
**Non-conductive coatings on
non-magnetic electrically conductive
basis materials — Measurement of
coating thickness — Amplitude-sensitive
eddy current method**

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*Revêtements non conducteurs sur matériaux de base non magnétiques
conducteurs de l'électricité — Mesurage de l'épaisseur de
revêtement — Méthode par courants de Foucault sensible aux
variations d'amplitude*

[ISO 2360:2003](#)

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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.org
Web www.iso.org

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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 2.

The main task of technical committees is to prepare International Standards. 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 document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 2360 was prepared by Technical Committee ISO/TC 107, *Metallic and other inorganic coatings*, Subcommittee SC 2, *Test methods*.

This third edition cancels and replaces the second edition (ISO 2360:1982), which has been technically revised.

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Non-conductive coatings on non-magnetic electrically conductive basis materials — Measurement of coating thickness — Amplitude-sensitive eddy current method

1 Scope

This International Standard describes a method for non-destructive measurements of the thickness of non-conductive coatings on non-magnetic, electrically conductive (generally metallic) basis materials, using amplitude-sensitive eddy current instruments.

NOTE This method can also be used to measure non-magnetic metallic coatings on non-conductive basis materials.

The method is particularly applicable to measurements of the thickness of most oxide coatings produced by anodizing, but is not applicable to all conversion coatings, some of which are too thin to be measured by this method (see Clause 6).

Although theoretically, the method can be used for measurements of the thickness of coatings on magnetic basis materials, its use for this application is not recommended. In such cases, the magnetic method specified in ISO 2178 should be used.

2 Principle

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An eddy current probe (or integrated probe/instrument) is placed on the surface of the coating(s) to be measured, and the thickness is read from the instrument's readout.

3 Apparatus

3.1 Probe, containing an eddy current generator and detector linked to a system capable of measuring and displaying the changes in amplitude, normally as a direct readout of coating thickness. The system may also be able to measure phase changes.

NOTE 1 The probe and measuring system/display may be integrated into a single instrument.

NOTE 2 Factors affecting measurement accuracy are discussed in Clause 5.

4 Sampling

Sampling depends on the specific application and coating to be tested. The area, location and number of test specimens shall be agreed between interested parties and shall be included in the test report (see Clause 9).

5 Factors affecting measurement uncertainty

5.1 Coating thickness

A measurement uncertainty is inherent in the method. For thin coatings, this measurement uncertainty (in absolute terms) is constant, independent of the coating thickness and, for a single measurement, is at least 0,5 µm. For coatings thicker than 25 µm, the uncertainty becomes relative to the thickness and is approximately a constant fraction of that thickness.

For measuring coating thicknesses of 5 µm or less, the average of several measurements shall be taken.

It may not be possible to obtain the measurement uncertainty specified in Clause 8 when measuring coatings of less than 3 µm in thickness.

5.2 Electrical properties of the basis materials

Measurements using eddy current instruments can be affected by the electrical conductivity of the basis metal, which is a function of the composition and heat treatment of the material. The influence of electrical conductivity on the measurement varies considerably with the make and type of instrument.

5.3 Basis metal thickness

For each instrument there is a critical minimum basis metal thickness above which measurements are not affected by an increase in thickness. Since this thickness depends on both the eddy current generation frequency of the probe system and the electrical properties of the basis material its value should be determined experimentally, unless otherwise specified by the manufacturer.

An explanation of Eddy current generation and the calculation of the required minimum basis material thickness, d_{\min} , is given in Annex A.

However, in the absence of any other information, the required minimum basis material thickness, d_{\min} , can be estimated from the equation:

$$d_{\min} = 2,5 \delta_0$$

where δ_0 is the standard penetration depth of the basis material (see A.1).

5.4 Edge effects

Eddy current instruments can be sensitive to abrupt changes in surface contour of test specimen. Therefore measurements made too near to an edge or corner may not be valid unless the instrument has been specifically calibrated for such measurements (see 6.2.4 and Annex B).

NOTE When compared with the phase-sensitive method of ISO 21968, the amplitude-sensitive eddy current instruments can be substantially more heavily affected by edge effects.

5.5 Surface curvature

Measurements are affected by the curvature of the test specimen. This influence of curvature varies considerably with the make and type of instrument and probe, but always becomes more pronounced as the radius of curvature decreases. Measurements made on curved test specimens might not, therefore, be valid unless the instrument is specifically calibrated for the surface curvature in question, or a special probe, which compensates for surface influence, is used.

5.6 Surface roughness

Measurements are influenced by the surface topography of the basis material and of the coating. Rough surfaces can cause both systematic and random errors. Random errors can be reduced by making multiple measurements, each measurement being made at a different location, and then calculating the average value of that series of measurements.

If the basis material is rough, the zero of the instrument shall be checked at several locations on a typical sample of the uncoated, rough, basis material. If no typical uncoated basis material is available, the coating of the test specimen shall be stripped, at least over part of its area, with a chemical solution that does not attack the basis material.

NOTE When compared with the phase-sensitive method of ISO 21968, the amplitude-sensitive eddy current measurement can be more heavily affected by basis material roughness.

5.7 Lift-off effect

If the probe is not placed directly on the coating, the gap between probe and coating ("lift-off") affects the measurement of the coating thickness. The measured thickness will be equal to the coating thickness plus the additional "lift-off" gap.

Lift-off can be produced unintentionally, e.g., by the presence of foreign particles between the probe and the coating.

The probe tip shall be checked frequently for cleanliness.

5.8 Probe pressure

The pressure with which the probe is applied to the test specimen affects the instrument readings and shall therefore be made constant.

This pressure effect is more noticeable when the coatings are soft. Most commercially-available instruments are supplied with constant pressure probes.

5.9 Probe tilt

Unless otherwise instructed by the manufacturer, the probe shall be applied perpendicularly to the coating surface as tilting the probe away from the perpendicular can cause measurement errors.

The possibility of tilt occurring inadvertently can be minimized by probe design or by the use of a probe-holding jig.

5.10 Temperature effects

Because temperature changes affect the characteristics of the probe, it should be used under approximately the same temperature conditions as those used for calibration unless the probe has built-in temperature compensation.

Most metals change their electrical conductivity with temperature. Because the measured coating thickness is influenced by changes in the electrical conductivity of the basis metal, large temperature changes should be avoided.

5.11 Intermediate coatings

The presence of an intermediate coating can affect the measurement of the coating thickness if the electrical characteristics of that intermediate coating differ from that of the coating or basis material. If a difference does exist then the measurements will, in addition, be affected by an intermediate coating thickness of less than

d_{\min} . If the thickness is greater than d_{\min} then the intermediate coating, if non-magnetic, can be treated as the basis material.

It has been found that some instruments having probe systems operating with multiple frequencies can measure both top and intermediate coatings.

6 Procedure

6.1 Calibration of instruments

6.1.1 General

Before use, each instrument shall be calibrated in accordance with the manufacturer's instructions, using suitable calibration standards. Particular attention shall be paid to the description given in Clause 3 and to the factors described in Clause 5.

In order to minimize conductivity changes due to temperature variations, at the time of calibration the instrument and the calibration standards shall be at a temperature close to the temperature of the items to be measured.

NOTE Calibration checks should also be carried out as necessary during the determinations to avoid instrument drift.

6.1.2 Calibration standards

Instrument calibration shall be made using at least two standards of different and known thicknesses. One of these standards may be of the uncoated basis material.

NOTE 1 Such standards should have their thicknesses traceable to a certifiable source.

The electrical conductivity and magnetic permeability of both coating and basis materials shall be identical to those properties of the parts to be measured.

NOTE 2 As calibration standards are subject to wear and deterioration with time and use, they should be recalibrated and/or replaced periodically at time intervals established locally or after consultation with the manufacturer.

6.1.3 Verification

The electrical properties of the basis material of the calibration standards shall be similar to those of the basis material of the test specimen.

NOTE To confirm their suitability, the readings obtained with the basis material of the uncoated calibration standard and with that of the test specimen should be compared.

If the basis material thickness exceeds the critical thickness, as defined in 5.3, the thickness measurement is not affected by the thickness of the basis material.

If the critical thickness is not exceeded, the thickness of the basis material for the test and for the calibration shall be the same. If, under practical conditions, this is not possible then it may be possible to back either the standard or the test specimen with a sufficient thickness of a material having similar electrical properties to make the readings independent of the basis material thickness. If this method is used, tests shall be undertaken to confirm that it is acceptable and to establish the presence of any additional errors.

If the curvature of the coated surface to be measured is such as to preclude calibration on a flat surface, the standards used for calibration shall have the same radii of curvature as the specimen to be measured, unless a special probe that compensates for the curvature influence is used.

6.2 Determination

6.2.1 General

Operate each instrument in accordance with the manufacturer's instructions, giving appropriate attention to the factors given in Clause 5.

Check the calibration of the instrument, using valid calibration standards, at the test site each time the instrument is put into service and at frequent intervals during use (at least once per hour) to ensure proper performance (see 6.1).

The precautions listed in 6.2.2 to 6.2.6 shall be observed.

6.2.2 Surface cleanliness

Before making measurements, remove any foreign matter such as dirt, oil, grease and corrosion products from the surface of standards and test specimen, without removing any coating material.

6.2.3 Basis metal thickness

Check that the basis material exceeds the critical thickness (see 5.3). If it does not, either use the back-up method described in 6.1.3 or ensure that the calibration was carried out on a calibration standard having the same thickness and electrical properties as the test specimen.

6.2.4 Edge effects

Do not make measurements close to an edge, hole, inside corner, etc., of a test specimen unless the validity of the calibration for such measurements has been demonstrated (see Annex B).

6.2.5 Curvature

Do not make measurements on a curved surface of a test specimen, unless the validity of the calibration for such measurements has been demonstrated.

6.2.6 Number of readings

A number of measurements made on the same spot, if necessary using a probe jig, will provide information on the repeatability (standard deviation) of the instrument and its probe at that time and at the thickness being measured.

NOTE A coefficient of variation, V , can be calculated from this standard deviation. V can be applied to a range of thicknesses.

A number of measurements made by moving the probe between each measurement, and within a specified area on the coated surface, will provide information on the repeatability of the instrument and coating within that specified area.

If a coating surface is rough or the test specimens are known to have large thickness gradients across their surfaces (e.g. because of size and/or shape) the origins of measurement variations should be established by multiple measurements.

7 Expression of results

The expression and presentation of results shall be agreed between interested parties and normally includes:

- a list of all the readings taken;
- the mean, maximum, minimum readings;
- the standard deviation and/or coefficient of variation.