Designation: F 947 – 85 (Reapproved 1996)

Standard Test Method for Determining Low-Level X-Radiation Sensitivity of Photographic Films[1]

This standard is issued under the fixed designation F 947; 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 determines the maximum x-ray sensitivity coefficient (slope of diffuse visual density versus x-ray exposure) of film/processing combinations for low quantities of x-ray exposure to silver halide photographic film. This coefficient can be used to assess the relative susceptibility of films to damage from x-ray exposure, such as that encountered in airport and similar security screening systems.

1.2 *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 *ANSI Standard*[2]

PH2.19 (1976) American National Standard Conditions for Diffuse and Doubly-Diffuse Transmission Measurements (Transmission Density)

3. Significance and Use

3.1 The x-ray sensitivity coefficient is used to estimate the amount of x-ray exposure that would produce a visually significant effect on a film. This value may be useful in establishing maximum allowable x-ray doses for classes of film products, for example, consumer color films, scientific and x-ray films, etc.

4. Calibration and Standardization

4.1 *Radiant Energy Quality*:

4.1.1 Tungsten target x-ray tubes shall be used to expose test films. Inherent filtration of the tube plus an additional aluminum[3] filter located as close to the x-ray tube as possible shall provide a total filtration equivalent to 3.7 ± 0.5 mm of aluminum.

4.1.2 The kilovoltage applied to the x-ray tube shall be adjusted to yield a half-value layer (HVL) of 3.4 ± 0.5 mm of aluminum as determined with a radiation measuring device having a quantum energy response flat within ±5 % over the effective energy range from 30 to 100 keV. That is, with the measuring device at or adjacent to the film exposing position, the tube kilovoltage shall be adjusted[4] such that the introduction of 3.4 mm of aluminum[3] into the x-ray beam close to the tube, in addition to the filtration specified in 4.1.1, will reduce the measured x-ray intensity to 50 ± 1 % of its value without this HVL aluminum in the beam. The HVL aluminum must of course be removed for subsequent film exposure and exposure measurement.

4.2 *Secondary X-Rays*:

4.2.1 To minimize secondary radiation during dosimetry and exposure of test films, x-ray beams shall be diaphragmed to as small a size as will properly include the exposure area for the films (and exposure measuring device, if included). Except for a 1 mm minimum thickness sheet of lead for backing the film container, the lightest supports possible of low-atomic-number material shall be used for supporting the film and exposure measuring device. Other materials in the x-ray beam shall be kept at least 50 cm distant from the film. The amount of secondary radiation reaching the film and measuring device shall be less than 3 % of the primary x-rays.

4.2.2 The presence of secondary (scattered) radiation shall be tested by plotting the inverse square root of the exposure rate as a function of distance from the source. Absence of significant secondary radiation is indicated when the resulting plot is a straight line passing through the origin. Such radiation is excessive if the point corresponding to the observed exposure rate at the distance used for film exposures is more than 3 % below the best straight line from the origin among the plotted points. Measurements shall be made at enough distances to provide a reliable indication of secondary radiation reaching the exposure plane and shall include distances approximately equally spaced from one-half that between the

[1] This test method is under the jurisdiction of ASTM Committee F-12 on Security Systems and Equipment and is the direct responsibility of Subcommittee F12.60 on Controlled Access Security, Search and Screening Equipment.

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

[3] Aluminum Association Alloy 1100, or the equivalent.

[4] The HVL specification should be satisfied with approximately 80 kV constant potential, approximately 80 kVp 3-phase, or approximately 95 kVp single phase applied to the x-ray tube.

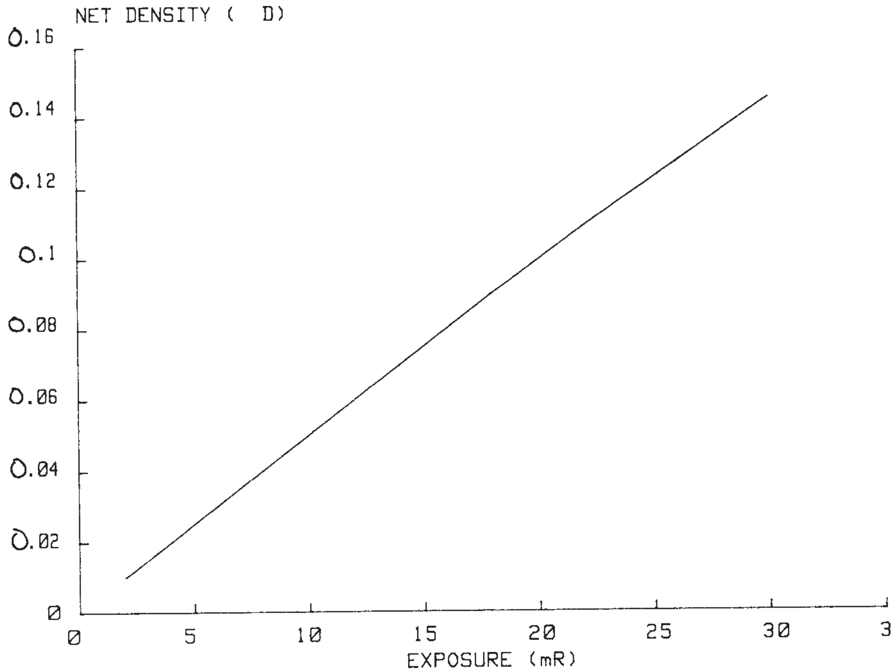

FIG. 1 Plot of Net Density versus Exposure for a Negative Film Product

x-ray tube focal spot and exposure plane to at least 10 % beyond the exposure plane, if possible (film container and lead backing removal).

5. Conditioning

5.1 The temperature of the film during exposure shall be 20 ± 5°C. The moisture content of the film shall be such that the film will be in equilibrium with a relative humidity ranging from 30 to 70 %.

6. Procedure

6.1 *Safelights*—All films shall be loaded, handled, and processed in complete darkness.

6.2 *Exposure Measurement*—Exposure shall be measured in or converted to roentgens by using an appropriate device calibrated for the radiant energy quality and exposure rate used for exposing the film.[5] It is permissible to calibrate the working instrument (that with which the film exposures are to be measured) against an instrument calibrated by a standardizing organization. This may be necessary when the standardizing organization is not equipped to calibrate an instrument of the most useful range for determining exposures of film.

6.3 *Exposure Uniformity*—Film shall be flat and oriented perpendicular to the x-ray beam. The exposure of the working area for each exposure step on the film and including the area occupied by the exposure measuring device shall be measured to be uniform within 3 %.

6.4 *Exposure Scale*—An area or separate sample of the film shall be left unexposed for the purpose of measuring unexposed density ($D_{fog}$of negative films or $D_{max}$of reversal processed positive films). Then separate areas or samples of the film shall be exposed to each of a graduated series of exposures under the conditions specified in Section 3, such as will result in a series of at least five densitites differing by no more than 0.1 *D* from the density of the unexposed film. The exposure increments for the series shall be arithmetic in progression and may be obtained by varying either exposure rate or exposure time including if desired, accumulation by repetition of the minimum increment (intermittent exposure). For example, if 15 mR of exposure on a particular film produced a density change of no more than 0.1 *D* from that of an unexposed area of the film, then exposure No. 1 of the series could be 3 mR, No. 2 ... 6 mR, etc. up to 15 mR for exposure No. 5.

6.5 *Processing*—All films shall be processed in a manner typical to customer usage, and the particular process must be referenced in statements of results from this procedure. All films of a given test, both x-ray exposed and nonexposed-fog films, shall be processed together to minimize process variability.

6.6 *Densitometry*—After the films have been processed, the diffuse visual densities of the exposed and unexposed films shall be determined in accordance with ANSI PH2.19 (1976).

6.7 *Determination of Sensitivity Coefficient*:

6.7.1 The diffuse visual density of an unexposed area or unexposed sample of the film shall be determined and designated as unexposed density.

6.7.2 Net densities (exposed densities minus unexposed density) shall be plotted against exposure expressed in milliroentgens (see Figs. 1 and 2).

6.7.3 *X-Ray Sensitivity Coefficient*—The x-ray sensitivity coefficient is the slope of the straight line drawn on the curve obtained in 6.7.2. The best-fit line of the straight-line portion of the curve shall be used for determining slope. For negative

[5] Calibration to National Bureau of Standards Technique M100 (100 kVcp, 5.0 mm inherent equivalent plus added aluminum filtration) for which the first half-value layer is 5.0 mm of aluminum is acceptable. This technique is explained in NBS Special Publication No. 250 (1983) Chapter 8.

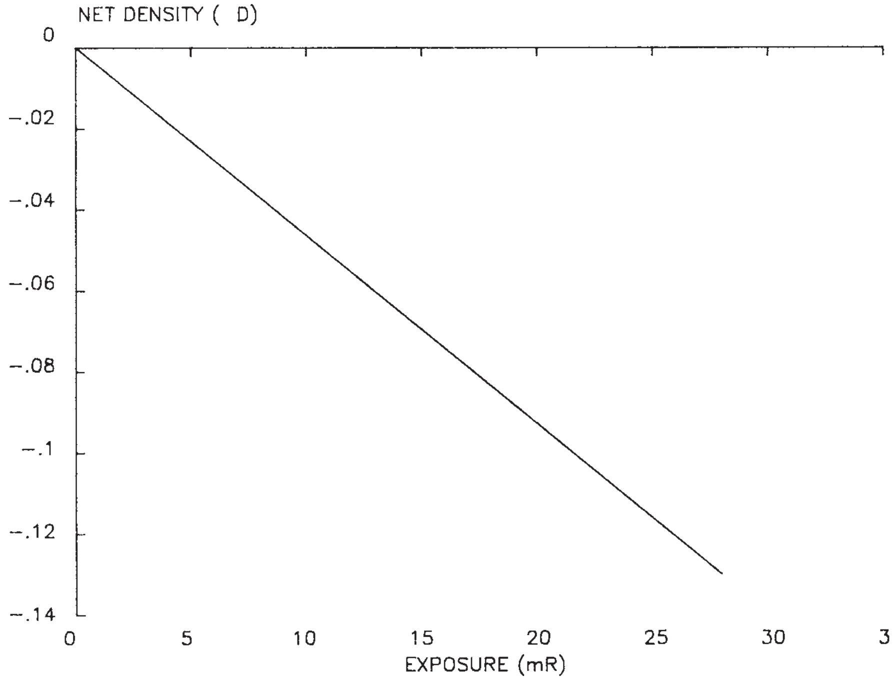

FIG. 2 Plot of Net Density versus Exposure for a Reversal Film Product

materials, this line normally starts at or very near the origin and proceeds up-scale for both density and exposure, thus having a positive value (Fig. 1). For films processed to a positive (reversal processed), the line proceeds down-scale density-wise, thus having a negative slope (Fig. 2).

7. Interpretation of Results

7.1 The sensitivity coefficient is most conveniently expressed in density units per milliroentgen of x-ray exposure and includes the negative sign for the reversal processed materials. Usually, only the visual density coefficient need be determined for reversal processed films, since such films are normally viewed directly or by projection. For negative material, the visual density coefficient is useful when direct observation of the x-ray exposure effect on the film is of concern, but the tri-color density coefficients or printing density coefficients may be needed for analyzing effects on prints made from the negative films.

7.2 The amount of x-ray exposure expressed in milliroentgens that would produce a visually significant effect on a film is estimated as 0.01 divided by the absolute value of the sensitivity coefficient obtained in 6.7.

8. Precision and Bias

8.1 The within-laboratory precision of this test method was evaluated using two films; KODACOLOR VR 400 Film (Film A), and KODACOLOR VR 200 Film (Film B).[6] Sensitivity coefficients were determined by this test method for each of two samples of the two films on each of five different days. The average (mean) sensitivity coefficent and standard deviation were calculated for each film:

$$\text{Film A: } 0.0048\,\frac{\Delta D}{\text{mR}}\,\sigma = 0.000081 \quad (1)$$

$$\text{Film B: } 0.0023\,\frac{\Delta D}{\text{mR}}\,\sigma = 0.000033 \quad (2)$$

The standard deviations correspond approximately to a 95 % confidence level (2σ) of ±3 % for a single determination of sensitivity coefficient. The largest sources contributing to this test variability were believed to be photographic processing and densitometry.

8.2 Consideration was given to the traceability or bias of this test method (or the ability of another laboratory to duplicate results). A sensitivity coefficient determined by this test method is predicted to be within 20 % of a true value. This prediction is based upon judgment and experience regarding the uncertainty of traceability of the spectral energy distribution of the x-ray exposing source and the photographic process. The specifications of these two experimental parameters are believed to be the largest sources contributing to the uncertainty of results.

[6] Supporting data are available from ASTM Headquarters. Request RR: F12-1000.