Designation: E 1417 – 99

Standard Practice for Liquid Penetrant Examination[1]

This standard is issued under the fixed designation E 1417; 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 establishes the minimum requirements for conducting liquid penetrant examination of nonporous metal, and nonmetal components.

1.2 The penetrant examination processes described in this practice are applicable to in-process, final, and maintenance (in-service) inspections. 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 inspection materials are harmful to the components to be examined.

1.4 The values stated in inch-pound units are regarded as standard. The SI units given in parentheses are for information only.

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.

1.6 *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 and health practices and determine the applicability of regulatory limitations prior to use.* Specific precautionary statements are given in Notes 2 and 3.

2. Referenced Documents

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

2.2 *ASTM Standards:*

D 95 Test Method for Water in Petroleum Products and Bituminous Materials by Distillation[2]

D 2512 Test Method for Compatibility of Materials with Liquid Oxygen (Impact Sensitivity Threshold and Pass-Fail Technique)[3]

E 165 Test Method for Liquid Penetrant Examination[4]

E 543 Practice for Evaluating Agencies that Perform Nondestructive Testing[4]

E 1135 Test Method for Comparing the Brightness of Fluorescent Penetrants[4]

E 1316 Terminology for Nondestructive Examinations[4]

2.3 *ASNT Document*

ANSI/ASNT-CP-189 Standard for Qualification and Certification of Nondestructive Testing Personnel[5]

SNT-TC-1A Recommended Practice for Personnel Qualification and Certification in Nondestructive Testing[5]

2.4 *Military Standards:*[6]

MIL-I-25135 Inspection Materials, Penetrant[7]

QPL 25135 Qualified Products of, Inspection Materials, Penetrant[7]

MIL-STD-410 Nondestructive Testing Personnel Qualification and Certification[7]

MIL-STD-792 Identification Marking Requirements for Special Purpose Components[7]

MIL-STD-1907 Liquid Penetrant and Magnetic Particle, Soundness Requirements for Materials, Parts, and Weldments[7]

MIL-STD-2175 Castings Classification and Inspection of[7]

QPL-AMS-2644 Qualified Products List, Inspection Material, Penetrant[7]

MIL-STD-6866 Inspection, Penetrant Method of[7]

MIL-STD-45662 Calibration System Requirements[7]

2.5 *ANSI/ISO/AIA Standards:*[8]

ANSI/NCSL Z540-1 General Requirement for Calibration Laboratories and Measuring Test Equipment

ISO 10012-1 Quality Assurance Requirements for Measuring Test Equipment

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[1] This practice is under the jurisdiction of ASTM Committee E-7 on Nondestructive Testing and is the direct responsibility of Subcommittee E07.03 on Liquid Penetrant and Magnetic Particle Methods.

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[2] *Annual Book of ASTM Standards*, Vol 05.01.

[3] *Annual Book of ASTM Standards*, Vol 15.03.

[4] *Annual Book of ASTM Standards*, Vol 03.03.

[5] Available from American Society for Nondestructive Testing, 1711 Arlingate Plaza, P.O. Box 28518, Columbus, OH 43228-0518.

[6] 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.

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

[8] Available from American National Standards Institute, 11 West 42nd Street, 13th Floor, New York, NY 10036.

NAS 410 Certification and Qualification of Nondestructive Test Personnel

2.6 *SAE Standard:*[9]

AMS 2644 Inspection Material, Penetrant

2.7 *DoD Contracts*—Unless otherwise specified, the issues 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.

2.8 *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 E 1316 shall apply to the terms used in this practice.

3.2 *Definitions of Terms Specific to This Standard:*

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

3.2.2 *cognizant engineering organization*—the company, agency, or other authority responsible for the design or after delivery, end use of the system or component for which liquid penetrant examination is required; in addition to design personnel, this may include personnel from material, and process engineering, stress analysis, NDT or quality groups and others, as appropriate.

3.2.3 *component*—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*—the final examination performed for the acceptance of the item. 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*—that which occurs during manufacturing before a component is in final form.

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

3.2.7 *linear indication*—penetrant indications with at least a three to one length to width ratio.

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

3.2.9 *rounded indication*—penetrant indication whose length to width ratio is less than three-to-one.

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

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

[9] Available from Society of Automotive Engineers, 400 Commonwealth Drive, Warrendale, PA 15096.

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. Test Method E 165 contains information to help develop detailed how-to requirements.

5. Classification

5.1 Penetrant examination processes and materials are classified in accordance with the material classification contained in MIL-I-25135 or 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 B*—Post-emulsifiable, lipophilic.

5.1.2.3 *Method C*—Solvent-removable.

5.1.2.4 *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 shall 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 purchaser 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. An example of such criteria is in MIL-STD-1907; however, other criteria may be utilized. 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 to this practice shall be qualified and certified in accordance with ASNT Personnel Qualification SNT-TC-1A, ANSI/ASNT CP-189, NAS 410, or MIL-STD-410 for military purposes, or as specified in the contract or purchase order.

6.4 *Agency Qualification*—The agency performing this practice may be evaluated in accordance with Practice E 543.

6.5 *Materials*:

6.5.1 *Qualified Materials*—Only materials listed or approved for listing on QPL-25135 or QPL-AMS 2644 (reference MIL-I-25135 or AMS 2644) shall be utilized for penetrant examination. Materials not conforming to the requirements of MIL-I-25135 or 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 tested in accordance with Test Method D 2512 and passing at 70 ft·lbf (95 J) or higher, shall be used on LOX wetted surfaces that cannot be thoroughly postcleaned. Use of these materials shall be 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 MIL-I-25135 or AMS-2644.

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.

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 (1000 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 (20 lx) at the examination surface. The black lights shall provide a minimum of 1000 $\mu W/cm^2$ at the examination surface. Black lights shall meet the requirements of 7.8.5.1. 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 black light intensity shall meet the above requirements.

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 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 of the actual oven temperature.

6.7 *Written Procedures*—All 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 a minimum, the following information is required either in individual procedures, 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 Test Method E 165 for detailed cleaning methods and instructions.

6.7.2 Classification of the penetrant examination materials required in accordance with Section 5 and MIL-I-25135 or 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 Test Method E 165 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 Test Method E 165 for additional details.

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 Test Method E 165 for additional details.

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, sandblasting, 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 1—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 inservice 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 MIL-I-25135 or 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 prior to a Type I penetrant examination of the same surface. This is not intended to eliminate the use of in-process Type II inspections 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*—The results of all 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: a reference to the specific procedures used; location, classification, and disposition of relevant indications; the inspector's inspection 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 Solvent cleaning, that includes vapor degreasing, solvent soak, ultrasonic cleaning, or aqueous-based cleaning solutions shall be used for the removal of oils, greases, waxes and as the final cleaning step prior to penetrant examination unless etching is required.

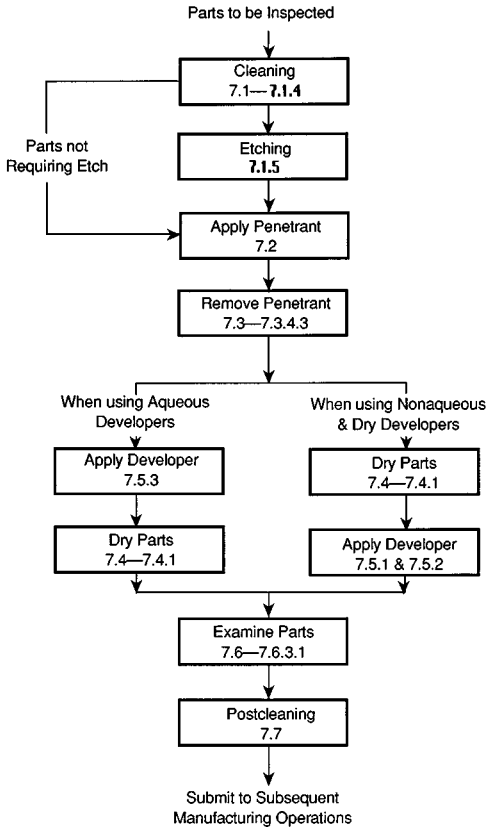

FIG. 1 Process Flow Chart

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.

NOTE 2—**Precaution:** 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.

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. Rotate or otherwise move components, if required, during dwell to prevent pooling of the penetrant. For dwell times greater than 2 h, the penetrant shall be reapplied as required to prevent drying. The component shall be immersed in penetrant, if that is the application method, for no longer than half the total dwell time.

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.

7.3.1.1 *Manual Spray*—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.

NOTE 3—**Caution:** 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 Test Method E 165.

7.3.1.2 *Automated Spray*—For automated spray systems, the wash parameters shall be such that the requirements of this practice 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).

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 for Method A.

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 spray removal of the penetrant/emulsifier mixture, the parameters of 7.3.1 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 shall apply.

7.3.4.2 Hydrophilic emulsifier shall be applied by immersion, flowing, foaming, or spray. 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. For immersion applications, the emulsifier or part may 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. For spray applications, the concentration shall not exceed 5 %.

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 shall

apply for the hydrophilic emulsifier. 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 illumination 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 MIL-I-25135 or AMS-2644 may be used without developer under either one of the following conditions: manufacturing examination of aluminum and magnesium castings classified by MIL-STD-2175 as Class 3 or 4, or with the expressed approval of the cognizant engineering organization. Minimum and maximum penetrant bleedout times without developer shall be 10 min and 2 h respectively. When developer is used, components that are not inspected before the maximum bleedout time shall be cleaned and reprocessed. When developer is not used, components that are not inspected before the maximum bleedout time shall be 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 inspected. Excess dry developer may be removed after the development time by light tapping or light air blow-off not exceeding 5 psi. 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 during application.

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 *Inspection*—The inspection area shall meet the appropriate requirements of 7.8.5.3. Components shall be inspected before the maximum developing time, and if required by specific procedures, monitored periodically during the developing time. Components not inspected before the maximum developing time shall be cleaned and reprocessed.

7.6.1 *Type I Processes*—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 black light. Black lights shall meet the requirements of 7.8.5.1. 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 inspection shall be evaluated in accordance with specified acceptance criteria.

7.6.3.1 *Indication Verification*—If allowed by the specific procedure, indications may be evaluated by wiping the indication with a solvent-dampened swab or brush, allowing the area to dry, and redeveloping. Redevelopment time shall be as long as the original development time, except nonaqueous redevelopment time shall be 3 min minimum. If no indication reappears, the original indication is considered false. This procedure may be performed twice for any given original indication.

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*—Either the indication or the discontinuity may be sized:

7.6.4.1 *Indication Sizing*—When sizing indications, the area shall be carefully evaluated under appropriate lighting after the required development time. Black and visible lights shall meet the requirements of 6.6.1.

7.6.4.2 *Discontinuity Sizing*—When sizing discontinuities, the area may be carefully wiped with solvent and the discontinuity measured using a scale and appropriate light that meets the requirements of 6.6.1. Discontinuities that are too small to be seen may be carefully wiped clean with solvent and the indication measured just as it is forming.

7.7 *Postcleaning*—Components shall be cleaned after examination to remove developers and other examination material residues if these are detrimental to subsequent operations or the components' intended function.

7.8 *Quality Control Provisions*—This section provides the controls necessary to ensure that the penetrant system materials and equipment provide an acceptable level of performance. The frequency of the required checks, as shown in Table 1 is based upon a facility operating in multi-shift operations daily. For facilities operating less frequently, the frequency of daily and weekly checks may be reduced, but must be performed prior to examinations. Other checks should be performed at the same frequency as for full-time operations. The NDT facility may perform these process control operations or contract for their performance with an independent laboratory.

7.8.1 *Material Conformance (New)*—Prior to being placed in use, the conformance of materials to the requirements of MIL-I-25135 or AMS-2644 shall be verified, normally by a certified report from the supplier. Use of materials not conforming to MIL-I-25135 or AMS-2644 shall be approved by the cognizant engineering organization prior to use and shall be allowed only when materials conforming to MIL-I-25135 or AMS-2644 are inadequate for the particular application. Operators shall be alert to any changes in performance, color, odor, consistency, or appearance of all penetrant materials in use and shall conduct the appropriate checks and tests if they have reason to believe the quality may have deteriorated. Penetrant examination shall be conducted in accordance with this practice only after acceptable quality of materials has been established.

TABLE 1 Tests and Test Frequency

Tests	Frequency	Paragraph
System Performance	Daily	7.8.3
Penetrant Contamination	Daily	7.8.2.1
Developer Contamination (Aqueous: Soluble and Suspendable)	Daily	7.8.2.5
Developer Concentration (Aqueous: Soluble and Suspendable)	Weekly	7.8.2.6
Developer Condition (Dry)	Daily	7.8.2.4
Water Wash Pressure[A]	Each shift	7.8.5.4
Water Wash Temperature[A]	Each shift	7.8.5.4
Back Light Intensity	Daily	7.8.5.1
Inspection Area Cleanliness[A]	Daily	7.8.5.3
Water-Based Penetrant Water Concentration	Weekly	7.8.2.2
Non-Water-Based Penetrant (Method A) Water Content	Monthly	7.8.2.2
Emulsifier Concentration (Hydrophilic)	Weekly	7.8.2.7
Penetrant Sensitivity[B]	Weekly	7.8.4.3
Fluorescent Brightness (Test Method E 1135)[B]	Quarterly	7.8.4.1
Penetrant Removability[B]	Monthly	7.8.4.2
Emulsifier Removability[B]	Monthly	7.8.4.4
Emulsifier Water Content (lipophilic)	Monthly	7.8.2.3
Drying Oven Calibration[C]	Quarterly	7.8.5.5
Light Meter Calibration[C]	Semiannually	7.8.5.2

[A] Need not be recorded.

[B] These checks can be combined and performed during the system performance check in accordance with 7.8.4.

[C] The maximum time between verifications may be reduced or extended when substantiated by actual technical/reliability data.

7.8.2 *Material Checks (In-Use)*—The tests identified in 7.8.2.1 through 7.8.4, whichever is applicable, shall be conducted on in-use materials at frequencies specified in Table 1 and recorded. Records shall be maintained in a specified location for audit by the cognizant engineering organization. Materials that are not recovered or reused, or both, such as materials packaged in aerosol containers, are not subject to the requirements of 7.8.2.

7.8.2.1 *Penetrant Contamination*—The in-use penetrant materials shall be viewed at intervals specified in Table 1 to determine if any of the following conditions are evident: precipitates, waxy deposits, white coloration, separation of constituents, surface scum, or any other evidence of contamination or breakdown. When any of the above conditions are detected the material shall be discarded or modified in accordance with the manufacturers' instructions.

7.8.2.2 *Water Content (Method A Penetrants Only)*—Water content of Method A penetrants shall be checked using the appropriate test method at the frequency specified in Table 1. The concentration of Method A, water-based penetrant shall be checked with a refractometer at the frequency specified in Table 1. The water content must be maintained according to manufacturer's recommendation. Water content of Method A, non-water-based penetrant shall be checked in accordance with Test Method D 95 or Karl Fischer Method as described in Annex A1. If the water content of the in-use penetrant exceeds 5 %, then either discard the penetrant or add sufficient unused penetrant to reduce the water content below 5 %.

7.8.2.3 *Water Content (Lipophilic Emulsifier)*—Water content shall be checked in accordance with Test Method D 95 or Karl Fischer method as described in Annex A1 at the frequency specified in Table 1. If the used emulsifier exceeds the water content of the original emulsifier by more than 5 % it shall be discarded or corrected, as appropriate.

7.8.2.4 *Developer Condition (Dry)*—Dry developer shall be checked at the frequency specified in Table 1 to ensure it is fluffy and not caked. Caked dry developer is unsatisfactory and shall be replaced. For dry developer that is recycled, ten or more fluorescent specks observed under black light in a 4-in. (10-cm) diameter circle when a sample is spread into a thin layer on a flat surface, is unsatisfactory.

7.8.2.5 *Developer Contamination (Aqueous: Soluble and Suspendable)*—Aqueous developers shall be checked for fluorescence, as appropriate, and coverage at the frequency specified in Table 1. Immerse a clean aluminum panel, about 3 by 10 in. (8 by 25 cm) and remove for drying and observation under

a black light. Failure to uniformly wet the panel or observed fluorescence is unsatisfactory and the developer shall be replaced.

7.8.2.6 *Developer Concentration (Aqueous: Soluble and Suspendable)*—Aqueous developer concentration shall be checked with a hydrometer at the frequency specified in Table 1. Concentration shall be in accordance with the developer supplier's recommendation.

7.8.2.7 *Emulsifier Concentration (Hydrophilic)*—Concentration of emulsifier solutions shall be checked with a refractometer at the frequency specified in Table 1 for conformance to 7.3.4.2. A longer period may be used if a plan justifying this extension is prepared by the NDT facility and approved by the cognizant engineering organization.

7.8.3 *System Performance*—The penetrant system shall be checked at the frequency specified in Table 1 for performance. The check shall be made with known defect standards. The check shall be performed by processing the known defect standard through the system using appropriate processing parameters and comparing the indications thus obtained to those obtained with unused samples of the same materials. This comparison may be made with other records of previously obtained indications or with a similar known defect standard processed with the unused materials. When the performance of the in-use materials falls below the performance of the unused materials, the in-use material quality shall be checked in accordance with the appropriate sections in 7.8.4 prior to conducting any penetrant examination in accordance with this practice. The unacceptable used material shall be discarded.

7.8.3.1 *Known Defect Standards*—The selection and procedures for the maintenance of known defect standards shall be approved by the cognizant engineering organization. The defects in the standard shall be capable of demonstrating unsatisfactory system performance. The maintenance procedures shall ensure that cleaning of the standards between usages is adequate and that physical changes in the standard that make it unsuitable for use can be detected.

7.8.4 *System Checks*—The test specified in 7.8.4.1 through 7.8.4.4 shall be made at frequencies specified in Table 1. These periodic checks of penetrant materials may be waived if the known defect standard(s) selected for the system performance check adequately monitor the serviceability of the penetrant materials and the results of the daily performance checks are documented in sufficient detail to allow an audit to detect deterioration of performance below satisfactory levels.

7.8.4.1 *Penetrant Brightness*—Brightness tests of in-use fluorescent penetrants shall be conducted at the frequency specified in Table 1. Tests shall be in accordance with Test Method E 1135 with a sample of the unused penetrant serving as the reference. Brightness values less than 90 % of the unused penetrant brightness are unsatisfactory and the in-use penetrants shall be discarded or otherwise corrected, as appropriate.

7.8.4.2 *Penetrant Removability (Method A Only)*—The removability of Method A penetrants shall be tested at the frequency specified in Table 1. The test piece specified in MIL-I–25135 or AMS-2644 shall be used for this test. Tests shall be by normal wash parameters used when processing production parts with a sample of the unused penetrant serving as a reference or in accordance with MIL-I-25135 or AMS-2644. If the removability is noticeably less than the reference, the in-use penetrant shall be replaced.

7.8.4.3 *Penetrant Sensitivity*—The sensitivity of penetrants shall be checked in accordance with the procedures of 7.8.3 when the in-use penetrant is used with the unused emulsifier, if applicable, and unused developer if applicable and compared to the results obtained using the unused penetrant, unused emulsifier, if applicable, and unused developer, if applicable. Sensitivity of the in-use penetrant noticeably less than the reference is unsatisfactory.

7.8.4.4 *Emulsifier Removability*—Removability of the in-use emulsifier shall be tested at the frequency specified in Table 1 by normal wash parameters used when processing production parts with a sample of the unused emulsifier serving as a reference or in accordance with MIL-I-25135 or AMS-2644. The test piece specified in MIL-I-25135 or AMS-2644 shall be used for this test. The in-use emulsifier will be used with the unused penetrant and compared to the reference system of unused emulsifier used with the unused penetrant. Removability less than that of the reference system is unsatisfactory.

7.8.5 *Equipment Checks*—The following equipment checks shall be made at frequencies specified in Table 1 and recorded. Records shall be maintained in a specified location and available for audit by the cognizant engineering organization. The calibration of equipment shall be traceable to the National Institute of Standards and Technology (NIST) or other recognized national standards, where applicable.

7.8.5.1 *Black Lights*—Blacklights, portable, hand-held, permanently mounted or fixed, which are used to inspect parts, shall be checked for output at the frequency specified in Table 1 and after bulb replacement. A longer period may be used if a plan justifying this extension is prepared by the NDT facility or its designated delegate. Minimum acceptable intensity is 1000 $\mu w/cm^2$ (10 W/m^2) at 15 in. (38.1 cm) from the front of the filter to the face of the sensor. Blacklights shall be checked periodically for cleanliness and integrity and shall be cleaned, repaired or replaced as appropriate.

7.8.5.2 *Light Meters*—Both the black and visible light meters shall be calibrated in accordance with MIL-STD-45662 or ANSI/NCSL Z540-1.

7.8.5.3 *Inspection Area*—The inspection area for stationary systems shall be clean and free from excessive fluorescent contamination and residual visible light background.

7.8.5.4 *Water Wash Operating Pressures/Temperatures*—Indicators and controls shall be checked at the start of each shift to ensure proper settings. Those indicators displaying out-of-control settings shall be adjusted to the proper settings. Indicators and controls shall be calibrated at intervals in accordance with MIL-STD-45662 or ANSI/NCSL Z540-1 or ISO 10012-1.

7.8.5.5 *Drying Oven Calibration*—The temperature controlling device and the temperature indicating device, if separate from the controller, on the drying oven shall be calibrated to the requirements of 6.6.2 at frequencies established in accordance with the requirements of MIL-STD-45662 or ANSI/NCSL Z540-1 or ISO 10012-1.

7.9 *Marking and Identification*—Components successfully passing the penetrant examination shall be identified and marked as follows:

7.9.1 *Marking*—Marking shall be applied in a manner and location that is harmless to the component, or its intended function, and to preclude removal, smearing, or obliteration by subsequent handling. When subsequent processing would remove such identification, the records accompanying the component shall be marked or shall specify components to the applicable documents. The methods of marking are listed in 7.9.2. Marking shall conform to MIL-STD-792.

7.9.2 *Impression Stamping Ink Stamping, Dyeing, Laser Marking, Vibro Engraving, Peening or Etching*—The specific method to be used shall be specified in the contract document (purchase order, drawing, specification, etc.). If not specified, ink stamping shall be used. Marking shall be located in areas adjacent to the part number or an area specified by the contract documents.

7.9.3 *Other Identification*—Other means of identification, such as tagging, may be applied when the construction, finish, or functional requirements of the component preclude etching, dyeing, or stamping. Items such as bolts, nuts, or other small parts may be identified by conspicuously marking each package.

7.9.4 *Symbols*—Each component that has successfully passed examination shall be marked as follows:

7.9.4.1 When etching or stamping is applicable, symbols shall be used. The stamping may contain an identification symbol or supplier number of the facility and a unique number or symbol identifying the examiner. Except for specialized applications, use the symbol "P" to denote 100 % examination. All components, in the lot sampled, accepted on sampling basis shall be marked with the symbol "P" enclosed by an ellipse.

7.9.4.2 When dyeing is used, maroon dye shall be used to denote components accepted on a 100 % examination basis. Yellow dye shall be used to denote a sampling basis when sampling is permitted.

8. Keywords

8.1 dye liquid penetrant inspection; dye penetrant inspection; fluorescent liquid penetrant inspection; fluorescent penetrant inspection; liquid penetrant inspection; liquid penetrant examination; liquid penetrant testing; nondestructive; nondestructive evaluation; nondestructive examination; nondestructive inspection; nondestructive testing; penetrant examination; penetrant inspection; penetrant testing

ANNEX

(Mandatory Information)

A1. METHOD FOR MEASURING WATER CONTENT

A1.1 Scope and Application—This modified Karl Fischer volumetric procedure is a practical alternative to Test Method D 95 for undiluted hydrophilic emulsifiers and water contamination of in-use lipophilic emulsifiers and Method A penetrants. The amount of sample used is adjusted to meet the water equivalent capacity of the titration agent employed (1 ml = 5 mg H_2O). For most materials required to meet the five percent (5 %) maximum allowable water content limit, 0.5 to 1.0 g sample size is sufficient.

A1.2 Apparatus:

A1.2.1 *Buret*, glass, 50-ml,

A1.2.2 *Flask*, wide-mouth Erlenmeyer type, 250-ml,

A1.2.3 *Pipets*, volumetric, two, 10-ml,

A1.2.4 *Weighing scale*, reads to at least two decimal places, and

A1.2.5 *White paper*.

A1.3 Reagents:

A1.3.1 *Buffer solution,*[10] Hydranal (Riedel de Haen) or Hydra-Point (J.T. Baker), 500 ml,

A1.3.2 *Titrant,*[10] Hydranal Composite 5 (Riedel de Haen) or Hydra-Point Titrant 5, 1 L, and

A1.3.3 *Methanol*, reagent grade, 500 mL.

A1.4 Analytical Procedure:

A1.4.1 Charge buret with Hydranal titrant.

A1.4.2 Pipet 10 mL of methanol into clean dry Erlenmeyer flask.

A1.4.3 Pipet 10 mL of Hydranal buffer into the same flask and gently swirl to mix.

A1.4.4 Place white paper below buret. Place the flask under the buret and slowly titrate, with gently swirling the Hydranal titrant into the flask until a light yellow-brown color persists (about 3 mL).

A1.4.5 Record titrant reading.

A1.4.6 Place the flask on balance and add about 0.5 g of test sample, and record weight. Gently swirl flask to mix sample.

A1.4.7 Place flask under buret and titrate back to the same yellow-brown color and record the reading.

A1.4.8 Repeat and average % H_2O readings.

A1.5 Calculate Water Content as follows:

$$\% H_2O = [\text{consumption titrant} \times \text{titer value} \times 100] \div \text{sample weight} \quad \text{(A1.1)}$$

where:

[10] The sole source of supply for the reagents known to the committee at this time is Crescent Chemical Company, Inc., 1324 Motor Parkway, Hauppauge, NY 11788. If you are aware of alternative suppliers, please provide this information to ASTM Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee,[1] which you may attend.

consumption = second buret reading of Hydranal Composite 5 Titrant minus the first buret reading, mL,
titer value = 5 mg/ml H_2O, mg/mL, and
sample weight = weight of sample added, mg.

A1.6 Repeat and average % H_2O readings.