



**International
Standard**

ISO 19403-3

**Paints and varnishes —
Wettability —**

**Part 3:
Determination of the surface
tension of liquids using the pendant
drop method**

Peintures et vernis — Mouillabilité —

*Partie 3: Détermination de la tension de surface des liquides par
la méthode de la goutte pendante*

**Second edition
2024-09**

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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.

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 document 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 of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 35, *Paints and varnishes*, Subcommittee SC 9, *General test methods for paints and varnishes*, in collaboration with the European Committee for Standardization (CEN) Technical Committee CEN/TC 139, *Paints and varnishes*, in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

This second edition cancels and replaces the first edition (ISO 19403-3:2017), which has been technically revised.

The main changes are as follows:

- the Worthington number has been introduced in [Annex B](#);
- the normative references have been updated.

A list of all parts in the ISO 19403 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Paints and varnishes — Wettability —

Part 3:

Determination of the surface tension of liquids using the pendant drop method

1 Scope

This document specifies a test method to measure the surface tension of liquids with an optical method using the pendant drop. The method can be applied for the characterization of liquid coating materials. If applied to liquids with non-Newtonian flow behaviour (as defined in ISO 3219-1:2021, 3.22) restrictions can apply.

NOTE For other methods to determine the surface tension, see e.g. EN 14370 and ISO 1409.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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: Pycnometer 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 4618, *Paints and varnishes — Vocabulary*

ISO 15528, *Paints, varnishes and raw materials for paints and varnishes — Sampling*

ISO 19403-1:2022, *Paints and varnishes — Wettability — Part 1: Vocabulary and general principles*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 4618 and ISO 19403-1 apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

- ISO Online browsing platform: available at <https://www.iso.org/obp>
- IEC Electropedia: available at <https://www.electropedia.org/>

4 Principle

One drop of the respective liquids to be tested is captured hanging from a needle, where the drop shall deviate significantly from the spherical shape due to its own mass. The surface tension is calculated from the shape of the pendant drop in accordance with the Young-Laplace equation.

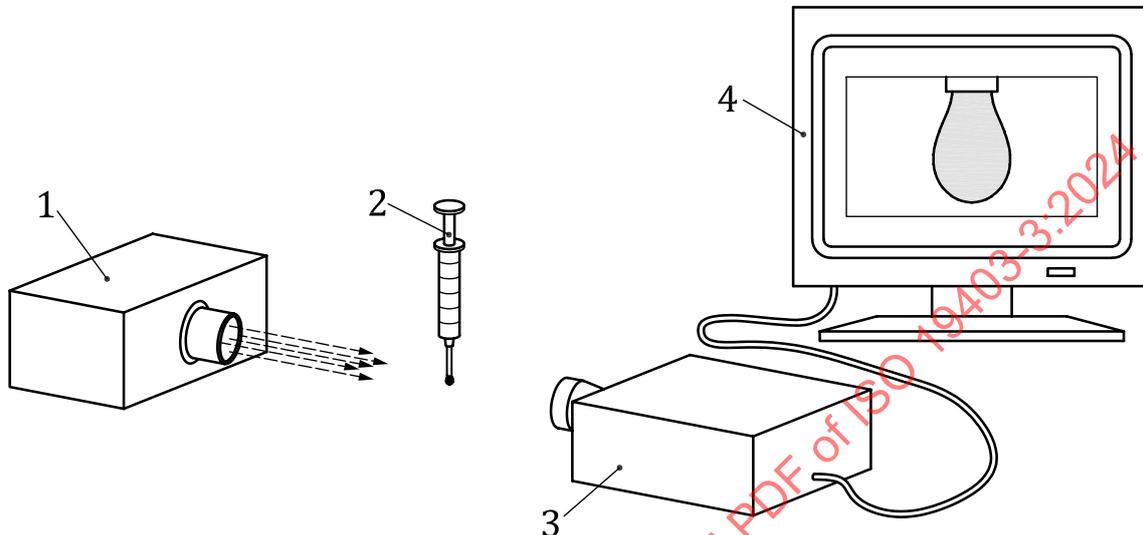
The polar and disperse fractions of the surface tension can be determined with at least two methods, which are specified in ISO 19403-4 and ISO 19403-5.

5 Apparatus and materials

Ordinary laboratory apparatus, together with the following shall be used.

5.1 Drop contour analysis system, for measuring the surface tension of pendant drops.

Any state-of-the-art drop contour analysis system with digital image capture and analysis can be used. [Figure 1](#) shows a schematic example of a drop contour analysis system.



Key

- 1 light source
- 2 graduated micro syringe
- 3 optical system
- 4 screen

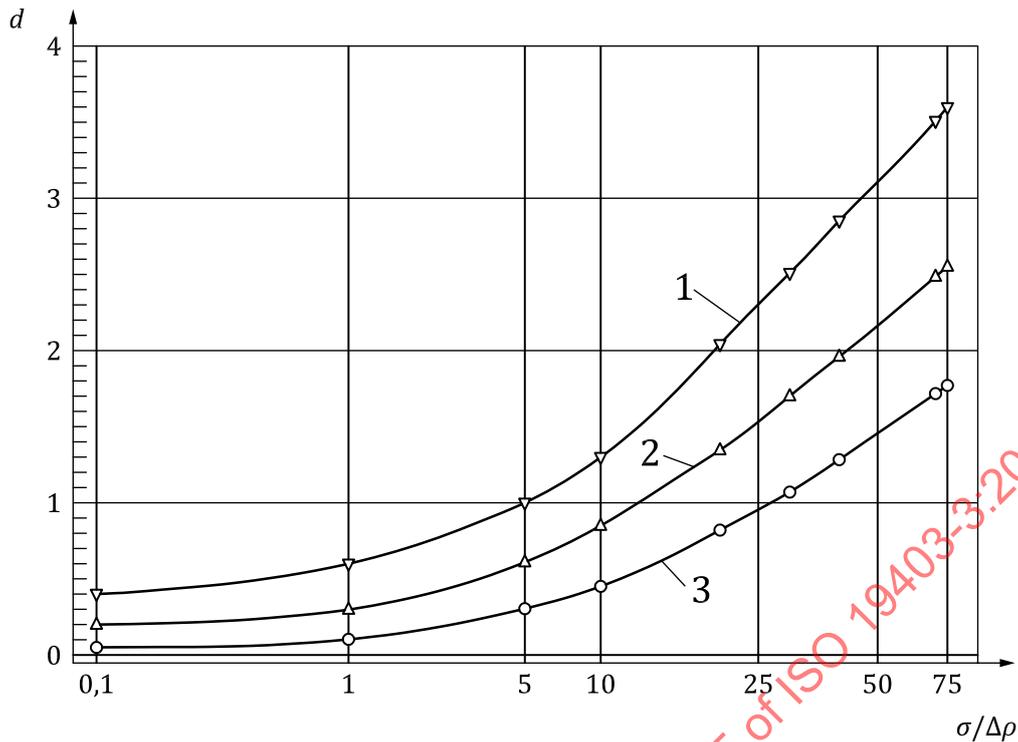
Figure 1 — Example of a drop contour analysis system

The image capturing system should be oriented in a way that the optimal image resolution ratio (ratio of width and height) can be used.

NOTE The device used can differ from the schematic diagram in [Figure 1](#) regarding light path and the set-up of the components.

5.2 Dosing unit, which makes it possible to dose a pendant liquid drop, which deviates significantly from the spherical shape due to its own mass, on a circular-cylindrical needle with constant thickness within the detection area of the camera.

To measure the surface tension on the pendant drop, usually a larger outside diameter of the needle is needed than for measuring the contact angle on the horizontal drop. The outside diameters of the needle used shall be in the range between 0,5 mm and 2,5 mm. The outside diameter of the needle to be chosen depends on the relationship between the surface tension, σ , and the density difference of the liquid to the ambient phase, $\Delta\rho$. The higher the quotient $\sigma/\Delta\rho$, the larger the outside diameter of the needle shall be. The dependence of the outside diameter of the needle, d , on the quotient of surface tension and density difference of the phases involved $\sigma/\Delta\rho$ is illustrated in [Figure 2](#).



Key

- d outside diameter of the needle, in mm
- $\sigma/\Delta\rho$ quotients from surface tension and density difference of the phases involved, in (mN/m)/g · cm⁻³
- 1 maximal valid outside diameter of the needle
- 2 optimal outside diameter of the needle
- 3 minimal valid outside diameter of the needle

Figure 2 — Diagram of the outside diameter of the needle, d , in dependence of the quotient from surface tension and density difference of the phases involved $\sigma/\Delta\rho$

6 Sampling

Take a representative sample of the liquid to be tested in accordance with ISO 15528.

7 Procedure

7.1 General

7.1.1 Setting up the drop contour analysis device

Choose the location of the drop contour analysis device, so that it is exposed to:

- no vibrations,
- no intense air flows (e.g. caused by air conditioning), and
- no intense exposure to light from outside (e.g. windows, bright lighting).

Align the drop contour analysis device horizontally.

Obtain the value of the local acceleration of gravity of the installation location and enter in the respective position of the manufacturer software. Values can be obtained, for example, by national metrology institutes.

7.1.2 Test conditions

Conduct the test at (23 ± 2) °C and a relative humidity of (50 ± 5) % (see ISO 3270) and make sure that all test media have this temperature.

7.2 Determination of the surface tension of the liquid

7.2.1 Preparations

In case it is not given, obtain the density of the liquid and ambient phase in accordance with a method specified in ISO 2811-1, ISO 2811-2, ISO 2811-3 or ISO 2811-4, and calculate the density difference. For a selection of densities of frequently used test liquids, see [Table A.1](#).

NOTE It can be reasonable to test the modes of operation of the optical components by means of two-dimensional images of drops. Such reference images are commercially available.

Determine the outside diameter of the needle precisely to $\pm 0,005$ mm. This can be done by means of a micrometer according to ISO 2808.

Move the needle to the upper margin of the image and bring the edges of the needle into focus. Set up the zoom of the drop contour analysis device so that the outside diameter of the needle takes up at least one eighth of the width of the image, refocus if necessary.

Fill the dosing system with the liquid to be tested. Pay attention to fill without contamination or bubbles.

7.2.2 Procedure

Produce a preferably large pendant drop.

NOTE In order to avoid movements of the pendant drop due to air flows, the drop can be positioned in an appropriate optical cell. To reduce changes in concentration due to evaporation, the optical cell can be filled in the lower part with the liquid to be tested.

After final focusing/zooming, carry out the length calibration of the imaging device. Update the lighting, if necessary.

Do not change the zoom and focus after this determination of scale.

Capture an image of the pendant drop with a drop contour appropriate for the evaluation in accordance with [Annex B](#).

It is recommended to save the original image for traceability reasons.

Repeat measuring on at least two more drops of the same liquid.

8 Evaluation

For the evaluation, the theoretical approach in accordance with Young-Laplace, which is specified in ISO 19403-1, is valid. For the practical procedure, it is recommended to use the software supplied by the manufacturers of the devices.^[10] With this software, the mathematical model, which is the basis of the evaluation, is adapted to the contour of the drop. An axially symmetric contour of the drop is a mandatory precondition for the evaluation.

For the quality of the evaluation, two essential criteria shall be regarded.

- a) The shape parameter, B , should lie within the recommended range of $0,60 \pm 0,06$ (see [Figure B.1](#)).
- b) The fit error,^[11] which describes the quality of the adaption, should lie below $1 \mu\text{m}$ per measuring point. In case $1 \mu\text{m}$ per measuring point is exceeded, it is recommended to check the measuring conditions, e.g. in regard to axial symmetry.

9 Precision

9.1 General

For the detailed results of an interlaboratory test, see [Annex C](#).

9.2 Repeatability limit, r

The repeatability limit, r , is the value below which the absolute difference between two single test results, each the mean of valid duplicates, can be expected to lie with a probability of 95 % when this method is used under repeatability conditions. In this case, the test results are obtained on identical material by one operator in one laboratory within a short interval of time using the standardized test method. In this document, the repeatability limit, r , is on average 0,7 mN/m for test liquids and coating materials.

9.3 Reproducibility limit, R

The reproducibility limit, R , is the value below which the absolute difference between two single test results, each the mean of valid duplicates, can be expected to lie with a probability of 95 % when this method is used under reproducibility conditions. In this case, the test results are obtained on identical material by operators in different laboratories using the standardized test method. In this document, the reproducibility limit, R , is on average 1,6 mN/m for test liquids and 2,2 mN/m for coating materials.

10 Test report

The test report shall contain at least the following information:

- a) all details necessary to identify the tested product; for test liquids including manufacturer and purity grade;
- b) a reference to this document, i.e. ISO 19403-3:2024;
- c) for the determination of the surface tension of the liquid:
 - 1) the shape parameter, B , for every drop, and, if appropriate, the Worthington number,
 - 2) the fit error (deviation of the contour of the drop obtained from the calculated contour of the drop),
 - 3) the amount of drops,
 - 4) the result of the measuring of the surface tension (arithmetic mean value and standard deviation), and
 - 5) the density of the tested liquid, including origin of the values;
- d) all deviations from the specified method and their possible influences on the results;
- e) any unusual observation (deviation) during the test;
- f) the type of device;
- g) the name of the person responsible for testing;
- h) the date of the test.

Annex A (informative)

Density of test liquids

Table A.1 — Density values of the test liquids

Test liquid	Density, ρ , depending on temperature					
	$T = 20\text{ °C}$ g/cm ³	$T = 21\text{ °C}$ g/cm ³	$T = 22\text{ °C}$ g/cm ³	$T = 23\text{ °C}$ g/cm ³	$T = 24\text{ °C}$ g/cm ³	$T = 25\text{ °C}$ g/cm ³
Water	0,998 2	0,998 0	0,997 8	0,997 5	0,997 3	0,997 0
Di-iodomethane	3,320 7	3,318 2	3,315 7	3,313 2	3,310 7	3,308 2
Ethylene glycol	1,113 2	1,112 6	1,111 9	1,111 2	1,110 5	1,109 8
Glycerol	1,261 3	1,260 6	1,259 9	1,259 3	1,258 6	1,258 0
Hexadecane	0,773 5	0,772 8	0,772 1	0,771 3	0,770 6	0,769 9
1-bromo-naphthalene	1,483 4	1,482 4	1,481 4	1,480 4	1,479 4	1,478 4
Benzyl alcohol	1,045 3	1,044 5	1,043 7	1,043 0	1,042 2	1,041 4
cis-Decalin	0,896 7	0,896 0	0,895 2	0,894 5	0,893 7	0,892 9
cis-/trans-Decalin	0,881 0	0,880 2	0,879 5	0,878 7	0,878 0	0,877 2

Annex B (normative)

Shape parameter, B , and Worthington number

B.1 Shape parameter

The shape parameter is defined in ISO 19403-1:2022, 3.2.3. It describes the contour of the drop and is a measure to detect if the drop is sufficiently deformed for the Young-Laplace evaluation.

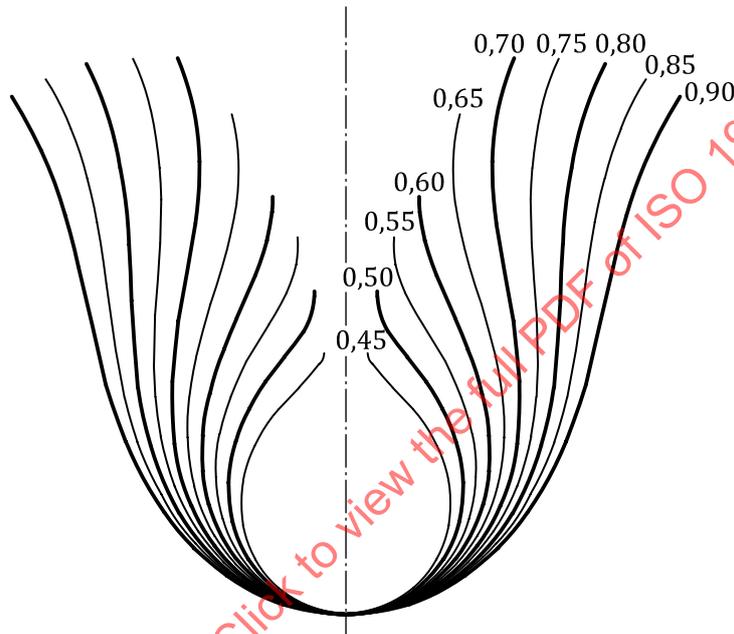


Figure B.1 — Theoretically calculated non-dimensional profiles of pendant drops

The x - and z -coordinates of the calculated drop contours in dependence of shape parameter, B , are illustrated in [Figure B.1](#). The numbers on the curves indicate the value of the shape parameter, B . The ideal drop contour exists for a B -parameter of $0,60 \pm 0,06$. Drops with B -values below 0,45 exhibit a shape which is too spherical. Drops with B -values above 0,75 exhibit a curvature which is too low.

If problems regarding compliance with the optimal B -parameter range occur, a needle with a different outside diameter shall be chosen so that B -values between 0,45 and 0,75 are achieved (see [5.2](#)).

B.2 Worthington number

The Worthington number^[13] accounts for the ratio of droplet volume to the critical droplet volume for the needle width. It is a non-dimensional number that scales the drop volume by the theoretical maximum drop volume that can be sustained for the system. The Worthington number scales from 0 to 1.

Annex C (informative)

Details of an interlaboratory test

C.1 General

An interlaboratory test was planned, conducted and evaluated according to ISO 5725-2.

Test liquids and different coating materials were used.

C.2 Test liquids

Twelve laboratories participated in the interlaboratory test.

The following three test liquids, which are recommended in ISO 19403-2, were used to obtain the precision data:

- water;
- di-iodomethane;
- ethylene glycol.

The determination was carried out in triplicate. The measured data were subjected to an outliers test in accordance with Grubbs and Cochran (see ISO 5725-2). Consequently, the data for water and ethylene glycol of one participant of the interlaboratory test were deleted. The precision results for test liquids are presented in [Table C.1](#) and [Figure C.1](#).

Table C.1 — Precision results for test liquids

		Water	Di-iodomethane	Ethylene glycol	Mean
Mean value	mN/m	72,2	50,7	47,9	
Standard deviation of repeatability, s_r	mN/m	0,32	0,26	0,16	0,24
Standard deviation of reproducibility, s_R	mN/m	0,68	0,33	0,58	0,53
Repeatability limit, r	mN/m	0,9	0,7	0,5	0,7
Reproducibility limit, R	mN/m	1,9	0,9	1,6	1,5