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Camera shutters — Timing — General definition and mechanical shutter measurements

Obturateurs d'appareils photographiques — Durée d'exposition — Définition générale et mesurages d'obturateur mécanique

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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.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 42, *Photography*.

This fourth edition cancels and replaces the third edition (ISO 516:1999) which has been technically revised. The following changes have been made:

— The title and scope have been updated to reflect that the document is applicable to mechanical shutters.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

A superseded edition of this document was developed in the mechanical-shutters-only era. The scope of this edition has been changed as many digital still cameras with non-mechanical shutters are now introduced to the market.

Camera shutters — Timing — General definition and mechanical shutter measurements

1 Scope

This document provides a uniform basis for determining the exposure times for all types of shutters used in still cameras and contains suitable definitions of the terms used.

It specifies the exposure-time markings for all types of shutters and their tolerances.

The characteristics of all types of mechanical shutters, which are mounted in still cameras and affect the control of exposure, motion-stopping ability and synchronization with a photoflash light source are also defined.

The tolerances specified are the target values for the shutter performance that can be expected to give good results. They are not intended for application as a general inspection standard in controlling the performance of mechanical shutters, since tolerances may vary with the feature and price class of camera tested.

Test methods are described for routine manufacturing testing and quality control. These test methods require access to the focal plane of the camera and can therefore not be applied to assembled digital still cameras.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

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

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

3.1
front shutter
any shutter in the vicinity of the lens

Note 1 to entry: The front shutter can be in front of, behind or between the lens elements and can consist of rotating discs, rotating slats, sliding blades, oscillating blades, etc. Programmed shutters are also included.

Note 2 to entry: The common characteristic for the front shutter is that the entire picture area is exposed almost simultaneously.

Note 3 to entry: When the shutter and diaphragm are located too far apart, both exposure and shutter speed may vary at different points in the picture area.

3.2
focal-plane shutter
any shutter in the vicinity of the focal plane

Note 1 to entry: The focal-plane shutter can consist of fixed or variable slit curtains, rotating discs, sliding blades, etc.

Note 2 to entry: The essential feature of the focal-plane shutter is that the picture area is exposed incrementally, in such a way that the time required to expose the entire picture area is greater than the exposure time of any one point.

3.3
effective time
t_e
best measure of the amount of light falling on the picture area

Note 1 to entry: Effective time is defined by the following formula:

$$t_e = \frac{H}{E_0}$$

Note 2 to entry: At any point on the picture area, t_e is generally the same for the entire picture area for front shutters when vignetting is not severe. For focal-plane shutters, t_e will vary with w and v_c. The formula in Note 1 to entry can be approximated with the below formula for convenience in measurement:

$$t_e = \frac{w}{v_c} \text{ (focal plane shutter)}$$

The formula in Note 2 to entry can only be applied under the condition of $w \geq d_s/A$.

3.4
exposure time
t_{eo}
effective time measured at the centre of the picture area

3.5
total time
t_o
the time for which any given point in the picture area is exposed to light

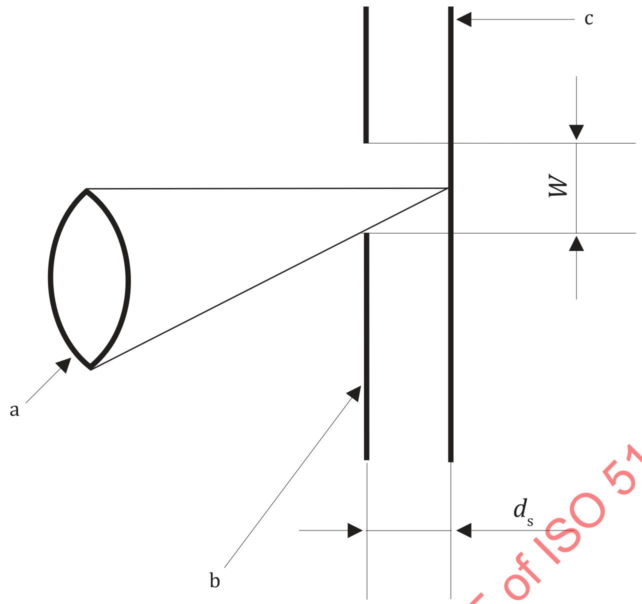
Note 1 to entry: At any point on the picture area, to is generally the same, or almost, on the entire picture area for front shutters.

Note 2 to entry: For a focal-plane shutter, however, to is dependent on w, A, d_s and V_c. The curtain displacement to completely expose one point becomes $w + d_s /A$, which can be converted to t_o, if the velocity is known, using the following formula:

$$t_o = \frac{w + \frac{d_s}{A}}{V_c}$$

Note 3 to entry: This formula can be inexact in the presence of vignetting.

See Figure 1.



a Taking lens.
b Curtain.
c Focal lens.

Figure 1 — Total time for a focal-plane shutter

3.6
shutter efficiency
η
ratio of effective time to total time

Note 1 to entry: The shutter efficiency is given by:

$$\eta = \frac{t_e}{t_o}$$

3.7
fluctuation of exposure time
p
the value of *p* is determined by the following formula

$$2^p = \frac{\bar{x} + \sigma}{\bar{\bar{x}} - \sigma}$$

where *x* and *σ* are the mean and standard deviation of the values of five successive measurements

3.8
ratio of two adjacent exposure times
q
ratio of the mean values of two adjacent shutter speed settings obtained from values of five successive measurements

Note 1 to entry: The ratio is expressed by the following formula:

$$2^p = \frac{t_{eo}(n)}{t_{eo}(n+1)}$$

Note 2 to entry: t_{eo} (n) and t_{eo} (n + 1) are the exposure times of two adjacent shutter speed settings represented by (n) and (n + 1).

3.9
non-uniformity of exposure
r
characteristic which may be found during any single exposure due to lack of coincidence with the principal plane (front shutter) or to variations in curtain velocity or slit width (focal-plane shutters)

Note 1 to entry: Such non-uniformity is expressed as the ratio of the maximum and minimum effective time found by exploring the picture area, and is derived from the following formula:

$$2^r = \frac{t_e \max}{t_e \min}$$

3.10
overall time
T
elapsed time for exposure of all points in the entire picture area

Note 1 to entry: For front shutters, $T = t_o$.

3.11
photoflash synchronization delay time
t_d
time interval from the initial closing of the shutter synchronization contacts to the moment at which the shutter element moves to the specified position (see 5.2)

Note 1 to entry: For details of ignition circuits of synchronizers, see ISO 10330.

3.12
X contact
synchronization contact for an electronic flash unit

Note 1 to entry: The contact closes while the shutter is fully opened to enable reception of the reflected light from the object through the aperture of the lens or for total illumination of the camera aperture. The X contact can sometimes be used for the M or MF class of photoflash lamp at the slower shutter speeds.

3.13
M contact
synchronization contact for M class of photoflash lamp

3.14
FP contact
synchronization contact for FP class of photoflash lamp

Note 1 to entry: This contact is provided only in the focal plane shutter and can be used for M or MF class of photoflash lamp at the slower shutter speeds.

4 Symbols

A f-number of the lens

b exposure time error

c tolerance for exposure time

d tolerance for stop

d_s distance between focal plane and curtain

E_o maximum illuminance (full open shutter)

E_v exposure value in units

e tolerance for exposure meter

f tolerance for film sensitivity

H exposure (time-integral of illuminance)

L film latitude

m magnification factor

n positive or negative integer, or zero

p fluctuation of exposure time, expressed in E_v

q ratio of two adjacent exposure times, expressed in E_v

r non-uniformity of exposure, expressed in E_v

s width of the mask slit in drum tester

T overall time, in seconds (see Figure 3)

t_c minimum contact duration, in seconds

t_d delay time, in seconds (see Figures 2 and 3)

t_E theoretical exposure time, in seconds [see Formula (1)]

t_e effective time, in seconds (see Figure A.2)

t_{eo} exposure time, in seconds (effective time measured at the centre of the picture area)

t_o total time, in seconds (see Figure A.2)

v_c average linear velocity of curtain

v_d linear velocity of rotating drum periphery

w width of the focal-plane curtain slit

η shutter efficiency

5 Required characteristics and their tolerances

5.1 Exposure time

Theoretical exposure times that form a series are given, in seconds, by the following formula:

$$t_E = \frac{1}{2^n} \tag{1}$$

Shutters shall be designed to provide exposure times selected from the series below, subject to the tolerances specified in 5.1.2.

....8,4,2,1,1/2,1/4,1/8,1/16,1/32,1/64,1/128,1/256,1/512,1/1 024,1/2 048...

NOTE 1 Timing of the shutters need be measured at the appropriate aperture of the lens used (see Figures 4 and 5). In the case of cameras that have interchangeable lenses, the standard lens is used for exposure-time measuring.

NOTE 2 In evaluating shutters without lenses, exposure times are measured under the conditions fixed so as to be equivalent to the requirements of this document.

NOTE 3 A change in n by one unit needs a change in time by a factor of 2. This unit is called E_V or a step.

5.1.1 Exposure time marking

The exposure-time marking shall be marked as the following rounded-off values of reciprocal numbers of the series specified in 5.1. Exposure times longer than 1 s shall not, however, be marked as reciprocal numbers, but should be made evident by colour or some other means of identification.

...8,4,2, 1,2,4,8, 15,30, 60, 125, 250, 500,1 000, 2 000...

The highest marking, however, need not necessarily be selected from this series, but the series beginning with the next lower number should be selected from this series, whenever practicable, and progressing as far as is required in the particular application.

5.1.2 Tolerances

The tolerances of exposure time error, fluctuation of exposure times, ratio of two adjacent exposure times and nonuniformity of exposure should be as shown in Table 1 (see also 7.1). The following Formula (2), in seconds, is applicable to the tolerance of the exposure time:

$$t_{eo} = \frac{1}{2^{(n+b)}} \tag{2}$$

Table 1 — Tolerances for *b*, *p*, *q* and *r*

Unit: E_V

Exposure time	Quantity			
	b[a]	p	q	r
1/125 and longer	±0,3	≤0,3	1 ± 0,45	≤0,2
shorter than 1/125	±0,45	≤0,45	1 ± 0,65	≤0,6

[a] The admissible values for individual exposure times are calculated and tabulated in Annex A.

Over the range of −10 °C to 40 °C, the tolerances specified in Table 1 should not be exceeded, with the exception of the tolerance for b which may be exceeded by ±0,25 E_V over the range of −10 °C to 0 °C. Furthermore, the relative humidity between −10 °C and 0 °C should be not more than 50 % and between 0 °C and 40 °C not more than 80 %.

5.2 Delay time

5.2.1 Front shutters

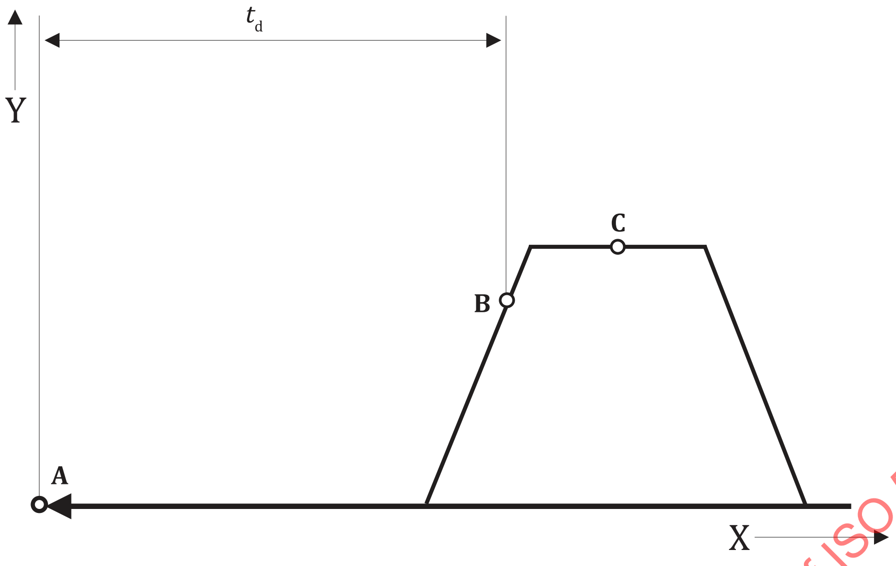
Delay time and minimum contact duration for synchronization shall be as given in Table 2.

Table 2 — Delay time of front shutter

Type of contact	Delay time of the synchronization contact		Minimum contact duration t_c ms
	t_d ms	Remarks	
X	—	Closing of the contacts shall take place between the moment (B) at which the shutter admits 80 % of the light admitted at the maximum aperture of the lens used and the moment (C) which is the halfway point of the fully open time of the shortest exposure time (see Figure 2). In spite of the above provision, closing of the contacts may take place after the moment (C) as long as the shutter admits more than 80 % of the light admitted at the maximum aperture of the lens used.	[a]
M	16 ± 3[b]	The time lapse from the closing of the contacts (A) to the moment (B) at which the shutter admits 80 % of the light admitted at the maximum aperture of the lens used. (See Figure 2.)	2,5

[a] The contact duration shall be 2,5 ms minimum for those ranges of shutter speeds listed in the instruction manual as suitable for use with any class of photoflash lamps. See ISO 10330 for use with the electronic flash.

[b] Not applicable to those shutters having a mechanism which changes the delay time in accordance with the exposure time.



Key

X time

Y illuminance

Figure 2 — Front-shutter delay time

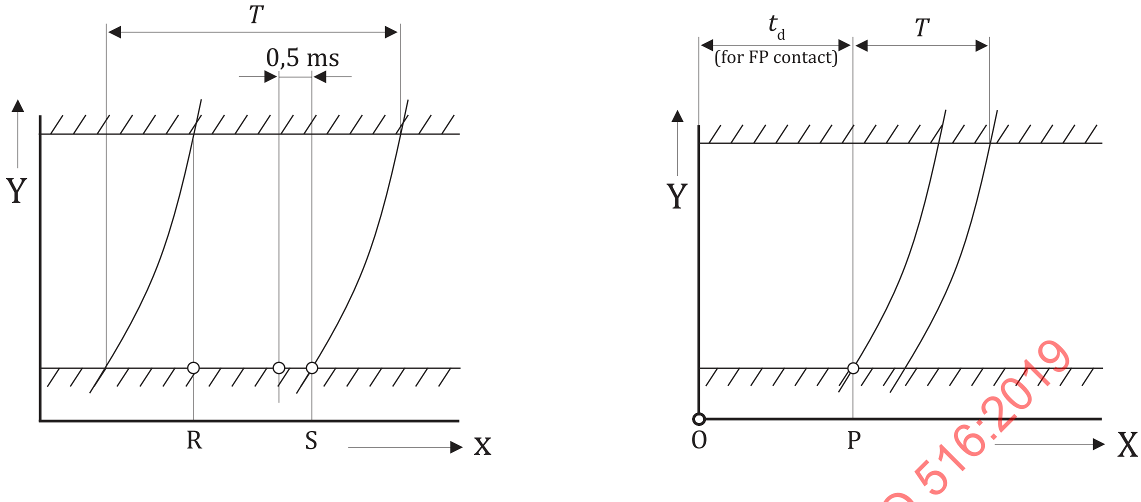
5.2.2 Focal-plane shutters

Delay time and minimum contact duration for synchronization shall be as given in Table 3.

Table 3 — Delay time of focal-plane shutter

Type of contact	Delay time of the synchronization contact		Minimum contact duration t_c ms
	t_d ms	Remarks	
X	—	Closing of contacts shall take place while the shutter is fully opened [after the moment (R) and not later than 0,5 ms before the moment (S) [shown in Figure 3 a)]	[a]
FP	10^{+5}_{-3}	The time laps from the closing of the contacts (O) to the moment (P) at which the shutter begins to open [see Figure 3 b)].	2,5

[a] The contact duration shall be 2,5 ms minimum for those ranges of shutter speeds listed in the instruction manual as suitable for use with any class of photoflash lamps. See ISO 10330 for use with the electronic flash.



a) For X-type contact

b) For FP-type contact

Key

X time

Y curtain stroke

Figure 3 — Focal-plane-shutter delay time

6 Test methods

6.1 General

The method described for each type of shutter, based on digital readout, is rapid and easy for routine manufacturing testing and quality control. As a rule, this method is applicable only to cases in which the character of the time-illuminance curve of the shutter has been proved consistent and acceptable by graphic methods such as those described in Annex A.

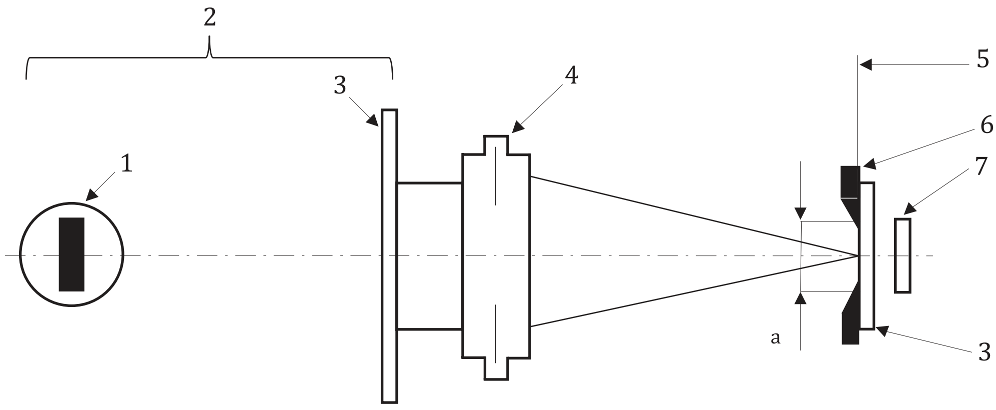
6.2 Apparatus

6.2.1 Apparatus

The light source shall consist of a lamp and a diffuser. Luminance at any point on the surface of the diffuser, measured perpendicular to the surface, shall be more than 95 % of the maximum luminance and the fluctuation of luminance shall not exceed ±5 %. Luminance of the diffuser, measured at any angle to the diffuser up to 60° from the normal, shall not be less than 85 % of the luminance measured perpendicular to the surface.

6.2.2 Detector

The frequency response of the combination of detector, cables and recording equipment shall be within ±3 dB from D.C. to $100/t_0$: for example for a total time of 1 ms, the frequency response shall be at least 100 kHz (50 % output power, i.e. 70 % output voltage, with sinusoidal input). This combination shall have a linear sensitivity characteristic between 1 % and 100 % of E_0. The sensitive area of the detector shall be large enough to receive all the light passing through the entrance aperture. (See Figure 4).



Key

1 lamp
2 light source
3 diffuser (the one in front of the detector is removable if the detector has uniform sensitivity over the entire sensitive area)
4 shutter with taking lens
5 focal plane
6 auxiliary mask
7 detector
a Entrance aperture (area < detector sensitive area).

Figure 4 — Test assembly for front-shutter timing measurement

6.2.3 Time-interval meter

A meter shall have an internal time base, a selection of ranges and an adjustable sensitivity. The frequency of the time base shall be sufficiently high for at least 100 samples to be taken during the minimum effective time to be measured.

6.3 Front-shutter test

6.3.1 Test assembly

The test assembly is shown in Figure 4. The fully opened standard lens shall be used as a taking lens.

6.3.2 Procedure

Pass a uniform light bundle through the shutter and into the detector (6.2.2) whose output is used to control the time-interval meter (6.2.3). Adjust the sensitivity of the meter to start and stop measurement when the detector output is at the level corresponding to the time (t_o or t_e) measured as in 6.3.2.1 and 6.3.2.2.

6.3.2.1 Total time, t_o

Adjust the light intensity and meter sensitivity so that gating occurs at 1 % ± 0,5 % E_o.

6.3.2.2 Effective time, t_e

Adjust the light intensity and meter sensitivity so that gating occurs at the fraction of E_0 that yields a time measurement, which is identical to effective time.

Determine the fraction as follows:

a) determine t_0 and t_e as in A.3;

b) read the height, E, above the baseline at which the rising and falling positions of the curve are separated by t_e;

c) the height, E, divided by E_0 is the fraction of illuminance at which the time measurement is started and stopped.

NOTE 1 If the trace is trapezoidal, t_e can be measured at 0,5 E_0.

NOTE 2 For front shutters, effective time varies with the aperture of the lens. Therefore, the fully opened lens shall be used for the measurement.

NOTE 3 For programmed shutters, effective time shall be measured at the aperture determined by the programming of the shutter.

6.3.2.3 Delay time, t_d

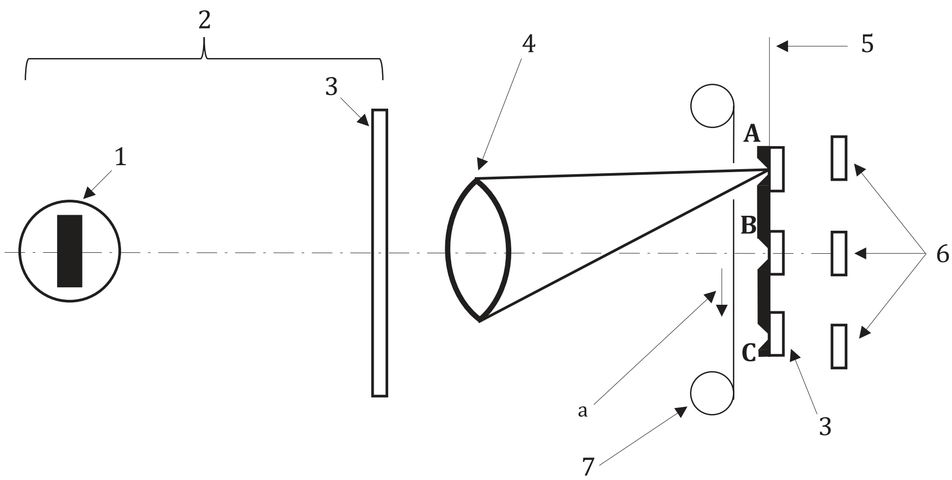
To measure the delay time of a M contact of the synchronization mechanism, adjust the time-interval meter to start the measurement with the closing of the synchronization contacts and to stop it when the detector output is at 0,8 E_0.

To check the closing time of an X contact, adjust the time-interval meter to start the measurement when the detector output reaches 0,8 E_0 and to stop it with the closing of the synchronization contacts. The measured value is compared with the time interval BC in Figure 2.

6.4 Focal-plane-shutter test

6.4.1 Test assembly

The test assembly is shown in Figure 5 (see also 7.2).



Key

1 lamp
2 light source
3 diffuser (the ones in front of the detector are removable if the detector has uniform sensitivity over the entire sensitive area)
4 taking lens
5 auxiliary mask with entrance slit A, B, C (focal plane)
6 detectors
7 curtain
a Travel.

Figure 5 — Test assembly for focal-plane shutter timing measurement

6.4.2 Procedure

Check the effective time by timing the passage of the shutter slit past a parallel entrance slit, using a technique similar to the method for the front shutters. Stop down the taking lens to the extent that the output of the shutter trace at the highest shutter speed setting forms a trapezoid.

Care shall be taken to ensure that the width of entrance slit is less than *w*. Use the standard lens as the taking lens.

Adjust the time-interval meter (6.2.3) to start the measurement when the detector (6.2.2) output corresponds to 0,5 E_0 (when one-half of the entrance slit is exposed) and to stop it when the output falls to 0,5 E_0 (when one-half of the entrance slit is again covered). Care shall also be taken, as in 6.3.2, when adjusting the meter sensitivity.

After the shutter design has been qualified, and consistency of operation proved by the method given in A.4, measurement in production line work may be carried out by digital methods, provided effective times are measured at three points (the centre and two points of about 45 % of the picture width from the centre) when r is to be measured. Some examples are shown in Table 4.

Table 4 — Examples of measuring points for non-uniformity of exposure

Dimensions in millimetres

Distance from the centre of the picture area	Picture size along shutter travel
10,5	24
16	36
25	56

6.4.2.1 Effective time, t_e

Read the effective time, t_e, independently for each slit point.

6.4.2.2 Non-uniformity of exposure, r

Calculate the non-uniformity of exposure, r , as the ratio of the extremes using formula in 3.9. The extremes usually occur at each end of the picture area.

6.4.2.3 Delay time, t_d

Determine the delay time of each contact as follows:

a) FP contact: Adjust the time-interval meter (6.2.3) to start measurement upon closing of the synchronization contacts and to stop it when the output of the detector (6.2.2) behind the slit A is at 0,5E_0. Calculate the delay time by subtracting the time that the curtain runs between the edge of the picture area and the slit A from the measured time.

b) X contact: To check the closing time, adjust the meter to start measurement when the output of the detector behind the slit C is at 0,5E_0 and to stop it upon closing of the synchronization contact. Calculate the delay time by subtracting the time that the curtain runs between the slit C and the edge of the picture area from the measured time.

Also adjust the meter to start measurement upon closing of the synchronization contacts and to stop it when the output of the detector behind the slit A is at 0,5E_0. Calculate the delay time by subtracting the time that the curtain runs between the edge of the picture area and the slit A from the measured time.

Both delay times shall be positive.

7 Explanatory notes

7.1 Tolerance

If tolerances are given for

— exposure time: *c*,

— stop: *d*,

— exposure meter: *e*,

— film sensitivity: *f*.

and those elements are controlled to show a normal distribution, the relationship of these tolerances and the film latitude L, to ensure good results, is as follows:

$$\sqrt{c^2+d^2+e^2+f^2}<L$$

However, as the scope of this document is limited to only the tolerance of exposure time, the tolerance of exposure time that has been conventionally employed is used in this document. At the low temperature range of −10 °C to 0 °C, a change of t_e up to 0,25E_v is allowed.

The value q is obtained if t_e, at each time setting, is controlled to make a normal distribution within the tolerance. For b = 0,45

$$q=\sqrt{0,45^2+0,45^2}$$

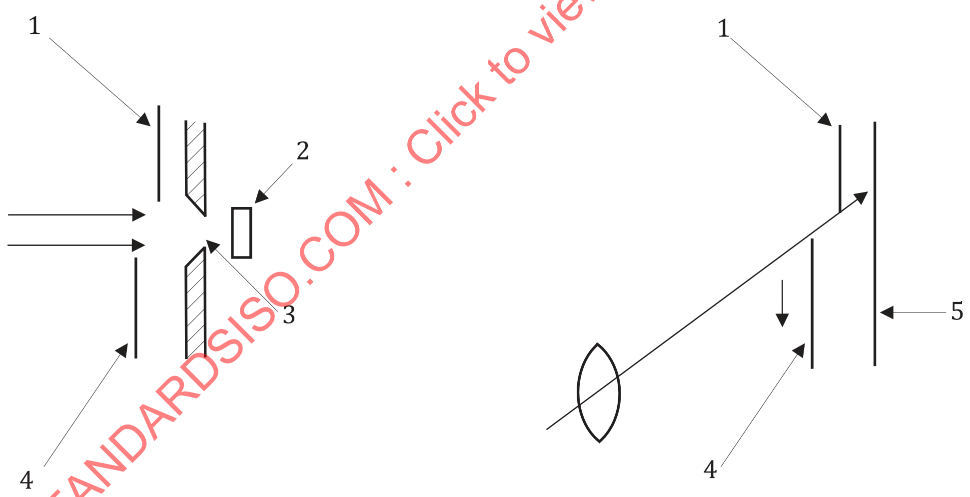
$$= 0,636$$

Hence, the rounded-off number 0,65 is used herein.

7.2 Test method

In general, most focal-plane shutters have front and rear curtains that cannot run on the same plane. Therefore, the value t_e measured with the parallel ray of light deviates from the value measured with an oblique ray of light (see Figure 6).

The test assembly as shown in Figure 5 represents the actual situation.



Key

1 rear curtain

2 detector

3 slit

4 front curtain

5 focal plane

Figure 6 — Measurement of t_e with parallel ray of light and oblique ray of light

Annex A
(normative)

Graphic test methods

A.1 General

Test methods for each shutter type described in this annex are graphic in nature, providing the most complete information about the shutter and providing a permanent record if desired. Electronic means may also be used to provide measurements of exposure and peak illuminance with high precision.

A.2 Apparatus

A.2.1 Cathode-ray tube oscilloscope.

An instrument with DC input is recommended for all times longer than 0,01 s. It is also recommended to use an oscilloscope with an internally calibrated horizontal linear sweep velocity; however, Z-axis modulation with an audio oscillator may be used but with the risk of inferior accuracy due to the difficulty in counting dots that are too closely spaced for an adequate time-resolution. If a storage oscilloscope is used, photography is required only to provide a permanent record.

A.2.2 Camera.

The trace recording camera shall introduce no error (such as parallax or distortion) greater than 3 % of the measured quantity.

A.2.3 Connecting leads.

Leads associated with the detector and the connections to the meter or scope shall be large (approximately 6 mm in diameter), shielded coaxial cable, kept as short as possible. Otherwise, false measurement may result because of excessive capacitance or induced pick-up.

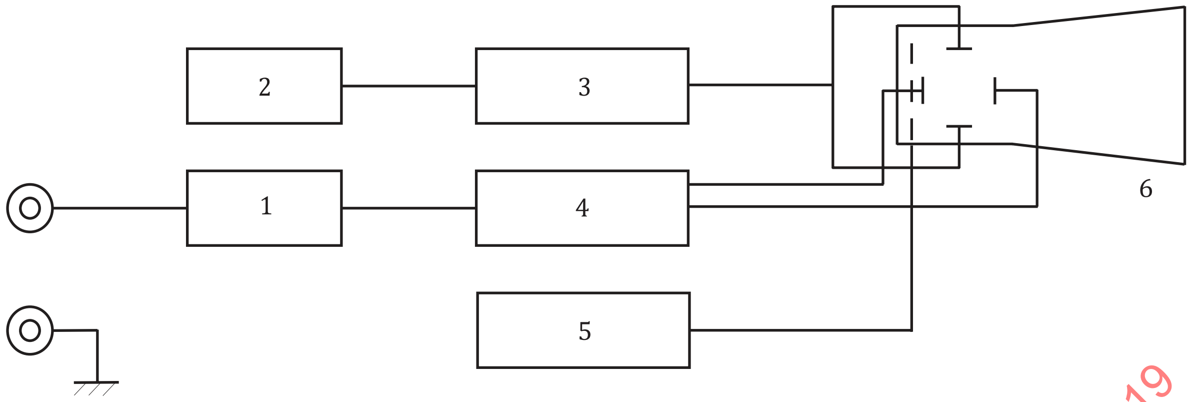
A.2.4 Revolving-drum tester (for focal-plane shutters).

A typical tester consists of a cylindrical drum having a diameter of approximately 100 mm with a means of tightly securing a strip of sensitized film or paper to the circumference of the drum. The drum is enclosed in a light-tight housing and driven by a motor. A variable-speed drive between motor and drum shall permit a variation of drum speed between 300 r/min and 150 r/min. The housing shall contain a slit less than 5 mm wide, parallel to the drum axis.

A.3 Front-shutter test

A.3.1 Test assembly

The test assembly is shown in Figures 4 and A.1.



Key

1 delay circuit
2 detector
3 amplifier
4 single sweep generator
5 timemaker
6 oscilloscope

Figure A.1 — Test assembly for front shutters

A.3.2 Procedure

Pass a uniform light bundle through the shutter and into the detector whose output is used to drive the vertical amplifier of the oscilloscope (A.2.1) set to single-sweep mode.

Use the delayed signal of the closing of the M contact to start sweeping. Set the sweep velocity to the most convenient calibrated value, for example 0,5 ms per division for an effective time of 1 ms.

The resulting trace and the illuminated gratitude may be recorded photographically or retained for viewing by a storage oscilloscope. Typical traces are shown in Figure A.2.

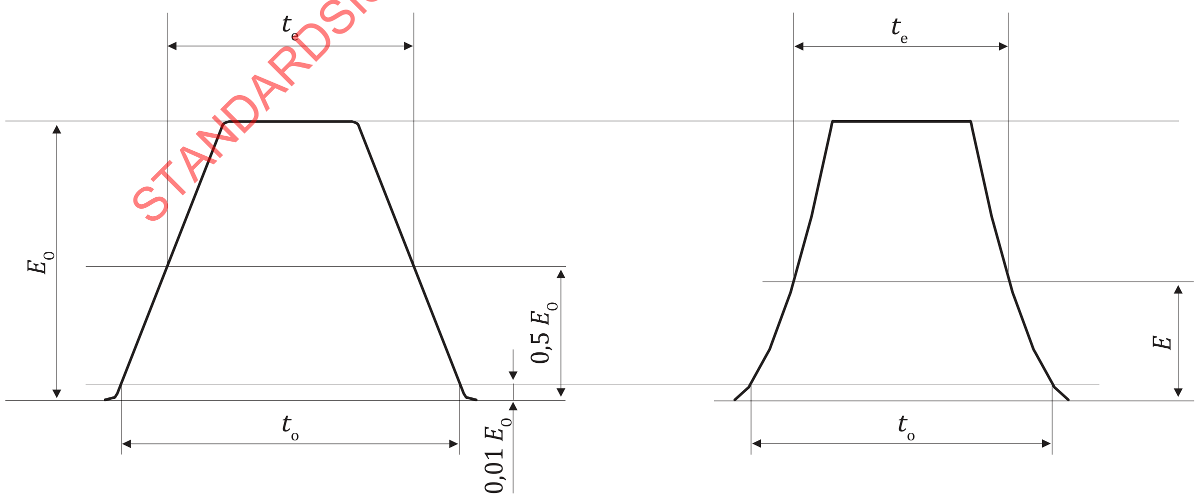


Figure A.2 — Typical shutter traces

A.3.2.1 Effective time, t_e

Read the effective time in the following way:

a) If the trace is trapezoidal, measure directly between the mid-intensity points on the trace.

b) If the trace is irregular, use a plainmeter or other method of measuring area in conjunction with a photographic recording of the trace.

A.3.2.2 Total time, t_o

Read directly from the trace, at a level of 0,01 E_o.

A.3.2.3 Non-uniformity of exposure, r

Compare the area of an off-axis trace with that of the on-axis trace obtained in this clause, using the equation

$$2^r = \frac{H_{max}}{H_{min}}$$

Move the mask to the point at which it is desired to check off-axis performance and adjust the position of the detector to pick up light in the correct spot. Adjust the light level or the oscilloscope sensitivity, or both, to obtain the same maximum oscilloscope deflection used in the on-axis trace. Compare the areas of the two traces.

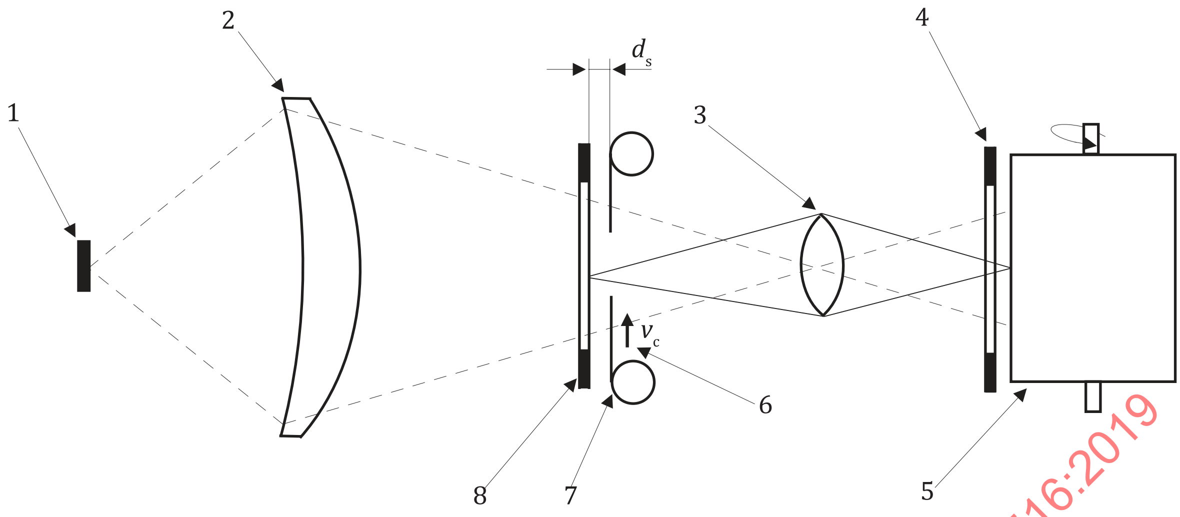
A.3.2.4 Delay time, t_d

Measure directly between the starting point of the sweep and the point on the trace at a level of 0,8 E_o. Add the delayed time generated by the delay circuit to the measured time. To check the X contact, move the trace at a certain rate upon closing of the synchronization contacts.

A.4 Focal-plane-shutter test

A.4.1 Test assembly

The test assembly is shown in Figure A.3.



Key

1 lamp
2 condenser lens
3 taking lens
4 entrance slit
5 revolving drum
6 travel
7 curtain
8 mask with slit

Figure A.3 — Graphic method for focal plane shutter

A.4.2 Procedure

Place the shutter to be tested in front of the mask with slit so that the active shutter element is as close to the slit as possible and the shutter travel is parallel to the slit and the axis of drum rotation.

Secure a piece of photographic film or paper to the drum, and with all extraneous light excluded, bring the drum to a known speed suitable for the run-down time of the shutter. Use a suitable taking lens to focus the slit on the photographic film or paper on the drum. With sufficient illumination for proper exposure of the recording medium used, trip the shutter, producing a record similar to that shown in Figures A.4 or A.5.

