ARTICLE 6
LIQUID PENETRANT EXAMINATION

T-610 SCOPE

When specified by the referencing Code Section, the liquid penetrant examination techniques described in this Article shall be used. In general, this Article is in conformance with SE-165, Standard Test Method for Liquid Penetrant Examination. This document provides details to be considered in the procedures used.

When this Article is specified by a referencing Code Section, the liquid penetrant method described in this Article shall be used together with Article 1, General Requirements. Definitions of terms used in this Article appear in Mandatory Appendix I of this Article and Article 1, Appendix I.

T-620 GENERAL

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-621 Written Procedure Requirements

T-621.1 Requirements. Liquid penetrant examination shall be performed in accordance with a written procedure which shall as a minimum, contain the requirements listed in Table T-621. The written procedure shall establish a single value, or range of values, for each requirement.

T-621.2 Procedure Qualification. When procedure qualification is specified by the referencing Code Section, a change of a requirement in Table T-621 identified as an essential variable shall require requalification of the written procedure by demonstration. A change of a requirement identified as a nonessential variable does not require requalification of the written procedure. All changes of essential or nonessential variables from those specified within the written procedure shall require revision of, or an addendum to, the written procedure.

T-630 EQUIPMENT

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 examination process. The descriptions of the liquid penetrant classifications and material types are provided in SE-165 of Article 24.

T-640 MISCELLANEOUS 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 or duplex stainless steels, and titanium. These certifications shall include the penetrant manufacturers' batch numbers and the test results obtained in accordance with Mandatory Appendix II of this Article. These records shall be maintained as required by the referencing Code Section.

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.

(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

TABLE T-621
REQUIREMENTS OF A LIQUID PENETRANT EXAMINATION PROCEDURE

Requirement	Essential Variable	Nonessential Variable
Identification of and any change in type or family group of penetrant materials including developers, emulsifiers, etc.	X	...
Surface preparation (finishing and cleaning, including type of cleaning solvent)	X	...
Method of applying penetrant	X	...
Method of removing excess surface penetrant	X	...
Hydrophilic or lipophilic emulsifier concentration and dwell time in dip tanks and agitation time for hydrophilic emulsifiers	X	...
Hydrophilic emulsifier concentration in spray applications	X	...
Method of applying developer	X	...
Minimum and maximum time periods between steps and drying aids	X	...
Decrease in penetrant dwell time	X	...
Increase in developer dwell time (Interpretation Time)	X	...
Minimum light intensity	X	...
Surface temperature outside 40°F to 125°F (5°C to 52°C) or as previously qualified	X	...
Performance demonstration, when required	X	...
Personnel qualification requirements	...	X
Materials, shapes, or sizes to be examined and the extent of examination	...	X
Post-examination cleaning technique	...	X

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 as required in T-642(a) 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 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 40°F (5°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 40°F to 125°F (5°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

When it is not practical to conduct a liquid penetrant examination within the temperature range of 40°F to 125°F (5°C to 52°C), the examination procedure at the proposed lower or higher temperature range requires qualification of the penetrant materials and processing in accordance with Mandatory Appendix III of this Article.

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.

TABLE T-672 MINIMUM DWELL TIMES (10)

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

NOTE:
(1) For temperature range from 50°F to 125°F (10°C to 52°C). For temperatures from 40°F (5°C) up to 50°F (10°C), minimum penetrant dwell time shall be 2 times the value listed.

T-660 CALIBRATION

Light meters, both visible and fluorescent (black) light meters, shall be calibrated at least once a year or whenever the meter has been repaired. If meters have not been in use for one year or more, calibration shall be done before being used.

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 (Dwell) Time

Penetration (dwell) 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 (dwell) 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 (350 kPa), and the water temperature shall not exceed 110°F (43°C).

T-673.2 Post-Emulsification 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 pre-rinsed with water spray using the same process as for water-washable penetrants. Pre-rinsing time shall not exceed 1 min. After pre-rinsing, 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 (52°C). Blotting is not permitted.

(b) Nonaqueous Developer Application. Nonaqueous developers shall be applied by spraying, except where safety or restricted access preclude it. Under such conditions, developer may be applied by brushing. For water-washable or post-emulsifiable penetrants, the developer shall be applied to a dry surface. For solvent removable penetrants, the developer may be applied as soon as practical after excess penetrant removal. Drying shall be by normal evaporation.

(10) **T-675.3 Developing Time.** Developing time for final interpretation begins immediately after the application of a dry developer or as soon as a wet developer coating is dry.

T-676 Interpretation

(10) **T-676.1 Final Interpretation.** Final interpretation shall be made not less than 10 min nor more than 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).

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 100 fc (1000 lx) is required on the surface to be examined to ensure adequate sensitivity during the examination and evaluation of indications. The light source, technique used, and light level verification is required to be demonstrated one time, documented, and maintained on file.

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) Examiners shall be in a darkened area for at least 5 min prior to performing examinations to enable their eyes to adapt to dark viewing. Glasses or lenses worn by examiners shall not be photosensitive.

(c) Black lights shall achieve a minimum of 1000 $\mu W/cm^2$ on the surface of the part being examined throughout the examination.

(d) Reflectors and filters should be checked and, if necessary, cleaned prior to use. Cracked or broken filters shall be replaced immediately.

(e) The black light intensity shall be measured with a black light meter prior to use, whenever the light's power source is interrupted or changed, and at the completion of the examination or series of examinations.

T-677 Post-Examination Cleaning

When post-examination cleaning is required by the procedure, it should be conducted as soon as practical after Evaluation and Documentation 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

T-691 Recording of Indications

T-691.1 Nonrejectable Indications. Nonrejectable indications shall be recorded as specified by the referencing Code Section.

T-691.2 Rejectable Indications. Rejectable indications shall be recorded. As a minimum, the type of indications (linear or rounded), location and extent (length or diameter or aligned) shall be recorded.

T-692 Examination Records

For each examination, the following information shall be recorded:

(a) procedure identification and revision;

(b) liquid penetrant type (visible or fluorescent);

(c) type (number or letter designation) of each penetrant, penetrant remover, emulsifier, and developer used;

(d) examination personnel identity and if required by referencing Code Section, qualification level;

(e) map or record of indications per T-691;

(f) material and thickness;

(g) lighting equipment; and

(h) date of examination.

ARTICLE 6
MANDATORY APPENDICES

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 I.

(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.

APPENDIX II — CONTROL OF CONTAMINANTS FOR LIQUID PENETRANT EXAMINATION

II-610 SCOPE

This Appendix contains requirements for the control of contaminant content for all liquid penetrant materials used on nickel base alloys, austenitic stainless steels, and titanium.

II-640 REQUIREMENTS

II-641 Nickel Base Alloys

When examining nickel base alloys, all penetrant materials shall be analyzed individually for sulfur content in accordance with SE-165, Annex 4. Alternatively, the material may be decomposed in accordance with SD-129 and analyzed in accordance with SD-516. The sulfur content shall not exceed 1% by weight.

II-642 Austenitic or Duplex Stainless Steel and Titanium

When examining austenitic or duplex stainless steel and titanium, all penetrant materials shall be analyzed individually for halogens content in accordance with SE-165, Annex 4. Alternatively, the material may be decomposed and analyzed in accordance with SD-808 or SE-165, Annex 2 for chlorine and SE-165, Annex 3 for fluorine. The total halogens content shall not exceed 1% by weight.

II-690 DOCUMENTATION

Certifications obtained on penetrant materials shall include the penetrant manufacturers' batch numbers and

the test results obtained in accordance with II-640. These records shall be maintained as required by the referencing Code Section.

APPENDIX III — QUALIFICATION TECHNIQUES FOR EXAMINATIONS AT NONSTANDARD TEMPERATURES

III-610 SCOPE

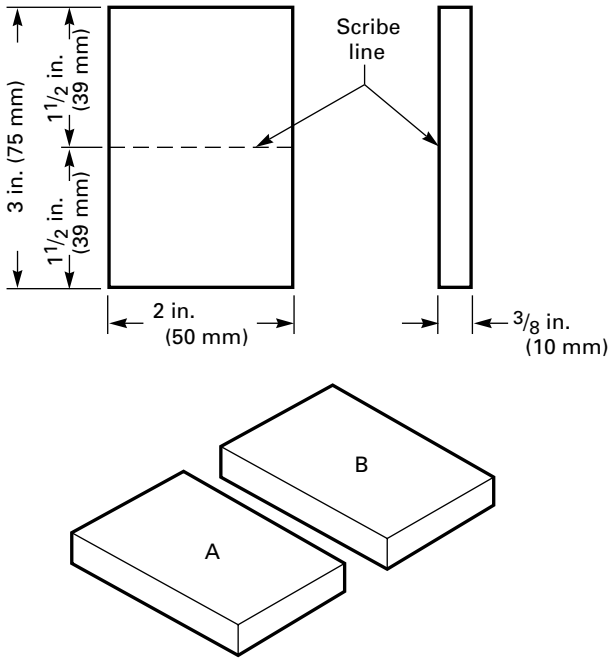
When a liquid penetrant examination cannot be conducted within the standard temperature range of 40°F to 125°F (5°C to 52°C), the temperature of the examination shall be qualified in accordance with this Appendix.

III-630 MATERIALS

A liquid penetrant comparator block shall be made as follows. The liquid penetrant comparator blocks shall be made of aluminum, ASTM B 209, Type 2024, $\frac{3}{8}$ in. (9.5 mm) thick, and should have approximate face dimensions of 2 in. × 3 in. (50 mm × 75 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 III-630 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. (50 mm × 75 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."

FIG. III-630 LIQUID PENETRANT COMPARATOR
(NOTE: Dimensions given are for guidance only and are not critical.)



III-640 REQUIREMENTS

III-641 Comparator Application

III-641.1 Temperature Less Than 40°F (5°C). If it is desired to qualify a liquid penetrant examination procedure at a temperature of less than 40°F (5°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 40°F to 125°F (5°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 40°F to 125°F (5°C to 52°C), the proposed procedure shall be considered qualified for use. A procedure qualified at a temperature lower than 40°F (5°C) shall be qualified from that temperature to 40°F (5°C).

III-641.2 Temperature Greater Than 125°F (52°C). 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 III-641.1 while block "B" is at the proposed temperature and block "A" is at the 40°F to 125°F (5°C to 52°C) temperature range.

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. [As an example, to qualify a procedure for the temperature range 126°F (52°C) to 200°F (93°C), the capability of a penetrant to reveal indications on the comparator shall be demonstrated at both temperatures.]

III-641.3 Alternate Techniques for Color Contrast Penetrants. As an alternate to the requirements of III-641.1 and III-641.2, 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.

(a) When the single comparator block and photographic technique is used, the processing details (as applicable) described in III-641.1 and III-641.2 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 III-641.1 shall apply.

(b) Identical photographic techniques shall be used to make the comparison photographs.