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Paints and varnishes — Determination of the percentage volume of non-volatile matter —

Part 3: Determination by calculation from the non-volatile-matter content determined in accordance with ISO 3251, the density of the coating material and the density of the solvent in the coating material

Peintures et vernis — Détermination du pourcentage en volume de matière non volatile —

Partie 3: Détermination par calcul à partir de la teneur en matière non volatile déterminée conformément à l'ISO 3251, de la masse volumique du produit de peinture et de la masse volumique du solvant du produit de peinture

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT), see the following URL: Foreword — Supplementary information.

The committee responsible for this document is ISO/TC 35, *Paints and varnishes*, Subcommittee SC 9, *General test methods for paints and varnishes*.

This first edition of ISO 3233-3 cancels and replaces ISO 23811:2009, which has been technically revised and, in addition to the change in number, contains the following changes:

— symbols have been harmonized with those used in ISO 3233-1 and ISO 3233-2;

— determination of dry film thickness has been added;

— statement on the density of the solvents of waterborne systems has been added;

— informative annex (Annex D) for an overview on the existing methods for determination of non-volatile matter content and volume of non-volatile matter has been added;

— text has been editorially revised and Normative References has been updated.

ISO 3233 consists of the following parts, under the general title *Paints and varnishes — Determination of percentage volume of non-volatile matter*:

— *Part 1: Method using a coated test panel to determine non-volatile matter and to determine dry film density by the Archimedes principle*

— *Part 2: Method using the determination of non-volatile-matter content in accordance with* ISO 3251 *and determination of dry film density on coated test panels by the Archimedes principle*

— *Part 3: Determination by calculation from the non-volatile-matter content determined in accordance with* ISO 3251, *the density of the coating material and the density of the solvent in the coating material*

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.

Other methods for determination of the percentage volume of non-volatile matter are described in ISO 3233-1 and ISO 3233-2. The method described in this part of ISO 3233 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 this part of ISO 3233 differs from the methods described in ASTM D 2697 and ASTM D 5201-05, 5.5 and gives different results.

Paints and varnishes — Determination of the percentage volume of non-volatile matter —

Part 3: Determination by calculation from the non-volatile-matter content determined in accordance with ISO 3251, the density of the coating material and the density of the solvent in the coating material

1 Scope

This part of ISO 3233 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 part of ISO 3233, it is possible to calculate the theoretical spreading rate of a coating material.

This part of ISO 3233 is not applicable to coating materials which exceed the critical pigment volume concentration (CPVC).

2 Normative references

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

ISO 2808, *Paints and varnishes — Determination of film thickness*

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 to entry: It is expressed in m^2/l or m^2/kg.

Note 2 to entry: See also practical spreading rate and theoretical spreading rate.

[SOURCE: ISO 4618:2014, 2.238, modified — Application rate was deleted in Note 2.]

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

Note 1 to entry: Instead of the term "non-volatile matter", different terms, such as solid, dry residue, dry matter, solid matter, and stoving residue, are being used commonly with the respective abbreviations. The term "non-volatile matter", which is also applied in ISO 3251, should be used together with the abbreviation "NV" instead of these terms.

[SOURCE: ISO 4618:2014, 2.176]

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

[SOURCE: ISO 4618:2014, 2.203]

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

[SOURCE: ISO 4618:2014, 2.256]

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

[SOURCE: ISO 4618:2014, 2.177]

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 has 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.

Determine the non-volatile matter by mass (NV) as described in ISO 3251.

5.2 Determination of the density

Determine the density of the coating material (ρ_1) and that of the solvents in the coating material (ρ_2) to the nearest 0,001 g/cm^3 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.

5.3 Determination of film thickness

Determine the dry film thickness using one of the methods described in ISO 2808.

6 Calculation

6.1 Calculation of the theoretical dry film density

Calculate the theoretical dry film density (ρ_t), in grams per cubic centimetre, as given in Formula (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:

$$\rho_t = \frac{\rho_1 \cdot \mathrm{NV}}{100 - \frac{\rho_1}{\rho_2} \cdot (100 - \mathrm{NV})} \qquad (1)$$

where

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

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

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 total solvent composition, including water or the density which is recommended in Table 1.

Table 1 — Recommended density values of solvents in waterborne coating materials

Composition of the solvent	Recommended values for ρ_2, if the density of the solvents is not known g/cm^3
predominantly aliphatic hydrocarbons	0,80
predominantly aromatic hydrocarbons	0,87
water, VOC ≤ 5 %[a]	1,00
[a] VOC Volatile organic compound.	

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

The theoretical non-volatile matter by volume, $NV_{V,t}$, expressed as a percentage by volume, is given by Formula (2):

$$NV_{V,t} = \frac{\rho_1 \cdot NV}{\rho_t} \tag{2}$$

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 cubic centimetre;
ρ_t	is the theoretical dry film density, in grams per cubic centimetre.

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.

Therefore, based on the definition of the spreading rate, the theoretical spreading rate, s_t, is the quotient of the surface area coated and the mass required for this [Formula (3)] or the volume [Formula (4)]:

$$s_{t,m} = \frac{NV}{\rho_t \cdot t_d} \cdot 10 \tag{3}$$

$$s_{t,V} = \frac{NV \cdot \rho_1}{\rho_t \cdot t_d} \cdot 10 = \frac{NV_{V,t}}{t_d} \cdot 10 \tag{4}$$

where

$s_{t,m}$	is the theoretical spreading rate relative to the mass, expressed in square metres per kilogram;
$s_{t,V}$	is the theoretical spreading rate relative to the volume, expressed in square metres per litre;
NV	is the non-volatile matter content of the coating material, expressed as a percentage by mass;
$NV_{V,t}$	is the theoretical 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 cubic centimetre;
ρ_1	is the density of the coating material, in grams per cubic centimetre;
10	is a factor relating to the conversion of various units.

For information on the derivation of the dry film thickness and of the theoretical spreading rate, see Annex A and Annex 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 value given in Formula (5):

$$0,48+\left(0,008\,6\cdot \mathrm{NV}_{\mathrm{V,t}}\right) \qquad (5)$$

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 value given in Formula (6):

$$1,06+\left(0,009\,6\cdot \mathrm{NV}_{\mathrm{V,t}}\right) \qquad (6)$$

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) reference to this part of ISO 3233 (i.e. ISO 3233-3);

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

d) 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) 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 cubic centimetre, 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, Formula (A.4), Formula (A.5), and Formula (A.6) are valid:

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

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

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

where

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

Considering Formula (A.3) to Formula (A.6), the dry film density of the coating (ρ_t), in grams per cubic centimetre, can be calculated using Formula (A.7):

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

Considering Formula (A.1), Formula (A.2), and Formula (A.4), the volume can be calculated using Formula (A.8) and Formula (A.9):

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

$$V_2 = \frac{\dfrac{m_1 \cdot (100 - NV)}{100}}{\rho_2} \quad (A.9)$$

The relation of V_1 and V_2 is calculated using Formula (A.10):

$$\frac{V_2}{V_1} = \frac{m_1 \cdot (100 - NV)}{100 \cdot \rho_2} \cdot \frac{\rho_1}{m_1} = \frac{\rho_1}{\rho_2} \cdot \frac{100 - NV}{100} \quad (A.10)$$

When inserting the dry film density, it follows that:

$$\rho_t = \frac{\rho_1 \cdot NV}{100 \cdot (1 - \dfrac{\rho_1}{\rho_2} \cdot \dfrac{100 - NV}{100})} = \frac{\rho_1 \cdot NV}{100 - \dfrac{\rho_1}{\rho_2} \cdot (100 - NV)} \quad (A.11)$$

NOTE See also Formula (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, Formula (B.1) is valid:

$$V_t = t_d \cdot A \tag{B.1}$$

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 Formula (A.3), the dry film density equals the quotient of mass and volume of the dried film, as shown in Formula (B.2):

$$\rho_t = \frac{m_t}{V_t} \tag{B.2}$$

Considering a 100 % non-volatile coating material,

$$m_t = \rho_t \cdot V_t = \rho_t \cdot t_d \cdot A \tag{B.3}$$

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 Formula (B.4):

$$\mathrm{NV} = \frac{m_t}{m_1} \cdot 100 \tag{B.4}$$

where

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

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

$$m_1 = \frac{m_t}{NV} \cdot 100 = \frac{\rho_t \cdot t_d \cdot A}{NV} \cdot 100 \quad (B.5)$$

After transformation of the formula, the spreading rate relative to the mass $s_{t,m}$, in square metres per kilogram, is given in Formula (B.6):

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

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;

t_d is the dry film thickness of the coating, in metres.

When converting the basic SI units to the practical units measured (i.e. grams per cubic centimetre, micrometres), the factor × 1 000 has to be inserted, as shown in Formula (B.7)

$$s_{t,m} = \frac{NV}{\rho_t \cdot t_d \cdot 100} \times 1\,000 = \frac{NV}{\rho_t \cdot t_d} \cdot 10 \quad (B.7)$$

NOTE See also Formula (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, given in Formula (B.8):

$$V_1 = V_t + V_2 \tag{B.8}$$

Considering Formula (B.9) for the volume

$$V = \frac{m}{\rho} \tag{B.9}$$

Formula (B.7) can be converted to

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

When inserting Formula (B.3) for the mass of the coating materials, m_1, it follows Formula (B.11):

$$V_1 = \frac{m_1}{\rho_1} = \frac{\rho_t \cdot t_d \cdot A \cdot 100}{\rho_1 \cdot \mathrm{NV}} \tag{B.11}$$

After transformation of the formula, the spreading rate relative to the volume $s_{t,V}$, in square metres per cubic metre, is given in Formula (B.12):

$$s_{t,V} = \frac{A}{V_1} = \frac{A \cdot \mathrm{NV} \cdot \rho_1}{A \cdot \rho_t \cdot t_d \cdot 100} = \frac{\mathrm{NV} \cdot \rho_1}{\rho_t \cdot t_d \cdot 100} \tag{B.12}$$

When converting the basic SI units to the practical units measured (i.e. grams per cubic centimetre, micrometres), the factor × 1 000 has to be inserted, as shown in Formula (B.13):

$$s_{t,V} = \frac{\mathrm{NV} \cdot \rho_1}{\rho_t \cdot t_d \cdot 100} \times 1\,000 = \frac{\mathrm{NV} \cdot \rho_1}{\rho_t \cdot t_d} \cdot 10 \tag{B.13}$$

NOTE See also Formula (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 following usual measurements and their units are used:

NV = 60 %

ρ_t = 1,8 g/cm^3

t_d = 35 µm

When inserting these values into Formula (3), the theoretical spreading rate relative to the mass, in square metres per kilogram, is given in Formula (C.1):

$$s_{t,m} = \frac{A}{m} = \frac{NV}{\rho_t \cdot t_d} \cdot 10 = \frac{60}{1{,}8 \cdot 35} \cdot 10 = 9{,}5 \quad \text{(C.1)}$$

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/cm^3

ρ_t = 1,8 g/cm^3

ρ_2 = 0,9 g/cm^3

t_d = 35 µm

When inserting these values into Formula (4), the theoretical spreading rate relative to the volume, in square metres per litre, is given in Formula (C.2):

$$s_{t,V} = \frac{A}{V} = \frac{NV \cdot \rho_1}{\rho_t \cdot t_d} \cdot 10 = \frac{60 \cdot 1{,}3}{1{,}8 \cdot 35} \cdot 10 = 12{,}4 \quad \text{(C.2)}$$

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