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Skärmning av neutronstrålning – Beräkningsprinciper och val av lämpliga material (ISO 14152:2001, IDT)

Neutron radiation protection shielding – Design principles and considerations for the choice of appropriate materials (ISO 14152:2001, IDT)

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The International Standard ISO 14152:2001 has the status of a Swedish Standard. This document contains the official version of ISO 14152:2001.

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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.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 3.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this International Standard may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 14152 was prepared by Technical Committee ISO/TC 85, *Nuclear energy*, Subcommittee SC 2, *Radiation protection*.

Annexes A to F of this International Standard are for information only.

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Introduction

In its Publication 60 (1991), the International Commission on Radiological Protection (ICRP) recommended annual limits in terms of effective dose and equivalent dose to the skin, to the lenses of eyes the and to extremities. Due to the tissue weighting factors in its definitions, the effective dose is destined to be an instable quantity. In fact, its values strongly depend on the geometrical conditions of irradiation and can only be determined using anthropomorphic phantoms approaching the human body.

For monitoring purposes, the International Commission on Radiation Units and Measurements (ICRU) and the ICRP recommended so-called operational quantities [ICRU Report 39 (1985), ICRU Report 51 (1993) and ICRP Publication 74 (1996)] [4]. The operational quantity recommended for area monitoring of strongly penetrating radiation is the ambient dose equivalent.

Unfortunately the ambient dose equivalent does not give a conservative estimate of the effective dose for all the energies of interest for neutron radiation [ICRP Publication 74 (1996)] [4] and, at high energies, both for neutron and photon radiation. Moreover, the ambient dose equivalent has not been introduced for shielding purposes.

All the experimental data found in literature are expressed in terms of maximum dose equivalent, a quantity based on superseded Q vs LET relationship [ICRP Publication 21 (1971)] [3].

This International Standard makes use of the ambient dose equivalent as radiation protection quantity, based on the new Q-L relation as recommended in ICRP Publication 60. Due to the above-mentioned limitation, the field of application is restricted to neutrons of energy below 20 MeV.

For practical purposes, some data expressed in terms of maximum dose equivalent are also included in this International Standard. It is recommended that these data be conservatively multiplied by a factor 2 if used for purposes of shielding calculations [ICRU Publication 51 (1993)].

To establish an operational neutron radiation protection shielding system, several consecutive steps should be performed:

— choice of the radiological objectives and other design criteria;

— characterization of the radiation sources;

— identification of the constraints on placement and construction;

— choice of the shielding materials and arrangement within the shielding;

— implementation of a calculation method;

— choice of the final solution;

— experimental verification.

This International Standard outlines, in the body of the text, the basic requirements and the general provisions for the implementation of each of these previous steps.

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Detailed annexes complete these general considerations, especially in the following fields:

— characterization of neutron sources;

— criteria for the choice of neutron shielding materials;

— review of shielding calculation methods (manual methods or computer codes).

NOTE The general principles provided in this International Standard are mainly applicable to simple slab geometries. For neutron shielding of complex geometries, including local lessenings such as service penetrations, ducts, labyrinths, zigzag mountings, the guidance given in this International Standard apply, but are generally not sufficient. For that purpose, special calculation techniques and arrangement of the shielding materials are needed. These specific considerations are out of the scope of this International Standard.

The same remark can be made for criticality shielding, for which the principles given in this International Standard apply, but are generally not sufficient. In this case additional considerations should be taken into account.

For these two items (criticality shielding and neutron radiation protection shielding of complex geometries), further standards will be studied in the near future.

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Neutron radiation protection shielding — Design principles and considerations for the choice of appropriate materials

1 Scope

This International Standard presents the general methodology governing the design of neutron radiation protection shielding and the choice of neutron radiation protection shielding materials.

This International Standard is applicable to facilities and operations where neutron sources are located and used, and where workers are occupationally exposed. These operations and facilities vary considerably in design and purpose. These facilities and operations include, but are not limited to:

- nuclear power plants;
- research reactors;
- particle accelerators and neutron generators;
- fusion research facilities;
- transportation packaging for radioactive materials operations;
- medical treatment and research facilities and applications;
- industrial applications such as use of devices for measuring and detecting moisture and density level;
- space applications;
- calibration facilities;
- radiographic installations;
- nuclear fuel cycle installations (reprocessing plants, plutonium solution handling facilities, shielded cells, waste storage, etc.).

The criteria for the design of neutron shielding and the choice of shielding materials contained in this International Standard should be applied to the design of neutron radiation protection shielding systems in such facilities.

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2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this International Standard. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.

ISO 921:1997, *Nuclear energy — Vocabulary*

ISO 7212, *Enclosures for protection against ionizing radiation — Lead shielding units for 50 mm and 100 mm thick walls*

ISO 8529-1, *Reference neutron radiations — Part 1: Characteristics and methods of production*

ISO 8529-3, *Reference neutron radiations — Part 3: Calibration of area and personal dosimeters and determination of response as a function of energy and angle of incidence*

ISO 9404-1, *Enclosures for protection against ionizing radiation — Lead shielding units for 150 mm, 200 mm and 250 mm thick walls — Part 1: Chevron units of 150 mm and 200 mm thickness*

ISO 15080, *Nuclear facilities — Ventilation penetrations for shielded enclosures*

ICRP 60 (1991), *1990 Recommendations of the International Commission on Radiological Protection*, ICRP Publication 60, Annals of the ICRP, 21, (1-3), Pergamon Press, Oxford (1991)

ICRU 39 (1985), *Determination of Dose Equivalents Resulting from External Radiation Sources*, ICRU Report 39, 1985 (International Commission on Radiation Units and Measurements, Bethesda, MD)

ICRU 51 (1993), *Quantities and Units in Radiation Protection Dosimetry*, ICRU Report 51, 1993 (International Commission on Radiation Units and Measurements, Bethesda, MD)

ICRU 57 (1998), *Conversion Coefficients for use in Radiological Protection against External Radiation*, ICRU Report 57, 1998 (International Commission on Radiation Units and Measurements, Bethesda, MD)

ICRU 60 (1998), *Fundamental Quantities and Units for Ionizing Radiation*, ICRU Report 60, 1998 (International Commission on Radiation Units and Measurements, Bethesda, MD)

IAEA[1)] (1986), Safety Guides, Safety Series No. 76, *Radiation Protection Glossary*, Vienna

IAEA (1996), Safety Guides, Safety Series No. 115, *International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources*, Vienna

1) International Atomic Energy Agency.

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3 Terms and definitions

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

3.1 Quantities [2] and units

3.1.1
equivalent dose in a tissue or organ
H_T
absorbed dose in a tissue or organ T, weighted for the type of radiation R

$$H_T = W_R \times D_{T,R}$$

where $D_{T,R}$ is the absorbed dose, averaged over tissue or organ T, due to the radiation R and W_R is the radiation weighting factor, which is dependent of the energy of the neutrons

[ICRP 60:1991, IAEA Safety Series No.115:1996]

NOTE 1 In the case of several radiation qualities, the equivalent dose in a tissue or organ, H_T, is the sum of the products of the radiation weighting factor W_R and the mean absorbed dose, $D_{T,R}$:

$$H_T = \sum_R W_R \times D_{T,R}$$

NOTE 2 The SI unit of the equivalent dose is the joule per kilogram ($J \cdot kg^{-1}$), with the special name sievert (Sv).

3.1.2
effective dose
E
sum of the weighted equivalent doses in all the tissues and organs of the body

$$E = \sum_T W_T \times H_T$$

where H_T is the equivalent dose in tissue or organ T and W_T is the weighting factor for tissue T

[ICRP 60: 1991, ICRU 51:1993, IAEA Safety Series No.115:1996]

NOTE 1 These tissue weighting factors take into account the varying sensitivity of organs with respect to stochastic effects of radiation. The weighting factor, W_T, represents the part of the contribution of the tissue T to the total exposure of the whole body when uniformly exposed ($\sum W_T = 1$).

The effective dose can also be expressed as the sum of the doubly weighted absorbed dose in all the tissues and organs of the body. The following applies based on the definition of H_T:

$$E = \sum_R \sum_T W_T \times W_R \times D_{T,R}$$

NOTE 2 The SI unit of the effective dose is the joule per kilogram ($J \cdot kg^{-1}$), with the special name sievert (Sv).

2) According to ICRP Publication 74, “equivalent dose” and “effective dose” are “Radiation Protection Quantities”, while “ambient dose equivalent”, e.g. is an “Operational Quantity”.