



Standard Test Method for Liquid Penetrant Examination¹

This standard is issued under the fixed designation E 165; 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 test method² covers procedures for penetrant examination of materials. They are nondestructive testing methods for detecting discontinuities that are open to the surface such as cracks, seams, laps, cold shuts, laminations, through leaks, or lack of fusion and are applicable to in-process, final, and maintenance examination. They can be effectively used in the examination of nonporous, metallic materials, both ferrous and nonferrous, and of nonmetallic materials such as glazed or fully densified ceramics, certain nonporous plastics, and glass.

1.2 This test method 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.

1.2.2 For 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.

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

1.3 This 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.

1.4 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.* For specific hazard statements, see Note 5, Note 12, and Note 20.

2. Referenced Documents

2.1 ASTM Standards:

D 129 Test Method for Sulfur in Petroleum Products (General Bomb Method)³

D 516 Test Method for Sulfate Ion in Water⁴

D 808 Test Method for Chlorine in New and Used Petroleum Products (Bomb Method)³

D 1193 Specification for Reagent Water⁴

D 1552 Test Method for Sulfur in Petroleum Products (High-Temperature Method)³

D 4327 Test Method for Anions in Water by Chemically Suppressed Ion Chromatography⁴

E 433 Reference Photographs for Liquid Penetrant Inspection⁵

E 543 Practice for Evaluating Agencies that Perform Nondestructive Testing⁵

E 1208 Test Method for Fluorescent Liquid Penetrant Examination Using the Lipophilic Post-Emulsification Process⁵

E 1209 Test Method for Fluorescent Liquid Penetrant Examination Using the Water-Washable Process⁵

E 1210 Test Method for Fluorescent Liquid Penetrant Examination Using the Hydrophilic Post-Emulsification Process⁵

E 1219 Test Method for Fluorescent Liquid Penetrant Examination Using the Solvent-Removable Process⁵

E 1220 Test Method for Visible Penetrant Examination Using the Solvent-Removable Process⁵

E 1316 Terminology for Nondestructive Examinations⁵

E 1418 Test Method for Visible Penetrant Examination Using the Water-Washable Process⁵

2.2 ASNT Document:

Recommended Practice SNT-TC-1A for Nondestructive Testing Personnel Qualification and Certification⁶

2.3 Military Standard:

MIL-STD-410 Nondestructive Testing Personnel Qualification and Certification⁷

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² For ASME Boiler and Pressure Vessel Code applications see related Recommended Test Method SE-165 in the Code.

³ *Annual Book of ASTM Standards*, Vol 05.01.

⁴ *Annual Book of ASTM Standards*, Vol 11.01.

⁵ *Annual Book of ASTM Standards*, Vol 03.03.

⁶ Available from the American Society for Nondestructive Testing, 1711 Arlington Lane, Columbus, OH 43228-0518.

⁷ Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

2.4 APHA Standard:
429 Method for the Examination of Water and Wastewater⁸

3. Terminology

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

4. Summary of Test Method

4.1 A liquid penetrant which may be a visible or a fluorescent material 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.

NOTE 2—**Caution:** 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 time and excess penetrant removal methods, are determined by 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 examination methods indicate the presence, location and, to a limited extent, the nature and magnitude of the detected discontinuities. Each of the various 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 service requirements.

6. Classification of Penetrations and Methods

6.1 Liquid penetrant examination methods and types are classified as shown in Table 1.

6.2 *Fluorescent penetrant examination* utilizes penetrants that fluoresce brilliantly when excited by black light (see 8.9.1.2). The sensitivity of fluorescent penetrants depends on their ability to be retained in the various size discontinuities during processing, 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 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).

TABLE 1 Classification of Penetrant Examination Types and Methods

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

7. Types of Materials

7.1 *Liquid penetrant examination materials* (see Notes 3-5) consist of fluorescent and visible penetrants, emulsifiers (oil-base and water-base; fast and slow acting), 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 materials from various manufacturers is not recommended.

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

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

NOTE 5—**Warning:** These materials may be flammable or emit hazardous and toxic vapors. Observe all manufacturer’s instructions and precautionary statements.

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 to be selectively removed from the surface using a separate emulsifier. The emulsifier, properly applied and given a proper emulsification time, combines with the excess surface penetrant to form a water-washable mixture, which can be rinsed from the surface, leaving the surface free of fluorescent background. Proper emulsification time must be experimentally established and maintained to ensure that over-emulsification does not occur, resulting 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 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.

7.2.3 *Solvent-Removable Penetrants* are designed 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 8.6.4.1). To minimize 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.

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,

⁸ Available from American Public Health Association, Publication Office, 1015 Fifteenth Street, NW, Washington, DC 20005.

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).

7.3.2 *Hydrophilic Emulsifiers* are water-miscible liquids used to emulsify the excess oily fluorescent penetrant on the surface of the part, rendering it water-washable (see 8.6.3). 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 the use of 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 .

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.

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.

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).

NOTE 6—**Caution:** 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 supplied as suspensions of developer particles in a nonaqueous solvent carrier ready for use as supplied. Nonaqueous, wet developers form a coating on the surface of the part when dried, which serves as the developing medium (see 8.8.4).

NOTE 7—**Caution:** 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 8.8.5).

8. Procedure

8.1 The following general processing guidelines apply (see Figs. 1-3) to both fluorescent and visible penetrant examination methods (see Fig. 4).

8.2 *Temperature Limits*—The temperature of the penetrant

materials and the surface of the part to be processed should be between 50 and 100°F (10 and 38°C). Where it is not practical to comply with these temperature limitations, qualify the procedure as described in 10.2 at 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.)

NOTE 8—When agreed between purchaser and supplier, grit blasting without subsequent etching may be an acceptable cleaning method.

NOTE 9—**Caution:** Sand or shot blasting may possibly close discontinuities and extreme care should be used with grinding and machining operations to avoid masking discontinuities.

NOTE 10—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.

8.4 Removal of Surface Contaminants: [astm-e165-95](#)

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).

NOTE 11—**Caution:** Residues from cleaning processes such as strong alkalis, pickling solutions and chromates, in particular, may adversely react with the penetrant and reduce its sensitivity and performance.

8.4.2 *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.

Incoming Parts

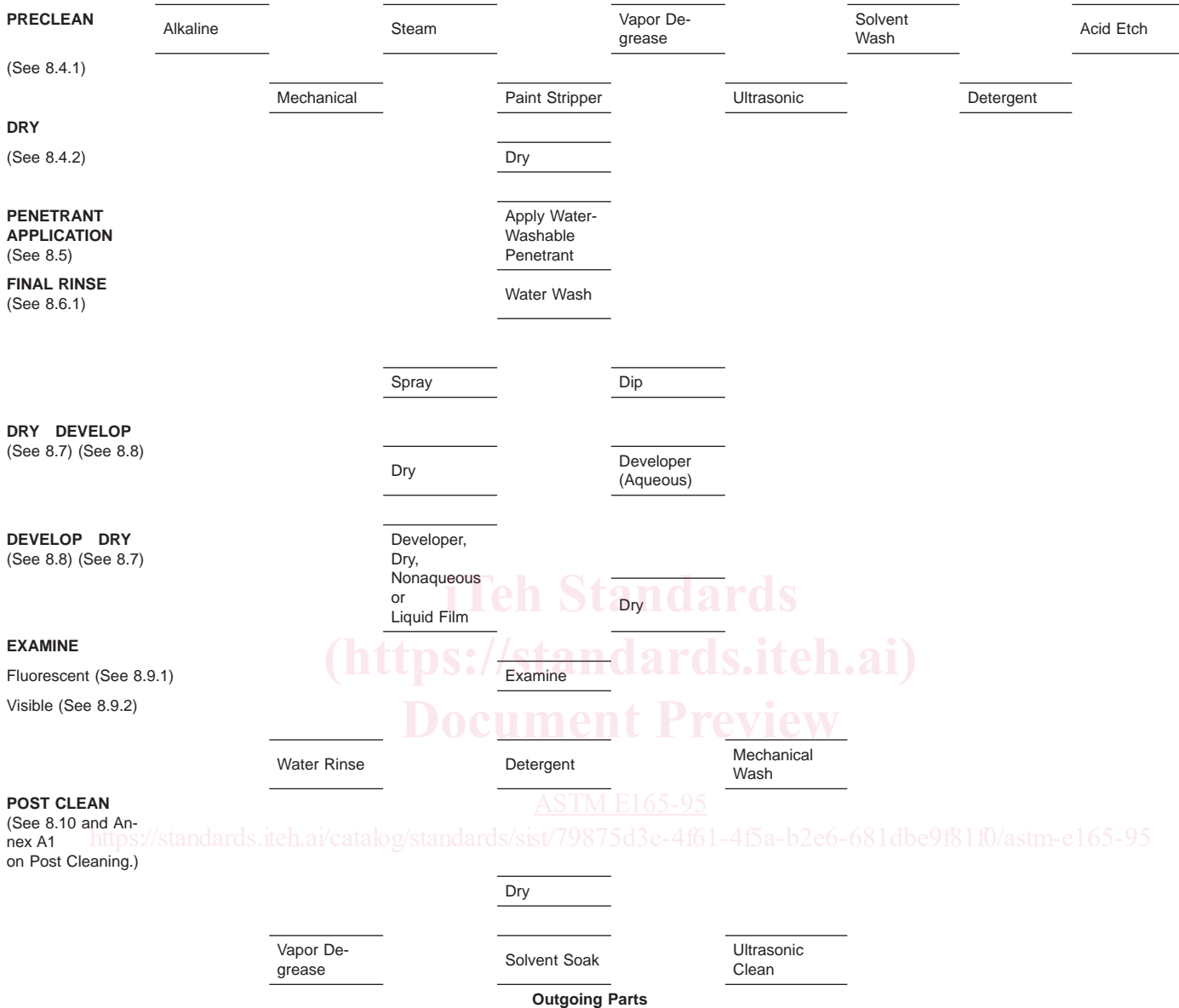


FIG. 1 General Procedure Flowsheet for Penetrant Examination Using the Water-Washable Process (Test Method E 1209 for Fluorescent and Test Method E 1220 for Visible Light)

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.

NOTE 12—**Caution:** Not all penetrant materials are suitable for electrostatic spray applications, so tests should be conducted prior to use.

NOTE 13—**Warning:** 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 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

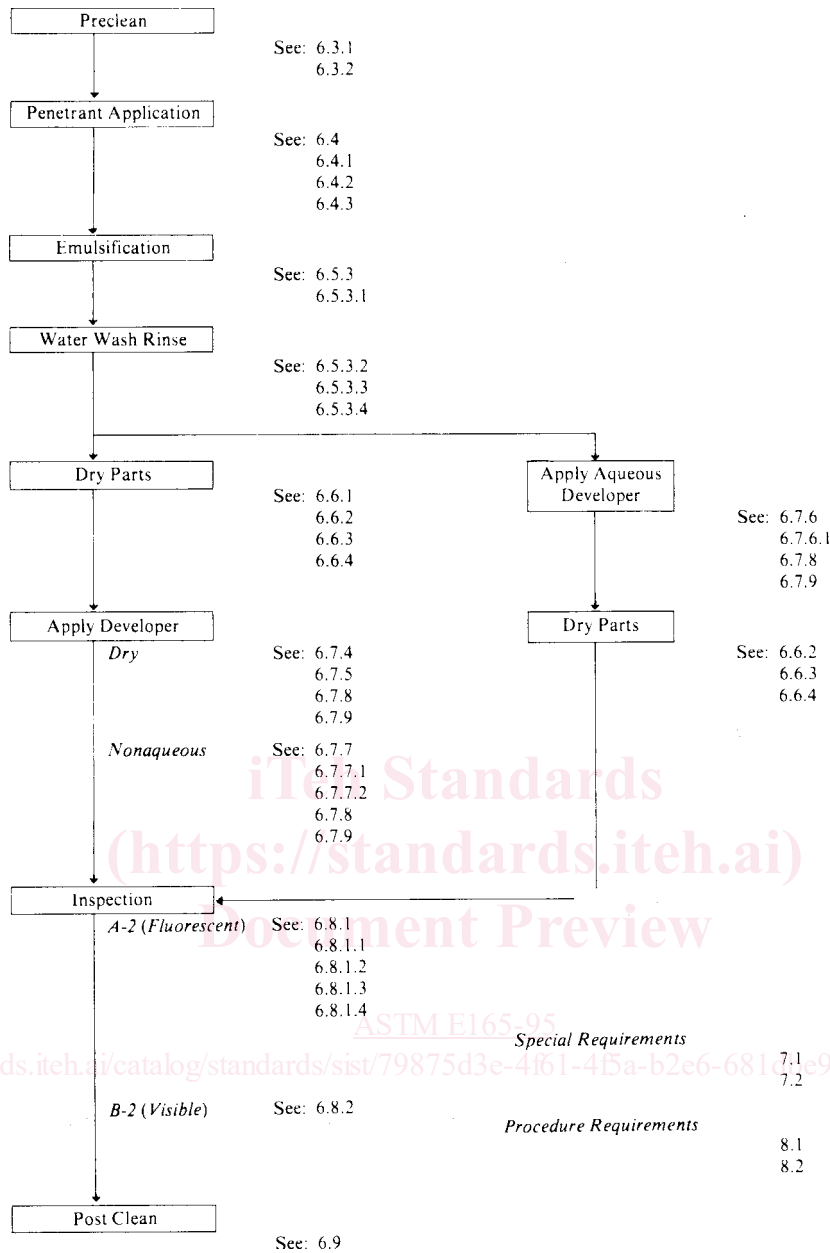


FIG. 2 Type 2—Post Emulsifiable Procedures A-2 (Fluorescent) and B-2 (Visible)

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 14—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.

8.6 Penetrant Removal

8.6.1 Water Washable:

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.

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

(c) Rinse time should not exceed 120 s unless otherwise

Incoming Parts

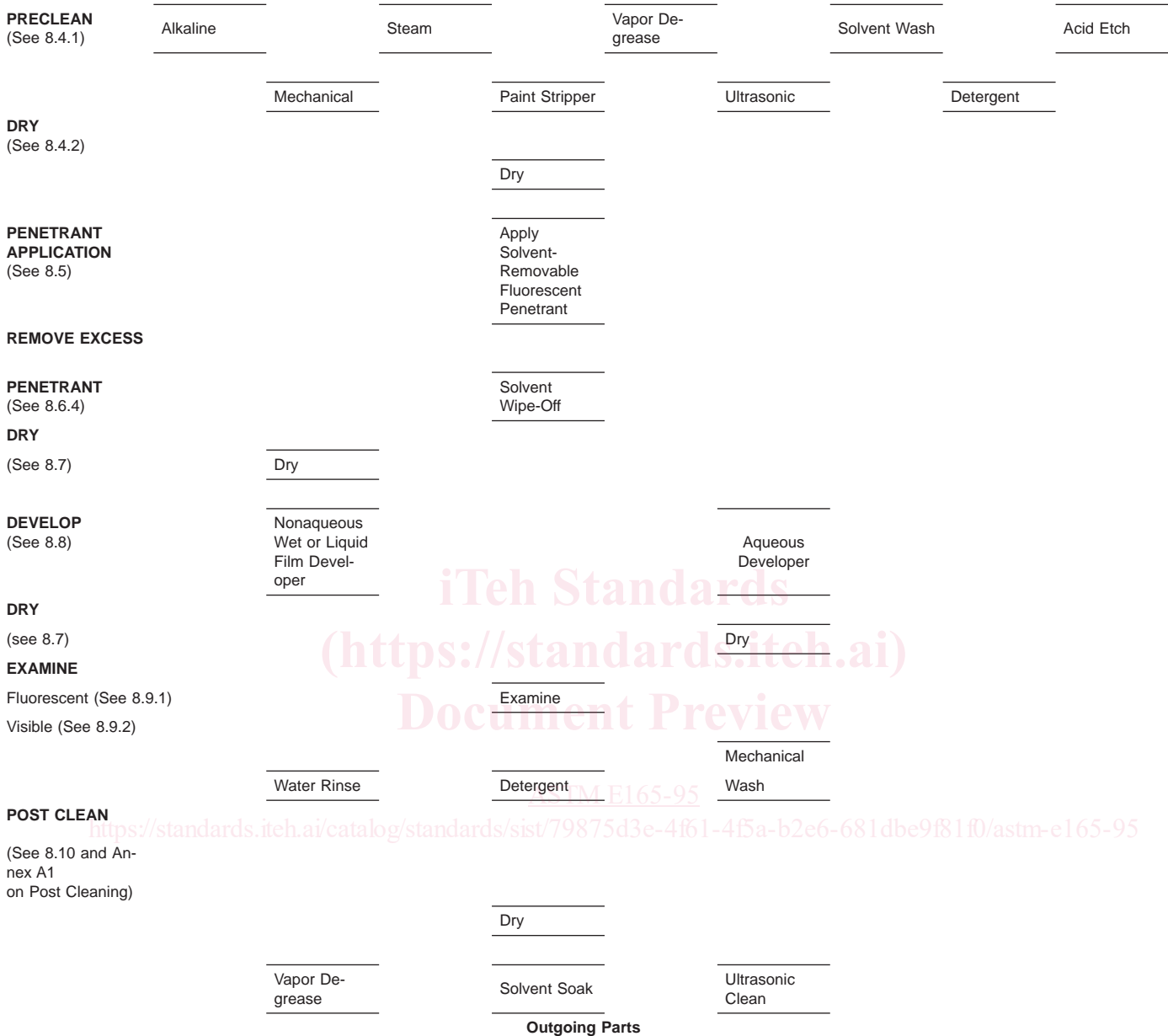


FIG. 3 Solvent-Removable Penetrant Examination General Procedure Flowsheet (Test Method E 1219 for Fluorescent and Test Method E 1220 for Visible Light)

specified by part of material specification.

NOTE 15—**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:*

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).

8.6.2.2 *Emulsification Dwell Time* begins as soon as the emulsifier has been 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

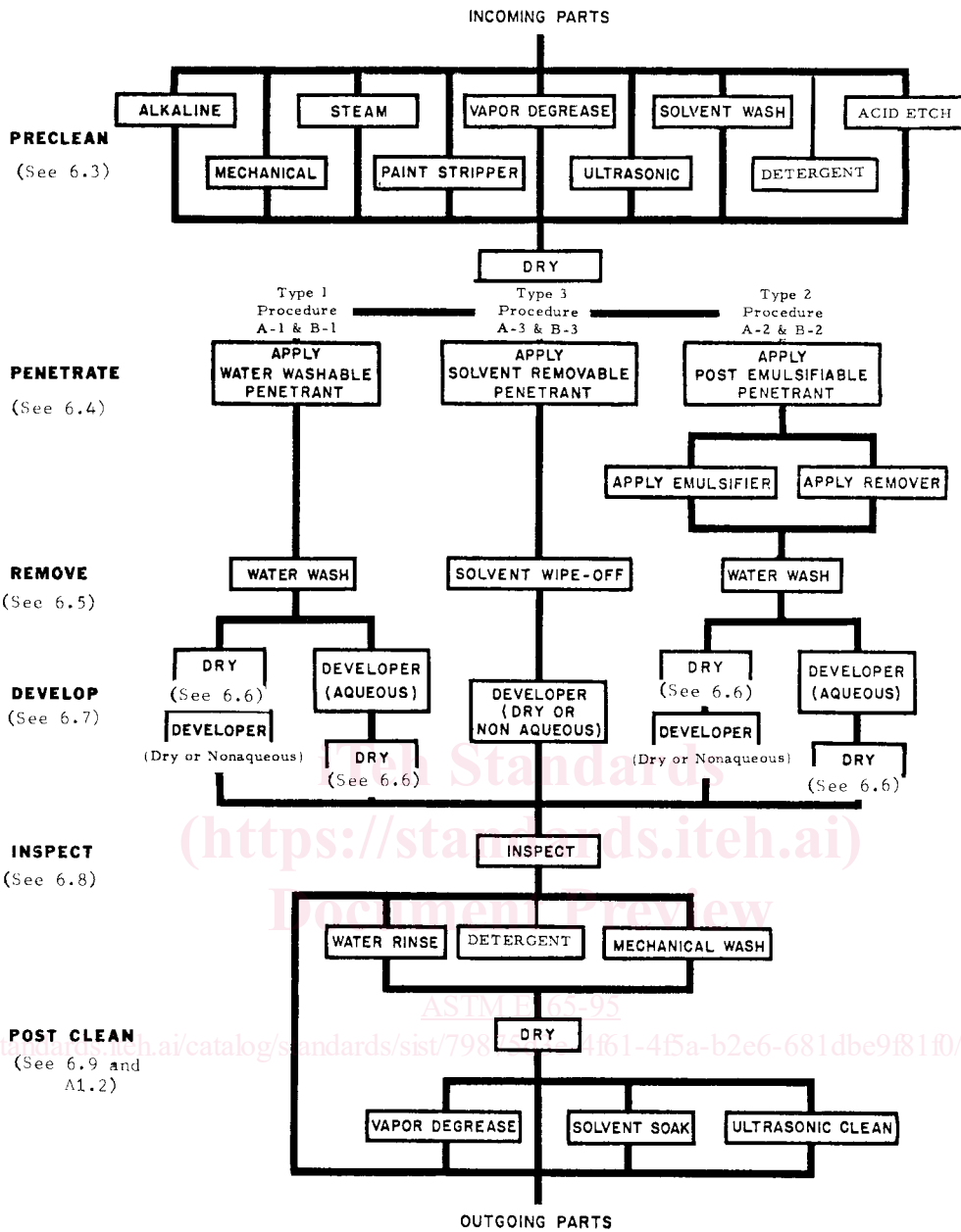


FIG. 4 Fluorescent and Visible Penetrant Inspection General Processing Procedures Flowsheet

the surface condition (smooth or rough). 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 be kept to the least possible time consistent with an acceptable background and should not exceed the maximum time specified for the part or material.

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 *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 be in accordance with manufacturers' recommendations.

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

8.6.2.6 *Rinse Effectiveness*—If the emulsification and final

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 100°F (10 to 38°C) for fluorescent penetrants and 50 to 125°F (10 to 52°C) for visible penetrant.

^B Maximum penetrant dwell time in accordance with 8.5.2.

^C Development time begins as soon as wet developer coating has dried on surface of parts (recommended minimum). Maximum development time in accordance with 8.8.6.

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:

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.

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 *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 *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. Most hydrophilic emulsifiers are used within the range of 20 to 33 % in water. 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 kept to the minimum time consistent with an acceptable background and should not exceed 120 s or the maximum time stipulated by the part or material specification.

(d) Emulsifier drain time begins immediately after parts have been withdrawn from the emulsifier tank and continues until the parts are washed in the final rinse station (8.6.3.6). This drain time should be kept to a minimum to avoid over emulsification and should not exceed 90 s.

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.

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.

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 be in accordance with manufacturer's instructions.

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

8.6.3.9 If 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.

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.

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.

8.7.1 *Drying Modes*—Parts can be dried by using a hot-air recirculating oven, a hot or cold air blast, or by exposure to ambient temperature, particularly when the excess surface penetrant was removed with a solvent. Drying is best done in a thermostatically controlled recirculating hot-air dryer. Local heating or cooling is permitted provided the temperature of the part remains in the range of 50 to 100°F (10 to 38°C) for fluorescent methods and in the range of 50 to 125°F (10 to 52°C) for visible methods unless otherwise agreed by the contracting parties.

NOTE 16—**Caution:** Drying oven temperature should not exceed 160°F (71°C).

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 *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, and so forth, will influence the choice of developer application.

8.8.2 *Dry Powder Developer*—Dry powder developers should be applied immediately after drying in such a manner as to ensure complete part coverage. 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 dusted evenly over the entire surface being examined. Excess powder may be removed by shaking or tapping the part, or by blowing with low-pressure (5 to 10 psi) (34 to 70 kPa) dry, clean, compressed air.

NOTE 17—**Caution:** The air stream intensity should be established experimentally for each application.

8.8.3 *Aqueous Developers*—Aqueous developers should be applied to the part immediately after the excess penetrant has been removed and prior to drying. Aqueous developers should be prepared and maintained in accordance with the manufacturer's instructions and applied in such a manner as to ensure complete, even, part coverage. Caution should be exercised when using an aqueous developer with water-washable penetrants to avoid possible stripping of indications. Aqueous developers may be applied by spraying (see Note 17), flowing, or immersing the part. It is common to immerse the parts in a prepared developer bath. Immerse parts only long enough to coat all of the part surfaces with the developer (see Note 18). Then remove parts from the developer bath and allow 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.

NOTE 18—**Caution:** Atomized spraying is not recommended since a spotty film may result.

NOTE 19—**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 (see Note 20). 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 20—**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 *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 *Developing Time*—The length of time the developer is to remain on the part prior to examination should be not less than 10 min. Developing time begins immediately after the application of dry powder developer and as soon as the wet (aqueous and nonaqueous) developer coating is dry (that is, the solvent carrier has evaporated to dryness). The maximum permitted developing times are 2 h for aqueous developers and 1 h for nonaqueous developers.

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:*

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 light intensity, minimum of 1000 $\mu\text{W}/\text{cm}^2$, should be measured on the surface being examined, with a suitable black light meter. 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.

NOTE 21—The recommended minimum light intensity in 8.9.1.2 is intended for general usage. For critical examinations, higher intensity levels may be required.

8.9.1.3 *Black Light Warm-Up*—Allow the black light to warm up for a minimum of 10 min prior to its use or measurement of the intensity of the ultraviolet light emitted.

8.9.1.4 *Visual Adaptation*—The examiner should be in the darkened area for at least 1 min before examining parts. Longer times may be necessary under some circumstances.

NOTE 22—**Caution:** Photochromic lenses shall not be worn during examination.

8.9.2 *Visible Light Examination:*

8.9.2.1 *Visible Light Level*—Visible penetrant indications can be examined in either natural or artificial light. Adequate illumination is required to ensure no loss in the sensitivity of the examination. A minimum light intensity at the examination site of 100 fc (1000 Lx) is recommended.

8.9.3 *Housekeeping*—Keep the examination area free of interfering debris, including fluorescent objects. Practice good housekeeping at all times.

8.9.4 *Evaluation*—Unless otherwise agreed, it is normal practice to interpret and evaluate the discontinuity based on the size of the indication (see Reference Photographs E 433).

8.10 *Post Cleaning*—Post cleaning is necessary in those cases where residual penetrant or developer could interfere with subsequent processing or with service requirements. It is particularly important where residual penetrant examination

materials might combine with other factors in service to produce corrosion. A suitable technique, such as a simple water rinse, waterspray, machine wash, vapor degreasing, solvent soak, or ultrasonic cleaning may be employed (see Annex on Post Cleaning). It is recommended that if developer removal is necessary, it should be carried out as promptly as possible after examination so that it does not “fix” on the part.

NOTE 23—**Caution:** Developers should be removed prior to vapor degreasing. Vapor degreasing can bake the developer on parts.

9. Special Requirements

9.1 *Impurities:*

9.1.1 When using penetrant materials on austenitic stainless steels, titanium, nickel-base or other high-temperature alloys, the need to restrict impurities such as sulfur, halogens and alkali metals must be considered. These impurities may cause embrittlement or corrosion, particularly at elevated temperatures. Any such evaluation should also include consideration of the form in which the impurities are present. Some penetrant materials contain significant amounts of these impurities in the form of volatile organic solvents. These normally evaporate quickly and usually do not cause problems. Other materials may contain impurities which are not volatile and may react with the part, particularly in the presence of moisture or elevated temperatures.

9.1.2 Because volatile solvents leave the surface quickly without reaction under normal examination procedures, penetrant materials are normally subjected to an evaporation procedure to remove the solvents before the materials are analyzed for impurities. The residue from this procedure is then analyzed in accordance with Test Method D 129, Test Method D 1552, or Test Method D 129 decomposition followed by Test Method D 516, Method B (Turbidimetric Method) for sulfur. The residue may also be analyzed by Test Method D 808 or Annex A2 on Methods for Measuring Total Chlorine Content in Combustible Liquid Penetrant Materials (for halogens other than fluorine) and Annex A3 on Method for Measuring Total Fluorine Content in Combustible Liquid Penetration Materials (for fluorine). An alternative procedure, Annex A4 on Determination of Anions by Ion Chromatography, provides a single instrumental technique for rapid sequential measurement of common anions such as chloride, fluoride, and sulfate. Alkali metals in the residue are determined by flame photometry or atomic absorption spectrophotometry.

NOTE 24—Some current standards indicate that impurity levels of sulfur and halogens exceeding 1 % of any one suspect element may be considered excessive. However, this high a level may be unacceptable for some applications, so the actual maximum acceptable impurity level must be decided between supplier and user on a case by case basis.

9.2 *Evaluated-Temperature Examination*—Where penetrant examination is performed on parts that must be maintained at elevated temperature during examination, special materials and processing techniques may be required. Such examination requires qualification in accordance with 10.2. Manufacturer’s recommendations should be observed.

10. Qualification and Requalification

10.1 *Personnel Qualification*—When required by user/supplier agreement, all examination personnel shall be