Home Office

Scientific Development Branch

Performance Standards and Test Protocols for Radiological Equipment

Number 3 — Alpha, Beta and Photon Contamination Instrumentation

Publication No. 2C/10

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Abstract

This document is the third 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

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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.

Instruments that are designed to measure alpha (α) or beta (β) surface contamination can utilise a variety of different types of detector, the most common being the Geiger-Muller (GM) tube, the ionisation chamber and the scintillation detector.

1.1 Contamination Monitoring Instrumentation

In all but controlled laboratory environments, there are inevitably large uncertainties associated with the direct measurement of deposited radioactive surface contamination. The uncertainties are primarily as a result of the nature of the source and not the instrumentation. In most practical circumstances, significant amounts of activity will effectively be masked by the fact that the radioactive material is present in a relatively thick (in atomic terms) layer and also the presence of other materials such as dust, debris, oil and water. Any of these will serve to offer sufficient attenuation, particularly for weaker penetrating radiation such as alpha and some beta radiation, to potentially render such materials undetectable. In addition, the presence of any penetrating photon field will further serve to corrupt the determination of contamination levels. In such circumstances, accurate measurements can only be made by the removal of the radioactive material for laboratory analysis. However, it is recognised that such practice is impractical in a wide variety of circumstances and hence a wide range of equipment exists for the real-time determination of deposited radioactive surface contamination.

In principle, it is possible to *estimate* the surface activity at a given location by using the measurements obtained from a hand-held portable contamination instrument. However, for the majority of contamination monitoring instruments, we are generally presented with an instrument whose response changes significantly with nuclide/ energy. As a result, the best we can do is to apply the most appropriate calibration factor and, for this purpose, manufacturers' type test data is likely to include the response to a range of common radionuclides. This should then have been confirmed in any routine or test before first use. However, once again our calibration environment is very different from any practical situation and it is important that we retain an appreciation of this in our application of these factors. It should be emphasised that all calculations of surface activity make such a large number of assumptions that any results must be viewed with a degree of scepticism.

A fundamental problem with contamination measurements is that of self-absorption, which affects not only the magnitude, but also the energy spectrum of the radiations that emerge from the surface. Contamination calibration sources are specifically designed to eliminate, as far as is practically possible, this problem. Sources produced for calibration work are designed to recognised international standards (ISO 8769) and approach the ideal where the deposited activity is contained within a monatomic layer on the surface of the source. In addition the substrate is designed to minimise the amount of backscattered radiation. They are usually constructed of an electrically conducting backing material with the radioactive material deposited upon or incorporated into one face. Because the sources match this specification reasonably closely, we estimate the value of the deposited activity by measuring the surface emission rate, from the top surface (2π geometry) using an absolute instrument and simply multiply this value by a factor of 2. Essentially we assume that half the radiation from the deposited activity goes up, and we measure it all, and half goes down and we don't measure any of it. This factor of 2 is known as the P-factor and is defined as the ratio of particle or photon generation rate to the 2π emission rate from the surface.

P-factors can be applied to any thin activity deposits on a surface, but they can only be 2 for a perfect source. In a practical monitoring situation, the nature of the surface, backscatter from surroundings, self-absorption and surface coating will all affect the P-factor. For alpha emissions, even on a perfect surface, it can be assumed that half of the emissions in the 2π direction (upward) will be self-absorbed, so a P-factor of *at least* 4 is required. Where active material has leached into surfaces or been otherwise covered, direct contamination measurements may be unable to detect the presence of activity due to the total absorption of the alpha particles within the surface. In this case, calculations will severely underestimate the actual activity present and the P-factor may approach infinity. Although usually more penetrating than α particles, β particles also suffer from significant spectral degradation both from passage through overlying material and from the much larger backscatter component. This change in energy spectrum can result in a significantly different instrument response, making calculations of surface activity extremely difficult. For low energy β, like α, it can be assumed that half of the emission in the 2π direction will be self-absorbed, again contributing to a P-factor of at least 4. Gamma radiation is generally penetrating and does not suffer too much from spectral degradation. Thus it is possible to apply relatively simple P-factors.

Figure 1. Schematic diagram of an 'ideal' source

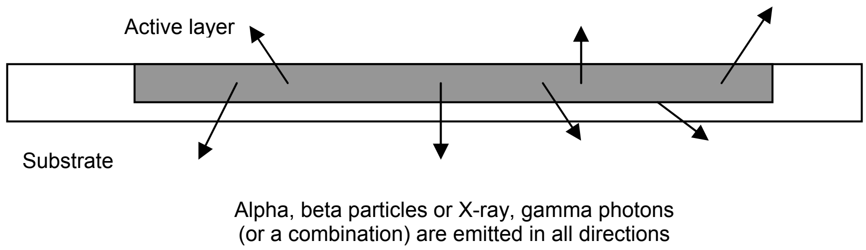
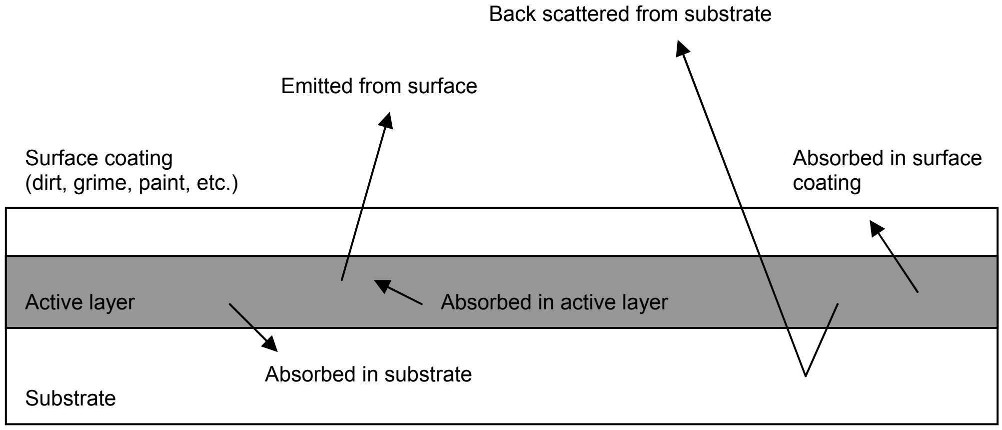


Figure 2. Radiated RF emission limits



1.2 Effects on Surface Emission

Table 1. Effects on surface emission

Effect	Particle Affected	Description and Approximate Magnitude of Effect
Backscatter from substrate	High energy betas	Increases surface emission by 10-20% on high atomic number substrates (e.g. steel).
Self-absorption in active layer	Alphas	Decreases surface emission rate by a factor of 2.
	Low energy betas (0.15-0.4 MeV)	Even thin deposits produce a significant reduction in surface emission rate.
	High energy betas	Surface emission rate unaffected by thin deposits (<1 mg cm^{-2}).
Absorption in surface coating	Alphas	Layer of 5 mg cm^{-2} thickness will totally absorb alpha radiation.
	Low energy betas	Layer of 5 mg cm^{-2} thickness will decrease surface emission rate by a factor of 2.
	High energy betas	Layer of 5 mg cm^{-2} thickness will decrease surface emission rate by 30%.

In essence, the conditions we encounter in workplace monitoring situations will be nothing like those we go to significant lengths to try to achieve in the calibration process. The likelihood of the activity being evenly distributed in a monatomic layer is extremely remote. Serious self-absorption and/or attenuation from other contaminants or materials are much more likely. Under such circumstances, there are inevitably serious shortcomings in the applicability of the derived calibration factor and one needs to be very careful in the interpretation of the results obtained.

2 Reference Documents

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

IEC 60325:2004	Radiation protection instrumentation — Alpha, beta and alpha/beta (beta energy > 60 keV) contamination meters and monitors.
IEC 60529:1992	Degrees of protection provided by enclosures (IP code).
ISO 8769 2007	DRAFT — Reference sources for the calibration of surface contamination monitors — alpha, beta and photon emitters.
NPL GPG 14	Measurement Good Practice Guide No 14: The Examination, Testing and Calibration of Portable Radiation Protection Instruments.
NPL GPG 30	Measurement Good Practice Guide No 30: Practical Radiation Monitoring.
IEC 62363:2008	Radiation protection instrumentation — Portable photon contamination meters and monitors.
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 Activity

Activity is defined as the number of spontaneous nuclear transitions arising from a radionuclide in a particular energy state during a specified time interval. SI unit: s^{-1}.

The special name for the SI unit of activity is the Becquerel (Bq) (1 Bq = 1 s^{-1}).

3.2.2 Becquerel (Bq)

The Becquerel (Bq) is the special name for the SI unit of activity. 1 Bq = 1 s^{-1}.

3.2.3 Becquerels per square centimetre (Bq cm^{-2})

The amount of activity (Becquerels) within one square centimetre.

3.2.4 Particle

A very small portion of matter or energy.

3.2.5 Photon

A quantum of electromagnetic radiation considered as an elementary particle of energy hv; where h is the Planck constant and v the frequency of the radiation.

3.2.6 P-Factor

The P-factor is the ratio of particle generation rate to the emission rate from the surface.

3.2.7 Self-absorption

Absorption of radiation that occurs within the material of the source itself.

3.2.8 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.

3.2.9 Small area source (Point source)

A source whose active surface area has a maximum dimension not exceeding 1 cm.

3.2.10 Surface emission rate (of a radioactive source)

The number of photons or particles of a given type, whose energies are above a given value, emerging from the face (active area) of the radioactive source per unit time.

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 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 instrument shall be scaled in appropriate units.

The units most commonly found on contamination monitoring instruments are counts per second (cs^{-1}, cps, ps^{-1} and s^{-1}).

It should be noted that the dimensions of counts per second are s^{-1}.

4.2 Measuring Ranges

4.2.1 Essential

All contamination instruments shall, as a minimum, display count rate in counts per second and have an audible indication of the count rate.

A means of muting the audible indication shall be provided as well as provision for a head-set to be used in areas of high noise levels or during covert operations.

The instrument should not have the option to read directly in Becquerels.

4.3 Storage and Transport

4.3.1 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.

4.3.2 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.

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 2. Reference conditions and standard test conditions

Influence Qualities	Reference Conditions	Standard Test Conditions
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)
Power supply voltage	Nominal power supply voltage.	Nominal power supply voltage ±10%.
Radiation background	1 $\mu Sv\ h^{-1}$ or less if practical	Known field less than 1 $\mu Sv\ h^{-1}$
Orientation of instrument	To be stated by the manufacturer.	Stated orientation ±2°
Setting up instrument	Set up for normal operation	Set up for normal operation
Contamination by radioactive materials	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 8769.

Any contamination response figures determined during testing shall be determined by reference to ISO standard point and extended area contamination reference sources.

Care must be taken to properly correct for the radioactive decay of the source; especially those radionuclides that have a short half-life.

5.2.1 Reference standard sources

ISO standard reference sources are constructed of an electrically conducting backing material with radioactive material deposited upon or incorporated into one face.

It should be noted that these are essentially perfect or ideal sources and hence any quoted instrument response figures have to be considered as representing the best achievable performance. However, in virtually all practical situations, it will be impossible to realise such a performance.

5.2.2 Traceability of reference sources – Class 1

Reference standard sources that have been calibrated directly in terms of surface emission rate at a national standards laboratory.

5.2.3 Traceability of reference sources – Class 2

Reference standard sources that have been calibrated at an approved laboratory in terms of surface emission rate on a reference instrument.

The efficiency of the reference instrument shall have been measured by calibration with a Class 1 reference standard source of the same radionuclide and of the same general construction using the same geometry.

5.2.4 Activity and surface emission rate

When reference sources are calibrated, the surface emission rate is stated on the calibration certificate. This is referred to as 2π geometry. It should be noted that after manufacture it is not possible to make a measurement of deposited activity without destroying the source.

The surface emission rate of the reference source shall be determined with an uncertainty that shall not exceed ±10%.

5.2.5 Source uniformity

The source uniformity should ideally be within ±5% for Class 1 and ±10% for Class 2.

5.3 Reference Radionuclides

5.3.1 Alpha emitters

The reference radionuclide shall be ^{241}Am or ^{238}Pu.

5.3.2 Beta emitters

The reference radionuclide shall be ^{36}Cl or $^{90}Sr/^{90}Y$ unless the instrument has been designed for the measurement of beta particles with a maximum energy of less than 200 keV, in which case the reference radionuclide shall be ^{14}C.

5.3.3 Photon emitters

For instruments designed to measure photon contamination, the reference radiation will be dependent on the photon energy range of the instrument. This range shall be stated by the manufacturer. The reference photon radionuclides and their associated energy ranges shall be:

- Greater than 50 keV ^{137}Cs
- Between 20 keV and 50 keV ^{129}I
- Less than 10 keV ^{55}Fe

Photon emitting reference sources shall include the filtration specified in ISO 8769-2. The filters should normally be an integral part of the source and should not be removable. The area of the filter should be such that it extends 10 mm beyond the active area of the source.

5.4 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 specified reference point accurately positioned at the point of test in the radiation field. The instrument orientation and reference point used must be clearly stated in the test report.

5.5 Source to Detector Separation

It is important to perform all calibrations with a precisely reproducible geometry. This can be achieved by using a source holder designed to hold both the source and the detector probe. The distance between the front face of the detector and the active surface of the source should be as recommended by the manufacturer. For surface contamination monitors, the recommended separation is normally 3 mm.

5.5.1 Desirable

The contamination monitor should be able to measure its speed of travel and its distance from the surface (optically to avoid contamination), and instruct the user if they are monitoring too quickly or too far away.

5.6 Setting up the Instrument

Before any testing commences, the instrument shall be fully set up in accordance with the manufacturer’s instruction manual.

5.6.1 Essential

Any required adjustments shall be effected quickly and accurately.

5.6.2 Desirable

Any required adjustments shall be effected quickly and accurately without the necessity of dismantling the instrument or using special tools.

6 Radiological Performance Requirements

6.1 Linearity of Response

6.1.1 Essential

With the instrument set up as specified by the manufacturer's instructions and under standard test conditions, the relative intrinsic error in the response to the reference radiation (linearity) shall not exceed ±30% over the entire effective range of surface emission rates.

6.1.2 Desirable

With the instrument set up as specified by the manufacturer's instructions and under standard test conditions, the relative intrinsic error in the response to the reference radiation (linearity) shall not exceed ±20% over the entire effective range of surface emission rates.

6.1.3 Test radiation

6.1.3.1 Alpha contamination monitors

For alpha contamination monitors these measurements shall be carried out using ^{241}Am or ^{238}Pu.

6.1.3.2 Beta contamination monitors

For beta contamination monitors these measurements shall be carried out using ^{36}Cl, ^{90}Sr/^{90}Y or ^{14}C.

For beta contamination monitors where a higher range is required, this test may alternatively be carried out using an ambient dose equivalent radiation field generated by ^{137}Cs. The ambient dose equivalent rate will need to be converted to a surface emission rate per unit area for ^{36}Cl by multiplying by a conversion factor. This factor can be derived by taking a ratio of the response to ambient dose equivalent dose rates to the response per surface emission rate at the same indicated count rate.

6.1.3.3 Photon contamination monitors

For photon contamination instruments these measurements shall be carried out using ^{137}Cs, ^{129}I and ^{55}Fe (dependent on the photon energy range of the instrument — see section 5.3 Reference Radionuclides).

6.1.4 Method of test

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 to establish a mean indication with an accuracy of ±10% the standard deviation of the mean.

Where the contamination meter utilises more than one radiation detector, these requirements apply to the relevant ranges for each detector separately.

Where the relative intrinsic error is defined as the ratio of the contamination instrument's value to the conventionally true value.

Equation 1. Contamination instrumentation linearity of response:

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

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

6.2 Response Time

The manufacturer shall state the maximum response time of the instrument. When the instrument is subjected to a step increase or decrease in surface emission rate, its indication shall reach the value given by the response time equation.

Equation 2. 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.

6.2.1 Essential

When the instrument is subjected to a step increase or decrease in surface emission rate, its indication shall reach the value given by the response time equation in less than 7 seconds.

6.2.2 Desirable

When the instrument is subjected to a step increase or decrease in surface emission rate, its indication shall reach the value given by the response time equation in less than 3 seconds.

6.2.3 Test radiation

6.2.3.1 Alpha contamination monitors

For alpha contamination instruments these measurements shall be carried out using ^{241}Am or ^{238}Pu.

The source must be capable of producing an alpha indication of at least 50 counts s^{-1}.

6.2.3.2 Beta contamination monitors

For beta contamination instruments these measurements shall be carried out using ^{36}Cl, $^{90}Sr/^{90}Y$ or ^{14}C.

The source must be capable of producing a beta indication of at least 10 times the background indication.

6.2.3.3 Photon contamination monitors

For photon contamination instruments these measurements shall be carried out using ^{137}Cs, ^{129}I or ^{55}Fe (dependent on the photon energy range of the instrument – see section 5.3 Reference Radionuclides).

The source must be capable of producing an indication of at least 10 times the background indication.

6.2.4 Method of test

This test shall be performed for both an increase and a decrease in the surface emission rate by at least a factor of 10.

The instrument shall first be exposed to the appropriate reference radiation source for a time sufficient for the indication to reach a steady value and the indication recorded. This is the value H_f.

Next, remove the radiation source so the instrument is only subjected to background radiation. After a time sufficient for the indication to reach a steady indication, record the indication. This is the value H_i.

Using the response time formula above, calculate the value required for the next step.

Finally, being careful to ensure the same geometry as before, expose the instrument to the reference radiation source as quickly as possible (less than 1 second) and record the time taken to reach the value given by the response time equation.

For the decreasing surface emission rate test, this test shall be repeated but with the values of surface emission rates corresponding to H_i and H_f interchanged.

6.3 Statistical Fluctuations

Since radioactive decay is a random process, depending on the intensity of the radiation, the fluctuations in the instrument indication could be a significant fraction of the variation permitted in the test. Therefore, sufficient readings shall be taken to ensure that the mean value may be determined with sufficient precision. To ensure that the readings are statistically independent, the interval between such readings shall be at least three times the response time.

This test applies to contamination levels that exceed that corresponding to the following indications:

- Logarithmic scales — three times the lowest significant graduation on the scale.
- Linear scales — one third of the scale maximum on the most sensitive range.
- Digital display — ten times the value of the least significant digit.

Where the instrument has selectable time constants, the manufacturer shall state which ones meet this requirement.

6.3.1 Essential

The statistical fluctuation shall be less than ±20% at the specified contamination levels.

6.3.2 Desirable

The statistical fluctuation should be less than ±10% at the specified contamination levels.

6.3.3 Test radiation

For alpha contamination instruments these measurements shall be carried out using ^{241}Am or ^{238}Pu.

For beta contamination instruments these measurements shall be carried out using ^{36}Cl, $^{90}Sr/^{90}Y$ or ^{14}C.

For photon contamination instruments these measurements shall be carried out using ^{137}Cs, ^{129}I or ^{55}Fe (dependent on the photon energy range of the instrument – see section 5.3 Reference Radionuclides).

6.3.4 Method of test

First, expose the instrument to a radiation source that gives an indication as follows:

- Linear ranges — an indication between one third and one half of scale maximum on the most sensitive range.
- Logarithmic ranges — an indication between one third and one half of scale maximum on the most sensitive decade.
- Digital displays — an indication of the figure ‘1’ in the second least significant digit.

Next, take a series of at least 20 readings. To ensure that these readings are statistically independent, the interval between these readings shall be at least three times the response time. Determine the mean value and the standard deviation of the readings.

6.4 Background Indications

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 and consequently the displayed background could also vary significantly. In addition, for some types of detector, variations in background material can lead to easily observable differences in count rates.

6.4.1 Essential

The manufacturer shall state the count rate or indication, due to background radiation, in the absence of any contamination.

For alpha instruments the indicated background shall be as close to zero as possible.

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

6.4.2 Desirable

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

6.4.3 Test radiation

An area known to have a low, stable background rate less than 1 μSv h^{-1}.

6.4.4 Method of test

The background indication of an instrument shall be determined by taking at least 20 readings at time intervals that exceed three time constants. This is to ensure that each reading taken is statistically independent.

6.5 Overload Performance

6.5.1 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 on a digital display). The instrument 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 activity until the exposed activity is within measuring range. On the completion of the overload test the instrument shall function correctly in a time period of less than 1 minute.

NOTE: The overload test can be ignored for instruments that are likely to be damaged by performing this test. Where damage to the instrument is possible, then this test should be done after other tests. If this test is omitted then this must be clearly recorded in the test report.

6.5.2 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 30 seconds.

6.5.3 Test radiation

For photon contamination instruments these measurements shall be carried out using ^{137}Cs.

For beta contamination instruments these measurements shall be carried out using ^{90}Sr/^{90}Y.

For the purpose of this test, the value of the true emission 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%.

For scintillation-based alpha contamination instruments where suitable sources are unavailable, a simulated overload condition may be achieved by puncturing or loosening the foil so that light enters the photo-multiplier tube.

6.5.4 Method of test

The instrument shall be exposed to 10 times the range maximum rate for a period of at least 5 minutes.

After the overload test the instrument's performance shall return back to normal within the time specified.

6.6 Variation of Response over the Surface of the Detector (Detector Uniformity)

The response of the detection assembly to a small area source (or a masked large area source), situated on the surface under examination will, in general, vary according to the position of the source relative to the probe and the transmission of elements on the surface, for example, the grille.

Small area sources shall be used to confirm the uniformity of response over the surface of the detector.

NOTE: For some instruments, if the detector surface area is smaller than 8 cm^2, this test may not be applicable.

6.6.1 Essential

The maximum deviation away from the mean response of the total detector, determined with the source in various positions over the surface of the detector, shall be less than 30%.

6.6.2 Desirable

The maximum deviation away from the mean response of the total detector, determined with the source in various positions over the surface of the detector, shall be less than 30%.

6.6.3 Test radiation

For alpha contamination instruments these measurements shall be carried out using ^{241}Am or ^{238}Pu.

For beta contamination instruments these measurements shall be carried out using ^{36}Cl, ^{90}Sr/^{90}Y or ^{14}C.

For photon contamination instruments these measurements shall be carried out using ^{137}Cs, ^{129}I or ^{55}Fe (dependent on the photon energy range of the instrument – see section 5.3 Reference Radionuclides).

6.6.4 Method of test

The sensitive area of the detector shall be divided into sections of approximately 25 x 25 mm. The maximum number of sections should not be greater than 100 and where this limit is applied each section should be increased in size proportionally.

A small area source of the reference radionuclide shall be placed in contact with the detector window and as close as possible to the centre of each section and the response determined.

The variation in response across the detector shall be recorded in terms of the indicated count rate. The maximum deviation away from the mean response of the detector shall be determined and calculated as a percentage of the mean.

6.7 Variation of Surface Emission Rate Response with Radiation Energy

The response of the instrument in counts s^{-1} above background to uniformly distributed surface contamination over an area greater than that of the probe shall be determined for various radionuclides.

The instrument responses shall be quoted in terms of counts per second per Becquerel per cm^2 above background. Where the instrument response is defined as:

Equation 3. Calculation of contamination response:

$$\text{Contamination} = \frac{\text{Net indication}}{\text{Surface emission rate x P factor per unit area}}$$

6.7.1 Essential and desirable (see tables below)

The manufacturer shall state which radionuclides have been used and the value for surface emission rate response for each of them.

6.7.1.1 Alpha contamination instruments

Table 3. Minimum responses for alpha contamination instruments

Energy Range (Radionuclide)	Essential	Desirable
^{241}Am or ^{238}Pu	Response >7	Response >15

6.7.1.2 Beta contamination instruments

Table 4. Minimum responses for beta contamination instruments

Energy Range (Radionuclide)	Essential	Desirable
<200 keV (e.g. ^{14}C)	Response >0.5	Response >1
>200 keV and <500 keV (e.g. ^{147}Pm, ^{60}Co)	Response >1	Response >2
>500 keV (e.g. ^{36}Cl, ^{204}Tl, ^{90}Sr/^{90}Y)	Response >3	Response >6

6.7.1.3 Photon contamination instruments

Table 5. Minimum responses for photon contamination instruments

Energy Range (Radionuclide)	Essential	Desirable
<10 keV (e.g. ^{55}Fe)	Response >0.25	Response >0.5
>10 keV and <50 keV (e.g. ^{129}I)	Response >4	Response >8

6.7.2 Test radiation

The surface emission rate response shall be determined using a large area contamination calibration source. The area of the source shall be sufficient to irradiate the entire sensitive area of the detector. Where this is not possible, a source with a smaller active area may be used. In this case, additional measurements shall be performed with the source in different locations such that all areas of the detector are eventually covered without any overlapping of adjacent areas.

6.7.2.1 Alpha contamination instruments

For alpha contamination instruments these measurements shall be carried out using ^{241}Am or ^{238}Pu. Alternatively, ^{230}Th or natural uranium may be used.

6.7.2.2 Beta contamination instruments

The surface emission rate response shall be measured with beta emitters of at least three different maximum energies distributed as follows:

- less than 200 keV (e.g. ^{14}C);
- greater than 200 keV and less than 500 keV (e.g. ^{147}Pm, ^{60}Co);
- greater than 500 keV (e.g.^{36}Cl, ^{90}Sr/^{90}Y).

6.7.2.3 Photon contamination instruments

The surface emission rate response shall be measured with photon emitters of at least two different energies distributed as follows:

- less than 10 keV (e.g. ^{55}Fe);
- greater than 10 keV and less than 50 keV (e.g. ^{129}I, ^{238}Pu).

6.7.3 Method of test

The test shall be performed for one alpha emitting radionuclide in each of the alpha energy bands, one beta emitting radionuclide in each of the beta energy bands and one photon emitting radionuclide in each of the photon energy bands.

6.8 Interference Ionising Radiations

Instruments intended for the measurement of surface contamination shall be designed to minimise sensitivity from other ionising radiations.

A beta probe may be provided with a shield to enable beta radiation to be distinguished from gamma radiation.

6.8.1 Alpha rejection for beta detectors

This test is only applicable to beta contamination instruments that have a window thickness of less than 5 mg cm^{-2} and are designed to distinguish between alpha and beta radiation.

6.8.1.1 Essential

Whilst in a mode designed to detect only beta radiation, the alpha response shall be less than 1/100 of the beta response. The presence of the alpha source shall not affect the instrument's beta performance.

6.8.1.2 Desirable

Not currently defined.

6.8.1.3 Test radiation

A sealed ^{36}Cl, $^{90}Sr/^{90}Y$ or ^{14}C beta contamination point source.

For this test the beta source shall have dimensions that are small compared to the area of the detector window. The source shall also be of sufficiently low activity for the instrument indication to be in the most sensitive range or decade.

A sealed ^{241}Am or ^{238}Pu alpha contamination source.

6.8.1.4 Method of test

With the instrument set up as per the manufacturer's instructions, ensure that the instrument is in a beta-only mode.

Next, place the beta contamination point source at a distance of 3 mm in front of the detector and record the indicated count rate.

Finally, without moving the beta source or detector, also place the alpha source in contact with the front of the detector and record the indicated count rate.

6.8.2 Beta rejection for alpha detectors

This test is not applicable to instruments that are designed to detect alpha and beta radiation simultaneously, unless these radiations are clearly distinguishable on the display or the individual detection modes can be set.

6.8.2.1 Essential

Whilst in a mode designed to detect only alpha radiation, the beta response shall be less than 1/100 of the alpha response when exposed to a beta source. The presence of the beta source shall not affect the instrument's alpha performance.

6.8.2.2 Desirable

Not currently defined.

6.8.2.3 Test radiation

A sealed ^{241}Am or ^{238}Pu alpha contamination point source.

For this test the alpha source shall have dimensions that are small compared to the area of the detector window. The source shall also be of sufficiently low activity for the instrument indication to be in the most sensitive range or decade.

A sealed ^{36}Cl, ^{90}Sr/^{90}Y or ^{14}C beta contamination source.

6.8.2.4 Method of test

With the instrument set up as per the manufacturer's instructions, ensure that the instrument is in an alpha-only mode.

Next, place the alpha contamination point source at a distance of 3 mm in front of the detector and record the indicated count rate.

Finally, without moving the alpha source or detector, also place the beta source in contact with the front of the detector and record the indicated count rate.

6.8.3 Gamma rejection for alpha detectors

Some types of alpha contamination instruments are affected indirectly by gamma radiation. Although the gamma radiation itself may not produce any indication, the instrument sensitivity to alpha radiation may be altered.

In many cases, gamma radiation will have a much greater effect with low energy and hence this test shall be performed with ^{241}Am as well as ^{137}Cs.

6.8.3.1 Essential

The instrument's performance shall not be affected by an ambient dose equivalent rate of 10 mSv h^{-1} from a ^{137}Cs gamma radiation source, or an ambient dose equivalent rate of 100 µSv h^{-1} from a ^{241}Am gamma radiation source.

6.8.3.2 Desirable

Not currently defined.

6.8.3.3 Test radiation

An ambient dose equivalent rate of at least 10 mSv h^{-1} shall be provided by a sealed ^{137}Cs gamma dose rate source.

An ambient dose equivalent rate of at least 100 µSv h^{-1} shall be provided by a sealed ^{241}Am gamma dose rate source.

A sealed ^{241}Am or ^{238}Pu alpha contamination source of sufficiently low activity for the instrument indication to be in the most sensitive range or decade.

6.8.3.4 Method of test

First, the entire instrument shall be subjected to an ambient dose equivalent rate of at least 10 mSv h^{-1} from a sealed ^{137}Cs gamma dose rate source and the indicated count rate recorded.

Next, the instrument shall be irradiated with just the alpha source and the indicated count rate recorded.

Next, using the same source configurations as above, the entire instrument shall be subjected to an ambient dose equivalent rate of at least 10 mSv h^{-1}, at the same time as being irradiated with the alpha source, and the indicated count rate recorded.

Finally, this test will be repeated using the ^{241}Am gamma dose rate source instead of the ^{137}Cs gamma dose rate source.

6.8.4 Gamma rejection for beta detectors

6.8.4.1 Essential

The manufacturer shall state the instrument's response in terms of counts s^{-1} or activity per unit area for a gamma ambient dose equivalent rate of 10 μSv h^{-1}.

6.8.4.2 Desirable

Not currently defined.

6.8.4.3 Test radiation

An ambient dose equivalent rate of at least 10 μSv h^{-1} shall be provided by a sealed ^{137}Cs gamma dose rate source.

6.8.4.4 Method of test

The instrument shall be subjected to an ambient dose equivalent rate of at least 10 μSv h^{-1} and the indicated count rate recorded.

6.8.5 Neutron rejection

The testing of instruments with neutron radiation is not covered in this document. The manufacturer shall state the instrument's response to neutron radiation.

6.9 Light Leakage

6.9.1 Essential

The contamination monitor shall not be affected by bright sunlight shining directly on the detector window.

6.9.2 Desirable

Not currently defined.

6.9.3 Method of test

Pointing the instrument's detector window towards a bright light, e.g. 150 watt security light, can simulate conditions similar to sunlight. Care should be taken not to get too close to the light source as the heat from the light source could damage the detector window. The separation between the detector window and the light source should be between 300 and 500 mm.

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 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 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

For alpha contamination instruments these measurements shall be carried out using ^{241}Am or ^{238}Pu.

For beta contamination instruments these measurements shall be carried out using ^{36}Cl, $^{90}Sr/^{90}Y$ or ^{14}C.

For photon contamination instruments these measurements shall be carried out using ^{137}Cs, ^{129}I and ^{55}Fe (dependent on the photon energy range of the instrument – see section 5.3 Reference Radionuclides).

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 and record the supply voltage, instrument indication and any other observations until the instrument switches off. 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.

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 the instrument 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 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

For alpha contamination instruments these measurements shall be carried out using ^{241}Am or ^{238}Pu.

For beta contamination instruments these measurements shall be carried out using ^{36}Cl, ^{90}Sr/^{90}Y or ^{14}C.

For photon contamination instruments these measurements shall be carried out using ^{137}Cs, ^{129}I and ^{55}Fe (dependent on the photon energy range of the instrument – see section 5.3 Reference Radionuclides).

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 and record the supply voltage, resistance, current drawn, instrument indication and any other observations until the instrument switches off. 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.

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 the instrument exposed to a dose equivalent rate that triggers the audible or visual alarms.

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 or illumination features in operation at their maximum intensity for at least 1 hour.

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 communication 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)

Due to the fragile nature of the detector window, it is unlikely to withstand the mechanical shock test without severe damage. Where the detector is remote from the instrument, such as in a separate probe, the mechanical shock test may only be performed on the rate meter and not on the probe itself.

Where the detector is not remote from the instrument, the mechanical shock test may be omitted. The manufacturer will state which parts of the instrument comply with the mechanical shock requirements.

9.1.1 Essential

The rate meter shall be able to withstand drops 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 rate meter shall be able to withstand drops 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

For alpha contamination instruments these measurements shall be carried out using ^{241}Am or ^{238}Pu.

For beta contamination instruments these measurements shall be carried out using ^{36}Cl, ^{90}Sr/^{90}Y or ^{14}C.

For photon contamination instruments these measurements shall be carried out using ^{137}Cs, ^{129}I and ^{55}Fe (dependent on the photon energy range of the instrument — see section 5.3 Reference Radionuclides).

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 rate meter shall be dropped on to each face in turn from a height of 1 metre onto the specified surface. After each drop, the instrument’s response to the appropriate reference radionuclide shall be confirmed and recorded. 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 mean response of the instrument shall not vary by more than 20% as a result of these vibrations.

9.2.2 Desirable

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

9.2.3 Test radiation

For alpha contamination monitors these measurements shall be carried out using ^{241}Am or ^{238}Pu.

For beta contamination monitors these measurements shall be carried out using ^{36}Cl, $^{90}Sr/^{90}Y$ or ^{14}C.

9.2.4 Method of test

The instrument shall be exposed to the appropriate reference radiation in reproducible geometry and the mean indication determined. The instrument 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 instrument.

10 Environmental Performance Requirements

The types of environments where contamination monitoring may be required are likely to be very varied; for example, office spaces, industrial plants, asphalt car parks or pebble beaches. The presence of sharp objects, which are capable of puncturing instrument windows, is therefore a general problem.

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 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

For alpha contamination monitors these measurements shall be carried out using ^{241}Am or ^{238}Pu.

For beta contamination monitors these measurements shall be carried out using ^{36}Cl, $^{90}Sr/^{90}Y$ or ^{14}C.

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.

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

For alpha contamination monitors these measurements shall be carried out using ^{241}Am or ^{238}Pu.

For beta contamination monitors these measurements shall be carried out using ^{36}Cl, $^{90}Sr/^{90}Y$ or ^{14}C.

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. Both the instrument 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 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.

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 variation of the relative response due to humidity shall be less than ±20%.

10.5.2 Desirable

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

10.5.3 Test radiation

For alpha contamination monitors these measurements shall be carried out using ^{241}Am or ^{238}Pu.

For beta contamination monitors these measurements shall be carried out using ^{36}Cl, $^{90}Sr/^{90}Y$ or ^{14}C.

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.

Next, 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 but 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 and 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 usefully be 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 instrument shall fit into a volume of less than 2 litres excluding any external probes.

Probes, where supplied, shall have a window area greater 15 cm^2.

12.2.2 Desirable

The instrument should fit into a volume of less than 1 litre excluding any external probes.

12.3 Weight

12.3.1 Essential

The instrument shall be as light as possible with a maximum weight of 2 kg.

The instrument shall be well balanced.

12.3.2 Desirable

The instrument should 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 controls, displays or visual alarm are located such that 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.

12.4.2 Desirable

Any support straps provided must be adjustable and compatible for use while wearing personal protective equipment (PPE); for example, 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 so that they can be operated by touch alone. Buttons, switches and controls should be well-spaced.

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; this is 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 Assemblies

For the majority of contamination instrumentation the detector should be external to the instrument, connected via a cable, as this configuration is more suitable for monitoring around complex objects and less accessible areas. However, the detector may be incorporated into the body of the rate meter where this is deemed more appropriate for the application.

The detector shall be mounted so that its sensitive area can be placed less than 5 mm (alpha detectors) or less than 10 mm (beta and photon detectors) from the surface under examination. The recommended surface to detector separation is 3 mm.

The manufacturer shall quantify the effect of any protective grille fitted over the detector window. The protective grille shall be kept as thin as possible to reduce its shielding effects at all angles (a collimation effect is to be avoided).

Where applicable the manufacturer shall state the type of gas and required flow rate.

Consideration shall be given to the ease of decontamination of the detector. For example, in the event of contamination of the window of a scintillation probe, the window can be exchanged quickly and cheaply; whereas it would be much more difficult to decontaminate the window of an end-window Geiger-Muller tube as it is likely to be damaged during the cleaning process.

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 functions of all controls (that are not displayed via soft menus) and indicators.

Probes should also be clearly marked to show their intended function.

12.12 Visual Display

12.12.1 Essential

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 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/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 count rate, an audible indication of count 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.

The minimum size of the display shall be at least 45 x 15 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 minimum size of the display shall be at least 70 x 40 mm.

12.13 Additional Indications

12.13.1 Low battery

12.13.1.1 Essential

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

12.13.2 Detector failure

12.13.2.1 Essential

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

12.15.1.1 Essential

Not currently defined.

12.15.1.2 Desirable

The instrument should 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.

12.16 Communication Interface

12.16.1 Essential

Not currently defined.

12.16.2 Desirable

The instrument should be able to communicate data to an external device, such as a computer. The type of data to transfer could include count rate/activity 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 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.

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 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 6. Summary of radiological performance criteria

Requirement	Essential	Desirable
Linearity of response	Linearity better than ±30%	Linearity better than ±20%
Response time	Less than 7 seconds	Less than 3 seconds
Statistical fluctuations	Statistical fluctuations less than ±20%	Statistical fluctuations less than ±10%
Background indications	Statistical fluctuation less than ±30 % at less than 1 μSv h^{-1}	Statistical fluctuation less than ±15 % at less than 1 μSv h^{-1}
Overload performance	Satisfactory overload and return to normal function in less than 1 minute.	Satisfactory overload and return to normal function in less than 30 seconds.
Variation of response over the surface of the detector (detector uniformity)	The maximum deviation away from the mean response of the total detector shall be less than 30%.	The maximum deviation away from the mean response of the total detector shall be less than 20%.
Surface emission rate response with photon radiation energy (alpha)	See table 3. Minimum responses for alpha contamination instruments.	See table 3. Minimum responses for alpha contamination instruments.
Surface emission rate response with photon radiation energy (beta)	See table 4. Minimum responses for beta contamination instruments.	See table 4. Minimum responses for beta contamination instruments.
Surface emission rate response with photon radiation energy (photon)	See table 5. Minimum responses for photon contamination instruments.	See table 5. Minimum responses for photon contamination instruments.
Interference ionising radiation	Beta response less than 1/100 of the alpha response. Alpha response less than 1/100 of the beta response.	Not currently defined.

Requirement	Essential	Desirable
Interference ionising radiation (Photon)	Instrument performance shall not be affected by an ambient dose equivalent rate of 10 mSv h^{-1} from a ^{137}Cs gamma radiation source nor by an ambient dose equivalent rate of 100 µSv h^{-1} from a ^{241}Am gamma radiation source.	Not currently defined.
Light leakage	Not affected by bright sunlight shining directly on the detector window.	Not currently defined.

A.2 Alarms

Table 7. 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.	Adjustable alarm intensity in conjunction with vibrating alarm.
Visual alarm	Positioned so that if triggered it 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 8. 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.

Requirement	Essential	Desirable
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 fun-ction (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.

A.4 Mechanical

Table 9. Summary of mechanical performance criteria

Requirement	Essential	Desirable
Mechanical shock (drop test)	Rate meter able to withstand drops from 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%.	Rate meter able to withstand drops from 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%.
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.

A.5 Environmental

Table 10. 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 20% in indications for humidity levels between 20% and 90%.	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 11. Summary of ergonomic performance criteria

Requirement	Essential	Desirable
General	Features are reasonably satisfactory.	Features are fully satisfactory and could not be usefully improved.
Size	Fits in to a volume of less than 2 litres excluding any external probes. Probes, where supplied, shall have a window area greater than 15 cm^2.	Fits in to a volume of less than 1 litre excluding any external probes.
Weight	Maximum weight of 2 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.	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.

Requirement	Essential	Desirable
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; this is to increase the ease of operation of the dose meter while the operator is in full gas tight PPE.
Ease of operation	Designed so that it can be used safely and efficiently without a high level of specialist knowledge.	Not currently defined.
Visual display	Clear and easy to read under normal and extreme conditions. Minimum size of 45 x 15 mm.	Intensity of the display illumination should be fully adjustable. Minimum size of 70 x 40 mm.
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.

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