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Optics and optical instruments — Test lenses for calibration of focimeters —

Part 2:
Test lenses for focimeters used for measuring contact lenses

Optique et instruments optiques — Verres étalons pour l'étalonnage des frontofocomètres —

Partie 2: Verres étalons pour frontofocomètres pour le mesurage des lentilles de contact

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Foreword

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ISO 9342-2 was prepared by Technical Committee ISO/TC 172, *Optics and photonics*, Subcommittee SC 7, *Ophthalmic optics and instruments*.

ISO 9342 consists of the following parts, under the general title *Optics and optical instruments — Test lenses for calibration of focimeters*:

— *Part 1: Test lenses for focimeters used for measuring spectacle lenses*

— *Part 2: Test lenses for focimeters used for measuring contact lenses*

Optics and optical instruments — Test lenses for calibration of focimeters —

Part 2:
Test lenses for focimeters used for measuring contact lenses

1 Scope

This part of ISO 9342 specifies requirements for test lenses for focimeters that are used to measure contact lenses. These test lenses are used to find the precise correction values that are needed to convert the power values measured to back vertex power values, as defined in Clause 3.

This part of ISO 9342 applies to focimeters meeting the requirements of ISO 8598.

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 7944:1998, *Optics and optical instruments — Reference wavelengths*

ISO 8598:1996, *Optics and optical instruments — Focimeters*

3 Terms and definitions

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

3.1
back vertex power
F_{bv}
reciprocal of the paraxial value of the back vertex focal length, measured in metres

NOTE 1 The unit for expressing vertex power is the reciprocal metre (m^{-1}). The name for this unit is “dioptre”, and the symbol is D.

NOTE 2 Conventionally, the back vertex power is specified as the “power“ of a contact lens.

3.2
spherical test lenses
test lenses having spherical front and back surfaces so that their back vertex power may be expressed by a single value

3.3
reference wavelength
wavelengths specified in ISO 7944

NOTE For the purpose of this part of ISO 9342, the reference wavelength can be either the green mercury line (λ_e = 546,07 nm) or the yellow helium line (λ_d = 587,56 nm).

4 Design requirements and recommendations for test lenses

4.1 General

Test lenses should be made of homogeneous white crown glass selected to be free of bubbles and striae in an area of 4 mm radius surrounding the centre of the free aperture.

It is accepted that other materials can also be used provided their use result in lenses with a durability and optical reproducibility within the given tolerance over time and that can be manufactured to the same standard of uncertainty and form, as the glass lenses specified above.

Test lenses should have a protective mount that is designed so that, when the lens is correctly placed on the lens support, the focimeter is not obstructed.

4.2 Spherical test lens

For a complete set of spherical test lenses, the following set of nominal back vertex powers is recommended:

– 20 D, – 15 D, – 10 D, – 5 D, + 5 D, + 10 D, + 15 D, + 20 D.

Spherical test lenses should have a free aperture of at least 8 mm.

The curvature of the back surface shall approximately correspond to those of common contact lenses, which are in the range 7 mm to 9 mm, so that the spherical aberration of the test lenses approximates that exhibited by common contact lenses.

The nominal curvature of the back surface is recommended as 8 mm, a value meeting the requirement of ISO 18369-3, which is approximately equal to the front surface radius of cornea for the human eye. The radius tolerance for back surface curvature is ± 0,1 mm.

The centre thickness for a given back vertex power shall be chosen to be in the range given in Table 1.

These centre thickness value ranges are required to guarantee the durability of the test lenses during use. It is for this reason that they are generally greater than those for common contact lenses.

Table 1 — Design range for the standard test lenses

Nominal back vertex power, F_{bv} (m^{-1})	Range for centre thickness (mm)
− 20	0,5 to 1,5
− 15	0,5 to 1,5
− 10	0,5 to 1,5
− 5	0, 5 to 1,5
+ 5	1 to 2
+ 10	1 to 2
+ 15	1 to 2
+ 20	1 to 2

5 Tolerances for spherical test lenses

The design value of each lens shall be stated along with the reference wavelength used to determine this value. The permissible tolerances for all spherical test lenses shall be within ± 0,03 m^{-1} of their stated values.

NOTE In Annex A, an example is given for the proper design of test lenses that meets this requirement and the requirement of Table 1.

Annex A
(informative)

Manufacture of test lenses for calibration of focimeters used for measuring contact lenses

A.1 General

Spherical test lenses, which meet the tolerances given in 4.2 and Clause 5, can be manufactured by observing the specifications and procedure described in A.2 to A.8.

To manufacture test lenses in accordance with this annex, the manufacturer will need a selection of master test surfaces against which the test lens surfaces can be checked, using standard precision optical techniques.

A.2 Selection of glass

To manufacture spherical test lenses using this method, precision grade homogeneous optical glass shall be used.

The refractive index should be known to an accuracy of $\pm 5 \times 10^{-5}$.

A.3 The nominal back surface radius of curvature

The nominal radius of the back surface (i.e. the surface that is put on to the lens support of the focimeter) is $(8 \pm 0,1)$ mm.

A.4 Selection of the back surface radius

Using the nominal radius of the back surface in A.3, the master test surfaces radius should be selected closest to the desired value of A.3.

A.5 Calculation of lens thickness and selection of front surface radius

Using the selected value of the back surface radius, the desired back vertex power and a centre thickness, that is in the range specified by Table 1, the front surface radius of curvature, r_1, is calculated using the standard thick lens paraxial power formulae given in A.6. An explicit expression for r_1 is given by

$$r_1 = (n-1)\left[1/(F_{\text{bv}} - F_2) + t/n\right]$$

where

F_{bv} is the back vertex power of contact lens, in dioptres (m^{-1});

F_2 is the back surface power of the contact lens (the surface in contact with cornea), in dioptres (m^{-1}).

This radius value is then compared to the available master test surfaces and the master surface radius closest to the desired value is chosen as the front surface radius. Finally, the paraxial power formula is again used with the selected values of front and back radius and the known refractive index to calculate the centre lens thickness.

A.6 Calculation of back vertex power

The back vertex power, as defined in 3.1, is calculated using the known values front surface of the curvature radius, r_1, back surface radius, r_2, the central thickness, t, and the refractive index, n, of optical glass, using the formulae given below:

$$F_1 = (n-1)/r_1$$

$$F_2 = (1-n)/r_2$$

$$K = 1/(1-tF_1/n)$$

$$F_{bv} = KF_1 + F_2$$

where

F_1 is the front surface power of the contact lens (the surface in contact with air), in dioptres (m^{-1});

K is the vertex correction factor of the contact lens which vertex corrects the front surface power into the plane of the back surface.

Based on the precisely measured parameters of r_1, r_2, t and n, the back vertex powers of the lens are calculated using the above formulae. This value is assigned to the lens.

A.7 Production tolerances

Errors may exist in any or all of the four basic lens parameters (front surface radius, back surface radius, thickness and refractive index). If these errors are known, their effect on the total lens power can be directly calculated. However, there are always uncertainty errors associated with any measurement and these errors shall be accounted for. If the production tolerances given in Table A.1 are met, the test lenses will meet the permissible tolerance of Clause 5.

The radius values of the master test surface should be known to sufficient precision to ensure that the error they induce in the total power of the test lens is no more than 0,002 m^{-1} per surface.

NOTE If another thickness range, different to that given in Table 1 is being used, the production tolerance for thickness can be changed within a limited amount in order to ensure an expected nominal power value which has a good confidence level and which should not exclude the permissible tolerances of ± 0,03 m^{-1} given in Clause 5.

Table A.1 — Production tolerances

Nominal back vertex power m^{-1}	Centre thickness mm	Refractive index	Fit of lens surface to master test surface
− 20, − 15, − 10, − 5	± 0,005	$\pm 5 \times 10^{-5}$	1 interference ring at 10 mm diameter
+ 5, + 10	± 0,003		
+ 15, + 20	± 0,002		

A.8 Expanded uncertainty

A.8.1 General

The analysis for expanded uncertainties on the measurement of production tolerance for test lenses is as given in A.8.2, A.8.3 and A.8.4.

A.8.2 Components of uncertainty

A.8.2.1 The standard uncertainty, $u\,(r_1)$, of the radius of curvature of the front surface, r_1 (for the lens master ball and the interference rings), is the square root of the sum of the squares of:

a) the standard uncertainty, $u\,(r_{1a})$, for the diameter of lens master ball: $u\,(r_{1a})$, and

b) the standard uncertainty, $u\,(r_{1b})$, for the lens surface: $u\,(r_{1b})$.

If one interference ring at 10 mm diameter were obtained while fitting the lens surface to the master test surface, the relevant standard deviation in segment height, $u(h)$, would be 0,5 interference rings. This will in turn cause a relevant standard deviation, $u\,(r_{1b})$, in the radius of curvature of the surface as is found in the following manner.

From equation:

$$r = a^2/2h + h/2$$

the relevant standard deviation is found by the equation

$$u\left(r_{1b}\right) = \left[\left(1/2 - a^2/2h^2\right)^2 \times u^2\left(h\right)\right]^{1/2}$$

where a = 5 mm (half of the hypotenuse).

Then the standard uncertainty, $u\,(r_1)$, is given by:

$$u\left(r_1\right) = \left[u^2\left(r_{1a}\right) + u^2\left(r_{1b}\right)\right]^{1/2}$$

A.8.2.2 The standard uncertainty, $u\,(r_2)$, of the radius of curvature of the back surface, r_2 (for the lens master ball and one interference ring at 10 mm diameter), is the square root of the sum of the squares of:

a) the standard uncertainty, $u\,(r_{2a})$, for the diameter of lens master ball: $u\,(r_{2a})$, and

b) the standard uncertainty, $u\,(r_{2b})$, for the lens surface: $u\,(r_{2b})$.

The standard uncertainties, $u\,(r_{2a})$ and $u\,(r_{2b})$, are found using the method given in A.8.2.1 for $u\,(r_{1a})$ and $u\,(r_{1b})$.

A.8.2.3 The standard uncertainty, $u\,(t)$, of the central thickness, t.

A.8.2.4 The standard uncertainty, $u\,(n)$, of the refractive index of optical glass, n.

A.8.3 Combined standard uncertainty

Using the partial differential equation of the standard formula, the combined uncertainty from the four components of uncertainty are calculated to be:

$$u_1 = c_1 u(r_1)$$

$$u_2 = c_2 u(r_2)$$

$$u_3 = c_3 u(t)$$

$$u_4 = c_4 u(n)$$

where

$$c_1 = -K^2 F_1 / r_1$$

$$c_2 = -F_2 / r_2$$

$$c_3 = K^2 F_1^2 / n$$

$$c_4 = \left(KF_1 + F_2 + K^2 F_1^2 t / n^2\right) / (n - 1)$$

NOTE 1 $c_1 = \partial F_{bv} / \partial r_1$; $c_2 = \partial F_{bv} / \partial r_2$; $c_3 = \partial F_{bv} / \partial t$; $c_4 = \partial F_{bv} / \partial n$

NOTE 2 K is the vertex correction factor of the contact lens.

Then the combined standard uncertainty, u_c:

$$u_c = \left(u_1^2 + u_2^2 + u_3^2 + u_4^2\right)^{1/2}$$

A.8.4 Expanded uncertainty

The expanded uncertainty, U, is obtained by multiplying the combined standard uncertainty, u_c, by a coverage factor, k. If we take the coverage factor as 3, which will produce an interval having a level of confidence of approximately 99 %, then the expanded uncertainty is given by

$$U = 3u_c$$

A.9 Example for a test lens + 10,0 m^{-1}

A.9.1 Calculation of production data

Refractive index	n_e = 1,528 25
Nominal back surface radius	r_2' = 8 mm
Selection of the closest available master test surface	r_2 = 7,942 mm
Selection of centre thickness within the range of Table 1	t' = 1,3 mm

Calculation of the front surface radius $r_1' = 7{,}353$ mm

Selection of the closest available master test surface $r_1 = 7{,}345$ mm

Calculation of final centre thickness $t = 1{,}275$ mm

A.9.2 Consideration of uncertainty summation

Standard uncertainty of refractive index $u(n) = 2{,}5 \times 10^{-5}$

Standard uncertainty of centre thickness $u(t) = 0{,}001$ mm

Standard uncertainty of front surface radius equivalent to one interference ring fit at 10 mm diameter $u(r_{1b}) = 0{,}000\ 411$ mm

Standard uncertainty of master surface radius $u(r_{1a}) = 0{,}000\ 125$ mm

Standard uncertainty of front surface radius $u(r_1) = \sqrt{u^2(r_{1a}) + u^2(r_{1b})} = 0{,}000\ 429$ mm

Standard uncertainty of back surface radius equivalent to one interference ring fit at 10 mm diameter $u(r_{2b}) = 0{,}000\ 522$ mm

Standard uncertainty of master surface radius $u(r_{2a}) = 0{,}000\ 125$ mm

Standard uncertainty of back surface radius $u(r_2) = \sqrt{u^2(r_{2a}) + u^2(r_{2b})} = 0{,}000\ 537$mm

Taking into account these standard uncertainties of all parameters of a thick lens, the combined standard uncertainty of power will result in

$$u_c = 0{,}007\ 6 \text{ m}^{-1}$$

At a level of confidence of approximately 99 % (coverage factor is 3), the expanded uncertainty is given by

$$U = 3\ u_c = 0{,}023 \text{ m}^{-1}$$

Bibliography

[1] ISO 18369-3:—[1]), *Ophthalmic optics — Contact lenses — Part 3: Measurement methods*

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