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Nuclear energy — Radioprotection — Procedure for radiation protection monitoring in nuclear installations for external exposure to weakly penetrating radiation, especially to beta radiation

Énergie nucléaire — Radioprotection — Procédure de surveillance dosimétrique de radioprotection dans les installations nucléaires pour l'exposition externe aux rayonnements faiblement pénétrants, en particulier au rayonnement bêta

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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 15382 was prepared by Technical Committee ISO/TC 85, *Nuclear energy*, Subcommittee SC 2, *Radiation protection*.

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

Introduction

A high percentage of weakly penetrating radiation, mainly beta radiation, has to be expected in nuclear power plants, especially during maintenance work. Special rules need to be respected and particular protection procedures are required for external exposure to this radiation. Dosimetry methods usually applied in radiation protection monitoring of strongly penetrating radiation cannot be directly applied to weakly penetrating radiation.

Exposures of persons to weakly penetrating radiation are mainly caused by unshielded open radioactive sources. This type of exposure may occur, in particular, in connection with contamination. Nuclear installations may involve large-area contamination with locally different nuclide composition, which can vary with time. In addition, the activity per unit area may assume high values. Exposure to weakly penetrating radiation from radioactive noble gases in room air has also to be considered. Particular attention has to be paid to work performed on heavily contaminated parts at close proximity. This requires special rules and procedures for the nuclear power plants, some of which may be applicable to the handling of radioactive sources in other disciplines.

In order to achieve and maintain high radiation protection standards, it is necessary to utilize a special standard dedicated to the particular concern pertaining to protection against, and monitoring of, external exposures to weakly penetrating radiation.

Nuclear energy — Radioprotection — Procedure for radiation protection monitoring in nuclear installations for external exposure to weakly penetrating radiation, especially to beta radiation

1 Scope

This International Standard specifies a procedure for radiation protection monitoring in nuclear installations for external exposure to weakly penetrating radiation, especially to beta radiation and describes the procedure in radiation protection monitoring for external exposure to weakly penetrating radiation in nuclear installations. This radiation comprises β^- radiation, β^+ radiation and conversion electron radiation as well as photon radiation with energies below 15 keV. This International Standard describes the procedure in radiation protection planning and monitoring as well as the measurement and analysis to be applied. It applies to regular nuclear power plant operation including maintenance, waste handling and decommissioning.

The recommendations of this International Standard may also be transferred to other nuclear fields including reprocessing, if the area-specific issues are considered. This International Standard may also be applied to radiation protection at accelerator facilities and in nuclear medicine, biology and research facilities.

2 Normative reference

The following normative document contains 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 document 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 6980:1996, *Reference beta radiations for calibrating dosemeters and dose-rate meters and for determining their response as a function of beta-radiation energy*

3 Terms and definitions

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

3.1 Quantities and units

3.1.1

equivalent dose in a tissue or organ

H_T

product of the absorbed dose $D_\mathrm{T,R}$, averaged over the tissue or organ T, in the case of skin averaged over the whole surface, and the relevant radiation weighting factor w_R for the radiation R

$$H_\mathrm{T} = w_\mathrm{R} \cdot D_\mathrm{T,R}$$

NOTE 1 When the radiation fields are composed of radiations with different values of w_R, the equivalent dose in a tissue or organ is the sum of the products of the radiation weighting factor w_R and the absorbed dose, $D_{T,R}$, thus

$$H_T = \sum_R w_R \cdot D_{T,R} \tag{1}$$

NOTE 2 The equivalent dose quantities defined in "Equivalent dose in a tissue or organ" cannot be directly measured. Instead, the dose equivalent is measured with dosimeters positioned on appropriate parts of the body. These dosimeters are calibrated on appropriate phantoms.

NOTE 3 The unit of equivalent dose in a tissue or organ is joule per kilogram ($J \cdot kg^{-1}$) with the special name sievert (Sv).

NOTE 4 For β and photon radiation, the numerical values of dose equivalent and equivalent dose are practically the same.

3.1.1.1
partial-body dose

equivalent dose to tissue, organs or parts of the body identified by the name of the part of the particular tissue, organ or body, e.g. bone marrow dose, skin dose, hand dose, testes dose or dose to the lens of the eyes

NOTE 1 In regulations still based on ICRP 26[1], the dose equivalent to a part of the body or organ, H_T, is defined, for beta and photon radiation, as the product of the absorbed dose, D_T, in the organ and the quality factor Q for the radiation under consideration. Q is defined as a function of the linear collision stopping power in water; for low energy photons, and for beta particles Q is equal to 1 in this International Standard.

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

3.1.1.2
localized skin dose

H_{skin}

equivalent dose averaged over an area of 1 cm^2 of skin at a nominal depth of 0,07 mm and at the respective point of interest

NOTE 1 The maximum localized skin dose is predominant in monitoring the skin limit for external radiation.

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

3.1.2
effective dose

E

sum of the equivalent doses, H_T, in relevant organs and tissues multiplied by the appropriate tissue weighting factors, w_T

$$E = \sum_T w_T \cdot H_T$$

NOTE 1 The following expression applies based on the definition of H_T.

$$E = \sum_T \sum_R w_T \cdot w_R \cdot D_{T,R} \tag{2}$$

NOTE 2 The equivalent dose quantities defined in “Effective dose“ cannot be directly measured. Instead the dose equivalent is measured with dosimeters positioned on appropriate parts of the body. These dosimeters are calibrated on appropriate phantoms.

NOTE 3 The unit of effective dose is joule per kilogram ($J \cdot kg^{-1}$), with the special name sievert (Sv).

3.1.3

weighting factor

w_T

factor which represents the relative contribution of that organ or tissue to the total detriment due to the stochastic effects resulting from uniform irradiation of the whole body

3.1.4

effective dose equivalent

H_E

weighted average of the dose equivalent in a tissue or organ, T, each weighted by a tissue or organ weighting factor, w_T, as formerly recommended by ICRP 26 [1]

3.1.5

personal dose equivalent

$H_p(d)$

dose equivalent in soft tissue measured at an appropriate depth, d, below a specified point of the body

NOTE 1 For strongly penetrating radiation, the depth, 10 mm, is frequently recommended (see 3.3.1). For weakly penetrating radiation a depth of 0,07 mm for the skin and 3 mm for the lens of the eye are employed (see 3.3.1). For these purposes, $H_p(d)$, is written as, $H_p(10)$, $H_p(3)$ and $H_p(0,07)$, respectively

NOTE 2 This definition ensures that the personal dose equivalent, $H_p(10)$, for a whole-body exposure to strongly penetrating radiation, represents an estimate of the effective dose and the equivalent dose for deep-lying organs, whereas the personal dose equivalent, $H_p(0,07)$, permits the skin dose to be monitored for a partial-body exposure of the skin or of the extremities.

NOTE 3 The unit of personal dose equivalent is joule per kilogram ($J \cdot kg^{-1}$), with the special name sievert (Sv).

NOTE 4 As noted in ICRU 56[2], in most cases the only value of the depth that is of concern for beta radiation is 0,07 mm while in a few instances a depth of 3 mm is of interest for protection of the lens of the eye. The ambient dose equivalent $H^*(10)$ used for the monitoring of strongly penetrating radiation is not appropriate for any beta radiation, even that which is considered as strongly penetrating ($E_{max} > 2,5$ MeV) (see 3.1.6.1).

3.1.6

area monitoring

for purposes of routine radiation protection, it is desirable to characterize the potential irradiation of individuals in terms of a single dose-equivalent quantity that would exist in a phantom approximating the human body

NOTE 1 The phantom selected is called the ICRU sphere.

NOTE 2 For area monitoring, it is useful to stipulate certain radiation fields that are derived from the actual radiation field. The terms ”expanded” and ”aligned” are used to characterize these derived radiation fields. In the expanded field, the fluence and its angular and energy distribution have the same values throughout the volume of interest as in the actual field at the point of reference. In the aligned and expanded field, the fluence and its energy distribution are the same as in the expanded field but the fluence is unidirectional.

3.1.6.1

ambient dose equivalent

$H^*(d)$

dose equivalent that would be produced, at a point in a radiation field, by the corresponding aligned and expanded radiation field in the ICRU sphere at a depth, d, on the radius opposing the direction of the aligned field

NOTE 1 The recommended depth for strongly penetrating radiation is $d = 10$ mm.

NOTE 2 The ambient dose equivalent $H^*(10)$ is not suitable for measurements in pure beta radiation fields.

NOTE 3 The unit of ambient dose equivalent is joule per kilogram ($J \cdot kg^{-1}$), with the special name sievert (Sv).

3.1.6.2
directional dose equivalent

$H'(d,\Omega)$

dose equivalent that would be produced, at a point in a radiation field by the corresponding expanded radiation field in the ICRU sphere at depth, d, on a radius in a specified direction, Ω

NOTE 1 The recommended depth for weakly penetrating radiation is d = 0,07 mm.

NOTE 2 In an expanded radiation field with given directional radiation distribution, the value of the quantity, $H'(d)$, is generally dependent on the orientation of the specified sphere radius.

NOTE 3 The use of ambient and directional dose equivalents ensures that, for strongly penetrating radiation, the ambient dose equivalent gives an estimate of the effective dose and the equivalent dose in deep-lying organs and, for weakly penetrating radiation, the directional dose equivalent gives an estimate of a person's skin dose during measurement at the location where the dose is measured.

NOTE 4 The dose equivalent for area monitoring for strongly penetrating radiation is given by, $H^*(10)$, and for weakly penetrating radiation by, $H'(0{,}07)$. If strongly penetrating radiation and weakly penetrating radiation are considered simultaneously, the dose equivalent is characterized by the pair of values, $H^*(10)$ and $H'(0{,}07)$. This quantity definition corresponds approximately to the directional dependence of readings in measurements with an area dosimeter designed for simultaneous measurement of strongly and weakly penetrating radiation.

NOTE 5 The unit of directional dose equivalent is joule per kilogram ($\mathrm{J \cdot kg^{-1}}$), with the special name sievert (Sv).

3.1.7
dose-equivalent rate

quotient of dose equivalent in a time interval divided by the time interval

NOTE 1 For area monitoring, the dose-equivalent rate for strongly penetrating radiation is given by $H^*(10)$, and for weakly penetrating radiation by $H'(0{,}07)$. If strongly penetrating radiation and weakly penetrating radiation have to be considered, the pair of values, $H^*(10)$ and $H'(0{,}07)$, should be reported

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

3.2 Personal dosimeters

3.2.1
approved dosimeter

personal dosimeter used to determine the personal dose equivalent and issued by a measurement office in compliance with national regulations

NOTE In some countries, the approved dosimeters are named official or accredited dosimeters.

3.2.2
approved whole-body dosimeter

approved dosimeter for measuring the personal dose equivalent due to whole-body exposure

NOTE The reading of the whole-body dosimeter worn on the front of the trunk is often used as an estimate of the effective dose.

3.2.3
approved partial-body dosimeter

approved dosimeter for measuring the personal dose equivalent to the part of the body concerned (see informative annex A)

NOTE The reading of the partial-body dosimeter is often used as an estimate of the dose equivalent for the affected part of the body.

3.3 Other terms

3.3.1

weakly penetrating radiation

radiation when the personal dose equivalent received by any small area of the sensitive layer of the skin is more than 10 times larger than the effective dose for a given orientation of the body in a uniform and unidirectional radiation field

3.3.2

strongly penetrating radiation

radiation when the equivalent dose received by any small area of the skin is less than 10 times larger than the effective dose for a given uniform and unidirectional field and orientation of the body

3.3.3

soft tissue

for dosimetry purposes, homogeneous material composed of (in weight percentages): 10,1 % hydrogen, 11,1 % carbon, 2,6 % nitrogen and 76,2 % oxygen ICRU tissue, with a specific gravity of 1 g·cm^{-3}

NOTE For ICRU tissue see ICRU 33[3].

3.3.4

investigation level

value of the personal dose equivalent which, when exceeded, requires investigations into the effectiveness of radiation protection measures

NOTE 1 The investigation level is dependent on the respective operation or application type.

NOTE 2 The investigation level in this International Standard is a dose equivalent specified for various parts of the body for a fixed time period. For personal dose-equivalent readings below or equal the investigation level, the dosimeter reading is taken as representing the effective dose, or equivalent dose to specified organs or parts of the body. For a personal dose equivalent reading exceeding the investigation level, it needs to be verified whether a calculation of the corresponding equivalent dose is required.

NOTE 3 Investigation levels are established by national authorities.

3.3.5

transmission factor

T

ratio of the dose-equivalent rate determined behind a shielding and the dose-equivalent rate without this shielding

NOTE 1 For X-rays and gamma radiation, the attenuation factor, which is equal to the reciprocal of the transmission factor, is often used.

NOTE 2 In mixed beta and photon radiation fields, the transmission factor can also be specified for components of the radiation field.

NOTE 3 Reference should be made to the geometry for which the transmission factor is calculated or measured.

4 Radiation protection planning

Weakly penetrating radiation is to be expected in the vicinity of unsealed radioactive materials, for example, on contaminated inner surfaces of plant components, on system components or tools and in contaminated areas. High values of the directional dose-equivalent rate can be produced, in particular, by beta radiation. Therefore, weakly penetrating radiation should be considered already at the stage of radiation protection planning.

The components on which contamination can occur are, as a rule, known from operational experience. If a high gamma ambient-dose-equivalent rate is measured on closed components (e.g. pumps, steam generator), a high percentage of weakly penetrating radiation has to be expected when the component is opened.

The radiation fields from contaminated surfaces or air may be subject to considerable variation in time and location.

NOTE Information on weakly penetrating radiation, in particular beta radiation, in nuclear power plants is given in references [4] to [10] in the bibliography.

5 Characterization of radiation fields

5.1 Introduction

The effective dose from weakly penetrating radiation, in particular from beta radiation, depends on the directional dose-equivalent rate, the duration of the exposure, on the direction considered and the attenuation by the protective clothing. Information about the energy of beta radiation is obtained from the radionuclide composition, beta spectrometry or the attenuation of the radiation.

5.2 Nuclide composition of contamination

The composition of a radionuclide mixture can be determined, for example, by radiochemical analysis, by direct measurements with gamma spectrometers on surfaces or by the evaluation of wipe or scratch tests.

In determining the radionuclide composition, all radionuclides which contribute significantly to the directional dose equivalent due to the emission of weakly penetrating radiation shall be recorded.

NOTE 1 The radionuclide composition may be subject to variations in time and location.

NOTE 2 Wipe tests alone do not always provide the complete radionuclide spectrum, especially in the case of fixed contamination.

NOTE 3 Whereas weakly penetrating radiation is partially attenuated by absorbers (e.g. air), beta radiation components of high maximum energy (e.g. ^{124}Sb with $E_{\beta,\mathrm{max}}$ = 2,3 MeV) can contribute significantly to the dose equivalent even if their concentration in the radionuclide mixture is small (see Figure 1).

NOTE 4 Gamma spectrometers do not provide information on the complete radionuclide spectrum since pure beta emitters are not detected.