INTERNATIONAL STANDARD

ISO 11929-4

First edition
2001-06-01

Determination of the detection limit and decision threshold for ionizing radiation measurements —

Part 4: Fundamentals and application to measurements by use of linear-scale analogue ratemeters, without the influence of sample treatment

Détermination de la limite de détection et du seuil de décision des mesurages des rayonnements ionisants —

Partie 4: Principes fondamentaux et leur application aux mesurages réalisés à l'aide d'ictomètres analogiques à échelle linéaire, sans l'influence du traitement d'échantillon

Reference number
ISO 11929-4:2001(E)

PDF disclaimer

This PDF file may contain embedded typefaces. In accordance with Adobe's licensing policy, this file may be printed or viewed but shall not be edited unless the typefaces which are embedded are licensed to and installed on the computer performing the editing. In downloading this file, parties accept therein the responsibility of not infringing Adobe's licensing policy. The ISO Central Secretariat accepts no liability in this area.

Adobe is a trademark of Adobe Systems Incorporated.

Details of the software products used to create this PDF file can be found in the General Info relative to the file; the PDF-creation parameters were optimized for printing. Every care has been taken to ensure that the file is suitable for use by ISO member bodies. In the unlikely event that a problem relating to it is found, please inform the Central Secretariat at the address given below.

ISO copyright office
Case postale 56 • CH-1211 Geneva 20
Tel. + 41 22 749 01 11
Fax + 41 22 749 09 47
E-mail copyright@iso.ch
Web www.iso.ch

Printed in Switzerland

Contents

Page

Annex

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 3.

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 part of ISO 11929 may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

International Standard ISO 11929-4 was prepared by Technical Committee ISO/TC 85, *Nuclear energy*, Subcommittee SC 2, *Radiation protection*.

ISO 11929 consists of the following parts, under the general title *Determination of the detection limit and decision threshold for ionizing radiation measurements*:

— *Part 1: Fundamentals and application to counting measurements without the influence of sample treatment*

— *Part 2: Fundamentals and application to counting measurements with the influence of sample treatment*

— *Part 3: Fundamentals and application to counting measurements by high resolution gamma spectrometry, without the influence of sample treatment*

— *Part 4: Fundamentals and applications to measurements by use of linear-scale analogue ratemeters, without the influence of sample treatment*

— *Part 5: Fundamentals and applications to measurements of aerosols or gaseous or liquid effluents while running*

Annex A of this part of ISO 11929 is for information only.

Introduction

ISO 11929 gives basic information on the statistical principles for determination of the detection limit and decision threshold (and directives for specification of the confidence interval) for nuclear radiation measurements based on the principles defined by Altschuler and Pasternack [1], Nicholson [8], Currie [4].

This part of ISO 11929 applies to linear-scale analogue pulse-rate measurements as they are frequently used in the routine monitoring of clothes, hands, feet, body, surfaces, air filters, working places, desks and other flat materials, wipe-test papers, and other contamination checks in stationary use of equipment and sources. For scanning of surfaces, this measurement can be used when the detector is moved slowly enough for the surface to be measured to remain under the detector area for twice the time constant of the integrating circuit in the equipment.

ISO 11929-1 and ISO 11929-2 deal with integral counting measurements with or without consideration of the sample treatment. Specific problems which occur in case of spectrometric measurements or continuous monitoring of radioactive effluents are covered in ISO 11929-3 and ISO 11929-5.

This part of ISO 11929 deals with ionizing radiation measurements in which events, in particular pulses, are measured using linear-scale analogue ratemeters, without considering the influence of a sample treatment. It considers exclusively the random character of radioactive decay and of pulse-rate counting by use of a linear-scale analogue ratemeter, and ignores other influences (e.g. due to sample treatment, weighting, enrichment, or instability of the equipment). It is based on the assumption that the product of pulse rate and time constant of the meter is sufficient to permit approximation of the real pulse/time distribution by a normal standard distribution, and that dead-time losses are negligible. Wherever activities or specific activities are to be determined, it is assumed that the factors for the conversion of pulse rates into activities or specific activities have been determined with sufficient accuracy to ignore the influence of their uncertainty in the measurement.

This part of ISO 11929 should not be used for ratemeters with cyclic digital counters. In this case, ISO 11929-1 should be applied.

For this purpose, Bayesian statistical methods are used to specify values of statistics characterized by the following given error probabilities.

— The decision threshold, which allows a decision to be made for each measurement with a given probability of error as to whether the registered pulses include a contribution by the sample.

— The detection limit, which specifies the minimum sample contribution which can be detected with a given probability of error using the measuring procedure in question. This consequently allows a decision to be made as to whether a measuring method checked using this part of ISO 11929 satisfies certain requirements and is consequently suitable for the given purpose of measurement.

— The confidence limits, which define a confidence interval of the measurand with a given probability if the measured value exceeds the decision threshold.

NOTE The difference between using the decision threshold and using the detection limit is that measured values are to be compared with the decision threshold while the detection limit is to be compared with the guideline value.

Determination of the detection limit and decision threshold for ionizing radiation measurements —

Part 4: Fundamentals and application to measurements by use of linear-scale analogue ratemeters, without the influence of sample treatment

1 Scope

This part of ISO 11929 specifies suitable statistical values which allow an assessment of the detection capabilities in ionizing radiation measurements, without the influence of sample treatment, using linear-scale analogue ratemeters. For this purpose, statistical methods are used to specify statistical values characterizing given probabilities of error.

2 Terms and definitions

For the purposes of this part of ISO 11929, the following terms and definitions apply.

2.1
linear-scale analogue rate-meter
electronic device whose output increases suddenly with every incoming pulse, and decreases with a given time constant until the next pulse arrives

NOTE The pulses should be of equal electrical charge, and the time constant should be independent of the pulse rate.

2.2
measuring method
use of a linear-scale analogue ratemeter for pulse-rate measurements under specified conditions

2.3
decision threshold
critical value of a statistical test for the decision between the null hypothesis $\rho_\mathrm{s} = \rho_0$ and the alternative hypothesis $\rho_\mathrm{s} > \rho_0$

NOTE It should be the value R_n^* which, when exceeded by the determined value R_n, is taken to indicate that the null hypothesis should be rejected. The statistical test should be designed such that the probability of wrongly rejecting the null hypothesis (error of the first kind) is equal to a value α which is fixed prior to commencement of the measurement.

2.4
detection limit
smallest difference $\rho_n = \rho_\mathrm{s} - \rho_0$ associated with the statistical test concerned for the decision between the null hypothesis $\rho_\mathrm{s} = \rho_0$ and the alternative hypothesis $\rho_\mathrm{s} > \rho_0$ and having the following characteristic: if in reality $\rho_n \geqslant \rho_n^*$, the probability of wrongly not rejecting the null hypothesis $\rho_\mathrm{s} = \rho_0$ (error of the second kind) shall be at most equal to a value β which is fixed prior to commencement of the measurement

2.5
confidence interval
interval for ρ_n to be specified for the measured value obtained for R_n

NOTE This interval includes the true value of ρ_n in at least $(1 - \gamma) \times 100$ % of all cases.

2.6
sample
whole amount or an aliquot of a material, the content of radioactive nuclides of which has to be determined by ionizing radiation measurement

2.7
background effect
measured counting rate without radioactivity of interest in the sample

NOTE This covers radiation caused by external sources and detector noise.

2.8
gross effect
measured counting rate from the sample (sample contribution) and the background radiation

2.9
net effect
⟨sample contribution⟩ gross effect minus the background effect

2.10
guideline value
value which corresponds to scientific, legal or other requirements for which the measuring procedure is intended to assess, for example, as activity, specific activity, surface activity, or dose rate

3 Symbols

R_0 Ratemeter output without sample (background pulse rate)

ρ_0 Expectation value of R_0

R_s Ratemeter output with sample (gross effect pulse rate) R_n

ρ_s Expectation value of R_s

R_n Net counting rate (difference between gross and background pulse rate), $R_n = R_s - R_0$

ρ_n Expectation value of R_n

R_n^* Decision threshold for the net counting rate R_n

ρ_n^* Detection limit for the expectation value of the net counting rate R_n

s^2 Squared standard deviation

δ^2 Expectation value of s^2

α Error of the first kind; the probabilitiy of rejecting the null hypothesis $\rho_s = \rho_0$ for the alternative hypothesis $\rho_s > \rho_0$ when the null hypothesis is true

β Error of the second kind; the probability of accepting the null hypothesis $\rho_s = \rho_0$ against the alternative hypothesis $\rho_s > \rho_0$ when the null hypothesis is false

$1 - \gamma$ Confidence level of the confidence interval for ρ_n

τ Time constant of the ratemeter

τ_0 Time constant for background measurement

τ_s Time constant for sample measurement

$k_{1-\alpha}, k_{1-\beta}, k_{1-\gamma/2}$ Quantiles of the standard normal distribution (see Table 2)

4 Statistical values and confidence interval

4.1 Principles

4.1.1 General aspects

The definition of the statistical values for decision threshold, detection limit and confidence interval are based on the squared standard deviation of the measured results. They are dependent on the squared standard deviation caused by counting statistics. Measurement equipment instability normally can be neglected because usually it is small compared with the other influences. The contribution of counting statistics can be calculated by the Poisson equation in combination with the Campbell theorem [2].

4.1.2 Model

If device instabilities are neglected, the following model may be applied:

$$\rho_n = \rho_s - \rho_0$$

The pulse rate measured without a sample, R_0, is caused by background radiation (external sources and activity in detector and shielding). The gross pulse rate, R_s, measured with a sample is the sum of background counting rate and sample radiation (net counting rate):

$$R_s = R_0 + R_n$$

It is assumed that, for a constant radioactive emission rate and a given time constant, both the number of pulses counted in a measurement of the gross effect, as well as in an independent measurement of the background effect, follow a Poisson distribution. Therefore, the expectation values of the counting rates R_0 and R_s are ρ_0 and $\rho_s = \rho_0 + \rho_n$, and the variances are $s^2(R_0) = \rho_0/2\tau$ and $s^2(R_s) = \rho_s/2\tau$, respectively (Campbell theorem); τ = time constant.

The net counting rate $R_n = (R_s - R_0)$ has the expectation ρ_n and the variance

$$\text{Var}(R_n) = \text{Var}(R_0) + \text{Var}(R_s) \quad (1)$$

For $\rho_n = 0$ this variance is (with $\rho_s = \rho_0$)

$$\text{Var}(R_n = 0) = \rho_0 \left(\frac{1}{\tau_0} + \frac{1}{\tau_s} \right)$$

where

τ_0 is the time constant at background-effect measurement;

τ_s is the time constant at gross-effect measurement.

In this case, ρ_0 and ρ_s are unknown parameters.