic controls, including proper system time constants, under ramp and step changes.

Each procedure should require necessary nonstandard arrangements to be restored to their normal status after the test is complete. Control measures such as jumper logs should be specified. Nonstandard bypasses, valve configurations, and instrument settings should be identified and highlighted for return to normal. Nonstandard arrangements should be carefully examined to assure that temporary arrangements do not invalidate the test by interference with the proper testing of the as-built system.

9. **Documentation of Test Results.** The test procedures should state that the completed procedure, along with the data collected, will be retained as part of the plant historical record. Records should identify the observer or data recorder, the type of observation, the results, the acceptability, and the action taken to correct any deficiencies. Administrative procedures should specify the retention period of test result summaries and should require permanent retention of documented summaries and evaluations.

B. Fuel Loading

This section provides guidance on information to be included in the detailed fuel loading procedure.

An applicant should conduct the loading operation as if it had no prior knowledge of similar cores. Neither should it depend on data obtained from previous loadings of similar cores. To load on this basis requires that specific safety measures be followed. Therefore, the procedures for constituting the core should prescribe continuous monitoring of the neutron flux throughout core loading so that all changes in the multiplication factor are known. The test procedure should require periodic data taking, audible indication of abnormal flux increases, observation of neutron count rate instruments when fuel is being inserted or when other operations are performed which affect core reactivity, and plotting of inverse multiplication to determine subsequent safe loading increments. Predictions of the anticipated behavior of the core reactivity should be available to aid the applicant in his evaluations of the loading. If actual measurements deviate significantly from predicted values the applicant's procedures should require the loading to be delayed until the circumstances are analyzed and the reasons for the anomalies are determined.

To provide further assurance of a safe fuel loading, the applicant's procedure should require that an emergency shutdown system (boron or control rods) be operable while core alterations are being made and while other operations that can affect reactivity are being conducted.

The following information should be included in the fuel loading procedure:

1. **Prerequisites for Fuel Loading**

a. The status of all systems required for fuel loading should be specified, and they should be in readiness as specified.

b. Inspections of fuel, control rods, and poison curtains should have been made.

c. Nuclear instruments should be calibrated, operable, and properly located (source-fuel-detector geometry). One operating channel should have audible indication or annunciation in the control room.

d. A response check of nuclear instruments to a neutron source should be required within eight hours prior to loading or resumption of loading, if delayed for eight hours or more.

e. The status of containment should be specified and established.

f. The status of the reactor vessel should be specified. Components should be either in place or out of the vessel as specified to make it ready to receive fuel.

g. The vessel water level should be established and the minimum level prescribed.

h. Coolant circulation for borated reactors should be specified and established. Precautions such as valve and pump lockouts should be taken to prevent deboration.

i. The emergency boron addition system (or other negative reactivity insertion system) should be operable and in readiness.

j. Fuel handling equipment should be checked and dry runs performed.

k. The status of protection systems, interlocks, mode switch, alarms, and radiation protection equipment should be prescribed and verified. For reactors that have operable control rods during fuel loading, the high flux trip points should be set for a relatively low power level (normally not greater than 1% of full power).

l. Water quality should be established and limits identified.

m. Fuel loading boron concentration should be established.

2. Procedure Details

The procedure should include instructions or information for the following:

a. The loading sequence and pattern for fuel, control rods, poison curtains, and other components. It should also provide guidance on fuel addition increments and should, in general, require constituting the core so that the reactivity worth of added individual fuel elements becomes less as the core is assembled.

b. The maintaining of a display for indicating the status of the core and of appropriate records of core loading.

c. Proper seating and orientation of fuel and components.

d. Functional testing of the associated control rod as the installation of each fuel cell is completed (boiling water reactors).

e. Nuclear instrumentation and neutron source requirements for monitoring subcritical multiplication, including source or detector relocation and normalization of count rate after relocation. (Normally a minimum of three source range monitors on a BWR and two on a PWR should be operable whenever operations are performed that could affect core reactivity.)

f. Flux monitoring, including counting times and frequencies, and rules for plotting inverse multiplication and interpreting plots. An inverse multiplication plot from at least two channels should be maintained. Limits on subsequent fuel loading increments should be based on an extrapolation and conservative interpretation of these plots and on other predetermined limits on loading increments specified in advance by the procedure.

g. The expected subcritical multiplication behavior.

h. Determination of adherence to the minimum shutdown margin and rod worth tests in unborated reactors and the frequency of determination. The minimum shutdown margin should be proved periodically during loading and at the completion of loading.

i. Determination of the boron concentration in borated reactors and frequency of determination. The frequency of determination should be commensurate with the worst possible dilution capability as determined by consideration of piping systems that attach to the reactor coolant system.

j. Actions, especially those pertaining to flux monitoring, for periods when fuel loading is interrupted.

k. The maintaining of continuous voice communication between control room and loading station.

l. Minimum crew required to load fuel.

m. Crew work time. If personnel are scheduled for consecutive daily duty, they should not normally be expected to work more than 12 hours out of each 24.

n. Approvals required for changing the procedure.

3. Limitations and Actions

a. Establishment of criteria for stopping fuel loading. Some circumstances which might warrant this are unexpected subcritical multiplication behavior, loss of communications between control room and fuel loading station, inoperable source-range detector, and inoperability of the emergency boration system.

b. Establishment of criteria for reducing the fuel loading increment. If an increment is reduced because of excessive subcritical multiplication, it should not be increased again.

c. Establishment of criteria for emergency boron injection (or insertion of cocked control rods).

d. Establishment of criteria for containment evacuation.

e. Action to be followed in the event of fuel damage.

f. Actions to be followed or approvals to be obtained before routine loading may resume after one of the above limitations has been reached or invoked.

C. *Startup-to-Critical Procedures*

This section provides some specific guidance for the detailed procedure for operations associated with bringing the reactor critical for the first time. The guidance provided in Section A, "Preoperational Test Procedures," is also considered applicable. This procedure should include steps to assure that the startup will proceed in a slow and orderly manner, that changes in reactivity will be continuously monitored, and that inverse multiplication plots will be maintained and interpreted. All systems needed for startup should be aligned and in proper operation. The emergency liquid poison system should be operable and in readiness. Technical specification requirements must be met.

The poison removal sequence should be prescribed, and the procedure should require a more cautious approach (smaller adjustments in positive reactivity) in achieving criticality after significant subcritical multiplication has been experienced to prevent passing through critical on a short period.

For reactors that will achieve initial criticality by boron dilution, control rods should be withdrawn before dilution begins. The control rod insertion limits prescribed in the technical specifications must be complied with when criticality is achieved.

Nuclear instruments should be calibrated. A neutron count rate (on the order of at least two counts per second) should register on startup channels before the startup begins, and the signal-to-noise ratio should be at least two. A conservative startup rate limit (no smaller than a 60-second period) should be employed in attaining low power. Power should be leveled after attaining criticality and before attaining sensible nuclear heat. Low-power testing should be performed at this level.

D. Power-Ascension Procedures

This section provides specific guidance for the planning and preparation of procedures for conducting the initial ascension to rated power. The guidance provided in Section A, "Preoperational Test Procedures," is also considered applicable. The program should be planned to increase power in discrete steps. Major testing should be performed at approximately the 10%, 25%, 50%, 75%, and 100% levels.

If the hot functional test or the tests to verify the unrestrained expansion of equipment must be delayed until generation of nuclear heat, the first power level should be as low as practicable to accomplish such tests (approximately 5%).

Either the procedure for initial power ascension or the individual test procedures should include instructions and precautions for establishing special conditions necessary for conducting tests. The test procedures should require the following operations to be performed at appropriate steps in the initial power ascension:

1. Conduct any tests that are scheduled.

2. Examine the radial flux for symmetry and verify that the axial flux is within expected values.

3. Determine reactor power by heat balance, calibrate nuclear instruments accordingly, and determine adequacy of instrumentation overlap.

4. Just prior to ascending to the next level, reset high-flux trips to a value no greater than 20% beyond the power of the next level.

5. Complete temperature surveys (core, vessel, and comonents).

6. Check for unexpected radioactivity in process systems and effluents.

7. Perform reactor coolant leak checks.

8. Review the completed testing program at each plateau, perform preliminary evaluations, and obtain the required management approvals before ascending to the next power level.

Following the attainment of rated power, the full-power testing program should be completed and the results of all testing evaluated. Reports to the Commission on the testing and plant performance should be made as described in Regulatory Guide 1.16, "Reporting of Operating Information."