

Nuclear instrumentation — Thickness measurement systems utilizing ionizing radiation — Definitions and test methods

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Summary of pages

This document comprises a front cover, an inside front cover, pages i and ii, the CEI IEC title page, pages ii to iv, pages 1 to 29 and a back cover.

This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

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Nuclear instrumentation –

**Thickness measurement systems
utilizing ionizing radiation –
Definitions and test methods**



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Foreword

1) The IEC (International Electrotechnical Commission) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of the IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, the IEC publishes International Standards. Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. The IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.

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International Standard IEC 1336 has been prepared by IEC technical committee 45: Nuclear instrumentation.

This standard cancels and replaces IEC 769 published in 1983 and constitutes a technical revision.

The text of this standard is based on the following documents:

FDIS	Report on voting
45/388/FDIS	45/404/RVD

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

Annex A forms an integral part of this standard.

Annex B is for information only.

Introduction

Since 1983, there have been many advances in the state-of-the-art technology that influence the test procedures which are in common use for measurement systems utilizing ionizing radiation. These include the following.

- Common usage of laboratory PC computers with data acquisition modules for nearly all primary performance measurement purposes, which means automated data collection; statistical data processing; more extensive use of calculated variables (such as thickness) instead of raw radiation signals (such as volts or counts); spreadsheet presentation and manipulation of data and results; much larger data sets.
- New measurement system-related features for accessing measurement information such as: very high speed sampling; integrated work-station data logging, statistical data processing, and video/printer tabular and graphical data presentations; high resolution scanning measurement profiles; extensive data bases with long-term performance characteristics logging and reporting of trends; predictive failure analysis, etc.
- New design features to maximize absolute measurement accuracy in adverse environments including such things as: elimination of errors due to foreign material (dirt) in the measurement path, temperature effects, electrostatic charge influences, vibration/microphonics; measurement air column compensation; internal measurement reference samples; microcomputers and microcontrollers built directly into the sensors.

In light of the complexity of process control signals in current state-of-the-art technology with cross-machine controls, DCS architecture and other variations in control processes, this standard does not include the test point B of IEC 769. The original Appendix B has also been deleted as it is obsolete and inadequate in view of today's automated data collection methods and statistical data processing techniques. However, a number of new tests and test methods have been added to this standard.

1 General

1.1 Scope and object

This standard relates to definitions, test methods, and procedures for ionizing radiation measurement systems designed for either continuous or discrete measurements and checks of mass per unit area, mass per unit length, or thickness of materials produced in industrial processes. The measured process material may be in such forms as sheets, coatings, laminates, tubes, or rods. This standard applies to systems with one or more outputs for display or control purposes. The signals may be either analogue or digital. The measurement system may also include multiple input signals with various means of compensation and signal conditioning prior to the output signals.

Safety aspects are covered in other IEC and ISO standards (for example IEC 405, ISO 2919, ISO 7205). Consideration will also be given to compliance with all applicable national and local regulations and codes of practice.

Thickness measurement systems which are the object of this standard are generally built for industrial applications covering a very broad range of industries, applications, and specifications. The objective is to identify the common parameters and variables, and to specify standard tests and documentation that will facilitate direct comparison of the performance characteristics of the different measurement systems which are available. These tests are applicable to systems with either fixed or traversing measuring heads and with transmission, backscatter, or X-ray fluorescence sensors.

Many ionizing radiation measurement systems in use today have multiple sensors, and employ various means of compensating the basic sensor signals to minimize the effects of extraneous influence quantities that introduce measurement errors. Dedicated microprocessors and minicomputers have further enhanced multiple input signal processing and error compensation techniques. In the more complex systems, it is difficult to fully evaluate the effectiveness of interactive signal processing and compensation algorithms by static testing. For example, the response times and data collection times for sensors, whose signals are to be combined in some analytical function, are of little importance under the static testing conditions in this standard, but they can lead to large errors under dynamic measuring conditions if they are not properly matched. The relative magnitude of the influence quantity errors to be compensated is also quite important.

The compensation means for sensors with high sensitivity to influence quantities should be more precise than for sensors which exhibit smaller errors in order to achieve the same overall results. Therefore, it is necessary to have performance tests, in the standard, which may include all the interactive signal processing and compensations. This has been facilitated in this standard by identifying different test points throughout the measurement system under evaluation.

It is important to estimate the potential performance degradation in adverse environments. Although it is difficult to duplicate exactly the influence of long-term and short-term process conditions during a limited test period, this set of procedures includes some artificially introduced environmental disturbances.

In this standard the term “thickness” is used interchangeably to mean mass per unit area, mass per unit length, or thickness. Radiometric sensors, in general, measure mass per unit area and the output signals can be expressed in true thickness units only if the effective atomic number and density of the material being measured are known, or if the system is calibrated against actual production samples, and if the effective atomic number and density of the material produced do not change relative to those samples. In the case of rod-shaped products, with a known or constant cross-sectional area, the output signal may be expressed in terms of mass per unit length.

NOTE It is recommended that the reader refers to the block diagram of Annex B for a better understanding of the specification.

1.2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this International Standard. At the time of publication, the editions indicated were valid. All normative documents are subject to revision, and parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

IEC 359:1987, *Expression of the performance of electrical and electronic measuring equipment*.

IEC 405:1972, *Nuclear instruments: Constructional requirements to afford personal protection against ionizing radiation*.

ISO 2919:1980, *Sealed radioactive sources — Classification*.

ISO 7205:1986, *Radionuclide gauges — Gauges designed for permanent installation*.

1.3 Definitions

For the purpose of this International Standard the following definitions apply:

1.3.1

thickness gauge (ionizing radiation)

a measuring assembly that includes an ionizing radiation source and is designed to measure non-destructively the mass per unit area of a material by means of ionizing radiation

1.3.2

transmission measurement system

a thickness gauge system that utilizes the ionizing radiation transmitted through the material being measured. The source and detector are positioned on opposite sides of the measured material. The system may include compensation sensors to measure and correct for the effects of undesirable influence quantities

1.3.3

backscatter measurement system

a thickness gauge system that utilizes the ionizing radiation backscattered by the material being measured and any backing material adjacent to the material being measured. The source and detector are positioned on the same side of the material being measured. The system may include compensation sensors to measure and correct for the effects of undesirable influence quantities

1.3.4

X-ray fluorescence measurement system

a thickness gauge system that utilizes the X-ray fluorescence excited in the material to be measured or in the supporting material

the system may include compensation sensors to measure and correct for the effects of undesirable influence quantities

1.3.5

measuring head

a subassembly comprising one or more radiation sources and radiation detectors together with any compensation sensors that may be used to measure and correct the effects of undesirable influence quantities

NOTE The radiation source may be a radioactive sealed source or a radiation generator emitting X-rays of fixed or variable energy. The measuring head subassembly may also include electronic devices for signal processing.

1.3.6**electronic measuring subassembly**

a subassembly which, by means of incorporated electrical or electronic devices, serves to process the electrical quantities delivered by the measuring head and to supply electrical quantities having convenient values for measurement purposes

1.3.7 test point

A point in the measurement system where electrical signals may be monitored.

1.3.7.1**test point A**

the point in the measurement system where the detector output signal may be monitored in its original basic form

NOTE For an integrating ionization chamber, the test point A typically would be after the preamplifier and before any conversion to a digital form.

1.3.7.2**test point B**

the point in the measurement system at which normal measurement display readouts occur

1.3.7.3**test points — other**

other points in the measurement system at which measurement system signals may be monitored and evaluated

1.3.8 measuring head supporting mechanism

A mechanical assembly on which the measuring head is mounted.

1.3.8.1**fixed mechanism**

a measuring head supporting mechanism that does not move

1.3.8.2**retractable mechanism**

a measuring head supporting mechanism that is able to be withdrawn from the measurement position

1.3.8.3**traversing mechanism**

a measuring head supporting mechanism which allows the measuring head to be traversed across the material being measured

1.3.9 measuring gap**1.3.9.1****transmission thickness gauge**

the distance between opposing faces of the radiation emitting assembly and the detector assembly between which the material being measured is located

1.3.9.2**backscattering thickness gauge**

the distance from the nearest face of the emitting assembly or the detector assembly to the rearmost surface of the material being measured or to the surface of the backing material

NOTE The term “measuring gap” is sometimes used to describe the space or free volume in which the measurement is made. This space may be less than the distance described above.

1.3.10**pass line**

the position of the material to be measured in the measuring gap

1.3.11**reference pass line**

the pass line in the measuring gap corresponding to the position of the material at which calibration is normally made. It is usually defined at a specified distance from either the surface of the source holder housing, or the surface of the detector housing to the adjacent surface of the measured material

1.3.12 measurement area**1.3.12.1****total measurement area**

the minimum area of a given material located at the reference pass line which contributes 100 % of the output signal

1.3.12.2**effective measurement area**

the area of a given material located at the reference pass line which provides the optimum correlation between the output signal and the sheet variable being measured (typically this area will be in the range of 65 % to 95 % of the total measurement area)

1.3.12.3**streak resolution**

the width of a constant thickness streak of material in the process machine direction that will be measured to 70 % of the amplitude of an infinitely wide streak of the same mass per unit area

1.3.13**mass per unit area (surface mass, surface density, mass cross-section, basis weight)**

a quantity equal to the product of the density (mass of a unit volume) of a material and the thickness of the same material. The mass per unit area may be calculated in practice by weighing a sample of material and dividing it by its cross-sectional (surface) area

1.3.14**accuracy**

degree of conformity of an indicated value to a recognized standard value, or ideal value

NOTE 1 It is usually measured as an inaccuracy and expressed as accuracy.

NOTE 2 It is typically expressed in terms of the measured variable, percent of span, percent of upper range value, or percent of actual output reading.

NOTE 3 It must be expressed with some statistically significant notation; for example “ $\pm 2 B$ ” or “absolute worst case”.

1.3.15**reproducibility**

the closeness of agreement among a number of consecutive measurements of the output for the same value of the input under the same operating conditions

NOTE It is usually measured as a non-reproducibility and expressed as reproducibility in percent of upper range value or percent of actual output reading for a specified time period or number of measurements.

1.3.16**rated range**

the range of a quantity to be measured, observed, supplied, or set which the manufacturer has assigned to the apparatus (see IEC 359)

1.3.17**effective range**

the part of the rated range where measurements can be made within the stated limits of error (IEC 359)

NOTE The effective range may be subdivided in order to characterize the instrument more fully.

1.3.18**calibration transfer**

the capability to read a common set of standard samples in two or more thickness gauges and obtain the same results within a specified error band

1.3.19**resolution**

the smallest change of the quantity being measured that can be observed or detected. Due regard shall be given to the statistical nature of the signal and the influence of any sampling techniques being used. Sampled data should be normalized for the effects of signal filtering and data measurement time

1.3.20**system geometrical resolution length**

the minimum length in a specified direction of a standard sample having a determined mass per unit area which can be measured with a given factor of error. In the case of thickness measurements for scanning measurement systems, the geometrical resolution length is a function of the effective measuring area, the settling time of the instrument, the scanning speed of the measuring head, and of the accumulated data sampling time

1.3.21**electrical instability**

variation of the output signal under reference conditions, while all influence quantities are held constant and the detector is not irradiated

1.3.22**overall radiometric instability (noise)**

variation of the output signal under reference conditions, while all influence quantities are held constant and the detector is in an irradiated condition

1.3.23**time response**

an output expressed as a function of time, resulting from the application of a specified input under specified operating conditions. Typical parameters defined are the response time, and settling time as indicated in Figure 1

in digital systems, the output signal is composed of discrete values. The response to a change in the measured variable appears as discrete output steps from the initial to final value of the variable. Figure 2 illustrates a typical example. The parameters rise time and mean response time cannot be defined in a general way because the occurrence of the step change is not defined. The only useful parameter is the mean settling time expressed in terms of discrete time intervals depending upon the system sampling time, sampling rate, and integration time