IEC 61468

Edition 2.0 2021-04

INTERNATIONAL STANDARD

Nuclear power plants – Instrumentation systems important to safety – In-core instrumentation: Characteristics and test methods of self-powered neutron detectors

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

ICS 27.120.20

ISBN 978-2-8322-9706-3

Warning! Make sure that you obtained this publication from an authorized distributor.

® Registered trademark of the International Electrotechnical Commission

CONTENTS

FOREWORD 4
INTRODUCTION 6
1 Scope 8
2 Normative references 8
3 Terms and definitions 8
4 Abbreviated terms 12
5 Self-powered neutron detectors general advantages and disadvantages 13
6 Composition and construction 13
7 Application recommendations 16
7.1 General 16
7.2 Fluence rate mapping – Core monitoring and surveillance 16
7.3 Power regulation – Feedback control 16
7.4 Core protection 16
7.5 Reactor noise analysis 16
7.6 Classification 16
8 Design recommendations 17
8.1 General 17
8.2 Reproducibility of SPND characteristics 17
8.3 Background signal 17
8.4 Electrical interference noise 17
8.5 Lifetime 17
9 Test methods 17
9.1 General 17
9.2 Prototype testing 18
9.3 Production tests 18
10 Detector calibration 18
10.1 Place of calibration 18
10.2 Absolute calibration 19
10.3 Comparison calibration 19
10.4 In-core calibration 19
10.5 Calibration procedure 19
10.6 Recommended calibration periods 20
Annex A (informative) Self-powered detector principles and characteristics 21
A.1 SPND response mechanisms 21
A.2 Beta decay (delayed response) 21
A.3 Neutron capture (prompt response) 21
A.4 Photoelectric effect (prompt response) 21
A.5 Compton effect (prompt response) 21
A.6 Nature of SPND response 22
A.7 Thermal neutron interactions 22
A.8 Gamma interactions 22
A.9 Dynamic characteristics of SPND 22
A.10 Detector burn-up life 23
A.11 Measurement errors 23
A.11.1 General 23
A.11.2 Error for determination of SPND actual response 23

A.11.3 Error determined by gamma-component of SPND current 24
A.11.4 Error determined by leakage currents 24
A.11.5 Error determined by signal wire current 25
A.12 Self-powered detector operating characteristics 25
A.12.1 General 25
A.12.2 Vanadium emitter characteristics 26
A.12.3 Cobalt emitter characteristics 26
A.12.4 Rhodium emitter characteristics 26
A.12.5 Silver emitter characteristics 27
A.12.6 Platinum emitter characteristics 27
A.12.7 Hafnia emitter characteristics 27
A.13 Self-powered detector assemblies 28
A.13.1 General 28
A.13.2 Typical bottom-mounted rhodium self-powered detector assembly for pressurized light water reactors 28
A.13.3 Typical top-mounted rhodium self-powered detector assembly for VVER–type light water reactors 28
A.13.4 Typical top-mounted cobalt self-powered detector assembly for pressurized light water reactors 28
A.13.5 Typical heavy water reactor self-powered detector assembly 29
Bibliography 34

Figure 1 – Typical integral self-powered neutron detector 13
Figure 2 – Typical modular self-powered neutron detector 13
Figure 3 – Typical background detector 15
Figure 4 – Typical SPND with built-in background detector 16
Figure A.1 – Simplified equivalent circuit of the SPND 25
Figure A.2 – Bottom-mounted rhodium self-powered detector assembly for pressurized water reactors 29
Figure A.3 – Top-mounted rhodium self-powered detector assembly for VVER reactors with four thermocouples 30
Figure A.4 – Top-mounted rhodium self-powered detector assembly for VVER reactors with level sensor 31
Figure A.5 – Top-mounted cobalt self-powered detector assembly for pressurized water 32
Figure A.6 – CANDU pressurized heavy water reactor self-powered detector assembly 33

Table 1 – Characteristics of SPND emitters 14
Table A.1 – Examples of specifications for typical SPNDs used in power reactors 26

INTERNATIONAL ELECTROTECHNICAL COMMISSION

_____

NUCLEAR POWER PLANTS – INSTRUMENTATION SYSTEMS IMPORTANT TO SAFETY – IN-CORE INSTRUMENTATION: CHARACTERISTICS AND TEST METHODS OF SELF-POWERED NEUTRON DETECTORS

FOREWORD

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
2) The formal decisions or agreements of IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees.
3) IEC Publications have the form of recommendations for international use and are accepted by IEC National Committees in that sense. While all reasonable efforts are made to ensure that the technical content of IEC Publications is accurate, IEC cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.
4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC Publication and the corresponding national or regional publication shall be clearly indicated in the latter.
5) IEC itself does not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC marks of conformity. IEC is not responsible for any services carried out by independent certification bodies.
6) All users should ensure that they have the latest edition of this publication.
7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.
8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.
9) Attention is drawn to the possibility that some of the elements of this IEC Publication may be the subject of patent rights. IEC shall not be held responsible for identifying any or all such patent rights.

International Standard IEC 61468 has been prepared by subcommittee 45A: Instrumentation, control and electrical power systems of nuclear facilities, of IEC technical committee 45: Nuclear instrumentation.

This second edition cancels and replaces the first edition, published in 2000, and its Amendment 1, published in 2003. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

a) Title modified.
b) Justify the requirements for SPND characteristics in terms of influencing factors.
c) Align the terminology with the current state of the regulatory framework.

The text of this International Standard is based on the following documents:

FDIS	Report on voting
45A/1381/FDIS	45A/1383/RVD

Full information on the voting for its approval can be found in the report on voting indicated in the above table.

The language used for the development of this International Standard is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/standardsdev/publications.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under webstore.iec.ch in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

INTRODUCTION

a) Technical background, main issues and organisation of the Standard

This International Standard focuses on self-powered neutron detectors (SPNDs).

It is intended that this document be used by operators of NPPs (utilities), systems evaluators and by licensors.

b) Situation of the current Standard in the structure of the IEC SC 45A standard series

IEC 61468 is a third level IEC/SC 45A document.

IEC 61468 is to be read in conjunction with IEC 61513 which establishes general requirements for I&C systems and with IEC 60568 which establishes general requirements for in-core instrumentation for neutron fluence rate (flux) measurements in power reactors.

For more details on the structure of the IEC SC 45A standard series, see item d) of this introduction.

c) Recommendations and limitations regarding the application of the Standard

To ensure that the Standard will continue to be relevant in future years, the emphasis has been placed on issues of principle, rather than specific technologies.

d) Description of the structure of the IEC SC 45A standard series and relationships with other IEC documents and other bodies documents (IAEA, ISO)

The top-level documents of the IEC SC 45A standard series are IEC 61513 and IEC 63046. IEC 61513 provides general requirements for I&C systems and equipment that are used to perform functions important to safety in NPPs. IEC 63046 provides general requirements for electrical power systems of NPPs; it covers power supply systems including the supply systems of the I&C systems. IEC 61513 and IEC 63046 are to be considered in conjunction and at the same level. IEC 61513 and IEC 63046 structure the IEC SC 45A standard series and shape a complete framework establishing general requirements for instrumentation, control and electrical systems for nuclear power plants.

IEC 61513 and IEC 63046 refer directly to other IEC SC 45A standards for general topics related to categorization of functions and classification of systems, qualification, separation, defence against common cause failure, control room design, electromagnetic compatibility, cybersecurity, software and hardware aspects for programmable digital systems, coordination of safety and security requirements and management of ageing. The standards referenced directly at this second level should be considered together with IEC 61513 and IEC 63046 as a consistent document set.

At a third level, IEC SC 45A standards not directly referenced by IEC 61513 or by IEC 63046 are standards related to specific equipment, technical methods, or specific activities. Usually these documents, which make reference to second-level documents for general topics, can be used on their own.

A fourth level extending the IEC SC 45A standard series, corresponds to the Technical Reports which are not normative.

The IEC SC 45A standards series consistently implements and details the safety and security principles and basic aspects provided in the relevant IAEA safety standards and in the relevant documents of the IAEA nuclear security series (NSS). In particular this includes the IAEA requirements SSR-2/1, establishing safety requirements related to the design of nuclear power plants (NPPs), the IAEA safety guide SSG-30 dealing with the safety classification of structures, systems and components in NPPs, the IAEA safety guide SSG-39 dealing with the design of instrumentation and control systems for NPPs, the IAEA safety guide SSG-34 dealing with the design of electrical power systems for NPPs and the implementing guide NSS17 for computer security at nuclear facilities. The safety and security terminology and definitions used by SC 45A standards are consistent with those used by the IAEA.

IEC 61513 and IEC 63046 have adopted a presentation format similar to the basic safety publication IEC 61508 with an overall life-cycle framework and a system life-cycle framework. Regarding nuclear safety, IEC 61513 and IEC 63046 provide the interpretation of the general requirements of IEC 61508-1, IEC 61508-2 and IEC 61508-4, for the nuclear application sector. In this framework IEC 60880, IEC 62138 and IEC 62566 correspond to IEC 61508-3 for the nuclear application sector. IEC 61513 and IEC 63046 refer to ISO as well as to IAEA GS-R part 2 and IAEA GS-G-3.1 and IAEA GS-G-3.5 for topics related to quality assurance (QA). At level 2, regarding nuclear security, IEC 62645 is the entry document for the IEC/SC 45A security standards. It builds upon the valid high level principles and main concepts of the generic security standards, in particular ISO/IEC 27001 and ISO/IEC 27002; it adapts them and completes them to fit the nuclear context and coordinates with the IEC 62443 series. At level 2, IEC 60964 is the entry document for the IEC/SC 45A control rooms standards and IEC 62342 is the entry document for the ageing management standards.

NOTE It is assumed that for the design of I&C systems in NPPs that implement conventional safety functions (e.g. to address worker safety, asset protection, chemical hazards, process energy hazards) international or national standards would be applied.

NUCLEAR POWER PLANTS – INSTRUMENTATION SYSTEMS IMPORTANT TO SAFETY – IN-CORE INSTRUMENTATION: CHARACTERISTICS AND TEST METHODS OF SELF-POWERED NEUTRON DETECTORS

1 Scope

This document applies to in-core neutron detectors, viz. self-powered neutron detectors (SPNDs), which are intended for application in systems important for nuclear reactor safety: protection, instrumentation and control. This document contains SPND characteristics and test methods. In this document, the main sources of errors, and the possibilities for their minimization are also considered.

Self-powered neutron detectors can be used for measurement of neutron fluence rate and associated parameters in nuclear reactors. Most popular for the indicated applications are detectors with rhodium emitters.

In this document dynamic characteristics, emitter burn-up, identity and other factors influencing operational characteristics of detectors are considered.

Besides SPNDs with rhodium emitters, SPNDs with emitters from other materials and their main characteristics are also considered in this document.

This document contains requirements, recommendations and instructions concerning selection of SPND type and characteristics for various possible applications. This document about SPNDs uses the basic requirements of IEC 61513 and IEC 60568 and complements them with more specific provisions in compliance with IAEA Safety Guides.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60515:2007, *Nuclear power plants – Instrumentation important to safety – Radiation detectors – Characteristics and test methods*

IEC 60568:2006, *Nuclear power plants – Instrumentation important to safety – In-core instrumentation for neutron fluence rate (flux) measurements in power reactors*

IEC/IEEE 60780-323:2016, *Nuclear facilities – Electrical equipment important to safety – Qualification*

IEC 61226, *Nuclear power plants – Instrumentation, control and electrical power systems important to safety – Categorisation of functions and classification of systems*

IEC 61513, *Nuclear power plants – Instrumentation and control important to safety – General requirements for systems*