IEC 62957-1

Edition 1.0 2017-09

INTERNATIONAL STANDARD

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Radiation protection instrumentation – Semi-empirical method for performance evaluation of detection and radionuclide identification –
Part 1: Performance evaluation of the instruments, featuring radionuclide identification in static mode

Instrumentation pour la radioprotection – Méthode semi-empirique pour l'évaluation des performances de détection et d'identification de radionucléides –
Partie 1: Evaluation de la performance des instruments avec l'identification des radionucléides en mode statique

IEC 62957-1:2017-09(en-fr)

IEC Central Office
3, rue de Varembé
CH-1211 Geneva 20
Switzerland

Tel.: +41 22 919 02 11
Fax: +41 22 919 03 00
info@iec.ch
www.iec.ch

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

COMMISSION ELECTROTECHNIQUE INTERNATIONALE

ICS 13.280

ISBN 978-2-8322-4822-5

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Part 1: Performance evaluation of the instruments, featuring radionuclide identification in static mode

FOREWORD

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International Standard 62957-1 has been prepared by subcommittee 45B: Radiation protection instrumentation, of IEC technical committee 45: Nuclear instrumentation.

The text of this International Standard is based on the following documents:

FDIS	Report on voting
45B/876/FDIS	45B/880/RVD

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

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

A list of all parts in the IEC 62957 series, published under the general title *Radiation protection instrumentation – Semi-empirical method for performance evaluation of detection and radionuclide identification*, can be found on the IEC website.

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

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- withdrawn,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

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INTRODUCTION

There are known challenges associated with the application of traditional methods[1] for the performance evaluation of instruments used for the detection and identification of radionuclides. These challenges mainly originate from test logistics and the resources required for qualification type pass/fail tests.

As an alternative approach, a semi-empirical performance evaluation method has been developed [1][2]. The concept of this technique, also known as injection study, is based on computerized interpretation of detection or identification reports, obtained by injection of processed data into instrument–specific replay software for detection or radionuclide identification. The method does not prohibit the use of synthetic data if experimental data is not available.

While remaining reasonably accurate, semi-empirical methods do not require significant resources for performance evaluation. In some applications, where full scope performance testing is not feasible or practical, the use of semi-empirical methods can provide reasonable confidence in the instrument performance. By no means are semi-empirical methods meant to fully replace traditional tests, but rather to complement them.

It is envisioned that this standard will comprise three parts. Part 1 of the standard is specific to the performance evaluation of radionuclide identification in static mode, i.e. when measurement geometry does not change.

Future parts of the standard will address detection and radionuclide identification in dynamic scenarios.

1 Instrumental tests.

2 Numbers in square brackets refer to the Bibliography.

RADIATION PROTECTION INSTRUMENTATION – SEMI-EMPIRICAL METHOD FOR PERFORMANCE EVALUATION OF DETECTION AND RADIONUCLIDE IDENTIFICATION –

Part 1: Performance evaluation of the instruments, featuring radionuclide identification in static mode

1 Scope

This part of IEC 62957 specifies requirements for data preparation and data injection when using the semi-empirical method for performance evaluation of detection and radionuclide identification. This document recommends approaches for results interpretation and consolidation and establishes a method to share data and analysis results.

This part 1 of the standard is specific to the performance evaluation of radionuclide identification in static mode, i.e. when measurement geometry does not change (e.g. radionuclide identification devices in start-stop mode).

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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 60050-395:2014, *International Electrotechnical Vocabulary (IEV) – Part 395: Nuclear instrumentation: Physical phenomena, basic concepts, instruments, systems, equipment and detectors*

IEC 62755:2012, *Radiation protection instrumentation – Data format for radiation instruments used in the detection of illicit trafficking of radioactive materials*

ISO 8601:2004, *Date and time format*

3 Terms, definitions and abbreviated terms

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60050-395 apply, as well as the following.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp

3.1.1
acceptable response table
list of expected radionuclide identification result(s) reported by the instrument or its replay software

3.1.2
base material
radioactive material that contains one or several radionuclides of known isotopic composition

3.1.3
base material composition table
list of radionuclide(s) that are present in each of the base materials in a sufficient quantity for radionuclide identification by gamma-ray spectrometry

3.1.4
base spectrum
processed raw spectrum used as an input for the generation of sample spectra

3.1.5
confidence index
measure provided by the instrument of the reliability assigned to the radionuclide identification results

Note 1 to entry: Higher values indicate a higher likelihood of the presence of the radionuclide(s), or group of nuclide(s).

3.1.6
confidence index threshold
minimum level of reliability of the radionuclide identification result (i.e. minimum value of the corresponding confidence index) that is required for an isotope to be indicated as present

3.1.7
distortion model
result of distortion modelling evaluation, generally a formula describing how spectra from a given instrument model are affected by a given non-ideal environmental condition

3.1.8
distortion modelling
evaluation of the functional relationship between pulse heights in the non-distorted and distorted spectra acquired under specific environmental, electromagnetic, or other conditions

3.1.9
false negative result
detection or radionuclide identification result that was not reported although it was expected to be

3.1.10
false positive result
detection or radionuclide identification result that was reported although it was expected not to be

3.1.11
detection (identification) report
file containing all detection (radionuclide identification) results generated by an instrument's replay software upon injection of a sample spectrum

3.1.12
identification result
name of a radionuclide or aggregate material which has been identified. It is one item of the identification report

3.1.13
influencing factor
quantity that is not the measurand but that affects the result of the measurement

3.1.14
injection
process of submitting processed data (sample spectra) to the replay software for detection and/or radionuclide identification

3.1.15
raw spectrum
gamma ray spectrum of base material obtained with high statistical accuracy by the instrument under evaluation

3.1.16
replay software
software that utilizes the detection and/or radionuclide identification analysis algorithm of a particular instrument model on the computer used for injection to create a detection or identification report corresponding to an injected sample spectrum

3.1.17
sample spectrum
instrument–specific amplitude spectrum produced by processing one or more base spectra for injection

3.1.18
scenario
description of the test conditions

Note 1 to entry: for example:

- presence of one or several base material(s) and the given ambient gamma dose equivalent rate for each;
- acquisition time;
- presence of influencing factor(s).

3.1.19
semi-empirical performance evaluation
process of injection of the processed measured data into the instrument–specific replay software for analysis followed by computerized interpretation and consolidation of the results

3.1.20
sensitivity
ratio of the net total count rate (cps) to the known ambient gamma dose equivalent rate (μSv/h) due to exposure to the given base material by independent means obtained either by calculation or by measurement using a calibrated instrument

3.2 Abbreviated terms

ASCII	American standard code for information interchange
cps	counts per second
EMI	electromagnetic interference
MCA	multichannel analyser
HEU	highly-enriched uranium
LEU	low-enriched uranium
NORM	naturally occurring radioactive materials
PET	positron emission tomography

PMMA polymethyl methacrylate

FN false negative

FP false positive

RGPu reactor grade plutonium

WGPu weapons grade plutonium

XML extensible markup language

UTF universal character set transformation format

4 General requirements

The semi-empirical performance evaluation method shall consist of the following steps:

– base material characterization and acquisition of raw spectra;
– generation of base spectra from raw spectra;
– distortion modelling;
– generation of the sample spectra according to predefined scenarios;
– injection of the sample spectra into the replay software;
– interpretation and generalization of the radionuclide identification results;
– validation.

Guidance for choosing the base materials can be taken from the relevant standards (e.g. IEC 62327 [3]).

The base spectra, base material composition table, distortion model and replay software shall meet the requirements of this document. The manufacturer shall provide the full list of all possible messages (e.g. identification results) which might appear as the results of radionuclide identification along with a detailed explanation of the meaning of each message. This will enable interpretation of the identification results. One or more instruments shall be used for experimental validation of the semi-empirical performance evaluation results.

A detailed description of the process and relevant requirements are given in the following clauses.

NOTE This method does not account for pileup or increased dead time due to high count rates.

5 Base material characterization and acquisition of input data

5.1 General

The semi-empirical performance evaluation method initially requires base material characterization and input data acquisition. Input data consists of raw spectra and static efficiencies for the instrument(s) under evaluation.

5.2 Base material characterization requirements

All base materials shall be characterized with a high-resolution gamma spectrometer to assess their radionuclide composition. Characterization spectra shall be formatted according to IEC 62755 and provided by the manufacturer, or organization owning the base material, along with the date on which the spectrum was taken. Care should be taken that the base materials do not show significant impurities. If the base material has impurities that can be identified by the instrument, then those radionuclides might appear in the replay software or instrument identification results, and shall be accounted for in the base materials list. Information on sources used should be provided and distributed with the corresponding base spectra. This will include relevant information such as mass, shape, density and chemical composition (e.g. metal or oxide).

5.3 Base material composition table requirements

The manufacturer or owner of the base material shall provide a base material composition table describing the radionuclide composition of each base material and the measured and validated activity of each source, along with the measurement's date and uncertainty of the measured activity. For the purpose of naming base materials that contain significant quantities of daughter elements, the name of the parent radionuclide shall be used. An example base material composition table is given in Annex A.

5.4 Raw spectra requirements

Raw spectra shall be collected for each base material, including natural radiation background, using the instrument under evaluation. To the extent possible, the same instrument should be used throughout the collection effort.

Conditions for acquisition of the raw spectra shall, to the extent possible, be similar to static operational conditions. Commerce material containing NORM shall be used in bulk form to account for radiation scattering and self-absorption processes.

6 Generation of base spectra from raw spectra

6.1 General

Radiation background shall be subtracted from all spectra, except the spectrum of natural radiation background. Prior to this subtraction, the spectra shall be adjusted to account for differing live times and re-binned as needed to account for any gain shifts. The background subtracted spectrum for each base material becomes the base spectrum. Each base spectrum shall be typical for the model being used (e.g. consideration of differences in energy resolution, low-level discriminators and variation in calibrations).

Base spectra should be named according to Annex B. They should be formatted according to IEC 62755. An example is given in Annex B.

All base spectra shall be defined over the same number of MCA channels and shall have the same energy calibration.

If the instrument under evaluation is designed to identify shielded radionuclide(s), the base spectra of shielded material should be obtained.

Whenever possible, the ambient gamma dose equivalent rate produced by the base material at the instrument under evaluation should be at least 10 times greater than that of background.

Acquisition times for raw spectra shall be adjusted such that the base spectra they are processed into contain at least ten times the number of counts contained in any individual sample spectrum expected to be generated from them. This should be according to the formula:

$$D_0 \, T_0 \geq 10 \, D_s \, T_s \tag{1}$$

Where:

D_0 is the dose rate produced by the base material at the distance at which the base spectrum was collected;

T_0 is the live time of the base spectrum;

D_s is the maximum dose rate to be simulated in the sample spectra;

T_s is the maximum live time to be simulated in the sample spectra.

Care should be taken to ensure that the dead time is as low as possible to avoid pileup, but no more than 2 %. As these raw spectra are collected over long periods of time, care should also be taken to avoid conditions which can lead to gain shifts.

6.2 Base spectra data element requirements

The following data elements shall be included in each base spectrum:

- <RealTimeDuration>: Real time in the format “PT1H15M05.2S”, “PT75M5.2S”, or “PT4505.2S”.
- <LiveTimeDuration>: Live time in the format “PT1H15M05.2S”, “PT75M5.2S”, or “PT4505.2S”.
- <EnergyCalibration>: Energy calibration information that spectrum measurements can reference as applicable to a particular spectrum. There are two methods available for providing energy calibration information: either in the form of a second-order polynomial equation in which the *CoefficientValues* child element shall be specified, or in a table in which the *EnergyBoundaryValues* child element shall be specified. Only one of the two methods applies to a particular energy calibration. The *EnergyDeviationValues* and *EnergyValues* child elements provide a means to account for the difference in the energy predicted by the second-order polynomial equation and the true energy.
- <DoseRateValue>: The measured ambient radiation dose equivalent rate value in µSv/h.
- <ChannelData>: A list of values, one for each of a spectrum’s channels. The values represent the number of counts per channel.
- <Sensitivity>: a ratio of the net total count rate (cps) to the known ambient gamma dose equivalent rate (µSv/h) due to exposure to the given base material by independent means obtained either by calculation or by measurement using a calibrated instrument. Parent element: <Measurement>.
- <StartDateTime>: Time corresponding to the start of the collection of the data contained in the base spectrum. This should be in the format “2004-11-03T14:36:04.3-06:00”, where “-06:00” represents the difference between universal coordinated time and local time.

For the time format, the number preceding “H” gives the hours of the measurement duration, the number preceding “M” gives the minutes of the measurement duration and the number preceding “S” gives the seconds of the measurement duration. This duration can be expressed with hours, minutes and seconds or can be expressed as minutes and seconds or seconds only. This is according to ISO 8601.

Additionally, the following data elements should be recorded:

- <RadDetectorName>: The name of the radiation detector.
- <Nuclide>: The radionuclide used to obtain the base spectrum.

- Neutron counts: Number of neutron counts collected over the duration of the measurement. This should be stored under a <GrossCounts> tag as in the following example:

  <GrossCounts id=“M112N” radDetectorInformationReference=“Neutron”>

  <LiveTimeDuration>PT3.08</LiveTimeDuration>

  <CountData>2</CountData>

  </GrossCounts>

6.3 Sensitivity requirements

The sensitivity of the instrument to the given base material shall be obtained with an uncertainty of less than 20 % (with a confidence level of 95 %).

The position of the instrument under evaluation shall be determined based on accuracy requirements. The instrument’s orientation with respect to the source shall be the same as how it is intended to be used in the field. Raw spectra shall be acquired at a count rate where the effects of pile-up are negligible.

The sensitivity shall be calculated according to formula (2).

$$Sensitivity = \frac{net\_count\_rate\ (cps)}{ambient\_gamma\_dose\_equivalent\_rate\ (\mu Sv/h)} \quad (2)$$

Obtained sensitivities for each base material shall be included in the base spectra under the element <Sensitivity> as shown in Clause B.2.

7 Distortion modelling

7.1 General requirements

To assess an instrument’s tolerance to specified influencing factors, distortion modelling should be obtained. Distortion is defined as the change in position of the peaks in the spectrum due to influencing factors. Some common influences affecting the instrument’s energy scale are temperature, magnetic field and high count rate. Other influences can be modelled as desired.

The file containing the parameters of the distortion model shall be named and formatted according to Annex C.

7.2 Acquisition of model parameters

The generic process of distortion modelling is as follows:

– Establish the reference peak centroid values from the spectra under normal test conditions[3]; At a minimum, three peaks, covering nearly the full energy range shall be used for the modelling (e.g. 59,5 keV from ^{241}Am, 661,5 keV from ^{137}Cs, and 2 614 keV from ^{232}Th decay chain).

– Keeping all other conditions the same as that for the reference spectra expose the instrument to the influence and obtain influence spectra using the same process as that used to establish reference spectra.

3 Conditions established in the standard applicable to the instrument type.