Designation: ~~E2297 – 15~~ 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 ~~describes~~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 ~~help support the needs for appropriate light intensities and light measurement.~~establish practices and procedures to measure irradiance and illuminance levels.

1.2 This guide also ~~provides~~ acts as a reference:

1.2.1 To assist in the selection of ~~light~~ 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~~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 and health~~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

[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.

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

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~~E1417/E1417M Practice for Liquid Penetrant Testing
E1418 Practice for Visible Penetrant Testing Using the Water-Washable Process
~~E1444~~E1444/E1444M Practice for Magnetic Particle Testing for Aerospace
E3022 Practice ~~For~~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
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—*~~*source, n—*a ~~light source~~ UV-A source or lamp that produces UV-A irradiance greater than 10 000 µW⁄cm² (100 W⁄m²) at 38.1 cm (15 in.).

3.2.2 ~~*illuminance—*~~*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 ~~metre~~meter (lm/m²~~)~~), or footcandle (fc).

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

3.2.4 ~~*irradiance—*~~*irradiance, n—*the power of electromagnetic radiation incident on a surface, per unit area. Typically reported in units of watts per square ~~metre~~meter (W/m²) or microwatts per square centimetre (µW/cm²).

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

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

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

examination. This guide also describes the properties of radiometers and ~~light meters used to determine if adequate light levels (UV-A or visible, or both) are present~~ 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 ~~light~~illumination levels for liquid penetrant and magnetic particle examination. ~~Radiometers and light meters~~UV-A sources, UV-A radiometers, visible light sources, and illuminance photometers are used to verify ~~that specified light levels are available.~~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 ~~energy from the~~ UV-A radiation and re-emit light energy in the visible spectrum. This ~~energy transfer~~ process allows fluorescence to be observed by the human eye.

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

6. Equipment

6.1 *Ultraviolet (UV)/Visible ~~Light~~Irradiation Spectrum*

6.1.1 UV ~~light~~ sources emit radiation in the ultraviolet section of the electromagnetic spectrum, between ~~180 nm (1800~~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 ~~180 nm (1800~~100 nm (1000 Å) and 280 nm (2800 Å).

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 ~~Most~~ 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

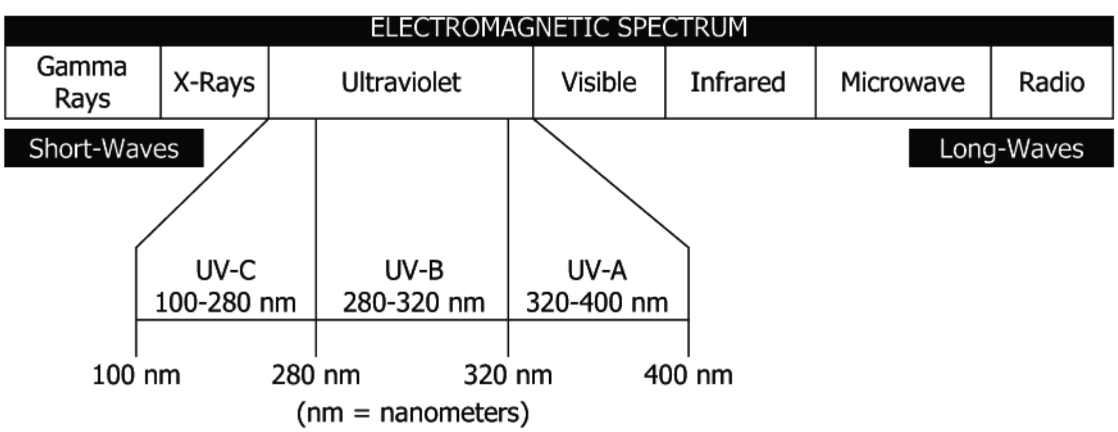

FIG. 1 The Electromagnetic Radiation Spectrum

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 ~~light source,~~ 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 ~~(luminescent~~(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 ~~lighting~~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 ~~0.25 % to~~ 1 % of its total intensity outside of the UV-A range. A ~~typical~~ lamp ~~is~~ 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, or bulbs based on the Philips HPW 125-watt bulb~~characteristics will not differ greatly in UV-A output, but may produce more visible light in the blue/violet part of the spectrum.

~~NOTE 1—The Philips HPW 125-watt bulb has been restricted from use in the inspection station by many aerospace companies.~~

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

6.3.1 Borescopes, fiberscopes, and video-image-scopes are thin rigid or flexible tubular optical telescopes. They are ~~non destructive~~ 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 ~~white~~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~~ 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

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

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~~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 ~~Light~~ Sources*

6.5.1 *Metal Halide UV-A ~~Sources:~~ Sources—*The high intensity flood fixture normally uses a high wattage metal halide ~~bulb. This lamp will also contain some type of specially coated parabolic~~ 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:~~ Sources—*The MDL lamp uses a ~~35 watt~~ 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 *Xenon Bulb UV-A Sources:* 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 ~~sources~~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.

~~**Warning—**UV-A light 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.~~**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 ~~UV-A sources utilizing a single UV-A LED or an array of UV-A LEDs need to have emission characteristics that are comparable to those of other UV-A sources.~~ 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~~E3022.~~.

~~**Warning—**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.~~**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~~E1417/E1417M, E1444/E1444M~~and~~, ~~E1444~~and E3024 provide UV-A ~~light~~ requirements for fluorescent magnetic particle and fluorescent penetrant inspection processes.~~ See also the forthcoming E07 standard, Practice for Magnetic Particle Testing for General Industry.~~

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

[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.