SLOVENSKI STANDARD
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Dozimetrija za merjenje izpostavljenosti kozmičnemu sevanju v civilnem letalskem prometu - 3. del: Meritve na višini letenja (ISO/DIS 20785-3:2022)

Dosimetry for exposures to cosmic radiation in civilian aircraft - Part 3: Measurements at aviation altitudes (ISO/DIS 20785-3:2022)

Dosimetrie zu Expositionen durch kosmische Strahlung in Zivilluftfahrzeugen - Teil 3: Messungen auf Flughöhen (ISO/DIS 20785-3:2022)

Dosimétrie pour les expositions au rayonnement cosmique à bord d'un avion civil - Partie 3: Mesurages à bord d'avions (ISO/DIS 20785-3:2022)

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Dosimetry for exposures to cosmic radiation in civilian aircraft —

Part 3: Measurements at aviation altitudes

Dosimétrie pour les expositions au rayonnement cosmique à bord d'un avion civil —

Partie 3: Mesurages à bord d'avions

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Contents

Page

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 on 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 the following URL: www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 85, *Nuclear energy, nuclear technology, and radiological protection*, Subcommittee SC 2, *Radiological protection*.

This second edition cancels and replaces the first edition (ISO 20785-3:2015), which has been technically revised.

The main changes compared to the previous edition are as follows:

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A list of all parts in the ISO 20785 series can be found on the ISO website.

Introduction

Aircraft crews are exposed to elevated levels of cosmic radiation of galactic and solar origin and secondary radiation produced in the atmosphere, the aircraft structure and its contents. Following recommendations of the International Commission on Radiological Protection in Publication 60[1], confirmed by Publication 103[2], the European Union (EU) introduced a revised Basic Safety Standards Directive[3] which included exposure to natural sources of ionizing radiation, including cosmic radiation, as occupational exposure. The Directive requires account to be taken of the exposure of aircraft crew liable to receive more than 1 mSv per year. It then identifies the following four protection measures: (i) to assess the exposure of the crew concerned; (ii) to take into account the assessed exposure when organizing working schedules with a view to reducing the doses of highly exposed crew; (iii) to inform the workers concerned of the health risks their work involves; and (iv) to apply the same special protection during pregnancy to female crew in respect of the ‘child to be born’ as to other female workers. The EU Council Directive has to be incorporated into laws and regulations of EU Member States and has to be included in the aviation safety standards and procedures of the Joint Aviation Authorities and the European Air Safety Agency. Other countries such as Canada and Japan have issued advisories to their airline industries to manage aircraft crew exposure. ICRP has recommended a graded approach for radiological protection of flyers by setting three groups: aircraft crews, frequent flyers, and occasional flyers and encourages frequent flyers to perform self-assessment of their doses from cosmic radiation so that they could consider adjustment of their flight frequency as necessary[4].

For regulatory and legislative purposes, the radiation protection quantities of interest are equivalent dose (to the foetus) and effective dose. The cosmic radiation exposure of the body is essentially uniform and the maternal abdomen provides no effective shielding to the foetus. As a result, the magnitude of equivalent dose to the foetus can be put equal to that of the effective dose received by the mother. Doses on board aircraft are generally predictable, and events comparable to unplanned exposure in other radiological workplaces cannot normally occur (with the rare exceptions of extremely intense and energetic solar particle events). Personal dosemeters for routine use are not considered necessary. The preferred approach for the assessment of doses of aircraft crew, where necessary, is to calculate directly effective dose rate, as a function of geographic location, altitude and solar cycle phase, and to fold these values with flight and staff roster information to obtain estimates of effective doses for individuals. This approach is supported by guidance from the European Commission, the ICRP in Publication 75[5] and the ICRU in Report 84[6].

The role of calculations in this procedure is unique in routine radiation protection and it is widely accepted that the calculated doses should be validated by measurement. As effective dose is not directly measurable, the operational quantity of interest is ambient dose equivalent, $H^*(10)$. Although the new recommendations on operational quantities have recently been published by ICRU[7], there would be a delay before being introduced into future ISO and IEC standards. As indicated in particular in ICRU Report 84, the ambient dose equivalent is considered to be a conservative estimator of effective dose if isotropic or superior isotropic irradiation can be assumed. In order to validate the assessed doses obtained in terms of effective dose, calculations can be made of ambient dose equivalent rates or route doses in terms of ambient dose equivalent, and values of this quantity determined by measurements traceable to national standards. The validation of calculations of ambient dose equivalent for a particular calculation method may be taken as a validation of the calculation of effective dose by the same computer code, but this step in the process may need to be confirmed. The alternative is to establish, *a priori*, that the operational quantity ambient dose equivalent is a good estimator of effective dose and equivalent dose to the foetus for the radiation fields being considered, in the same way that the use of the operational quantity personal dose equivalent is justified for the estimation of effective dose for radiation workers. Ambient dose equivalent rate as a function of geographic location, altitude and solar cycle phase is then calculated and folded with flight and staff roster information.

The radiation field in aircraft at altitude is complex, with many types of ionizing radiation present, with energies ranging up to many GeV. The determination of ambient dose equivalent for such a complex radiation field is difficult. In many cases, the methods used for the determination of ambient dose equivalent in aircraft are similar to those used at high-energy accelerators in research laboratories. Therefore, it is possible to recommend dosimetric methods and methods for the calibration of dosimetric devices, as well as the techniques for maintaining the traceability of dosimetric measurements to national standards. Dosimetric measurements made to evaluate ambient dose equivalent have to be performed using accurate and reliable methods that ensure the quality of readings provided to workers and regulatory authorities. This part of ISO 20785 gives procedures for the characterization of the response of instruments for the determination of ambient dose equivalent in aircraft.

Requirements for the determination and recording of the cosmic radiation exposure of aircraft crew have been introduced into the national legislation of EU Member States and other countries. Harmonization of methods used for determining ambient dose equivalent and for calibrating instruments is desirable to ensure the compatibility of measurements performed with such instruments.

This part of ISO 20785 is intended for the use of primary and secondary calibration laboratories for ionizing radiation, by radiation protection personnel employed by governmental agencies, and by industrial corporations concerned with the determination of ambient dose equivalent for aircraft crew.

Dosimetry for exposures to cosmic radiation in civilian aircraft —

Part 3:
Measurements at aviation altitudes

1 Scope

This part of ISO 20785 gives the basis for the measurement of ambient dose equivalent at flight altitudes for the evaluation of the exposures to cosmic radiation in civilian aircraft.

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.

ISO/IEC Guide 98-1, *Uncertainty of measurement — Part 1: Introduction to the expression of uncertainty in measurement*

ISO/IEC Guide 98-3, *Uncertainty of measurement — Part 3: Guide to the expression of uncertainty in measurement (GUM:1995)*

ISO/IEC 80000-10:2019, *Quantities and units — Part 10: Atomic and nuclear physics*

ISO 20785-1, *Dosimetry for exposures to cosmic radiation in civilian aircraft — Part 1: Conceptual basis for measurements*

ISO 20785-2, *Dosimetry for exposures to cosmic radiation in civilian aircraft — Part 2: Characterization of instrument response*

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 Quantities and units

3.1.1
particle fluence
fluence
Φ
differential quotient of N with respect to a, where N is the number of particles incident on a sphere of cross-sectional area a:

$$\Phi = \frac{dN}{da}$$

Note 1 to entry: The unit of the fluence is m^{-2}, a frequently used unit is cm^{-2}.

Note 2 to entry: The energy distribution of the particle fluence, Φ_E, is the quotient $d\Phi$ by dE, where $d\Phi$ is the fluence of particles of energy between E and $E+dE$. There is an analogous definition for the direction distribution, Φ_Ω, of the particle fluence. The complete representation of the double differential particle fluence can be written (with arguments) $\Phi_{E,\Omega}\,(E,\Omega)$, where the subscripts characterize the variables (quantities) for differentiation and where the symbols in the brackets describe the values of the variables. The values in the brackets are needed for special function values, e.g. the energy distribution of the particle fluence at the energy $E = E_0$ is written as $\Phi_E(E_0)$. If no special values are indicated, the brackets may be omitted.

3.1.2
particle fluence rate
fluence rate

$\dot{\Phi}$

$$\dot{\Phi} = \frac{d\Phi}{dt} = \frac{d^2N}{da \cdot dt}$$

where $d\Phi$ is the mean increment of the particle fluence during an infinitesimal time interval with duration dt

Note 1 to entry: The unit of the fluence rate is m^{-2} s^{-1}, a frequently used unit is cm^{-2} s^{-1}.

3.1.3
linear energy transfer (LET)

L_Δ

quotient of the mean energy dE_Δ lost by the charged particles due to electronic interactions in traversing a distance, dl, minus the mean sum of the kinetic energies in excess of Δ, of all the electrons released by the charged particles and dl :

$$L_\Delta = \frac{dE_\Delta}{dl}$$

L_∞ (i.e. with $\Delta = \infty$) is termed the *unrestricted linear energy transfer* in defining the *quality factor*.

L_Δ is also known as the *restricted linear collision stopping power*.

Note 1 to entry: The unit of the linear energy transfer is J m^{-1}, a frequently used unit is keV µm^{-1}.

3.1.4
dose equivalent

H

product of the absorbed dose D to tissue at the point of interest and the quality factor Q at that point:

$$H = DQ$$

Note 1 to entry: Q is determined by the unrestricted linear energy transfer, L_∞ (often denoted as L or LET), of charged particles passing through a small volume element (domains) at this point (the value of L_∞ is given for charged particles in water, not in tissue; the difference, however, is small). The dose equivalent at a point in tissue is then given by:

$$H = \int_{L=0}^{\infty} Q(L) D_L dL$$

where $D_L = dD/dL$ is the distribution of D in L at the point of interest.

Note 2 to entry: The relationship of Q and L is given in Reference [2].

Note 3 to entry: The unit of dose equivalent is J kg^{-1}, called sievert (Sv).

3.1.5
ambient dose equivalent
$H^*(10)$
dose equivalent at a point in a radiation field, that would be produced by the corresponding expanded and aligned field, in the ICRU sphere at 10 mm depth on the radius opposing the direction of the aligned field

Note 1 to entry: The unit of ambient dose equivalent is J kg^{-1}, called sievert (Sv).

3.1.6
particle fluence-to-ambient dose equivalent conversion coefficient
$h(10)^*_{\Phi}$
quotient of the particle ambient dose equivalent, $H^*(10)$, and the particle fluence, Φ

$$h(10)^*_{\Phi} = \frac{H^*(10)}{\Phi}$$

Note 1 to entry: The unit of the particle fluence-to-ambient dose equivalent conversion coefficient is J m^2 kg^{-1} with the special name Sv m^2, a frequently used unit is pSv cm^2.

3.1.7
correction factor
K
factor applied to the indication to correct for deviation of the measurement conditions from reference conditions

3.1.8
atmosphere depth
X_v
mass of a unit-area column of air above a point in the atmosphere

Note 1 to entry: The unit of atmosphere depth is kg m^{-2}; a frequently used unit is g cm^{-2}.

3.1.9
standard barometric altitude
pressure altitude
altitude determined by a barometric altimeter calibrated with reference to the International Standard Atmosphere (ISA) (ISO, 1975) when the altimeter's datum is set to 1 013,25 hPa

Note 1 to entry: The flight level is sometimes given as FL 350, where the number represents multiples of 100 feet of pressure altitude, based on the ISA and a datum setting of 1 013,25 hPa. However, in some countries flight levels are expressed in meters, in which case appropriate conversions should be made before applying the data given in this part of ISO 20785.

3.1.10
magnetic rigidity
P
momentum per charge (of a particle in a magnetic field), given by:

$$P = \frac{p}{Ze}$$

where p is the particle momentum, Z the number of charges of the particle and e the charge of the proton

Note 1 to entry: The base unit of magnetic rigidity is the tesla metre (T m) (= V m^{-1} s). A frequently used unit is V (or GV) in a system of units where the values of the speed of light, c, and the charge on the proton, e, are both 1, and the magnetic rigidity is given by pc/Ze.

Note 2 to entry: Magnetic rigidity characterizes charged-particle trajectories in magnetic fields. All particles having the same magnetic rigidity have identical trajectories in a magnetic field, independent of particle mass or charge.