UDC 77

Ref. No.: ISO/R 6 - 1954 (E)

Revisee

ISO

INTERNATIONAL ORGANIZATION FOR STANDARDIZATION

ISO RECOMMENDATION
R 6

METHOD FOR DETERMINING PHOTOGRAPHIC SPEED AND EXPOSURE INDEX

1st EDITION
October 1955

For each individual country the only valid standard is the national standard of that country.

Printed in Switzerland

Also issued in French and Russian. Copies to be obtained through the national standards organizations.

BRIEF HISTORY

This ISO Recommendation R 6 was prepared by Technical Committee ISO/TC 42 — Photography, the Secretariat of which is held by the American Standards Association, Inc. (ASA).

In April 1948, the Secretariat asked the General Secretariat to submit, as a Draft Proposal, for study by the Technical Committee, the American Standard Z 38.2.1. - 1947, concerning the method for determining photographic speed and exposure index. This Draft Proposal was distributed on 12 May 1948 to all the Members of the Technical Committee. In view of the fact that no observations were received, the Secretariat considered the Draft Proposal as adopted by the Technical Committee as a Draft ISO Recommendation.

In January 1951, this Draft ISO Recommendation was submitted to all the ISO Member Bodies by the General Secretariat. The following 15 Member Bodies (out of the existing total of 29) sent in their approval:

Australia	Italy	Sweden
Austria	Mexico	Union of South Africa
Belgium	Netherlands	United Kingdom
Czechoslovakia	New Zealand	U.S.A.
Finland	Portugal	Yugoslavia

One Member Body stated that it had no objection to the approval of the Draft:

Denmark

The ISO/TC 42 Secretariat amended the Draft, taking account of the observations made by various Member Bodies.

The revised text was then submitted by correspondence to the ISO Council Members who decided, in May 1954, to accept it as an ISO RECOMMENDATION.

ISO Recommendation R 6 May 1954

METHOD FOR DETERMINING PHOTOGRAPHIC SPEED AND EXPOSURE INDEX

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INTRODUCTION

This recommendation describes a sensitometric method for determining and expressing the photographic speed of roll films, film packs, miniature camera films, sheet films and plates. It is believed that the method represents an improvement over other commonly used procedures, since it more fully satisfies the two fundamental requirements of a system intended for international use:

(1) The method must give results which can be applied directly and significantly to picture-taking practice.

(2) The method must be simple to operate and must give unequivocal results.

The recommendation applies to individual samples and to a product as a whole. The sensitometric criterion upon which the method is based was first suggested by experimental work reported in various technical journals.*

A quantity called "Exposure Index" is specified in this recommendation. It is a rating for a film or plate for use in connection with exposure tables, exposure computers, exposure meters and similar devices for obtaining properly exposed negatives. The term "Exposure Index" was chosen to avoid confusion with Speed. Exposure Indexes are expressed in cube-root-of-2 steps, and may be calculated on either an arithmetic or a logarithmic scale. The arithmetic numbers may be used directly with most American-made exposure meters and exposure computers. Similarly, the logarithmic scale numbers may be used directly with many meters and computers of European manufacture.

* Loyd A. Jones: The evaluation of negative film speeds in terms of print quality. *Journal of the Franklin Institute*, p. 227, 297 and 497 (1939).

Loyd A. Jones and C. N. Nelson: A study of various sensitometric criteria of negative film speeds. *Journal of the Optical Society of America*, p. 30, 93 (1940).

ISO Recommended Method for Determining Photographic Speed and Exposure Index

1. Scope

1.1 This method of determining Speed and Exposure Index applies to roll films, film packs, miniature camera films*, sheet films and plates intended for the making of monochromatic, continuous-tone negatives in pictorial photography, exclusive of photography in the infrared. Process films and other graphic arts films and plates, radiographic films, and aerial photographic films are excluded.

2. Discussion of Problem and Explanation of Terms

2.1 Concept of Speed for the Materials in this Specification. The photographic Speed of the negative materials referred to in 1.1 is to be considered as inversely proportional to the minimum exposure which must be incident upon the negative material, from the scene element of minimum brightness in which detail is visible, in order that a print of as good quality can be made from the resultant negative as from negatives resulting from increased exposure of the same negative material. It is understood that the word "visible" as used in the previous sentence implies visibility of detail from the camera position to a human observer having normal visual acuity and normal sensitivity to brightness differences. It is also understood that this concept of photographic Speed presupposes a scene of approximately normal brightness contrast**.

In the field of negative-positive, black-and-white materials, this concept implies that Speed can be measured by making the best possible print from each of a series of negatives (which differ only in the exposure given) and then deciding by observation the minimum negative exposure that will lead to a print which is as good in quality as any print made from the series of negatives. Speed measured by this psychophysical method is called "absolute Speed". In practice, it is found difficult to obtain precise values of absolute Speed since, in addition to making suitable negatives, many prints must be made and a large panel of judges must make a multitude of observations.

A practical method of measuring Speed has been found in the field of sensitometry. The method is reasonably simple and rapid to operate, is reproducible, and gives results in close agreement with those obtained by the laborious process of making picture negatives and prints.

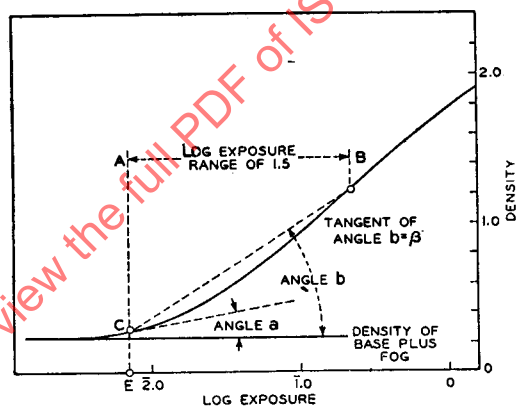

FIG. 1

2.2 Sensitometric Criterion of Speed. The operation of this method is illustrated in Fig. 1. Essentially, it consists of plotting the density/log-exposure curve of a photographic material for a given set of conditions (exposure, development, etc.). A log exposure range of 1.50, represented in the figure by the distance AB, is then moved along the horizontal axis from left to right until the slope (or gradient) of the curve at the low end of the range is 0.30 of the average slope over the entire range. When the slope or tangent of angle a is 0.30 of β (i.e., the tangent of angle b), the point C, at the low end of the log exposure range, represents the exposure value (E) from which the Speed of the material is derived. A gradient meter * simplifies the operation of locating point C.

Speed is then computed by use of the formula:

$$\text{Speed} = 1/E$$

* Miniature camera films, of the negative-positive, black-and-white type, are considered to be films not more than 35 mm in width used in still cameras for the making of negatives which normally require enlargement in printing.

** Such a normal scene may be characterized with sufficient precision for the present purposes as one in which the ratio of the maximum to the minimum brightness is 128. With a typical camera, such as is used by the amateur, this results in a ratio of maximum to minimum illumination on the negative material in the camera of 32. With the use of coated lenses this average illumination ratio may be somewhat greater.

* L. D. Clark: Gradient meter for use in photographic sensitometry. *PSA Journal, Photographic Science and Technique*, p. 87, 17B (1951).

Adoption of this sensitometric criterion for determining Speed is basic to this recommendation.

Since several systems for determining Speed are quite widely used throughout the world, Speed measured by using the ISO Recommended sensitometric criterion should be clearly marked to avoid confusion. This may be accomplished by using the prefix 0. For example, if $1/E$ equals 200, the Speed would be written 0200.

If, in addition to use of the ISO Recommended sensitometric criterion for calculating Speed, the ISO Recommended testing technique (exposure, processing, etc.) is used, as described in these specifications, the Speed shall be known as "ISO Recommended Speed." For example, a sample of film exposed, processed, and evaluated in strict accordance with the complete method might give a value for Speed which would be written "ISO Recommended Speed 0200". If, in the presentation of these data, insufficient space is available for the use of the full term "ISO Recommended", as in tabular material, sales or promotional literature, the initials "ISO" may be used in substitution of the full designation. The value of Speed would then be written "ISO Speed 0200".

Should some factor be varied in the testing technique (that is, in the production of the density/log-exposure curve), the designation "ISO Recommended" or the initials "ISO" must not be used. However, as stated above, if the sensitometric criterion has been used, the Speed may still be written with the prefix 0, such as 0160.

2.3 Exposure Index. An Exposure Index is the rating of a film for use in connection with exposure tables, exposure computers, and exposure meters. Experience has shown that if the ISO Recommended Speed is divided by 4, the numbers resulting will correspond to those now commonly used in exposure tables, exposure computers, and exposure meters employing arithmetic scales. The numbers so derived are called "Arithmetic Exposure Indexes".

It should be remembered that Speed obtained by the use of these specifications relates to the minimum camera exposure which will lead to a print of as good a quality as can be obtained from negatives resulting from increased exposure. In normal photographic work it is customary to recommend a somewhat greater exposure in order to allow for uncertainties in processing, lighting conditions, camera operation, etc. Exposure tables, computers, and exposure meters applying Exposure Indexes are designed to take into consideration this additional exposure.

Values of Arithmetic Exposure Index are not written with the prefix 0 and, consequently, are readily distinguishable from values of Speed.

Where films are used with exposure meters or exposure computers marked in logarithmic units, it may be desirable to express the Exposure Indexes in logarithmic units. For this purpose the logarithmic Exposure Indexes shown in Table 1 may be used as an alternative to the arithmetic Exposure Indexes. The formula for obtaining the logarithmic values is given in 3.2.1. The logarithmic indexes are referred to in degrees to distinguish them from the arithmetic indexes.

If Exposure Indexes have been obtained by following the details of one of these methods, they shall be designated either "ISO Recommended Arithmetic Exposure Index" or "ISO Recommended Logarithmic Exposure Index". A value would then be designated "ISO Recommended Arithmetic Exposure Index 50" or "ISO Recommended Logarithmic Exposure Index 28°". If, in the presentation of these data, insufficient space is available for use of the full designation "ISO Recommended", as for example in tabular material, sales or promotional literature, the initials "ISO" may be used in substitution for the full designation. The value for Exposure Index would then be written "ISO Exposure Index 50" or "ISO Exposure Index 28°".

3. Determination of ISO Recommended Speed and ISO Recommended Exposure Index of a Specific Sample

3.1 Determination of Speed

3.1.1 Speed shall be computed by the use of the formula:

$$\text{Speed} = 1/E$$

where E is the exposure (expressed in meter-candle-seconds) corresponding to the point on the density/log-exposure curve at which the gradient is 0.3 times the average gradient for a log exposure range of 1.50 of which E is the minimum exposure.

3.1.2 Speed Scale. Values of Speed shall be expressed arithmetically on a cube-root-of-2 scale. They shall be calculated as described above but shall be rounded off to the nearest cube-root-of-2 step as indicated by Table 1.

3.1.3 Speed shall be written with the prefix 0.

3.1.4 Speeds determined by the above formula are not intended for use with ordinary exposure meters or exposure calculators.

3.2 Determination of Exposure Index

3.2.1 Exposure Indexes for the types of photographic materials covered by this recom-

TABLE 1

For a log E Value between *			Speed	Arithmetic Exposure Index	Logarithmic Exposure Index
(6.35 — 10)	and	(6.45 — 10)	04000	1000	41°
(6.45 — 10)	and	(6.55 — 10)	03200	800	40°
(6.55 — 10)	and	(6.65 — 10)	02500	650	39°
(6.65 — 10)	and	(6.75 — 10)	02000	500	38°
(6.75 — 10)	and	(6.85 — 10)	01600	400	37°
(6.85 — 10)	and	(6.95 — 10)	01250	320	36°
(6.95 — 10)	and	(7.05 — 10)	01000	250	35°
(7.05 — 10)	and	(7.15 — 10)	0800	200	34°
(7.15 — 10)	and	(7.25 — 10)	0650	160	33°
(7.25 — 10)	and	(7.35 — 10)	0500	125	32°
(7.35 — 10)	and	(7.45 — 10)	0400	100	31°
(7.45 — 10)	and	(7.55 — 10)	0320	80	30°
(7.55 — 10)	and	(7.65 — 10)	0250	64	29°
(7.65 — 10)	and	(7.75 — 10)	0200	50	28°
(7.75 — 10)	and	(7.85 — 10)	0160	40	27°
(7.85 — 10)	and	(7.95 — 10)	0125	32	26°
(7.95 — 10)	and	(8.05 — 10)	0100	25	25°
(8.05 — 10)	and	(8.15 — 10)	080	20	24°
(8.15 — 10)	and	(8.25 — 10)	064	16	23°
(8.25 — 10)	and	(8.35 — 10)	050	12	22°
(8.35 — 10)	and	(8.45 — 10)	040	10	21°
(8.45 — 10)	and	(8.55 — 10)	032	8	20°
(8.55 — 10)	and	(8.65 — 10)	025	6	19°
(8.65 — 10)	and	(8.75 — 10)	020	5	18°
(8.75 — 10)	and	(8.85 — 10)	016	4	17°
(8.85 — 10)	and	(8.95 — 10)	012	3	16°
(8.95 — 10)	and	(9.05 — 10)	010	2.5	15°
(9.05 — 10)	and	(9.15 — 10)	08	2.0	14°
(9.15 — 10)	and	(9.25 — 10)	06	1.6	13°
(9.25 — 10)	and	(9.35 — 10)	05	1.2	12°
(9.35 — 10)	and	(9.45 — 10)	04	1.0	11°
(9.45 — 10)	and	(9.55 — 10)	03	0.8	10°
(9.55 — 10)	and	(9.65 — 10)	02.5	0.6	9°

* When the log E value is exactly on the border line of two groups, the group giving the lower value of Speed shall be used.

mendation shall be determined by the use of one of the formulas:

Arithmetic Exposure Index $= 1/4E =$ Speed/4 *
Logarithmic Exposure Index $= 5 - 10 \log E$ *
Logarithmic Exposure Indexes shall be referred to in degrees.

3.2.2 Exposure Index Scales. The arithmetic and logarithmic Exposure Indexes shall be expressed on a cube-root-of-2 scale. They shall be calculated as described above but shall be rounded off to the nearest cube-root-of-2 step as indicated in Table 1.

3.2.3 The prefix 0 shall not be used with the Exposure Index.

* In the case of reversal and color films, which are not included in this recommendation, a different ratio of Speed to Exposure Index may apply.

3.3 Testing Technique

3.3.1 Conditioning of Sample for Testing. The test sample shall be in equilibrium with an atmosphere maintained at a temperature of 20 °C ± 5 degrees and a relative humidity of (60 ± 10) percent.

3.3.2 Exposure

3.3.2.1 Type of Sensitometer. The sensitometer shall be a nonintermittent intensity-scale type.

3.3.2.2 Exposure Time *. Exposure time shall be between 1/20 and 1/80 second.

* The required illumination depends upon the time of exposure and the Speed of the sample. The portion of the D-log E curve obtained must include the 1.50 log E interval used in the Speed determination.

3.3.2.3 Modulation. The light modulator shall be spectrally nonselective from a wavelength of 350 mμ to a wavelength of 700 mμ. The difference between the maximum and minimum transmission densities in this wavelength interval must be less than 0.08.

The change in exposure with distance along the test strip for either continuous or stepped exposures shall be not greater than a factor of 2 per centimeter.

If stepped increments are used, the exposure increment shall be not greater than a factor of square-root-of-2 per step.

3.3.2.4 Light Source *. The quality of the light source shall be that defined by the International Congress of Photography in establishing the international unit of photographic intensity. The unit of photographic intensity shall be the intensity of a filtered source of radiation having a luminous intensity of one candela, and produced by a gray body at a color temperature of 2360 °K together with a selectively absorbing filter made up as follows:

Two solutions compounded according to the following formulas, the complete filter to consist of a 1-cm layer of each solution contained in a double cell made by using three pieces of borosilicate crown glass (refractive index, $D = 1.51$), each 2.5 mm thick.

SOLUTION A

Copper sulfate ($CuSO_4.5H_2O$)	3.71 g
Mannite ($C_6H_8(OH)_6$)	3.71 g
Pyridine (C_5H_5N)	30 cm³
Water (distilled) to make	1000 cm³

SOLUTION B

Cobalt ammonium sulfate ($CoSO_4(NH_4)_2SO_4.6H_2O$)	26.83 g
Copper sulfate ($CuSO_4.5H_2O$)	27.18 g
Sulfuric acid (density at 15°: 1.835)	10 cm³
Water (distilled) to make	1000 cm³

The light transmission of the filter to 2360 °K radiation is 13.52 percent.

Alternative light sources may consist of a tungsten lamp operated at a color temperature between 2360 °K and 2848 °K, together with the appropriate Davis-Gibson filter. The filter shall consist of two solutions compounded according to the sample formulas in Table 2, the complete filter to consist of a 1-cm layer of each solution contained in a double cell made by using three pieces of borosilicate crown glass (refractive index, $D = 1.51$), each 2.5 mm thick.

* The unit of photographic intensity. Proceedings of the *Seventh International Congress of Photography*, July 1928 (W. Heffer and Sons, Ltd, Cambridge, England).

Raymond Davis and K. S. Gibson: Filters for the reproduction of sunlight and daylight and the determination of color temperature. *Miscellaneous Publication No. 114*, National Bureau of Standards, USA.

Raymond Davis and K. S. Gibson: Artificial sunlight for photographic sensitometry. *Transactions of the Society of Motion Picture Engineers*, 12,225 (1928).

3.3.2.5 Tolerance of Exposure. The product of intensity and time shall be expressed in meter-candle-seconds to an accuracy of ± 5 percent.

3.3.3 Processing

3.3.3.1 Conditioning of Samples. In the interval between exposure and processing, the samples shall be kept under conditions which will not significantly affect the latent image. The processing shall be commenced not earlier than 1 hour and not later than 2 hours after exposure.

3.3.3.2 Developer * and Extent of Development

a) Roll Films and Film Packs. The developing solution shall be the following:

**Monomethyl para-aminophenol sulfate	2.0 g
Sodium sulfite (anhydrous)	50.0 g
Hydroquinone	4.0 g
Sodium carbonate (anhydrous)	6.0 g
Potassium bromide	0.75 g
Air-free distilled water to make	1000 cm³

TABLE 2

COMPOSITION AND LIGHT TRANSMISSIONS OF DAVIS-GIBSON FILTERS

The values in columns 2, 3 and 4 give the number of grams per liter of the designated constituents***.

Color temperature in °K	Copper sulfate and mannite	Cobalt ammonium sulfate	Copper sulfate	Light Transmission (percent)
	Solution A	Solution B	Solution B	
2 400	3.58	25.87	26.48	14.4
2 460	3.41	24.49	25.43	15.8
2 500	3.29	23.59	24.73	16.8
2 560	3.13	22.27	23.69	18.3
2 600	3.02	21.40	23.00	19.3
2 660	2.87	20.14	21.98	20.9
2 700	2.78	19.33	21.30	22.0
2 760	2.64	18.16	20.33	23.6
2 800	2.55	17.40	19.72	24.8
2 848	2.45	16.52	19.02	26.2

* Chemicals shall be used in which impurities known to be photographically harmful are limited to a safe quantity, while inert impurities are restricted to amounts not reducing the required assay strength.

** Sold under such trade names as Metol, Elon, Rhodol, and Pictol.

*** The following constituents are present in the indicated amounts in all filters:

SOLUTION A

Pyridine	30 cm³
Water (distilled) to make	1000 cm³

SOLUTION B

Sulfuric acid (density at 15°: 1.835)	10 cm³
Water (distilled) to make	1000 cm³

The time of development shall be 4.0 minutes, provided the average gradient (designated by the Greek letter β) for the log exposure range from which the Speed is determined is not less than 0.50. If the value of β is less than this minimum, the time of development shall be extended to 4.5 minutes. If the value of β continues to be less than 0.50, the time of development shall be further extended to 5.0, 5.5, 6.0, 7.0, or 8.0 minutes, whichever is the minimum required to produce a value of β not less than 0.50.

Fresh developing solutions shall be used for every test.

(b) Miniature Camera Films. The developing solution shall be the following:

* Monomethyl para-aminophenol sulfate	2.0 g
Sodium sulfite (anhydrous)	80.0 g
Hydroquinone	4.0 g
Borax	4.0 g
Potassium bromide	0.5 g
Air-free distilled water to make	1000 cm³

The time of development shall be 8.0 minutes, provided the average gradient (designated by the Greek letter β) for the log exposure range from which the Speed is determined is not less than 0.50. If the value of β is less than this minimum, the time of development shall be extended to 10.0 minutes. If the value of β continues to be less than 0.50, the time of development shall be further extended to 12.0, 15.0, 18.0, or 20 minutes, whichever is the minimum required to produce a value of β not less than 0.50.

Fresh developing solutions shall be used for every test.

(c) Sheet Films and Plates. The developing solution shall be the same as that specified for roll films and film packs.

The time of development shall be 5.0 minutes, provided the average gradient (designated by the Greek letter β) for the log *E* from which Speed is determined is not less than 0.60 and not greater than 0.80. If the value of β is less than 0.60, the time of development shall be prolonged to produce a value of β equal to 0.60, and if the value of β is greater than 0.80, the time of development shall be shortened to produce a value of β equal to 0.80.

3.3.3.3 Temperature of the Developing Solution. The temperature of the developing solution shall be 20 °C ± 0.5 degrees.

3.3.3.4 Agitation. The test sample may be developed in any suitable vessel, provided the agitation of the solution during development is equivalent in efficiency to that produced by the following method:

The developer is poured into a vacuum flask having an internal length of approximately 22 cm and an internal diameter of about 4 cm. The developer is added until three-quarters of the free space is filled. The negative material to be tested is fastened by means of rubber bands to a glass strip having a width of about 3.5 cm and a length of about 20 cm. The glass strip is fixed to an inert stopper and projects into the flask when the stopper is in place. The stopper carrying the glass strip and test films is inserted in the flask and the development is carried out at the prescribed temperature. During development the vessel is given an oscillatory movement by tilting it in a vertical plane to an angle of about 45 degrees above and below the horizontal. The rate is such that one complete cycle is made in about 1 second. At the same time, the vessel is revolved about its axis, the time for one revolution being about 5 seconds. To terminate development the films are withdrawn and immediately immersed in the fixing bath.

3.3.3.5 Fixing *. The test samples shall be immersed in the following fixing bath immediately after development:

Sodium thiosulfate (hypo)	250 g
Sodium sulfite (desiccated)	10 g
** Sodium bisulfite	25 g
Water to make	1000 cm³

The fixing solution shall be held at 20 °C ± 5 degrees and the fixing time shall be approximately 15 minutes.

3.3.3.6 Washing. Washing shall be done in water at 20 °C ± 5 degrees.

3.3.3.7 Drying. The samples shall be dried in evenly circulated air maintained at a temperature of 20 °C ± 5 degrees and a relative humidity of (70 ± 10) percent.

3.3.4 Density. The density used in obtaining the characteristic curve of the photographic material shall be ISO Recommended diffuse density *** as defined by the ISO Recommendation

* Sold under such trade names as Metol, Elon, Rhodol, and Pictol.

* Chemicals shall be used in which impurities known to be photographically harmful are limited to a safe quantity.

** Potassium pyrosulfite may be substituted in equal quantities.

*** The specification of the spectral conditions for the determination of density for ISO Recommended Speed evaluation is unnecessary for ordinary films covered by this standard because the ISO Recommended developer produces photographic deposits which are nearly spectrally nonselective for these films. As pointed out in ISO Recommendation ISO/R 5 the specification of the geometric type of density (ISO Recommended diffuse density) is sufficient for samples of this type.

In case films are encountered which are so spectrally selective that the fractional gradient speed is significantly affected by variations in the spectral conditions in the densitometry, ISO Recommended diffuse printing density, Type P2-b, as defined by ISO Recommendation ISO/R 5, shall be used.

Spectral conditions approximately equal to those involved in the determination of visual density, Type V1; printing density, Type P2; photoelectric density, Type P.E. 4; and photoelectric density, Type P.E. 10, as outlined in ISO Recommendation ISO/R 5, are in common use in practical densitometers and all of these spectral conditions are ordinarily suitable for use in ISO Recommended Speed determination. The geometric conditions in the densitometry are, however, important and ISO Recommended diffuse density is specified for ISO Recommended Speed determination.