ARTICLE 6

ARTICLE 6
LIQUID PENETRANT EXAMINATION

T-600 SCOPE

The liquid penetrant examination method is an effective means for detecting discontinuities which are open to the surface of nonporous metals and other materials. Typical discontinuities detectable by this method are cracks, seams, laps, cold shuts, laminations, and porosity.

In principle, a liquid penetrant is applied to the surface to be examined and allowed to enter discontinuities. All excess penetrant is then removed, the part is dried, and a developer is applied. The developer functions both as a blotter to absorb penetrant that has been trapped in discontinuities, and as a contrasting background to enhance the visibility of penetrant indications. The dyes in penetrants are either color contrast (visible under white light) or fluorescent (visible under ultraviolet light).

T-610 REFERENCING DOCUMENTS

01 **T-610.1** When specified by the referencing Code Section, the liquid penetrant examination techniques described in this Article shall be used. The following SE Standard provides details that may be considered in the specific procedures used:

(a) SE-165 Standard Test Method for Liquid Penetrant Examination

T-610.2 The liquid penetrant method described in this Article shall be used together with Article 1, General Requirements.

T-610.3 Definitions of terms used in this Article are in Mandatory Appendix I of this Article.

T-620 GENERAL

01 T-621 Procedure Requirements

01 **T-621.1** Liquid penetrant examination shall be performed in accordance with a written procedure. Each procedure shall include at least the following information, as applicable:

(a) the materials, shapes, or sizes to be examined, and the extent of the examination;

(b) type (number or letter designation if available) of each penetrant, penetrant remover, emulsifier, and developer;

(c) processing details for pre-examination cleaning and drying, including the cleaning materials used and minimum time allowed for drying;

(d) processing details for applying the penetrant: the length of time that the penetrant will remain on the surface (dwell time), and the temperature of the surface and penetrant during the examination if outside 50°F (10°C) to 125°F (52°C) range;

(e) processing details for removing excess penetrant from the surface, and for drying the surface before applying the developer;

(f) processing details for applying the developer, and length of developing time before interpretation;

(g) processing details for post-examination cleaning.

T-621.2 Procedure Revision. A revised procedure may be required:

(a) whenever a change or substitution is made in the type or family group of penetrant materials (including developers, emulsifiers, etc.) or in the processing techniques;

(b) whenever a change or substitution is made in the type of precleaning materials or processes;

(c) for any change in part processing that can close surface openings of discontinuities or leave interfering deposits, such as the use of grit blast cleaning or acid treatments.

T-630 EQUIPMENT

T-631 Penetrant Materials

The term *penetrant materials*, as used in this Article, is intended to include all penetrants, emulsifiers, solvents or cleaning agents, developers, etc., used in the examina-

tion process. The descriptions of the liquid penetrant classifications and material types are provided in SE-165.

T-640 REQUIREMENTS

T-641 Control of Contaminants

The user of this Article shall obtain certification of contaminant content for all liquid penetrant materials used on nickel base alloys, austenitic stainless steels, and titanium. These certifications shall include the penetrant manufacturers' batch numbers and the test results obtained in accordance with (a) and (b) below. These records shall be maintained as required by the referencing Code Section.

(a) When examining nickel base alloys, all materials shall be analyzed individually for sulfur content as follows.

(1) An individual sample of the penetrant materials with exception of cleaners shall be prepared for analysis by heating 50 g of the material in a 150 mm nominal diameter glass Petri dish at a temperature of 194°F to 212°F (90°C to 100°C) for 60 min.

PRECAUTION: Provide adequate ventilation to dissipate the emitted vapor.

(2) Analysis of the residue shall be as follows: If the residue is less than 0.0025 g, the material is acceptable without further analysis. If the residue is 0.0025 g or more, the procedure shown in (a)(1) above shall be repeated and the residue analyzed in accordance with SD-129 or SD-1552. Alternately, the material may be decomposed in accordance with SD-129 and analyzed in accordance with SD-516 Method B. The sulphur content shall not exceed 1% of the residue by weight.

(3) An individual sample of cleaner/remover material shall be prepared for analysis by heating 100 g of the material in a 150 mm nominal diameter glass Petri dish at a temperature of 194°F to 212°F (90°C to 100°C) for 60 min.

PRECAUTION: Provide adequate ventilation to dissipate the emitted vapor.

(4) Analysis of the residue shall be as follows: If the residue is less than 0.005 g, the material is acceptable without further analysis. If the residue is 0.005 g or more, the procedure shown in (a)(3) above shall be repeated and the residue analyzed in accordance with SD-129 or SD-1552. Alternately the material may be decomposed in accordance with SD-129 and analyzed in accordance with SD-516 Method B. The sulphur content shall not exceed 1% of the residue by weight.

(b) When examining austenitic stainless steel or titanium, all materials shall be analyzed individually for chlorine and fluorine content as follows.

(1) An individual sample of the penetrant materials with the exception of cleaners shall be prepared for analysis by heating 50 g of the material in a 150 mm nominal diameter glass Petri dish at a temperature of 194°F to 212°F (90°C to 100°C) for 60 min.

PRECAUTION: Provide adequate ventilation to dissipate the emitted vapor.

(2) If the residue is 0.0025 g or more, the procedure shown in (b)(1) above shall be repeated. The residue may be analyzed in accordance with SD-808 and the total shall not exceed 1% by weight. Or, alternately, the residue shall be analyzed in accordance with SE-165, Annex 2 for chlorine and SE-165, Annex 3 for fluorine, and the total chlorine plus fluorine content shall not exceed 1% by weight.

(3) An individual sample of the cleaner/remover material shall be prepared for analysis by heating 100 g of the material in a 150 mm nominal diameter glass Petri dish at a temperature of 194°F to 212°F (90°C to 100°C) for 60 min.

PRECAUTION: Provide adequate ventilation to dissipate the emitted vapor.

(4) If the residue is 0.005 g or more, the procedure shown in (b)(3) above shall be repeated. The residue may be analyzed in accordance with SD-808 and the total shall not exceed 1% by weight. Or, alternately, the residue shall be analyzed in accordance with SE-165, Annex 2 for chlorine and SE-165, Annex 3 for fluorine, and the total chlorine plus fluorine content shall not exceed 1% by weight.

(c) As an alternative to (a) and (b) above, SE-165, Annex A4 may be used for determination of anions by ion chromatography, which provides a single instrumental technique for rapid sequential measurement of common anions such as chloride, fluoride, and sulfate.

T-642 Surface Preparation

(a) In general, satisfactory results may be obtained when the surface of the part is in the as-welded, as-rolled, as-cast, or as-forged condition. Surface preparation by grinding, machining, or other methods may be necessary where surface irregularities could mask indications of unacceptable discontinuities.

(b) Prior to each liquid penetrant examination, the surface to be examined and all adjacent areas within at least 1 in. (25 mm) shall be dry and free of all dirt, grease, lint, scale, welding flux, weld spatter, paint, oil, and other extraneous matter that could obscure

surface openings or otherwise interfere with the examination.

(c) Typical cleaning agents which may be used are detergents, organic solvents, descaling solutions, and paint removers. Degreasing and ultrasonic cleaning methods may also be used.

(d) Cleaning solvents shall meet the requirements of T-641. The cleaning method employed is an important part of the examination process.

NOTE: Conditioning of surfaces prior to examination may affect the results. See SE-165, Annex A1.

T-643 Drying After Preparation

After cleaning, drying of the surfaces to be examined shall be accomplished by normal evaporation or with forced hot or cold air. A minimum period of time shall be established to ensure that the cleaning solution has evaporated prior to application of the penetrant.

T-650 PROCEDURE/TECHNIQUE

T-651 Techniques

Either a color contrast (visible) penetrant or a fluorescent penetrant shall be used with one of the following three penetrant processes:

(a) water washable

(b) post-emulsifying

(c) solvent removable

The visible and fluorescent penetrants used in combination with these three penetrant processes result in six liquid penetrant techniques.

T-652 Techniques for Standard Temperatures

As a standard technique, the temperature of the penetrant and the surface of the part to be processed shall not be below 50°F (10°C) nor above 125°F (52°C) throughout the examination period. Local heating or cooling is permitted provided the part temperature remains in the range of 50°F to 125°F (10°C to 52°C) during the examination. Where it is not practical to comply with these temperature limitations, other temperatures and times may be used, provided the procedures are qualified as specified in T-653.

T-653 Techniques for Nonstandard Temperatures

T-653.1 General. When it is not practical to conduct a liquid penetrant examination within the temperature range of 50°F to 125°F (10°C to 52°C), the examination procedure at the proposed lower or higher temperature range requires qualification. This shall require the use of a quench cracked aluminum block, which in this Article is designated as a liquid penetrant comparator block.

T-653.2 Liquid Penetrant Comparator. The liquid penetrant comparator blocks shall be made of aluminum, ASTM B 209, Type 2024, $^{3}/_{8}$ in. (10 mm) thick, and should have approximate face dimensions of 2 in. × 3 in. (52 mm × 76 mm). At the center of each face, an area approximately 1 in. (25 mm) in diameter shall be marked with a 950°F (510°C) temperature-indicating crayon or paint. The marked area shall be heated with a blowtorch, a Bunsen burner, or similar device to a temperature between 950°F (510°C) and 975°F (524°C). The specimen shall then be immediately quenched in cold water, which produces a network of fine cracks on each face.

The block shall then be dried by heating to approximately 300°F (149°C). After cooling, the block shall be cut in half. One-half of the specimen shall be designated block "A" and the other block "B" for identification in subsequent processing. Figure T-653.2 illustrates the comparator blocks "A" and "B." As an alternate to cutting the block in half to make blocks "A" and "B," separate blocks 2 in. × 3 in. (52 mm × 76 mm) can be made using the heating and quenching technique as described above. Two comparator blocks with closely matched crack patterns may be used. The blocks shall be marked "A" and "B."

T-653.3 Comparator Application

(a) If it is desired to qualify a liquid penetrant examination procedure at a temperature of less than 50°F (10°C), the proposed procedure shall be applied to block "B" after the block and all materials have been cooled and held at the proposed examination temperature until the comparison is completed. A standard procedure which has previously been demonstrated as suitable for use shall be applied to block "A" in the 50°F to 125°F (10°C to 52°C) temperature range. The indications of cracks shall be compared between blocks "A" and "B." If the indications obtained under the proposed conditions on block "B" are essentially the same as obtained on block "A" during examination at 50°F to 125°F (10°C to 52°C), the proposed procedure shall be considered qualified for use.

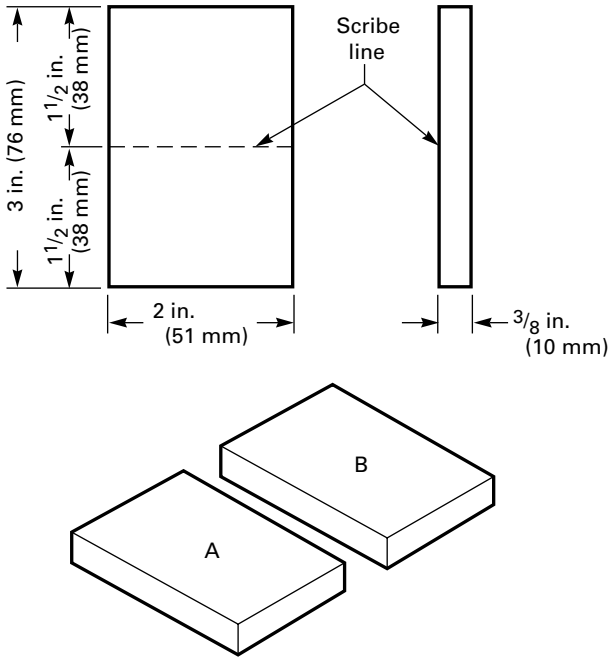

FIG. T-653.2 LIQUID PENETRANT COMPARATOR
(NOTE: Dimensions given are for guidance only and are not critical.)

(b) If the proposed temperature for the examination is above 125°F (52°C), block "B" shall be held at this temperature throughout the examination. The indications of cracks shall be compared as described in T-653.3(a) while block "B" is at the proposed temperature and block "A" is at the 50°F to 125°F (10°C to 52°C) temperature range.

(c) A procedure qualified at a temperature lower than 50°F (10°C) shall be qualified from that temperature to 50°F (10°C).

(d) To qualify a procedure for temperatures above 125°F (52°C), the upper and lower temperature limits shall be established and the procedure qualified at these temperatures.

(e) As an alternate to the requirements of T-653.3(a) and T-653.3(b) when using color contrast penetrants, it is permissible to use a single comparator block for the standard and nonstandard temperatures and to make the comparison by photography.

(1) When the single comparator block and photographic technique is used, the processing details (as applicable) described in T-653.3(a) and T-653.3(b) apply. The block shall be thoroughly cleaned between the two processing steps. Photographs shall be taken after processing at the nonstandard temperature and then after processing at the standard temperature. The indication of cracks shall be compared between the two photographs. The same criteria for qualification as T-653.3(a) shall apply.

(2) The identical photographic techniques shall be used to make the comparison photographs.

T-654 Technique Restrictions

Fluorescent penetrant examination shall not follow a color contrast penetrant examination. Intermixing of penetrant materials from different families or different manufacturers is not permitted. A retest with water washable penetrants may cause loss of marginal indications due to contamination.

T-670 EXAMINATION

T-671 Penetrant Application

The penetrant may be applied by any suitable means, such as dipping, brushing, or spraying. If the penetrant is applied by spraying using compressed-air-type apparatus, filters shall be placed on the upstream side near the air inlet to preclude contamination of the penetrant by oil, water, dirt, or sediment that may have collected in the lines.

T-672 Penetration Time

Penetration time is critical. The minimum penetration time shall be as required in Table T-672 or as qualified by demonstration for specific applications.

T-673 Excess Penetrant Removal

After the specified penetration time has elapsed, any penetrant remaining on the surface shall be removed, taking care to minimize removal of penetrant from discontinuities.

T-673.1 Water-Washable Penetrants. Excess water-washable penetrant shall be removed with a water spray. The water pressure shall not exceed 50 psi (345 kPa), and the water temperature shall not exceed 110°F (43°C).

T-673.2 Postemulsification Penetrants

(a) Lipophilic Emulsification. After the required penetrant dwell time, the excess surface penetrant shall be emulsified by immersing or flooding the part with the emulsifier. Emulsification time is dependent on the type of emulsifier and surface condition. The actual

emulsification time shall be determined experimentally. After emulsification, the mixture shall be removed by immersing in or rinsing with water. The temperature and pressure of the water shall be as recommended by the manufacturer.

(b) Hydrophilic Emulsification. After the required penetrant dwell time and prior to emulsification, the parts shall be prerinsed with water spray using the same process as for water-washable penetrants. Prerinsing time shall not exceed 1 min. After prerinsing, the excess surface penetrant shall be emulsified by immersing in or spraying with hydrophilic emulsifier. Bath concentration shall be as recommended by the manufacturer. After emulsification, the mixture shall be removed by immersing in or rinsing with water. The temperature and pressure of the water shall be as recommended by the manufacturer.

NOTE: Additional information may be obtained from SE-165.

T-673.3 Solvent Removable Penetrants. Excess solvent removable penetrants shall be removed by wiping with a cloth or absorbent paper, repeating the operation until most traces of penetrant have been removed. The remaining traces shall be removed by lightly wiping the surface with cloth or absorbent paper moistened with solvent. To minimize removal of penetrant from discontinuities, care shall be taken to avoid the use of excess solvent. **Flushing the surface with solvent, following the application of the penetrant and prior to developing, is prohibited.**

T-674 Drying After Excess Penetrant Removal

(a) For the water washable or post-emulsifying technique, the surfaces may be dried by blotting with clean materials or by using circulating air, provided the temperature of the surface is not raised above 125°F (52°C).

(b) For the solvent removable technique, the surfaces may be dried by normal evaporation, blotting, wiping, or forced air.

T-675 Developing

The developer shall be applied as soon as possible after penetrant removal; the time interval shall not exceed that established in the procedure. Insufficient coating thickness may not draw the penetrant out of discontinuities; conversely, excessive coating thickness may mask indications.

With color contrast penetrants, only a wet developer shall be used. With fluorescent penetrants, a wet or dry developer may be used.

T-675.1 Dry Developer Application. Dry developer shall be applied only to a dry surface by a soft brush, hand powder bulb, powder gun, or other means, provided the powder is dusted evenly over the entire surface being examined.

T-675.2 Wet Developer Application. Prior to applying suspension type wet developer to the surface, the developer must be thoroughly agitated to ensure adequate dispersion of suspended particles.

(a) Aqueous Developer Application. Aqueous developer may be applied to either a wet or dry surface. It shall be applied by dipping, brushing, spraying, or other means, provided a thin coating is obtained over the entire surface being examined. Drying time may be decreased by using warm air, provided the surface temperature of the part is not raised above 125°F. Blotting is not permitted.

(b) Nonaqueous Developer Application. Nonaqueous developer shall be applied only to a dry surface. It shall be applied by spraying, except where safety or restricted access preclude it. Under such conditions, developer may be applied by brushing. Drying shall be by normal evaporation.

T-675.3 Developing time for final interpretation begins immediately after the application of a dry developer or as soon as a wet developer coating is dry. The minimum developing time shall be as required by Table T-672.

T-676 Interpretation

T-676.1 Final Interpretation. Final interpretation shall be made within 7 to 60 min after the requirements of T-675.3 are satisfied. If bleed-out does not alter the examination results, longer periods are permitted. If the surface to be examined is large enough to preclude complete examination within the prescribed or established time, the examination shall be performed in increments.

T-676.2 Characterizing Indication(s). The type of discontinuities are difficult to evaluate if the penetrant diffuses excessively into the developer. If this condition occurs, close observation of the formation of indication(s) during application of the developer may assist in characterizing and determining the extent of the indication(s).

TABLE T-672 MINIMUM DWELL TIMES

Material	Form	Type of Discontinuity	Dwell Times [Note (1)] (minutes) Penetrant	Developer
Aluminum, magnesium, steel, brass and bronze, titanium and high-temperature alloys	Castings and welds	Cold shuts, porosity, lack of fusion, cracks (all forms)	5	7
	Wrought materials — extrusions, forgings, plate	Laps, cracks (all forms)	10	7
Carbide-tipped tools		Lack of fusion, porosity, cracks	5	7
Plastic	All forms	Cracks	5	7
Glass	All forms	Cracks	5	7
Ceramic	All forms	Cracks, porosity	5	7

NOTE:
(1) For temperature range from 50°F to 125°F (10°C to 52°C).

T-676.3 Color Contrast Penetrants. With a color contrast penetrant, the developer forms a reasonably uniform white coating. Surface discontinuities are indicated by bleed-out of the penetrant which is normally a deep red color that stains the developer. Indications with a light pink color may indicate excessive cleaning. Inadequate cleaning may leave an excessive background making interpretation difficult. A minimum light intensity of 50 fc (500 Lx) is required to ensure adequate sensitivity during the examination and evaluation of indications.

T-676.4 Fluorescent Penetrants. With fluorescent penetrants, the process is essentially the same as in T-676.3, with the exception that the examination is performed using an ultraviolet light, called *black light*. The examination shall be performed as follows:

(a) It shall be performed in a darkened area.

(b) The examiner shall be in the darkened area for at least 1 min prior to performing the examination to enable his eyes to adapt to dark viewing. If the examiner wears glasses or lenses, they shall not be photosensitive.

(c) The black light shall be allowed to warm up for a minimum of 5 min prior to use or measurement of the intensity of the ultraviolet light emitted.

(d) The black light intensity shall be measured with a black light meter. A minimum of 1000 $\mu W/cm^2$ on the surface of the part being examined shall be required. The black light intensity shall be measured at least once every 8 hr, and whenever the work station is changed.

T-677 Post-examination Cleaning

When post-examination cleaning is required by the procedure, it should be conducted as soon as practical using a process that does not adversely affect the part.

T-680 EVALUATION

(a) All indications shall be evaluated in terms of the acceptance standards of the referencing Code Section.

(b) Discontinuities at the surface will be indicated by bleed-out of penetrant; however, localized surface irregularities due to machining marks or other surface conditions may produce false indications.

(c) Broad areas of fluorescence or pigmentation which could mask indications of discontinuities are unacceptable, and such areas shall be cleaned and reexamined.

T-690 DOCUMENTATION/RECORDS

T-690.1 Documentation/records shall be in accordance with the referencing Code Section.

ARTICLE 6
MANDATORY APPENDIX

APPENDIX I — GLOSSARY OF TERMS FOR LIQUID PENETRANT EXAMINATION

I-610 SCOPE

This Mandatory Appendix is used for the purpose of establishing standard terms and definition of terms which appear in Article 6, Liquid Penetrant Examination.

I-620 GENERAL REQUIREMENTS

(a) The Standard Terminology for Nondestructive Examinations (ASTM E 1316) has been adopted by the Committee as SE-1316.

(b) SE-1316 Section G provides the definitions of terms listed in I-630(a).

(c) For general terms, such as *Indication, Flaw, Discontinuity, Evaluation*, etc., refer to Article 1, Mandatory Appendix 1.

(d) Paragraph I-630(b) provides a list of terms and definitions, which are in addition to SE-1316 and are Code specific.

I-630 REQUIREMENTS

(a) The following SE-1316 terms are used in conjunction with this Article: black light; bleedout; blotting; clean; contaminant; contrast; developer; developer, aqueous; developer, dry; developer, nonaqueous; developing time; drying time; dwell time; emulsifier; family; fluorescence; overemulsification; penetrant; penetrant comparator; penetrant fluorescent; penetrant, water washable; post-cleaning; post emulsification; precleaning; rinse; solvent remover.

(b) The following Code terms are used in conjunction with this Article:

black light intensity — a quantitative expression of ultraviolet irradiance

color contrast penetrant — a highly penetrating liquid incorporating a nonfluorescent dye, which produces indications of such intensity that they are readily visible during examination under white light

post emulsification penetrant — a type of penetrant containing no emulsifier, but which requires a separate emulsifying step to facilitate water rinse removal of the surface penetrant

solvent removable penetrant — a type of penetrant used where the excess penetrant is removed from the surface of the part by wiping using a nonaqueous liquid