

INTERNATIONAL STANDARD

**ISO
2808**

Third edition
1997-09-15

Paints and varnishes — Determination of film thickness

Peintures et vernis — Détermination de l'épaisseur du feuil

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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.

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.

International Standard ISO 2808 was prepared by Technical Committee ISO/TC 35, *Paints and varnishes*, Subcommittee SC 9, *General test methods for paints and varnishes*.

This third edition cancels and replaces the second edition (ISO 2808:1991) of which it constitutes a technical revision.

The main technical changes are:

a) Addition of the following methods of film thickness determination:

- 1) Gravimetric (dissolving) method (Method 9)
- 2) Determination of dry-film thickness on blast-cleaned steel substrates (Method 10).

b) Table 1 includes typical instrument bias and precision for each method.

Annex A forms an integral part of this International Standard.

Paints and varnishes — Determination of film thickness

1 Scope

This International Standard reviews and specifies a number of methods that are applicable to the measurement of the thickness of organic coatings applied to a substrate. It does not apply to metallic coatings. Some of the techniques described can be adapted for the measurement of the thickness of detached coatings. The principles of the methods, their particular field of application and the expected precision are given in table 1.

This International Standard also defines terms concerning the determination of film thickness.

Table 1 - Methods of film thickness measurement

Note 1: Many of the methods referred to below may be adapted for use with detached films.

Number and description	Techniques and applications	Typical instrument bias ¹⁾ and precision	Remarks
Method No. 1	A Comb gauge	-----	Measurements give an approximate indication of the thickness of the wet film. May be used in laboratories and on site.
Assessment of wet-film thickness	B Wheel gauge	Bias: $\pm 2,5\%$ + 1 μm	Method 1C may also be used for determining the dry-film thickness, but in the laboratory only.
	C By weighing For measurement of wet-film thickness of freshly painted surfaces.	Reproducibility: $\pm 15\ \mu\text{m}$	
Method No. 2	For use on films too soft to be measured by methods which use a presser foot or probe.	Determinations are not precise	Provides a check that the mean thickness lies between specified limits. The film remains undamaged.
Determination of dry-film thickness by calculation from the ratio of dry-film mass to dry-film area			

Method No. 3

Measurement of dry-film thickness by mechanically contacting instruments

A Micrometer method. For use on test panels or painted surfaces that are substantially plane.

Bias: $\pm 2 \mu\text{m}$
 Reproducibility: $\pm 30 \%$ for low and 20% for higher film thicknesses

The film has to be hard enough to resist indentation on closing the micrometer jaws. The film is damaged in the test. The film thickness shall be greater than $25 \mu\text{m}$ unless the film is detached.

B Dial gauge method
 Test panels or painted surfaces that are substantially plane or have a curvature in one direction

Reproducibility: $\pm 10 \%$, with a lower limit of $2 \mu\text{m}$

The film has to be hard enough to resist indentation on lowering the gauge or electric-device presser foot.

Method No. 4

Measurement of dry-film thickness by the profilometric method

Recommended as a referee method for painted surfaces that are substantially plane.

Reproducibility: $\pm 10 \%$, with a lower limit of $2 \mu\text{m}$

The film has to be hard enough to resist indentation by the profile-tracing stylus.
 The film is damaged in the test.

Method No. 5

Measurement of dry-film

thickness by microscope methods

A Microscopic examination of cross-section.	Bias: 2 µm	A portion of the painted article is cut out and mounted in resin. The film is damaged in the test.
Recommended as a referee method for films on substrates of varying profile, for example grit-blasted surfaces.	Reproducibility: ± 10 %	
B Wedge cut method. Not applicable to brittle or friable films.	Reproducibility: ± 10 %, with a lower limit of 2 µm	A special cutting tool or paint borer is required to cut through the film. The film is damaged in the test.
Both A and B can be used for thicknesses of individual coats in a paint system		
C Surface profile measuring method. Applies to transparent films and to films which can be cleanly removed from the substrate.	Reproducibility: ± 10 %	A special microscope is used to examine the profile of the film (split-beam microscope). Only transparent films remain undamaged.

Method No. 6 Magnetic methods	For magnetic metallic substrates		The film has to be hard enough to withstand the pressure of the probe. May be used on site.
	A Magnetic-induction principle	Bias: $\pm 2\% + 1\text{ }\mu\text{m}$ Reproducibility: $\pm 10\%$	
	B Permanent-magnet pull-off principle	Bias: $\pm 5\% + 1\text{ }\mu\text{m}$	
Method No. 7 Eddy current method	For non-magnetic metallic substrates	Bias: $\pm 2\% + 1\text{ }\mu\text{m}$	Instruments operate on the eddy-current principle.
		Reproducibility: $\pm 10\%$	The film has to be hard enough to withstand the pressure of the probe.
			May be used on site.

<p>Method No. 8</p> <p>Non-contact methods</p>	<p>Used when contact by the measuring instrument with the coating needs to be avoided. Applicable to painted surfaces which are substantially flat.</p>	<p>Instruments operate on the beta-particle back-scatter principle (method No. 8A) or the X-ray fluorescence principle (method No. 8B).</p> <p>Reproducibility: $\pm 10\%$</p>
<p>Paint films have to be homogeneous for measurements to be accurate.</p>		
<p>Method No. 9</p> <p>Gravimetric (dissolving) method</p>	<p>Applicable to films on substrates of varying profiles, for example grit-blasted steel panels, and to films on polymeric substrates if the substrate is not affected by the paint solvent.</p>	<p>The coating mass is determined by dissolving the coating without dissolving the substrate. The mass of coating divided by the density and the area of the coating gives the average coating thickness.</p>

<p>Method No. 10</p> <p>Determination of dry-film thickness on blast-cleaned steel substrates</p>	<p>For dry coatings on magnetic metallic substrates having a rough (blast-cleaned) surface.</p>	<p>Instruments operate on the magnetic-induction principle.</p> <p>May be used on site.</p> <p>In some cases, method No. 5A or method No. 9 may also be used.</p>
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1) The bias data are based on information supplied by the instrument manufacturers

2 Normative References

The following standards contain provisions which, through reference in this text, constitute provisions of this International Standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the standards listed below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 1463:1982, Metallic and oxide coatings - Measurement of coating thickness - Microscopical method

ISO 1514:1993, Paints and varnishes - Standard panels for testing

ISO 2178:1982, Non-magnetic coatings on magnetic substrates - Measurement of coating thickness - Magnetic method

ISO 2360: 1982, Non -conductive coatings on non-magnetic basis metals - Measurement of coating thickness - Eddy current method

ISO 2811:1997, Paints and varnishes - Determination of density -

Part 1: Pyknometer method

Part 2: Immersed body (plummet) method

Part 3: Oscillation method

Part 4: Pressure cup method

ISO 3233:1984,¹⁾ Paints and varnishes - Determination of volume of dry coating (non-volatile matters) obtained from a given volume of liquid coating.

ISO 3497:1990, Metallic coatings - Measurement of coating thickness - X-ray spectrometric methods

ISO 3543:1981, Metallic and non-metallic coatings - Measurement of thickness - Beta backscatter method

ISO 4518: 1980, Metallic coatings - Measurement of coating thickness - Profilometric method

ISO 7254:1984, Paints and varnishes - Assessment of natural spreading rate - Brush application

ISO 8503-1:1988, Preparation of steel substrates before application of paints and related products - Surface roughness characteristics of blast-cleaned steel substrates - Part 1: Specifications and definitions for ISO surface profile comparators for the assessment of abrasive blast-cleaned surfaces.

1) Under revision.

3 Required supplementary information

The methods of measurement specified require to be completed, for any particular application, by the following supplementary information.

This information should be derived from the International Standard or national standard or other document for the product under test or, if appropriate, may be the subject of agreement between the interested parties.

- a) The method of application of the coating to the substrate and whether it is a single coating or a multi-coat system.
- b) The duration and conditions of drying (or stoving) and ageing (if applicable) of the coating before measurement.
- c) The method of film thickness measurement to be used (see table 1).
- d) The significant area (see 4.2) of the coated article and, if necessary, the number of measurements.

4 Definitions

For the purpose of this International Standard, the following definitions apply:

4.1 film thickness: The thickness of a coating applied to a substrate is the distance between the surface of the film and the surface of the substrate.

NOTE 1 - The value of a film thickness depends, to some extent, on the method of measurement used. To give a correct value would only be possible if the coating and substrate had flat and even surfaces. In practice, neither the surface of the coating nor the surface of the substrates is even. In many cases, the surface irregularities exceed 10% of the film thickness. The results of the measurements by different methods are influenced by these irregularities. The influence is different for each method. Therefore, the results of different methods applied to the same specimen may differ markedly. This is the reason why the results of film thickness measurements always have to be reported together with information on the method of measurement and which type of instrument was used, plus the bias of the instrument, if known.

4.2 significant surface area: That part of an article covered or to be covered by the coating and for which the coating is essential for serviceability and/or appearance.

4.3 reference area: That part of the significant surface area within which a specified number of single measurements are required to be made.

4.4 measurement area: The area over which a single measurement is made.

In this International Standard the measurement area (test area) is specified as follows:

- a) for analytical (dissolution) methods, the area over which the coating is removed;
- b) for microscopical methods, the point at which a single measurement is made;
- c) for non-destructive methods, the probe area or the area influencing the reading.

4.5 local film thickness: The mean of the specified number of thickness measurements made within a given reference area.

4.6 minimum local film thickness: The lowest value of the local thicknesses found on the significant surface area of a particular article.

4.7 maximum local thickness: The highest value of the local thicknesses found on the significant surface area of a particular article.

4.8 mean film thickness: The mean value of a specified number of local thickness measurements that are evenly distributed over a significant surface area, or the result of a gravimetric film thickness determination.

4.9 wet-film thickness: The thickness of a freshly applied coating material, measured immediately after application.

5 General requirements

5.1 General

In this standard, information is given concerning the number and location of measurement areas to be adopted when determining paint film thickness on typical test panels (see ISO1514). On other test panels and on painted articles the number and location of test areas shall be such as to provide as the measurement result a representative film thickness and shall be the subject of agreement between the interested parties.

Follow the manufacturer's instructions for operation of the instruments.

Always check the instruments for repeatability. Check calibration and the condition of the probe tip at regular intervals.

Make sure that the pressure of the probe tip does not alter the film thickness significantly.

5.2 Rough surfaces

The surface roughness of the substrate influences the determination of film thickness. For the optical methods it is proposed to agree upon reference lines or areas.

If a non-destructive method is used, the calibration of the instrument has to be made and checked on the same kind of uncoated substrate as is used for the test piece.

For blast-cleaned steel substrates, special conditions apply (see method No. 10).

5.3 Edge effect

Some instruments are affected by the presence of an edge of the article, and of these some can be calibrated to allow for this effect. Measurement shall be made at more than 25 mm from the edge of an article or panel or at the distance from the edge for which the instrument has been calibrated.

5.4 Surface curvature

Some instruments are particularly sensitive to surface curvature and must always be calibrated using samples of the same curvature as the test piece.

6 Method No.1 – Determination of wet-film thickness

6.1 General

This method describes three ways of measuring the thickness of wet paint films.

It can be used to measure the spreading rate of a paint.

The equation linking the spreading rate, A_s , in m^2/L , and the wet-film thickness, t_w , in μm , is

$$A_s = \frac{1000}{t_w}$$

NOTE2 – The spreading rate is usually determined using ISO 7254.

In addition, by using a suitable correlation procedure, it is possible to estimate the approximate thickness of a dry film, by measuring its wet film thickness immediately after application. This is useful when dry film thickness methods are destructive or not very accurate, e.g. on wood or masonry substrates. The dry film thickness is calculated using the following equation:

$$t_D = t_w \times \frac{V_s}{100}$$

where

t_D = dry film thickness in micrometres

t_w = wet film thickness in micrometres

V_s = percentage non-volatile content by volume

The method described is suitable for use on rigid substrates with a suitable surface profile.

The method may be used both in the laboratory and on site to check paint application.

6.2 Method 1A – Comb gauge

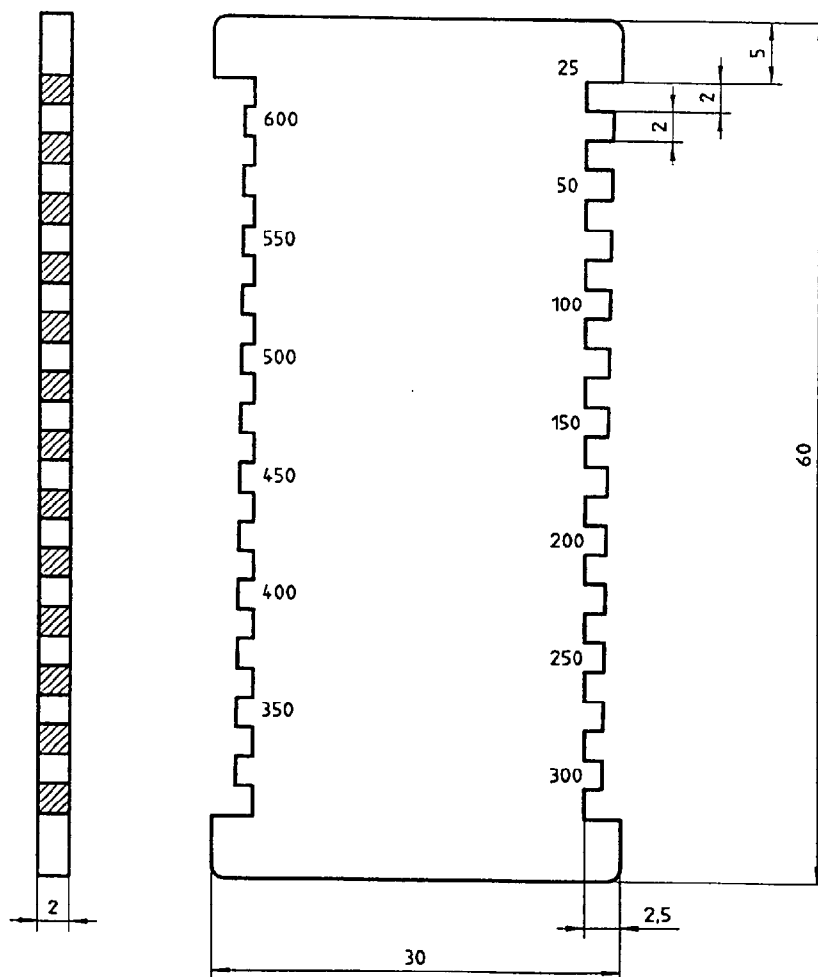
6.2.1 Apparatus

The gauge consists of a comb made of stainless steel or of a suitable plastic unaffected by the solvents in the paint, the outer teeth of which form a baseline. The inner teeth are progressively shorter so as to present a range of gaps between the teeth and the baseline, and the size of each gap can be read from a scale on the gauge. A typical comb gauge is illustrated in figure 1.

6.2.2 Procedure

Immediately after the application of the paint, place the comb gauge firmly onto the substrate in such a way that the teeth are normal to the plane of the surface and the gauge does not slip. Remove the gauge, and examine the teeth to determine which is the shortest one to touch the wet paint film. Record the film thickness as a range lying between the last 'touching' tooth and first 'non-touching' tooth as shown on the tooth calibrations marked on the gauge. Take at least two further measurements in different places in the same manner to obtain representative results over the painted area.

Dimensions in millimetres, except for the gauge
graduations



Not to scale: the differences between the lengths of the teeth are exaggerated for clarity.

NOTE - The comb illustrated is for 25 μm to 600 μm ; combs are available in a range of scales.

Figure 1
Comb gauge

6.3 Method 1B – Wheel gauge

6.3.1 Apparatus

The gauge consists of a wheel of which the perimeter has three equally spaced rims, the central one of which is smaller than and eccentric to the outer ones. When the gauge is rolled over a wet film, the eccentric central rim shows a position at which it just touches the wet paint surface, and a calibrated scale engraved on the outer wheel enables the wet paint thickness at this point to be noted. A range of gauges is available. A typical gauge showing a calibration series is shown in figure 2.

Several measurements are taken in the same manner to obtain representative results over the painted area.

The touch of wet film and eccentric rim is influenced by the surface tension of the paint. Hence it is necessary to observe first and last touch and to calculate the mean.

Dimensions in micrometres

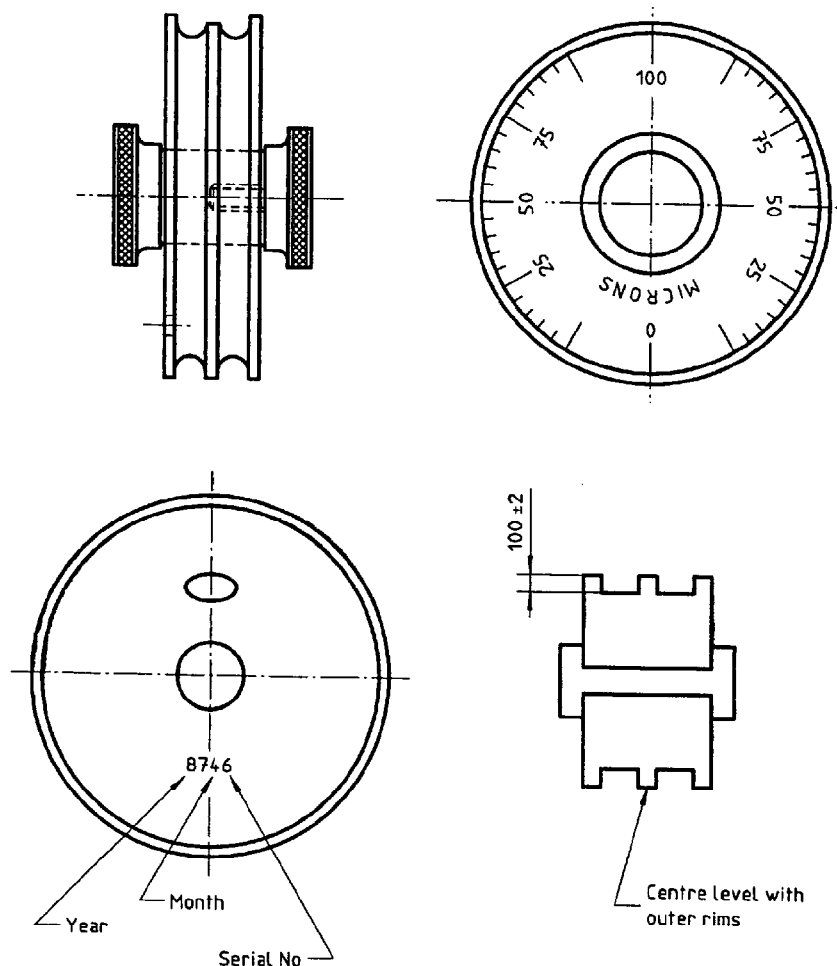


Figure 2
Typical wheel gauge

6.3.2 Procedure

Immediately after the application of the paint, place the rims of the wheel gauge into the paint film so that the two outer rims are in contact with the substrate at the point of maximum gap (i.e. the largest reading on the scale). Rotate the wheel through nearly 360° along the surface and remove.

Examine the centre rim to determine the position at which contact was made with the wet film. For uneven films, note the first and last complete and continuous contact made with the film surface. The scale shows the wet-film thickness at these points. Read the film thickness at the next lower and next higher scale divisions and calculate the mean. Record the result.

Repeat the procedure at least twice in different places in a similar manner to obtain representative results over the painted area.

6.4 Method 1C – By weighing

This method is applicable to test pieces of conveniently measurable area which fit on a suitably sensitive balance.

This method is also suitable for dry-film thickness measurement.

This method is not suitable for paints containing fast-evaporating solvents.

6.4.1 Procedure

6.4.1.1 Measure the linear dimensions of the test pieces to an accuracy of 1 % and calculate the surface area of the face to be painted.

6.4.1.2 Weigh the test piece to the nearest 1 mg.

6.4.1.3 Coat the test piece and reweigh to the nearest 1 mg while wet (as soon as possible after coating) and after drying.

6.4.1.4 Calculate the wet-film thickness in μm from the following equation:

$$t_w = \frac{M_w - M_p}{A \cdot \ell_w}$$

Where

M_w = mass, in grams, of the wet coated test piece

M_p = mass, in grams, of the test piece alone

A = area in square metres of the test piece

ℓ_w = density in grams per millilitre of the wet paint.

The density of the wet paint can be determined using one of the parts of ISO 2811.

6.4.1.5 Calculate the dry film thickness from the following equation:

$$t_d = \frac{M_d - M_p}{A \cdot \ell_d}$$

Where

M_d = mass, in grams, of the dried coated test piece

ℓ_d = density, in grams per millilitre, of the dried film.

The density of the dried film can be determined using ISO 3233.

7 Method No 2 - Determination of dry-film thickness by calculation from film mass per unit area

7.1 General

This method describes a way of checking that the thickness of a dried film of paint on a test panel lies within the limits specified. It is not intended to give a precise measurement of the actual thickness of the film.

The measurement is obtained by reference to a graph showing the relationship between film thickness and film mass for the product under test.

It is intended for use with air-drying paints that produce films requiring several days before they are sufficiently hard to permit thickness measurements by instrumental methods. It gives an overall mean value for the thickness of the paint film based on its dry mass and does not cause any mechanical damage to the paint film.

7.2 Procedure

Details of the method are given in annex A.

NOTE 3 – Method 1C (see 6.4) can also be used to measure dry-film thicknesses.

8 Method No 3 – Measurement of dry-film thickness by mechanically contacting methods

Measurements are made on coatings after the film has dried to a condition that the jaws of the micrometer or the presser foot of the dial gauge do not produce any visible indentation in the film.

The method is only suitable for painted panels or articles that are substantially plane or of circular cross-section (e.g. wire) and for coatings that can be removed by solvent or paint remover.

8.1 Method 3A – Micrometer method

8.1.1 General

This method describes a means for measuring, to within 5 μm , the thickness of a dried paint film on a painted article or test panel.

8.1.2 Apparatus

Suitable micrometer, capable of measurement to 5 μm or less, fitted with a ratchet.

8.1.3 Procedure

8.1.3.1 Select positions, where readings are to be taken, that are free from surface irregularities and are not less than 20 mm from any paint film edge and not less than approximately 50 mm apart.

For large areas, select the number and distribution of the test areas to give a representative indication of the film thickness.

Mark an area around each test position by lightly drawing a circle approximately 10 mm in diameter and designate each position with a different reference number alongside.

8.1.3.2 Support the painted specimen rigidly in a manner such that all the test positions are accessible to the micrometer (8.1.2).

8.1.3.3 Position the micrometer with the fixed jaw in plane contact with the underside of the test specimen and immediately opposite the first test area. Gently screw home the movable jaw until a resistance is felt and no further movement of the jaw occurs on turning the ratchet.

Note the reading on the micrometer, using an underlying mirror if necessary to read the vernier scale. Record the reading and the position reference number on a test record sheet.

Release the micrometer and repeat the whole procedure at each of the other test positions.

8.1.3.4 Carefully remove the paint film from within the circle at each test area with a suitable solvent or paint remover, taking care not to obliterate the distinctive number. This may be done by covering the test area with a small circle of thick filter paper and applying to it a few drops of a suitable solvent.

Measure the thickness of the substrate by repeating the procedures 8.1.3.2 and 8.1.3.3 at each test area.

NOTE 4 – The thickness of the substrate can sometimes be measured before painting in order to avoid having to remove the paint.

8.1.4 Calculation

8.1.4.1 Calculate the film thickness at each test position by subtracting the reading obtained after removal of the film from that obtained before removal.

8.1.4.2 Calculate the mean value for the thickness of the film on the test panel to the nearest multiple of 5 μm or less (depending on the accuracy of the micrometer).

8.2 Method 3B – Dial gauge method

8.2.1 General

This method describes a means for measuring, to an accuracy of within 2 μm , the thickness of a dried paint film on a painted article or test panel.

8.2.2 Apparatus

Dial gauge or any suitable indicator for linear measurement, having a mechanically contacting foot and mechanical, optical, or electronic read-out, capable of measurement to an accuracy of 2 μm , mounted on a rigid support.

8.2.3 Procedure

8.2.3.1 Select positions, where readings are to be taken, that are free from surface irregularities and are not less than 20 mm from any paint film edge and not less than approximately 50 mm apart.

For large areas, select the number and distribution of measuring areas to give a representative indication of the film thickness.

Mark an area around each test position by lightly drawing a circle approximately 10 mm in diameter and designate each position with a different reference number alongside.

8.2.3.2 Support the painted specimen rigidly in a manner such that neither the lowering of the presser foot nor the removing of the paint film allow any movement of the specimen.

Place the indicator vertical to the test panel so that the presser foot is immediately above the centre of the first measuring area. Carefully lower the presser foot until it is in good contact with the paint film. Record the reading and the measuring area reference number on a test record sheet. Lower the presser foot several times and record the readings.

Raise the presser foot and carefully remove the paint film within the circle of the measuring area with a suitable solvent or paint remover. This may be done by covering the test area with a small circle of thick filter paper and applying to it a few drops of a suitable solvent.

Carefully lower the presser foot until it is in good contact with the cleaned surface of the substrate and record the reading. Measure several times.

8.2.3.3 Repeat the procedure at each measuring area.

8.2.4 Calculation

8.2.4.1 Calculate the film thickness at each test position by subtracting the reading obtained after removal of the film from that obtained before removal.

8.2.4.2 Calculate the mean value of the thickness of the film on the test panel to the nearest multiple of 2 μm

9 Method No. 4 – Measurement of dry-film thickness by the profilometer method

9.1 General

This method describes a procedure for measuring the thickness of a hard dried paint film (i.e. one hard enough not to be penetrated or deformed by the profilometer stylus) on a painted article or test panel to within 2µm.

NOTE 5 – For reliable results, the minimum coating thickness should be not less than 10 times the roughness amplitude of the substrate.

The measurement is made after the film has dried to a condition such that the contact of the profile-tracing stylus does not cause any detectable indentation of the film.

This method is only suitable for specimens that are small enough to be accommodated on the test apparatus, unless a portable compact apparatus is available. It is most suitable for substantially flat specimens and for coatings that can be removed by solvent, paint remover, or use of a tube drill.

For sufficiently large painted articles it is possible to set a portable compact apparatus on the painted surface.

This method is recommended as a referee method to be used in cases of dispute provided that the substrate is substantially flat.

More detailed information on this method is given in ISO 4518.

9.2 Apparatus

Assembly comprising a traversing stylus with suitable amplifying and recording equipment. The apparatus is generally used to measure surface roughness but, for the purpose of this International Standard, is used to record the profile of a step between the coating and substrate formed by removal of part of the coating. Portable compact instruments are available.

9.3 Procedure

9.3.1 Remove a portion of the coating with a suitable solvent or paint remover. Alternatively, cut through the paint film to the substrate with a borer of diameter 10 mm and remove the isolated section of paint film.

For example, this may be done by covering the test area with a small circle of thick filter paper and applying to it a few drops of a suitable solvent or paint remover. If the solvent or paint remover causes the paint film adjacent to the test area to swell, the alternative method for removal, as given above, can be used. Ensure that the surface of the coating forming the top of the step is not damaged and that the exposed substrate is free of all traces of the coating.

9.3.2 Record the profile of the step in accordance with the instrument manufacturer's instructions, selecting a suitable sensitivity to ensure the maximum use of the recording chart.

9.3.3 Draw a mean line through each recording of the upper and lower levels of the step and extend them so that the two mean lines overlap. Assess the step height from the two mean lines at the midpoint of the step.

It is also possible – if agreed upon – not to use the mean line through the recording of the lower level but to choose another line, e.g. a line marking the upper peaks of the substrate.

10 Method No. 5 – Measurement of dry-film thickness using microscope methods

10.1 General

These methods specify three procedures by which microscopes are used for measuring the dry-film thickness of individual paint layers of systems in the form of a free (detached) film or still on the substrate.

Method A is a general method for measuring, to within 2 μm or better, the thickness of a dried film of paint on a section cut from a test panel or painted article.

It is recommended as a referee method in any dispute concerning the thickness of the paint film on a painted specimen. It is particularly useful in measuring variations in thickness that occur due to unevenness of the substrate, for example on grit-blasted steel.

When using method B the coating is cut at a prescribed angle through to the substrate. The method is not applicable to brittle or friable coatings or to those with a film thickness of less than 2 μm .

Method C employs an apparatus by means of which an image of the surface profile of the test specimen is viewed in a special microscope. It does not involve cutting out a section of the substrate as described in method A but it is destructive to the coating.

The split-beam microscope (light-section microscope) is also used for measuring the film thickness of transparent coatings. The method can be used where sufficient light is reflected from the coating/substrate interface to give a clear image in the microscope. For transparent coatings the method is non-destructive.

The number of specimens prepared by any of the methods shall be such as to be representative of the painted article or test panel.

10.2 Method 5A – Microscopic examination of cross-section

10.2.1 Apparatus and materials

10.2.1.1 Microscope, with a suitable objective, and an eyepiece bearing a scale capable of measuring to an accuracy of 2 μm or better.

10.2.1.2 Waterproof silicon-carbide abrasive paper, grades 280, 400 and 600.

10.2.1.3 Diamond paste, or similar paste, with grade 1200 grit.

10.2.1.4 Cold-setting potting or casting resin that has no deleterious effect on the paint film.

The colour of the mounting resin shall be such that it can be distinguished clearly from the paint film under test. This may be achieved by the incorporation of suitable dyestuffs or pigments into the resin.

10.2.2 Procedure

A suitable procedure is given in detail in ISO 1463. Follow this procedure and finally mount the polished specimen section on a microscope slide with the polished face uppermost and parallel to the plane of the slide.

Place the slide under the microscope and measure the thickness of the paint film by the scale of the eyepiece.

Record at least five measurements along the edge of the paint film and calculate the mean thickness.

If the film thickness is markedly variable along the specimen, supplement the readings by pictorial illustrations such as photomicrographs or drawings.

10.3 Method 5B – Wedge cut method

10.3.1 Apparatus

A special apparatus is available which includes a microscope with illumination devices and cutting tool.

If not available use:

10.3.1.1 Microscope, with a suitable objective, and an eyepiece bearing a scale with a resolution of 2 μm or better.

10.3.1.2 Cutting tool, with knife edge ground to an angle appropriate to the film thickness (see table 2). The cutting tool shall be mounted in a suitable guide.

NOTE 6 – Instead of a cutting tool, a special paint borer with edges ground to a defined angle (see table 2) may be used.

Table 2 – Cutting tool edge angle

Appropriate range of film thickness μm	Cutting angle, α degrees	$\tan \alpha$
20 to 2000	45	1,0
10 to 1000	26,6	0,5
8 to 800	21,8	0,4
2 to 200	5,7	0,1

10.3.2.1 Procedure

In order to facilitate the determinations, mark the test piece with a felt tip pen in a contrasting colour at the areas where the determinations are to be made. Whilst holding the guide firmly against the coated specimen, press the cutting tool so as to produce a clean wedge-shaped cut through the film and into the substrate (see figure 3).

NOTE 7 – Coatings with pronounced elasticity may give invalid results due to deformation during cutting. This effect may be reduced by cooling the specimen before carrying out the determination.

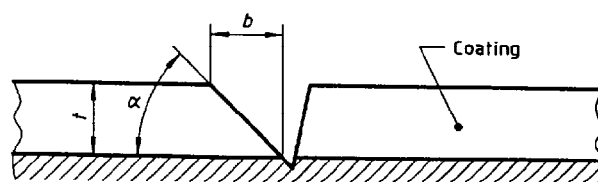


Figure 3

Diagrammatic representation of the wedge cut

10.3.2.2 Using the marking to locate the cut with the microscope, measure the projected width b , in micrometres, of the wedge cut.

10.3.3 Calculation

Calculate the film thickness from the equation:

$$t = b \cdot \tan \alpha$$

where

t = film thickness, in micrometres;

b = projected width, in micrometres, of the cut measured by the microscope;

α = ground angle, in degrees, of the cutting tool.

NOTE 8 – If the determination has been carried out on a curved surface, correction of the equation for the effect of the curvature may be necessary.

10.4 Method 5C – Surface profile measuring microscope method

10.4.1 General

Applied to transparent or translucent coatings, the converted reading has to be corrected for the refractive index of the film by the formula

$$t = t' \cdot \sqrt{2 \cdot n^2 - 1}$$

to give the film thickness t . t' is the measured film thickness, uncorrected. The refractive index n of transparent paint coatings is usually 1,50 to 1,52. With an uncertainty of 5%, the correction formula is:

$$t = 1,9 \cdot t'$$

10.4.2 Apparatus

Profile measuring microscope (split-beam microscope, light-section microscope), consisting of an illuminator projecting a flat parallel beam of light on to the surface at an angle of 45° and an objective viewing the reflected light beam so that an image of the surface profile is seen in the microscope.

Applied to transparent or translucent coatings, part of the beam is reflected from the surface of the coating while the other part penetrates the coating and is reflected from the coating/metal substrate interface. The distance which separates the two images observed in the eyepiece of the microscope is proportional to the thickness of the coating and can be measured by means of a vernier screw which controls a calibrated graticule.

To measure the thickness of opaque coatings, a small area of the coating has to be removed. The step between the surface of the coating and the substrate produces a deflection of the light beam which gives an absolute measure of the coating thickness.

NOTE 9 – In some instruments, the vernier attachment does not give the true thickness but only scale divisions. In this case, using the calibration factor, the reading in scale divisions has to be converted into a corresponding thickness, in micrometres.

10.4.3 Procedure

To measure the thickness of opaque coatings, carefully remove a small portion of the paint film with a sharp cutting tool in such a manner as to expose completely a small area of the substrate, but taking care not to cut into the substrate (see figure 4).

Direct the beam from the illuminator on to the measuring area and along the length of the incision. Determine the thickness of the paint film by using the vernier attachment and converting the reading in scale divisions into the corresponding thickness in micrometres.

Figure 5 shows the appearance of a typical specimen as seen in the viewing microscope. Reading d in eyepiece scale divisions is converted into the corresponding film thickness t in micrometres (see figure 5).

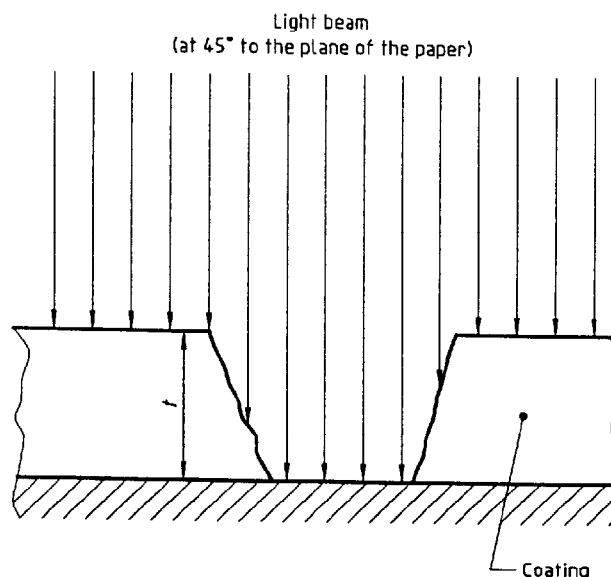


Figure 4
Sectioned view of incised painted specimen

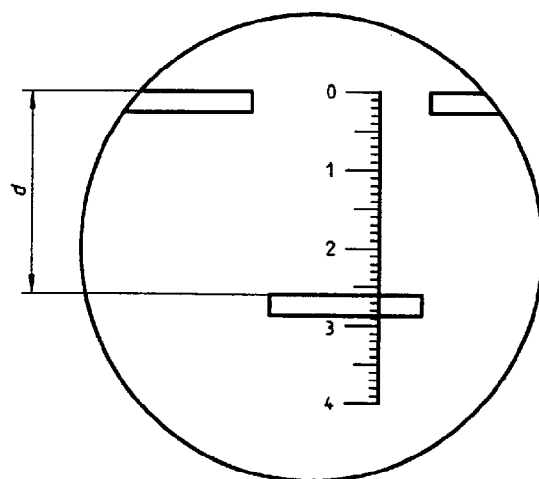


Figure 5 - Typical image as seen in the microscope

11 Method No 6 – Magnetic method (see ISO 2178)

11.1 General

These methods describe non-destructive procedures for determining the thickness of non-magnetic dry paint films on magnetic metallic substrates.

11.2 Principle

11.2.1 Magnetic induction principle (Method No 6A)

Instruments for this method measure the reluctance of a magnetic flux passing through the coating and the substrate.

11.2.2 Permanent magnet pull-off principle (Method No 6B)

Instruments for this method measure the magnetic attraction between a permanent magnet and the substrate, as influenced by the presence of a coating.

11.3 Calibration of instruments

11.3.1 General

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

11.3.2 Calibration standards

Calibration standards of known and uniform thickness are available either as foils or shims, or as coated standards with assigned values traceable to nationally recognized standards.

Calibration foils are generally made of suitable plastic materials. They are subject to indentation and shall, therefore, be replaced frequently.

The surface and magnetic properties of the base metal of the coated calibration standards shall be similar to those of the test specimen.

The thickness of the substrate of the test specimen and of the calibration standards has to be the same, if the critical thickness, defined in 11.4.2, is not exceeded.

11.4 Procedure

11.4.1 General

Operate each instrument in accordance with the manufacturer's instructions.

Check the calibration of the instrument (see subclause 11.3) 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.

11.4.2 Base metal thickness

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

Check whether the base metal thickness exceeds the critical thickness. If not, either use the back-up method (i.e. back up the basis metal with a sufficient thickness of similar metal) or ensure that the calibration has been made on a calibration standard having the same thickness and magnetic properties as the test specimen.

11.4.3 Number of readings

Because of normal instrument variability, it is necessary to take several readings in each reference area (e.g. three readings) to get the local thickness as the mean of the measurements. The number and distribution of reference areas which are necessary to get the average thickness of a painted article may be the subject of agreement between the interested parties.

12 Method No 7 – Eddy current method (see ISO 2360)

12.1 General

The method describes a non-destructive procedure for determining the thickness of non-conductive dry paint films on non-magnetic metallic substrates.

12.2 Principle

Eddy current instruments work on the principle that a high frequency electromagnetic field generated in the probe system of the instrument will produce eddy currents in a conductor upon which the probe is placed, and that the amplitude and phase of these currents is a function of the thickness of a non-conductive coating present between the conductor and the probe.

12.3 Calibration

12.3.1 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 at frequent intervals.

12.3.2 Calibration standards

Calibration standards of known and uniform thickness are available either as foils or as coated standards, with assigned values traceable to nationally recognized standards.

Calibration foils are generally made of suitable plastic materials. They are subject to indentation and shall, therefore, be replaced frequently.

Coated standards consist of non-conductive coatings of known, uniform thickness permanently bonded to a substrate.

12.4 Procedure

12.4.1 General

Operate each instrument in accordance with the manufacturer's instructions.

Check the calibration of the instrument (see subclause 12.3) 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.

12.4.2 Number of readings

Because of normal instrument variability, it is necessary to take several readings in each reference area (e.g. three readings) to get the local thickness as the mean of the measurements. The number and distribution of reference areas which are necessary to get the average thickness of a painted article may be the subject of agreement between the interested parties.

13 Method No. 8 – Non-contact methods

Methods of this kind are preferably used for on-line process control, such as in the evaluation of coatings.

13.1 Principle

13.1.1 Method 8A – Beta-particle backscatter (see ISO 3543)

Beta ray gauges use radioisotopes which emit beta rays and detectors for measuring the intensity of the beta rays backscattered by the test specimen. The intensity of the backscattered beta rays will be between two values, the backscatter intensity of the coating and that of the basis metal. The measurement is only possible if the atomic number of the coating material is sufficiently different from that of the substrate. The instrument is calibrated with calibration standards having the same coating and substrate as the specimen to be measured. The measured intensity of the beta rays backscattered by the test specimen is used to calculate the mass per unit area of the coating, which, provided that the latter is of uniform density, is directly proportional to the thickness.

13.1.2 Method 8B – X-ray fluorescence (see ISO 3497)

When materials are irradiated by X-rays, a secondary (fluorescence) radiation with a discrete spectrum is emitted, the energy (wavelength) of which depends on the atomic number of the substrate. If a substrate is coated with a paint, the atomic number of which is different to that of the substrate, the fluorescence from the coating can be distinguished from that of the substrate. A correlation exists between the intensity of the X-rays and the coating thickness; this is established using calibration standards.

13.2 Apparatus

13.2.1 Beta-particle backscatter

In general, a beta backscatter gauge will comprise a radiation source (isotope), a measuring system with a range of apertures located at a fixed distance from the surface area on which the coating thickness is to be measured, and a read out instrument. The display is proportional to the coating thickness expressed either in thickness units or in mass per unit area.

13.2.2 X-ray fluorescence

By means of a single-crystal spectrometer, a selected wavelength characteristic of either the coating or the substrate is separated for individual measurement. The intensity of the selected wavelength is measured by means of an appropriate radiation detector in conjunction with electronic pulse-counting circuitry. The values are converted into film thickness. The distance between coating and probe is largely irrelevant.

13.3 Procedure

Operate each instrument in accordance with the manufacturer's instructions.

14 Method No 9 – Gravimetric method (dissolving method)

14.1 General

The method describes a procedure which damages the film. It is applicable to films on metallic substrates of varying surface profiles, for example grit-blasted steel panels. It can also be applied to films on polymeric substrates, provided that the substrate is not affected by the solvent used.

14.2 Procedure

The coating is dissolved from the substrate on the reference area without dissolving the substrate material. The mass difference is determined by weighing the specimen or article before and after dissolving the coating. The mass difference divided by the test area gives the average mass per unit area, which, provided that the density of the coating is known and that the coating is of uniform density, allows the average film thickness to be calculated.

15 Method No 10 – Determination of dry-film thickness on blast-cleaned steel substrates

15.1 General

If a coating is applied to a blast-cleaned steel substrate, the measurement of its film thickness is more complicated than for smooth surfaces. The measurement results are influenced by the properties of the substrate, which change from point to point, and by the construction of the measuring equipment, e.g. the probe. The procedure used to set up instruments on blast-cleaned substrates has in practice led to significant variability in the dry-film thickness readings.

The object of this method is to minimize variability and achieve a uniformity of practice in the measurement of film thicknesses on coated blast-cleaned surfaces. The method entails the measurement of film thickness using an instrument of the magnetic induction type after calibrating it on a smooth steel surface.

This method will determine the coating thickness over a magnetic plane in the rough surface at which the thickness is greater than the thickness over the peaks. This thickness corresponds to about 25 micrometres (which corresponds to about half of the surface roughness, expressed as the height from the bottom to the top of the peaks, of the blast-cleaned surface) except for surfaces prepared to ISO 8503-1, grade "fine".

Calibrating the instrument on a blast-cleaned surface introduces problems in addition to the normal variation of results with the type of probe and instrument, such as:

- a) poor repeatability;
- b) variability in the measured thickness of a shim over such a surface (the thicker the shim the greater the apparent increase in shim thickness);
- c) a coated steel surface whose surface roughness is unknown.

15.2 General

The procedure describes the determination of a parameter related to the thickness of a dried paint film applied to a blast-cleaned steel substrate. The actual film thickness as measured by a reference method shall not be less than 25 microns and preferably above 50 microns for meaningful results.

15.3 Apparatus and materials

Film thickness measuring instrument, magnetic induction principle type, as used in method No 6A.

NOTE 10- The use of equipment additionally fitted with facilities for converting measurements into mean standard deviation and other statistical values should be treated with caution and preferably only used by those trained in statistical techniques.

Calibration shims, of the foil type, with assigned values traceable to nationally recognized standards, of thicknesses near to the expected film thickness.

NOTE 11- The use of uncertified shims is permitted provided they are verified on site using a micrometer.

Smooth piece of steel, free of mill scale and rust, similar in magnetic nature to the painted steel and at least 1,2 mm thick, for use in calibration.

15.4 Procedure

15.4.1 Calibration

Before use, the instrument shall be calibrated in accordance with the manufacturer's instructions for steel, using the piece of smooth steel which shall be burnished with 400 grit abrasive paper to remove all staining and corrosion products. The calibration shims shall be interposed between the probe and the piece of smooth steel. Calibration shims of thicknesses above and below the expected value of coating thickness to be measured shall be used.

15.4.2 Measurement

Measurements on the dry paint film shall be made in accordance with the instrument manufacturer's operating instructions for smooth steel. The number of readings shall be in accordance with the number of spots recommended in 15.4.3.

15.4.3 Number of readings

It is advisable to take at least three readings evenly spread in each reference area.

NOTE 12 -As a guide, it is recommended that there should be two reference areas every square metre for flat plates, four every metre length for a web, two every metre length for a flange and for a pipe two reference areas every metre length, with more for large diameter pipes.

It is generally recommended that for off-shore and marine work increased frequency of readings is conducted.

16 Test report

The test report shall contain at least the following information:

- a) all details necessary to indentify the product tested;
- b) a reference to this International Standard (ISO 2808);
- c) the items of supplementary information referred to in clause 3;
- d) a reference to the national standard or other document supplying the information referred to in c);

- e) the result of the test (the individual thickness values and the mean with standard deviation; alternatively the individual thickness values and the minimum and maximum values measured);
- f) any deviation from the test method specified;
- g) the date of the test.

Annex A (normative)**Method No 2****Procedure****A.1 Apparatus and materials**

A.1.1 Thin plastic sheet, resistant to a temperature of $(105 \pm 2)^{\circ}\text{C}$ and unaffected by paint solvents.

NOTE 13 -Polyester sheet, approximately 25 μm thick, has been found to be suitable for this method.

A.1.2 Film spreading devices, capable of producing uniform films approximately 50 μm and 100 μm thick.

A.1.3 Glass plates, not less than 250 mm in length, not less than 100 mm in width and approximately 6 mm thick, of a size suitable for use with the film spreading devices (A.1.2).

A.1.4 Balance, accurate to 1 mg or better.

A.1.5 Dial gauge, capable of measurement to 2 μm , mounted on a rigid support.

A.1.6 Oven, capable of being maintained at $(105 \pm 2)^{\circ}\text{C}$.

A.1.7 Metal template, 80 mm square.

A.1.8 Mineral hydrocarbon solvent

A.2 Calibrating of dry film mass against dry film thickness

NOTE 14- Calibration is required only the first time any particular coating is tested.

A.2.1 Cut the thin plastic sheets (A.1.1) to the size of the glass plates (A.1.3), and weigh each sheet to the nearest 1 mg.

Select six of the cut sheets with masses not differing by more than 3 mg.

A.2.2 Wet the surface of one of the glass plates with the solvent (A.1.8) and squeegee one of the selected plastic sheets into intimate contact with the surface of the glass plate, taking care to avoid trapping air bubbles or solid particles.

Repeat the procedure with three further glass plates and plastic sheets.

A.2.3 Place a suitable quantity of the paint on one end of one of the four plastic sheets and distribute it evenly over the surface of the sheet on the plate using the film spreading device (A.1.2) to give a film 50 μm thick.

Repeat the procedure with a second plastic sheet and plate.

A.2.4 Repeat procedures A.2.2 and A.2.3 on a third and fourth plastic sheet using the spreading device to give a film 100 μm thick.

A.2.5 Remove the coated plastic sheets from the glass plates and after 15 min dry for 2 h at $(105 \pm 2)^\circ\text{C}$ in the oven (A.1.6) together with the two unpainted sheets, maintaining the sheets in a horizontal position throughout the operation.

NOTE 15 – If appreciable decomposition or wrinkling of the product under test occurs under these drying conditions, other more suitable conditions may be used by agreement between the interested parties.

A.2.6 Remove all six sheets from the oven and allow them to cool for 1 h at room temperature.

A.2.7 Using the template (A.1.7), cut two squares from the central area of each sheet.

Weigh each square to the nearest 1 mg and initially calculate the mean mass of the four unpainted squares.

Determine the mass of paint on each of the eight painted squares by subtracting the mean mass of the unpainted squares from the mass of the painted square. Calculate the mass per unit area of the paint film, in grams per square metre.

A.2.8 Measure the thickness of each painted square with the dial gauge (A.1.5) in six places and calculate the mean thickness for each square.

Measure the thickness of each unpainted square in six places with the dial gauge and so calculate the mean thickness of the plastic sheet.

Calculate the mean thickness of the paint film on each painted square by subtracting the mean thickness of the unpainted squares from the thickness of the painted square.

A.2.9 Construct a graph showing the relation between the film thickness and film mass per unit area on the eight painted squares, drawing the best straight line passing through the origin and between the plotted points.

A.3 Procedure for determining the dry-film thickness on the test panels

A.3.1 Use a weighed test panel prepared in accordance with the requirements of ISO 1514.

A.3.2 Coat the panel with the product under test by the appropriate method.

Allow the panel to dry for 24 h at $(23 \pm 2) ^\circ\text{C}$ and a relative humidity of $(50 \pm 5) \%$.

A.3.3 Weigh the panel and calculate the mass per unit area of the dry film, in grams per square metre.

A.3.4 Determine the mean equivalent film thickness by reference to the graph.

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