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The Examination and Testing of Electronic Personal Dosemeters

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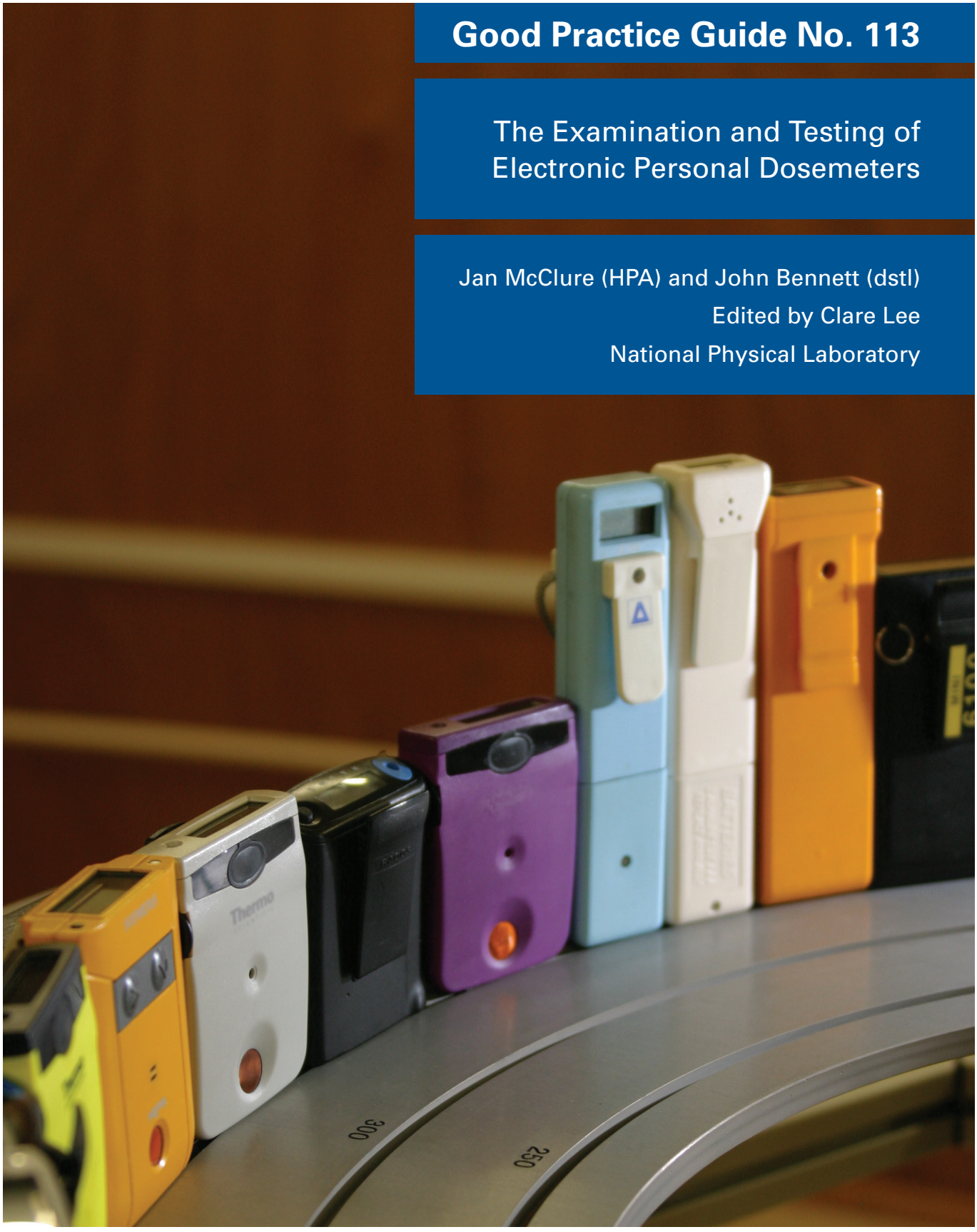

National
Measurement
System

Measurement Good Practice Guide No.113

The Examination and Testing of Electronic Personal Dosemeters

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ABSTRACT

This guide describes recommended procedures for the examination and testing of electronic personal dosemeters in order to satisfy the requirements of the Ionising Radiation Regulations and the Provision and Use of Work Equipment Regulations.

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This Good Practice Guide has been written by the UK Ionising Radiation Metrology Forum in collaboration with the ionising radiation user community. It describes recommended procedures for the general examination and testing of electronic personal dosemeters. Test procedures recommended in this document are not legally binding: they are general methods based on currently accepted good practice.

Although the testing regimes presented here are for general application, qualified persons responsible for the testing of electronic personal dosemeters may modify them, with the agreement of the Radiation Protection Adviser, as necessary to suit their particular purpose, provided that the employer is satisfied that the overall quality of the testing is not compromised.

Membership of the IRMF working party that produced this Guide was as follows:

John Bennett	Dstl
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Norman Butler	VT
Bill Croydon	Thermo Electron (now at BAE Systems)
Chris Hill	Thermo Electron (now at Nuvia)
Duncan McClure	Health Protection Agency
Jan McClure	Health Protection Agency
John Simpson	Nuvia (now a Consultant)
Jon Wardle	AWE

This publication has been formulated by NPL, operating in primarily a co-ordinating role, with technical input from the organisations listed above. Whilst every effort has been made to ensure the quality and robustness of the material, NPL cannot be held responsible for the accuracy of the information contained within this Guide.

CONTENTS

TABLES

Introduction

1

IN THIS CHAPTER

- Introduction

Regulation 5 of the Health and Safety Executive document, Provision and Use of Work Equipment Regulations (PUWER) 1998[1], states "Every employer shall ensure that work equipment is maintained in an efficient state, in efficient working order and in good repair".

This Good Practice Guide provides recommended procedures for the examination and testing of electronic personal dosemeters in order to ensure that the requirements of PUWER regulation 5 are met. The Ionising Radiations Regulations of 1999 and their accompanying Approved Code of Practice and guidance are not explicit about the use and testing of electronic personal dosemeters. However, EPDs serve a number of valuable functions in the workplace, any of which could result in the necessity to examine and test them. EPDs used as warning devices to alert the wearer to local high dose rates are regulated in 8(2) in order to restrict exposure and 10(1) to ensure that they are properly maintained, examined and tested at suitable intervals. The testing of EPDs employed for their dosimetric capabilities is required under regulations 12(2) and 23(1) when worn as part of a contingency plan for potential accident situations. Regulation 18(3) states that, for non-classified workers entering a controlled area, an employer must demonstrate, by personal dose monitoring or other suitable means, that doses are restricted so as not to exceed the relevant dose limit. The guidance states "dosemeters or monitoring instruments (except those supplied by an ADS) need to be subject to adequate tests, periodically, to ensure that any measurements made remain suitable". Even if EPDs are used for purposes not pursuant with the regulations, it is considered good practice to have them examined and tested regularly in order to have confidence in their continued fitness for the intended use.

While the regulatory responsibilities lie with the employer, it is recognised that, in practice, this individual is unlikely to have sufficient expertise in personal dose monitoring to be able to define the scope of testing etc. and will take advice from the Radiation Protection Advisor (RPA) and/or qualified person as appropriate.

Recommendations made in documents published by the International Organization for Standardisation (ISO)[3-10] and the International Electrotechnical Commission (IEC)[11] have been consulted during the preparation of this Guide. The testing regimes contained herein have no legal standing and employers may implement their own schemes, provided they ensure compliance with the relevant regulations. However, the regimes presented here have been developed from the combined deliberations of the Ionising Radiation Metrology Forum (IRMF) and, it is the opinion of the IRMF that adoption of the regimes presented in this Guide will normally enable employers to comply with their statutory obligations.

The testing procedures detailed in this guidance provide an appropriate level of testing recommended for dosemeters used in normal operating conditions. Users with particularly demanding conditions will need to consider additional appropriate test procedures in consultation with the qualified person and the Radiation Protection Adviser (RPA). The qualified person is expected to be consulted on, and to have an in-depth knowledge of, how

the instrument works and likely modes of failure. This is required in order to define an appropriate set of tests that will identify any shortcomings in the response of the selected instrument. The RPA will also need to be consulted in order to establish a thorough understanding of the radiation fields likely to be encountered. The testing should be performed or supervised by a qualified person who is able to determine if the results obtained are consistent with type test data and the instruments tested are therefore fit for purpose.

It should be noted that the calibration sources specified in this guidance may not correspond to those situations encountered in the workplace: it would be impossible to produce a set of guidelines that specifically accommodated each individual work practice. The objective of testing is to demonstrate that the dosemeter is suitable and fit for use. The use of specific sources, etc., allows users to select from a variety of testing laboratories (including themselves) for the examination and testing of their dosemeters, in the knowledge that each is using the same criteria and testing conditions. Comparisons between test results for a particular dosemeter can therefore be made regardless of the identity of the testing laboratory.

Testing Regime

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IN THIS CHAPTER

This guidance provides techniques to assess a dosemeter's performance to determine its suitability or continued fitness for a particular use. The number of tests required can be reduced if there are well justified manufacturer's recommendations, based for example on adequate Type Test data, as to why a particular test need not be performed. For example, a justification that the dose indication is always tied to the dose rate indication and that there is no mechanism by which if the dose rate function is typical of type, the dose indication could not be typical of type. In addition, for certain types of dosemeter, it may be possible to combine test elements in order to simplify the testing process: again this is likely to be dependent on the availability of adequate Type Test data. An example might be the testing of an alarm function using a low energy source such as ^{241}Am, thus the response to low energy radiation would be confirmed at the same time as an alarm function was tested. A reduced testing regime can also be justified if a substantial body of statistical data exists to back-up any reductions made in the testing. If a dosemeter has had some functions locked out, then those functions need not be tested. Tests need not be performed on phantom, however suitable On/Off phantom correction ratios must be applied; examples of these corrections are given in Appendix 1.

All tests must be traceable and repeatable. A full record of test results, including details of any significant adjustments made to the instrument, should be kept for a minimum period of 2 years.

Some dosemeters perform a self-test when switched on, or a self-test can be triggered manually, however these must be treated with caution and the limitations and scope of any such test fully understood. For example a self-test may check the audio output of a dosemeter but this should not be used to confirm the alarm function of the dosemeter unless the manufacturer states that the two functions are linked.

Care must be taken when reading the display of digital display instruments. It is impractical to perform testing to ensure that each segment of every digit displayed is working correctly, however, close attention should be paid to the display during testing and if any of the segments are not working or appear to have been corrupted then this must be reported.

2.1 Type Tests

It is the responsibility of the employer to ensure that a dosemeter is suitable for the intended use before purchase. Decisions about dosemeter selection should be made taking into account advice from the RPA, the qualified person, information from the manufacturer and other authoritative data that might be available.

The body of information regarding the characteristics and expected performance of dosemeters is called Type Test data and is usually based on established recommendations from international organisations such as IEC, ISO, etc. A number of IEC documents exist which detail the tests that are appropriate for the Type Testing of particular types of instrument: the relevant document for testing electronic personal dosemeters is IEC 61526 which was published in the UK by the British Standards Institute (BSI) as BS EN 61526[11]. Type Tests are very comprehensive and may require specialised facilities. The tests should be performed by someone with appropriate expertise and insight into the use of dosemeters. Such tests should be carried out in a laboratory with secondary standard or similar status, for example, a laboratory accredited by UKAS, using measurement quantities specified by the International Commission on Radiation Units and Measurements (ICRU)[12-14].

The results of any tests carried out during the lifetime of a dosemeter should be compared with Type Test data to ensure that it continues to operate as expected. It is necessary to have access to the Type Test data for each dosemeter type. For the purpose of the tests in this guidance, the minimum Type Test data required are the results of tests equivalent to those defined in the Tests Before First Use for a particular dosemeter type (these tests are listed in Table 1).

For most new dosemeters, the manufacturers or suppliers provide Type Test data that will enable the qualified person and RPA to decide the necessary scope of Tests Before First Use. In the absence of independent or manufacturers Type Test data, other sources of information, for example, published peer reviewed instrument evaluations may be useful. When Type Test data are not available, or are insufficient in the judgement of the qualified person and RPA, users should perform sufficient tests to establish their own baseline data and identify any limitations at the Tests Before First Use stage.

2.2 Tests Before First Use

Assuming that the dosemeter is delivered in good condition and set up according to it's specifications, the Tests Before First Use should demonstrate that it conforms to type and confirm its suitability for the intended use. The tests should check for any potential faults and may identify any limitations of the dosemeter with respect to its intended use. The manufacturer, the employer, or an independent laboratory can undertake these tests.

Tests Before First Use should, as appropriate, provide information on the following characteristics of the dosemeter:

a) Dose response at low dose rate
b) Dose response at high dose rate
c) Dose rate response at low dose rate
d) Dose rate response at high dose rate
e) Background accumulation
f) Response at or below the minimum energy of interest
g) Directional dependence
h) Confirmation of beta/neutron response
i) Alarm(s) function

Section 3 describes the various generic types of dosemeter covered by this guidance. Table 1 summarises the tests required for the Tests Before First Use for each type of electronic personal dosemeter. The recommended procedures for each test are detailed in Section 4. Some of these tests should be repeated periodically as the performance of a dosemeter can vary with age, key components may deteriorate and damage may occur during use. It is necessary to repeat some of the Tests Before First Use after any repair that could affect the performance of the dosemeter, for example, the replacement of a Geiger-Müller tube or replacement of a beta window.

2.3 Periodic Tests

The purpose of Periodic Testing is to check that the dosemeter remains fit for use and to confirm that its performance has not changed since the Tests Before First Use. Although more than just a simple function check is required, the extensive range of specialised facilities required for Type Testing are not necessary for Periodic Testing: however, the facilities should be capable of performing the required measurements to a known accuracy.

It is the responsibility of the employer to determine the frequency of Periodic Tests based upon considerations such as the age of the equipment, the environment in which it is used and the frequency of use, etc. It is the recommendation of this guidance, that in order to be consistent with other guidance, such as that contained within GPG 14, The Examination, Testing and Calibration of Portable Radiation Protection Instruments[14], that annual examination and testing is performed for most dosemeters.

The tests required are summarised in Table 1 and are generally similar to those for the Test Before First Use; the exception is the directional dependence of the dosemeter which is not required in Periodic Testing. More detail of the tests required is provided in Section 4.

Since a dosemeter may suffer from wear and tear or misuse during its lifetime, attention should be paid to the physical components such as the casing, display surround and clip. It is essential that any radiological deficiencies in performance are identified and reported to the user before any repair is undertaken.

2.4 Analysis of Test Results

The results of the Tests Before First Use of a dosemeter should be compared with the Type Test data, and, the Periodic Tests should be compared, where available, with the Tests Before First Use and Type Test data to confirm that the dosemeter still conforms to type and remains fit for use.

The Employer should keep a full record of test results, including details of any significant adjustments made to the dosemeter. Current test results should be compared with previous results and any significant changes noted and investigated, even if all the results fall within specification. For example, the performance of a dosemeter should be regarded as suspicious if a previously consistent response is now significantly different, even if it is still within acceptable limits.

If a dosemeter passes a Test Before First Use or Periodic Test only after adjustment, a statement indicating the nature and magnitude of the adjustment should be made on the test report or certificate.

A dosemeter may fail if the result of any component of the appropriate tests is not within the acceptable limits defined in Tables 2, 3, 4 and 5, or, if the qualified person deems the dosemeter's performance or condition unsatisfactory. If a dosemeter does fail, the testing laboratory must inform the customer or dosemeter user of the nature of the problem. It is the responsibility of the customer to decide whether the dosemeter should be repaired (if possible), or replaced.

Table 1: Summary of Tests Before First Use and Periodic Tests

Type of Dosemeter	Tests Before First Use	Periodic Tests
Bleepers	Background accumulation*[*] Dose rate response at low dose rate Dose rate response at high dose rate Response at or below the minimum energy of use Directional dependence	Background accumulation Dose rate response at low dose rate Dose rate response at high dose rate Response at or below the minimum energy of use
Simple dosemeters No Alarm	Background accumulation Dose response at low dose rate Dose response at high dose rate Response at or below the minimum energy of use Directional dependence	Background accumulation Dose response at low dose rate Dose response at high dose rate Response at or below the minimum energy of use
Simple dosemeters Alarm	Background accumulation Dose response at low dose rate Dose response at high dose rate Response at or below the minimum energy of use Directional dependence Alarm Function	Background accumulation Dose response at low dose rate Dose response at high dose rate Response at or below the minimum energy of use Alarm Function
Complex dosemeters	Background accumulation Dose response at low dose rate Dose response at high dose rate Dose rate response at low dose rate Dose rate response at high dose rate Response at or below the minimum energy of use Directional dependence Alarm Function Beta and/or Neutron function	Background accumulation Dose response at low dose rate Dose response at high dose rate Dose rate response at low dose rate Dose rate response at high dose rate Response at or below the minimum energy of use Alarm Function Beta and/or Neutron function

[*] Ensure that the bleep rate is typical of that which would be expected for the particular type of instrument (i.e. not an excessive bleep rate, which is the most commonly observed mode of failure) rather than monitoring each bleeper for up to 16 hours in order to determine a background bleep rate.

Dosemeters

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IN THIS CHAPTER

- Bleepers
- Simple Dosemeters - Without Alarms
- Simple Dosemeters - With Alarms
- Complex Dosemeters

The type, nature and intensity of radiation that a dosemeter may encounter and the conditions under which it may be used should be considered when selecting a dosemeter. The employer/dosemeter purchaser should seek advice from their RPA and a qualified person when dosemeter selection is made.

Electronic Personal Dosemeters vary from simple to complex and offer a variety of readouts to the user: some provide only an audible indication of an increased dose rate by emitting a bleep at a correspondingly increased rate, while others provide electronic readouts of dose rate and doses including both $H_p(10)$ and $H_p(0.07)$[*]. Unless all tests are to be performed in all output modes, the particular mode normally employed by the dosemeter user should be confirmed and adopted for the test. If a range of output modes is used then each one should be tested. For example, if dose rate information is transmitted to a remote monitoring point where the users dose rate is monitored, then this output should be confirmed. A statement of any output modes not tested should be included in the certificate or test report.

3.1 Bleepers

For the purpose of this document an electronic bleeper is defined as an instrument that gives no numeric readout of either the dose accrued by the instrument or the dose rate to which the instrument is exposed. The output is simply an audible 'bleep' that increases in rate when exposed to an increase in intensity of the radiation field. Table 2 is a quick reference guide for bleepers and provides a brief description of each of the tests. The tests required to establish the linearity, energy dependence, directional dependence and other relevant characteristics are detailed in Section 4.

3.2 Simple Dosemeters – Without Alarms

For the purpose of this document a simple dosemeter without an alarm is defined as one which gives a numeric display of the accumulated dose to which the dosemeter is exposed. Whilst this type of dosemeter has no alarm function, there may be an audible output in which case the correct function of this output should also be confirmed. Table 3 is a quick reference guide for simple dosemeters without alarms and provides a brief description of each of the tests. The tests required to establish the linearity, energy dependence, directional dependence and other relevant characteristics are detailed in Section 4.

[*] For definition of these quantities see Section 8.

3.3 Simple Dosemeter - With Alarms

For the purpose of this document a simple dosemeter with alarms is defined as one which gives a numeric display of the accumulated dose to which the dosemeter is exposed and gives an alarm indication when a pre-set dose alarm level is exceeded. Table 4 is a quick reference guide for simple dosemeters with alarms and provides a brief description of each of the tests. The tests required to establish the linearity, energy dependence, directional dependence and other relevant characteristics are detailed in Section 4.

3.4 Complex Dosemeters

For the purpose of this document a complex dosemeter is defined as one which gives a numeric display of both the dose and dose rate to which the dosemeter is exposed. The dosemeter is likely to have pre-settable alarm levels for both dose and dose rate: most can also display values for both $H_p(10)$ and $H_p(0.07)$ and may also have beta or neutron capabilities. Table 5 is a quick reference guide for these dosemeters and provides a brief description of each of the tests. The tests required to establish the linearity, energy dependence, directional dependence and other relevant characteristics are detailed in Section 4.

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Table 2: Bleepers

Test Required	Comments	Pass/Fail Criteria	Tests Before First Use	Periodic Tests	Detailed Reference
Dose rate response at low dose rate Mount the dosemeter in the calibration orientation with its reference point at the point of test in an appropriate radiation field. Record the dosemeter response to a dose rate of no more than 100 $\mu Sv\ h^{-1}$.		Agreement to within ± 30 % of Type Test data	Yes	Yes	4.1
Dose rate response at high dose rate Mount the dosemeter in the calibration orientation with its reference point at the point of test in an appropriate radiation field. Expose the dosemeter to a dose rate in excess of that which it could reasonably encounter in practice, for at least 30 seconds, and record its response.	A minimum dose rate of 10 $mSv\ h^{-1}$ should be used.	Agreement to within ± 30 % of Type Test data. Overload indication should operate if the maximum range of the dosemeter is exceeded.	Yes	Yes	4.1 and 4.3
Background accumulation The background-accumulated dose should be checked in an area known to have a low, stable, background dose rate.	The bleep rate should be confirmed as not being excessive when compared to Type Test data. It is impractical to listen for a minimum period of 12 hours to ensure a satisfactory number of bleeps.	[i]See note below	Yes	Yes	4.4

<u>Response at or below minimum energy of interest</u> Mount the dosemeter in the calibration orientation with its reference point at the point of test in a 60 keV photon field and determine its response.	Filtered x-radiation from the ISO Low or Narrow series[5] may be used. If the dosemeter is expected to be used to monitor photons less than 60 keV, a test at a lower energy is necessary.	Agreement to within ± 30 % of Type Test data	Yes	Yes	4.5
<u>Directional Dependence</u> Mount the dosemeter in a 60 keV photon field as in the energy dependence test. Determine its response at +60° and -60° about it's reference point.	Users may wish to use other angles between 45˚ and 60˚ if more appropriate for the dosemeter type. Type Test data should be consulted and used to determine the most appropriate single angle.	Agreement to within ± 30 % of Type Test data	Yes	No	4.6

[i] It is impossible to provide a definitive pass/fail value for a particular dosemeter type since background accumulation will be specific to both dosemeter type and facility. The background accumulation rate should be recorded for each dosemeter type in a particular facility, and the mean and standard deviation determined in order to define a limiting acceptable value.

Table 3: Simple Dosemeters

Test Required	Comments	Pass/Fail Criteria	Tests Before First Use	Periodic Tests	Detailed Reference
Dose response at low dose rate Mount the dosemeter in the calibration orientation with its reference point at the point of test in an appropriate radiation field. Record the dosemeter response to a dose delivered at a rate of no more than 100 μSv h^{-1}.		Agreement to within ± 30 % of Type Test data	Yes	Yes	4.2
Dose response at high dose rate Mount the dosemeter in the calibration orientation with its reference point at the point of test in an appropriate radiation field. Expose the dosemeter to a dose rate in excess of that which it could reasonably encounter in practice, for at least 30 seconds, and record its response.	A minimum dose rate of 10 mSv h^{-1} should be used.	Agreement to within ± 30 % of Type Test data. Overload indication should operate if the maximum range of the dosemeter is exceeded.	Yes	Yes	4.2 and 4.3
Background accumulation The background-accumulated dose should be checked in an area known to have a low, stable, background dose rate.		[ii]See note below	Yes	Yes	4.4

<u>Response at or below minimum energy of interest</u> Mount the dosemeter in the calibration orientation with its reference point at the point of test in a 60 keV photon field and determine its response.	Filtered x-radiation from the ISO Low or Narrow series[5] may be used. If the dosemeter is expected to be used to monitor photons less than 60 keV, a test at a lower energy is necessary.	Agreement to within ± 30 % of Type Test data	Yes	Yes	4.5
<u>Directional Dependence</u> Mount the dosemeter in a 60 keV photon field as in the energy dependence test above. Determine its response at +60° and -60° about it's reference point.	Users may wish to use other angles between 45˚ and 60˚ if more appropriate for the dosemeter type. Type Test data should be consulted and used to determine the most appropriate single angle.	Agreement to within ± 30 % of Type Test data	Yes	No	4.6

[ii] It is impossible to provide a definitive pass/fail value for a particular dosemeter type since background accumulation will be specific to both dosemeter type and facility. The background accumulation rate should be recorded for each dosemeter type, in a particular facility, and the mean and standard deviation determined in order to define a limiting acceptable value.

Table 4: Simple Dosemeters with Alarms

Test Required	Comments	Pass/Fail Criteria	Tests Before First Use	Periodic Tests	Detailed Reference
<u>Dose response at low dose rate</u> Mount the dosemeter in the calibration orientation with its reference point at the point of test in an appropriate radiation field. Record the dosemeter response to a dose delivered at a rate of no more than 100 μSv h^{-1}.		Agreement to within ± 30 % of Type Test data	Yes	Yes	4.2
<u>Dose response at high dose rate</u> Mount the dosemeter in the calibration orientation with its reference point at the point of test in an appropriate radiation field. Expose the dosemeter to a dose rate in excess of that which it could reasonably encounter in practice, for at least 30 seconds, and record its response.	A minimum dose rate of 10 mSv h^{-1} should be used.	Agreement to within ± 30 % of Type Test data. Overload indication should operate if the maximum range of the dosemeter is exceeded.	Yes	Yes	4.2 and 4.3
<u>Background accumulation</u> The background-accumulated dose should be checked in an area known to have a low, stable, background dose rate.		[iii]See note below	Yes	Yes	4.4
<u>Response at or below minimum energy of interest</u> Mount the dosemeter in the calibration orientation with its reference point at the point of test in a 60 keV photon field and determine its response.	Filtered x-radiation from the ISO Low or Narrow series[5] may be used. If the dosemeter is expected to be used to monitor photons less than 60 keV, a test at a lower energy is necessary.	Agreement to within ± 30 % of Type Test data	Yes	Yes	4.5

Directional Dependence Mount the dosemeter in a 60 keV photon field as in the energy dependence test above. Determine its response at +60° and -60° about it's reference point.	Users may wish to use other angles between 45˚ and 60˚ if more appropriate for the dosemeter type. Type Test data should be consulted and used to determine the most appropriate single angle.	Agreement to within ± 30 % of Type Test data	Yes	No	4.6
Alarm function Dose: expose the dosemeter to a doses close to 85 % and then 115 % of the value at which the alarm has been set to trigger.	For dosemeters with multiple alarm levels the function of all alarms should be confirmed. For some applications it should also be confirmed that the alarm does not trigger too early.	Alarm(s) should trigger only when the dose set level is exceeded appropriately	Yes	Yes	4.7

[iii] It is impossible to provide a definitive pass/fail value for a particular dosemeter type since background accumulation will be specific to both dosemeter type and facility. The background accumulation rate should be recorded for each dosemeter type, in a particular facility, and the mean and standard deviation determined in order to define a limiting acceptable value.

Table 5: Complex Dosemeters

Test Required	Comments	Pass/Fail Criteria	Tests Before First Use	Periodic Tests	Detailed Reference
Dose rate response at low dose rate Mount the dosemeter in the calibration orientation with its reference point at the point of test in an appropriate radiation field. Record the dosemeter response to a dose rate of no more than 100 μSv h^{-1}.		Agreement to within ± 30 % of Type Test data	Yes	Yes	4.1
Dose rate response at high dose rate Mount the dosemeter in the calibration orientation with its reference point at the point of test in an appropriate radiation field. Expose the dosemeter to a dose rate in excess of that which it could reasonably encounter in practice, for at least 30 seconds, and record its response.	A minimum dose rate of 10 mSv h^{-1} should be used.	Agreement to within ± 30 % of Type Test data. Overload indication should operate if maximum range of dosemeter is exceeded.	Yes	Yes	4.1 and 4.3
Dose response at low dose rate Mount the dosemeter in the calibration orientation with its reference point at the point of test in an appropriate radiation field. Record the dosemeter response to a dose delivered at a rate of no more than 100 μSv h^{-1}.		Agreement to within ± 30 % of Type Test data	Yes	Yes	4.2
Dose response at high dose rate Mount the dosemeter in the calibration orientation with its reference point at the point of test in an appropriate radiation field. Expose the dosemeter to a dose rate in excess of that which it could reasonably encounter in practice, for at least 30 seconds, and record its response.	A minimum dose rate of 10 mSv h^{-1} should be used.	Agreement to within ± 30 % of Type Test data. Overload indication should operate if the maximum range of the dosemeter is exceeded.	Yes	Yes	4.2 and 4.3
Background accumulation The background-accumulated dose should be checked in an area known to have a low, stable, background dose rate.		[iv]See note below	Yes	Yes	4.4

Response at or below minimum energy of interest Mount the dosemeter in the calibration orientation with its reference point at the point of test in a 60 keV photon field and determine its response.	Filtered x-radiation from the ISO Low or Narrow series[5] may be used. If the dosemeter is expected to be used to monitor photons less than 60 keV, a test at a lower energy is necessary.	Agreement to within ± 30 % of Type Test data	Yes	Yes	4.5
Directional Dependence Mount the dosemeter in a 60 keV photon field as in the energy dependence test above. Determine its response at +60° and -60° about it's reference point.	Users may wish to use other angles between 45˚ and 60˚ if more appropriate for the dosemeter type. Type Test data should be consulted and used to determine the most appropriate single angle.	Agreement to within ± 30 % of Type Test data	Yes	No	4.6
Alarm function Dose rate: expose the dosemeter to a dose rate close to 130 % of the value at which the alarm has been set to trigger. Dose	For dosemeters with multiple alarm levels the function of all alarms should be confirmed.	Alarm(s) should trigger appropriately	Yes	Yes	4.7
Beta and/or neutron function Confirm the dosemeter's response with a suitable beta source or a ^{241}Am/-Be,^{252}Cf or an accelerator produced source of neutrons.		Agreement to within ± 30 % of Type Test data	Yes	Yes	4.8

[iv] It is impossible to provide a definitive pass/fail value for a particular dosemeter type since background accumulation will be specific to both dosemeter type and facility. The background accumulation rate should be recorded for each dosemeter type, in a particular facility, and the mean and standard deviation determined in order to define a limiting acceptable value.

Specific Tests

4

IN THIS CHAPTER

- Linearity of Dose Rate Response
- Linearity of Dose Response with Dose Rate
- Response to High Dose Rate
- Background Accumulation
- Energy Dependence
- Directional Dependence
- Alarm Function
- Response to Beta and/or Neutron Radiations

Table 1 lists the tests that are applicable to the Tests Before First Use and the Periodic Tests for all dosemeter types covered in this Guide. Tables 2 to 5 are specific to particular types of dosemeter and provide brief summaries of the tests and their pass/fail criteria: the tables are not comprehensive and should not be used without reference to the detailed information in the sections of text. The tests do not have to be performed in the order in which they are listed in the tables and may be undertaken in an order which is convenient to the testing laboratory. However, the response of a dosemeter to low dose rates should be checked after its response to high dose rates to be sure that the high dose rate has not adversely affected it.

4.1 Linearity of Dose Rate Response

The following test is suitable for X and γ dosemeters: it can also be used for β and neutron dosemeters provided a suitable reference source is used. The recommended radiation sources are: ^{137}Cs (or ^{60}Co if ^{137}Cs is not available) for photon dosemeters; ^{241}Am-Be or ^{252}Cf sources or accelerator produced neutrons of an appropriate energy can be used for neutron dosemeters; and, a suitable traceable beta source, most commonly ^{90}Sr + ^{90}Y for beta dosemeters. The conventional true value of the personal dose at the point of test should be known to an accuracy of at least ± 10 %.

The dosemeter under test should be mounted in the calibration orientation with its reference point (marked calibration point on the dosemeter) at the point of test in the radiation field. In the absence of a marked calibration point, or information in the manufacturer's literature about the position of the reference point, the geometric centre of the detector should be used. The linearity of the dose rate response should be determined using at least two dose rates, the maximum value of the low dose rate should be 100 μSv h^{-1} $H_p(10)$ and the minimum value of the high dose rate should be the greatest rate that could be reasonably encountered in practice or 10 mSv h^{-1}, whichever is the greatest.

The test should be performed on the required phantom (see Section 5.1), however, if this is not practicable, then the irradiation can be performed free-in-air. If a free-in-air method is employed then the specific on/off phantom correction ratio for irradiating free-in-air, instead of on phantom, should be applied; this ratio is unique to the type of dosemeter under test, the facility in which it is tested and the radiation quality employed. A suitable technique to determine on/off phantom ratios and some sample data are provided in Appendix 1.

4.2 Linearity of Dose Response with Dose Rate

The following test is suitable for X and γ dosemeters: it can also be used for β and neutron dosemeters provided a suitable reference source is used. The recommended radiation sources are: ^{137}Cs (or ^{60}Co if ^{137}Cs is not available) for photon dosemeters; ^{241}Am-Be or ^{252}Cf sources or accelerator produced neutrons of an appropriate energy can be used for neutron dosemeters; and, a suitable traceable beta source, most commonly ^{90}Sr + ^{90}Y for beta dosemeters. The conventional true value of the personal dose at the point of test should be known to an accuracy of at least ± 10 %.

The dosemeter under test should be mounted in the calibration orientation with its reference point (marked calibration point on the dosemeter) at the point of test (the point at which, for a given radiation field, the conventional true value of the quantity to be determined is known). In the absence of a marked calibration point, or information in the manufacturer's literature about the position of the reference point, the geometric centre of the detector should be used. The linearity of the dose response with dose rate should be determined using at least two dose rates to ensure that the dose response is independent of the dose rate at which the dose is delivered. The maximum value of the low dose rate should be 100 μSv h^{-1} $H_p(10)$ and the minimum value of the high dose rate should be the greatest rate that could be reasonably encountered in practice or 10 mSv h^{-1}, whichever is the greatest.

The statistical uncertainty of the resolution of the indication should be considered, particularly at low dose rates. The minimum dose delivered should ensure that any uncertainty associated with the increment of the display is less than 10 %. For example, if a dosemeter only displays in mSv, the minimum delivered dose should be 10 mSv since anything less only increments the least significant digit. This is not a requirement for the background accumulation check.

The test should be performed on the required phantom (see Section 5.1). However if this is not practical, for example because the required dose rate cannot be produced, then the irradiation can be performed free-in-air. If a free-in-air method is employed then the specific on/off phantom correction ratio for irradiating free-in-air instead of on phantom should be applied; this is unique for the type of dosemeter under test, the facility in which it is tested and the radiation quality employed. Some examples of on/off phantom correction ratios are provided in Appendix 1.

4.3 Response to High Dose Rate

The dosemeters should be exposed to a dose rate of 10 times that which could reasonably be expected to be encountered during use or 10 mSv h^{-1}, which ever is the greater. The dosemeter should continue to indicate either a valid displayed rate, or an overload indication, at all times when in the high dose rate field.

4.4 Background Accumulation

The dosemeters should be placed in a stable, low dose rate environment for a minimum of 12 hours and the indicated dose compared to the expected dose. It is impossible to provide a definitive value for a particular dosemeter type since background accumulation will be specific to both dosemeter type and facility. The background accumulation rate should be recorded for each dosemeter type, and the mean and standard deviation determined in order to define a limiting acceptable value.

4.5 Energy Dependence

The energy dependence of dosemeters used in the workplace is governed by the type of detector and, in some cases, on the setting up of the electronics or software. The following test is designed to confirm that the response of the dosemeter does not vary with energy in a manner that is significantly different to that quoted in Type Test data. For most dosemeter types the test utilises information obtained in the linearity of dose with dose rate test (Section 4.2), and combines it with a further test performed at, or below, the minimum energy of interest for the particular environment in which the dosemeter is intended to be used.

Information at one energy (^{137}Cs or ^{60}Co for photon dosemeters) should have been obtained in the linearity of dose response with dose rate test. The test at low energy should be performed at approximately the same dose rate and dose indication as either the dose response at low dose rate or the dose response at high dose rate. The recommended radiation energy for photon dosemeters is 60 keV (photons from ^{241}Am) although an appropriate X radiation from the ISO Low or Narrow series of reference radiation[5] can be used. Dosemeters designed to operate down to very low energies (i.e. 30 keV or less) should be tested using lower energy photon radiation such that the lowest rated energy of the dosemeter can be compared to Type Test data.

For bleepers which do not have a dose response, the dose rate response to ^{137}Cs at either low or high dose rate (Section 4.1) should be compared to the dose rate response to ^{241}Am at the same dose rate.

The dosemeter should be mounted in the calibration orientation with its reference point at the point of test in the radiation field and it's response to the low energy radiation obtained. The ratio of the low energy response to that for high energy radiation should be calculated and compared with Type Test data; agreement to within ± 30 % is required.

Most testing laboratories have limited access to neutron sources and are rarely able to perform tests at two energies; therefore, without specialist facilities such as those found at a primary standards laboratory, it is not generally possible to test the energy dependence of neutron dosemeters and it is not a requirement of this guidance.

4.6 Directional Dependence

The directional dependence test is required in the Tests Before First Use of personal dosemeters. It is not necessary in subsequent Periodic Tests, however, it may be necessary to repeat this test after repairs that may affect the response of the dosemeter; this should be decided by the qualified person.

Dosemeters are designed to measure the quantity $H_p(d)$ where d denotes the depth, however, this quantity depends on the angle of incidence of the applied radiation. The degree to which the dosemeter response matches the angle dependence of the quantity is normally investigated during Type Test, however, it is possible to introduce defects in the dosemeter response by, for example, missing out components in the energy compensation filter of a Geiger-Müller tube, that may not be detected in the energy dependence test.

The directional dependence test can normally be performed by rotating a dosemeter around it's reference point and comparing its response at + 60˚, 0˚ and - 60˚; for some dosemeters, an angle between 45˚ and 60˚ could be more appropriate. Type Test data should be consulted to determine the most appropriate single angle, however, this should not be less than 45˚. The radiation quality used for this test should be the same as that used in the energy dependence test. A relatively low energy is preferable since the test is more sensitive at lower energies.

4.7 Alarm Function

An alarm indication can follow a number of different forms, for example, the alarm may be audible, visual or may cause the device to vibrate. For the purpose of this guide an alarm is taken to be anything that draws the users attention to the device. If it is possible to set a number of different alarms then each alarm and mode of indication should be checked. For some applications it should also be confirmed that the alarm does not trigger too early.

For personal dose rate alarms, the dosemeter should be exposed to a dose rate close to 130 % of the alarm set level and the satisfactory operation of the alarm within 180 seconds confirmed. This time limit is considered to be the 'worst case' and should be satisfactory for a relatively insensitive device at dose rates of the order of 10 $\mu Sv\ h^{-1}$. The dosemeters dose rate alarm function should easily meet these criteria at higher dose rates and/or for more sensitive detectors.

For personal dose alarms, the dosemeter should be exposed to a dose close to 115 % of the dose alarm set level and the satisfactory alarm operation confirmed.

4.8 Response to Beta and/or Neutron Radiations

This test is required for dosemeters that have a beta or neutron capability. For beta sensitive dosemeters it is necessary to identify dosemeters that may have an incorrect window thickness or where the electronic threshold has been incorrectly set. Since beta radiation is more strongly attenuated by the beta window than all but the lowest energy photon radiations, it is not possible to confirm the beta response using photon radiation.

The beta dose response test should be performed using, or by reference to, a secondary standard beta dose rate source that conforms to ISO 6980[7-9] and with a mean energy towards the low end of the useful energy range. Such sources are not widely available, in their absence the beta response can be confirmed using a beta point source or contamination plaque whose mean energy is towards the low end of the useful energy range, provided such a measurement formed part of the Type Test or Test Before First Use and the data are available for comparison, or that a suitable traceable route exists for the cross calibration of such sources.

Neutron sensitive dosemeters should be tested using ^{241}Am-Be, ^{252}Cf or an accelerator produced source of neutrons, suitably moderated where appropriate, to confirm that the response is within ± 30 % of Type Test data.

Facilities

5

IN THIS CHAPTER

- Phantoms / Free in Air

The Type Tests, Tests Before First Use and Periodic Tests should be performed in appropriate radiation facilities, which ensure measurements are traceable to national standards. The basic requirements for most tests are a selection of suitable sources and a calibration track or other device capable of providing a range of dose rates. Very elaborate facilities such as those that may be found in large organisations, nuclear installations, UKAS accredited and other laboratories of comparable standing, may not necessarily be required. However, a detailed knowledge of the scattering characteristics of the facility is necessary for the testing of neutron personal dosemeters.

The facilities should be able to provide the range of radiation fields required for testing. The recommendations of the International Organization for Standardisation, the United Kingdom Accreditation Service[16], and the International Atomic Energy Agency may be helpful here but they are not mandatory for the tests required by the regulations.

It is recognised that for routine testing, instrument specific test rigs are likely to offer the most appropriate solution. Test rigs should be such that the overall uncertainty due to the positioning of the reference point of the dosemeter at the point of test, or positioning of the source, are less than ± 5 % at dose rates within the normal range of use.

All tests should be performed under suitable conditions of temperature and humidity.

5.1 Phantoms/Free in Air

Since personal dosemeters are designed to be worn on the body and include in their response the back-scattered radiation generated, a backscatter element should be included in their testing. This On/Off phantom correction ratio is defined as the ratio of the indication of the dosemeter when placed in the radiation field in the presence and absence of a phantom. This ratio is dosemeter and facility specific since it depends on the point of test (the distance from the surface and from the central axis of the radiation field), the diameter of the radiation field, the phantom size and on the radiation energy. For the purpose of determining the absolute value of the dose or dose rate response of the dosemeter, the dosemeter should be irradiated on an appropriate phantom as defined in ISO 4037-3[5]: these are the rod phantom, the pillar phantom and the water slab phantom, however, when using reference gamma radiation with a mean energy of 662 keV (^{137}Cs) or above, a solid PMMA slab of standard dimensions may be used. If testing is not carried out on an appropriate phantom, then an On/Off phantom ratio must be applied; this ratio is specific for the dosemeter under test, the facility in which it is tested and the radiation quality used and must therefore be determined specifically. A list of common types of dosemeter at the time of publication of this document is provided in

Appendix 1, along with On/Off phantom correction ratios for a number of common test radionuclides as determined for one specific UK facility.

Traceability

6

IN THIS CHAPTER

- Traceability

Measurements used to demonstrate compliance with the regulations should be traceable to national standards of measurement via the testing route for the dosemeter. It is necessary to establish the route of traceability to national standards and to estimate the uncertainties in measurements[17,18]. As a general rule, publications from BSI, IEC, ISO and UKAS should be consulted, but the UKAS accreditation of laboratories is not required in order to comply with the regulations.

Secondary standard instruments include ionisation chambers for X and γ-ray fields, and, source and filter assemblies for β dose rate measurements. These secondary standard instruments should be calibrated by the primary or national laboratory at least every four years with the overall uncertainties in best measurement capabilities usually of the order of ± 5 %, these being the combined Type A and Type B uncertainties as defined by UKAS[17]. Radionuclide sources of γ rays and neutrons, with traceable output or activity, may also be used as secondary standards, provided they are mounted in a repeatable geometry and used in a way that avoids significant errors from scattered radiation; these sources will need to be calibrated after two half lives or at least every four years. In addition, traceability may be demonstrated by the use of a tertiary standard that has traceability back to the national primary standard. Appropriate transfer standard instruments, such as examples of the dosemeters under test (often referred to as 'Golden dosemeters'), can also be used to demonstrate traceability; this route can often produce a lower overall uncertainty of calibration. Tertiary standards should be calibrated against a secondary standard at least every four years and be the subject of at least an intercomparison check every two years. As tertiary standards are generally more frequently used at a working level, they are more vulnerable to loss of calibration and therefore require more regular calibration against the secondary standard.

Certification of Tests

7

IN THIS CHAPTER

- Test Certificate
- Test Label

The results of tests performed under the current regulations[2] should be communicated to the user in a formal manner. If a dosemeter fails to meet the pass/fail criteria of any component of a test, the test laboratory shall label the dosemeter as failed and make some indication of the nature of the failure on the test certificate.

7.1 Test Certificate

The precise format of a test certificate is not specified in the regulations, but the following basic information should be provided:

a) the name and address of the customer or user;

b) a description of the dosemeter (including type, serial number, and unique identifier);

c) the type of test, i.e. Tests Before First Use, Periodic Test or Retest After Repair;

d) any limitations of the test performed including identification of the output modes or ranges not tested;

e) a basic description of the test, including any specific dosemeter settings used and any adjustments or repairs performed;

f) the results of the tests including dosemeter response and a statement of the uncertainty with the confidence level at which the uncertainty is quoted;

g) a record of the background dose rate and any relevant environmental conditions during the tests;

h) the value of any conversion coefficient applied to the results;

i) a statement that the test was carried out for the purpose of the appropriate regulation(s) and was successful;

j) the name and signature of the qualified person responsible for the test;

k) the name, address and contact details of the laboratory at which the test was performed;

l) the date of test;

m) the test certificate reference number.

7.2 Test Label

As test certificates are usually filed away for Quality Assurance purposes and tend not to accompany dosemeters in the workplace, it is recommended that dosemeters themselves are labelled with the following information after testing:

a) the unique identifier of the dosemeter;

b) the date of test;

c) the test certificate reference number.

Quantities & Units

8

IN THIS CHAPTER

- Quantities and Units

Throughout this document the term 'dose' has been used as a general term for various dose equivalent quantities. A brief description of these is given here.

In The Ionising Radiations Regulations[2], the dose limits for whole body external irradiation are expressed in terms of the protection quantity, *effective dose, E*. This quantity is a weighted average of dose equivalents in various organs of the human body and is considered to be immeasurable. In ICRU Report 39[12], operational dose equivalent quantities were proposed for use with radiation protection dosemeters. These quantities provide adequate approximations to the *effective dose*, and current practice is to calibrate personal dosemeters in terms of the relevant ICRU operational quantity i.e. *personal dose equivalent* $H_p(d)$. Any statement of personal dose equivalent should include a specification of the reference depth, *d*, expressed in mm. For weakly penetrating radiation, a depth of 0.07 mm is employed for the skin and the *personal dose equivalent* is denoted by $H_p(0.07)$. For strongly penetrating radiation a depth of 10 mm is usually employed with analogous notation.

Primary standards for photons and electrons are realised in terms of the quantities air kerma and absorbed dose respectively: for neutrons, the corresponding primary quantity is neutron fluence. Certificates issued by national standards laboratories when calibrating secondary standard instruments usually quote these quantities: note that for electrons, certificates will normally be in terms of absorbed dose to tissue. Published conversion coefficients can be used to convert air kerma, absorbed dose and neutron fluence to the required operational dose equivalent values. Values for the conversion coefficients for monoenergetic photons and neutrons can be found in ICRP Report 74[19] or ICRU Report 57[20]. For calibration spectra that cover a broad energy range, spectrum averaged conversion coefficients should be used: details of these are contained in ISO Standards 4037 – Part 3[5] and 8529 – Part 3[10].

The Units of Measurement Regulations, 1986 (as amended)[21] implementing an EC Directive[22], stipulate the use of SI units in any measurement required for economic public health, public safety or administrative purposes: the results of the Tests Before First Use and the Periodic Tests should therefore be given in SI units, whether or not the dosemeter is scaled in them. Users of dosemeters with scales in non-SI units are encouraged to rescale them or purchase new dosemeters. A dosemeter scaled in the old units may, however, be used in compliance with the Ionising Radiations Regulations[2], provided the appropriate response or calibration factor is used to convert to SI units when compiling the records: any response or calibration factors given in test certificates should therefore relate to SI units.

References

9

IN THIS CHAPTER

- References

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Appendix 1

10

IN THIS CHAPTER

- Example On/Off Phantom Ratios

Electronic Personal Dosemeters should be tested using a suitable phantom. However, in practice, unless only 1 or 2 are to be tested, this method is not suitable and free-in-air tests are usually carried out instead. Testing free-in-air is considered to be satisfactory providing the ratio of their response "on-phantom" to that "off-phantom" is known. It is necessary to determine On/Off phantom correction ratios for each type of dosemeter tested, at each radiation quality, in each facility in which the tests are performed. Most test houses use ^{137}Cs and ^{241}Am sources to test dosemeters however, if other sources are used, then On/Off phantom ratios for those sources must also be determined.

A1.1 Determination of On/Off Phantom Ratios

Whenever possible a minimum of 5 examples of the dosemeter type being tested should be selected at random from the batch available, consideration should be made to ensure that those chosen are representative of a production batch and therefore "type".

A1.1.1 Off-Phantom Free-in-Air Exposures

a) Place the dosemeters on a suitable free-in-air jig; expanded polystyrene may serve as an adequate jig providing it is relatively thin and no other means of support is available;
b) Position the jig such that the reference point of the central dosemeter in the array is at the point of test in an appropriate radiation field;
c) Note the environmental conditions at which the dosemeters are exposed; these may prove relevant if it is necessary to repeat the measurements at a later date;
d) Zero the dosemeters;
e) Expose the dosemeters to the required dose of the first radiation quality; a target dose of 100 μSv delivered at a rate of 100 μSv.h^{-1} is likely to be suitable;
f) Record the dosemeter readings and calculate the mean;
g) Repeat d) to f) for each additional radiation quality required.

A1.1.2 On-Phantom Exposures

a) Place the dosemeters on a suitable phantom (see Section 5.1);
b) Position the phantom such that the reference point of the central dosemeter in the array is at the point of test in an appropriate radiation field;
c) Follow steps c) to g) in A1.1.1 for the off-phantom free-in-air exposures.

A1.1.3 Calculation of On/Off Phantom Ratios

For each radiation quality, calculate the On/Off phantom ratio as follows:

$$\text{On/Off phantom ratio} = \frac{\text{Mean On-Phantom Reading}}{\text{Mean Free-In-Air Reading}}$$

A1.2 Example On/Off Phantom Ratios

To demonstrate the importance of a testing facility determining and applying dosemeter, and radiation quality, specific On/Off phantom ratios, Table A1.1 provides real ratios that were measured by a UK laboratory[23]. These ratios were determined from a very small number of each type of dosemeter; only one or two examples of each were available for testing. All ratios were obtained in a gamma facility with a highly collimated radiation field where the scatter characteristics vary greatly from those facilities that operate using a 4π exposure system. For these reasons, these data should not be assumed to be definitive values for the On/Off phantom ratios of these dosemeters.

Table 6: Example On/Off Phantom Ratios For Some Common Dosemeters

Instrument Type	Radionuclide	On/Off phantom ratios
Autonnic	^{241}Am	1.20
	^{60}Co	1.04
	^{137}Cs	1.07
Bleeper Sv	^{241}Am	1.21
	^{60}Co	1.05
	^{137}Cs	1.10
DMC 2000	^{241}Am	1.02
	^{137}Cs	1.03
Dose RAE	^{241}Am	1.19
	^{60}Co	1.03
	^{137}Cs	1.08
Harwell 975002-1	^{241}Am	1.25
	^{60}Co	1.06
	^{137}Cs	1.09
PD 12i	^{241}Am	1.11
	^{60}Co	1.04
	^{137}Cs	1.26
PD 2i	^{241}Am	1.16
	^{60}Co	1.05
	^{137}Cs	1.16
PM1203M	^{241}Am	1.12
	^{60}Co	1.03
	^{137}Cs	1.06
PM1604A	^{241}Am	1.09
	^{60}Co	1.04
	^{137}Cs	1.09
Rados-52S	^{241}Am	1.12
	^{60}Co	1.08
	^{137}Cs	1.11
Siemens EPD mk2.3	^{241}Am	1.02
	^{60}Co	1.05
	^{137}Cs	1.06

All factors quoted have an associated uncertainty of ± 5 % at the 95 % confidence level.