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Radiological protection — Procedures for monitoring the dose to the lens of the eye, the skin and the extremities

Radioprotection — Procédures pour la surveillance des doses au cristallin, à la peau et aux extrémités

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Foreword

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The committee responsible for this document is ISO/TC 85, *Nuclear energy, nuclear technologies and radiological protection*, Subcommittee SC 2, *Radiological protection*.

This second edition cancels and replaces the first edition (ISO 15382:2002), which has been technically revised. The main changes are the addition of procedures for monitoring the dose to the lens of the eye.

Introduction

The human body has to be protected from effects of ionizing radiation. The stochastic effects are covered by the limit on the effective dose while tissue reactions (deterministic effects) are covered by the dose limits for specific organs. The human skin has to be protected from tissue reactions, like erythema and ulceration. For the lens of the eye, there is the risk of radiation induced opacities and cataract at elevated exposures. To protect the skin of the whole body, the extremities, and the lens of the eye, separate dose limits are recommended by the International Commission on Radiological Protection (ICRP). These separate dose limits are needed because, in case of localized exposures, the organ doses to the skin and the lens of the eye could exceed these limits even if the effective doses were lower than the limit.

Specific dosimetry is needed to monitor these doses and to assess compliance with applicable limits. There are some situations where the correct assessment of the exposure of the skin, extremities, and lens of the eye can be important. In the nuclear sector, there can be exposure due to weakly penetrating radiation caused by unshielded open radioactive sources, or by work in glove boxes. These types of exposure can occur, in particular, in connection with contamination. Exposure to weakly penetrating radiation from radioactive noble gases in room air also has to be considered. In the medical field, doses to extremities and doses to the lens of the eye can be important during interventional procedures and in nuclear medicine.

Monitoring the extremities and the lens of the eye is not always straightforward, and many practical problems arise for the application of monitoring in the workplace. As a result, monitoring is often not done as it should be, or not done at all. This International Standard provides guidance on how and when this monitoring should be done, for all the different types of workplace fields.

This International Standard is directed to all who are involved in the dosimetry of the skin, extremities, and the lens of the eye, like for example, radiation protection officers, regulators, workers, dosimetry services, etc.

Radiological protection — Procedures for monitoring the dose to the lens of the eye, the skin and the extremities

1 Scope

This International Standard provides procedures for monitoring the dose to the skin, the extremities, and the lens of the eye. It gives guidance on how to decide if such dosemeters are needed and to ensure that individual monitoring is appropriate to the nature of the exposure, taking practical considerations into account. National regulations, if they exist, provide requirements that need to be followed.

This International Standard specifies procedures for individual monitoring of radiation exposure of the skin, extremities (hands, fingers, wrists, forearms, feet and ankles), and lens of the eye in planned exposure situations. It covers practices which involve a risk of exposure to photons in the range of 8 keV to 10 MeV and electrons and positrons in the range of 60 keV to 10 MeV.

This International Standard gives guidance for the design of a monitoring program to ensure compliance with legal individual dose limits. It refers to the appropriate operational dose quantities, and it gives guidance on the type and frequency of individual monitoring and the type and positioning of the dosemeter. Finally, different approaches to assess and analyse skin, extremity, and lens of the eye doses are given.

It is not in the scope of this International Standard to consider exposure due to alpha or neutron radiation fields.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO/TS 18090-1, *Radiological protection — Characteristics of reference pulsed radiation — Part 1: Photon radiation*.

IEC 62387, *Radiation protection instrumentation — Passive integrating dosimetry systems for personal and environmental monitoring of photon and beta radiation*

IEC 60846-1, *Radiation protection instrumentation — Ambient and/or directional dose equivalent (rate) meters and/or monitors for beta, X and gamma radiation — Part 1: Portable workplace and environmental meters and monitors*

IEC 61526, *Radiation protection instrumentation — Measurement of personal dose equivalents Hp(10) and Hp(0,07) for X, gamma, neutron and beta radiations — Direct reading personal dose equivalent meters*

ICRP, 2007. The 2007 Recommendations of the International Commission on Radiological Protection, ICRP Publication 103. Ann. ICRP 37 (2-4)

ICRP, 2010. Conversion Coefficients for Radiological Protection Quantities for External Radiation Exposures, ICRP Publication 116, Ann. ICRP 40(2–5), 2010

ICRP, 2012. ICRP Statement on Tissue Reactions / Early and Late Effects of Radiation in Normal Tissues and Organs – Threshold Doses for Tissue Reactions in a Radiation Protection Context, ICRP Publication 118. Ann. ICRP 41(1/2)

ICRU, 2011. Fundamental Quantities and Units for Ionizing Radiation, ICRU Publication 85. J. ICRU 11(1)

3 Terms and definitions

For the purposes of this document, the terms, definitions and units given in ICRP 103, ICRP 116, ICRP 118 and ICRU 85 apply.

4 Individual monitoring

4.1 Quantities

Skin and extremity monitoring involves the measurement of $H_p(0,07)$, the estimator of the equivalent dose to the skin.

Lens of the eye monitoring involves the measurement of $H_p(3)$, the estimator of the equivalent dose to the lens of the eye. If the radiation field is well known, $H_p(3)$ can be estimated by the use of dosemeters type tested and calibrated in terms of other quantities, i.e. $H_p(0,07)$ and $H_p(10)$, as in many cases they can provide an adequate estimate of the dose to the lens of the eye (depending on the radiation field). Technical specifications of dosemeters are provided in Annex A. Guidance on which type of dosemeter can be used for the lens of the eye (depending on the radiation field) is provided in Annex B.

4.2 Dose limits and monitoring levels

The dose limits for skin, extremities, and lens of the eye for planned exposure situations are given in national regulations.

ICRP has given more recent recommendations on the dose limits (ICRP 103 and ICRP 118) to avoid tissue reactions. Requirements equivalent to these recommendations are given by the IAEA in the Basic Safety Standards (BSS).[1] These recommendations from ICRP and IAEA constitute the basis for the recommendations in this International Standard.

The ICRP recommended dose limits are the following:

a) an equivalent dose limit to the extremities (hands and feet) or the skin of 500 mSv in a year. The equivalent dose limits for the skin apply to the average dose over 1 cm^2 of the most highly irradiated area of the skin. In practice, an estimate of equivalent dose to the skin is a conservative estimate of equivalent dose to the extremities;

b) an equivalent dose limit to the lens of the eye of 20 mSv per year averaged over 5 consecutive years (100 mSv in 5 years) and of 50 mSv in any single year.

Individual monitoring is required to verify compliance with dose limits as they are described in the national legislation. Extremity, skin, and lens of the eye monitoring should be undertaken for workers who have a reasonable probability of receiving per year an equivalent dose higher than 3/10th of one of the above mentioned yearly limits. National regulations can require monitoring from different values, in that case they replace the following values.

The following monitoring levels are recommended:

a) for the extremities or the skin, this means monitoring should be undertaken if there is a reasonable probability to receive a dose greater than 150 mSv per year;

b) for the lens of the eye, monitoring should be undertaken if there is a reasonable probability to receive a dose in a single year greater than 15 mSv or in consecutive years greater than 6 mSv per year.

For dose levels expected to be lower than the recommended monitoring levels given above, a survey demonstrating that the levels are not exceeded, should be sufficient.

The expected annual dose can be estimated via one or more of the methods given in Clause 5.

4.3 Monitoring period

The choice of the length of the monitoring period is related to the levels of the expected doses and to the relevant dose limit.

For doses above the monitoring level, a monitoring period of one month is recommended. For workers whose doses are likely to stay below the monitoring level, providing monitoring can be considered. The monitoring period in the latter case can be longer, e.g. three months. Shorter monitoring periods can be chosen (weekly monitoring or even monitoring per procedure), when setting up new procedures, when optimizing working conditions or when there is a risk of potential high exposure.

Regulatory bodies and/or expert committees also can provide appropriate recommendations for monitoring periods.

4.4 Extremity, skin and lens of the eye monitoring

The dose to the extremities, skin, and the lens of the eye needs to be monitored in situations with non-homogeneous exposure conditions for which the whole-body monitoring does not provide an adequate estimate of the dose to the skin, the dose to the extremities, or the dose to the lens of the eye. Exposures can be significant when weakly penetrating radiation such as low energy photons or beta radiation is present.

Hand or finger monitoring shall be considered for workplaces where extremities are particularly close to the radiation emitter or radiation beam, such as situations where radioactive sources are handled in, for example, research, nuclear medicine, and dismantling applications. Other important examples where extremity monitoring can be necessary are interventional radiology and nuclear medicine workplaces. Skin monitoring shall be considered for workplaces where skin is close to the radiation emitter or the beam. Also when there is a risk for skin contamination, monitoring should be considered. Examples of such situations are handling of contaminated components or unsealed radioactive sources.

Monitoring of the lens of the eye shall be specifically considered for workplaces where the eyes are particularly close to the radiation emitter (which can also be a source of scattered radiation) or the radiation beam (for example in interventional radiology) while the rest of the body can be protected by, e.g. a lead apron. Workers exposed in high energy beta fields can receive significant doses to the lens of the eye.

4.5 Uncertainties

An essential aspect of quality assurance in individual monitoring is assessing the quality of the measurement results. In the evaluation of the uncertainty, all knowledge of the dosemeter and evaluating system should be used, possibly in combination with information from the client/customer such as local exposure and storage conditions. The amount of effort put into the uncertainty should be realistic in view of its purpose in radiation protection.

ICRU makes recommendations on the acceptable levels for total uncertainty in Report 47[2] which are broadly consistent with the ICRP recommendation (ICRP 75).[3] ICRU recommends for single measurements of the operational quantities that "....in most cases, an overall uncertainty of one standard deviation of 30 % should be acceptable."

The expanded uncertainty (95 % coverage probability) for values of assessed annual dose values at or near the dose limit should not exceed 0,67 to 1,5 (factor 1,5) after all corrections have been made (ICRP 75).[3] This applies to values of effective dose, equivalent dose to a small area of skin, equivalent dose to lens of the eye or extremities, summed for all radiation types of the radiation field.

It shall be recognized that different requirements on accuracy may be needed for an estimate of the equivalent dose at another part of the body than the position of the dosemeter, for example an estimate of the equivalent dose to the finger tips from a measurement of $H_p(0,07)$ several centimetres away (RP160).[4]

4.6 Characteristics of radiation fields

Characterization of the radiation fields is an important step to determine the need for and the type of monitoring required.

Photon fields (X and gamma radiation) of any energy can contribute to the skin, extremity, and lens of the eye exposure.

Electrons (beta radiation) with energy above 60 keV penetrate 0,07 mm of tissue and can, therefore, contribute to the skin dose. Electrons (beta radiation) with energy above 700 keV penetrate 3 mm of tissue and can, therefore, contribute to the dose to the lens of the eye.

In medical fields, the type of radiation and radionuclides are very well known. Whole body exposures are mostly limited because of protection by the use of protective aprons and appropriate shielding, but doses to the extremities and to the lens of the eye can be high. Typical examples are the preparation of radionuclides in nuclear medicine and radio pharmacy, and the exposures to physicians during interventional procedures.

In nuclear installations, low energy betas are to be expected in the vicinity of unsealed radioactive materials, for example, on contaminated inner surfaces of power 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. In nuclear installations handling used fuel as well as in nuclear reactors experiencing fuel leakage, high energy betas (above 700 keV) should be expected. These are more readily monitored than the low energy betas.

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 generators), a high percentage of low energy betas has to be expected when the component is opened. Information about the energy of beta radiation is obtained from the radionuclide composition, spectrometry or the attenuation of the radiation. Attenuation measurements can be used to characterize the radiation field by estimation of the penetration ability as well as the maximum energy of beta radiation.

5 Assessment of dose levels prior to routine monitoring

5.1 General

Prior to routine monitoring, it is important to assess the dose levels to the skin, the extremities, or the lens of the eye in a workplace field situation in order to decide which method, if any, and which period of routine monitoring is necessary.

The doses obtained by one or more of the following methods (5.2 to 5.6) should be extrapolated to annual doses and compared with the monitoring levels given in 4.2.

The assessment should be repeated when the working conditions or workload change significantly, or if the effect of such changes on doses to the skin, the extremity, or the lens of the eye cannot be estimated with confidence.

5.2 Indications from workplace measurements

In work situations with radiation fields that are predictable for a specific work task or over a long period (at least for several months) and with well established procedures, it can be possible to estimate the doses which workers will receive using workplace measurements at relevant locations.

Workplace surveys are recommended (for example measuring the dose equivalent rates) before starting to work on contaminated or activated objects in the nuclear sector, unless it is known from radionuclide analysis, or from earlier measurements that the working conditions (e.g. distance to the source) and the protective equipment is sufficient to attenuate and/or shield this type of radiation.

For determining the directional dose-equivalent rate $H'(0,07)/t$, suitable dose-equivalent rate meters (i.e. with thin walls and small detector thickness) shall be used. If protective clothing is worn, $H'(0,07)$ shall be measured behind the respective layer of clothing.

The measurement position shall be representative of the exposure conditions of the person surveyed. Also the distance that low energy photons and betas travel in air is important. If it cannot be avoided that contaminated objects are touched with the hands, measurements shall be performed both near the surface (at closest position) and at the usual working distance of the trunk (approximately 30 cm). If tools are used, measurements shall be performed at the distance appropriate for the use of such tools.

On the basis of the measured dose-equivalent rates $H'(0,07)/t$, $H'(3)/t$, and $H^*(10)/t$, and the time the person is present in the radiation field, it can be evaluated whether the work to be carried out requires wearing a personal dosemeter and/or additional protective measures.

The technical specifications for area dosemeters measuring the quantities $H'(0,07)$ and $H^*(10)$ shall be as defined in IEC 62387 for passive dosemeters and IEC 60846-1 for active dosemeters. For area dosemeters measuring the quantity $H'(3)$, no International Standard is yet available.

5.3 Indications from whole body dosimetry

When individual monitoring is performed, a dosemeter worn on the trunk is used for the estimation of effective dose. The results from the whole body dosemeter can give an indication of the level of exposure to the extremities, the skin, or the lens of the eye, provided the exposure conditions and the radiation field characteristics (especially the spatial distribution) are taken into account.

The approach of using a single dosemeter worn at the collar of the protective apron potentially provides an option for informing the radiation protection practice. Such a system can provide indications of when dedicated eye dosimetry is required.

When the whole body dosemeter is worn under the protective clothing, its reading strongly underestimates the dose to the unprotected extremities and the lens of the eye and can therefore not be used to provide an indication of the level of these doses.

5.4 Indications from literature data

In the literature, some typical dose values are given for various workplace situations. These can in principle be used to judge if monitoring is needed. When using literature values it should be ensured that the data are truly representative of the current workplace conditions regarding the radiation source (for example, which radionuclides or which high voltage of X-ray tubes is used), the geometry (for example, under or over couch setting in radiology) and types of protective measures (like shielding) that are used. Examples of literature data can be found in Annex C for medical applications.

5.5 Indications from simulations

Numerical simulations can be very powerful and can provide important information on the parameters affecting and influencing the doses in given exposure scenarios. To date, there are no readily available packages that can be easily used to obtain fast evaluations on operator's doses to the skin, the extremities, or the lens of the eye, but general purpose numerical codes (e.g. MCNP, EGS, GEANT, PENELOPE, etc.) can be applied to the particular investigated case. Simulations are often complex and time consuming, depending on the treated case. When using simulations, it is necessary to validate the results with measurements.

5.6 Indications from confirmatory measurements

Another way to determine if individual monitoring is needed is by performing confirmatory measurements with personal dosemeters. Confirmatory measurements are measurements intended to assess the level of doses to the workers in the specific workplace field. These confirmatory

measurements can be used as guidance in determining whether the monitoring level might be reached. Such confirmatory measurements shall fulfil the following requirements:

— the confirmatory measurements shall mimic routine measurements;

— they shall be performed as described in Clause 6;

— the working procedures shall not be changed because of the confirmatory measurements, otherwise the confirmatory measurements need to be restarted;

— the confirmatory measurements shall be performed for a minimum of 3 consecutive periods unless it is to mimic a single work task. The intention is to have a representative sample of the annual doses. If the activities are very irregular (large fluctuations from month to month), longer periods of monitoring are needed. A confirmatory measurement survey lasting a whole year might be needed.

6 Personal dosimetry

6.1 Extremity and skin dosimetry

6.1.1 Locations to monitor

For radiation fields where there is a significant spatial non-uniformity, the doses to the extremities can be of great concern. The skin of the extremities is the limiting organ rather than the extremity itself. An estimate of the equivalent dose to the skin, H_{skin}, is normally a conservative estimate of the equivalent dose to the extremities. Therefore, an extremity dosemeter becomes a skin dosemeter and shall be designed to measure $H_{\text{p}}(0{,}07)$ and be placed as close as possible to the most exposed part of the skin surface.

The monitoring location needs special consideration. In non-uniform fields, it is often difficult to place one single extremity dosemeter at the most highly exposed part of the skin since this part is not known a priori. In addition, it is not always the hands or fingers that are the most exposed area, also legs or feet as well as unprotected skin can be the most exposed area.

For direct or close handling of radioactive sources, finger-stall dosemeters on the fingertip, or ring dosemeters should be used on the finger which is frequently the most exposed. The monitored hand should be chosen as the most exposed between the left and right one. This can be found by doing some specific tests or using recommendations from the literature. In the case of nuclear medicine,[5] the recommended position is the index finger tip or the base of index finger of the non-dominant hand. The dosemeter should be oriented towards the radiation source.

For nuclear industry fields, interventional radiology, or other similar radiation fields, either a ring dosemeter or a wrist dosemeter worn at the most exposed hand shall be used. The dosemeter shall be oriented towards the radiation field if possible.

For leg monitoring, wrist dosemeters worn at the ankle can be used. The monitored leg shall be chosen as the most exposed between the left and right one. The leg chosen is the closest to the radiation source and/or the least protected. The dosemeter shall be oriented towards the radiation field if possible.

It can be necessary to monitor the doses at different locations using several dosemeters simultaneously (e.g. both hands).

The dosemeter shall be worn under protective clothing, especially inside gloves, if such clothing is worn. The dosemeter can also be worn outside the protective clothing, but under an appropriate thickness of material that approximates the type and thickness of the protective clothing. This protects the dosemeter from perspiration, permits easier removal, and gives an accurate measurement of the skin dose.

6.1.2 Types of dosemeters

Skin and extremity doses shall be estimated by measuring the operational quantity $H_{\text{p}}(0{,}07)$.

