International Standard ISO 516

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Photography — Camera shutters — Timing

Photographie — Obturateurs d'appareils photographiques — Durée d'exposition

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Foreword

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Draft International Standards adopted by the technical committees are circulated to the member bodies for approval before their acceptance as International Standards by the ISO Council. They are approved in accordance with ISO procedures requiring at least 75 % approval by the member bodies voting.

International Standard ISO 516 was prepared by Technical Committee ISO/TC 42, *Photography*.

This second edition cancels and replaces the first edition (ISO 516-1973), of which it constitutes a technical revision.

Users should note that all International Standards undergo revision from time to time and that any reference made herein to any other International Standard implies its latest edition, unless otherwise stated.

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Photography — Camera shutters — Timing

0 Introduction

This International Standard is intended to provide a uniform basis for determining the timing and marking of exposure times of all types of shutters used in still cameras, and to give suitable definitions of the terms used. (See also 6.1.)

1 Scope and field of application

This International Standard defines the characteristics of all types of shutters which are mounted in still cameras and affect the control of exposure, motion-stopping ability and synchronization with a photoflash light source.

It also specifies the exposure-time markings for the shutters and their tolerances.

The tolerances specified are the target values for the shutter performance which can be expected to give good results. They are not intended for application as a general inspection standard in controlling the performance of 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.

2 Reference

ISO 2691, *Photography — Expendable photoflash lamps — Definitions and requirements for luminous flux/time characteristics.*

3 Definitions

For the purpose of this International standard the following definitions apply : (The meanings of symbols used in this clause are given in clause 4.)

3.1 front shutter : Any shutter in the vicinity of the lens. It may be in front of, behind or between the lens elements and may consist of rotating discs, rotating slats, sliding blades, oscillating blades, etc. Programmed shutters are also included.

The common characteristic for the front shutter being that the entire picture area is exposed almost simultaneously. 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. It may consist of fixed or variable slit curtains, rotating discs, sliding blades, etc.

The essential feature for the focal plane shutter being 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 : The best measure of the amount of light falling on the picture area as defined by the following equation :

$$t_e = \frac{H}{E_o} \qquad \ldots (1)$$

t_e at any point on the picture area 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. Equation (1) may be approximated with the following equation for convenience in measurement :

$$t_e = \frac{w}{v_c} \text{ (focal-plane shutter)} \qquad \ldots (2)$$

NOTE — Equation (2) may only be applied under the condition of $w > d_s/A$.

3.4 exposure time, t_{eo} : The 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.

t_o at any point on the picture area is generally the same, or almost, on the entire picture area for front shutters.

For a focal-plane shutter, however, t_o is dependent on w, A, d_s and v_c. The curtain travel to completely expose one point becomes $w + d_s/A$, which can be converted to t_o if the velocity is known by the following equation :

$$t_o = \frac{w + \dfrac{d_s}{A}}{v_c} \qquad \ldots (3)$$

NOTE — This equation may be inexact in the presence of vignetting.

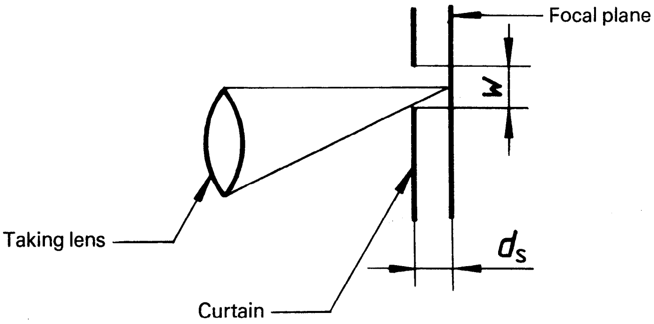


Figure 1 — Focal-plane shutter-total time

3.6 shutter efficiency, η **:** The ratio of effective time to total time.

$$\eta = \frac{t_e}{t_o} \qquad \ldots (4)$$

3.7 fluctuation of exposure time, p **:** The value of p is determined by the following equation :

$$2^p = \frac{\bar{x} + \sigma}{\bar{x} - \sigma} \qquad \ldots (5)$$

where $\bar{x}$ and σ are the mean and standard deviation of the values of five successive measurements.

3.8 ratio of two adjacent exposure times, q **:** The ratio of the mean values of two adjacent shutter speed settings obtained from values of five successive measurements, expressed by the following equation :

$$2^q = \frac{t_{eo}^{(n)}}{t_{eo}^{(n+1)}} \qquad \ldots (6)$$

where $t_{eo}^{(n)}$ 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 **:** A 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).

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 equation :

$$2^r = \frac{t_e \text{ max.}}{t_e \text{ min.}} \qquad \ldots (7)$$

3.10 overall time, T **:** The elapsed time for exposure of all points in the entire picture area.

For front shutter T is same as t_o.

3.11 photoflash synchronization delay time, t_d **:** The 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).

3.12 X contact : Synchronization contact for an electronic flash unit. 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 may sometimes be used for 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. This contact is provided only in the focal plane shutter and may 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 = a 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 equation (8)]

t_e = effective time in seconds (see figure 8)

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

t_o = total time in seconds (see figure 8)

t_s = synchronization contact duration

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 which form a series are given, in seconds, by the following equation :

$$t_E = \frac{1}{2^n} \qquad \ldots (8)$$

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, 1/1024, 1/2048 ...

NOTES

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

2 In evaluating shutters without lenses, exposure times should be measured under the conditions so fixed as to be equivalent to the requirements of this International Standard.

3 A change in n by one unit requires 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 non-uniformity of exposure should be as shown in table 1 (see also 7.1). The following equation, in seconds, is applicable to the tolerance of the exposure time :

$$t_{eo} = \frac{1}{2^{(n+b)}} \qquad \ldots (9)$$

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

Unit : E_v

Exposure time \ Quantity	b*	p	q	r
1/125 and longer	± 0,3	0,3 max.	1 ± 0,45	0,2 max.
shorter than 1/125	± 0,45	0,45 max.	1 ± 0,65	0,6 max.

* The admissible values for individual exposure times are calculated and tabulated in the annex.

Over the range of − 10 °C to 40 °C, the tolerances specified above 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 not be 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 follows :

Table 2 — Delay time of front shutter

Type of contact	Delay time of the synchronization contact		Minimum contact duration
	t_d (ms)	Remarks	t_c (ms)
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.	1
M	16 ± 3**	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

* 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.

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

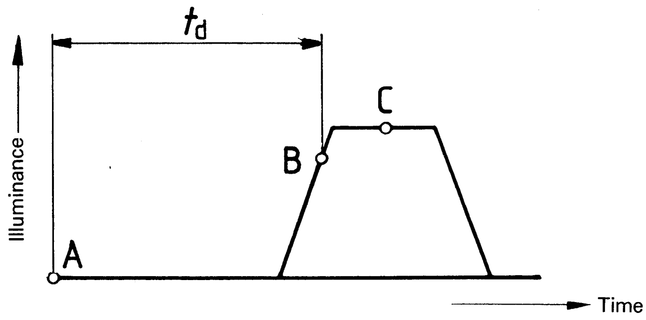
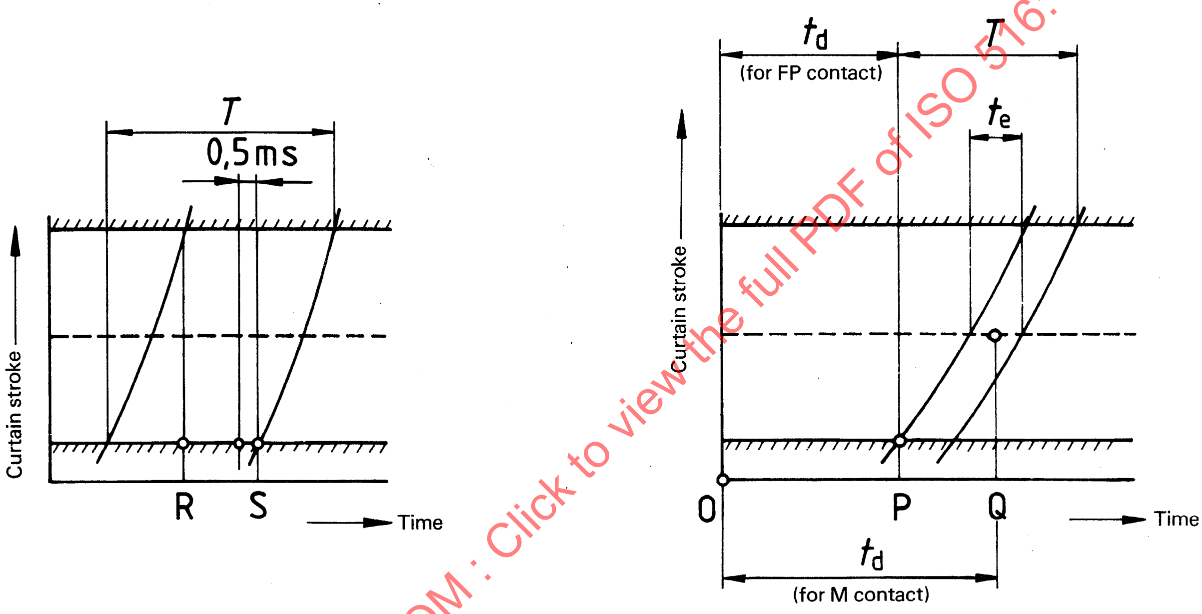


Figure 2 — Front shutter delay time



a) For X-type contact

b) For FP- and M-type contacts

Figure 3 — Focal-plane shutter-delay time

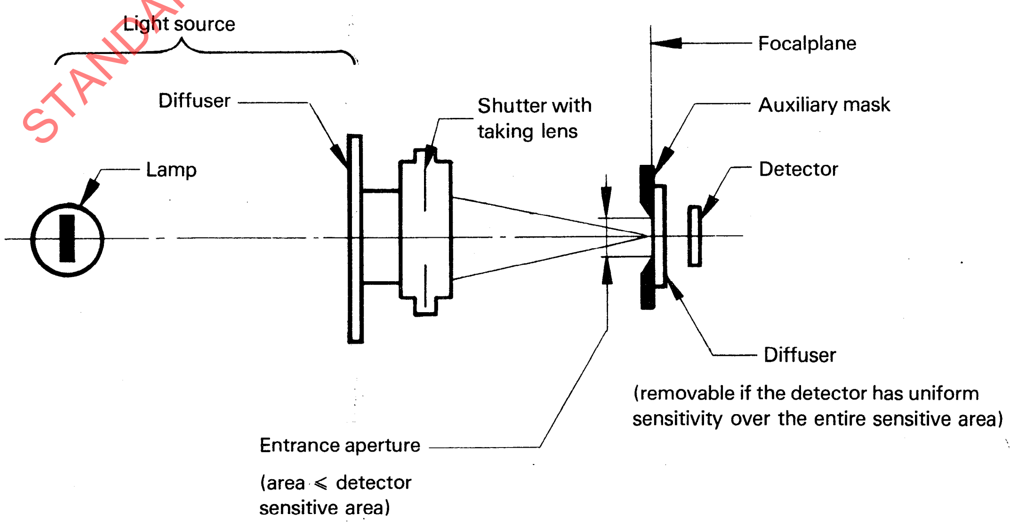


Figure 4 — Test assembly for front shutter timing measurement

5.2.2 Focal-plane shutters

Delay time and minimum contact duration for synchronization shall be as follows :

Table 3 — Delay time of focal-plane shutter

Type of contact	Delay time of the synchronization contact		Minimum contact duration
	t_d (ms)	Remarks	t_c (ms)
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 3a)].	1
FP	$10\ ^{+5}_{-3}$	The time lapse from the closing of the contacts (O) to the moment (P) at which the shutter begins to open [see figure 3b)].	2,5
M**	18 ± 3	The time lapse from the closing of the contacts (O) to the moment (Q) which is one-half of the exposure time at the centre of the picture area (see figure 3b).	

* 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.

** Applicable to those shutters having a mechanism which changes the delay time in accordance with the exposure time and whose overall time is less than the effective duration of a M-class photoflash-lamp (see ISO 2691).

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 such graphic methods as described in the annex.

6.2 Apparatus

6.2.1 Light source

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 $100/t_o$: 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_o. The sensitive area of the detector shall be large enough to receive all the light passing through the entrance aperture. (See figure 4.)

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 so that at least 100 samples are 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) being 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_o which yields a time measurement which is identical to effective time. Determine the fraction as follows :

a) determine t_o and t_e as in clause A.3 of the annex;

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_o is the fraction of illuminance at which the time measurement is started and stopped.

NOTES

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

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

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_o.

To check the closing time of X contact, adjust the time-interval meter to start the measurement when the detector output reaches 0,8 E_o 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).

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_o (when one-half of the entrance slit is exposed) and to stop it when the output falls to 0,5 E_o (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 clause A.4 of the annex, measurement in production line work may be done 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

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

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 equation (7). (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 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 0,5 E_o. 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) **M contact :** 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 B is at 0,5 E_o. Calculate the delay time by adding one half of the exposure time at the slit B to the measured time.

c) **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 0,5 E_o 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 0,5 E_o. 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 International Standard is limited to only the tolerance of exposure time, the tolerance of exposure time which has been conventionally employed is used in this International Standard. At the low temperature range of − 10 °C to 0 °C, a change of t_e up to 0,25 E_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 which can not 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.

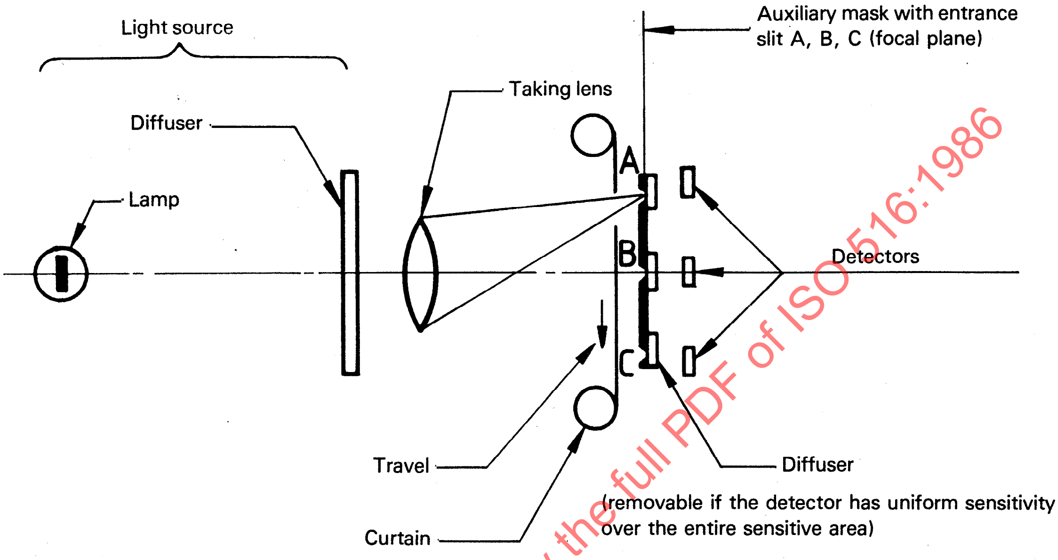


Figure 5 — Test assembly for focal-plane shutter timing measurement

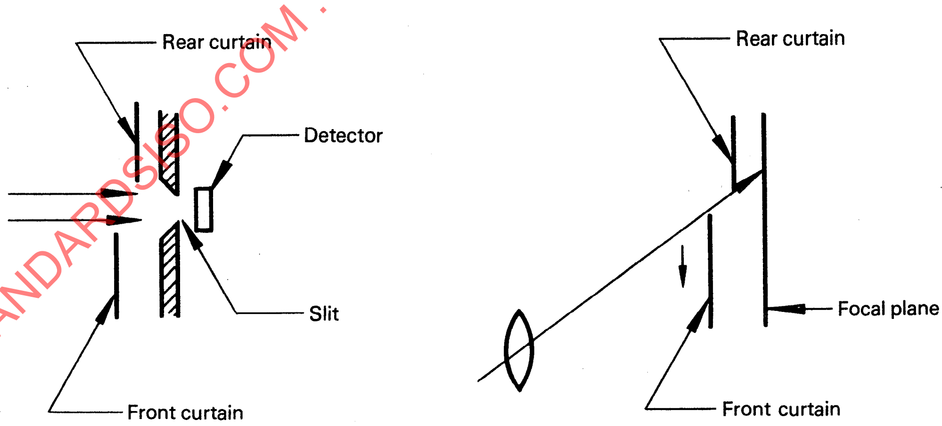


Figure 6 — Measurement of t_e with parallel ray of light and oblique ray of light

Annex
Graphic test methods

(This annex forms part of the standard.)

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 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 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 7.

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 graticule may be recorded photographically or retained for viewing by use of a storage oscilloscope. Typical traces are shown in figure 8.

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 planimeter 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 under clause A.3, 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.