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Reload startup physics tests for pressurized water reactors

Essais physiques au redémarrage pour les réacteurs à eau pressurisée

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 85, *Nuclear energy, nuclear technologies, and radiological protection*, Subcommittee SC 6, *Reactor technology*.

This second edition cancels and replaces the first edition (ISO 18077:2018), which has been technically revised.

The main changes are as follows:

— discussion of the difference between review criteria and acceptance criteria was moved from the annex to the main part of the document with a clear statement that the document uses only review criteria;

— a new Subclause 5.3 was added to clarify that testing at the next power plateau should proceed only after acceptable results are obtained at the current power plateau;

— a footnote was added to Table A.1 to address cores designed to be asymmetric;

— several editing changes were made.

Any feedback or questions on this document should be directed to the user’s national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

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Introduction

In conjunction with each refuelling shutdown or other significant reactor core alteration, nuclear design calculations are performed to ensure that the reactor physics characteristics of the new core will be consistent with the safety limits. Prior to return to normal operation, successful execution of a physics test program is required to determine if the operating characteristics of the core are accurately represented by the design predictions and to ensure that the core can be operated as designed.

This document specifies the content of the minimum acceptable startup physics test program for commercial pressurized water reactors (PWRs) and provides the bases for each of the tests. Previously used acceptable methods for performing the individual tests are provided in Annex A[1)]. Alternate methods may be used as long as they are shown to meet the requirements of Clause 6.

Successful completion of the physics test program is demonstrated when the test results agree with the predicted results within predetermined test criteria. Successful completion of the physics test program and successful completion of other tests that are performed after each refuelling or significant reactor core alteration provide assurance that the plant can be operated as designed.

This document assumes that the same previously accepted analytical methods are used for both the design of the reactor core and the startup test predictions. It also assumes that the expected operation of the core will fall within the historical database established for the plant and/or sister plants.

When major changes are made in the core design, the test program should be reviewed to determine if more extensive testing is needed. Typical changes that might fall in this category include the initial use of novel fuel cycle designs, significant changes in fuel enrichments, fuel assembly design changes, burnable absorber design changes, and cores resulting from unplanned short cycles. Changes such as these may lead to operation in regions outside of the industry's experience database and therefore may necessitate expanding the test program.

1) Annex A is the User's guidance, which provides acceptable methods, guidelines, precautions, suggestions and typical test criteria for each required test.

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Reload startup physics tests for pressurized water reactors

1 Scope

This document applies to the reactor physics tests that are performed following a refuelling or other core alteration of a PWR for which nuclear design calculations are required. This document does not address the physics test program for the initial core of a commercial PWR.

This document specifies the minimum acceptable startup reactor physics test program to determine if the operating characteristics of the core are consistent with the design predictions, which provides assurance that the core can be operated as designed.

This document does not address surveillance of reactor physics parameters during operation or other required tests such as mechanical tests of system components (for example, the rod drop time test), visual verification requirements for fuel assembly loading, or the calibration of instrumentation or control systems (even though these tests are an integral part of an overall program to ensure that the core behaves as designed).

2 Normative references

There are no normative references in this document.

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1
all rods out
ARO
all full-length control rods withdrawn

Note 1 to entry: Part-length rods may be inserted.

3.2
control rod
one or more reactivity control members mechanically attached to a single fixture

3.3
control rod group
one or more rods that are inserted or withdrawn simultaneously

Note 1 to entry: The term “all control rod groups” means all safety and regulating control rod groups. This term may also be shortened to simply “rod group.”

Note 2 to entry: Some utilities use the term "bank" instead of "group". A control rod bank is the same as a control rod group.

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3.4
decades per minute
DPM
unit used to measure a rate of change in flux as measured by the ex-core detectors

3.5
hot full power
full power
rated thermal power
HFP
licensed core thermal power level

3.6
hot zero power
HZP
reactor operating state where the core is essentially critical but is not producing measurable heat from nuclear fission, the reactivity due to xenon is negligible, and the primary coolant system is at design temperature and pressure for zero power

Note 1 to entry: At HZP, the flux signal should be high enough so that the reactivity computer can account for contamination sources such as noise, gamma background, and leakage.

3.7
isothermal temperature coefficient
ITC
change in reactivity per unit change in the fuel and moderator temperature when the fuel and moderator are at the same temperature

3.8
part-length rod
control rod (3.2) whose primary absorber material does not extend the entire length of the *control rod* (3.2) (typically the lower half of the control rod's active length)

Note 1 to entry: It is used for axial shape control. For the purposes of this document, the term "part-length rod" can also represent a "part-strength" control rod.

3.9
percent milli-rho
pcm
unit of reactivity worth equivalent to 10^{-3} % $\Delta\rho$

Note 1 to entry: See definition of "reactivity worth" below.

Note 2 to entry: Throughout this document, pcm is the unit of reactivity to be used.

3.10
reactivity computer
analog or digital device that calculates the core reactivity by using an external signal that is proportional to the core neutron flux

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3.11
reactivity worth
change in reactivity expressed in terms of percent

$$\%\Delta\rho = \frac{(k_2 - k_1)\cdot 100}{k_1 \cdot k_2}$$

where

k_1 is the effective multiplication constant for reactor state 1

k_2 is the effective multiplication constant for reactor state 2

3.12
regulating control rod group
group of *control rods* (3.2) that may be partially or fully inserted in the core during normal operation

3.13
safety rod group
control rod group (3.3) that remains withdrawn from the core during normal operation and is inserted during abnormal or accident conditions

3.14
test criterion
predetermined value for evaluating the result of each test

Note 1 to entry: There are two different levels of criteria, review and acceptance. A review criterion is based on differences between calculations and measurements that would suggest a problem with the as-built core, the measurement, or the prediction. Only review criteria are applicable to this document. An acceptance criterion is based on a safety analysis assumption or a Technical Specification limit and is outside of the scope of this document. See Annex A for a more complete discussion of the test criteria and applicability.

4 Relation to other standards

ANSI/ANS-3.2-2012(R2022)[2] provides requirements and recommendations for an administrative control and quality assurance program for the safe and efficient operation of nuclear power plants. Provisions for test and applicable test equipment control required by this document are also included in ANSI/ANS-3.2-2012(R2022). ANSI/ANS 3.1-2014(R2020)[3] provides for the selection, qualification, and training of personnel for nuclear power plants, including personnel responsible for startup testing.

ANSI/ANS-19.4-2017(R2022)[4] addresses reactor physics measurements that are intended to yield documented data of both the type and quality required for validating nuclear analysis methods. ANSI/ANS-19.11-2017(R2022)[5] describes how to calculate and measure the moderator temperature coefficient of reactivity. ANSI/ANS 19.6.1-2019[6] defines the minimum acceptable startup physics test program and acceptable test methods to determine if the reactor core operating characteristics are consistent with the design predictions and is the basis for this document.

5 Physics test program and selection criteria

5.1 Bases for startup physics test program

During the reload design process, the reactor safety is determined by analysis. Following the reload, specific core characteristics shall be confirmed by measurement to ensure that the reconstructed core is accurately represented by that analysis and is operating as designed. Thus, the testing results seek to confirm that the reactor can be operated within the bounds of the technical specifications, that there is sufficient operational flexibility, and that the plant can be expected to safely deliver the designed power output. The paramount objective of a physics test program is to demonstrate that the reconstructed

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