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Nuclear energy — Waste-packages activity measurement —

Part 1: High-resolution gamma spectrometry in integral mode with open geometry

Énergie nucléaire — Mesurage de l'activité de colis de déchets —

Partie 1: Spectrométrie gamma haute résolution en mode intégral et géométrie ouverte

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 14850-1 was prepared by Technical Committee ISO/TC 85, *Nuclear energy*, Subcommittee SC 5, *Nuclear fuel technology*.

ISO 14850 consists of the following parts, under the general title *Nuclear energy — Waste-packages activity measurement*:

— *Part 1: High-resolution gamma spectrometry in integral mode with open geometry*

— *Part 2: Gamma-ray spectrometry using HPGe detectors*

Introduction

Several non destructive methods may be used after calibration to determine the radioactive characteristics of a waste package:

— gamma spectrometry;

— passive neutron counting, with or without discrimination of neutrons originating from (α,n) reactions;

— active neutron counting, with detection of neutrons resulting from induced fission reactions (prompt or delayed neutrons).

This part of ISO 14850 describes one procedure for measuring the activity contained in waste packages by gamma spectrometry and points out recommendations for the calibration of a measurement chain.

Nuclear energy — Waste-packages activity measurement —

Part 1: High-resolution gamma spectrometry in integral mode with open geometry

1 Scope

This part of ISO 14850 describes a procedure for measurements of gamma-emitting radionuclide activity in the following homogeneous objects:

— unconditioned waste, including process waste (filters, control rods, etc.), dismantling waste, etc.;

— waste conditioned in various matrices (bitumen, hydraulic binder, thermosetting resins, etc.), notably in the form of 100 l, 200 l, 400 l or 800 l drums, and test specimens or samples, (vitrified waste);

— waste packaged in a container, notably technological waste.

It also specifies the calibration of the gamma spectrometry chain.

The gamma energies used generally range from 0,05 MeV to 3 MeV.

2 Terms, definitions and symbols

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

2.1
reference source
radionuclide sealed in a suitable containment, of which the radioactive characteristics are determined by comparison with a reference material

2.2
source volume
volume in m^3 taken up by the matrix (or by the waste) in which the activity is distributed

2.3
source weight
weight in kg of the matrix in which the activity is distributed

2.4
package
object to be characterized, comprising an outer shell (container or canister) surrounding the (conditioned or unconditioned) source volume

2.5
mockup
package consisting of a container and of well-known materials representative of a matrix

2.6
reference package
mockup containing reference sources in a well-known configuration

2.7
apparent density of the source
ratio of the mass of the source to its volume

2.8
container
envelope of source volume

2.9
matrix
structural material immobilizing the radioactivity

2.10
radioprotection-shield
material of suitable nature and thickness placed around a package to attenuate the photon emission flux

2.11
gamma ray attenuator
material of suitable nature and thickness placed between the package and detector to attenuate the photon flux

2.12
detector
any type of high-purity germanium semiconductor

2.13
efficiency
ε
ratio between the number of detected events and the number of emitted gamma photons

2.14
collimator and background shield
protective devices for the detector to decrease background by limitation of the solid angle and gamma background (collimator) and reduction of the ambient background incident (background shielding)

2.15
background noise
B_e
number of counts in s^{-1} recorded at energy e in the background spectrum in the absence of any source, sample or package

2.16
decision threshold
T_D
value (in s^{-1}) above which an observed quantity is considered true, within the risk α

NOTE This limit corresponds the risk α of affirming the presence of the true quantity when it is in fact not present. The recommended value of α is 2,5 %

2.17
detection limit
L_D
value (in Bq) of the measured quantity that can be detected with a given probability $(1 - \beta)$, i.e. capable of providing a corrected result exceeding the decision threshold

NOTE The risk β corresponds to the risk of affirming the absence of the true quantity when it is in fact present. The recommended β value is 2,5 %

2.18
combined standard uncertainty
u_{cx}
sum-of-the-squares combination of standard uncertainties arising from a Type A evaluation (applying statistical methods, expressed as a standard deviation s_i) and a Type B evaluation (non-statistical methods, expressed as a standard deviation u_j):

$$u_{cx} = \left[\sum_i (s_i)^2 + \sum_j (u_j)^2 \right]^{1/2}$$

2.19
coverage factor
k
user-defined value, depending on the probability law, the level of confidence, and the precision of the estimated standard deviation, with

$k = 1$ for standard deviation calculations, and

$k = 2$ for the normal law, for a 95 % confidence level assuming a known standard deviation

2.20
expanded uncertainty
product of the standard deviation by the coverage factor, k

3 Principle

This part of ISO 14850 describes a non-destructive method implemented using fixed or mobile equipment, which is based on measuring the photon emission rate at different energies by gamma spectrometry:

- to identify detectable radionuclides in the objects in Clause 1, either by direct measurement or by using decay schemes;
- to determine the activity of the identified radionuclides from the counting rates recorded under each total absorption peak, weighted by a calibration factor.

The method implies optimization of the equipment parameters, energy calibration and efficiency calibration (by modelling the transfer function or by fabricating mockups):

- choice of detector(s), electronic circuitry and shielding;
- choice of measurement geometry;
- choice of calibration geometry.

The method may be validated:

- by comparison with destructive examination results on representative samples;
- by measurement of reference packages for which the activity, the nature of the radionuclides, the nature of the elements composing the waste and homogeneity are accurately known.

4 Detectors and ancillary equipment

The measuring station usually comprises the following equipment.

a) Mechanical equipment:

— a package-positioning system (rotation, with optional vertical movement);

— a detector-positioning system (vertical, horizontal and distance);

— a weighing station (optional);

— a turntable;

— collimator, background shielding, gamma ray attenuators,

b) Detector and signal-processing electronics:

— a detector and preamplifier;

— an amplifier;

— an analog-digital converter,

— a “stand alone” module or a computer interface card,

c) Computer with measurement processing and interpretation software.

4.1 Mechanical equipment

4.1.1 Package-positioning system

The package-positioning system is designed to support the package to be measured, and to move it in rotation about its vertical axis. It may also allow for vertical moving of the package, and may be equipped with a weighing system.

4.1.2 Detector-positioning system

This system carries the detector with its protective shielding, and positions it in elevation and azimuth with respect to the package to be measured. It may be equipped with a system to determine the relative position of the package with respect to the detector.

4.2 Detector and preamplifier

The method covers only high-purity germanium semiconductor detectors. Two types of detectors may be selected depending on the energy of the radionuclides to be measured:

— planar or flat coaxial detectors provide better resolution at low energy (below 400 keV),

— coaxial detectors give higher efficiency at high energies.

The semiconductor crystal requires a cryogenic system. The detector signal is collected by a charge sensitive preamplifier; this can be of either the resistive feedback type, transistor reset type or pulsed optical feedback type depending upon the application.

4.3 Amplifier

The amplifier implements Gaussian or triangular pulse shaping with a time constant adjustable from 0,25 μs to 15 μs. A pileup rejector is generally used, and in some cases the amplifier is equipped with a gated integrator.

Various types of amplifiers may be used in conjunction with this method. The choice of an amplifier depends on the other components in the counting system.

4.4 Analog-digital converter (ADC)

Two types of ADC converters are used in gamma spectrometry:

— Wilkinson ADCs, with a variable dead time; counting losses depend on the conversion frequency and the signal amplitude;

— successive approximation ADCs, with a fixed dead time independent of the signal amplitude.

4.5 Multi-channel analyzer (MCA) and data processing system

The analyzer stores the encoded data in a basic memory array available to the computer.

NOTE A digital signal processing module may replace the functions described in 4.2, 4.3 and 4.4. It quantizes the preamplifier output signal, allowing higher counting rates

4.6 Background shielding

The unit is shielded against external radiation by (preferably low-activity) lead or other high-density materials. The dimensions depend on the characteristics of the measurement environment.

4.7 Collimator

The collimator is made of a high-density material (Pb, W, Ta, Cu) with a geometry corresponding to the desired detection solid-angle acceptance. The collimator geometry is designed to maximize the ratio of the gamma activity signal from the material of interest, to the gamma activity signal arising from the surrounding area, i.e the ambient background.

4.8 Gamma ray attenuators

Gamma ray attenuators can be placed in front of the detector to attenuate the incident photon flux. The material and thickness are selected according to the flux characteristics.

5 Calibration

Calibration consists of determining the efficiency (or yield) versus energy curve(s) of each detector (or of the complete measuring unit). The curve(s) is_used to evaluate the ratio between the number of detected events and the number of gamma photons emitted from several single-energy sources or from a few multiple-energy sources with well-spaced energy lines covering the gamma ray region of the radionuclides present in the measured samples or in the measured packages.

The energy/channel relation shall first be established by means of several single-energy (or multiple energy) sources covering the energy band relevant to the measured samples or packages.