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INTERNATIONAL STANDARD

NORME INTERNATIONALE

Nuclear instrumentation – Housed scintillators – Test methods of light output and intrinsic resolution

Instrumentation nucléaire – Scintillateurs montés – Méthodes d'essai de lumière sortante et de résolution intrinsèque

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NUCLEAR INSTRUMENTATION – HOUSED SCINTILLATORS – TEST METHODS OF LIGHT OUTPUT AND INTRINSIC RESOLUTION

FOREWORD

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International Standard IEC 62372 has been prepared by IEC technical committee 45: Nuclear instrumentation.

This second edition cancels and replaces the first edition published in 2006. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

- Title has been modified.
- To review the existing requirements and to update the terminology, definitions and normative references.

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

FDIS	Report on voting
45/913/FDIS	45/915/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.

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- withdrawn,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.

NUCLEAR INSTRUMENTATION – HOUSED SCINTILLATORS – TEST METHODS OF LIGHT OUTPUT AND INTRINSIC RESOLUTION

1 Scope

This document is applicable to housed scintillators for registration and spectrometry of alpha-, beta-, gamma-, X-ray and neutron radiation.

The main parameters, such as a light output and intrinsic resolution are established. This document specifies the requirements for the testing equipment and test methods of the basic parameters of housed scintillators, such as:

- the direct method is applicable to measure the light output of housed scintillators based on scintillation material. The housed scintillators certified by this method can be used as working standard of housed scintillators (hereinafter: working standard) when performing measurements by a relative method of comparison.
- the relative method of comparison with the working standard is applicable to housed scintillators based on the same scintillation material as the working standard.

This document does not apply to gas or liquid scintillators and scintillators for counting and current modes.

The numerical values of the parameters are set to the specific type of scintillators in the specifications.

2 Normative references

There are no normative references in this document.

3 Terms, definitions, symbols and abbreviated terms

3.1 Terms and definitions

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

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
scintillator
luminescent material, usually liquid or solid, showing radioluminescence with a short afterglow

[SOURCE: IEC 60050-845:1987, 845-04-37]

3.1.2
housed scintillator
scintillator, housed in a container with a reflector and optical window

3.1.3
scintillation detector
radiation detector consisting of a scintillator that is usually optically coupled to a photosensitive device, directly or through light guides

Note 1 to entry: The scintillator consists of a scintillating material in which the ionizing particle produces a burst of luminescence radiation along its path. A common scintillator is NaI(Tl).

[SOURCE: IEC 60050-395:2014, 395-03-01]

3.1.4
assembly
light protective chamber containing a housed scintillator, photomultiplier (PMT), PMT voltage divider

Note 1 to entry: Assembly is used for testing of the housed scintillator.

3.1.5
light yield
η
ratio of scintillation photons summed energy (E_p) to energy (E) lost by ionizing particles in the scintillator

$$\eta = \frac{E_p}{E}$$

Note 1 to entry: Value of η depends on type and energy of ionizing particle.

3.1.6
light output
C
ratio of total energy (L_{ph}) of scintillation photons, which pass through the output window of the housed scintillator of ionizing radiation, to energy (E), lost by ionizing particles in the scintillator

$$C = \frac{L_{ph}}{E}$$

3.1.7
intrinsic resolution of housed scintillator of ionizing radiation
R_d
component, given by housed scintillator of ionizing radiation to energy resolution of the scintillation detector

Note 1 to entry: The intrinsic resolution R_d is defined from the relation:

$$R_d = \sqrt{R_a^2 - R_{pm}^2},$$

where

R_a is the energy resolution of the scintillation detector;

R_{pm} is PMT intrinsic resolution.

3.1.8
total absorption peak
portion of the spectral response curve corresponding to the total absorption of photon energy in a radiation detector

Note 1 to entry: This peak represents the total absorption of photon energy from all interactive processes, namely, a) photoelectric absorption, b) Compton effect, and c) pair production.

[SOURCE: IEC 60050-395:2014, 395-03-94]

3.1.9
photomultiplier tube spectrometric constant
A
parameter, characterizing properties of the photomultiplier tube

Note 1 to entry: Defined by the following formula:

$$A = (R_a^2 - R_d^2) \times C_{ph}$$

where C_{ph} is light output, photons/MeV.

3.1.10
working standard
working standard of housed scintillator that is used to check the measuring system and to measure the light output by a method of comparison

3.1.11
full width at half maximum
FWHM
in a distribution curve comprising a single peak, the distance between the abscissa of two points on the curve whose ordinates are half of the maximum ordinate of the peak

Note 1 to entry: If the curve considered comprises several peaks, a full width at half maximum exists for each peak.

3.1.12
expanded uncertainty
expanded uncertainty quantity defining an interval about the result of a measurement that may be expected to encompass a large fraction of the distribution of values that could reasonably be attributed to the measurand

Note 1 to entry: The fraction may be viewed as the coverage probability or level of confidence of the interval.

Note 2 to entry: To associate a specific level of confidence with the interval defined by the expanded uncertainty requires explicit or implicit assumptions regarding the probability distribution characterized by the measurement result and its combined standard uncertainty. The level of confidence that may be attributed to this interval can be known only to the extent to which such assumptions may be justified.

[SOURCE: JCGM 100:2008, 2.3.5]

3.1.13
relative expanded uncertainty
ratio of the expanded uncertainty of a measurement to average value of quantity. It expresses the relative size of the uncertainty of a measurement (its precision)

3.2 Symbols and abbreviated terms

A the photomultiplier tube spectrometric constant;

a the assembly conversion factor with the housed scintillator;

a_i the value of conversion response, measured at energy value of E_i;

a_{max} the maximal value of a;

a_{min} the minimal value of a;

Δa the value of nonlinearity;

C the light output, in relative units;

C_{ph} the light output, photons/MeV;

C_{pho} the light output of the working standard, photons/MeV;

FWHM the full width at half maximum of peak;

E energy lost by ionizing particle in the scintillator;

E_{max} the maximum gamma radiation energy;

E_p summed energy of scintillation photons, which have arisen in scintillator;

eps the initial point of housed scintillator conversion response, in energy units;

k the coverage factor;

k_a the assembly conversion factor;

L_{ph} total energy of scintillation photons;

m coefficient of spectral matching;

n the number of energy values used;

N the average value of conversion factor;

PMT a photomultiplier tube;

Q the PMT photocathode quantum sensitivity;

$S(\lambda)$ the PMT photocathode spectral characteristic;

R_a the energy resolution of the scintillation detector;

R_{ao} the energy resolution of scintillation detector with working standard;

R_d the intrinsic resolution of the measured housed scintillator;

R_{et} the intrinsic resolution of the working standard;

R_{pm} the PMT intrinsic resolution;

U_p the expanded uncertainty;

u_c the combined standard uncertainty;

V the value of pulse height corresponding to total absorption peak maximum of the measured housed scintillator;

V_d the initial point of housed scintillator conversion response;

V_{et} the value of pulse height corresponding to total absorption peak maximum of the working standard;

V_i the value of pulse height corresponding to total absorption peak maximum for single measurement;

V_{in} pulse height at the input of the assembly, the number of channels;

V_{max} the value of pulse height which corresponds to E_{max}, the number of channels;

V_o the initial point of assembly conversion response;

V_{od} the initial point of assembly conversion response with the housed scintillator;

V_{out} pulse height at the output of the assembly, the number of channels;

ΔV the value of FWHM;

y_1 the average value of the controlled parameter at the beginning of the measurement;

y_2 the average value of controlled parameter at the end of the measurement;

$y(\lambda)$ the scintillator spectral characteristic;

Δy the instability value;

η light yield.

4 Test methods of basic parameters of housed scintillators

4.1 General

4.1.1 Test conditions

Measurements shall be made under normal conditions, unless otherwise specified in the specifications of the manufacturer of housed scintillators.

Measurements should start at least 0,5 h after the last device has been switched on, unless otherwise specified by the manufacturer specifications.

Before measuring, the housed scintillator and the PMT are kept under high voltage for the time necessary for getting to the operation condition. Before measuring, the PMT is kept under high voltage for the time necessary for getting to the operation condition.

All parameters are measured during the complete blackout of the housed scintillator and PMT.

Optical contact between the housed scintillator and the PMT is provided by the material specified in the manufacturer specifications of the housed scintillator.

For the measuring, the following condition of choosing PMT should be reached: the working part of the photocathode shall overlap the output window of the scintillator.

It is allowed to apply a light guide or an assembly of several PMT, if technical characteristics and use conditions of light guide or assembly are specified in the specifications.

The measured housed scintillator is mounted on the PMT photocathode by optical contact, unless otherwise is specified in the manufacturer's specifications.

It is allowed to place a source of ionizing radiation inside the light protective chamber.

PMT voltage should correspond to its attached data for operation conditions.

The spectrum of pulse height should be measured to define operation conditions of the assembly.

4.1.2 The sources of ionizing radiation

Enclosed radioactive sources of alpha-, beta-, gamma-, X- and neutron radiation with known energies should be used. The source of radiation shall be selected depending on the application of measured housed scintillator according to Table 1.

Table 1 – Source of ionizing radiation

The application of housed scintillator	Source of radiation according to application
Alpha-radiation of radionuclides	^{239}Pu,^{241}Am, ^{244}Cm or ^{237}Np
Beta- radiation	^{137}Cs or ^{207}Bi
Gamma-radiation of radionuclide	^{137}Cs
Low gamma- and X-radiation	^{55}Fe, ^{109}Cd, ^{241}Am and ^{57}Co
Neutron radiation	^{239}Pu+Be, ^{241}Am+Be or ^{252}Cf

For measurements with the gamma- or X-radiation sources, they should be placed along the scintillator axis at minimum distance of not less than two diameters or a diagonal of the scintillator.

For measurements with the alpha- or beta-radiation sources, they should be placed directly on the entrance window of the housed scintillator.

For measurements with the alpha- or beta- sources, it is allowed to use a single-hole or multi-hole collimator with a hole diameter less than the thickness of the collimator.

4.1.3 The assembly test conditions

The current of the divider should exceed the PMT average anode current more than 10 times.

PMT power supplies shall provide high voltage stability better than 0,05 % and divider current more than 0,5 mA.

At low-resistance inputs of subsequent stages of the measurement section the measurements may be performed without matching stage.

For a recording device providing a pulse heights spectrum suitable for further processing multi-channel pulse analyzers, which have an output recording device of any type that registers and allows to give the pulse height spectrum in form convenient for processing, should be used.

4.2 Test methods of nonlinearity and instability of the assembly

4.2.1 Nonlinearity measurement

4.2.1.1 General

The dependence of the pulse height (V_{out}) at the output of the assembly on the signal (V_{in}) at the input of the assembly (assembly conversion response) is defined according to formula:

$$V_{out} = k_a \times V_{in} + V_o,$$

where

k_a is the assembly conversion factor;

V_o is the initial point of assembly conversion response.

If conversion response of the housed scintillator is linear, the assembly conversion response with the housed scintillator is also linear:

$$V_{out} = a \times E + V_{od}$$

Then

$$V_{od} = V_o + V_d = V_o + a \times eps, \quad (1)$$

where

E is energy lost by ionizing particle in the scintillator;

a is the assembly conversion factor with the housed scintillator;

V_{od} is the initial point of assembly conversion response with the housed scintillator;

V_d is the initial point of housed scintillator conversion response;

eps is the initial point of housed scintillator conversion response, in energy units.