INTERNATIONAL STANDARD

**ISO 9342-1**

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

## Part 1:
## Test lenses for focimeters used for measuring spectacle lenses

*Optique et instruments d'optique — Verres étalons pour l'étalonnage des frontofocomètres —*

*Partie 1: Verres étalons pour frontofocomètres pour le mesurage des verres de lunettes*

Reference number
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# Foreword

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ISO 9342-1 was prepared by Technical Committee ISO/TC 172, *Optics and photonics*, Subcommittee SC 7, *Ophthalmic optics and instruments*.

This first edition cancels and replaces ISO 9342:1996, of which Clause 1 and Clauses A.5 to A.7 have been technically revised.

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*

**INTERNATIONAL STANDARD** **ISO 9342-1:2005(E)**

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

## Part 1:
## Test lenses for focimeters used for measuring spectacle lenses

## 1 Scope

This part of ISO 9342 specifies requirements for test lenses for the calibration of focimeters that are used for the measurement of spectacle form lenses.

NOTE It is accepted that other test lenses can also be used with powers within the given range, manufactured to the same standard of accuracy and form, but different back vertex powers. However, only lenses with integer nominal powers, as described in Annex A, can be used for the calibration of digitally-rounding focimeters.

## 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, *Optics and optical instruments — Reference wavelengths*

## 3 Terms and definitions

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

**3.1**
**spherical test lenses**
lenses used for the calibration of the dioptric power measurements by focimeters, in which the power of each lens is expressed as its back vertex power in dioptres (D)

**3.2**
**prismatic test lenses**
lenses used for the calibration of the prismatic deviation measurements by focimeters, in which the prismatic power of each lens is expressed in centimetres deviation per metre distance (cm/m)

NOTE The special name for the unit for expressing prismatic power is the “prism dioptre” for which the symbol “Δ” is used.

**3.3**
**cylindrical test lenses**
lenses with cylindrical faces which are used to calibrate the axis marker and axis indicator with respect to the adjustment orientation of the rail

NOTE These lenses are usually specially designed and marked.

### 3.4
**reference wavelength**
wavelengths specified in ISO 7944

NOTE For the purposes of this part of ISO 9342, the reference wavelengths are either the green mercury e-line ($\lambda_e$ = 546,07 nm) or the yellow helium d-line ($\lambda_d$ = 587,56 nm).

# 4 Design requirements and recommendations for test lenses

## 4.1 General

Test lenses shall be made of homogeneous white crown glass with a refractive index $n_d$ = 1,523 ± 0,002, or $n_e$ = 1,525 ± 0,002 selected to be free of bubbles and striae in an area of 4 mm radius surrounding the centre of the free aperture.

The reference wavelength for which the test lenses are calibrated should be stated.

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

## 4.2 Spherical test lenses

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

– 25 D, – 20 D, – 15 D, – 10 D, – 5 D, + 5 D, + 10 D, + 15 D, + 20 D, + 25 D

Spherical test lenses should have a free aperture of at least 15 mm.

In order to minimize the influence of spherical aberration, the curvature of the back surface and the centre thickness shall approximately correspond to those of common spectacle lenses. Table 1 gives nominal back surface powers and ranges for centre thickness, which will ensure that the lenses are of this form.

**Table 1 — Design range for the standard test lenses**

| **Nominal back vertex power BVP** $m^{-1}$ (D) | **Nominal back surface power BSP** $m^{-1}$ (D) | **Power range for BSP** $m^{-1}$ (D) | **Range for centre thickness**[a] mm |
|---|---|---|---|
| −25 | −25 | ± 1 | 2 to 6 |
| −20 | −20 | | 2 to 6 |
| −15 | −15 | | 2 to 6 |
| −10 | −12 | | 2 to 8 |
| −5 | −9 | | 2 to 8 |
| +5 | −5 | | 3 to 7 |
| +10 | −3 | | 3 to 7 |
| +15 | −1 | | 5 to 7 |
| +20 | 0 | | 7 to 9 |
| +25 | 0 | | 9 to 11 |

NOTE Surface power is defined by the equation:

surface power = (refractive index −1) / radius of curvature in metres

[a] The centre thicknesses are required to guarantee stability in the negative power range.

### 4.3 Prismatic test lenses

The optical surfaces of prismatic test lenses shall be planar.

The number of prismatic test lenses that should be used to adjust or to check a focimeter depends on the measuring range of the instrument. If a test lens is used, it shall meet the requirements of this part of ISO 9342.

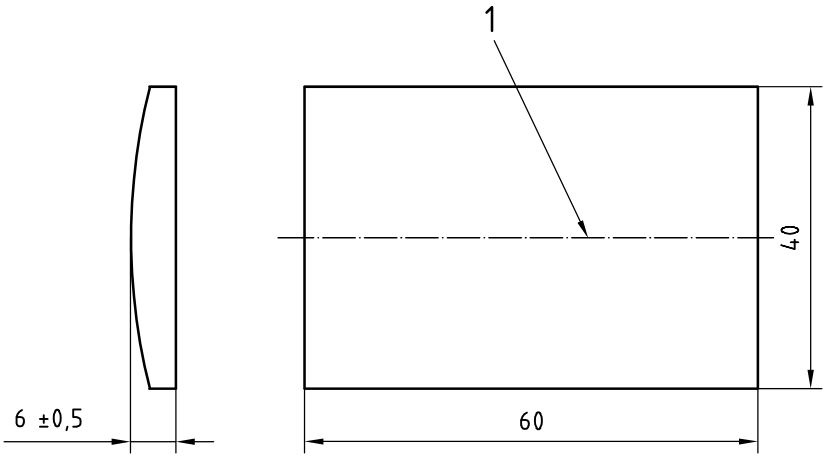
For a complete set, the following set of prismatic deviations is recommended:

2 Δ 5 Δ 10 Δ 15 Δ 20 Δ

### 4.4 Cylindrical test lenses

The test lens shall be a rectangular positive plano-cylinder of at least 5 D and shall have the dimensions shown in Figure 1. The cylinder axis shall be parallel to the longer side of the rectangle and shall be marked by a centreline. One of the longer sides shall be marked as the reference side.

Dimensions in millimetres



**Key**

1 centreline

Figure 1 — Cylindrical test lens

## 5 Tolerances

### 5.1 Tolerances for spherical test lenses

The permissible tolerances for spherical test lenses are specified in Table 2.

NOTE In Annex A an example is given for the proper design of test lenses that meet the requirements of Tables 1 and 2 for free apertures of up to 9 mm diameter.

**Table 2 — Tolerances for spherical test lenses**

| **Nominal back vertex power** $m^{-1}$ (D) | **Tolerance (maximum deviation)** $m^{-1}$ (D) |
|---|---|
| −25 | 0,03 |
| −20 | 0,02 |
| −15 | 0,02 |
| −10 | 0,01 |
| −5 | 0,01 |
| +5 | 0,01 |
| +10 | 0,02 |
| +15 | 0,02 |
| +20 | 0,03 |
| +25 | 0,03 |

## 5.2 Tolerances for prismatic test lenses

The free aperture of prismatic test lenses shall be at least 15 mm. The tolerances shall not exceed the values given in Table 3.

**Table 3 — Tolerances for prismatic test lenses**

| **Prismatic deviation** cm/m (Δ) | **Tolerance** cm/m (Δ) |
|---|---|
| 2 | ± 0,02 |
| 5 | ± 0,03 |
| 10 | ± 0,05 |
| 15 | ± 0,10 |
| 20 | ± 0,15 |

## 5.3 Tolerances for cylindrical test lenses

The angular deviation between the cylinder axis and the longer side of the rectangle (see Figure 1) shall not exceed 20′ of arc.

The displacement of the centreline from the afocal meridian shall not exceed 0,1 mm.

These tolerances shall not be additive and allow the angular deviation between the cylinder axis and the centreline to be greater than 20′ of arc.

# Annex A
(informative)

# Manufacture of test lenses for focimeters

## A.1 General

Spherical test lenses, which meet the tolerances given in 5.1, can be manufactured by observing the following specifications and procedure.

To manufacture test lenses according to 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 at least $\pm 5 \times 10^{-5}$. Glass should be selected with a refractive index $n_e = 1{,}525 \pm 0{,}001$; $n_d = 1{,}523 \pm 0{,}001$. The dispersion value should be $\nu = 59 \pm 4$. Schott glass K5[1] is an example of a suitable glass.

## A.3 Calculation of nominal back surface radius of curvature

The nominal radius of the back surface (i.e. the surface that is put onto the lens support of the focimeter) is found by using Table 1.

For every nominal back vertex power a nominal back surface power is given. The nominal radius of the back surface is found by using the formula given in the Note to Table 1.

## A.4 Selection of the closest standard radius

Using the result of A.3, select from the available master test surfaces the one whose radius is closest to the value calculated according to 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 in Table 1, the front surface radius is calculated using Equation (A.2) below. 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, Equation (A.3) is used with the selected values of the front and back radius and the known refractive index to calculate the centre thickness.

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[1] Schott glass K5 is an example of a suitable product available commercially. This information is given for the convenience of users of this part of ISO 9342 and does not constitute an andorsernent by ISO of this product.

The formula for back vertex power, $F_{\text{bv}}$, as a function of the four variables, front surface radius of curvature, back surface radius of curvature, refractive index of the lens material, and centre lens thickness, is:

$$F_{\text{bv}} = (n-1)\left[\frac{1}{r_{\text{f}} - t\left(\frac{n-1}{n}\right)} - \left(\frac{1}{r_{\text{b}}}\right)\right] \tag{A.1}$$

where

$r_{\text{f}}$ is the radius of curvature of the front surface;

$r_{\text{b}}$ is the radius of curvature of the back surface;

$t$ is the centre thickness of the lens;

$n$ is the refractive index of the lens material at a reference wavelength.

Equation (A.1) is re-arranged to give Equation (A.2) for finding the front surface radius of curvature when the back vertex power, back surface radius of curvature, refractive index and centre thickness are known.

$$r_{\text{f}} = \frac{n-1}{F_{\text{bv}} + \left(\frac{n-1}{r_{\text{b}}}\right)} + t\left(\frac{n-1}{n}\right) \tag{A.2}$$

Equation (A.2) is re-arranged to give Equation (A.3) for finding the centre thickness when the back vertex power, back surface radius of curvature, refractive index and front surface radius of curvature are known.

$$t = n\left[\left(\frac{r_{\text{f}}}{n-1}\right) - \frac{1}{F_{\text{bv}} + \left(\frac{n-1}{r_{\text{b}}}\right)}\right] \tag{A.3}$$

## A.6 Determination of lens back surface power and error tolerance

While a lens produced using the method given in A.3, A.4 and A.5 will have a back vertex power very close to the calculated value, a more precise value is needed for a master test lens. To find the precise value for the back vertex power of a test lens, it is necessary to measure the lens parameters. The refractive index of the material will typically be supplied by the glass manufacturer and shall be known to ± 0,000 05. The radius of curvature of the surfaces can be measured using interferometric means with an error of no more than $\pm 1 \times 10^{-5}$ m (10 µm). The centre thickness can be measured with a precision of $\pm 3 \times 10^{-6}$ m (3 µm).

The error in back vertex power of the test lens due to error in one of the variables with the other three held constant is given as multiplying the variable error by the partial derivative of $F_{\text{bv}}$ with respect to that variable. The expressions for the four partial derivatives are as follows.

$$\frac{\partial F_{\text{bv}}}{\partial r_{\text{f}}} = \frac{-(n-1)}{\left[r_{\text{f}} - t\left(\frac{n-1}{n}\right)\right]^2}$$

$$\frac{\partial F_{\text{bv}}}{\partial r_{\text{b}}} = \frac{n-1}{{r_{\text{b}}}^2}$$

$$\frac{\partial F_{\mathrm{bv}}}{\partial t}=\frac{(n-1)^2}{n\left[r_{\mathrm{f}}-t\left(\frac{n-1}{n}\right)\right]^2}$$

$$\frac{\partial F_{\mathrm{bv}}}{\partial n}=\left[\frac{1}{r_{\mathrm{f}}-t\left(\frac{n-1}{n}\right)}-\frac{1}{r_{\mathrm{b}}}\right]+\frac{(n-1)t}{n^2\left[r_{\mathrm{f}}-t\left(\frac{n-1}{n}\right)\right]^2}=\frac{F_{\mathrm{bv}}}{n-1}+\frac{(n-1)t}{n^2\left[r_{\mathrm{f}}-t\left(\frac{n-1}{n}\right)\right]^2}$$

These equations can be simplified by defining

$$P'_{\mathrm{f}}=\frac{n-1}{r_{\mathrm{f}}-t\left(\frac{n-1}{n}\right)}$$

where $P'_{\mathrm{f}}$ is thickness corrected front surface power;

$$P_{\mathrm{b}}=\frac{-(n-1)}{r_{\mathrm{b}}}$$

where $P_{\mathrm{b}}$ is the back surface power;

$$F_{\mathrm{bv}}=P'_{\mathrm{f}}+P_{\mathrm{b}}$$

where $F_{\mathrm{bv}}$ is the back vertex power.

The error in $F_{\mathrm{bv}}$ due to an error in $r_{\mathrm{f}}$ is given by $\mathrm{d}F_{\mathrm{bv}r_{\mathrm{f}}}$ as follows:

$$\mathrm{d}F_{\mathrm{bv}r_{\mathrm{f}}}=\frac{-P'^{2}_{\mathrm{f}}}{n-1}\mathrm{d}r_{\mathrm{f}}$$

where $\mathrm{d}r_{\mathrm{f}}$ is the expected error in $r_{\mathrm{f}}$.

The error in $F_{\mathrm{bv}}$ due to an error in $r_{\mathrm{b}}$ is given by $\mathrm{d}F_{\mathrm{bv}r_{\mathrm{b}}}$ as follows:

$$\mathrm{d}F_{\mathrm{bv}r_{\mathrm{b}}}=\frac{P_{\mathrm{b}}^{2}}{n-1}\mathrm{d}r_{\mathrm{b}}$$

where $\mathrm{d}r_{\mathrm{b}}$ is the expected error in $\mathrm{r_b}$.

The error in $F_{\mathrm{bv}}$ due to an error in $n$ is given by $\mathrm{d}F_{\mathrm{bv}n}$ as follows:

$$\mathrm{d}F_{\mathrm{bv}n}=\left[\frac{F_{\mathrm{bv}}}{n-1}+\frac{tP'^{2}_{\mathrm{f}}}{n^2(n-1)}\right]\mathrm{d}n$$

where $\mathrm{d}n$ is the expected error in $n$.

The error in $F_{\mathrm{bv}}$ due to an error in $t$ is given by $\mathrm{d}F_{\mathrm{bv}t}$ as follows:

$$\mathrm{d}F_{\mathrm{bv}t} = \frac{{P'_{\mathrm{f}}}^2}{n}\mathrm{d}t$$

where $\mathrm{d}t$ is the expected error in $t$.

The total error associated with a test lens, $\mathrm{d}F_{\mathrm{bv}}$, which results from all four parameter errors acting at once is given by

$$\mathrm{d}F_{\mathrm{bv}} = \sqrt{\mathrm{d}F_{\mathrm{bv}r_{\mathrm{f}}}{}^2 + \mathrm{d}F_{\mathrm{bv}r_{\mathrm{b}}}{}^2 + \mathrm{d}F_{\mathrm{bv}t}{}^2 + \mathrm{d}F_{\mathrm{bv}n}{}^2}$$

## A.7 Example of a calculation for expected error

To illustrate the method for calculating expected error using the method given in A.6 consider the following case.

The nominal back vertex power of the test lens is 15 D. It is constructed of spectacle crown glass, $n_{\mathrm{d}}$ = 1,522 49, and has a centre thickness of 5,40 mm. The radii of curvature of the lens surfaces are $r_{\mathrm{f}}$ = 34,47 mm and $r_{\mathrm{b}}$ = 510,53 mm.

This combination of parameters produces a lens with surface powers:

$$P'_{\mathrm{f}} = \frac{1{,}522\,49 - 1}{0{,}034\,47 - 0{,}005\,4\dfrac{(1{,}522\,49 - 1)}{1{,}522\,49}} = 16{,}02\ \mathrm{D}$$

$$P_{\mathrm{b}} = \frac{-(1{,}522\,49 - 1)}{0{,}510\,53} = -1{,}02\ \mathrm{D}$$

and a back vertex power of:

$$F_{\mathrm{bv}} = 16{,}02\ \mathrm{D} - 1{,}02\ \mathrm{D} = 15{,}00\ \mathrm{D}$$

The errors in the measurement of the parameters found using their values given above and the errors given in A.6:

$\mathrm{d}r_{\mathrm{f}} = 1 \times 10^{-5}$ m

$\mathrm{d}r_{\mathrm{b}} = 1 \times 10^{-5}$ m

$\mathrm{d}n = 3 \times 10^{-5}$

$\mathrm{d}t = 3 \times 10^{-6}$ m

$$\mathrm{d}F_{\mathrm{bv}r_{\mathrm{f}}} = \frac{-16{,}02^2}{1{,}522\,49 - 1}10^{-5} = 4{,}9 \times 10^{-3}\ \mathrm{D}$$

$$\mathrm{d}F_{\mathrm{bv}r_{\mathrm{b}}} = \frac{1{,}02^2}{1{,}522\,49 - 1}10^{-5} = 2{,}0 \times 10^{-5}\ \mathrm{D}$$

$$\mathrm{d}F_{\mathrm{bv}n} = \left( \frac{15{,}00}{1{,}522\,49 - 1} + \frac{(0{,}005\,4)16{,}02^{2}}{(1{,}522\,49)^{2}(1{,}522\,49 - 1)} \right) 3{,}0 \times 10^{-5} = 9{,}0 \times 10^{-4}\ \mathrm{D}$$

$$\mathrm{d}F_{\mathrm{bv}t} = \frac{16{,}02^{2}}{1{,}522\,49} 3 \times 10^{-6} = 5{,}1 \times 10^{-4}\ \mathrm{D}$$

$$\mathrm{d}F_{\mathrm{bv}} = \sqrt{\left(4{,}9 \times 10^{-3}\right)^{2} + \left(2{,}0 \times 10^{-5}\right)^{2} + \left(9{,}0 \times 10^{-4}\right)^{2} + \left(5{,}1 \times 10^{-4}\right)^{2}} = 0{,}005\ \mathrm{D}$$

This master test lens therefore has a power of 15,00 ± 0,005 D which meets the requirements of Table 2.

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