Designation: E1417/E1417M – 21

Standard Practice for Liquid Penetrant Testing[1]

This standard is issued under the fixed designation E1417/E1417M; 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.

This standard has been approved for use by agencies of the U.S. Department of Defense.

1. Scope*

1.1 This practice establishes the minimum requirements for conducting liquid penetrant examination of nonporous metal and nonmetal components.

NOTE 1—This practice replaces MIL-STD-6866.

1.2 The penetrant examination processes described in this practice are applicable to in-process, final, and maintenance (in-service) examinations. These processes are applicable for the detection of discontinuities, such as lack of fusion, corrosion, cracks, laps, cold shuts, and porosity, that are open or connected to the surface of the component under examination.

1.3 Caution must be exercised in the usage of elevated temperature with components manufactured from thermoplastic materials. Also, some cleaners, penetrants, and developers can have a deleterious effect on nonmetallic materials such as plastics. Prior to examination, tests should be conducted to ensure that none of the cleaning or examination materials are harmful to the components to be examined.

1.4 *Units*—The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system are not necessarily exact equivalents; therefore, to ensure conformance with the standard, each system shall be used independently of the other, and values from the two systems shall not be combined.

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.

NOTE 2—Throughout this document, the term *blacklight* has been changed to *UV-A* to conform with the latest terminology in Terminology E1316. *Blacklight* can mean a broad range of ultraviolet radiation; fluorescent penetrant examination only uses the UV-A range.

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

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 The following documents form a part of this practice to the extent specified herein:

2.2 *ASTM Standards:*[2]

D95 Test Method for Water in Petroleum Products and Bituminous Materials by Distillation

D6304 Test Method for Determination of Water in Petroleum Products, Lubricating Oils, and Additives by Coulometric Karl Fischer Titration

E165/E165M Practice for Liquid Penetrant Testing for General Industry

E203 Test Method for Water Using Volumetric Karl Fischer Titration

E543 Specification for Agencies Performing Nondestructive Testing

E1135 Test Method for Comparing the Brightness of Fluorescent Penetrants

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

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

***A Summary of Changes section appears at the end of this standard**

2.3 *ASNT Standards:*[3]
ANSI/ASNT-CP-189 Standard for Qualification and Certification of Nondestructive Testing Personnel
SNT-TC-1A Recommended Practice for Personnel Qualification and Certification in Nondestructive Testing

2.4 *Military Standards:*[4,5]
MIL-STD-6866 Inspection, Liquid Penetrant
QPL-AMS-2644 Qualified Products List, Inspection Material, Penetrant

2.5 *ANSI/ISO/EN Standards:*[6]
ANSI/NCSL Z540.3 General Requirement for Calibration Laboratories and Measuring Test Equipment
EN 4179 Qualification and Approval of Personnel for Nondestructive Testing
ISO 9712 Non-destructive Testing-Qualification and Certification of NDT Personnel
ISO 10012 Measure Management Systems—Requirements for Measurement Processes and Measuring Equipment
ISO/IEC 17025 General Requirements for the Competence of Testing and Calibration Laboratories

2.6 *AIA Standard:*[7]
NAS 410 Certification and Qualification of Nondestructive Test Personnel

2.7 *SAE Standards:*[8]
AMS 2175 Castings, Classification and Inspection of
AMS 2644 Inspection Material, Penetrant
AMS 3158 Solution, Fluorescent Penetrant Water Base for LOX Compatibility

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

3. Terminology

3.1 *Definitions:*

3.1.1 The terminology relating to liquid penetrant examination that appears in Terminology E1316 shall apply to the terms used in this practice.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *aerospace, n*—any component that will be installed on a system that flies.

3.2.2 *cognizant engineering organization, n*—reference Terminology E1316.

3.2.3 *component, n*—the part(s) or element(s) of a system described, assembled, or processed to the extent specified by the drawing.

3.2.4 *final examination, n*—the final examination performed for the acceptance of the item.

3.2.4.1 *Discussion*—Any change to the item's surface such as machining, grinding, welding, heat treatment, or etching by subsequent manufacturing operation, may render the previous examination invalid, requiring reexamination of all affected surfaces, unless otherwise approved in the contract.

3.2.5 *in-process, adj*—that which occurs during manufacturing before a component is in final form.

3.2.6 *in-service, adj*—refers to components that are in use or storage for their intended function.

3.2.7 *reprocess, v*—repeat, after cleaning, the application and appropriate processing of penetrant, emulsifier (as required), and developer (as required).

3.2.8 *supplier, n*—the organization contracted to supply the material, parts, or assembly.

3.2.9 *turbine engine critical components, n*—any component on turbine engine designated by the manufacturer as "critical."

4. Significance and Use

4.1 This practice establishes the basic parameters for controlling the application of the liquid penetrant method. This practice is written so it can be specified on the engineering drawing, specification, or contract. It is not a detailed how-to procedure to be used by the inspector and, therefore, must be supplemented by a detailed procedure that conforms to the requirements of this practice. Practice E165/E165M contains information to help develop detailed requirements.

5. Classification

5.1 Penetrant examination processes and materials are classified in accordance with the material classification contained in AMS 2644. Penetrant systems covered by this practice shall be of the following types, methods, and sensitivity levels:

5.1.1 *Type:*
5.1.1.1 *Type I*—Fluorescent dye.
5.1.1.2 *Type II*—Visible dye.
5.1.2 *Method:*
5.1.2.1 *Method A*—Water washable.
5.1.2.2 *Method A(W)*—Water washable-water containing.
5.1.2.3 *Method B*—Post-emulsifiable, lipophilic.
5.1.2.4 *Method C*—Solvent-removable.
5.1.2.5 *Method D*—Post-emulsifiable, hydrophilic.

5.1.3 *Sensitivity*—(These levels apply to Type I penetrant systems only. Type II penetrant systems have only a single sensitivity and it is not represented by any of the levels listed as follows):
5.1.3.1 *Sensitivity Level ½* —Very low.
5.1.3.2 *Sensitivity Level 1*—Low.
5.1.3.3 *Sensitivity Level 2*—Medium.
5.1.3.4 *Sensitivity Level 3*—High.
5.1.3.5 *Sensitivity Level 4*—Ultrahigh.

5.2 Developers shall be of the following forms:

[3] Available from American Society for Nondestructive Testing (ASNT), P.O. Box 28518, 1711 Arlingate Ln., Columbus, OH 43228-0518, http://www.asnt.org.
[4] Copies of specifications, standards, drawings, and publications required by manufacturers in connection with specific acquisition functions should be obtained from the contracting activity or as directed by the contracting officer.
[5] Available from Standardization Documents Order Desk, DODSSP, Bldg. 4, Section D, 700 Robbins Ave., Philadelphia, PA 19111-5098, http://dodssp.daps.dla.mil.
[6] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.
[7] Available from Aerospace Industries Association (AIA), 1000 Wilson Blvd., Suite 1700, Arlington, VA 22209, http://www.aia-aerospace.org.
[8] Available from SAE International (SAE), 400 Commonwealth Dr., Warrendale, PA 15096-0001, http://www.sae.org.

5.2.1 *Form a*—Dry powder.

5.2.2 *Form b*—Water-soluble.

5.2.3 *Form c*—Water-suspendable.

5.2.4 *Form d*—Nonaqueous for Type I fluorescent penetrant.

5.2.5 *Form e*—Nonaqueous for Type II visible dye.

5.2.6 *Form f*—Specific application.

5.3 Solvent removers shall be of the following classes:

5.3.1 *Class 1*—Halogenated.

5.3.2 *Class 2*—Nonhalogenated.

5.3.3 *Class 3*—Specific application.

6. General Practices

6.1 *Responsibility for Examination*—Unless otherwise specified in the contract or purchase order, the cognizant engineering organization is responsible for the performance of all examination requirements as specified herein. The cognizant engineering organization may specify more stringent requirements than the minimum specified in this practice when necessary to ensure that a component meets its functional and reliability requirements. Except as otherwise specified, the supplier may utilize his own facilities or any other facilities suitable for the performance of the examination requirements specified herein. The cognizant engineering organization reserves the right to perform any of the examinations set forth in this practice where such examinations are deemed necessary to ensure that supplies and services conform to prescribed requirements.

6.2 *Specifying*—When examination is required in accordance with this practice, the orders, contracts, or other appropriate documents shall specify the criteria by which the acceptability of components is to be evaluated. Engineering drawings or other applicable documents shall indicate the acceptance criteria for the entire component; zoning may be used. Examination on a sampling basis shall not be allowed unless specifically permitted by the contract.

6.3 *Personnel Qualification*—Personnel performing examinations in accordance with this practice shall be qualified and certified in accordance with SNT-TC-1A, ANSI/ASNT-CP-189, NAS 410, EN 4179, ISO 9712, or as specified in the contract or purchase order.

6.4 *Agency Qualification*—The agency performing this practice may be evaluated in accordance with Specification E543.

6.5 *Materials:*

6.5.1 *Qualified Materials*—Only materials listed or approved for listing on QPL-AMS-2644 (reference AMS 2644) shall be utilized for penetrant examination. Materials not conforming to the requirements of AMS 2644 may be used only when a waiver is obtained from the cognizant engineering organization.

6.5.2 *Liquid Oxygen (LOX) Compatible Materials*—Penetrant materials used on LOX wetted surfaces that cannot be thoroughly post-cleaned shall be compliant with AMS 3158, be used in accordance with the material supplier instructions, and shall require approval of the cognizant engineering organization when such materials do not meet the requirements of AMS 2644.

6.5.3 *Shelf Life*—Penetrant materials that have exceeded their initial shelf life date are permissible to use provided the requirements of 7.8.2 and 7.8.3 produce acceptable results. Ready-to-use materials as identified in 7.8 need only meet the requirements of 7.8.3.

6.6 *Equipment and Facilities*—Processing equipment used in the penetrant examination process shall be constructed and arranged to permit a uniform and controlled operation. The equipment shall meet all applicable national and local safety requirements as well as the requirements specified herein. In facilities using both Type I and Type II penetrant, provisions shall be made to prevent cross-contamination between penetrant types.

6.6.1 *Viewing Areas*—Areas where parts are reviewed shall be kept clean at all times. For visible dye examination, Type II, the lighting system shall provide at least 100 fc [1076 lx] of visible light when measured at the examination surface. For stationary fluorescent dye examination, Type I, the ambient visible light background shall not exceed 2 fc [21.5 lx] at the examination surface. The UV-A lamp shall provide a minimum of 1000 μW/cm^2 at the examination surface. UV-A lamps shall meet the requirements of 7.8.4.1. Viewing areas for portable fluorescent dye examination shall utilize dark canvas, photographer's black cloth, or other methods to reduce the visible light background to the lowest possible level during examination and UV-A intensity shall meet the above requirements.

6.6.1.1 Where lamps are physically too large to directly illuminate the examination surface, special lighting, such as UV-A pencil lamps, or UV-A light guides, or remote visual examination equipment shall be used. When using a borescope, the image viewed must have sufficient resolution to effectively evaluate the indication. UV-A intensity shall be measured at the expected working distance and shall be a minimum 1000 μW/cm^2. Special lighting shall meet the requirements of 7.8.4.2.

6.6.1.2 LED UV-A lamps used for evaluation purposes shall comply with Practice E3022, excluding those referenced in 6.6.1.1 and 7.8.4.2.

6.6.2 *Drying Oven*—When components are oven dried, the dryer must be a forced-air recirculating type. In automated systems, where parts are dried by radiant heat and forced air, the travel speed of the system shall be such as to preclude overdrying of parts. The forced air does not have to be recirculating but must preclude contamination of the parts. The temperature shall be controlled with a calibrated device capable of maintaining the oven temperature at ±15 °F [±8.3 °C] of the temperature for which it is set. The oven shall not exceed 160 °F [71 °C]. The temperature indicator shall be accurate to ±10 °F [±5.6 °C] of the actual oven temperature.

6.7 *Written Procedures*—When liquid penetrant examination procedures are similar for many components, a master written procedure may be utilized that covers the details common to a variety of components as well as guidance in the event of a process control failure which, as a minimum, shall include notification of the failure to the Penetrant Testing Level

3 (III). All written procedures, including technique sheets for specific parts shall be approved by an individual who is a qualified and certified Level 3 (III) for penetrant examination in accordance with the requirements of 6.3. As a minimum, the following information is required either in individual procedures, specific technique sheets, or a master procedure, or a combination thereof:

6.7.1 Details of the precleaning and etching process, including the materials used and specification or other document controlling the examination process, the drying parameters, and the processing times. If these operations are performed by other than examination personnel, details concerning the operations may be specified in other documents but must be referenced in the procedure(s). Reference Practice E165/E165M for guidance on cleaning methods and instructions.

6.7.2 Classification of the penetrant examination materials required in accordance with Section 5 and AMS 2644.

6.7.3 Complete processing parameters for the penetrant examination materials, including concentrations, application methods, dwell times, drying times, temperatures, and controls to prevent excessive drying of penetrant or overheating of component, as appropriate. Reference Practice E165/E165M for additional details.

6.7.4 Complete examination/evaluation requirements, including light intensities (both examination and ambient), the accept/reject criteria, and the method and location of marking. Reference Practice E165/E165M for additional details.

6.7.4.1 The method and measurement frequency shall be defined for meeting the minimum examination intensity for all UV-A lamps, including battery-powered lamps. Any requirements for documentation of the measurements shall be defined in the procedure.

6.7.4.2 When the examination is performed in accordance with this practice, engineering drawings, specifications, technique sheets, or other applicable documents shall indicate the accept/reject criteria by which the components are judged acceptable.

6.7.5 Identification of the components or areas within a component to be examined in accordance with the procedure.

6.7.6 Complete postcleaning procedures. If postcleaning is performed by other than examination personnel, details concerning this operation may be specified in other documents but must be referenced in the procedure. Reference Practice E165/E165M for additional details.

6.7.7 Identification of the name and address of the facility of which the procedure applies.

6.8 *Examination Sequence*—Final penetrant examination shall be performed after 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.

6.8.1 *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, abrasive blasting, lapping, or peening. Performance of final penetrant examination after such surface treatments requires that etching be included in the precleaning operation unless otherwise agreed on between the cognizant engineering organization and the NDT facility.

NOTE 3—Final penetrant examination should always precede peening.

6.8.2 *Surface Coatings*—All coatings and other surface conditions, such as paint, plating, corrosion, etc., shall be removed from the area to be examined prior to penetrant examination. The penetrant examination shall precede any surface finish, such as anodize, except for in-service parts that may be examined without removing the anodize.

6.9 *Material and Process Limitations*—Not all penetrant sensitivity levels, materials, and process methods are applicable to all examination requirements. The sensitivity level shall be adequate for the intended purpose of the examination. Unless there is an approval for deviation given by the cognizant engineering organization, the following selections are mandatory or forbidden, as indicated:

6.9.1 Forms *a* and *b* (dry powder and water soluble) developers shall not be used with Type II (visible dye) penetrant systems. This is not intended to prohibit the use of a Form *f* developer that has been qualified with a particular Type II system in accordance with AMS 2644.

6.9.2 Type II penetrant examination shall not be used for final acceptance examination of aerospace products. In addition, Type II penetrant examination shall not be used at any point in the process if a Type I penetrant examination of the same surface is to be performed. This is not intended to eliminate the use of in-process Type II examinations where subsequent fabrication/forming operations remove the surfaces inspected.

6.9.3 The maintenance or overhaul examination of turbine engine critical components shall be done only with Type I, Methods C or D (solvent removable or post emulsified, hydrophilic) processes and either sensitivity Levels 3 or 4 penetrant materials.

6.10 *Records*—Results of all final penetrant examinations shall be recorded. All recorded results shall be identified, filed, and made available to the cognizant engineering organization upon request. Records shall provide for traceability to the specific part or lot inspected. As a minimum, the records shall include: identification of the procedure used, disposition of the examination; identification of the inspector's examination stamp, electronic ID, or signature; and the date of examination. Records shall be kept for a minimum of three years or as otherwise specified in the purchase order or contract.

7. Specific Practices (Fig. 1)

7.1 *Surface Preparation*—All surfaces to be examined shall be clean, dry, and free of soils, oil, grease, paint and other coatings (except as allowed by 6.8.2), corrosion products, scale, smeared metal, welding flux, chemical residues, or any other material that could prevent the penetrant from entering discontinuities, suppress dye performance, or produce unacceptable background. Cleaning methods, including etching, selected for a particular component shall be consistent with the contaminants to be removed and shall not be detrimental to the component or its intended function.

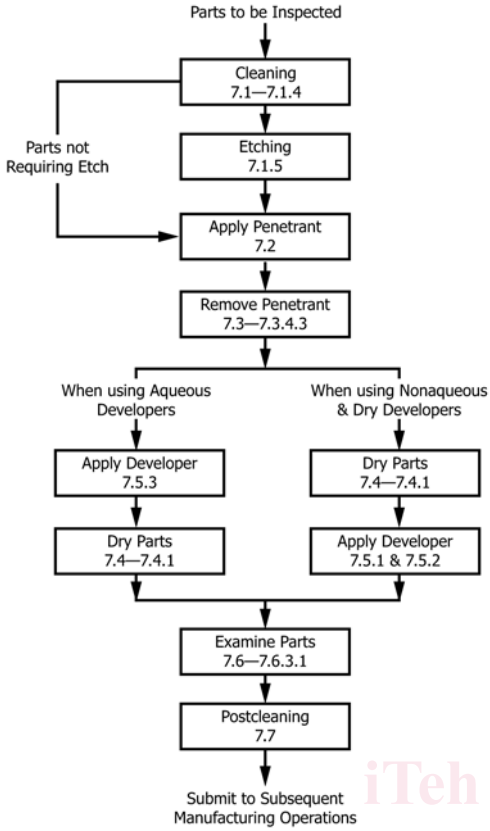

FIG. 1 Process Flow Chart

7.1.1 One or more appropriate cleaning methods, such as solvent cleaning, vapor degreasing, ultrasonic cleaning, aqueous-based cleaning, or methods agreed upon with the cognizant engineering organization shall be used for the removal of oils, greases, and waxes, and as the final step before penetrant examination. If etching is required, the parts shall be appropriately cleaned, then etched and delivered to penetrant examination.

7.1.2 Chemical cleaning shall be used for the removal of paints, varnishes, scale, carbon, or other contaminants that are not removable by solvent cleaning methods. (**Warning—** Caution should be exercised when using chemicals because they may irritate the eyes or skin.)

7.1.3 Mechanical cleaning shall be used for the removal of soils and other contaminants that cannot be removed by solvent or chemical cleaning methods.

7.1.4 Grit blasting without etching may be an acceptable cleaning method if it can be demonstrated that a sufficiently fine abrasive (150 grit or finer) will not cause peening and can be removed by a detergent or alkaline cleaner.

7.1.5 Etching, unless otherwise specified, shall be performed when evidence exists that previous cleaning, surface treatments, or service usage has produced a surface condition that degrades the effectiveness of penetrant examination. Etching processes shall be developed and controlled to prevent damage to the component under test. Etching is not required for those features such as close tolerance holes, close tolerance surfaces, faying surfaces, etc., where the function of the component or assembly would be degraded. Etching is not required for intermediate examination when the surface(s) are not retained in the final part/component configuration or when the final penetrant examination is preceded by etching. Reference 6.8.1.

7.2 *Penetrant Application*—Unless otherwise specified, the entire surface of the component shall be covered with penetrant. Large components may be examined in sections. Penetrant shall be applied by spraying, dipping, brushing, or other method to provide coverage as required. The component, penetrant, and ambient temperatures shall all be in the range from 40 to 125 °F [4 to 52 °C] unless otherwise specified.

7.2.1 *Penetrant Dwell Time*—The dwell time, unless otherwise specified, shall be a minimum of 10 min. For temperatures between 40 and 50 °F [4.4 and 10 °C], dwell time shall be a minimum of 20 min. It is recommended to rotate or otherwise move components as necessary during dwell to prevent pooling of the penetrant. For dwell times greater than 2 h, the penetrant shall be reapplied as required.

7.3 *Penetrant Removal:*

7.3.1 *Method A Process*—Water-washable penetrants shall be removed with a manual or automated water spray, or a manual wipe, or an air agitated immersion wash, or a combination thereof.

7.3.1.1 *Manual Spray*—For handheld spray guns, water pressure adequate to remove the penetrant shall be used but shall not exceed 40 psi [275 kPa]. Water temperature shall be between 50 to 100 °F [10 to 38 °C]. When hydro-air nozzles are used, the air pressure shall not exceed 25 psi [172 kPa]. A coarse spray shall be used with a minimum distance of 12 in. [30 cm], when possible, between the spray nozzle and the part. Washing shall be conducted under appropriate illumination. Caution shall be exercised to ensure that over-washing does not occur. If over-washing occurs, the component(s) shall be thoroughly dried and reprocessed. After rinsing, drain water from the component and utilize repositioning, suction, blotting with clean absorbent materials, or filtered shop air at less than 25 psi [172 kPa] to prevent pooling in cavities, recesses, and pockets. (Over-removal of the surface penetrant shall require that the component be cleaned and reprocessed. A good indicator of over-wash or over-removal of the surface penetrant is evidenced by the total lack of residue that may occur on all or a specific area of the part; see Practice E165/E165M.)

7.3.1.2 *Automated Spray*—For automated spray systems, the wash parameters shall be such that the requirements of 7.8.3 are met. Water temperature shall be maintained between 50 to 100 °F [10 to 38 °C].

7.3.1.3 *Manual Wipe*—Excess penetrant shall be removed with a clean, dry, lint-free cloth or absorbent toweling. The remainder of the surface penetrant shall then be removed with a water-dampened cloth or towel. The surface shall not be flushed with water and the cloth or towel shall not be saturated with water. The component shall be examined under appropriate illumination to ensure adequate removal of the surface penetrant. The surface shall be dried by blotting with a clean, dry towel or cloth, or by evaporation.

7.3.1.4 *Immersion*—Immersion wash may be utilized if the water is air agitated and good circulation is maintained throughout the wash operation. Water temperature shall be

maintained between 50 and 100 °F [10 and 38 °C]. When immersion wash is used, a final spray rinse shall be included. The spray rinse parameters of 7.3.1.1 shall apply.

7.3.2 *Method B Process*—Lipophilic post-emulsifiable penetrant shall be removed by air agitated water immersion or with a water spray or hydro-air spray rinse after application of an emulsifier and an appropriate emulsifier dwell time. Water pressure and temperature and air pressure shall meet the requirements specified in 7.3.1.1, 7.3.1.2, and 7.3.1.4.

7.3.2.1 Lipophilic emulsifiers shall be applied by immersion or flowing. Lipophilic emulsifiers shall not be applied by spray or brush and shall not be agitated while on the surface of the component. Maximum dwell times, unless otherwise specified, shall be 3 min for Type I systems and 30 s for Type II systems, or as recommended by the manufacturer. Actual dwell times shall be the minimum necessary to produce an acceptable background on the component.

7.3.2.2 *Rinsing*—After the appropriate emulsifier dwell time, emulsification shall be stopped by immersion or water spray. For removal of the penetrant/emulsifier mixture, the parameters of 7.3.1.1, 7.3.1.2, and 7.3.1.4 apply. Dwell time in an agitated immersion rinse, if used, shall be the minimum required to remove the emulsified penetrant. Examine the components under appropriate illumination after rinsing. Clean and reprocess those components with excessive background. After rinsing, drain water from the component and utilize repositioning, suction, blotting with clean absorbent materials or filtered shop air at less than 25 psi [172 kPa] to prevent pooling. Caution shall be exercised to ensure that the air nozzle is held at a sufficient distance from the part to ensure that the developing indication is not smeared by the air blast. If over-emulsification is observed, the component must be cleaned and reprocessed.

7.3.3 *Method C Process*—Solvent-removable penetrants are removed by first wiping the excess penetrant with a clean, lint-free, dry cloth or absorbent toweling. The remainder of the surface penetrant is then removed with a solvent-dampened lint-free cloth or towel. The surface of the component shall not be flushed with solvent, and the cloth or towel shall not be saturated with solvent. The component and cloth or toweling shall be observed under appropriate illumination to ensure adequate removal of the surface penetrant. Over-removal of the surface penetrant shall require the component to be cleaned and reprocessed. The surface shall be dried by blotting with a lint-free, dry cloth or towel, or by evaporation. Method C can also be used for water-washable penetrants using water or solvent for removal of excess penetrant.

7.3.4 *Method D Process*—Hydrophilic post emulsifiable penetrant shall be removed with a water prerinse, application of the hydrophilic emulsifier, and then a postrinse.

7.3.4.1 *Rinse*—The water prerinse shall be applied for the minimum amount of time required to achieve removal of the bulk surface penetrant. The rinse parameters of 7.3.1.1 or 7.3.1.2 shall apply.

(1) For spray application of the emulsifier, a water prerinse may be omitted.

7.3.4.2 Hydrophilic emulsifier shall be applied by immersion, flowing, or spray. Hydrophilic emulsifier shall not be applied by brush. Foaming application of hydrophilic emulsifier is permissible when approved by the cognizant engineering organization.

(1) For immersion applications, 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. While immersed, the emulsifier or part should be mildly agitated. Dwell time shall be the minimum required for adequate surface penetrant removal, but unless otherwise approved by the cognizant engineering organization, shall not exceed 2 min.

(2) For spray or flowing applications, the concentration shall not exceed 5 %. Spray applications may include fixed spray nozzles, spray wands, pump sprayers, or spray bottles provided the concentration is tested and meets the requirements of 7.8.2.6. Dwell time shall be the minimum required for adequate surface penetrant removal, but unless otherwise approved by the cognizant engineering organization, shall not exceed 2 min per surface area.

7.3.4.3 *Postrinse*—After the application and dwell of the hydrophilic emulsifier, the component being examined shall be rinsed with water. The spray rinse parameters of 7.3.1.1, 7.3.1.2, and 7.3.1.4 shall apply. Evidence of over-removal shall require the part to be cleaned and reprocessed. Excessive background may be removed by additional (touchup) application of the hydrophilic emulsifier provided its maximum allowable dwell time is not exceeded. Additional rinsing of the touch-up area will be required after application and dwell of the hydrophilic emulsifier. If careful touch-up application of the hydrophilic emulsifier does not produce an acceptable background, the part shall be cleaned and reprocessed. Manual systems shall require the use of appropriate UV-A irradiance to ensure adequate penetrant removal.

7.4 *Drying*—The components shall be dried prior to the application of dry developer, nonaqueous developer, or examination without developer. The components should be drained of excess water but not dried before the application of aqueous soluble or suspendable developers. The components shall be dried after the application of aqueous developers.

7.4.1 *Drying Parameters*—Components shall be air dried at room temperature or in a drying oven. Oven temperatures shall not exceed that specified in 6.6.2. 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.

7.5 *Developing*—Unless otherwise specified, developers shall be utilized for penetrant examination. Type I penetrants that are qualified to AMS 2644 may be used without developer under either one of the following conditions: manufacturing examination of aluminum and magnesium castings classified by AMS 2175 as Class 3 or 4, or with the expressed approval of the cognizant engineering organization. Minimum and maximum developing times shall be 10 min and 2 h, respectively. Components that are not examined before the maximum developing time shall be cleaned and reprocessed.

7.5.1 *Dry Developers*—Components shall be dry before the developer is applied. Dry developer shall be applied in such a

manner as to contact all surfaces to be examined. Excess dry developer may be removed after the development time by light tapping or light air blow-off. If compressed air is used, the pressure shall not exceed 5 psi [34 kPa]. Minimum and maximum developer dwell times shall be 10 min and 4 h, respectively. Dry developers shall not be used with Type II penetrants.

7.5.2 *Nonaqueous Developers*—Components, or areas requiring examination, shall be dry before application of the developer. Nonaqueous developer shall be applied by spraying. For Type I penetrants, the developer shall be applied as a uniform thin coating over the entire surface to be inspected. For Type II penetrants, the developer shall be applied over the entire surface to form a uniform, white coating to provide suitable color contrast for the penetrant indications. The uniformity and thickness of the developer coating is important for both types of penetrant systems. If the developer coating thickness is too heavy for Type I systems such that the metallic surface is completely masked, the component shall be cleaned and reprocessed. Unless otherwise specified, the minimum and maximum development times for nonaqueous developers are 10 min and 1 h, respectively. For nonaqueous suspendable developer, the developer container shall be frequently agitated between applications.

7.5.3 *Aqueous Developer*—Aqueous soluble developers shall not be used with Type II penetrants or Type I, Method A penetrants. Aqueous suspendable developers can be used with both Type I and Type II penetrants. Aqueous developers may be applied to the component after rinsing. Developers shall be applied by spray, flowing, or immersion. The applied developer shall not be allowed to puddle and shall completely cover all surfaces to be inspected. Components shall be air dried or oven dried to the requirements of 7.4.1. Minimum and maximum development times, after the component is dry, are 10 min and 2 h. Aqueous suspendable developers must be either constantly agitated to keep the particles from settling out of suspension or they must be thoroughly agitated prior to use to ensure that particles are in suspension.

7.6 *Examination*—The interpretation area shall meet the appropriate requirements of 7.8.4.5. Components shall be interpreted before the maximum developing time, and if required by specific procedures, monitored periodically during the developing time. Components not interpreted before the maximum developing time shall be cleaned and reprocessed.

7.6.1 *Type I Processes—UV-A Irradiation*—Examine fluorescent penetrant indications under UV-A radiation in a darkened area. A minimum of 1000 μW/cm^2 is required on the surface being examined.

7.6.1.1 *UV-A Source Warm-Up*—For all UV-A sources except LED UV-A sources, allow source to warm up for a minimum of 10 min prior to its use or the measurement of UV-A irradiation. LED UV-A sources are at full intensity at power-on and the intensity may decrease as the lamp warms up.

7.6.1.2 Upon entering the darkened examination area, the inspector's vision shall be dark adapted for a minimum of 1 min prior to examining components. Longer times for more complete adaptation should be used if necessary. Inspectors shall not wear photochromic or permanently darkened lenses while processing or reviewing parts under UV-A irradiance. UV-A lamps shall meet the requirements of 7.8.4.1. All areas of fluorescence shall be interpreted. Components with no indications or only nonrelevant indications shall be accepted. Components with relevant indications shall be evaluated with respect to the applicable acceptance criteria. Components with excessive background fluorescence shall be cleaned and reprocessed.

7.6.2 *Type II Processes*—All indications shall be interpreted. Components with no indications or only nonrelevant indications shall be accepted. Components with relevant indications shall be evaluated with respect to the applicable acceptance criteria. Components with excessive background shall be cleaned and reprocessed.

7.6.3 *Evaluation*—All indications found during the examination shall be evaluated in accordance with specified acceptance criteria.

7.6.3.1 *Indication Verification*—When addressed in the user's procedure, it is permissible to verify indications by wiping the indication with a solvent-dampened swab, brush, or lint-free cloth, avoiding flooding the area with solvent, allowing the area to dry, and redeveloping the area. Redevelopment time shall be a minimum of 10 min, except nonaqueous redevelopment time shall be a minimum of 3 min. If the indication does not reappear, the original indication may be considered false. This procedure may be performed up to two times for any given original indication. Unless otherwise specified, isopropyl alcohol, acetone, or QPL-AMS2644 approved solvents are permissible.

7.6.3.2 *Discontinuity Removal*—When allowed by the specific examination procedure, discontinuity(ies) may be removed by an approved procedure such as sanding, either powered or manual, or grinding to determine the depth and extent of the discontinuity(ies). After the mechanical operation, the area shall be cleaned, etched (if permitted), and reexamined. The process used for reexamination shall be at least as sensitive as the original process.

7.6.4 *Sizing*—If the acceptance criteria are written in terms of indication sizes, the indication size shall be measured. If the acceptance criteria is written in terms of discontinuity or flaw sizes, the discontinuity shall be measured.

7.6.4.1 *Indication Sizing*—When sizing indications for judgment against appropriate acceptance criteria, the penetrant indication shall be carefully evaluated under appropriate lighting (visible light for visible dye penetrant and UV-A radiation for fluorescent penetrant), after the required development or redevelopment time as applicable. Measure the indication size at its largest dimension with a measuring device and the appropriate illumination that meets the requirements of 6.6.1.

7.6.4.2 *Discontinuity Sizing*—When sizing discontinuities for judgment against appropriate acceptance criteria, the area may be carefully wiped with a solvent-dampened cotton swab or brush, ensuring rapid evaporation so that the area for examination is not flooded with solvent. Immediately measure the discontinuity using a measuring or comparison device and the appropriate illumination that meets the requirements of 6.6.1.