Designation: E 1815 – 96 (Reapproved 2001)

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

This standard is issued under the fixed designation E 1815; 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 the 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 and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

E 94 Guide for Radiographic Examination[2]

E 999 Guide for Controlling the Quality of Industrial Radiographic Film Processing[2]

E 1079 Practice for Calibration of Transmission Densitometers[2]

E 1316 Terminology for Nondestructive Examinations[2]

2.2 *ANSI Standards:*[3]

PH 2.18 Photography (Sensitometry)—Density Measurements, Spectral Conditions

PH 2.19 Photography Density Measurements—Part 2: Geometric Conditions for Transmission Density

PH 2.40 Root Mean Square (rms) Granularity of Film (Images on One Side Only) Method of Measuring

2.3 *ISO Standards:*[3]

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

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

ISO 7004 Photography—Industrial Radiographic Film, Determination of ISO Speed and Average Gradient When Exposed to X and Gamma Radiation

3. Terminology

3.1 *Definitions*—For definitions of terms used in this test method, refer to Terminology E 1316.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *film system*—the film and associated film-processing requirements according to the criteria established by the manufacturers of the film and processing chemicals.

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

3.2.3 *granularity*, σ_D—the stochastic density fluctuations in the radiograph that are superimposed to the object image.

3.2.4 *ISO speed S*—determined by the dose K_s, measured in gray at a specified optical density, *D*, in the radiograph.

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 6 describes specific parameters used for this test method. In general, the classification for hard X rays, as described in Section 6, 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 signal and noise parameters. The signal is represented by gradient and the noise by granularity.

4.1.2 A film is assigned a particular class if it meets all four of the minimum performance parameters: for Gradient *G* at $D = 2.0$ and $D = 4.0$, granularity σ_D at $D = 2.0$, and gradient/noise ratio at $D = 2.0$.

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[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] *Annual Book of ASTM Standards*, Vol 03.03.

[3] Available from American National Standards Institute, 11 W. 42nd St., 13th Floor, New York, NY 10036.

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 will be the users of this test method. The result is a classification table as shown by the example given in Table 1. This table also includes speed data for user information. Users of industrial radiographic film systems may also perform the tests and measurements outlined in this 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 7.2.

5. Sampling and Storage

5.1 For determination of the gradient and granularity of a film system, it is important that the samples evaluated yield the average results obtained by users. This will require evaluating several different batches periodically, under the conditions specified in this test method. 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. Several independent evaluations shall be made to ensure the proper calibration of equipment and processes. The basic objective in selecting and storing samples as described above is to ensure that the film characteristics are representative of those obtained by a consumer at the time of use.

6. Procedure

6.1 *Principle*:

6.1.1 Film to be tested 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 target as possible, shall provide filtration equivalent to 8.00 ± 0.2 mm of copper.

6.1.2 The film system includes a front and a back screen of 0.02 to 0.25-mm lead. If single-coated films are used, the emulsion-coated surface must face the X-ray tube. Vacuum or pressure cassettes may be used to ensure sufficient contact between the film and screen.

6.2 *X-ray Spectral Quality*:

6.2.1 Use the same X-ray spectral quality for determining both the film gradient and its root mean square granularity. Make the film exposures with an 8-mm (0.32-in.) copper filter at the X-ray tube and the kilovoltage set such that the half-value layer in copper is 3.5 mm (0.14 in.). The kilovoltage setting will be approximately 220 kV.

6.2.2 Determine the required kilovoltage setting by making an exposure (or exposure rate) measurement with the detector placed at a distance of at least 750 mm (29.5 in.) from the tube target and with an 8-mm (0.32-in.) copper filter at the tube. Then make a second measurement with a total of 11.5 mm (0.45 in.) of copper at the tube. These filters should be made of 99.9 % pure copper.

6.2.3 Calculate the ratio of the first and second readings. If this ratio is not 2, adjust the kilovoltage up or down and repeat the measurements until a ratio of 2 (within 5 %) is obtained. Record the machine setting of the kilovoltage for use with the film tests.

6.3 *Film Cassette and Screens*:

6.3.1 The film cassette (holder) shall provide a means of ensuring good film screen contact. A vacuum cassette may be used.

6.3.2 Lead-foil screens shall be used with the front-screen thickness being 0.130 ± 0.013 mm (0.005 ± 0.05 in.) and the back-screen thickness being 0.250 ± 0.025 mm (0.010 ± 0.001 in.).

NOTE 1—These thicknesses reflect commercially available tolerances in lead foil for use as radiographic screens.

6.3.3 It is especially important that the exposure to the film specimen for the granularity measurements be spatially uniform. Any nonuniformities in X-ray transmission of the cassette front or nonuniformities or defects in the lead-foil screens could influence the granularity measurement. Therefore, exercise considerable care in selection and maintenance of the cassette and lead screens to minimize these effects.

6.3.4 Expose single-coated films with the emulsion-coated surface in contact with the front screen.

TABLE 1 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	300	5.0

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

6.4 *Film Processing*—The film image quality will vary with the processing variables, such as chemistry, temperature, and method of processing (manual or automatic). The film processing and record requirements shall be in accordance with Guide E 999.

6.5 *Exposure Conditions*:

6.5.1 The plane of the film shall be normal to the central ray of the X-ray beam. Use a diaphragm at the tube to limit the field of radiation to the film area. The X-ray tube target to film distance shall be adequate to ensure that the exposure over the useful area of each exposure step is uniform to within 3 %.

6.5.2 To minimize the effects of backscattered radiation, use a 6.3 ± 0.8-mm (¼ ± 1⁄32-in.) thick lead shielding behind the cassette. The shielding lead shall extend at least 25 mm (1 in.) beyond each edge of the cassette. Alternatively, the shielding lead may be omitted, provided that the cassette is supported such that the X-ray beam strikes no scattering material, other than air, for a distance of at least 2 m (78.7 in.) behind the cassette.

6.5.3 Modulation of the X-ray exposure may be accomplished by changing the exposure time or tube target to film distance. Changing the tube current is not recommended but may be done, provided it is verified by measurement (see 6.2) that the X-ray spectral quality does not change.

6.5.4 Measure exposures with an air-ionization chamber, or other types of X-ray detectors, having linear response over the range of X-ray intensities and exposure times used for the film exposures.

6.5.5 During and after exposure, prior to processing, keep the film at a temperature of 23 ± 5°C (59.7 ± 5°F) and a relative humidity of 50 ± 20 %. Start processing of the film between 30 min and 8 h after exposure. Process an unexposed specimen of the film sample with the X-ray-exposed specimen in order to determine the base plus fog density.

6.5.6 Measure the visual diffuse transmission density of the processed films with a densitometer complying with the requirements of ANSI PH 2.19 and ISO 5-2 and calibrated by the method of Practice E 1079. Use a minimum aperture of 7 mm (0.275 in.).

6.6 *Measurement of Gradient G*:

6.6.1 Gradient *G* relates to a *D* versus log *K* curve. In the scope of this test method, *G* is calculated from the slope of a *D* versus *K* curve at density ($D - D_o$), as follows:

$$G = \frac{dD}{d\log K} = \frac{K}{\log e} \times \frac{dD}{dK} \qquad (1)$$

where:

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

D_o = fog and base density.

6.6.2 The *D* versus *K* curve is approximated by a polynomial of the third order. To obtain a regular and reliable shape of this curve, make a series of exposures to obtain at least 12 uniformly distributed measuring points between density 1.0 and 5.0 above D_o.

6.6.3 Average the Gradient *G* measurements, with a maximum inaccuracy of ± 5 %.

6.7 *Root Mean Square (rms) Granularity*, σ_D:

6.7.1 Determine the rms granularity of the film in accordance with ANSI PH 2.40, with the following exceptions:

6.7.2 The procedure is limited to the measurement of continuous tone black-and-white industrial X-ray films viewed by transmitted light. The film may have emulsion coated on one side or both sides of the film support.

6.7.3 Expose the film specimen with X rays having the spectral quality described in 6.2. The cassette and lead-foil screens shall be as specified in 6.3. Expose the film specimen in accordance with the exposure conditions of 6.5. Exercise care to ensure that the film specimen does not contain density variations arising from the exposing equipment (such as nonuniform beam filters or damaged or defective lead screens). During and after exposure, prior to processing, maintain the film specimen at the temperature and relative humidity conditions specified in 6.5.5. The film processing chemicals and procedures shall be the same as those used for determining gradient, and they shall be described completely as specified in 6.4.

6.7.4 The film specimen for granularity measurement shall have a diffuse density of 2.00 ± 0.05 above base plus fog. 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 smooth curve drawn through a plot of the data points. The granularity value shall be in terms of diffuse density.

6.7.4.1 The microdensitometer scanner output is measured as projection density. Thus to obtain the desired diffuse density, convert the data using the slope of the curve of diffuse density versus projection density at the mean density value of the granularity film specimen. Determine this curve using a film having a stepped series of densities, which is prepared using the same type film, exposure, and processing techniques as used for the granularity film specimen. Measure the diffuse density of each step with a microdensitometer. 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. The stepped series of densities shall lie within that range. Choose the number of steps such that the slope of the curve, at the mean density of the granularity film specimen, is determined to an accuracy of ± 5 %.

6.7.5 Determine the granularity of the film specimen by evaluating no fewer than three samples of the specimen and determining their mean so that a maximal uncertainty of 10 % is achieved.

6.7.6 Adjust the optical system of the microdensitometer so that both emulsions, or the one emulsion in the case of a single-coated film, are in focus at all points in the scan.

6.7.7 Scan the film specimen along three different paths within the test area. Take the median of the three granularity readings as the granularity of the film specimen at the mean measured density.

6.7.8 *Microdensitometer Requirements*:

6.7.8.1 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.

6.7.8.2 Both the influx objective and the efflux objective shall be a high-quality microscope objective having a numerical aperture no greater than 0.10.

6.7.8.3 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.

6.7.8.4 The efflux (or measuring aperture) shall be circular in shape. Its effective diameter referred to the specimen plane shall be 100± 2µ m.

6.7.8.5 The scan path of the microdensitometer may be linear or circular. If circular, the radius of the path shall not be less than 16 mm. In either case, the total scan length shall not be less than 100 mm (3.94 in.).

6.7.8.6 The spectral response of the microdensitometer system shall be visual, as specified by ANSI PH 2.18 and ISO 5-3.

6.7.8.7 The 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.

6.8 *Measurement of ISO Speed S*—The ISO Speed S is evaluated for an optical density, $D = 2.0$, above fog and base, D_o. Use Table 2 for determination of the ISO speed.

7. Range of Classification and Limiting Values

7.1 There are film system classes that differ by their gradients and granularities. The limiting values are assigned to the film classes whose observance must be proved by the measuring methods in 6.6 and 6.7.

7.1.1 In order to assign a film system to a system class, it must meet all four limiting values of the gradient (at $D = 2.0$ and $D = 4.0$), the granularity (at $D = 2.0$), and the gradient/granularity parameter of the system class. The classification is valid only for the complete film system.

7.2 Film system manufacturers will provide their classification table, upon request, with a classification table that contains full data on the four parameters according to Table 3. In addition, the following two parameters (see Table 2 for data) will be listed with the classification table: ISO speed S, and dose, K_s.

7.2.1 The classification table will additionally contain the following information on the processing system: manual or automatic, type of chemistry, developer immersion time, and developer temperature.

7.3 For examples of a classification table, see Table 1.

TABLE 2 Determination of ISO Speed S from dose, K_s, Needed for a Film Density, $D = 2.0$, above D_o

$\log_{10}K_s$		ISO Speed S[A]
From	To	
−3.05	−2.96	1000
−2.95	−2.86	800
−2.85	−2.76	640
−2.75	−2.66	500
−2.65	−2.56	400
−2.55	−2.46	320
−2.45	−2.36	250
−2.35	−2.26	200
−2.25	−2.16	160
−2.15	−2.06	125
−2.05	−1.96	100
−1.95	−1.86	80
−1.85	−1.76	64
−1.75	−1.66	50
−1.65	−1.56	40
−1.55	−1.46	32
−1.45	−1.36	25
−1.35	−1.26	20
−1.25	−1.16	16
−1.15	−1.06	12
−1.05	−0.96	10
−0.95	−0.86	8
−0.85	−0.76	6
−0.75	−0.66	5
−0.65	−0.56	4

[A] See ISO 7004.

TABLE 3 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 [A]	$D = 4.0$ 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

[A] D_o = density of an unexposed and processed film including base (fog and base density).

8. Precision and Bias

8.1 No statement is made about either the precision or bias of this test method for measuring a film system classification of industrial radiographic film since the results state merely whether there is conformance to the criteria for success specified in the procedure.

9. Keywords

9.1 ASTM system class; film system; film system classification; gradient; gradient/noise; granularity; industrial radiographic film; speed

APPENDIX

(Nonmandatory Information)

X1. GENERAL PRINCIPLES OF CLASSIFICATION

X1.1 The purpose of this test method is to classify industrial radiographic film systems based on their image quality performance over the practical working range of densities (for example, from 2.0 to 4.0). The classes are differentiated in image quality performance based on limiting values for four measurable image quality parameters, that is, gradient at density 2.0 and 4.0 and granularity and gradient/granularity ratio at density 2.0. See Table 3.

X1.1.1 The result of classification can be documented in a table with the following details:

X1.1.1.1 Description of the film system (film and processing),

X1.1.1.2 Values for four image quality parameters and the corresponding system class, and

X1.1.1.3 Speed of the film system.

X1.1.2 The optimal film system based on system classification (imaging performance) and speed (exposure time) can be selected with this information. See Table 1 for an example.

X1.2 *Significance of Classes:*

X1.2.1 Various codes and specifications require film selection based on a class (Type 1, 2, or 3) from a version of Guide E 94 dated before 1984. In Guide E 94 – 83, speed, contrast, and graininess were specified as limiting values, but only in a subjective way. According to this guide, a range of films was classified in order of increasing speed and decreasing image quality (contrast and graininess). Image quality was optimized for a given speed.

X1.2.2 This test method has similar classes: Special, I, II, and III (see Table 3). The film systems that will generally fit this classification are of high-contrast technology. Image quality is optimized for every speed. Granularity increases with speed, and gradient is a maximum for the slower speed film systems.

X1.2.3 The slower film systems give the highest image quality, through a combination of low granularity and high gradient for both Density 2.0 and 4.0 and a corresponding high gradient/granularity ratio.

X1.2.4 Four classes of this test method were selected to correspond to the former film classification standard table of Guide E 94 – 83. See Table X1.1.

X1.2.5 Table X1.2 provides classification of wide-latitude film systems. In comparison to traditional high-contrast technology, these film systems are generally characterized by a lower gradient for a given speed, producing wider exposure latitude and correspondingly lower image quality. The gradient will be lower at density 2.0 and significantly lower at high densities. Limiting values for image quality parameters are as follows (classes of wide-latitude film systems do not correspond directly to classes of former Guide E 94 – 83):

X1.2.6 The wide-latitude system classes are described as follows:

X1.2.6.1 *W-A and W-B*—Films with ASTM System Class III or better image quality. In general, these films use intermediate technology (between traditional high contrast and low contrast). Applications are judged by comparing all four image quality parameters.

X1.2.6.2 *W-C*—Film systems with lower image quality performance than ASTM System Class III. In general, this is low-contrast (medical) film technology in combination with direct exposure technique.

NOTE X1.1—The combination of Table X1.1 and Table X1.2 corresponds to Table 3.

NOTE X1.2—Fundamental differences between this test method and Guide E 94 – 83 are as follows: (*1*) with this test method, film systems are classified instead of film types (as in Guide E 94 – 83); and (*2*) in this test method, classification is based only on imaging performance. Speed is not a classification parameter.

TABLE X1.1 Classification Comparison of Test Method E 1815 and Guide E 94 – 83 for High-Contrast Film Systems

Test Method E 1815 System Class	Minimum Gradient *G* at		Minimum Gradient/ Granularity Ratio at *D* = 2.0	Maximum Granularity at *D* = 2.0	Guide E 94 – 83 Film Type	Description		
	D = 2.0	*D* = 4.0				Speed	Contrast	Graininess
Special	4.5	7.5	300	0.018				
I	4.1	6.8	150	0.028	1	low	very high	very low
II	3.8	6.4	120	0.032	2	medium	high	low
III	3.5	5.0	100	0.039	3	high	medium	high

TABLE X1.2 Test Method E 1815 Classification of Wide-Latitude Film Systems

Test Method E 1815 Film 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		
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