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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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Foreword

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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).

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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,* in collaboration with the European Committee for Standardization (CEN) Technical Committee CEN/TC 430, *nuclear energy, nuclear technologies and radiological protection,* in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

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

The main changes are as follows:

— revision of the definitions of the terms;

— updated references.

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

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.

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 (ICRP) in Publication 60[3], confirmed by Publication 103[4], the European Union (EU) introduced a revised Basic Safety Standards Directive[5] 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:

a) to assess the exposure of the crew concerned;

b) to take into account the assessed exposure when organizing working schedules with a view to reducing the doses of highly exposed crew;

c) to inform the workers concerned of the health risks their work involves;

d) to apply the same special protection during pregnancy to female crew in respect of the 'child to be born' as to other female workers; after declaration of pregnancy, to ensure that the additional dose to the embryo/foetus would not exceed 1 mSv.

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[6].

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[7] and the ICRU in Report 84[8].

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[9], 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 document 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 document 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 document 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, *Quantities and units — Part 10: Atomic and nuclear physics*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO/IEC 80000-10 for consistent uses of quantities and units, and the following apply.

ISO and IEC maintain terminology 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:

$$\Phi = \frac{\mathrm{d}N}{\mathrm{d}a}$$

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