

**Installed monitors for the control and detection of gamma radiations
contained in recyclable or non-recyclable materials
transported by vehicles
(IEC 62022:2004, modified)**

Moniteurs fixes de contrôle et de détection
d'émetteurs de rayonnements gamma
contenus dans des matériaux recyclables
ou non recyclables, transportés
dans des véhicules
(CEI 62022:2004, modifiée)

Fest installierte Monitore
für die Überwachung und den Nachweis
von Gammastrahlen-Emittern
in von Fahrzeugen transportierten,
wiederverwertbaren
oder nicht wiederverwertbaren Materialien
(IEC 62022:2004, modifiziert)

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CENELEC

European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

Central Secretariat: rue de Stassart 35, B - 1050 Brussels

Foreword

The text of the International Standard IEC 62022:2004, prepared by SC 45B, Radiation protection instrumentation, of IEC TC 45, Nuclear instrumentation, together with the common modifications prepared by CENELEC BTTF 111-3, Nuclear instrumentation and radiation protection instrumentation, was submitted to the formal vote and was approved by CENELEC as EN 62022 on 2007-07-01.

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Clauses, subclauses, notes, tables and figures which are additional to those in IEC 62022:2004 are prefixed “Z”.

Annex ZA has been added by CENELEC.

Endorsement notice

The text of the International Standard IEC 62022:2004 was approved by CENELEC as a European Standard with agreed common modifications.

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INSTALLED MONITORS FOR THE CONTROL AND DETECTION OF GAMMA RADIATIONS CONTAINED IN RECYCLABLE OR NON-RECYCLABLE MATERIALS TRANSPORTED BY VEHICLES

1 Scope

This International Standard is applicable to installed monitors for the control and detection of radioactivity of gamma emitters contained in recyclable or non-recyclable material waste to be transported by vehicles.

This standard is designed to provide the purchaser with an indication of the performance of the equipment in detecting radioactive sources left in the material being monitored, and not to measure quantity.

This standard does not apply to hand-held equipment. It is not applicable to the monitoring of materials on conveyors, in grabs or being moved by electromagnets.

This standard is not intended for the monitoring of radioactive waste or detection of fissile materials.

The object of this standard is to define an installed monitor for the control and detection of radioactivity of gamma emitters contained in recyclable or non-recyclable materials transported by vehicle, the conceptual requirements, general characteristics, mechanical characteristics, environmental conditions, minimal requirements, test procedures and documentation.

The selection of the location of the instrumentation on the site needs to be optimised to achieve the best performance of measurement, but this is beyond the scope of this standard.

The gamma radiation detected by these monitors may be emitted by one or several discrete radioactive sources included in the loading, or by the presence of radioactive material in the vehicle being monitored.

These monitors are to be used outdoors. The radiations detected are gamma emissions of energy at least from 50 keV to 1 500 keV.

It is advantageous if the equipment can give the approximate location of a radioactive source but this is not a mandatory requirement of this standard.

Conformance with the requirements of this standard is no guarantee that a radioactive source will always be discovered. The shielding of the high-density materials will mean radioactive substances buried deep in the material could be missed.

2 Normative references

The following referenced documents should be used for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60038:1983, *IEC standard voltages*
Amendment 1 (1994)
Amendment 2 (1997)

IEC 60050(151):2001, *International Electrotechnical Vocabulary (IEV) – Chapter 151: Electrical and magnetic devices*

IEC 60050(393):1996, *International Electrotechnical Vocabulary (IEV) – Chapter 393: Nuclear instrumentation: Physical phenomena and basic concepts*

IEC 60050(394):1995, *International Electrotechnical Vocabulary (IEV) – Chapter 394: Nuclear instrumentation: Instruments*

IEC 60068-2-27:1987, *Basic environmental testing procedures – Part 2: Tests – Test Ea and guidance: Shock*

☐ IEC 61000-4-3:2006, *Electromagnetic compatibility (EMC) – Part 4-3: Testing and measurement techniques – Radiated, radio-frequency, electromagnetic field immunity test*

IEC 61000-4-4:2004, *Electromagnetic compatibility (EMC) – Part 4-4: Testing and measurement techniques – Electrical fast transient/burst immunity test.*

IEC 61000-4-5:2005 *Electromagnetic compatibility (EMC) – Part 4-5: Testing and measurement techniques – Surge immunity test*

IEC 61000-4-6:2006, *Electromagnetic compatibility (EMC) – Part 4-6: Testing and measurement techniques – Immunity to conducted disturbances, induced by radio-frequency fields*

IEC 61000-4-11:2004, *Electromagnetic compatibility (EMC) – Part 4-11: Testing and measurement techniques – Voltages dips, short interruptions and voltage variation immunity tests* ☐

IEC 61187:1993, *Electrical and electronic measuring equipment – Documentation*

ISO 4037-1:1996, *X and gamma reference radiation for calibration dosimeters and doserate meters and for determining their response as a function of photon energy – Part 1: Radiation characteristics and production methods*

3 Terms, definitions, quantities and units

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60050(393) and IEC 60050(394), as well as the following, apply.

3.1.1

sensitivity

for a given value of the measured quantity, ratio of the variation of the observed variable to the corresponding variation of the measured quantity

[IEV 394-19-07]

NOTE In this standard, sensitivity is the ratio between the net true count rate and the activity of radiation source. This sensitivity depends on the nature of the radiation issuing radionuclide.

3.1.2

background level

gamma radiation field in which the equipment is intended to operate, which includes natural background (including eventually radiation due to radioactive sources adjacent to the equipment), without monitored vehicle.

For a measuring assembly, when the assembly is placed under its normal conditions of operation, value indicated in the absence of the source whose radiation is to be measured

[IEV 394-19-08, modified]

3.1.3

detector efficiency

ratio of the number of detected photons to the number of photons of the same type which are incident on the detector in the same time interval

[IEV 394-18-21, modified]

3.1.4

radiation detection assembly

assembly intended for converting ionizing radiation energy into a normalized signal, carrying information about ionizing radiation physical quantities, and which provides the signal for transmission to the information treatment assembly

[IEV 394-01-15, modified]

3.1.5

information treatment assembly

assembly which treats the count rates issued from the radiation detection assembly over a period of time, performs the necessary corrections for statistical variations, background level and eventually shielding effects, and compares it to alarm threshold

3.1.6

alarm assembly

assembly that provides visual or audio signals or both to call attention to events

[IEV 393-08-03, modified]

3.1.7

reference point of radiation detection assembly

physical mark on the assembly to be used in order to position it at a precise point, to define the geometric conditions of tests

3.1.8**manufacturer and purchaser**

the term "manufacturer" includes the designer of the equipment. The term "purchaser" includes the user of the equipment

3.1.9**qualification tests**

qualification tests are performed in order to verify that the requirements of a specification are fulfilled

NOTE Qualification tests are subdivided into type tests and routine tests, as defined in 3.1.10 and 3.1.11.

3.1.10**type test**

conformity test made on one or more items representative of the production

[IEV 151-16-16]

3.1.11**routine test**

test to which each individual device is subjected during or after manufacture to ascertain whether it complies with certain criteria

[IEV 394-20-08]

3.1.12**acceptance test**

contractual test to prove to the customer that the device meets certain conditions of its specification

[IEV 394-20-09]

3.1.13**supplementary tests**

tests intended to provide supplementary information on certain characteristics of the assemblies

3.2 Quantities and units

In this standard, units of the International System (SI) are used¹. The definitions of radiation quantities are given in IEC 60050(393) and IEC 60050(394). The corresponding old units (non SI) are indicated in brackets.

Nevertheless, the following units may also be used:

- for energy: electron-volt (symbol: eV);
1 eV = $1,602 \times 10^{-19}$ J;
- for time: years (symbol: y), days (symbol: d), hours (symbol: h), minutes (symbol: min).

Multiples and submultiples of SI units will be used, when practicable, according to the SI system.

¹ International Bureau of Weights and Measures: *The International System of Units (SI)*, Seventh edition, 1998.

4 Design requirements

4.1 General characteristics

The equipment is a warning system designed to detect radioactivity of gamma emitters contained in recyclable or non-recyclable materials, issuing a visual and/or audible alarm, when the signal from the radiation detection system exceeds an alarm threshold. [C] The alarm threshold is not a fixed value, but an expected value depending on the measuring conditions, e.g. the material and energy ranges expected. [C]

The equipment shall give indications linked to the fluence rate of gamma photons incident to the radiation detection assembly. The energy range of the gamma photons detected by the equipment shall be specified by the manufacturer, at least between 50 keV and 1 500 keV.

The alarm shall be activated if at least one of the indications issued from one of the detection assemblies, after treatment and correction of possible disruptive effects, exceeds an alarm threshold.

[C] In the case of the dynamic mode (the vehicle passing the equipment) alarm occurs when there is a statistically significant increase in the detected fluence rate of gamma photons when the vehicle is passing the detection system. This fluence may however be less than that due to normal background.

In the case of the static mode (vehicle stationary within the equipment) an alarm occurs when the fluence rate of gamma photons detected is greater than a pre-established level. [C]

4.2 Configuration

[C] The equipment is composed of one or several radiation detection assemblies adjacent to the vehicle in the static mode and close to the vehicle whilst it passes in the dynamic mode, and an information treatment assembly, linked to an alarm assembly. The radiation detection assembly is the elementary device produced by the manufacturer, containing generally one or several contiguous radiation detectors. [C]

The design shall be such that operation is possible with radiation detection assembly and information treatment assembly separated by at least 100 m.

The radiation detection assembly shall be designed to operate under all expected weather conditions.

The equipment enclosure shall be such that it does not deteriorate during prolonged installation under these conditions and that access for repair shall be unhindered by corrosion.

The radiation detection assembly could also be subjected to amounts of vibration due to the heavy vehicles being monitored. The design shall be such as to withstand this vibration.

The equipment shall meet the relevant requirements in relation to electromagnetic compatibility.

The reference point of the radiation detection assembly shall be clearly marked on the external surface.

For the testing in free air, the orientation of the radiation detection assembly relative to the reference calibration direction shall be given in relation to its enclosure.

Controls and adjustments which affect calibration and alarm settings shall be so designed that access to them can be limited to authorised persons.

Provisions shall be made to permit testing of visual or sound warning indicators.

The equipment should include at least one test point accessible during setting up, preferably in the information treatment assembly, for the connection of a count scaler to determine at any time the processed signals from the radiation detection assembly as required under test procedures.

If the equipment can display signals from each radiation detection assembly as appropriate, the inclusion of a test point is not necessary.

Provisions should be made to allow introduction of a signal input simulating any radiation detection assembly output and, where possible, this should not require access to any radiation detection assembly. These are in addition to the alarm check facilities and may simply be arrangements for the injection of a suitable test signal. Full details of any special test equipment required shall be provided.

☐ Sensors should indicate the approach of the vehicle to inhibit any further storage of background information. Further sensors should indicate the vehicle is in the monitoring position or passing through the monitoring area. ☐

An occupancy sensor should be specified to allow update of ambient background if the equipment is not monitoring.

The manufacturer should state the sensitive area of each radiation detection assembly and the associated detection volume.

☐ Equipment shall be provided with appropriate facilities for indicating faults, for example loss of detector voltage or failure of electronics. The number and type of faults to be indicated shall be by agreement between the manufacturer and purchaser. ☐

4.3 Indication facilities

Prior to monitoring any intended vehicle, the equipment shall be allowed to store the background readings.

The equipment shall be capable of giving at least a local indication and alarm signal.

The alarm shall be activated if at least one of the indications issued from one of the radiation detection assemblies, after treatment and correction of possible disruptive effects, exceeds an alarm threshold.

Indications issued from detection and information treatment assemblies shall correspond to count rates linked to fluence rate of incident photons, eventually corrected of disruptive effects.

These indications shall be accessible during type tests.

The information treatment assembly should be capable of correcting the alarm threshold to take into account the reduction in the background count rate due to the shielding effect of the vehicle and its loading.

The equipment should allow for the capability to store and display time history data. This may be accomplished, for example, by providing outputs for recorders or computers.

☐ It should be possible to transfer these data to an additional remote station at a distance greater than 100 m. ☐ This additional remote station may be a portable computer or processing and display unit. The equipment performance shall be unaffected by and completely independent of any operational mode or malfunction of the remote station.

The equipment should be capable of providing records of vehicle time history data. The record format should be agreed upon between the manufacturer and the purchaser.

4.4 Vehicle speed

Because the performance of the equipment is dependent on the speed of the vehicle being monitored, alarm facilities shall indicate if the average speed of the vehicle is excessive. The monitoring of any vehicle giving a speed alarm is invalid and an indication of this should be given to the operator.

The maximum acceptable speed should be defined by agreement between the manufacturer and the purchaser.

The system of determination of speed shall be designed to remain operational in case of weather precipitation, for example in case of snow.

5 Test procedures

5.1 General test conditions

5.1.1 Nature of tests

Unless otherwise specified in the individual subclauses, all tests enumerated in this standard are to be considered as type tests.

Tests to be performed with only one radiation detection assembly in static mode, linked to information treatment and alarm assemblies:

- measurement of the value of the background without a reference loaded stationary vehicle present;
- measurement of sensitivity in free air at a distance of 1 m from the face of the detection assembly in the plane containing the reference point; if possible also at distances of 0,50 m and 2,50 m;
- verification of the setting of the alarm for given values of activity near the preset alarm threshold;
- overload test.

Tests to be performed with calibration and alarm settings identical to operating mode, with the complete equipment (radiation detection assemblies linked to information treatment and alarm assemblies), in dynamic mode and/or in static mode:

- measurement of the values of the background with and without a reference loaded stationary vehicle present ☐ (see 5.1.6) ☐ ;
- verification of the setting of the alarm for given values of activity buried in reference loading ☐ (see 5.1.6) ☐ .

5.1.2 Reference conditions and standard test conditions

Reference and standard test conditions are given in Table 1. Reference conditions are those conditions to which the performances of the instrument are valid and standard test conditions indicate the necessary tolerances in practical testing. Except where otherwise specified, the tests in this standard shall be performed under the standard test conditions given in the third column of Table 1.

5.1.3 Tests performed under standard test conditions

Tests which are performed under standard test conditions are listed in Table 2. The table indicates, for each characteristic under test, the requirements according to the subclause where the corresponding test method is described. For these tests, the value of temperature, pressure and relative humidity at the time of the test shall be stated and the appropriate corrections made to give the response under reference conditions.

5.1.4 Tests performed with variation of influence quantities

For those tests, intended to determine the effects of variations in the influence quantities given in Table 2, all other influence quantities shall be maintained within the limits for the standard test conditions given in Table 1 unless otherwise specified in the test procedure concerned.

5.1.5 Statistical fluctuations

For any test involving the use of radiation, if the magnitude of the statistical fluctuations of the indication, arising from the random nature of radiation alone, is a significant fraction of the variation of the indication permitted in the test, then sufficient readings shall be taken to ensure that the mean value of such readings may be estimated with sufficient accuracy to demonstrate compliance with the test in question.

The interval between such readings shall be sufficient to ensure that the readings are statistically independent.

5.1.6 Test vehicle

The tests require a vehicle designed so that a radioactive source assembly can be positioned at various reproducible locations, representative of detection in all the volume monitored.

The handling of these radioactive sources shall be performed under appropriate safety conditions.

The vehicle shall be representative of vehicles typically monitored by the equipment tested. The specific configuration and its dimensions may be defined by agreement between the manufacturer and the purchaser.

The manufacturer shall provide the characteristics of the vehicles used for testing.

Recommended vehicles and reference loads are given in Annex A.

The vehicles shall be filled homogeneously with fragments of materials of density and effective atomic number representative of materials to be monitored. For example fragments of steel or of wood (wood for non-metal applications only) should be used.

5.2 Radiation characteristics

5.2.1 Reference gamma radiation

All tests involving the use of gamma radiation, shall be carried out using ^{137}Cs as reference gamma radiation source. The production and conditions of use of the radiation sources shall be in accordance with ISO 4037-1.

5.2.2 Reference radioactive sources

- a) A source or sources of combined activity of 3 MBq to 10 MBq of ^{137}Cs mounted in a capsule of outside diameter less than 50 mm.

☐ These sources have been designed for use with test vehicles defined in 5.1.6, loaded with steel fragments of average density around $1\,000\text{ kg/m}^3$. For other materials or vehicles, the determination of the activity of sources shall be adapted.

These reference radioactive sources shall be used when the equipment is tested with a test vehicle. ☐

- b) A source or sources of combined activity of at least 50 MBq of ^{137}Cs mounted in a lead shielded cylinder of outside diameter less than 10 cm, producing a maximum dose rate of $10\text{ }\mu\text{Gy}\cdot\text{h}^{-1}$ in air at a distance of 30 cm from the centre of the source in any direction.

☐ These reference radioactive sources shall be used when the equipment is tested with a test vehicle. ☐

- c) For tests which do not need any test vehicle, a source of 50 kBq of ^{137}Cs or of ^{60}Co , should be sufficient. An additional source, which emits gamma radiation of low energy, such as ^{241}Am should be used for testing the lowest value of the energy range.
- d) For tests performed with radioactive sources in close contact with the reference point, the level of activity of the source should be given by the manufacturer.

5.2.3 Background effect

The ambient background at which any tests are performed shall be recorded.

5.2.3.1 Requirements

The background shall be recorded before and after every test.

When the equipment is not in use, the count rate from the ambient background shall be recorded to use for correction of the count rate obtained during use.

The manufacturer shall specify the time during which the background counts are integrated, in order to calculate average count rate.

The ambient air kerma rate should be stable and shall be less than $250\text{ nGy}\cdot\text{h}^{-1}$, with a suggested value of $100\text{ nGy}\cdot\text{h}^{-1}$.

The range of ambient background radiation in which the equipment is designed to work without adjustment shall be specified by the manufacturer.

5.2.3.2 Method of test

One radiation detection assembly linked to information treatment and alarm assemblies, is placed in free air. The average background count rates shall be recorded. This reference background shall be used when calculating the sensitivity for sources placed in free air.

The complete equipment, radiation detection assembly linked to information treatment and alarm assemblies, shall be placed in operating configuration.

Before the passage of the test vehicle, values of count rates induced by background shall be recorded and their average value calculated.

During the passage of the test vehicle with or without loading, values of count rates induced by background shall be periodically recorded, and graphically displayed to notice the influence of that vehicle. This vehicle shall be driven at $(5 \pm 2) \text{ km}\cdot\text{h}^{-1}$ as centrally as possible in relation to symmetry of the equipment.

5.2.4 Sensitivity of the radiation detection assembly for radioactive sources placed in free air

5.2.4.1 Requirements

Sensitivity in free air for radiation sources placed in the calibration direction and in the plane containing the reference point at a distance of 1 m and for radiation energy between 50 keV and 1,5 MeV shall be given by the manufacturer.

5.2.4.2 Testing method

The geometrical conditions shall be stated in the certificate.

The radiation detection assembly shall be positioned so that the reference point of the detector is placed to \boxed{C} 2 m \boxed{C} above the ground.

Each source shall be placed in air in front of the reference point. The distance between the source and the reference point of the radiation detection assembly shall be 1 m, with possibility of complementary tests at distances of 0,50 m or 2,50 m.

The test shall be performed for each radiation detection assembly with ^{137}Cs (662 keV). Complementary tests using ^{60}Co (1,17 MeV and 1,33 MeV) should be performed. A source of lower energy such as ^{241}Am should also be used to determine the energy detection threshold.

The activities of these radioactive sources should be at the same level as defined in item c) of 5.2.2.

Indications produced by the equipment shall be recorded.

For each radiation source and for each distance to the reference point of the radiation detection assembly, the results shall be expressed in terms of sensitivity, as the ratio between the net true count rate and the activity of radiation source.

5.2.5 Alarm test with test vehicle

The tests require a vehicle as defined in 5.1.6, designed so that a source assembly defined in item a) or item b) of 5.2.2 can be positioned at various locations.

An example of a test vehicle is shown in Annex A.

The source assembly shall be placed in the loading of the test vehicle, at least at three points in each tube. The vehicle shall then be driven at $(5 \pm 2) \text{ km}\cdot\text{h}^{-1}$ as centrally as possible in relation to the symmetry of the equipment. This shall be repeated ten times or until there has been at least five indications that radioactive substances are present.

The count rates given by the equipment shall be recorded.

If five indications of the presence of radioactive substances are not achieved, the test shall be repeated with the source moved to a location nearer the edge of the vehicle. If five indications are achieved, the source assembly should be moved further from the edge. This shall be repeated until one can determine the furthest location where at least 50 % of the vehicle passes result in an alarm condition.

The manufacturer shall specify the mass per unit of volume of materials between the source and detector assembly under these circumstances.

5.2.6 False alarm test with test vehicle

The test vehicle defined in 5.1.6, loaded with the materials for which it is designed, shall pass at $(5 \pm 2) \text{ km} \cdot \text{h}^{-1}$ as centrally as possible in relation to the symmetry of the equipment, at least 25 times without giving an alarm indicating the presence of radioactivity.

The count rates given by the equipment shall be recorded.

5.3 Overload test

5.3.1 Requirements

For photon fluency rates giving a dose rate greater than $100 \mu\text{Gy} \cdot \text{h}^{-1}$ at the reference point of the detector, the indication of the equipment shall activate the alarm and this alarm shall remain so during such exposure.

The manufacturer shall state the time taken by the equipment to return to the appropriate on-scale readings following the irradiation to this over-exposure. This time shall not be greater than 1 min.

5.3.2 Method of test

a) Testing geometry

The detection assembly should be positioned so that the reference point is placed in geometrical conditions, similar to those described in 5.2.4.2.

The source shall be placed in free air in front of the reference point at a distance at least 0,5 m.

b) Operating mode

The indications issued by the ambient background are recorded.

In this testing geometry, the detection assembly shall be irradiated for at least 2 min with a radiation source of ^{137}Cs whose activity is giving a dose rate greater than $100 \mu\text{Gy} \cdot \text{h}^{-1}$ at a distance of 0,5 m.

In this testing geometry, the alarm shall be activated and it shall remain in this state during all the time of irradiation.

After the reference gamma radiation source is removed, the count rate level indicated by the equipment shall return to within 20 % of the initial readings within 1 min.

5.4 Electrical characteristics

5.4.1 Requirements for power supplies

Mains operated equipment shall be designed to operate from single phase a.c. supply voltage in one of the following categories in accordance with IEC 60038.

- Series I: 230 V.
- Series II: 120 V and/or 240 V.

The equipment shall be capable of operating from mains with a supply voltage tolerance of $+10\%$ -15% and a supply frequency of 47 Hz to 51 Hz or 57 Hz to 61 Hz (in those countries where the frequency is 60 Hz). \square The indicated count rate shall not vary by more than $\pm 5\%$ over this range of supply voltage and frequency. \square

5.4.2 Method of test

Place the radioactive source defined in item c) of 5.2.2 at the reference point. With the supply voltage at its nominal value, take the means of sufficient number of readings.

The count rates given by the equipment shall be recorded.

Take sufficient readings with the supply voltage 10 % above the nominal value and a sufficient number of readings with the supply voltage 15 % below the nominal value. The mean values shall not differ from those obtained with nominal supply voltage by more than $\square \pm 5\% \square$.

These above tests shall be repeated, but instead of changing the voltage, the frequency shall be changed:

- a) from 47 Hz to 51 Hz, and the readings at these frequencies shall not vary by more than $\square \pm 5\% \square$ of the values stated above compared to the readings at 50 Hz, or
- b) from 57 Hz to 61 Hz, and the readings at these frequencies shall not vary by more than $\square \pm 5\% \square$ of the values stated above compared to the readings at 60 Hz.

5.5 Mechanical characteristics

5.5.1 Mechanical shocks

Detection assemblies should be able to withstand, without affecting their performance, mechanical shocks from six directions involving an acceleration of $300 \text{ m}\cdot\text{s}^{-2}$ for a time interval of 18 ms, the shape of the shock being semi-sinusoidal (see IEC 60068-2-27). After this test the assembly should be operating.

The time for the instrument to recover its initial performance shall not exceed 200 s.

\square The detection assemblies should be protected by physical barriers. \square

5.5.2 Vibration test

5.5.2.1 Requirements

\square The count rate shall not vary more than 20 % from a correspondent set of reference indications following harmonic loadings of $2 g_n$ applied for 15 min in the frequency range of 10 Hz to 33 Hz: the physical condition of the equipment shall not be affected by this vibration (for example, solder joints shall hold, nuts and bolts shall not come loose and no alarm shall appear). \square

5.5.2.2 Method of test

Components of the equipment shall be exposed to a source of photon radiation having sufficient intensity to minimise the effect of statistical fluctuations of the equipment indications, such as a radioactive source defined at item c) of 5.2.2 at a distance of 50 cm from the reference point.

The count rates given by the equipment shall be recorded. The mean correspondent indications shall be determined.

The detection assembly shall then be subjected to harmonic loadings of $2 g_n$ for 15 min in each of three orthogonal directions at one or more frequencies in each of the following ranges: 10 Hz to 21 Hz and 22 Hz to 33 Hz. **[C]** No alarm and no physical changes **[C]** shall occur during operation. After each 15 min vibration interval, the mean correspondent equipment indications shall be determined in the same exposure geometry as used initially and compared to the pre-vibration correspondent set of indications.

The equipment shall be inspected and the physical condition documented.

5.6 Environmental characteristics

5.6.1 Ambient temperature

5.6.1.1 Requirements

When the ambient background is measured and the ambient temperature varies from $-25\text{ }^{\circ}\text{C}$ to $+40\text{ }^{\circ}\text{C}$, the variation of the count rate produced by the instrument shall be within 20 % count rate measured at $+20\text{ }^{\circ}\text{C}$.

This variation shall be less than 50 % when the ambient temperature varies from $-25\text{ }^{\circ}\text{C}$ to $+50\text{ }^{\circ}\text{C}$.

5.6.1.2 Method of test

This test shall include indications of count rate induced by ambient background.

This test shall normally be carried out in a climatic box. It is not, in general, necessary to control the humidity of the air in the box unless the instrument is particularly sensitive to changes of humidity. Humidity levels should be low enough to prevent condensation. The rate of change for temperature should not exceed $10\text{ }^{\circ}\text{C}$ per hour.

The temperature shall be maintained at each of its extreme values for at least 4 h and the indication of the equipment measured every 30 min during this period. The limits of variation of indications shall be within the value given in Table 2.

Portions of the system that are intended for installation in a controlled environment may be excluded from this test.

The operating range of this equipment shall be agreed upon between the manufacturer and the purchaser.

5.6.2 Relative humidity

5.6.2.1 Requirements

The variation in the indications due to the effect of relative humidity shall be within 10 % of those values obtained prior to the test, as indicated in Table 2.

5.6.2.2 Method of test

The test shall be carried out at a single temperature of +35 °C using a climatic box, with relative humidity varying from 40 % to 90 %. For this test, the detection assembly shall be switched on. Then the humidity shall be maintained at each of its extreme values for at least 4 h and the indications of the assembly noted every 30 min during this period. The permitted variation in the indications as specified in Table 2, is additional to the permitted variations due to temperature alone.

Portions of the system that are intended for installation in a controlled environment may be excluded from this test.

5.6.3 Sealing

The manufacturer shall state the precautions that have been taken to prevent the ingress of moisture and describe the tests and results used to demonstrate the effectiveness of the sealing where appropriate.

5.6.4 External magnetic fields

5.6.4.1 Requirements

If the indications of an assembly may be influenced by the presence of external magnetic fields, a warning to this effect shall be given by the manufacturer and this shall be stated in the instruction manual.

5.6.4.2 Method of test

This shall be subject to agreement between the manufacturer and the purchaser

5.6.5 Storage

All equipments designed for use in non temperate regions shall be designed to operate within the specification of this standard following storage (or transport), without batteries, for a period of at least three months in the manufacturer's packaging at any temperature between –25 °C and +50 °C. In certain circumstances, more severe specifications may be required such as capability of withstanding air transport at low ambient pressure.

5.7 Electromagnetic compatibility

5.7.1 Radiated electromagnetic fields

5.7.1.1 Requirements

The maximum spurious variation in the count rate from the detection assemblies (both transient and permanent) due to electromagnetic fields shall be less than \boxed{C} 10 % \boxed{C} of the count rate under standard test conditions. There shall also be no change in operating settings.

5.7.1.2 Method of test

Compliance with the performance requirements shall be checked by recording count rates and operating settings with and without the presence of the radio-frequency field around the complete equipment. (For the purpose of this test, and subsequent tests, the equipment can be collected together in a compact fashion and provided all the operational functions can be exactly simulated, the equipment can be reduced to a single detection assembly where more than one would normally be used.)

☐ The electromagnetic field strength shall be 10 V/m in the frequency range 80 MHz to 6 GHz in steps of 1 % (severity level 3 as described in IEC 61000-4-3). To reduce the amount of measurements needed to show compliance with this requirement, tests at 41 frequencies, 80, 90, 100, 110, 120, 130, 140, 150, 160, 180, 200, 220, 240, 260, 290, 320, 350, 380, 420, 460, 510, 560, 620, 680, 750, 820, 900, 1 000, 1 400, 1 500, 1 600, 1 800, 2 000, 2 200, 2 400, 3 000, 5 100, 5 300, 5 500, 5 700 and 5 900 MHz with a field strength of 20 V/m may be performed in one orientation only. ☐

If any change in count rate greater than 5 % of the count rate under standard test conditions is observed at one of these given frequencies, additional tests between ± 5 % around this frequency in steps of 1 % with a field strength of 10 V/m shall be carried out with the equipment in all three orientations described in IEC 61000-4-3. ☐ There shall be no unintended change in the operating settings from before to after the test and no false indications during or after the test. ☐

5.7.2 Conducted disturbances induced by bursts and radio-frequencies

5.7.2.1 Requirements

The maximum spurious variation in the count rate from the detection assemblies (both transient and permanent) due to conducted disturbances induced by bursts and radio-frequencies shall be less than ☐ 10 % ☐ of the count rate under standard test conditions. There shall be no incorrect change in ☐ operating settings. ☐

5.7.2.2 Method of test

Compliance shall be checked by recording count rates and ☐ operating settings ☐, both with and without the presence of conducted disturbances induced by bursts (IEC 61000-4-4) and conducted disturbances induced by radio-frequency fields (IEC 61000-4-6). The severity shall in both cases be level 3 as described in these documents. The count rate shall not vary by more than ☐ 10 % ☐ of the count rate under standard test conditions. ☐ There shall be no unintended change in the operating settings from before to after the test and no false indications during or after the test. ☐

5.7.3 Surges

5.7.3.1 Requirements

The maximum count rate changes (either transient or permanent) shall be less than ☐ 10 % ☐ of the count rate under standard test conditions and there shall be no incorrect change in ☐ operating setting. ☐

5.7.3.2 Method of test

Compliance shall be checked by recording count rates and ☐ operating settings ☐ both with and without the presence of disturbances induced by surges (IEC 61000-4-5). The severity level shall be level 3 as described in this document. The count rate shall not vary by more than ☐ 10 % ☐ of the count rate under standard test conditions. ☐ There shall be no unintended change in the operating settings from before to after the test and no false indications during or after the test. ☐

5.7.4 Voltage dips and short interruptions

5.7.4.1 Requirements

The maximum count rate changes (both transient and permanent) shall be less than ☐ 10 % ☐ of the count rate under standard test conditions and there shall be no incorrect change in ☐ operating setting ☐.

5.7.4.2 Method of test

Compliance shall be checked by recording the count rates and operating setting both with and without the presence of disturbances induced by voltage dips and short interruptions as described in IEC 61000-4-11 except those described in 5.4.2 (voltage variations). The count rate shall not vary by more than \boxed{C} 10 % \boxed{C} of the count rate under standard test conditions. \boxed{C} There shall be no unintended change in the operating settings from before to after the test and no false indications during or after the test. \boxed{C}

6 Documentation

6.1 Type test report

The manufacturer shall make available, at the request of the purchaser, the report on the type tests performed to the requirements of this standard.

6.2 Certificate

A certificate shall be provided with each equipment, including at least the following information in accordance to IEC 61187:

- manufacturer's name or registered trade mark;
- type of the assembly and serial number;
- \boxed{C} types of radiation the assembly is intended to detect \boxed{C} ;
- reference point of the detection assembly;
- locations and dimensions of the sensitive volumes;
- materials of the wall surrounding the sensitive volumes and surface mass of each of them (in g/cm²);
- power supply requirements;
- results of type tests;
- \boxed{C} detailed description of the reference vehicle and reference load used for the testing. \boxed{C}

6.3 Operation and maintenance manual

An operation and maintenance manual containing at least the following information in accordance with IEC 61187 shall be supplied:

- schematic electrical diagrams including spare parts list;
- operational details, maintenance and testing procedures.

Table 1 – Reference conditions and standard test conditions

Influence quantities	Reference conditions (unless otherwise indicated by the manufacturer)	Standard test conditions (unless otherwise indicated by the manufacturer)
Reference gamma radiation source	^{137}Cs ^{b)}	^{137}Cs
Warm-up time	15 min	>15 min
Ambient temperature	20 °C	18 °C to 22 °C ^{a)}
Relative humidity	65 %	50 % to 75 % ^{a)}
Atmospheric pressure	101,3 kPa	96 kPa to 106 kPa ^{a)}
Power supply voltage	Nominal power supply voltage	Nominal power supply voltage ± 1 %
Power supply frequency	Nominal frequency	Nominal frequency ± 1 %
Power supply waveform	Sinusoidal	Sinusoidal with total harmonic distortion lower than 5 %
Gamma radiation background	Air kerma rate 0,1 $\mu\text{Gy}\cdot\text{h}^{-1}$ (10 $\mu\text{rad}\cdot\text{h}^{-1}$)	Less than air kerma rate of 0,25 $\mu\text{Gy}\cdot\text{h}^{-1}$ (25 $\mu\text{rad}\cdot\text{h}^{-1}$)
Electromagnetic field of external origin	Negligible	Less than the lowest value that causes interference
Magnetic induction of external origin	Negligible	Less than twice the value of the induction due to earth's magnetic field
Assembly controls	Set-up for normal operation	Set-up for normal operation
Contamination by radioactive elements	Negligible	Negligible
^{a)} The values in the table are intended for tests performed in temperate climates. In other climates, the actual values of the quantities at the time of test shall be stated. Similarly a lower limit of pressure of 70 kPa may be permitted at higher altitudes.		
^{b)} ^{60}Co may be used as an alternative (see 5.2.2).		

Table 2 – Tests performed with variations of influence quantities

Characteristic under test or influence quantity	Range of values of influence quantities	Limits of variation of indications or of the responses	Method of tests (subclause)
Overload	Air kerma rate > 100 µGy·h ⁻¹ at the reference point	Alarm activated	5.3
Power supply voltage	From 85 % to 110 % of nominal power supply voltage	±5 %	5.4.1
Power supply frequency	From 47 Hz to 51 Hz or 57 Hz to 61 Hz	±5 %	5.4.1
Vibration test	10 Hz to 33 Hz	±20 % and no alarm	5.5.2
Ambient temperature	–25 °C to +40 °C	±20 %	5.6.1
	–25 °C to +50 °C	±50 %	
Relative humidity	40 % to 90 % at +35 °C	±10 %	5.6.2
External magnetic fields	To be stated by the manufacturer	To be stated by the manufacturer	5.6.4
Radiated electromagnetic fields	According to IEC 61000-4-3	±10 %	5.7.1
Bursts and radio- frequencies	According to IEC 61000-4-4 and IEC 61000-4-6	±10 %	5.7.2
Surges	According to IEC 61000-4-5	±10 %	5.7.3
Voltages dips and short interruptions	According to IEC 61000-4-11	±10 %	5.7.4

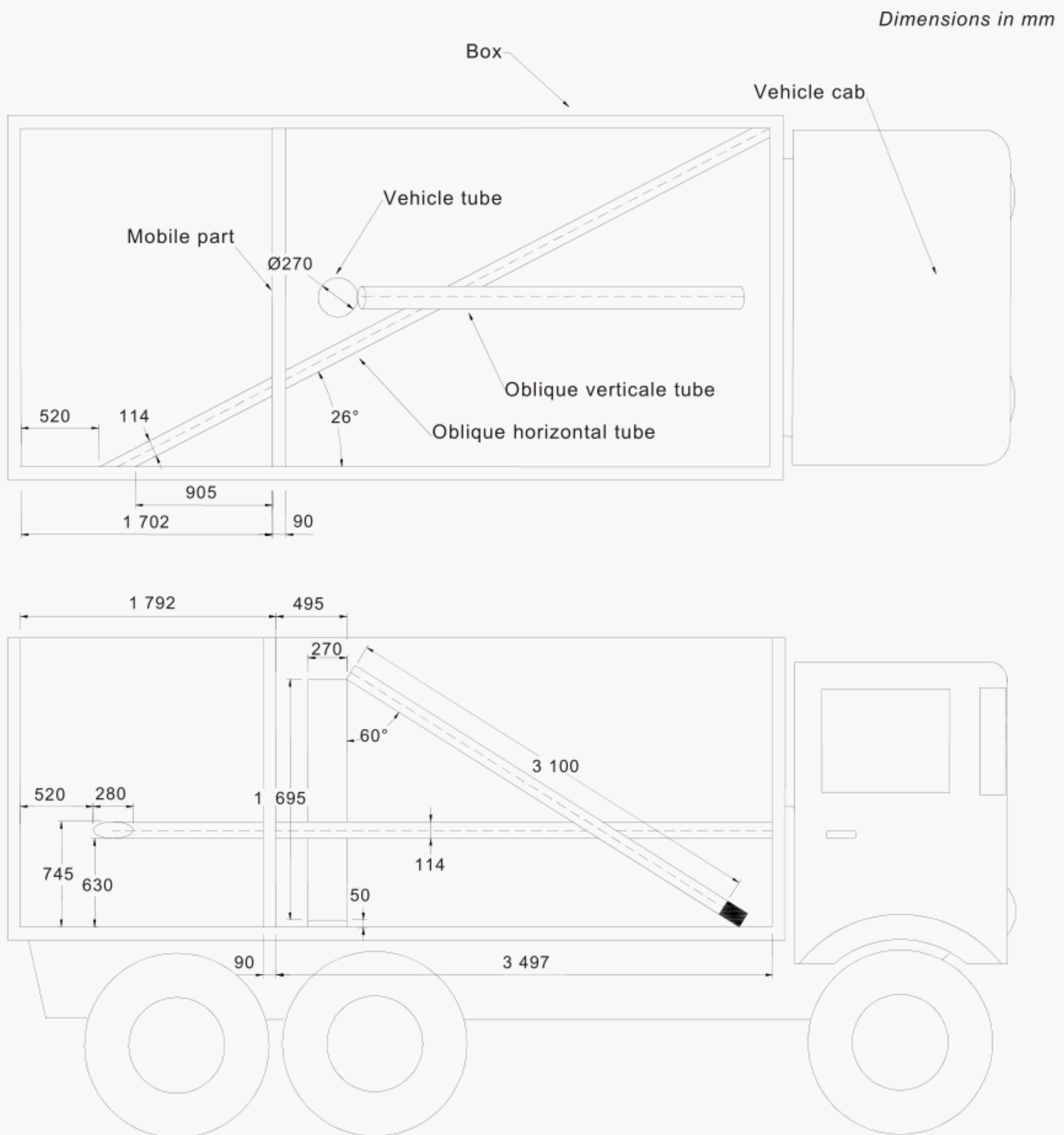
Annex A (informative)

☐ Recommended test vehicles and reference loads ☐

This annex shows examples of test vehicles in compliance with conditions of this standard.

Test vehicles may be replaced by standardized container intended for these tests.

They shall be instrumented to permit a precise and reproducible location of radioactive sources, under appropriate safety conditions, and contain shielding material representative of the loadings mainly monitored by the equipment, homogeneously distributed.

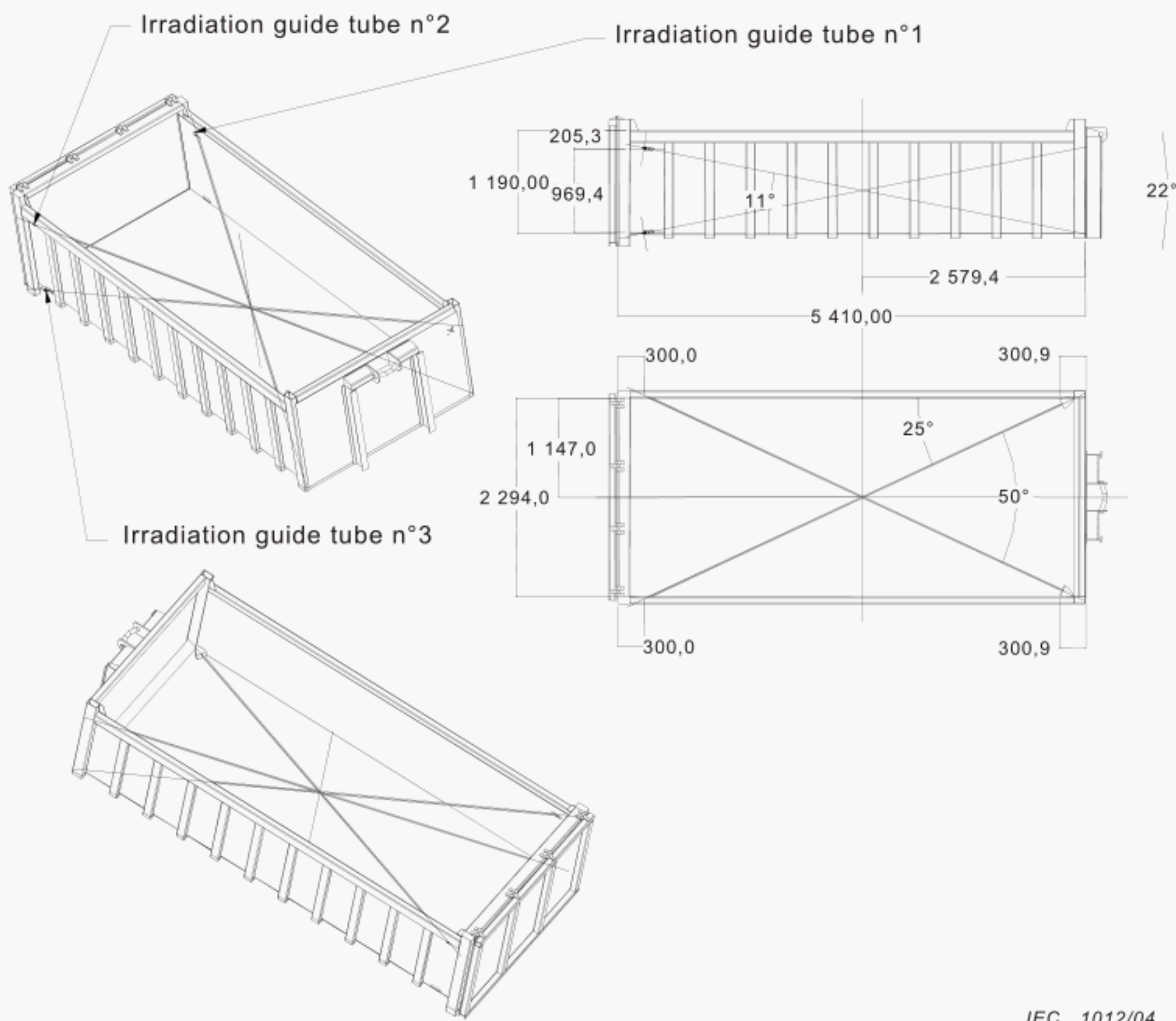


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Figure A.1 – Top view and sectional view of a test vehicle

☐ NOTE Z1 The reference point of the detector is 2 m above ground, see 5.2.4.2. ☐

Dimensions in mm



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Figure A.2 – Container as reference load – alternative to the test vehicle of Figure A.1

Annex ZA (normative)

Normative references to international publications with their corresponding European publications

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

NOTE When an international publication has been modified by common modifications, indicated by (mod), the relevant EN/HD applies.

<u>Publication</u>	<u>Year</u>	<u>Title</u>	<u>EN/HD</u>	<u>Year</u>
IEC 60038 (mod)	1983	IEC standard voltages	HD 472 S1 ¹⁾ + corr. February	1989 2002
A1	1994		-	-
A2	1997		-	-
IEC 60050-151	2001	International Electrotechnical Vocabulary (IEV) - Part 151: Electrical and magnetic devices	-	-
IEC 60050-393	1996	International Electrotechnology Vocabulary (IEV) - Chapter 393: Nuclear instrumentation: Physical phenomena and basic concepts	-	-
IEC 60050-394	1995	International Electrotechnical Vocabulary (IEV) - Chapter 394: Nuclear instrumentation: Instruments	-	-
IEC 60068-2-27	1987	Basic environmental testing procedures - Part 2: Tests - Test Ea and guidance: Shock	EN 60068-2-27	1993
IEC 61000-4-3	2006	Electromagnetic compatibility (EMC) - Part 4-3 : Testing and measurement techniques - Radiated, radio- frequency, electromagnetic field immunity test	EN 61000-4-3	2006
IEC 61000-4-4	2004	Electromagnetic compatibility (EMC) - Part 4-4: Testing and measurement techniques - Electrical fast transient/burst immunity test	EN 61000-4-4	2004
IEC 61000-4-5	2005	Electromagnetic compatibility (EMC) - Part 4-5: Testing and measurement techniques - Surge immunity test	EN 61000-4-5	2006
IEC 61000-4-6	2003	Electromagnetic compatibility (EMC) - Part 4-6: Testing and measurement techniques - Immunity to conducted disturbances, induced by radio- frequency fields	EN 61000-4-6	2007

¹⁾ The title of HD 472 S1 is: Nominal voltages for low voltage public electricity supply systems.

IEC 61000-4-11	2004	Electromagnetic compatibility (EMC) - Part 4-11: Testing and measurement techniques - Voltage dips, short interruptions and voltage variations immunity tests	EN 61000-4-11	2004
IEC 61187 (mod)	1993	Electrical and electronic measuring equipment - Documentation	EN 61187 + corr. March	1994 1995
ISO 4037-1	1996	X and gamma reference radiation for calibrating dosimeters and doserate meters and for determining their response as a function of photon energy - Part 1: Radiation characteristics and production methods	-	-