U.S. NUCLEAR REGULATORY COMMISSION

Revision 2
August 1978

REGULATORY GUIDE

OFFICE OF STANDARDS DEVELOPMENT

(4)

REGULATORY GUIDE 1.68

INITIAL TEST PROGRAMS FOR WATER-COOLED NUCLEAR POWER PLANTS

A. INTRODUCTION

Section 50.34, "Contents of Applications: Technical Information," of 10 CFR Part 50, "Domestic Licensing of Production and Utilization Facilities," requires, in part, that an applicant for a license to operate a production or utilization facility include the principal design criteria for the proposed facility in the safety analysis report (SAR). The Introduction to Appendix A, "General Design Criteria for Nuclear Power Plants," to 10 CFR Part 50 states that these principal design criteria are to establish the necessary design, fabrication, construction, testing, and performance requirements for structures, systems, and components important to safety, i.e., structures, systems, and components that provide reasonable assurance that the facility can be operated without undue risk to the health and safety of the public.

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 ensure that structures, systems, and components will perform satisfactorily in service. Since all functions designated in the general design criteria (GDC) are important to safety, all structures, systems, and components required to perform these functions need to be tested to ensure that they will perform properly. These functions, as noted throughout the specific GDC, are those necessary to ensure that specified design conditions of the facility are not exceeded during any condition of normal operation, including anticipated operational occurrences, or as a result of postulated accident conditions.

The GDC and this guide recognize and provide for successive levels of plant features for achieving safety of the facility. This is to provide for a systematic approach to the "defense-in-depth" concept. This concept requires that the plant be designed, constructed, and tested 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 off-normal 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 margin exists 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.

While it is required that all structures, systems, and components important to safety be tested, it is not required that all of them be tested to the same stringent requirements. Specifically, Criterion 1 of Appendix A to 10 CFR Part 50 requires, in part, that structures, systems, and components important to safety be tested to quality standards commensurate with the importance of the safety functions to be performed.

A graded approach is also inherent in the testing requirements of Criterion XI of Appendix B to 10 CFR Part 50.

Section 50.34 of 10 CFR Part 50 also requires, in part, that the applicant include plans for preoperational testing and initial operations in the final safety analysis report (FSAR). Chapter 14 of Regulatory Guide 1.70, "Standard Format and Content of Safety Analysis Reports for Nuclear Power Plants," provides guidance on the information pertaining to initial test programs to be included in both the preliminary safety analysis report (PSAR) and the FSAR for the NRC staff to perform its safety evaluations for construction permits and operating licenses.

This guide describes the general scope and depth of initial test programs acceptable to the NRC staff for light-water-cooled nuclear power plants. Appendix A to this guide provides a representative listing of the plant structures, systems, and components and the design fea-

* Lines indicate substantive changes from previous issue.

USNRC REGULATORY GUIDES

Regulatory Guides are issued to describe and make available to the public methods acceptable to the NRC staff of implementing specific parts of the Commission's regulations, to delineate techniques used by the staff in evaluating specific problems or postulated accidents, or to provide guidance to applicants. Regulatory Guides are not substitutes for regulations, and compliance with them is not required. Methods and solutions different from those set out in the guides will be acceptable if they provide a basis for the findings requisite to the issuance or continuance of a permit or license by the Commission.

Comments and suggestions for improvements in these guides are encouraged at all times, and guides will be revised, as appropriate, to accommodate comments and to reflect new information or experience. This guide was revised as a result of substantive comments received from the public and additional staff review.

Comments should be sent to the Secretary of the Commission, U.S. Nuclear Regulatory Commission, Washington, D.C. 20555, Attention: Docketing and Service Branch.

The guides are issued in the following ten broad divisions:

1. Power Reactors
2. Research and Test Reactors
3. Fuels and Materials Facilities
4. Environmental and Siting
5. Materials and Plant Protection
6. Products
7. Transportation
8. Occupational Health
9. Antitrust Review
10. General

Requests for single copies of issued guides (which may be reproduced) or for placement on an automatic distribution list for single copies of future guides in specific divisions should be made in writing to the U.S. Nuclear Regulatory Commission, Washington, D.C. 20555, Attention: Director, Division of Document Control.

tures and performance capability tests that should be demonstrated during the initial test program. No particular significance should be attached to the order in which the tests are listed, although, in general, those under "1. Preoperational Testing" should precede those listed under "2. Initial Fuel Loading and Precritical Tests," and so on. Appendix B to this guide provides information on inspections, relating to initial test programs, that will be performed by the NRC Office of Inspection and Enforcement. Appendix C to this guide provides guidance on the preparation of procedures for the conduct of initial test programs.

The Advisory Committee on Reactor Safeguards has been consulted concerning this guide and has concurred in the regulatory position.

B. DISCUSSION

The applicant for a construction permit or operating license is responsible for ensuring that a suitable initial (preoperational and startup) test program will be conducted for the facility. The primary objectives of a suitable program are (1) to provide additional assurance that the facility has been adequately designed and, to the extent practical, to validate the analytical models and to verify the correctness or conservatism of assumptions used for predicting plant responses to anticipated transients and postulated accidents and (2) to provide assurance that construction and installation of equipment in the facility have been accomplished in accordance with design. Other key objectives are to familiarize the plant operating and technical staff with the operation of the facility and to verify by trial use, to the extent practical, that the facility operating procedures and the emergency procedures are adequate. Initial test programs satisfying these objectives should provide the necessary assurance that the facility can be operated in accordance with design requirements and in a manner that will not endanger the health and safety of the public.

As mentioned in the Introduction, the test program is required to include suitable testing of all structures, systems, and components important to safety. Both Appendices A and B to 10 CFR Part 50 recognize that some structures, systems, and components are more important to safety than others. For example, those structures, systems, and components that are designated as Seismic Category I by Regulatory Guide 1.29, "Seismic Design Classification," are considered more important to safety than some of the other structures, systems, and components that are identified as important to safety in the functional design criteria of Appendix A to 10 CFR Part 50. It is not intended that the same test requirements be established for all structures, systems, and components important to safety. A graded approach to testing should be implemented in order that adequate assurance, considering the importance to safety of the item, is provided that the item will perform satisfactorily while, at the same time, the testing is accomplished in a cost-effective manner. Documentation associated with testing such as procedures and records should be commensurate with the importance to safety of the item being tested.

To provide for the development and safe execution of the initial test program, the applicant should formulate advance plans for the entire testing program prior to completion of the NRC staff's construction permit review. Because of the complexity of these tests and the large amount of manpower needed for developing and executing the complete program, it is important for the applicant to give early consideration to the following:

1. Defining the responsibilities of the organization that will carry out the program. This should include the degree of participation of principal design organizations in formulating test objectives and acceptance criteria.

2. Developing realistic schedules for the preparation of detailed testing, plant operating, and emergency procedures. Schedules need to be established for conducting the major phases of the test program relative to the expected fuel loading date.

3. Establishing methods or plans for providing the necessary manpower at the times needed to maintain the schedules. If service contracts are to be used, it is necessary to have sufficient trained staff for good contract management. Hiring and training schedules for the plant operating and technical staff need to be established so that experienced and qualified personnel will be available for the development of testing, operating, and emergency procedures. It is important to consider the effects on staffing that could result from overlapping initial test programs at multi-unit sites.

4. Formulating administrative controls to govern the development and conduct of the initial test program including (a) controls that will provide for orderly turnover of plant systems and components from construction forces or other preliminary checkout groups to the preoperational testing group for testing and (b) controls that will ensure that general prerequisites such as completion of construction, construction or preliminary tests, and inspections will be satisfied prior to preoperational and/or startup tests of individual systems or components.

Establishment of early plans for using available information on operating experience, including reportable occurrences from other operating power reactors, is important in the development and conduct of the test program to help minimize recurrence of significant problems that could have been avoided by more complete testing. If new, unique, or first-of-a-kind principal design features will be used in the facility, the in-plant functional testing requirements necessary to verify their performance need to be identified at an early date to permit these test requirements to be appropriately accounted for in the final design.

The initial test program consists of preoperational and initial startup tests. Preoperational testing, as used in this guide, consists of those tests conducted following completion of construction and construction-related inspections and tests, but prior to fuel loading, to demonstrate, to the extent practical, the capability of structures, systems, and components to meet performance requirements to satisfy design criteria.

Initial startup testing, as used in this guide, consists of those test activities scheduled to be performed during and following fuel loading. These activities include fuel loading, precritical tests, initial criticality, low-power tests, and power-ascension tests that confirm the design bases and demonstrate, to the extent practical, that the plant will operate in accordance with design and is capable of responding as designed to anticipated transients and postulated accidents as specified in the SAR.

The initial test program should be designed to demonstrate the performance of structures, systems, components, and design features that will be used during normal operations of the facility and also demonstrate the performance of standby systems and features that must function to maintain the plant in a safe condition in the event of malfunctions or accidents. It is very important that the sequence of startup tests be ordered so that the safety of the plant is never totally dependent on the performance of untested structures, systems, and components.

The NRC staff's safety evaluations of initial test programs are based on information provided in the PSAR and FSAR. This information is used to support decisions to issue a construction permit or operating license. The information provided in SARs is also used by the NRC Office of Inspection and Enforcement as a basis for the inspection activities associated with initial test programs. The satisfactory performance of approved test programs provides the confirmation that adequate margins of safety exist such that there is no undue risk to the health and safety of the public as a result of facility operation.

The power-ascension test phase of the initial test program should be completed in an orderly and expeditious manner. Failure to complete the power-ascension test phase within a reasonable period of time may indicate inadequacies in the applicant's operating and maintenance capabilities or may result from basic design problems. Also, design or construction-related problems disclosed during power-ascension testing can be more readily rectified if the reactor power production, and consequently the radioactive buildup, has been kept to a minimum during this testing phase. Baseline data on the performance of plant systems obtained and documented early in the plant life will permit early determination of degradation or undesirable trends.

Appendix A references existing regulatory guides that are applicable to initial test programs. The referenced guides provide detailed guidance for particular tests.

C. REGULATORY POSITION

1. Criteria for Selection of Plant Features To Be Tested

Each applicant or licensee should prepare and conduct an initial test program to demonstrate that the plant can be operated in accordance with design requirements important to safety, as defined by Appendix A to 10 CFR Part 50. Suitable tests should be conducted to verify the performance capabilities, as delineated in Appendix A to 10 CFR Part 50, of structures, systems, and components that:

a. Will be used for shutdown and cooldown of the reactor under normal plant conditions and for maintaining the reactor in a safe condition for an extended shutdown period.

b. Will be used for shutdown and cooldown of the reactor under transient (infrequent or moderately frequent events) conditions and postulated accident conditions and for maintaining the reactor in a safe condition for an extended shutdown period following such conditions.

c. Will be used for establishing conformance with safety limits or limiting conditions for operation that will be included in the facility technical specifications.

d. Are classified as engineered safety features or will be relied on to support or ensure the operations of engineered safety features within design limits.

e. Are assumed to function or for which credit is taken in the accident analysis of the facility, as described in the FSAR, and

f. Will be used to process, store, control, or limit the release of radioactive materials.

Appendix A to this guide provides a representative listing of systems to be tested and performance capabilities important to safety, as defined by Appendix A to 10 CFR Part 50, that should be demonstrated for light-water-cooled nuclear power plants. However, applicants should also conduct in-plant testing to verify the adequacy of construction, installation, and design for other systems and design features not listed in Appendix A if the systems or design features meet any of the above criteria.

The initial test program may be developed and implemented using a graded approach. The graded approach should ensure that the greatest attention is given to the most important structures, systems, and components such as those considered engineered safety features.

2. Prerequisites for Testing

The construction or installation of structures, systems, and components should be essentially completed (to the degree that outstanding construction items could

not be expected to affect the validity of test results). The designated construction-related inspections and tests should also be completed prior to beginning preoperational tests.

Tests designated in the FSAR as preoperational tests should be completed and the results of such tests evaluated and approved by the applicant prior to issuance of the Operating License. The overall test program should also include surveillance tests necessary to demonstrate the proper operation of interlocks, setpoints, and other protective features, systems, and equipment required by the technical specifications. Administrative controls should be established to ensure adequate retest of systems or design features returned to construction custody, maintained, or modified during or following preoperational testing.

3. Scope, Testing Conditions, and Length of Testing

The initial test program should include, to the extent practical, simulation of the effects of control system and equipment failures or malfunctions that could reasonably be expected to occur during the plant lifetime. The test program should also include testing to determine that the system and component interactions are in accordance with design. To the extent practical, the plant conditions during the tests should simulate the actual operating and emergency conditions to which the structure, system, or component may be subjected. To the extent practical, the duration of the tests should be sufficient to permit equipment to reach its normal equilibrium conditions, e.g., temperatures and pressures, and thus decrease the probability of failures, including "run-in" type failures, from occurring during plant operation.

4. Procedures

The initial test program should be conducted using test procedures that include appropriate checklists and signature blocks to control test performance and the sequence of testing. The test procedures should be developed and reviewed by personnel with appropriate technical backgrounds and experience. The procedures should receive final approval by persons filling designated management positions within the applicant's organization. Acceptance criteria that account for the uncertainties used in transient and accident analyses should be included as part of each test procedure. Procedures should ensure that temporary instrument cables and test leads used during the startup test phase are routed in a manner that will not compromise electrical separation criteria. Principal design organizations should participate in establishing test performance requirements and test acceptance criteria. Available information on operating experience, including reportable occurrences at operating power reactors, should be used appropriately in the development and execution of the test procedures. Approved test procedures for satisfying FSAR testing commitments should be made available to NRC staff personnel from the Office of Inspection and Enforcement approximately 60 days prior to their intended use.

Prior to commencement of fuel loading, results of completed preoperational tests should be evaluated by personnel or groups designated by the applicant. Appropriate remedial actions, including retesting, should be taken if acceptance criteria are not satisfied.

5. Schedule

Sufficient time should be scheduled to perform orderly and comprehensive testing. The applicant's schedules for conducting the preoperational phase and the initial startup phase should provide for a minimum time of approximately 9 months and 3 months, respectively.

6. Participation of Plant Operating and Technical Staff

The applicant's plant operating and plant technical staff should participate, to the extent practical, in the development and conduct of the initial test program and the evaluation of the test results.

7. Trial-Testing of Plant Operating and Emergency Procedures

Plant operating and emergency procedures should, to the extent practical, be developed, trial-tested, and corrected during the initial test program prior to fuel loading to establish their adequacy.

8. Milestones and Power Hold Points

Appropriate hold points should be established by the applicant at selected milestones throughout the power-ascension test phase to ensure that relevant test results are evaluated and approved by personnel or groups designated by the applicant prior to progressing with the power-ascension test phase. As a minimum, hold points should be established for PWRs at approximately 25%, 50%, and 75% power level test conditions and for BWRs at appropriate power-to-flow test conditions.

9. Test Reports

The preoperational testing procedures and results should be retained as part of the plant historical record. A summary of the startup testing should be included in a startup report as discussed in Regulatory Guide 1.16, "Reporting of Operating Information—Appendix A Technical Specifications." This summary should include:

a. A description of the test method and objectives for each test.

b. A comparison of applicable test data with the acceptance criteria, including the response of the systems to major plant transients such as scram and turbine trip.

c. Deficiencies relating to design and construction found during conduct of the tests, system modifications and corrective actions required to correct these deficien-

cies, and the schedule for implementing these modifications and corrective actions unless previously reported to the Nuclear Regulatory Commission.

d. Justification for acceptance of systems or components not in conformance with design predictions or performance requirements.

e. Conclusions regarding system or component adequacy.

D. IMPLEMENTATION

The purpose of this section is to provide further information to applicants regarding the NRC staff's plans for using this regulatory guide.

Except in those cases in which the applicant proposes an acceptable alternative method for complying with specified portions of the Commission's regulations, the method described herein will be used in the evaluation of construction permit and operating license applications docketed after August 15, 1978.

If an applicant wishes to use this regulatory guide in developing submittals for applications docketed on or before August 15, 1978, the pertinent portions of the application will be evaluated on the basis of this guide.

APPENDIX A

INITIAL TEST PROGRAM

1. Preoperational Testing

Following plant construction, testing should be accomplished to demonstrate the proper performance of structures, systems, components, and design features in the assembled plant. To ensure valid test results, the preoperational tests should not proceed until the construction of the system has been essentially completed and the designated construction tests and inspections have been satisfactorily completed. Construction and preliminary tests and inspections typically consist of items such as initial instrument calibration, flushing, cleaning, wiring continuity and separation checks, hydrostatic pressure tests, and functional tests of components.

Preoperational tests should demonstrate that structures, systems, and components will operate in accordance with design in all operating modes and throughout the full design operating range. Testing should include, as appropriate, manual operation, operation of systems and components within systems, automatic operation, operation in all alternate or secondary modes of control, and operation and verification tests to demonstrate expected operation following loss of power sources and degraded modes for which the systems are designed to remain operational. Tests should also include, as appropriate, verifications of the proper functioning of instrumentation and controls, permissive and prohibit interlocks, and equipment protective devices whose malfunction or premature actuation may shut down or defeat the operation of systems or equipment. System vibration, expansion (in discrete temperature step increments), and restraint tests should also be conducted. This testing should include verification by observations and measurements, as appropriate, that piping and component movements, vibrations, and expansions are acceptable for (1) ASME Code Class 1, 2, and 3 systems, (2) other high-energy piping systems inside Seismic Category I structures, (3) high-energy portions of systems whose failure could reduce the functioning of any Seismic Category I plant feature to an unacceptable level, and (4) Seismic Category I portions of moderate-energy piping systems located outside containment.

The structures, systems, components, and tests listed in items a. through o. of this section are representative of the plant features that should undergo preoperational testing. The listing is provided to indicate the extent of testing necessary to demonstrate that the facility can be operated in accordance with design requirements. In general, items a. through o. make no distinction between pressurized water reactors and boiling water reactors. An applicant may combine tests of items listed in this appendix and should include preoperational tests of the listed structures, systems, and components as appropriate for the facility. Preoperational tests should not be limited to the listing provided in items a. through o. since additional or different tests may be dictated by the particular plant design and/or the nomenclature applied to plant systems and features.

a. 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 paragraph 50.2(v) of 10 CFR Part 50.

(1) *Integrated Systems Test.* Expansion and restraint tests to confirm acceptability of clearances and displacements of vessels, piping, piping hangers, and seismic and other holddown, support, or restraining devices in the as-built system during normal hot functional testing plant conditions. Hot and/or cold testing of the system with simultaneous operation of auxiliary systems.

(2) *Component Tests.* Appropriate tests and measurements of the following reactor coolant system components:

(a) Pressurizer.

(b) Pumps, motors, and associated power sources.

(c) Steam generators.

(d) Pressure relief valves and associated dump tanks and supports and restraints for discharge piping.

(e) Main steam isolation valves.

(f) Other valves.

(g) Instrumentation used for monitoring system performance or performing permissive and prohibit interlock functions.

(h) Reactor vessel and internals, including reactor internals vent valves.

(i) Safety valves.

(j) Jet pumps.

(3) *Vibration Tests.* Vibration monitoring of reactor internals[1] and of other components such as piping systems, heat exchangers, and rotating machinery.

(4) *Pressure Boundary Integrity Tests.* Hydrostatic tests; obtain baseline data for subsequent inservice testing.

[1]Regulatory Guide 1.20, "Comprehensive Vibration Assessment Program for Reactor Internals During Preoperational and Initial Startup Testing," should be used as guidance for vibration monitoring of reactor internals and other components.

b. Reactivity Control Systems

(1) *Control Rod System Tests.* Demonstrate normal operation and scram capability of the control rods (BWR) and control rod drive system. Demonstrate proper operation of functions such as control rod withdrawal inhibit features, runback features, rod withdrawal sequence control devices, and rod worth minimizers. Demonstrate proper operation of rod position instrumentation and proper interaction of the control rod drive system with other systems and design features such as automatic reactor power control systems and refueling equipment. Demonstrate proper operation, including correct failure mode on loss of power, for the control rod drive system and proper operation of system alarms.

(2) *Chemical Control System Tests.* Verify proper blending of boron solution and water, uniform mixing, adequacy of sampling and analytical techniques, operation of heaters and heat tracing, and operation of instrumentation, controls, interlocks, and alarms. Demonstrate proper rate injection into the reactor coolant system and rate of dilution from the primary system. Verify redundancy, electrical independence, and operability of system components. Demonstrate correct failure mode on loss of power to system components.

(3) *Standby Liquid Control System Tests.* Demonstrate proper operation of the system with demineralized water. Verify proper mixing of solution and adequacy of sampling system. Demonstrate operability of instrumentation, controls, interlocks, and alarms. Verify operability of heaters, air spargers, and heat tracing. Conduct test firings of squib-actuated valves, and demonstrate design injection capability. Tests should be conducted as appropriate to verify redundancy and electrical independence.

c. Reactor Protection System and Engineered-Safety-Feature Actuation Systems

Verify by test the response time of each of the protection channels, including sensors.[2] Acceptance criteria for the response time of the protection channels should account for the response time of the associated hardware between the measured variable and the input to the sensor (snubbers, sensing lines, flow-limiting devices, etc.). Verify proper operation in all combinations of logic; calibration and operability of primary sensors; proper trip and alarm settings; proper operation of permissive, prohibit, and bypass functions; and operability of bypass switches. Demonstrate redundancy, electrical independence,[3] coincidence, and safe failure on loss of power. If appropriate for the facility design, demonstrate operability of backup scram solenoid valves and devices, including detectors, logic, and final control elements to protect the facility for anticipated transients without scram (ATWS).

d. Residual or Decay Heat Removal Systems

Verify operability of systems and design features provided or relied on to dissipate or channel thermal energy from the reactor to the atmosphere or to the main condenser or other systems following off-normal conditions or anticipated transients, including reactor scram. Verify operability of systems and design features provided for makeup of coolant, to dissipate residual heat, to cool the reactor down to a cold shutdown condition, and to maintain long-term cooling. Tests should be conducted as appropriate to verify redundancy and electrical independence.[3] The following list is illustrative of the systems and components that should be tested:

(1) Turbine bypass valves.

(2) Steam line atmospheric dump valves.

(3) Relief valves.

(4) Safety valves.

(5) Decay or residual heat removal system.

(6) Reactor core isolation cooling system.

(7) Main steam isolation valves, branch steam isolation valves, and nonreturn valves.

(8) Auxiliary feedwater systems. Testing should include demonstrations that the systems will meet design performance requirements at approximately normal operating primary and secondary coolant system pressures and temperatures and over the range of expected steam generator levels. Operability of system pumps, valves, controls, and instrumentation should be demonstrated, and, to the extent practical, testing should provide reasonable assurance that flow instabilities, e.g., "water hammer," will not occur in system components, piping, or inside the steam generators during normal system startup and operation.

(9) Condensate storage system.

(10) Emergency cooling towers.

(11) Cooling water systems.

e. Power Conversion System

The power conversion system includes all components provided to channel the reactor thermal energy

[2] Regulatory Guide 1.118, "Periodic Testing of Electric Power and Protection Systems," provides a test criterion also acceptable for preoperational testing of protection channels, including sensors.

[3] Regulatory Guide 1.41, "Preoperational Testing of Redundant Onsite Electric Power Systems to Verify Proper Load Group Assignments," should be used as guidance for appropriate tests.

during normal operation from the boundaries of the reactor coolant system to the main condenser and those systems and components provided for return of condensate and feedwater[4] from the main condenser to complete the cycle.

Appropriate system expansion, restraint, and operability tests should be conducted, to the extent practical, for the following systems and components:

(1) Steam generators.

(2) Main steam system.

(3) Main steam isolation valves.

(4) Steam generator pressure relief and safety valves.

(5) Steam extraction system.

(6) Turbine stop, control, bypass, and intercept valves.

(7) Main condenser hotwell level control system.

(8) Condensate system.

(9) Feedwater system.

(10) Feedwater heater and drain systems.

(11) Makeup water and chemical treatment systems.

(12) Main condenser auxiliaries used for maintaining condenser vacuum.

f. Waste Heat Rejection Systems

The waste heat rejection systems include systems and components provided to remove the unused or wasted thermal energy from systems such as the power conversion and residual heat removal system and to channel or direct this energy to the environment. Tests should be conducted as appropriate to verify redundancy and electrical independence.[3] Appropriate system operability tests should also be conducted to demonstrate, to the extent practical, that the following waste heat rejection systems and components, including associated instrumentation and controls, will perform as designed:

(1) Circulating water system.

(2) Cooling towers and associated auxiliaries.

(3) Raw water and service water cooling systems.

g. Electrical Systems

The plant electrical systems include the normal a.c. power distribution system, the emergency a.c. power distribution system including vital buses, the emergency a.c. power supplies or sources, and the d.c. systems. Appropriate system and component tests should be conducted to verify, to the extent practical, that these systems will operate in accordance with design.

(1) *Normal A.C. Power Distribution System.* Demonstrate proper operation of protective devices, initiating devices, relaying and logic, transfer and trip devices, permissive and prohibit interlocks, instrumentation and alarms, and load-shedding features. Testing should also be conducted to demonstrate proper operation and load-carrying capability of breakers, motor controllers, switchgear, transformers, and cables. This testing should simulate, as closely as practical, actual service conditions, e.g., fully loading motor control centers and operation of supplied loads at rated conditions, etc. Redundancy and electrical independence[3] should be demonstrated where appropriate.

Tests should demonstrate that the integrated system will perform as designed to a simulated partial and full loss of offsite power sources. Tests should also demonstrate the design capability to transfer from onsite to offsite power sources.

(2) *Emergency A.C. Power Distribution System.* Demonstrate proper operation of protective devices, relaying and logic, transfer and trip devices, permissive and prohibit interlocks, instrumentation and alarms, and load-shedding or stripping features. Testing should also be conducted to demonstrate proper operation and load-carrying capability of breakers, motor controllers, switchgear, transformers, and cables. This testing should simulate, as closely as practical, actual service conditions, e.g., fully loading motor control centers and operation of supplied loads at rated conditions. Tests should demonstrate that emergency or vital loads will start in the proper sequence and operate under simulated accident conditions with both the normal (preferred) a.c. power source(s) and the emergency (standby) power source.

Emergency loads should also be tested to demonstrate that they can start and operate with the maximum and minimum design voltage available. To the extent practical, the testing of emergency or vital loads should be conducted for a sufficient period of time to provide assurance that equilibrium conditions are attained. System redundancy and electrical independence should be verified by appropriate tests.[3]

Loads supplied from the system, such as motor generator (m-g) sets with flywheels, that are designed to provide noninterruptible power to plant loads should be tested to demonstrate proper operation. If applicable for the facility design, testing should include underfrequency and undervoltage relays associated with such m-g sets. Full-load tests for vital buses should be conducted using normal and emergency sources of power supplies to the bus. Testing should also demonstrate the adequacy of the plant's emergency and essential lighting system. Tests

[4] Regulatory Guide 1.68.1, "Preoperational and Initial Startup Testing of Feedwater and Condensate Systems for Boiling Water Reactor Power Plants," should be used as guidance for appropriate tests.

should be conducted to demonstrate the proper operation of indicating and alarm devices used to monitor the availability of the emergency power system in the control room.

(3) *Emergency or Standby A.C. Power Supplies.* Appropriate tests should be conducted for emergency a.c. power supplies to demonstrate system reliability,[5] redundancy, electrical dependence, and proper voltage and frequency regulation under transient and steady-state conditions. Auxiliary systems such as those used for starting, cooling, heating, ventilating, lubricating, and fueling should also be appropriately tested to demonstrate that their performance is in accordance with design. Testing should be conducted for a sufficient period of time to ensure that equilibrium conditions are attained. Testing should also demonstrate the proper logic, correct setpoints for trip devices, and proper operation of initiating devices and permissive and prohibit interlocks and should also demonstrate redundancy and electrical independence.[3] Emergency loads supplied should be confirmed to be in agreement with design sizing assumptions used for the power supplies.[6]

(4) *D.C. System.* Demonstrate proper calibration and trip settings of protective devices, including relaying, and proper operation of permissive and prohibit interlocks. Demonstrate design capability of battery chargers, transfer devices and inverters, and the emergency lighting systems. Testing should also be conducted to demonstrate proper operation of breakers, transfer devices, inverters, and cables. This testing should simulate, as closely as practical, actual service conditions. Demonstrate operation of instrumentation and alarms and ground detection instrumentation. Demonstrate redundancy and electrical independence[3] and that actual total system amperage loads are in agreement with design loads. A discharge test of each battery bank should be conducted at full load and for design duration to demonstrate that the battery bank voltage minimum limit and individual cell limits are not exceeded.

h. Engineered Safety Features

Engineered safety features are those plant design features provided to prevent, limit, or mitigate the consequences of postulated accidents that are described in the safety analysis report. For the purpose of this guide, engineered safety features include features that prevent accidents from occurring or that bound accident assumptions such as cold water injection interlocks for pressurized water reactors and rod worth minimizers for boiling water reactors. Since engineered safety features vary for different plant designs, the listing below is only illustrative of those commonly used to prevent, limit, or mitigate the consequences of postulated accidents. If additional or different types of engineered safety features are provided than those listed below, they should also be appropriately tested. Additionally, it should be noted that other categories of systems listed in Section 1 of this appendix include plant features commonly designated as engineered safety features that should be appropriately tested; for example, emergency a.c. power distribution system [Section 1.g (2)], emergency or standby a.c. power supplies [Section 1.g (3)], the d.c. system [Section 1.g (4)], and primary and secondary containments (Section 1.i).

The testing of engineered safety features should demonstrate that such features will perform satisfactorily in all expected operating configurations or modes. Testing should include demonstrations of proper operation of initiating devices, correct logic and setpoints, proper operation of bypasses, proper operation of prohibit and permissive interlocks, and proper operation of equipment protective devices that could shut down or defeat the operation or functioning of such features. Concurrent testing of systems or features provided to ensure or support the operation of engineered safety features should also be conducted to demonstrate that they meet design requirements with the minimum number of operable components available for which these systems are designed to function. Examples of these types of systems are heating, ventilation, and air-conditioning systems used to maintain the environment within design limits in the spaces housing engineered safety features, cooling water and seal injection systems, and protected compressed gas supplies. Appropriate tests should also be conducted to verify the functioning of protective devices such as leaktight covers, structures, or housings (low pressure pneumatic or vacuum tests) provided to protect engineered safety features from flooding or keep-full systems used to prevent water hammer and possible damage to fluid systems.

Tests should be conducted as appropriate to verify redundancy and electrical independence.[3] The following list is illustrative of the systems and components that should be tested:

(1) *Emergency core cooling systems (ECCS)*[7]

(a) Perform expansion and restraint tests.

(b) Demonstrate operability using normal and emergency power supplies.

(c) Demonstrate operability in all modes of op-

[5] Regulatory Guide 1.108, "Periodic Testing of Diesel Generator Units Used As Onsite Electric Power Systems at Nuclear Power Plants," should be used as guidance for applicable tests.

[6] Regulatory Guide 1.9, "Selection, Design, and Qualification for Diesel-Generator Units Used As Onsite Electric Power Systems at Nuclear Power Plants," should be used as guidance for applicable tests.

[7] Regulatory Guide 1.79, "Preoperational Testing of Emergency Core Cooling Systems for Pressurized Water Reactors," provides specific guidance for pressurized water reactors.

eration, including design pump/system runout conditions and injection at required flow rate and pressure.

(d) Demonstrate operability of interlocks and isolation valves provided for overpressure protection for low pressure cooling systems connected to the reactor coolant system.

(e) Demonstrate operability, including proper flow rates, for systems used for dilution of boron in the reactor vessel during post-loss-of-coolant-accident long-term cooling.

(2) *Autodepressurization system.* Testing should include items such as accumulator capacity, relief valves, and operability using all alternate power and pneumatic supplies.

(3) *Containment postaccident heat removal systems.* Testing of the containment spray system should include demonstrations that the spray nozzles, spray headers, and piping are free of debris; chemical addition systems operate properly; and proper transfer to the recirculation phase can be accomplished.

(4) *Containment combustible gas control system* (includes the backup purge system). For containment combustible gas control systems located outside containment, testing should include demonstration that the containment hydrogen monitoring is functional without the operation of the hydrogen recombiner. For hydrogen recombiners shared between plants or sites, tests should include demonstrations that the shared recombiner can be transported and connected to the combustible gas control system within the time stated in the FSAR.

(5) *Cold water interlocks,* including logic, circuitry, and final control devices used to prevent cold water injection into the reactor vessel.

(6) *Air return fans* used in ice condenser containments and suppression pool makeup systems used in BWR Mark III containments.

(7) *Ventilation, recirculation, and filter systems* provided to minimize radioactive releases as a result of postulated accidents, including fuel handling accidents.[8]

(8) *Tanks and other sources of water used for ECCS.* Testing should include demonstrations of proper operation of associated alarms, indicators, controls, heating and chilling systems, and valves.

(9) *Containment recirculation fans* (if used as part of postaccident containment heat removal systems). Testing should include demonstrations that fans can operate in accordance with design requirements at the containment design peak accident pressure.

(10) *Ultimate heat sink.*

i. Primary and Secondary Containments

Appropriate tests should be conducted to demonstrate that primary and secondary containments will function as designed. Testing methods and acceptance criteria for such tests should give due consideration to all systems and components that must operate for the containments to function as designed. In certain designs, normally operating or intermittently operating systems may be required to shut down and isolate to achieve containment isolation. For example, the secondary containment ventilation system in BWRs is required to shut down and isolate the normal ventilation paths to permit the standby gas treatment system to perform its design function. Therefore, appropriate testing should be conducted to demonstrate the operability of all components, features, and systems required to operate for the primary or secondary containment to function properly.

Due consideration should also be given to plant features such as heating, ventilation, and air-conditioning systems required to maintain environmental conditions within design limits for components or equipment provided to effect containment isolation. Testing should be sufficient to demonstrate redundancy, electrical independence[3] requirements for isolation valves, and proper operation of features (including proper operation of devices upon loss or failure of motive power) provided for isolation valves and other devices. To the extent practical, it should be demonstrated that isolation devices perform as required under simulated accident conditions. The listing below is illustrative of systems, features, and performance demonstrations that should be included in the test program:

(1) Containment design overpressure structural tests[9] and vacuum tests (for subatmospheric containments).

(2) Containment isolation valve functional and closure timing tests.

(3) Containment isolation valve leak rate tests[10] and inleakage tests (for subatmospheric containments).

(4) Containment penetration leakage tests.[10]

(5) Containment airlock leak rate tests.[10]

(6) Integrated containment leakage tests.[10]

[8] These tests should be consistent with the provisions of Regulatory Guide 1.52, "Design, Testing, and Maintenance Criteria for Engineered-Safety-Feature Atmosphere Cleanup System Air Filtration and Adsorption Units of Light-Water-Cooled Nuclear Power Plants."

[9] Per Section III of the ASME Boiler and Pressure Vessel Code.

[10] The requirements for such tests are given in Appendix J to 10 CFR Part 50

In general, the sequences of testing should proceed from the low-pressure test to the accident-pressure test, or sufficient time should be allowed between tests to ensure that outgassing from concrete or components within the containment will not affect test results.

(7) Main steam line leakage sealing systems.

(8) Primary and secondary containment isolation initiation logic tests.

(9) Containment purge system tests.

(10) Containment and containment annulus vacuum-breaker tests.

(11) Containment supplementary leak collection and exhaust system tests.

(12) Containment air purification and cleanup system tests.

(13) Containment inerting system tests.

(14) Standby gas treatment system tests.

(15) Containment penetration pressurization system tests.

(16) Containment ventilation system tests.

(17) Secondary containment system ventilation tests.

(18) Containment annulus and cleanup system tests, including demonstrating the ability to maintain design pressure control in all modes of operation.

(19) Bypass leakage tests on pressure suppression containments.

(20) Ice-condenser containments. Sufficient measurements should be made to ensure that gross bypass leakage paths are not present.

(21) Containment penetration cooling system tests.

j. Instrumentation and Control Systems

The nomenclature applied to instrumentation and control systems varies widely with different plant designs; however, the primary functions are similar for all reactors. The principal functions of instrumentation and control systems are to (1) control the normal operation of the facility within design limits, (2) provide information and alarms in the control room to monitor the operation and status of the facility and to permit corrective actions to be taken for off-normal plant conditions, (3) establish that the facility is operating within design and license limits, (4) permit or support the correct operation of engineered safety features, and (5) monitor and record important parameters during and following postulated accidents.

In the design of nuclear power plants, postulated accident assumptions are often explicitly or implicitly bounded by the design of control and instrumentation systems (e.g., pressurizer level or feedwater flow control). In such cases, operation of the instrumentation and controls over the design operating range should be performed, and the effects of limiting malfunctions or failures should be simulated to demonstrate the adequacy of design and installation and the validity of accident analysis assumptions. Tests should be conducted, as appropriate, to verify redundancy and electrical independence.[3]

The listing provided below is illustrative of instrumentation and control systems that should be included in the test program (some of these tests can be conducted in conjunction with the appropriate system level tests):

(1) Pressurizer pressure and level control systems.

(2) Main, auxiliary, and emergency feedwater control systems.

(3) Secondary system steam pressure control system.

(4) Recirculation flow control system.

(5) Reactor coolant system leak detection systems.

(6) Loose parts monitoring system.

(7) Leak detection systems used to detect failures in ECCS and containment recirculating spray systems located outside containment.

(8) Automatic reactor power control system, integrated control system, and T-average control system.

(9) Pressure control systems used to maintain design differential pressures to prevent leakage across boundaries provided to contain fission products; for example, those used to pressurize spaces between containment isolation valves.

(10) Seismic instrumentation.

(11) Traversing incore probe system.

(12) Failed fuel detection system.

(13) Incore and excore neutron instrumentation.

(14) Instrumentation and controls that effect transfers of water supplies to auxiliary feedwater pumps, ECCS pumps, and containment spray pumps.

(15) Automatic dispatcher control systems.

(16) Hotwell level control system.

(17) Feedwater heater temperature, level, and bypass control systems.

(18) Auxiliary startup instrument tests (neutron response checks).

(19) Instrumentation and controls used for shutdown from outside the control room.

(20) Instrumentation used to detect external and internal flooding conditions that could result from such sources as fluid system piping failures.

(21) Reactor mode switch and associated functions.

(22) Instrumentation that can be used to track the course of postulated accidents such as containment wide-range pressure indicators, reactor vessel water level monitors, containment sump or pressure suppression level monitors, high-range radiation detection devices, and humidity monitors.

(23) Postaccident hydrogen monitors and analyzers used in the combustible gas control system.

(24) Annunciators for reactor control and engineered safety features.

(25) Process computers.

k. Radiation Protection Systems

Appropriate tests should be conducted to demonstrate the proper operation of the following types of systems and components used to monitor or measure radiation levels, to provide for personnel protection, or to control or limit the release of radioactivity:

(1) Process, criticality, effluent, and area radiation monitor tests.

(2) Personnel monitors and radiation survey instrument tests.

(3) Laboratory equipment used to analyze or measure radiation levels and radioactivity concentrations.

(4) High Efficiency Particulate Air (HEPA) filter and charcoal adsorber efficiency and in-place leak tests.[8]

Tests should be conducted as appropriate to verify redundancy and electrical independence.[3]

l. Radioactive Waste Handling and Storage Systems

Appropriate tests should be conducted to demonstrate the functional operability and design flow rates of systems and components used to process, store, and release or control the release of radioactive liquid, gaseous, and solid wastes. Testing should demonstrate, to the extent practical, that the pumps, tanks, controls, valves, and other equipment, including automatic isolation and protective features and instrumentation and alarms, will operate and function in accordance with design. Testing or calculations should include, as appropriate, verification of tank volumes, capacities, holdup times, and proper operation and calibration of associated instrumentation. Spiked samples of the typical media or sources should be used where necessary to verify operability and/or proper calibration of radiation detectors and monitors.

The following list is illustrative of the systems, components, and features whose operability should be demonstrated during the test program:

(1) Liquid radioactive waste handling systems.

(2) Gaseous radioactive waste handling systems.

(3) Solid waste handling systems. Solidification system tests should include verification that no free liquids are present in packaged wastes.

(4) Isolation features for steam generator blowdown.

(5) Isolation features for condenser offgas systems.

(6) Isolation features for ventilation systems.

(7) Isolation features for liquid radwaste effluent systems.

(8) Plant sampling systems.

m. Fuel Storage and Handling Systems

Appropriate tests should be conducted for equipment and components used to handle or cool irradiated fuel and to handle nonirradiated fuel to demonstrate that they will operate in accordance with design. Tests should be conducted as appropriate to verify redundancy and electrical independence.[3] The following list is illustrative of the equipment and component tests that should be included in the test program:

(1) Spent fuel pit cooling system tests, including the testing of antisiphon devices, high radiation alarms, and low water level alarms.

(2) Refueling equipment tests, including hand tools, power equipment, bridge and overhead cranes, and grapples. Testing should demonstrate the operability of protective interlocks and devices.

(3) Operability and leak tests of sectionalizing devices and drains and leak tests of gaskets or bellows in the refueling canal and fuel storage pool.

(4) Dynamic and static load testing[11] of cranes, hoists, and associated lifting and rigging equipment, including the fuel cask handling crane. Static testing at 125% of rated load and full operational testing at 100% of rated load.

(5) Fuel transfer devices.

(6) Irradiated fuel pool or building ventilation system tests.

---

[11] Regulatory Guide 1.104, "Overhead Crane Handling Systems for Nuclear Power Plants," should be used as guidance for tests on single-failure-proof overhead crane handling systems.

n. Auxiliary and Miscellaneous Systems

Appropriate tests should be conducted to demonstrate the operability of auxiliary and miscellaneous systems. Tests should be conducted, as appropriate, to verify redundancy and electrical independence.[3]

The following list is illustrative of the types of systems or features whose performance should be demonstrated by testing:

(1) Service and raw water cooling systems.

(2) Closed loop cooling water systems.

(3) Component cooling water systems.

(4) Reactor coolant makeup system.

(5) Reactor coolant and secondary sampling systems.

(6) Chemistry control systems for the reactor coolant and secondary coolant systems.

(7) Fire protection systems, including demonstrations of proper manual and automatic operation of fire detection, alarm, and suppression systems.

(8) Seal water systems.

(9) Vent and drain systems for contaminated or potentially contaminated systems and areas and drain and pumping systems serving essential areas, e.g., spaces housing diesel generators, essential electrical equipment, and essential pumps.

(10) Purification and cleanup systems for the reactor coolant system.

(11) Compressed gas systems[12] supplying pneumatic equipment, components, or instrumentation that are required to function to support the normal operation of the facility or are essential for the operation of standby safety equipment or engineered safety features.

(12) Boron recovery system.

(13) Communication systems. Tests should include demonstrations of the proper operation of evacuation and other alarms, the public address system within the plant, systems that may be used if the plant is required to be shut down from outside the control room, and communication systems required by the facility emergency plan.

(14) Heating, cooling, and ventilation systems serving the following:

(a) Spaces housing engineered safety features.

(b) Primary containment.

(c) Battery rooms.

(d) Diesel generator buildings.

(e) Auxiliary buildings, reactor building, turbine building, and radioactive waste handling building.

(f) Control room habitability systems. Testing should include, as appropriate, demonstrations of the proper operation of smoke and toxic chemical detection systems and ventilation shutdown devices, including leaktightness of ducts and flow rates, proper direction of airflows, and proper control of space temperatures.

(15) Shield cooling systems.

(16) Cooling and heating systems for the refueling water storage tank.

(17) Equipment and controls for establishing and maintaining subatmospheric pressures in subatmospheric containments.

(18) Heat tracing and freeze protection systems.

o. Reactor Components Handling Systems

Include the following:

(1) Dynamic and static load tests[11] of cranes, hoists, and associated lifting and rigging equipment (e.g., slings and strongbacks used during refueling or the preparation for refueling). Static testing at 125% of rated load and full operational testing at 100% of rated load.

(2) Demonstration of the operability of protective devices and interlocks.

(3) Demonstration of the operability of safety devices on equipment.

2. Initial Fuel Loading and Precritical Tests

Licensees should conduct the initial fuel loading cautiously to preclude inadvertent criticality. To load on this basis requires that specific safety measures be established and followed such as (a) ensuring that all applicable technical specification requirements and other prerequisites have been satisfied, (b) establishing requirements for continuous monitoring of the neutron flux throughout the core loading so that all changes in the multiplication factor are observed, (c) establishing requirements for periodic data-taking, and (d) independently verifying that the fuel and control components have been properly installed.

Predictions of core reactivity should be prepared in advance to aid in evaluating the measured responses to specified loading increments. Comparative data of neutron detector responses from previous loadings of essentially identical core designs may be used in lieu of these predictions. Licensees should establish criteria and requirements for actions to be taken if the measured results deviate from expected values. Shutdown margin verifications should be performed at

[12] Regulatory Guide 1.80, "Preoperational Testing of Instrument Air Systems," provides detailed guidance on testing of instrument air systems.

appropriate loading intervals (BWR), including full core shutdown margin tests. It should be established that the required shutdown margin exists, without achieving criticality.

To provide further assurance of safe loading, licensees should establish requirements for the operability of plant systems and components, including reactivity control systems and other systems and components necessary to ensure the safety of plant personnel and the public in the event of errors or malfunctions. The initial core loading should be directly supervised by a Senior Licensed Operator having no other concurrent duties and the loading operation should be conducted in strict accordance with detailed approved procedures. Typical prerequisites, precautions, and details that should be included in the initial fuel loading and precritical check procedures are described in Appendix C to this guide.

After the core is fully loaded, sufficient tests and checks should be performed to ensure that the facility is in a final state of readiness to achieve initial criticality and to perform low-power tests. The list below is illustrative of the types of tests and verifications that should be conducted during or following initial fuel loading:

a. Shutdown margin verification for partially (BWR) and fully loaded core.

b. Testing of the control rod withdrawal and insert speeds and sequencers, control rod position indication, protective interlocks, control functions, alarms, and scram timing (and friction tests for BWRs) of control rods after the core is fully loaded. Scram time tests should be sufficient to provide reasonable assurance that the control rods will scram within the required time under plant conditions that bound those under which the control rods might be required to function to achieve plant shutdown. To the extent practical, testing should demonstrate control rod scram times at both hot zero power and cold temperature conditions, with flow and no-flow conditions in the reactor coolant system as required to bound conditions under which scram might be required. For each test condition, those control rods whose scram times fall outside the two-sigma limit of the scram time data for all control rods should be retested a sufficient number of times (≥ 3 times) to reasonably ensure proper performance during subsequent plant operations. For facilities using more than one type of control element or control rod drive design, scram times should be compared with identical designs (e.g., two control rods attached to a single drive mechanism.)

Additionally, the proper operation of decelerating devices used to prevent mechanical damage to the control rods should be demonstrated during this testing.

c. Final functional testing of the reactor protection system to demonstrate proper trip points, logic, and operability of scram breakers and valves. Demonstrate operability of manual scram functions.

d. Final test of the reactor coolant system to verify that system leak rates are within specified limits.

e. Measurements of the water quality[13] and boron concentration (PWR) of the reactor coolant system.

f. Reactor coolant system flow tests to establish that vibration levels are acceptable, that differential pressures across the fully loaded core and major components in the reactor coolant system are in accordance with design values, and that piping reactions to transient conditions (e.g., pump starting and stopping) and flows are as predicted for all allowable combinations of pump operation. Loss of flow tests should be conducted to measure flow coastdown. (Differential pressure measurements across the fully loaded core and major components need not be repeated for plants using calculation models and designs identical to prototype plants.)

g. Final calibration of source-range neutron flux measuring instrumentation. Verification of proper operation of associated alarms and protective functions of source- and intermediate-range monitors.

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

3. Initial Criticality

Licensees should conduct the initial approach to criticality in a deliberate and orderly manner using the same rod withdrawal sequences and patterns that will be used during subsequent startups. Neutron flux levels should be continuously monitored and periodically evaluated. A neutron count rate at least ½ count per second should register on the startup channels before the startup begins, and the signal-to-noise ratio should be known to be greater than two. All systems required for startup or protection of the plant, including the reactor protection system and emergency shutdown system, should be operable and in a state of readiness. The control rod or poison removal sequence should be accomplished using detailed procedures approved by personnel or groups designated by the licensee. For reactors that will achieve initial criticality by boron dilution, control rods should be withdrawn before dilution begins. The control rod insertion limits defined in the technical specifications should be observed and complied with.

Criticality predictions for boron concentration (PWR) and control rod positions should be provided, and criteria and actions to be taken should be estab-

[13]Design features of BWRs to maintain water quality are discussed in Regulatory Guide 1.56, "Maintenance of Water Purity in Boiling Water Reactors."

lished if actual plant conditions deviate from predicted values. The reactivity addition sequence should be prescribed, and the procedure should require a cautious approach in achieving criticality to prevent passing through criticality on a period shorter than approximately 30 seconds (<1 decade per minute).

4. Low-Power Testing

Following initial criticality, licensees should conduct appropriate low-power tests (normally at less than 5% power) to (a) confirm the design and, to the extent practical, validate the analytical models and verify the correctness or conservatism of assumptions used in the safety analyses for the facility and (b) confirm the operability of plant systems and design features that could not be completely tested during the preoperational test phase because of the lack of an adequate heat source for the reactor coolant system and main steam system.

The listing below is illustrative of the tests that should be conducted if they have not been previously completed during preoperational hot functional testing. Tests that are specific to one type of light-water reactor are noted by the symbols PWR for pressurized water reactors and BWR for boiling water reactors.

a. Determination of boron and moderator temperature reactivity coefficients over the temperature and boron concentration ranges in which the reactor may initially be taken critical. (PWR)

b. Measurements of control rod and control rod bank reactivity worths to (1) ensure that they are in accordance with design predictions and (2) confirm by analysis that the rod insertion limits will be adequate to ensure a shutdown margin consistent with accident analysis assumptions throughout core life, with the greatest worth control rod stuck out of the core. (PWR)

c. Pseudo-rod-ejection test to verify calculational models and accident analysis assumptions. (PWR)

d. Determination that adequate overlap of source- and intermediate-range neutron instrumentation exists and verification that proper operations of associated protective functions and alarms provide for plant protection in the low-power range (if not previously performed).

e. Determination of flux distribution for comparison with distribution assumptions or predictions to provide a check for potential errors in the loading or enrichment of fuel elements or lumped poison elements and to check for mispositioned or uncoupled control rods. Measurements may be performed at a higher power level depending on the sensitivity of incore flux instrumentation.

f. Neutron and gamma radiation surveys.

g. Determination of proper response of process and effluent radiation monitors. To the extent practical, responses of installed process and effluent radiation monitors should be verified by laboratory analyses of samples from the process and/or effluent systems.

h. Chemical and radiochemistry tests and measurements to demonstrate design capability of chemical control systems and installed analysis and alarm systems to maintain water quality within limits in the reactor coolant and secondary coolant systems.

i. Demonstration of the operability of control rod withdrawal and insertion sequencers and control rod withdrawal inhibit or block functions over the reactor power level range during which such features must be operable.

j. Demonstration of the capability of primary containment ventilation system to maintain the containment environment and important components in the containment within design limits with the reactor coolant system at rated temperature and with the minimum availability of ventilation system components for which the system is designed to operate.

k. Demonstration of the operability of steam-driven engineered safety features and steam-driven plant auxiliaries and power conversion equipment.

l. Demonstration of the operability, including stroke times, of main steam line and branch steam line valves and bypass valves used for protective isolation functions at rated temperature and pressure conditions.

m. Demonstration of the operability of main steam line isolation valve leakage control system. (BWR—during hot standby conditions.)

n. Demonstration of the operability of control room computer system.

o. Control rod scram time testing at rated temperature in the reactor coolant system, if not previously conducted.

p. Demonstration of the operability of pressurizer and main steam system relief valves at rated temperature.

q. Demonstration of the operability of residual or decay heat removal systems, including atmospheric steam dump valves (PWR) and turbine bypass valves.

r. Demonstration of the operability of reactor coolant system purification and cleanup systems.

s. Vibration measurements of reactor vessel internals[14] and reactor coolant system components, if not previously conducted.

[14] Regulatory Guide 1.20, "Comprehensive Vibration Assessment Program for Reactor Internals During Preoperational and Initial Startup Testing," should be used as guidance for these measurements.

t. Performance of natural circulation tests of the reactor coolant system to confirm that the design heat removal capability exists or to verify that flow (without pumps) or temperature data are comparable to prototype designs for which equivalent tests have been successfully completed. (PWR)

u. Demonstration of the operability of major or principal plant control systems, as appropriate.

5. Power-Ascension Tests

Licensees should complete low-power tests, as described in the FSAR, and evaluate and approve the low-power test results prior to beginning power-ascension tests. Power-ascension tests should demonstrate that the facility operates in accordance with design both during normal steady-state conditions and, to the extent practical, during and following anticipated transients. To validate the analytical models used for predicting plant responses to anticipated transients and postulated accidents, these tests should establish that measured responses are in accordance with predicted responses. The predicted responses should be developed using real or expected values of items such as beginning-of-life core reactivity coefficients, flow rates, pressures, temperatures, pump coastdown characteristics, and response times of equipment and the actual status of the plant and not those values or plant conditions assumed for conservative evaluations of postulated accidents.

Tests and acceptance criteria that demonstrate the ability of major or principal plant control systems to automatically control process variables within design limits should be prescribed. This should provide assurance that the integrated dynamic response of the facility is in accordance with design for plant events such as reactor scram, turbine trip, reactor coolant pump trip, and loss of feedwater heaters or pumps. Testing should be sufficiently comprehensive to establish that the facility can operate in all operating modes for which the facility has been designed to operate; however, tests should not be conducted or operating modes or plant configurations established if they have not been analyzed or if they fall outside the range of assumptions used in analyzing postulated accidents in the FSAR for the facility.

Appropriate consideration should be given to testing at the extremes of possible operating modes for facility systems. Testing under simulated conditions of maximum and minimum equipment availability within systems should be accomplished if the facility is intended to be operated in these modes, e.g., testing with different reactor coolant pump configurations, single loop reactor coolant system operation, operation with the minimum allowable number of pumps, heat exchangers, or control valves in the feedwater, condensate, circulating, and other cooling water systems.

The following list is illustrative of the types of performance demonstrations, measurements, and tests that should be included in the power-ascension test phase. Parenthetical numbers following the items listed below indicate the approximate power levels for conducting the tests. If no number follows the listed item, the test should be performed at the lowest practical power level. Tests that are specific to one type of light-water reactor are noted by the symbols PWR for pressurized water reactors and BWR for boiling water reactors.

a. Determine that power reactivity coefficients (PWR) or power vs. flow characteristics (BWR) are in accordance with design values. (25%, 50%, 75%, 100%)

b. Determine that steady-state core performance is in accordance with design. Sufficient measurements and evaluations should be conducted to establish that flux distributions, local surface heat flux, linear heat rate, departure from nucleate boiling ratio (DNBR), radial and axial power peaking factors, maximum average planar linear heat generation rate (MAPLHGR), minimum critical power ratio (MCPR), quadrant power tilt, and other important parameters are in accordance with design values throughout the permissible range of power-to-flow conditions. (25%, 50%, 75%, 100%)

c. Demonstrate that core limits will not be exceeded during or following exchange of control rod patterns that will be permitted during operation (the demonstration test should be conducted at the highest power level at which control rod pattern exchanges will be allowed during plant operation). (BWR)

d. Demonstrate the capabilities of plant features such as part-length control rods and of procedures for controlling core xenon transients. Acceptance criteria for the test should account for expected changes in core performance throughout core life. (75%–85%) (PWR) Results of xenon oscillation tests performed at plants of essentially identical design can be used to substitute for or supplement this testing.

e. Pseudo-rod-ejection test to validate the rod ejection accident analysis. (Greater than 10% power with control rod banks at the full power rod insertion limit) (PWR) This test need not be repeated for facilities using calculational models and designs identical to prototype facilities.

f. Demonstrate that core thermal and nuclear parameters are in accordance with predictions with a single high worth rod fully inserted and during and following return of the rod to its bank position. (50%) (PWR)

g. Demonstrate that control rod sequencers, control rod worth minimizers, and rod withdrawal block functions operate in accordance with design, if not previously demonstrated. (25%)

h. Check rod scram times from data recorded during scrams that occur during the startup test phase to determine that the scram times remain within allowable limits.

i. Demonstrate capability and/or sensitivity, as appropriate for the facility design of incore and excore neutron flux instrumentation, to detect a control rod misalignment equal to or less than the technical specification limits. (50%, 100%) (PWR)

j. Verify that plant performance is as expected for rod runback and partial scram.

k. Demonstrate that ECCS high-pressure coolant injection systems can start under simulated accident conditions and inject into the reactor coolant system as designed. (At a power level in the 25%–50% range for BWRs with steam-driven pumps and for BWRs with electric-driven pumps, if not previously conducted.) (BWR) (For PWRs, the testing should be in accordance with Regulatory Guide 1.79.[7])

l. Demonstrate design capability of all systems and components provided to remove residual or decay heat from the reactor coolant system, including turbine bypass system, atmospheric steam dump valves, residual heat removal (RHR) system in steam condensing mode, reactor core isolation cooling (RCIC) system, and auxiliary feedwater system. Testing of the auxiliary feedwater system should include provisions that will provide reasonable assurance that excessive flow instabilities (e.g., water hammer) will not occur during subsequent normal system startup and operation. (Prior to exceeding 25% power)

m. Demonstrate that the reactor coolant system operates in accordance with design. Sufficient measurements and evaluations should be conducted with the plant at steady-state conditions to establish that flow rates, reverse flows through idle loops or jet pumps, core flow, differential pressures across the core and major components in the reactor coolant system, vibration levels of reactor coolant system components, and other important parameters are in agreement with design values, if not previously demonstrated.

n. Obtain baseline data for reactor coolant system loose parts monitoring system, if not previously done.

o. Calibrate instrumentation and demonstrate the proper response of reactor coolant leak detection systems, if not previously demonstrated.

p. Conduct vibration monitoring of reactor internals during steady-state and transient operation to establish that design limits are not exceeded (see Regulatory Guide 1.20[1]), if this testing has not been previously completed.

q. Verify the proper operation of failed fuel detection systems. (25%, 100%)

r. Verify by review and evaluation of printouts and/or cathode ray tube (CRT) displays that the control room or process computer is receiving correct inputs from process variables, and validate that performance calculations performed by the computer are correct. (25%, 50%, 75%, 100%)

s. Calibrate, as necessary, and verify the performance of major or principal plant control systems, including T-average controller; automatic reactor control system; boron addition systems (PWR); integrated control system; pressurizer control system; reactor coolant flow control system; main, auxiliary, and emergency feedwater control systems; hotwell level control systems; steam pressure control systems; and reactor coolant makeup and letdown control systems. (25%, 50%, 75%, 100%)

t. If not previously accomplished, verify, as appropriate, the operability, response times, relieving capacities, setpoints, and reset pressures for pressurizer relief valves; main steam line relief valves; atmospheric steam dump valves; turbine bypass valves; and turbine stop, intercept, and control valves. (25%) (During transient tests, verify operability, setpoints, and reset pressures of relief valves.)

u. Verify operability and response times of main steam line isolation and branch steam line isolation valves. For PWRs, justification for conducting this test at low power and/or a description of design qualification tests for valves of the same size and design may be submitted. (25%)

v. Verify that the main steam system and feedwater systems operate in accordance with design performance requirements. (25%, 50%, 75%, 100%)

w. Demonstrate adequate beginning-of-life performance margins for shielding and penetration cooling systems to provide assurance that they will be capable of maintaining temperatures of cooled components within design limits with the minimum design capability of cooling system components available. (100%)

x. Demonstrate adequate beginning-of-life performance margins for auxiliary systems required to support the operation of engineered safety features or to maintain the environment in spaces that house engineered safety features to provide assurance that the engineered safety features will be capable of performing their design functions over the range of design capability of operable components in these auxiliary systems. (50%, 100%)

y. Calibrate, as required, and verify the proper operation of important instrumentation systems, including reactor coolant system flow; core flow, level, and temperature; incore and excore neutron flux; and instruments and systems used to calculate thermal power level (heat balance) of the reactor. (25%, 50%, 75%, 100%)

z. Demonstrate that process and effluent radiation monitoring systems are responding correctly by performing independent laboratory or other analyses.

a.a. Demonstrate that chemical and radiochemical control systems function in accordance with design, and sample to establish that reactor coolant system and secondary coolant system limits are not exceeded. (25%, 50%, 75%, 100%)

b.b. Conduct neutron and gamma radiation surveys to establish the adequacy of shielding and to identify high radiation zones as defined in 10 CFR Part 20, "Standards for Protection Against Radiation." (50%, 100%)

c.c. Demonstrate that gaseous and liquid radioactive waste processing, storage, and release systems operate in accordance with design.

d.d. Demonstrate the capability to shut down and maintain the reactor in a hot standby condition from outside the control room, using the minimum shift crew, as well as the potential capability for placing the reactor in a cold shutdown condition.[15] (Greater than or equal to 10% generator load)

e.e. Demonstrate that primary containment inerting and purge systems operate in accordance with design, if not previously demonstrated.

f.f. Demonstrate or verify that important ventilation and air-conditioning systems, including those for the primary containment and steam line tunnel, continue to maintain their service areas within the design limits. (50%, 100%)

g.g. If appropriate for the facility design, conduct tests to determine operability of equipment provided for anticipated transient without scram (ATWS), if not previously done. (25%)

h.h. Demonstrate that the dynamic response of the plant to the design load swings for the facility, including step and ramp changes, is in accordance with design. (25%, 50%, 75%, 100%)

i.i. Demonstrate that the dynamic response of the plant is in accordance with design for limiting reactor coolant pump trips and/or closure of reactor coolant system flow control valves (BWR). The method for initiating the pump trip or control valve closure should result in the fastest credible coastdown in flow for the system. (100%)

j.j. Demonstrate that the dynamic response of the plant is in accordance with design for a condition of loss of turbine-generator coincident with loss of all sources of offsite power (i.e., station blackout). (In the 10-to-20% power range)

k.k. Demonstrate that the dynamic response of the plant is in accordance with design for the loss of or bypassing of the feedwater heater(s) from a credible single failure or operator error that would result in the most severe case of feedwater temperature reduction. (50%, 90%)

l.l. Demonstrate that the dynamic response of the plant is in accordance with design requirements for turbine trip. This test may be combined with item n.n. below if a turbine trip is initiated directly by all remote-manual openings or automatic trips of the generator main breaker, i.e., a direct electrical signal, not a secondary effect such as a turbine overspeed. (100%)

m.m. Demonstrate that the dynamic response of the plant is in accordance with design for the case of automatic closure of all main steam line isolation valves. For PWRs, justification for conducting the test at a lower power level, while still demonstrating proper plant response to this transient, may be submitted for NRC staff review. (100%)

n.n. Demonstrate that the dynamic response of the plant is in accordance with design for the case of full load rejection. The method used for opening of the generator main breakers (by simulating an automatic or manual trip) should be selected such that the turbine-generator will be subjected to the maximum credible overspeed condition. The test should be initiated with the plant's electrical distribution system aligned for normal full power operation. (100%)

o.o. Verify by observations and measurements, as appropriate, that piping and component movements, vibrations, and expansions are acceptable for (1) ASME Code Class 1, 2, and 3 systems, (2) other high-energy piping systems inside Seismic Category I structures, (3) high-energy portions of systems whose failure could reduce the functioning of any Seismic Category I plant feature to an unacceptable level, and (4) Seismic Category I portions of moderate-energy piping systems located outside containment. Tests performed earlier in the test program need not be repeated.

[15] Regulatory Guide 1.68.2, "Initial Startup Test Program to Demonstrate Remote Shutdown Capability for Water-Cooled Nuclear Power Plants," should be used as guidance for demonstration of this capability.

APPENDIX B

INSPECTION BY THE OFFICE OF INSPECTION AND ENFORCEMENT

The NRC Office of Inspection and Enforcement conducts a series of inspections of the initial test program beginning before preoperational testing and continuing throughout startup. These inspections are intended to determine, on a selective basis, whether the applicant's test 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 inspection effort focuses on the manner in which the applicant has fulfilled his commitments for ensuring that adequate programs have been developed and carried out, as exemplified by the methods he has used for establishing procedures and the results that the methods have produced.

For the NRC to implement this inspection program, the applicant should have copies of the test procedures available for examination by the NRC regional personnel approximately 60 days prior to the scheduled performance of the preoperational tests, and, not less than 60 days prior to the scheduled fuel loading date, copies of procedures for fuel loading, initial startup testing, and supporting activities. Drafts of these procedures should be made available as early as practical. Examination by NRC personnel does not constitute approval of the procedures. The possession of such procedures by NRC personnel should not impede the revision, review, and refinement of the procedures by the applicant.

The inspections by NRC personnel generally 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 ensure 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 test procedures contain appropriate acceptance criteria, and whether the procedures require the documentation of sufficient information to permit adequate evaluation of the results of the test. Also, an examination, on a selective basis, that changes to approved test procedures have been reviewed and authorized.

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 item 1 above.

4. Confirmation that the applicant has evaluated the results of the testing and has concluded that the results are satisfactory and meet the acceptance criteria or has initiated corrective action.

5. Confirmation that the applicant has reviewed the results of the 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 are valid.

7. Witnessing parts of preoperational, fuel loading, and startup 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 and precritical tests, startup-to-critical low-power tests, and power-ascension tests.

1. Preoperational Test Procedures

a. Prerequisites

Each test of the operation of a system normally requires that certain other activities be performed first, e.g., completion of construction, construction and/or preliminary tests, inspections, and certain other preoperational tests or operations. The preoperational testing procedures should include, as appropriate, specific prerequisites. The following are typical prerequisites:

(1) Confirmation that construction activities associated with the system have been completed and documented. Field inspections should have been made to ensure that the equipment is ready for operation, including inspection for proper fabrication and cleanness; checkout of wiring continuity and electrical protective devices; adjustment of settings on torque-limiting devices and calibration of instruments; verification that all instrument loops are operable and respond within required response times; and adjustment and settings of temperature controllers and limit switches.

(2) Confirmation that test equipment is operable and properly calibrated.

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

(a) Valves[1]
- Leakage
- Opening and closing times
- Valve stroke
- Position indication
- Torque- and travel-limiting settings
- Operability against pressure

(b) Pumps[1]
- Direction of rotation
- Vibration
- Motor load versus time
- Seal or gland leakage
- Seal cooling
- Flow and pressure characteristics
- Lubrication
- Acceleration and coastdown

(c) Motors and Generators
- Direction of rotation
- Vibration
- Thermal overload protection, margins between setpoints, and full load running amps
- Lubrication
- Megger or hi-pot tests
- Supply voltage
- Phase-to-phase checks
- Neutral current
- Acceleration under load
- Temperature rise
- Phase currents
- Load acceptance capability versus both time and load (generators)

(d) Piping and Vessels
- Hydrostatic test
- Leaktightness
- Cleaning, flushing, and layup[2]
- Clearance of obstructions
- Support adjustments
- Proper gasketing
- Bolt torque
- Insulation
- Filling and venting

(e) Electrical and Instrumentation and Control
- Verification that sensing lines are clear for process sensors and that instrument root valves are open
- Voltage
- Frequency
- Current
- Circuit breaker operation
- Power source identification
- Bus transfers
- Trip settings
- Operation of interlocks, prohibits, and permissives
- Operation of logic systems
- Calibration
- Control transformer settings
- Temperature effects
- Range checks
- Response times

[1] Section XI of the ASME Boiler and Pressure Vessel Code provides requirements for inservice testing of pumps and valves in nuclear power plants. The applicant should examine these requirements for applicability to its preoperational test programs.

[2] Regulatory Guide 1.37, "Quality Assurance Requirements for Cleaning of Fluid Systems and Associated Components of Water-Cooled Nuclear Power Plants," should be used as guidance.

b. Test Objectives

Objectives of the test should be stated. Many systems tests will be intended to demonstrate that each of several initiation events will produce one or more expected responses. These initiating events and the corresponding responses should be identified.

c. Special Precautions

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

d. System Initial Conditions

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

e. Environmental Conditions

Most tests will be run at ambient conditions; however, procedures should include provisions to test the equipment under environmental conditions as close as practical to those the equipment will experience in both normal and accident situations.

f. Acceptance Criteria

The criteria against which the success or failure of the test will be judged should be clearly identified and should account for measurement errors and uncertainties. In some cases, these will be qualitative criteria. In other cases, quantitative values with appropriate tolerances should be designated as acceptance criteria.

g. Data Collection

The test procedures should prescribe the data to be collected and the form in which the data are to be recorded. All entries should be permanent entries. The administrative controls should include an acceptable method for correcting an entry.

h. Detailed Procedures

Detailed step-by-step procedures should be provided for each test. To the extent practical, the test procedures should use approved normal plant operating procedures.

Each procedure should require necessary nonstandard arrangements to be restored to their normal status after the test is completed. Control measures such as jumper logs and checkoff lists 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 ensure that temporary arrangements do not invalidate the test by interference with the proper testing of the as-built system.

i. Documentation of Test Results

Records should identify each observer and/or data recorder participating in the test, the type of observation, the identifying numbers of test or measuring equipment, 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.

2. Fuel Loading

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

a. Prerequisites for Fuel Loading

(1) The composition, duties, and emergency procedure responsibilities of the fuel handling crew should be specified.

(2) Radiation monitors, nuclear instrumentation, manual initiation, and other devices to actuate building evacuation alarm and ventilation control should have been tested and verified to be operable.

(3) The status of all systems required for fuel loading should be specified.

(4) Inspections of fuel, control rods, and poison curtains should have been made.

(5) 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.

(6) A response check of nuclear instruments to a neutron source should be required within 8 hours prior to loading (or resumption of loading, if delayed for 8 hours or more).

(7) The status of containment should be specified and established.

(8) 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.

(9) The vessel water level should be established and the minimum level prescribed for fuel loading and unloading.

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

(11) The emergency boron addition system (or other negative reactivity insertion system) should be operable.

(12) Fuel handling equipment should be checked and dry runs performed.

(13) 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).

(14) Water quality should be established and limits identified.

(15) Fuel loading boron concentration should be established and verified.

b. Procedure Details

The procedure should include instructions or information for the following areas:

(1) 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.

(2) The maintaining of a display for indicating the status of the core and fuel pool. Maintaining appropriate records of core loading.

(3) Proper seating and orientation of fuel and components. A visual check of each assembly in each core position should be specified.

(4) Functional testing of each control rod immediately following fuel loading. (BWR)

(5) 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.)

(6) Flux monitoring, including counting times and frequencies and rules for plotting inverse multiplication and interpreting plots. The counting period for count rates should be specified. An inverse multiplication plot should be maintained.

(7) The expected subcritical multiplication behavior.

(8) 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. Shutdown margin verifications should not involve a planned approach to criticality using nonstandard rod patterns or with operational interlocks bypassed.

(9) 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.

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

(11) The maintaining of continuous voice communication between control room and loading station.

(12) Minimum crew required to load fuel. The presence of at least two persons at any location where fuel handling is taking place should be required. A Senior Reactor Operator with no other concurrent duties should be in charge.

(13) 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.

(14) Approvals required for changing the procedure.

c. Limitations and Actions

(1) Criteria for stopping fuel loading should be established. Some circumstances that 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.

(2) Criteria for emergency boron injection should be established.

(3) Criteria for containment evacuation should be established.

(4) Action to be followed in the event of fuel damage should be outlined.

(5) 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 should be listed.

3. Initial Criticality 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 1, "Preoperational Test Procedures," of this appendix is also considered applicable. This procedure should include steps to ensure that the startup will proceed in a deliberate and

orderly manner, that the changes in reactivity will be continuously monitored, and that inverse multiplication plots will be maintained and interpreted. A critical rod position (boron concentration) should be predicted so that any anomalies may be noted and evaluated. 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.

Nuclear instruments should be calibrated. A neutron count rate (of at least ½ count per second) should register on startup channels before the startup begins, and the signal-to-noise ratio should be known to be greater than two. A conservative startup rate limit (no shorter than approximately a 30-second period) should be established. High-flux scram trips should be set at their lowest value (approximately 5%–20%).

4. Low-Power and Power-Ascension Procedures

This section provides guidance for the planning and preparation of procedures for conducting the initial ascension to rated power. The guidance provided in Section 1, "Preoperational Test Procedures," of this appendix is also considered applicable. The program should be planned to increase power in discrete steps. Major testing should be performed at approximately 25%, 50%, 75%, and 100% power levels.

If tests intended to verify that movements and expansion of equipment are in accordance with design are not conducted during hot functional tests and must be delayed until generation of nuclear heat, the first power level for conducting such tests should be as low as practical (approximately 5%).

Individual test procedures should include instructions and precautions for establishing special conditions necessary for conducting tests. The individual procedures should highlight these special conditions and specifically provide for restoration to normal following the test. The overall or governing power-ascension test plan should typically require the following operations to be performed at appropriate steps in the power-ascension test phase:

a. Conduct any tests that are scheduled at the test condition or power plateau.

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

c. Determine reactor power by heat balance, calibrate nuclear instruments accordingly, and determine that adequate instrumentation overlap between the intermediate- and power-range detectors exists.

d. 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 unless technical specification limits are more restrictive.

e. Perform general surveys of plant systems and equipment to determine that they are operating within expected values.

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

g. Perform reactor coolant leak checks.

h. Review the completed testing program at each plateau, perform preliminary evaluations, including extrapolation of minimum DNBR and maximum linear heat rate values to the high-flux trip setpoint for the next power level, and obtain the required management approvals before ascending to the next power level or test condition.