Home Office

Scientific Development Branch

Performance Standards and Test Protocols for Radiological Equipment

Number 5 — Portable Spectrometry / Identification Systems

Publication No. 2E/10

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FIRST PUBLISHED FEBRUARY 2010

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Contents

Abstract

This document is the fifth 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 equipments. 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. Where possible, destructive tests should only be performed on a single instrument. 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 an instrument's suitability for its 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 instrument's radiological performance under laboratory conditions, but also test the environmental, electrical and mechanical aspects, which may affect the instrument's performance out in the field.

1.1 Portable Spectrometry / Identification Systems

The availability of practical hand-held portable spectrometry instrumentation is a relatively recent innovation in the field of radiological protection. A limited number of such devices have been available in the past, but these have generally exhibited a number of significant operational limitations. There are now a number of relatively easy-to-use devices on the market that combine the ability to measure dose rate as well as potentially identify the source (nuclide) of the radiation field. Manufacturers have not unreasonably concentrated on the development of the spectrometric performance of these instruments. This has resulted in many of them exhibiting relatively poor, certainly compared to normal dose rate monitors, dose rate performance.

These devices generally have no contamination capability. They are only sensitive to penetrating X and Gamma radiation, hence the nuclides for which they are likely to be applicable are: ^{241}Am, ^{137}Cs, ^{60}Co, ^{192}Ir, ^{226}Ra and ^{75}Se. They cannot be used to identify sources of weakly penetrating radiation such as alpha and beta radiation in isolation.

Instruments of this type usually acquire the photon spectrum over a period of time and then attempt to identify the radionuclide(s) through comparison with a stored radionuclide library. In all but controlled laboratory environments, there are inevitably large uncertainties associated with the correct identification of radioactive material. The more radionuclides that are present in the sample, the more difficult it is to match to individual nuclides stored in the library. This problem is enhanced further the more nuclides that are stored in the library.

1.2 Secondary Functions (Dose Rate)

This standard provides for the testing of the performance of any dose rate capability incorporated in this type of equipment. Any dose rate function should not be assessed against the separate Home Office dose rate standard.

2 Reference Documents

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

IEC 60846:2004	Radiation protection instrumentation — Ambient and/or directional dose equivalent (rate) meters and/or monitors for beta, X and gamma radiation.
IEC 62327:2006	Radiation protection instrumentation — Hand-held instruments for the detection and identification of radionuclides and for the indication of ambient dose equivalent rate from photon radiation.
IEC 60529:1992	Degrees of protection provided by enclosures (IP code).
ANSI N42.33-2003	American National Standard for Portable Radiation Detection Instrumentation of Homeland Security.
ANSI N42.34-2003	American National Standard Performance Criteria for Hand-held Instruments for the Detection and Identification of Radionuclides.
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 keV to 1.3 MeV and 4 MeV 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 14	Measurement Good Practice Guide No 14: The Examination, Testing and Calibration of Portable Radiation Protection Instruments.
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).

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

3.2.3 Ambient dose equivalent *H**(10)

Dose equivalent at a point in a radiation field that would be produced by the corresponding aligned and expanded field, in the ICRU sphere at a depth of 10 mm, on the radius opposing the direction of the aligned field.

The ICRU sphere (ICRU report 33, 1980) is a 30 cm diameter, tissue equivalent sphere with a density of 1 g cm^{-3}.

3.2.4 Ambient dose equivalent rate *H**(10)

Ratio of dH*(10) by dt, where dH*(10) is the increment of ambient dose equivalent in the time interval dt.

$$H^*(10) = \frac{dH^*(10)}{dt}$$

The SI unit of ambient dose equivalent rate is the Sievert per second (Sv s^{-1}). Units of ambient dose equivalent rate are any quotient of the Sievert or its multiples or sub-multiples by a suitable unit of time (e.g. μSv h^{-1}).

3.2.5 Portable system

The system shall be entirely battery operated and carried easily by one or two persons. Measurements shall be able to be made in the field while being carried.

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 Guide 14 (GPG14).

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 Guide 14 (GPG14).

It is recommended that the performance 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 instrument shall be scaled in appropriate units. 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). It is recommended that this unit is prefixed as required; for example, 'μSv' (microsievert: 10^{-6} Sv) or 'mSv' (millisievert: 10^{-3} Sv). For dose rate instrumentation a suitable unit of time is also required and in most cases per hour (h^{-1}) is the most appropriate.

Instruments which provide an indication of photon ambient dose equivalent shall use the measuring quantity H*(10).

4.2 Measuring Ranges

The instrument shall be able to collect spectra over a wide range of energies as specified below.

4.3 Essential

The instrument shall be capable of collecting spectra of energy between 60 keV to 1.5 MeV within the dose rate range from 0.5 to 100 μSv h^{-1}.

4.3.1 Desirable

The instrument should be capable of collecting spectra of energy between 20 keV to 3 MeV within the dose rate range from 0.5 to 1 mSv h^{-1}.

4.3.2 Desirable Instrument Features

It is desirable that the instrument has a neutron detection capability. In addition, the instrument should not trigger any neutron alarm when exposed to a gamma source or trigger any gamma alarm when exposed to a neutron source.

It is also desirable that the instrument starts spectral analysis automatically when it encounters any elevated radiation field.

4.4 Storage and Transport

4.4.1 Essential

The instrument shall be supplied in a bespoke foam-lined carry-case. 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 °C and +50 °C.

4.4.2 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.

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 table 1 below.

Table 1. Reference conditions and standard test conditions

Influence Quantity	Reference Conditions	Standard Test Conditions
Stabilisation time	As stated by the manufacturer.	As stated by the manufacturer.
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)
Power supply voltage	Nominal power supply voltage.	Nominal power supply voltage ±10%.
Angle of incidence of radiation	Calibration direction supplied by manufacturer.	Direction given ±5°
Instrument controls	Set up for normal operation.	Set up for normal operation.
Radiation background	1 μSv h^{-1} or less if practical	Known field less than 1 μSv 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 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, 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 that 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 Instrument 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.

6 Radiological Performance Requirements

For instruments with linear scales, measurements shall be performed on all scale ranges and at a minimum of three instrument indications in each range. It is recommended these indications be at approximately 30%, 60% and 90% of the maximum scale indication for each range.

For instruments with logarithmic scales, or a digital display, measurements shall be performed at a minimum of three instrument indications in each order of magnitude. It is recommended these indications be at approximately 20%, 40% and 80% of each order of magnitude.

Any ranges or decades that have been untested must be clearly indicated in the test report.

Sufficient readings should be taken such that the standard error of the mean is less than 10% of the mean.

Equation 1. Standard deviation of the mean**:**

$$SDoM = \frac{\sigma}{\sqrt{n}}$$

where σ is the standards deviation of the data set and n is the number of readings taken.

Where the dose equivalent rate meter utilises more than one radiation detector to cover the full range of dose equivalent rates indicated by the meter, these requirements apply to the relevant ranges for each detector separately.

The relative intrinsic error, I, is defined as the ratio of the dose equivalent rate meter's value to the conventionally true value.

Equation 2. Dose rate instrumentation linearity of response:

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

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

6.1 Response Time (Dose Rate Function)

Where the spectrometer has a dose rate function the following test shall be performed.

6.1.1 General

When the instrument 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.

6.1.2 Essential

When the instrument is subjected to a step increase or decrease in H_f dose equivalent rate, its indication shall reach the value given by the response time equation in less than 10 seconds for values of H_f between 1 μSv h^{-1} and 10 mSv h^{-1}.

For values of H_f above this the time shall be 2 seconds or less.

The manufacturer shall state the maximum response time of the instrument.

6.1.3 Desirable

When the instrument is subjected to a step increase or decrease in dose equivalent rate, its indication shall reach the value given by the response time equation in less than 3 seconds for values of H_f between 1 μSv h^{-1} and 10 mSv h^{-1}.

For values of H_f above this the time shall be 2 seconds or less.

6.1.4 Test radiation

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

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

6.1.5 Method of test

The initial and final dose equivalent rates shall differ by at least a factor of 10. This test shall be performed for both an increase and a decrease in the dose equivalent rate by this factor.

Where instruments have a digital or a logarithmic display, measurements shall be made over every order of magnitude of indication. Where instruments have a linear display, measurements shall be made on each scale range.

For linear scale instruments, the lower dose equivalent rate may be taken as zero (or background) and the upper as that corresponding to at least 90% of the scale maximum on each range.

For the increasing dose equivalent rate test, the instrument shall first be subjected to the higher dose equivalent rate for a time sufficient for the indication to reach a steady value and the indication H_f recorded.

Next, the instrument shall be subjected to the lower dose equivalent rate for a time sufficient for the indication H_i to reach a steady value and this indication noted.

With the instrument still subjected to the lower dose equivalent rate, this rate shall then be increased as quickly as possible (less than 1 second) to that corresponding to the indication H_f. The time taken to reach the value given by the response time equation shall be recorded.

For the decreasing dose equivalent rate test, the test shall be performed in the same way but with the values of dose equivalent rates corresponding to H_i and H_f interchanged.

6.2 Statistical Fluctuations (Dose Rate Function)

Where the spectrometer has a dose rate function the following test shall be performed.

6.2.1 General

Due to the random nature of the emissions from radioactive materials, any test of the statistical variation of an instrument reading will have an additional fluctuation superimposed. Where this additional fluctuation is a significant fraction of the variation of indication, then a significant number of readings shall be taken to ensure that the mean value of the readings is obtained with sufficient accuracy. In order to ensure these readings are statistically independent, the interval between such readings shall be a minimum of at least three times the instrument's response time.

6.2.2 Essential

The statistical fluctuation shall be less than ±10% at approximately 10 μSv h^{-1}.

6.2.3 Desirable

The statistical fluctuation should be less than ±5% at approximately 10 μSv h^{-1}.

6.2.4 Test radiation

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

6.2.5 Method of test

The limit of variation of the statistical fluctuation shall be determined at approximately 10 μSv h^{-1}, which is considered a level that would be unlikely to arise due to the effects of natural background only.

6.3 Background Indications (Dose Rate Function)

Where the spectrometer has a dose rate function the following test shall be performed.

6.3.1 General

Variation in background readings can arise for a variety of reasons, some of which are more applicable for certain types of radiation monitoring equipment. Radioactive decay is a random process and therefore the number of events 'seen' by a detector can vary over short time periods; for this reason the displayed background can vary significantly. Also, for some types of detector, variations in background environments can lead to easily observable differences in displayed count rates.

Where photon detectors have no shielding, the cosmic-ray component is normally dominant. The background in photon detectors can be expected to increase roughly with the detector volume. Therefore, in critical situations where low background is at a premium, it is important to select a detector size that is not larger than necessary to give a reasonable counting efficiency for the samples to be counted.

6.3.2 Essential

The statistical fluctuation shall be less than ±30% at less than 1 μSv h^{-1}.

6.3.3 Desirable

The statistical fluctuation shall be less than ±15% at less than 1 μSv h^{-1}.

6.3.4 Test radiation

The background indication shall be determined for a known background with an ambient dose equivalent rate of less than 1 μSv h^{-1} and, where applicable, for a number of background environments.

6.3.5 Method of test

The background indication of an instrument shall be determined by taking sufficient readings at time intervals that exceed three time constants, in order to ensure that each reading is statistically independent.

6.4 Overload Performance (Dose Rate Function)

Where the spectrometer has a dose rate function the following test shall be performed.

The overload test may be ignored for instruments that are likely to be damaged by performing this test. If this test is omitted then this must be clearly recorded in the test report.

6.4.1 Essential

On all ranges, when exposed to dose rates greater than its measuring range, the instrument shall remain 'off scale' at the higher end of the scale (or display an overload indication). The instrument must remain in this overload state whilst exposed to this, 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 instrument shall function correctly in a time period of less than 5 minutes.

6.4.2 Desirable

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

6.4.3 Test radiation

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

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

6.4.4 Method of test

The instrument shall be exposed to the following rates as appropriate for a period of at least 5 minutes. A minimum of 10 mSv h^{-1} should be used.

- 100 times the range maximum for ranges with a maximum indication up to and including 100 mSv h^{-1}.
- 10 times the range maximum for ranges with a maximum indication greater than 100 mSv h^{-1}.

After the overload test the instrument's performance shall return back to normal within the time specified for both the spectral and dose rate functions.

6.5 Photon Energy Response (Dose Rate Function)

Where the spectrometer has a dose rate function the following test shall be performed for all detectors.

6.5.1 General

The photon energy response of the instrument shall be determined using the narrow spectrum series of X-radiation qualities 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, depending upon sufficient dose rate range.

6.5.2 Essential

The instrument's ambient dose equivalent response to the ^{137}Cs (662 keV) reference gamma radiation source shall be approximately unity.

The instrument's response to incident photon radiation between 60 keV and 1.25 MeV shall not vary by more than ±50% from the response to the ^{137}Cs (662 keV) reference gamma radiation source.

6.5.3 Desirable

The instrument's response to incident photon radiation between 20 keV and 1.25 MeV shall not vary by more than ±20% from the response to the ^{137}Cs (662 keV) reference gamma radiation source.

6.5.4 Test radiation

The recommended reference radiation sources are:

- Narrow series of X-radiation qualities as defined in ISO 4037-1.
- ^{241}Am or filtered X-rays of approximately 60 keV.
- Gamma (γ) radiation from ^{137}Cs at 662 keV.
- ^{60}Co at 1.25 MeV (mean energy).

6.5.5 Method of test

Ideally, the same instrument indication should be used for each radiation energy used. Where this isn't possible the instrument indication for each energy used shall be corrected for intrinsic error of the indicated rate.

Measurements shall be performed, starting with high energies and repeated with lower energies, until the first energy where the response normalised to that obtained for ^{137}Cs provides a normalised response of less than 0.5.

For dose equivalent rate meters, the response normalised to ^{137}Cs, is defined as:

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

$$I_{norm} = \frac{I_{energy_n}}{I^{137}_{Cs}}$$

- Where I_{energy} = response at energy n
- n = 20 keV to 1.25 MeV
- I^{137}_{Cs} = response at ^{137}Cs

6.6 Polar Response (Dose Rate Function)

Where the spectrometer has a dose rate function the following test shall be performed for all detectors.

6.6.1 Essential

For angles of ±180°, in both horizontal and vertical planes, the response normalised to the reference radiation at 0° shall be unity ±30%.

6.6.2 Desirable

For angles of ±180°, in both horizontal and vertical planes, the response normalised to the reference radiation at 0° shall be unity ±20%.

6.6.3 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 0.6.

The conventionally true ambient 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

The instrument shall be mounted in its calibration orientation as specified by the manufacturer. The instrument indication and its response to the reference radiation in this orientation (0°) shall be recorded.

Next, the instrument shall be rotated about its reference point from angles 0° to ±180° in 10° steps. This shall be performed in two planes: vertical and horizontal. At each step, expose the instrument to the same dose rate as at 0° and record the instrument indication and its response to the reference radiation. These responses shall then be normalised to the reference radiation at 0°.

6.7 Polar Response (Identification)

6.7.1 Essential

The instrument shall be able to identify nuclides correctly over incident angles from 0° to ±45°.

6.7.2 Desirable

Not currently defined.

6.7.3 Test radiation

This test shall be performed with ^{241}Am, ^{60}Co and ^{137}Cs gamma radiation.

6.7.4 Method of test

The instrument shall be mounted in its calibration orientation as specified by the manufacturer. Expose the instrument to a ^{241}Am source that provides a dose rate that exercises the identification detector in this orientation (0°) and record the instrument's dose rate indication and determine its response.

Next, perform a radionuclide identification.

Next, repeat the test with the incident angle at +45° and -45° in each of the two orthogonal planes.

Finally, repeat the test using ^{60}Co and ^{137}Cs.

The test shall consist of 10 measurements for each orientation. The performance criteria are met when the instrument correctly identifies each radionuclide in 8 out of 10 tests.

6.8 Radionuclide Identification

6.8.1 Essential

The instrument shall be able to identify radionuclides that fall within the range of approximately 60 keV to 1.5 Mev. The manufacturer shall state which may be identified, i.e. those that are stored in the instrument's library.

In addition, the instrument shall be able to distinguish mixed radionuclides. This shall be determined using ^{137}Cs and separated natural uranium.

The instrument shall indicate if the dose rate is too high or too low for radionuclide identification.

6.8.2 Desirable

The instrument should be able to identify radionuclides and typical bremsstrahlung spectra that fall within the range of approximately 20 keV to 3 MeV. The manufacturer shall state which radionuclides may be identified, i.e. those that are stored in the instrument's library.

The instrument should have an indication of the confidence level that the radionuclide has been correctly identified.

The identification measurement time should be both automatic and user defined; in addition, it should count down so the user knows how long they will have to wait. The user should be able to increase the measurement time if the identification confidence level is too low. If the measurement is stopped early, the instrument should provide its best guess along with the associated confidence level.

6.8.3 Test radiation

The radionuclides to be used are listed in table 2 below and represent medical, industrial or nuclear uses, as well as NORM radioisotopes. The 17.4 keV Molybdenum X-rays are intended as a simulation of fluorescence X-radiation characteristic of plutonium isotopes; the test is also good for investigating the low energy capability of the analysis mode.

Table 2. Radionuclides for identification tests

Radionuclide	Type	Abundant photon energies (approximate keV)
^{137}Cs	Industrial radionuclide	662
^{60}Co	Industrial radionuclide	1173 and 1332
^{241}Am	Industrial radionuclide	60
^{133}Ba	Industrial radionuclide	31, 81, 276, 303, 356 and 384
^{129}I (mock ^{125}I)	Medical radionuclide	27
17.4 keV Mo X-rays	Nuclear radionuclide	17.4
^{40}K	NORM	1461
^{238}U + decay products	NORM	13, 351, 609 and 1764
^{226}Ra + decay products	NORM	351, 609 and 1764

6.8.4 Method of test

The instrument shall be exposed to a variety of radionuclides producing a range of photon energies as specified above.

Samples for all nuclides should be taken over a time period of between 1 and 10 minutes, depending on source activity.

Next, the spectra shall be analysed by the instrument and any supplied PC-based software programmes. The energies of identified photopeaks shall be compared with those anticipated, and the instrument's ability to correctly identify the radionuclides determined. Any spectral plots generated during this test shall be recorded where possible.

In addition, the Full-Width-Half-Maximum shall also be recorded as specified in section 6.9.1.

6.9 Resolution of Detector

For most spectrometers, spectra is acquired as histograms. The horizontal axis of the histogram is divided into small equal intervals (energy channels), whilst the vertical axis records the number of photons detected, categorised by their energy into the appropriate energy channel. There are normally up to 1024 energy channels, which

represent a range of energies, and the resulting histogram displays the energy peaks within that range.

The number of energy channels available affects the accuracy of determining the mean energy of a peak. Ideally, the Full-Width-Half-Maximum (see section 6.9.1 for definition) of the narrowest peak in the spectrum should cover at least 5 energy channels. Under these conditions the error in determining the mean energy of a peak is then normally dominated by the random error from counting statistics. In order to further improve the accuracy of measuring either the mean energy of the peak or the area of the peak, the number of events counted within the peak would need to be increased.

It is not uncommon for two or more peaks in the spectrum to overlap and, in order to identify each peak, their individual contributions will need to be separated. As the overlap increases, the statistical uncertainties in identifying each peak also increases, especially for small peaks that suffer a domineering overlap from a tall peak.

6.9.1 Full-Width-Half-Maximum definition

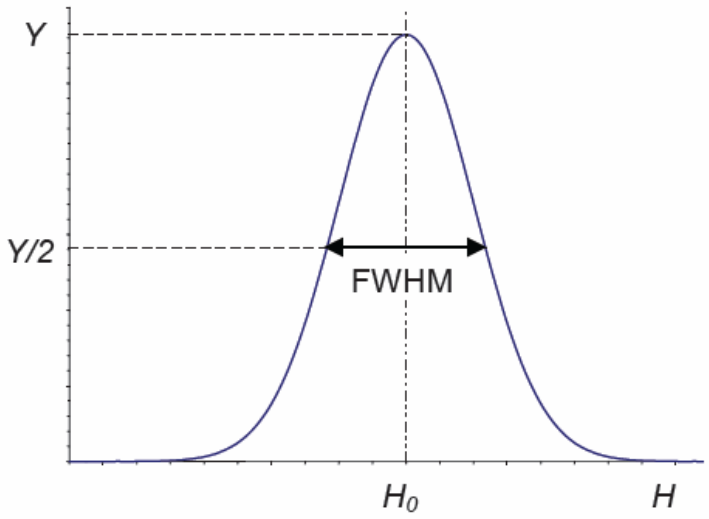
The FWHM (Full-Width-Half-Maximum) is defined as the width of the distribution at a level that is just half of the maximum ordinate of the peak. The energy resolution of the detector is defined as the FWHM divided by the location of the peak centroid H_0. The energy resolution R is thus a dimensionless fraction, which is normally expressed as a percentage.

Equation 5. Detector resolution**:**

$$R = \frac{FWHM}{H_0}$$

where *R* is the energy resolution of the detector.

Figure 1. Definition of detector resolution



6.9.2 Essential

The table below specifies the maximum allowable Full-Width-Half-Maximum for a selection of nuclides, when identified by an instrument based on a Germanium crystal detection system.

6.9.2.1 Germanium-based detection system

The table below specifies the maximum allowable Full-Width-Half-Maximum for a selection of nuclides when identified by an instrument based on a Germanium crystal detection system.

Table 3. Maximum resolution of germanium based detection systems

Nuclide	FWHM
^{241}Am	Less than 5%
^{137}Cs	Less than 1%
^{60}Co	Less than 0.5%

6.9.2.2 Non germanium-based detection system

The table below specifies the maximum allowable Full-Width-Half-Maximum for a selection of nuclides when identified by an instrument not based on a Germanium crystal detection system.

Table 4. Maximum resolution of non-germanium-based detection systems

Nuclide	FWHM
^{241}Am	Less than 30%
^{137}Cs	Less than 10%
^{60}Co	Less than 10%

6.9.3 Test radiation

This test shall be performed with ^{241}Am, ^{60}Co and ^{137}Cs gamma radiation.

6.9.4 Method of test

This test should be performed in conjunction with the radionuclide identification test specified in section 6.8.

6.10 False Identification

6.10.1 Essential

The instrument, in 8 out of 10 consecutive trials, shall not identify any radionuclides that are not present.

6.10.2 Desirable

The instrument shall not identify any radionuclides that are not present.

6.10.3 Test radiation

A known low and stable ambient radiation background is required. A shielded box or enclosure may be used to perform this test.

6.10.4 Method of test

First, with the instrument set up for identification as per the manufacturer's instructions, ensure that it is in a stable and low ambient radiation background and that there are no radiation sources present.

Next, perform a radionuclide identification. For the essential criteria to be met no unexpected radionuclides shall be identified in 8 out of 10 consecutive trials.

If any naturally occurring radionuclides are identified that were expected and cannot be removed, then the test result shall be acceptable.

6.11 Radionuclide Categorisation

6.11.1 Essential

The manufacturer shall state which radionuclides the instrument can identify and their category. The categories used should be based on the list below.

6.11.2 Desirable

When a radionuclide is identified the instrument shall store the radionuclide name and category along with the spectral data.

6.11.3 Radionuclide categorisation

Identified radionuclides shall be categorised into one of the four categories below. It should be noted that this is only an informative list and should not be considered as all-inclusive.

6.11.3.1 Special nuclear materials

Uranium (used to indicate ^{233}U, ^{235}U), ^{237}Np, Pu.

6.11.3.2 Medical radionuclides

^{67}Ga, ^{51}Cr, ^{75}Se, ^{99m}Tc, ^{103}Pd, ^{111}In, Iodine (^{123}I, ^{125}I, ^{131}I), ^{201}Tl, ^{133}Xe.

6.11.3.3 Naturally occurring radioactive materials (NORM)

^{40}K, ^{232}Th and daughters, ^{238}U and daughters.

6.11.3.4 Industrial radionuclides

^{57}Co, ^{60}Co, ^{133}Ba, ^{137}Cs, ^{192}Ir, ^{201}Tl, ^{226}Ra and ^{241}Am.

6.12 Response to Neutron Radiation

The testing of instruments with neutron radiation is not covered in this document.

6.12.1 Essential

The manufacturer shall state the instrument's response to neutron radiation.

6.12.2 Desirable

Not currently defined.

6.13 Response to Beta Radiation

The testing of instruments with beta radiation is not covered in this document.

6.13.1 Essential

The manufacturer shall state the instrument's response to beta radiation.

6.13.2 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 then they shall be protected from unauthorised and accidental changes.

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

Where it is possible to turn off or reduce intensity of any alarm then the instrument 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 instrument.

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 instrument shall have a vibrating alarm.

The instrument should have the ability to attach earphones.

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, the user 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 instrument 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 dosemeter 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 instrument 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 instrument 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 instrument under realistic operating conditions.

The total number of batteries or cells required to power the instrument 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 instrument's batteries discharge through normal use.

8.1.1.1 Essential

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

8.1.1.2 Desirable

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

8.1.1.3 Test radiation

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

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

8.1.1.4 Method of test

With the instrument's internal batteries removed, connect the instrument 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 instrument in background conditions, decrease the supply voltage in small decrements until the instrument switches off. At each change in supply voltage the following shall be recorded: supply voltage, instrument indication, ability to record a ^{137}Cs spectrum, ability to identify ^{137}Cs, plus any other observations. Particular attention should be made as to when the low battery indication is triggered or if the indication varies by more than ±10% from the indication recorded with an optimal battery voltage.

Where the instrument has a dose rate function this test should then be repeated with the instrument exposed to a selection of dose equivalent rates that will exercise all of the instrument's detectors. If possible a dose rate should be chosen that doesn't trigger any audible or visual alarms.

Finally, this test should be repeated with any audible and visual alarms triggered.

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 instrument is displaying the low battery indication all functions shall operate correctly and the mean instrument indication will not vary by more than ±20% from the indication recorded with an optimal battery voltage.

8.1.2.2 Desirable

Unless the instrument is displaying the low battery indication all functions shall operate correctly and the mean instrument indication will not vary by more than ±10% from the indication recorded with an optimal battery voltage.

8.1.2.3 Test radiation

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

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

8.1.2.4 Method of test

With the instrument's internal batteries removed, connect the instrument 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 instrument in background conditions, increase the series resistance in small increments until the instrument switches off. At each change in series resistance the following shall be recorded: supply voltage, resistance, current drawn, instrument indication, ability to record a ^{137}Cs spectrum, ability to identify ^{137}Cs, plus any other observations. Particular attention should be made as to when the low battery indication is triggered or if the indication varies by more than ±10% from the indication recorded with an optimal battery voltage.

Where the instrument has a dose rate function this test should then be repeated with the instrument exposed to a selection of dose equivalent rates that will exercise all of the instrument's detectors. If possible a dose rate should be chosen that doesn't trigger any audible or visual alarms.

Finally, this test should be repeated with any audible and visual alarms triggered.

8.1.3 Battery test function (applicable to all instruments)

The instrument 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 instrument.

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 instruments)

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 instrument electronics.

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

In the event of a CBRN incident, instrumentation will be required to operate in the field. The instrument, therefore, shall be capable of running solely on a battery supply. Any chargers supplied should be capable of recharging the batteries from a vehicle 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 instrument 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 instrument. 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 instrument 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 instrument must be capable of operating under standard test conditions with no alarms or illumination features in operation for at least 12 hours.

After fresh or fully recharged batteries have been fitted, the instrument must be capable of operating under standard test conditions with ALL alarms and 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 instrument must be capable of operating under standard test conditions with no alarms or illumination features in operation for at least 24 hours.

After fresh or fully recharged batteries have been fitted, the instrument must be capable of operating under standard test conditions with ALL alarms and illumination features in operation at their maximum intensity for at least 2 hours.

8.3 External DC or AC Power Supplies

8.3.1 Essential

For the majority of uses the instrument 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 instrument 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

8.5 Warm Up / Initialisation / Stabilisation Time

This test is only applicable for germanium-based detection systems. For other systems this test may be omitted.

The manufacturer shall state the time required for the instrument to become fully operational from both a 'cold' start and a standby condition. After the specified time period from switching the instrument on, the instrument, whilst exposed to the reference radiation, shall identify the reference radiation correctly. For instruments with a dose rate function, these shall give an indication that does not differ by more than 10% from the final indication obtained after 1 hour under standard test conditions.

8.5.1 Essential

The instrument shall be fully operational within 12 hours after switching it on from a 'cold' start (i.e. detector at ambient temperature) and within 15 minutes from switching it on from a standby condition (i.e. detector already cooled).

8.5.2 Desirable

The instrument shall be fully operational within 6 hours after switching it on from a 'cold' start (i.e. detector at ambient temperature) and within 5 minutes from switching it on from a standby condition (i.e. detector already cooled).

8.5.3 Test radiation

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

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

8.5.4 Method of test

From both a 'cold' start and a standby condition, switch the instrument on, expose it to the reference radiation and perform a radionuclide identification. The time taken switching the instrument on to when it correctly identifies the reference radiation shall be recorded.

9 Mechanical Requirements

9.1 Mechanical Shock (Drop Test)

Due to the fragile nature of the detector in this type of instrument it is unlikely to withstand the mechanical shock test without severe damage. For this reason this test may be omitted.

9.1.1 Essential

Not currently defined.

9.1.2 Desirable

The instrument shall be able to withstand drops from heights of 1 metre onto a concrete surface without severe mechanical damage. The instruments ability to identify ^{137}Cs shall not be affected by the drop and in addition, where applicable, the drop shall not affect the indicated dose rate reading by more than 10%.

9.1.3 Test radiation

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

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

9.1.4 Method of test

First, the instrument's response to the appropriate reference radionuclide shall be determined in a reproducible geometry.

Next, the instrument shall be dropped on to each face in turn from a height of 1 metre on to the specified surface. After each drop, the instrument's ability to identify the reference radionuclide shall be confirmed and recorded, as well as, where applicable, its dose rate response to reference radionuclide. The instrument shall also be checked for any mechanical damage or loose fittings and any observations recorded.

9.2 Vibration

The physical condition of the instrument 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 specified vibrations do not affect the instrument's ability to identify radionuclides. In addition, where applicable, the indicated dose rate reading shall not be affected by more than 20%.

9.2.2 Desirable

The specified vibrations do not affect the instrument's ability to identify radionuclides. In addition, where applicable, the indicated dose rate reading shall not be affected by more than 10%.

9.2.3 Test radiation

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

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

9.2.4 Method of test

First, the instrument's response to the appropriate reference radionuclide shall be determined in a reproducible geometry.

Next, the instrument shall 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 instrument's ability to identify the reference radionuclide shall be confirmed and recorded, as well as, where applicable, its dose rate response to reference radionuclide. The instrument shall also be checked for any mechanical damage or loose fittings and any observations recorded.

10 Environmental Performance Requirements

Instruments 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 instrument response on temperature.

10.2.1 Essential

The instrument's ability to identify ^{137}Cs shall not be affected by stable temperatures at -10 °C and +40 °C.

In addition, where applicable, the worst case percentage change of the dose rate 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 instrument's ability to identify ^{137}Cs shall not be affected by stable temperatures at -10 °C and +60 °C.

In addition, where applicable, 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 is ^{137}Cs.

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

10.2.4 Method of test

The instrument 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 instrument 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 instrument left for a minimum of 4 hours to achieve thermal equilibrium. The instrument response at background and the higher indication shall be recorded. The instrument's ability to identify ^{137}Cs shall be assessed.

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

10.3 Temperature Shock

10.3.1 Essential

Instrument should be capable of working up to temperatures of +60 °C.

10.3.2 Desirable

Not currently defined.

10.3.3 Test radiation

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

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

10.3.4 Method of test

The instrument 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. The instrument's ability to identify ^{137}Cs shall be assessed. In addition, where applicable, both the instrument background dose rate indication and a higher dose rate 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 instrument's ability to identify ^{137}Cs shall be assessed. In addition, where applicable, 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 instrument's ability to identify ^{137}Cs shall be assessed. In addition, where applicable, 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 instrument's ability to identify ^{137}Cs shall be assessed. In addition, where applicable, 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 instrument shall switch on and operate correctly at -10 °C.

10.4.2 Method of test

The instrument 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 instrument shall then be switched on and operate normally. The instrument's ability to identify ^{137}Cs shall be assessed.

10.5 Humidity Stability

10.5.1 Essential

The instrument shall be capable of working at relative humidity levels between 20% RH and 90% RH. The instrument shall be able to identify ^{137}Cs between these humidity levels and, where applicable, the variation of the relative dose rate response due to humidity shall be less than ±20%.

10.5.2 Desirable

Where applicable, the variation of the relative dose rate response due to humidity shall be less than ±10%.

10.5.3 Test radiation

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

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

10.5.4 Method of test

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

Whilst keeping the temperature at 35 °C, increase the relative humidity inside the chamber to 90% RH. The instrument shall be left in these conditions switched off for a minimum of 24 hours. In the last 30 minutes of this period, the instrument should be switched on and both the instrument 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 instrument should be capable of satisfactory operation after being fully submerged under water for 5 minutes.

10.6.3 Method of test

The instrument 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 instrument background reading and a higher indication produced by a radioactive source shall be recorded.

10.7 Explosive Atmospheres

Circumstances can be foreseen where it may be 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 and 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 & Usability Requirements

12.1 General

The object of this assessment is to give some idea of the ease of regular use of the instrumentation. 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 instruments. 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

12.2.1.1 Germanium-based detection system

The dimensions of the instrument shall be as small as possible and not exceed 400 x 400 x 200 mm (not including any docking base units).

12.2.1.2 Non germanium-based detection system

The dimensions of the instrument shall be as small as possible and not exceed 300 x 200 x 150 mm.

12.2.2 Desirable

12.2.2.1 Germanium-based detection system

The dimensions of the instrument shall be as small as possible and should not exceed 300 x 300 x 100 mm (not including any docking base units).

12.2.2.2 Non germanium-based detection system

The dimensions of the instrument shall be as small as possible and not exceed 150 x 120 x 120 mm.

12.3 Weight

12.3.1 Essential

The instrument shall be well-balanced.

12.3.1.1 Germanium-based detection system

The instrument shall be as light as possible with a maximum weight of 15 kg.

12.3.1.2 Non germanium-based detection system

The instrument shall be as light as possible with a maximum weight of 3 kg.

12.3.2 Desirable

12.3.2.1 Germanium-based detection system

The instrument shall be as light as possible with a maximum weight of 5 kg.

12.3.2.2 Non germanium-based detection system

The instrument shall be as light as possible with a maximum weight of 1 kg.

12.4 Case Construction

12.4.1 Essential

The instrument 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 instrument's radiological performance.

Care shall be taken to ensure that any control, display or visual alarm is located so they are visible to the operator.

The case shall be provided with the facility to attach support straps. These will allow for freedom of movement whilst carrying out strenuous work. Any support straps provided must be adjustable and compatible for use while wearing personal protection equipment (PPE), e.g. a full gas-tight suit.

12.4.2 Desirable

Any supporting straps/lanyards should be adjustable and compatible for use while wearing PPE, e.g. a full gas-tight suit.

12.5 Resistance to Contamination (Ease of Decontamination)

12.5.1 Essential

The instrument shall be easy to decontaminate. Ideally, the instrument should not have 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 Desirable

Capable of surviving high altitude air transport.

12.7 Cabling and Connections

12.7.1 Essential

All cabling shall be substantial and have strain relief where it is terminated. Rugged connectors shall be used and these should be securable. The integrity of non-securable connectors shall be protected.

12.7.2 Desirable

Not currently defined.

12.8 Switches and Controls

12.8.1 Essential

All switches and other controls shall be designed to ensure that the instrument 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.

12.8.2 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 at least 15 mm, so as to increase the ease of operation of the instrument 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.

12.9 Ease of Operation

12.9.1 Essential

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

The instrument must be easy to operate with the operator in full gas-tight PPE.

12.9.2 Desirable

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

12.10 Detector Location

For the majority of spectrometry instrumentation the detector should be integral to the instrument, although external probes are acceptable.

Other than an external probe, the instrument shall not require any other external devices to be attached for it to function normally in the field. The provision for the attachment of an earphone is acceptable for use in noisy environments.

12.11 External Markings

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

The instrument shall be clearly marked with the following:

- Manufacturer’s name
- Model type

- Unique serial number
- The function of all controls (that are not displayed via soft menus) and indicators.

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

Probes should be clearly marked to show their intended function.

12.12 Visual Display

12.12.1 Essential

The display must be clear and easy to read under normal and extreme conditions, which includes 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.

Where applicable, in addition to the visual indication of dose rate, an audible indication of dose rate shall be provided. A facility for muting this indication shall also be provided. Where the equipment has been designed for use where ambient noise levels could be high, provision for the connection of a headset shall be made. Whether the instrument has an analogue or digital display (or a hybrid of the two) for indicating the dose rate, the display shall react instantly to any change of measuring range. In addition, the display shall clearly indicate the measuring quantity.

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

12.12.2 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 display should be colour and of high resolution to enable the instrument to clearly display collected spectra.

The minimum size of the display shall be at least 100 x 100 mm.

12.13 Additional Indications

12.13.1 Low battery

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

12.13.2 Detector failure

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

12.14 Firmware

12.14.1.1 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, else the instrument shall identify them as invalid. Invalid commands shall not affect any data or functions of the instrument.

12.14.1.2 Desirable

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

12.15 Data Logging

The instrument shall have a data logging capability, with 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.

12.15.1 Essential

The instrument shall have the ability to store and transfer (unprocessed) spectra. Each spectrum shall also contain the following information:

- Time and date
- Identified radionuclides, categories and associated confidence levels
- Spectrum collection time
- Measured gamma dose rate (where applicable)
- Neutron count rate at the time of measurement (where applicable).

If a radionuclide cannot be identified then an indication shall be provided (e.g. “not identified”, “not in library” or “unknown”).

The instrument shall indicate if the dose rate is too high or too low for radionuclide identification.

12.15.2 Desirable

Not currently defined.

12.16 Communication Interface

12.16.1 Essential

The instrument shall be able to communicate data to an external device, such as a computer. The type of data to transfer may include spectral information, dose equivalent rate indication 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.

12.16.2 Desirable

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 their radio communications.

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 instrument. 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
- Instrument type and serial number
- Probe type and serial number (if applicable)
- Types and energies of radiations for which the instrument is intended
- Reference point of device
- Calibration orientation relative to radiation sources
- Effective range of use.

13.3 Operation and Maintenance Manual

13.3.1 Essential

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

- Operating instructions and restrictions
- Schematic electrical diagrams, spare parts list and specifications
- Troubleshooting guide
- Contact information for the manufacturer.

13.3.2 Desirable

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

14 Training

14.1.1 Essential

Not currently defined.

14.1.2 Desirable

Training simulator options should be available for realistic training.

Appendix A: Summary of Performance Criteria

A.1 Radiological

Table 5. Summary of radiological performance criteria

Requirement	Essential	Desirable
Linearity of response (dose rate function)	Linearity better than ±30%	Linearity better than ±20%
Response time	Less than 10 seconds below 10 mSv h^{-1}. Less than 2 seconds above 10 mSv h^{-1}.	Less than 3 seconds below 10 mSv h^{-1}. Less than 2 seconds above 10 mSv h^{-1}.
Statistical fluctuations (dose rate function)	Statistical fluctuations less than ±10% at approximately 10 µSv h^{-1}.	Statistical fluctuations less than ±5% at approximately 10 µSv h^{-1}.
Background indications (dose rate function)	Statistical fluctuations less than ±30% at less than 1 µSv h^{-1}.	Statistical fluctuations less than ±15% at less than 1 µSv h^{-1}.
Overload performance (dose rate function)	Satisfactory overload and return to normal function in less than 5 minutes.	Satisfactory overload and return to normal function in less than 2 minutes.
Photon energy response (dose rate function)	Across the specified energy range of the instrument the response is unity ±50%.	Across the specified energy range of the instrument the response is unity ±20%.
Polar response (dose rate function)	For angles of ±180°, in both horizontal and vertical planes, the response normalised to the reference radiation at 0°, shall be unity ±30%.	For angles of ±180°, in both horizontal and vertical planes, the response normalised to the reference radiation at 0°, shall be unity ±20%.
Polar response (identification)	The identification of nuclides shall be acceptable over incident angles from 0° to ±45°.	Not currently defined.
Radionuclide identification	Able to identify the radio-nuclides that fall within the range of approximately 60 keV to 1.5 Mev.	Able to identify the radio-nuclides that fall within the range of approximately 20 keV to 3 Mev
Resolution of detector (germanium-based detect-ion system)	^{241}Am: FWHM less than 5% ^{137}Cs: FWHM less than 1% ^{60}Co: FWHM less than 0.5%	Not currently defined.

Requirement	Essential	Desirable
Resolution of detector (non germanium-based detect-ion system)	^{241}Am: FWHM less than 30% ^{137}Cs: FWHM less than 10% ^{60}Co: FWHM less than 10%	Not currently defined.
False identification	Shall not, in 8 out of 10 consecutive trials, identify any radionuclides that are not present when operated in a known low and stable am-bient radiation background.	Shall not identify a radionuclide that is not present when operated in a known low and stable am-bient radiation background.
Radionuclide categorisation	The manufacturer shall state which radionuclides the instrument can identify and their category.	When a radionuclide is identified, the instrument shall store the radionuclide name and category along with the spectral data.
Response to neutron radiation	The manufacturer shall state the instrument's response to neutron radiation.	Not currently defined.
Response to beta radiation	The manufacturer shall state the instrument's response to beta radiation.	Not currently defined.

A.2 Alarms

Table 6. 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 emer-gency service equipment.	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 dosemeter shall have a vibrating alarm.

A.3 Electrical

Table 7. Summary of electrical performance criteria

Requirement	Essential	Desirable
Voltage dependence	Unless the instrument is displaying the low battery indication, all functions shall operate correctly and the mean instrument indication will not vary by more than ±20% from the indication recorded with an optimal battery voltage.	Unless the instrument is displaying the low battery indication, all functions shall operate correctly and the mean instrument indication will not vary by more than ±10% from the indication recorded with an optimal battery voltage.
Current dependence	Unless the instrument is displaying the low battery indication, all functions shall operate correctly and the mean instrument indication will not vary by more than ±20% from the indication recorded with an optimal battery voltage.	Unless the instrument is displaying the low battery indication, all functions shall operate correctly and the mean instrument indication will not vary by more than ±10% from the indication recorded with an optimal battery voltage.
Battery test function (applicable to all instruments)	The battery test shall provide an accurate assessment of the condition of the cells and their suitability for further powering the instrument.	Not currently defined.
Battery test function (applicable only to digital instruments)	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	At least 12 hours with no alarms or illumination features in operation. At least 1 hour with ALL alarms or illumination features in operation.	At least 24 hours with no alarms or illumination features in operation. At least 2 hours with ALL alarms or illumination features in operation.
Warm up / initialisation / stabilisation time (germanium-based detection system)	Fully operational within 12 hours after switching it on from a ‘cold’ start (i.e. detector at ambient temperature) and within 15 minutes from switching it on from a standby condition (i.e. detector already cooled).	Fully operational within 6 hours after switching it on from a ‘cold’ start (i.e. detector at ambient temperature) and within 5 minutes from switching it on from a standby condition (i.e. detector already cooled).

A.4 Mechanical

Table 8. Summary of mechanical performance criteria

Requirement	Essential	Desirable
Mechanical shock (drop test)	Not currently defined.	Withstands drops from 1 metre on to concrete without severe mechanical damage and its ability to identify radionuclides is not affected. In addition, where applicable, the indicated dose rate reading shall not be affected by more than 10%.
Vibration	The specified vibrations do not affect the instrument's ability to identify radionuclides. Also, where applicable, the indicated dose rate reading shall not be affected by more than 20%.	The specified vibrations do not affect the instrument's ability to identify radionuclides. Also, where applicable, the indicated dose rate reading shall not be affected by more than 10%.

A.5 Environmental

Table 9. Summary of environmental performance criteria

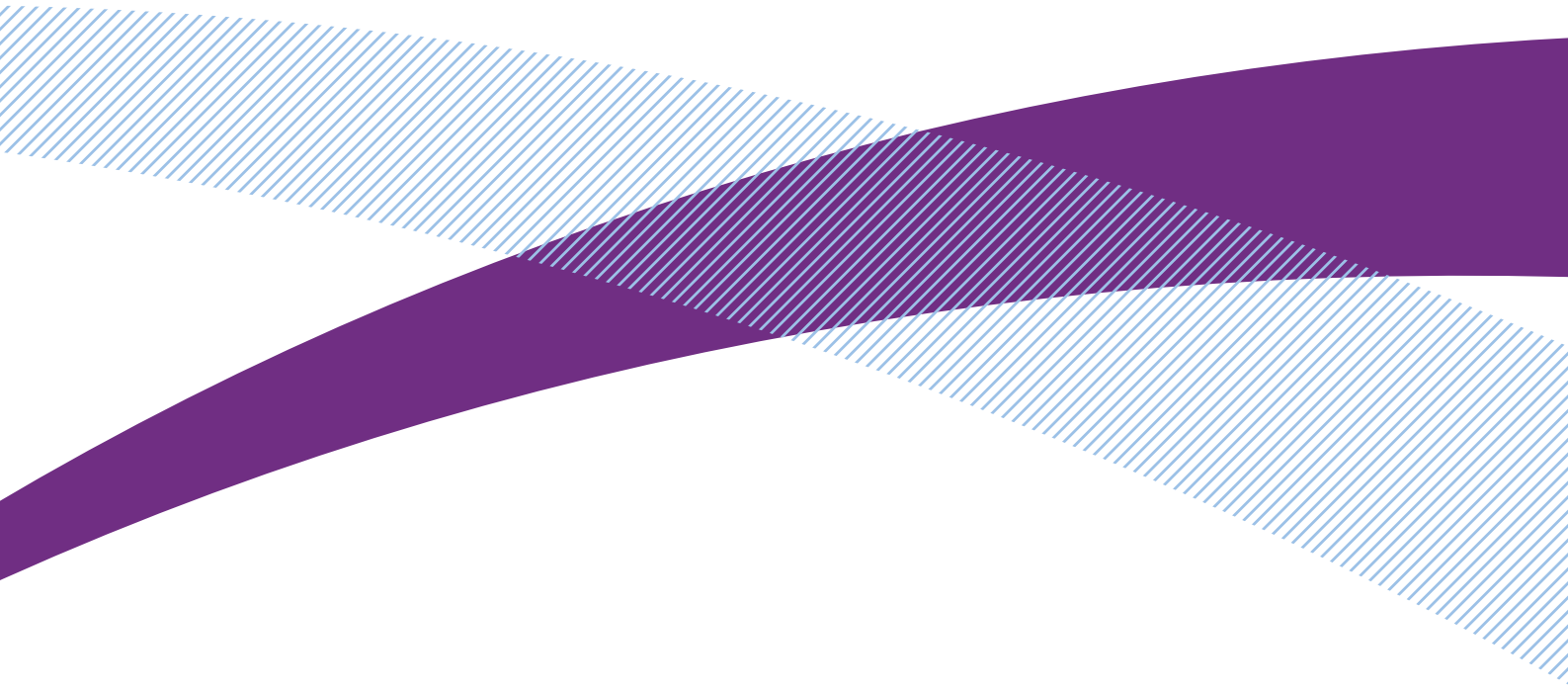
Requirement	Essential	Desirable
Environmental protection	IP rating of at least IP54.	IP rating close to IP67.
Temperature stability	Able to identify ^{137}Cs at temperatures of -10 °C and +40 °C. Where applicable, a change of less than 50% for indications at -10 °C and +40 °C compared to the indication at 20 °C.	Able to identify ^{137}Cs at temperatures of -10 °C and +60 °C. Where applicable, 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	Able to identify ^{137}Cs at humidity levels between 20 and 90%. Where applicable, a change of less than 20% in indications for humidity levels between 20% and 90%.	Where applicable, a change of less than 10% in indications for humidity levels between 20% and 90%.
Submersion	The level of water resistance shall be clearly stated in the manual.	Capable of satisfactory operation after being fully submerged for 5 minutes.
Explosive atmospheres	The manufacturer shall clearly state the level of intrinsic safety.	Intrinsically safe.

A.6 Ergonomic

Table 10. Summary of ergonomic performance criteria

Requirement	Essential	Desirable
General	Features are reasonably satisfactory.	Features are fully satisfactory and could not usefully be improved.
Size (germanium-based detection system)	Does not exceed 400 x 400 x 200 mm (not including any docking base units).	Does not exceed 300 x 300 x 100 mm (not including any docking base units).
Size (non germanium-based detect-ion system)	Does not exceed 300 x 200 x 150 mm.	Does not exceed 150 x 120 x 120 mm.
Weight (germanium-based detect-ion system)	Maximum weight of 15 kg.	Light as possible with a maximum weight of 5 kg.
Weight (non germanium-based detect-ion system)	Maximum weight of 3 kg.	Light as possible with a maximum weight of 1 kg.
Case construction	Instrument case shall be smooth, rigid, shock resistant, splash proof and dust resistant.	Any supporting straps/ lanyards should be adjustable and compatible for use while wearing PPE; e.g a full gas-tight suit.
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.
Cabling and connectors	Substantial cabling with strain relief where terminated. Rugged securable connectors.	Not currently defined.
Switches and controls	Designed to ensure that the instrument 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 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
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.
Visual display	Clear and easy to read under normal and extreme conditions. Minimum size of 50 x 50 mm.	Intensity of the display illumination should be fully adjustable. Minimum size of 100 x 100 mm.
Firmware / software	The software shall have a version number for identification.	Firmware stored in the instrument should be easy to update.
Data logging	The ability to store and transfer (unprocessed) spectra.	Not currently defined.
Communica-tion interface	Be able to communicate with an external device such as a computer.	Wireless communication of spectral data.



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