SLOVENSKI STANDARD
SIST EN ISO 3543:1999

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Kovinske in nekovinske prevleke - Merjenje debeline – Metoda z beta povratnim sipanjem (ISO 3543:1981)

Metallic and non-metallic coatings - Measurement of thickness - Beta backscatter method (ISO 3543:1981)

Metallische und nichtmetallische Schichten - Dickenmessung - Betarückstreu-Verfahren (ISO 3543:1981)

Revetements métalliques et non métalliques - Mesurage de l'épaisseur - Méthode par rétrodiffusion des rayons beta (ISO 3543:1981)

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Descriptors: coatings, metal coatings, non metallic coatings, dimensional measurement, thickness, non destructive tests, beta backscatter method

English version

Metallic and non-metallic coatings - Measurement of thickness - Beta backscatter method (ISO 3543:1981)

Revêtements métalliques et non métalliques - Mesurage de l'épaisseur - Méthode par rétrodiffusion des rayons bêta (ISO 3543:1981)

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This European Standard was approved by CEN on 1994-10-26. CEN 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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The European Standards exist in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CEN member into its own language and notified to the Central Secretariat has the same status as the official versions.

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CEN

European Committee for Standardization
Comité Européen de Normalisation
Europäisches Komitee für Normung

Central Secretariat: rue de Stassart,36 B-1050 Brussels

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Foreword

This European Standard was taken over by the Technical Committee CEN/TC 262 "Protection of metallic materials against corrosion" from the work of ISO/TC 107 "Metallic and other inorganic coatings" of the International Standards Organization (ISO).

CEN/TC 262 had decided to submit the final draft for Formal Vote. The result was positive.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by April 1995, and conflicting national standards shall be withdrawn at the latest by April 1995.

According to the CEN/CENELEC Internal Regulations, the following countries are bound to implement this European Standard: Austria, Belgium, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, United Kingdom.

Endorsement notice

The text of the International Standard ISO 3543:1981 was approved by CEN as a European Standard without any modification.

International Standard ISO 3543

INTERNATIONAL ORGANIZATION FOR STANDARDIZATION•МЕЖДУНАРОДНАЯ ОРГАНИЗАЦИЯ ПО СТАНДАРТИЗАЦИИ•ORGANISATION INTERNATIONALE DE NORMALISATION

Metallic and non-metallic coatings — Measurement of thickness — Beta backscatter method

Revêtements métalliques et non métalliques — Mesurage de l'épaisseur — Méthode par rétrodiffusion des rayons bêta

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards institutes (ISO member bodies). The work of developing International Standards is carried out through ISO technical committees. Every member body interested in a subject for which a technical committee has been set up 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.

Draft International Standards adopted by the technical committees are circulated to the member bodies for approval before their acceptance as International Standards by the ISO Council.

International Standard ISO 3543 was developed by Technical Committee ISO/TC 107, *Metallic and other non-organic coatings*, and was circulated to the member bodies in May 1978.

It has been approved by the member bodies of the following countries :

Australia	India	Sweden
Czechoslovakia	Israel	Switzerland
Egypt, Arab Rep. of	Italy	United Kingdom
France	Japan	USA
Germany, F.R.	Mexico	USSR
Hungary	South Africa, Rep. of	

No member body expressed disapproval of the document.

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Metallic and non-metallic coatings — Measurement of thickness — Beta backscatter method

1 Scope and field of application

This International Standard specifies a method for the non-destructive measurement of coating thicknesses using beta backscatter gauges. It applies to both metallic and non-metallic coatings on both metallic and non-metallic substrates. To employ this method, the atomic numbers or equivalent atomic numbers of the coating and the substrate must differ by an appropriate amount.

CAUTION — Beta backscatter instruments used for the measurement of coating thicknesses employ a number of different radioactive sources. Although the activities of these sources are normally very low, they can present a hazard to health, if incorrectly handled. Therefore, all rules and regulations of local or national authorities must be observed.

2 Definitions

For the purpose of this International Standard, the following definitions apply.

2.1 radioactive decay : A spontaneous nuclear transformation in which particles or gamma radiation are emitted or X-radiation is emitted following orbital electron capture or in which the nucleus undergoes spontaneous fission.*

2.2 beta particle : An electron, of either positive or negative charge, which has been emitted by an atomic nucleus or neutron in a nuclear transformation.*

2.3 beta-emitting isotope; beta-emitting source; beta emitter : A material the nuclei of which emit beta particles.

It is possible to classify beta emitters by the maximum energy level of the particles which they release during their disintegration.

2.4 electron-volt : A unit of energy equal to the change in energy of an electron in passing through a potential difference of 1 V. (1 eV = $1{,}602\ 10 \times 10^{-19}$ J)*

Since this unit is too small for the energies encountered with beta particles, the mega-electronvolt (MeV) is commonly used.

2.5 activity : The number of spontaneous nuclear disintegrations occurring in a given quantity of material during a suitably small interval of time divided by that interval of time.*

Therefore, in beta backscatter measurements, a higher activity corresponds to a greater emission of beta particles.

The SI unit of activity is the becquerel (Bq). The activity of a radioactive element used in beta backscatter gauges is generally expressed in microcuries (μCi) (1 μCi = $3{,}7 \times 10^4$ Bq, which represents $3{,}7 \times 10^4$ disintegrations per second).

2.6 half-life, radioactive : For a single radioactive decay process, the time required for the activity to decrease to half its value by that process.*

2.7 scattering : A process in which a change in direction or energy of an incident particle or incident radiation is caused by a collision with a particle or a system of particles.*

2.8 backscatter : Scattering as a result of which a particle leaves a body of matter from the same surface at which it entered.

NOTE — Radiations other than beta rays are emitted or backscattered by a coating and substrate and some of these may be included in the backscatter measurement. Whenever the term "backscatter" is used in this International Standard, it is to be assumed that reference is made to the total radiation measured.

* Definition taken from ISO 921, *Nuclear energy glossary*.

2.9 backscatter coefficient, R (of a body) : The ratio of the number of particles backscattered to that entering the body.

This number R is independent of the activity of the isotope and of the measuring time.

2.10 backscatter count :

2.10.1 absolute backscatter count, X : The number of particles backscattered during a fixed interval of time, and received by a detector.

X will, therefore, depend on the activity of the isotope, the measuring time, the geometric configuration of the measuring system, and the properties of the detector. The count produced by the uncoated substrate is generally designated by X_o, and that of the coating material by X_s. To obtain these values, it is necessary that both these materials are available with a thickness greater than the saturation thickness (see 2.13).

2.10.2 normalized backscatter count, x_n : A quantity which is independent of the activity of the isotope, the measuring time, and the properties of the detector, and defined by the equation :

$$x_n = \frac{X - X_o}{X_s - X_o}$$

where

X_o is the absolute backscatter count of the saturation thickness of the substrate material;

X_s is the absolute backscatter count of the saturation thickness of the coating material;

X is the absolute backscatter count of the coated specimen;

each of these counts being taken over the same interval of time.

For simplicity, it is often advantageous to express the normalized backscatter count as a percentage by multiplying x_n by 100.

2.11 normalized backscatter curve : The curve obtained by plotting the coating thickness as a function of x_n.

2.12 equivalent [apparent] atomic number : For a material, which can be an alloy or a compound, the atomic number of an element which has the same backscatter coefficient R as the material.

2.13 saturation thickness : The minimum thickness of a material which produces a backscatter which is not changed when the thickness is increased. (See also annex C.)

2.14 sealed source : A radioactive source sealed in a container or having a bonded cover, the container or cover being strong enough to prevent contact with and dispersion of the radioactive material under the conditions of use and wear for which it was designed.*

(Also called sealed isotope.)

2.15 aperture : The opening of the mask abutting the test specimen, which determines the size of the area on which the coating thickness is to be measured. (This mask is also often referred to as a platen, an aperture platen, or a specimen support.)

2.16 source geometry : The spatial arrangement of the source, the aperture, and the detector, with respect to each other.

2.17 dead time : The time period during which a Geiger-Müller tube is unresponsive to the receipt of further beta particles.

2.18 resolving time : The recovery time of the Geiger-Müller tubes and associated electronic equipment during which the counting circuit is unresponsive to further pulses.

3 Principle

When beta particles impinge upon a material, a certain portion of them is backscattered. This backscatter is essentially a function of the atomic number of the material.

If the body has a surface coating, and if the atomic numbers of the substrate and of the coating material are sufficiently different, the intensity of the backscatter will be between two limits: the backscatter intensity of the substrate, and that of the coating. Thus, with proper instrumentation and, if suitably displayed, the intensity of the backscatter can be used for the measurement of mass per unit area of the coating which, provided that it is of uniform density, is directly proportional to the thickness, that is, to the mean thickness within the measuring area.

The curve expressing coating thickness versus beta backscatter intensity is continuous and can be subdivided into three distinct regions, as shown in figure 1, on which the normalized count, x_n, is plotted on the X-axis, and the logarithm of the coating thickness on the Y-axis. In the range $0 \leqslant x_n \leqslant 0{,}35$ the curve is essentially linear. In the range $0{,}35 \leqslant x_n \leqslant 0{,}85$ the curve is nearly logarithmic; this means that, when drawn on semi-logarithmic graph paper, as in figure 1, the curve approximates a straight line. In the range $0{,}85 \leqslant x_n \leqslant 1$ the curve is nearly hyperbolic.

* Definition taken from ISO 921, *Nuclear energy glossary*.

4 Instrumentation

In general, a beta backscatter gauge will comprise :

a) a radiation source (isotope) emitting mainly beta particles having an energy appropriate to the coating thickness to be measured;

b) a probe or measuring system with a range of apertures that limit the beta particles to the area of the test specimen on which the coating thickness is to be measured, and containing a detector capable of counting the number of backscattered particles, for example a Geiger-Müller counter (or tube);

c) a readout instrument where the intensity of the backscatter is displayed. The display, which can be in the form of a meter reading or a digital readout, is either proportional to the absolute count, or to the absolute normalized count, or to the coating thickness expressed either in thickness units or in mass per unit area.

5 Factors relating to accuracy

5.1 Counting statistics

Radioactive decay takes place in a random manner. This means that, during a fixed time interval, the number of beta particles backscattered will not always be the same. This gives rise to statistical errors inherent in radiation counting. In consequence, an estimate of the counting rate based on a short counting interval (for example, 5 s) may be appreciably different from an estimate based on a longer counting period, particularly if the counting rate is low. To reduce the statistical error to an acceptable level, it is necessary to use a counting interval long enough to accumulate a sufficient number of counts.

For counts normally made, the standard deviation (σ) will closely approximate the square root of the absolute count, that is $\sigma = \sqrt{X}$; in 95 % of all cases, the true count will be within $X \pm 2\sigma$. To judge the significance of the precision, it is often helpful to express the standard deviation as a percentage of the count, that is $100\sqrt{X}/X$, or $100/\sqrt{X}$. Thus, a count of 100 000 will give a value ten times more precise than that obtained with a count of 1 000. Whenever possible, a counting interval shall be chosen that will provide a total count of at least 10 000, which would correspond to a standard deviation of 1 % arising from the random nature of radioactive decay.

Direct reading instruments are also subject to these statistical random errors. However, if these instruments do not permit the display of the actual count rate, one way to determine the measuring precision is to make a large number of repetitive measurements at the same location on the same coated specimen, and to calculate the standard deviation by conventional means.

IMPORTANT NOTE — The precision of a thickness measurement by beta backscatter is always less than the precision described above, inasmuch as it also depends on other factors which are listed below.

5.2 Coating and substrate materials

As the backscatter intensity of a measurement depends on the atomic numbers of the substrate and the coating, the accuracy of the measurement will depend to a large degree on the difference between these atomic numbers; thus, with the same measuring parameters, the greater this difference, the more accurate the measurement will be.

As a rule of thumb, for most applications, it can be stated that the difference in atomic numbers should be at least 5. For materials with atomic numbers below 20, this difference may be reduced to 25 % of the higher atomic number; for materials with atomic numbers higher than 50, this difference should be at least 10 % of the higher atomic number. Most unfilled plastics and related organic materials (for example photoresists) may be assumed to have an equivalent atomic number close to 6.

(Annex B gives atomic numbers of commonly used coating and substrate materials.)

5.3 Aperture

Despite the collimated nature of the sources used in commercial backscatter gauges, the backscatter recorded by the detector is, nearly always, the sum of the backscatter produced by the test specimen exposed through the aperture and that of the specimen support. It is, therefore, advantageous to use for the platen construction a material with a low atomic number, and to select the largest aperture possible. However, measuring errors will still occur if the edges of the aperture opening are worn or damaged, or if the test specimen does not properly contact these edges.

Because the measuring area on the test specimen has to be constant to prevent the introduction of another variable, namely the dimensions of the test specimen, the aperture shall be smaller than the area of the surface on which the measurement is made.

5.4 Coating thickness

5.4.1 In the logarithmic range, the *relative measuring error* is nearly constant, and has its smallest value.

5.4.2 In the linear range, the *absolute measuring error*, expressed in mass per unit area or thickness, is nearly constant, which means that as the coating thickness decreases, the relative measuring error increases. At, or near, $x_n = 0{,}35$, the relative errors of the linear and logarithmic ranges are about the same. This means that the relative error at this point may, for all practical purposes, be used to calculate the absolute error over the entire linear range.

5.4.3 In the hyperbolic range, the measuring error is always large, because a small variation in the intensity of the beta backscatter will produce a large variation in the measured value of coating thickness.