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International Standard ISO 787/24

INTERNATIONAL ORGANIZATION FOR STANDARDIZATION•МЕЖДУНАРОДНАЯ ОРГАНИЗАЦИЯ ПО СТАНДАРТИЗАЦИИ•ORGANISATION INTERNATIONALE DE NORMALISATION

General methods of test for pigments and extenders — Part 24 : Determination of relative tinting strength of coloured pigments and relative scattering power of white pigments — Photometric methods

Méthodes générales d'essai des pigments et matières de charge — Partie 24 : Détermination du pouvoir colorant relatif des pigments colorés et du pouvoir diffusant relatif des pigments blancs — Méthodes photométriques

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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.

Draft International Standards adopted by the technical committees are circulated to the member bodies for approval before their acceptance as International Standards by the ISO Council. They are approved in accordance with ISO procedures requiring at least 75 % approval by the member bodies voting.

International Standard ISO 787/24 was prepared by Technical Committee ISO/TC 35, *Paints and varnishes*.

This second edition cancels and replaces the first edition (ISO 787/24-1982), of which it constitutes a minor revision.

Users should note that all International Standards undergo revision from time to time and that any reference made herein to any other International Standard implies its latest edition, unless otherwise stated.

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The purpose of this International Standard is to establish a series of general test methods for pigments and extenders which are suitable for all or many of the individual pigments and extenders for which specifications might be required. In such cases, a cross-reference to the general method should be included in the International Standard relating to that pigment or extender, with a note of any detailed modification which might be needed in view of the special properties of the product in question.

Technical Committee ISO/TC 35, *Paints and varnishes*, decided that all the general methods should be published as they become available, as parts of a single International Standard, in order to emphasize the relationship of each to the whole series.

The Technical Committee also decided that, where two or more procedures were widely used for determining the same or a similar characteristic of a pigment or extender, there would be no objection to including more than one of them in the ISO series. In such cases it will, however, be essential to state clearly in a specification which method is to be used and, in the test report, which method has been used.

Parts of the series already published are as follows :

Part 1 : Comparison of colour of pigments
Part 2 : Determination of matter volatile at 105 °C
Part 3 : Determination of matter soluble in water — Hot extraction method
Part 4 : Determination of acidity or alkalinity of the aqueous extract
Part 5 : Determination of oil absorption value
Part 7 : Determination of residue on sieve — Water method — Manual procedure
Part 8 : Determination of matter soluble in water — Cold extraction method
Part 9 : Determination of pH value of an aqueous suspension
Part 10 : Determination of density — Pyknometer method
Part 11 : Determination of tamped volume and apparent density after tamping
Part 13 : Determination of water-soluble sulfates, chlorides and nitrates
Part 14 : Determination of resistivity of aqueous extract
Part 15 : Comparison of resistance to light of coloured pigments of similar types
Part 16 : Determination of relative tinting strength (or equivalent colouring value) and colour on reduction of coloured pigments — Visual comparison method
Part 17 : Comparison of lightening power of white pigments
Part 18 : Determination of residue on sieve — Water method — Mechanical flushing procedure
Part 19 : Determination of water-soluble nitrates — Salicylic acid method
Part 20 : Comparison of ease of dispersion — Oscillatory shaking method
Part 21 : Comparison of heat stability of pigments using a stoving medium
Part 22 : Comparison of resistance to bleeding of pigments
Part 23 : Determination of density (using a centrifuge to remove entrained air)
Part 24 : Determination of relative tinting strength of coloured pigments and relative scattering power of white pigments — Photometric methods

General methods of test for pigments and extenders — Part 24 : Determination of relative tinting strength of coloured pigments and relative scattering power of white pigments — Photometric methods

0 Introduction

This document is a part of ISO 787, *General methods of test for pigments and extenders.*

1 Scope and field of application

This part of ISO 787 describes photometric methods of test for comparing in the visible spectrum

a) the tinting strength of two similar (see note 1) coloured pigments dispersed in an alkyd resin without a drier;

b) the scattering power of two white pigments of the same type dispersed in an alkyd resin without a drier.

These methods of test provide an instrumental alternative to those described in ISO 787/16 and ISO 787/17 respectively, avoiding the necessity of visual matching.

NOTES

1 This International Standard is not appropriate for the comparison of coloured pigments that on reduction differ greatly in colour.

2 When one of these general methods is applicable to a given pigment, only a cross-reference to the appropriate method should be included in the International Standard relating to that pigment, indicating any detailed modification which may be needed in view of the special properties of the product in question. Only when the appropriate method in this part of ISO 787 is not applicable to a particular product should different photometric methods for determination of relative tinting strength and determination of relative scattering power be specified.

2 References

ISO 591, *Titanium dioxide pigments for paints.*

ISO 787, *General methods of test for pigments and extenders —*

Part 2 : Determination of matter volatile at 105 °C.

Part 9 : Determination of pH value of an aqueous suspension.

Part 10 : Determination of density — Pyknometer method.

Part 16 : Determination of relative tinting strength (or equivalent colouring value) and colour on reduction of coloured pigments — Visual comparison method.

Part 17 : Comparison of lightening power of white pigments.

Part 23 : Determination of density (using a centrifuge to remove entrained air).

ISO 842, *Raw materials for paints and varnishes — Sampling.*

ISO 1524, *Paints and varnishes — Determination of fineness of grind.*

ISO 3219, *Plastics — Polymers in the liquid, emulsified or dispersed state — Determination of viscosity with a rotational viscometer working at defined shear rate.*

ISO 3262, *Extenders for paints.*

ISO 3682, *Binders for paints and varnishes — Determination of acid value — Titrimetric method.*

ISO 4629, *Binders for paints and varnishes — Determination of hydroxyl value — Titrimetric method.* [1]

ISO 4652, *Rubber compounding ingredients — Carbon black — Determination of specific surface area — Nitrogen adsorption methods.*

ISO 6209, *Rubber compounding ingredients — Carbon black — Determination of solvent extractable material.*

1) In course of preparation. (Revision of ISO 4629-1978.)

3 Definitions

3.1 For coloured and black pigments

3.1.1 tinting strength : The ability of a pigment (see the note) to absorb incident light, thereby having the power to colour or darken, for example, a white paint in which it is incorporated.

NOTE — Although the properties tested are strictly those of the pigmented binder, absorption and scattering by the binder are relatively small and it is assumed in this International Standard that the material under test is the dispersed pigment.

3.1.2 spectral absorption coefficient $K(\lambda)$: The fraction of the diffusely incident spectral radiant flux of wavelength λ that is absorbed in an elementary layer within a material, divided by the thickness of the layer (Kubelka-Munk analysis).

NOTE — $K(\lambda)$ is a measure of the tinting strength of coloured pigments in a material and is expressed in units of reciprocal film thickness.

3.1.3 absorbance index $K_p(\lambda)$: The spectral absorption coefficient of the pigmented binder divided by the pigment concentration C_m :

$$K_p(\lambda) = \frac{K(\lambda)}{C_m} \qquad \ldots (1)$$

where C_m is the pigment concentration, for example, expressed as the ratio by mass of pigment to binder.

3.1.4 relative tinting strength $K_r(\lambda)$: The ratio of the absorbance index of the test sample $K_{p1}(\lambda)$ to that of an agreed reference pigment $K_{p2}(\lambda)$, expressed as a percentage :

$$K_r(\lambda) = \frac{K_{p1}(\lambda)}{K_{p2}(\lambda)} \times 100 \qquad \ldots (2)$$

3.2 For white pigments

3.2.1 scattering power : The ability of a pigment (see the note to 3.1.1) to diffuse incident light, thereby having the power to confer opacity and lightness to, for example, a paint in which it is incorporated.

3.2.2 spectral scattering coefficient $S(\lambda)$: The net transfer of spectral radiant flux of wavelength λ in the outward direction from an elementary layer within a body of material illuminated from outside, divided by the product of the thickness of the layer and the difference between the magnitude of the flux in the two directions through the layer (Kubelka-Munk analysis).

NOTE — $S(\lambda)$ is a measure of the scattering power of white pigments in a material and is expressed in units of reciprocal film thickness.

3.2.3 scattering index $S_p(\lambda)$: The spectral scattering coefficient of the pigmented binder divided by the pigment concentration C_m (see 3.1.3) :

$$S_p(\lambda) = \frac{S(\lambda)}{C_m} \qquad \ldots (3)$$

3.2.4 relative scattering power $S_r(\lambda)$: The ratio of the scattering index of the test sample $S_{p3}(\lambda)$ to that of an agreed reference pigment $S_{p4}(\lambda)$, expressed as a percentage :

$$S_r(\lambda) = \frac{S_{p3}(\lambda)}{S_{p4}(\lambda)} \times 100 \qquad \ldots (4)$$

3.3 reflectivity ϱ_∞ : The reflectance of a paste or a paint film of such thickness that further increase in thickness gives no further change in reflectance.

The reflectivity ϱ^*_∞, corrected according to equation (10), is related to K/S by the equation

$$\frac{K}{S} = \frac{(1 - \varrho^*_\infty)^2}{2\,\varrho^*_\infty} \qquad \ldots (5)$$

Values of K/S as a function of 100 ϱ_∞ or 100 R_∞ are given in annex B.

NOTES

1 Kubelka-Munk analysis is strictly applicable only to monochromatic radiation, as indicated in equations (1) to (4). In practice, however, correct results are often also obtained if the mean value for wider wavebands is taken, as is the case when filters are used. Hence, in the subsequent equations the symbol λ is omitted.

2 In a dispersion containing a coloured or black pigment and a white pigment, K is assumed to be characteristic of the coloured or black pigment and S of the white pigment.

3.4 reflectance factor R_∞ : The ratio of the radiant flux reflected in the directions within a given cone by a paste or a paint film to that reflected in the same directions by a perfect reflecting diffuser identically irradiated, when the thickness of the paste or the paint film is such that further increase in thickness gives no further change in the ratio.

4 Principle

4.1 Coloured and black pigments

Equal masses of a coloured pigment p_1 and of an agreed reference pigment p_2 are separately dispersed in the same mass of the same white pigment paste. The reflectivity ϱ_∞ or the reflectance factor R_∞ of each dispersion is measured photometrically at a wavelength giving a minimum value of ϱ_∞ or R_∞. From the corresponding values of K/S, the relative tinting strength, K_r, of the test pigment is given by the equation

$$K_r = \frac{(K_{p1}/S)}{(K_{p2}/S)} \times 100 = \frac{K_{p1}}{K_{p2}} \times 100 \qquad \ldots (6)$$

where

K_{p1}/S is the K/S value corresponding to ϱ_∞ or R_∞ of the test pigment;

K_{p2}/S is the K/S value corresponding to ϱ_∞ or R_∞ of the agreed reference pigment.

4.2 White pigments

Equal masses of a white test pigment p_3 and of an agreed reference pigment p_4 are separately dispersed in the same mass of the same black pigment paste. The reflectivity ϱ_∞ or the reflectance factor R_∞ of each dispersion is measured photometrically at 550 nm or using a Y-filter. From the corresponding values of K/S, the relative scattering power, S_r, of the test pigment, is given by the equation

$$S_r = \frac{(K/S_{p4})}{(K/S_{p3})} \times 100 = \frac{S_{p3}}{S_{p4}} \times 100 \qquad \ldots (7)$$

where

K/S_{p3} is the K/S value corresponding to ϱ_∞ or R_∞ of the test pigment;

K/S_{p4} is the K/S value corresponding to ϱ_∞ or R_∞ of the agreed reference pigment.

5 Materials and equipment

5.1 White pigment paste, with the following composition

- 40 parts by mass of titanium dioxide, Grade R2, complying with the requirements of ISO 591;
- 56 parts by mass of alkyd resin (see note 3 to 5.2);
- 4 parts by mass of calcium stearate.

Using a spatula, mix well so as to achieve preliminary wetting of the solids.

Then grind on the triple-roll mill (6.1) until the particle size is less than 5 µm when tested on a fineness-of-grind gauge (see ISO 1524). Store the paste in an airtight container, preferably a collapsible tube with a screw cap.

5.2 Black pigment paste (see note 1), prepared as follows.

5.2.1 Mix 18,7 parts by mass of carbon black pigment (see note 2) with 81,3 parts by mass of alkyd resin (see note 3) by use of a spatula. Pass the mixture six times through the triple-roll mill (6.1) to achieve a uniform fine dispersion.

5.2.2 Mix 3,25 g of the intermediate paste prepared as described in 5.2.1 with 91,64 g of alkyd resin (see note 3) and 5,11 g of fumed silica (see note 4); pass the mixture once through the triple-roll mill.

NOTES

1 The black pigment paste is available commercially. The mixture specified in 5.2.2 is suitable for testing at a pigment volume concentration of 17 %.

2 Carbon black pigment of the lampblack type complying with the following requirements :

		Test method
nigrometer index value	102	
volatile matter content	about 1 %	ISO 787/2
toluene extractable matter	0,15 % max.	ISO 6209
specific surface area (BET)	20 m^2/g	ISO 4652
pH value	7	ISO 787/9

3 Alkyd resin, based on a mixture of 63 % (*m/m*) linseed oil and 23 % (*m/m*) phthalic anhydride, and complying with the following requirements :

		Test method
acid value	15 mg KOH/g max.	ISO 3682
viscosity (solvent free)	7 to 10 Pa·s	ISO 3219
hydroxyl content	about 40 mg KOH/g	ISO 4629

This alkyd resin is commercially available.

4 Fumed silica complying with the following requirements :

		Test method
specific surface area (BET)	175 to 225 m^2/g	
pH value of a 4 % dispersion in water	3,6 to 4,5	ISO 787/9

6 Apparatus

6.1 Triple-roll mill.

6.2 Automatic muller, with ground glass plates, preferably water cooled (see the note), of diameter 180 to 250 mm to which a variable but known force of up to about 1 kN may be applied. The driven glass plate should have a speed of rotation of between 70 and 120 r/min and the apparatus should have an arrangement for pre-setting the number of revolutions in multiples of 25.

Pre-condition new muller plates by milling a pigment in a suitable binder (system) for 1 000 revolutions with a load applied to the plates. Remove the paste and discard.

Before use, check the surface of both plates for freedom from score marks, freedom from polished areas and for an even opaque appearance.

NOTE — If the automatic muller does not have water-cooled plates, take care that the temperature during the grinding operation does not rise by more than 10 °C.

6.3 Paste film holders, for example a suitable dish, for each test dispersion to support a paste film of about 250 µm thickness; it may have a spacing ring.

NOTE — Alternatives are to prepare a drawdown that is sufficiently thick to be completely opaque and to cover this with a template so that an area corresponding to the sample port of the photometer is exposed, or to prepare an opaque drawdown on a glass plate and measure through the glass.

6.4 Spectrophotometer capable of measuring at wavelengths between 400 and 700 nm or a **tristimulus colorimeter** with illuminant D_{65}.

If a tristimulus colorimeter is used, appropriate filters are required for the coloured pigments under test, and a CIE Y-filter for the testing of white pigments.

NOTE — For certain purposes, it is sometimes informative to compare the scattering power of white pigments at other wavelengths; by agreement between the interested parties the tristimulus values X or Z or the spectral reflectance or the reflectance factor at an agreed wavelength may be measured and used for the calculation of the relative scattering power.

7 Sampling

Take a representative sample of the product to be tested as described in ISO 842.

8 Procedure

8.1 Determination of relative tinting strength

8.1.1 Test pigment dispersion

Weigh 3 ± 0,01 g of the white pigment paste (5.1) and 0,12 g of the test sample. Place the white pigment paste in the centre of the lower plate of the automatic muller (6.2). Sprinkle the test sample on to the white pigment paste and mix together, using the minimum of effort with the aid of a spatula. Distribute the paste at several points at a distance of about 35 mm from the centre of the lower plate or spread within a ring with an internal diameter of 40 mm and an external diameter of 100 mm (see note 1).

Clean the spatula as much as possible by wiping it on the upper plate of the muller.

Close the plates of the muller and grind the mixture in four stages of 25 revolutions under a force of 1,0 ± 0,2 kN (see note 2). After each stage, collect the paste with the spatula from both plates and spread it as described above on the lower plate, wiping the spatula on the upper plate as before.

NOTES

1 It is advisable to lay a paper ring of the requisite shape as a pattern beneath the glass plate.

2 A different grinding force may be applied by agreement between the interested parties, but should be stated in the test report.

8.1.2 Reference pigment dispersion

With the agreed reference pigment, repeat the dispersion procedure described in 8.1.1, using the same mass of the agreed reference pigment and the same mass of white pigment paste (5.1).

NOTE — A different mass of the coloured pigment or another method of dispersion (for example see ISO 787/16 clause 8) may be used by agreement between the interested parties, but should be stated in the test report.

8.1.3 Preparation of test films

Place the test pigment dispersion (8.1.1) and the reference pigment dispersion (8.1.2) in the paste film holders (6.3), ensuring that the exposed surface is uniform and level.

8.1.4 Measurement of ϱ_∞ or R_∞

Measure ϱ_∞ or R_∞ of each film with the photometer (see 6.4). Both measuring geometries including and excluding gloss are suitable.

If a spectrophotometer is used, vary the wavelength of light entering the photometer between 400 and 700 nm until a minimum value of ϱ_∞ or R_∞ is obtained (at the wavelength of maximum absorption) and record the value of ϱ_∞ or R_∞ at that wavelength for each film.

If a tristimulus colorimeter is used, select a filter that restricts the measurements to wavelengths close to that of maximum absorption. Note the reading given by the colorimeter and divide it by 100 to obtain the value of ϱ_∞ or R_∞.

8.2 Determination of relative scattering power

NOTE — According to the procedure described in 8.2.1 to 8.2.4 a pigment volume concentration of 17 % is chosen. This concentration is preferred because in practice the white pigment volume concentration of many air-drying paints is between 15 and 20 %.

8.2.1 Test pigment dispersion

Take a quantity of the white test sample, such that

$$m = 0{,}478\,\varrho_m \qquad \ldots (8)$$

where

m is the mass, in grams, of the white pigment sample;

ϱ_m is the density, in grams per millilitre, of the white pigment sample, determined according to ISO 787/10 or ISO 787/23;

0,478 is a conversion factor, expressed in millilitres.

NOTE — The value of this factor is chosen to give a pigment volume concentration (p.v.c.) of 17 % with titanium dioxide pigments.

Weigh 2,5 ± 0,01 g of the black pigment paste (5.2) and the calculated mass of the test sample. Place the black pigment paste in the centre of the lower plate of the automatic muller (6.2). Sprinkle the test sample on to the black pigment paste and mix together, using the minimum of effort with the aid of a spatula. Distribute the paste at several points at a distance of about 35 mm from the centre of the lower plate or spread within a ring with an internal diameter of 40 mm and on an external diameter of 100 mm (see note 1).

Clean the spatula as much as possible by wiping it on the upper plate of the muller.

Close the plates of the muller and grind the mixture in four stages of 25 revolutions under a force of 1,0 ± 0,2 kN (see note 2). After each stage, collect the paste with the spatula from both plates and spread it as described above on the lower plate, wiping the spatula on the upper plate as before.

NOTES

1 It is advisable to lay a paper ring of requisite shape as a pattern beneath the glass plate.

2 A different grinding force may be applied by agreement between the interested parties, but should be stated in the test report.

8.2.2 Reference pigment dispersion

With the agreed reference white pigment, repeat the dispersion procedure described in 8.2.1, using the same mass m of the agreed reference white pigment as in 8.2.1 calculated for the white pigment under test, and the same mass of black pigment paste (5.2).

8.2.3 Preparation of test films

Place the test pigment dispersion (8.2.1) and the reference pigment dispersion (8.2.2) in the paste film holders (6.3), ensuring that the exposed surface is uniform and level.

8.2.4 Measurement of ϱ_∞ or R_∞

Measure ϱ_∞ or R_∞ of each film either with a spectrophotometer using a wavelength of 550 nm or with a tristimulus colorimeter using a Y-filter. Both measuring geometries including and excluding gloss are suitable.

If a tristimulus colorimeter is used, note the reading and divide it by 100 to obtain the value of ϱ_∞ or R_∞.

9 Expression of results

From the measured values of ϱ_∞ or R_∞, obtain the corresponding values of K/S as given in annex B. If the measured value of ϱ_∞ or R_∞ includes gloss, subtract 0,04 before using the table in annex B. Calculate the relative tinting strength or the relative scattering power of the test sample from equation (6) or equation (7) respectively, expressed as a percentage of that of the agreed reference pigment. (See 4.1 or 4.2.)

10 Test report

The test report shall contain at least the following information :

For all pigments

a) the type and identification of the product tested and of the agreed reference pigment;

b) a reference to this International Standard (ISO 787/24);

c) the measuring geometry (including or excluding gloss — see 8.1.4 and 8.2.4);

d) the number of revolutions of the muller if different from 100 and the grinding force if different from 1 kN (see 8.1.1 and 8.2.1);

e) any deviation, by agreement or otherwise, from the test method described;

f) the date of the test.

For coloured and black pigments only

g) the relative tinting strength as calculated.

For white pigments only

h) the density values used for the calculation of the mass of pigments in the dispersions;

j) the relative scattering power as calculated.

Annex A

Reflectivity and absorption and scattering coefficients

(This annex forms an integral part of the standard.)

The ratio of the spectral absorption coefficient K to the spectral scattering coefficient S of a pigment system is related to the internal reflectivity ϱ^*_∞ according to the Kubelka-Munk equation (9) :

$$\frac{K}{S} = \frac{(1 - \varrho^*_\infty)^2}{\varrho^*_\infty} \qquad \ldots (9)$$

where ϱ^*_∞ is the reflectivity in the interior of the pigment system needed for the Kubelka-Munk analysis. ϱ^*_∞ is calculated from the Saunderson formula according to equation (10) :

$$\varrho^*_\infty = \frac{\varrho_\infty}{0{,}96 - 0{,}6\,(0{,}96 - \varrho_\infty)} = \frac{\varrho_\infty}{0{,}6\,\varrho_\infty + 0{,}384} \qquad \ldots (10)$$

NOTE — In this equation, ϱ_∞ may be replaced by R_∞.

Equation (10) and the table in annex B are valid if ϱ_∞ or R_∞ is measured when the effect of the gloss of a high gloss sample is excluded. In all other cases (any surface, ϱ_∞ or R_∞ measured including gloss) subtract 0,04 from ϱ_∞ or R_∞ as the surface reflection.

The constants of in equation (10) depend on the refractive index of the medium. The constants given are valid for a refractive index of 1,5 and have been found to be satisfactory for most practical situations likely to be encountered when using this method.

Annex B

K/S values as a function of measured ϱ_∞ or R_∞

(This annex forms an integral part of the standard.)

NOTE — The table is valid if ϱ_∞ or R_∞ is measured when excluding the gloss of a high gloss sample, see annex A.

100 ϱ_∞ or 100 R_∞	K/S	100 ϱ_∞ or 100 R_∞	K/S	100 ϱ_∞ or 100 R_∞	K/S	100 ϱ_∞ or 100 R_∞	K/S
		5,5	2,856 858	11,0	1,167 677	16,5	0,634 444
0,1	191,301 468	5,6	2,795 623	11,1	1,152 900	16,6	0,628 256
0,2	95,302 643	5,7	2,736 571	11,2	1,138 399	16,7	0,622 150
0,3	63,303 925	5,8	2,679 591	11,3	1,124 170	16,8	0,616 125
0,4	47,305 222	5,9	2,624 577	11,4	1,110 206	16,9	0,610 178
0,5	37,706 482	6,0	2,571 429	11,5	1,096 498	17,0	0,604 309
0,6	31,307 755	6,1	2,520 057	11,6	1,083 038	17,1	0,598 516
0,7	26,737 595	6,2	2,470 374	11,7	1,069 823	17,2	0,592 798
0,8	23,310 287	6,3	2,422 301	11,8	1,056 846	17,3	0,587 154
0,9	20,644 882	6,4	2,375 760	11,9	1,044 100	17,4	0,581 581
1,0	18,512 817	6,5	2,330 679	12,0	1,031 580	17,5	0,576 080
1,1	16,768 631	6,6	2,286 995	12,1	1,019 278	17,6	0,570 648
1,2	15,315 344	6,7	2,244 645	12,2	1,007 192	17,7	0,565 285
1,3	14,085 828	6,8	2,203 569	12,3	0,995 314	17,8	0,559 988
1,4	13,032 135	6,9	2,163 712	12,4	0,983 641	17,9	0,554 759
1,5	12,119 089	7,0	2,125 018	12,5	0,972 166	18,0	0,549 594
1,6	11,320 328	7,1	2,087 443	12,6	0,960 885	18,1	0,544 493
1,7	10,615 692	7,2	2,050 938	12,7	0,949 795	18,2	0,539 455
1,8	9,989 471	7,3	2,015 459	12,8	0,938 890	18,3	0,534 478
1,9	9,429 295	7,4	1,980 965	12,9	0,928 165	18,4	0,529 563
2,0	8,925 260	7,5	1,947 412	13,0	0,917 616	18,5	0,524 707
2,1	8,469 336	7,6	1,914 772	13,1	0,907 240	18,6	0,519 910
2,2	8,054 968	7,7	1,883 001	13,2	0,897 033	18,7	0,515 170
2,3	7,676 740	7,8	1,852 069	13,3	0,886 990	18,8	0,510 488
2,4	7,330 125	7,9	1,821 942	13,4	0,877 109	18,9	0,505 861
2,5	7,011 335	8,0	1,792 594	13,5	0,867 384	19,0	0,501 289
2,6	6,717 152	8,1	1,763 991	13,6	0,857 813	19,1	0,496 772
2,7	6,444 851	8,2	1,736 110	13,7	0,848 393	19,2	0,492 308
2,8	6,192 079	8,3	1,708 921	13,8	0,839 120	19,3	0,487 896
2,9	5,956 818	8,4	1,682 400	13,9	0,829 990	19,4	0,483 536
3,0	5,737 318	8,5	1,656 526	14,0	0,821 002	19,5	0,479 226
3,1	5,532 049	8,6	1,631 273	14,1	0,812 151	19,6	0,474 967
3,2	5,339 687	8,7	1,606 623	14,2	0,803 435	19,7	0,470 756
3,3	5,159 047	8,8	1,582 551	14,3	0,794 850	19,8	0,466 595
3,4	4,989 097	8,9	1,558 041	14,4	0,786 395	19,9	0,462 480
3,5	4,828 927	9,0	1,536 074	14,5	0,778 066	20,0	0,458 413
3,6	4,677 715	9,1	1,513 630	14,6	0,769 861	20,1	0,454 392
3,7	4,534 738	9,2	1,491 693	14,7	0,761 777	20,2	0,450 416
3,8	4,399 342	9,3	1,470 246	14,8	0,753 812	20,3	0,446 485
3,9	4,270 945	9,4	1,449 275	14,9	0,745 963	20,4	0,442 598
4,0	4,149 022	9,5	1,428 763	15,0	0,738 228	20,5	0,438 755
4,1	4,033 100	9,6	1,408 697	15,1	0,730 605	20,6	0,434 955
4,2	3,922 750	9,7	1,389 061	15,2	0,723 091	20,7	0,431 197
4,3	3,817 581	9,8	1,369 843	15,3	0,715 684	20,8	0,427 480
4,4	3,717 244	9,9	1,351 032	15,4	0,708 382	20,9	0,423 804
4,5	3,621 411	10,0	1,332 613	15,5	0,701 184	21,0	0,420 168
4,6	3,529 794	10,1	1,314 576	15,6	0,694 086	21,1	0,416 573
4,7	3,442 120	10,2	1,296 908	15,7	0,687 088	21,2	0,413 016
4,8	3,358 141	10,3	1,279 601	15,8	0,680 186	21,3	0,409 498
4,9	3,277 634	10,4	1,262 642	15,9	0,673 380	21,4	0,406 018
5,0	3,200 388	10,5	1,246 021	16,0	0,666 667	21,5	0,402 575
5,1	3,126 211	10,6	1,229 731	16,1	0,660 046	21,6	0,399 170
5,2	3,054 929	10,7	1,213 759	16,2	0,653 515	21,7	0,395 800
5,3	2,986 375	10,8	1,198 099	16,3	0,647 072	21,8	0,392 467
5,4	2,920 398	10,9	1,182 741	16,4	0,640 715	21,9	0,389 169

100 ϱ_∞ or 100 R_∞	K/S	100 ϱ_∞ or 100 R_∞	K/S	100 ϱ_∞ or 100 R_∞	K/S	100 ϱ_∞ or 100 R_∞	K/S
22,0	0,385 906	28,0	0,239 338	34,0	0,153 822	40,0	0,100 513
22,1	0,382 677	28,1	0,237 527	34,1	0,152 720	40,1	0,099 808
22,2	0,379 482	28,2	0,235 732	34,2	0,151 628	40,2	0,099 109
22,3	0,376 321	28,3	0,233 953	34,3	0,150 543	40,3	0,098 415
22,4	0,373 192	28,4	0,232 189	34,4	0,149 468	40,4	0,097 725
22,5	0,370 097	28,5	0,230 441	34,5	0,148 400	40,5	0,097 041
22,6	0,367 033	28,6	0,228 708	34,6	0,147 341	40,6	0,096 361
22,7	0,364 000	28,7	0,226 990	34,7	0,146 290	40,7	0,095 686
22,8	0,360 999	28,8	0,225 288	34,8	0,145 246	40,8	0,095 016
22,9	0,358 029	28,9	0,223 599	34,9	0,144 211	40,9	0,094 350
23,0	0,355 089	29,0	0,221 926	35,0	0,143 184	41,0	0,093 690
23,1	0,352 179	29,1	0,220 267	35,1	0,142 165	41,1	0,093 033
23,2	0,349 299	29,2	0,218 622	35,2	0,141 154	41,2	0,092 382
23,3	0,346 448	29,3	0,216 991	35,3	0,140 150	41,3	0,091 735
23,4	0,343 625	29,4	0,215 374	35,4	0,139 154	41,4	0,091 093
23,5	0,340 831	29,5	0,213 771	35,5	0,138 165	41,5	0,090 455
23,6	0,338 065	29,6	0,212 182	35,6	0,137 184	41,6	0,089 821
23,7	0,335 326	29,7	0,210 606	35,7	0,136 210	41,7	0,089 192
23,8	0,332 615	29,8	0,209 043	35,8	0,135 244	41,8	0,088 568
23,9	0,329 931	29,9	0,207 494	35,9	0,134 285	41,9	0,087 948
24,0	0,327 273	30,0	0,205 958	36,0	0,133 334	42,0	0,087 332
24,1	0,324 641	30,1	0,204 434	36,1	0,132 389	42,1	0,086 720
24,2	0,322 036	30,2	0,202 924	36,2	0,131 451	42,2	0,086 113
24,3	0,319 455	30,3	0,201 426	36,3	0,130 521	42,3	0,085 509
24,4	0,316 901	30,4	0,199 941	36,4	0,129 597	42,4	0,084 910
24,5	0,314 370	30,5	0,198 468	36,5	0,128 681	42,5	0,084 316
24,6	0,311 865	30,6	0,197 007	36,6	0,127 771	42,6	0,083 725
24,7	0,309 384	30,7	0,195 559	36,7	0,126 868	42,7	0,083 138
24,8	0,306 926	30,8	0,194 122	36,8	0,125 972	42,8	0,082 556
24,9	0,304 493	30,9	0,192 698	36,9	0,125 082	42,9	0,081 977
25,0	0,302 082	31,0	0,191 285	37,0	0,124 200	43,0	0,081 403
25,1	0,299 695	31,1	0,189 884	37,1	0,123 323	43,1	0,080 832
25,2	0,297 331	31,2	0,188 494	37,2	0,122 453	43,2	0,080 265
25,3	0,294 989	31,3	0,187 116	37,3	0,121 590	43,3	0,079 703
25,4	0,292 669	31,4	0,185 749	37,4	0,120 733	43,4	0,079 144
25,5	0,290 371	31,5	0,184 393	37,5	0,119 882	43,5	0,078 589
25,6	0,288 095	31,6	0,183 048	37,6	0,119 037	43,6	0,078 037
25,7	0,285 841	31,7	0,181 715	37,7	0,118 199	43,7	0,077 490
25,8	0,283 607	31,8	0,180 392	37,8	0,117 367	43,8	0,076 946
25,9	0,281 394	31,9	0,179 079	37,9	0,116 541	43,9	0,076 406
26,0	0,279 202	32,0	0,177 778	38,0	0,115 721	44,0	0,075 870
26,1	0,277 031	32,1	0,176 487	38,1	0,114 907	44,1	0,075 337
26,2	0,274 879	32,2	0,175 206	38,2	0,114 099	44,2	0,074 808
26,3	0,272 748	32,3	0,173 936	38,3	0,113 296	44,3	0,074 283
26,4	0,270 636	32,4	0,172 676	38,4	0,112 500	44,4	0,073 761
26,5	0,268 543	32,5	0,171 426	38,5	0,111 709	44,5	0,073 242
26,6	0,266 470	32,6	0,170 186	38,6	0,110 925	44,6	0,072 728
26,7	0,264 415	32,7	0,168 955	38,7	0,110 146	44,7	0,072 217
26,8	0,262 380	32,8	0,167 735	38,8	0,109 372	44,8	0,071 709
26,9	0,260 363	32,9	0,166 524	38,9	0,108 604	44,9	0,071 204
27,0	0,258 364	33,0	0,165 323	39,0	0,107 842	45,0	0,070 703
27,1	0,256 383	33,1	0,164 132	39,1	0,107 085	45,1	0,070 206
27,2	0,254 420	33,2	0,162 950	39,2	0,106 333	45,2	0,069 712
27,3	0,252 475	33,3	0,161 777	39,3	0,105 587	45,3	0,069 221
27,4	0,250 548	33,4	0,160 614	39,4	0,104 847	45,4	0,068 733
27,5	0,248 637	33,5	0,159 459	39,5	0,104 111	45,5	0,068 249
27,6	0,246 744	33,6	0,158 314	39,6	0,103 381	45,6	0,067 768
27,7	0,244 868	33,7	0,157 178	39,7	0,102 657	45,7	0,067 290
27,8	0,243 008	33,8	0,156 050	39,8	0,101 937	45,8	0,066 816
27,9	0,241 165	33,9	0,154 931	39,9	0,101 222	45,9	0,066 344

100 ϱ_∞ or 100 R_∞	K/S	100 ϱ_∞ or 100 R_∞	K/S	100 ϱ_∞ or 100 R_∞	K/S	100 ϱ_∞ or 100 R_∞	K/S
46,0	0,065 876	52,0	0,042 794	58,0	0,027 209	64,0	0,016 667
46,1	0,065 411	52,1	0,042 481	58,1	0,026 998	64,1	0,016 524
46,2	0,064 949	52,2	0,042 171	58,2	0,026 787	64,2	0,016 382
46,3	0,064 490	52,3	0,041 862	58,3	0,026 578	64,3	0,016 241
46,4	0,064 035	52,4	0,041 555	58,4	0,026 371	64,4	0,016 101
46,5	0,063 582	52,5	0,041 251	58,5	0,026 164	64,5	0,015 962
46,6	0,063 132	52,6	0,040 948	58,6	0,025 959	64,6	0,015 824
46,7	0,062 686	52,7	0,040 647	58,7	0,025 756	64,7	0,015 687
46,8	0,062 242	52,8	0,040 349	58,8	0,025 553	64,8	0,015 551
46,9	0,061 801	52,9	0,040 052	58,9	0,025 352	64,9	0,015 416
47,0	0,061 363	53,0	0,039 757	59,0	0,025 153	65,0	0,015 281
47,1	0,060 929	53,1	0,039 464	59,1	0,024 954	65,1	0,015 148
47,2	0,060 497	53,2	0,039 173	59,2	0,024 757	65,2	0,015 015
47,3	0,060 068	53,3	0,038 884	59,3	0,024 561	65,3	0,014 883
47,4	0,059 641	53,4	0,038 597	59,4	0,024 367	65,4	0,014 753
47,5	0,059 218	53,5	0,038 311	59,5	0,024 174	65,5	0,014 623
47,6	0,058 797	53,6	0,038 028	59,6	0,023 982	65,6	0,014 494
47,7	0,058 380	53,7	0,037 746	59,7	0,023 791	65,7	0,014 365
47,8	0,057 965	53,8	0,037 466	59,8	0,023 601	65,8	0,014 238
47,9	0,057 552	53,9	0,037 188	59,9	0,023 413	65,9	0,014 112
48,0	0,057 143	54,0	0,036 912	60,0	0,023 226	66,0	0,013 986
48,1	0,056 736	54,1	0,036 637	60,1	0,023 040	66,1	0,013 861
48,2	0,056 332	54,2	0,036 364	60,2	0,022 855	66,2	0,013 737
48,3	0,055 931	54,3	0,036 093	60,3	0,022 672	66,3	0,013 614
48,4	0,055 532	54,4	0,035 824	60,4	0,022 490	66,4	0,013 492
48,5	0,055 136	54,5	0,035 557	60,5	0,022 309	66,5	0,013 371
48,6	0,054 742	54,6	0,035 291	60,6	0,022 129	66,6	0,013 250
48,7	0,054 351	54,7	0,035 027	60,7	0,021 950	66,7	0,013 130
48,8	0,053 963	54,8	0,034 765	60,8	0,021 772	66,8	0,013 011
48,9	0,053 577	54,9	0,034 504	60,9	0,021 596	66,9	0,012 893
49,0	0,053 194	55,0	0,034 245	61,0	0,021 421	67,0	0,012 776
49,1	0,052 813	55,1	0,033 988	61,1	0,021 247	67,1	0,012 659
49,2	0,052 435	55,2	0,033 732	61,2	0,021 074	67,2	0,012 544
49,3	0,052 059	55,3	0,033 478	61,3	0,020 902	67,3	0,012 429
49,4	0,051 686	55,4	0,033 226	61,4	0,020 731	67,4	0,012 314
49,5	0,051 315	55,5	0,032 975	61,5	0,020 562	67,5	0,012 201
49,6	0,050 947	55,6	0,032 726	61,6	0,020 393	67,6	0,012 089
49,7	0,050 581	55,7	0,032 479	61,7	0,020 226	67,7	0,011 977
49,8	0,050 217	55,8	0,032 233	61,8	0,020 060	67,8	0,011 866
49,9	0,049 856	55,9	0,031 989	61,9	0,019 894	67,9	0,011 755
50,0	0,049 497	56,0	0,031 746	62,0	0,019 730	68,0	0,011 646
50,1	0,049 141	56,1	0,031 505	62,1	0,019 567	68,1	0,011 537
50,2	0,048 787	56,2	0,031 265	62,2	0,019 405	68,2	0,011 429
50,3	0,048 435	56,3	0,031 027	62,3	0,019 245	68,3	0,011 322
50,4	0,048 085	56,4	0,030 791	62,4	0,019 085	68,4	0,011 215
50,5	0,047 738	56,5	0,030 556	62,5	0,018 926	68,5	0,011 110
50,6	0,047 393	56,6	0,030 323	62,6	0,018 768	68,6	0,011 005
50,7	0,047 050	56,7	0,030 091	62,7	0,018 612	68,7	0,010 900
50,8	0,046 710	56,8	0,029 860	62,8	0,018 456	68,8	0,010 797
50,9	0,046 372	56,9	0,029 632	62,9	0,018 301	68,9	0,010 694
51,0	0,046 036	57,0	0,029 404	63,0	0,018 148	69,0	0,010 592
51,1	0,045 702	57,1	0,029 178	63,1	0,017 995	69,1	0,010 490
51,2	0,045 370	57,2	0,028 954	63,2	0,017 844	69,2	0,010 390
51,3	0,045 041	57,3	0,028 731	63,3	0,017 693	69,3	0,010 290
51,4	0,044 714	57,4	0,028 509	63,4	0,017 543	69,4	0,010 190
51,5	0,044 388	57,5	0,028 289	63,5	0,017 395	69,5	0,010 092
51,6	0,044 065	57,6	0,028 070	63,6	0,017 247	69,6	0,009 994
51,7	0,043 744	57,7	0,027 853	63,7	0,017 101	69,7	0,009 897
51,8	0,043 426	57,8	0,027 637	63,8	0,016 955	69,8	0,009 800
51,9	0,043 109	57,9	0,027 422	63,9	0,016 810	69,9	0,009 704

$100\,\varrho_\infty$ or $100\,R_\infty$	K/S	$100\,\varrho_\infty$ or $100\,R_\infty$	K/S	$100\,\varrho_\infty$ or $100\,R_\infty$	K/S	$100\,\varrho_\infty$ or $100\,R_\infty$	K/S
70,0	0,009 609	76,0	0,005 013	82,0	0,002 183	88,0	0,000 638
70,1	0,009 515	76,1	0,004 952	82,1	0,002 148	88,1	0,000 621
70,2	0,009 421	76,2	0,004 893	82,2	0,002 113	88,2	0,000 604
70,3	0,009 328	76,3	0,004 834	82,3	0,002 078	88,3	0,000 588
70,4	0,009 235	76,4	0,004 775	82,4	0,002 044	88,4	0,000 572
70,5	0,009 143	76,5	0,004 717	82,5	0,002 011	88,5	0,000 556
70,6	0,009 052	76,6	0,004 659	82,6	0,001 977	88,6	0,000 540
70,7	0,008 962	76,7	0,004 602	82,7	0,001 944	88,7	0,000 525
70,8	0,008 872	76,8	0,004 545	82,8	0,001 911	88,8	0,000 509
70,9	0,008 783	76,9	0,004 489	82,9	0,001 879	88,9	0,000 494
71,0	0,008 694	77,0	0,004 433	83,0	0,001 847	89,0	0,000 480
71,1	0,008 606	77,1	0,004 378	83,1	0,001 815	89,1	0,000 465
71,2	0,008 519	77,2	0,004 323	83,2	0,001 784	89,2	0,000 451
71,3	0,008 432	77,3	0,004 269	83,3	0,001 753	89,3	0,000 437
71,4	0,008 346	77,4	0,004 215	83,4	0,001 722	89,4	0,000 424
71,5	0,008 261	77,5	0,004 161	83,5	0,001 692	89,5	0,000 410
71,6	0,008 176	77,6	0,004 108	83,6	0,001 661	89,6	0,000 397
71,7	0,008 092	77,7	0,004 056	83,7	0,001 632	89,7	0,000 384
71,8	0,008 008	77,8	0,004 003	83,8	0,001 602	89,8	0,000 371
71,9	0,007 925	77,9	0,003 952	83,9	0,001 573	89,9	0,000 359
72,0	0,007 843	78,0	0,003 900	84,0	0,001 544	90,0	0,000 346
72,1	0,007 761	78,1	0,003 849	84,1	0,001 516	90,1	0,000 334
72,2	0,007 680	78,2	0,003 799	84,2	0,001 488	90,2	0,000 322
72,3	0,007 600	78,3	0,003 749	84,3	0,001 460	90,3	0,000 311
72,4	0,007 520	78,4	0,003 699	84,4	0,001 432	90,4	0,000 300
72,5	0,007 441	78,5	0,003 650	84,5	0,001 405	90,5	0,000 288
72,6	0,007 362	78,6	0,003 602	84,6	0,001 378	90,6	0,000 278
72,7	0,007 284	78,7	0,003 553	84,7	0,001 352	90,7	0,000 267
72,8	0,007 206	78,8	0,003 505	84,8	0,001 325	90,8	0,000 257
72,9	0,007 129	78,9	0,003 458	84,9	0,001 300	90,9	0,000 246
73,0	0,007 053	79,0	0,003 411	85,0	0,001 274	91,0	0,000 236
73,1	0,006 977	79,1	0,003 364	85,1	0,001 248	91,1	0,000 227
73,2	0,006 902	79,2	0,003 318	85,2	0,001 223	91,2	0,000 217
73,3	0,006 827	79,3	0,003 272	85,3	0,001 199	91,3	0,000 208
73,4	0,006 753	79,4	0,003 227	85,4	0,001 174	91,4	0,000 199
73,5	0,006 679	79,5	0,003 182	85,5	0,001 150	91,5	0,000 190
73,6	0,006 606	79,6	0,003 137	85,6	0,001 126	91,6	0,000 181
73,7	0,006 534	79,7	0,003 093	85,7	0,001 103	91,7	0,000 173
73,8	0,006 462	79,8	0,003 049	85,8	0,001 079	91,8	0,000 164
73,9	0,006 390	79,9	0,003 006	85,9	0,001 056	91,9	0,000 156
74,0	0,006 319	80,0	0,002 963	86,0	0,001 034	92,0	0,000 149
74,1	0,006 249	80,1	0,002 920	86,1	0,001 011	92,1	0,000 141
74,2	0,006 179	80,2	0,002 878	86,2	0,000 989	92,2	0,000 134
74,3	0,006 110	80,3	0,002 836	86,3	0,000 967	92,3	0,000 127
74,4	0,006 041	80,4	0,002 795	86,4	0,000 946	92,4	0,000 120
74,5	0,005 973	80,5	0,002 754	86,5	0,000 924	92,5	0,000 113
74,6	0,005 906	80,6	0,002 713	86,6	0,000 903	92,6	0,000 106
74,7	0,005 838	80,7	0,002 673	86,7	0,000 883	92,7	0,000 100
74,8	0,005 772	80,8	0,002 633	86,8	0,000 862	92,8	0,000 094
74,9	0,005 706	80,9	0,002 593	86,9	0,000 842	92,9	0,000 088
75,0	0,005 640	81,0	0,002 554	87,0	0,000 822	93,0	0,000 082
75,1	0,005 575	81,1	0,002 515	87,1	0,000 802	93,1	0,000 077
75,2	0,005 511	81,2	0,002 477	87,2	0,000 783	93,2	0,000 071
75,3	0,005 447	81,3	0,002 439	87,3	0,000 764	93,3	0,000 066
75,4	0,005 383	81,4	0,002 401	87,4	0,000 745	93,4	0,000 061
75,5	0,005 320	81,5	0,002 364	87,5	0,000 727	93,5	0,000 057
75,6	0,005 258	81,6	0,002 327	87,6	0,000 708	93,6	0,000 052
75,7	0,005 196	81,7	0,002 290	87,7	0,000 690	93,7	0,000 048
75,8	0,005 134	81,8	0,002 254	87,8	0,000 673	93,8	0,000 044
75,9	0,005 073	81,9	0,002 218	87,9	0,000 655	93,9	0,000 040

100 ϱ_∞ or 100 R_∞	K/S
94,0	0,000 036
94,1	0,000 032
94,2	0,000 029
94,3	0,000 026
94,4	0,000 023
94,5	0,000 020
94,6	0,000 017
94,7	0,000 015
94,8	0,000 013
94,9	0,000 011
95,0	0,000 009
95,1	0,000 007
95,2	0,000 006
95,3	0,000 004
95,4	0,000 003
95,5	0,000 002
95,6	0,000 001
95,7	0,000 001
95,8	0,000 000