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Standard Test Method for Classification of Film Systems for Industrial Radiography[1]

This standard is issued under the fixed designation E1815; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method covers a procedure for determination of the performance of film systems used for industrial radiography. This test method establishes minimum requirements that correspond to system classes.

1.2 This test method is to be used only for direct exposure-type film exposed with lead intensifying screens. The performance of films exposed with fluorescent (light-emitting) intensifying screens cannot be determined accurately by this test method.

1.3 The values stated in SI units are to be regarded as standard. The values given in parentheses are for information only.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.5 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

E94 Guide for Radiographic Examination Using Industrial Radiographic Film

E1316 Terminology for Nondestructive Examinations

2.2 *ISO Standards:*[3]

ISO 5-2 Photography Density Measurements—Part 2: Geometric Conditions for Transmission Density

ISO 5-3 Photography and Graphic Technology—Density Measurements—Part 3: Spectral Conditions

ISO 7004 Photography—Industrial Radiographic Films, Determination of ISO Speed, ISO average gradient and ISO gradients G2 and G4 When Exposed to X and Gamma Radiation

ISO 11699-1 Non-Destructive Testing—Industrial Radiographic Film—Part 1: Classification of Film Systems for Industrial Radiography

ISO 11699-2 Non-Destructive Testing—Industrial Radiographic Film—Part 2: Control of Film Processing by Means of Reference Values

ISO/IEC 17025 General Requirements for the Competence of Testing and Calibration Laboratories

2.3 *European CEN Standard:*[3]

EN 584-1 Non-Destructive Testing—Industrial Radiographic Film—Part 1: Classification of Film Systems for Industrial Radiography

3. Terminology

3.1 *Definitions*—For definitions of terms used in this test method, refer to Terminology E1316.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *characteristic curve*—curve showing the relationship between the common logarithm of exposure logK, and the optical density *D*.

3.2.2 *diffuse density*—quantitative measure of film blackening (optical density) as determined by a densitometer. It is the sum of all transmitted and scattered light into the half sphere behind the film.

3.2.3 *film gradient G*—the slope of the characteristic curve at a specified optical density, *D*, and a measure of the contrast of the film system.

[1] This test method is under the jurisdiction of ASTM Committee E07 on Nondestructive Testing and is the direct responsibility of Subcommittee E07.01 on Radiology (X and Gamma) Method.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.

TABLE 1 Limiting Values for Gradient, Gradient/Granularity Ratio, and Granularity

ASTM System Class	Minimum Gradient G at		Minimum Gradient/ Granularity Ratio, G/σ_D, at $D = 2.0$ above D_o	Maximum Granularity, σ_D, at $D = 2.0$ above D_o
	$D = 2.0$ above D_o	$D = 4.0$ above D_o		
Special	4.5	7.5	300	0.018
I	4.1	6.8	150	0.028
II	3.8	6.4	120	0.032
III	3.5	5.0	100	0.039
W-A	3.8	5.7	135	0.027
W-B	3.5	5.0	110	0.032
W-C	<3.5	<5.0	80	0.039

The classification is only valid for the complete film system. In general, the classification for X-rays as described in 7.1 can be transferred to other radiation energies and metallic screen types as well as films without screens and single coated films.
A certificate shall contain the following information:
–reference to this standard
–date
–measured values of gradient at $D = 2$ and $D = 4$ above fog and base
–measured granularity at $D = 2$ above fog and base
–calculated value of (D/σ_D) at $D = 2$ above fog and base
–Dose K_S for $D = 2$ above fog and base
–Processing conditions:
–Manual or automatic
–Type of chemistry
–Developer immersion time
–Developer temperature
–Classification in accordance with Table 1
Table 2 gives an example for a classification result of different film types, a developer system and given developing conditions.

3.2.4 *film system*—the film and associated film-processing requirements in accordance with the criteria established by the manufacturers of the film and processing chemicals.

3.2.5 *film system class*—classification taking into account of limiting values given in Table 1.

3.2.6 *gradient/noise ratio*—ratio of the gradient G and the granularity σ_D. It relates directly to the signal/noise ratio. All further parameters determining the signal, such as the modulation transfer function or the energy of the radiation, are considered to be constant.

3.2.6.1 *Discussion*—The limiting values given in this standard are related to fixed radiation energies and specified screens.

3.2.7 *granularity, σ_D*—stochastic fluctuation in a radiographic image, superimposed on the image of the object and typically caused by random, statistical groupings of individual silver particles in processed film.

3.2.8 *ISO speed S*—reciprocal value of the dose K_S measured in Gray, which results in a specified diffuse optical transmission density $D - D_0 = 2$ on the processed film, where D_0 is the fog and base density:

$$S = \frac{1}{K_S} \tag{1}$$

3.2.9 *signal/noise ratio*—in industrial radiography the ratio of a local film density to the granularity σ_D at this density level. It is correlated to the gradient/noise ratio.

3.2.10 *specular density*—quantitative measure of film blackening (optical density) when light passing the optics of a microdensitometer transmits the film.

4. Significance and Use

4.1 This test method provides a relative means for classification of film systems used for industrial radiography. The film system consists of the film and associated processing system (the type of processing and processing chemistry). Section 9 describes specific parameters used for this test method. In general, the classification for hard X-rays, as described in Section 9, can be transferred to other radiation energies and metallic screen types, as well as screens without films. The usage of film system parameters outside the energy ranges specified may result in changes to a film/system performance classification.

4.1.1 The film performance is described by contrast and noise parameters. The contrast is represented by gradient and the noise by granularity.

4.1.2 A film system is assigned a particular class if it meets the minimum performance parameters: for Gradient G at $D - D_0 = 2.0$ and $D - D_0 = 4.0$, and gradient/noise ratio at $D - D_0 = 2.0$, and the maximum performance parameter: granularity σ_D at $D = 2.0$.

4.2 This test method describes how the parameters shall be measured and demonstrates how a classification table can be constructed.

4.3 Manufacturers of industrial radiographic film systems and developer chemistry will be the users of this test method. The result is a classification table as shown by the example given in Table 2. Another table also includes speed data for user information. Users of industrial radiographic film systems may also perform the tests and measurements outlined in this

TABLE 2 Typical Film System Classification

Automatic Film Processing
Developer: Type A
Developer immersion time: XXX seconds
Developer temperature: XX°C/YY°F

Film Type[A]	ASTM System Class	Minimum Gradient G at		Minimum Gradient/ Granularity Ratio, G/σ_D, at $D = 2.0$ above D_o	Maximum Granularity, σ_D, at $D = 2.0$ above D_o	ISO Speed S	Dose, K_s, m Gy, $D = 2.0$
		$D = 2.0$ above D_o	$D = 4.0$ above D_o				
A	Special	5.4	9.1	360	0.015	32	29.0
B	I	4.5	8.4	281	0.016	64	14.0
C	I	4.4	7.6	232	0.019	100	8.7
D	I	4.4	7.6	169	0.026	200	4.6
E	II	4.4	7.6	142	0.031	320	3.2
F	III	4.0	5.2	114	0.035	400	2.5
G	W-A	4.2	6.5	225	0.019	100	8.6
H	W-B	4.1	5.3	170	0.025	200	5.0

[A] Family of films ranging in speed and image quality.

test method, provided that the required test equipment is used and the methodology is followed strictly.

4.4 The publication of classes for industrial radiography film systems will enable specifying bodies and contracting parties to agree to particular system classes, which are capable of providing known image qualities. See 8.2.

4.5 ISO 11699–1 and European standard EN 584-1 describe the same method for classification of film systems for industrial radiography, but its class definitions and number of classes do not align exactly with this test method. International users of these standards should be aware of these differences for their particular applications.

NOTE 1—ASTM research report E07–1005 contains documentation of technical methods used during the development of this test method.[4]

5. Microdensitometer Requirements

5.1 The influx aperture of the microdensitometer shall be approximately circular in shape, with a diameter (referred to the plane of the specimen) not less than 1.2× or more than 2× the diameter of the efflux aperture.

5.2 The reduction of the influx aperture by the influx optics and the magnification of the specimen onto the efflux aperture by the efflux optics shall lie in the range from 20 to 100×. The two magnifications need not be equal.

5.3 The efflux (or measuring aperture) shall be preferably circular in shape. Its effective diameter referred to the specimen plane shall be 100 ± 5 µm.

5.4 The spectral response of the microdensitometer system shall be visual, as specified by ISO 5-3.

5.5 An electronic band-pass filter, used to reduce the unwanted signal caused by system artifacts, shall have its low-frequency boundary set so the system response is 3 dB down at a temporal frequency corresponding to a spatial frequency of 0.1 cycles/mm. Its high-frequency boundary shall be set so that the system response is 3 dB down at a temporal frequency corresponding to the first zero in the spatial frequency response of the circular aperture. Mathematical procedures that can be shown to produce equivalent reductions in the effects of system artifacts are acceptable alternatives to the use of this filter (see 7.3).

6. Sampling and Storage

6.1 For product specification it is important that the samples evaluated yield the average results obtained by users. This will require the evaluation of several different batches periodically under conditions specified in this standard. Prior to evaluation, the samples shall be stored according to the manufacturers' recommendations for a length of time to simulate the average age at which the product is normally used. The basic objective in selecting and storing samples as described above is to ensure the film characteristics are representative of those obtained by a consumer at the time of use.

7. Test Method

7.1 *Preparation*

7.1.1 The film samples shall be exposed to X-rays from tungsten target tubes. Inherent filtration of the tube, plus an additional copper filter located as close to the X-ray tube target as possible shall provide filtration equivalent to (8.00 ± 0.05) mm of copper. The potential across the X-ray tube shall be adjusted until the half-value-absorption is obtained with (3.5 ± 0.2) mm of copper. A potential of approximately 220 kV generally meets this requirement.

7.1.2 The film system shall include a front and a back screen of 0.02 to 0.04 mm lead. If single coated films are used, the emulsion coated surface shall face the X-ray tube. Good film screen contact shall be ensured.

7.1.3 Exercise care to ensure that the film specimen does not contain density variations arising from the exposing equipment (such as non-uniform beam filters or damaged, or defective lead screens) or processing system. During and after exposure, prior to processing, maintain the film specimen at the temperature of 23°C ± 5°C and relative humidity of 50 ± 20 %. The film processing chemicals and procedures shall be the same for

[4] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Reports RR:E07-1005 and RR:E07-1007.

determining gradient and granularity, and they shall be used and described completely as specified.

7.1.4 Use manufacturer certified film test strips in accordance with ISO 11699-2 to test the specified developer system with the specified immersion time and developer temperature. The speed index S_x shall be within ±5 % of the manufacturer's certificate. The developer temperature may differ by ±1°C from the certified value to adjust S_X within ±5 % of the manufacturer certificate value. The obtained S_X and used developer temperature shall be documented in the test report. This test shall be done, on a daily basis, before and after the development of the exposed films for classification with the same developer temperature and immersion time.

7.1.5 If a manufacturer certificate is not available, film test strips shall be manufactured and calibrated according to ISO 11699-2 by the user.

7.2 *Measurement of Gradient G:*

7.2.1 Gradient G relates to a D versus $\log_{10} K$ curve. In the scope of this test method, G is calculated from the slope $^{dD}/_{dK}$ of a D versus K curve at density $(D - D_o)$, as follows:

$$G = \frac{dD}{d \log_{10} K} = \frac{K}{\log_{10} e} \times \frac{dD}{dK} \tag{2}$$

where:

K = dose required for density $D - D_o$, and
D_o = fog and base density.

7.2.2 The D versus K curve is approximated by a polynomial of third order. To obtain a reliable curve, a series of exposures are made with the same film sample to obtain at least twelve uniformly distributed measuring points covering at least density 1.0 and 4.5 above D_0. The polynomial approximation shall include all measured values between 1,0 and 4,5. For the numerical approximation (fit procedure) no zero value shall be included. At least six gradient measurements shall be made on different film samples to determine the mean gradient value G. The densitometer used shall be calibrated regularly up to a diffuse density of $D \geq 4.8$. For the calibration, a certified film step tablet shall be used. This shall be generated from double sided X-ray film of System Class 1 or special.

NOTE 2—Densitometers may have limited accuracy for measurements at $D > 4$ and need careful calibration correction in the full range. Small deviations of the density values at $D > 4$ have considerable influence to the accuracy of the G at $D - D_0 = 4$ – value due to the properties of the polynomial approximation procedure.

7.2.3 The mean gradient values shall be determined with a maximum uncertainty of ±5 % for the gradient at $D = 2$ above fog and base (G2) at a confidence level of 95 % and ±7 % for the gradient at $D = 4$ above fog and base (G4) at a confidence level of 95 %.

7.2.4 Measurement laboratories, which certify film systems, shall participate in a proficiency test on a periodical basis. A new film, exposed in accordance with this standard, shall be used in all participating laboratories and for each periodical test.

7.3 *Measurement of Granularity* σ_D

7.3.1 The granularity is measured by linear or circular scanning of a film of constant diffuse optical density with a microdensitometer. Both emulsion layers shall be recorded; this means that the depth of focus of the microdensitometer has to include both layers.

7.3.2 The granularity value shall be determined in terms of diffuse density.

7.3.3 If the optical density is measured as specular density, it shall be converted into diffuse optical density, using the plot of the curve of diffuse density versus specular density at the mean density value of the granularity film specimen. The diffuse density of each step shall be measured with the calibrated densitometer.

7.3.4 Determine this curve using a film having a stepped series of densities, which is prepared using the same type of film, exposure, and processing techniques as used for the granularity film specimen. The specimen film shall be scanned using identical microdensitometer settings. A limited range of densities can typically be measured for a given microdensitometer gain setting.

7.3.5 The stepped series of densities shall lie within that range.

7.3.6 The calibration shall be made from the diffuse vs specular density plot with at least five values between diffuse density 1.5 and 2.8 (including fog and base). The conversion can be performed on basis of a linear regression analysis of the log (diffuse density) vs. log (specular density) plot. The determined coefficients shall be used for the conversion of the specular density into diffuse density values.

7.3.7 The conversion shall be performed before the numerical determination of the standard deviation σ_D, which is a measure of the granularity. σ_D is calculated by:

$$\sigma_D = \sqrt{\frac{1}{N-1} \cdot \sum_{i=1}^{N} \left(D_i - \bar{D}\right)^2} \tag{3}$$

7.3.8 The diffuse optical density of the measured film shall be above fog and base. The determined σ_D value shall be corrected on the basis of the diffuse mean density above fog and base of this film. The corrected σ_D-value is calculated by:

$$\sigma_{D-corr} = \sigma_D \cdot \sqrt{2/\bar{D}} \tag{4}$$

7.3.9 As an alternative, three or more samples of the film specimen at different density levels, within the range from 1.80 to 2.20, may be measured, and the granularity value at a diffuse density of 2.00, above base plus fog, shall be taken from a linear regression analysis of the plot of granularity as a function of the square root of diffuse density above fog and base.

7.3.10 The scanning length on the radiographic film shall be at least 116 mm. The diameter of a circular measuring aperture of the microdensitometer shall be (100 ± 5) µm. A square aperture of 88.6 µm by 88.6 µm has the same area as a circular one of 100 µm diameter and is concerning the measured granularity equivalent to a circular one with 100 µm diameter.

7.3.11 The determined $\sigma_{D\text{-}corr\text{-}value}$ shall be corrected on the basis of the real (measured) aperture diameter A_d (in µm) of a circular aperture. The corrected σ_D-value is calculated by:

$$\sigma_{D-corr-a} = \sigma_{D-corr} \cdot (A_d / 100) \tag{5}$$