Designation: E 1418 – 98

Standard Test Method for Visible Penetrant Examination Using the Water-Washable Process[1]

This standard is issued under the fixed designation E 1418; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method describes procedures for visible liquid penetrant examination utilizing the water-washable process. It is a nondestructive test method for detecting discontinuities that are open to the surface such as cracks, seams, laps, cold shuts, laminations, isolated porosity, through leaks or lack of fusion and is applicable to in-process, final, and maintenance examination. This test method can be effectively used in the examination of nonporous, metallic materials, both ferrous and nonferrous, and of nonmetallic materials such as glazed or fully densified ceramics, and certain nonporous plastics, and glass.

1.2 This test method also provides the following references:

1.2.1 A reference by which visible penetrant examination procedures using the water-washable process can be reviewed to ascertain their applicability and completeness.

1.2.2 For use in the preparation of process specifications dealing with the visible, water-washable liquid penetrant examination of materials and parts. Agreement between the user and the supplier regarding specific techniques is strongly recommended.

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

1.3 This test method does not indicate or suggest criteria for evaluation of the indications obtained. It should be noted, however, that after indications have been produced, they must be interpreted or classified and then evaluated. For this purpose there must be a separate code, specification, or a specific agreement to define the type, size, location, and orientation of indications considered acceptable, and those considered unacceptable.

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

1.5 *Basis of Application*—There are areas in this test method that may require agreement between the cognizant engineering organization and the supplier, or specific direction from the cognizant engineering organization. These areas are identified as follows:

1.5.1 Penetrant type, method and sensitivity,
1.5.2 Accept/reject criteria,
1.5.3 Personnel qualification requirements,
1.5.4 Grit blasting,
1.5.5 Etching,
1.5.6 Indication/discontinuity sizing,
1.5.7 Total processing time, and
1.5.8 Marking of parts.

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.* For specific precautionary statements, see Notes 1, 3, 4, 5, 7, 9, 10, 11, 13, 14, 15, 16, and 17.

2. Referenced Documents

2.1 *ASTM Standards:*

D 129 Test Method for Sulfur in Petroleum Products (General Bomb Method)[2]
D 516 Test Methods for Sulfate Ion in Water[3]
D 808 Test Method for Chlorine in New and Used Petroleum Products (Bomb Method)[2]
D 1552 Test Method for Sulfur in Petroleum Products (High-Temperature Method)[2]
E 165 Test Method for Liquid Penetrant Examination[4]
E 433 Reference Photographs for Liquid Penetrant Inspection[4]
E 543 Practice for Evaluating Agencies that Perform Nondestructive Testing[4]
E 1316 Terminology for Nondestructive Examinations[4]

[1] This test method 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.

Current edition approved Dec. 10, 1998. Published February 1999. Originally published as E 1418 – 91. Last previous edition E 1418 – 92.

[2] *Annual Book of ASTM Standards*, Vol 05.01.
[3] *Annual Book of ASTM Standards*, Vol 11.01.
[4] *Annual Book of ASTM Standards*, Vol 03.03.

2.2 *ASNT Standards:*

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

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

2.3 *Military Standard:*

MIL-STD-410 Nondestructive Testing Personnel Qualification and Certification[6]

2.4 *AIA Standard:*

NAS-410 Certification and Qualification of Nondestructive Test Personnel[7]

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

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

3. Terminology

3.1 *Definitions:*

3.1.1 The definitions relating to liquid penetrant examination that appear in Terminology E 1316, shall apply to the terms used in this test method.

4. Summary of Test Method

4.1 A liquid penetrant is applied evenly over the surface being examined and allowed to enter open discontinuities. After a suitable dwell time, the excess surface penetrant is removed with water and the surface is dried prior to the application of a developer. A developer is then applied, drawing the entrapped penetrant out of the discontinuities and staining the developer. If an aqueous developer is to be employed, the developer is applied prior to the drying step. After application of the developer, a suitable development time is allowed to permit the entrapped penetrant to exit from the discontinuities. The test surface is then examined visually under adequate illumination to determine the presence or absence of indications.

4.2 The selection of specific water-washable penetrant process parameters depends upon the nature of the application, conditions under which the examination is to be performed, availability of processing equipment, and type of materials to perform the examination.

NOTE 1—**Caution:** A controlled method for applying water and disposing of the water is essential.

4.3 Processing parameters, such as precleaning, penetration time and wash times, are determined by the specific materials used, the nature of the part under examination (that is, size, shape, surface condition, alloy) and type of discontinuities expected.

5. Significance and Use

5.1 Liquid penetrant examination methods indicate the presence, location, and, to a limited extent, the nature and magnitude of the detected discontinuities. This test method is normally used for production examination of large volumes of parts or structures, where emphasis is on productivity. This test method offers a wide latitude in applicability when extensive and controlled conditions are available.

6. Reagents and Materials

6.1 *Visible, Water-Washable Liquid Penetrant Examination Materials*, consisting of applicable visible penetrants as recommended by the manufacturer, and are classified as Type II Visible Method A—Water-Washable (see Note 2).

NOTE 2—Refer to 8.1 for special requirements for sulfur, halogen, and alkali metal content.

NOTE 3—**Caution:** While approved penetrant materials will not adversely affect common metallic materials, some plastics or rubber may be swollen or stained by certain penetrants.

6.2 *Water-Washable Penetrants*, designed to be directly water-washable from the surface of the part, after a suitable penetrant dwell time. Because the emulsifier is "built-in" to the water-washable penetrant, it is extremely important to exercise proper process control in removing excess penetrant to ensure against overwashing. Water-washable penetrants can be washed out of discontinuities if the washing step is too long or too vigorous. Some penetrants are less resistant to overwashing than others.

6.3 *Developers*—Development of penetrant indications is the process of bringing the penetrant out of open discontinuities through the blotting action of the applied developer, thus increasing the visibility of the penetrant indications. Several types of developers are suitable for use in the visible penetrant water-washable process.

6.3.1 *Aqueous Developers*, normally supplied as dry powder particles to be either suspended or dissolved (soluble) in water. The concentration, use, and maintenance shall be in accordance with the manufacturer's recommendations (see 7.1.7.1).

NOTE 4—**Caution:** Aqueous developers may cause stripping of indications, if not properly applied and controlled. The procedure should be qualified in accordance with 9.2.

6.3.2 *Nonaqueous, Wet Developers*, normally supplied as suspensions of developer particles in a volatile solvent carrier and are ready for use as supplied. They are applied to the surface by spraying after the excess penetrant has been removed and the surface has dried. Nonaqueous wet developers form a white coating on the surface of the part when dried and serve as a contrasting background for visible penetrants (see 7.1.7.2).

NOTE 5—**Caution:** This type of developer is intended for application by spray only.

6.3.3 *Liquid Film Developers*, solutions or colloidal suspensions of resins/polymer in a suitable carrier. These developers

[5] Available from the American Society for Nondestructive Testing, 1711 Arlingate Lane, PO Box 28518, Columbus, OH 43228–0518.

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

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

will form a transparent or translucent coating on the surface of the part. Certain types of film developers will fix indications and may be stripped from the part and retained for record purposes (see section 7.1.7.3).

7. Procedure

7.1 The following general procedures applies to the water-washable, visible penetrant examination method (see Fig. 1).

7.1.1 *Temperature Limits*—The temperature of the penetrant materials and the surface of the part to be processed should be from 40 to 120°F (4 to 49°C). When it is not practical to comply with these temperature limitations, the procedure must be qualified at the temperature of intended use as described in 9.2.

7.1.2 *Surface Conditioning Prior to Penetrant Examination*—Satisfactory results can usually be obtained on surfaces in the as-welded, as-rolled, as-cast, or as-forged conditions (or for ceramics in the densified condition). When only loose surface residuals are present, these may be removed by wiping with a clean lint-free cloth. However, pre-cleaning of metals to remove processing residuals such as oil, graphite, scale, insulating materials, coatings, etc. should be done using cleaning solvents, vapor degreasing, or chemical removing processes. Surface conditioning by grinding, machining, polishing, or etching shall follow shot, sand, grit, and vapor blasting to remove the peened skin, and when penetrant entrapment in surface irregularities might mask the indications of unacceptable discontinuities or otherwise interfere with the

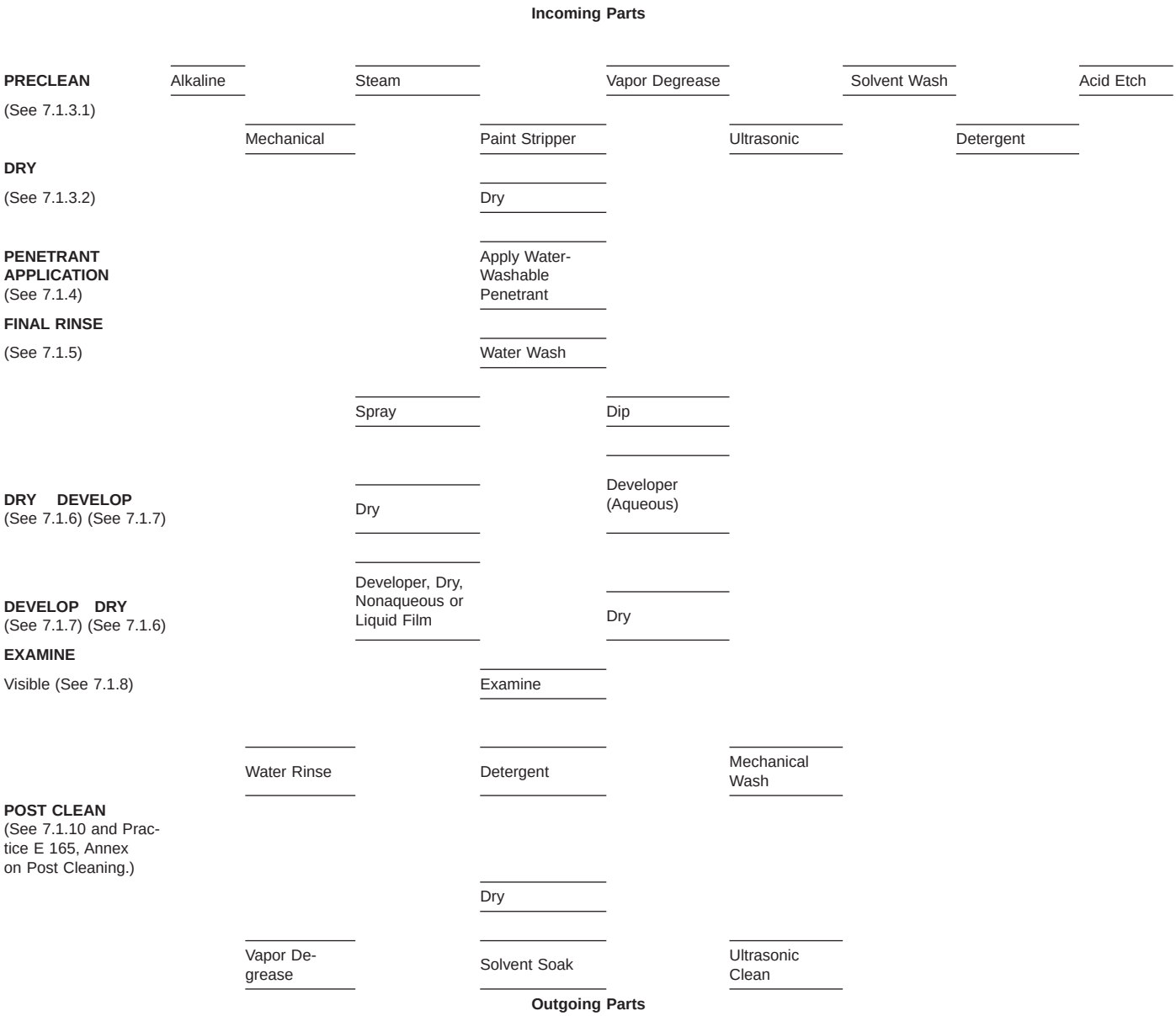

FIG. 1 General Procedure Flowsheet for Visible Penetrant Examination Using the Water-Washable Process

effectiveness of the examination. For metals unless otherwise specified, perform etching when evidence exists that previous cleaning, surface treatments, or service usage have produced a surface condition that degrades the effectiveness of penetrant examination. (See Annex A1.1.1.8 in Test Method E 165 for precautions).

NOTE 6—When agreed between purchaser and supplier, grit blasting without subsequent etching may be an acceptable cleaning method.

NOTE 7—**Caution:** Sand or shot blasting may possibly close indications and extreme care should be used with grinding and machining operations.

NOTE 8—For structural or electronic ceramics, surface preparation by grinding, sand blasting and etching for penetrant examination is not recommended because of the potential for damage.

7.1.3 *Removal of Surface Contaminants*:

7.1.3.1 *Precleaning*—The success of any penetrant examination procedure is greatly dependent upon the surface and discontinuity being free of any contaminant (solid or liquid) that might interfere with the penetrant process. All parts or areas of parts to be examined must be clean and dry before the penetrant is applied. If only a section of a part, such as weld, including the heat affected zone is to be examined, remove all contaminants from the area being examined as defined by the contracting parties.“ Clean” is intended to mean that the surface must be free of rust, scale, welding flux, spatter, grease, paint, oily films, dirt, etc., that might interfere with penetration. All of these contaminants can prevent the penetrant from entering discontinuities. (See the annex on cleaning of parts and materials in Test Method E 165 for more detailed cleaning methods.)

NOTE 9—**Caution:** Residues from cleaning processes such as strong alkalies, pickling solutions, and chromates, in particular, may adversely react with the penetrant and reduce its sensitivity and performance.

7.1.3.2 *Drying After Cleaning*—It is essential that the surfaces be thoroughly dry after cleaning, since any liquid residue will hinder the entrance of the penetrant. Drying may be accomplished by warming the parts in drying ovens, with infrared lamps, forced hot or cold air, or by exposure to ambient temperature.

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

7.1.4.1 *Modes of Application*—There are various modes of effective application of penetrant such as immersion, brushing, flooding, or spraying. Small parts are quite often placed in suitable baskets and dipped into a tank of penetrant. On larger parts, and those with complex geometries, penetrant can be applied effectively by brushing or spraying. Both conventional and electrostatic spray guns are appropriate means of applying liquid penetrants to the part surfaces. Electrostatic spray application can eliminate excess liquid build-up of penetrant on the surface, minimize overspray, and minimize the amount of penetrant entering hollow-cored passages that might serve as penetrant reservoirs, causing severe bleedout problems during examination. Aerosol sprays are also very effective and a convenient portable means of application.

NOTE 10—**Caution:** Not all penetrant materials are suitable for electrostatic spray applications, so tests should be conducted prior to use.

NOTE 11—**Warning:** With spray applications, it is important that there be proper ventilation. This is generally accomplished through the use of a properly designed spray booth or exhaust system, or both.

7.1.4.2 *Penetrant Dwell Time*—After application, allow excess penetrant to drain from the part (care should be taken to prevent pools of penetrant on the part), while allowing for proper penetrant dwell time (see Table 1). The length of time the penetrant must remain on the part to allow proper penetration should be as recommended by the penetrant manufacturer. Table 1, however, provides a guide for selection of penetrant dwell times for a variety of materials, their form, and types of discontinuities.

NOTE 12—For some specific applications in structural ceramics (for example, detecting parting lines in slip-cast material), the required penetrant dwell time should be determined experimentally and may be longer than that shown in Table 1 and its notes.

7.1.5 *Removal of Excess Penetrant*—After the required penetration time, the excess penetrant on the surface being examined must be removed with water, usually a washing operation. It can be washed off manually, by the use of automatic or semi-automatic water-spray equipment or by immersion. Accumulation of water in pockets or recesses of the surface must be avoided. If the final rinse step is effective, as evidenced by difficulty in removing the excess penetrant, dry (see 7.1.6) and reclean the part, then reapply the penetrant for the prescribed dwell time.

NOTE 13—**Caution:** Avoid overwashing. Excessive washing can cause

TABLE 1 Recommended Minimum Dwell Times

Material	Form	Type of Discontinuity	Dwell Times[A] (minutes)	
			Penetrant[B]	Developer[C]
Aluminum, magnesium, steel, brass and bronze, titanium and high-temperature alloys	castings and welds	cold shuts, porosity, lack of fusion, cracks (all forms)	5	10
	wrought materials—extrusions, forgings, plate	laps, cracks (all forms)	10	10
Carbide-tipped tools		lack of fusion, porosity, cracks	5	10
Plastic	all forms	cracks	5	10
Glass	all forms	cracks	5	10
Ceramic	all forms	cracks, porosity	5	10

[A] For temperature range from 40 to 120°F (4 to 49°C).

[B] Maximum penetrant dwell time 60 min in accordance with 7.1.4.2.

[C] Development time begins as soon as wet developer coating has dried on surface of parts (recommended minimum). Minimum development time in accordance with 7.1.7.2.

penetrant to be washed out of discontinuities.

7.1.5.1 *Rinsing*—For immersion rinsing, parts are completely immersed in the water bath with air or mechanical agitation. Effective rinsing of water-washable penetrants by spray application can be accomplished by either manual or automatic water-spray rinsing of the parts.

(a) (*a*) Rinse time should not exceed 120 s unless otherwise specified by part or material specification.

(b) (*b*) The temperature of the water should be relatively constant and should be maintained within the range of 50 to 100°F (10 to 38°C).

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

7.1.5.2 *Removal by Wiping*—In special applications, penetrant removal may be performed by wiping the surface with a clean, absorbent material dampened with water until the excess surface penetrant is removed, as determined by visual examination. A solvent cleaner may be used instead of water to wipe off excess penetrant.

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

7.1.6.1 *Modes of Drying*—Parts can be dried by using a hot-air recirculating oven, a hot- or cold-air blast, or by exposure to ambient temperature. Drying is best done in a thermostatically controlled, recirculating hot-air dryer.

NOTE 14—**Caution:** Drying oven temperature should not exceed 160°F (71°C).

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

7.1.7 *Developer Application*—There are various modes of effective application of the various types of developers such as immersing, flooding, or spraying. The size, configuration, surface condition, number of parts to be processed, etc., will influence the choice of developer application.

7.1.7.1 *Aqueous Developers*—Apply aqueous developers to the part immediately after the excess penetrant has been removed from the part and prior to drying. The dried developer coating appears as a translucent or white coating on the part. Prepare and maintain aqueous developers in accordance with the manufacturer's instructions and apply them in such a manner as to ensure complete and even part coverage. Exercise caution when using a wet developer with water-washable penetrants to avoid possible stripping of indications. Aqueous developers may be applied by flowing, or immersing the part. Atomized spraying is not recommended since a spotty film may result. It is most common to immerse the parts in the prepared developer bath. Immerse parts only long enough to coat all of the part surfaces with the developer, since if parts are left in bath too long, penetrant entrapments may leach out. Immediately remove parts from the developer bath and allow to drain. Drain all excess developer from recesses and trapped sections to eliminate developer pooling, that can obscure discontinuities. Dry the parts in accordance with 7.1.6.

7.1.7.2 *Nonaqueous, Wet Developers*—Nonaqueous, wet developer carriers evaporate very rapidly at normal room temperature and do not, therefore, require the use of a dryer. After the excess penetrant has been removed and the surface has been dried, apply these developers to the surface by spraying in such a manner as to ensure complete coverage with a thin even film of developer. Application of excessive developer should be avoided. Dipping or flooding parts with nonaqueous, wet developers is prohibited, since it will flush (dissolve) the penetrant from within the discontinuities because of the solvent action of these types of developers.

NOTE 15—**Warning:** The vapors from the evaporating, volatile, solvent developer carrier may be hazardous. Proper ventilation should be provided in all cases, but especially when the surface to be examined is inside a closed volume such as a process drum or a small storage tank.

7.1.7.3 *Liquid Film Developers*—Apply by spraying or dipping as recommended by the manufacturer. Spray parts in such a manner as to ensure complete coverage of the area being examined with a thin and even film of developer.

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

7.1.8 *Examination*—Perform examination of parts after the applicable development time as specified in 8.1.7.5 to allow for bleedout or penetrant from discontinuities onto the developer coating. It is good practice to observe the surface while applying the developer as an aid in evaluating indications.

7.1.8.1 *Visible Light Level*—Visible penetrant indications can be examined in either natural or artificial light. Adequate illumination is required to ensure no loss of the sensitivity of the examination. A minimum light intensity at the examination site of 100 fc (1000 $1x/m^2$) is recommended.

7.1.8.2 *Housekeeping*—Keep the examination area free of interfering debris. Practice good housekeeping at all times.

7.1.9 *Evaluation*—Unless otherwise agreed upon, it is normal practice to evaluate the discontinuity indication based on the size of the developer stain created by the developer's absorption of the penetrant (see Reference Photographs E 433).

7.1.10 *Post Cleaning*—Post cleaning is necessary in those cases where residual penetrant or developer could interfere with subsequent processing or with service requirements. It is particularly important where residual penetrant examination materials might combine with other factors in service to produce corrosion. A suitable technique, such as machine wash, vapor degreasing, solvent soak, or ultrasonic cleaning may be employed (see the annex on post cleaning in Test Method E 165). In the case of developers, it is recommended that if developer removal is necessary, carry it out as promptly as possible after examination so that it does not fix on the part.

NOTE 16—**Caution:** Developers should be removed prior to vapor degreasing. Vapor degreasing can bake developer on parts.

8. Special Requirements

8.1 *Impurities*:

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

8.1.2 Because volatile solvents leave the surface quickly without reaction under normal inspection procedures, penetrant materials are normally subjected to an evaporation procedure to remove the solvents before the materials are analyzed for impurities. The residue from this procedure is then analyzed in accordance with Practice D 129, Test Method D 1552, or Practice D 129 for decomposition followed by Method B (Turbidimetric Method) of Test Methods D 516 for sulfur. The residue may also be analyzed in accordance with Test Method D 808 or the annex on methods for measuring total chlorine content in combustible liquid penetrant materials in Test Method E 165 (for halogens other than fluorine) and the annex on method for measuring total fluorine content in combustible liquid penetrant materials in Test Method E 165 (for fluorine). The Annex on Determination of Anions and Cations by Ion Chromatography in Test Method E 165 can be used as an alternate procedure. Alkali metals in the residue are determined by flame photometry or atomic absorption spectrophotometry.

NOTE 17—Some current standards indicate that impurity levels of sulfur and halogens exceeding 1 % of any one suspect element are considered excessive. However, this high a level may be unacceptable for some applications, so the actual maximum acceptable impurity level must be decided between supplier and user on a case by case basis.

8.2 *Elevated Temperature Examination*—Where penetrant examination is performed on parts that must be maintained at elevated temperature during examination, special materials and processing techniques may be required. Such examination requires qualification in accordance with 9.2. The manufacturer's recommendations should be observed.

9. Qualification and Requalification

9.1 *Personnel Qualification*—When required by user/supplier agreement, all examination personnel shall be qualified/certified in accordance with a written practice conforming to the applicable edition of Recommended Practice SNT-TC-1A, ANSI/ASNT-CP-189, NAS-410, or MIL-STD-410.

9.2 *Procedure Qualification*—Qualification of procedures using times or conditions differing from those specified or for new materials may be performed by any of several methods and should be agreed upon by the contracting parties. A test piece containing one or more discontinuities of the smallest relevant size is used. The test piece may contain real or simulated discontinuities, providing it displays the characteristics of the discontinuities encountered in production examinations.

9.3 *Nondestructive Testing Agency Qualification*—If a nondestructive testing agency as described in Practice E 543 is used to perform the examination, the agency shall meet the requirements of Practice E 543.

9.4 *Requalification* may be required when a change or substitution is made in the type of penetrant materials or in the procedure (see 9.2).

10. Keywords

10.1 nondestructive testing; visible liquid penetrant testing; water-washable method