Designation: ~~E1417/E1417M – 20~~ 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.*

[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.

Current edition approved ~~Dec. 1, 2020~~Sept. 1, 2021. Published October 2021. Originally approved in 1991. Last previous edition approved in ~~2016~~2020 as ~~E1417/E1417M – 16.~~E1417/E1417M – 20. DOI: ~~10.1520/E1417_E1417M-20.~~10.1520/E1417_E1417M-21.

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

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

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 Non-destructive 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.

[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 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.

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:

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.

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

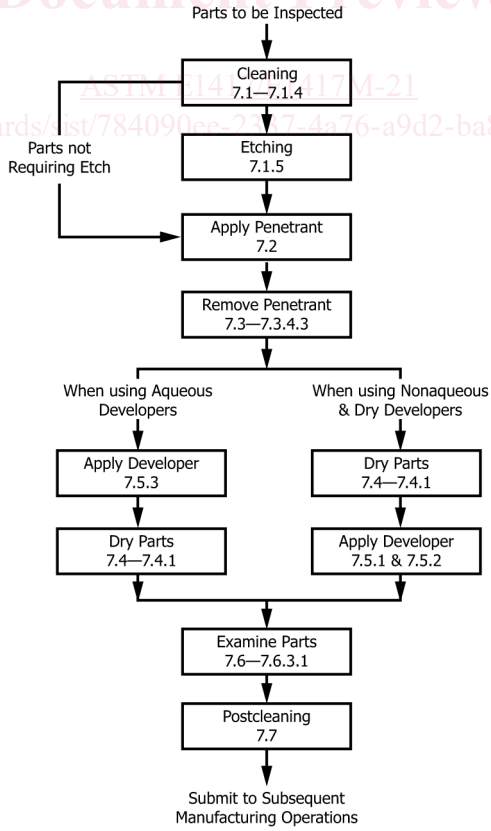

FIG. 1 Process Flow Chart