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# International Standard



# 2361

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

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## Electrodeposited nickel coatings on magnetic and non-magnetic substrates — Measurement of coating thickness — Magnetic method

*Revêtements électrolytiques de nickel sur métal de base magnétique et non magnétique — Mesurage de l'épaisseur — Méthode magnétique*

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Descriptors : nickel coatings, dimensional measurement, thickness.

## 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 2361 was developed by Technical Committee ISO/TC 107 *Metallic and other non-organic coatings*, and was circulated to the member bodies in November 1980.

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

Australia	Italy	Spain
Bulgaria	Japan	Sweden
Czechoslovakia	Netherlands	Switzerland
Egypt, Arab Rep. of	Poland	United Kingdom
France	Portugal	USA
Hungary	Romania	USSR
India	South Africa, Rep. of	

No member body expressed disapproval of the document.

This second edition cancels and replaces the first edition (i.e. ISO 2361-1972).

# Electrodeposited nickel coatings on magnetic and non-magnetic substrates — Measurement of coating thickness — Magnetic method

## 1 Scope and field of application

This International Standard specifies the method of using coating thickness instruments of the magnetic type for non-destructive measurements of the thickness of electrodeposited nickel coatings on magnetic or non-magnetic substrates.

The method may not be applicable to autocatalytic (electroless) nickel coatings depending on their chemical composition.

For the purposes of this International Standard, two types of nickel coating are distinguished

- a) nickel coatings on magnetic substrates (type A coatings);
- b) nickel coatings on non-magnetic substrates (type B coatings).

It should not be assumed that all instruments are applicable to both types of coating.

The effective measuring ranges of instruments using the principle of magnetic attraction are up to 50  $\mu\text{m}$  for type A coatings, and up to 25  $\mu\text{m}$  for type B coatings.

For instruments using the principle of reluctance, the effective ranges are much greater and measurements up to 1 mm, or more, can be made on both types of coating.

## 2 References

ISO 1463, *Metallic and oxide coatings — Measurement of coating thickness — Microscopical method.*

ISO 2064, *Metallic and other non-organic coatings — Definitions and conventions concerning the measurement of thickness.*

ISO 2177, *Metallic coatings — Measurement of coating thickness — Coulometric method by anodic dissolution.*<sup>1)</sup>

1) At present at the stage of draft. (Revision of ISO 2177-1972.)

2) For the purpose of this International Standard, the measuring uncertainty is defined as that obtained with an instrument correctly calibrated and used.

## 3 Principle

Coating thickness instruments of the magnetic type measure either the magnetic attraction between a permanent magnet and the coating/substrate combination, or the reluctance of a magnetic flux path passing through the coating and the substrate.

## 4 Factors affecting the measuring accuracy<sup>2)</sup>

The following factors may affect the accuracy of measurements of coating thickness.

### 4.1 Coating thickness

The precision of a measurement changes with coating thickness depending on the instrument design. For thin coatings, the precision is constant, independent of the thickness. For thick coatings, the precision is an approximately constant fraction of the thickness.

### 4.2 Magnetic properties of the basis metal (type A coatings only)

Thickness measurements by the magnetic method are affected by variations in the magnetic properties of the basis metal. For practical purposes, magnetic variations in low carbon steels can be considered to be insignificant.

### 4.3 Basis metal thickness (type A coatings only)

For each instrument, there is a critical thickness of basis metal above which measurements will not be affected by an increase in thickness. Since it depends on the instrument probe and the nature of the basis metal, its value should be determined experimentally, unless it is specified by the manufacturer.

#### 4.4 Edge effects

The method is sensitive to abrupt changes in surface contour of the test specimen. Therefore, measurements made too near an edge or inside corner will not be valid unless the instrument is specifically calibrated for such measurements. The effect may extend up to about 20 mm from the discontinuity, depending on the instrument.

#### 4.5 Curvature

Measurements are affected by the curvature of the test specimen. The influence of curvature varies considerably with the make and type of instrument, but always becomes more pronounced as the radius of curvature decreases.

Instruments with two-pole probes may also produce different readings if the poles are aligned in planes parallel or perpendicular to the axis of a cylindrical surface. A similar effect can occur with a single-pole probe if the tip is unevenly worn.

Measurements made on curved test specimens may not, therefore, be valid unless the instrument is specifically calibrated for such measurements.

#### 4.6 Surface roughness

If the range of a series of measurements, made within the same reference area (see ISO 2064) on a rough surface, substantially exceeds the inherent repeatability of the instrument, the number of measurements required should be increased to at least five.

#### 4.7 Direction of mechanical working of the basis metal (type A coatings only)

Measurements made by an instrument having a two-pole probe or an unevenly worn single-pole probe may be influenced by the direction in which the magnetic basis metal has been subjected to mechanical working (such as rolling), the reading changing with the orientation of the probe on the surface.

#### 4.8 Residual magnetism (type A coatings only)

Residual magnetism in the basis metal affects measurements made by instruments which employ a stationary magnetic field. Its influence on measurements made by reluctance instruments employing an alternating magnetic field is much smaller (see 6.7).

#### 4.9 Magnetic fields

Strong magnetic fields, such as those produced by various types of electrical equipment, can seriously interfere with the operation of instruments which employ a stationary magnetic field (see 6.7).

#### 4.10 Foreign particles

The probes of the instruments have to make physical contact with the test surface because these instrument are sensitive to

foreign material that prevents intimate contact between the probe and the surface of the coating. The probe tip should be checked for cleanliness.

#### 4.11 Magnetic properties of the coating

Measurements are affected by variations in the magnetic properties of the coating. These properties depend on the conditions under which the deposit is made, the type and composition of the coating, and its stress conditions. Heat treatment at 400 °C for 30 min will equalize the magnetic permeability of dull (sulphur-free or nearly sulphur-free) nickel coatings of the same composition. Bright nickel deposits may or may not have the same magnetic properties after heat treatment; heat treatment may also damage the article. The magnetic properties of multiple layer nickel coatings will also depend on the relative thickness of each of the layers.

#### 4.12 Nickel coatings on the back of the substrate (type B coatings only)

Nickel coatings on the back of the substrate can affect the measurements depending on the thickness of the substrate.

#### 4.13 Probe pressure

The poles of the test probe have to be applied at a constant but sufficiently high pressure, such that no deformation of the coating occurs.

#### 4.14 Probe orientation

The readings of instruments using the magnetic attraction principle may be affected by the orientation of the magnet in relation to the field of gravity of the earth. Thus, the operation of an instrument probe in a horizontal or upside-down position may require a different calibration, or may be impossible.

### 5 Calibration of instruments

#### 5.1 General

Before use, each instrument shall be calibrated in accordance with the manufacturer's instructions, using suitable calibration standards.

During use, the calibration of the instrument shall be checked after a warm-up period and at regular intervals of at least once a day. Appropriate attention shall be given to the factors listed in clause 4 and to the procedures specified in clause 6.

#### 5.2 Calibration standards

5.2.1 Calibration standards shall be coated standards obtained by electroplating nickel adherently onto a substrate.

The surface roughness and magnetic properties of the substrate and the coating of the standards shall be similar to

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those of the test specimen (see 4.2 and 4.11). To confirm the similarity of the magnetic properties of the substrates, a comparison of the readings obtained from the basis metal of the uncoated calibration standard and that of the uncoated test specimen is recommended.

Similarly, to ensure the validity of the calibration of the instrument, it is necessary to use, as a calibration standard, a representative test specimen, the thickness of which has been determined using either the coulometric method (see ISO 2177) or the microscopical method (see ISO 1463).

**5.2.2** In some cases, the calibration of the instrument has to be checked by rotating the probe through increments of 90° (see 4.7 and 4.8).

**5.2.3** For type A coatings, the thickness of the basis metal of the test specimen and of the calibration standard has to be the same, if the critical thickness, defined in 4.3, is not exceeded. Additional errors will occur if the substrate is coated on both sides. If the critical thickness is not exceeded, back up the basis metal of the calibration standard, or of the test specimen, with a sufficient thickness of similar material in order to make the readings independent of the basis metal thickness.

**5.2.4** If the curvature of the coating to be measured is such as to preclude calibration on a flat surface, the curvature of the coated standard shall be the same as that of the test specimen.

## 6 Procedure

### 6.1 General

Operate each instrument in accordance with the manufacturer's instructions, giving appropriate attention to the factors listed in clause 4.

The following precautions shall be observed.

### 6.2 Basis metal thickness (type A coatings only)

Check whether the basis metal thickness exceeds the critical thickness. If not, either use the back-up method mentioned in 5.2.3 or ensure that the calibration has been made on a calibration standard having the same thickness and magnetic properties as the test specimen.

### 6.3 Edge effects

Do not make measurements in the proximity of a discontinuity, such as an edge, hole, inside corner, of a test specimen, unless the validity of the calibration for such measurements has been demonstrated.

### 6.4 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.

### 6.5 Number of readings

Because of normal instrument variability, it is necessary to take several readings at each position in each measuring area (see also ISO 2064). Local variations in coating thickness may also require that a number of measurements be made in the reference area; this applies particularly if the surface is rough.

Instruments of the attractive-force type are sensitive to vibrations and readings that are obviously too high shall be rejected.

### 6.6 Direction of mechanical working

(type A coatings only)

If the direction of mechanical working has a pronounced effect on the reading, measurements on test specimens shall be made with the probe in the same orientation as that used during calibration. If this is impossible, four measurements shall be made in the same measuring area by rotating the probe through increments of 90°.

### 6.7 Residual magnetism

If residual magnetism is present in the basis metal, it is necessary, if using a two-pole instrument employing a stationary magnetic field, to make measurements in two orientations differing by 180°.

It may be necessary to demagnetize the test specimen to obtain valid results.

### 6.8 Surface cleanliness

Before making measurements, remove any foreign matter, such as dirt, grease and corrosion products, from the surface, without removing any coating material. When making measurements, avoid any areas having visible defects that are difficult to remove, such as welding or soldering flux, acid spots, dross, or oxide.

### 6.9 Techniques

The results obtained may depend on the technique of the operator. For example, the pressure applied to a probe, or the rate of applying a balancing force to a magnet, will vary from one individual to another. Such effects can be reduced or minimized either by having the instrument calibrated by the same operator who will make the measurement, or by using constant pressure probes.

### 6.10 Positioning of the probe

In general, the instrument probe shall be placed perpendicular to the test surface at the point of measurement. For some instruments of the attractive force type, this is essential. With some instruments, however, it is desirable to tilt the probe slightly and to select the angle of inclination giving the minimum reading. If, on a smooth surface, the results obtained

vary substantially with the angle of inclination, it is probable that the probe is worn and needs to be replaced.

If an instrument of the attractive force type is to be used in a horizontal or upside-down position, it shall be calibrated separately for that position if the measuring system is not supported at the centre of gravity.

## 7 Accuracy requirement

The calibration and operation of the instrument shall be such that the coating thickness can be determined to within 10 % of its true thickness or to within 1,5  $\mu\text{m}$ , whichever is the greater (see clause 5). The method is capable of better accuracy.

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