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Non-magnetic metallic and vitreous or porcelain enamel coatings on magnetic basis metals — 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 drawn up by Technical Committee ISO/TC 107, *Metallic and other non-organic coatings.*

It was approved in June 1971 by the Member Bodies of the following countries :

Australia	Ireland	Sweden
Belgium	Israel	Switzerland
Czechoslovakia	Italy	Thailand
Egypt, Arab Rep. of	Korea, Rep. of	Turkey
France	New Zealand	United Kingdom
Germany	Portugal	U.S.A.
Greece	Romania	U.S.S.R.
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India	Spain	

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Non-magnetic metallic and vitreous or porcelain enamel coatings on magnetic basis metals — Measurement of coating thickness — Magnetic method

1 SCOPE AND FIELD OF APPLICATION

This International Standard specifies the method of using magnetic instruments for the non-destructive measurement of the thickness of a non-magnetic coating (including vitreous and porcelain coatings) on a magnetic basis metal.

These instruments 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.

2 REFERENCE

ISO/R 2064, *Metallic and other non-organic coatings — Definition of terms concerning the measurement of the thickness.*

3 FACTORS AFFECTING THE MEASURING ACCURACY

The following factors may affect the accuracy of a coating thickness measurement :

3.1 Coating thickness

The precision of a measurement changes with the coating thickness depending on the method used and the instrument design.

On thin coatings the error is constant, independent of the measured thickness, but over the thickness range of greatest interest the error is an approximately constant fraction of the coating thickness.

3.2 Magnetic properties of the basis metal

Magnetic thickness measurements are affected by variations in the magnetic properties of the basis metal. (For all practical purposes, magnetic variations in low carbon steels can be considered to be insignificant.)

3.3 Basis metal thickness

For each instrument, there is an effective depth of penetration of the magnetic field created by the instrument probe (or magnet[1]). This is the critical depth or thickness beyond which the measurements will not be affected by an increase in the thickness of the basis metal. Since it depends on the instrument probe and the nature of the basis metal, its value must be determined experimentally, if not supplied by the manufacturer.

3.4 Edge effect

The method is sensitive to abrupt changes in the 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 a measurement. The effect may extend up to about 20 mm from the discontinuity, depending on the instrument.

3.5 Curvature

The 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 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.

3.6 Surface roughness

Measurements are influenced by the surface topography of the basis metal and of the coating. It is therefore necessary on a rough surface, for example, to make a greater number of measurements at different positions to obtain a mean value that is representative of the average coating thickness.

If the basis metal is rough, it may be necessary to check the zero of the instrument at several positions on a portion of the uncoated, rough basis metal.

3.7 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

1) In this International Standard, the term "instrument probe" also includes the term "permanent magnet".

metal has been subjected to mechanical working (such as rolling), the reading changing with the orientation of the probe on the surface.

3.8 Residual magnetism

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

3.9 Stray magnetic fields

Strong stray magnetic fields, such as are produced by various types of electrical equipment, can seriously interfere with the operation of magnetic thickness measuring instruments.

3.10 Foreign particles

Magnetic instruments of all types must make physical contact with the test surface and are therefore sensitive to foreign material that prevents intimate contact between the probe and the surface of the coating.

3.11 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.

3.12 Pressure

Instrument readings are sensitive to the pressure with which the probe is applied to the test specimen.

3.13 Probe orientation

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

4 CALIBRATION OF INSTRUMENTS

4.1 Before use, each instrument shall be calibrated either

a) in accordance with the instructions of the manufacturer, employing suitable thickness standards, or

b) by comparing magnetic thickness measurements made on a selection of the coated parts to be tested with thickness measurements made by the method specified in the International Standard for the particular coating concerned.

During use the calibration shall be checked at frequent intervals.

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

4.2.1 *Calibration foils*

NOTE – In the following paragraphs, the use of the word "foil" implies 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 based on the principle of magnetic attraction, but they are suitable for use in some circumstances provided the 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 an intimate contact is established between foil and basis metal. Resilient foils should be avoided if possible.

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

4.2.2 *Coated standards*

These calibration standards consist of coatings of known, uniform thickness permanently bonded to the basis metal.

4.3 The basis metal of the calibration standards shall have similar magnetic properties to those of the basis metal of the coated test specimen. To confirm their suitability, a comparison of the readings obtained with the basis metal of the bare standard and that of the test specimen is recommended.

4.4 In some cases, the calibration of the instrument must be checked by rotating the probe in increments of 90° (see 3.7 and 3.8).

4.5 The basis metal thickness for the test and the calibration shall be the same if the critical depth of penetration, defined in 3.3, is not exceeded.

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

4.6 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.

5 MEASURING PROCEDURE

5.1 Each instrument shall be operated in accordance with the instructions of the manufacturer.

5.2 The calibration of the instrument shall be checked, at the test site, each time the instrument is put into service, and at frequent intervals during use, to assure proper performance.

5.3 The following precautions shall be observed :

5.3.1 *Basis metal thickness*

Check whether the basis metal thickness exceeds the critical thickness. If not, either use the back-up method mentioned in 4.5 or make sure that the calibration has been made on a standard having the same thickness and magnetic properties as the test specimen.

5.3.2 *Edge effects*

Readings shall not be made near an edge, hole, inside corner, etc., of a specimen unless the validity of the calibration for such a measurement has been demonstrated.

5.3.3 *Curvature*

Readings shall not be made on a curved surface of a specimen, unless the validity of the calibration for such a measurement has been demonstrated.

5.3.4 *Number of readings*

Because of the normal instrument variability it is necessary to make several readings at each position. Local variations in coating thickness may also require that a number of measurements be made in a given area; this particularly applies when the surface is rough. Instruments of the attractive force type are sensitive to vibrations, and readings that are obviously too high shall be rejected.

These requirements are additional to those set out in ISO/R 2064.

5.3.5 *Direction of mechanical working*

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

5.3.6 *Residual magnetism*

When residual magnetism is present in the basis metal it is necessary with two-pole instruments employing a stationary magnetic field to make measurements in two orientations differing by 180°. With single-pole instruments employing a stationary magnetic field it is necessary to demagnetize the test specimen in order to get valid results, and this may also be advisable with two-pole instruments.

5.3.7 *Surface cleanliness*

Before making measurements, any foreign matter such as dirt, grease, corrosion products, etc. shall be cleaned from the surface without removing any coating material. Any areas having visible defects that are difficult to remove, such as welding or soldering flux, acid spots, dross, or oxide, shall be avoided when making measurements.

5.3.8 *Lead coatings*

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

5.3.9 *Techniques*

The readings 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.

5.3.10 *Positioning of the probe*

In general, the instrument probe shall be placed perpendicularly to the specimen 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 select the angle of inclination giving the minimum reading. If, on a smooth surface, the readings obtained vary substantially with the angle of inclination it is probable that the probe is worn and needs to be replaced.

If a magnetic instrument is to be used in a horizontal or upside-down position, it shall be separately calibrated for that position.

6 MEASURING ACCURACY

Accuracy of measurement depends upon the test specimen and the design and calibration of the instrument. Except on thin coatings (less than about 5 μm), the method is normally accurate within ± 10 %. Higher accuracy may be consistently achieved in special cases.

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