INTERNATIONAL STANDARD

ISO 517

Third edition
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Photography — Apertures and related properties pertaining to photographic lenses — Designations and measurements

Photographie — Ouvertures et grandeurs associées relatives aux objectifs photographiques — Désignations et mesurages

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Foreword

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ISO 517 was prepared by Technical Committee ISO/TC 172, *Optics and photonics*, Subcommittee SC 1, *Fundamental standards*.

This third edition cancels and replaces the second edition (ISO 517:1996) which has undergone minor technical revision.

Photography — Apertures and related properties pertaining to photographic lenses — Designations and measurements

1 Scope

This International Standard pertains to apertures and related properties of photographic lenses affecting the illuminance at the centre of the image.

This International Standard specifies aperture markings for all types of lenses used in still cameras, and gives tolerances for the stop numbers. It also defines aperture stop, entrance pupil, focal length, relative aperture and stop numbers, and gives methods for their measurement or determination.

This International Standard applies only to lenses focused on objects at infinity; that is, at least 50 times the focal length of the lens.

2 Terms and definitions

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

2.1
aperture stop
physical stop that limits the cross-section of the light beam that can pass through the lens to reach the centre of the on-axis image

2.2
entrance pupil
image of the aperture stop as viewed from a point in the object space on its optical axis (the image of the aperture stop formed by the front elements of the lens)

2.3
exit pupil
image of the aperture stop as viewed from a point in the image plane of the lens and on its optical axis (the image of the aperture stop formed by the rear elements of the lens)

2.4
focal length of the photographic lens
f
limiting value of the image size h' of a sharp imaged far-distant object h divided by its angular extension ω in the object space i.e.

$$f = -\lim_{\omega \to 0} \frac{h'}{\tan(\omega)}$$

See Figure 1.

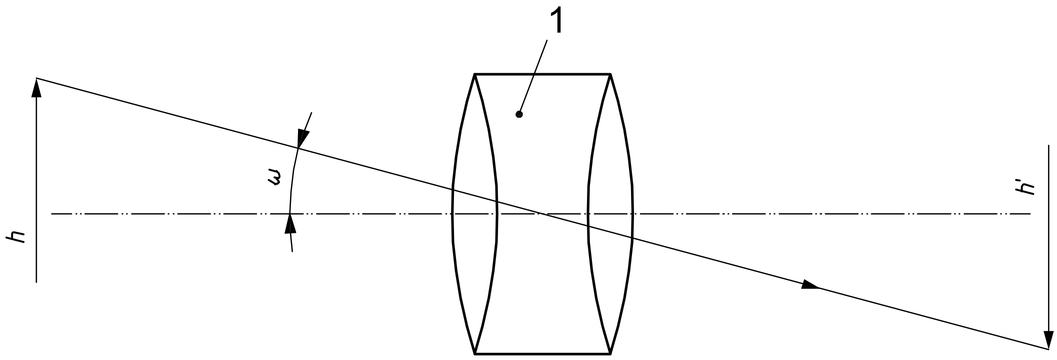
2.5
relative aperture of a photographic lens
twice the numerical aperture where the numerical aperture is the sine of the semi-angle subtended by the exit pupil at the focal plane

NOTE For photographic applications, the relative aperture is equivalent (within a 1/3 stop) to the ratio of the diameter of the entrance pupil to the focal length.

2.6
***f*-number**
stop number
the reciprocal value of the relative aperture (2.5)

2.7
true *f*-number
unrounded standard *f*-number

See 3.2.2.



Key

1 lens under test

NOTE The object size h is positive, the image size h' is negative and ω is positive.

Figure 1 — Focal length of a photographic lens (2.4)

3 Aperture markings

3.1 Designations

The relative aperture of a lens shall be designated by 1: followed by the numerical value of *f*-number, for example 1:2,8.

Where preferable, the symbol *f*/ followed by the number value may be used, for example *f*/2,8.

3.2 Marking series

3.2.1 Standard series of *f*-number marking

The standard series of *f*-number marking shall be as follows:

0,5 – 0,7 – 1 (or 1,0) – 1,4 – 2 – 2,8 – 4 – 5,6 – 8 – 11 – 16 – 22 – 32 – 45 – 64 – 90 – 128.

NOTE When *f*-numbers are marked on a lens, points may be used as decimal signs instead of commas.

3.2.2 Standard *f*-number series

The standard *f*-number, or “whole stop” series shall be calculated according to the following formula:

$$f\text{-number} = 2^{\frac{m}{2}}$$

where $m = -2, -1, 0, 1, 2, \ldots$ (m is an integer).

3.2.3 *f*-number of the maximum relative aperture

The *f*-number of the maximum relative aperture, that is the smallest *f*-number pertaining to the given lens, need not be selected from the standard series, but shall be followed by the series, beginning with the next larger number whenever practical, and progressing as far as required in the individual application.

EXAMPLE A 1:1,9 lens could be marked 1,9 − 2,8 − 4 − 5,6 − 8 etc., if it were believed that to mark it 1,9 − 2,0 − 2,8 − 4,0 − 5,6 etc., would confuse the markings at the 1,9 end of the scale.

3.2.4 Subdivisions of the standard *f*-number

Each standard *f*-number, or "whole stop", division of scale markings may be divided into two or three subdivisions in 1/2 or 1/3 steps of a stop calculated, for 1/2 subdivision, in a geometric series with first term 0,5 and factor $\sqrt[4]{2}$ and for 1/3 subdivision in a geometric series with first term 0,5 and factor $\sqrt[6]{2}$.

Table 1 gives the calculated whole, half and third stops.

Table 1 — *f*-number series

Whole stop	Half stop	Third stop	Whole stop	Half stop	Third stop
0,500	0,500	0,500			
	0,595	0,561	22,63	22,63	22,63
	0,707	0,630		26,91	25,40
0,707	0,841	0,707		32,00	28,51
	1,000	0,794	32,00	38,05	32,00
	1,189	0,891		45,25	35,92
1,000	1,414	1,000		53,82	40,32
	1,682	1,122	45,25	64,00	45,25
	2,000	1,260		76,11	50,80
1,414	2,378	1,414		90,51	57,02
	2,828	1,587	64,00	107,6	64,00
	3,364	1,782		128,0	71,84
2,000	4,000	2,000			80,63
	4,757	2,245	90,51		90,51
	5,657	2,520			101,6
2,828	6,727	2,828			114,0
	8,000	3,175	128,0		128,0
	9,514	3,564			
4,000	11,31	4,000			
	13,45	4,490			
	16,00	5,040			
5,657	19,03	5,657			
		6,350			
		7,127			
8,000		8,000			
		8,980			
		10,08			
11,31		11,31			
		12,70			
		14,25			
16,00		16,00			
		17,96			
		20,16			

4 Tolerances of *f*-numbers for photographic lenses

The measured *f*-numbers shall equal the true *f*-number within the tolerances given in Table 2. If the full aperture *f*-number is selected from the standard series, the tolerance shall be applied to the true *f*-number.

Table 2 — Tolerances of measured *f*-numbers

Marked *f*-number	**Tolerances** (to true *f*-number)
Full aperture	± 5 %
Smaller than *f*/5,6	+ 12 % − 11 % (± 1/3 stop)
f/5,6 and larger	+ 19 % − 16 % (± 1/2 stop)

5 Methods for measuring effective entrance pupil and focal length

5.1 General

There are a number of possible procedures for measuring the effective entrance pupil and focal length of a photographic lens, which may be used if the measuring errors are within the permissible tolerances. As examples, two of the methods most frequently used for measuring the entrance pupil and two methods for measuring the focal length are given in 5.2.

NOTE These measurement methods are appropriate for lenses of focal lengths from 20 mm to 500 mm and with apertures from 5 mm to 100 mm. For lenses outside this range, other methods might be appropriate.

5.2 Measurement methods

5.2.1 Effective entrance pupil

5.2.1.1 Method 1 for measuring the diameter of the effective pupil of a photographic lens

5.2.1.1.1 Principle

Method 1 uses a direct measurement of the entrance pupil diameter.

5.2.1.1.2 Apparatus

5.2.1.1.2.1 Travelling compound microscope, with means for shifting the microscope in a direction at right angles to its axis through a measured distance not less than the diameter of the effective entrance pupil to be measured. The microscope shall have a working distance sufficiently long to permit the microscope to be focused on the limiting opening of the photographic lens through its front element, and shall be fitted with a reticle.

5.2.1.1.2.2 Extended light source.

5.2.1.1.3 Procedure

Mount the photographic lens, the effective entrance pupil of which is to be measured, with its axis parallel to the axis of the measuring microscope (5.2.1.1.2.1). Illuminate the lens using the extended light source (5.2.1.1.2.2) through its rear element and direct the front element of the lens towards the measuring microscope.

Focus the microscope upon the edge of the opening with the smallest apparent diameter. The microscope is then traversed. By measuring its displacement, determine the diameter of this opening, which is the effective entrance pupil. If the opening is not circular, the diameter of a circle with the same area as that of the actual entrance pupil shall be used.

5.2.1.2 Method 2 for measuring the diameter of the effective entrance pupil of a photographic lens

5.2.1.2.1 Principle

Method 2 uses the telecentric projection system method.

5.2.1.2.2 Apparatus

5.2.1.2.2.1 Telecentric projection system, (hereafter referred to as "projection system") consisting of

— a projection lens;

— a telecentric aperture stop;

— a screen.

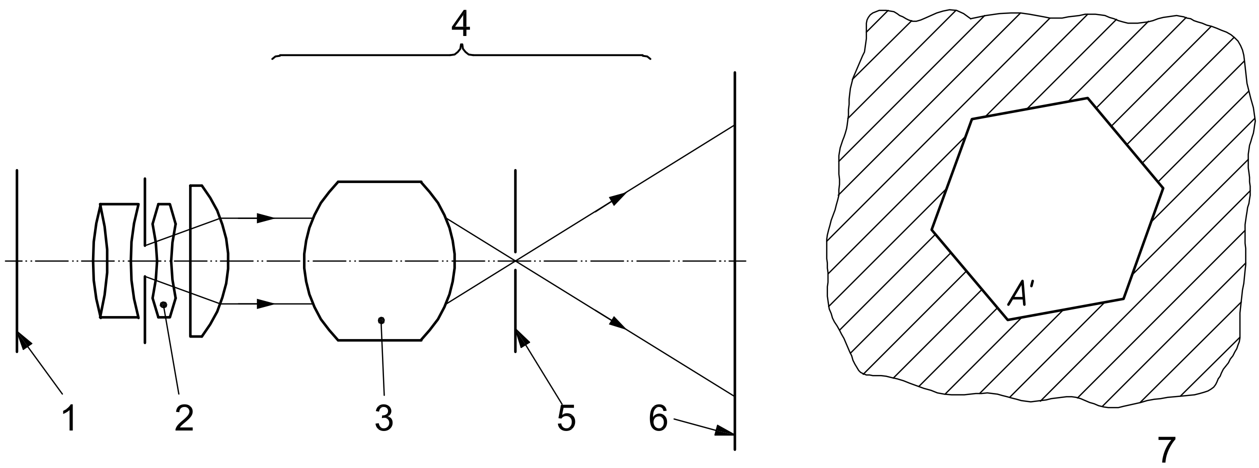
The projection system shall be aligned as shown in Figure 2.

5.2.1.2.2.2 Extended light source.

5.2.1.2.3 Procedure

5.2.1.2.3.1 Place the lens under test between the extended light source (5.2.1.2.2.2) and the projection system (5.2.1.2.2.1). The image side of the lens shall face the extended light source, with the optical axis of the lens coinciding with that of the projection system.

5.2.1.2.3.2 Move the lens under test along the optical axis of the projection system so as to obtain the sharpest image of the entrance pupil of the lens on the screen. Measure the area or diameter of the image. In doing this, the diameter of the telecentric aperture is adjusted so that the edge of the aperture's image A' (see Figure 2) is sharp enough for accurate measurement.



Key

1 extended light source
2 lens under test
3 projection lens
4 telecentric projection system
5 telecentric aperture stop
6 screen
7 image of the entrance pupil
A' area, in square millimetres, of the image of the entrance pupil

Figure 2 — Schematic layout of telecentric projection system apparatus (see 5.2.1.2.2)

5.2.1.2.3.3 Calibrate the lateral magnification of the projection system in the following manner.

Replace the lens by an object of known area or diameter, the shape and dimensions of which shall be approximately the same as those of the entrance pupil of the lens during normal use.

Project the image of the known object on the screen and measure the projected area or diameter.

In measuring the area or diameter of the known object, the diameter of the telecentric aperture stop shall be the same as in 5.2.1.2.3.2.

Determine the magnification by taking the ratio of the dimensions of the image to those of the known object.

5.2.1.2.4 Diameter of the relative aperture

Calculate this using the following equation:

$$d = \frac{2}{m}\sqrt{\frac{A'}{\pi}} = \frac{1{,}13}{m}\sqrt{A'}$$

where

d is the diameter, in millimetres, of the effective entrance pupil used to calculate the relative aperture;

A' is the area, in square millimetres, of the image of the entrance pupil (see Figure 2);

m is the magnification of the projection system.

NOTE If the shape of the lens aperture is circular, or can be regarded as a circle, the diameter of the relative aperture can be obtained from the following equation:

$$d = \frac{d'}{m}$$

where d' is the diameter, in millimetres, of the image of the entrance pupil.

5.2.2 Focal length

5.2.2.1 Method 1 for measuring the focal length of a photographic lens

5.2.2.1.1 Principle

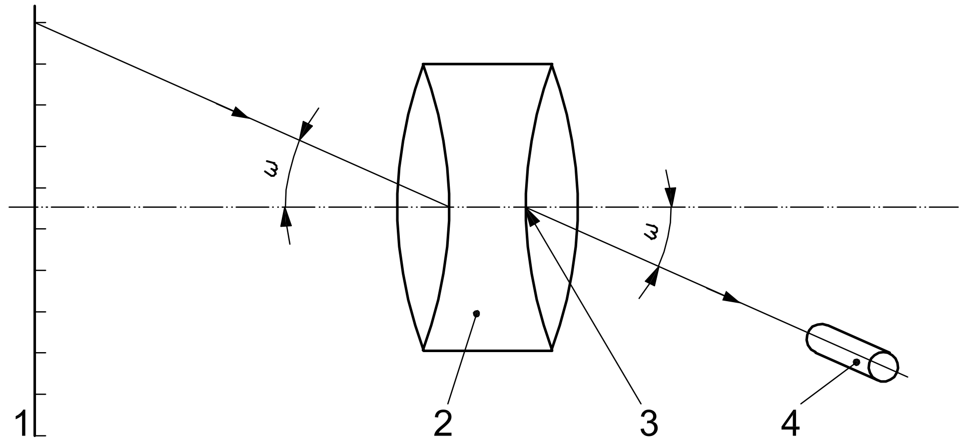
Method 1 for measuring the focal length of a photographic lens uses the formula given in 2.4.

5.2.2.1.2 Apparatus

5.2.2.1.2.1 **Telescope fitted with a reticle**, and of focal length suitable for observing the image at infinity of each graduation of the scale. The telescope shall be able to pivot approximately around the centre of the first nodal point of the test lens by an amount equal to or greater than the angle ω (see 2.4 and Figure 3). The aberrations of the telescope shall be small enough to not affect the measured values. The diameter of the telescope shall be greater than that of the entrance pupil of the lens to be tested.

5.2.2.1.2.2 **Extended monochromatic light source**, of wavelength $\lambda = 546$ nm (green mercury line).

5.2.2.1.2.3 **Engraved scale**.



Key

1 scale illuminated with light of wavelength $\lambda = 546$ nm

2 lens under test

3 first nodal point

4 teleoptics

Figure 3 — Schematic layout of apparatus for measuring the focal length (Method 1) (see 5.2.2.1)

5.2.2.1.3 Procedure

Place the engraved scale (5.2.2.1.2.3) with engraving h in the second focal plane of the test lens and illuminate it with the extended light source (5.2.2.1.2.2). If possible, focus the lens and measure the focal length at an aperture of f/5,6. Otherwise carry out the measurement at full aperture. Pivot the telescope (5.2.2.1.2.1) in such a way that the image of the graduations of the scale is aligned with the centre of the reticle and record the corresponding angle ω. In order to avoid measuring errors due to distortion, measure the relation

$$\frac{h'}{\tan(\omega)} \text{ (see 2.4)}$$

for several values of image heights h' and corresponding angles ω to evaluate the limiting value $\omega \rightarrow 0$.

5.2.2.2 Method 2 for measuring the focal length of a photographic lens

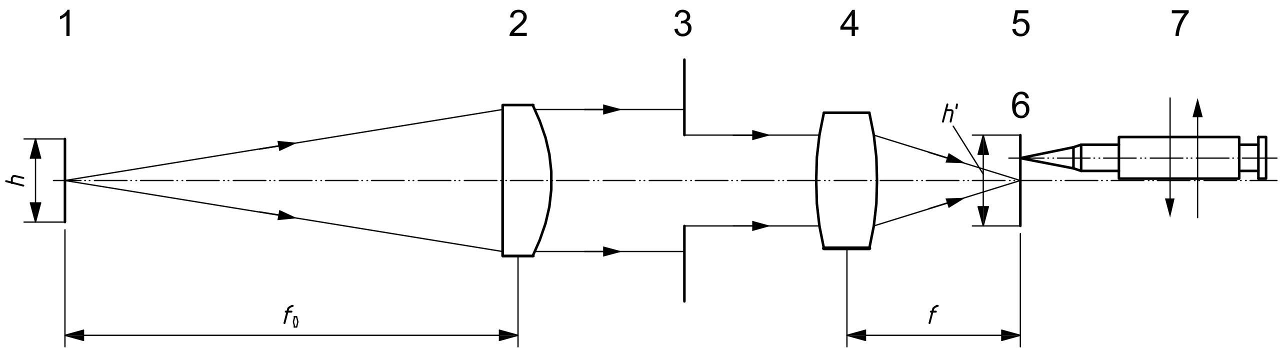
5.2.2.2.1 Apparatus

5.2.2.2.1.1 Collimator, of known focal length with target of known size in its focal plane, the size of the target not being more than 1/50 of the focal length of the collimator. The focal length of the collimator shall be at least three times the focal length of the lens under test. The aberrations of the collimator shall be small enough to not affect the measured values. The diameter of the exit pupil of the collimator shall be much greater than that of the entrance pupil of the lens to be tested (see Figure 4).

5.2.2.2.1.2 Microscope, with total magnification of approximately $\times$ 50.

5.2.2.2.1.3 Graduated scale, with an accuracy of 0,002 mm.

5.2.2.2.1.4 Extended monochromatic light source, of wavelength $\lambda = 546$ nm.



Key

1	target	h	height of the target
2	collimator	h'	height of the image of the target
3	aperture stop	f_0	focal length of the collimator
4	lens under test	f	focal length of the lens under test
5	image of the target		
6	screen		
7	microscope		

Figure 4 — Schematic layout of apparatus for measuring the focal length (Method 2) (see 5.2.2.2)

5.2.2.2.2 Procedure

Place the lens under test facing the collimator (5.2.2.2.1.1) and, using the extended light source (5.2.2.2.1.4), produce the image of the target on the screen. The aperture of the lens shall be set to f/5,6 if the full aperture f-number is f/5,6 or smaller, otherwise carry out the measurement at full aperture.

Measure the length of the image using the graduated scale (5.2.2.2.1.3) and calculate the focal length using the following equation:

$$f = f_0 \frac{h'}{h}$$

where

f is the focal length of the lens under test;

f_0 is the focal length of the collimator;

h is the length of the target at the focal plane of the collimator;

h' is the length of the image of the target at the focal plane of the lens under test.

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