

STANDARDS AUSTRALIA

RECONFIRMATION

OF

AS 2331.1.5—2001

Methods of test for metallic and related coatings

Method 1.5: Local thickness tests—Beta-backscatter method

RECONFIRMATION NOTICE

Technical Committee MT-009 has reviewed the content of this publication and in accordance with Standards Australia procedures for reconfirmation, it has been determined that the publication is still valid and does not require change.

Certain documents referenced in the publication may have been amended since the original date of publication. Users are advised to ensure that they are using the latest versions of such documents as appropriate, unless advised otherwise in this Reconfirmation Notice.

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The following are represented on Technical Committee MT-009:

Australasian Institute of Surface Finishing
Australian Chamber of Commerce and Industry
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Australian Steel Institute
Bureau of Steel Manufacturers of Australia
Galvanizers Association of Australia
Galvanizing Association of New Zealand
New Zealand Metal Roofing Manufacturers

NOTES

Australian Standard™

AS 2331.1.5

Methods of test for metallic and related coatings

Method 1.5: Local thickness tests— Beta-backscatter method

PREFACE

This Standard was prepared by members of the Joint Standards Australia/Standards New Zealand Committee MT-009. After consultation with stakeholders in both countries, Standards Australia and Standards New Zealand decided to develop this Standard as an Australian, rather than an Australian/New Zealand Standard. The objective of this revision is to upgrade the requirements so that they closely align with ISO 3543:1981, *Metallic and non-metallic coatings—Measurement of thickness—Beta backscatter method*.

The terms ‘normative’ and ‘informative’ have been used in this Standard to define the application of the appendix to which they apply. A ‘normative’ appendix is an integral part of a Standard, whereas an ‘informative’ appendix is only for information and guidance.

METHOD

1 SCOPE

This 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 need to differ by an appropriate amount.

WARNING: 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.

NOTES:

- 1 Characteristics of isotopes used with beta-backscatter gauges are given in Appendix A.
- 2 The atomic numbers of some commonly used coatings and substrates are given in Appendix B.



2 DEFINITIONS

For the purpose of this Standard, the definitions below apply.

2.1 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.

NOTE: 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). $1 \mu\text{Ci} = 3.7 \times 10^4 \text{ Bq}$, which represents 3.7×10^4 disintegrations per second.

2.2 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 often referred to as a platen, an aperture platen, or a specimen support.)

2.3 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 Standard, it is to be assumed that reference is made to the total radiation measured.

2.4 Backscatter coefficient, R (of a body)

The ratio of the number of particles backscattered to the number entering the body.

The backscatter coefficient is independent of the activity of the isotope and of the measuring time.

2.5 Backscatter count

2.5.1 Absolute backscatter count, X

The number of particles backscattered during a fixed interval of time, and received by a detector.

The absolute backscatter count 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 be available with a thickness greater than the saturation thickness (see Clause 2.15).

2.5.2 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 = the absolute backscatter count of the coated specimen

X_o = the absolute backscatter count of the saturated thickness of the substrate material

X_s = the absolute backscatter count of the saturation thickness of the coating material

Each of these counts is taken over the same interval of time.

The value of x_n is valid between 0 and 1.

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

2.6 Beta-emitting isotope; beta-emitting source; beta emitter

A material in which the nuclei emit beta particles.

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

2.7 Beta particle

High energy electrons that are emitted from the nucleus of materials undergoing nuclear transformation.

2.8 Dead time

The time period during which a Geiger-Müller tube is unresponsive to the receipt of further beta particles, (see Clause 2.14).

2.9 Electron-volt

A unit of energy equal to the change in energy of an electron in passing through a potential difference of 1 V. ($1 \text{ eV} = 1.602 \times 10^{-19} \text{ J}$).

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

2.10 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.

2.11 Half-life, radioactive

For a single radioactive decay process, the time required for the activity to decrease by half.

2.12 Normalized backscatter curve

The curve obtained by plotting the coating thickness as a function of x_n .

2.13 Radioactive decay

A spontaneous nuclear transformation that may not involve fission, during which beta particles are emitted, often accompanied by gamma radiation.

2.14 Resolving time

The recovery time of the Geiger-Müller tube and associated electronic equipment during which the counting circuit is unresponsive to further pulses, (see Clause 2.8).

2.15 Saturation thickness

The minimum thickness of a material which produces a backscatter which is not changed when the thickness is increased.

2.16 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.

2.17 Sealed source

A radioactive source sealed in a container or having a bonded cover, the container or cover being robust 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'.)

2.18 Source geometry

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

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 a suitable display, 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 $0 \leq x_n \leq 0.35$ the relationship is essentially linear. In the range $0.35 \leq x_n \leq 0.85$ the relationship is nearly logarithmic; this means that the curve approximates a straight line, as shown in Figure 1. In the range $0.85 \leq x_n \leq 1$ the relationship is nearly hyperbolic.

4 INSTRUMENTATION

In general, a beta-backscatter gauge will comprise the following components:

- (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 which contains a detector capable of counting the number of backscattered particles, for example a Geiger-Müller counter (or tube).
- (c) An instrument where the intensity of the backscatter is displayed by meter reading or by digital readout. The reading may be either proportional to the absolute count or the absolute normalized count, or may give the thickness directly, either in thickness units or in equivalent mass per surface area units.

5 FACTORS RELATING TO ACCURACY

5.1 Counting statistics

Radioactive decay takes place in a random manner; hence, 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 1000. 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.

NOTE: The precision of a thickness measurement by beta-backscatter is always less than the precision described in this Clause, inasmuch as it also depends on other factors which are described in Clauses 5.2 to 5.17.

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, 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.

NOTE: Atomic numbers of commonly used coating and substrate materials are listed in Appendix B.

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 needs 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 measurement errors

5.4.1 In the logarithmic range

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