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In the event of any differences in interpretation of this guide, the Finnish version shall take precendence over this translation.

# PREOPERATIONAL AND START-UP TESTING OF NUCLEAR POWER PLANTS

## 1 GENERAL

One objective of the preoperational and start-up testing of nuclear power plants is to attain additional assurance that

- the plant has been designed and constructed so as to make it possible to operate it safely
- the operating modes of the plant permitted by the Technical Specifications are safe, and the operating instructions of the plant are adequate for maintaining these modes
- the operating personnel is familiar with the plant and capable of operating the plant in a safe manner

The Institute of Radiation Protection (IRP) supervises the preoperational and start-up testing of nuclear power plants by reviewing the general start-up test plans submitted as part of the preliminary and final safety analysis reports, by reviewing testing programs, by witnessing the conduct of tests at the power plant and by examining test reports.

"Start-up testing", as used in this guide, means all phases of start-up testing. Terms "program" or "start-up testing program" mean a detailed testing program; the requirements concerning such a program are set forth in section 3. The start-up testing is divided into the following major phases:

- system performance tests
- initial fuel loading and precritical tests of reactor systems
- initial criticality and low-power testing
- power ascension tests

Each major phase of testing is defined in greater detail in relevant sections of this guide. The major phases are subdivided into tests. A test means a part of start-up testing for which a separate, detailed test program is prepared. In the case of system

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performance tests, one test may, for example, consists of all those measures performed to demonstrate that the boron control system conforms to established requirements. In the case of power ascension tests, one test may consists of a turbine trip from a specified power level, or of a measurement of the reactivity worth of the control rods.

## 2 START-UP TESTING PLANS

Start-up testing plans shall be complied early enough to be presented in the safety analysis reports. Their scope is determined by the requirements of Chapter 14 of reference /1/. Thus, the following items of information shall be included in the Preliminary Safety Analysis Report:

- the scope of start-up testing including the resposibilities assigned to the various organizations participating in the preparation of test programs, execution of testing and review of test results
- guides and regulations to be complied with in planning start-up testing
- utilization of experiences available from similar plants in the planning of start-up test programs
- the lengt of time required by the major phases of testing
- identification of items requiring special attention because of their prototype nature including separate summaries of the tests to be conducted on these items
- a preliminary plan for evaluation of the role of start-up testing in determining the adequacy of the operating instruction of the plant
- the number of personnel needed in the various organizations during start-up testing

The plannin of pre-operational and start-up testing must proceed at such a pace that the following facts are known when the Final Safety Analysis Report is submitted

- the major phases of start-up testing including test objectives
- identification of organizations participating in start-up testing including their responsibilities, the definition of duties assigned to the most important individuals

- the procedure adhered to in the preparation of detailed test programs including the division of duties

- the authorities of the various persons during start-up testing, the principles established to assure conformance to test programs as well as a description of the procedure for modifying test programs during execution

- the procedure for evaluating test results including the division of duties as well as actions to be taken in case the results of some test do no meet the acceptance criteria

- a system for retention of test records

- guides and regulations to be complied with in the preparation of detailed start-up test programs

- utilization of experiences available from similar plants in the preparation of detailed test programs

- a schedule for development of plant operating instructions and the role of start-up testing in determining the adequacy of these instructions

- a testing schedule defining the duration and sequence of the various testing phases including deadlines for completion of test programs

- a summary plan for system performance tests and precritical tests of reactor systems including the names of the detailed test procedures to be prepared for each test, prerequisites set for the conduct of the test if any,test objectives and a brief description of scope of tests and acceptance criteria

- procedures to be followed in core loeading and achieving criticality including safety measures and precautions

- a summary plan for low-power and power ascension tests including the names of the detailed test procedures to be prepared for each test, test objectives, a brief description of the scope and acceptance criteria of the tests as well as a list of the power levels at which the test is intended to be conducted

## 3 SYSTEM PERFORMANCE TESTS

System performance tests mean all tests performed prior to fuel loading as well as those tests of individual auxiliary systems that can be conducted only during loading or thereafter.

System performance tests shall demonstrate that each system important to safety, and each part of such a system separately, can fulfil the designed safety functions. Also, it shall be demonstrated that the various systems are capable of functioning together as designed. To the extent feasible, the tests shall provide confidence that the systems will perform adequately in normal conditions as well as in those accident conditions in which they are required to function.

System performance tests shall include the tests that are listed under item A of Appendix A to reference/2/ and that are suitable for the plant type involved. Attention shall be paid to the more delailed requirements set forth in references /3/, /4/, /5/, /6/ and /7/, as applicable, when palnning tests. In case there are Safety Class 1, 2 or 3 systems at the plant that are not covered by the above references, the tests to be conducted on such systems shall be separately agreed upon with the IRP. A system performance test may be carried out after commencement of core loading only for a special reason which must be substantiated for each test in the Final Safety Analysis Report.

For each test, there shall be a detailed test program which, in regard to its scope, conforms to the requirements of item A of Appendix C to reference /2/. The program is divided into the following main parts in accoradance with these requirements:

- prerequisites for test performance
- test objectives
- system initial conditions
- environmental conditions
- acceptance criteria
- data collection
- special precautions
- detailed procedures
- documentation of test results

Also, the program shall include a description of measuring equipment or systems that may be needed and that are not part of the fixed plant equipment.

The tests shall be conducted in accordance with the programs and non-conformances and their causes shall be documented. All test results shall be recorded on forms or drawings prepared in advance.

In addition to final test results, the test report shall describe the corrective actions taken during the start-up testing that have been necessary for attaining acceptable results.

On the basis of the summary test plan presented in the Final Safety Analysis Report, the licensee shall agree with the IRP on those tests whose programs will be submitted to the IRP for approval. As a rule, IRP approval is required for all tests to be conducted on Safety Class 1, 2 or 3 systems. If test programs are written in two stages, first more general preliminary programs and then detailed final programs, the preliminary programs can be sent to IRP for comments. Thus potential requirements for increasing the scope of testing can be presented earlier, and the review of detailed test programs will require less time.

The Insitute of Radiation Protection witnesses system performance testsat the nuclear power plant to the extent it considers appropriate. As a rule, the IRP will witness all tests conducted on Class 1 and 2 systems including some of Class 3 systems tests. For the purpose of witnessing tests, the IRP shall be provided with a test schedule in good time. The IRP shall be notified of all changes in the schedule without delay.

Test reports shall be submitted to the IRP for approval on all those tests for the programs of which an prior IRP approval was required.

If an IRP approval of the program is required, the test may be begun only after receiving the decision of approval. "Beginning the test" means the first action which is taken to demonstrate the performance capability of an item and the results of which are recorded for the purposes of subsequent reviews. In other words, calibration of instrumentation, flushing the piping and other preparatory measures including preliminary tests are permitted prior to approval of the program. It should be pointed out, however, that each pressure vessel in the plant is subject to a verification of the commissioning inspection in accordance with Guide YVL 3.7

before the vessel may by operated under pressure. Absence of an IRP representative does not prevent the licensee from conducting the test, provided that the IRP has been notified thereof well in advance. This does not apply to the functional tests of pressure vessel equipment that are part of the commissioning inspection pursuant to Guide YVL 3.7 and that are witnessed by the IRP independently of the Safety Class.

The approval of test reports on system performance tests conducted prior to fuel loading is one precondition for that the IRP regards the overall inspection of the nuclear power plant referred to in Guide YVL 1.1 as completed and submits the inspection records necessary for the issuance of an operating license to the Ministry of Trade and Industry.

## 4 FUEL LOADING AND PRECRITICAL TESTS OF REACTOR SYSTEMS

Fuel loading is regarded as beginning at the moment when the first fuel bundle is inserted into the reactor vessel. After completion of loading, those systems that can be made operational only after the primary coolant system is closed shall be tested. In this guide the tests to be conducted on these systems are called pre-critical tests of reactor systems.

Fuel loading shall be conducted as cautiosuly as if it were the first time that the reactor type in question was being loaded. Neutron flux and gamma radiation levels shall be continuously monitored in the vicinity of the reactor. Neutron flux monitoring system shall be fitted with an audible-alarm device. More detailed requirements concerning fuel loading are not presented in this guide, since different vendors employ different loading methods. The acceptablity of the method is considered on a case-by-case basis in connection with the review of the loading program.

A procedure for loading shall be prepared, specifying

- a summary of the equipment needed for monitoring neutron fluc and gamma radiation and other potential measuring equipment needed during loading
- number and duties of personnel participating in loading
- the status of reactor containment including all systems inside it during loading
- detailed loading instructions

- special safety regulations and precautions to be adhered to during loading

Unanticipated occurences taking place during fuel loading that may affect fuel integrity shall be recorded.

It must be verified upon completion of loading that each fuel bundle is in correct place and position.

The precritical tests of reactor systems shall include the tests that are listed under item B of Appendix A to reference /2/ and that are relevant for the plant type involved. The programs, conduct and reporting of these tests are subject to the same requirements as apply to system performance tests as presented in section 3 of this guide.

An IRP approval is required for the loading procedure and all precritical tests of reactor systems. The IRP witnesses loading and inspects thereafter that each fuel bundle is in its right place as designed. The IRP witnesses precritical tests of reactor systems as it considers appropriate. The test reports of all these tests shall be submitted to the IRP for approval.

Fuel loading may be started when the Ministry of Trade and Industry has issued the operating license for the plant and the IRP approved the loading procedure.

The primary coolant system may be closed and the precritical tests of reactor systems commenced after the IRP has inspected the arrangement of fuel bundles and approved the precrtitical test programs.

When results conforming to the established acceptance criteria have been attained in the preciritical tests of reactor systems, an application for a permission to bring the reactor critical and conduct low-power tests can be filed with the IRP. The application shall provide

- assurance that the results of all the tests performed until then fulfil the acceptance criteria

- information on the maximum low-power level desired

The reports of preciritical tests of reactor systems shall be enclosed with the application, or equivalent documentation must be presented to an IRP representative on site. In the latter case, the test report shall be submitted to the IRP within one month following the granting of the aforementioned permission, in which case the approval of the report is only a confimation entitling the licensee to continue start-up testing as planned.

## 5 INITIAL CRITICALITY AND LOW-POWER TESTS

The process of bringing the reactor critical is regarded as beginning when

- boron dilution is commenced in a pressurized water reactor
- the withdrawal of the first control rod is commenced in a boiling water reactor.

Low-power tests mean tests where the highest permissible reactor power is limited to 5 % of nominal power.

The requirements presented under item C of Appendix C to reference /2/ shall be taken into account when bringing the reactor critical. The procedure shall be described in a detailed program which meets, where applicable, the requirements set for system performance test programs.

Low-power tests shall include tests that are listed under item C of Appendic A to reference /2/ and that are suitable for the plant type involved. The programs, conduct and reports of these tests are subject to the same requirements that apply to system performance tests presented in section 3 of this guide.

IRP approval is required for the procedure for bringing the reactor critical as well as for low-power test programs. The IRP witnesses the process of bringing the reactor critical and low-power tests as it deems appropriate. Reports of low power tests shall be submitted to the IRP for approval.

Bringing the reactor critical may be initiated after the IRP has given its permission and approved the program describing the related pocedure. The same permission is valid for low-power tests as well, provided that the associated test programs have been approved.

After attaining results conforming to the acceptance criteria, the licensee may ask the IRP for a permission to use higher power levels. The following information shall be provided in the application

- assurance that the results of all the tests performed until then fulfil the acceptance criteria
- the maximum power level desired

A test report of low-power tests shall be enclosed with the application, or equivalent documentation must be presented to an IRP representative on site. In the latter case, the test report shall be submitted to the IRP within one month following the granting of the aforementioned permission, in which case the approval of the report is only a confimation entitling the licensee to continue the start-up testing as planned.

## 6 POWER ASCENSION TESTS

In power ascension tests, the performance of the plant is tested at different power levels, for example 10 %, 25 %, 50 %, 75 % and 100 % of the nominal power. The power levels are determined by the license applicant and there shall be at least four of them.

Power ascension tests shall include the tests that are listed under item D of Appendix A to reference /2/ and that are relevant for the plant type involved. The power levels suggested for each test in the aforementioned list are not binding but can be taken as recommendations. The programs, conduct and reporting of power ascension tests are subject to the same requirements as apply to the system performance tests as presented in section 3 of this guide. In addition to actual tests, the inspections required by item D of Appendix C to reference /2/ shall be conducted at each power level.

IRP approval is required for power ascension test programs. The IRP witnesses the tests as it deems appropriate. Test reports must be submitted to the IRP for approval.

During power ascension tests, power may be increased to a new, higher level after the IRP has given its permission and approved the procedures for the tests to be conducted at this level. The highest allowable power level may in each case be defined as somewhat higher than the level at which the tests are carried out. The purpose of this arrangement is to make allowance for the inaccuracy of measurements and control.

After attaining results conforming to the acceptance cirteria at a certain power level, the licensee may apply to the IRP for a permission to increase the plant power. The same procedure is adhered to as when going over from low-power tests to power ascension tests.

7 REFERENCE

1 Standard Format and Content of Safety Analysis Reports for Nuclear Power Plants, Regulatory Guide 1.70, U.S. Nuclear Regulatory Commission, Rev. 2, September 1975.

2 Preoperational and Initial Startup Test Programs for Water-Cooled Power Reactors, Regulatory Guide 1.68, U.S. Nuclear Regulatory Commission.

3 Comprehensive Vibration Assessment Program for Reactor Internals During Preoperational and Initial Startup Testing, Regulatory Guide 1.20, U.S. Nuclear Regulatory Commission.

4 Preoperational Testing of Redundant On-Site Electric Power Systems to Verify Proper Load Group Assignments, Regulatory Guide 1.41, U.S. Nuclear Regulatory Commission.

5 Preoperational and Initial Startup Testing of Feedwater and Condensate Systems for Boiling Water REactor Power Plants, Regulatory Guide 1.68.1, U.S. Nuclear Regulatory Commission.

6 Preoperational Testing of Emergency Core Cooling Systems for Pressurized Water Reactors, Regulatory Guide 1.79, U.S. Nuclear Regulatory Commission.

7 Preoperational Testing of Instrument Air Systems, Regulatory Guide 1.80, U.S. Nuclear Regulatory Commission.