



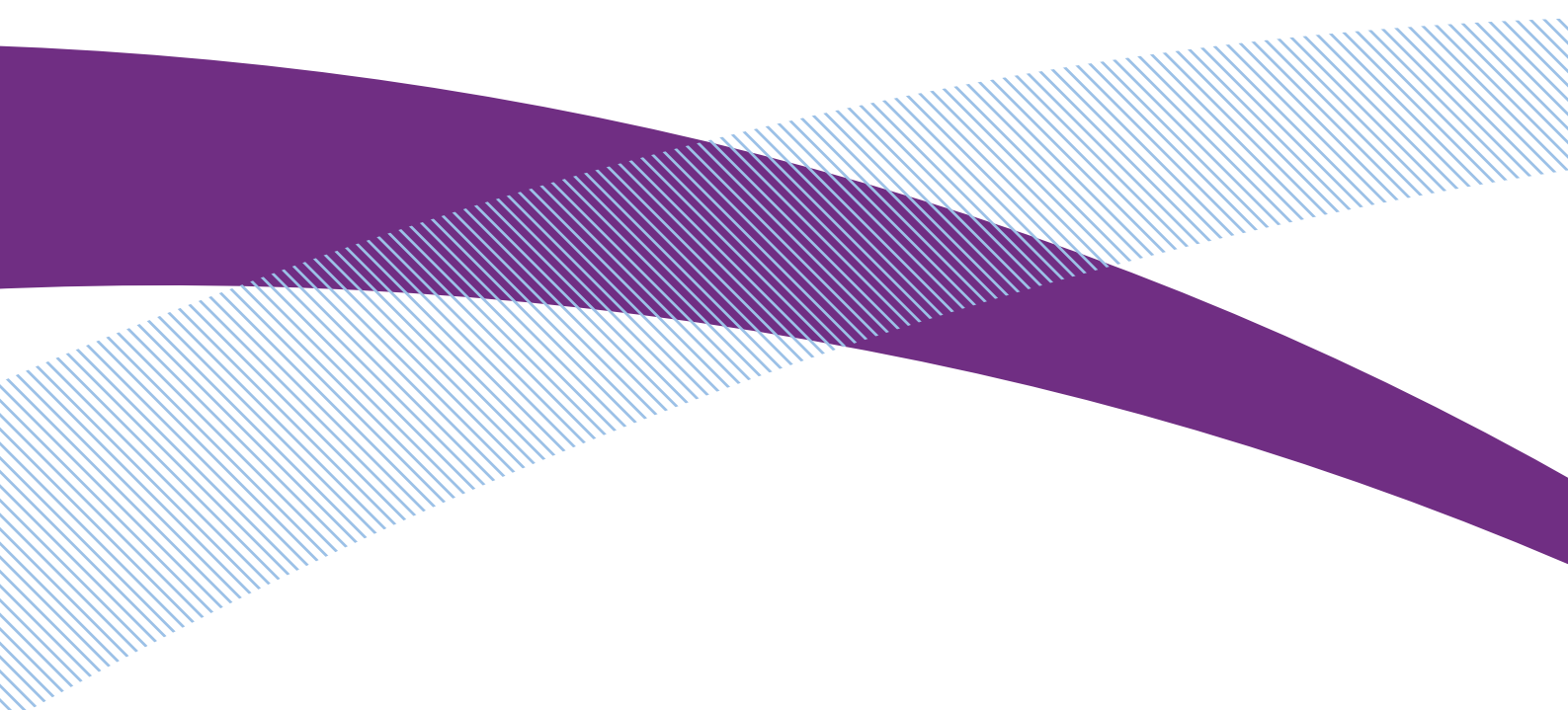
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**Scientific
Development Branch**

Performance Standards and Test Protocols for Radiological Equipment

Number 1 — Electronic Personal Dose Meters

Publication No. 2A/10



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Home Office Scientific Development Branch
Sandridge
St Albans
AL4 9HQ
United Kingdom

Telephone: +44 (0)1727 865051
Fax: +44 (0)1727 816233
E-mail: RNStandardsEnquiries@homeoffice.gsi.gov.uk
Website: <http://science.homeoffice.gov.uk/hosdb/>

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Abstract

This document is the first in a set of five performance standards. The purpose of the standards is to ensure best current capability across a broad range of radiological equipment and provide a national benchmark against which any radiological equipment can be assessed. This assessment will help to improve the quality and consistency of radiological equipment used by emergency services in the event of CBRN incidents. The primary purpose of this equipment is to alert the user to the presence of radiation.

The first element of this document establishes appropriate and targeted technical performance criteria against which radiological equipment can be assessed. These criteria are identified as 'essential' requirements. A second element of this document will aim to stimulate the development of radiological equipment beyond current best measurement capability, with particular focus on end user requirements. These criteria are identified as 'desirable' requirements.

The test methodologies to be used are specified. Testing should be carried out on at least three fully operational production instruments for the duration of the tests, although exception could be made for specialist equipment. A user manual for the instruments shall also be provided to carry out the tests. It should be noted that some tests might cause significant damage to the instrument, and so agreement from the manufacturer should be sought before any destructive tests are performed. Destructive tests should only be performed on a single instrument where possible. If any tests are excluded then these shall be stated.

The five standards in the series each relate to one of the following categories: dose rate instrumentation, contamination-monitoring instrumentation, electronic personal dose meters, portable spectrometry/identification systems and detection/alert devices. Each standard addresses the following broad areas: radiological, environmental, electrical and ergonomic aspects of performance.

Acknowledgements

The standards were written and produced by the Radiation Metrology Group of the Health Protection Agency and reviewed by representatives of the Defence Science and Technology Laboratory (Dstl), the National Physical Laboratory (NPL) and the Atomic Weapons Establishment (AWE).

1 Introduction

To assess a dose meter's suitability for use by emergency services in the event of CBRN incidents, a number of tests are required. The tests detailed in this report are designed to not only assess the dose meters radiological performance under laboratory conditions, but also test the environmental, electrical and mechanical aspects, which may affect the dose meters performance out in the field.

Dose meters are designed to measure personal doses and can utilise a variety of different types of detector; the most common being the Geiger-Muller (GM) tube or a solid state detector.

1.1 Personal Dose Meters

The modern generation of personal dose meters has been developed principally to provide an active and accurate measure of individual personal dose. The nature of modern electronics is such that most offer a range of additional features, usually in the form of dose and dose rate alarms. Unfortunately, the inclusion of dose rate features has given the impression that such devices can be used as area dose rate meters. This is a false premise for two main reasons; firstly, they are not designed to realise the appropriate quantity for area monitoring, and secondly, they lack the sensitivity necessary to make accurate measurements at low dose rate levels. The dose rate alarms offered by many of these units are also of limited use because of this. As a result, it is vital that they should not be thought of as substitutes for other dose rate monitoring equipment.

Personal dose meters must be worn on the body (preferably the trunk) in order to provide an accurate measure of dose.

The use of dose and dose rate alarms (at higher dose rates) offer distinct operational advantages over other forms of personal dosimetry.

Generally, personal dose meters also require some form of additional reader/system in order to realise their full operational potential.

Personal dose meters have no contamination measurement capability. Primarily they are only sensitive to penetrating X and gamma radiation, although some are sensitive to higher energy beta emitters, such as $^{90}\text{Sr}/^{90}\text{Y}$, or have neutron capability.

2 Reference Documents

This document has been compiled with reference to the following documents:

IEC 61526:2005	Radiation protection instrumentation. Measurement of personal dose equivalents $H_p(10)$ and $H_p(0.07)$ for X, gamma, neutron and beta radiations — direct reading personal dose equivalent meters and monitors.
EC 60529:1992	Degrees of protection provided by enclosures (IP code).
ANSI N42.32-2003	American National Standard. Performance Criteria for Alarming Personal Radiation Detectors for Homeland Security.
ISO 4037-1:1996	X and gamma reference radiation for calibrating dose meters and dose rate meters and for determining their response as a function of photon energy. Part 1: Radiation characteristics and production methods.
ISO 4037-2:1997	X and gamma reference radiation for calibrating dose meters and dose rate meters and for determining their response as a function of energy. Part 2: Dosimetry for radiation protection over the energy ranges 8 to 1.3 MeV and 4 to 9 MeV.
ISO 4037-3:1999	X and gamma reference radiation for calibrating dose meters and dose rate meters and for determining their response as a function of energy. Part 3: Calibration of area and personal dose meters and the measurement of their response as a function of energy and angle of incidence.
ISO 6980-1:2006	Nuclear energy. Reference beta-particle radiation. Part 1: Methods of production.
NPL GPG (No.XXX)	Measurement Good Practice Guide (Number TBA): Good Practice Guide for the Examination, Testing and Calibration of Electronic Personal Dose Meters (Title TBC). NOTE: final draft version available and published version anticipated in 2010.
RPD-OP-004-2006	Suitability of Radiation Monitoring Equipment — Comparison of Type-test Data. (RESTRICTED — Commercial).

3 Terminology

3.1 Special Word Usage

The following word usage applies:

- The word “shall” signifies a mandatory requirement.
- The word “should” signifies a recommended specification or method.
- The word “may” signifies an acceptable method or an example of good practice.

3.2 Definitions

3.2.1 SI Units

The units of the ‘International System of Units’. Multiples and sub-multiples of the SI units will be used in accordance with the SI.

3.2.2 Sievert

The SI unit of dose equivalent is the joule per kilogram (J kg^{-1}), which has been named the Sievert (Sv) by the International Commission on Radiological Protection (ICRP).

$$1 \text{ Sv} = 1 \text{ J kg}^{-1}$$

3.2.3 Personal dose equivalent $H_p(10)$

The dose equivalent for penetrating radiation in soft tissue at a depth of 10 mm in the human body. Unit: Sv $H_p(10)$.

3.2.4 Personal dose equivalent $H_p(0.07)$

The dose equivalent for superficial radiation in soft tissue at a depth of 0.07 mm in the human body. Unit: Sv $H_p(0.07)$.

3.3 Operating Modes

3.3.1 User mode (Routine)

The default operating mode whilst the instrument is being operated by non-expert users. Any parameters that may affect the operation of the instrument shall be protected via password or other appropriate security measures. The ability to view these parameter settings is desirable, but they shall be protected to prevent any changes. This mode may also be referred to as ‘simple’ mode.

3.3.2 Supervisor mode (Restricted)

An advanced operating mode that can only be accessed by an expert user, via password or other appropriate security measures, to edit parameters that will affect the operation of the instrument, i.e. calibration parameters, alarm thresholds, etc. This mode may also be referred to as 'advanced' or 'expert' mode.

3.4 Test Nomenclature

3.4.1 Acceptance test (Pre-use test / Test before first use)

The acceptance test shall demonstrate that the instrument conforms to type-test data. The acceptance test checks for any potential faults and provides a reference of performance for comparison with subsequent routine tests for the lifetime of the instrument. Further information on the tests required can be found in current UK guidance, such as the NPL Measurement Good Practice Guides (EPD GPG Publication anticipated in 2010).

3.4.2 Routine test (Periodic test)

This test confirms that the performance of the instrument has not deteriorated since the acceptance test. It is more than a simple check. Further information on the tests required can be found in current UK guidance, such as the NPL Measurement Good Practice Guides (EPD GPG Publication anticipated in 2010).

It is recommended that the performances of the instrument's electrical and mechanical systems are also inspected during the routine test. For example, batteries, cables, connectors and controls shall be inspected and repaired or replaced where necessary. Depending on the severity of the repair, it may be necessary to repeat the acceptance tests if, for example, the detector has been repaired or replaced.

3.4.3 Type-test

This test is performed on at least one or more standard production instruments picked at random. Ideally, all non-destructive tests should be performed on at least three standard production instruments. Destructive tests, however, may be performed on just a single instrument. The type-test investigates all aspects of the instrument's design to show the extent of compliance with pre-defined specifications.

4 General Requirements

4.1 Quantities and Units

The dose meter shall be scaled in appropriate units.

Dose meters designed to measure photon personal dose equivalent shall use the measuring quantity $H_p(10)$.

Dose meters designed to measure beta personal dose equivalent shall use the measuring quantity $H_p(0.07)$.

4.2 Measuring Ranges

4.2.1 Essential

The dose meter shall be capable of determining dose equivalent over the range 1 μSv to 100 mSv.

4.2.2 Desirable

The dose meter should be capable of determining dose equivalent over the range 1 μSv to 10 Sv.

4.3 Storage and Transport

4.3.1 Essential

The dose meters shall be supplied in a bespoke foam-lined carry-case designed to hold at least 12 dose meters. The case shall be waterproof and impact resistant. The case shall have provision to store the batteries when removed from the instrument. The instrument should not be stored for long periods of time with the batteries installed.

The instrument shall be designed to operate within the requirements of this document following storage or transport during a period of at least 3 months in the supplied carry case at any temperature between $-25\text{ }^{\circ}\text{C}$ and $+50\text{ }^{\circ}\text{C}$.

4.3.2 Desirable

It is desirable that the carry-case can protect the instrument during any possible air transport at low ambient pressure. Where this is not possible and the instrument could be damaged by air transport, this shall be clearly stated on the instrument and the case.

4.4 Desirable Dose Meter Features

4.4.1 Time to reach maximum dose

It is desirable that the dose meter can calculate the remaining time left on task before a pre-determined dose limit is reached. The remaining time should be easily visible on the display.

5 Standard Test Conditions

5.1 Reference Conditions

Reference conditions are given in the table below. Except where otherwise specified, the tests in this standard shall be carried out under the standard test conditions as indicated in the table below.

Table 1. Reference conditions and standard test conditions

Influence Quantity	Reference Conditions	Standard Test Conditions
Photon radiation energy for: Hp(10) Hp(0.07)	Gamma radiation from ^{137}Cs or ^{60}Co N-80 or ^{241}Am	Gamma radiation from ^{137}Cs or ^{60}Co N-80 or ^{241}Am
Beta radiation energy, Hp(0.07)	$^{90}\text{Sr}/^{90}\text{Y}$	$^{90}\text{Sr}/^{90}\text{Y}$
Neutron radiation energy, Hp(10)	$^{241}\text{Am-Be}$ or ^{252}Cf	$^{241}\text{Am-Be}$ or ^{252}Cf
Angle of incidence of radiation	Reference direction as supplied by the manufacturer	Direction given $\pm 5\%$
Dose for: Hp(10) Hp(0.07)	0.3 mSv 3 mSv	0.1 mSv to 10 mSv 0.5 mSv to 50 mSv
Dose rate for: Hp(10) Hp(0.07)	0.3 mSv h^{-1} 3 mSv h^{-1}	0.1 mSv h^{-1} to 10 mSv h^{-1} 0.2 mSv h^{-1} to 50 mSv h^{-1}
Stabilisation time	15 minutes	Minimum of 15 minutes
Ambient temperature	20 °C	18 °C to 22 °C ⁽¹⁾
Relative humidity	65%	55% to 75% ⁽¹⁾
Atmospheric pressure	101.3 kPa	86.0 to 106.6 kPa ⁽¹⁾
Battery voltage	Nominal voltage	Battery used up to half it's useful life
Orientation of dose meter	To be stated by the manufacturer	Stated orientation $\pm 5\%$
Dose meter controls	Set up for normal operation	Set up for normal operation
Radiation background	$1 \mu\text{Sv h}^{-1}$ or less if practical	Known field less than $1 \mu\text{Sv h}^{-1}$
Contamination by radioactive elements	Negligible	Negligible

⁽¹⁾ The actual values of these quantities at the time of test shall be stated.

5.2 Reference Radiations

Unless specified otherwise in individual methods within this document, the nature, construction and conditions of use of radiation sources shall be in accordance with the relevant parts of ISO 4037 and ISO 6980.

If the complete range of dose rates is not available from a single source of radiation, then additional sources, normalised to the original source of radiation, may be used.

Where an X-ray set is used to generate reference radiations, its output should be monitored by means of a monitor ionisation chamber which is permanently mounted in the radiation beam, as specified in ISO 4037-2:1997. This is to ensure that the X-ray set is stable. Where a monitor chamber is not available, the X-ray set output shall be measured immediately before and after any irradiation and any fluctuations found shall be accounted for.

The value of the quantity to be measured at the point of test shall be known with an uncertainty of less than 10%. All dose rates shall be traceable to national standards.

The radiation beam diameter shall be sufficient to irradiate the detector(s) of the instrument to be tested. The beam shall be uniform to within 10% over the useful beam area.

5.3 Dose Meter Orientation

The instrument under test shall be placed in an orientation with respect to the direction of the radiation field, as indicated by the manufacturer, and with the marked reference point accurately positioned at the point of test in the radiation field. In the absence of a marked reference point, the geometric centre of the detector shall be used. The instrument orientation and reference point used must be clearly stated in the test report.

5.4 Phantoms

Personal dose meters are designed to be worn on the body and will therefore detect backscattered radiation from the body. To simulate this, a backscatter element should be included in the calibration. To determine the absolute dose or dose rate response of the dose meter, it should be irradiated on an appropriate phantom as defined in ISO 4037-3; i.e. the ISO water slab phantom, which represents the torso.

If testing is not carried out on an appropriate phantom, i.e. free in air, then a backscatter correction factor, specific for the dose meter under test, will need to be determined and applied.

6 Radiological Performance Requirements

6.1 General

Where the dose meter has additional functions, then these functions shall be tested as appropriate. If any such additional functions are inhibited, then no additional testing is required.

6.2 Variation in Dose Response Due to Dose Rate

The response at approximately 80% of each order of magnitude shall be determined using a number of dose rates.

6.2.1 Essential

With the dose meter set up as specified by the manufacturer's instructions and under standard test conditions, the variation of the dose response due to dose rate shall not exceed 20%.

6.2.2 Desirable

With the dose meter set up as specified by the manufacturer's instructions and under standard test conditions, the variation of the dose response due to dose rate shall not exceed 10%.

6.2.3 Test radiation

The recommended reference radiation source is ^{137}Cs .

For the purpose of this test, the value of the true personal dose equivalent rate produced by the reference radiation at the point of test shall be known with an uncertainty of less than 10% at a confidence level of 95%.

The following dose rates shall be approximately generated:

1 $\mu\text{Sv h}^{-1}$, 10 $\mu\text{Sv h}^{-1}$, 100 $\mu\text{Sv h}^{-1}$, 1 mSv h^{-1} , 10 mSv h^{-1} , 100 mSv h^{-1} and 1 Sv h^{-1} .

Doses that would require exposure times to be less than 10 seconds or more than 10 hours duration may be excluded.

6.2.4 Method of test

With the dose meter mounted on the ISO slab phantom, place the dose meter in its calibration orientation as specified by the manufacturer.

The dose meter shall be exposed to each of the specified dose rates in turn for a time period to generate an indicated dose of approximately 80%. This shall be performed for each order of magnitude over the dose meter's effective range of measurement.

The dose responses shall be calculated and the percentage variation in dose response due to dose rate determined.

Response factor is defined as the ratio of the indicated personal dose equivalent to the true personal dose equivalent

Equation 1. Personal dose meter variation of dose measurements with dose rate:

$$I = \frac{H_i}{H_t}$$

where H_i is the indicated personal dose equivalent value above background and H_t is the conventionally true personal dose equivalent value at the point of reference.

6.3 Dose Rate Linearity

6.3.1 Essential

With the dose meter set up as specified by the manufacturer's instructions and under standard test conditions, the relative intrinsic error in the response to the reference gamma radiation (linearity) shall not exceed $\pm 30\%$ over the entire effective range of personal dose equivalent rates.

6.3.2 Desirable

With the dose meter set up as specified by the manufacturer's instructions and under standard test conditions, the relative intrinsic error in the response to the reference gamma radiation (linearity) shall not exceed $\pm 20\%$ over the entire effective range of personal dose equivalent rates.

6.3.3 Test radiation

The conventionally true personal dose equivalent (rate) produced by the reference radiation at the point of test shall be known with an uncertainty of less than 10% at the 95% confidence level.

For measurements performed in terms of $H_p(10)$, the reference radiation shall be ^{137}Cs gamma radiation. For measurements performed in terms of $H_p(0.07)$, the reference beta radiation shall be $^{90}\text{Sr}/^{90}\text{Y}$ beta dose rate radiation, and the reference photon radiation shall be N-80 or ^{241}Am .

6.3.4 Method of test

With the dose meter mounted on the ISO slab phantom, place the dose meter in its calibration orientation as specified by the manufacturer.

For personal dose equivalent (rate) meters provided with digital scales, this test shall be performed for at least three values in each order of

magnitude of dose equivalent indicated. These shall be at approximately 20%, 40% and 80% of each order of magnitude.

At high dose equivalent, the required dose equivalent rate range may be obtained using an X-ray generator, with corrections made for the dose meter's variation in response with dose rate. For these rates, suitable corrections shall also be made for any difference in the response of the dose equivalent rate meter to such radiation generated and the response to the reference radiation.

Equation 2. Personal dose meter linearity of response:

$$I = \frac{H_i}{H_t}$$

where H_i is the (mean) indicated personal dose equivalent (rate) value above background and H_t is the conventionally true personal dose equivalent (rate) value at the point of reference.

6.4 Retention of Dose Equivalent Reading

These tests shall be performed separately for both $H_p(10)$ and $H_p(0.07)$.

6.4.1 Essential

6.4.1.1 Without loss or interruption of the power source

After any exposure period, the reading of the dose meter shall not change by more than $\pm 2\%$ or a single change in the least significant digit, whichever is the greatest, over the next 8 hours. Any change to the indicated value due to background radiation shall be excluded.

6.4.1.2 With loss or interruption of the power source

Upon replacement of the power source, the dose meter indication shall not change by more than $\pm 5\%$ from the indication obtained before the power source was removed, or by a single change in the least significant digit, whichever is the greatest. Any change to the indicated value due to background radiation shall be excluded.

6.4.2 Desirable

Not currently defined.

6.4.3 Test radiation

The conventionally true personal dose equivalent (rate) produced by the reference radiation at the point of test shall be known with an uncertainty of less than 10% at the 95% confidence level.

For measurements performed in terms of $H_p(10)$, the reference radiation shall be ^{137}Cs gamma radiation. For measurements performed

in terms of $H_p(0.07)$, the reference beta radiation shall be $^{90}\text{Sr}/^{90}\text{Y}$ beta dose rate radiation, and the reference photon radiation shall be N-80 or ^{241}Am .

6.4.4 Method of test

With the dose meter mounted on the ISO slab phantom, place the dose meter in its calibration orientation as specified by the manufacturer.

The dose meter shall be exposed to a source of radiation to give a dose sufficiently high that any subsequent increase in indication due to background radiation can be ignored. The irradiation shall cease and the dose meter indication recorded as soon as the required dose equivalent is reached.

6.4.4.1 Without loss or interruption of the power source

The indication shall then be recorded every hour for an 8-hour period.

6.4.4.2 With loss or interruption of the power source

The power source shall then be removed from the dose meter for a period of 24 hours. After 24 hours the power source shall be replaced and the indication recorded.

6.5 Response Time (Dose Rate Alarm Function)

The manufacturer shall state the maximum response time of any dose meter alarm from background to a dose equivalent rate that is 50% greater than the alarm level.

When the dose meter is subjected to a step increase in dose equivalent rate, the time taken to alarm shall be determined.

The response time test provides a measure of the time taken for an alarm to be triggered. The word alarm signifies anything that would alert the user and may be an audible, visual or vibrating alarm. Alarms such as the source indication alarm and the personal protection alarm should be tested where available.

6.5.1 Essential

The dose meter's alarm shall be triggered when the dose meter is exposed to a radiation level that is 50% greater than any alarm threshold within 30 seconds of the step change. The alarm shall be audible and visual.

6.5.2 Desirable

The dose meter's alarm shall be triggered when the dose meter is exposed to a radiation level that is 50% greater than the alarm threshold within 10 seconds of the step change. The alarm shall be audible and visual.

6.5.3 Test radiation

For measurements performed in terms of $H_p(10)$, the reference radiation shall be ^{137}Cs gamma radiation. For measurements performed in terms of $H_p(0.07)$, the reference beta radiation shall be $^{90}\text{Sr}/^{90}\text{Y}$ beta dose rate radiation, and the reference photon radiation shall be N-80 or ^{241}Am .

The conventionally true personal dose equivalent (rate) produced by the reference radiation at the point of test shall be known with an uncertainty of less than 10% at the 95% confidence level.

6.5.4 Method of test

First, set the dose rate alarm to trigger above $100 \mu\text{Sv h}^{-1}$.

With the dose meter mounted on the ISO slab phantom, place the dose meter in its calibration orientation as specified by the manufacturer.

Next, determine the minimum dose rate that causes the alarm to be triggered.

Next, from a background dose rate of less than $1 \mu\text{Sv h}^{-1}$, quickly increase the dose rate, within 1 second, to a dose rate 50% greater than the minimum dose rate which causes the alarm to be triggered. The time for the alarm to be triggered shall be recorded.

Next, the dose rate shall be returned to a background level for sufficient time (at least 60 seconds) for the dose meter to return to a typical background dose rate indication.

The dose meter meets the relevant criteria if the alarm is triggered within the specified time for 9 out of 10 tests.

6.6 Response Time (Dose Rate Indication)

The manufacturer shall state the maximum response time of the dose meter.

When the dose meter is subjected to a step increase or decrease in dose equivalent rate, its indication shall reach the value given by the response time equation.

Equation 3. Response time:

$$H_i + \frac{90}{100}(H_f - H_i)$$

where H_i is the initial indication and H_f is the final indication.

6.6.1 Essential

When the dose meter experiences a sudden change in dose equivalent rate, the dose meter shall indicate the new dose equivalent rate within the specified time with an error of less than 20%.

Table 2. Dose rate indication response time limits (essential)

Initial Indication	Final Indication	Time to 90% of Final Indication
10 $\mu\text{Sv h}^{-1}$	100 $\mu\text{Sv h}^{-1}$	Less than 120 seconds
100 $\mu\text{Sv h}^{-1}$	1 mSv h^{-1}	Less than 20 seconds

6.6.2 Desirable

When the dose meter experiences a sudden change in dose equivalent rate, the dose meter shall indicate the new dose equivalent rate within the specified time with an error of less than 20%.

Table 3. Dose rate indication response time limits (desirable)

Initial Indication	Final Indication	Time to 90% of Final Indication
10 $\mu\text{Sv h}^{-1}$	100 $\mu\text{Sv h}^{-1}$	Less than 20 seconds
100 $\mu\text{Sv h}^{-1}$	1 mSv h^{-1}	Less than 10 seconds

6.6.3 Test radiation

Measurements shall be performed in terms of $H_p(10)$. The reference radiation shall be ^{137}Cs gamma radiation.

The conventionally true personal dose equivalent (rate) produced by the reference radiation at the point of test shall be known with an uncertainty of less than 10% at the 95% confidence level.

6.6.4 Method of test

With the dose meter mounted on the ISO slab phantom, place the dose meter in its calibration orientation as specified by the manufacturer.

First, set up the dose meter in the irradiation facility and allow it to stabilise in non-irradiating conditions.

The dose meter should then be rapidly exposed to the upper dose rate value and the readings recorded continuously until the dose meter has stabilised at the new dose rate.

The time taken for the dose meter to indicate 90% of the stable upper dose rate indication shall be determined.

Next, with the dose meter stabilised at the high dose rate value, the facility shall be rapidly set back to a non-irradiating condition and the readings recorded continuously until the dose meter has stabilised at the new dose rate.

The time taken for the dose meter to indicate 20% of the stable upper dose rate indication shall be determined. In addition, with the alarm set

to half the upper dose rate value, the time taken for the alarm to stop shall be determined.

6.7 Accuracy of Personal Dose Equivalent Alarm

6.7.1 Essential

When the dose meter receives a dose that is 15% lower than the set dose alarm point, the alarm shall not be triggered.

In addition, when the dose meter receives a dose that is 15% higher than the set dose alarm point, the alarm shall be triggered.

6.7.2 Desirable

When the dose meter receives a dose that is 5% lower than the set dose alarm point, the alarm shall not be triggered.

In addition, when the dose meter receives a dose that is 5% higher than the set dose alarm point, the alarm shall be triggered.

6.7.3 Test radiation

The conventionally true personal dose equivalent (rate) produced by the reference radiation at the point of test shall be known with an uncertainty of less than 10% at the 95% confidence level.

For measurements performed in terms of $H_p(10)$, the reference radiation shall be ^{137}Cs gamma radiation and measurements performed in terms of $H_p(0.07)$, the reference radiation shall be $^{90}\text{Sr}/^{90}\text{Y}$ beta dose rate radiation.

6.7.4 Method of test

With the dose meter mounted on the ISO slab phantom, place the dose meter in its calibration orientation as specified by the manufacturer.

First, zero the dose on the dose meter and then set up the dose meter in the irradiation facility in non-irradiating conditions.

Using the appropriate reference radiation, expose the dose meter to a dose rate that would not cause the set dose alarm to be triggered in less than 100 seconds. The time taken for the dose meter to alarm shall be measured and the dose given in this time calculated.

NOTE: To avoid any confusion, the dose rate alarm should be set so as not to be triggered by this test.

6.8 Accuracy of Personal Dose Equivalent Rate Alarm

6.8.1 Essential

When the dose meter is subjected to a dose rate that is 5% lower than the dose rate to which the alarm is set, the alarm shall not be triggered more than 5% of the time.

When the dose meter is subjected to a dose rate that is 5% greater than the dose rate to which the alarm is set, the alarm shall remain triggered more than 95% of the time.

6.8.2 Desirable

Currently not defined.

6.8.3 Test radiation

The conventionally true personal dose equivalent (rate) produced by the reference radiation at the point of test shall be known with an uncertainty of less than 10% at the 95% confidence level.

For measurements performed in terms of $H_p(10)$, the reference radiation shall be ^{137}Cs gamma radiation and measurements performed in terms of $H_p(0.07)$, the reference radiation shall be $^{90}\text{Sr}/^{90}\text{Y}$ beta dose rate radiation.

6.8.4 Method of test

With the dose meter mounted on the ISO slab phantom, place the dose meter in its calibration orientation as specified by the manufacturer.

First, the dose meter should be subjected to a dose equivalent rate that is 5% lower than the dose rate to which the alarm is set. During a period of 10 minutes record the total length of time that the alarm is triggered.

Next, the dose meter should be subjected to a dose equivalent rate that is 5% greater than the dose rate to which the alarm is set. During a period of 10 minutes, record the total length of time that the alarm is triggered.

6.9 Background Accumulation

The dose meter shall be left to accumulate a background increment in an area known to have a low, stable background dose rate. Where dose rate indications are available, these shall be obtained from direct measurement.

NOTE: It is impossible to provide a definitive value for a particular dose meter type since background accumulation will be specific to both dose meter type and facility. The background accumulation rate should be recorded for each type, the mean and standard deviation determined, and a limiting acceptable value defined.

6.9.1 Essential

During a 24 hour period, the dose meter shall not accumulate greater than 5 μSv in an area known to have a low, stable background rate.

6.9.2 Desirable

It is desirable that whilst the dose meter is accumulating background dose, this dose increment is not shown to the wearer. It is essential, however, that any dose received, background or otherwise, shall be included in the total dose and retained by the dose meter.

6.9.3 Test radiation

An area known to have a low, stable background rate less than 0.2 $\mu\text{Sv h}^{-1}$.

6.9.4 Method of test

The dose meter shall be zeroed and then placed in a known low and stable dose rate environment for 24 hours. The indicated dose after 24 hours shall be recorded.

6.10 Overload Performance

If the methods of detection differ for different radiation types, then these tests must be performed separately for each type of radiation.

6.10.1 Essential

6.10.1.1 Dose equivalent rate dose meters

The dose meter shall continue to indicate a valid displayed dose rate or an overload indication at all times while in the high dose equivalent field.

On all ranges, when exposed to dose rates greater than its measuring range, the dose meter shall remain 'off scale' at the higher end of the scale (or display an overload indication on a digital display). The dose meter must remain in this overload state whilst exposed to that or a greater radiation field and should not return 'on scale' or display any indication of dose rate until the exposed dose rate is within measuring range. On the completion of the overload test, the dose meter shall function correctly in a time period not exceeding 15 minutes.

6.10.1.2 Dose equivalent dose meters

The dose meter shall continue to indicate a valid displayed dose or an overload indication until it is reset.

6.10.2 Desirable

As previous requirement, but with the following change: on the completion of the overload test, the dose meter shall function correctly in a time period not exceeding 5 minutes.

6.10.3 Test radiation

The conventionally true personal dose equivalent (rate) produced by the reference radiation at the point of test shall be known with an uncertainty of less than 10% at the 95% confidence level.

For measurements performed in terms of $H_p(10)$, the reference radiation shall be ^{137}Cs gamma radiation and measurements performed in terms of $H_p(0.07)$, the reference radiation shall be $^{90}\text{Sr}/^{90}\text{Y}$ beta dose rate radiation.

6.10.4 Method of test

6.10.4.1 Dose equivalent rate dose meters

With the dose meter mounted on the ISO slab phantom, place the dose meter in its calibration orientation as specified by the manufacturer.

The dose meter, in its dose rate mode, should be exposed to a dose equivalent rate of 10 times the maximum range value, but not greater than 10 Sv h^{-1} for at least 10 minutes.

6.10.4.2 Dose equivalent dose meters

The dose meter shall be given a dose of 10 times the maximum range value, but not greater than 10 Sv.

6.11 Photon Energy Response

6.11.1 Essential

The dose meter's $H_p(10)$ response to radiation of energies between 60 keV and 1.25 MeV shall differ by less than $\pm 30\%$ from the response to ^{137}Cs .

6.11.2 Desirable

The dose meter's $H_p(10)$ response to radiation of energies between 16 keV and 1.25 MeV shall differ by less than $\pm 30\%$ from the response to ^{137}Cs .

6.11.3 Test radiation

The photon energy response of the dose meter shall be determined using the narrow-spectrum series of X-radiation qualities between N-20 (16 keV) and N-250 (208 keV), as defined in ISO 4037-1. In addition,

the gamma radiations of ^{137}Cs (662 keV), ^{241}Am (59.5 keV) and ^{60}Co (1.25 MeV) shall be used.

The conventionally true personal dose equivalent rate produced by the reference radiation at the point of test shall be known with an uncertainty of less than 10% at the 95% confidence level.

6.11.4 Method of test

With the dose meter mounted on the ISO slab phantom, place the dose meter in its calibration orientation as specified by the manufacturer.

Where possible, the measurements shall be performed at the same approximate indication for all energies. Where this is not possible, the indication shall be corrected for the relative intrinsic error for the same indication using ^{137}Cs . This may be interpolated where required.

Starting with the highest energy and working down, for each energy in turn, determine the $H_p(10)$ response normalised to ^{137}Cs to at least the first energy where the normalised response is less than 0.5.

For dose meters with a superficial dose capability, i.e. $H_p(0.07)$, readings shall be obtained at the same time as $H_p(10)$ measurements and the appropriate conversion factors applied to the true $H_p(10)$ dose to obtain the true $H_p(0.07)$ dose.

For personal dose equivalent meters the response normalised to the reference radiation, is defined as:

Equation 4. Photon energy response, calculation of normalised response:

$$I_{norm} = \frac{I_{energy_n}}{I_r}$$

where,

I_{energy} = response at energy n

n = 16.3 keV to 1.25 MeV

I_R = response at reference radiation, ^{137}Cs or 65 keV X-radiation

6.12 Polar Response

6.12.1 Essential

For angles defined in table 4, in both horizontal and vertical planes, the dose meter's $H_p(10)$ response normalised to the reference radiation at 0° shall be within 30% of the values given in table 4.

6.12.2 Desirable

For angles defined in table 4, in both horizontal and vertical planes, the dose meter's $H_p(10)$ response normalised to the reference radiation at 0° shall be within 20% of the values given in table 4.

6.12.3 Test radiation

This test shall be performed with ^{137}Cs , ^{241}Am (or the equivalent filtered X-radiation) and also with the lowest energy found during the energy response measurements that produced a normalised response greater than 0.8.

For dose meters with a $H_p(0.07)$ capability, polar response measurements shall also be performed at $\pm 45^\circ$ and $\pm 60^\circ$ in the horizontal plane using $^{90}\text{Sr}/^{90}\text{Y}$ or ^{85}Kr (beta), and ^{241}Am or N-80 (photon).

The conventionally true personal dose equivalent (rate) produced by the reference radiation at the point of test shall be known with an uncertainty of less than 10% at the 95% confidence level.

6.12.4 Method of test

With the dose meter mounted on the ISO slab phantom, place the dose meter in its calibration orientation as specified by the manufacturer. The dose meter's response to the reference radiation in this orientation (0°) shall be recorded.

Next, the dose meter and the phantom shall be rotated about the reference point of the dose meter from angles 0° to $\pm 90^\circ$ in 15° steps. This shall be performed in two planes: vertical and horizontal. At each step, expose the dose meter to the same dose rate as at 0° and record the dose meter indication and its response to the reference radiation. These responses shall then be normalised to the reference radiation at 0° and compared to the values in table 4.

NOTE: For this test the reference radiation does not require any additional corrections to be applied for angle.

Table 4. Required ratio of indication at angle α relative to the reading at $\alpha=0^\circ$. $H_p(10)$

Radiation source	Photon energy (keV)	Ratio = reading at α / reading at 0°			
		$\alpha = 15^\circ$	$\alpha = 30^\circ$	$\alpha = 45^\circ$	$\alpha = 60^\circ$
N25	20	0.98	0.91	0.75	0.51
N30	24	0.98	0.94	0.82	0.62
N40	33	0.99	0.96	0.87	0.73
N60	48	0.99	0.96	0.89	0.77
^{241}Am	60	0.99	0.97	0.91	0.79
^{137}Cs	662	1.01	1.01	1.01	0.98

NOTE: Calculated using data from ISO 4037-3:1999 (Page 34, table 30).

6.13 Variation in Neutron Response Due to Dose Rate

This test is only required for dose meters that have a neutron capability.

The response at approximately 80% of each order of magnitude shall be determined using a number of dose rates.

6.13.1 Essential

With the dose meter set up as specified by the manufacturer's instructions and under standard test conditions, the variation of the $H_p(10)$ dose response due to dose rate shall not exceed 30%.

6.13.2 Desirable

With the dose meter set up as specified by the manufacturer's instructions and under standard test conditions, the variation of the $H_p(10)$ dose response due to dose rate shall not exceed 20%.

6.13.3 Test radiation

Neutron sensitive dose meters should be tested using ^{252}Cf , $^{241}\text{Am(Be)}$ or an accelerator-produced source of neutrons, suitably moderated where appropriate, to confirm that the response is within the limits specified.

For the purpose of this test, the value of the true personal dose equivalent rate produced by the reference radiation at the point of test shall be known with an uncertainty of less than 10% at a confidence level of 95%.

The following list of approximate dose rates to be generated is for guidance only and some may be excluded:

$1\ \mu\text{Sv h}^{-1}$, $10\ \mu\text{Sv h}^{-1}$, $100\ \mu\text{Sv h}^{-1}$, $1\ \text{mSv h}^{-1}$, $10\ \text{mSv h}^{-1}$, $100\ \text{mSv h}^{-1}$ and $1\ \text{Sv h}^{-1}$.

Doses that would require exposure times to be less than 10 seconds or more than 10 hours duration may be excluded.

6.13.4 Method of test

With the dose meter mounted on the ISO slab phantom, place the dose meter in its calibration orientation as specified by the manufacturer.

The dose meter shall be exposed to each of the specified dose rates in turn for a time period to generate an indicated dose of approximately 80%. This shall be performed for each order of magnitude over the dose meter's effective range of measurement.

The dose responses shall be calculated and the percentage variation in dose response due to dose rate determined.

Response factor is defined as the ratio of the indicated personal dose equivalent to the true personal dose equivalent

Equation 5. Personal dose meter variation of dose measurements with dose rate:

$$I = \frac{H_i}{H_r}$$

where H_i is the indicated personal dose equivalent value above background and H_r is the conventionally true personal dose equivalent value at the point of reference.

6.14 Variation in Beta Response Due to Dose Rate

This test is only required for dose meters that have a beta capability.

For beta sensitive dose meters there is a need to identify where the dose meter 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 response at approximately 80% of each order of magnitude shall be determined using a number of dose rates.

6.14.1 Essential

With the dose meter set up as specified by the manufacturer's instructions and under standard test conditions, the variation of the $H_p(0.07)$ dose response due to dose rate shall not exceed 30%.

6.14.2 Desirable

With the dose meter set up as specified by the manufacturer's instructions and under standard test conditions, the variation of the $H_p(0.07)$ dose response due to dose rate shall not exceed 20%.

6.14.3 Test radiation

The beta dose response should be performed using, or by reference to, a secondary standard beta dose rate source that conforms to ISO 6980 and with a mean energy towards the low end of the useful energy range. However, such sources are not widely available.

For dose meters with a $H_p(0.07)$ capability, this test shall be performed using $^{90}\text{Sr}/^{90}\text{Y}$ or ^{85}Kr .

For the purpose of this test, the value of the true personal dose equivalent rate produced by the reference radiation at the point of test shall be known with an uncertainty of less than 10% at a confidence level of 95%.

The following list of approximate dose rates to be generated is for guidance only and some may be excluded:

1 $\mu\text{Sv h}^{-1}$, 10 $\mu\text{Sv h}^{-1}$, 100 $\mu\text{Sv h}^{-1}$, 1 mSv h^{-1} , 10 mSv h^{-1} , 100 mSv h^{-1} and 1 Sv h^{-1} .

Doses that would require exposure times to be less than 10 seconds or more than 10 hours duration may be excluded.

6.14.4 Method of test

With the dose meter mounted on the ISO slab phantom, place the dose meter in its calibration orientation as specified by the manufacturer.

The dose meter shall be exposed to each of the specified dose rates in turn for a time period to generate an indicated dose of approximately 80%. This shall be performed for each order of magnitude over the dose meter's effective range of measurement.

The dose responses shall be calculated and the percentage variation in dose response due to dose rate determined.

Response factor is defined as the ratio of the indicated personal dose equivalent to the true personal dose equivalent.

Equation 6. Personal dose meter variation of dose measurements with dose rate:

$$I = \frac{H_i}{H_t}$$

where H_i is the indicated personal dose equivalent value above background and H_t is the conventionally true personal dose equivalent value at the point of reference.

6.15 Interference Ionising Radiations

6.15.1 Neutron rejection

6.15.1.1 Essential

For dose meters that do not have a neutron capability, the manufacturer shall state the dose meters response to neutron radiation.

6.15.1.2 Desirable

Not currently defined.

6.15.2 Gamma rejection

6.15.2.1 Essential

For dose meters that do not have a gamma capability, the manufacturer shall state the dose meters response to gamma radiation.

6.15.2.2 Desirable

Not currently defined.

7 Alarms

7.1 General

For the purpose of this standard, an alarm is taken to be anything that draws the user's attention to the device.

If alarm trigger points are settable, they shall be protected from unauthorised and accidental changes. It shall not be possible to set alarm trigger points by external switches on the dose meter. The alarm trigger points shall be set by an external system.

If any alarm can be switched off or reduced in intensity, they shall be protected from unauthorised and accidental changes.

Where it is possible to turn off or reduce intensity of any alarm then the dose meter shall have a vibrating alarm.

7.2 Audible Alarm

7.2.1 Essential

Audible alarms shall exceed 100 dBA at a distance of 30 cm and be within the frequency range of 1 to 4 kHz. The maximum sound level for audible alarms shall not be greater than 120 dBA at the minimum hearing distance from the dose meter.

An option to mute the alarm shall be provided, but only available through the supervisor mode to prevent inadvertent muting of the alarm.

Where multiple alarms are available each alarm shall have a unique sound.

Any alarm shall not sound similar to any other emergency service equipment alarms, such as distress signals or low oxygen alarms. Alarms should be distinguishable from these by amplitude, frequency modulation or pattern where possible.

Examples of emergency service equipment alarms currently in use are defined below:

- Honeywell O2 meter: audible alarm with a pure tone at 3875 Hz;
- Diktron: various audible alarms with an upper frequency of 2900 Hz (± 200 Hz).

7.2.2 Desirable

The intensity of the alarm should be fully adjustable from off to the maximum sound level. This is particularly important for covert operations.

Where it is possible to adjust the alarm intensity the dose meter shall have a vibrating alarm.

7.3 Visual Alarm

7.3.1 Essential

The visual alarm (such as a flashing light or display indication) shall be positioned so that, if triggered, it the operator will easily notice it.

7.3.2 Desirable

Where the visual alarm is of high intensity, such as a beacon or similar, then the intensity of the visual alarm should be fully adjustable from off to the maximum brightness level. This is particularly important for covert operations or during use in dark conditions.

Where it is possible to adjust the alarm intensity the dose meter shall have a vibrating alarm.

7.4 Vibrating Alarm

A vibrating alarm is desirable for use in covert operations or in situations where other alarms may cause distress.

7.4.1 Essential

The vibrating alarm shall have sufficient intensity to be easily felt by the user through gloved hands.

7.4.2 Desirable

If it is possible to turn off or reduce the intensity of any visual or audible alarms then the dose meter shall have a vibrating alarm.

8 Electrical Performance Requirements

8.1 Power Supply (Batteries)

The object of this element of the test is to evaluate the battery test mode of the dose meter so as to demonstrate that it provides a valid check on the state of the batteries and connectors. In addition to low voltage checks, the test simulates the presence of a good battery but with significant corrosion on the battery terminals or connectors. This can be achieved by connecting the dose meter under test to a variable power supply and a variable resistor in series.

An estimation of the battery life shall be determined from information on the current drawn by the dose meter under realistic operating conditions.

The total number of batteries or cells required to power the dose meter shall be noted and the ease of their supply and replacement determined.

8.1.1 Voltage dependence

This test is designed to simulate any problems that may occur as the dose meter batteries discharge through normal use.

8.1.1.1 Essential

Unless the dose meter is displaying the low battery indication, all functions shall operate correctly and the mean dose meter indication will not vary by more than $\pm 20\%$ from the indication recorded with an optimal battery voltage.

8.1.1.2 Desirable

Unless the dose meter is displaying the low battery indication, all functions shall operate correctly and the mean dose meter indication will not vary by more than $\pm 10\%$ from the indication recorded with an optimal battery voltage.

8.1.1.3 Test radiation

The recommended reference radiation source is ^{137}Cs .

8.1.1.4 Method of test

With the dose meter's internal batteries removed, connect the dose meter to a variable power supply, a variable resistance and a means to monitor the voltage and current in the circuit. The power supply shall be set to supply the optimal battery operating voltage and the variable resistance shall be negligible.

With the dose meter in background conditions, decrease the supply voltage in small decrements and record the supply voltage, dose meter indication and any other observations, until the dose meter switches off. Particular attention should be made as to when the low battery indication is triggered, or if the indication varies by more than $\pm 10\%$ from the indication recorded with an optimal battery voltage.

This test should then be repeated with the dose meter exposed to a dose equivalent rate of between $10 \mu\text{Sv h}^{-1}$ and $100 \mu\text{Sv h}^{-1}$. If possible, a dose rate should be chosen that doesn't trigger any audible or visual alarms.

Finally, this test should be repeated with the dose meter exposed to a dose equivalent rate that triggers the audible or visual alarms.

8.1.2 Current dependence

This test is designed to simulate the presence of a good battery, but with significant corrosion on the battery terminals or connectors.

8.1.2.1 Essential

The current drawn by the instrument shall be as low as possible.

Unless the dose meter is displaying the low battery indication, all functions shall operate correctly and the mean dose meter indication will not vary by more than $\pm 20\%$ from the indication recorded with an optimal battery voltage.

8.1.2.2 Desirable

Unless the dose meter is displaying the low battery indication, all functions shall operate correctly and the mean dose meter indication will not vary by more than $\pm 10\%$ from the indication recorded with an optimal battery voltage.

8.1.2.3 Test radiation

The recommended reference radiation source is ^{137}Cs .

8.1.2.4 Method of test

With the dose meter's internal batteries removed, connect the dose meter in series to a variable power supply, a variable resistance and a means to monitor the voltage and current in the circuit. The power supply shall be set to supply the optimal battery operating voltage and the variable resistance shall be negligible.

With the dose meter in background conditions, increase the series resistance in small increments and record the supply voltage, resistance, current drawn, dose meter indication and any other observations, until the dose meter switches off. Particular attention should be made as to when the low battery indication is triggered or if

the indication varies by more than $\pm 10\%$ from the indication recorded with an optimal battery voltage.

This test should then be repeated with the dose meter exposed to a dose equivalent rate of between $10 \mu\text{Sv h}^{-1}$ and $100 \mu\text{Sv h}^{-1}$. If possible, a dose rate should be chosen that doesn't trigger any audible or visual alarms.

Finally, this test should be repeated with the dose meter exposed to a dose equivalent rate that triggers the audible or visual alarms.

8.1.3 Battery test function (applicable to all dose meters)

The dose meter shall have a means to assess the battery condition. The battery condition shall be indicated to enable the operator to assess when the battery condition is no longer suitable.

The rating for the battery test function should be based upon data provided by the voltage and current dependence tests.

8.1.3.1 Essential

The battery test shall provide an accurate assessment of the condition of the cells and their suitability for further powering the dose meter.

8.1.3.2 Desirable

Not currently defined.

8.1.3.3 Failure

Indicates a battery test with serious deficiencies that could result in incorrect measurements being made.

8.1.4 Battery test function (applicable only to digital dose meters)

The instrument shall have a means to estimate the remaining battery life under the normal and maximum load conditions expected during use. The battery condition shall be indicated and the operator alerted when the battery condition is becoming unsuitable for the instrument to meet the requirements in this document.

The rating for the battery test function should be based upon data provided by the voltage and current dependence tests.

8.1.4.1 Essential

During normal operation, the battery condition shall be monitored such that the operator is alerted when the expected remaining life of the battery falls below 30 minutes.

8.1.4.2 Desirable

During normal operation, the battery condition shall be monitored such that the operator is alerted when the expected remaining life of the battery falls below 1 hour.

8.2 Batteries

8.2.1 General

Consideration shall be given to the fact that below -10 °C the capacity of most types of batteries significantly decreases with decreasing temperature.

8.2.1.1 Essential

Batteries shall be installed in separate compartments to the dose meter electronics.

Batteries shall be easily accessible for replacement and routine maintenance. The correct polarity shall be clearly indicated on the dose meter.

Personal dose meters are designed to be worn on the body and therefore shall be capable of running solely on a battery supply. However, any chargers supplied should be capable of recharging the batteries from a vehicle's 12 volt cigarette lighter socket as well as a standard 240 volt mains supply.

8.2.1.2 Desirable

All batteries should be easy to change in the field without a special tool.

Batteries should be of a standard recognised type and be easy to obtain off the shelf from retail suppliers. The preferred commercially available battery size is AA (also known internationally as LR6 or MN1500). Standard type rechargeable batteries are acceptable (see requirements for rechargeable batteries in section 8.2.3).

8.2.2 Bespoke batteries

Bespoke batteries are acceptable if they can sustain the operation of the dose meter for a significant increase of time over standard batteries. If bespoke batteries are required then a second (spare) battery must be supplied and, in addition, a reliable supply of additional batteries shall be guaranteed for a minimum of 10 years.

8.2.3 Rechargeable batteries

8.2.3.1 Essential

All rechargeable batteries shall be able to be charged independently of the dose meter. A second set of rechargeable batteries and a fast charger shall be supplied. A fully discharged battery shall be able to be fully recharged within 2 hours.

8.2.3.2 Desirable

It should be possible to operate the dose meter whilst its installed batteries are recharging. There should be an indication of the current status of charging.

8.2.4 Battery lifetime

8.2.4.1 Essential

After fresh or fully recharged batteries have been fitted, the dose meter must be capable of operating under standard test conditions with no alarms or illumination features in operation for at least 1000 hours.

After fresh or fully recharged batteries have been fitted, the dose meter must be capable of operating under standard test conditions with ALL alarms or illumination features in operation at their maximum intensity for at least 1 hour.

8.2.4.2 Desirable

After fresh or fully recharged batteries have been fitted, the dose meter must be capable of operating under standard test conditions with no alarms or illumination features in operation for at least 3000 hours.

After fresh or fully recharged batteries have been fitted, the dose meter must be capable of operating under standard test conditions with ALL alarms or illumination features in operation at their maximum intensity for at least 5 hours.

8.3 External DC or AC Power Supplies

8.3.1 Essential

For all uses, personal dose meters will be powered solely by a battery supply. If rechargeable batteries are supplied, then some means of charging these batteries shall also be supplied. Power supplies for charging the batteries shall include one or more power adapters to enable charging from a standard UK 240 volt mains supply and from a nominal 12 volt vehicle electrical system. Protection against over voltage and reverse polarity shall be provided.

8.4 Electromagnetic Compatibility

The dose meter shall be electronically compatible and not interfere with emergency service communications equipment, including UHF hand-held radios, VHF main schemes radios and mobile radios. The electronic interference tolerance of the unit shall be quoted.

An example of frequencies currently utilised by emergency service communication equipment is defined below:

- 380 to 400 MHz

9 Mechanical Requirements

9.1 Mechanical Shock (Drop Test)

9.1.1 Essential

The instrument shall be able to withstand a drop from heights of 1 metre on to a hardwood surface without severe mechanical damage. The drop shall not affect the indicated dose rate reading by more than 20%.

9.1.2 Desirable

The instrument shall be able to withstand a drop from heights of 1 metre on to a concrete surface without severe mechanical damage. The drop shall not affect the indicated dose rate reading by more than 10%.

9.1.3 Test radiation

The conventionally true personal dose equivalent (rate) produced by the reference radiation at the point of test shall be known with an uncertainty of less than 10% at the 95% confidence level.

For measurements performed in terms of $H_p(10)$, the reference radiation shall be ^{137}Cs gamma radiation and measurements performed in terms of $H_p(0.07)$, the reference radiation shall be $^{90}\text{Sr}/^{90}\text{Y}$ beta dose rate radiation.

9.1.4 Method of test

First, the dose meter's response to the appropriate reference nuclide shall be determined in a reproducible geometry.

Next, the dose meter shall be dropped on to each face in turn from a height of 1 metre on to the specified surface. After each drop, the dose meter's response to the appropriate reference nuclide shall be confirmed and recorded. The dose meter shall also be checked for any mechanical damage or loose fittings and any observations recorded.

9.2 Vibration

The physical condition of the dose meter shall not be affected by harmonic loadings of 2 g applied for 15 minutes in the frequency range 10 to 33 Hz, i.e. all electrical connections and mechanical fastenings shall hold and not become loose.

9.2.1 Essential

The mean response of the dose meter shall not vary by more than 20% as a result of these vibrations.

9.2.2 Desirable

The mean response of the dose meter shall not vary by more than 10% as a result of these vibrations.

9.2.3 Test radiation

The conventionally true personal dose equivalent (rate) produced by the reference radiation at the point of test shall be known with an uncertainty of less than 10% at the 95% confidence level.

For measurements performed in terms of $H_p(10)$, the reference radiation shall be ^{137}Cs gamma radiation and measurements performed in terms of $H_p(0.07)$, the reference radiation shall be $^{90}\text{Sr}/^{90}\text{Y}$ beta dose rate radiation.

9.2.4 Method of test

The dose meter shall be exposed to photon radiation in reproducible geometry and the mean indication determined. The dose meter shall then be subjected to harmonic loadings of 2 g applied for 15 minutes in each of three planes. At least one test shall be performed within each of the ranges 10 to 21 Hz and 22 to 33 Hz. After each vibration, the mean indication will be determined using the same radiation conditions and geometry as before. All pre- and post-vibration readings shall be recorded, as well as the physical condition of the dose meter.

9.3 Mechanical Impact (Microphonic Tests)**9.3.1 Essential**

During microphonic conditions, which may occur from low intensity impacts, the dose meter's response shall remain within $\pm 30\%$ of the pre-test values.

9.3.2 Desirable

Not currently defined.

9.3.3 Test radiation

The recommended reference radiation source is ^{137}Cs .

9.3.4 Method of test

First, the dose meter shall be exposed to photon radiation in reproducible geometry and the mean indication determined.

Next, the dose meter case shall be subjected to three impacts on each side of its case. Each impact shall have an intensity of approximately 0.2 Joules. The dose meter indication shall be recorded after every impact.

An impact intensity of approximately 0.2 Joules may be generated, for example, by dropping a 200 g weight from a height of 10 cm.

[Gravitational energy (Joules) = Mass (kg) x Gravity (N/kg) x Height raised (m)]

10 Environmental Performance Requirements

Dose meters shall be so designed and constructed as to be capable of performing their intended function in full safety in changing environmental situations.

10.1 Environmental Protection

The manufacturer should state the environmental protection classification of the instrument. Where this is not supplied, a visual inspection of probable ingress shall be performed and recorded.

10.1.1 Essential

The instrument shall have an IP rating of at least IP54. Instruments shall be designed to resist ingress from dust, wind driven rain, high humidity or condensation. If the instrument has been disassembled for any reason, the manufacturer shall state which seals or gaskets would need to be replaced to retain acceptable weather protection.

[IP 5x — dust protected: ingress of dust is not totally prevented, but dust shall not penetrate in a quantity to interfere with the satisfactory operation of the apparatus or to impair safety.]

[IP x4 — protected against splashing water: water splashed against the enclosure from any direction shall have no harmful effects.]

10.1.2 Desirable

The instrument should have an IP rating close to IP67. Instruments should be designed to resist water ingress from temporary immersion.

[IP 6x — dust tight: no ingress of dust.]

[IP x7 — protected against temporary immersion: ingress of water in harmful quantity shall not be possible when the enclosure is immersed in water under defined conditions of pressure and time.]

10.2 Temperature Stability

The object of this test is to determine the dependency of the dose meter response on temperature.

10.2.1 Essential

The worst case percentage change of the indications at -10 °C and +40 °C compared to the indication at 20 °C for both radiation levels shall be less than 50%.

10.2.2 Desirable

The worst case percentage change of the indications at -10 °C and +60 °C compared to the indication at 20 °C for both radiation levels shall be less than 20%.

10.2.3 Test radiation

The recommended reference radiation source for photon and β dose rate personal dose meters is ^{137}Cs .

10.2.4 Method of test

The dose meter shall be placed in a climatic chamber initially set to an operating temperature of 20 °C and allowed to stabilise for a minimum of 60 minutes. Both the dose meter background reading and a higher indication produced by a radioactive source shall be recorded.

The chamber temperature shall be increased to the specified upper temperature and the dose meter left for a minimum of 4 hours to achieve thermal equilibrium. The dose meter response at background and the higher indication shall be recorded.

This test shall then be repeated with a temperature of -10 °C.

10.3 Temperature Shock

10.3.1 Essential

The dose meter should be capable of satisfactory operation up to temperatures of +60 °C.

10.3.2 Desirable

Not currently defined.

10.3.3 Test radiation

The recommended reference radiation source for photon and β dose rate personal dose meters is ^{137}Cs .

10.3.4 Method of test

The dose meter shall be placed in a climatic chamber initially set to an operating temperature of 20 °C and allowed to stabilise for a minimum of 60 minutes. Both the dose meter background reading and a higher indication produced by a radioactive source shall be recorded.

Next, the chamber temperature shall be increased to the specified upper temperature within 5 minutes. The readings at background and the higher indication shall be repeated and recorded every 15 minutes for 2 hours.

Next, the chamber temperature shall be returned to the original temperature of 20 °C within 5 minutes. The readings at background and the higher indication shall be repeated and recorded every 15 minutes for 2 hours.

Finally, the chamber temperature shall be decreased to -10 °C within 5 minutes. The readings at background and the higher indication shall be repeated and recorded every 15 minutes for 2 hours.

10.4 Low Temperature Start-up

10.4.1 Essential

The dose meter shall switch on and operate correctly at -10 °C.

10.4.2 Desirable

Not currently defined.

10.4.3 Method of test

The dose meter shall be placed in a climatic chamber initially set to an operating temperature of -10 °C and allowed to stabilise for a minimum of 4 hours. The dose meter shall then be switched on and operate normally.

10.5 Humidity Stability

10.5.1 Essential

The dose meter shall be capable of working at relative humidity levels between 20% RH and 90% RH. The variation of the relative response due to humidity shall be less than ±15%.

10.5.2 Desirable

The variation of the relative response due to humidity shall be less than ±10%.

10.5.3 Test radiation

The recommended reference radiation source for photon and β dose rate personal dose meters is ^{137}Cs .

10.5.4 Method of test

The dose meter shall be placed in a climatic chamber initially set to an operating temperature of +35 °C and a relative humidity of 65% RH. The dose meter shall be left switched off in these conditions for a minimum of 24 hours. In the last 30 minutes of this period, the dose meter should be switched on and both the dose meter background reading and a higher indication produced by a radioactive source shall be recorded.

Keeping the temperature at 35 °C, increase the relative humidity inside the chamber to 90% RH. The dose meter shall left switched off in these conditions for a minimum of 24 hours. In the last 30 minutes of this period, the dose meter should be switched on and both the dose meter background reading and a higher indication produced by a radioactive source shall be recorded.

This test shall then be repeated with a relative humidity of 20% RH.

NOTE: For this test the reference response is determined at +35 °C and not +20 °C.

10.6 Submersion

10.6.1 Essential

The level of water resistance shall be clearly stated in the manual. Where the level of water resistance has not been tested then this shall be stated in the manual.

10.6.2 Desirable

The dose meter should be capable of satisfactory operation after being fully submerged under water for 5 minutes.

10.6.3 Method of test

The dose meter shall be submerged under water at a depth of approximately 30 mm for a period of at least 5 minutes and then thoroughly dried. Both the dose meter's background reading and a higher indication produced by a radioactive source shall be recorded.

10.7 Explosive Atmospheres

Circumstances can be foreseen where it is necessary for instruments to be used in flammable atmospheres or close to explosive devices.

10.7.1 Essential

The manufacturer shall clearly state the level of intrinsic safety.

10.7.2 Desirable

The instrument should be intrinsically safe. Potential ignition sources, such as sparks, electric arcs or high surface temperatures, should not occur.

Instruments shall be designed so that the opening of equipment parts, which may be sources of ignition, is only possible under non-active or intrinsically safe conditions. Where it is not possible to render the equipment non-active, a warning label shall be affixed to the opening part of the equipment.

11 Maintenance Requirements

The manufacturer must define the time limit that the instrument will be supportable for spares and repairs. This shall be a minimum of 10 years. The manufacturer shall provide details of technical support and advice options as well as recommendations and information on the testing and maintenance regime required.

The instrument shall be supplied with a comprehensive instruction manual. In addition, a maintenance manual shall be available upon request.

The instrument shall contain a sufficient amount of easily accessible test points to facilitate fault location. Any maintenance aids, such as fault diagnosis software, extension leads and special maintenance tools, shall be available from the manufacturer upon request.

Unauthorised access to all the set-up functions of the equipment shall be prevented (see paragraph 3.3 Operating Modes).

12 Ergonomic Requirements

12.1 General

The object of this assessment is to give some idea of the ease of regular use of the dose meter. Owing to the nature of the parameters assessed, the ratings are, to a large extent, subjective and should be based on impressions gained during the testing and handling of the dose meters. Factors to be considered are:

- ease of operation;
- clarity of the display;
- ease of decontamination;
- susceptibility to damage.

12.1.1 Essential

Features are reasonably satisfactory.

12.1.2 Desirable

Features are fully satisfactory and could not be usefully improved.

12.1.3 Failure

Indicates a poor feature that could be irritating or inconvenient during regular use.

12.2 Size

12.2.1 Essential

The dimensions of the dose meter shall not exceed 100 mm in length, 30 mm in depth and 80 mm in width, excluding any clip or retaining device. In addition, the dose meter shall fit into a volume of less than 250 cm³, excluding any clip or retaining device.

For dose meters that have mixed neutron/photon detection capability, the dose meter shall fit into a volume of less than 300 cm³, excluding any clip or retaining device.

12.2.2 Desirable

The dose meter should be as small as possible, whilst still accommodating the required minimum sizes for the controls and display.

12.3 Weight

12.3.1 Essential

Dose meters that have photon and/or beta capability shall be as light as possible with a maximum weight of 200 g.

Dose meters that have mixed neutron and photon capability shall be as light as possible with a maximum weight of 350 g.

12.3.2 Desirable

The dose meter should be as light as possible with a maximum weight of 100 g.

12.4 Case Construction

12.4.1 Essential

The dose meter case shall be smooth, rigid, shock resistant, splash proof and dust resistant. An additional rubberised outer to minimise damage can be utilised but where this is removable it shall not affect the dose meter's radiological performance.

A means for fixing the dose meter to clothing shall be provided; for example, a strong clip or adjustable lanyard to allow for freedom of movement whilst carrying out strenuous work. Special attention should be given to the necessary orientation of the detector and, in addition, to ensure that any control, display or visual alarm is located such that they are visible to the operator.

12.4.2 Desirable

Not currently defined.

12.5 Resistance to Contamination (Ease of Decontamination)

12.5.1 Essential

The instrument shall be easy to decontaminate, ideally without any areas where contaminants could become difficult to remove. A smooth non-porous external surface that is free from crevices is recommended. The instrument may be fitted with an additional protective cover providing this doesn't affect any aspects of the instrument's performance.

12.5.2 Desirable

Not currently defined.

12.6 Transportation

12.6.1 Essential

Not currently defined.

12.6.2 Essential

Capable of surviving high altitude air transport.

12.7 Visual Display

12.7.1 Essential

Whether the dose meter has an analogue or digital display (or a hybrid of the two), the display shall react instantly to any change of measuring range. In addition, the display shall clearly indicate the measuring quantity.

The display must be clear and easy to read under normal and extreme conditions, which include the use in bright sunlight and in total darkness. The display shall have an illumination function that can be turned on and off and this must not time out. A provision to test for failure of the display shall be installed. The display should not be influenced by gravity.

In addition to the visual indication of dose, a visual and audible indication of exceeding a dose limit shall be provided. A facility for temporally muting the audible indication shall be provided.

The size of the display shall be at least 25 x 5 mm.

12.7.2 Desirable

The brightness of the display illumination should be fully adjustable from off to the maximum brightness. There should be an option for the illumination brightness to adjust automatically dependent on the ambient lighting conditions.

The size of the display shall be at least 50 mm x 15 mm.

12.8 Additional Indications

12.8.1 Low battery

12.8.1.1 Essential

An indication of the battery condition shall be displayed on the display.

12.8.1.2 Desirable

Not currently defined.

12.8.2 Detector failure

12.8.2.1 Essential

The dose meter shall detect when the detector has failed and alert the operator.

12.8.2.2 Desirable

Not currently defined.

12.9 Ease of Operation

12.9.1 Essential

The dose meter must be designed so that it can be used safely and efficiently without a high level of specialist knowledge.

The dose meter must be easy to operate when the operator is in full gas tight personal protection equipment (PPE).

12.9.2 Desirable

The dose meter should be controlled via a menu operation with “soft keys”. One-handed operation is possible.

12.10 Switches and Controls

12.10.1 Essential

All switches and other controls shall be designed to ensure that the dose meter can be properly operated while minimising accidental operation of any controls. All switches and controls shall have a positive feel that they have been operated.

12.10.2 Desirable

All switches and controls should be illuminated such that their location and function can be identified in dark conditions. The spacing between each switch or control should be at least 15 mm so as to increase the ease of operation of the dose meter while the operator is in full gas tight PPE. NOTE: The finger diameter of the gloves used with full gas tight PPE is approximately 25 to 30 mm.

12.11 Detector Location

For the majority of personal dose meters, the detector should be integral.

12.12 External Markings

All external markings shall remain permanently fixed under both normal conditions and those during normal decontamination procedures.

The dose meter shall be clearly marked with the following:

- manufacturer's name;
- model type;
- unique serial number;
- function of all controls (that are not displayed via soft menus) and indicators.

Dose meters with internal radiation detectors shall have markings to clearly indicate the calibration reference point of each detector in at least two planes.

12.13 Firmware

12.13.1.1 Essential

In the design of any firmware-controlled instrumentation, special account shall be taken of the risks arising from faults in the program.

The software shall have a version number for identification. It shall be possible to display this identification whilst the software is running.

All commands or parameters shall be defined; i.e. they shall have a clearly defined function that can be processed by the instrument, otherwise the instrument shall identify them as invalid. Invalid commands shall not affect any data or functions of the instrument.

12.13.1.2 Desirable

If applicable, firmware stored in the dose meter should be easy to update. Any updates shall be possible using only a PC with USB or other standard communications port. The dose meter shall request re-calibration after any update and this shall be made clear to the operator on every occasion before any updates are made.

12.14 Data Logging

12.14.1.1 Essential

Not currently defined.

12.14.1.2 Desirable

The instrument should have a data logging capability, with a download facility for extracting and/or interrogating data and logging faults to a computer. In the event of a power/battery failure the instrument should retain this data.

12.15 Communication Interface

12.15.1 Essential

Not currently defined.

12.15.2 Desirable

The dose meter should be able to communicate data with an external device, such as a computer. The type of data to transfer could include dose equivalent history with time and date and/or GPS location.

The data transfer shall be via a bi-directional serial port that meets the requirements of Ethernet, USB or other, by other electronic means, such as a standard removable media device (e.g. SD Card). The protocol used shall conform to applicable IEEE protocols (e.g. IEEE 802) and proprietary protocols shall not be used. The transferred data shall be of a format (e.g. ASCII) that can be easily imported into common analysis programs. The manufacturer shall provide a full description of the transfer format and, if required, proprietary software for data interpretation.

Whilst it is acceptable in some circumstances for data to be communicated wirelessly (e.g. via Bluetooth® or Wi-Fi), all instruments shall have the option to fully disable its radio communications.

The option to wirelessly monitor the wearer's dose and dose rate is desirable. This would enable better control of an individual's received dose.

13 Documentation

13.1 Type-test Report

The manufacturer shall make the relevant type-test report available to any user or potential user of the dose meter. If requested, the type-test report shall be supplied in its entirety.

13.2 Calibration Certificate Requirements

A certificate shall be provided giving at least the following information:

- manufacturer's name or registered trade mark;
- dose meter type and serial number;
- probe type and serial number (if applicable);
- types and energies of radiations for which the dose meter is intended;
- reference point of dose meter;
- calibration orientation relative to radiation sources;
- effective range of use.

13.3 Operation and Maintenance Manual

1.1.1 Essential

The manufacturer shall supply an operational and maintenance manual containing a minimum of the following information:

- operating instructions and restrictions;
- schematic electrical diagrams, spare parts list and specifications;
- troubleshooting guide;
- contact information for the manufacturer.

1.1.2 Desirable

The manufacturer should supply a quick reference guide that explains the basic operations.

14 Training

14.1 **Essential**

Not currently defined.

14.2 **Desirable**

Training simulator options should be available for realistic training.

Appendix A: Summary of Performance Criteria

A.1 Radiological

Table 1: Summary of radiological performance criteria

Requirement	Essential	Desirable
Variation in dose response due to dose rate	Dose variation better than $\pm 20\%$.	Dose variation better than $\pm 10\%$.
Dose rate linearity	Linearity better than $\pm 30\%$.	Linearity better than $\pm 20\%$.
Retention of dose	Without loss or interruption of the power source, after any exposure period, the reading of the dose meter shall not change by more than $\pm 2\%$ or a single change in the least significant digit, whichever is the greatest, over the next 8 hours. Upon replacement of the power source after loss or interruption, the dose meter indication shall not change by more than $\pm 5\%$ from the indication obtained before the power source was removed or by a single change in the least significant digit, whichever is the greatest.	Not currently defined.
Response time (dose rate alarm function)	The dose meter's alarm shall be triggered when the dose meter is exposed to a radiation level that is 50% greater than any alarm threshold within 30 seconds of the step change. The alarm shall be audible and visual.	The dose meter's alarm shall be triggered when the dose meter is exposed to a radiation level that is 50% greater than the alarm threshold within 10 seconds of the step change. The alarm shall be audible and visual.
Response time (dose rate indication)	When the dose meter experiences a sudden change in dose equivalent rate (as specified in table 2), the dose meter shall indicate the new dose equivalent rate within the specified time with an error of less than 20%.	When the dose meter experiences a sudden change in dose equivalent rate (as specified in table 3), the dose meter shall indicate the new dose equivalent rate within the specified time with an error of less than 20%.

Requirement	Essential	Desirable
Accuracy of personal dose equivalent alarm	When the dose meter receives a dose that is 15% lower than the set dose alarm point, the alarm shall not be triggered. In addition, when the dose meter receives a dose that is 15% higher than the set dose alarm point, the alarm shall be triggered.	When the dose meter receives a dose that is 5% lower than the set dose alarm point, the alarm shall not be triggered. In addition, when the dose meter receives a dose that is 5% higher than the set dose alarm point, the alarm shall be triggered.
Accuracy of personal dose equivalent rate alarm	When the dose meter is subjected to a dose rate that is 5% lower than the dose rate to which the alarm is set, the alarm shall not be triggered more than 5% of the time. When the dose meter is subjected to a dose rate that is 5% greater than the dose rate to which the alarm is set the alarm shall remain triggered more than 95% of the time.	Not currently defined.
Background accumulation	In a 24-hour period the dose meter shall not accumulate greater than 5 μSv in an area known to have a low, stable background rate less than 0.2 $\mu\text{Sv h}^{-1}$.	Whilst the dose meter is accumulating background dose, this dose increment is not shown to the wearer.
Overload performance	Dose rate: satisfactory overload and return to normal function in no more than 15 minutes. Dose: indicate a valid displayed dose or an overload indication until it is reset.	Dose rate: satisfactory overload and return to normal function in less than 5 minutes.
Photon energy response	The dose meter's $\text{Hp}(10)$ response to radiation of energies between 60 keV and 1.25 MeV shall differ by less than $\pm 30\%$ from the response to ^{137}Cs .	The dose meter's $\text{Hp}(10)$ response to radiation of energies between 16 keV and 1.25 MeV shall differ by less than $\pm 30\%$ from the response to ^{137}Cs .
Polar response	For angles defined in table 4, in both horizontal and vertical planes, the dose meter's $\text{Hp}(10)$ response normalised to the reference radiation at 0° shall be within 30% of the values given in table 4.	For angles defined in table 4, in both horizontal and vertical planes, the dose meter's $\text{Hp}(10)$ response normalised to the reference radiation at 0° shall be within 20% of the values given in table 4.
Variation in neutron response due to dose rate	$\text{Hp}(10)$ dose variation better than $\pm 30\%$.	$\text{Hp}(10)$ dose variation better than $\pm 20\%$.

Requirement	Essential	Desirable
Variation in beta response due to dose rate	Hp(0.07) dose variation better than $\pm 30\%$.	Hp(0.07) dose variation better than $\pm 20\%$.
Interference radiations: neutron rejection	For dose meters that do not have a neutron capability, the manufacturer shall state the dose meter's response to neutron radiation.	Not currently defined.
Interference radiations: gamma rejection	For dose meters that do not have a gamma capability, the manufacturer shall state the dose meter's response to gamma radiation.	Not currently defined.

A.2 Alarms

Table 2: Summary of alarm performance criteria

Requirement	Essential	Desirable
Audible alarm	Audible alarms shall exceed 100 dBA at a distance of 30 cm and have a unique sound, which shall not sound similar to any other emergency service equipment. Alarms should be distinguishable from these by amplitude, frequency modulation or pattern.	Adjustable alarm intensity in conjunction with vibrating alarm.
Visual alarm	Positioned so that, if triggered, the user will easily notice it.	Adjustable alarm intensity in conjunction with vibrating alarm.
Vibrating alarm	The vibrating alarm shall have sufficient intensity to be easily felt by the user through gloved hands.	If it is possible to turn off or reduce the intensity of any visual or audible alarms then the dose meter shall have a vibrating alarm.

A.3 Electrical

Table 3: Summary of electrical performance criteria

Requirement	Essential	Desirable
Voltage dependence	Unless the dose meter is displaying the low battery indication, all functions shall operate correctly and the mean dose meter indication will not vary by more than $\pm 20\%$ from the indication recorded with an optimal battery voltage.	Unless the dose meter is displaying the low battery indication, all functions shall operate correctly and the mean dose meter indication will not vary by more than $\pm 10\%$ from the indication recorded with an optimal battery voltage.
Current dependence	Unless the dose meter is displaying the low battery indication, all functions shall operate correctly and the mean dose meter indication will not vary by more than $\pm 20\%$ from the indication recorded with an optimal battery voltage.	Unless the dose meter is displaying the low battery indication, all functions shall operate correctly and the mean dose meter indication will not vary by more than $\pm 10\%$ from the indication recorded with an optimal battery voltage.
Battery test function (applicable to all dose meters)	The battery test shall provide an accurate assessment of the condition of the cells and their suitability for further powering the dose meter.	Not currently defined.
Battery test function (applicable only to digital dose meters)	Operator alerted when the expected remaining life of the battery falls below 30 minutes.	Operator alerted when the expected remaining life of the battery falls below 1 hour.
Battery lifetime	Must be capable of operating under standard test conditions with no alarms or illumination features in operation for at least 1000 hours and for at least 1 hour with ALL alarms or illumination features in operation at their maximum intensity.	Must be capable of operating under standard test conditions with no alarms or illumination features in operation for at least 3000 hours and for at least 5 hours with ALL alarms or illumination features in operation at their maximum intensity.

A.4 Mechanical

Table 4: Summary of mechanical performance criteria

Requirement	Essential	Desirable
Mechanical shock (drop test)	Dose meter withstands drops from 1 metre on to hardwood without severe mechanical damage or affecting the indicated dose rate reading by more than 20%.	Dose meter withstands drops from 1 metre on to concrete without severe mechanical damage or affecting the indicated dose rate reading by more than 10%.
Vibration	Response shall not vary by more than 20% as a result of the specified vibrations.	Response shall not vary by more than 10% as a result of the specified vibrations.
Mechanical impact (microphonic tests)	During microphonic conditions, which may occur from low intensity impacts, the dose meter's response shall remain within $\pm 30\%$ of the pre-test values.	Not currently defined.

A.5 Environmental

Table 5: Summary of environmental performance criteria.

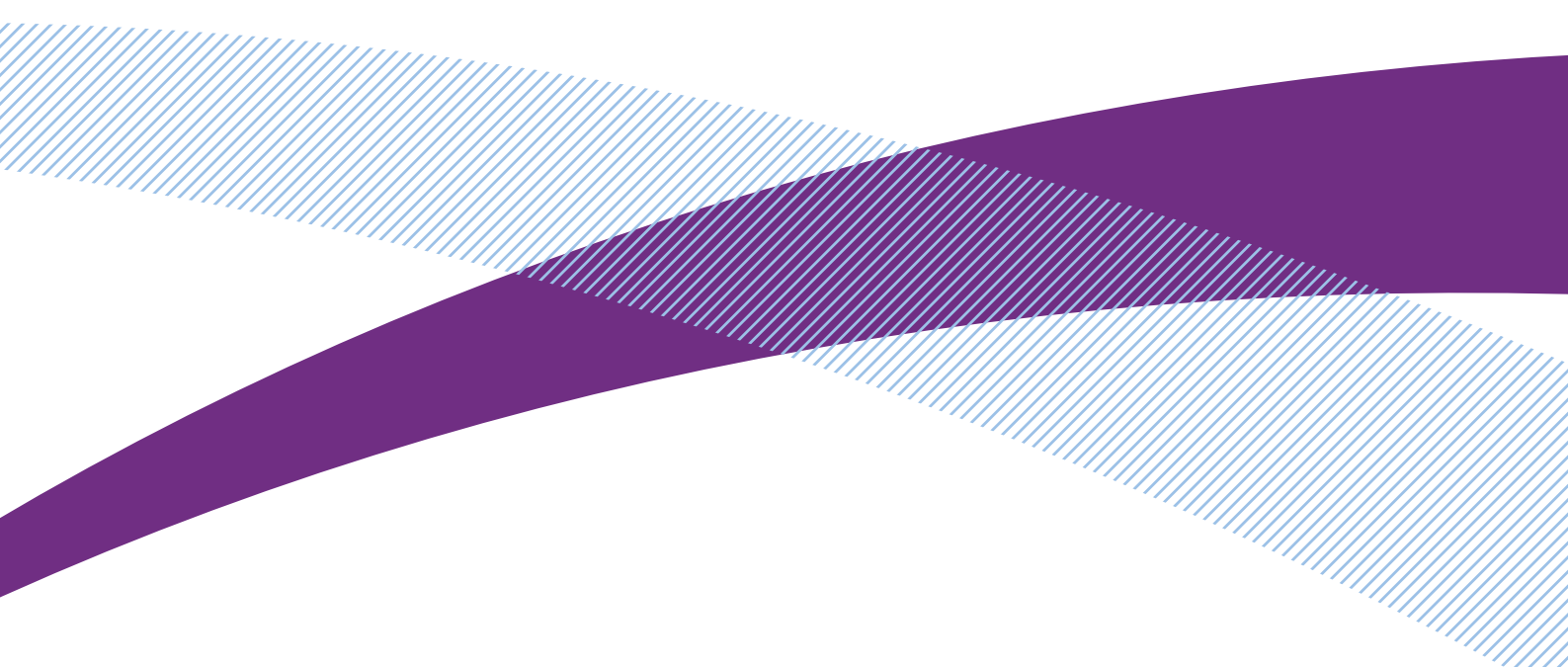
Requirement	Essential	Desirable
Environmental protection	IP rating of at least IP54.	IP rating close to IP67.
Temperature stability	A change of less than 50% for indications at -10 °C and +40 °C compared to the indication at 20 °C.	A change of less than 20% for indications at -10 °C and +60 °C compared to the indication at 20 °C.
Temperature shock	Capable of satisfactory operation up to +60 °C	Not currently defined.
Low temperature start-up	Shall switch on and operate correctly at -10 °C.	Not currently defined.
Humidity stability	A change of less than 15% in indications for humidity levels between 20% and 90%.	A change of less than 10% in indications for humidity levels between 40% and 90%.
Submersion	The level of water resistance shall be clearly stated in the manual.	Capable of satisfactory operation after being fully submerged for five minutes.
Explosive atmospheres	The manufacturer shall clearly state the level of intrinsic safety.	Intrinsically safe.

A.6 Ergonomic

Table 6: Summary of ergonomic performance criteria

Requirement	Essential	Desirable
General	Features are reasonably satisfactory.	Features are fully satisfactory and could not be usefully improved.
Size	Dimensions shall not exceed 100 mm in length, 30 mm in depth, 80 mm in width, and fit into a volume of less than 250 cm ³ (or 300 cm ³ for dose meters that have mixed neutron/ photon detection capability), excluding any clip or retaining device.	As small as possible whilst still accommodating the required minimum sizes for the controls and display.
Weight	Maximum weight of 200 g (or 350 g for dose meters that have mixed neutron/ photon detection capability).	As light as possible with a maximum weight of 100 g.
Case construction	Instrument case shall be smooth, rigid, shock resistant, splash proof and dust resistant.	Not currently defined.
Resistance to contamination (ease of de-contamination)	Should not have any areas where contaminants could become difficult to remove.	Not currently defined.
Transportation	Not currently defined.	Capable of surviving high altitude air transport.
Visual display	The minimum size of the display shall be at least 30 x 5 mm.	The minimum size of the display shall be at least 50 x 15 mm.
Ease of operation	Designed so that it can be used safely and efficiently without a high level of specialist knowledge.	The instruments should be controlled via a menu operation with "soft keys". One-handed operation is possible.
Switches and controls	Designed to ensure that the dose meter can be properly operated while minimising accidental operation of any controls.	Illuminated such that their location and function can be identified in dark conditions. The spacing between each switch or control should be at least 15 mm so as to increase the ease of operation of the dose meter while the operator is in full gas-tight PPE.

Requirement	Essential	Desirable
Additional indications	Low battery: an indication of the battery condition shall be shown on the display. Detector failure: the dose meter shall detect when the detector has failed and alert the operator.	Not currently defined.
Firmware / software	The software shall have a version number for identification.	Firmware stored in the dose meter should be easy to update.
Data logging	Not currently defined.	Yes
Communi- cation interface	Not currently defined.	Be able to communicate with an external device such as a computer. Option to wirelessly monitor the wearer's dose and dose rate.



Home Office Scientific Development Branch
Sandridge
St Albans
AL4 9HQ
United Kingdom

Telephone: +44 (0)1727 865051
Fax: +44 (0)1727 816233
E-mail: RNStandardsEnquiries@homeoffice.gsi.gov.uk
Website: <http://science.homeoffice.gov.uk/hosdb/>