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Photography — Electronic still-picture cameras — Determination of ISO speed

Photographie — Appareils de prises de vue électroniques — Détermination de la sensibilité ISO

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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.

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 12232 was prepared by Technical Committee ISO/TC 42, *Photography*.

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

Attention is drawn to the possibility that some of the elements of this International Standard may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patents.

Introduction

The ISO speed rating is an important attribute of photographic systems. Standardization assists users and manufacturers in obtaining proper exposures and in determining the low light capability of electronic still cameras. The camera exposure is determined by the exposure time, the lens aperture, the lens transmittance, the level and colour temperature of the scene illumination, and the scene reflectance. When an image from an electronic still-picture camera is obtained using an insufficient exposure, proper tone reproduction can generally be maintained by increasing the electronic gain, but the image will contain an unacceptable amount of noise. As the exposure is increased, the gain can be decreased, and therefore the image noise can normally be reduced to an acceptable level. If the exposure is increased excessively, the resulting signal in bright areas of the image may exceed the maximum signal level capacity of the image sensor or camera signal processing. This can cause the image highlights to be clipped to form a uniformly bright area, or to bloom into surrounding areas of the image. Therefore, it is important to guide the user in setting exposures properly. An ISO speed rating is intended to serve as such a guide. The methods for assigning an ISO speed rating to electronic cameras should harmonize with current photographic standards and practice. In order to be easily understood by photographers, the ISO speed rating for an electronic camera should directly relate to the ISO speed rating for photographic film cameras. For example, if an electronic camera has an ISO speed rating of ISO 100, then the same exposure time and aperture should be appropriate for an ISO 100 rated film/process system.

The ISO speed ratings for electronic cameras described in this International Standard are intended to harmonize with ISO speed ratings for films. However, there are differences between electronic and film imaging systems that preclude exact equivalency in use. Cameras with variable gain, and digital processing after the data has been captured, allow desired tone reproduction to be achieved over a range of camera exposures. It is therefore possible for electronic cameras to have a range of speed ratings.[1)] This range is defined as the ISO speed latitude. To prevent confusion, a single value is designated as the ISO speed, with the upper and lower limits of the ISO speed latitude indicating the speed range.

1) While it is also possible to use many films at a variety of camera exposures, the behaviour of film is fundamentally different from that of electronic sensors. For example, significant underexposure typically results in uncorrectable tone reproduction errors in film-based photographic systems.

The camera measurements described in this International Standard are performed in the digital domain, using digital analysis techniques. For electronic cameras that include only analog outputs, the analog signal should be digitized, so that the digital measurement can be performed. The digitizing equipment should be characterized, so that the effects of the digitization can be removed from the measurement results. When this is not possible, the type of digitizing equipment used should be reported along with the measurement results.

Since the noise performance of an image sensor may vary significantly with exposure time and operating temperature, these operating conditions are specified. The visibility of noise to human observers depends on the magnitude of the noise, the apparent tone of the area containing the noise, and the spatial frequency of the noise. The magnitude of the noise present in an output representation depends on the noise present in the stored image data and the contrast amplification or gain applied to the data in producing the output. The noise visibility is different for the luminance (or monochrome) channel and the colour (or colour difference) channels. Therefore, this International Standard accounts for these factors in measuring the noise-based speed and speed latitude values.

Photography — Electronic still-picture cameras — Determination of ISO speed

1 Scope

This International Standard specifies a method for assigning exposure index values, ISO speed ratings, and ISO speed latitude ratings to electronic still-picture cameras. The standard applies to both monochrome and colour electronic still-picture cameras.

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

ISO 2721:1982, *Photography — Cameras — Automatic controls of exposure.*

ISO 7589:1984, *Photography — Illuminants for sensitometry — Specifications for daylight and incandescent tungsten.*

ISO 14524:—[2], *Photography — Electronic still-picture cameras — Methods for measuring opto-electronic conversion functions (OECFs).*

ITU-R BT.709:1993, *Basic parameter values for the HDTV standard for the studio and for international programme exchange.*

3 Definitions

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

3.1 electronic still-picture camera: Camera incorporating an image sensor that outputs an analog or digital signal representing a still picture, and/or records an analog or digital signal representing a still picture on a removable media, such as a memory card or magnetic disk.

3.2 exposure index: Numerical value that is inversely proportional to the exposure provided to an image sensor to obtain an image. Images obtained from a camera using a range of exposure index values will normally provide a range of image quality levels.

2) To be published.

3.3 exposure series: Series of images of the same subject taken using different exposure index values.

3.4 image sensor: Electronic device that converts incident electromagnetic radiation into an electronic signal; for example, a charge-coupled device (CCD) array.

3.5 ISO speed: Numerical value calculated from the exposure provided at the focal plane of an electronic camera to produce specified camera output signal characteristics using the methods described in this International Standard. The ISO speed should correlate with the highest exposure index value that provides peak image quality for normal scenes.

3.6 ISO speed latitude: Set of two numerical values calculated from the exposure provided at the focal plane of an electronic camera to produce specified camera output signal characteristics using the methods described in this International Standard. The ISO speed latitude should correlate with the range of exposure index values that provide acceptable image quality for normal scenes.

3.7 photosite integration time: Total time period during which the photosites of an image sensor are able to integrate the light from the scene to form an image.

3.8 signal processing: Operations performed by electronic circuits or algorithms that convert or modify the output of an image sensor.

4 Exposure index values

An exposure index (EI) is a numerical value that is inversely proportional to the exposure provided to an image sensor to obtain an image. Images obtained from a camera, using a range of EI values, will normally provide a range of image quality levels. The ISO speed of an electronic still-picture camera is equal to a particular exposure index value calculated from the exposure provided at the focal plane of an electronic camera to produce specified camera output signal characteristics using the methods described in this International Standard. The equations used in this International Standard have been chosen to create a link between electronic and conventional silver halide based photographic systems. Using a particular ISO speed value as the exposure index on an electronic still camera should result in the same camera exposure settings, and resulting focal plane exposures, as would be obtained using the same exposure index on a film camera or other photographic exposure meter.

4.1 Focal plane measurement

For electronic still (or other) camera exposure meters, where the arithmetic mean focal plane exposure is measured within a circle lying in the centre of the image with a diameter of 75/100 times the shorter dimension of the image field, the exposure index values should be computed using equation (1), as described in ISO 2721.

$$\mathrm{EI} = \frac{10}{H_\mathrm{a}} \qquad \text{. . . (1)}$$

where H_a is the arithmetic mean focal plane exposure, in lux seconds [3)4)].

3) Note that the value of 10 as the constant in equation (1) is consistent with ISO 2721 and ISO 5763. These International Standards assume that the exposure is an arithmetic mean value, as is normally provided by a camera light meter. If the geometric mean exposure was used in place of the arithmetic mean exposure, a lower value for this constant would be appropriate. Note that the arithmetic mean exposure is obtained when the linear exposure values are averaged, while a geometric mean exposure is obtained by taking the antilog of the average of the logarithmic exposure values. An approximation to the geometric mean is also obtained by taking the antilog of the average measured film densities in conventional photographic systems, provided that the film Hurter and Driffield (H and D) curve has a straight line characteristic over the film exposure range. Note also that the brightness response of the human visual system to the luminances of objects in a scene is approximately logarithmic.

4) Note that the arithmetic mean focal plane exposure for statistically average scenes is equal to approximately 18 % of the focal plane exposure which would be obtained from a perfectly diffuse 100 % reflectance object in a statistically average scene. Therefore, the arithmetic mean focal plane exposure equals 2/10 times the focal plane exposure which would be obtained from a 90 % reflectance test card in a statistically average scene.

4.2 Scene luminance measurement

For electronic still (or other) camera exposure meters where the arithmetic mean scene luminance is measured, the expected value of the arithmetic mean focal plane exposure required in equation (1) can be computed using equation (2). The derivation of equation (2) is given in annex B.

$$H_a = \frac{65 L_a t}{100 A^2} \qquad \text{. . . (2)}$$

where

A is the effective *f*-number of the lens;

L_a is the arithmetic mean luminance, in candelas per square metre;

t is the photosite integration time, in seconds.

NOTE — Note that the laboratory measurement of L_a can be simplified by using a full-frame uniformly illuminated diffuse-reflecting test card, so that the arithmetic mean luminance can be measured by simply measuring the luminance at the centre of the image.

The effective *f*-number of the lens for the focused image shall be calculated using the equation:

$$\text{Effective } f\text{-number} = (1 + 1/R)\ f\text{-number} \qquad \text{. . . (3)}$$

where R is the ratio of the height of the camera field of view at the focal distance to the height of the image at the focal plane. If the camera is focused at infinity, the effective *f*-number is equal to the *f*-number of the lens.

Therefore, for electronic still (or other) camera exposure meters where the arithmetic mean scene luminance is measured, exposure index values should be computed using equation (4), derived by substituting equation (2) into equation (1).

$$\mathrm{EI} = \frac{154 A^2}{10 L_a t} \qquad \text{. . . (4)}$$

5 Test conditions

The following measurement conditions should be used as nominal conditions when determining the ISO speed rating of an electronic still-picture camera. If it is not possible or appropriate to achieve these nominal operating conditions, the actual operating conditions shall be listed along with the ISO speed-rating value.

5.1 Illumination

The ISO speed rating shall indicate whether the daylight or tungsten illuminant was used. ISO 7589 describes the procedures for determining if the illumination used in a specific speed-rating determination test is an acceptable match to the daylight and tungsten sensitometric illuminants.

5.1.1 Daylight illumination

For daylight ISO speed measurements without the camera lens, the ISO sensitometric daylight illuminant given in table 1 of ISO 7589:1984 shall be used. This illuminant is defined as the product of the spectral power distribution of CIE standard colorimetric illuminant D_{55} and the spectral transmittance of the International Standard camera lens. For measurements with the camera lens in place, the spectral radiance characteristics of the light used for the measurement should be equivalent to the daylight ISO standard source provided in the second column of table 1 of ISO 7589:1984. In order to apply the ISO/SDI (Spectral Distribution Index) criterion, the spectral radiance of the light shall be measured and then multiplied by the relative spectral transmittance of the ISO standard lens, which is also described in ISO 7589, prior to multiplying by the weighted spectral sensitivities.

5.1.2 Tungsten illumination

For tungsten ISO speed measurements without the camera lens, the ISO sensitometric tungsten illuminant given in table 2 of ISO 7589:1984 shall be used. This illuminant is defined as the product of the average spectral power distribution of experimentally measured sources having a colour temperature of approximately 3050 K and the spectral transmittance of the International Standard camera lens. For measurements with the camera lens in place, the spectral radiance characteristics of the light used for the measurement should be equivalent to the tungsten ISO standard source provided in the second column of table 2 of ISO 7589:1984. In order to apply the ISO/SDI (Spectral Distribution Index) criterion, the spectral radiance of the light shall be measured and then multiplied by the relative spectral transmittance of the ISO standard lens, which is also described in ISO 7589, prior to multiplying by the weighted spectral sensitivities.

5.2 Temperature and relative humidity

The ambient temperature during the acquisition of the test data shall be 23 °C ± 2 °C, as specified in ISO 554, and the relative humidity should be 50 % ± 20 %.

5.3 White balance

For a colour camera, the camera white balance should be adjusted, if possible, to provide proper white balance (equal RGB signal levels) for the illumination light source, as specified in ISO 14524.

5.4 Infrared (IR) blocking filter

If required, an infrared (IR) blocking filter shall be used, as specified in ISO 14524.

5.5 Photosite integration time

The photosite integration time should not be longer than 1/30 s.

6 Determination of ISO speed

With appropriate electrical gain, an electronic camera can provide an appropriate output signal level for a range of sensor exposure levels. The maximum exposure level is the exposure level where typical picture highlights will be clipped as a result of saturating the image sensor signal capacity or reaching the maximum signal level for camera signal processing. The minimum exposure level depends on the amount of noise that can be tolerated in the image. These situations lead to two different types of speed values, saturation-signal-based values, and noise-based values. The ISO speed is preferably determined using a noise-based method. The saturation-based value is preferably used to indicate the camera's overexposure speed latitude. A second noise-based value is preferably used to indicate the camera’s underexposure speed latitude. For some types of electronic still-picture cameras, such as those employing lossy compression methods that cannot be bypassed or those with excessively high noise levels, it is not possible to correctly determine the noise-based ISO speed. In such cases, the ISO speed of the camera is determined using the saturation-based measurement, and the ISO speed latitude values are not reported.

6.1 Saturation-based speed

In photographic applications where the scene illumination level can be controlled, for example in studio photography, the photographer normally prefers to use a camera exposure index which provides the best possible image quality. In this situation, a saturation-signal-based rating is appropriate. This rating allows the user to set the camera exposure so that image highlights are just below the maximum possible (saturation) camera signal value.

6.1.1 Focal plane measurement

The saturation-based speed, S_{sat}, of an electronic still-picture camera is defined as[5]:

$$S_{sat} = \frac{78}{H_{sat}} \qquad \text{. . . (5)}$$

where H_{sat} is the minimum focal plane exposure, in lux seconds, that produces the maximum valid (not clipped or bloomed) camera output signal.

6.1.2 Scene luminance measurement

If the focal-plane exposure cannot be measured, S_{sat} shall be computed using equation (6).

$$S_{sat} = \frac{120A^2}{L_{sat}t} \qquad \text{. . . (6)}$$

where

A is the effective *f*-number of the lens;

L_{sat} is the minimum luminance, in candelas per square metre, of a uniform diffuse reflecting medium;

t is the exposure time, in seconds.

6.2 Noise-based speed

In many photographic applications, it is desirable to use the highest exposure index (lowest exposure) possible, in order to maximize the depth of field, minimize the exposure time, and offer the maximum acceptable speed latitude for exposure of image highlights. An exposure index that provides an appropriately low noise image for typical electronic camera applications is called a “noise-based speed”. The value is based on an objective correlation to subjective judgements of the acceptability of various noise levels in exposure series images. Two different noise-based speeds are determined, one that provides the “first excellent” image and a second that provides the “first acceptable” image. The recommended procedure for determining these noise-based speeds is given in annex A.

6.2.1 Focal plane method

The two noise-based speeds of an electronic still-picture camera, $S_{noise10}$ and $S_{noise40}$, shall be determined from the focal plane exposure required to produce specific image incremental signal-to-noise ratio values using the following equation[6]:

$$S_{noisex} = \frac{10}{H_{S/Nx}} \qquad \text{. . . (7)}$$

where $H_{S/Nx}$ is the exposure which provides a camera signal-to-noise ratio satisfying the following criterion:

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5) Note that equation (5) provides 1/2 “stop” of headroom (41 % additional headroom) for specular highlights above the signal level that would be obtained from a theoretical 100 % reflectance object in a statistically average scene, so that a theoretical 141 % reflectance object in a statistically average scene would produce a focal plane exposure of H_{sat}. Therefore, an 18 % reflectance test card in a statistically average scene would produce a focal plane exposure of 128/1 000 H_{sat}. Thus, the multiplicative constant 78 in equation (5) is equal to 10 times 1 000/128, where the value 10 is the constant from equation (1).

6) The constants used in the numerator place the specified signal-to-noise ratio at a middle gray image tone, or approximately an 18 % reflectance value for a standard 160:1 contrast ratio scene.

$$S/Nx = \frac{H \cdot g(H)}{\sigma(D_H)} \qquad (8)$$

where

- S/Nx is 40 for S_{noise40}, corresponding to the “first excellent” image;
- S/Nx is 10 for S_{noise10}, corresponding to the “first acceptable” image;
- H is the input photometric exposure, in lux seconds;
- $g(H)$ is the incremental gain (the rate of change in the output level divided by the rate of change in the input exposure) of the monochrome output channel (for monochrome cameras) or the luminance channel (for colour cameras);
- $\sigma(D_H)$ is the standard deviation of the monochrome output level values (for monochrome cameras) or weighted colour output level values (for colour cameras), taken from a 64 by 64 pixel area[7].

The S/N values of 40 for the "first excellent" image and 10 for the "first acceptable" image were determined using subjective experiments performed during the development of this International Standard. These incremental signal-to-noise ratios were judged to provide "excellent" and "acceptable" quality prints of typical pictorial images using a high quality printer at approximately 70 sensor pixels per cm on the print (just small enough to be visually imperceptible) using normal tone reproduction. Note that 70 pixels per cm at a standard viewing distance of 25 cm corresponds to 30 pixels per degree of visual subtense. For prints made using significantly higher sensor pixels per cm values, lower S/N values may still yield acceptably low noise prints, while for prints made using signficantly lower sensor pixels per cm values, higher S/N values may be required to provide acceptably low noise prints. In these cases, the S/N value for "excellent" quality prints is approximately equal to $(70/P)$ times the S/N values listed, where P is the actual number of sensor pixels per cm on the print.

If an electronic still-picture camera is too noisy to meet the $S/N = 40$ criterion, the noise-based values shall not be reported, and the saturation-based value shall be reported as the ISO speed of the camera.

6.2.2 Scene luminance method

If the focal plane exposure of the electronic still-picture camera cannot be measured, the ISO noise-based speeds shall be determined from the scene luminance required to produce specific image incremental signal-to-noise ratio values using the following equation:

$$S_{\text{noise}} = \frac{154A^2}{10L_{S/Nx} \times t} \qquad (9)$$

where

- A is the effective *f*-number of the taking lens;
- t is the photosite integration time;

and $L_{S/Nx}$ is the luminance that provides a camera signal-to-noise ratio satisfying the following criterion:

$$S/Nx = \frac{L \cdot g(L)}{\sigma(D_L)} \qquad (10)$$

where

- S/Nx is 40 for S_{noise40}, corresponding to the “first excellent” image;
- S/Nx is 10 for S_{noise10}, corresponding to the “first acceptable” image;
- L is the luminance, in candelas per square meter;

7) If there is no significant effect on the resulting S/N value, a smaller or larger area is permitted.

g(L) is the incremental gain (the rate of change in the mean output level divided by the rate of change in the input luminance) of the monochrome output channel (for monochrome cameras) or the luminance channel (for colour cameras);

$\sigma(D_L)$ is the standard deviation of the monochrome output level values (for monochrome cameras) or weighted colour output level values (for colour cameras), taken from a 64 by 64 pixel area.

If an electronic still-picture camera is too noisy to meet the S/N = 40 criterion, the noise-based speed shall not be reported, and the saturation-based speed shall be reported as the ISO speed of the camera.

6.2.3 Colour cameras

For colour cameras using a single exposure process, $\sigma(H)$ or $\sigma(L)$ shall be determined using the weighted sum of the luminance channel noise and the colour-difference channel noise.If the proper luminance weighting values for the RGB channel spectral sensitivities are known, they shall be used to calculate the luminance channel data. If these values are not known, the following weighting, given in ITU-R BT.709, shall be used:

$$Y = 2125/10000\ R + 7154/10000\ G + 721/10000\ B \qquad \ldots (11)$$

The standard deviation of the camera noise, $\sigma(D_H)$ or $\sigma(D_L)$ shall be computed from the luminance channel standard deviation σ(Y), the red-minus luminance channel standard deviation σ(R-Y), and the blue-minus luminance channel standard deviation σ(B-Y), using the following equation:

$$\sigma(D_H) \text{ or } \sigma(D_L) = \{\sigma(Y)^2 + 64/100\ \sigma(R\text{-}Y)^2 + 16/100\ \sigma(B\text{-}Y)^2\}^{1/2} \qquad \ldots (12)$$

NOTE — Note that the R-Y and B-Y colour difference signals are not scaled by constants, unlike the C_1 and C_2 colour difference signals in ITU-R BT.709.

6.2.4 Compression

If the electronic still-picture camera includes any form of lossy compression, the compression shall be disabled, if possible, during the determination of $\sigma(D_H)$ or $\sigma(D_L)$. If it is not possible to disable the camera compression, the noise-based values cannot be properly determined, and shall not be reported.

6.2.5 Quantization effects

If the electronic still-picture camera has quantization steps which are similar in magnitude to, or larger than, the measured standard deviation, quantization effects may result in the measured standard deviation being incorrect. This type of error may be corrected to some extent by repeated measurements on different image files, but if the actual standard deviation is small, even repeated measurements may result in the value determined being too low. To compensate for this effect, the value of $\sigma(D_H)$ or $\sigma(D_L)$ used in equations (8) and (10) shall be not less than 1/2.

6.3 Method of reporting

The ISO speed of an electronic still-picture camera shall be denoted “ISO xxx D” for daylight illumination, and “ISO xxx T” for tungsten illumination. The reported number “xxx” is the value from the third column of table 1, from the same row as the $S_{noise40}$ value (in the second column of table 1) determined in 6.2.The ISO speed latitude shall be denoted “ISO Speed Latitude yyy-zzz D” for daylight illumination, and “ISO Speed Latitude yyy-zzz T” for tungsten illumination. The reported number “yyy” is the value from the third column of table 1, from the same row as the S_{sat} value (in the first column of table 1) determined in 6.1. The reported number “zzz” is the value from the third column of table 1, from the same row as the $S_{noise10}$ value determined in 6.2.

If $S_{noise40}$ is lower than S_{sat}, or if $S_{noise40}$ cannot be determined because the noise level of the camera does not allow for a S/N = 40 value, the ISO speed of the camera shall be denoted “ISO yyy D” for daylight illumination and “ISO yyy T” for tungsten illumination, where “yyy” is the speed rating from table 1 corresponding to the S_{sat} value determined in 6.1. The reported number “yyy” is the value from the third column of table 1, from the same row as the S_{sat} value (in the first column of table 1) determined in 6.1. The ISO speed latitude shall be denoted as described in the preceding paragraph, unless the $S_{noise10}$ value is lower than the S_{sat} value, or the noise level of the camera does not allow for a $S/N = 10$ value, in which case an ISO speed latitude shall not be reported.

If the camera includes lossy compression that cannot be disabled, the ISO noise-based speed value and speed latitude cannot be determined, and the ISO speed of the camera shall be denoted “ISO yyy D” for daylight illumination and “ISO yyy T” for tungsten illumination. The reported number “yyy” is the value from the third column of table 1, from the same row as the S_{sat} value (in the first column of table 1) determined in 6.1, and an ISO speed latitude shall not be reported.

Some electronic still-picture cameras form a colour image using a monochrome image sensor and a colour-filter wheel to provide colour sequential image records. These cameras may use different photosite integration times, or different lens apertures, for the different colour sequential exposures. For such cameras, the ISO speed and ISO speed latitude of each colour should be measured and reported separately for each colour.

Table 1 — ISO speed and ISO speed latitude reported values

S_{sat} (from 6.1)	S_{noise} (from 6.2)	Reported value
$3 < S_{sat} \leqslant 4$	$4 \leqslant S_{noise} < 5$	4
$4 < S_{sat} \leqslant 5$	$5 \leqslant S_{noise} < 6$	5
$5 < S_{sat} \leqslant 6$	$6 \leqslant S_{noise} < 8$	6
$6 < S_{sat} \leqslant 8$	$8 \leqslant S_{noise} < 10$	8
$8 < S_{sat} \leqslant 10$	$10 \leqslant S_{noise} < 12$	10
$10 < S_{sat} \leqslant 12$	$12 \leqslant S_{noise} < 16$	12
$12 < S_{sat} \leqslant 16$	$16 \leqslant S_{noise} < 20$	16
$16 < S_{sat} \leqslant 20$	$20 \leqslant S_{noise} < 25$	20
$20 < S_{sat} \leqslant 25$	$25 \leqslant S_{noise} < 32$	25
$25 < S_{sat} \leqslant 32$	$32 \leqslant S_{noise} < 40$	32
$32 < S_{sat} \leqslant 40$	$40 \leqslant S_{noise} < 50$	40
$40 < S_{sat} \leqslant 50$	$50 \leqslant S_{noise} < 64$	50
$50 < S_{sat} \leqslant 64$	$64 \leqslant S_{noise} < 80$	64
$64 < S_{sat} \leqslant 80$	$80 \leqslant S_{noise} < 100$	80
$80 < S_{sat} \leqslant 100$	$100 \leqslant S_{noise} < 125$	100
$100 < S_{sat} \leqslant 125$	$125 \leqslant S_{noise} < 160$	125
$125 < S_{sat} \leqslant 160$	$160 \leqslant S_{noise} < 200$	160
$160 < S_{sat} \leqslant 200$	$200 \leqslant S_{noise} < 250$	200
$200 < S_{sat} \leqslant 250$	$250 \leqslant S_{noise} < 320$	250
$250 < S_{sat} \leqslant 320$	$320 \leqslant S_{noise} < 400$	320
$320 < S_{sat} \leqslant 400$	$400 \leqslant S_{noise} < 500$	400
$400 < S_{sat} \leqslant 500$	$500 \leqslant S_{noise} < 640$	500
$500 < S_{sat} \leqslant 640$	$640 \leqslant S_{noise} < 800$	640
$640 < S_{sat} \leqslant 800$	$800 \leqslant S_{noise} < 1\,000$	800
$800 < S_{sat} \leqslant 1\,000$	$1\,000 \leqslant S_{noise} < 1\,250$	1 000
$1\,000 < S_{sat} \leqslant 1\,250$	$1\,250 \leqslant S_{noise} < 1\,600$	1 250
$1\,250 < S_{sat} \leqslant 1\,600$	$1\,600 \leqslant S_{noise} < 2\,000$	1 600
$1\,600 < S_{sat} \leqslant 2\,000$	$2\,000 \leqslant S_{noise} < 2\,500$	2 000
$2\,000 < S_{sat} \leqslant 2\,500$	$2\,500 \leqslant S_{noise} < 3\,200$	2 500
$2\,500 < S_{sat} \leqslant 3\,200$	$3\,200 \leqslant S_{noise} < 4\,000$	3 200
$3\,200 < S_{sat} \leqslant 4\,000$	$4\,000 \leqslant S_{noise} < 5\,000$	4 000
$4\,000 < S_{sat} \leqslant 5\,000$	$5\,000 \leqslant S_{noise} < 6\,400$	5 000
$5\,000 < S_{sat} \leqslant 6\,400$	$6\,400 \leqslant S_{noise} < 8\,000$	6 400
$6\,400 < S_{sat} \leqslant 8\,000$	$8\,000 \leqslant S_{noise} < 10\,000$	8 000
$8\,000 < S_{sat} \leqslant 10\,000$	$10\,000 \leqslant S_{noise} < 12\,500$	10 000

Annex A
(informative)

Recommended procedure for determining the noise-based ISO speed

The value of $H_{S/Nx}$ in equation (7) or $L_{S/Nx}$ in equation (9) may be determined by plotting the incremental S/N as a function of H or L (see figure A.1) and estimating the value that produces an incremental S/N value equal to 40 for S_{noise40} and 10 for S_{noise10}. A preferred procedure for making this determination is as follows.

a) Determine the system opto-electronic conversion function (OECF) according to ISO 14524. Focal plane OECF values are preferred, although alternative focal plane values may be used for cameras with fixed lenses, and camera OECF values may be used for cameras with fixed lenses and non-overrideable automatic exposure control.

b) With colour cameras, calculate Y, R-Y, and B-Y image data as specified in 6.2.3. It is usually necessary to add an offset in calculating the difference channels to prevent the difference values from wrapping around zero. Wrapped values will produce incorrectly low standard deviation values.

c) Determine the standard deviation of the pixel values in each 64 by 64 area selected for the OECF measurement, using equation (12) to calculate $\sigma(D_H)$ or $\sigma(D_L)$ for colour cameras.

d) Determine the incremental gain of the system at each exposure, g(H_j), by averaging the change in Y output level divided by the change in exposure when going from the exposure immediately below the exposure to it, with the change in Y output level divided by the change in exposure when going from the exposure to the exposure immediately above it [see equation (A.1)]. Incremental gain values should not be determined for the endpoint exposures using this method, but these values should not be needed for speed determination. Note that exposure values, not log exposure values, are used in determining incremental gain of the Y image data.

$$g(Hj) = \frac{\mathrm{OL}(Hj) - \mathrm{OL}(Hj - \delta Hi,j)}{2\delta Hi,j} + \frac{\mathrm{OL}(Hj) + \delta Hj,k) - \mathrm{OL}(Hj)}{2\delta Hj,k} \quad \text{. . . (A.1)}$$

where

OL is the output level;

$\delta Hi,j$ is the change in exposure between exposure i and exposure j.

A similar procedure is used to determine luminance incremental gain, with "luminance" substituted for "exposure" in the above procedure.

e) Calculate signal-to-noise values as a function of exposure or luminance using equation (8) or (10). Determine the exposure or luminance value which produces signal-to-noise values of 10 for S_{noise10} and 40 for S_{noise40}. These values are the $H_{S/Nx}$ or $L_{S/Nx}$ values used in the equations (7) or (9) to determine the ISO noise-based values.

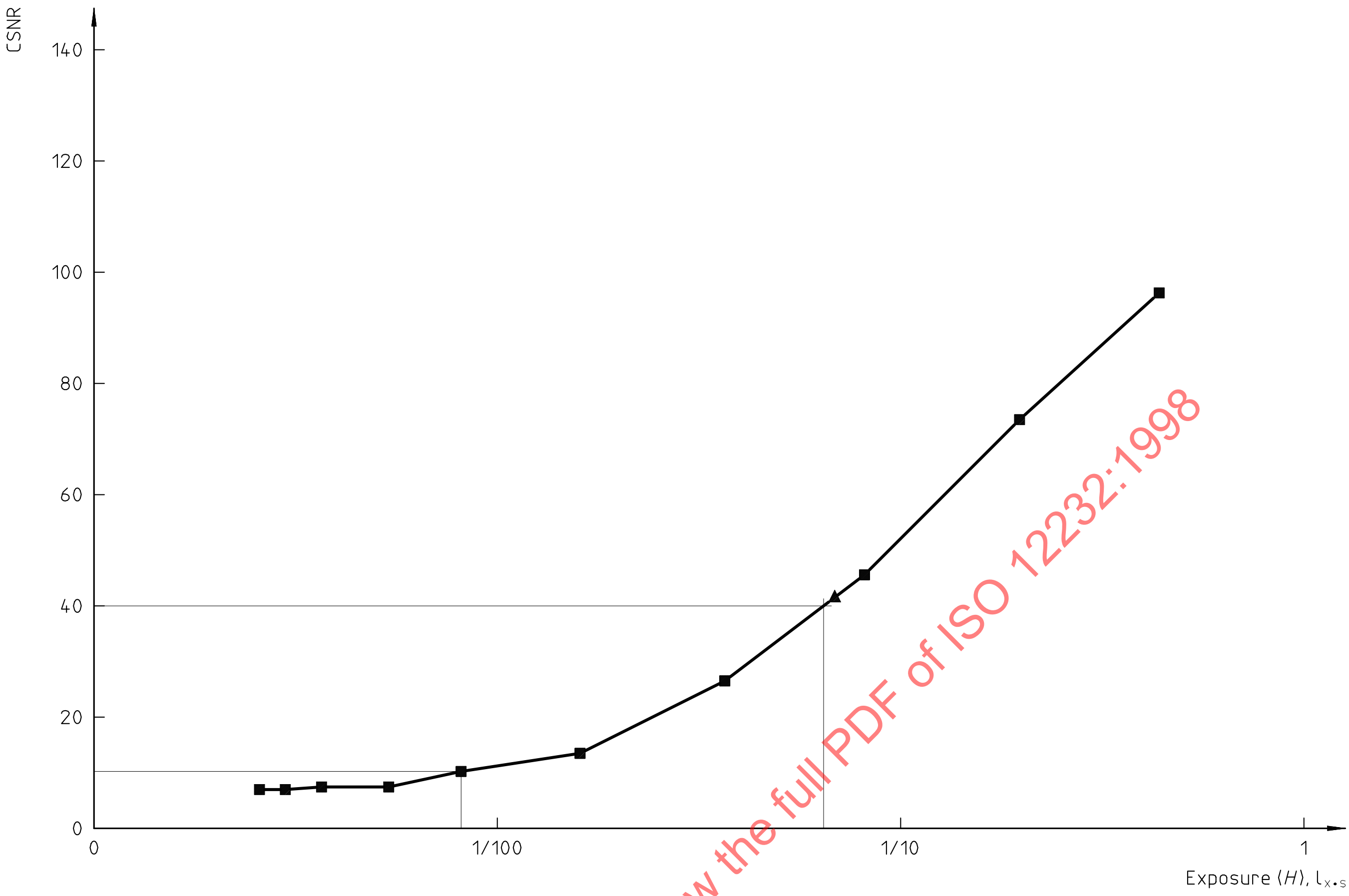

Figure A.1