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 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.

1.2 This guide also provides a reference:

1.2.1 To assist in the selection of light 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 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 and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

E165 Practice for Liquid Penetrant Examination 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 Practice for Liquid Penetrant Testing
E1418 Practice for Visible Penetrant Testing Using the Water-Washable Process
E1444 Practice for Magnetic Particle Testing
E3022 Practice For Measurement of Emission Characteristics and Requirements for LED UV-A Lamps Used in Fluorescent Penetrant and Magnetic Particle Testing

3. Terminology

3.1 The definitions that appear in 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.

3.2 *Definitions:*

3.2.1 *high-intensity UV-A source*—a light source 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*—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 (lm/m^2) or footcandle (fc).

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

3.2.4 *radiometer*—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 and visible light sources used for liquid penetrant and magnetic particle examination. This guide also describes the properties of radiometers and light meters used to determine if adequate

[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 light levels (UV-A or visible, or both) are present 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 levels for liquid penetrant and magnetic particle examination. Radiometers and light meters are used to verify that specified light levels are available.

5.2 Fluorescence is 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 allows fluorescence to be observed by the human eye.

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

6. Equipment

6.1 *Ultraviolet (UV)/Visible Light Spectrum*

6.1.1 UV light sources emit radiation in the ultraviolet section of the electromagnetic spectrum, between 180 nm (1800 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).

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 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).

6.2 *Mercury Vapor UV-A Sources*

6.2.1 Most 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 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 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 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 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

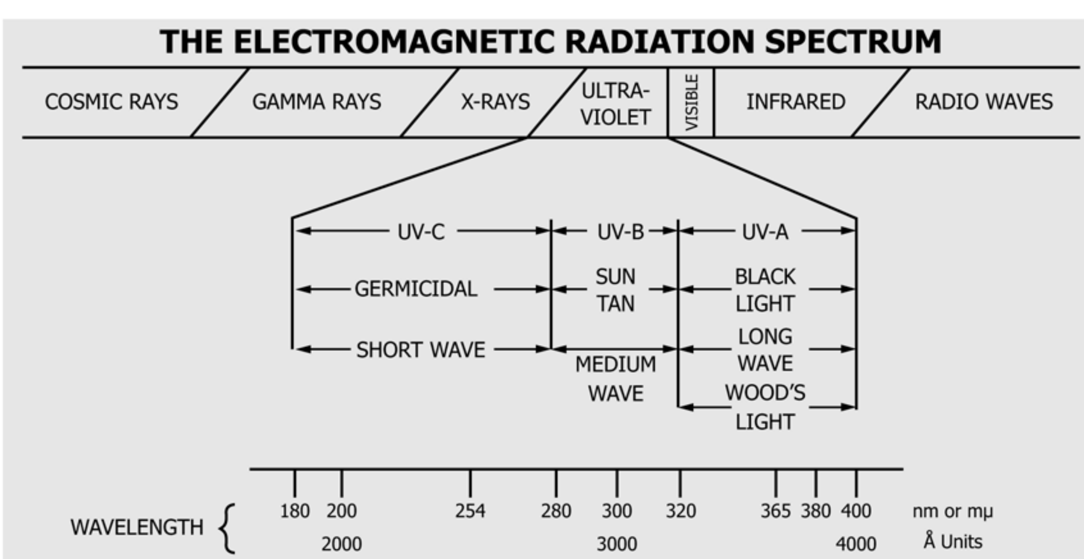

FIG. 1 The Electromagnetic Radiation Spectrum

Kopp 1041 or Kopp 1071[3] 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[4] 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, 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 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 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.

6.4 *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 2—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 Light Sources*

6.5.1 *Metal Halide UV-A 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 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 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.

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.

6.5.4 High Intensity UV-A sources 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.

6.6 *Light Emitting Diode (LED) UV-A Sources*[5]

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. For specific requirements, refer to Practice 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.

NOTE 3—Guide E709 and Practices E165, E1208, E1209, E1210, E1219, E1417, and E1444 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.

6.7 *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. The visible energy spectrum is easily absorbed by the eye's photoreceptors.

6.7.2 These 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 is unable to

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

[4] Philips HPW 125 watt is a registered trademark of Philips Lighting Co., Somerset, NJ.

[5] 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.

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 4—Guide E709 and Practices E165, E1220, E1417, E1418, and E1444 provide visible light requirements for magnetic particle and penetrant examination. See also the forthcoming E07 standard, Practice for Magnetic Particle Testing for General Industry.

6.8 *Radiometers and Light Meters*

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).

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 generally have a sensor approximately 1 cm^2, and contain specific optical components that define the spectral range and convert the radiation into electrical current. The current is then processed by the instrument's solid-state electronics and displayed digitally.

6.8.2 *Visible Light Meters:*

6.8.2.1 Just like UV-A meters, there are two types of visible light meters, digital and analog. Visible light meters use photodiodes to measure illuminance. Because photodiodes may be sensitive to both visible light and UV, visible light meters for use in fluorescent NDT must have filters to limit the meter response to the visible spectrum (6.1.5).

Warning—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 Unlike UV-A radiometers, visible light meters can provide illuminance readings in different units. Typical units are lux (lx) or foot-candles (fc). 1 foot candle equals 10.76 lux. Meter response in foot candles is generally used for NDT inspections in the United States.

6.8.2.3 Photodiodes, photometers, or visible light meters are not considered adequate for directly measuring the visible emission of UV-A lamps.

7. UV-A/Visible Light Measurement

7.1 *UV-A Light Measurement*

7.1.1 UV-A sources are evaluated by measuring the emission in the UV-A range (6.1.2) at a specific distance. Measurement distance is typically 38.1 cm (15 in.) from the face of the UV-A pass filter or front of the source to the surface of the sensor of the radiometer.

7.1.2 This measurement is performed for two reasons. The first is to develop a history on the UV-A source and the second is to ensure that the light output is in compliance with the specification in use.

7.1.3 If the distance is controlled, then the irradiation of the lamp can be observed and the degradation of the source can be recorded to ensure that the bulb (if used) is replaced in a timely manner. There are many types of fixtures that may be used to control the measured distance. The measurement should be taken from the face of the lamp (front of filter/source) to the top surface of the sensor. With the distance controlled, irradiation can be accurately measured. Many specifications define the required distance and light irradiation. A minimum of 1000 $\mu W/cm^2$ at 38.1 cm (15 in.) is typically specified.

NOTE 5—Turn on the UV-A lamp and allow it to warm up before measuring light intensities.

7.2 *Visible Light Contamination*

7.2.1 Most specifications will list the maximum visible light contamination allowable in the inspection area with few or no guidelines defining where the measurement should be taken. Since visible light contamination may interfere with UV-A inspection, the concern is not how much visible light is in the inspection area, but how much visible light is at the viewing surface of the part or in the inspector's eyes. It is recommended that the visible light contamination measurement be taken at the viewing surface. If visible light from a hole, seam, or other source impinges upon the inspector's eyes, it is recommended that the light be eliminated or reduced as much as possible.

NOTE 6—Visible light contamination can come from walls, ceilings, table tops, flooring, inspectors' clothing, computers, or light from outside the booth. (Any clothing that will fluoresce can cause white light contamination.)

7.3 *Visible Light Measurement*

7.3.1 In the case of visible light, most sources are either on or off. There is very little degradation, so the measurement is made to ensure that enough light is available to perform a good visual inspection. As discussed above, a visible light meter that measures the visible range of the electromagnetic spectrum should be used. The measurement should be taken from the front of the bulb to the top surface of the sensor. This distance may be fixed, or a minimum light intensity at the part surface may be required for performing a visible light inspection.

NOTE 7—Line voltage variations will cause differences in the measured light intensity. Tubular fluorescent white light intensity may fade with age and use.

8. Safety Considerations for the Use of UV-A Irradiation

8.1 *UV-A Exposure*

8.1.1 There have been a number of studies undertaken to provide a threshold limit for UV-A exposure. These studies however, have produced at times contradictory results, with no absolute values. For more information on threshold limit value studies, consult: The American Conference of Governmental Industrial Hygienists (ACGIH); ASNT Handbook, Volume 6

Magnetic Particle Testing; or the Chemical & Engineering News, August 4, 2003 edition, page 25.

NOTE 8—Photosensitive individuals or individuals exposed to photosensitizing agents, such as special medication may have adverse health effects when exposed to UV-A radiation.

8.2 *Safety Considerations for UV-A Lamps*

8.2.1 Although UV-A radiation is known to be relatively safe compared to UV-B or UV-C radiation, all operators and supervisors should be aware of certain safety precautions. Personnel using UV-A sources should avoid looking directly at the light with unshielded eyes. This could cause ocular fluorescence and consequently lower the user's ability to detect an indication. The filter on the UV-A source must always be in good condition and free from cracks, since radiation at wavelengths below 320 nm (3200 Å) is harmful and the visible light emitted will be detrimental to the inspection. It is recommended by most UV-A lamp manufacturers that users wear non-photochromatic eyewear (goggles or glasses) when performing inspections. The eyewear should be made of clear optical material (not tinted) and possess UV-blocking capabilities. It is also recommended by UV-A light manufacturers that users wear long- sleeve clothing, gloves and a hat to minimize direct exposure of radiation to the skin.

9. Keywords

9.1 electromagnetic spectrum; UV-A exposure limits; UV-A light; UV-A measurement; UV-A radiometers; UV-A sources; visible light contamination; visible light measurement; visible light meters; visible light sources

SUMMARY OF CHANGES

Committee E07 has identified the location of selected changes to this standard since the last issue (E2297-04(2010) that may impact the use of this standard.

(1) Revised Terminology, Section 3.
(2) Revised Sections 4, 5, and 7.
(3) Revised subsections 6.2, 6.5, and 6.8, and added subsection 6.6.