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Designation: ~~E1210 – 16~~ E1210 – 21

Standard Practice for Fluorescent Liquid Penetrant Testing Using the Hydrophilic Post-Emulsification Process[1]

This standard is issued under the fixed designation E1210; 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 practice covers procedures for fluorescent penetrant examination utilizing the hydrophilic post-emulsification process. It is a nondestructive testing method for detecting discontinuities that are open to the surface such as cracks, seams, laps, cold shuts, laminations, isolated porosity, through leaks, or lack of fusion and is applicable to in-process, final, and maintenance examination. It 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 and certain nonporous plastics and glass.

1.2 This practice also provides a reference:

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1.2.1 By which a fluorescent penetrant examination hydrophilic post-emulsification process recommended or required by individual organizations can be reviewed to ascertain their applicability and completeness.

1.2.2 For use in the preparation of process specifications dealing with the fluorescent penetrant examination of materials and parts using the hydrophilic post-emulsification process. Agreement by the purchaser and the manufacturer 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 practice does not indicate or suggest standards for evaluation of the indications obtained. It should be pointed out, however, that indications 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.

1.3.1 The user is encouraged to use materials and processing parameters necessary to detect conditions of a type or severity which could affect the evaluation of the product.

1.4 *Units*—The values stated in inch-pound units are to be regarded as standard. ~~SI units~~The values given in parentheses are ~~for information only.~~mathematical conversions to SI units that are provided for information only and are not considered standard.

1.5 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] This 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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1.6 *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~~ safety, health, and ~~health~~environmental practices and determine the applicability of regulatory limitations prior to use.*

~~1.6 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.~~

1.7 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D129 Test Method for Sulfur in Petroleum Products (General High Pressure Decomposition Device Method)
D516 Test Method for Sulfate Ion in Water
D808 Test Method for Chlorine in New and Used Petroleum Products (High Pressure Decomposition Device Method)
D1552 Test Method for Sulfur in Petroleum Products by High Temperature Combustion and Infrared (IR) Detection or Thermal Conductivity Detection (TCD)
E165/E165M Practice for Liquid Penetrant Testing for General Industry
E433 Reference Photographs for Liquid Penetrant Inspection
E543 Specification for Agencies Performing Nondestructive Testing
E1316 Terminology for Nondestructive Examinations
E2297 Guide for Use of UV-A and Visible Light Sources and Meters used in the Liquid Penetrant and Magnetic Particle Methods
E3022 Practice for Measurement of Emission Characteristics and Requirements for LED UV-A Lamps Used in Fluorescent Penetrant and Magnetic Particle Testing

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2.2 *ASNT Documents:*[3]

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

2.3 *Other Standards:*

ISO 9712 Nondestructive Testing–Qualification and vertificaiton of NDT Personnel[4]
AMS 2644 Inspection Material Penetrant[5]

2.4 *AIA Standard:*[6]

NAS410 Certification and Qualification of Nondestructive Testing Personnel

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2.5 ~~*AIA Standard:*~~*DoD Contracts—*

~~NAS 410 Certification and Qualification of Nondestructive Testing Personnel~~[6]

~~2.5 *DoD Contracts*—Unless otherwise specified, the issue of the documents that are DoD adopted are those listed in the issue of the DoDISS (Department of Defense Index of Specifications and Standards) cited in the solicitation.~~Unless

~~2.6 *Order of Precedence*—In the event of conflict between this practice and the references cited herein, this practice takes precedence.~~ otherwise specified, the issue of the documents that are DoD adopted are those listed in the issue of the DoDISS (Department of Defense Index of Specifications and Standards) cited in the solicitation.

2.6 *Order of Precedence*—In the event of conflict between this practice and the references cited herein, this practice takes precedence.

3. Terminology

3.1 *Definitions*~~—definitions~~—Definitions relating to liquid penetrant examination, which appear in Terminology E1316, shall apply to the terms used in this practice.

~~Throughout~~Throughout this practice, the term "black light" has been changed to "UV-A" to conform with the latest terminology in E1316. "Black light" can mean a broad range of ultraviolet radiation; fluorescent penetrant inspection only uses the UV-A range.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from The American Society for Nondestructive Testing (ASNT), P.O. Box 28518, 1711 Arlingate Lane, Columbus, OH 43228-0518.

[4] Available from International Organization for Standardization (ISO), ISO Central Secretariat, BIBC II, Chemin de Blandonnet 8, CP 401, 1214 Vernier, Geneva, Switzerland, http://www.iso.org.

[5] Available from SAE International (SAE), 400 Commonwealth Dr., Warrendale, PA 15096, http://www.sae.org.

[6] Available from the Aerospace Industries Association of America, Inc., 1250 Eye St., N.W., Washington, DC 20005.

4. Summary of Practice

4.1 A post-emulsifiable, liquid, fluorescent penetrant is applied evenly over the surface being tested and allowed to enter open discontinuities. After a suitable dwell time and prerinse, the excess surface penetrant is removed by applying a hydrophilic emulsifier and the surface is rinsed and dried. A developer is then applied drawing the entrapped penetrant out of the discontinuity and staining the developer. If an aqueous developer is to be employed, the developer is applied prior to the drying step. The test surface is then examined visually under UV-A radiation in a darkened area to determine the presence or absence of indications. (**Warning—**Fluorescent penetrant examination shall not follow a visible penetrant examination unless the procedure has been qualified in accordance with 9.2, because visible dyes may cause deterioration or quenching of fluorescent dyes.)

4.2 Processing parameters such as precleaning, penetration time, prerinsing, hydrophilic emulsifier concentration, etc., are determined by the specific materials used, the nature of the part under examination (that is, size, shape, surface condition, alloy), type of discontinuities expected, etc.

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. This practice is normally used for production examination of critical components, where reproducibility is essential. More procedural controls and processing steps are required than with other processes.

6. Reagents and Materials

6.1 *Liquid Fluorescent Penetrant Testing Materials,* for use in the hydrophilic post-emulsification process, (see Note 1) consist of a family of post-emulsifiable fluorescent penetrant, hydrophilic remover, and appropriate developer and are classified as Type I Fluorescent, Method D—Post-Emulsifiable, Hydrophilic. Penetrant materials shall conform to AMS 2644 unless approved by the contract or Level III. Each penetrant and emulsifier are approved together as a pair. Intermixing of materials from various manufacturers is not recommended.

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NOTE 1—Refer to 8.1 for special requirements for sulfur, halogen, and alkali metal content. (**Warning—**While approved penetrant materials will not adversely affect common metallic materials, some plastics or rubbers may be swollen or stained by certain penetrants.)

6.2 *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 by the use of a separate hydrophilic emulsifier. The hydrophilic emulsifier, at the proper concentration, properly applied, and given a proper emulsification time, combines with the excess surface penetrant to form a water-washable mixture, which can then be rinsed from the surface leaving the surface free of fluorescent background. Proper concentration and hydrophilic emulsification time must be experimentally established and maintained to assure that over-emulsification does not occur, resulting in loss of indications.

6.3 *Hydrophilic Emulsifiers* are liquids used to emulsify the excess oily fluorescent penetrant on the surface of the part, rendering it water-washable (see 7.1.6). They are water-base emulsifiers (detergent-type removers) that 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.

6.3.1 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. Its concentration can be monitored by the use of a suitable refractometer.

6.4 *Developers*—Development of penetrant indications is the process of bringing the penetrant out of discontinuities through blotting action of the applied developer, thus increasing the visibility of the penetrant indications. Several types of developers are suitable for use with the hydrophilic penetrant process.

6.4.1 *Dry Powder Developers* are used as supplied (that is, free-flowing, noncaking powder) in accordance with 7.1.9.1(*a*). Care should be taken not to contaminate the developer with fluorescent penetrant, as the penetrant specks can appear as indications.

6.4.2 *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 7.1.9.1(*b*). (**Warning—**Aqueous developers may cause stripping of indications if not properly applied and controlled. The procedure should be qualified in accordance with 9.2.)

6.4.3 *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 for fluorescent penetrants (see 7.1.9.1(*c*). (**Warning—**This type of developer is intended for application by spray only.)

~~6.4.4 *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 7.1.9.1(*d*).~~

7. Procedure

7.1 The following general procedure applies to the fluorescent penetrant examination hydrophilic post-emulsification method (see Fig. 1).

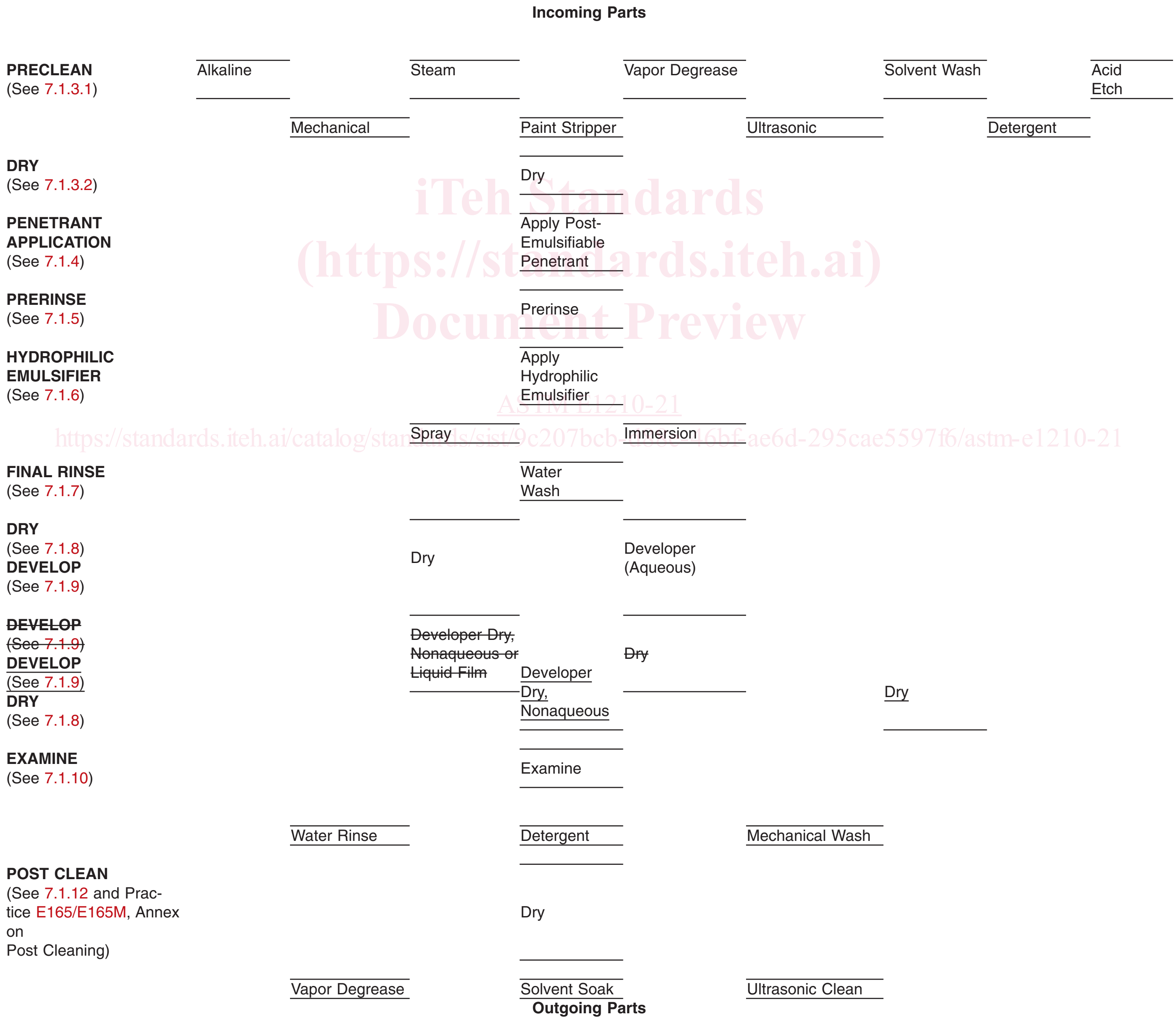

FIG. 1 General Procedure Flowsheet for Fluorescent Penetrant Examination Using the Hydophilic Post-Emulsification Process

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7.1.1 *Temperature Limits*—The temperature of the penetrant materials and the surface of the part to be processed should be between 40 and ~~125°F~~125 °F (4 and ~~52°C).~~52 °C). Where it is not practical to comply with these temperature limitations, qualify the procedure at the temperature of intended use as described in 9.2.

7.1.2 *Surface Conditioning Prior to Penetrant Inspection*—Satisfactory results may be obtained on surfaces in the as-welded, as-rolled, as-cast, or as-forged conditions or for ceramics in the densified condition. These sensitive penetrants are generally less easily rinsed away and are therefore less suitable for rougher surfaces. When only loose surface residuals are present, these may be removed by wiping the surface 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 and 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 the examination. (See Annex on Cleaning Parts and Materials in Practice E165/E165M for general precautions relative to surface preparation.)

NOTE 2—When agreed between purchaser and supplier, grit blasting without subsequent etching may be an acceptable cleaning method. (**Warning—**Sand or shot blasting may possibly close indications and extreme care should be used with grinding and machining operations.)

NOTE 3—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.

7.1.3 *Removal of Surface Contaminants:*

7.1.3.1 *Precleaning*—The success of any penetrant examination procedure is greatly dependent upon the 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 inspected 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 any rust, scale, welding flux, spatter, grease, paint, oily films, dirt, etc., that might interfere with penetration. All of these contaminants can prevent the penetrant from entering discontinuities. (See Annex on Cleaning of Parts and Materials in Practice E165/E165M for more detailed cleaning methods.) (**Warning—**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.)

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7.1.3.2 *Drying After Cleaning*—It is essential that the surface 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 or cold air, or exposure to ambient temperature.

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

7.1.4.1 *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 buildup 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. (**Warning—**Not all penetrant materials are suitable for electrostatic spray applications.) (**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.)

7.1.4.2 *Penetrant Dwell Time*—After application, allow excess penetrant to drain from the part (care should be taken to prevent pools of penetrant on the part), while allowing for proper penetrant dwell time (see Table 1). The length of time the penetrant must remain on the part to allow proper penetration should be as recommended by the penetrant manufacturer. Table 1, 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.

TABLE 1 Recommended Minimum Dwell Times

Material	Form	Type of Discontinuity	Dwell Times[A] (minutes) Pene-trant[B]	Devel-oper[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 40 to ~~120 °F~~125 °F (4 to ~~49 °C).~~52 °C).
[B] Maximum penetrant dwell time 60 min in accordance with 7.1.4.2.
[C] Development time begins as soon as wet developer coating has dried on surface of parts (recommended minimum). Maximum development time in accordance with 7.1.9.2.

NOTE 4—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.

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7.1.5 *Prerinsing*—Directly after the required penetration time, it is recommended that the parts be prerinsed (7.1.5.1) prior to emulsification (7.1.6). 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 allows for the minimization of possible oily penetrant pollution in the final rinse step of this process This is accomplished by collecting the prerinsings in a hold tank, separating the penetrant from water.

NOTE 5—Prerinse is not necessary for a spray application of hydrophilic emulsifier.

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

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

(b) Spray rinse at water pressure of 25 to 40 psi (172 to 275 kPa).

(c) Prerinse time should be maintained at the least possible time to provide a consistent residue of penetrant on parts, nominally 60 s maximum wash time to be as specified by the part or material specification.

(d) 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.

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

7.1.6 *Application of Emulsifier*—After the required penetration time and following the prerinse, the residual surface penetrant on parts is emulsified by immersing the parts in a hydrophilic emulsifier bath (7.1.6.1) or by spraying the parts with the emulsifier (7.1.6.2) thereby rendering the remaining residual surface penetrant water-washable in the final rinse station (7.1.7).

7.1.6.1 *Immersion*—For immersion application of hydrophilic emulsifier, parts are completely immersed in the emulsifier bath. The hydrophilic emulsifier is gently air agitated throughout the contact cycle.

(a) The concentration, percent volume, shall be no higher than specified by the penetrant system supplier, and shall not exceed that for which the system was qualified.

(b) 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.

(c) 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 (7.1.7).

7.1.6.2 *Spray Application*—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) The spray pressure should not exceed 40 psi (275 kPa).

(c) Temperature to be maintained at 50 to 100 °F (10 to 38 °C).

(d) Contact time should be kept to the least possible time consistent with an acceptable background and should not exceed 120 s or the maximum time specified by the part or material specification.

(e) If over-removal is suspected, dry (see 7.1.8) and reclean the part and reapply the penetrant for the prescribed dwell time.

7.1.7 *Post-Rinsing of Hydrophilic Emulsified Parts—*
Effective post-rinsing of emulsified penetrant from the surface can be accomplished using either manual, semiautomatic, or automatic water spray or immersion equipment or combinations thereof.

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

(a) The maximum immersion 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).

7.1.7.2 *Spray Post-Rinsing*—Following emulsification parts can be post-rinsed by either manual or automatic water spray rinsing as follows:

(a) Spray rinse water pressure shall not exceed 40 psi (275 kPa) when manual, automated, 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).

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

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

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7.1.8 *Drying*—During the preparation of parts for examination, drying is necessary either following the application of the aqueous, wet developer or prior to applying dry or nonaqueous developers. Drying time will vary with the size, nature, and number of parts under examination.

7.1.8.1 *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. Drying is best done in a thermostatically controlled recirculating hot-air dryer. (**Warning—**Drying oven temperature should not exceed ~~160°F (71°C).~~160 °F (71 °C).)

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7.1.8.2 *Drying Time Limits*—Do not allow parts to remain in the drying oven any longer than is necessary to dry the part. Excessive time in the dryer may impair the sensitivity of the examination.

7.1.9 *Developer Application:*

7.1.9.1 *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, etc., will influence the choice of developer application.

(a) Dry Powder Developers—Apply immediately after drying in such a manner as to assure complete coverage. Parts can be immersed into a container of dry developer or dipped into a fluid bed of dry developer; they can also be dusted with the powder developer through a hand powder bulb or a powder gun. It is quite common and most 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 gently, or by blowing with low-pressure, (5 to 10 psi (34 to 70 kPa)), dry, clean, compressed air.

(b) Aqueous Developers—Apply to the surface immediately after the excess penetrant has been removed from the part and prior to drying. The dried developer coating appears as a translucent or white coating on the part. Prepare and maintain aqueous developers in accordance with the manufacturer's instructions and apply them in such a manner as to assure complete, even coverage. Aqueous developers may be applied by spraying, flowing, or immersing the part. It is most common to immerse the parts in the prepared developer bath. Immerse parts only long enough to coat all of the part surfaces with the developer. 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 7.1.8. (**Warning—**Atomized spraying is not recommended since a spotty film may result.) (**Warning—**If the parts are left in the bath too long, indications may leach out.)