International Standard 2178

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Non-magnetic coatings on magnetic substrates — Measurement of coating thickness — Magnetic method

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Foreword

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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 2178 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	Sweden
Bulgaria	Japan	Switzerland
Czechoslovakia	Netherlands	United Kingdom
France	Poland	USA
Germany, F. R.	Romania	USSR
Hungary	South Africa, Rep. of	
India	Spain	

No member body expressed disapproval of the document.

This second edition cancels and replaces the first edition (i.e. ISO 2178-1972).

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Non-magnetic coatings on 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 non-magnetic coatings (including vitreous and porcelain enamel coatings) on magnetic basis metals.

The method is applicable only for measurements on reasonably flat specimens. In the case of nickel coatings on non-magnetic substrates, the preferred method is that specified in ISO 2361.

2 References

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

ISO 2361, *Electrodeposited nickel coatings on magnetic and non-magnetic substrates — Measurement of coating thickness — Magnetic method.*

3 Principle

Coating thickness instruments of the magnetic type measure either the magnetic attraction between a permanent magnet and the basis metal, as influenced by the presence of the coating, or the reluctance of a magnetic flux path passing through the coating and the basis metal.

4 Factors affecting the measuring accuracy[1)]

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

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. To avoid the influences of several, or localized, heat treatments and cold working, the instrument should be calibrated using a calibration standard having a basis metal with the same properties as that of the test specimen or, preferably, and if available, with a sample of the part to be tested before application of the coating.

4.3 Basis metal thickness

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.

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

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

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

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 instruments 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 Conductivity of coating

Some magnetic instruments work at frequencies between 200 and 2 000 Hz. At these frequencies, eddy currents produced in thick, highly conductive coatings may interfere with the reading.

4.12 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, even if the coating material is soft. Alternatively, soft coatings may be covered with foils, and the thickness of the foils subtracted from the test results. Such considerations are also necessary if measuring the thickness of phosphate coatings.

4.13 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 or by comparing magnetic thickness measurements made on a selection of the test specimens with thickness measurements made by the method specified in the International Standard for the particular coating concerned. For instruments which cannot be calibrated, the deviation from the nominal value shall be determined by comparison with calibration standards and shall be taken into consideration for all measurements.

During use, the calibration of the instrument shall be checked at frequent intervals. Appropriate attention shall be given to the factors listed in clause 4 and to the procedures specified in clause 6.

5.2 Calibration standards

Calibration standards of uniform thickness are available either as shims or foils, or as coated standards.

5.2.1 Calibration foils

NOTE — In this sub-clause, the word "foil" is used to imply a non-magnetic metallic or non-metallic foil or shim.

Because of the difficulty of ensuring adequate contact, foils are not generally recommended for the calibration of instruments using the magnetic attraction principle, but they are suitable for use in some circumstances provided that necessary precautions are taken. They can normally be used for the calibration of other types of instruments.

Foils are advantageous for calibration on curved surfaces and are more readily available than coated standards.

To prevent measurement errors, it is necessary to ensure that intimate contact is established between foil and basis metal. Resilient foils should be avoided, if possible.

Calibration foils are subject to indentation and shall, therefore, be replaced frequently.

5.2.2 Coated standards

Coated standards consist of coatings of known, uniform thickness permanently bonded to a basis metal.

5.3 Verification

5.3.1 The surface roughness and magnetic properties of the basis metal of the calibration standards shall be similar to those

of the test specimen. To confirm their suitability, a comparison of the readings obtained from the basis metal of the uncoated calibration standard and that of the uncoated test specimen is recommended.

5.3.2 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).

5.3.3 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.

It is often possible to back up the basis metal of the calibration standard or of the test specimen with a sufficient thickness of similar metal to make the readings independent of the basis metal thickness.

5.3.4 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, or of the substrate on which the calibration foil is placed, 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.

Check the calibration of the instrument (see clause 5) at the test site, each time the instrument is put into service, and at frequent intervals during use, to ensure proper performance.

The following precautions shall be observed.

6.2 Basis metal thickness

Check whether the basis metal thickness exceeds the critical thickness. If not, either use the back-up method described in 5.3.3 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 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

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, make four measurements 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 Lead coatings

If using instruments of the attractive force type, lead coatings may stick to the magnet. The application of a very thin film of oil will generally improve the reproducibility of the measurements, but excess oil shall be wiped off so that the surface is virtually dry when measurements are taken with a pull-off type gauge. Oil shall not be used on coatings other than lead.

6.10 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. In appropriate cases when a constant pressure probe is not being used, the use of a measuring stand is strongly recommended.

6.11 Positioning of the probe

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 µm, whichever is the greater (see clause 5). The method is capable of better accuracy.