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Radiological protection — Recommendations for dealing with discrepancies between personal dosimeter systems used in parallel

Radioprotection — Recommandations relatives au traitement des écarts entre systèmes dosimétriques individuels utilisés en parallèle

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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*.

Introduction

For decades, active dosimeters have been used in parallel with passive dosimeters in many installations. Experience has shown that active dosimeters integrated over a period of one month indicate a higher or lower personal dose equivalent than passive dosimeters used for the same period. The differences can sometimes be quite large. With other combinations of dosimeters, used for the same time, differences in the indicated dose are also to be expected. Additionally, differences in the indicated dose can influence the confidence of the dosimetry results in the workforce.

In some nuclear installations, procedures are in place for dealing with such discrepancies (see References,[1],[2] and[3]). In others, investigation has been done and a need to examine such discrepancies was found. The Institute of Nuclear Power Operations (INPO) has also given advice in this area (see Reference[4]).

This International Standard was developed to provide recommendations to deal with discrepancies that can be observed between dosimeters that are used in parallel and to help achieve and maintain high radiation protection quality. It can also be used as a common tool for the management of doses for stakeholders involved in radiation protection management.

The recommendations presented in this International Standard are applicable under the following conditions:

— two or more dosimeters assessing the same operational quantity for one person are used in parallel;

— national regulation/national authorities allow a dosimetry processor or a practice involving ionising radiation to be informed of both values.

Radiological protection — Recommendations for dealing with discrepancies between personal dosimeter systems used in parallel

1 Scope

This International Standard provides recommendations for dealing with discrepancies between dosimeter systems used in parallel, in order to comply with established criteria and national regulations.

This International Standard gives guidelines for investigating and analysing the discrepancies between the results of personal dosimetry systems, using two or more dosimeters (often one passive dosimeter and one active dosimeter), worn in parallel by the same worker.

This International Standard identifies when the difference between measurements made by personal dosimetry systems used in parallel is considered significant and, hence, needs to be investigated.

It specifies the treatment of this difference.

In this International Standard, only the personal dose equivalent, $H_p(10)$, from photon radiation is considered. Exposure to beta particles and neutrons might need to be taken into account when identified discrepancies are investigated.

This International Standard applies to situations where the period of wearing can be integrated to the same period of time for both systems.

2 Normative references

The following referenced documents are indispensable for the application 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 14146, *Radiation protection — Criteria and performance limits for the periodic evaluation of processors of personal dosemeters for X and gamma radiation*

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

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

3 Terms and definitions

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

3.1 Operational quantities

3.1.1
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 to entry: For strongly penetrating radiation, a depth of 10 mm is frequently recommended. For weakly penetrating radiation, a depth of 3 mm for the lens of the eye and 0,07 mm for the skin are employed. For these purposes, $H_p(d)$ is written as $H_p(10)$, $H_p(3)$, and $H_p(0,07)$, respectively.

Note 2 to entry: 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.

Note 3 to entry: In many instances, the angular distribution needs to be considered for these situations. The personal dose equivalent is defined as $H_p(d,\alpha)$, where α represents the angle of incidence.

Note 4 to entry: $H_p(d,\alpha)$ cannot be directly measured. It is approximated using an ICRU slab phantom.

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 1 to entry: In some countries, the approved dosimeters are named legal, official, or accredited dosimeters.

Note 2 to entry: When more than one approved dosimeter is used at the same time for one person, only one of the measured doses should be considered to be the technical basis used for the recorded personal dose equivalent. This choice of using measurements from one approved dosimeter for official (legal) purposes should be documented.

3.2.2
passive integrating dosimeter
personal dosimeter that utilises one or more detectors to integrate information about the absorbed energy and needs a readout unit to display the information

Note 1 to entry: The integration time is usually one month. The latent signal needs to be assessed by a competent dosimetry laboratory to determine the personal dose equivalent at the end of a wear period and to enter the personal dose equivalent into dose registers. National legislation/decisions can allow for integrating times other than one month.

3.2.3
active integrating dosimeter
personal dosimeter that utilises one or more detectors to integrate information about the absorbed energy and to convert and display this as $H_p(d)$

Note 1 to entry: The integration time is usually as short as a one entry period into controlled areas. These detectors normally give a direct reading of the personal dose equivalent. Alarms can warn the worker when preset dose or dose rate levels are exceeded. They are normally connected to electronic readout units at exit from controlled areas. The output is used to assess the personal dose equivalent and entered into computers with dose registers.

4 Assessing the differences between dosimeters used in parallel

4.1 General

The objective for a personal dosimetry service is to assign the correct dose to each individual. The dosimetry service shall fulfil requirements according to ISO 14146 and IEC 62387. This is sometimes performed with individual passive dosimeters used for the required time period (often on a monthly base). Active (electronic) dosimeters are often used for each entry into controlled areas and these dosimeters shall fulfil requirements according to IEC 61526. Individual dosimetry using passive dosimeters for the required time period should be compatible with the individual doses summed from the active dosimeters for the same time period. Numerical criteria for this recommendation are given in this International Standard.

Guidance for calibrating personal dosimeters can be found in ISO 4037,[5-8] and in publications from the International Commission on Radiation Units and Measurements (ICRU) and International Commission on Radiological Protection (ICRP).[9-18] Guidance is also available on the calibration of active dosimeters in NPL GPG113.[19]

Normally, national authorities test and approve dosimetry services including, for example, the procedures laid down in ISO 14146 or in RP 160,[20] S106,[21] and ANSI N13.11.[22]

When dosimetry systems are used in parallel, the collective dose assessed by the dosimetry systems normally differs slightly.

It is to be expected that the individual doses estimated by different systems differ slightly. The need for investigations of differences in the individual doses depends on the level of the individual doses as well as on the size of the difference. The difference in the assessed dose values should be investigated in light of the uncertainties given in the characterisation standards (see IEC 61526, IEC 62387).

4.2 Comparison between dosimeters used in parallel by individual users

4.2.1 General

In the case of a passive and an active dosimeter used in parallel by the same person, after the reading of the passive dosimeter (reading occurring monthly or for the required wearing period), the dose is compared with the dose calculated as the sum of the doses measured with active dosimeters used for the same required time period. The comparison is often performed with the computer system used by the dosimetry service (or by the responsible user of the active dosimetry system).

When the recommended criteria for the difference in dosimeter results, given in 4.2.2, are exceeded, those responsible for the dosimetry should look for malfunctions in the dosimetry procedure; in the response of the personal dosimeter in question; or, request the Radiation Protection Department to evaluate the reasons for the difference. If needed, the legal individual dose is corrected. Also, the dose registered by the dosimeter used in parallel with the legal dosimeter might need to be corrected. The correction is registered and the person is informed about this correction. If a correction is not needed, then this is also registered.

The recommended criteria correspond well with those given in ICRU's Report 47[11] but are slightly different compared to those recommended in ISO 14146 for approving a dosimetry service. To restrict the comparison to significant discrepancies and to avoid research of discrepancies close to the registration level for legal dosimeters, it is recommended to make comparisons when the dose for a wearing period, measured by at least one of the dosimeters, is above 1 mSv.

To take into consideration the case of low monthly doses which could lead to a dose of a few mSv per year, recommended criteria to investigate differences between results for the dosimeters used in parallel are also proposed. In this case, to restrict the comparison to significant discrepancies, it is recommended to make comparisons when the dose for one year, measured by at least one of the dosimeters, is above 3 mSv.

4.2.2 Recommended criteria for further research of difference in dosimeter results

For dose evaluations summed for the required wearing period for the dosimeters with the longest wearing period, it is recommended to research explanations for differences in dosimeter results, if

— estimated dose > 1 mSv (one or both dosimeters), and

— low reading dosimeter dose < 0,7 × high reading dosimeter dose.

In practice, when the majority of the personal doses are below 1 mSv, a lower threshold than 1 mSv should be used when investigating the differences. National recommendations or company practices may also determine alternative recommended criteria to follow when investigating differences.

Particular attention might need to be paid to the fact that the threshold dose for the registration of doses from passive dosimeters is usually much higher than for active dosimeters.

In the case of low doses for each wearing period, the same kind of criteria could be defined over a period of time of one year.

For dose evaluations summed over one year for dosimeters of the same kind (two active or two passive dosimeters), it is recommended to research explanations for differences in dosemeter results, if

— estimated dose > 3 mSv (one or both dosimeters), and

— low reading dosimeter dose < 0,7 × high reading dosimeter dose.

When considering that small differences are added period after period, the criteria would need to be increased to take into account uncertainties such as the registration threshold for each dose evaluated from passive dosimeters. Therefore, for dose evaluations summed over one year for combinations of active and passive dosimeters, it is recommended to research explanations for differences in dosimeter results, if

— estimated dose > 3 mSv (active or passive dosimeter), and

— active dosimeter dose < 0,7 × passive dosimeter dose, or

— active dosimeter dose > 1,7 × passive dosimeter dose.

4.3 Assessment of the differences outside the recommended criteria

The discrepancies in most cases depend on:

a) differences between the dosimeter systems and malfunctions in the procedures used for quality control of the dosimetry systems; or

b) differences in the use of the dosimeters in the controlled area.

The persons responsible for the dosimetry may wish to consider some procedures to identify any reasons for the discrepancy. Radiation protection personnel can investigate where and how the dosimeters were used to identify any reasons for the discrepancy.

Examples of reasons for discrepancies are given in Annex A. For several examples, a detailed description is given in the annex.

NOTE 1 It may be useful to consider a longer time period, for instance, to compare the dose values received by the worker during the past year for each period of wear. This could help to detect a systematic difference between the systems.

NOTE 2 When discrepancies exist, a way to investigate is to retrospectively recreate the irradiation conditions and to place a sample of each of the dosimeters in a similar irradiation field. This provides a direct comparison of the dosimeter types. In other circumstances, it may be possible to determine the nature of the discrepancy by more straightforward means, for example, referring to type test data and comparing the angular response, the effect of scattered radiations, the local background conditions, the effects of RF interference.

The reasons for the discrepancies should be reported to the person responsible for the registration of doses. If no reasons are found, it should also be reported to this person. If he/she needs to amend the registered dose, the responsible person should take into consideration these elements.

4.4 Documentation of evaluated differences in evaluated dose

For the purpose of transparent use for documenting and registering individual personal dose equivalents, it is recommended that the results of evaluated differences shall be documented as follows:

a) reason for evaluating the difference;

b) date;

c) relevant dosimeters and results, as received and normalised to one dosimeter;

d) dosimeter providers (if from more than one organisation);

e) wear dates;

f) wearer;

g) position of wear of the dosimeters;

h) main location and sub-location where the dosimeters were used;

i) what the wearer was doing during the wear period;

j) analysis of the potential reasons for differences in estimated dose if known, suggested reason if not known;

k) identification of the anticipated differences that would be predicted;

l) comparison with the observed results;

m) statement that the differences are justified, or an admission that the results are not explicable;

n) suggested dose for registering and (if known) the registered personal dose equivalent;

o) information given to the dosimeter user;

p) name and signature of the person evaluating the difference.

Annex A
(informative)

Factors related to discrepancies between assessed individual doses when dosimetry systems are used in parallel

A.1 General

The persons responsible for the dosimetry may wish to consider some procedures to identify any reasons for the discrepancy:

— calibration results for the dosimeters in use (differences in the collective dose may be useful when assessing this);

— individual response of the dosimeters used in the specific case;

— annealing records (when relevant);

— background subtraction;

— threshold dose.

NOTE The threshold dose for the registration of doses from passive dosimeters is usually much higher than for active dosimeters.

Radiation protection personnel can investigate where and how the dosimeters were used to identify any reasons for the discrepancy, including for example:

— improper use (including the passive dosimeters being used for longer or shorter times than required);

— loss of or damage to one or both dosimeters, including contamination of a dosimeter leading to excess readings;

— work performed in diverging radiation fields;

— work performed where electromagnetic or radiofrequency fields might have influenced the response (as e.g. mobile phones or welding equipment);

— work performed where the humidity and/or the temperature is outside the normal values;

— work performed in fields for which the dosimeters are known to over or under respond, e.g. due to photon energy, neutron irradiation, high energy beta irradiation, pulsed radiation;

— use outside the controlled areas.

A.2 Comments concerning possible influencing factors presented in A.1

A.2.1 Calibration results for the dosimeters in use and individual response of the dosimeters used in the specific case

When dosimetry systems are used in parallel, it is expected that the individual dose measurements differ slightly. However, the calibration of both systems should allow knowing, in advance, the differences of the average response between both systems. A comparison of the collective dose estimated from the systems can give some information concerning drift in the response for one or both of the systems. Nevertheless, when a particular active dosimeter is used, the response can be slightly different than the

average response. If specific response correction factors are not used, this can explain differences. If the dosimeters are calibrated individually, then a drift in the response needs to be ruled out.

A.2.2 Annealing records

Some passive dosimeters are annealed before/during the evaluation. In many dosimeter evaluation systems, information from glow curves are stored and can be investigated after the evaluation of the passive dosimeter.

A.2.3 Background subtraction

For passive dosimeters, a background value adapted to the time of the wear period is often subtracted from the result. For active dosimeters, this is not needed as long as the dosimeters are used only for work in controlled areas and evaluated after each exit from controlled areas. For an example, see A.3.1.

A.2.4 Improper use (including that the passive dosimeters have been used for longer or shorter times than required)

One classic example is using the electronic dosimeter as a survey monitor to identify hotspots. This normally shows up as an alarm and a spike in the dose rate profile.

A.2.5 Loss of or damage to one or both dosimeters

If the legal dosimeter is lost and not found, then the integrated dose registered by active dosimeters for the respective wear period should be inserted into the dose registry. If the legal dosimeter is temporarily lost, it might have led to make the dosimeter having received a higher or lower dose than the individual that has lost the dosimeter. This can be one of the reasons for a discrepancy and should be investigated further. If an active dosimeter is lost, then the dose for the respective wear period might need to be estimated. This can be done by comparison with other workers' doses for the same work and wear period or from calculation of dose rate x time. Similar concerns are relevant if a dosimeter is damaged or contaminated.

A.2.6 Work performed in inhomogeneous radiation fields

When a person is exposed in a diverging radiation field or when a person is exposed to a narrow radiation beam, it often happens that one of the dosimeters is positioned where the dose rate is not the highest. For an example, see A.3.2.

A.2.7 Work performed where electromagnetic or radiofrequency fields might have influenced the response (e.g. mobile phones or welding equipment)

There are numerous examples of electronic dosimeters that have shown excess readings after being in electromagnetic or radiofrequency fields, including those close to mobile phones or welding equipment. Results from type tests according to IEC 61526 might give information concerning this.

A.2.8 Work performed where the humidity and/or the temperature is outside the normal values

The dosimeters might overread or underread if they have been used where their response has changed due to high or low humidity as well as high or low temperature. Results from type tests according to IEC 61526 and IEC 62387 might give information concerning this.

A.2.9 Work performed in fields where the dosimeters are known to over or under respond

For instance, dosimeters are known to over or under respond due to photon energy, neutron irradiation, high energy beta irradiation, pulsed radiation. For an example concerning differences in energy response, see A.3.3.

A.2.10 Use outside the controlled areas

If a dosimeter is used in radiation fields outside the controlled areas, then a dose is assigned to the wearer, although it might not be associated with the person's radiation work.

If a legal dosimeter is used outside the controlled areas, the dosimeter is used in places where the dose rate is different from the background dose rate measured by control dosimeters and, hence, the background correction evaluated by control dosimeters is not adapted.

If an active dosimeter is used outside controlled areas, then the dosimeter registers dose for time periods when the dosimeter normally should not have been used and, hence, result in a higher reading than expected.

A.3 Examples of situations for which significant differences can be found and how these differences can be dealt with

A.3.1 Change in background radiation

Differences in collective dose between the active and passive dosimeter systems can occur when incorrect radiation background subtraction has occurred. A site with 1 000 monitored workers could see an increase in collective dose of 10 mmanSv if just 0,01 mSv less background was subtracted from each worker's dose. In situations where the workplace is under normal operations and a total mmanSv difference is detected between the active and passive dosimeters, it may become important to review control dosimeters and background radiation subtraction methods. The term collective dose is explained in References[15] and[18].

A change in historical control subtraction values may alert the investigator to a modification in the policies for handling controls. For example, moving the storage location of the controls can have an adverse effect. If the controls were placed in an area with more or less background radiation, a discrepancy could be noted between the active and passive total mmanSv. Dosimeters stored on concrete or brick walls may be exposed to a different radiation field than those stored on sheet rock board. Separating the control storage location from the dosimeter storage location may also result in discrepancies in the amount of background subtracted. Storage locations that differ by less than a few tenths of a μSv per day can have some impact when integrated over a monthly or quarterly wear period.

A.3.2 Work performed in inhomogeneous radiation fields

When a person works in inhomogeneous radiation fields, e.g. diverging radiation fields close to radiation sources or where there are narrow radiation beams, dosimeters used in parallel are likely not to be exposed with the same dose. This can be because the dosimeters are at different distance from a source or one or both dosimeters are more or less irradiated by a narrow radiation beam. Other influencing factors might be known or should be investigated, e.g. primary radiation nuclides, shielding, scatter, distributed activity or point sources. Any measurements of the field using handheld gamma spectrometry, absorbers, directional instruments, etc. are useful when investigating the sources for the discrepancies.

EXAMPLE A worker has worked close to a highly contaminated open pipe in a nuclear power station. During his work, one of the dosimeters is in the direct beam from the pipe while the other dosimeter is only temporarily in the direct beam. The dose according to the active dosimeter is 3 mSv. If not noticed before, the discrepancy will probably be great enough to trigger an investigation into the difference in dosimeter results. A quick check with the radiation protection personnel reveals that the person probably has been irradiated in a non-uniform radiation field and a simple investigation is performed by the radiation protection personnel. The result of the investigation is that the high-reading dosimeter has been most of the time in the direct beam. The results from the investigation is given to the person responsible for the registration of doses, who should decide if the dose according to the legal dosimeter should be entered into the dose registry or if a correction of this dose value should be performed. How this should be treated depends on national regulations and procedures for radiation protection management.

