Pre-operational and start-up testing of nuclear power plants

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Authorization

By virtue of section 55, second paragraph, point 3 of the Nuclear Energy Act (990/91) and section 29 of the Council of State Decision (395/91) on the General Regulations for the Safety of Nuclear Power Plants, the Finnish Centre for Radiation and Nuclear Safety issues detailed regulations concerning the safety of nuclear power plants.

The YVL Guides are rules an individual licensee or any other organization concerned shall comply with, unless the Finnish Centre for Radiation and Nuclear Safety has been presented with some other acceptable procedure or solution by which the safety level set forth in YVL Guides is achieved.

1 General

In accordance with sections 2 and 8 of the Nuclear Energy Act, the construction and operation of a nuclear power plant are subject to licencing. Licences are granted by the Council of State. The pre-operational and start-up testing of nuclear power plants is an essential part of plant commissioning. The licencing procedure and regulatory control of commissioning are described in Guide YVL 1.1.

The general requirements for and regulatory control of nuclear power plant pre-operational and start-up testing are presented in this Guide. For applicable parts, this Guide is also concerned with testing after modifications made during plant operation.

Pre-operational and start-up testing aims to demonstrate that the plant has been constructed and operates according to the design intent. The principal stages of testing are as follows:

- system performance tests
- fuel loading and reactor system pre-critical tests
- initial criticality and low-power tests
- power tests.

System performance tests mean tests conducted prior to fuel loading and those individual tests of auxiliary systems which can be conducted only during fuel loading or after it. Reactor system pre-critical tests mean loading measures and tests of systems which can be made ready for operation only during primary circuit closure. Low-power tests mean tests during which reactor power does not exceed 5 % of rated power.

The principal stages of pre-operational and start-up testing are divided into sub-stages. One sub-stage is part of the pre-operational and start-up test and a detailed test programme is drawn up for it. During system performance tests one sub-stage may comprise e.g. all measures to demonstrate that the boron control system meets the requirements made of it. During power testing one sub-stage may be e.g. a turbine trip test.

The Finnish Centre for Radiation and Nuclear Safety controls nuclear power plant pre-operational and start-up testing by reviewing the general test plans submitted as part of the preliminary and final safety analysis report; by reviewing test programmes; by witnessing tests at the plant and by reviewing the documentation of test results.

For applicable parts, this Guide is also observed in the regulatory control of pre-operational and start-up testing of other nuclear facilities.

2 General pre-operational and start-up test objectives

The scope of pre-operational and start-up testing shall be such that the plant can be ascertained to function according to the design intent and that potential errors in design and construction, observable by testing, are identified. In connection with pre-operational and start-up testing, the documentation and instructions pertinent to plant systems, structures, components and their operation and periodic tests shall be given the final touch. It shall be ensured that the instructions are free from error; their clarity and unambiguity shall also be ascertained.

During pre-operational and start-up testing, the training given to operators shall be complemented and its sufficiency ascertained. At the same time, the suitability for their purpose of the monitoring and control equipment required during operation shall be ascertained.

In connection with the tests, the operating parameters of systems and components shall be adjusted and quantitative basic data collected which will be the starting point later for the assessment of periodic test reports.

3 Pre-operational and start-up test plans

Pre-operational and start-up test plans shall be so written that they can be contained in the plant safety analysis reports. For the preliminary safety analysis report, the following items shall have been clarified:

- the scope and main stages of pre-operational and start-up tests; the areas of responsibility assigned to organizations participating in the planning of test programmes and in the implementation of the tests
- guides and regulations to be complied with in the planning of test programmes
- how experience gained at similar plants is utilized in the planning of test programmes
- identification of items requiring special attention owing to their prototype nature, including separate summaries of the tests to be conducted on these items
- the length of time required by the main stages of testing
- the role of testing in the validation of the plant operating instructions
- the number of personnel required in various organizations during testing.

For the final safety analysis report, the following items shall have been clarified:

- pre-operational and start-up testing principal stages and the objectives for each stage
- organizations participating in the tests and their areas of responsibility; definition of duties of the most important persons
- guides and regulations to be complied with in the drawing up of the test programme
- the procedure to be followed in the drawing up of the test programme, including the division of duties
- delineation of authority during the tests; principles ensuring compliance with the test programme; the procedure for amending the test programme during implementation
- how experience gained at similar plants is utilized in the planning of test programmes
- a schedule for drawing up the plant operating instructions and a plan specifying the role of testing to ensure the correctness and adequacy of these instructions
- a testing schedule specifying the planned duration and mutual chronological order of the various sub-stages of testing, including dead-lines for the completion of detailed test programmes
- a system performance and reactor system pre-critical test summary plan with the names of detailed programmes for each test; possible preliminary requirements for the conduct of the tests; test objective and a brief description of test scope and acceptance criteria
- procedures to be followed in fuel loading and in the achievement of criticality, including safety measures and precautions
- a low-power and power test summary plan with the names of detailed test programmes for each test; test objective, a brief description of test scope and acceptance criteria and a description of the power levels at which the tests are intended to be conducted

- procedure for the assessment of test results, including division of duties; actions to be taken in case some test results fail to meet the acceptance criteria
- the records retention procedure.

4 System performance tests

4.1 Requirements

It shall be demonstrated by system performance tests that every system important to safety and every individual part thereof is capable of fulfilling its functional duty. It shall be further demonstrated that the systems are capable of functioning together as designed. As far as possible, the tests shall ascertain operability under normal operating conditions and also under the transient and accident conditions in which the systems are required to function.

An example of system performance tests is given in Ref. /1/, Annex I, points 1-3. For applicable parts, the recommendations and instructions given in Ref. /1/, point 3.2 and in Refs. /2/, /3/, /4/, /5/, /6/, /7/ shall also be taken into account in test planning. Test by test justification shall be given if a system performance test has been planned to take place after the commencement of fuel loading.

A detailed test programme shall be drawn up for each test in advance; the programme scope shall conform to the recommendations of Ref. /1/, point 4.2. The programme main categorization is as follows:

- introduction
- description of test sequence, if necessary due to test nature, scope or clarity
- test objective and methods
- acceptance criteria
- constraints on plant operation and other conditions for test performance
- systems initial state
- prerequisites for test performance
- conditions and instructions for test performance
- description of provision made for transients during test performance
- instruments to be employed and other testing equipment required
- number of personnel participating in the test; requirements for and delineation of responsibilities of the personnel
- specific instructions concerning industrial safety and component shielding
- test completion
- documentation of data to be monitored during the test
- documentation of test results.

In addition to the above, the programme shall have, as a separate entry, a description of the measuring instruments or systems which may be required and which are not included in the plant fixed equipment.

The tests shall be conducted as closely in accordance with established programmes as possible; any non-conformances including their causes shall be documented. All arrangements for measurement and output shall be checked prior to the test and test results shall be documented in a way agreed upon in advance.

Apart from final test results, the test report shall present any non-conformances, their causes and the repairs and modifications during testing which were necessary for attaining acceptable results.

4.2 Regulatory control

Based on the pre-operational and start-up testing plan presented in the final safety analysis report, STUK determines the system tests for whose programmes STUK's approval shall be obtained by the utility. The overall principle is that all tests involving Safety Class 1, 2 or 3 systems are subject to STUK's approval. If programmes of a more

general nature are first drawn up as a basis for test programmes, STUK's assessment of these can be obtained on request.

If a programme is subject to STUK's approval, testing may be commenced only upon receipt of the approval. Commencement of testing means the first procedure aimed at demonstrating the performance capability of an inspected item; the results will be documented for use during the approval procedure. Instrument calibrations, flushing of pipework and other preparatory measures, as well as preliminary tests, can be carried out before programme approval, however. Prior to operation under pressure, each plant pressure vessel is subjected to a verification inspection as part of the commissioning inspection referred to in Guide YVL 3.7.

The Finnish Centre for Radiation and Nuclear Safety witnesses system tests at the power plant as it deems necessary. The overall principle is to oversee Safety Class 1, 2 and 3 system tests and part of Safety Class 3 system tests. For the purpose of overseeing the tests, STUK shall be provided with a pre-operational testing schedule well in advance. STUK shall be promptly informed of any changes in the schedules. STUK shall be informed of the tests early enough but the presence of STUK's representative is not a prerequisite for conducting a test. This does not apply to pressure vessel auxiliary equipment functional tests, however, which are part of the commissioning inspection, as presented in Guide YVL 3.7, and which are overseen by STUK, safety class notwithstanding.

To support a fuel loading application, documentation of preliminary system test results, which have been reviewed by the pre-operational testing organization, shall be submitted of all tests whose programmes are subject to approval by STUK. Final documentation of test results, which have been reviewed by the plant supplier, shall be submitted to STUK for approval within two months from the accomplishment of the tests in question.

5 Fuel loading and reactor system pre-critical tests

5.1 Requirements

Guide YVL 1.1 presents requirements for the commencement of fuel loading. There shall be a loading plan which gives

- a summary of the neutron flux and gamma radiation monitoring equipment required during loading and of other special measuring instruments which may be required
- the organization responsible for loading; the number, training and duties of personnel required during loading
- the status of the reactor containment building and the systems contained in it during loading
- detailed loading instructions
- special safety instructions and precautions to be observed during loading.

The recommendations of Ref. /1/, point 3.3.2 shall be taken into account, where applicable, when planning fuel loading.

An example of reactor system pre-criticality tests is given in Ref. /1/, Annex I, points 1-4.1. The requirements for system tests presented in point 4 of this Guide also apply to pre-criticality test programmes, conduct of tests and the documentation of test results.

5.2 Regulatory control

The loading plan and reactor system pre-criticality test programmes are subject to STUK's approval.

STUK oversees fuel loading and inspects, upon its accomplishment, that every fuel assembly's position is according to design.

Primary circuit closure and reactor system pre-criticality tests may be commenced after STUK has inspected the core configuration and approved the pre-critical test programmes. STUK oversees reactor system pre-critical tests as it deems necessary.

When results in accordance with the acceptance criteria have been attained in the tests, STUK's approval for the commencement of the initial approach to criticality and for the carrying out of low-power tests at a power specified in the application may be requested. Previous preliminary test results reviewed by the pre-operational testing organization shall be presented in support of the application, in the extent necessary to demonstrate the meeting of acceptance criteria.

Pre-critical test final documentation, which has been reviewed by the plant supplier, shall be submitted to STUK for approval within two months from the accomplishment of the tests in question.

6 Initial criticality and low-power tests

6.1 Requirements

The approach to criticality is considered to commence with

- the start of boron dilution at a PWR
- the withdrawal of the first control rod from the reactor at a BWR.

During the approach to criticality, the recommendations of Ref. /1/, point 3.3.3 and of Annex I, point I-4.1 shall be taken into account for applicable parts. The procedure shall be described in a detailed programme which, for applicable parts, meets the requirements made of system performance test programmes.

In planning low-power tests, the recommendations of Ref. /1/, point 3.3.4 shall be taken into account, for applicable parts. An example of low-power tests is given in Ref. /1/, Annex I, point I-4.2. The requirements for system performance tests presented in point 4 of this Guide also apply to low-power tests, their performance and test reports.

6.2 Regulatory control

The programme concerning the approach to criticality and low-power test programmes are subject to STUK's approval.

The approach to criticality may be commenced upon receipt of STUK's consent and approval of the programme describing the procedure in question. The same consent may also apply to low-power tests, provided that associated programmes have already been approved. STUK oversees the approach to criticality and low-power tests as it deems necessary.

After attaining results conforming to the acceptance criteria in low-power tests, STUK's approval for performing power tests at a power level specified in the application may be requested; previous preliminary test results reviewed by the pre-operational testing organization shall be submitted in support of the application, in the extent necessary to demonstrate the meeting of the acceptance criteria.

Low power test final documentation which has been reviewed by the plant supplier, shall be submitted to STUK for approval within two months from the accomplishment of the tests in question.

7 Power tests

7.1 Requirements

During power tests, the performance of the plant is tested at various power levels, e.g. at 10 %, 25 %, 50 %, 75 % and 100 % of rated power.

In planning power tests, the recommendations given in Ref /1/, point 3.4 shall be taken into account for applicable parts. An example concerning power tests is given in Ref /1/, Annex I, point I-5.

The requirements presented in point 4 of this Guide and which apply to system tests also apply to power test programmes, their performance and documentation of the test results.

7.2 Regulatory control

Power test programmes are subject to STUK's approval.

STUK oversees the tests as it deems necessary.

Upon achieving at a certain power level results which conform to the acceptance criteria, STUK's consent for increasing plant power may be requested. To support the application, previous preliminary test results reviewed by the pre-operational testing organization shall be submitted, in the extent necessary to demonstrate the meeting of the acceptance criteria. Power ascension to a new, higher power level may take place upon receipt of STUK's consent and approval of test programmes at this power level.

Power test final documentation which has been reviewed by the plant supplier, shall be submitted to STUK for approval within two months from the accomplishment of the tests in question.

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3 Preoperational Testing of Redundant On-Site Electric Power Systems to Verify Proper Load Group Assignments, Regulatory Guide 1.41, U.S. Atomic Energy Commission, 3/16/73.

4 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, Rev. 1, January/1977.

5 Preoperational Testing of Emergency Core Cooling Systems for Pressurized Water Reactors, Regulatory Guide 1.79, U.S. Nuclear Regulatory Commission, Rev.1, September/1975.

6 Preoperational Testing of Instrument and Control Air Systems, Regulatory Guide 1.68.3 (Task RS 709-4), U.S. Nuclear Regulatory Commission, April/1982.

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The YVL-guides without any language marking are available both in English and Finnish.