Designation: E 2297 – 04

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 E 2297; 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 *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]

E 165 Test Method for Liquid Penetrant Examination

E 709 Guide for Magnetic Particle Examination

E 1208 Test Method for Fluorescent Liquid Penetrant Examination Using the Lipophilic Post-Emulsification Process

E 1209 Test Method for Fluorescent Liquid Penetrant Examination Using the Water-Washable Process

E 1210 Test Method for Fluorescent Liquid Penetrant Examination Using the Hydrophilic Post-Emulsification Process

E 1219 Test Method for Fluorescent Liquid Penetrant Examination Using the Solvent-Removable Process

E 1220 Test Method for Visible Penetrant Examination Using the Solvent-Removable Process

E 1316 Standard Terminology for Nondestructive Examination

E 1417 Standard Practice for Liquid Penetrant Examination

E 1418 Test Method for Visible Penetrant Examination Using the Water-Washable Process

E 1444 Standard Practice for Magnetic Particle Examination

3. Terminology

3.1 The definitions that appear in E 1316, 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.

4. Summary of Guide

4.1 This guide shows how the proper meter is correctly used to determine if adequate light levels (UV-A and/or visible) are available for use 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. 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 High Intensity UV-A light sources produce light intensity greater than 10,000 $\mu W/cm^2$ at 38.1 cm [15 in.].

6. Equipment

6.1 *Ultraviolet (UV)/Visible Light Spectrum*

6.1.1 The most common UV 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

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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.

violet/blue color of the visible spectrum and the weak X-ray spectrum. (See Fig. 1.)

6.1.2 The UV-A range (used for fluorescent liquid penetrant and fluorescent magnetic particle examinations) is considered to be between 320 nm [3200 Å] and 400 nm [4000 Å]. The UV-B range (medium UV) is considered to be between 280 nm [2800 Å] and 320 nm [3200 Å]. The UV-C range (short UV) is considered to be between 180 nm [1800 Å] and 280 nm [2800 Å]. 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 used in fluorescent NDT utilize a lamp containing a mercury-gas plasma that emits radiation specific to the mercury atomic transition spectrum. There are several discrete lines of the mercury spectrum in the ultraviolet section of the electromagnetic spectrum (between 180 nm [1800 Å] and 400 nm [4000 Å]). 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.

6.2.2 UV-A sources used for NDT, employ appropriate filters, either internal or external to the light source to minimize the visible light output (400 nm [4000 Å] to 760 nm [7600 Å]) that is detrimental to the fluorescent inspection process. These filters should also block harmful radiation below 320 nm [3200 Å].

6.2.3 UV-A sources are generally low or medium pressure vapor sources. Low pressure lamps are coated with a special phosphor in order to maximize the UV-A output. Medium pressure lamps do not have phosphor coatings but operate at higher electrical power levels, resulting in significantly higher UV-A output.

6.2.4 Typically, low pressure lamps (tubes) are used in wash stations or for general UV-A lighting in the inspection room. Medium pressure lamps are used in fluorescent inspection stations. A well designed medium pressure UV-A lamp should emit less that 0.25 % to 1 % of its total intensity under 320 nm [3200 Å] and above 400 nm [4000 Å]. A UV-A bulb 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 using a Kopp 1041[3] UV filter. Other newer lamps using the same bulb but with the Kopp 1071[3] UV filter or bulbs based on the Philips HPW 125-watt bulb[4] will not differ greatly in UV-A output, but in general will produce more visible light in the blue/violet part of the spectrum. **Warning—**Certain high-intensity UV-A light sources may emit unacceptable amounts of visible light, which will cause fluorescent indications to disappear. Care should be taken to use only bulbs certified by the supplier to be suitable for such examination purposes.

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, Videoimagescope and Special UV-A Light Source Systems*

6.3.1 Borescopes, fiberscopes and videoimagescopes 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 videoimagescopes may be a poor transmitter of UV-A radiation. These fibers transmit white light in the 450 nm [4500 Å] to 760 nm [7600 Å] range, but do not effectively transmit light in the 350 nm [3500 Å] to 380 nm [3800 Å] range.

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

[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.

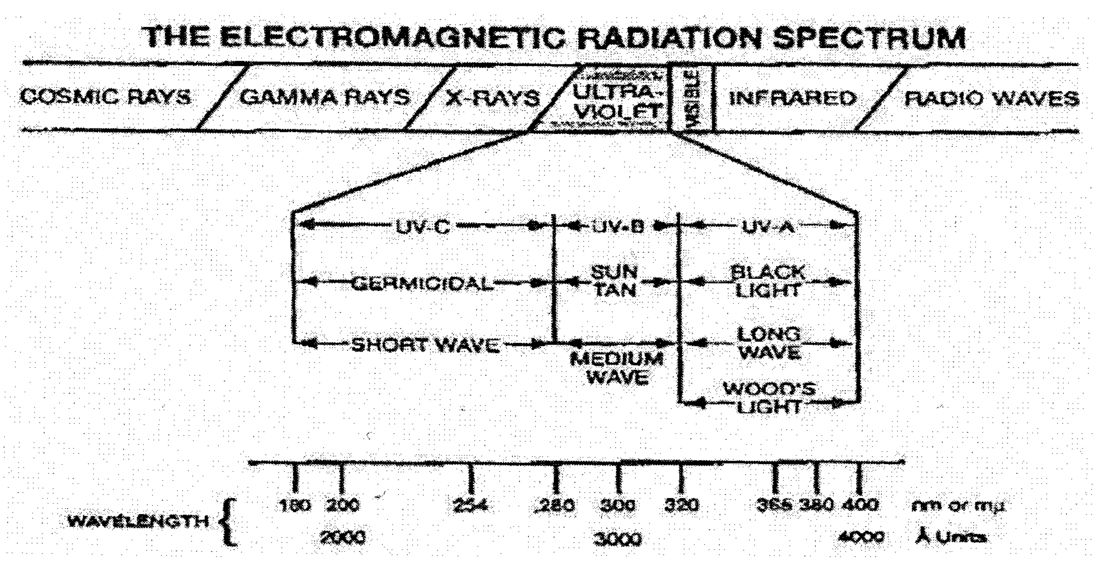

FIG. 1 The Electromagnetic Radiation Spectrum

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 be dependent upon dust and other contaminants collecting on the lamp and its reflecting and transmissive elements can cause more UV-A intensity loss at the irradiated surface than the age of the lamp.

6.5 *High Intensity UV-A Light Sources* There are two types of high intensity UV-A sources; 1) a UV flood fixture and 2) a hand held ultra-high intensity micro discharge lamp (MDL).

6.5.1 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 The MDL lamp uses a 35 watt metal halide bulb and therefore produces very little heat. Normally, a cooling fan is not required. **Warning—**When a high intensity UV-A lamp (light sources that produce light intensity greater than 10,000 μW/cm^2 at 38.1 cm [15 in.]) is used for inspection, care must be exercised to prevent the UV fading of indications and that the excess blue light that is produced, does not mask blue/white indications.

NOTE 3—ASTM E 1208, E 1209, E 1210, E 1219, E 1417, and E 1444 provide UV-A light requirements for fluorescent magnetic particle and fluorescent penetrant inspection processes.

6.6 *Visible Light Sources*

6.6.1 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.

6.6.2 These photoreceptors are of two types, cones and rods.

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

6.6.2.2 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—ASTM E 1220, E 1417, E 1418, and E 1444 provide visible light requirements for magnetic particle and penetrant examination.

6.7 *Light Meters*

6.7.1 *UV-A Light Intensity Meter*:

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.

6.7.1.1 The thermopile uses two dissimilar metals and depends on electromotive force (EMF) to measure UV radiation.

6.7.1.2 The bolometer is a wheatstone bridge, one arm of which is heated by the optical radiation to produce a response to UV radiation.

6.7.1.3 Even though the above two instruments are very sensitive, they are extremely delicate and their use is restricted to the laboratory.

6.7.2 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 digital and analog meters must have a filter system to produce the maximum response at 365 nm [3650 Å] (the wavelength used by magnetic particle and penetrant fluorescent dyes and pigments to produce fluorescence).

NOTE 5—The radiometer measures UV-A light intensity in units of μW/cm^2.

6.7.2.1 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.

6.7.2.2 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.

6.7.3 *Visible Light Meters*:

Visible Light Meters Just like UV-A meters, there are two types of visible light meters, digital and analog. Visible light meters must have filters to limit the meter response to the 400 nm [4000 Å] to 760 nm [7600 Å] region in the electromagnetic spectrum. Visible light meters use silicon photodiodes to measure light intensity. Unlike UV-A meters, visible light meters offer a choice of response in either lux or foot-candles (1 foot candle equals 10.76 lux). Meter response in foot candles is generally used for NDT inspections in the United States. **Warning—**Many meters purchased over the counter, do not have the proper filters to measure light from 400 nm [4000 Å] to 760 nm [7600 Å].

7. UV-A/Visible Light Measurement

7.1 UV-A light measurement may require two types of measurement for fluorescent examinations.

7.1.1 The first is to measure the UV-A radiation produced by the light source at a specified distance.

7.1.1.1 This measurement is performed for two reasons. The first is to develop a history on the light source and the second is to assure that the light output is in compliance with the specification in use.

7.1.1.2 If the distance is controlled, then the intensity of the lamp can be observed and the degradation of the bulb can be recorded to assure that the bulb 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/bulb) to the top surface of the sensor. With the distance controlled, source intensity can be accurately observed. Many specifications define the required distance and light intensity.

7.1.2 The second measurement that may be taken, is at the viewing distance and angle used for inspecting parts. This value will ensure that adequate UV-A radiation is available to perform an adequate fluorescent examination.

NOTE 6—Turn on the UV-A lamp and allow it to warm up for 15 minutes or per the manufacturer's recommendation, before measuring light intensities.

7.2 *Visible Light Measurement*

7.2.1 In the case of visible light, most bulbs are either on or off. There is very little degradation, so the measurement is made to assure 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.

7.3 *Visible Light Contamination*

7.3.1 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, when the UV-A lamp is held at the angle and distance used for inspection. This measurement will address all the visible light in the inspection area and not just the UV-A bulb. Also, 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 8—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.)

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

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 9—Photosensitive Individuals or individuals exposed to photo-sensitizing 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 sources; UV-A measurement; UV-A meters; visible light contamination; visible light measurement; visible light meters; visible light sources