INTERNATIONAL STANDARD

ISO 23811

First edition
2009-02-15

Paints and varnishes — Determination of percentage volume of non-volatile matter by measuring the non-volatile matter content and the density of the coating material, and calculation of the theoretical spreading rate

Peintures et vernis — Détermination du pourcentage en volume de matières non volatiles par mesurage de la teneur en matières non volatiles et de la masse volumique d'un produit de peinture et calcul du rendement d'application théorique

Reference number
ISO 23811:2009(E)

PDF disclaimer

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

Adobe is a trademark of Adobe Systems Incorporated.

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

Contents

Page

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 23811 was prepared by Technical Committee ISO/TC 35, *Paints and varnishes*, Subcommittee SC 9, *General test methods for paints and varnishes*.

Introduction

This method is used to determine the volume of the dry coating obtainable using a coating material by calculation of the percentage volume of non-volatile matter. The value obtained by this method might not be the same as that measured or calculated by adding together the masses and volumes of the raw materials in a formulation. The volume occupied by a combination of resin and solvent might be the same as, greater than or less than the combined volume of the separate components, since contraction or expansion of resin and the solvent can occur. A second factor affecting the volume of a dry coating is the degree to which the spaces between pigment particles are filled with binder. A third factor is the use of volatile components in reactive systems that, by their reaction, change into non-volatile film-building materials, i.e. amines and reactive solvents in high-build two-component coating materials.

Above and close to the critical pigment volume concentration, the volume of a dry paint film is greater than the theoretical volume, due to an increase in unfilled voids between pigment particles. The porosity of the film means that this method is unsuitable.

Another method for determination of the percentage volume of non-volatile matter is described in ISO 3233. The method described in ISO 23811 is a quick method which needs only the results of the non-volatile matter and the density of the coating material and the density of the solvents for the calculation. The precision of the method depends mainly on the determination of the non-volatile matter content and the unknown densities. But the precision of the combination of measurements and calculation is better than the precision of pure calculation methods with no measurements. The simple practical method is often used in the automotive industry, especially for commercial vehicles.

The method described in ISO 23811 differs from the methods described in ASTM D 2697 and Section 5.5 of ASTM D 5201-05a and gives different results.

Paints and varnishes — Determination of percentage volume of non-volatile matter by measuring the non-volatile matter content and the density of the coating material, and calculation of the theoretical spreading rate

1 Scope

This International Standard specifies a simple practical method for calculating the non-volatile matter by volume, NV_V, of a coating material from the non-volatile-matter content, NV, the density of the coating material and the density of the solvents. Using the non-volatile matter by volume results and the density obtained in accordance with this International Standard, it is possible to calculate the theoretical spreading rate of a coating material.

This International Standard is not applicable to coating materials which exceed the critical pigment volume concentration (CPVC).

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 2811-1, *Paints and varnishes — Determination of density — Part 1: Pyknometer method*

ISO 2811-2, *Paints and varnishes — Determination of density — Part 2: Immersed body (plummet) method*

ISO 2811-3, *Paints and varnishes — Determination of density — Part 3: Oscillation method*

ISO 2811-4, *Paints and varnishes — Determination of density — Part 4: Pressure cup method*

ISO 3251, *Paints, varnishes and plastics — Determination of non-volatile-matter content*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1
spreading rate
surface area that can be covered by a given quantity of coating material to give a dried film of requisite thickness

NOTE 1 It is expressed in m^2/l or m^2/kg.

[ISO 4618:2006]

NOTE 2 See also **practical spreading rate** (3.3) and **theoretical spreading rate** (3.5).

3.2
non-volatile matter
NV
residue by mass obtained by evaporation under specified conditions

[ISO 4618:2006]

3.3
practical spreading rate
spreading rate which is obtained in practice on the particular substrate being coated

[ISO 4618:2006]

3.4
practical dry film density
practically determined density of a dried and cured coating

3.5
theoretical spreading rate
spreading rate calculated solely from the volume of non-volatile matter

[ISO 4618:2006]

3.6
theoretical dry film density
coating density calculated from the densities of the solvents, coating materials and the non-volatile-matter content of the coating material

3.7
non-volatile matter by volume
NV_V
percentage residue by volume obtained by evaporation under specified conditions

4 Principle

The non-volatile matter by volume is calculated from the quotient of the density of the coating material and the density of the dry film, with the dry film density being determined theoretically.

5 Procedure

5.1 Determination of the theoretical dry film density

The dry film density can be determined theoretically, although the density of the solvents and of the coating material and the coating material's non-volatile matter by mass also have to be determined. Since it is often not possible to specify the density of all the solvents present in the coating material, the density of the solvent in highest proportion is used in the calculation.

The non-volatile matter by mass (NV) is determined as described in ISO 3251.

5.2 Determination of the density

The density of the coating material (ρ_1) and that of the solvents in the coating material (ρ_2) is determined to the nearest 0,001 g/ml in accordance with one of the methods specified in the series of standards ISO 2811-1, ISO 2811-2, ISO 2811-3 and ISO 2811-4.

6 Calculation

6.1 Calculation of the theoretical dry film density

Calculate the theoretical dry film density (ρ_t), in grams per millilitre, as given in Equation (1) using the determined non-volatile matter by mass, the density of the coating material and the density of the solvents or main solvent in the coating material:

$$\rho_t = \frac{\rho_1 \times NV}{100 - \frac{\rho_1}{\rho_2} \times (100 - NV)} \quad (1)$$

where

ρ_1 is the density of the coating material, in grams per millilitre;

ρ_2 is the density of the solvents or the main solvent in the coating material, in grams per millilitre;

NV is the non-volatile matter of the coating material, expressed as a percentage by mass.

In the case of waterborne coating materials, the density of the solvents (ρ_2) shall be the density of the main organic solvent and not the density of water.

6.2 Calculation of the non-volatile matter by volume using the theoretical dry film density

The theoretical non-volatile matter by volume, NV_V, expressed as a percentage by volume, is given by Equation (2):

$$NV_V = \frac{\rho_1 \times NV}{\rho_t} \quad (2)$$

where

NV is the non-volatile matter of the coating material, expressed as a percentage by mass;

ρ_1 is the density of the coating material, in grams per millilitre;

ρ_t is the theoretical dry film density, in grams per millilitre.

6.3 Determination of the theoretical spreading rate

The theoretical spreading rate is a value which is calculated solely from the non-volatile matter by volume. The practical spreading rate, on the other hand, is a value which is obtained when coating an individual work specimen in practice.

Based on the definition of the spreading rate, therefore, the theoretical spreading rate, s_t, is the quotient of the surface area coated and the mass required for this, in square metres per kilogram [Equation (3)] or the volume, in square metres per litre [Equation (4)]:

relative to the mass:

$$s_{t,m} = \frac{NV}{\rho_t \times t_d} \times 10 \quad (3)$$

relative to the volume:

$$s_{t,V} = \frac{NV \times \rho_1}{\rho_t \times t_d} \times 10 = \frac{NV_V}{t_d} \times 10 \quad (4)$$

where

NV is the non-volatile-matter content of the coating material, expressed as a percentage by mass;

NV_V is the non-volatile matter of the coating material by volume, expressed as a percentage by volume;

t_d is the dry film thickness of the coating, in micrometres;

ρ_t is the theoretical dry film density, in grams per millilitre;

ρ_1 is the density of the coating material, in grams per millilitre.

For information on the derivation of the dry film thickness and of the theoretical spreading rate see Annexes A and B, respectively. An example for the calculation of the theoretical spreading rate is given in Annex C.

7 Precision

7.1 Repeatability limit

The repeatability limit r is the value below which the absolute difference between two test results (each being the average of two valid determinations) of this test method can be expected under similar conditions. The test results shall be determined on the same test material by the same test technician in the same laboratory within a short period of time in accordance with the standard test method.

Two results of the non-volatile matter by volume calculated on the basis of the theoretical dry film density are regarded as acceptable and in compliance with the standard for the repeatability limit if they do not differ by more than the following value:

$0,48 + (0,008\,6 \times NV_V)$

7.2 Reproducibility limit

The reproducibility limit R is the value below which the absolute difference between two test results (each being the average of two valid determinations) of this test method can be expected under matching conditions. The test results shall be determined on the same test material by different test technicians in different laboratories in accordance with the standard test method.

Two results of the non-volatile matter by volume calculated on the basis of the theoretical dry film density are regarded as acceptable and in compliance with the standard for the reproducibility limit if they do not differ by more than the following value:

$1,06 + (0,009\,6 \times NV_V)$

8 Test report

The test report shall contain at least the following information:

a) all details necessary to identify the product tested (manufacturer, product code, batch number, etc.);

b) a reference to this International Standard (ISO 23811:2009);

c) an indication of the test method used for determination of the density;

d) the result of the test, as specified in Clause 6;

e) any deviations from the procedure specified;

f) any unusual features (anomalies) observed during the test;

g) the date of the test.

Annex A
(informative)

Derivation of the theoretical dry film thickness

The density of the coating material (ρ_1), the density of the solvents or main solvent in the coating material (ρ_2) and the theoretical dry film density (ρ_t), in grams per millilitre, are defined as follows:

$$\rho_1 = \frac{m_1}{V_1} \tag{A.1}$$

$$\rho_2 = \frac{m_2}{V_2} \tag{A.2}$$

$$\rho_t = \frac{m_t}{V_t} \tag{A.3}$$

where

m_1 is the mass of the coating material, in grams;

V_1 is the volume of the coating material, in millilitres;

m_2 is the mass of the solvents or the main solvent in the coating material, in grams;

V_2 is the volume of the solvents or the main solvent in the coating material, in millilitres;

m_t is the mass of the dried film, in grams;

V_t is the volume of the dried film, in millilitres.

Considering that the coating material is containing solvents, the following is valid:

$$m_2 = \frac{m_1 \times (100 - \mathrm{NV})}{100} \tag{A.4}$$

$$V_t = V_1 - V_2 \tag{A.5}$$

$$m_t = m_1 - m_2 \tag{A.6}$$

where NV is the non-volatile-matter content of the coating material, expressed as a percentage by mass.

So the dry film density of the coating (ρ_t), in grams per millilitre, can be calculated following Equation (A.7):

$$\rho_t = \frac{m_t}{V_t} = \frac{m_1 - m_2}{V_1 - V_2} = \frac{m_1 - \dfrac{m_1 \times (100 - \mathrm{NV})}{100}}{V_1 - V_2} = \frac{\dfrac{m_1 \times \mathrm{NV}}{100}}{V_1 - V_2} = \frac{\dfrac{\rho_1 \times V_1 \times \mathrm{NV}}{100}}{V_1 - V_2} = \frac{\dfrac{\rho_1 \times \mathrm{NV}}{100}}{1 - \dfrac{V_2}{V_1}} = \frac{\rho_1 \times \mathrm{NV}}{100 \times (1 - \dfrac{V_2}{V_1})} \tag{A.7}$$

Considering

$$V_1 = \frac{m_1}{\rho_1} \qquad \text{(A.8)}$$

and

$$V_2 = \frac{\frac{m_1 \times (100 - \text{NV})}{100}}{\rho_2} \qquad \text{(A.9)}$$

it follows that:

$$\frac{V_2}{V_1} = \frac{m_1 \times (100 - \text{NV})}{100 \times \rho_2} \times \frac{\rho_1}{m_1} = \frac{\rho_1}{\rho_2} \times \frac{100 - \text{NV}}{100} \qquad \text{(A.10)}$$

When inserting the dry film density, it follows that:

$$\rho_\text{t} = \frac{\rho_1 \times \text{NV}}{100 \times (1 - \frac{\rho_1}{\rho_2} \times \frac{100 - \text{NV}}{100})} = \frac{\rho_1 \times \text{NV}}{100 - \frac{\rho_1}{\rho_2} \times (100 - \text{NV})}$$

(A.11) [See also Equation (1).]

Annex B
(informative)

Derivation of the theoretical spreading rate

B.1 Spreading rate relative to the mass

The spreading rate of a coating material indicates the area which can be covered by a given quantity of coating material (see 3.1).

When considering a defined area which is covered by the minimum film thickness to give a hiding coat (see ISO 6504-3) and considering further that the used coating material is containing no volatile matter, Equation (B.1) is valid:

$$V_{\mathrm{t}} = t_{\mathrm{d}} \times A \tag{B.1}$$

where

V_{t} is the volume of the dried film, in cubic metres;

t_{d} is the dry film thickness of the hiding coat, in metres;

A is the coated area, in square metres.

Following Equation (A.3), the dry film density equals the quotient of mass and volume of the dried film:

$$\rho_{\mathrm{t}} = \frac{m_{\mathrm{t}}}{V_{\mathrm{t}}} \tag{B.2}$$

Considering a 100 % non-volatile coating material,

$$m_{\mathrm{t}} = \rho_{\mathrm{t}} \times V_{\mathrm{t}} = \rho_{\mathrm{t}} \times t_{\mathrm{d}} \times A \tag{B.3}$$

where m_{t} is the mass of the dried film, in kilograms.

Many coating materials are containing non-volatile matters which need to be considered in the calculation. When the non-volatile matter content decreases the coating material consumption increases. Consequently the non-volatile-matter content, NV, is given as

$$\mathrm{NV} = \frac{m_{\mathrm{t}}}{m_1} \times 100 \tag{B.4}$$

where m_1 is the mass of the coating material, in kilograms.

When inserting Equation (B.3), it follows that:

$$m_1 = \frac{m_{\mathrm{t}}}{\mathrm{NV}} \times 100 = \frac{\rho_t \times t_{\mathrm{d}} \times A}{\mathrm{NV}} \times 100 \tag{B.5}$$

After transformation of the equation, the spreading rate relative to the mass $s_{t,m}$, in square metres per kilogram, is given as follows:

$$s_{t,m} = \frac{A}{m_1} = \frac{A \times NV}{A \times \rho_t \times t_d \times 100} = \frac{NV}{\rho_t \times t_d \times 100} \quad (B.6)$$

where

m_1 is the mass of the coating material, in kilograms;

V_1 is the volume of the coating material, in cubic metres;

ρ_1 is the density of the coating material, in kilograms per cubic metre;

m_2 is the mass of the solvents or the main solvent in the coating material, in kilograms;

V_2 is the volume of the solvents or the main solvent in the coating material, in cubic metres;

ρ_2 is the density of the solvents or the main solvent in the coating material, in kilograms per cubic metre;

m_t is the mass of the dried film, in kilograms;

V_t is the volume of the dried film, in cubic metres;

ρ_t is the theoretical dry film density, in kilograms per cubic metre.

When converting the basic SI units to the practical units measured, the factor × 1 000 has to be inserted:

$$s_{t,m} = \frac{NV}{\rho_t \times t_d \times 100} \times 1000 = \frac{NV}{\rho_t \times t_d} \times 10$$

(B.7) [See also Equation (3).]

B.2 Spreading rate relative to the volume

The volume of the coating material is the sum of the volume of the coat and the volatile matter (solvents), in cubic metre:

$$V_1 = V_t + V_2 \quad (B.8)$$

Considering the following relation for the volume

$$V = \frac{m}{\rho} \quad (B.9)$$

Equation (B.7) can be converted to

$$\frac{m_1}{\rho_1} = \frac{m_t}{\rho_t} + \frac{m_2}{\rho_2} \quad (B.10)$$

When inserting the relation (B.3) for the mass of the coating materials, m_1, it follows

$$V_1 = \frac{m_1}{\rho_1} = \frac{\rho_t \times t_d \times A \times 100}{\rho_1 \times NV} \quad (B.11)$$

After transformation of the equation, the spreading rate relative to the volume $s_{t,V}$, in square metres per cubic metre, is given as follows:

$$s_{t,V} = \frac{A}{V_1} = \frac{A \times NV \times \rho_1}{A \times \rho_t \times t_d \times 100} = \frac{NV \times \rho_1}{\rho_t \times t_d \times 100} \quad \text{(B.12)}$$

When converting the basic SI units to the practical units measured, the factor × 1 000 has to be inserted:

$$s_{t,V} = \frac{NV \times \rho_1}{\rho_t \times t_d \times 100} \times 1\,000 = \frac{NV \times \rho_1}{\rho_t \times t_d} \times 10 \quad \text{(B.13) [See also Equation (4).]}$$

Annex C
(informative)

Example for the calculation of the theoretical spreading rate

C.1 Example for the calculation of the theoretical spreading rate relative to the mass

For this example of a typical filler for automotive coatings, the usual measurements and their units are used:

NV = 60 %

ρ_t = 1,8 g/ml

t_d = 35 µm

When inserting these values into Equation (3), the theoretical spreading rate relative to the mass, in square metres per kilogram, is as follows:

$$s_{t,m} = \frac{A}{m} = \frac{NV}{\rho_t \times t_d} \times 10 = \frac{60}{1,8 \times 35} \times 10 = 9,5$$

In this example, 1 kg of the coating material can be used for coating an area of 9,5 m^2.

C.2 Example for the calculation of the theoretical spreading rate relative to the volume

For this example of the same filler as in C.1, the usual measurements and their units are used:

NV = 60 % ρ_1 = 1,3 g/ml

ρ_t = 1,8 g/ml ρ_2 = 0,9 g/ml

t_d = 35 µm

When inserting these values into Equation (4), the theoretical spreading rate relative to the volume, in square metres per litre, is as follows:

$$s_{t,V} = \frac{A}{V} = \frac{NV \times \rho_1}{\rho_t \times t_d} \times 10 = \frac{60 \times 1,3}{1,8 \times 35} \times 10 = 12,4$$

In this example, 1 l of the coating material can be used for coating an area of 12,4 m^2.

Bibliography

[1] ISO 3233, *Paints and varnishes — Determination of percentage volume of non-volatile matter by measuring the density of a dried coating*

[2] ISO 4618:2006, *Paints and varnishes — Terms and definitions*

[3] ISO 6504-3, *Paints and varnishes — Determination of hiding power — Part 3: Determination of contrast ratio of light-coloured paints at a fixed spreading rate*

[4] ASTM D 2697, *Standard Test Method for Volume Nonvolatile Matter in Clear or Pigmented Coatings*

[5] ASTM D 5201-05a, *Standard Practice for Calculating Formulation Physical Constants of Paints and Coatings*

ICS 87.040

Price based on 12 pages