Designation: E2297 – 23

Standard Guide for Use of UV-A and Visible Light Sources and Meters used in the Liquid Penetrant and Magnetic Particle Methods[1]

This standard is issued under the fixed designation E2297; 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 guide addresses the use of UV-A/Visible light sources and meters used for the examination of materials by the liquid penetrant and magnetic particle processes. This guide may be used to establish practices and procedures to measure irradiance and illuminance levels.

1.2 This guide also acts as a reference:

1.2.1 To assist in the selection of irradiance and illumination sources and meters that meet the applicable specifications or standards.

1.2.2 For use in the preparation of internal documentation dealing with liquid penetrant or magnetic particle examination of materials and parts.

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

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]

E165 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
E1220 Practice for Visible Penetrant Testing Using Solvent-Removable Process
E1316 Terminology for Nondestructive Examinations
E1417/E1417M Practice for Liquid Penetrant Testing
E1418 Practice for Visible Penetrant Testing Using the Water-Washable Process
E1444/E1444M Practice for Magnetic Particle Testing for Aerospace
E3022 Practice for Measurement of Emission Characteristics and Requirements for LED UV-A Lamps Used in Fluorescent Penetrant and Magnetic Particle Testing
E3024 Practice for Magnetic Particle Testing for General Industry

2.2 *ANSI Standard:*[3]

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

2.3 *ICNIRP Document:*[4]

International Commission on Nonionizing Radiation Protection Statement (ICNIRP Publication-2010) on Protection of Workers Against Ultraviolet Radiation

2.4 *ISO/IEC Standards:*[5]

IEC 62471 Photobiological Safety of Lamps and Lamp Systems

[1] This guide 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] 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.

[4] Available from International Commission on Nonionizing Radiation Protection (ICNIRP), https://www.icnirp.org.

[5] Available from International Organization for Standardization (ISO), ISO Central Secretariat, Chemin de Blandonnet 8, CP 401, 1214 Vernier, Geneva, Switzerland, https://www.iso.org.

***A Summary of Changes section appears at the end of this standard**

ISO/CIE 17166:2019(E) Erythema Reference Action Spectrum and Standard Erythema Dose
ISO 3059 Non-Destructive Testing – Penetrant Testing and Magnetic Particle Testing – Viewing Conditions
ISO 10012 Measurement Management Systems – Requirements for Measurement Processes and Measuring Equipment
ISO/IEC 17025 General Requirements for the Competence of Testing and Calibration Laboratories

2.5 *ASNT Documents:*[6]

ASNT Handbook, Volume 1, Liquid Penetrant Testing
ASNT Handbook, Volume 8, Magnetic Particle Testing

3. Terminology

3.1 The definitions that appear in Terminology E1316, relating to UV-A radiation and visible light used in liquid penetrant and magnetic particle examinations, shall apply to the terms used in this guide. The terms source and lamp are used interchangeably in this guide.

3.2 *Definitions:*

3.2.1 *high-intensity UV-A source, n*—a UV-A source or lamp that produces UV-A irradiance greater than 10 000 µW ⁄cm^2 (100 W ⁄m^2) at 38.1 cm (15 in.).

3.2.2 *illuminance, n*—the amount of visible light, weighted by the luminosity function to correlate with human perception, incident on a surface, per unit area. Typically reported in units of lux (lx), lumens per square meter (lm/m^2), or footcandle (fc).

3.2.3 *illuminance photometer, n*—an instrument incorporating a sensor and optical filters to measure illuminance.

3.2.4 *irradiance, n*—the power of electromagnetic radiation incident on a surface, per unit area. Typically reported in units of watts per square meter (W/m^2) or microwatts per square centimetre (µW/cm^2).

3.2.5 *radiometer, n*—*in NDT*, an instrument incorporating a sensor and optical filters to measure the irradiance of light over a defined range of wavelengths.

[6] Available from American Society for Nondestructive Testing (ASNT), P.O. Box 28518, 1711 Arlingate Ln., Columbus, OH 43228-0518, http://www.asnt.org.

4. Summary of Guide

4.1 This guide describes the properties of UV-A sources and visible light sources used for liquid penetrant and magnetic particle examination. This guide also describes the properties of radiometers and photometers used to measure UV-A or visible light as applicable, while conducting a liquid penetrant or magnetic particle examination.

5. Significance and Use

5.1 UV-A and visible light sources are used to provide adequate illumination levels for liquid penetrant and magnetic particle examination. UV-A sources, UV-A radiometers, visible light sources, and illuminance photometers are used to verify specified viewing conditions.

5.2 Fluorescence is typically produced by irradiating the fluorescent dyes/pigments with UV-A radiation. The fluorescent dyes/pigments absorb the UV-A radiation and re-emit light energy in the visible spectrum. This process allows fluorescence to be observed by the human eye.

5.3 UV-A sources may emit visible light above 400 nm (4000 Å), which may reduce the visibility of fluorescent indications. High intensity UV-A sources may cause UV fade, causing fluorescent indications to degrade or disappear.

6. Equipment

6.1 *Ultraviolet (UV)/Visible Irradiation Spectrum*

6.1.1 UV sources emit radiation in the ultraviolet section of the electromagnetic spectrum, between 100 nm (1000 Å) to 400 nm (4000 Å). Ultraviolet radiation is a part of the electromagnetic radiation spectrum between the violet/blue color of the visible spectrum and the weak X-ray spectrum. (See Fig. 1.)

6.1.2 The UV-A range is considered to be between 320 nm (3200 Å) and 400 nm (4000 Å). This UV-A range is specific to the liquid penetrant and magnetic particle inspection methods and may not be consistent with other international standards.

6.1.3 The UV-B range (medium UV) is considered to be between 280 nm (2800 Å) and 320 nm (3200 Å).

6.1.4 The UV-C range (short UV) is considered to be between 100 nm (1000 Å) and 280 nm (2800 Å).

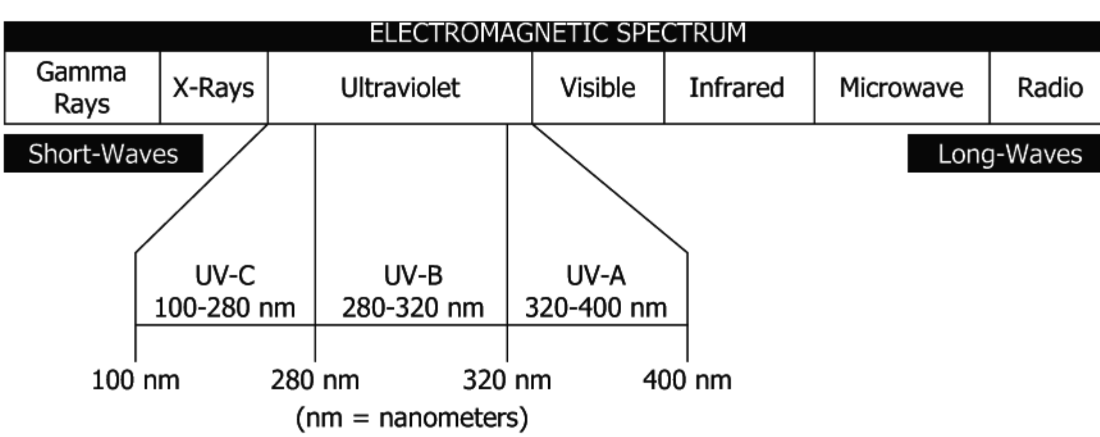

FIG. 1 The Electromagnetic Radiation Spectrum

6.1.5 The visible spectrum is considered to be between 400 nm (4000 Å) and 760 nm (7600 Å). This range of visible light is specific to the liquid penetrant and magnetic particle inspection methods and may not be consistent with other international standards.

6.2 *Mercury Vapor UV-A Sources*

6.2.1 Mercury vapor UV-A sources utilize a lamp containing a mercury-gas plasma that emits radiation specific to the mercury atomic transition spectrum. There are several discrete element emission lines of the mercury spectrum in the ultraviolet section of the electromagnetic spectrum. The irradiance output is dependent on the gas pressure and the amount of mercury content. Higher values of gas pressure and mercury content result in significant increase in its UV emission. Irradiance output is also dependent on the input voltage and the age of the lamp bulb. As the bulb ages, mercury diffuses into the enclosing glass, causing the emission to decrease.

6.2.2 Mercury vapor UV-A sources used for NDT must have appropriate filters, either internal or external to the lamp, to pass UV-A (6.1.2) and minimize visible light (6.1.5) output that is detrimental to the fluorescent inspection process. These UV-A pass filters should also block harmful UV-B (6.1.3) and UV-C (6.1.4) radiation.

6.2.3 Mercury vapor bulbs used for fluorescent NDT are generally low- or medium-pressure vapor sources.

6.2.3.1 Low-pressure bulbs (fluorescent tubes) are coated with a special phosphor in order to maximize the UV-A output. Typically, low-pressure lamps are used in wash stations or for general UV-A irradiance in the inspection room.

6.2.3.2 Medium-pressure bulbs do not have phosphor coatings but operate at higher electrical power levels, resulting in significantly higher UV-A output.

6.2.4 Medium-pressure lamps are typically used for fluorescent examination. A well designed medium pressure UV-A lamp with a suitable UV-A pass filter should emit less than 1 % of its total intensity outside of the UV-A range. A lamp based on the American National Standards Institute's Specification H 44 GS-R100, is a 100 watt mercury-vapor bulb in the Par 38 configuration, and normally uses a Kopp 1041 or Kopp 1071[7] UV filter. Other lamps using the same bulb but with an alternate UV-A pass filter with similar transmission characteristics will not differ greatly in UV-A output, but may produce more visible light in the blue/violet part of the spectrum.

6.3 *UV-A Borescope, Fiberscope, or Video-image-scope and Special UV-A Source Systems*

6.3.1 Borescopes, fiberscopes, and video-image-scopes are thin rigid or flexible tubular optical telescopes. They are nondestructive inspection quality control instruments for the visual detection of surface discontinuities in small bores, castings, pipe interiors, and on internal components of complex machinery.

6.3.2 The conventional optical glass fiber used as a light guide in borescopes, fiberscopes, and video image scopes may be a poor transmitter of UV-A radiation. These fibers transmit visible light in the 450 to 760 nm (4500 to 7600 Å) range, but do not effectively transmit light in the 350 to 380 nm (3500 to 3800 Å) range.

6.3.3 Three non-traditional light guide materials for improved UV-A transmission in borescopes, fiberscopes, or video-image-scopes, are liquid light guides, silica or quartz fibers, or special new glass fibers.

6.3.3.1 Silica or quartz fibers are good transmitters of UV-A energy, but are brittle and cannot be bent into a tight radius without breaking, nor can they accommodate the punishing stresses of repeated scope articulation.

6.3.3.2 Liquid light guides are very effective transmitters of UV-A, but have minimum diameter limitations at 2.5 mm and also exhibit problems with collapsing, kinking, or loss of fluids.

6.3.3.3 A special glass fiber configuration offers the best UV performance plus durability. Special glass fiber light bundles combine high UV output with the necessary flexibility and durability required in these scopes.

6.3.4 Electronic digital borescopes have one end composed of a small LED source and a digital embedded camera. As the guide only carries electric signals, the length can be several meters.

6.4 *UV-A Pencil Lamps*

6.4.1 The pencil lamp is one of the smallest sources of UV-A radiation. It is generally a lamp coated with conversion phosphors that absorb the 254 nm (2540 Å) line of energy and convert this energy into a band peaking at 365 nm (3650 Å). The lamp may be encased in a tubular glass filter that absorbs visible light while transmitting maximum ultraviolet intensity. The pencil lamp is useful for fluorescent analysis and boroscopic inspection in inaccessible locations.

NOTE 1—Pencil lamps produce low levels of UV-A radiation.

6.4.2 As with all metal vapor discharge lamps, the output of a quartz pencil lamp slowly decreases throughout its life. The actual useful life will primarily be dependent upon dust and other contaminants collecting on the lamp and its reflecting and transmissive elements. UV-A intensity loss also occurs as the lamp ages.

6.5 *High Intensity UV-A Sources*

6.5.1 *Metal Halide UV-A Sources*—The high intensity flood fixture normally uses a high wattage metal halide bulb with a reflector. The high intensity of this lamp will produce a great deal of heat, so some type of cooling fan must be used.

6.5.2 *Micro-Discharge (MDL) Lamp UV-A Sources*—The MDL lamp uses a 35-watt metal halide bulb and therefore produces very little heat. Normally, a cooling fan is not required. These lamps use a high-pressure arc bulb containing xenon gas or a mixture of mercury vapor and xenon gas.

6.5.3 High Intensity UV-A lamps have broad emission spectra, which may include more than one peak within the UV-A range (6.1.2). For use in fluorescent NDT, these lamps must have appropriate filters, either internal or external to the light source, to pass UV-A (6.1.2) and minimize visible light (6.1.5) output that is detrimental to the fluorescent inspection process. These UV-A filters should also block harmful UV-B (6.1.3) and UV-C (6.1.4) radiation.

[7] Kopp 1041 UV and Kopp 1071 UV are registered trademarks of Kopp Glass Inc., Pittsburgh, PA.

Caution—UV-A sources may emit visible light above 400 nm (4000 Å), which may reduce the visibility of fluorescent indications. High intensity UV-A sources may cause UV fade, causing fluorescent indications to disappear.

6.6 *Light Emitting Diode (LED) UV-A Sources*[8]

6.6.1 LED UV-A sources utilize one or more UV-A LEDs and must have spectral emission characteristics optimized for use in fluorescent penetrant and fluorescent magnetic particle inspections. Tests are performed by lamp manufacturers to certify specific lamp models meet minimum performance requirements with respect to the specific lamp design (housing, filter, diodes, electronic design, optical elements, cooling system and power supply combinations including AC and battery operations). Performance requirements include, but are not limited to, emission characteristics, beam profiles, etc. For specific requirements, refer to Practice E3022.

Caution—Many UV-A LED lamps available at the retail level or purchased over the counter do not have emission characteristics that are acceptable for use in fluorescent liquid penetrant or magnetic particle examinations. See Practice E3022.

NOTE 2—Guide E709 and Practices E165, E1208, E1209, E1210, E1219, E1417/E1417M, E1444/E1444M, and E3024 provide UV-A requirements for fluorescent magnetic particle and fluorescent penetrant inspection processes.

6.6.2 *Differences in Practice (Mercury Vapor Versus UV-A LED Sources)*

6.6.2.1 While traditional mercury vapor lamps increase in intensity during their warm-up, LED UV-A sources typically decrease in intensity during warm-up and stabilization. The user should be aware of the stabilization time for the specific UV-A sources in use.

6.6.2.2 The traditional mercury vapor lamp shows a small central beam spot (area with more than 1000 μW/cm^2) in conjunction with a large surrounding area where the UV-A irradiance drops off gradually. LED UV-A sources offer various beam profiles with different minimum working distances depending on their design. LED UV-A sources should be selected to fit the application. For local inspection or inspection of smaller parts/areas, spot lamps are appropriate. For inspection of larger parts/areas, LED UV-A sources with a larger central beam and large surrounding area with a soft UV-A drop are recommended.

6.6.2.3 If operated long enough without recharging, battery powered lamps can drop below the minimum required intensity during use. Some lamp designs incorporate a constant power control that maintains UV-A irradiance at a relatively constant level until the battery charge is depleted at which point the lamp shuts off automatically.

6.7 *Visible Light Sources*

6.7.1 Visible light sources produce radiation in the 400 nm (4000 Å) to 760 nm (7600 Å) region in the electromagnetic spectrum. They have various intensities and different color responses that are easily observed by the human eye.

6.7.2 These human photoreceptors are of two types: cones and rods.

6.7.2.1 Rods are highly sensitive to low intensities of light and contain only a single photopigment and are unable to discriminate color. The eye response under low intensity lighting is referred to as scotopic and uses rod photoreceptors.

6.7.2.2 Cone photoreceptors respond to higher light intensities and are referred to as photopic. The cones are composed of three different photopigments that are able to discriminate colors.

NOTE 3—Guide E709 and Practices E165, E1220, E1417/E1417M, E1418, E1444/E1444M, and E3024 provide visible illumination requirements for magnetic particle and penetrant examination.

6.8 *Radiometers and Illuminance Photometers*

6.8.1 *UV-A Radiometer:*

6.8.1.1 Radiant energy is a physical quantity that can be measured directly in the laboratory by several types of optical radiation detectors; such as thermopiles, bolometers, pyroelectric instruments, and radiometric meters. All UV measuring devices are selective, and their sensitivity depends upon the wavelength of the radiation being measured.

6.8.1.2 The most practical measurement tool suitable for NDT fluorescent inspection is the radiometer. There are two types of radiometers, one with a digital and one with an analog response. The radiometer must have a filter system to limit the meter response to the UV-A range (6.1.2) with either a top-hat curve or a maximum response at 365 nm (3650 Å) such as defined by ISO 3059.

6.8.1.3 The digital meter is usually the meter of choice because of its ease of use. Another advantage is that the digital meter can measure high and low intensities of UV-A radiation without using screens or a mask to restrict the amount of UV-A radiation impinging on the sensor.

6.8.1.4 Digital meters and their sensors contain specific optical and electronical components that define the spectral range and convert the radiation into an electrical signal. The signal is then processed by the instrument's solid-state electronics and displayed digitally.

6.8.2 *Illuminance Photometers:*

6.8.2.1 Just like UV-A radiometers, there are two types of illuminance photometers: digital and analog. Illuminance photometers use photodiodes to measure illuminance. They are equipped with a non-fluorescent photopic filter to mimic the responsivity of the eye and to prevent UV-A illumination from reaching the detector.

Caution—Many meters available at the retail level or purchased over the counter do not have the proper filters to measure only visible light from 400 nm (4000 Å) to 760 nm (7600 Å) according to 6.1.5.

6.8.2.2 Photometers can provide illuminance readings in different units. Typical units are lux (lx) or foot-candles (fc). 1 foot candle equals 10.76 lux.

6.8.2.3 Some illuminance photometers are not considered adequate for directly measuring the visible emission of UV-A lamps.

[8] The use of LED lamps for liquid penetrant and magnetic particle 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, attn: E07 Chairman. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend.