

Personal eye-protection — Optical test methods

The European Standard EN 167:2001 has the status of a
British Standard

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National foreword

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The UK participation in its preparation was entrusted by Technical Committee PH/2, Eye protection, to Subcommittee PH/2/2, Industrial eye protectors, which has the responsibility to:

- aid enquirers to understand the text;
- present to the responsible European committee any enquiries on the interpretation, or proposals for change, and keep the UK interests informed;
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Persönlicher Augenschutz - Optische Prüfverfahren

This European Standard was approved by CEN on 3 September 2001.

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This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CEN member into its own language and notified to the Management Centre has the same status as the official versions.

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Foreword

This document has been prepared by Technical Committee CEN/TC 85, "Eye-protective equipment", the secretariat of which is held by AFNOR.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by May 2002, and conflicting national standards shall be withdrawn at the latest by May 2002.

This European Standard replaces EN 167:1995.

This document has been prepared under a mandate given to CEN by the European Commission and the European Free Trade Association, and supports essential requirements of EU Directive(s).

For relationship with EU Directive(s), see informative annex ZA, which is an integral part of this document.

Annex A is normative. The annexes B and ZA are informative.

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and the United Kingdom.

1 Scope

This European Standard specifies optical test methods for eye-protectors, the requirements for which are contained in other ENs.

Alternative methods may be used if shown to be equivalent.

Non-optical test methods are given in EN 168.

Specifications are given in EN 166.

A definition of terms is given in EN 165.

2 Normative references

This European Standard incorporates by dated or undated reference, provisions from other publications. These normative references are cited at the appropriate places in the text, and the publications are listed hereafter. For dated references, subsequent amendments to or revisions of any of these publications apply to this European Standard only when incorporated in it by amendment or revision. For undated references the latest edition of the publication referred to applies (including amendments).

EN 165, *Personal eye-protection — Vocabulary.*

EN 166, *Personal eye-protection — Specifications.*

EN 168, *Personal eye-protection — Non-optical test methods.*

3 Test for spherical, astigmatic and prismatic refractive powers

NOTE The reference methods for assessment of refractive power are contained in 3.1 and 3.2.

If during measurement using the telescope a doubling or other aberration of the image is observed then the ocular may either be classified as a defective, or subjected to further examination using the method described in annex A.

3.1 Testing unmounted oculars covering one eye

3.1.1 Apparatus

3.1.1.1 Telescope

A telescope with an aperture of nominally 20 mm and a magnification between 10 and 30, fitted with an adjustable eyepiece incorporating a reticule.

3.1.1.2 Illuminated target

A target, consisting of a black plate incorporating the cut-out pattern shown in Figure 1, behind which is located a light source of adjustable luminance with a condenser, if necessary, to focus the magnified image of the light source on the telescope objective.

The large annulus of the target has an outer diameter of $(23,0 \pm 0,1)$ mm with an annular aperture of $(0,6 \pm 0,1)$ mm. The small annulus has an inner diameter of $(11,0 \pm 0,1)$ mm with an annular aperture of $(0,6 \pm 0,1)$ mm. The central aperture has a diameter of $(0,6 \pm 0,1)$ mm. The bars are nominally 20 mm long and 2 mm wide with a nominal 2 mm separation.

3.1.1.3 Filter

A filter with its maximum transmittance in the green part of the spectrum may be used to reduce chromatic aberrations.

3.1.1.4 Calibration lenses

Lenses with positive and negative spherical refractive powers of $0,06 \text{ m}^{-1}$, $0,12 \text{ m}^{-1}$ and $0,25 \text{ m}^{-1}$ (tolerance $\pm 0,01 \text{ m}^{-1}$).

3.1.2 Arrangement and calibration of apparatus

The telescope and illuminated target are placed on the same optical axis ($4,60 \pm 0,02$) m apart.

The observer focuses the reticule and the target and aligns the telescope to obtain a clear image of the pattern. This setting is regarded as the zero point of the focusing scale of the telescope. The telescope shall be aligned so that the central aperture of the target is imaged on the centre of the cross-line graticule. This setting is regarded as the zero point of the prism scale.

The focusing adjustment of the telescope is calibrated with the calibration lenses (3.1.1.4) so that a power of $0,01 \text{ m}^{-1}$ may be measured. Any other equivalent calibration method may be used.

3.1.3 Procedure

Position the ocular in front of the telescope in the as-worn position, or other position as specified by the manufacturer. If the as-worn position is unknown, or if no position is specified by the manufacturer then the ocular shall be positioned normal to the telescopic axis and the tests conducted at the geometric centre.

3.1.3.1 Spherical refractive power and astigmatic refractive power

3.1.3.1.1 Oculars without astigmatic refractive power

The telescope is adjusted until the image of the target is clearly focussed. The spherical power of the ocular is then read from the scale of the telescope.

3.1.3.1.2 Oculars with astigmatic refractive power

The target, or the ocular, is rotated in order to align the principal meridians of the ocular with the bars of the target. The telescope is focused firstly on one set of bars (measurement D_1) and then on the perpendicular bars (measurement D_2). The spherical power is the mean, $\frac{D_1 + D_2}{2}$ the astigmatic refractive power is the absolute difference, $|D_1 - D_2|$, of the two measurements.

NOTE During this process the best focus shall be used across the whole target for each meridian.

3.1.3.2 Prismatic refractive power

The ocular to be tested is placed in front of the telescope, and, if the point of intersection of the lines of the reticule falls outside the image of the large circle, the prismatic power exceeds $0,25 \text{ cm/m}$. If the point of intersection of the lines of the reticule falls inside the image of the small circle of the target, the prismatic power is less than $0,12 \text{ cm/m}$.

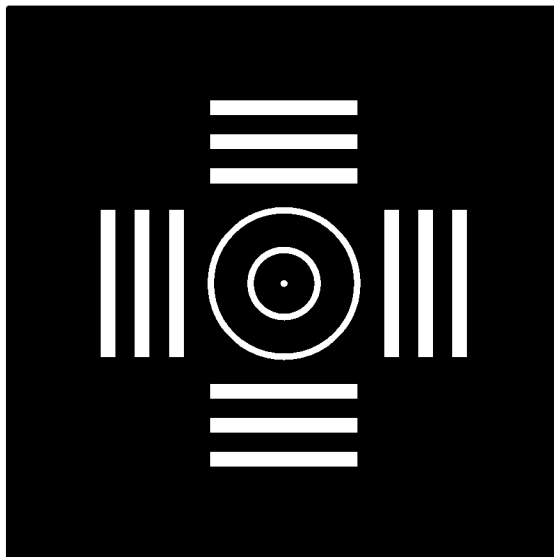


Figure 1 — Telescope target (dimensions are given in 3.1.1.2)

3.2 Testing unmounted oculars covering both eyes and mounted oculars (spectacles, goggles and face-shields)

3.2.1 Determination of the spherical and astigmatic refractive power

Position the ocular such that it is in an “as-worn” orientation in front of the telescope.

Measurements of spherical and astigmatic powers shall be taken based on the visual centre of the ocular using the procedures specified in 3.1.3.1.

3.2.2 Determination of the difference in prismatic refractive power

3.2.2.1 Apparatus

The arrangement of the reference method is shown in Figure 2.

3.2.2.2 Procedure

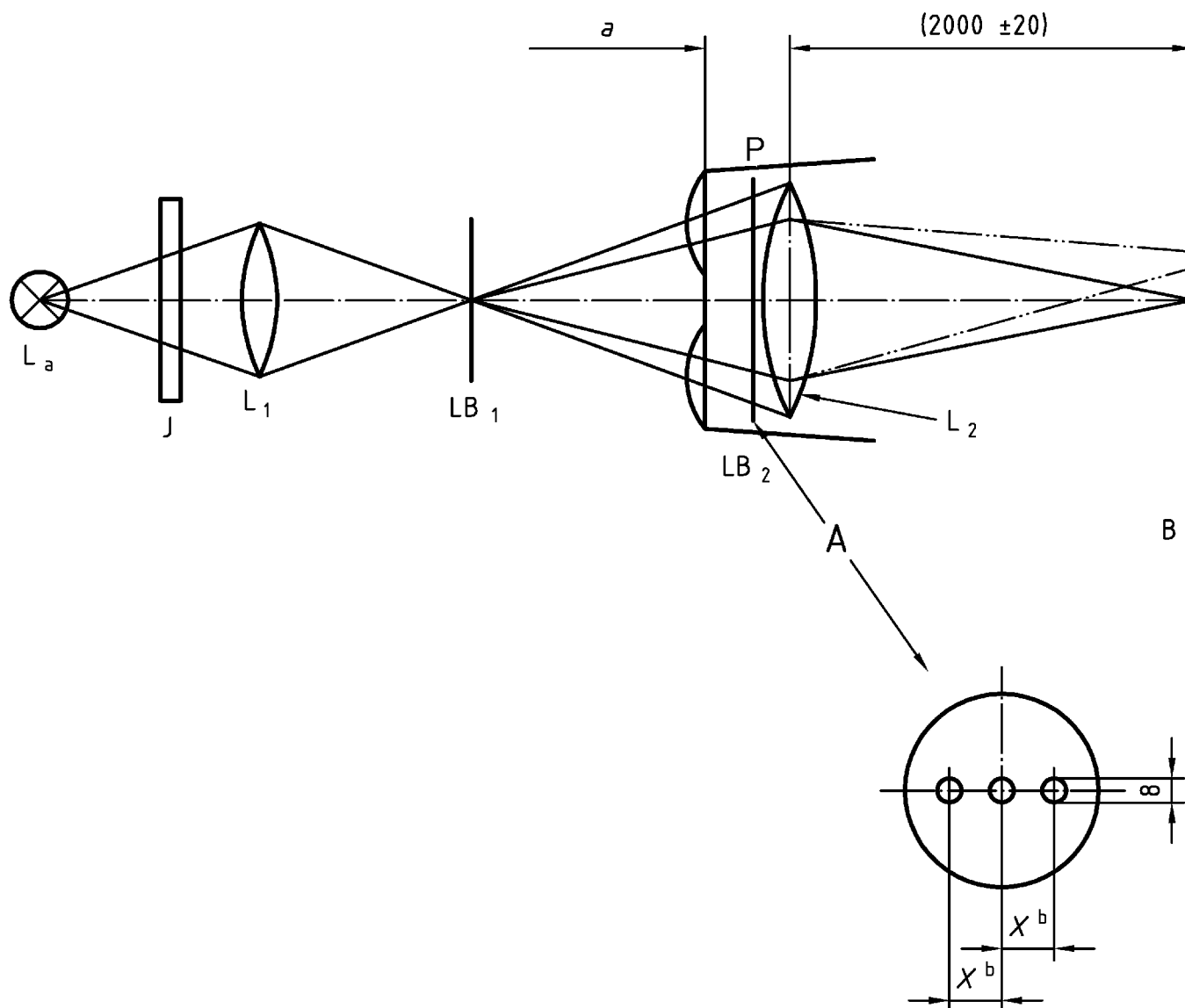
The diaphragm LB_1 , illuminated by the light source, is adjusted in such a way that it produces an image on the plane B when the eye-protector (P) is not in position. The eye-protector is placed in front of the lens L_2 in the as-worn position so that the axis of the eye-protector is parallel to the optical axis of the test assembly. Adjustable tilt eye-protectors are positioned with their oculars normal to the optical axis of the test equipment.

Measure the vertical and horizontal distances between the two displaced images arising from the two ocular regions of the eye-protector.

These distances in centimetres are divided by two to give the horizontal and vertical prismatic differences in centimetres per metre.

If the light paths which correspond to the two eye regions cross, the prismatic refractive power is ‘base in’ and if the light paths do not cross, it is ‘base out’.

Dimensions in millimetres (nominal unless toleranced)



Key

- L_a Light source, for example, small filament lamp, laser with wavelength of (600 ± 70) nm, etc.
- J Interference filter with peak transmittance in the green part of the spectrum (required only if a filament lamp is used as the light source)
- L_1 Achromatic lens, focal length between 20 mm and 50 mm
- LB_1 Diaphragm, diameter of aperture 1 mm nominal
- P Eye-protector
- LB_2 Diaphragm as shown in detail A
- L_2 Achromatic lens, 1 000 mm nominal focal length and 75 mm nominal diameter
- B Image plane
- ^a As close as possible.
- ^b $X = (32,0 \pm 0,2)$ mm or $(27,0 \pm 0,2)$ mm depending on the size of the head-form specified in EN 168.

Figure 2 — Arrangement of apparatus for measurement of prismatic difference

4 Light diffusion test

4.1 Principle

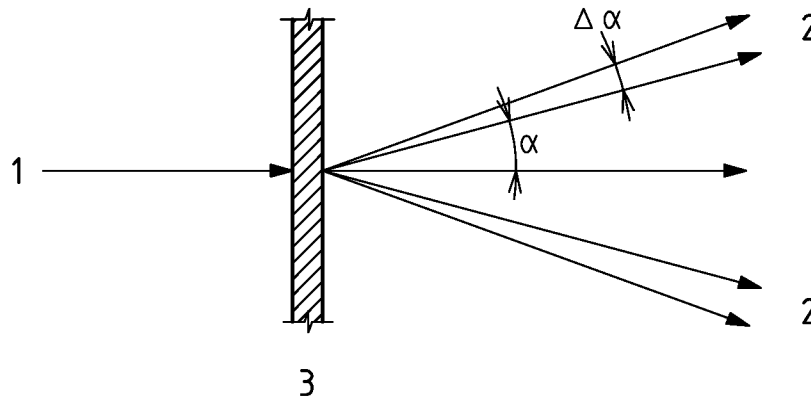
The luminance (L_s) of an illuminated ocular is a measure of its light diffusion and is proportional to the illuminance (E). The proportionality factor is the luminance factor $I = L_s/E$, which is expressed in candelas per square metre per lux $\frac{\text{cd/m}^2}{\text{lx}}$.

To obtain a factor I^* which is independent of the transmittance of the ocular, the luminance factor is divided by the transmittance τ .

$$I^* = \frac{L_s}{\tau E}$$

This quantity is known as the reduced luminance factor and is expressed in the same units as the luminance factor.

NOTE Most oculars have diffusion properties which are symmetrical about the optical axis. For these oculars, the mean value of the reduced luminance factor is measured within an angle limited by the two cones shown in Figure 3. This mean value depends upon values α and $\Delta\alpha$.



Key

- 1 Incident light on optical axis
- 2 Diffused light
- 3 Ocular

Figure 3 — Diffusion angles

4.2 Test methods

Two test methods are specified which use the same measurement principle. The 'basic method' detailed in 4.2.1 may be used for oculars without corrective effect and for all shade numbers. The 'simplified method' detailed in 4.2.2 has to be used for oculars with corrective effect.

The results obtained with the two methods may be considered to be equivalent; whichever method is used the relative measurement uncertainty for the reduced luminance factor shall not be greater than 25 %.

Measurements of light diffusion shall be taken at the visual centre of the ocular. If the visual centre is not known then the geometric centre shall be used.

NOTE Visual centre is as defined in EN 166.

4.2.1 Basic method

4.2.1.1 Apparatus

The arrangement is shown in Figure 4.

The spherical concave mirror H_1 forms an image of light L of identical dimensions at diaphragm LB. The spherical concave mirror H_3 forms an image of diaphragm LB in the plane of diaphragms B_L and B_R . The achromatic lens A is positioned immediately behind the diaphragm so that a reduced image of the test sample in position P appears on diffusing screen MS. The image of iris diaphragm IB_1 is formed at the same time as IB_2 .

The arrangement collects all the light originating from the filter between angles $\alpha = 1,5^\circ$ and $\alpha + \Delta\alpha = 2^\circ$ in relation to the optical axis.

4.2.1.2 Procedure

The ocular is placed in the parallel beam at position P, then diaphragm B_L is put in place. The flux Φ_{1L} falling onto the photodetector corresponds to the undiffused light transmitted by the sample. Diaphragm B_L is then replaced by annular diaphragm B_R ; flux Φ_{1R} falling onto the photodetector corresponds to the total diffused light originating from the filter and from the apparatus. The test sample is then placed at position P'. The flux Φ_{2R} which then falls onto the photodetector corresponds to the diffused light coming from the apparatus only.

The difference $\Phi_{1R} - \Phi_{2R}$ corresponds to the light diffused by the filter. The mean reduced luminance factor l^* for the solid angle ω is calculated from the preceding fluxes by means of the formula:

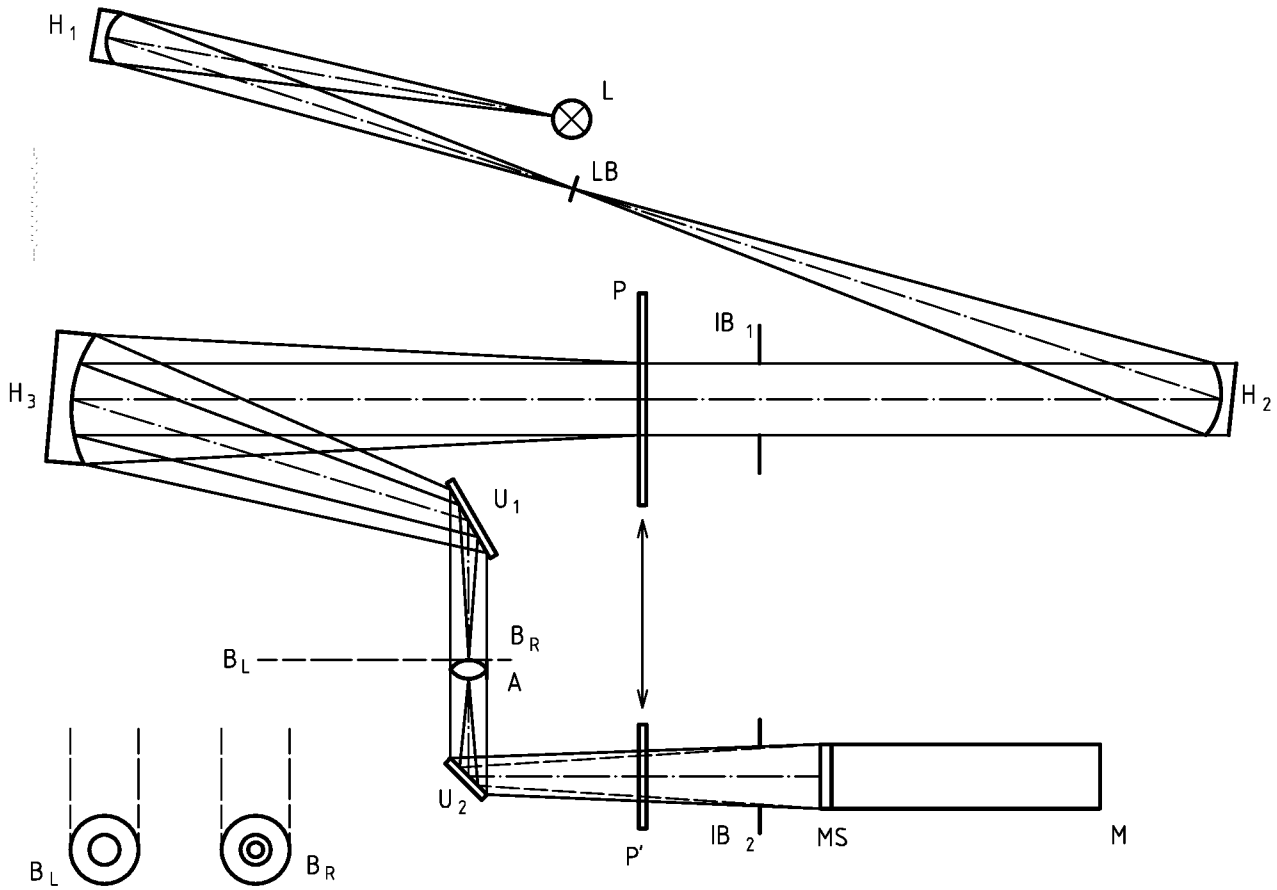
$$l^* = \frac{l}{\omega} \cdot \frac{\Phi_{1R} - \Phi_{2R}}{\Phi_{1L}}$$

where

Φ_{1R}, Φ_{2R} are the luminance fluxes with the annular diaphragm;

Φ_{1L} is the luminous flux with the circular diaphragm;

ω is the solid angle defined by the annular diaphragm.



- Key**
- L High-pressure xenon lamp (for example XB0 150 W or CSX150 W)
 - H₁ Spherical concave mirror; nominal focal length 150 mm; nominal diameter 40 mm
 - H₂ Spherical concave mirror; nominal focal length 300 mm; nominal diameter 40 mm
 - H₃ Spherical concave mirror; nominal focal length 300 mm; nominal diameter 70 mm
 - A Achromatic lens; nominal focal length 200 mm; nominal diameter 30 mm
 - U₁, U₂ Flat mirrors
 - B_R Annular diaphragm; diameter of outer circle (21,0 ± 0,1) mm, diameter of inner circle (15,75 ± 0,10) mm. See note below
 - B_L Circular diaphragm; diameter of aperture (7,5 ± 0,1) mm
 - M Photomultiplier corrected according to curve V (λ) with diffusing screen
 - IB₁ Iris-diaphragm to adjust diameter of field of measurement
 - IB₂ Iris-diaphragm to eliminate edge effects from IB₁
 - LB Circular diaphragm, diameter of aperture (1,0 ± 0,1) mm
 - MS Diffusing screen
 - P, P' Positions of test ocular

Figure 4 — Arrangement of apparatus for measurement of light diffusion - basic method

NOTE The diameters of the annular diaphragm circles shall be measured to an uncertainty not exceeding 0,01 mm in order that the solid angle ω may be determined accurately; any deviation from the nominal diameters shall be taken into account by calculation.

4.2.2 Simplified method

4.2.2.1 Apparatus

The test arrangement is shown in Figure 5.

NOTE The measurement principle is identical to that given in 4.2.1, but the diameter of the measuring zone is smaller (approximately 2,5 mm) and the test arrangement is simplified.

The beam of the laser (L) is expanded using the two lenses L_1 and L_2 and is directed towards the measuring point of the ocular (P). Ocular (P) is positioned in such a way that it can rotate around the axis of the beam.

The deviation of the beam is a function of the prismatic refractive power at the measuring point.

The annular or circular diaphragm, whichever is chosen, is at a distance of (400 ± 2) mm from the centre of the ocular.

The lens A then produces the image of the centre of the ocular on the photoreceptor S.

The part of the test arrangement, comprising the diaphragms, the lens and the receptor, is designed to rotate about the vertical axis through the centre of the ocular.

The ocular and the detector part of the apparatus have to pivot in order to compensate for any prismatic refractive power of the ocular.

NOTE For oculars without corrective effect, it is not necessary, in most cases, for the ocular and the detector part to pivot.

4.2.2.2 Procedure

4.2.2.2.1 Calibration of the apparatus

Set up the apparatus, the essential features of which are shown in Figure 5, without the ocular in place. Put the annular diaphragm B_R in place. Rotate the detector part of the apparatus (consisting of a photoreceptor S, a lens A and the annular diaphragm B_R) horizontally about P so as to align the light beam from the beam expander (consisting of a lens L_1 with a typical focal length of 10 mm, a lens L_2 with a typical focal length of 30 mm and a circular diaphragm B with a pinhole of sufficient size so as to provide a uniform beam) with the centre of the annular diaphragm B_R . Measure the flux Φ_{1R} falling onto the photoreceptor S, corresponding to the total diffused light. Replace the annular diaphragm B_R by the circular diaphragm B_L .

Measure the flux Φ_{1L} falling onto the photoreceptor, corresponding to the total non-diffused light.

Obtain the reduced luminance factor for the apparatus, l_a^* , for the solid angle ω using the following equation :

$$l_a^* = \frac{l}{\omega} \cdot \frac{\Phi_{1R}}{\Phi_{1L}}$$

where

Φ_{1R} is the luminous flux without the ocular in the parallel beam and with the annular diaphragm B_R in place ;

Φ_{1L} is the luminous flux without the ocular in the parallel beam and with circular diaphragm B_L in place ;

ω is the solid angle defined by the annular diaphragm B_R .

4.2.2.2.2 Testing of the ocular

Place the ocular in the parallel beam at position P as shown in Figure 5. Repeat 4.2.2.2.1 with the ocular in place, and with the ocular rotated about the axis of the beam to a position such that the prismatic deviation by the ocular is horizontal.

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Rotate the detector part of the apparatus so that the light beam falls on the centre of B_R . Obtain the reduced luminance factor for the apparatus including the ocular, l_g^* , for the solid angle ω using the following equation:

$$l_g^* = \frac{l}{\omega} \cdot \frac{\Phi_{2R}}{\Phi_{2L}}$$

where

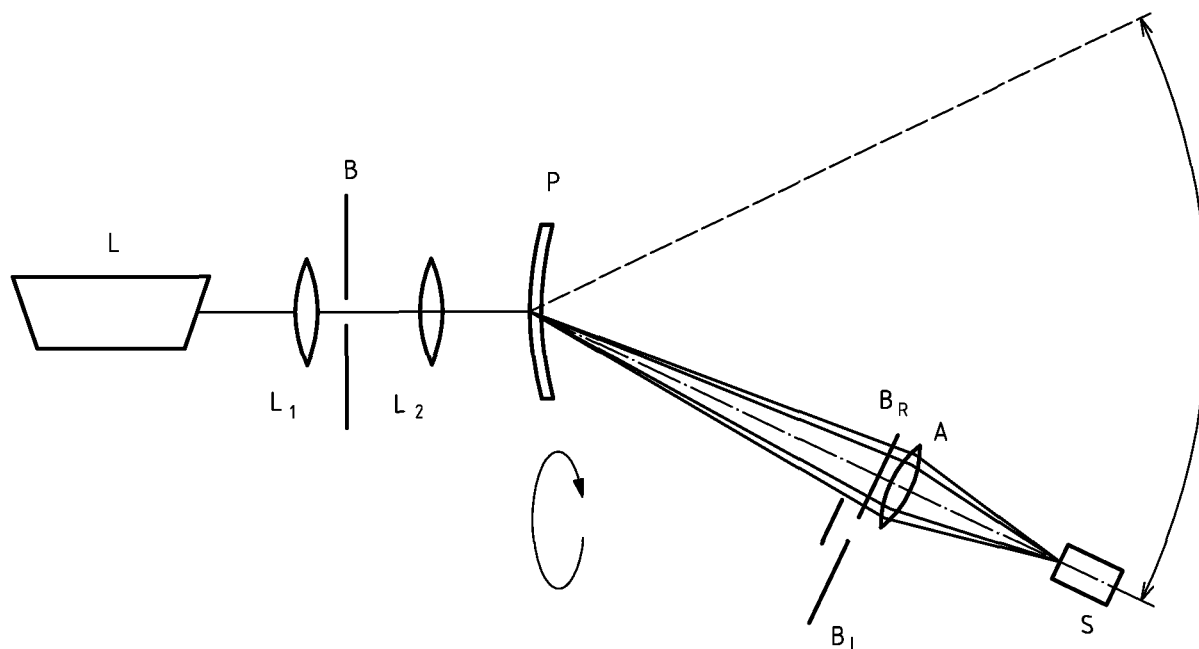
Φ_{2R} is the luminous flux with the ocular in the parallel beam and with the annular diaphragm B_R in place;

Φ_{2L} is the luminous flux with the ocular in the parallel beam and with the circular diaphragm B_L in place;

ω is the solid angle defined by the annular diaphragm B_R .

Then calculate the reduced luminance factor l^* of the ocular using the following equation:

$$l^* = l_g^* - l_a^*$$



NOTE 1 The focal length of the lenses is only given as a guide. Other focal lengths may be used, for example, if a wider beam is desired or a smaller image of the sample is to be formed on the receptor.

NOTE 2 The diameters of the annular diaphragm circles shall be measured to an uncertainty not exceeding 0,01 mm in order that the solid angle ω may be determined accurately; any deviation from the nominal diameters shall be taken into account by calculation.

Key

L Laser with wavelength of (600 ± 70) nm

NOTE Class 2 laser recommended, <1 mW. Diameter of beam between 0,6 mm and 1,0 mm.

L₁ 10 mm nominal focal length lens

L₂ 30 mm nominal focal length lens

B Circular diaphragm (a hole of 0,1 mm approximately produces a uniform light beam)

P Ocular sample

B_R Annular diaphragm, the diameter of the external circle being $(28,0 \pm 0,1)$ mm and the inner circle $(21,0 \pm 0,1)$ mm. See note 2 below

B_L Circular diaphragm of 10 mm nominal diameter

A Lens, 200 mm nominal focal length and 30 mm nominal diameter

S Photoreceptor

The distance between the annular/circular diaphragm and the centre of the ocular shall be (400 ± 2) mm.

Figure 5 — Arrangement of apparatus for measurement of light diffusion - Simplified method

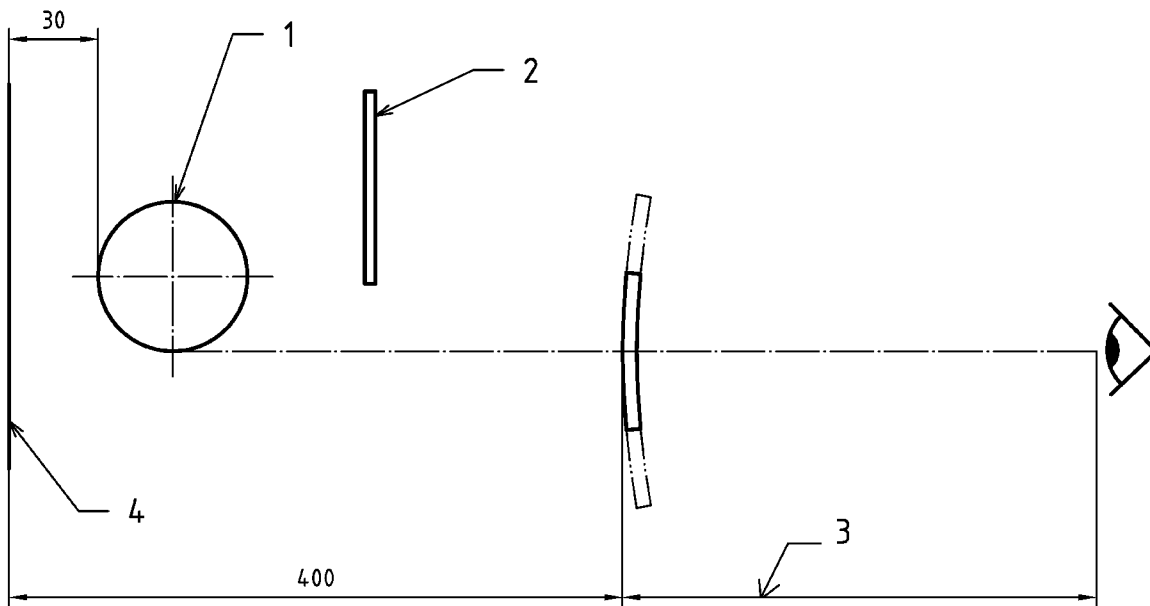
5 Assessment of quality of material and surface

The assessment of the quality of material and surface is conducted by visual inspection with the aid of a 'light box' or illuminated grid.

One method of inspection in current use consists of an illuminated grid as a background to be viewed through the ocular which is held at various distances from the eye. Another method is to illuminate the ocular by means of a fluorescent lamp mounted within a dull black chamber and with the amount of illumination adjusted by means of an adjustable opaque black mask. A suitable arrangement is shown in Figure 6.

If there is any doubt concerning the acceptability of the quality of the material and surface then this may be resolved by examining the areas in question with a light beam of 5 mm nominal diameter using the objective tests for transmittance (see clause 6), light diffusion (see clause 4) and the method for determining optical refractive powers defined in 3.1 or 3.2.

Dimensions in millimetres



Key

- 1 Lamp
- 2 Adjustable opaque dull black mask
- 3 Near vision distance (≈ 300)
- 4 Dull black background (200×360)

Figure 6 — Arrangement of apparatus for assessment of quality of material and surface

6 Determination of transmittance

Transmittance is measured with incident radiation falling normally on the ocular and the surface of the portion of the frame to be tested.

Test methods shall be used which have relative uncertainties less than or equal to those given in Table 1.

Table 1 — Relative uncertainty of measured transmittance

Transmittance value		Relative uncertainty %
Less than %	To %	
100	17,8	± 5
17,8	0,44	± 10
0,44	0,023	± 15
0,023	0,0012	± 20
0,0012	0,000023	± 30

Measurements of transmittance of oculars shall be taken at the visual centre of the ocular. If the visual centre is not known then the geometric centre shall be used.

NOTE Visual centre is as defined in EN 166. Measurements of transmittance of frames shall be taken at all parts of the frame through which radiation could directly pass to the eye when the frame is mounted on the test head.

7 Determination of variations in luminous transmittance

7.1 Unmounted oculars covering one eye

Locate the visual centre of the ocular. If the visual centre is not known the geometric centre shall be used. Refer to this as “the centre”.

NOTE Visual centre is as defined in EN 166.

Determine a circular area around the centre with diameter d , calculated as follows:

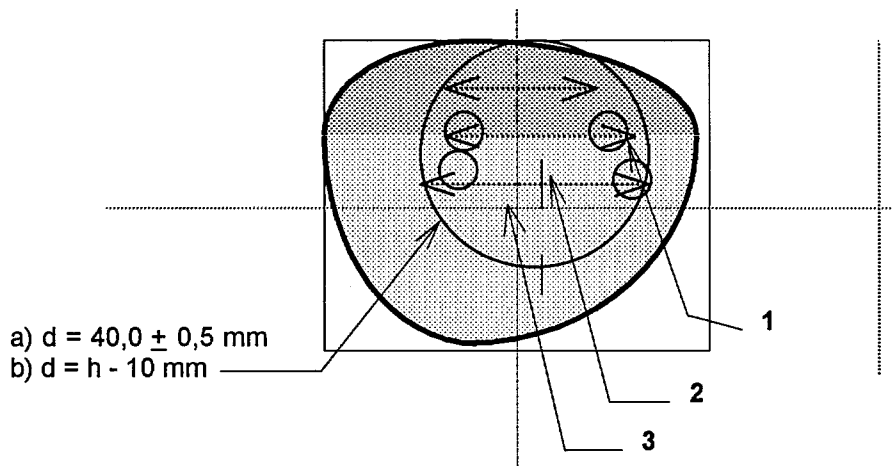
- a) for oculars more than 50 mm in vertical depth, $d = (40,0 \pm 0,5)$ mm;
- b) for oculars less than 50 mm in vertical depth, $d = (\text{vertical depth of ocular} - 10)$ mm.

Scan this circular area with a 5 mm nominal diameter light beam whilst at the same time measuring the luminous transmittance.

NOTE No measurements are to be recorded in a marginal region 5 mm wide around the periphery of the ocular.

For oculars with bands or gradients of different luminous transmittance, the requirement for variations in luminous transmittance applies in this circular area but perpendicularly to the gradient (see Figure 7).

Changes of luminous transmittance that are caused by thickness variations due to the design of the lens are permitted and are determined using the correction procedure detailed in 7.3.



Key

- 1 Light beam of 5 mm
- 2 Visual centre
- 3 Geometric centre

Figure 7 — Ocular luminous transmittance bands

The ocular and the light beam are positioned so that the incident light is falling normally to the surface of the ocular or parallel to the line of vision. Whichever angle is chosen, any correction for thickness shall be appropriate to this angle and in accordance with the correction formula contained in 7.3.

Measure and record the maximum value of luminous transmittance τ_{\max} , the minimum value of luminous transmittance τ_{\min} , and the value of luminous transmittance at the centre τ_c

Calculate the values of Δ_1 , and Δ_2 from the following equations:

$$\Delta_1(\%) = \frac{(\tau_{\max} - \tau_c)}{\tau_c} \times 100$$

$$\Delta_2(\%) = \frac{(\tau_c - \tau_{\min})}{\tau_c} \times 100$$

Choose the value of Δ_1 or Δ_2 , whichever is the greatest. Record this as the value of P_1 .

7.2 Mounted oculars and unmounted oculars covering both eyes

Locate the visual centre(s) of the ocular(s). If the visual centre(s) is(are) not known, then the geometric centre(s) shall be used. Refer to this(these) as the "centre(s)".

NOTE Visual centre is as defined in EN 166.

Determine circular areas around each of these centres with diameters d , calculated as follows:

- a) for oculars more than 50 mm in vertical depth, $d = (40,0 \pm 0,5)$ mm;
- b) for oculars less than 50 mm in vertical depth, $d = (\text{vertical depth of ocular} - 10)$ mm.

Scan each area with a 5 mm nominal diameter light beam whilst at the same time measuring the luminous transmittance.

NOTE No measurements are to be recorded in a marginal region 5 mm wide around the periphery of the ocular.

For oculars with bands or gradients of different luminous transmittance, the requirement for variations in luminous transmittance applies in each circular area but perpendicularly to the gradient.

Changes of luminous transmittance that are caused by thickness variations due to the design of the lens are permitted and are determined using the correction procedure detailed in 7.3

For the left ocular, measure and record the maximum value of luminous transmittance τ_{Lmax} , the minimum value of luminous transmittance τ_{Lmin} , and the value of luminous transmittance at the centre τ_{Lc} .

Calculate the values of Δ_{L_1} , and Δ_{L_2} from the following equations:

$$\Delta_{L_1}(\%) = \frac{(\tau_{Lmax} - \tau_{Lc})}{\tau_{Lc}} \times 100$$

$$\Delta_{L_2}(\%) = \frac{(\tau_{Lc} - \tau_{Lmin})}{\tau_{Lc}} \times 100$$

Choose the value of Δ_{L_1} or Δ_{L_2} , whichever is the greatest. Record this as the value of P_1 .

Similarly, for the right ocular, determine Δ_{R_1} or Δ_{R_2} . Choose the value of Δ_{R_1} or Δ_{R_2} , whichever is the greatest. Record this as the value of P_2 .

Divide the lower value of the luminous transmittance at one of the two visual centres by the higher value of the luminous transmittance at the other visual centre and express the difference of this ratio to 1, as a percentage. Record this percentage as P_3 .

7.3 Method to correct transmittance for variations in thickness of the ocular

The following relation holds between the transmittance τ and the thickness t if multiple reflections within the sample are neglected:

$$\tau = (1 - \rho_1)x(1 - \rho_2)e^{-kt}$$

where

ρ_1 is the reflectance at the front surface;

ρ_2 is the reflectance of the back surface;

t is the thickness;

k is the absorption coefficient.

The absorption coefficient k may be calculated from the transmittance τ for the reference thickness t as follows:

$$k = -\ln\left(\frac{\tau}{(1 - \rho_1)x(1 - \rho_2)}\right) / t$$

The expected transmittance for a different thickness can then be calculated using the first formula above.

Where the refractive index n is known and there is no surface treatment, the reflectance ρ is given by the following formula:

$$\rho = \left(\frac{n - 1}{n + 1}\right)^2$$

8 Determination of spectral reflectance in infrared

Measure the spectral reflectance of the ocular $\zeta(\lambda)$ in the wavelength range from 780 nm to 2 000 nm at a nominal angle of incidence of 8° with a relative measurement uncertainty of less than 5 %.

The mean spectral reflectance in the infrared of the ocular is calculated using the formula

$$\zeta_{IR} = \frac{1}{1220 \text{ nm}} \cdot \int_{780 \text{ nm}}^{2000 \text{ nm}} \zeta(\lambda) d\lambda.$$

Annex A (normative)

Method for measuring spherical and astigmatic refractive powers over small areas

A.1 Principle

The deflection of a parallel light beam of 5 mm nominal diameter (eye-pupil diameter) is detected by a photodiode.

Whereas the telescope method gives a mean value of refractive properties over an area of 20 mm in diameter, this method permits assessment over a much smaller area. The resolution is better than 10^{-6} m^{-1} .

The principle of this method is shown in Figure A.1.

If two parallel rays, 1 and 2, pass through the test ocular at different points, they meet in the focal plane at a distance f from the test ocular. Its refractive power is then $1/f$. In the case of a test ocular with different curvatures in two mutually perpendicular directions or if light falls obliquely on a spherical surface, an astigmatic refractive power will result which is equal to the difference between the refractive powers in the two main meridians.

If, in addition to this the central ray 1 is deflected by an angle δ , the test ocular will have, in addition to its spherical refractive power, a prismatic refractive power Δ , where:

$$\Delta = 100 \tan \delta \text{ cm/m}$$

If the deflection of the light ray is measured in a plane at a distance w from the ocular, then from Figure A.1:

$$\frac{l}{f} = \frac{u - v}{u \cdot w}$$

where

u is the distance between the two parallel rays 1 and 2 in front of the sample;

v is the distance between the refracted rays in the measuring plane.

The prismatic refractive power Δ in cm/m is given by: $\Delta = 100 \frac{V_0}{w}$

The astigmatic refractive power is equal to the difference between the refractive powers in the two principal meridians.

A.2 Apparatus

The apparatus comprises the following main elements (see Figure A.2):

- a) a He-Ne laser supplying a parallel light beam of wavelength $(600 \pm 70) \text{ nm}$;
- b) two lenses with a diaphragm at the common focal point to enlarge the laser beam to a nominal diameter of 5 mm (the mean size of the eye-pupil);

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- c) a carriage to move the test ocular continuously on a spiral path in a plane perpendicular to the direction of the laser beam. During measurement, the test ocular should not turn in relation to the photodiode. The carriage runs on two guides perpendicular to each other, keeping the directions of the axes of the carriage and the test ocular constant during measurement. A pivot guided by a spiral transmits the corresponding movement to the carriage. The pitch of the spiral is 1,08 mm nominal.

The 5 mm diameter laser beam continuously scans the whole surface of the test ocular. By appropriate markings, the position of the light beam on the filter and its deflection can be noted clearly.

The entire measurement beam of 5 mm diameter shall lie within the measurement area of 20 mm diameter. A peripheral area 5 mm wide around the ocular shall be excluded from the examination;

- d) a position sensing diode to measure the deflection of the laser beam (see Figure A.3). On this photodiode (for example, PIN SC 25) a rectangular system of co-ordinates is established by five electrical connections. When the centre connection, 5, is illuminated, the photo-current of the remaining connections is equal. When the light spot moves over the sensitive surface, the photo-current of connections 1 to 4 changes according to the position of the light spot in relation to the centre.

The photo-current of connection 5 remains constant and is directly proportional to the radiant flux.

The potential difference between the connections of one axis is proportional to the displacement on this axis as well as to the radiant flux. The photodiode has an active sensitive surface of 1,9 cm × 1,9 cm (minimum dimensions). In this apparatus, it can be positioned at distances between 50 cm and 250 cm from the test ocular as required, so that, for a scanned area of 30 mm diameter, a refractive quantity up to a maximum of $2D \text{ m}^{-1}$ can be measured.

A.3 Measurements

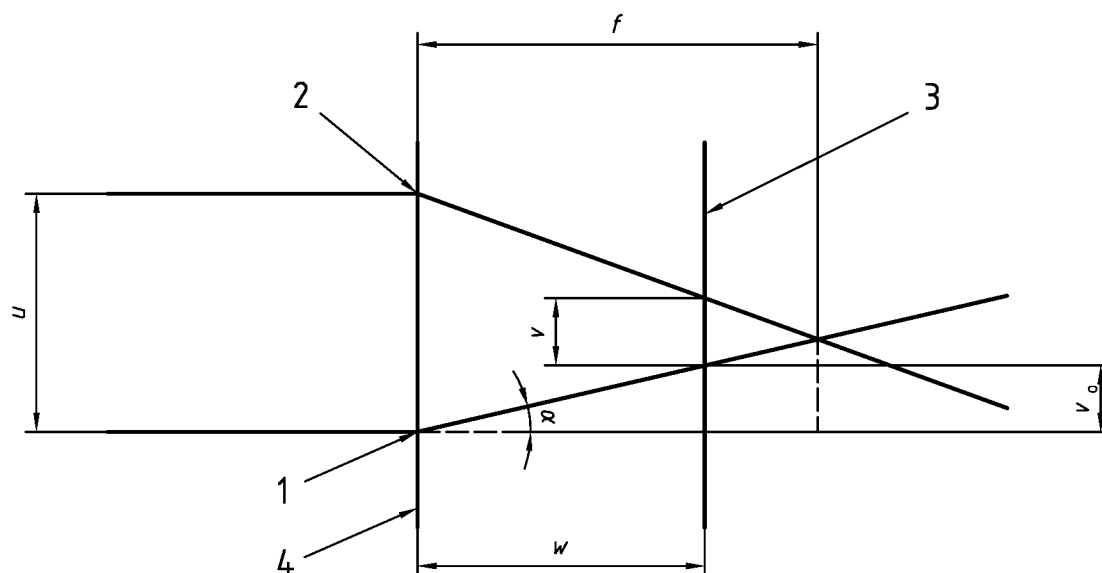
With a flat specimen, the direction of the emergent light beam is independent of its position on the ocular as the ray is not deflected when it passes through the ocular. As a first approximation, the image on the recorder is therefore a point. With a curved specimen without refractive power, the point may be slightly broadened because of light refraction within the glass. An ocular with uniform refractive power (lens) has the same focal length at all points. Therefore the scanning path is reproduced either reduced or enlarged depending on the refractive power (see Figure A.4) without changing its form. The spiral scanning path is also drawn on the recorder as a spiral with constant distances between adjacent lines (see Figure A.5 (a)).

Oculars with astigmatic refractive power, i.e. different focal lengths in different meridians, record a similar curve.

Since the dimensions of the curve depend on the refractive power, the distance from one line to the next is different for the different meridians and the spiral is therefore distorted (see Figure A.5 (b)).

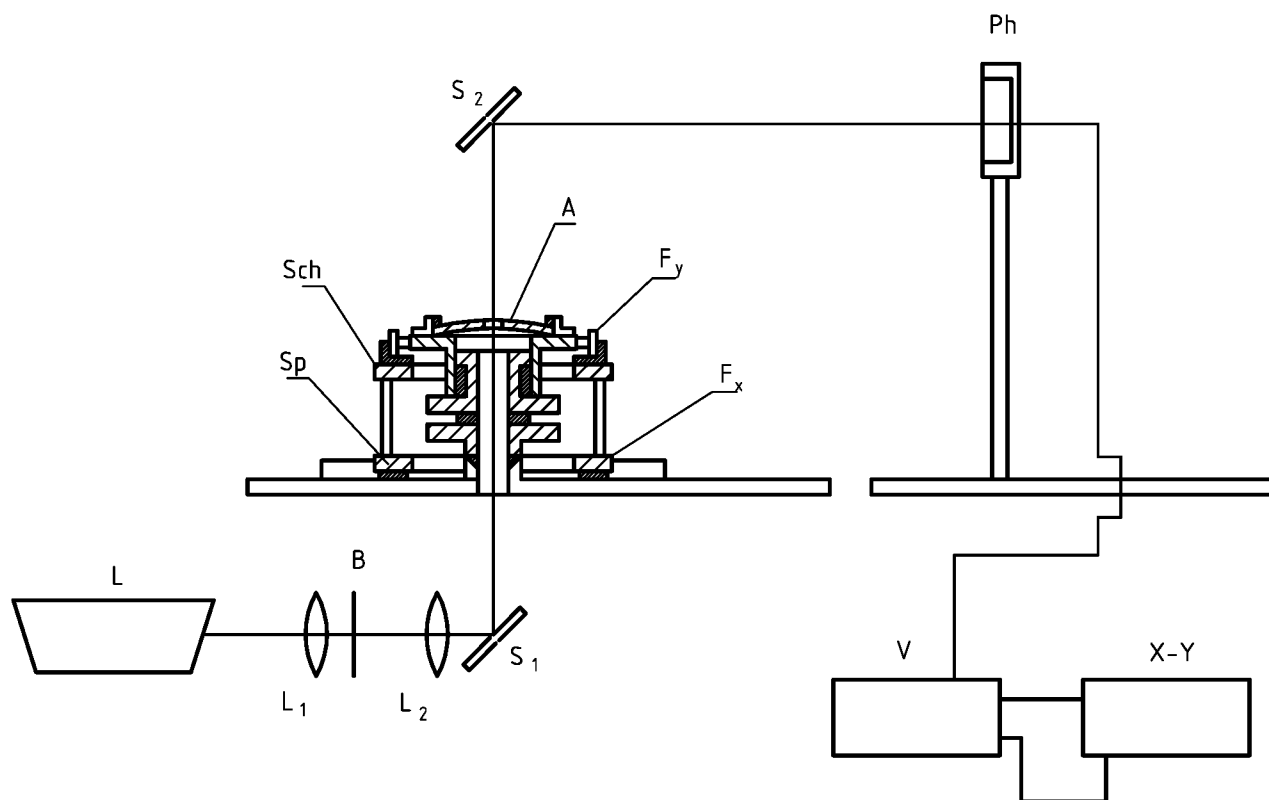
Oculars with irregularly varying focal lengths produce a deformed spiral path (see Figure A.5 (c)). From this distorted spiral the refractive powers at all points on the surface of the ocular may be obtained by analysis.

The apparatus may be calibrated using samples of known prismatic refractive power or by lateral displacement of the detector using a micrometer.

**Key**

- 1 Ray 1
- 2 Ray 2
- 3 Measuring plane
- 4 Test ocular
- f Focal length of ocular
- u Distance between the parallel rays 1 and 2
- v Distance between the refracted rays 1 and 2 in the measuring plane
- w Distance between the test ocular and measuring plane
- δ Angle of deflection of the central ray 1
- V_0 Deflection of the central ray from the optical axis in the measuring plane

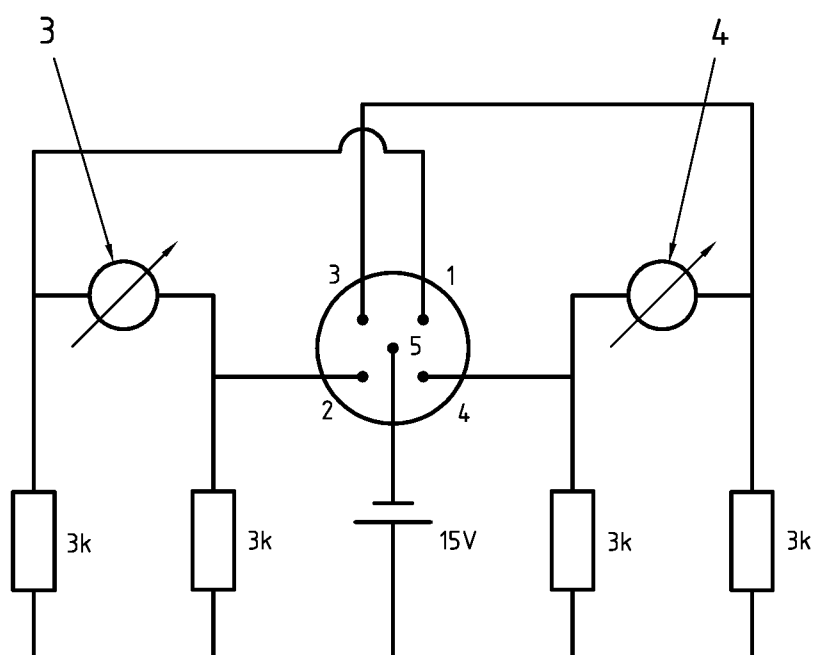
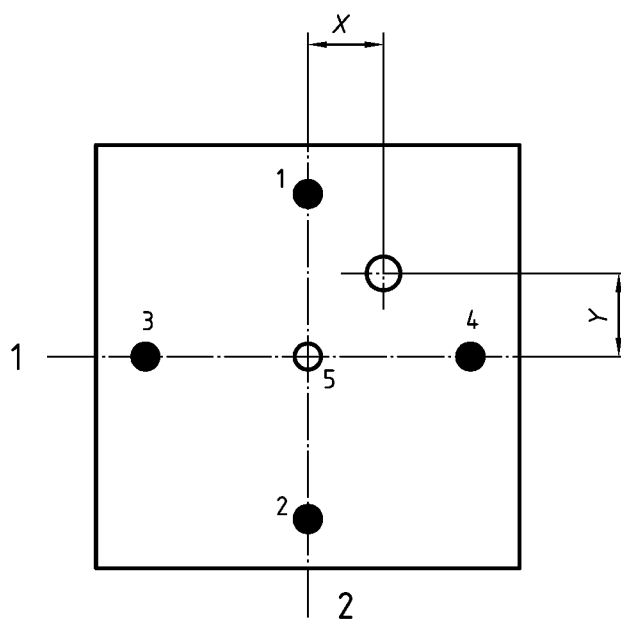
Figure A.1 — Determination of the distance f of the focal plane from the test ocular by means of two parallel rays 1 and 2



Key

- He-Ne Laser, wavelength = (600 ± 70) nm
- L1, L2 Lenses
- B Diaphragm, 0,1 mm nominal
- S1, S2 Deflection mirrors
- Sp Spiral
- Sch Carriage
- Fx, Fy Guides in x and y directions
- A Test sample
- Ph Photo-detector
- V Preamplifier
- XY XY recorder

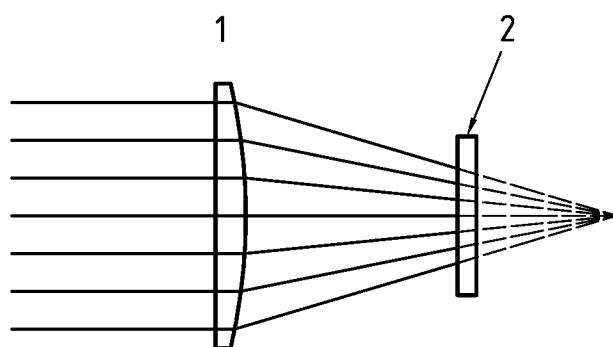
Figure A.2 — Test apparatus



Key

- 1 Axe x
- 2 Axe y
- 3 xy recorder (y axis)
- 4 xy recorder (x axis)

Figure A.3 — Position sensing diode



Key

- 1 Test sample
- 2 Measuring plane

Figure A.4 — Diagrammatic view of the image in the measuring plane



a) refractive power without astigmatic refractive power



b) refractive power with astigmatic power



c) irregular refractive power

Figure A.5 — Measuring curves for oculars with different refractive properties

Annex B (informative)

Uncertainty of measurement and results interpretation

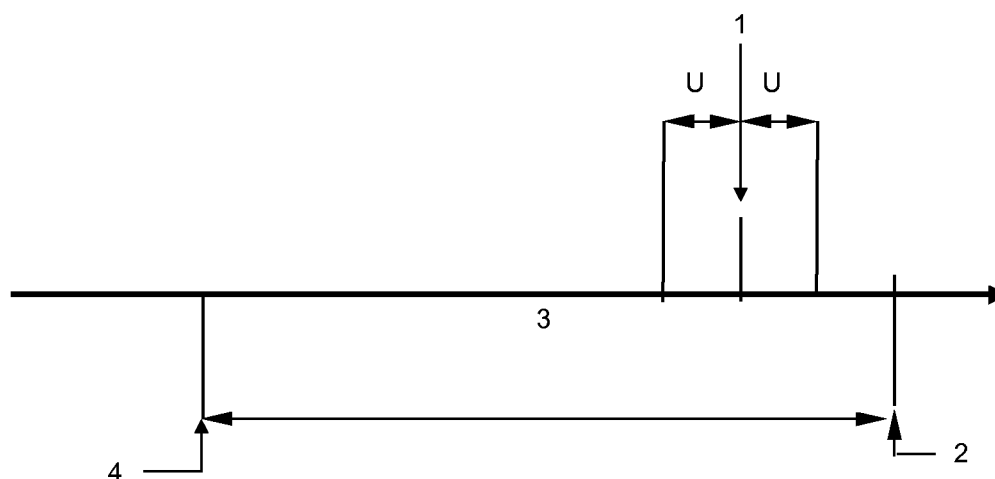
B.1 Test report and uncertainty of measurement

For each of the required measurements performed in accordance with this standard, a corresponding estimate of the uncertainty of measurement shall be evaluated.

This estimate of uncertainty shall be applied and stated when reporting test results, in order to enable the user of the test report to assess the reliability of the data.

The following protocol with regard to uncertainty of measurement shall be applied to test results:

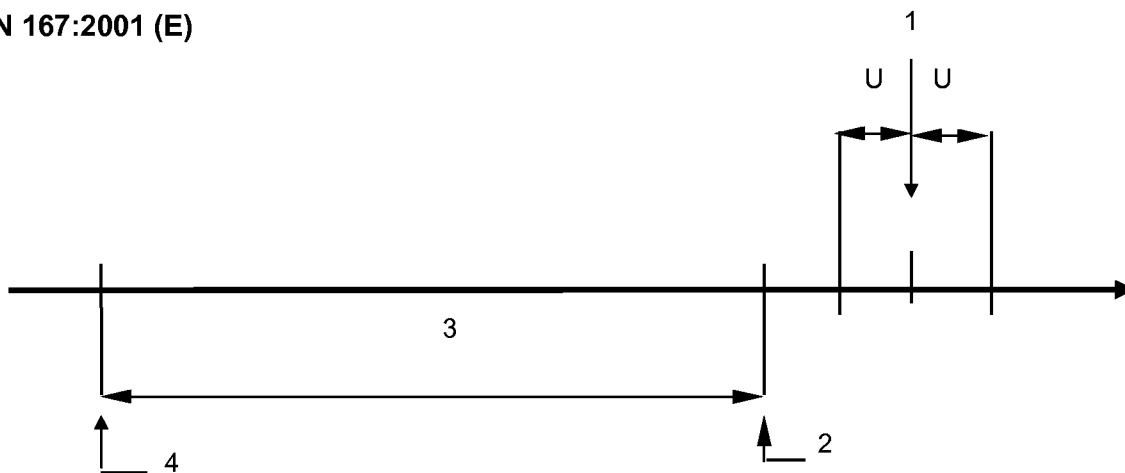
If the limit value for the particular test given in the standard, falls outside of the range of values calculated from the test data plus/minus the uncertainty U of measurement, then the result shall be deemed to be a straightforward pass or fail (Figures B.1 and B.2).



Key

- 1 Result of a measurement
- 2 Upper specification limit (USL)
- 3 Specification zone
- 4 Lower specification limit (LSL)

Figure B.1 — Result pass

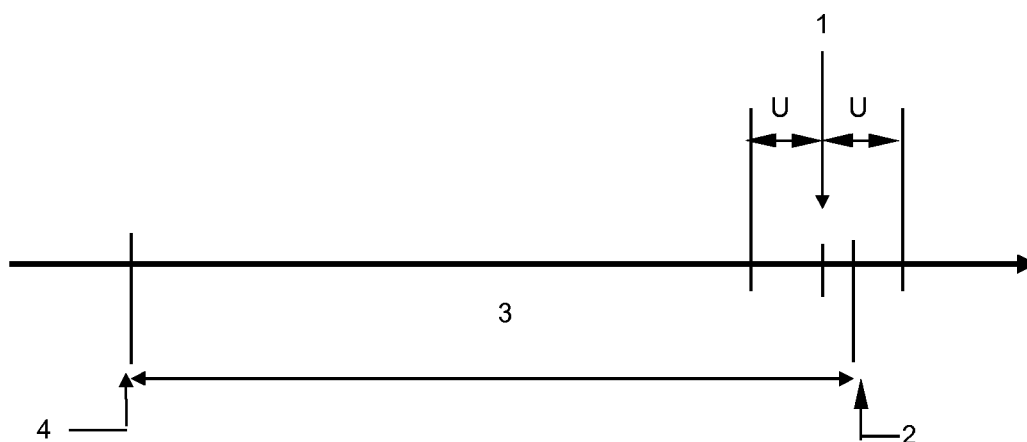


Key

- 1 Result of a measurement
- 2 Upper specification limit (USL)
- 3 Specification zone
- 4 Lower specification limit (LSL)

Figure B.2 — Result fail

If the limit value for the particular test given in the standard, falls within the range of values calculated from the test data plus/minus the uncertainty U of measurement, then the assessment of pass or fail shall be determined on the basis of safety, that is considering the safest conditions for the user of the PPE (Figure B.3).



Key

- 1 Result of a measurement
- 2 Upper specification limit (USL)
- 3 Specification zone
- 4 Lower specification limit (LSL)

Figure B.3 — Result fail

Annex ZA (informative)

Clauses of this European Standard addressing essential requirements or other provisions of EU Directives

This European Standard has been prepared under a mandate given to CEN by the European Commission and the European Free Trade Association and supports essential requirements of EU Directive 89/686/EEC.

WARNING Other requirements and other EU Directives may be applicable to the product(s) falling within the scope of this standard.

The clauses of this standard specify test methods relating to EN 166 and other European Standards to support requirements of Directive 89/686/EEC, Annex II, clauses 1.1.2.1, 1.1.2.2, 1.2.1.3, 2.3 and 3.9.1

Compliance with the clauses of this standard provides one means of conforming with the specific essential requirements of the Directive concerned and associated EFTA regulations.

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