~~Designation:E 165–02~~

~~Standard Test Method for Liquid Penetrant Examination~~Designation: E165 – 09

Standard Practice for Liquid Penetrant Examination for General Industry[1]

This standard is issued under the fixed designation E165; 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

~~1.1This test method~~

1.1 This practice[2] covers procedures for penetrant examination of materials. ~~They are~~ Penetrant testing is a nondestructive testing ~~methods~~method for detecting discontinuities that are open to the surface such as cracks, seams, laps, cold shuts, shrinkage, laminations, through leaks, or lack of fusion and ~~are~~is applicable to in-process, final, and maintenance ~~examination. They~~testing. It can be effectively used in the examination of nonporous, metallic materials, ~~both~~ ferrous and nonferrous metals, and of nonmetallic materials such as nonporous glazed or fully densified ceramics, as well as certain nonporous plastics, and glass.

1.2 This ~~test method~~practice also provides a reference:

1.2.1 By which a liquid penetrant examination process recommended or required by individual organizations can be reviewed to ascertain its applicability and completeness.

~~1.2.2For use in the preparation of process specifications dealing with the liquid penetrant examination of materials and parts. Agreement by the user and the supplier regarding specific techniques is strongly recommended.~~

~~1.2.3For use in the organization of the facilities and personnel concerned with the liquid penetrant examination.~~

~~1.3This test method does not indicate or suggest criteria for evaluation of the indications obtained. It should be pointed out, however, that after indications have been produced, they must be interpreted or classified and then evaluated. For this purpose there must be a separate code or specification or a specific agreement to define the type, size, location, and direction of indications considered acceptable, and those considered unacceptable.~~

1.2.2 For use in the preparation of process specifications and procedures dealing with the liquid penetrant testing of parts and materials. Agreement by the customer requesting penetrant inspection is strongly recommended. All areas of this practice may be open to agreement between the cognizant engineering organization and the supplier, or specific direction from the cognizant engineering organization.

1.2.3 For use in the organization of facilities and personnel concerned with liquid penetrant testing.

1.3 This practice does not indicate or suggest criteria for evaluation of the indications obtained by penetrant testing. It should be pointed out, however, that after indications have been found, they must be interpreted or classified and then evaluated. For this purpose there must be a separate code, standard, or a specific agreement to define the type, size, location, and direction of indications considered acceptable, and those considered unacceptable.

1.4 The values stated in inch-pound units are to be regarded as the standard. SI units are provided for information only.

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 and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[3]

D129 Test Method for Sulfur in Petroleum Products (General Bomb Method)

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[1] This ~~test method~~ practice 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 ASME Boiler and Pressure Vessel Code applications see related Recommended Test Method SE-165 in the Code.

[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* ~~, Vol 05.01.~~volume information, refer to the standard's Document Summary page on the ASTM website.

D516Test Method for Sulfate Ion in Water E516 Practice for Testing Thermal Conductivity Detectors Used in Gas Chromatography
D808 Test Method for Chlorine in New and Used Petroleum Products (Bomb Method)
D1193 Specificationfor Reagent Water[4] 1193 Specification for Reagent Water
D1552 Test Method for Sulfur in Petroleum Products (High-Temperature Method)
D43274327 Test Method for Anions in Water by Chemically Suppressed Ion Chromatography
E433 Reference Photographs for Liquid Penetrant Inspection
E543 Practice for Evaluating Agencies that Perform Nondestructive Testing[5] Specification for Agencies Performing Nondestructive Testing
E1208 Test Method for Fluorescent Liquid Penetrant Examination Using the Lipophilic Post-Emulsification Process
E1209 Test Method for Fluorescent Liquid Penetrant Examination Using the Water-Washable Process
E1210 Test Method for Fluorescent Liquid Penetrant Examination Using the Hydrophilic Post-Emulsification Process
E1219 Test Method for Fluorescent Liquid Penetrant Examination Using the Solvent-Removable Process
E1220 Test Method for Visible Penetrant Examination Using the Solvent-Removable Process
E1316 Terminology for Nondestructive Examinations[5] Terminology for Nondestructive Examinations
E1417 Practice for Liquid Penetrant Testing
E1418 Test Method for Visible Penetrant Examination Using the Water-Washable Process

2.2 *ASNT Document:* [4]

Recommended Practice SNT-TC-1A Recommended Practice for Nondestructive Testing Personnel Qualification and Certification
ANSI/ASNT CP-189 Standard for Qualification and Certification of Nondestructive Testing Personnel

2.3 *Military Standard:*

MIL-STD-410 Nondestructive Testing Personnel Qualification and Certification[5]

2.4 *APHA Standard:*

429 Method for the Examination of Water and Wastewater[6]

2.5 *AIA Standard:*

NAS-410Certification and Qualification of Nondestructive Test Personnel[6] Certification and Qualification of Nondestructive Test Personnel[7]

2.6 *SAE Standards:*[8]

AMS 2644 Inspection Material, Penetrant
QPL-AMS-2644 Qualified Products of Inspection Materials, Penetrant

3. Terminology

3.1 The definitions relating to liquid penetrant examination, which appear in Terminology E 1316E1316, shall apply to the terms used in this standard. practice.

4. Summary of Test MethodPractice

4.1A liquid 4.1 Liquid penetrant which may be aconsist of visible or a fluorescent material. The liquid penetrant is applied evenly over the surface being examined and allowed to enter open discontinuities. After a suitable dwell time, the excess surface penetrant is removed. A developer is applied to draw the entrapped penetrant out of the discontinuity and stain the developer. The test surface is then examined to determine the presence or absence of indications.

NOTE 1—The developer may be omitted by agreement between purchaser and supplier. the contracting parties.
NOTE2—Caution:Fluorescent 2—Fluorescent penetrant examination shall not follow a visible penetrant examination unless the procedure has been qualified in accordance with 10.2, because visible dyes may cause deterioration or quenching of fluorescent dyes.

4.2 Processing parameters, such as surface precleaning, penetration penetrant dwell time and excess penetrant removal methods, are determined bydependent on the specific materials used, the nature of the part under examination, (that is, size, shape, surface condition, alloy) and type of discontinuities expected.

5. Significance and Use

5.1 Liquid penetrant examinationtesting methods indicate the presence, location and, to a limited extent, the nature and

[4] Annual Book of ASTM Standards, Vol 11.01.
[4] Available from American Society for Nondestructive Testing (ASNT), P.O. Box 28518, 1711 Arlingate Ln., Columbus, OH 43228-0518, http://www.asnt.org.
[5] Annual Book of ASTM Standards, Vol 03.03.
[5] Available from Standardization Documents Order Desk, DODSSP, Bldg. 4, Section D, 700 Robbins Ave., Philadelphia, PA 19111-5098, http://www.dodssp.daps.mil.
[6] Available from the American Society for Nondestructive Testing, 1711 Arlingate Lane, Columbus, OH 43228-0518.
[6] Available from American Public Health Association, Publication Office, 1015 Fifteenth Street, NW, Washington, DC 20005.
[7] Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.
[7] Available from Aerospace Industries Association of America, Inc. (AIA), 1000 Wilson Blvd., Suite 1700, Arlington, VA 22209-3928, http://www.aia-aerospace.org.
[8] Available from American Public Health Association, Publication Office, 1015 Fifteenth Street, NW, Washington, DC 20005.
[8] Available from Society of Automotive Engineers (SAE), 400 Commonwealth Dr., Warrendale, PA 15096-0001, http://www.sae.org.

magnitude of the detected discontinuities. Each of the various penetrant methods has been designed for specific uses such as critical service items, volume of parts, portability or localized areas of examination. The method selected will depend accordingly on the design and service requirements of the parts or materials being tested.

6. ~~Classification of Penetrations and Methods~~

~~6.1Liquid penetrant examination methods and types are classified as shown in~~ Classification of Penetrant Materials and Methods

6.1 Liquid penetrant examination methods and types are classified in accordance with MIL-I-25135 and AMS 2644 as listed in Table 1.

6.2 *Fluorescent ~~penetrant examination~~ Penetrant Testing (Type 1)*~~utilizes~~ —Fluorescent penetrant testing utilizes penetrants that fluoresce brilliantly when excited by black light ~~(see 8.9.1.2).~~ (UVA). The sensitivity of fluorescent penetrants depends on their ability to be retained in the various size discontinuities during processing, and then to bleed out into the developer coating and produce indications that will fluoresce. Fluorescent indications are many times brighter than their surroundings when viewed under appropriate black light illumination.

6.3 ~~*Visible penetrant examination* uses a penetrant that can be seen in visible light. The penetrant is usually red, so that the indications produce a definite contrast with the white background of the developer. The visible penetrant process does not require the use of black light. However, visible penetrant indications must be viewed under adequate white light (see 8.9.2.1).~~ Visible Penetrant Testing (Type 2)—Visible penetrant testing uses a penetrant that can be seen in visible light. The penetrant is usually red, so that resultant indications produce a definite contrast with the white background of the developer. Visible penetrant indications must be viewed under adequate white light.

7. ~~Types of Materials~~ Materials

7.1 ~~*Liquid penetrant examination materials*(see Notes 3 and 4) consist of fluorescent and visible penetrants, emulsifiers (oil-base and water-base), solvent removers and developers. A family of liquid penetrant examination materials consists of the applicable penetrant and emulsifier or remover, as recommended by the manufacturer. Intermixing of penetrants and emulsifiers from various manufacturers is not recommended.~~ Liquid Penetrant Testing Materials consist of fluorescent or visible penetrants, emulsifiers (oil-base and water-base), removers (water and solvent), and developers (dry powder, aqueous and nonaqueous). A family of liquid penetrant examination materials consists of the applicable penetrant and emulsifier, as recommended by the manufacturer. Any liquid penetrant, remover and developer listed in QPL-25135/QPL-AMS2644 can be used, regardless of the manufacturer. Intermixing of penetrants and emulsifiers from different manufacturers is prohibited.

NOTE 3—Refer to 9.1 for special requirements for sulfur, halogen and alkali metal content.

NOTE~~4—**Caution:** While~~ 4—While approved penetrant materials will not adversely affect common metallic materials, some plastics or rubbers may be swollen or stained by certain penetrants.

7.2 *Penetrants*:

7.2.1 *Post-Emulsifiable Penetrants* are ~~designed to be~~ insoluble in water and cannot be removed with water rinsing alone. They are ~~designed~~formulated to be selectively removed from the surface using a separate emulsifier. ~~The emulsifier, properly~~ Properly applied and given a proper emulsification time, the emulsifier combines with the excess surface penetrant to form a water-washable mixture, which can be rinsed from the surface, leaving the surface free of excessive fluorescent background. Proper emulsification time must be experimentally established and maintained to ensure that over-emulsification does not ~~occur, resulting~~result in loss of indications.

7.2.2 *Water-Washable Penetrants*~~are designed to be directly water-washable from the surface of the test part, after a suitable penetrant dwell time. Because the emulsifier is "built-in" to the water-washable penetrant, it is extremely important to exercise~~

TABLE 1 Classification of Penetrant Examination Types and Methods

Type I—Fluorescent Penetrant Examination
~~Method A—Water-washable (see Test Method E 1209-E 1209)~~
Method A—Water-washable (see Test Method E1209)
~~Method B—Post-emulsifiable, lipophilic (see Test Method E 1208-E 1208)~~
Method B—Post-emulsifiable, lipophilic (see Test Method E1208)
~~Method C—Solvent removable (see Test Method E 1219-E 1219)~~
Method C—Solvent removable (see Test Method E1219)
~~Method D—Post-emulsifiable, hydrophilic (see Test Method E 1210-E 1210)~~
Method D—Post-emulsifiable, hydrophilic (see Test Method E1210)
Type II—Visible Penetrant Examination
~~Method A—Water-washable (see Test Method E 1418-E 1418)~~
Method A—Water-washable (see Test Method E1418)
~~Method C—Solvent removable (see Test Method E 1220-E 1220)~~
Method C—Solvent removable (see Test Method E1220)

proper process control in removal of excess surface penetrant to ensure against overwashing. Water-washable penetrants can be washed out of discontinuities if the rinsing step is too long or too vigorous. Some penetrants are less resistant to overwashing than others. are formulated to be directly water-washable from the surface of the test part, after a suitable penetrant dwell time. Because the emulsifier is "built-in," water-washable penetrants can be washed out of discontinuities if the rinsing step is too long or too vigorous. It is therefore extremely important to exercise proper control in the removal of excess surface penetrant to ensure against overwashing. Some penetrants are less resistant to overwashing than others, so caution should be exercised.

7.2.3 *Solvent-Removable Penetrants* are designedformulated so that excess surface penetrant can be removed by wiping until most of the penetrant has been removed. The remaining traces should be removed with the solvent remover (see 8.6.4.18.6.4). To minimizeprevent removal of penetrant from discontinuities, care should be taken to avoid the use of excess solvent. Flushing the surface with solvent to remove the excess penetrant is prohibited as the penetrant indications could easily be washed away.

7.3 *Emulsifiers*:

7.3.1 *Lipophilic Emulsifiers*are oil-miscible liquids used to emulsify the excess oily penetrant on the surface of the part, rendering it water-washable. The rate of diffusion establishes the emulsification time. They are either slow- or fast-acting, depending on their viscosity and chemical composition, and also the surface roughness of the area being examined (see 8.6.2). are oil-miscible liquids used to emulsify the post-emulsified penetrant on the surface of the part, rendering it water-washable. The individual characteristics of the emulsifier and penetrant, and the geometry/surface roughness of the part material contribute to determining the emulsification time.

7.3.2 *Hydrophilic Emulsifiers* are water-miscible liquids used to emulsify the excess oily fluorescent post-emulsified penetrant on the surface of the part, rendering it water-washable (see 8.6.3). water-washable. These water-base emulsifiers (detergent-type removers) are supplied as concentrates to be diluted with water and used as a dip or spray. The concentration, use and maintenance shall be in accordance with manufacturer's recommendations.

7.3.2.1 Hydrophilic emulsifiers function by displacing the excess penetrant film from the surface of the part through detergent action. The force of the water spray or air/mechanical agitation in an open dip tank provides the scrubbing action while the detergent displaces the film of penetrant from the part surface. The emulsification time will vary, depending on its concentration, which can be monitored by individual characteristics of the emulsifier and penetrant, and the geometry and surface roughness of the use ofpart material contribute to determining the emulsification time. Emulsification concentration shall be monitored weekly using a suitable refractometer.

7.4 *Solvent Removers* function by dissolving the penetrant, making it possible to wipe the surface clean and free of excess penetrant as described in 8.6.1.2 and 8.6.4. —Solvent removers function by dissolving the penetrant, making it possible to wipe the surface clean and free of excess penetrant.

7.5 *Developers*—Development of penetrant indications is the process of bringing the penetrant out of open discontinuities through blotting action of the applied developer, thus increasing the visibility of the indications. —Developers form a translucent or white absorptive coating that aids in bringing the penetrant out of surface discontinuities through blotting action, thus increasing the visibility of the indications.

7.5.1 *Dry Powder Developers*are used as supplied (that is, free-flowing, non-caking powder) in accordance with 8.8.2. Care should be taken not to contaminate the developer with fluorescent penetrant, as the penetrant specks can appear as indications. —Dry powder developers are used as supplied, that is, free-flowing, non-caking powder (see 8.8.1). Care should be taken not to contaminate the developer with fluorescent penetrant, as the contaminated developer specks can appear as penetrant indications.

7.5.2 *Aqueous Developers*are normally supplied as dry powder particles to be either suspended or dissolved (soluble) in water. The concentration, use and maintenance shall be in accordance with manufacturer's recommendations (see 8.8.3). —Aqueous developers are normally supplied as dry powder particles to be either suspended (water suspendable) or dissolved (water soluble) in water. The concentration, use and maintenance shall be in accordance with manufacturer's recommendations. Water soluble developers shall not be used with Type 2 penetrants or Type 1, Method A penetrants.

NOTE5—**Caution:**Aqueous 5—Aqueous developers may cause stripping of indications if not properly applied and controlled. The procedure should be qualified in accordance with 10.2.

7.5.3 *Nonaqueous Wet Developers*are —Nonaqueous wet developers are supplied as suspensions of developer particles in a nonaqueous solvent carrier ready for use as supplied. Nonaqueous, wet developers are sprayed on to form a thin coating on the surface of the part when dried, which dried. This thin coating serves as the developing medium (see 8.8.4). medium.

NOTE6—**Caution:**This 6—This type of developer is intended for application by spray only.

7.5.4 *Liquid Film Developers* are solutions or colloidal suspensions of resins/polymer in a suitable carrier. These developers will form a transparent or translucent coating on the surface of the part. Certain types of film developer may be stripped from the part and retained for record purposes (see 8.8.58.8.4).

8. Procedure

8.1The following processing guidelines apply to both fluorescent and visible penetrant examination methods (see Figs. 1-3).

8.1 The following processing parameters apply to both fluorescent and visible penetrant testing methods.

8.2 *Temperature Limits*—The temperature of the penetrant materials and the surface of the part to be processed should be between 40° and 125°F (4° and 52°C). Where it is not practical to comply with these temperature limitations, qualify the procedure

as described in —The temperature of the penetrant materials and the surface of the part to be processed shall be between 40° and 125°F (4° and 52°C) or the procedure must be qualified at the temperature used as described in 10.2at the temperature of intended use and as agreed to by the contracting parties. .

8.3 *Surface Conditioning Prior to Penetrant Examination* —Satisfactory results usually may be obtained on surfaces in the as-welded, as-rolled, as-cast, or as-forged conditions (or for ceramics in the densified conditions). Sensitive penetrants are generally less easily rinsed away and are therefore less suitable for rough surfaces. When only loose surface residuals are present, these may be removed by wiping with clean lint-free cloths. However, precleaning of metals to remove processing residuals such as oil, graphite, scale, insulating materials, coatings, and so forth, should be done using cleaning solvents, vapor degreasing or chemical removing processes. Surface conditioning by grinding, machining, polishing or etching shall follow shot, sand, grit or vapor blasting to remove the peened skin and when penetrant entrapment in surface irregularities might mask the indications of unacceptable discontinuities or otherwise interfere with the effectiveness of the examination. For metals, unless otherwise specified, etching shall be performed when evidence exists that previous cleaning, surface treatments or service usage have produced a surface condition that degrades the effectiveness of penetrant examination. (See A1.1.1.8 for precautions.) Examination Sequence—Final penetrant examination shall be performed after the completion of all operations that could cause surface-connected discontinuities or operations that could expose discontinuities not previously open to the surface. Such operations include, but are not limited to, grinding, welding, straightening, machining, and heat treating. Satisfactory inspection results can usually be obtained on surfaces in the as-welded, as-rolled, as-cast, as-forged, or ceramics in the densified condition.

8.3.1 *Surface Treatment*—Final penetrant examination may be performed prior to treatments that can smear the surface but not by themselves cause surface discontinuities. Such treatments include, but are not limited to, vapor blasting, deburring, sanding, buffing, sandblasting, or lapping. Performance of final penetrant examination after such surface treatments necessitates that the part(s) be etched to remove smeared metal from the surface prior to testing unless otherwise agreed by the contracting parties. Note that final penetrant examination shall always precede surface peening.

NOTE7—When agreed between purchaser and supplier, grit blasting without subsequent etching may be an acceptable cleaning method. 7—Sand or shot blasting can close discontinuities so extreme care should be taken to avoid masking discontinuities. Under certain circumstances, however, grit blasting with certain air pressures and/or mediums may be acceptable without subsequent etching when agreed by the contracting parties.

NOTE8—**Caution:**Sand or shot blasting may possibly close discontinuities and extreme care should be used with grinding and machining operations to avoid masking discontinuities.

NOTE9—For structural or electronic ceramics, surface preparation by grinding, sand blasting and etching for penetrant examination is not recommended because of the potential for damage. 8—Surface preparation of structural or electronic ceramics for penetrant testing by grinding, sand blasting and etching is not recommended because of the potential for damage.

8.4 *Removal of Surface Contaminants* :

8.4.1*Precleaning*—The success of any penetrant examination procedure is greatly dependent upon the surrounding surface and discontinuity being free of any contaminant (solid or liquid) that might interfere with the penetrant process. All parts or areas of parts to be examined must be clean and dry before the penetrant is applied. If only a section of a part, such as a weld, including the heat affected zone is to be examined, all contaminants shall be removed from the area being examined as defined by the contracting parties. "Clean" is intended to mean that the surface must be free of rust, scale, welding flux, weld spatter, grease, paint, oily films, dirt, and so forth, that might interfere with the penetrant process. All of these contaminants can prevent the penetrant from entering discontinuities (see Annex on Cleaning of Parts and Materials). Note10—**Caution:**Residues from cleaning processes such as strong alkalies, pickling solutions and chromates, in particular, may adversely react with the penetrant and reduce its sensitivity and performance.

8.4.2

8.4.1 *Drying after Cleaning*—It is essential that the surface of parts be thoroughly dry after cleaning, since any liquid residue will hinder the entrance of the penetrant. Drying may be accomplished by warming the parts in drying ovens, with infrared lamps, forced hot air, or exposure to ambient temperature.

8.5*Penetrant Application*—After the part has been cleaned, dried, and is within the specified temperature range, the penetrant is applied to the surface to be examined so that the entire part or area under examination is completely covered with penetrant.

8.5.1*Modes of Application*—There are various modes of effective application of penetrant such as dipping, brushing, flooding, or spraying. Small parts are quite often placed in suitable baskets and dipped into a tank of penetrant. On larger parts, and those with complex geometries, penetrant can be applied effectively by brushing or spraying. Both conventional and electrostatic spray guns are effective means of applying liquid penetrants to the part surfaces. Electrostatic spray application can eliminate excess liquid build-up of penetrant on the part, minimize overspray, and minimize the amount of penetrant entering hollow-cored passages which might serve as penetrant reservoirs, causing severe bleedout problems during examination. Aerosol sprays are conveniently portable and suitable for local application.

NOTE11—**Caution:**Not all penetrant materials are suitable for electrostatic spray applications, so tests should be conducted prior to use. 9—Residues from cleaning processes such as strong alkalies, pickling solutions and chromates, in particular, may adversely react with the penetrant and reduce its sensitivity and performance.

8.5 *Penetrant Application*—After the part has been cleaned, dried, and is within the specified temperature range, the penetrant is applied to the surface to be examined so that the entire part or area under examination is completely covered with penetrant.

Application methods include dipping, brushing, flooding, or spraying. Small parts are quite often placed in suitable baskets and dipped into a tank of penetrant. On larger parts, and those with complex geometries, penetrant can be applied effectively by brushing or spraying. Both conventional and electrostatic spray guns are effective means of applying liquid penetrants to the part surfaces. Not all penetrant materials are suitable for electrostatic spray applications, so tests should be conducted prior to use. Electrostatic spray application can eliminate excess liquid build-up of penetrant on the part, minimize overspray, and minimize the amount of penetrant entering hollow-cored passages which might serve as penetrant reservoirs, causing severe bleedout problems during examination. Aerosol sprays are conveniently portable and suitable for local application.

NOTE ~~12—**Warning:** With~~ 10—With spray applications, it is important that there be proper ventilation. This is generally accomplished through the use of a properly designed spray booth and exhaust system.

~~8.5.2~~8.5.1 *Penetrant Dwell Time*—After application, allow excess penetrant to drain from the part (care should be taken to prevent pools of penetrant from forming on the part), while allowing for proper penetrant dwell time (see Table 2). The length of time the penetrant must remain on the part to allow proper penetration should be as recommended by the penetrant manufacturer. Table 2~~, however, provides a guide for selection of penetrant dwell times for a variety of materials, forms, and types of discontinuity. Unless otherwise specified, the dwell time shall not exceed the maximum recommended by the manufacturer.~~

NOTE ~~13—For some specific applications in structural ceramics (for example, detecting parting lines in slip-cast material), the required penetrant dwell time should be determined experimentally and may be longer than that shown in Table 1 and its notes.~~ , however, provides a guide for selection of penetrant dwell times for a variety of materials, forms, and types of discontinuities. Unless otherwise specified, the dwell time shall not exceed the maximum recommended by the manufacturer.

8.6 *Penetrant Removal*

~~8.6.1 *Water Washable*~~

8.6.1 *Water Washable (Method A)*:

8.6.1.1 ~~*Removal of Excess Penetrant*—After the required penetration time, the excess penetrant on the surface being examined must be removed with water, usually a washing operation. It can be washed off manually, by the use of automatic or semi-automatic water-spray equipment or by immersion. For immersion rinsing, parts are completely immersed in the water bath with air or mechanical agitation. Accumulation of water in pockets or recesses of the surface must be avoided. If the final rinse step is not effective, as evidenced by excessive residual surface penetrant after rinsing, dry (see 8.7) and reclean the part, then reapply the penetrant for the prescribed dwell time.~~ Removal of Water Washable Penetrant—After the required penetrant dwell time, the excess penetrant on the surface being examined must be removed with water. It can be removed manually with a coarse spray or wiping the part surface with a dampened rag, automatic or semi-automatic water-spray equipment, or by water immersion. For immersion rinsing, parts are completely immersed in the water bath with air or mechanical agitation.

(a) The temperature of the water ~~should be relatively constant and should~~shall be maintained within the range of 50° to 100°F (10° to 38°C).

(b) ~~Spray-rinse water pressure should not be greater than 40 psi (280 kPa).~~

(c) ~~Rinse time should not exceed 120 s unless otherwise specified by part of material specification.~~ Spray-rinse water pressure shall not exceed 40 psi (275 kPa). When hydro-air pressure spray guns are used, the air pressure should not exceed 25 psi (172 kPa).

NOTE ~~14—**Caution:** Avoid overwashing. Excessive washing can cause penetrant to be washed out of discontinuities. With fluorescent penetrant methods perform the rinsing operation under black light so that it can be determined when the surface penetrant has been adequately removed.~~

~~8.6.1.2 *Removal by Wiping*—In special applications, penetrant removal may be performed by wiping the surface with a clean, absorbent material dampened with water until the excess surface penetrant is removed, as determined by examination under black light for fluorescent methods and white light for visible methods.~~

~~8.6.2 *Lipophilic Emulsification*~~ 11—Overwashing should be avoided. Excessive washing can cause penetrant to be washed out

TABLE 2 Recommended Minimum Dwell Times

Material	Form	Type of Discontinuity	Dwell Times[A] (minutes)	
			Penetrant[B]	Developer[C]
Aluminum, magnesium, steel, brass and bronze, titanium and high-temperature alloys	castings and welds	cold shuts, porosity, lack of fusion, cracks (all forms)	5	10
	wrought materials—extrusions, forgings, plate	laps, cracks (all forms)	10	10
Carbide-tipped tools		lack of fusion, porosity, cracks	5	10
Plastic	all forms	cracks	5	10
Glass	all forms	cracks	5	10
Ceramic	all forms	cracks, porosity	5	10

[A] For temperature range from 50° to 125°F (10° to 52°C). For temperatures between 40° and 50°F (4.4° and 10°C), recommend a minimum dwell time of 20 minutes.
[B] Maximum penetrant dwell time in accordance with 8.5.21.
[C] Development time begins as soon as wet developer coating has dried on surface of parts (recommended minimum). Maximum development time in accordance with 8.8.65.

of discontinuities. With fluorescent penetrant methods perform the rinsing operation under black light so that it can be determined when the surface penetrant has been adequately removed.

8.6.1.2 *Removal by Wiping (Method C)*—After the required penetrant dwell time, the excess penetrant is removed by wiping with a dry, clean, lint-free cloth/towel. Then use a clean lint-free cloth/towel lightly moistened with water or solvent to remove the remaining traces of surface penetrant as determined by examination under black light for fluorescent methods and visible light for visible methods.

8.6.2 *Lipophilic Emulsification (Method B)*:

8.6.2.1 ~~*Application of Emulsifier*—After the required penetration time, the excess penetrant on the part must be emulsified by immersing or flooding the parts with the required emulsifier (the emulsifier combines with the excess surface penetrant and makes the mixture removable with water rinsing). After application of the emulsifier, the parts are drained in a manner that prevents the emulsifier from pooling on the part(s).~~ Application of Lipophilic Emulsifier—After the required penetrant dwell time, the excess penetrant on the part must be emulsified by immersing or flooding the parts with the required emulsifier (the emulsifier combines with the excess surface penetrant and makes the mixture removable by water rinsing). Lipophilic emulsifier shall not be applied by spray or brush and the part or emulsifier shall not be agitated while being immersed. After application of the emulsifier, the parts shall be drained and positioned in a manner that prevents the emulsifier from pooling on the part(s).

8.6.2.2 *Emulsification ~~Dwell Time~~*~~begins~~ —The emulsification time begins as soon as the emulsifier ~~has been~~ is applied. The length of time that the emulsifier is allowed to remain on a part and in contact with the penetrant is dependent on the type of emulsifier employed and the surface ~~condition (smooth or rough).~~ roughness. Nominal emulsification time should be as recommended by the manufacturer. The actual emulsification time must be determined experimentally for each specific application. The surface finish (roughness) of the part is a significant factor in the selection of and in the emulsification time of an emulsifier. Contact time ~~should~~shall be kept to the ~~least possible~~ minimum time ~~consistent with~~to obtain an acceptable background and ~~should~~shall not exceed ~~the maximum time specified for the part or material.~~ three minutes.

8.6.2.3 *Post Rinsing*—Effective post rinsing of the emulsified penetrant from the surface can be accomplished using either manual, semi-automated, or automated water immersion or spray equipment or combinations thereof.

8.6.2.4 *Immersion*—~~For immersion post rinsing, parts are completely immersed in the water bath with air or mechanical agitation. The time and temperature should be kept constant.~~

~~*(a)* The maximum dip-rinse time should not exceed 120 s unless otherwise specified by part or material specification.~~

~~*(b)* The temperature of the water should be relatively constant and should be maintained within the range of 50° to 100°F (10° to 38°C). **Caution:** A touch-up rinse may be necessary after immersion.~~

~~8.6.2.5~~ *For immersion post rinsing, parts are completely immersed in the water bath with air or mechanical agitation. The amount of time the part is in the bath should be the minimum required to remove the emulsified penetrant. In addition, the temperature range of the water should be 50 to 100°F (10 to 38°C). Any necessary touch-up rinse after an immersion rinse shall meet the requirements of 8.6.2.5.*

8.6.2.5 *Spray Post Rinsing*—~~Effective post rinsing following emulsification can also be accomplished by either manual or automatic water spray rinsing of the parts as follows:~~

~~*(a)* Control rinse water temperature within the range of 50° to 100°F (10° to 38°C).~~

~~*(b)* Spray rinse water pressure should not exceed 40 psi (275 kPa).~~

~~*(c)* The maximum spray rinse time should not exceed 120 s unless otherwise specified by part or materials specification.~~ —Effective post rinsing following emulsification can also be accomplished by either manual or automatic water spray rinsing. The water temperature shall be between 50 and 100°F (10 and 38°C). The water spray pressure shall not exceed 40 psi (275 kPa) when manual spray guns are used. When hydro-air pressure spray guns are used, the air pressure should not exceed 25 psi (172 kPa).

8.6.2.6 *Rinse Effectiveness*—~~If the emulsification and final rinse step is not effective, as evidenced by excessive residual surface penetrant after emulsification and rinsing, dry (see 8.7) and reclean the part and reapply the penetrant for the prescribed dwell time.~~

~~8.6.3~~*~~Hydrophilic Emulsification~~* —If the emulsification and final rinse step is not effective, as evidenced by excessive residual surface penetrant after emulsification and rinsing; thoroughly reclean and completely reprocess the part.

8.6.3 *Hydrophilic Emulsification (Method D)*:

8.6.3.1 ~~*Prerinsing*—Directly after the required penetration time, it is recommended that the parts be prerinsed with water prior to emulsification (8.6.3.3). This step allows for the removal of excess surface penetrant from the parts prior to emulsification so as to minimize the degree of penetrant contamination in the hydrophilic emulsifier bath, thereby extending its life. In addition, prerinsing of penetrated parts minimizes possible oily penetrant pollution in the final rinse step of this process. This is accomplished by collecting the prerinsings in a holding tank, separating the penetrant from water.~~ Application of Hydrophilic Remover—Following the required penetrant dwell time, the parts may be prerinsed with water prior to the application of hydrophilic emulsifier. This prerinse allows for the removal of excess surface penetrant from the parts prior to emulsification so as to minimize penetrant contamination in the hydrophilic emulsifier bath, thereby extending its life. It is not necessary to prerinse a part if a spray application of emulsifier is used.

8.6.3.2 *Prerinsing Controls*—~~Effective prerinsing is accomplished by either manual or automated water spray rinsing of the parts as follows:~~

~~*(a)* Water should be free of contaminants that could clog spray nozzles or leave a residue on parts.~~

~~*(b)* Control water temperature within the range of 50 to 100°F (10 to 38°C).~~

~~*(c)* Spray rinse at a water pressure of 25 to 40 psi (175 to 275 kPa).~~

~~*(d)* Prerinse time should be the least possible time (nominally 60 s maximum) to provide a consistent residue of penetrant on parts. Wash time is to be as specified by the part or material specification.~~

~~*(e)* Remove water trapped in cavities using filtered shop air at a nominal pressure of 25 psi (175 kPa) or a suction device to remove water from pooled areas.~~

~~8.6.3.3~~*—Effective prerinsing is accomplished by manual, semi-automated, or automated water spray rinsing of the part(s). The water spray pressure shall not exceed 40 psi (275 kPa) when manual or hydro air spray guns are used. When hydro-air pressure spray guns are used, the air pressure shall not exceed 25 psi (172 kPa). Water free of contaminants that could clog spray nozzles or leave a residue on the part(s) is recommended.*

8.6.3.3 *Application of Emulsifier*~~—After the required penetration time and following the prerinse, the residual surface penetrant on part(s) must be emulsified by immersing the part(s) in a hydrophilic emulsifier bath (8.6.3.4) or by spraying the part(s) with the emulsifier (8.6.3.5) thereby rendering the remaining residual surface penetrant water-washable in the final rinse station (8.6.3.6).~~

~~8.6.3.4~~*—The residual surface penetrant on part(s) must be emulsified by immersing the part(s) in an agitated hydrophilic emulsifier bath or by spraying the part(s) with water/emulsifier solutions thereby rendering the remaining residual surface penetrant water-washable for the final rinse station. The emulsification time begins as soon as the emulsifier is applied. The length of time that the emulsifier is allowed to remain on a part and in contact with the penetrant is dependent on the type of emulsifier employed and the surface roughness. The emulsification time should be determined experimentally for each specific application. The surface finish (roughness of the part is a significant factor in determining the emulsification time necessary for an emulsifier. Contact emulsification time should be kept to the least possible time consistent with an acceptable background and shall not exceed two minutes.*

8.6.3.4 *Immersion*~~—For immersion application, parts are completely immersed in the emulsifier bath. The hydrophilic emulsifier should be gently agitated throughout the contact cycle.~~

~~*(a)* Bath concentration should be as recommended by the manufacturer. Nominal use concentration for immersion applications is 20%.~~

~~*(b)* Bath temperatures should be maintained between 50 and 100°F (10 to 38°C).~~

~~*(c)* Immersion contact time should be the minimum required for adequate surface removal and should not exceed two min. unless otherwise approved by the cognizant engineering organization.~~

~~8.6.3.5~~*—For immersion application, parts shall be completely immersed in the emulsifier bath. The hydrophilic emulsifier concentration shall be as recommended by the manufacturer and the bath or part shall be gently agitated by air or mechanically throughout the cycle. The minimum time to obtain an acceptable background shall be used, but the dwell time shall not be more than two minutes unless approved by the contracting parties.*

8.6.3.5 *Spray Application*~~—For spray application following the prerinse step, parts are emulsified by the spray application of an emulsifier. All part surfaces should be evenly and uniformly sprayed to effectively emulsify the residual penetrant on part surfaces to render it water-washable.~~

~~*(a)* The concentration of the emulsifier for spray application should be in accordance with the manufacturer's recommendations, but should not exceed 5%.~~

~~*(b)* Temperature to be maintained at 50 to 100°F (10 to 38°C).~~

~~*(c)* The spray pressure should be 25 psi (175 kPa) max for air and 40 psi (280 kPa) max for water.~~

~~*(d)* Contact time should be kept to the minimum consistent with an acceptable background and should not exceed 120 s or the maximum time stipulated by the part or material specification.~~

~~8.6.3.6*Post-Rinsing of Hydrophilic Emulsified Parts* —Effective post-rinsing of emulsified penetrant from the surface can be accomplished using either manual, semi-automated, or automated water immersion or spray equipment or combinations thereof.~~ —For spray applications, all part surfaces should be evenly and uniformly sprayed with a water/emulsifier solution to effectively emulsify the residual penetrant on part surfaces to render it water-washable. The concentration of the emulsifier for spray application should be in accordance with the manufacturer's recommendations, but it shall not exceed 5 %. The water spray pressure should be less than 40 psi (275 kpa). Contact with the emulsifier shall be kept to the minimum time to obtain an acceptable background and shall not exceed two minutes. The water temperature shall be maintained between 50 and 100°F (10 and 38°C).

8.6.3.6 *Post-Rinsing of Hydrophilic Emulsified Penetrants*—Effective post-rinsing of emulsified penetrant from the surface can be accomplished using either manual or automated water spray, water immersion, or combinations thereof. The total rinse time shall not exceed two minutes regardless of the number of rinse methods used.

8.6.3.7 *Immersion Post-Rinsing*~~—Parts are to be completely immersed in the water bath with air or mechanical agitation.~~

~~*(a)* The temperature of the water should be relatively constant and should be maintained within the range of 50 to 100°F (10 to 38°C).~~

~~*(b)* The maximum dip rinse time should not exceed 120 s unless otherwise specified by part or material specification. **Caution:** A touch-up rinse may be necessary after immersion.~~ —If an agitated immersion rinse is used, the amount of time the part(s) is (are) in the bath shall be the minimum required to remove the emulsified penetrant and shall not exceed two minutes. In addition, the

temperature range of the water shall be within 50 and 100°F (10 and 38°C). Be aware that a touch-up rinse may be necessary after immersion rinse, but the total wash time still shall not exceed two minutes.

8.6.3.8 *Spray Post-Rinsing*—Following emulsification parts can be post-rinsed by water spray rinsing as follows:

(a) Control rinse water temperature within the range of 50 to 100°F (10 to 38°C).

(b) Spray rinse water pressure should not exceed 40 psi (275 kPa).

(c) The maximum spray rinse time should not exceed 120 s unless otherwise specified by part or materials specification.

8.6.3.9If the emulsification and final rinse steps are not effective, as evidenced by excessive residual surface penetrant after emulsification and rinsing, dry (see 8.7) and reclean the part and reapply the penetrant for the prescribed dwell time. —Effective post-rinsing following emulsification can also be accomplished by manual, semi-automatic, or automatic water spray. The water spray pressure shall not exceed 40 psi (275 kPa) when manual or hydro air spray guns are used. When hydro-air pressure spray guns are used, the air pressure shall not exceed 25 psi (172 kPa). The water temperature shall be between 50 and 100°F (10 and 38°C). The spray rinse time shall be less than two minutes, unless otherwise specified.

8.6.3.9 *Rinse Effectiveness*—If the emulsification and final rinse steps are not effective, as evidenced by excessive residual surface penetrant after emulsification and rinsing, thoroughly reclean, and completely reprocess the part.

8.6.4 *Solvent-Removable Penetrants* :

8.6.4.1*Removal of Excess Penetrant*—After the required penetration time, the excess penetrant is removed insofar as possible, by using wipers of a dry, clean, lint-free material and repeating the operation until most traces of penetrant have been removed. Then using a lint-free material lightly moistened with solvent remover the remaining traces are gently wiped to avoid removing penetrant from discontinuities. Avoid the use of excess solvent. If the wiping step is not effective, as evidenced by difficulty in removing the excess penetrant, dry the part (see 8.7), and reapply the penetrant for the prescribed dwell time. Flushing the surface with solvent following the application of the penetrant and prior to developing is prohibited. Removal of Solvent-Removable Penetrant (Method C)—After the required penetrant dwell time, the excess penetrant is removed by wiping with a dry, clean, lint-free cloth/towel. Then use a clean, lint-free cloth/towel lightly moistened with solvent remover to remove the remaining traces of surface penetrant. Gentle wiping must be used to avoid removing penetrant from any discontinuity. On smooth surfaces, an alternate method of removal can be done by wiping with a clean, dry cloth. Flushing the surface with solvent following the application of the penetrant and prior to developing is prohibited.

8.7 *Drying*—Drying the surface of the part(s) is necessary prior to applying dry or nonaqueous developers or following the application of the aqueous developer. Drying time will vary with the size, nature, and number of parts under examination. —Regardless of the type and method of penetrant used, drying the surface of the part(s) is necessary prior to applying dry or nonaqueous developers or following the application of the aqueous developer. Drying time will vary with the type of drying used and the size, nature, geometry, and number of parts being processed.

8.7.1 *Drying Parameters*—Components shall be air dried at room temperature or in a drying oven. Oven temperatures shall not exceed 160°F (71°C). Drying time shall only be that necessary to adequately dry the part. Components shall be removed from the oven immediately after drying. Components shall not be placed in the oven with pooled water or pooled aqueous solutions/suspensions.

8.7.2*Drying Time Limits*—Do not allow parts to remain in the drying oven any longer than is necessary to dry the surface. Times over 30 min in the dryer may impair the sensitivity of the examination.

8.8—*Components shall be air dried at room temperature or in a drying oven. Room temperature drying can be aided by the use of fans. Oven temperatures shall not exceed 160°F (71°C). Drying time shall only be that necessary to adequately dry the part. Components shall be removed from the oven after drying. Components should not be placed in the oven with pooled water or pooled aqueous solutions/suspensions.*

8.8 *Developer Application*:

8.8.1*Modes of Application*—There are various modes of effective application of the various types of developers such as dusting, immersing, flooding or spraying. The size, configuration, surface condition, number of parts to be processed, developer form, the part size, configuration, and so forth,surface roughness will influence the choice of developer application.

8.8.28.8.1 *Dry Powder Developer (Form A)*—Dry powder developers shouldshall be applied immediately after drying the part is dry in such a manner as to ensure complete part coverage. coverage of the area of interest. Parts can be immersed in a container of dry developer or in a fluid bed of dry developer. They can also be dusted with the powder developer through a hand powder bulb or a conventional or electrostatic powder gun. It is common and effective to apply dry powder in an enclosed dust chamber, which creates an effective and controlled dust cloud. Other means suited to the size and geometry of the specimen may be used, provided the powder is dustedapplied evenly over the entire surface being examined. Excess developer powder may be removed by shaking or tapping the part, or by blowing with low-pressure 5 psi (34 kPa) dry, clean, compressed air.

NOTE15—**Caution:**The air stream intensity should dry, clean, compressed air not exceeding 5 psi (34 kPa). Dry developers shall not be established experimentally for each application.used with Type II penetrant.

8.8.38.8.2 *Aqueous Developers (Forms B and C)*—Aqueous—Water soluble developers should not be used (Form B) are prohibited for use with Type 2 penetrants or Type 1, Method A penetrants. AqueousWater suspendable developers (Form C) can be used with both Type 1 and Type 2 penetrants. Aqueous developers shouldshall be applied to the part immediately after the excess penetrant has been removed and prior to drying. Aqueous developers shouldshall be prepared and maintained in accordance with

the manufacturer's instructions and applied in such a manner as to ensure complete, even, part coverage. Aqueous developers may be applied by ~~spraying (see Note 16),~~ spraying, flowing, or immersing the ~~part. It is common to immerse the parts~~ part in a prepared developer bath. Immerse the parts only long enough to coat all of the part surfaces with the developer ~~(see Note 17). Then remove~~ since indications may leach out if the parts are left in the bath too long. After the parts are removed from the developer ~~bath and~~ bath, allow the parts to drain. Drain all excess developer from recesses and trapped sections to eliminate pooling of developer, which can obscure discontinuities. Dry the parts in accordance with 8.7~~. The dried developer coating appears as a translucent or white coating on the part.~~ . The dried developer coating appears as a translucent or white coating on the part.

8.8.3 *Nonaqueous Wet Developers (Forms D and E)*—After the excess penetrant has been removed and the surface has been dried, apply nonaqueous wet developer by spraying in such a manner as to ensure complete part coverage with a thin, even film of developer. The developer shall be applied in a manner appropriate to the type of penetrant being used. For visible dye, the developer must be applied thickly enough to provide a contrasting background. For fluorescent dye, the developer must be applied thinly to produce a translucent covering. Dipping or flooding parts with nonaqueous developers is prohibited, because the solvent action of these types of developers can flush or dissolve the penetrant from within the discontinuities.

~~NOTE 16—**Caution:** Atomized spraying is not recommended since a spotty film may result.~~
~~NOTE 17—**Caution:** If parts are left in the bath too long, indications may leach out.~~

~~8.8.4 *Nonaqueous Wet Developers*—After the excess penetrant has been removed and the surface has been dried, apply developer by spraying in such a manner as to ensure complete part coverage with a thin, even film of developer. These types of developer carrier evaporate very rapidly at normal room temperature and do not, therefore, require the use of a dryer. Dipping or flooding parts with nonaqueous developers is prohibited, since they may flush or dissolve the penetrant from within the discontinuities because of the solvent action of these types of developers.~~

~~NOTE 18—**Warning:** The vapors from the evaporating, volatile solvent developer carrier may be hazardous. Proper ventilation should be provided in all cases, but especially when the surface to be examined is inside a closed volume, such as a process drum or a small storage tank.~~

~~8.8.5~~ *12—The vapors from the volatile solvent carrier in the developer may be hazardous. Proper ventilation should be provided at all times, but especially when the developer is applied inside a closed area.*

8.8.4 *Liquid Film Developers*—Apply by spraying as recommended by the manufacturer. Spray parts in such a manner as to ensure complete part coverage of the area being examined with a thin, even film of developer.

~~8.8.6~~

8.8.5 *Developing Time*—The length of time the developer is to remain on the part prior to ~~examination should~~inspection shall be not less than ~~10 min.~~ten minutes. Developing time begins immediately after the application of dry powder developer ~~and~~or as soon as the wet (aqueous ~~and~~or nonaqueous) developer coating is dry (that is, the water or solvent carrier has evaporated to dryness). The maximum permitted developing times shall be ~~4 h~~four hours for dry powder developer (Form A),~~2~~ two hours for aqueous developer (Forms B and ~~1 h~~ C), and one hour for nonaqueous developer (Forms D and E).

8.9 ~~*Examination*—Perform examination of parts after the applicable development time as specified in 8.8.6 to allow for bleedout of penetrant from discontinuities into the developer coating. It is good practice to observe the bleedout while applying the developer as an aid in interpreting and evaluating indications.~~

~~8.9.1 *Fluorescent Light Examination* :~~ Inspection—After the applicable development time, perform inspection of the parts under visible or ultraviolet light as appropriate. It may be helpful to observe the bleed out during the development time as an aid in interpreting indications.

8.9.1 *Ultraviolet Light Examination*—Examine parts tested with Type 1 fluorescent penetrant under black light in a darkened area. Ambient light shall not exceed 2 fc (21.5 lx). The measurement shall be made with a suitable visible light sensor at the inspection surface.

NOTE 13—Because the fluorescent constituents in the penetrant will eventually fade with direct exposure to ultraviolet lights, direct exposure of the part under test to ultraviolet light should be minimized when not removing excess penetrant or evaluating indications.

~~8.9.1.1 *Visible Ambient Light Level*—Examine fluorescent penetrant indications under black light in a darkened area. Visible ambient light should not exceed 2 ft candles (20 Lx). The measurement should be made with a suitable photographic-type visible light meter on the surface being examined.~~

~~8.9.1.2~~*Black Light Level Control*—Black lights shall provide a minimum light intensity of 1000 μW/cm^2~~, at the examination surface. The black light wavelength shall be in the range of 320 to 380 nm. The intensity should be checked weekly to ensure the required output. Reflectors and filters should be checked daily for cleanliness and integrity. Cracked or broken ultraviolet (UV) filters should be replaced immediately. Defective bulbs, which radiate UV energy, must be replaced before further use. Since a drop in line voltage can cause decreased black light output with consequent inconsistent performance, a constant-voltage transformer should be used when there is evidence of voltage fluctuation.~~

~~**Caution:** Certain high-intensity black light 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.~~ , at a distance of 15 in. (38.1 cm). The intensity shall be checked daily to ensure the required output. Reflectors and filters shall also be checked daily for cleanliness and integrity. Cracked or broken ultraviolet filters shall be replaced immediately. Since a drop in line voltage can cause decreased black light output with consequent inconsistent performance, a constant-voltage