INTERNATIONAL STANDARD

ISO 9378

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Photography — Vesicular microfilm — Determination of ISO speed and ISO range

Photographie — Microfilm vésiculaire — Détermination de la sensibilité ISO et de l'étendue ISO

Reference number
ISO 9378:1993(E)

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.

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.

International Standard ISO 9378 was prepared by Technical Committee ISO/TC 42, *Photography*.

Annexes A, B and C of this International Standard are for information only.

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Introduction

This International Standard describes a method for determining the ISO speed and ISO range of vesicular microfilms used for making prints from microimages. The methods described are intended to standardize how manufacturers measure these film characteristics, which should aid users in selecting the best product for their application.

Highly acceptable prints are generally obtained if the log expose range (LER) of a vesicular microfilm is equal to the effective density range of negative or positive originals. Therefore, ISO range, which is directly related to LER provides a useful guide for selecting the proper product for a given effective density range, and for comparing products from various manufacturers.

Vesicular photography is based on the sensitivity of aryl diazonium salt to radiation in the 350 nm to 450 nm range. Vesicular film consists of a polymeric layer in which a diazonium salt and an image-enhancing dye are dispersed. This photosensitive layer is coated on a polyester support. The decomposition of the diazonium salt by radiation in the near-ultraviolet or violet end of the electromagnetic spectrum produces nitrogen gas and colourless photolytic products. After exposure, the nitrogen gas remains temporarily entrapped in the polymer matrix and constitutes the latent image. The latent image is developed by heat which softens the polymer and allows the nitrogen to expand and form microscopic vesicles. The vesicles, which become stable and rigid when the film cools, form the image by virtue of their light-scattering nature. After development, the image is fixed by re-exposing the film to decompose the diazo salt remaining in the unexposed areas. The nitrogen gas formed during re-exposure slowly diffuses out of the photosensitive layer without affecting the image.

Since the density of vesicular film results from scattering rather than by absorption of light incident on the film, the amount of light transmitted by the film and reaching the viewing plane depends on the aperture of the projecting optics. Standard practice for densitometry established that the optical system should have an effective aperture of *f*/4,5.

Vesicular film is used for duplicating computer output microfilm (COM) and to a lesser extent for source document work and micropublishing.

Photography — Vesicular microfilm — Determination of ISO speed and ISO range

1 Scope

This International Standard specifies a method for determining ISO speed and ISO range of vesicular microfilms which have their principal spectral sensitivity in the region of 350 nm to 450 nm and are used to produce negative-appearing images from positive originals and positive-appearing images from negative originals.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this International Standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 5-1:1984, *Photography — Density measurements — Part 1: Terms, symbols and notations.*

ISO 5-2:1991, *Photography — Density measurements — Part 2: Geometric conditions for transmission density.*

ISO 5-3:1984, *Photography — Density measurements — Part 3: Spectral conditions.*

ISO 554:1976, *Standard atmospheres for conditioning and/or testing — Specifications.*

ISO 8374:1986, *Photography — Determination of ISO safelight conditions.*

3 Definitions

For the purposes of this International Standard, the following definitions apply.

3.1 exposure, H: The time integral of irradiance over a specified wavelength interval on the film, expressed in joules per square metre.

NOTE 1 Exposure is usually expressed in terms of $\log_{10}H$. (See annex B for method of calculation.)

3.2 speed, S: A quantitative measure of the response of the photographic material to radiant energy for specified conditions of exposure, processing and image measurements.

3.3 log exposure range, LER: The range of log exposure values normally used to produce a final image. It is the difference in log exposure values required to produce two specified densities in the film.

4 Sampling and storage

In determining the ISO speed and ISO range of a product, it is important that the samples evaluated yield the average results obtained by users. This will require evaluating several different batches over a period of time. Prior to evaluation, the samples shall be stored according to the manufacturer's recommendations for a length of time to simulate the average age at which the product is normally used. To ensure that all components of variance are included in the sampling plan, it is recommended that procedures such as those outlined in ISO Standards Handbook 3 be used. Alternative reference sources are cited in annex C.

5 Test method

5.1 Principle

Samples are exposed and processed as specified below. Density measurements are obtained from the resultant images to produce a sensitometric curve from which values are taken and used to determine ISO speed and ISO range.

5.2 Safelights

Vesicular film can be handled safely for short periods of time in normal office illumination prior to exposure. However, precautions shall be taken to ensure that the ambient illumination does not affect sensitometric results using the procedures described in ISO 8374.

5.3 Exposure

5.3.1 Sample condition

At the time of exposure, the sample shall be at a temperature of 23 °C ± 2 °C and a relative humidity of (50 ± 5) %, as defined in ISO 554.

5.3.2 Type of sensitometer

The sensitometer shall be a non-intermittent intensity scale type.

5.3.3 Radiant energy quality

The spectral power distribution of the modulated radiant energy on the sample shall be within the tolerances specified in table 1. This distribution can be obtained with a gallium-iodide-doped mercury arc lamp employing a quartz envelope.

Table 1 — Relative energy tolerances

Wavelength nm	Relative energy
350 to 360	1,5 ± 1,0
361 to 372	10,0 ± 3,0
373 to 400	5,0 ± 3,0
401 to 413	30,0 ± 3,0
414 to 430	41,0 ± 3,0
431 to 445	11,0 ± 2,0
446 to 450	1,5 ± 2,0
greater than 451	less than 0,5

5.3.4 Modulation

The total range of spectral diffuse transmission density with respect to the film plane of each area of the energy modulation throughout the wavelength interval from 350 nm to 450 nm shall not exceed 10 % of the mean density or 0,06 density units, whichever is greater[1)].

If stepped increments are used, the logarithm to the base 10 of the exposure increment shall not be greater than 0,20. The length and width of a single step shall be adequate to obtain a uniform density within the reading aperture used for densitometry. If a continously variable modulator is used, the logarithm to the base 10 of the change in exposure with distance along the test strip shall not be greater than 0,04 per millimetre.

5.3.5 Exposure time

The exposure time shall correspond to usage practice but shall not be longer than 5 s. The sample shall be removed from the sample holder immediately after exposure. Since the speed is dependent on the exposure time because of reciprocity law failure effects, the exposure time should be specified in the use instructions. An area of the film shall be left unexposed in order to produce the minimum density possible.

5.4 Processing

5.4.1 Holding time

The time interval between exposure and processing shall not be more than 5 s in order to minimize latent image effects. For critical applications, the effects of latent image instability can be an important factor in controlling the quality of the vesicular film images. In such cases it is important to know the latent image characteristics of the film in terms of the duplicating process employed.

5.4.2 Development

Processing shall be carried out in accordance with the film manufacturer's recommendation. The combination of exposure and development conditions shall be sufficient to produce maximum density. Development shall be carried out so that the exposed film reaches the recommended temperature. Where a range of developing temperatures is given, the midpoint of that range shall be used. A sample of unexposed film shall be processed at the same time.

5.4.3 Fixing

5.4.3.1 Purpose of fixing

Following the heat development of the sample, the film shall be allowed to re-equilibrate to room temperature for at least 1 minute. It shall then be exposed to a sufficient amount of ultraviolet radiation to decompose the residual sensitizer.

5.4.3.2 Test for fixing (residual diazonium salt test)

Fixing shall be considered complete when the ISO standard visual *f*/4,5 projection transmission density

1) This precludes the use of standard silver radiation modulators but does not exclude carbon or other (e.g. Inconel) radiation modulators.

of the D_{min} increases by less than 0,03 with an additional exposure identical to that used to produce the sensitometric curve in figure 1. A one-hour delay is recommended in order to allow fixing to be completed before this test is done.

5.5 Densitometry

The ISO standard visual *f*/4,5 projection transmission density of the processed film images shall be measured using a densitometer complying with the geometric conditions specified in ISO 5-2 and the spectral conditions specified in ISO 5-3. These conditions are denoted D_T (6,4°; S_H: 6,4°; V_T). Density readings shall be taken at least 1 mm from the edges of the exposed areas.

5.6 Evaluation

5.6.1 Sensitometric curve

The ISO standard visual *f*/4,5 projection transmission densities shall be plotted against the logarithm to the base 10 of the corresponding exposure H to obtain a sensitometric curve similar to that illustrated in figure 1.

5.6.2 Minimum density, D_{min}

Minimum density is the combination of base and fog density and shall be determined from an unexposed sample of the same film processed simultaneously with the sample exposed for determining the sensitometric curve.

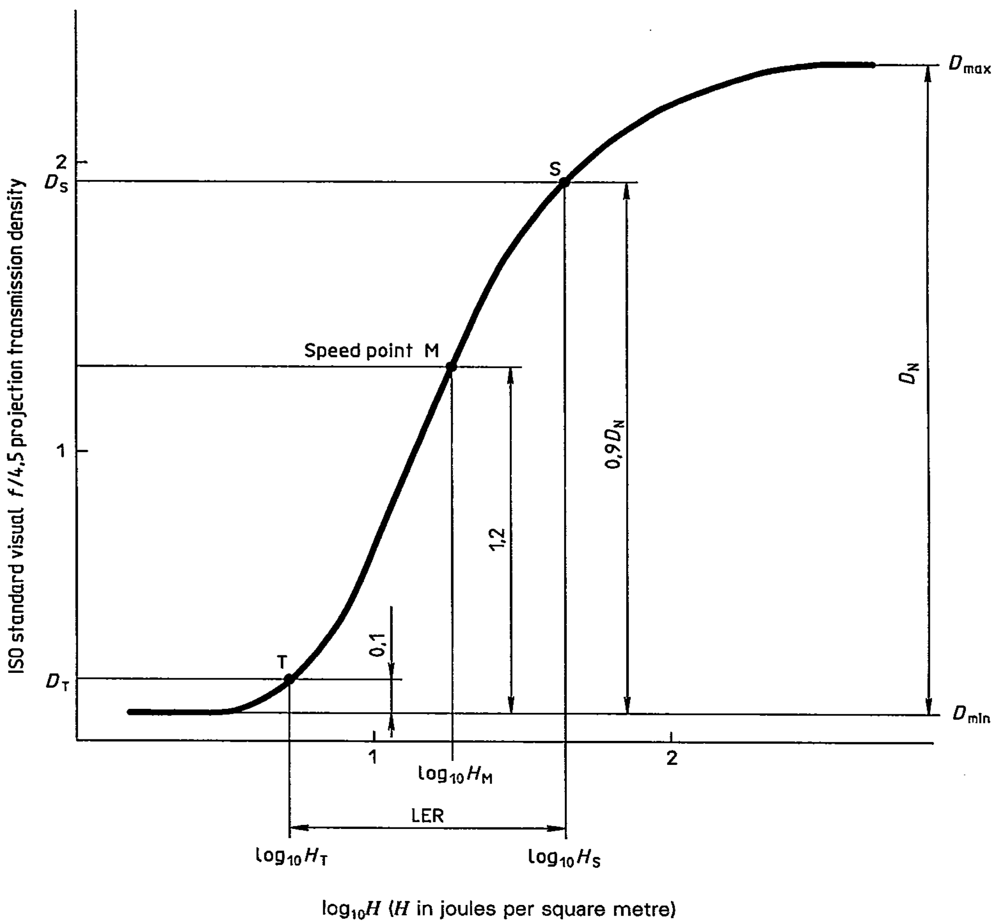

Figure 1 — Sensitometric curve

5.6.3 Maximum density, D_{max}

The value D_{max} represents the density of the sample whose density does not systematically increase with increasing exposure.

5.6.4 Maximum net density, D_N

The value D_N represents the maximum density of the sample, adjusted for D_{min}. This value is called maximum net density (see figure 1) and relates to the maximum image contrast achievable. It is derived from the formula

$$D_N = D_{max} - D_{min}$$

6 Product classification

The value for a sensitometric characteristic of a product (as distinguished from that of a specific sample) shall be based on the arithmetic mean of the values determined from various batches of the product when sampled, stored and tested as specified in clauses 4 and 5.

6.1 Speed calculation

Raw speed values, S, are derived from the formula

$$S = \frac{1\,000}{H_M}$$

where H_M is the exposure required to produce a density of 1,20 above D_{min}.

6.1.1 ISO speed

ISO speed shall be obtained directly from $\log_{10}H_M$ by use of table 2, which effectively translates it to one of the designated ISO speeds in the ISO speed scale. The procedure is to first determine $\log_{10}H_M$ as in figure 1. The appropriate $\log_{10}H_M$ range is then selected from the two columns on the left side of table 2 and the corresponding ISO speed is found in the right hand column of table 2.

6.1.2 ISO speed of a product

The ISO speed of a product (as distinguished from that of a specific sample) shall be based on the arithmetic mean of the base ten logarithms of exposures, $\log_{10}H_M$, on a statistical sampling of the product. The samples shall be chosen such that all the components of variance are included and shall be stored and tested as specified above (see clauses 4 and 5). The ISO speed of a product with proper rounding is then determined from the mean value of $\log_{10}H_M$ by use of table 2.

6.2 Range calculation

Log exposure range values, LER, are derived from the following formula:

$$\text{LER} = \log_{10}H_S - \log_{10}H_T$$

where

H_S is the exposure required to produce a density which is $0{,}90D_N$ above D_{min}; and

H_T is the exposure required to produce a density of 0,10 above D_{min}.

Points S and T generally correspond to the largest and smallest exposure received in producing a good print.

6.2.1 ISO range

ISO range may be obtained directly from ($\log_{10}H_S - \log_{10}H_T$) using table 3 which effectively multiplies this value by 100 and then rounds it to one of the designated ISO range values in the ISO range scale.

Table 2 — ISO speed scale

$\log_{10}H_M$ from	$\log_{10}H_M$ to	ISO speed
– 0,15	– 0,06	1 250
– 0,05	0,04	1 000
0,05	0,14	800
0,15	0,24	640
0,25	0,34	500
0,35	0,44	400
0,45	0,54	320
0,55	0,64	250
0,65	0,74	200
0,75	0,84	160
0,85	0,94	125
0,95	1,04	100
1,05	1,14	80
1,15	1,24	64
1,25	1,34	50
1,35	1,44	40
1,45	1,54	32
1,55	1,64	25
1,65	1,74	20
1,75	1,84	16
1,85	1,94	12
1,95	2,04	10
2,05	2,14	8
2,15	2,24	6
2,25	2,34	5
2,35	2,44	4

6.2.2 ISO range of a product

ISO range of a product (as distinguished from that of a specific sample) shall be based on the arithmetic mean of the difference values ($\log_{10}H_S - \log_{10}H_T$) on a statistical sampling of the product. The samples shall be chosen such that all the components of variance are included and shall be stored and tested as specified above (see clauses 4 and 5). The ISO range of a product with proper rounding is then determined from the mean value of LER using table 3.

6.3 Accuracy

The calibration of the equipment and processes involved in determining ISO speed and ISO range shall be adequate to ensure that the absolute value of the error in $\log_{10}H_M$ or LER is less than 0,05.

7 ISO speed and ISO range designation

Since ISO speed and ISO range are not only dependent on the film product, but also on the process used to develop the image, the processing specifications shall be given when ISO speed and ISO range values are quoted.

Table 3 — ISO range scale

$\log_{10}H_S - \log_{10}H_T$		ISO range
from	to	
0,15	0,24	20
0,25	0,34	30
0,35	0,44	40
0,45	0,54	50
0,55	0,64	60
0,65	0,74	70
0,75	0,84	80
0,85	0,94	90
0,95	1,04	100
1,05	1,14	110
1,15	1,24	120
1,25	1,34	130
1,35	1,44	140
1,45	1,54	150
1,55	1,64	160
1,65	1,74	170
1,75	1,84	180
1,85	1,94	190
1,95	2,04	200

Annex A
(informative)

Measurement of spectral irradiance of gallium-iodide-doped mercury lamps

The gallium-iodide-doped mercury lamp is an example of an exposure source for vesicular sensitometry. This lamp was selected because of its widespread use in the industry, availability from the manufacturers and its high output in the blue and ultraviolet region of the spectrum. Other lamps such as xenon, fluorescent, mercury and carbon arc are used as exposure sources but these were not selected due to various limitations for their use in sensitometric work.

Measurements were made on several gallium-iodide-doped mercury lamps to determine the consistency from one lamp to another and to define the distribution of the emitted radiant energy within the important wavelength regions.

The measurements were made using a spectral radiometer which accurately measures irradiance as a function of wavelength. The bandpass of the radiometer has to be narrow enough to separate the energy found in the discrete emission lines of this lamp.

The measurements taken showed that a lamp for sensitometric work should be defined throughout the important wavelength region as in table 1.

Total irradiance alone would lead to significant errors in film response if the energy was distributed differently within the peak response areas. A lamp with irradiance values falling within the percentages specified will give accurate sensitometric results. The irradiance values specified in table 1 were derived from controlled, extensive testing by two organizations.

Due to the difficulty of making accurate measurements of spectral irradiance, it is recommended that users establish secondary standards.

It is anticipated that lamp manufacturers will qualify their lamps through a national standards laboratory for use as a primary standard. However, the individual user should still be able to calculate the total energy which reaches the film plane in the sensitometer. The following information provides a starting point.

The equipment required for measurement of spectral irradiance is available from several manufacturers. Some important considerations in selection are accuracy traceable to a national standards laboratory, a monochromator for narrow bandpass capability, proper detector sensitivity and wavelength accuracy.

The following precautions should be taken when measuring the lamp output:

a) lamp surfaces should not be touched whether it be hot or cold as lamp surfaces can be etched by chemicals from the hand;

b) combustible materials should not be kept near the lamp, since lamps operate at very high temperatures;

c) lamps should be aligned with the sensor accurately and reproducibly to measure consistently with time;

d) lamp should be operated for a minimum of 15 min before making measurements;

e) background radiation (stray light) should be excluded from the sensor; measurements should be made in a darkened area;

f) the input line current should be accurately controlled; ideally the current should not vary by more than 0,1 A.

A typical measurement of spectral irradiance of a gallium-iodide-doped mercury lamp will indicate four peak emission lines and three background areas (see figure A.1). Measurements are taken with the spectroradiometer detector surface located at the film plane and are made every 5 nm if the irradiance values differ by less than 10 % from the previous measurement. If the values differ by more than 10 %, measurements are made every 1 nm in that region. When the entire 350 nm to 460 nm region has been measured, the results are integrated to record total irradiance.

The discussion outlined above provides a general guideline for the measurement of the energy emitted by a gallium-iodide-doped mercury lamp in the region important for vesicular sensitometry.

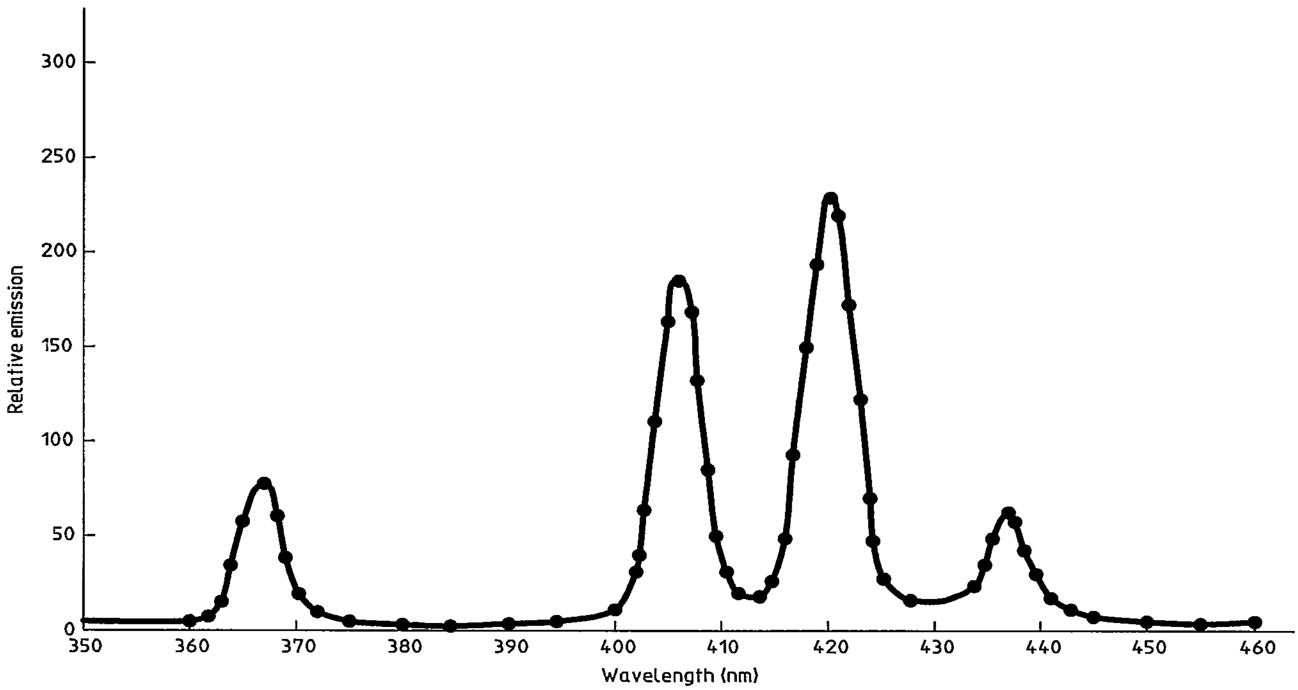

Figure A.1 — Typical spectral distribution of gallium-iodide-doped mercury lamp

Annex B
(informative)

Derivation of the equation for calculating the exposure

If the exposing light source, without filtration, produces, at the plane of the film, a spectral irradiance E_λ, expressed in watts per square metre per nanometre, then the spectral irradiance with the filter in place is

$$E_\lambda \tau(\lambda)\ \mathrm{d}\lambda$$

where $\tau(\lambda)$ is the spectral transmittance of the filter.

The total irradiance, E, in watts per square metre (joules per square metre second), with the filter in place, is then

$$E = \int_0^\infty E_\lambda \tau(\lambda)\ \mathrm{d}\lambda$$

The exposure H, in joules per square metre (or watt seconds per square metre), for an exposure time t, expressed in seconds, is then

$$H = Et = t\int_0^\infty E_\lambda \tau(\lambda)\ \mathrm{d}\lambda$$

Annex C
(informative)

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