

---

---

**Non-magnetic metallic coatings on  
metallic and non-metallic basis  
materials — Measurement of coating  
thickness — Phase-sensitive eddy-  
current method**

*Revêtements métalliques non magnétiques sur des matériaux de base  
métalliques et non métalliques — Mesurage de l'épaisseur de  
revêtement — Méthode par courants de Foucault sensible aux  
variations de phase*

ISO 21968:2005

<https://standards.iteh.ai/catalog/standards/sist/cb083640-9993-4290-a9c6-8ae0fc2d8884/iso-21968-2005>



**PDF disclaimer**

This PDF file may contain embedded typefaces. In accordance with Adobe's licensing policy, this file may be printed or viewed but shall not be edited unless the typefaces which are embedded are licensed to and installed on the computer performing the editing. In downloading this file, parties accept therein the responsibility of not infringing Adobe's licensing policy. The ISO Central Secretariat accepts no liability in this area.

Adobe is a trademark of Adobe Systems Incorporated.

Details of the software products used to create this PDF file can be found in the General Info relative to the file; the PDF-creation parameters were optimized for printing. Every care has been taken to ensure that the file is suitable for use by ISO member bodies. In the unlikely event that a problem relating to it is found, please inform the Central Secretariat at the address given below.

**iTeh STANDARD PREVIEW**  
**(standards.iteh.ai)**

ISO 21968:2005

<https://standards.iteh.ai/catalog/standards/sist/cb083640-9993-4290-a9c6-8ae0fc2d8884/iso-21968-2005>

© ISO 2005

All rights reserved. Unless otherwise specified, no part of this publication may be reproduced or utilized in any form or by any means, electronic or mechanical, including photocopying and microfilm, without permission in writing from either ISO at the address below or ISO's member body in the country of the requester.

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](mailto:copyright@iso.org)  
Web [www.iso.org](http://www.iso.org)

Published in Switzerland

## Contents

Page

Foreword.....	iv
<b>1 Scope .....</b>	<b>1</b>
<b>2 Principle .....</b>	<b>1</b>
<b>3 Equipment .....</b>	<b>2</b>
<b>4 Sampling.....</b>	<b>2</b>
<b>5 Factors affecting measurement accuracy.....</b>	<b>2</b>
5.1 Coating thickness .....	2
5.2 Electrical properties of the basis materials .....	2
5.3 Electrical properties of the coating materials.....	2
5.4 Basis-metal thickness .....	2
5.5 Edge effects.....	3
5.6 Surface curvature .....	3
5.7 Surface roughness .....	3
5.8 Lift-off effect.....	3
5.9 Probe pressure.....	4
5.10 Probe tilt .....	4
5.11 Temperature effects.....	4
5.12 Intermediate coatings.....	4
<b>6 Procedure .....</b>	<b>4</b>
6.1 Calibration of instruments .....	4
6.2 Determination.....	5
7 Expression of results .....	6
8 Measurement uncertainty .....	6
9 Test report .....	6
<b>Annex A (informative) Eddy-current generation in a metallic conductor.....</b>	<b>8</b>
<b>Annex B (normative) Test for edge effect.....</b>	<b>10</b>
<b>Bibliography .....</b>	<b>12</b>

## 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 21968 was prepared by Technical Committee ISO/TC 107, *Metallic and other inorganic coatings*, Subcommittee SC 2, *Test methods*.

## iTeh STANDARD PREVIEW (standards.iteh.ai)

[ISO 21968:2005](https://standards.iteh.ai/catalog/standards/sist/cb083640-9993-4290-a9c6-8ae0fc2d8884/iso-21968-2005)

<https://standards.iteh.ai/catalog/standards/sist/cb083640-9993-4290-a9c6-8ae0fc2d8884/iso-21968-2005>

# Non-magnetic metallic coatings on metallic and non-metallic basis materials — Measurement of coating thickness — Phase-sensitive eddy-current method

## 1 Scope

This International Standard describes a method of using phase-sensitive eddy-current instruments for non-destructive measurements of the thickness of non-magnetic metallic coatings on metallic and non-metallic basis materials, such as:

- a) zinc, cadmium, copper, tin or chromium on steel;
- b) copper or silver on composite materials.

The phase-sensitive method can be applied without thickness errors to smaller surface areas and to stronger surface curvatures than the amplitude-sensitive eddy-current method described in ISO 2360<sup>[1]</sup>, and is less affected by the magnetic properties of the basis material. However, the phase-sensitive method is more affected by the electrical properties of the coating materials.

When measuring metallic coatings on metallic basis materials, the product of conductivity and permeability ( $\sigma$ ,  $\mu$ ) of one of the materials should be at least a factor of 1,5 times the product of conductivity and permeability for the other material. Non-ferromagnetic materials have a relative permeability of 1.

## 2 Principle

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

For each instrument, there is a maximum measurable thickness of the coating.

Since this thickness range depends on both the applied frequency of the probe system and the electrical properties of the coating, the maximum thickness should be determined experimentally, unless otherwise specified by the manufacturer.

An explanation of eddy-current generation and the calculation of the maximum measurable coating thickness,  $d_{\max}$ , is given in Annex A.

However, in the absence of any other information, the maximum measurable coating thickness,  $d_{\max}$ , can be estimated using Equation (1):

$$d_{\max} = 0,8\delta_0 \quad (1)$$

where  $\delta_0$  is the standard penetration depth of the coating material [see Equation (A.1)].

### 3 Equipment

**3.1 Probe**, containing an eddy-current generator, and a **detector** linked to a system capable of measuring and displaying changes in amplitude and phase, normally as a direct readout of coating thickness.

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 accuracy

#### 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. The absolute value of the uncertainty depends on the applied frequency of the probe system, and also on the conductivity and permeability of the used sample materials. With increasing thickness within the measurement range of the probe system, this uncertainty becomes a function of the thickness and is approximately a constant fraction of that thickness.

The mean of several measurements should be used as the thickness value to reduce the uncertainty, especially in the lower part of the measurement range of the used probe system.

#### 5.2 Electrical properties of the basis materials

Both conductivity and permeability have some effect on the measurement, but these effects are small when compared to those with the amplitude method described in ISO 2360<sup>[1]</sup>.

#### 5.3 Electrical properties of the coating materials

Coating thickness measurements are affected by the electrical conductivity of the coating material, which in turn can be dependent upon composition, the coating process (additives, contaminants, etc.) and any post-coating treatments, such as heating or mechanical working.

#### 5.4 Basis-metal thickness

For each instrument, there is a critical minimum basis-metal thickness above which measurements will not be affected by an increase in thickness.

This thickness depends on both the applied frequency of the probe system and the electrical and magnetic 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 minimum basis-material thickness,  $d_{\min}$ , is given in Annex A.

However, in the absence of any other information, the required minimum thickness of basis material,  $d_{\min}$ , can be calculated from Equation (2):

$$d_{\min} = 2,5\delta_0 \quad (2)$$

where  $\delta_0$  is the standard penetration depth of the metallic basis material [see Equation (A.1)].

## 5.5 Edge effects

Eddy-current instruments can be sensitive to abrupt changes in surface contour of the 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 The phase-sensitive eddy-current instruments can be substantially less affected by edge effects when compared with the amplitude method of ISO 2360.

## 5.6 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 may 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.

The effect of surface curvature can be reduced by the use of so-called microprobes, in which the radial area of probe influence has been reduced.

NOTE The phase-sensitive eddy-current measurement can be substantially less affected by the surface curvature of the test specimen when compared with the amplitude-sensitive eddy-current method given in ISO 2360.

## 5.7 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, with each measurement being made at a different location, and then calculating the average value of this 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 which does not attack the basis material.

NOTE The phase-sensitive eddy-current measurement can be substantially less affected by basis-material roughness and coating roughness when compared with the amplitude-sensitive eddy-current method given in ISO 2360.

## 5.8 Lift-off effect

If the probe is not placed directly down onto the coating, the gap between probe and coating (lift-off) will affect the measurement of the metal coating thickness. The use of an appropriate electronic circuit design, and/or mathematical algorithm in the instrument, allows lift-off compensation to be applied for gaps of up to 1 mm.

Lift-off compensation shall be verified in accordance with the manufacturer's instructions, by the use of electrically non-conductive shims of known thickness which are inserted between the probe and the coating.

Lift-off can be produced intentionally, as when measuring a metallic coating through paint, or when it is necessary to make a contactless measurement, or unintentionally due to the presence of foreign particles between the probe and coating.

The probe tip shall be frequently checked for cleanliness.

## 5.9 Probe pressure

The pressure with which the probe is applied to the test specimen can affect the instrument reading and shall be made constant.

NOTE The phase-sensitive eddy-current measurement can be substantially less affected by the pressure with which the probe is placed onto the sample when compared with the amplitude-sensitive eddy-current method given in ISO 2360. Contactless measurements are possible (see 5.8.).

## 5.10 Probe tilt

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

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

## 5.11 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 both coating and basis metals, large temperature changes should be avoided.

## 5.12 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 can be treated as the basis material.

It has been found that some instruments having probe systems operating with multiple frequencies may be able to 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 factors listed in Clause 5.

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, in order to minimize conductivity changes due to temperature variations.

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 can sometimes be of the uncoated basis material.

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

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

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.

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 5.4, 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 should be the same for the test and for the calibration. 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 should be made 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 compensating for the curvature influence is used.

## 6.2 Determination

### 6.2.1 General

Operate the instrument in accordance with the manufacturer's instructions, giving appropriate attention to the factors mentioned 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 sufficient intervals during use as recommended by the manufacturer 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 specimens, without removing any coating material.

### 6.2.3 Basis-metal thickness

Check that the basis-material thickness exceeds the critical thickness (see 5.4). If 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.