# IEC 61275

Edition 2.0 2013-05

# INTERNATIONAL STANDARD

# NORME INTERNATIONALE

**Radiation protection instrumentation – Measurement of discrete radionuclides in the environment – In situ photon spectrometry system using a germanium detector**



**Instrumentation pour la radioprotection – Mesure de radionucléides discrets présents dans l'environnement – Système de spectrométrie gamma in situ utilisant un détecteur au germanium**



IEC 61275:2013

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International Standard IEC 61275 has been prepared by subcommittee 45B: Radiation protection instrumentation, of IEC technical committee 45: Nuclear instrumentation.

This second edition cancels and replaces the first edition issued in 1997. It constitutes a technical revision.

The main technical changes with regard to the previous edition are as follows:

– update the terminology to encompass the latest technologies,
– revise test methods to account for methodological developments and performance criteria with the latest HPGe detector technologies and digital electronics.

The text of this standard is based on the following documents:

| FDIS | Report on voting |
|---|---|
| 45B/762/FDIS | 45B/769/RVD |

Full information on the voting for the approval of this standard can be found in the report on voting indicated in the above table.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

# RADIATION PROTECTION INSTRUMENTATION – MEASUREMENT OF DISCRETE RADIONUCLIDES IN THE ENVIRONMENT – *IN SITU* PHOTON SPECTROMETRY SYSTEM USING A GERMANIUM DETECTOR

## 1 Scope and object

This International Standard is applicable to a portable or transportable photon spectrometry assembly using a high purity germanium (HPGe) detector to survey, *in situ*, generally at 1 m above ground level, areas in the environment for discrete radionuclides. Such equipment is used to make rapid assessments of activity levels and corresponding free air exposure rates from photon emitting radionuclides. Such measurements may be used to develop guidance for subsequent follow-up action, for example including radiological assessments, sampling and monitoring programmes. (This standard does not apply to mobile measurement systems that are covered by a separate standard. See IEC 62438.)

This standard specifies for such an assembly the general characteristics and test methods for evaluating radiation, electrical, mechanical, safety and environmental characteristics specific to the applications described above. Advice is also provided in annexes as to the calibration, appropriate use and interpretation of the system for *in situ* measurements.

An *in situ* spectrometry system is a combination of instruments or assemblies designed to measure, *in situ*, the fluence of gamma-rays incident on the detector, in order to rapidly survey areas for discrete radionuclides present in the soil or air, either natural or manmade.



The purpose of this standard is to specify the performance characteristics of assemblies intended for the determination of surface soil activity.



Accordingly, this standard

a) specifies the functions and performance characteristics of measuring assemblies; and

b) specifies the methods of testing compliance against the requirements of this standard.

## 2 Normative references

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

IEC 60068 (all parts), *Environmental testing*

IEC 61010-1, *Safety requirements for electrical equipment for measurement, control and laboratory use – Part 1: General requirements*

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

IEC 62438:2010, *Radiation protection instrumentation – Mobile instrumentation for the measurement of photon and neutron radiation in the environment*

ISO 4037 (all parts), *X and gamma reference radiation for calibrating dosimeters and dose ratemeters and for determining their response as a function of photon energy*

## 3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

NOTE The general terminology concerning detection and measurement of ionizing radiation, nuclear instrumentation and germanium detectors is given in IEC 60050-393, IEC 60050-394 and IEC 60973.

### 3.1 Definitions

**3.1.1**
**angular response**
the variation in response to a radionuclie of interest when it is moved in a fixed radius from the assembly through angle **theta** from the normal (usually $\theta$ = 0°; see Figure 1)

Note 1 to entry: For cylindrical detectors it is only necessary to do this in a single plane.

**3.1.2**
**coefficient of variation**
the ratio $V$ of the standard deviation $s$ to the arithmetic mean $\bar{x}$ of a set of $n$ measurements of $x_i$, given by the following formula:

$$V = \frac{s}{\bar{x}} = \frac{1}{\bar{x}} \sqrt{\frac{\sum_1^n (x_i - \bar{x})^2}{n-1}}$$



[SOURCE: IEC 60050-394:2007, 394-40-14]



**3.1.3**
**collimation**
shielding used to systematically reduce the angular response and thus field of view of a detector



**3.1.4**
**detection threshold**
**lower detection limit**
value of the indication of the measurement for which the relative random uncertainty equals ± 100 % at the probability level of 95 %

[SOURCE: IEC 60050-394:2007, 394-40-20]

**3.1.5**
**effective range of measurement**
range of values of the quantity to be measured over which the performance of an assembly meets the requirements of this standard

**3.1.6**
**energy calibration function**
the function required to convert channel number to gamma-ray energy (keV)

**3.1.7**
**energy resolution**
the range in keV over which the response is greater that 50 % (Full Width at Half maximum – FWHM) at a defined energy peak

**3.1.8**
**field of view**
the area and volume of soil "viewed" by detector (effective sample size), usually defined as the radial distance from which 90 % of the total incident gamma-ray fluence is derived

**3.1.9**
**internal background**
the count rate (counts per unit time) due to gamma-rays emitted from radionuclides intrinsic to the detector assembly

**3.1.10**
**N-type detector**
a HPGe detector with the ion implanted surface or rectifying surface being the P+ surface that is usually the outer surface of a detector crystal

**3.1.11**
**P-type detector**
a HPGe detector with the ion implanted surface or rectifying surface being the N+ surface that is usually the outer surface of a detector crystal

**3.1.12**
**portable system**
a system that can be carried by one or two persons and with which field measurements can be made while stationary or being carried. The system is completely battery-operated.



**3.1.13**
**relative efficiency**
The ratio, expressed in percentage, of the count rate in the 1 333 keV total absorption peak of $^{60}$Co to the corresponding one obtained with a 76 mm × 76 mm NaI(Tl) scintillator for normal incidence and at 25 cm from the source



**3.1.14**
**relative uncertainty of an indication**
the relative uncertainty, $I$, of the indication of an assembly is given, as a percentage, by the relationship:

$$I = \frac{(H_i - H_t)}{H_t} \times 100\ \%$$

where

$H_i$ is the indicated value and $H_t$ the conventionally true value.

**3.1.15**
**reference point of an assembly**
a physical mark or marks on the assembly to be used in order to position it at a point where the conventionally true value of the quantity to be measured is known. Generally, this point is taken to be the location of the face of the germanium detector but will be dependent on the exact construction of the detector assembly.

**3.1.16**
**reference soil**
an area of soil of extent greater than 10 m diameter for which the activity of particular radio-nuclides has been well characterized as to concentration (Bq/kg) and distribution with depth

**3.1.17**
**response**
the response, $R$, of an assembly is the ratio of the indicated value $H_i$ of the incident fluence at a given photon energy as inferred from the full energy peak area to the conventionally true value $H_t$ of the incident fluence. This may also be inferred to mean efficiency.

**3.1.18**
**transportable system**
a system that may be mounted in a vehicle, and is connected to the detector via a long signal cable. The system generally uses an external power source and cannot be easily carried by a single person.

### 3.2 Test nomenclature

**3.2.1**
**qualification test**
test performed in order to verify that the requirements of a specification are fulfilled. Qualification tests are divided into type tests and routine tests.

**3.2.2**
**type test**

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

[SOURCE: IEC 60050-394:2007, 394-40-02]



**3.2.3**
**routine test**
conformity test made on each individual item during or after manufacture



[SOURCE: IEC 60050-394:2007, 394-40-03]

**3.2.4**
**acceptance test**
contractual test to prove to the customer that the device fulfills certain specifications

[SOURCE: IEC 60050-394:2007, 394-40-05]

## 4 General requirements

### 4.1 Basic components

A complete *in situ* photon spectrometry system consists of a number of individual subsystems or instruments. The individual components are generally not unique in that the same components may all be routinely used in other field and laboratory gamma-ray counting systems. Their use *in situ*, as part of a special integrated portable or transportable system, requires stringent environmental and mechanical qualifications as well as special electrical, mechanical, and safety considerations not generally required for routine laboratory use. All individual components including preamplifier, spectroscopy amplifier, power supply, data acquisition and storage system, shall satisfy all applicable IEC standards governing their normal manufacture and usage as well as the particular requirements of this standard. Their use as an *in situ* system also requires special calibrations and careful interpretation of results. Usually the assembly comprises the following components:

a) a gamma-ray detector, HPGe N-type or P-type detector (the detector includes an integral cryostat and internally cooled charge-sensitive preamplifier);

b) a spectroscopy amplifier and high-voltage (HV) power electronics;

c) data processing equipment that includes data acquisition capability, data recording capability and visual display; it may be based on a multi-channel analyzer (MCA) with a minimum of 4 096 channels, personal computer with built-in MCA capability or other comparable devices;

d) a system power supply (see 9.4);

e) all necessary connecting cables;

f) a tripod or other type of support to mount the detector at a fixed height above the ground in the field during acquisition of a gamma-ray spectrum;

g) a detector cooling system, which needs to be either a liquid nitrogen storage system (cryostat and dewar) or an electromechanical cooler for maintaining the Ge crystal at correct operating temperature;

h) a lightweight rugged, stable platform for mounting the detector at a fixed height above ground shall be provided. The height and orientation of the mount should be repeatable. The manufacturer shall state the effect of the mount position relative to the field of view and the mass of material in the mount.

### 4.2 Examples of detector types

In a rapid survey of limited areas for discrete radionuclides, a portable system consisting of a hand-held HPGe detector-cooler assembly and a portable data processing assembly (generally a stand-alone or PC-based MCA with built-in detector bias HV and spectroscopy amplifier) is recommended. For applications where portability is not essential, a transportable system can be used. Transportable systems might, for example, consist of separate MCA, electronics and power supply modules mounted inside a vehicle connected by an umbilical cable to a HPGe detector in the field. For some applications, the detector may even be mounted on the vehicle (refer to IEC 62438). Where survey work requires the detection of low energy gamma-ray, below 100 keV and down to 3 keV, an N-type detector or specially adapted P-type detector with a suitable beryllium or carbon fibre window may be more suitable than a standard P-type detector encased in aluminum.



## 5 Classification of the performance characteristics

The limits of variation in the indication of an assembly are specified for each performance characteristic in Tables 1 to 5 and in the appropriate subclauses. For some applications it may not be deemed essential for an assembly to meet all the requirements set out below. In such cases, the requirements to be applied to the assemblies may be specified by agreement between the manufacturer and the purchaser, but the determination of the characteristics of the assemblies shall conform to the methods given in the present standard.

If the mass, overall dimensions and construction of the instrument does not permit the testing of the complete system as a whole by means of the existing test equipment, each component may be tested separately in conformity with the present standard followed by a complete check of the entire system under normal operating conditions. The procedure used for the test shall be specified.

## 6 General characteristics

### 6.1 Indication

The indications of the assembly shall be in units of counts per channel and total counts in selected total absorption peaks per unit time. The full spectrum, typically from 20 keV to 2 700 keV, should be accessible and energy calibrated to enable easy identification of radionuclides. The indications of the assembly shall also be in units of activity per unit area or mass for a given nuclide, for example $Bq \cdot m^{-2}$ or $Bq \cdot kg^{-1}$ for selected or defined depth profile(s), as agreed upon between the purchaser and the manufacturer.

### 6.2 Effective range of measurement of an assembly

When the test methods do not extend over the entire effective range of measurement and any of the observed variations are near the permitted limit, further tests to demonstrate compliance with the requirement in question over the whole effective range of measurement may be necessary. Such further tests shall be the subject of agreement between the manufacturer and the purchaser. For these systems the effective range of measurement is determined primarily by the characteristics of the analog to digital conversion (dead time) and pile-up of pulses in the amplifier and shall be specified by the manufacturer.

### 6.3 Detector cooling

The detectors should be maintained at a temperature between 80 K and 100 K and should be capable of at least 8 h of continuously uninterrupted use. The manufacturers should specify the cool down time.

### 6.4 Detector type

For maximizing low energy (E) detection (e.g., from $^{241}$Am 60 keV photons), an N-type or special modified P-type germanium detector should be preferred over a P-type detector.

### 6.5 Detector housing

The housing shall be designed to minimize the attenuation of gamma-ray and the intrinsic background. If found necessary, to minimize further the attenuation of low energy incident gamma-rays, an entrance window, typically beryllium or carbon of thickness less than 0,3 mg·cm$^{-2}$, shall be used. The maximum thickness of the entrance window shall be such that the attenuation of 1 333 keV gamma-rays incident axially ($\theta = 0$) shall be less than 2 %.



### 6.6 Detector window



The detector window should be designed to minimize the possibility of damage or breakage. If Be is used, instructions shall be provided for the safe handling of Be.

### 6.7 Ease of decontamination

The assembly shall be designed and constructed in such a manner as to facilitate decontamination.

### 6.8 Safety considerations

The instruments shall comply with the safety requirements of IEC 61010-1.

### 6.9 Calibration

The requirements to calibration should be specified by agreement between the manufacturer and the purchaser, but calibration recommendations is represented in Annex A.

## 7 General test procedures

### 7.1 Nature of tests

Unless otherwise specified in the individual clauses, all the tests enumerated in this standard shall be considered type tests (see 3.3.1). Certain tests may be considered acceptance tests by agreement between the manufacturer and the purchaser (see 3.3.1).

### 7.2 Reference conditions and standard test conditions

Reference conditions are given in the second column of Table 1. Except where otherwise specified, the tests in this standard shall be carried out under the standard test conditions given in the third column of Table 1.

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

### 7.3 Position of assembly for purposes of tests

For all tests involving the use of radiation, the reference point of the assembly (see 3.16) shall be placed at the point where the conventionally true value of the quantity to be measured is known, and in the orientation of the assembly indicated by the manufacturer.

### 7.4 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.



### 7.5 Low-level measurements

For the measurement of low levels of radioactive materials, it is necessary to take into account of the contribution of background radiation from the instrument assembly to the indication at the point of test (Annex E).



### 7.6 Reference radiation

Unless otherwise specified in the individual methods of test, all tests involving the use of gamma-ray radiation shall be carried out with the nuclide $^{60}$Co or $^{137}$Cs (see Table 1). The nature, construction and conditions of use of the radiation sources shall be in accordance with ISO 4037.

## 8 Radiation tests

### 8.1 Variation of response with photon radiation energy

#### 8.1.1 Requirements

The indication of the assembly when exposed to photon radiation point sources in the calibration direction and of energy between 60 keV and 2 500 keV shall not differ from the conventionally true value of the fluence of photons from such sources by more than the following limits:

60 keV to 300 keV: ± 10 %

300 keV to 2 500 keV: ± 5 %