

Equipment for monitoring of radionuclides in liquid effluents and surface waters

ICS 13.280

National foreword

This British Standard is the UK implementation of EN 60861:2008. It is derived from IEC 60861:2006. It supersedes BS IEC 60861:2006 which is withdrawn.

The CENELEC common modifications have been implemented at the appropriate places in the text. The start and finish of each common modification is indicated in the text by tags **Ⓒ** **Ⓒ**.

The UK participation in its preparation was entrusted to Technical Committee NCE/2, Radiation protection and measurement.

A list of organizations represented on this committee can be obtained on request to its secretary.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

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Amendments/corrigenda issued since publication

Date	Comments
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**Equipment for monitoring of radionuclides
in liquid effluents and surface waters
(IEC 60861:2006, modified)**

Equipements pour la surveillance
des radionucléides dans les effluents
liquides et les eaux de surface
(CEI 60861:2006, modifiée)

Einrichtungen zur Überwachung von
Radionukliden in flüssigen Ableitungen
und Oberflächengewässern
(IEC 60861:2006, modifiziert)

This European Standard was approved by CENELEC on 2008-02-01. CENELEC members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.

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CENELEC

European Committee for Electrotechnical Standardization
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Foreword

The text of the International Standard IEC 60861:2006, prepared by SC 45B, Radiation protection instrumentation, of IEC TC 45, Nuclear instrumentation, together with the common modifications prepared by the Technical Committee CENELEC TC 45B, Radiation protection instrumentation, was submitted to the formal vote and was approved by CENELEC as EN 60861 on 2008-02-01.

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Clauses, subclauses, notes, tables and figures which are additional to those in IEC 60861 are prefixed “Z”.

Annex ZA has been added by CENELEC.

Endorsement notice

The text of International Standard IEC 60861:2006 was approved by CENELEC as a European Standard with agreed common modifications.

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EQUIPMENT FOR MONITORING OF RADIONUCLIDES IN LIQUID EFFLUENTS AND SURFACE WATERS

1 Scope

This International Standard defines technical requirements for equipment for monitoring of alpha-, beta- or gamma-emitting radionuclides in liquid effluents and surface waters, provides some general guidance as to the possible detection capability of such equipment and indicates when and where its uses may be practicable.

NOTE Alpha monitoring in liquids is a possibility that has been demonstrated using a concentration device and collection of the concentrate in a filter, so this standard may also be applicable to alpha monitoring in liquids.

This standard is applicable to equipment for continuous monitoring of the activity:

- in liquid effluents which could be released in the environment during normal operations;
- in environmental waters.

This standard does not apply to equipment specifically for use in accident conditions that may require additional capabilities.

This standard is restricted to equipment for continuous monitoring  (including discrete sequential measurement) of gross alpha or gross beta of maximum energy higher than 150 keV or gamma activity in liquid effluent streams and environmental waters. It does not deal with sample extraction followed by  laboratory analysis.

The object of this standard is to lay down general requirements and give examples of acceptable methods for equipment to monitor continuously the activity of water.

This International Standard specifies, for the equipment described in the scope, the general characteristics, general test procedures, radiation, electrical, safety and environmental characteristics, and the identification and certification of the equipment. Performance requirements for the safe operation of electrical equipment are provided in IEC 61010-1. These safety requirements and corresponding tests are applicable if the manufacturer wants to, or is required to, label its equipment with the appropriate safety mark (for example, CE, UL, etc.).

This standard is applicable to water monitors intended to fulfil the following functions:

- measurement of the volumetric activity or count rate (see 5.1.2) due to radionuclides in the liquid and its variation with time;
- actuation of an alarm when a limit value of volumetric activity or count rate in water is exceeded.

Annex A gives some guidance for use with radioactive water monitors.

2 Normative references

The following referenced documents are indispensable for the application 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.

☐ ISO 11929 (Series) *Determination of the detection limit and decision threshold for ionizing radiation measurements* ☐

IEC 60038:1983, *IEC standard voltages*
Amendment 1 (1994)
Amendment 2 (1997)¹

IEC 60050-393:2003, *International Electrotechnical Vocabulary (IEV) – Part 393: Nuclear instrumentation – Physical phenomena and basic concepts*

IEC 60050-394:1995, *International Electrotechnical Vocabulary (IEV) – Chapter 394: Nuclear instrumentation – Instruments*
Amendment 1 (1996)
Amendment 2 (2000)

IEC 60068-2-38:1974, *Basic environmental testing procedures – Part 2-38: Tests – Test Z/AD: Composite temperature/humidity cyclic test*

IEC 61000-4-2:2001 *Electromagnetic compatibility (EMC) – Part 4-2: Testing and measurement techniques – Electrostatic discharge immunity test*
Amendment 1 (1998)
Amendment 2 (2000)²

IEC 61000-4-3:2006, *Electromagnetic compatibility (EMC) – Part 4-3: Testing and measurement techniques – Radiated, radio-frequency, electromagnetic field immunity test*

IEC 61000-4-4:2004, *Electromagnetic compatibility (EMC) – Part 4-4: Testing and measurement techniques – Electrical fast transient/burst immunity test*

IEC 61000-4-5:2005, *Electromagnetic compatibility (EMC) – Part 4-5: Testing and measurement techniques – Surge immunity test*

IEC 61000-4-6:2004, *Electromagnetic compatibility (EMC) – Part 4-6: Testing and measurement techniques – Immunity to conducted disturbances, induced by radio-frequency fields*
Amendment 1 (2004)³

IEC 61000-4-11:2004, *Electromagnetic compatibility (EMC) – Part 4-11: Testing and measurement techniques – Voltage dips, short interruptions and voltage variations immunity tests*

IEC 61000-4-12:1995, *Electromagnetic compatibility (EMC) – Part 4-12: Testing and measurement techniques – Oscillatory waves immunity test*
Amendment 1 (2000)⁴

IEC 61000-6-4:1997, *Electromagnetic compatibility (EMC) – Part 6: Generic standards – Section 4: Emission standard for industrial environments*

¹ There exists a consolidated edition 6.2 (2002) including edition 6.0 and its amendments 1 and 2.

² There exists a consolidated edition 1.2 (2001) including edition 1.0 and its amendments 1 and 2.

³ There exists a consolidated edition 2.1 (2004) including edition 2.0 and its amendment 1.

⁴ There exists a consolidated edition 1.1 (2001) including edition 1.0 and its amendment 1.

IEC 61010-1:2001, *Safety requirements for electrical equipment for measurement, control, and laboratory use – Part 1: General requirements*.

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

ISO Guide to the expression of uncertainty in measurement (GUM), 1995.

ISO 10012:2003, *Measurement management systems – Requirements for measurement processes and measuring equipment*

3 Terms and definitions

For the purposes of this document, the terms and definitions concerning detection and measurement of ionizing radiation and nuclear instrumentation given in IEC 60050-393 and IEC 60050-394, as well as the following, apply.

3.1

water monitor

☐ equipment intended for monitoring of radionuclides in liquid effluents and surface waters ☐

3.2

activity monitoring

different ways of monitoring:

Monitors with sampling,

simultaneous measurement,

discrete sequential measurement,

Monitors without sampling

direct measurement

3.3

☐ definition deleted ☐

3.4

simultaneous measurement

measurement of a sample taken at the same time as the sample is collected

NOTE Measurements carried out with the detector in contact with the liquid (beta detector) or inside it (gamma detector) are considered as a simultaneous measurement.

3.5

discrete sequential measurement

measurement of a sample that is undertaken separately from collection of the sample with a short collection time separated by a short delay from the time of measurement

☐ NOTE Z Immediately after collection of the sample the activity of the sample will be measured, during the time the next sample is collected. The time between taking each sample should be as short as possible. ☐

3.6

direct measurement

measurement, without sampling, with the detector immersed in liquid flow or adjacent to the duct where the liquid is flowing

3.7

sampling assembly

assembly for collecting a representative sample

3.8**detection assembly**

assembly used for measuring the activity. The detection assembly includes one or more radiation detectors

3.9**measurement assembly**

assemblies and function units designed to measure quantities connected with ionizing radiation (activity, volumetric activity, etc.)

3.10**alarm assembly**

assembly that will initiate an audible or visible alarm in the event of an alarm threshold being breached or in case of fault of the equipment

3.11**☐ total equivalent window thickness (density thickness)**

thickness, generally expressed in mass per unit area (mg/cm^2), which a particle emitted normally from the surface of the medium of deposition to be measured traverses to reach the sensitive volume of the detector

NOTE This thickness includes the distance covered in liquid or air plus the thickness of the entry window of the detector. This may include any screen or coating over the detector for protection against the liquid effluent and the sample container (if any). ☐

3.12**coefficient of variation**

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

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

3.13**relative intrinsic error**

relative error of indication of a piece of equipment or an assembly with respect to a quantity when subjected to a specified reference quantity under specified reference conditions expressed as

$$e_i = \frac{V - V_c}{V_c}$$

where

V is the indicated value of a quantity;

V_c is the conventionally true value of the quantity at the point of measurement

3.14**uncertainty of measurement**

parameter associated with the result of a measurement that characterizes the dispersion of the values that could reasonably be attributed to the measurand

NOTE 1 The parameter may be, for example, a standard deviation (or a given multiple of it) or the half-width of an interval having a stated level of confidence.

NOTE 2 Uncertainty of measurement comprises, in general, many components. Some of these components may be evaluated from statistical distribution of the result of series of measurements and can be characterized by experimental standard deviation. The other components, which can also be characterized by standard deviation, are evaluated from assumed probability distributions based on experience or other information.

NOTE 3 It is understood that the result of the measurement is the best estimate of the value of the measurand and that all components of uncertainty, including those arising from systematic effects, such as components associated with corrections and reference standards, contribute to the dispersion.

3.15 coverage factor

k

numerical factor, *k*, used as a multiplier of the combined standard uncertainty in order to obtain an expanded uncertainty

3.16 decision threshold

fixed value of the decision quantity by which, when exceeded by the result of an actual measurement of a measurand quantifying a physical effect, one decides that the physical effect is present

NOTE 1  The decision threshold is the critical value of a statistical test designed in such a way that the probability of wrongly rejecting the null hypothesis (H_0 : the physical effect is not present) (error of the first kind) is equal to a given value α .  For this standard, α equals 5% and the decision threshold (*DT*) is calculated using the following general formula:

$$DT = 1,64\sqrt{2\text{var}(b)} = 2,32 s(b)$$

where

s is the experimental standard deviation of the background.

NOTE 2 For equipment given an indication in terms of count rate the standard deviation used may be the estimated standard deviation of the background count rate, $u_{(b)}$, given by the following formula, instead of the experimental standard deviation, *s*:

$$u_{(b)} = \sqrt{\frac{b}{t}}$$

where

b is the count rate due to the background (counts/second);

t is the time of measurement (in seconds).

3.17 decision quantity

random variable for the decision whether the physical effect to be measured is present or not

3.18 effective range of measurement

range of values of the quantity to be measured over which the performance of a piece of equipment or an assembly meets the requirements of its specifications

3.19 dynamic range

quotient of the signal from the maximum measurable indication of a quantity to the signal from the decision threshold of that quantity

3.20 response time

time required after a step variation in the measured quantity for the output signal variation to reach a given percentage for the first time, usually from 10 % to 90 %, of its final value

3.21 volumetric activity

quotient of the measured activity by the total volume of the sample

NOTE This quantity is expressed in becquerel per cubic metre (Bq/m³).

3.22**surface emission rate of solid sources**

number of particles of a given type above a given energy emerging from the front face of the source per unit time

3.23**conventionally true value** (of a quantity)

best estimate of the value of a quantity used for a given purpose

NOTE A conventionally true value is, in general, regarded as sufficiently close to the true value for the difference to be insignificant for the given purpose. For example, a value determined from a primary or a secondary standard or by a reference instrument, may be taken as the conventionally true value.

3.24**reference response**

ratio, under standard test conditions, given by the relation

$$R_{\text{ref}} = \frac{A_v}{A_{vc}}$$

where

A_v is the value of the volumetric activity indicated by the equipment or assembly under test;

A_{vc} is the conventionally true value of the volumetric activity measured

3.25**sensitivity**

☐ for a given value of the measured quantity, the ratio of the observed indication to the corresponding conventionally true value of the measured quantity

$$S = \frac{I - B}{A_c}$$

where

I is the indicated value in presence of the radioactive source measured;

B is the indicated value of the background;

A_c is the conventionally true value of the activity, the volumetric activity, or surface emission rate of the source.

NOTE Z This definition is specific to this standard. ☐

3.26**relative response**

value calculated, during type testing, equal to the ratio between the reference response (or the reference sensitivity) of the equipment for a liquid source and the sensitivity of the same equipment for a solid source

NOTE The relative response allows for the determination of the reference response (or the reference sensitivity) of all identical equipment that the equipment type tested from the measurement or the sensitivity for solid source.

3.27**repeatability** (of a measuring instrument)

ability of a measuring instrument to provide closely similar indications for repeated applications of the same measurand under the same conditions of measurement

NOTE 1 These conditions include reduction to a minimum of variation due to the observer, the same measurand procedure, the same observer, the same measuring equipment used under the same conditions, the same location, repetition over a short period of time.

NOTE 2 Repeatability may be expressed quantitatively in terms of dispersion characteristics of the indications.

3.28

reproducibility (of results of measurements)

closeness of the agreement between the results of successive measurement of the same measurand carried out under the changed conditions of measurement

NOTE 1 A valid statement of reproducibility requires specification of the conditions changed.

NOTE 2 The changed conditions may include principle of measurement, method of measurement, observer-measuring instrument, reference standard location, conditions of use, time.

NOTE 3 Reproducibility may be expressed quantitatively in terms of the dispersion characteristics of the results.

NOTE 4 Results are here usually understood to be corrected results.

3.29

linearity error

deviation from a reference straight line of the curve representing the output indication variation as a function of the input quantity variation

3.30

exchange coefficient

for water loaded with particles in suspension, ratio between the mass activity of the particles and volumetric activity of the water. This coefficient, K_d , is expressed in (becquerels/kilogram)/(becquerels/liter)

3.31

type test

conformity testing on the basis of one or more specimens of a product representative of the production

3.32

routine test

test to which each individual instrument is subject during or after manufacture to ascertain whether it complies with certain criteria

3.33

acceptance test

contractual test to prove to the customer that the instrument meets certain conditions of its specification

3.34

maintenance test

prescribed test following specific maintenance

3.35

manufacturer

designer and seller of the equipment

3.36

purchaser

user of the equipment

3.37

units

SI system of units. The following units of practical importance will also be used where appropriate:

- for time: year (y), day (d), hour (h), minute (min);
- for energy: electronvolt (eV).

4 Classification of equipment

Monitors may be classified according to the type of radiation detected:

- gross beta and/or gamma monitors;
- gross alpha and/or beta monitors;
- gross gamma monitor including specific radionuclide channels.

They may be also classified according to their method of operation:

- simultaneous measurement;
- discrete sequential measurement;
- direct measurement.

5 Equipment design

5.1 Measurement and indication characteristics

5.1.1 Measurement characteristics

If the monitor indicates a gross activity or a volumetric activity, the manufacturer shall specify the radionuclide of reference for which the activity (or volumetric activity) is indicated (a list of reference radionuclides is given in Table 1).

The manufacturer shall indicate the decision threshold and the effective range of measurement of the equipment for nuclides of interest. These characteristics should be given for the specified radionuclides taking into account the reference gamma radiation background level (200 nGy/h).

The monitor shall give an indication when the measurement is outside the effective range.

The dynamic range of the equipment shall be at least 10^3 for the measurement of the environmental water and 10^5 for the liquid effluents.

NOTE For monitoring environmental water, the effective range of measurement should include a level of activity of 1×10^4 Bq/m³ and for liquid effluents 2×10^8 Bq/m³.

The manufacturer shall specify the response of the assembly to radionuclides other than that of the reference mentioned in Table 1. The list of radionuclides of interest shall be agreed upon between manufacturer and purchaser.

The manufacturer should specify the achievable decision threshold for nuclides of interest, as a function of the ambient gamma background at detector assembly.

 NOTE Z The decision threshold is calculated according to ISO 11929 series. 

5.1.2 Measurement display

The measurement display shall indicate the value in appropriate units to the measurement technique and shall be agreed upon between manufacturer and purchaser.

In the case of a beta measurement carried out directly on the liquid, the indication should be the observed quantities, for example, counts per second. Under referenced conditions, for example, for a known radionuclide and observed count rate, the indication may be expressed in activity or in volumetric activity.