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Optics and optical instruments — Test methods for telescopic systems —

Part 1:
Test methods for basic characteristics

Optique et instruments d'optique — Méthodes d'essai pour systèmes télescopiques —

Partie 1: Méthodes d'essai des caractéristiques fondamentales

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

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The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 14490-1 was prepared by Technical Committee ISO/TC 172, *Optics and photonics*, Subcommittee SC 4, *Telescopic systems*.

ISO 14490 consists of the following parts, under the general title *Optics and optical instruments — Test methods for telescopic systems*:

⎯ *Part 1: Test methods for basic characteristics*

⎯ *Part 2: Test methods for binocular systems*

⎯ *Part 3: Test methods for telescopic sights*

⎯ *Part 4: Test methods for astronomical telescopes*

⎯ *Part 5: Test methods for transmittance*

⎯ *Part 6: Test methods for veiling glare index*

⎯ *Part 7: Test methods for limit of resolution*

The following part is under preparation:

⎯ *Part 8: Test methods for night-vision devices*

Optics and optical instruments — Test methods for telescopic systems —

Part 1:
Test methods for basic characteristics

1 Scope

This part of ISO 14490 specifies the test methods for the determination of the following basic characteristics of telescopic systems and observational telescopic instruments:

— angular magnification (see Clause 4);

— entrance pupil diameter (see Clause 5);

— exit pupil diameter and eye relief (see Clause 6);

— angular field of view in the object space (see Clause 7);

— angular field of view in the image space (see Clause 8);

— angular field of view in the object space for spectacle wearers (see Clause 9);

— collimation of the bundle of rays emergent from the eyepiece (see Clause 10);

— image rotation (see Clause 11);

— closest distance of observation (see Clause 12).

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 14132-1:2002, *Optics and optical instruments — Vocabulary for telescopic systems — Part 1: General terms and alphabetical indexes of terms in ISO 14132*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 14132-1 apply.

4 Method of measurement of the angular magnification

4.1 General

In accordance with ISO 14132-1, the angular magnification Γ of a telescopic system is defined by the following equation:

$$\Gamma = \frac{\tan w'}{\tan w} \approx \frac{w'}{w} \qquad (1)$$

where w and w' are angles that the axes of conjugate beams make with the optical axis in the object space and image space, respectively.

The method of measurement of the angular magnification is based on the measurement of the angular size of an object placed in the field of view of a test specimen and that of its image.

4.2 Test arrangement

Measurement of the magnification shall be carried out with the angular test arrangement shown in Figure 1.

For systems for which the magnification is to be measured under a focus setting other than infinity, the collimator scale shall be adjusted in order to form the image of the scale at the specified distance from the test specimen.

The test arrangement shall be provided with a green optical filter to avoid any chromatism of the image. The maximum transmittance of the filter shall be at a wavelength of about 0,55 μm.

As an optical angular measuring device, one of the following shall be used:

— a telescope with a scale having divisions of known angular size;

— a telescope with a micrometer eyepiece;

— any other angle-measuring device which assures the required measurement precision.

The same method should be used for Galilean telescopes.
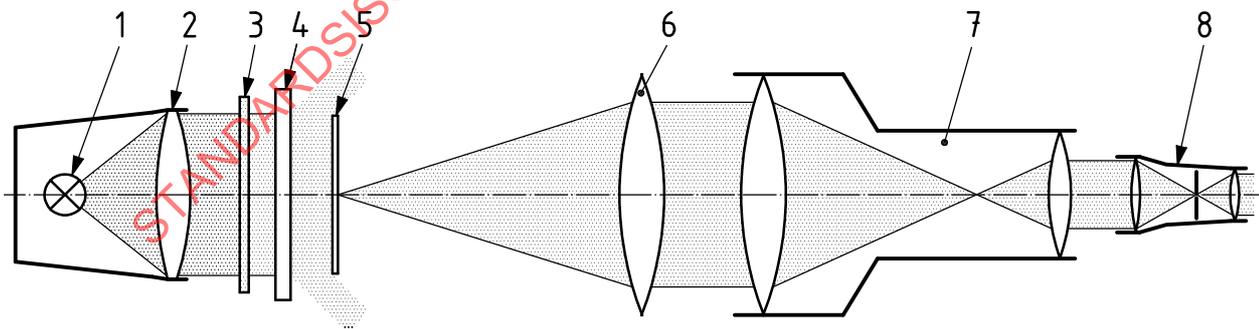
Key

1 light source
2 condenser
3 filter
4 diffusing plate
5 scale
6 collimator lens
7 test specimen
8 optical angle measuring telescope

Figure 1 — Test arrangement for measurement of the angular magnification

4.3 Procedure

Before starting the measurements, adjust the eyepiece of the test specimen to $0\ m^{-1}$ and focus the test specimen onto an infinitely remote object.

Determine the number of telescope (8 in Figure 1) scale divisions covered by an integral number of collimator scale (5 in Figure 1) image divisions produced by the test specimen.

If a telescope with a micrometer eyepiece is used, measure the angular size of the image of a part of the collimator scale (5 in Figure 1) produced by the test specimen.

4.4 Determination of results

The magnification Γ that is to be found is defined as the ratio of the size of the image of the collimator scale (5 in Figure 1) produced by the telescope to the size of the corresponding part of the collimator scale.

For the case in which a telescope with a micrometer eyepiece is used

$$\Gamma = \frac{n \cdot a_1}{m \cdot a_2}$$

(2)

where

n is the number of divisions of the telescope (8 in Figure 1) scale that corresponds to the number of divisions m of the collimator scale (5 in Figure 1) image;

a_1 is the scale division value of the measuring telescope scale;

a_2 is the scale division value of the collimator scale.

The uncertainty of magnification shall be less than one third of the maximum deviation from the nominal value specified in the relevant specification standard. For calculation of the magnification difference between the telescopes of a binocular having a magnification of 6× or more, this tolerance shall be reduced by half.

4.5 Test report

A test report shall be presented and shall include the general information specified in Clause 13 and the result of the test as specified in 4.4.

5 Method of measurement of the entrance pupil diameter

5.1 General

The method of measurement of the entrance pupil diameter D is based on viewing a reticle which is placed near the entrance pupil through the test specimen and reading off the linear size of the entrance pupil diameter.

5.2 Test arrangement

For a schematic representation of the test arrangement see Figure 2.

The test arrangement shall be provided with a green optical filter to avoid any chromatism of the image. The maximum transmittance of the filter should be at a wavelength of about 0,55 µm.

The same method shall be used for Galilean telescopes.
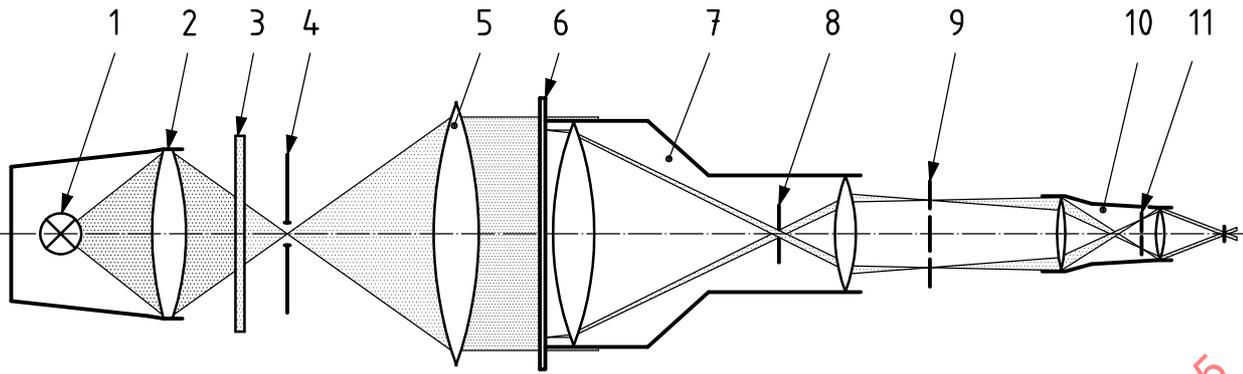
Key

1	light source	5	collimator lens	9	exit pupil; reticle optional
2	condenser	6	reticle	10	magnifier or microscope
3	filter	7	test specimen	11	scale
4	pinhole	8	intermediate image		

Figure 2 — Test arrangement for the measurement of the entrance pupil diameter

5.3 Procedure

To measure the entrance pupil diameter, set a reticle with a fixed scale (or two adjustable knife edges) immediately in front of the test specimen's objective lens.

Illuminate the reticle marks (or knife edges) with a collimator. Position a field stop, whose apparent size may not exceed three arc minutes, in the focal plane of the collimator.

Use a microscope or a magnifier behind the eyepiece of the test specimen. Determine which two reticle marks are coincident with the edges of the entrance pupil (or adjust the knife edges to be coincident with the edges of the entrance pupil).

The distance between the reticle marks (or knife edges) coincident with the edges of the entrance pupil is equal to the entrance pupil diameter.

5.4 Determination of results

The result is determined by reading off the distance (in mm) between the reticle marks (or knife edges).

The distance between the reticle marks (or knife edges) in front of the lens can easily be determined with a precision of 0,1 mm. In order to make sure the uncertainty is less than 1 %, a microscope or magnifier of sufficient magnification shall be chosen appropriately for the specimen being tested.

5.5 Test report

A test report shall be presented and shall include the general information specified in Clause 13 and the result of the test as specified in 5.4.

6 Method of measurement of the exit pupil diameter and eye relief

6.1 General

The exit pupil diameter D' is defined to be the size of the image of the entrance pupil produced by the test specimen.

The eye relief l' is defined as the distance of the exit pupil from the vertex of the last optical surface of the eyepiece.

6.2 Test arrangement

The exit pupil diameter of the test specimen and the eye relief shall be measured with the test arrangement shown in Figure 3.

The test arrangement shall be provided with a green optical filter to avoid any chromatism of the image. The maximum transmittance of the filter shall be at a wavelength of about 0,55 µm.
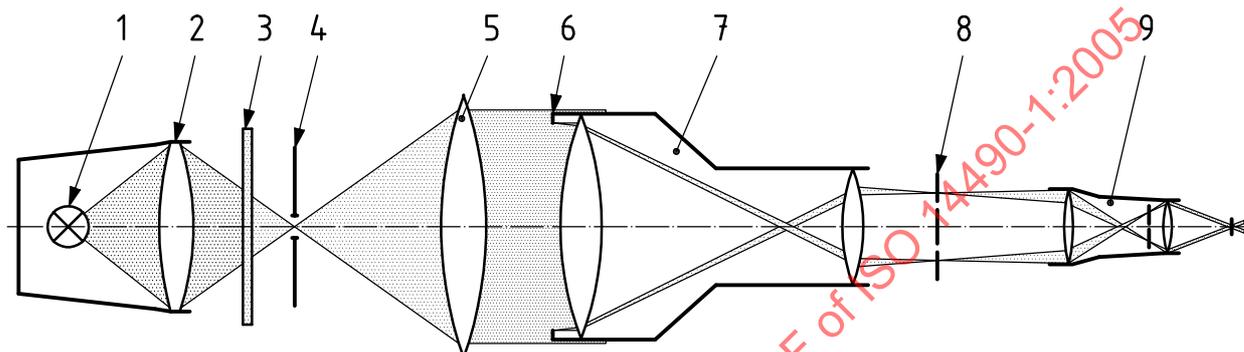
Key

1	light source	4	pinhole	7	test specimen
2	condenser	5	collimator lens	8	exit pupil; reticle optional
3	filter	6	entrance pupil	9	measuring microscope

Figure 3 — Test arrangement for the measurement of the exit pupil diameter and eye relief

6.3 Procedure

Before starting the measurements, adjust the eyepiece of the test specimen to 0 m^{-1} and focus the test specimen onto an infinitely remote object.

To measure the diameter of the exit pupil, focus the measuring microscope onto the exit pupil. Bring the image of the pupil into coincidence with the microscope reticle scale and count the number of scale divisions covering the diameter of the exit pupil image.

To measure the eye relief, focus the measuring microscope first onto the exit pupil, then onto the vertex of the last refracting surface of the test specimen.

6.4 Determination of results

Calculate the exit pupil diameter D' (in mm) in accordance with the equation

$$D' = n \cdot K \tag{3}$$

where

n is the number of scale divisions covering the exit pupil diameter of the test specimen;

K is the linear scale division value, in millimetres, of the measuring microscope.

Determine the eye relief l' (in mm) as the difference of readouts from the external scale of the measuring microscope during its axial travel:

$$l' = (a_1 - a_2)K_1 \tag{4}$$

where

a_1 and a_2 are the readouts from the external scale of the measuring microscope when it is focused on the exit pupil and on the last refracting surface of the eyepiece of the test specimen;

K_1 is the scale value of the external scale of the measuring microscope, in mm, per scale division.

The uncertainty of the exit pupil diameter shall be within ± 1 % of the nominal value.

The uncertainty of the eye relief shall be within ± 3 % of the nominal value.

6.5 Test report

A test report shall be presented and shall include the general information specified in Clause 13 and the result of the test as specified in 6.4.

7 Method of measurement of the angular field of view in the object space

7.1 General

The angular field of view 2ω is defined as the extent of the object space, in angular measure, observed through the telescopic system.

7.2 Test arrangement

The angular field of view in the object space shall be measured with the test arrangement shown in Figure 4.

An angular scale shall be placed in the focal plane of the wide-angle collimator.

For systems that require the angular field of view in the object space to be measured with a focus other than infinity, the collimator scale shall be adjusted in order to form the image of the scale at the specified distance from the test specimen.

7.3 Procedure

Install the test specimen lined-up in front of the collimator lens.

Adjust the eyepiece of the test specimen to 0 m^{-1}, then focus the test specimen to obtain a sharp image of the collimator scale.

During observation through the test specimen, count the number of the collimator scale divisions that cover the test specimen's field of view.

Key
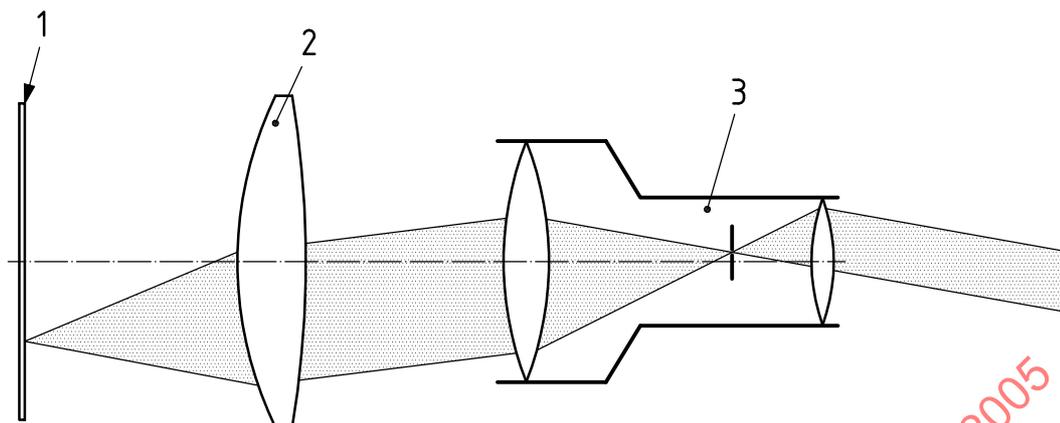
1   scale
2   wide-angle collimator lens
3   test specimen

Figure 4 — Test arrangement for the measurement of the angular field of view in the object space

Alternatively, the field of view may be measured by means of a goniometer. The test specimen should be placed in front of the collimator lens onto a rotational stage (which rotates about a vertical axis). A vertical line at the focal plane of the collimator lens should alternately be brought into coincidence with the right and left edge of the field stop of the test specimen. The field of view in the object space is determined by the difference between the angular readouts at the two positions.

7.4   Determination of results

Calculate the value of the full angular field of view 2ω (degree, minute of angle) by multiplication of the number of scale divisions m by the collimator scale division value b (degree, minute of angle):

$$2\omega = b \cdot m \tag{5}$$

For Keplerian telescopes, the uncertainty shall be less than $5'$. The image quality of the test specimen has an influence on the uncertainty.

7.5   Test report

A test report shall be presented and shall include the general information specified in Clause 13 and the result of the test as specified in 7.4.

8   Method of measurement of the angular field of view in the image space

8.1   General

The size of the angular field of view in the image space $2\omega'$ is determined by means of an angular measurement.
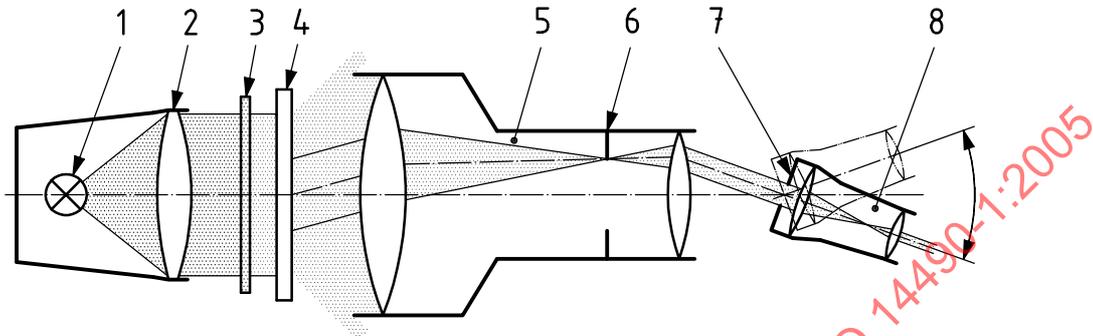
8.2   Test arrangement

On the eyepiece-side of the test specimen, an auxiliary telescope is mounted on a rotation table with an angle-measuring device.

An auxiliary telescope with approximately threefold magnification, an entrance pupil diameter of about 3 mm and a bearing mark (e.g. cross wire) should be used.

In order to suppress colour fringes in the image, the use of green light (wavelength about 0,55 µm) is recommended.

See Figure 5 for a schematic representation of the test arrangement for specimens with a real exit pupil.

Key

1	light source	5	test specimen
2	condenser	6	field stop
3	filter	7	position of exit pupil
4	diffusing plate	8	auxiliary telescope

Figure 5 — Test arrangement for the measurement of the angular field of view in the image space for test specimens with a real exit pupil

8.3 Procedure

8.3.1 Test specimens with a real exit pupil

The rotation axis of the auxiliary telescope (8 in Figure 5) lies in coincidence with the exit pupil (7 in Figure 5) and in the plane of the entrance pupil of the auxiliary telescope. The rotation axis intersects at right angles the optical axis of the test specimen (5 in Figure 5) and the optical axis of the auxiliary telescope.

With the auxiliary telescope (8 in Figure 5) focused on the field stop (6 in Figure 5) of the test specimen (5 in Figure 5), rotate the telescope to successively place its bearing mark on opposite edges of the field of view.

Read the angle difference from the scale of the rotation device.

8.3.2 Test specimens with a virtual exit pupil

On the objective lens side of the test specimen, position a collimator with target marks for the object space field of view of the test specimen.

Place a stop with an aperture of 5 mm diameter at a distance of 8 mm from the last optical surface of the test specimen. The rotation axis of the auxiliary telescope is also 8 mm behind the back vertex of the last eyepiece surface and close to the plane of the entrance pupil of the auxiliary telescope. The rotation axis intersects at right angles the optical axis of the test specimen and the optical axis of the auxiliary telescope

With the auxiliary telescope (8 in Figure 5) focused on the collimator target marks, rotate the telescope to successively place its bearing mark on opposite edges of the field of view.

Read the angle difference from the scale of the rotation device.

8.4 Determination of results

The result of the measurement is determined by reading the angle difference (in degrees) from the scale of the rotation device.

The uncertainty shall be less than 20′. The image quality of the test specimen has an influence on the uncertainty.

8.5 Test report

A test report shall be presented and shall include the general information specified in Clause 13 and the result of the test as specified in 8.4.

9 Method of measurement of the angular field of view in the object space for spectacle wearers

9.1 General

Due to the fact that during observation through a telescopic system by a spectacle wearer, the position of his/her eye can differ significantly from that without spectacles, the angular field of view in the object space for spectacle wearers is specified separately when required. For such an occasion, a standard method of measurement of the specified parameter is needed.

9.2 Test arrangement

The angular field of view in the object space for spectacle wearers shall be measured with the test arrangement shown in Figure 6.

The measurement is made by means of the adapter shown in Figure 7 that consists of a spectacle lens without optical power and a stop of 3 mm diameter positioned behind the spectacle lens. The stop represents the eye pupil under daylight conditions.

The distance between the stop and the front vertex of the spectacle lens shall be 19 mm. This correlates with a corneal vertex distance of about 14 mm for European types of faces.

An angular scale shall be placed in the focal plane of the wide-angle collimator.

For systems that require the angular field of view in the object space for spectacle wearers to be measured with a focus setting other than infinity, the collimator scale shall be adjusted in order to form the image of the scale at the specified distance from the test specimen.

9.3 Procedure

Line up the test specimen in front of the collimator lens.

Adjust the eyepiece of the test specimen to 0 m^{-1}, then focus the test specimen to obtain a sharp image of the collimator scale.

Adjust the eye cups in the position specified by the manufacturer for observation with spectacles. Fix the adapter behind the eyepiece of the test specimen perpendicular to the optical axis. With this arrangement, bring the eye as close as possible to the adapter's hole and observe the scale placed in the focal plane of the collimator.

During observation through the test specimen, count the number of the collimator scale divisions that cover the test specimen's remaining field of view.
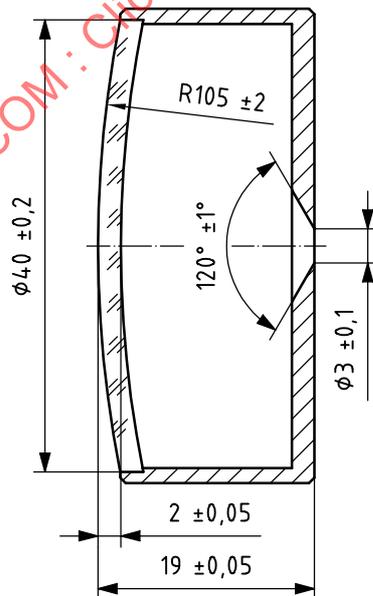
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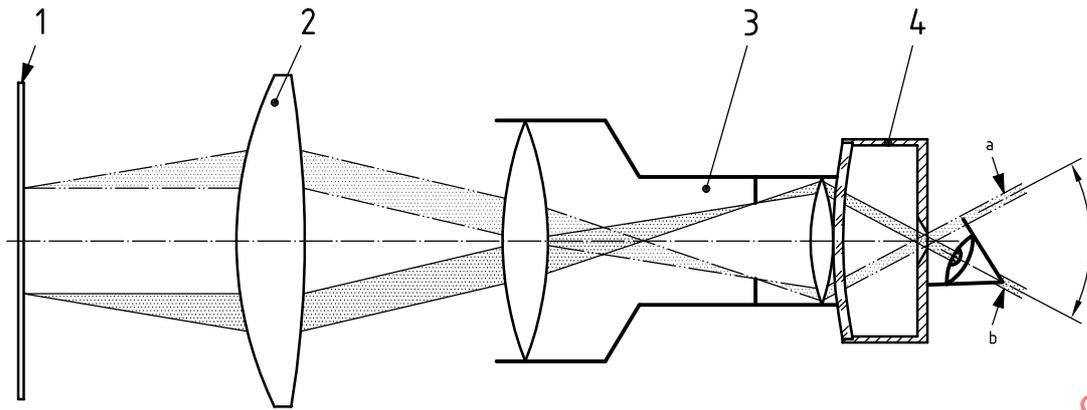
1   scale
2   wide-angle collimator lens
3   test specimen
4   adapter (see Figure 7)

a   Test position 1.
b   Test position 2.

**Figure 6 — Test arrangement for the measurement
of the angular field of view in the object space for spectacle wearers**

Dimensions in millimetres

**Figure 7 — Adapter for the measurement of the angular field of view
in the object space for spectacle wearers**

Alternatively, the field of view may be measured by means of a goniometer. The test specimen should be placed in front of the collimator lens onto the rotational stage (around the vertical axis). A vertical line at the focal plane of the collimator lens should alternately be brought into coincidence with the right and left edge of the field stop of the test specimen. The field of view in the object space is determined by the difference between the angular readouts at the two positions.

9.4 Determination of results

Calculate the value of the angular field of view for spectacle wearers $2\omega_s$ (degree, minute of angle) by multiplication of the number of scale divisions m by the collimator scale division value b (degree, minute of angle):

$$2\omega_s = b \cdot m \tag{6}$$

For Keplerian telescopes, the uncertainty shall be less than 10′. The image quality of the test specimen has an influence on the uncertainty.

9.5 Test report

A test report shall be presented and shall include the general information specified in Clause 13 and the result of the test as specified in 9.4.
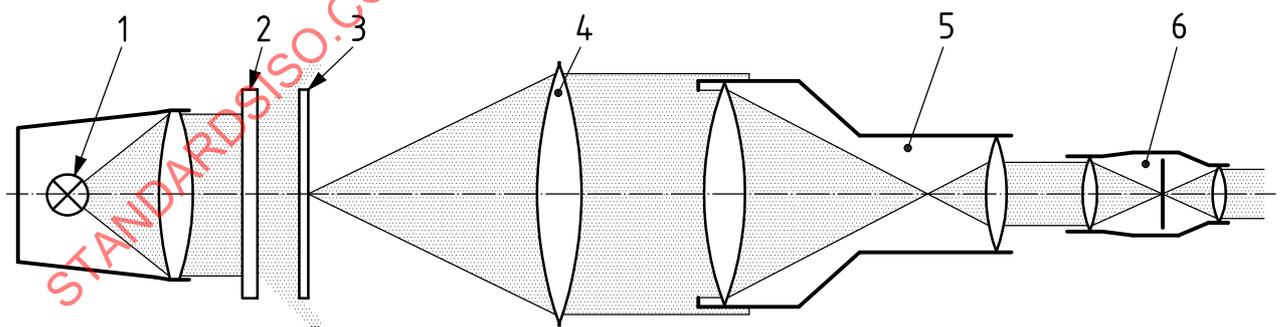
10 Method of measurement of the collimation of rays emergent from the eyepiece

10.1 General

The collimation of rays emergent from the eyepiece of the telescopic system shall be measured to ensure that the dioptre scale has been manufactured and assembled adequately and to determine the focusing range of the system.

10.2 Test arrangement

The collimation shall be measured with the test arrangement shown in Figure 8.

Key

1 light source
2 diffuser
3 test target
4 collimator lens
5 test specimen
6 dioptric tester

Figure 8 — Test arrangement for the measurement of the collimation