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.

Designation: E3022 – 18

Standard Practice for Measurement of Emission Characteristics and Requirements for LED UV-A Lamps Used in Fluorescent Penetrant and Magnetic Particle Testing [1]

This standard is issued under the fixed designation E3022; 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 practice covers the procedures for testing the performance of ultraviolet A (UV-A), light emitting diode (LED) lamps used in fluorescent penetrant and fluorescent magnetic particle testing (see Guides E709 and E2297, and Practices E165/E165M, E1208, E1209, E1210, E1219, E1417/E1417M and E1444).[2] This specification also includes reporting and performance requirements for UV-A LED lamps.

1.2 These tests are intended to be performed only by the manufacturer to certify performance of specific lamp models (housing, filter, diodes, electronic circuit design, optical elements, cooling system, and power supply combination) and also includes limited acceptance tests for individual lamps delivered to the user. This test procedure is not intended to be utilized by the end user.

1.3 This practice is only applicable for UV-A LED lamps used in the examination process. This practice is not applicable to mercury vapor, gas-discharge, arc or luminescent (fluorescent) lamps or light guides (for example, borescope light sources).

1.4 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

1.5 *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.*

1.6 *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:*[3]

E165/E165M Practice for Liquid Penetrant Testing for General Industry
E709 Guide for Magnetic Particle Testing
E1208 Practice for Fluorescent Liquid Penetrant Testing Using the Lipophilic Post-Emulsification Process
E1209 Practice for Fluorescent Liquid Penetrant Testing Using the Water-Washable Process
E1210 Practice for Fluorescent Liquid Penetrant Testing Using the Hydrophilic Post-Emulsification Process
E1219 Practice for Fluorescent Liquid Penetrant Testing Using the Solvent-Removable Process
E1316 Terminology for Nondestructive Examinations
E1348 Test Method for Transmittance and Color by Spectrophotometry Using Hemispherical Geometry
E1417/E1417M Practice for Liquid Penetrant Testing
E1444 Practice for Magnetic Particle Testing for Aerospace
E2297 Guide for Use of UV-A and Visible Light Sources and Meters used in the Liquid Penetrant and Magnetic Particle Methods

2.2 *Other Standards:*[4]

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

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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 E07.03 on Liquid Penetrant and Magnetic Particle Methods.

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[2] The use of LED lamps for penetrant examination may be covered by a patent. Interested parties are invited to submit information regarding the identification of alternative(s) to this patented item to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend.
NOTE: ASTM International takes no position respecting the validity of any patent rights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of the validity of any such patent rights, and the risk of infringement of such rights, are entirely their own responsibility.

[3] 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.

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

ANSI/NCSL Z540.3 Requirements for the Calibration of Measuring and Test Equipment

3. Terminology

3.1 *Definitions*—General terms pertaining to ultraviolet A (UV-A) radiation and visible light used in liquid penetrant and magnetic examination are defined in Terminology E1316 and shall apply to the terms used in this practice.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *battery-powered hand-held lamp, n*—lamp powered by a battery used in either stationary or portable applications where line power is not available or convenient.

3.2.1.1 *Discussion*—These lamps may also have the option to be line-powered (that is, alternating current power supply). Smaller lamps, often referred to as "flashlights" or "torches" are used for portable examination of focused zones and often have a single LED.

3.2.2 *current ripple, n*—unwanted residual periodic variation (spikes or surges) of the constant current that drives the LED at a constant power level.

3.2.2.1 *Discussion*—Ripple is due to incomplete suppression of DC (peak to peak) variance resulting from the power supply, stability of regulation circuitry, circuit design, and quality of the electronic components.

3.2.3 *excitation irradiance, n*—irradiance calculated in the range of 347 nm and 382 nm. This corresponds to the range of wavelengths that effectively excite fluorescent penetrant dyes (i.e. greater than 80% of relative peak excitation).

3.2.4 *irradiance, E, n*—radiant flux (power) per unit area incident on a given surface. Typically measured in units of micro-watts per square centimeter (μW/cm^2).

3.2.5 *lamp model, n*—A lamp with specific design. Any change to the lamp design requires a change in model designation and complete qualification of the new model.

3.2.6 *light-emitting diode, LED, n*—solid state electronic devices consisting of a semiconductor or semiconductor elements that emit radiation or light when powered by a current.

3.2.6.1 *Discussion*—LEDs emit a relatively narrow bandwidth spectrum when a specific current flows through the chip. The emitted wavelengths are determined by the semiconductor material and the doping. The intensity and wavelength can change depending on the current, age, and chip temperature.

3.2.7 *line-powered lamp, n*—corded hand-held or overhead lamps that are line-powered and typically used for stationary inspections within a controlled production environment.

3.2.7.1 *Discussion*—These lamps are used for examination of both small and large inspection zones and consist of an LED array. Overhead lamps are used in a stationary inspection booth to flood the inspection area with UV-A radiation. Handheld lamps are used to flood smaller regions with UV-A radiation and can also be used in portable applications where line power is available.

3.2.8 *minimum working distance, n*—the distance from the inspection surface where the lamp beam profile begins to exhibit non-uniformity.

3.2.9 *transmittance, τ*—ratio of the radiant flux transmitted through a body to that incident upon it.

4. Significance and Use

4.1 UV-A lamps are used in fluorescent penetrant and magnetic particle examination processes to excite fluorophores (dyes or pigments) to maximize the contrast and detection of discontinuities. The fluorescent dyes/pigments absorb energy from the UV-A radiation and re-emit visible light when reverting to its ground state. This excitation energy conversion allows fluorescence to be observed by the human eye.

4.2 The emitted spectra of UV-A lamps can greatly affect the efficiency of dye/pigment fluorescent excitation.

4.3 Some high-intensity UV-A lamps can produce irradiance greater than 10 000 μW/cm^2 at 15 in. (381 mm). All high-intensity UV-A light sources can cause fluorescent dye fade and increase exposure of the inspector's unprotected eyes and skin to high levels of damaging radiation.

4.4 UV-A lamps can emit unwanted visible light and harmful UV radiation if not properly filtered. Visible light contamination above 400 nm can interfere with the inspection process and must be controlled to minimize reflected glare and maximize the contrast of the indication. UV-B and UV-C contamination must also be eliminated to prevent exposure to harmful radiation.

4.5 Pulse Width Modulation (PWM) and Pulse Firing (PF) of UV-A LED circuits are not permitted.

NOTE 1—The ability of existing UV-A radiometers and spectroradiometers to accurately measure the irradiance of pulse width modulated or pulsed fired LEDs and the effect of pulsed firing on indication detectability is not well understood.

5. Classifications

5.1 LED UV-A lamps used for nondestructive testing shall be of the following types:

5.1.1 *Type A*—Line-powered lamps (LED arrays for handheld and overhead applications) (3.2.5 and 3.2.6).

5.1.2 *Type B*—Battery powered hand-held lamps (LED arrays for stationary and portable applications) (3.2.1).

5.1.3 *Type C*—Battery powered, handheld lamps (single LED flashlight or torch for special applications) (3.2.1, Discussion).

6. Apparatus

6.1 *UV-A Radiometer,* designed for measuring the irradiance of electromagnetic radiation. UV-A radiometers use a filter and sensor system to produce a bell-shaped (i.e. Gaussian) response at 365 nm (3650 Å) or top-hat responsivity centered near 365 nm (3650 Å). 365 nm (3650 Å) is the peak wavelength where most penetrant fluorescent dyes exhibit the greatest fluorescence. Ultraviolet radiometers shall be calibrated in accordance with ANSI/ISO/IEC 17025, ANSI/NCSL Z540.3, or equivalent. Radiometers shall be digital and provide a resolution of at least 5 μW/cm^2. The sensor front end aperture width or diameter shall not be greater than 0.5 in. (12.7 mm).

NOTE 2— Photometers or visible light meters are not considered adequate for measuring the visible emission of UV-A lamps which

TABLE 1 UV-A LED Lamp Test Requirements by Lamp Model

Type	Test Requirements
A	7.3 Maximum Irradiance
	7.4 Beam Irradiance Profile
	7.5 Minimum Working Distance
	7.6 Temperature Stability
	7.6.1 Maximum Housing Temperature
	7.6.4 Emission Spectrum
	7.6.4.7 Peak Wavelength
	7.6.4.8 Full Width Half Maximum (FWHM)
	7.6.4.8 Longest Wavelength at Half Maximum
	7.6.4.9 Excitation Irradiance
	7.6.5 Current Ripple
	7.8 Filter Transmittance
B, C	7.3 Maximum Irradiance
	7.4 Beam Irradiance Profile
	7.5 Minimum Working Distance
	7.6 Temperature Stability
	7.6.1 Maximum Housing Temperature
	7.6.4 Emission Spectrum
	7.6.4.8 Full Width Half Maximum (FWHM)
	7.6.4.8 Longest Wavelength at Half Maximum
	7.6.4.9 Excitation Irradiance
	7.6.5 Current Ripple
	7.7 Typical Battery Discharge Time and Discharge Plot
	7.8 Filter Transmittance

generally have wavelengths in the 400 nm to 450 nm range.

6.2 *Spectroradiometer,* designed to measure the spectral irradiance and absolute irradiance of electromagnetic emission sources. Measurement of spectral irradiance requires that such instruments be coupled to an integrating sphere or cosine corrector. This spectroradiometer shall have a resolution of at least 0.5 nm and a minimum signal-to-noise ratio of 50:1. The system shall be capable of measuring absolute spectral irradiance over a minimum range of 300 to 400 nm.

6.2.1 The system shall be calibrated using emission source reference standards.

6.3 *Spectrophotometer,* designed to measure transmittance or color coordinates of transmitting specimens. The system shall be able to perform a measurement of regular spectral transmittance over a minimum range of 300 to 800 nm.

7. Test Requirements

7.1 Lamp models used for nondestructive testing (NDT) shall be tested in accordance with the requirements of Table 1.

7.2 LEDs of UV-A Lamps shall be continuously powered with the LED drive current exhibiting minimum ripple (see 7.6.5). The projected beam shall also not exhibit any perceivable variability in projected beam intensity (i.e. strobing, flicker, etc.) (see 7.4.6).

7.3 *Maximum Irradiance*—Fixture the UV-A lamp 15 ± 0.25 in (381 ± 6 mm) above the surface of a flat, level workbench with the projected beam orthogonal to the workbench surface. The lamp face shall be parallel to the bench within ±0.25 in. (±6 mm). Ensure that battery-powered lamps (Types B and C) are fully charged. Turn on the lamp and allow to stabilize for 5 min. Place a UV-A radiometer, conforming to 6.1, on the workbench. Adjust the lamp position such that the filter of the lamp is 15.0 ± 0.25 in. (381 ± 12.7 mm) from the radiometer sensor. Scan the radiometer across the projected beam in two orthogonal directions to locate the point of maximum irradiance. Record the maximum irradiance value.

7.4 *Beam Irradiance Profile*—Affix the UV-A lamp above the surface of a flat, workbench with the projected beam orthogonal to the workbench surface.

7.4.1 Type A lamps shall be supplied with alternating current (ac) power supply at the manufacturer's rated power requirement. Power conditioning shall be used to ensure a stable power supply free of voltage spikes, ripples, or surges from the power supply network.

7.4.2 Type B and C lamps shall be powered using a constant voltage power direct current (DC) supply that provides constant DC power at the rated, fully charged battery voltage ±0.5 V.

7.4.3 The UV-A lamp shall be turned on and allowed to stabilize for a minimum of 30 min before taking measurements.

7.4.4 Place the UV-A radiometer on the workbench. Adjust the lamp position such that the face of the lamp is 15.0 ± 0.25 in. (381 ± 6 mm) from the radiometer sensor. Scan the radiometer across the projected beam in two orthogonal directions to locate the point of maximum irradiance. Record this location as the zero point. Using a 0.5-in. (12.7-mm) grid, translate the radiometer across the projected beam in 0.5-in. (12.7-mm) increments to generate a two-dimensional (2-D) plot of the beam profile (irradiance versus position). Position the radiometer using either an *x-y* scanner or by manually scanning. When manually scanning, use a sheet with 0.5-in. (1.27-cm) or finer squares and record the irradiance value in the center of each square. The beam irradiance profile shall extend to the point at which the irradiance drops below 200 µW ⁄cm2.

7.4.5 Generate and report the 2-D plot of the beam irradiance profile (see Fig. 1). Map the range of irradiance from 200 to 1000 $\mu W/cm^2$, >1000 to 5000 $\mu W/cm^2$, >5000 to 10 000 $\mu W/cm^2$, >10 000 $\mu W/cm^2$. Report the minimum beam diameter at 1000 and 200 $\mu W/cm^2$.

NOTE 3—The defined ranges are minimums. Additional ranges are permitted.

7.4.6 During the observations of 7.4.1 through 7.4.5, note any output power variations indicated by perceived changes in projected beam intensity, flicker, or strobing. Any variations in observed beam intensity, flicker, or strobing are unacceptable.

7.5 *Minimum Working Distance*—Affix the lamp approximately 36 in. (900 mm) above a flat, level workbench covered with plain white paper. The projected beam shall be orthogonal to the covered workbench surface.

7.5.1 Measurements shall be performed in a darkened environment with less than 2 fc (21.5 lux) of ambient light and a stable temperature at 77 ± 5°F (25 ±3°C).

7.5.2 Ensure that battery-powered lamps are fully charged. The UV-A lamp shall be turned on and allowed to stabilize for a minimum of 30 min before taking measurements.

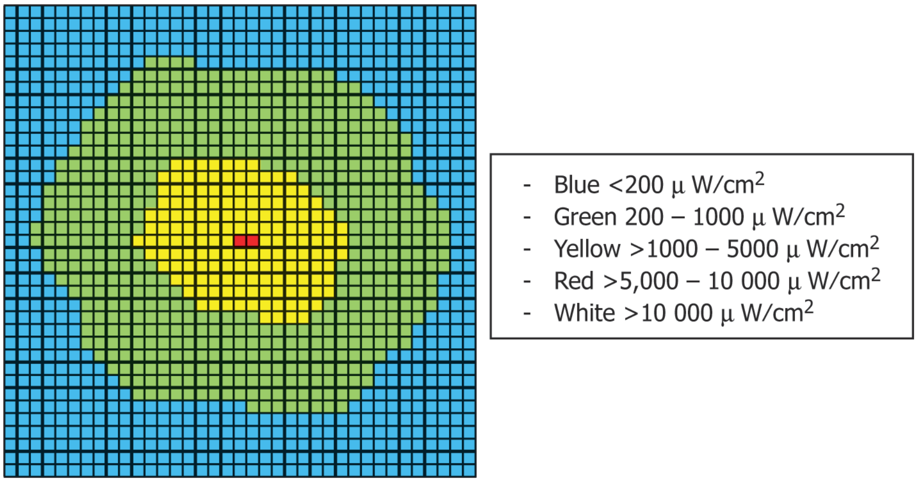

FIG. 1 Example of Beam Irradiance Profile

7.5.3 Observe the beam pattern produced on the paper. Lower the lamp until the beam pattern exhibits visible non-uniformity or reduction in intensity between the individual beams generated by each LED element or by irregularities in the lamp's optical path (Fig. 2). Measure the distance from the lamp face to workbench surface. Record this measurement as the minimum working distance.

7.6 *Temperature Stability—Emission Spectrum, Excitation Irradiance, Current Ripple*—Testing shall be performed in two steps, at ambient temperature conditions and at the maximum operating temperature reported by the manufacturer.

7.6.1 For ambient temperature testing conducted in 7.6.2 perform the following measurements:

(a) Emission spectrum (7.6.4.1 through 7.6.4.8),
(b) Excitation irradiance (7.6.4.9),
(c) Maximum lamp housing temperature, and
(d) Current ripple (7.6.5).

For elevated temperature tests conducted in 7.6.3 perform the following measurements:

(a) Emission spectrum (7.6.4.1 through 7.6.4.8),
(b) Excitation irradiance (7.6.4.9), and
(c) Current ripple (7.6.5).

7.6.2 *Ambient Temperature Test*—At lamp switch-on, perform the measurements defined by 7.6.4. Repeat the measurements every 30 min until the peak wavelength varies by no more than ±1 nm and the excitation irradiance does not vary more than 5% over three consecutive measurements. Once stabilized, measure the current ripple (7.6.5).

7.6.3 *Elevated Temperature Test*—Affix the lamp in an environmental chamber. Adjust the lamp and spectroradiometer position such that the filter of the lamp is 15.0 ± 0.25 in. (381 ± 6 mm) from the sensor aperture of the spectroradiometer. Adjust the lamp position such that the beam is centered on the sensor aperture. If the lamp uses a transformer or other power supply, those components shall also be placed in the environmental chamber. The change in temperature within the chamber shall not affect the accuracy of the measurements.

7.6.3.1 Set the chamber temperature to the maximum manufacturer's specified operating temperature of the lamp. At lamp switch on, perform the measurements defined by 7.6.4. Repeat the measurements every 30 min until the peak wavelength varies by no more than ±1 nm and the excitation irradiance does not vary more than 5% over three consecutive measurements. Once stabilized, measure the current ripple (7.6.5).

7.6.4 *Emission Spectrum Measurement*

7.6.4.1 Measurements shall be performed under dark laboratory conditions with a stable temperature.

7.6.4.2 A spectroradiometer conforming to 6.2 shall be used to collect data.

7.6.4.3 Power conditioning shall be used for both the spectroradiometer and Type A lamps to ensure a stable power supply free from voltage spikes, ripple, or surges from the power supply network.

7.6.4.4 Type B and C lamps may be powered using a constant voltage power DC supply that provides constant DC power at the rated, fully charged battery voltage ±0.5 V.

7.6.4.5 Adjust the lamp position such that the filter of the lamp is 15.0 ± 0.25 in. (381 ± 6 mm) from the spectroradiometer sensor aperture and the beam maximum irradiance is centered on the sensor aperture.

7.6.4.6 Measure and plot the emission spectrum between 300 and 400 nm (minimum range).

7.6.4.7 Determine the peak wavelength (i.e. wavelength with maximum spectral irradiance). See Fig. 3.

7.6.4.8 Calculate the width of the plotted spectrum at 50% of maximum spectral irradiance. Report this as the full-width-half maximum (FWHM) in nanometers. Also determine the longest wavelength at 50% of maximum spectral irradiance (i.e. half maximum). See Fig. 3.

7.6.4.9 Calculate the excitation irradiance in µW/cm², using:

$$\text{Excitation Irradiance} = \int_{347}^{382} N(\lambda)\, d\lambda \tag{1}$$

where:

$N(\lambda)$ = spectral irradiance (µW/cm² nm) and
$d\lambda$ = 1 nm (maximum interval)

7.6.5 *Current Ripple—Stability of the LED Current*