The Penetrant Discipline

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(Showing the different approaches industry has in applying the penetrant method of examination)

The original presentation of this paper was published in Materials Evaluation in October 1994. I have updated this paper to include current information regarding each response to each question. I have also added some additional sources that were not included in the 1994 paper.

Some observations:

- ✓ Errors in information presented (source documents) - could be classified as "typo errors"?
- ✓ Differences in how scientific notations (both digit and exponential terms) are presented between sources.
- ✓ Use of the terms shall, should and recommended.
- ✓ Differences between temperatures, times, pressures and intensities associated with the Liquid Penetrant Process.

This paper was developed for personnel in the NDT field. It is the intent of this paper to help NDT personnel identify, and obtain a better understanding of the many approaches industry has in developing guidelines for the penetrant discipline. This paper does not address all the possible issues associated with the Liquid Penetrant Process nor does it address all the possible responses, especially from sources that contain hundreds of pages of data.

There are numerous sources (i.e., specifications, papers, books, etc.) that address the specifics of the Liquid Penetrant Discipline. This paper provides a sampling of these sources.

Penetrant Inspection Discipline

The responses from the 1994 document are in **black** and current responses are in **blue** print.

By Danny N Marks

Question	Answer	Source
1. What temperature range (°F) should the penetrant and part be before applying the penetrant?	#1: The temperature of the penetrant materials and the surface of the part to be processed **should** be between 50 and 100°F (10and 38°C) (8.2). **Note**: Item "A" from table 2 states, for temperature range from 50 to 100°F for fluorescent penetrants and 50 to 125°F for visible penetrants.	**ASTM E 165-95** Liquid Penetrant Inspection Method. **Note**: AWS D1.1-92 (Chapter 6 – Inspection and API Standard 1104 (Section 8.3) States that E 165 shall be used for PT application/procedure.
	#1: 8.2 Temperature Limits – The temperature of the penetrant materials and the surface of the part to be processed **shall** be between 40° and 125°F [4° and 52°C] or the procedure must be qualified at the temperature used as described in 10.2 (Procedure Qualification).	**ASTM E165/E165M-12** Standard Practice for Liquid Penetrant Examination for General Industry
	#2: The penetrant materials and surface of the part **shall** be between 50 to 125°F (10° and 38°C) (Fluorescent Method) (7.1.1).	**ASTM E 1219-94** Standard Test Method for Fluorescent Liquid Penetrant Examination Using the Solvent-Removable Process
	#2: 7.1.1 **Temperature Limits** – The temperature of the penetrant materials and the surface of the part to be processed **should** be from 40 and 125°F (4° and 52°C). Where 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.	**ASTM E1219-16** Standard Practice for Fluorescent Liquid Penetrant Testing Using the Solvent-Removable Process
	#3: The penetrant materials and surface of part **should** be between 50 to 125°F (10 and 38°C) (Visible Method) (7.1.1)	**ASTM E 1220-92** Standard Test Method for Visible Liquid Penetrant Examination Using the Solvent-Removable Process

#3: 7.1.1 **Temperature Limits**: Same statement as per ASTM E1219-16.	**ASTM E1220-16** Standard Practice for Visible Penetrant Testing Using Solvent-Removable Process
#4: The component, penetrant, and ambient temperatures **shall** be in the range of 40 to 120°F (Type I Penetrants) and in the range of 60 to 125°F (16 to 52°C) Type II Penetrants. (7.2)	**ASTM E 1417-95a** Practice for Liquid Penetrant Examination
#4: 7.2 The component, penetrant, and ambient temperatures **shall all** be in the range from 40 to 125°F [4 to 52°C] unless otherwise specified.	**ASTM E1417/E1417M-16** Standard Practice for Liquid Penetrant Testing
#5: The component, penetrant, and ambient temperatures **shall** be in the range of 40 to 120°F unless otherwise specified.	**MIL-STD-6866 (1985)** Military Standard – Inspection, Liquid Penetrant
	MIL-STD-6866 (1985) Canceled and replaced by ASTM E1417-95a (Notice 2 dated 1996)
#6: The penetrant and surface of part, to be processed, **shall not** be below 60°F nor above 125°F throughout the examination period.	**ASME (1992)** Boiler and Pressure Vessel Code; Section V; Article 6 – Liquid Penetrant Examination
#6: 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. (T-652)	**2010 ASME Boiler & Pressure Vessel Code**, 2011a Addenda, July 1, 2011 - V Nondestructive Examination - Article 6 - Liquid Penetrant Examination
#7: The operating range for conventional penetrants is 40°F to 120°F – Test part temperatures **shall not** be less than 40°F. (6-215) (6-216)	**T.O. 33B-1-1** Air Force Technical Manual (change 2, 1990) -- Nondestructive Inspection Methods – Chapter 6
#7: **Temperature Limitations**. - Penetrants may be applied over a range of ambient temperatures; however, certain limits **must not** be exceeded as the inspection process may be degraded. The operating range for conventional penetrants is 40°F (4°C) to 125°F (52°C). There are	**TO 33B-1-1** **NAVAIR 01-1A-16-1** **TM 1-1500-335-23** Technical Manual -- Nondestructive Inspection Methods, Basic Theory - 15 October 2016

special penetrants formulated for hot applications exceeding these limits. Special purpose penetrants are discussed in (paragraph 2.7). (2.4.6) Penetrant inspection **SHALL NOT** be performed when the test part temperature is less than 40°F (4°C). (2.4.6.1) **NOTE**: When temperatures are between 40°F (4°C) and 60°F (15.6°C), the penetration dwell time **SHALL** be increased in accordance with (paragraph 2.4.7.4.2, Table 2-2) due to the increased viscosity. (2.4.6.1.4)	
#8: The normal temperatures of penetrant and article being tested are between 60 and 125°F.	**PI-4-2** Nondestructive Testing Liquid Penetrant Handbook by General Dynamics (fourth edition)
#8: **Effects of Temperature** (pg 60) - The standard temperature range for penetrant testing is 10 to 38 °C (50 to 100 °F). Colder temperatures will increase the viscosity of the penetrant and slow the capillary action. Some specifications allow temperatures of 4.4 to 65.5 °C (40 to 150 °F), but require doubling the dwell time for temperatures below 10 °C (50 °F). **Note**: Book does not address temperature of component or ambient temperature.	**ASNT Personnel Training Publications (PTP)** - Liquid Penetrant Testing Classroom Training Book - First Printing January 2005
#9: In any case, parts subject to penetrant inspection **should not** be processed at temperatures exceeding 100°F.	**MIL-HDBK-728/3 (1985)** Military handbook – Liquid Penetrant Testing
#9: No Change - same as above.	**MIL-HDBK-728/3** (NOTICE 1), MILITARY HANDBOOK: LIQUID PENETRANT TESTING (01 JUL 1992), MIL-HDBK-728/3, dated 16 December 1985, has been reviewed and determined to be valid for use in acquisition.

	#10: Prior to processing allow parts to attain a temperature of 40 to 120°F, also penetrant and ambient air temperature **must be** between 40 and 120°F for penetrant application. (6.4)	**P.S. 21202 Rev R (1993)** McDonnell Douglas Liquid Penetrant Process Specification
	#10: For penetrant application, the temperature of the component, penetrant and ambient air shall all be in the range of 50 to 125 F (10 to 50 C) unless otherwise specified. (7.2.1 {d})	**BSS7039, Rev. C - March 2015** Boeing Specification Support Standard - Liquid Penetrant Inspection
	#11: Temperatures around 80°F to 120°F produce optimum results (8-7). If dye-penetrant materials are used from pressurized spray cans, the temperature of the test area **should not** be lower than 60°F (6-21). Penetrants operate satisfactorily at temperatures as low as 40°F, but operation much below this temperature can result in unsatisfactory test. In open tanks up to 100°F (7-34).	**ASNT Nondestructive Testing Handbook (Vol I, Section 6)** – Edited by Robert C. McMaster - Copyright 1959
	#11: **Effects of Temperature of Part or Liquid Penetrant on Indications** (pg 138)- Material temperatures from 10 to 52 °C (50 to 125 °F) produce optimum results with conventional liquid penetrants. **Page 383 (Aerospace)** - The part and liquid penetrant **shall** both be in the range from 4 to 49 °C (40 to 120 °F) for fluorescent (Type 1) liquid penetrants unless otherwise specified.	**ASNT Nondestructive Testing Handbook, Third Edition, Volume Two Liquid Penetrant Testing** - Editor - Patrick O. Moore - Copyright 2000
	4.3.5.2: A requirement that components, penetrant, and ambient temperatures **shall** be maintained within the range of 50 °F (10°C) to 125 °F (52°C). Also see **6.7.1**.	**Nadcap Audit Criteria AC7114/1 Audit Criteria for Nondestructive Testing Facility Penetrant Survey** - To be used on audits starting on or after 31-Dec-2017.
2. What intensity level (fc) should visible light be at the examination site?	#1: Visible ambient light **should not** exceed 2 ft candles when examining fluorescent penetrant indications under black light in a darken area. For visible penetrant indications, a	**ASTM E 165-95** Liquid Penetrant Inspection Method. **Note**: AWS D1.1-92 (Chapter 6 – Inspection) and API Standard 1104 (Section 8.3) states that E

minimum visible light intensity at the examination site of 100 fc is **recommended**.	165 **shall** be used for PT applications/procedure.
#1: **Visible Light Examination** - A minimum light intensity at the examination surface of 100 fc [1076 lx] **is required** (see Guide E2297 for more information). (8.9.2) **Ultraviolet Light Examination** - Ambient light **shall not** exceed 2 fc [21.5 lx]. *8.9.1)	**ASTM E165/E165M-12** Standard Practice for Liquid Penetrant Examination for General Industry
#2: Visible ambient light **should not** exceed 2 fc when examining fluorescent penetrant indications under black light in a darken area. (7.1.8.1)	**ASTM E 1219-94** Standard Test Method for Fluorescent Liquid Penetrant Examination Using the Solvent-Removable Process
#2: Visible Ambient Light—Visible ambient light **shall not** exceed 2 fc (21.5 lux). The measurement should be made with a visible light meter on the surface being examined. (7.1.8.3)	**ASTM E1219-16** Standard Practice for Fluorescent Liquid Penetrant Testing Using the Solvent-Removable Process
#3: A **minimum** light intensity at the examination site of 100 fc is **recommended**. (7.1.8.1)	**ASTM E 1220-92** Standard Test Method for Visible Liquid Penetrant Examination Using the Solvent-Removable Process
#3: Visible Illuminance - A minimum illuminance at the examination site of 100 fc (1076 lux) is **recommended**. (7.1.8.1)	**ASTM E1220-16** Standard Practice for Visible Penetrant Testing Using Solvent-Removable Process
#4: For visible dye examination, Type II, the lighting system **shall** provide at least 100 fc 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 at the examination surface.	**ASTM E 1417-95a** Practice for Liquid Penetrant Examination
#4: **Visible Lights** - For Type II visible dye examinations, the lighting systems **shall** be checked at intervals specified in Table 1 to ensure a **minimum** of 100 fc [1076 lx] when measure at the **examination surface**.	**ASTM E1417/E1417M-16** Standard Practice for Liquid Penetrant Testing

(7.8.4.3)…it is **recommended** that a visible light contamination be taken at the viewing surface, when the UV-A lamp is on and is held at the angle and distance used for interpretation. The white light reading **shall not** exceed 2 fc [21.5 lx]. (7.8.4.1)	
#5: For visible dye inspection, Type II, the lighting system **shall** provide at least 200 foot-candles of white light at the surface of the component being inspected. For stationary fluorescent dye inspection, Type I, the ambient white light background **shall not** exceed 2 fc.	**MIL-STD-6866 (1985)** Military Standard – Inspection, Liquid Penetrant
	MIL-STD-6866 (1985) Canceled and replaced by ASTM E1417-95a (Notice 2 dated 1996)
#6: For color contrast penetrants (visible) **adequate illumination** is required to ensure adequate sensitivity during the examination and evaluation of indications (T-647.3).	**ASME (1992)** Boiler and Pressure Vessel Code; Section V; Article 6 – Liquid Penetrant Examination
#6: For color contrast penetrants (visible) 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. (T-676.3)	**2010 ASME Boiler & Pressure Vessel Code**, 2011a Addenda, July 1, 2011 - V Nondestructive Examination - Article 6 - Liquid Penetrant Examination
#7: The ambient light levels within the inspection station of the fluorescent penetrant inspection unit **shall not** exceed 2 lumens per square foot (1 lumen per sq foot equals 1 foot candle). The visible penetrant requirements are not addressed (6-374).	**T.O. 33B-1-1** Air Force Technical Manual (change 2, 1990) – Nondestructive Inspection Methods, Chapter 6
#7: **Ambient Visible Light** - Inspection of a part for fluorescent penetrant indications with UV-A lamps **SHALL** always be performed under the lowest possible level of ambient light. Ambient light in stationary inspection system booths	**TO 33B-1-1** **NAVAIR 01-1A-16-1** **TM 1-1500-335-23** Technical Manual -- Nondestructive Inspection Methods, Basic Theory - 15 October 2016

SHALL NOT exceed 2 foot-candles. If a stationary inspection booth is not adequate or appropriate, other provisions **SHALL** be made. (2.5.4.2.1) Ambient white light **SHALL** be measured with a white light meter with the UV-A lamps on. (2.5.4.1.3) For inspecting parts that have been processed with visible-dye penetrant (Type II), the lighting system in the viewing area **SHALL** provide at least 100-foot-candles (1000 lux) of visible white light at the examination surface. (2.5.4.2.3)	
#8: The lighting when viewing visible dye indications **should** be at least sufficient to ensure no loss of sensitivity. As a **minimum**, the lighting at the test surface should measure at least 32.5 foot candles (pg. 6-1). There is no reference to ambient white light levels in darken fluorescent penetrant inspection booths.	**PI-4-2** Nondestructive Testing Liquid Penetrant Handbook by General Dynamics (fourth edition)
#8: **Lighting** (pg 60) - The standard lighting for viewing and evaluating visible dye penetrant indications is a minimum of 1000 lx (100 fc) of white light at the test surface.	**ASNT Personnel Training Publications (PTP)** - Liquid Penetrant Testing Classroom Training Book - First Printing January 2005
#9: For visible – dye penetrants, a bright white light **should** be provided. For fluorescent penetrants, a low level of white light intensity (less than two foot candles is important).	**MIL-HDBK-728/3 (1985)** Military Handbook – Liquid Penetrant Testing
#9: No Change - same as above.	**MIL-HDBK-728/3** (NOTICE 1), MILITARY HANDBOOK: LIQUID PENETRANT TESTING (01 JUL 1992), MIL-HDBK-728/3, dated 16 December 1985, has been reviewed and determined to be valid for use in acquisition.
#10: For inspection with non-fluorescent methods, the white light intensity **is as least** 100 foot candles	**P.S. 21202 Rev R (1993)** McDonnel Douglas Liquid Penetrant Process Specification

at the working distance (7.1.8). For fluorescent penetrant method (inspection booth), a darkened booth or darken area where ambient white light does not exceed 2 foot-candles (4.4.1). The ambient white light intensity in the inspection booth (normal method) or inspection area (ultrahigh sensitivity method) **shall** be no more than 2 foot-candles (5.6.2).

#10: At least 100 fc (1,000 lx) of white light shall be available at the inspection surface for interpretation and evaluation of indications. (5.4.1, b, 2,b)
Type I Inspections - (7.3) Table IV - Darkened Inspection Area with Developer - 0 to 2 fc (o to 20 lx); Subdued Lighting with Developer >2 to 10 fc (>20 to 100 lx)

BSS7039, **Rev. C - March 2015** Boeing Specification Support Standard - Liquid Penetrant Inspection

#11: The proper intensity of illumination is determined by the nature of the inspection being carried out. For gross defects where indications are large, 30 to 50 foot-candles. For extremely critical inspection, 50 to 100 foot-candles or possibly higher (7-11)

ASNT Nondestructive Testing Handbook (Vol I, Section 6) – Edited by Robert C. McMaster - Copyright 1959

#11: **Aerospace -** The intensity of white light at the visual test level **shall** be equivalent to at least 750 lx (70ftc). Fluorescent liquid penetrant testing shall be ….background illumination preferably not exceeding 20 lx (2.0 ftc). {Page 155}

ASNT Nondestructive Testing Handbook, Third Edition, Volume Two Liquid Penetrant Testing - Editor - Patrick O. Moore - Copyright 2000

#12: **Visible penetrant**…
Lighting intensity **should** be adequate to ensure proper inspection; 320 to 540 lx (30 to 50 ftc) is recommended. (pg 83)
Table 2 states that White light **should** be checked weekly and the requirement is minimum 2200 lx (200 ftc) {pg 85}

ASM Handbook, Volume 17, Nondestructive Evaluation and Quality Control

	5.14.2.1: Is the ambient light level in the inspection area controlled not to exceed 2 ft candles (20 lux)? Compliance Assessment Guidance: This measurement is taken in the darkened inspection area to include the examination surface with the UV-A lights operating at a distance of 15 inches (38 cm). **5.14.3.1**: Is 100 ft-candles/1000 lux, or more, available at the part surface for visual verification of penetrant indications? Compliance Assessment Guidance: This question shall be applicable where accept/reject decisions rely on the use of white light.	**Nadcap Audit Criteria AC7114/1 Audit Criteria for Nondestructive Testing Facility Penetrant Survey** - To be used on audits starting on or after 31-Dec-2017.
3. What intensity level ($\mu W/cm^2$) should black light be (measured) at the inspection surface of the part?	#1: A **minimum** of 1000 $\mu W/cm^2$ **should** be measured on the surface being examined (general usage). Note 21 – For critical examinations, higher intensity levels may be required.	**ASTM E 165-95** Liquid Penetrant Inspection Method. **Note**: AWS D1.1-92 (Chapter 6 – Inspection) and API Standard 1104 (Section 8.3) states that E 165 **shall** be used for PT applications/procedure.
	#1: Black lights **shall** provide a **minimum** light intensity of 1000 $\mu W/cm^2$, at a distance of 15 in. [38.1 cm]. (8.9.1.1)	**ASTM E165/E165M-12** Standard Practice for Liquid Penetrant Examination for General Industry
	#2: Black light intensity, (recommended minimum of 1000 $\mu W/cm^2$) **should** be measured on the surface being examined. (7.1.8.2)	**ASTM E 1219-94** Standard Test Method for Fluorescent Liquid Penetrant Examination Using the Solvent-Removable Process
	#2: UV-A Irradiation - UV-A irradiance **shall** be measured with a UV-A radiometer on the surface to be examined. A minimum of 1000 $\mu W/cm2$ is **recommended**. (7.1.8.1)	**ASTM E1219-16** Standard Practice for Fluorescent Liquid Penetrant Testing Using the Solvent-Removable Process
	#3: The black lights **shall** provide a minimum of 1000 $\mu W/cm^2$ at the examination surface. Minimum acceptable intensity is 1000 $\mu W/cm^2$ at 15 inches from the front of the bulb or filter.	**ASTM E 1417-95a** Practice for Liquid Penetrant Examination

#3: Black Lights—Portable, hand-held, permanently mounted or fixed black lights used to inspect parts **shall** be checked for intensity as specified in Table 1 or prior to use, and after bulb replacement… The minimum acceptable intensity is 1000 µW/cm2 (10 W/m2) at 15 in. [38.1 cm] from the front of the filter to the face of the sensor. (7.8.4.1)	**ASTM E1417/E1417M-16** Standard Practice for Liquid Penetrant Testing
#4: Minimum acceptable intensity is 800 micro watts/cm^2 measured at a distance of at least 15 inches from the front of the bulb or filter (5.8.1) and **shall** provide a minimum of 1200 micro watts/cm^2 at the component surface (5.6.1).	**MIL-STD-6866 (1985)** Military Standard – Inspection, Liquid Penetrant
	MIL-STD-6866 (1985) Canceled and replaced by ASTM E1417-95a (Notice 2 dated 1996)
#5: A minimum of 800 µW/cm^2 on the surface of the part being examined **shall** be required.	**ASME (1992)** Boiler and Pressure Vessel Code; Section V; Article 6 – Liquid Penetrant Examination
#5: For 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.* Black lights **shall** achieve a minimum of 1000 µW/cm2 on the surface of the part being examined throughout the examination. (T-676.4)	**2010 ASME Boiler & Pressure Vessel Code**, 2011a Addenda, July 1, 2011 - V Nondestructive Examination - Article 6 - Liquid Penetrant Examination
#6: Measure the intensity of the black light at a distance of 15 inches from the front or out-side surface of the black light source filter. This intensity **shall** be a least 1000 µW/cm^2 and sources providing less than this intensity **shall not** be utilized. (6-373)	**T.O. 33B-1-1** Air Force Technical Manual (change 2, 1990) – Nondestructive Inspection Methods, Chapter 6
#6: The minimum UV-A output for a UV-A lamp **SHALL** be 1000 mW/cm 2 over a 5-inch diameter circle (minimum) for mercury vapor, gas-	**TO 33B-1-1** **NAVAIR 01-1A-16-1** **TM 1-1500-335-23** Technical Manual --

discharge lamps and Type A and B LED lamps when measured at a distance of 15-inches from the outside face of the filter. Type C LED lamps (single LED torch lamps) **SHALL** have a minimum UV-A output of 1000 mW/cm 2 over a 3-inch diameter circle when measured at a distance of 15-inches from the outside face of the filter. (2.5.4.1.4.2.1.1)	Nondestructive Inspection Methods, Basic Theory - 15 October 2016
#7: Black light intensity **should** measure at least 800 microwatts per square centimeter at the test surface.	**PI-4-2** Nondestructive Testing Liquid Penetrant Handbook by General Dynamics (fourth edition)
#7: **Lighting** (pg 60) - For fluorescent penetrant indications, the standard lighting is a minimum of 1000 $\mu W/cm^2$ ultraviolet radiation at the test surface, and a darkened test area of less than 20 lx (2 fc). **Ultraviolet Radiation** (pg 45) For correct test results, the lamp **should** produce an intensity of at least 800 $\mu W/cm^2$ at the test surface, and most specifications **require** the output to be 1000 $\mu W/cm^2$ measured at 38 cm (15 in.).-	**ASNT Personnel Training Publications (PTP)** - Liquid Penetrant Testing Classroom Training Book - First Printing January 2005
#8: For correct test results the lamp **should** produce an intensity of at least 800 microwatt/cm^2 at the test surface.	**MIL-HDBK-728/3 (1985)** Military Handbook – Liquid Penetrant Testing
#8: No Change - same as above.	**MIL-HDBK-728/3** (NOTICE 1), MILITARY HANDBOOK: LIQUID PENETRANT TESTING (01 JUL 1992), MIL-HDBK-728/3, dated 16 December 1985, has been reviewed and determined to be valid for use in acquisition.
#9: The ultraviolet light intensity **is required** to be at least 1200 microwatts per cm^2 at the normal working distance or 15 inches, whichever is greater (normal method). (5.6.2) The ultraviolet light intensity **is required** to be at least 5,000 microwatt/cm^2 at 6 inches from the	**P.S. 21202 Rev R (1993)** McDonnel Douglas Liquid Penetrant Process Specification

ultraviolet filter or bulb (ultrahigh sensitivity method). (5.6.2) During inspection with fluorescent penetrants, position the ultraviolet light at a distance from the test part surface such that the ultraviolet light intensity is a minimum of 1200 microwatts per cm^2 at the test part surface (normal method) (6.7) During inspection, … the ultraviolet light intensity is a minimum of 5,000 microwatts per cm^2 at the test part surface (ultrahigh sensitivity method) (6.7) The ultraviolet light intensity **shall** measure at least 1200 microwatts per cm^2 at a distance of 15 inches from the front of the ultraviolet filter or bulb with an ultraviolet light meter (normal method) (7.1.8.1) … except the ultraviolet light intensity **shall** measure at least 5,000 microwatts/cm^2 at 6 inches from the front of the ultraviolet filter or bulb (7.1.8.1)

#9: Minimum acceptable output at a minimum distance of 15 inches (38 cm) is 1000 µW/cm^2. (5.5, d, 3) **Type I Inspection,** Table IV (7.3) - Darkened Inspection Area with Developer 1,000 µW/cm^2 or Subdued Lighting with Developer 5,000 µW/cm^2 - **Notes**: (FL1) - Light intensity at the inspection surface. (FL 2) If possible, reduce ambient light to less than 2 fc (20 lx). (FL 3) - **Do not** conduct inspections with white light levels exceeding 10 fc (100 lx)

BSS7039, **Rev. C - March 2015** Boeing Specification Support Standard - Liquid Penetrant Inspection

#10: The amount of black light necessary for any job depends on the particular application. Examples are 50 foot-candles for gross porosity to 90 foot-candles where inspection is extremely critical (7-15).

ASNT Nondestructive Testing Handbook (Vol I, Section 6) – Edited by Robert C. McMaster - Copyright 1959

#10: **Aerospace** (pg 155) - Fluorescent liquid penetrant testing shall be conducted in a suitable darken area with an ultraviolet radiation intensity of at least 10 $W \cdot m^{-2}$ (1000 $\mu W \cdot cm^{-2}$).

ASNT Nondestructive Testing Handbook, Third Edition, Volume Two Liquid Penetrant Testing - Editor - Patrick O. Moore - Copyright 2000

	Page 237 - As an example, an ultraviolet radiation illumination level of about 8 to 10 $W \cdot m^{-2}$ (800 to 1000 $\mu W \cdot cm^{-2}$) is sufficient to reveal most anomaly indications. **Page 70** - …measurements are taken at distances of 380 mm (15 in.) from the face of the filter on the ultraviolet lamp, in the center of the ultraviolet light beam. Various specifications call for minimum ultraviolet radiation intensities of 8.6 to 10.2 $W \cdot m^{-2}$ (865 to 1020 $\mu W \cdot cm^{-2}$).	
	#11: **Inspections**: Recommended black light intensity is 1000 to 1600 $\mu W/cm^2$. (pg 83) **Table 2** states Black Lights checked daily and requirement is minimum 1000 $\mu W/cm^2$ at 381 mm (15 in.) {pg 85}	**ASM Handbook, Volume 17, Nondestructive Evaluation and Quality Control**
	5.13.10: Is the minimum acceptable limit 1200 $\mu W/cm^2$ and the maximum 10,000 $\mu W/cm^2$ at 15 inches (380 mm)? Compliance Assessment Guidance: Borescope intensity shall be a minimum of 1000 $\mu W/cm^2$ at the inspection surface as measured from the inspection distance.	**Nadcap Audit Criteria AC7114/1 Audit Criteria for Nondestructive Testing Facility Penetrant Survey** - To be used on audits starting on or after 31-Dec-2017.
4. How long do you let a black light warm up prior to use? (Mercury Vapor Lamp)	#1: Allow the black light to warm up for a minimum of 10 min. prior to its use or measurement of the intensity of the ultraviolet light emitted. (8.9.1.3) & (7.1.8.3)	**ASTM E 165-95** Liquid Penetrant Inspection Method. **Note**: AWS D1.1-92 (Chapter 6 – Inspection) and API Standard 1104 (Section 8.3) states that E 165 **shall** be used for PT applications/procedure. **ASTM E 1219-94** Standard Test Method for Fluorescent Liquid Penetrant Examination Using the Solvent-Removable Process
	#1: **Black Light Warm-Up** - Unless otherwise specified by the manufacture, allow the black light to warm up for a minimum of five minutes prior to use or measurement of its intensity. (8.9.1.2)	**ASTM E165/E165M-12** Standard Practice for Liquid Penetrant Examination for General Industry

#2: **Not addressed**	**ASTM E 1417-95a** Practice for Liquid Penetrant Examination **MIL-STD-6866 (1985)** Military Standard – Inspection, Liquid Penetrant
#2: **Not Addressed**: [**Author's Note**] "A specific warm up time for a typical Mercury Vapor style UV-A lamp is not addressed because of the assumption that if a lamp meets minimum intensity value, then the lamp has warmed up to the point of usage."	**ASTM E1417/E1417M-16** Standard Practice for Liquid Penetrant Testing **MIL-STD-6866 (1985)** Canceled and replaced by ASTM E1417-95a (Notice 2 dated 1996)
#3: 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.	**ASME (1992)** Boiler and Pressure Vessel Code; Section V; Article 6 – Liquid Penetrant Examination
#3: Does not address a specific time in Article 6 regarding time that a black light (UV-A source) is to be on before evaluation of intensity.	**2010 ASME Boiler & Pressure Vessel Code**, 2011a Addenda, July 1, 2011 - V Nondestructive Examination - Article 6 - Liquid Penetrant Examination
#4: Black lights **shall** be energized for 15 minutes before inspection is performed. (6-369)	**T.O. 33B-1-1** Air Force Technical Manual (change 2, 1990) – Nondestructive Inspection Methods, Chapter 6
#4: Does not specify a specific on time but provides a general statement for bulb life -- "Mercury vapor arc lamps that will be used periodically during the day **SHOULD** be allowed to remain on until their last use of the day." (2.5.4.1.5) Some UV-A lamps may be warmed-up in 2-3 minutes, refer to the owner's manual of the light you are using. (2.3.6.1.3.1)	**TO 33B-1-1** **NAVAIR 01-1A-16-1** **TM 1-1500-335-23** Technical Manual -- Nondestructive Inspection Methods, Basic Theory - 15 October 2016
#5: You **should** also allow at least 5 minutes for the light to warm up --	**PI-4-2** Nondestructive Testing Liquid Penetrant Handbook by General Dynamics (fourth edition)

#5: **Ultraviolet Radiation** (pg 45) - When using mercury vapor lamps, the full intensity of the lamp is not attained until the mercury arc is sufficiently heated. At least 5 min warm up is required to reach the required arc temperature.	**ASNT Personnel Training Publications (PTP)** - Liquid Penetrant Testing Classroom Training Book - First Printing January 2005
#6: At least **five** minutes warm-up is required to reach the required arc temperature.	**MIL-HDBK-728/3 (1985)** Military Handbook – Liquid Penetrant Testing
#6: No Change - same as above.	**MIL-HDBK-728/3** (NOTICE 1), MILITARY HANDBOOK: LIQUID PENETRANT TESTING (01 JUL 1992), MIL-HDBK-728/3, dated 16 December 1985, has been reviewed and determined to be valid for use in acquisition.
#7: When black light is used during inspection, allow the bulb to warm up for a minimum of 5 minutes prior to its use – (6.7)	**P.S. 21202 Rev R (1993)** McDonnel Douglas Liquid Penetrant Process Specification
#7: Document **does not** reference a specific warm up time for black light (100 watt, medium pressure, mercury vapor type)	**BSS7039**, **Rev. C - March 2015** Boeing Specification Support Standard - Liquid Penetrant Inspection
#8: Lamp Starting: The heating and ionization process requires about 5 minutes of starting time when the lamp is first turned on (7-13).	**ASNT Nondestructive Testing Handbook (Vol I, Section 6)** – Edited by Robert C. McMaster - Copyright 1959
#8: **Ultraviolet Lamp Warmup and Restart Times**: When the current to an ultraviolet lamp bulb of the mercury arc type is first turned on, it takes 300 s (5 minutes) or more for the bulb to warm up to its full output. No test **should** be started until this time has elapsed. (pg 237)	**ASNT Nondestructive Testing Handbook, Third Edition, Volume Two Liquid Penetrant Testing** - Editor - Patrick O. Moore - Copyright 2000
#9: **Inspections**: The intensity of the black light should be allowed to warm up prior to use - generally for about 10 min. (pg 83)	**ASM Handbook, Volume 17, Nondestructive Evaluation and Quality Control**

5. How long do you let your eyes adapt to darkness (less than 2 fc visible light) prior to inspecting a part under black light?	#1: The examiner **should** be in the darkened area for at least 1 minute before examining parts. (8.9.1.4) & (7.1.8.4)	**ASTM E 165-95** Liquid Penetrant Inspection Method. **Note**: AWS D1.1-92 (Chapter 6 – Inspection) and API Standard 1104 (Section 8.3) states that E 165 **shall** be used for PT applications/procedure. **ASTM E 1219-94** Standard Test Method for Fluorescent Liquid Penetrant Examination Using the Solvent-Removable Process
	#1: **Visual Adaption** - Personnel examining parts after penetrant processing **shall** be in the darkened area for at least one minute before examining parts. Longer times may be necessary under some circumstances.	**ASTM E165/E165M-12** Standard Practice for Liquid Penetrant Examination for General Industry
	#2: The inspector's vision **shall** be dark adapted for a minimum of 1 min prior to inspecting components. (7.6.1)	**ASTM E 1417-95a** Practice for Liquid Penetrant Examination
	#2: 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. (7.6.1)	**ASTM E1417/E1417M-16** Standard Practice for Liquid Penetrant Testing
	#3: Type I processes – personnel **shall** be dark adapted for a minimum of 1 minute prior to inspecting components and **shall not** wear photo chromic or permanently darken lenses.	**MIL-STD-6866 (1985)** Military Standard – Inspection, Liquid Penetrant
		MIL-STD-6866 (1985) Canceled and replaced by ASTM E1417-95a (Notice 2 dated 1996)
	#4: The examiner **shall** be in the darkened area for at least 5 min prior to performing the examination – If examiner wears glasses or lenses, they **shall not** be photosensitive.	**ASME (1992)** Boiler and Pressure Vessel Code; Section V; Article 6 – Liquid Penetrant Examination

#4: 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. (T-676.4[b])	**2010 ASME Boiler & Pressure Vessel Code**, 2011a Addenda, July 1, 2011 - V Nondestructive Examination - Article 6 - Liquid Penetrant Examination
#5: An inspector entering a darkened area **shall** allow at least 5 minutes for dark adaption before examining parts. (6-386)	**T.O. 33B-1-1** Air Force Technical Manual (change 2, 1990) – Nondestructive Inspection Methods, Chapter 6
#5: **Dark Adaptation**. - An inspector entering a darkened area **SHALL** allow at least 5-minutes for dark adaptation before examining parts. Furthermore, wearing clothing which fluorescences under ultraviolet light **SHALL NOT** be permitted during the performance of fluorescent penetrant inspection as it may raise the ambient white light in the inspection area to an unacceptable level. (2.5.5.1)	**TO 33B-1-1** **NAVAIR 01-1A-16-1** **TM 1-1500-335-23** Technical Manual -- Nondestructive Inspection Methods, Basic Theory - 15 October 2016
#6: You **should** allow at least 5 minutes for your eyes to become accustomed to the dark.	**PI-4-2** Nondestructive Testing Liquid Penetrant Handbook by General Dynamics (fourth edition)
#6: The subject of eye adaption is not specifically covered in this publication.	**ASNT Personnel Training Publications (PTP)** - Liquid Penetrant Testing Classroom Training Book - First Printing January 2005
#7: Not addressed	**MIL-HDBK-728/3 (1985)** Military Handbook – Liquid Penetrant Testing
#7: No Change - same as above.	**MIL-HDBK-728/3** (NOTICE 1), MILITARY HANDBOOK: LIQUID PENETRANT TESTING (01 JUL 1992), MIL-HDBK-728/3, dated 16 December 1985, has been reviewed and determined to be valid for use in acquisition.

	#8: Allow a minimum of 1 minute for dark adaption of the eyes when inspecting with fluorescent penetrant. (6.7)	**P.S. 21202 Rev R (1993)** McDonnel Douglas Liquid Penetrant Process Specification
	#8: Type 1 Processes - After exposure to visible light, the inspector's vision **shall** be dark adapted for a minimum of 1 minute before inspecting components.	**BSS7039, Rev. C - March 2015** Boeing Specification Support Standard - Liquid Penetrant Inspection
	#9: The inspector **should** become accustomed to the darkened area before looking for indications and **should** avoid going from the dark to the light, and back, without allowing sufficient time for his eyes to become "dark-adapted". (7-12)	**ASNT Nondestructive Testing Handbook (Vol I, Section 6)** – Edited by Robert C. McMaster - Copyright 1959
	#9: The time required for dark adaptation before testing can be performed varies with the individual and depends on the overall health and age of the individual operator. A dark adaptation time of 1 min is usually sufficient for fluorescent liquid penetrant testing with satisfactory ultraviolet radiation illumination. Complete dark adaptation may take as long as 20 min. (pg 229)	**ASNT Nondestructive Testing Handbook, Third Edition, Volume Two Liquid Penetrant Testing** - Editor - Patrick O. Moore - Copyright 2000
	#10: **Inspections**: The inspector should allow time for adapting to darkness; a 1-min period is usually adequate. (pg 83)	**ASM Handbook, Volume 17, Nondestructive Evaluation and Quality Control**
	6.15.1: Did inspectors allow at least 1 minute to condition their eyes to the darkness before conducting the inspection?	**Nadcap Audit Criteria AC7114/1 Audit Criteria for Nondestructive Testing Facility Penetrant Survey** - To be used on audits starting on or after 31-Dec-2017.
6. How long do you let a developer (after drying) dwell on part prior to inspection?	#1: The length of time the developer is to remain on the part prior to examination **should** be not less than 10 min. The maximum permitted developing times are 2 hr for aqueous developers and 1 hr for nonaqueous developers. (8.8.6) (7.1.7.6) (7.1.7.2)	**ASTM E 165-95** Liquid Penetrant Inspection Method. **Note**: AWS D1.1-92 (Chapter 6 – Inspection) and API Standard 1104 (Section 8.3) states that E 165 **shall** be used for PT applications/procedure.

	ASTM E 1219-94 Standard Test Method for Fluorescent Liquid Penetrant Examination Using the Solvent-Removable Process **ASTM E 1220-92** Standard Test Method for Visible Liquid Penetrant Examination Using the Solvent-Removable Process.
#1: **Developing Time**: - The length of time the developer is to remain on the part prior to inspection **shall** be not less than ten minutes. Developing time begins immediately after the application of dry power developer or as soon as the wet (aqueous or nonaqueous) developer coating is dry…The maximum permitted developing times **shall** be four hours for dry power developer (Form A), two hours for aqueous developer (Form B and C), and one hour for nonaqueous developer (Forms D and E). (8.8.5)	**ASTM E165/E165M-12** Standard Practice for Liquid Penetrant Examination for General Industry
#2: ***Dry Developers*** – Development time **shall** be between 10 min. minimum and up to 4 h maximum, and **shall not** be used with Type II penetrants. (7.5.1). ***Nonaqueous Developers*** – After drying, unless otherwise specified, the minimum and maximum dwell times are 10 minutes and 1 hour respectively. (7.5.2) ***Aqueous Developers*** – 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. Minimum and maximum dwell times, after the component is dry, are 10 minutes and 2 hours. (7.5.3)	**ASTM E 1417-95a** Practice for Liquid Penetrant Examination
#2: **Dry Developers** - Minimum and maximum developer dwell times **shall** be 10 min and 4 h, respectively. Dry developers **shall not** be used with Type II penetrants. (7.5.1)	**ASTM E1417/E1417M-16** Standard Practice for Liquid Penetrant Testing

Nonaqueous Developers - 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 between applications. (7.5.2) **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. Minimum and maximum development times, after the component is dry, are 10 min and 2 h. (7.5.3)	
#3: ***Dry Developers*** – Minimum dwell **shall** be 10 minutes, the maximum dwell shall be 4 hours. ***Nonaqueous Developers*** (after drying) – The minimum and maximum dwell times are 10 minutes and 1 hour respectively. ***Aqueous Developers*** (after drying) – Not used with Type II and Type I, Method A penetrants. Minimum and maximum dwell times are 10 minutes and 2 hours.	**MIL-STD-6866 (1985)** Military Standard – Inspection, Liquid Penetrant
	MIL-STD-6866 (1985) Canceled and replaced by ASTM E1417-95a (Notice 2 dated 1996)
#4: Final interpretation **shall** be made within 7 to 30 minutes after the developer is applied and is dry.	**ASME (1992)** Boiler and Pressure Vessel Code; Section V; Article 6 – Liquid Penetrant Examination
#4: Final Interpretation: **shall** be made not less than 10 min nor more than 60 min after the requirements of T-675.3 are satisfied. (T-676)	**2010 ASME Boiler & Pressure Vessel Code**, 2011a Addenda, July 1, 2011 - V Nondestructive Examination - Article 6 - Liquid Penetrant Examination
#5: The development time **should** be at least one-half of the penetrant dwell time, and **shall not** start until part is completely free of moisture.	**T.O. 33B-1-1** Air Force Technical Manual (change 2, 1990) – Nondestructive Inspection Methods, Chapter 6

Maximum developer dwell times are: Nonaqueous developer – 30 minutes; Aqueous developer – 1 hour; and Dry developer – 2 hours. (6-350)	
#5: **Table 2-4 (page 2-82)**: The developer dwell time **SHALL NOT** start until part is completely free of moisture or solvent. The dwell time for form a (dry developers) begins immediately after developer application. The dwell time for form b, c, d and e developers begins immediately after the developer is completely dry. (2.4.11.5) The minimum and maximum developer dwell times **SHOULD** be specified in the technical directives or part specific procedures mandating the inspection. Both the minimum and maximum developer dwell times that **SHALL** be used in the absence of specific technical directives or procedures are listed in (**Table 2-4**). These dwell times are based on the developer form, the ambient temperature, and the expected flaw condition. (2.4.11.5.1)	**TO 33B-1-1** **NAVAIR 01-1A-16-1** **TM 1-1500-335-23** Technical Manual -- Nondestructive Inspection Methods, Basic Theory - 15 October 2016
#6: With dry or nonaqueous wet developers, the accepted norm is 7 to 30 minutes (a "rule of thumb" is to use a time equal to one-half the penetrant or dwell time used) pg. 5-28.	**PI-4-2** Nondestructive Testing Liquid Penetrant Handbook by General Dynamics (fourth edition)
#6: **Development Time** (pg 18/19) - With a nonaqueous wet developer, the normal time until evaluation is 10 min to 1 h. With an aqueous developer, the normal time until evaluation is 10 min to 2 h. With a dry developer, the normal time until evaluation is 10 min to 4 h.	**ASNT Personnel Training Publications (PTP)** - Liquid Penetrant Testing Classroom Training Book - First Printing January 2005
#7: **No specific times given** – "After the developer is applied, time must be allowed for the penetrant to be drawn out of flaws by the developer". (3.2-3)	**MIL-HDBK-728/3 (1985)** Military Handbook – Liquid Penetrant Testing

#7: No Change - same as above.	**MIL-HDBK-728/3** (NOTICE 1), MILITARY HANDBOOK: LIQUID PENETRANT TESTING (01 JUL 1992), MIL-HDBK-728/3, dated 16 December 1985, has been reviewed and determined to be valid for use in acquisition.
#8: Apply dry and nonaqueous wet developers within 1 hour after the completion of the drying operation that follows removal of excess penetrant. (6.6.1 & 6.6.2)…Times are given in Table V (page 21). The minimum time is 10 minutes and a maximum time of 60 minutes, except dry developer, a maximum time of 4 hours.	**P.S. 21202 Rev R (1993)** McDonnel Douglas Liquid Penetrant Process Specification (***Amendment No. 1 – Issued 04 May, 1994***)
#8: Minimum and maximum development times are specified in **Table III** (7.2.6.6) **Examples**: Form a 10 minutes to 4 hours Form b 10 minutes to 2 hours Form c 10 minutes to 2 hours Form d 10 minutes to 1 hour **Note** (FL2) Reprocess parts exceeding the maximum development time.	**BSS7039**, **Rev. C - March 2015** Boeing Specification Support Standard - Liquid Penetrant Inspection
#9: A good rule of thumb is that the developing time **should not** be less than the minimum dwell time for the penetrant. (6-15)	**ASNT Nondestructive Testing Handbook (Vol I, Section 6)** – Edited by Robert C. McMaster - Copyright 1959
#9: Note that following drying of developer coatings or after applying dry developer to dried test parts, a sufficient period of time is required for liquid penetrant indications to develop. This time period is often known as the developer dwell time. (pg 205) The optimum indications are typically reached with developing times in the range from 2 to 10 min. Excessive bleedout of entrapped liquid penetrant may take 30 min or longer. (pg 59)	**ASNT Nondestructive Testing Handbook, Third Edition, Volume Two Liquid Penetrant Testing** - Editor - Patrick O. Moore - Copyright 2000

	#10: **Developing Time**: In general, 10 min is the recommended minimum developing time regardless of the developer form used. (pg 83)	**ASM Handbook, Volume 17, Nondestructive Evaluation and Quality Control**
	6.10.5: Are dwell times (in minutes) used by the supplier within the ranges noted below? **Form a** - 10 minutes minimum and 240 minutes maximum; **Form b** - 10 minutes minimum and 120 minutes maximum; **Form c** - 10 minutes minimum and 120 minutes maximum and **Form d** - 10 minutes minimum and 60 minutes maximum.	**Nadcap Audit Criteria AC7114/1 Audit Criteria for Nondestructive Testing Facility Penetrant Survey** - To be used on audits starting on or after 31-Dec-2017.
7. What are the dimensions and material composition of penetrant test panels/blocks and their purpose?	#1: **Not Addressed**	**ASTM E 165-95** Liquid Penetrant Inspection Method. **Note**: AWS D1.1-92 (Chapter 6 – Inspection) and API Standard 1104 (Section 8.3) states that E 165 **shall** be used for PT applications/procedure. **ASTM E 1219-94** Standard Test Method for Fluorescent Liquid Penetrant Examination Using the Solvent-Removable Process **ASTM E 1220-92** Standard Test Method for Visible Liquid Penetrant Examination Using the Solvent-Removable Process.
	#1: **Not Addressed**	**ASTM E165/E165M-12** Standard Practice for Liquid Penetrant Examination for General Industry
	#2: System performance (7.8.3) – The penetrant system **shall** be checked daily for performance. The check **shall** be made with known defect standards – System checks. (7.8.4)	**ASTM E 1417-95a** Practice for Liquid Penetrant Examination
	#2: Penetrant System Performance - (7.8.3) - The penetrant system's overall performance **shall** be checked as specified in Table 1. [**Daily**] The check shall be performed by processing a known defect standard through the system using in-use penetrant, emulsifier (if used) and	**ASTM E1417/E1417M-16** Standard Practice for Liquid Penetrant Testing

developer and appropriate processing parameters. The resulting indications will then be compared to the indications obtained using unused penetrant, emulsifier (if used) and developer. **Known Defect Standard** - The known defect standard used **shall** be approved by the cognizant engineering organization. (7.8.3.1)	
#3: System performance (5.8.3) – The penetrant system **shall** be checked daily for performance. The check **shall** be made with known defect standards. – Known defect standards (5.8.3.1) – The selection and procedures for the maintenance of know defect standards **shall** be approved by the contracting agency. --	**MIL-STD-6866 (1985)** Military Standard – Inspection, Liquid Penetrant
	MIL-STD-6866 (1985) Canceled and replaced by ASTM E1417-95a (Notice 2 dated 1996)
#4: Sensitivity panels not addressed – **Other** – Liquid Penetrant Comparator Block (T-648.1 thru T-648.3) **shall** be made of aluminum, Type 2024, 3/8 inch thick, and **should** have approximate face dimensions of 2 in X 3 in. **NOTE**: A liquid penetrant comparator block is use to qualify a procedure when it is not practical to conduct a liquid penetrant examination within the temperature range 60°F to 125°F.	**ASME (1992)** Boiler and Pressure Vessel Code; Section V; Article 6 – Liquid Penetrant Examination
#4: Appendix III - Qualification Techniques for Examinations at Nonstandard Temperatures: Addresses the use of an comparator block (Type 2024 material, 3/8 inch thick and face dimensions of 2 in. x 3 in.) (1) For temperature less than 40° F (5°C) and (2) Temperature greater than 125°F (52°C). (III-641)	**2010 ASME Boiler & Pressure Vessel Code**, 2011a Addenda, July 1, 2011 - V Nondestructive Examination - Article 6 - Liquid Penetrant Examination

#5: **System performance testing** (6-469) – The test panels used by the Air Force are made from 0.079 inch thick brass plate 3.94 inches long and 2.80 inches wide. A nickel plating is applied to the brass plate to a predetermined thickness, then flashed or plated with a thin layer of chromium to protect it against tarnishing. **Sensitivity** (6-196) – The test panels for penetrants of sensitivity Level I – Low, are thermally cracked aluminum blocks. The test panels for the rest of the sensitivity levels are a series of Titanium and Nickel alloy panels. – Therefore, non-qualification comparison tests are accomplished with cracked chrome plated panels.	**T.O. 33B-1-1** Air Force Technical Manual (change 2, 1990) – Nondestructive Inspection Methods, Chapter 6
#5: **Penetrant System Monitor (PSM),** also known as the "star burst" panel. The PSM is alternatively specified as Pratt and Whitney TAM Panel 146040, Sherwin Company P/N PSM-5 and Magnaflux Company P/N 198055. The PSM is especially suitable for high volume, semi-automated, and fully automated depot systems. It is intended for use as a daily or weekly monitor of the entire penetrant process. The PSM panel **SHALL NOT** be used as a substitute for the cracked-chrome plate panels. The PSM panels are authorized for use with automatic and semi-automatic spray systems used in some depot laboratories when directed by the Depot NDI Manager. (2.6.7.1) **The cracked-chrome panel** is made by burnishing a 2.80-inch wide brass or copper plate to a mirror finish, then electroplating a thin layer of chrome on this surface. After the plate is chrome plated and cracked, it is cut in half, lengthwise to produce two panels containing symmetrical crack patterns in each panel. Since the cracks extend across the original panel, the	**TO 33B-1-1** **NAVAIR 01-1A-16-1** **TM 1-1500-335-23** Technical Manual -- Nondestructive Inspection Methods, Basic Theory - 15 October 2016

two panels are provided as a set with each panel measuring 3.94-inches (100 mm) long and 1.38-inches (35 mm) wide. Panels are typically available with cracks of 10, 20, 30, and 50 microns. The 30 and 50-micron panels are most often used with low and medium sensitivity penetrants. The 10 and 20-micron panels are usually used with high and ultra-high sensitivity penetrants. The standard panel is the 20-micron panel. (2.6.7.2)

#6: Process control, page 7-12, mentions the use of artificially cracked test blocks.

PI-4-2 Nondestructive Testing Liquid Penetrant Handbook by General Dynamics (fourth edition)

#6: **System Monitor Panels** (pg 68) - Normally processed at the beginning of each shift to verify system performance. The panel is stainless steel, about 0.25 cm (0.1 in.) thick and 10 by 15 cm (4 by 6 in.).
Aluminum Reference Blocks (pg 69) - This type of block is widely used for comparing the performance of penetrants in field conditions. Blocks measure about 5 by 7.5 cm (2 by 3 in.), and are cut from 0.8 cm (0.3 in.) thick bare 2024-T3 aluminum alloy plate, with the 7.5 cm (3 in.) dimension in the direction of rolling.
Anodized and Plated Test Panels (pg 71) - Stress cracked anodized aluminum and chrome plated nickel test panels are frequently used for comparing penetrant sensitivity and washability.
Twin NiCr Sensitivity Panels (pg 72) - A set of two NiCr panels, each measuring 10 by 3.5 cm (3.9 by 1.4 inches) is sheared from the same stock. The panels come in sets having crack depths of 1 cm (0.4 in.), 2 cm (0.8 in.), 3 cm (1.2 in.) and 5 cm (2.0 in.).
***Note the discrepancy** (typo error?) in this document regarding crack depths of Ni-Cr Panels. Panels are normally*

ASNT Personnel Training Publications (PTP) - Liquid Penetrant Testing Classroom Training Book - First Printing January 2005

available in 10, 20, 30 and 50 microns (0.0004, 0.0008, 0.0012, 0.002 inch) flaw depth.	
#7: **System qualification Methods** (3.4.4) – Cracked aluminum block, 2024-T3 aluminum alloy, 3- by 2-inch panels from 5/16 to 3/8- inch thick. These panels, when first cracked, are satisfactory for evaluating fluorescent penetrants **only**. When re-cracked these panels provide a better pattern for evaluating visible penetrants. Chrome Nickel Test Panels provides a quantitative bases of comparison.	**MIL-HDBK-728/3 (1985)** Military Handbook – Liquid Penetrant Testing
#7: No Change - same as above.	**MIL-HDBK-728/3** (NOTICE 1), MILITARY HANDBOOK: LIQUID PENETRANT TESTING (01 JUL 1992), MIL-HDBK-728/3, dated 16 December 1985, has been reviewed and determined to be valid for use in acquisition.
#8: Test panels for measuring wash-ability **shall** be in accordance with MIL-I-25135. Test panels for determining sensitivity **shall** be in accordance with MIL-I-25135 and **shall** be chrome plated test panels containing fine crack pattern suitable for evaluation of penetrant sensitivity. Cracks may be in a starburst or parallel line pattern. (Commercial sources) (3.3)	**P.S. 21202 Rev R (1993)** McDonnel Douglas Liquid Penetrant Process
#8: **System Performance Tests** - Perform daily performance checks using a known defect standard. (6.3.2) The following standards are acceptable: (1) Actual or simulated production parts with known indications representative of anticipated defects; (2) Tesco cracked twin nickel-chrome panels in 10, 20, or 0 to 50 microns. (3) Pratt and Whitney TAM 146040 (PSM-5) panels or equivalent and (4) Sherwin Twin KDS Panels.	**BSS7039, Rev. C - March 2015** Boeing Specification Support Standard - Liquid Penetrant Inspection

Note: No specific dimensions or material compositions of standards are specified.

#9: Sensitivity (4.5.18) – Type II penetrant systems (4.5.18.1) – Preparation of test panels (4.5.18.1.1) – Aluminum panels 3 inches X 2 inches **shall** be cut from 5/16 inch thick 2024 aluminum alloy in the T3 condition … Type I penetrant systems (4.5.18.2) – Test Panels (4.5.18.2.1) – Test panels are 1 inch X 6 inches X ¼ inch thick bars, **some** of which are Ti 6 AL-4V alloy and the remainder are IN 718 alloy. **NOTE**: Quality assurance provisions (4) – Responsibility for inspection (4.1) – Unless otherwise specified in the contract or purchase order, the supplier is responsible for the performance of **all** inspection requirements as **specified herein.**	**MIL-I-25135E (1989)** Military Specification – Inspection Materials, Penetrants
#9: **Type 1 Penetrant Systems** (4.4.5.1) - Crack Specimens: The crack specimens **shall** have a sufficient number of cracks with varying size to provide a good baseline for comparison. A minimum of five cracks **shall** be used. The cracks **shall** produce indications with at least a five to one brightness ratio from the smallest to the largest when tested with a Level 4 sensitivity reference penetrant system. **Type 2 Penetrant Systems** (4.4.5.2) - These specimens are commercially available as cracked aluminum blocks, or they may be produced by a user as follows: Aluminum panels, approximately 3 x 2 inches (76 x 51 mm), shall be cut from 5/16 inch (7.9 mm) thick 2014 aluminum alloy conforming to AMS4035 in the T3 condition. The 3-inch (76 mm) dimension shall be parallel with the direction of rolling of the sheet. The panels …	**Aerospace Material Specification** AMS2644, Rev. F - Revised 2013-10

#10: Three-inch lengths are cut from a 3/8 X 2 inch bar of 2024 aluminum alloy. The block is heated at least 4 minutes to obtain a temperature of 525°C (977°F), then quenched in cold water (50°F or under), thus producing cracks I the aluminum alloy (7-26). Use cracked aluminum-alloy blocks in controlling the uniformity of a penetrant-materials system, **used materials** are supplied to half the block and **control materials** are applied to the other half for direct visual comparison of crack pattern results. (7-27)	**ASNT Nondestructive Testing Handbook (Vol I, Section 6)** – Edited by Robert C. McMaster - Copyright 1959
#10: **Chapter 8 Comparators and Reference Panels**: ***Specimen with Low Cycle Fatigue Cracks*** - materials of choice are high strength nickel and titanium alloys…The approximate size of each specimen, 150 x 25 x 6 mm (6.0 x 1.0 x 0.25 in.). (pages 246 & 247) ***Quench Cracked Aluminum Comparator Blocks*** - It is important to note that quench cracks rarely provide discrimination necessary for modern liquid penetrant materials and are not referenced in fracture control specifications. …discussion of quench crack panels is included primarily for historical reference. …made from as-rolled 2024-T3 aluminum…example reference is AMS 2644. (pg 248) ***Cracked Chrome Plated Panel*** was developed for the USAF under contract study programs. This type of panel is made by burnishing a brass or copper panel to mirror finish, then electroplating a thin layer of nickel followed by a layer of chrome on this polished surface. Variations in the composition of the plating baths and plating techniques determine the type and size of cracking in the nickel-chrome test panels: (1) **coarse crack panel** with cracks measuring about 10 µm (0.0004 in.) wide and 50 µm (0.002 in.) deep; (2) **medium crack panels**	**ASNT Nondestructive Testing Handbook, Third Edition, Volume Two Liquid Penetrant Testing** - Editor - Patrick O. Moore - Copyright 2000

	with cracks about 2 to 3 µm (8×10^{-5} in. to 1.2×10^{-4} in.) wide and 40 µm (0.0016 in.) deep; and **fine crack panel** with cracks about 0.5 µm (2×10^{-5} in.) in width. (pg 254)	
	5.9: Penetrant System Performance. **5.9.1**: Has the supplier performed an initial check to establish a baseline for each known defect standard and material in use? *Document implies the use of TAM panels and/or NiCr Panels.*	**Nadcap Audit Criteria AC7114/1 Audit Criteria for Nondestructive Testing Facility Penetrant Survey** - To be used on audits starting on or after 31-Dec-2017.
8. How are penetrants classified?	#1: **Type I – Fluorescent Penetrant Examination** ***Method A*** – Water-washable ***Method B*** – Post-emulsifiable, Lipophilic ***Method C*** – Solvent removable ***Method D*** – Post-emulsifiable, hydrophilic **Type II – Visible Penetrant Examination** ***Method A*** – Water-washable ***Method C*** – Solvent Removable	**ASTM E 165-95** Liquid Penetrant Inspection Method. **Note**: AWS D1.1-92 (Chapter 6 – Inspection) and API Standard 1104 (Section 8.3) states that E 165 **shall** be used for PT applications/procedure.
	#1: **Table 1** - Classification of Penetrant Examination Types and Methods. (Basically the same as identified above)	**ASTM E165/E165M-12** Standard Practice for Liquid Penetrant Examination for General Industry
	#2: **Not addressed** – (Only identifies type associated with standard)	**ASTM E 1219-94** **ASTM E 1220-92**
	#3: **Types:** ***Type I – Fluorescent dye*** ***Type II – Visible dye*** **Methods:** ***Method A*** – Water washable ***Method B*** – Post emulsifiable, lipophilic ***Method C*** – Solvent removable ***Method D*** – Post emulsifiable, hydrophilic	**ASTM E 1417-95a** Practice for Liquid Penetrant Examination

Sensitivity:
Sensitivity Level ½ - Very Low
Sensitivity Level 1 – Low
Sensitivity Level 2 – Medium
Sensitivity Level 3 – High
Sensitivity Level 4 – Ultrahigh

Note: Sensitivity levels apply to Type I penetrant systems only. Type II penetrant systems have only a single sensitivity and is not represented by any of these levels.

#3: **Classification**: (5)
5.1 Penetrant examination processes and materials are classified in accordance with the material classification contained in AMS 2644. Penetrant systems covered by this practice shall be of the following types, methods, and sensitivity levels:
Type:
Type I—Fluorescent dye.
Type II—Visible dye.

Method:
Method A—Water washable.
Method B—Post-emulsifiable, lipophilic.
Method C—Solvent-removable.
Method D—Post-emulsifiable, hydrophilic.

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):
Sensitivity Level 1⁄2 —Very low.
Sensitivity Level 1—Low.
Sensitivity Level 2—Medium.
Sensitivity Level 3—High.
Sensitivity Level 4—Ultrahigh.

Developers shall be of the following forms:
Form a—Dry powder.
Form b—Water-soluble.
Form c—Water-suspendable.

ASTM E1417/E1417M-16
Standard Practice for Liquid Penetrant Testing

Form d—Nonaqueous for Type I fluorescent penetrant.
Form e—Nonaqueous for Type II visible dye.
Form f—Specific application.

Solvent removers shall be of the following classes:
Class 1—Halogenated.
Class 2—Nonhalogenated.
Class 3—Specific application

#4: **Types:**

Type I – Fluorescent dye

Type II – Visible dye

Type III – Visible and fluorescent dye (dual mode)

Methods:
Method A – Water washable
Method B – Post emulsifiable, lipophilic
Method C – Solvent removable
Method D – Post emulsifiable, hydrophilic

Sensitivity:
Sensitivity Level 1 – Low
Sensitivity Level 2 – Medium
Sensitivity Level 3 – High
Sensitivity Level 4 - Ultrahigh

MIL-STD-6866 (1985) Military Standard – Inspection, Liquid Penetrant

MIL-STD-6866 (1985) Canceled and replaced by ASTM E1417-95a (Notice 2 dated 1996)

#5: Techniques (T-622)

Fluorescent water washable
Visible water washable
Fluorescent post-emulsifying
Visible post-emulsifying
Fluorescent solvent removable
Visible solvent removable

ASME (1992) Boiler and Pressure Vessel Code; Section V; Article 6 – Liquid Penetrant Examination

#5: 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. SE-165 is basically a copy of ASTM E 165-09.	**2010 ASME Boiler & Pressure Vessel Code**, 2011a Addenda, July 1, 2011 - V Nondestructive Examination - Article 6 - Liquid Penetrant Examination
#6: Same as MIL-STD-25135 (C&D), also addresses MIL-I-6866B & ASTM E 165 (Gives examples of each)	**T.O. 33B-1-1** Air Force Technical Manual (change 2, 1990) – Nondestructive Inspection Methods, Chapter 6
#6: The aerospace materials specification SAE AMS 2644 defines the categories universally used for classifying penetrant inspection materials. The categories are defined as follows and are further defined in (Table 2-1).	**TO 33B-1-1** **NAVAIR 01-1A-16-1** **TM 1-1500-335-23** Technical Manual -- Nondestructive Inspection Methods, Basic Theory - 15 October 2016
#7: **Type I** – Fluorescent Penetrant **Type II** – Color Contrast Dye Penetrant (9.1) Group I – Type II, Level 1, Method C Group II – Type II, Level 1, Method B Group III – Type II, Level 1, Method A Group IV – Type I, Level 1, Method A Group V – Type I, Level 2, Method B Group VI – Type I, Level 3, Method B Group VIA – Type I, Level 3, Method D Group VIB – Type I, Level 4, Method D Group VII – Type I, Level 3, Method C	**P.S. 21202 Rev R (1993)** McDonnel Douglas Liquid Penetrant Process
#7: **Classification** (1.2): **Type** Type 1 - Fluorescent Dye Type 2 - Visible Dye **Method** Method A - Water Washable	**BSS7039**, **Rev. C - March 2015** Boeing Specification Support Standard - Liquid Penetrant Inspection

Method B - Post Emulsifiable, Lipophilic
Method C - Solvent Removable
Method D - Post Emulsifiable, hydrophilic
Method E - Water-Washable, Water Based
Sensitivity Level
Sensitivity Level 1/2 - Ultra Low
Sensitivity Level 1 - Low
Sensitivity Level 2 - Medium
Sensitivity Level 3 - High
Sensitivity Level 4 - Ultrahigh
Note: Sensitivity levels established for Type 1 penetrants only
Developers
Form a - Dry Developer
Form b - Water Suspendable Developer
Form c - Water Suspendable Developer
Form d - Non aqueous Type 1 Developer Fluorescent
Form e - Non Aqueous Type 2 Developer
Form f - Special Applications
Form g - No Developer
Solvent Removers
Class 1 - Halogenated
Class 2 - Non-halogenated
Class 3 - Special Application

#8: **Type I** – Fluorescent dye
Type II – Visible dye
Type III – Visible and fluorescent dye (dual mode)

Method A – Water washable
Method B – Post emulsifiable, lipophilic
Method C – Solvent removable
Method D – Post emulsifiable, hydrophilic

Sensitivity Level ½
Sensitivity Level 1 – Low
Sensitivity Level 2 – Medium
Sensitivity Level 3 – High
Sensitivity Level 4 – Ultrahigh

Note: There are no sensitivity level

MIL-I-25135E (1989) Military Specification – Inspection Materials, Penetrants

classifications for types II and III systems. Sensitivity level ½ applies only to some Method A, Type I systems.

#8: **Classification** (1.4)
Penetrants **shall** be of the following types, methods, and sensitivity levels.
Type 1 Fluorescent Dye
Type 2 Visible Dye
Method A - Water washable
Method B - Post emulsifiable, lipophilic
Method C - Solvent removable
Method D - Post emulsifiable, hydrophilic
Sensitivity level 1/2 - Ultra low
Sensitivity level 1 - Low
Sensitivity level 2 - Medium
Sensitivity level 3 - High
Sensitivity level 4 - Ultra high
Sensitivity level 1/2 applies to Type 1, Method A penetrants only. There is no sensitivity level classification for Type 2 penetrants.
Developers shall be of the following forms:
Form a - Dry power
Form b - Water soluble
Form c - Water suspendable
Form d - Nonaqueous Type 1 Fluorescent (solvent based)
Form e - Nonaqueous Type 2 Visible Dye (solvent based)
Form f - Special Application
Solvent Removers shall be of the following classes:
Class 1 - Halogenated
Class 2 - Nonhalogenated
Class 3 - Special application

Aerospace Material Specification AMS2644, Rev. F - Revised 2013-10

#9: Penetrants are ordinarily classified in various groups. One major subdivision is the **type of dye** used, that is, whether (1) the fluoresces under black light, or (2) is highly contrasting under white light. A second major division of penetrant is determined by the manner in which they may be removed from the surface of parts (example: water-washable,

ASNT Nondestructive Testing Handbook (Vol I, Section 6) – Edited by Robert C. McMaster - Copyright 1959

	special solvents and post-emulsification penetrants.) (6-2_	
	#9: **Commercially Available Liquid Penetrant Materials** (pg 6) - The basic classification system remains fairly uniform and classifies the penetrant dye by type: fluorescent dye which is Type I, or visible dye which is Type II. Reference Table 1.1. (Types and methods of liquid penetrant testing). **Page 380 Aerospace**: All materials used for liquid penetrant testing **shall** conform to and be qualified per SAE AMS 2644 and appear on its qualified products list except ….	**ASNT Nondestructive Testing Handbook, Third Edition, Volume Two Liquid Penetrant Testing** - Editor - Patrick O. Moore - Copyright 2000
9. What are the dwell times for penetrant after it has been applied?	#1: The length of time the penetrant must remain on the part to allow proper penetration **should** be as recommended by the penetrant manufacture. Table 2 (a guide) gives **minimum** penetrant dwell times for different materials from 5 minutes to 10 minutes (8.5.2)	**ASTM E 165-95** Liquid Penetrant Inspection Method. **Note**: AWS D1.1-92 (Chapter 6 – Inspection) and API Standard 1104 (Section 8.3) states that E 165 **shall** be used for PT applications/procedure.
	#1: **Penetrant Dwell Time** (8.5.1) - Basically the same as stated above.	**ASTM E165/E165M-12** Standard Practice for Liquid Penetrant Examination for General Industry
	#2: Same as #1, except note "B" to table 1 states that maximum penetrant dwell time 60 in accordance with 7.1.4.2.	**ASTM E 1219-94** **ASTM E 1220-92**
	#2: **Table 1 Recommended Minimum Dwell Time**s - range from 5 to 10 minutes depending on material. (7.1.4.2)	**ASTM E1219-16** Standard Practice for Fluorescent Liquid Penetrant Testing Using the Solvent-Removable Process **ASTM E1209-10** Standard Practice for Fluorescent Liquid Penetrant Testing Using the Water-Washable Process
	#3: The dwell time, unless otherwise specified, **shall** be a minimum of 10 minutes. For dwell times greater than 2 hours, the penetrant **shall** be	**ASTM E 1417-95a** Practice for Liquid Penetrant Examination

reapplied as required to prevent drying. (7.2.1)	
#3: **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. For dwell times greater than two hours, the penetrant **shall** be reapplied as required.(7.2.1)	**ASTM E1417/E1417M-16** Standard Practice for Liquid Penetrant Testing
#4: The dwell time, unless otherwise specified, **shall** be a minimum of 10 minutes. For dwell times greater than 2 hours, the penetrant **shall** be reapplied as required to prevent drying. The component **shall** be immersed in penetrant, if that is the application method, no more than ½ the total dwell time.	**MIL-STD-6866 (1985)** Military Standard – Inspection, Liquid Penetrant
	MIL-STD-6866 (1985) Canceled and replaced by ASTM E1417-95a (Notice 2 dated 1996)
#5: The minimum penetration time **shall** be as recommended in SE Standards referenced in T-610 or as qualified by demonstration for specific applications. SE-165; SE-1209; SE-1220; & SE-1219 (T-643)	**ASME (1992)** Boiler and Pressure Vessel Code; Section V; Article 6 – Liquid Penetrant Examination
#5: The minimum penetration time **shall** be as required in Table T-672 or as qualified by demonstration for specific applications. Table list dwell times from 5 to 10 minutes for different materials.	**2010 ASME Boiler & Pressure Vessel Code**, 2011a Addenda, July 1, 2011 - V Nondestructive Examination - Article 6 - Liquid Penetrant Examination
#6: The **minimum** dwell time for service-induced defects **shall not** be less than 30 minutes. There is one exception to this requirement. When stress corrosion is suspected the minimum dwell time **shall not** be less than 240 minutes. These established dwell times are based on parts having a temperature of 60°F to 100°F.	**T.O. 33B-1-1** Air Force Technical Manual (change 2, 1990) – Nondestructive Inspection Methods, Chapter 6

#6: The minimum dwell time for service-induced defects **SHALL NOT** be less than 30-minutes, unless otherwise specified by a specific part procedure. Most dwell times are based on past experience with similar parts, materials and potential flaws. The minimum penetrant dwell time that **SHALL** be used is provided in (Table 2-2). Minimum penetrant dwell times for manufacturing induced defects **SHALL** be as specified by ASTM E 1417 or as specified by specific technical directive or procedures. (2.4.7.4.2)	**TO 33B-1-1** **NAVAIR 01-1A-16-1** **TM 1-1500-335-23** Technical Manual -- Nondestructive Inspection Methods, Basic Theory - 15 October 2016
#7: The **minimum** dwell times are from 5 to 20 minutes for a temperature range from 60 to 125°F and different types of materials. (pg. 3-16)	**PI-4-2** Nondestructive Testing Liquid Penetrant Handbook by General Dynamics (fourth edition)
#7: Document **does not** address a specific dwell time for penetrant. Dwell Time (pg 14) - The penetrant dwell time is the length of time that the penetrant is allowed to wet the surface and soak into discontinuities.	**ASNT Personnel Training Publications (PTP)** - Liquid Penetrant Testing Classroom Training Book - First Printing January 2005
#8: Step 3. After the liquid penetrant has been applied, sufficient time must be given to allow the penetrant to enter any flaws that are present. (general statement)	**MIL-HDBK-728/3 (1985)** Military Handbook – Liquid Penetrant Testing
#8: No Change - same as above.	**MIL-HDBK-728/3** (NOTICE 1), MILITARY HANDBOOK: LIQUID PENETRANT TESTING (01 JUL 1992), MIL-HDBK-728/3, dated 16 December 1985, has been reviewed and determined to be valid for use in acquisition.

#9: 6.4 – Use the applicable **minimum** penetrant dwell time listed in Table V (the **maximum** dwell time is 75 minutes for steel weldments and 60 minutes for all other cases). Table V states minimum dwell times to be between 2 and 30 minutes with applicable notes #1 - #6. (page 3 – amendment1)	**P.S. 21202 Rev R (1993)** McDonnel Douglas Liquid Penetrant Process ***(Amendment No. 1 – Issued 04 May, 1994)***
#9: **Penetrant Dwell Time (7.2.3)**: (1) Unless otherwise specified, allow 10 minutes minimum for penetrant dwell time. (2) Type 1 and 2 Method C inspections may be conducted at temperatures as low as 40 F (4.4 C) provided a minimum dwell time of 20 minutes is used. (3) The component shall not be immersed in penetrant for more than one half the total dwell time.	**BSS7039**, **Rev. C - March 2015** Boeing Specification Support Standard - Liquid Penetrant Inspection
#10: The recommended dwell or application times are approximate and may vary with local conditions. Application time in minutes: **(1)** parts & material with temperature range of 60°F - 90°F (3 to 5), (7 to 10) & (7 to 20**); (2)** parts & material with temperature range of 35°F - 60°F (10 to 15), (10 to 20), & (15 to 20). (section 6-14)	**ASNT Nondestructive Testing Handbook (Vol I, Section 6)** – Edited by Robert C. McMaster - Copyright 1959
#10: **Part 2. Liquid Penetrant Testing Processes**: Basically states for Method A, B & D - Allow sufficient time (termed dwell time) for the surface liquid penetrant to enter the discontinuities … (pg 42 & 43) **Note**: No specific time tables are given for this section. **Chapter 14, Aerospace** (pg 383) - The liquid penetrant dwell time, unless otherwise specified, **shall** be a minimum of 10 min. For dwell times greater than 2 h, the liquid penetrant **shall** be reapplied to prevent drying.	**ASNT Nondestructive Testing Handbook, Third Edition, Volume Two Liquid Penetrant Testing** - Editor - Patrick O. Moore - Copyright 2000
#11: **Dwell Time**: In most cases, however, a minimum of 10 min and a maximum of 30 min is adequate for	**ASM Handbook, Volume 17, Nondestructive Evaluation and Quality Control**

	both fluorescent and visible penetrants types. (pg 82)	
	6.7.7: Was the correct penetrant dwell time utilized as specified by customer requirements? **6.7.8**: If parts exceeded the maximum dwell time, was penetrant reapplied? *No specific times are identified, do not confuse the requirements outline in 6.10.5 (developer dwell times) for penetrant dwell times.*	**Nadcap Audit Criteria AC7114/1 Audit Criteria for Nondestructive Testing Facility Penetrant Survey** - To be used on audits starting on or after 31-Dec-2017.
10. When removing excess penetrant (Method A, B & D) with a manual water spray procedure, what parameters (temperature, pressure, distance, etc.) should be observed?	#1: **Method A**: The temperature of the water **should** be relatively constant and **should** be maintained with the range of 50 to 100°F. The rinse time should not exceed 120 seconds unless otherwise specified by part or material specification. The spray-rinse water pressure **should not** be greater than 40 PSI. (8.6.1.1) **Method B (Lipophilic):** Post rinsing following emulsification. Control rinse water temperature within the range of 50 to 100°F. Spray rinse water pressure **should be** in accordance with manufacturer's recommendations. The maximum spray rinse time **should not** exceed 120 s unless otherwise specified…(8.6.2.5) **Method D (Hydrophilic):** Pre-rinsing prior to emulsification (8.6.3.1). Spray rinse at a water pressure of 25 to 40 PSI and pre-rinse time should be the least possible time (nominally 60 s maximum) (8.6.3.2)	**ASTM E 165-95** Liquid Penetrant Inspection Method. **Note**: AWS D1.1-92 (Chapter 6 – Inspection) and API Standard 1104 (Section 8.3) states that E 165 **shall** be used for PT applications/procedure.
	#1: **Method A** - …the excess penetrant on the surface being examined **must** be removed with water. The temperature of the water **shall** be maintained within the range of 50° to 100°F [10° to 38°C]. Spray-rinse water pressure **shall not** exceed 40 psi [275 kPa]. When hydro-air pressure spray guns are used, the air pressure **should not** exceed 25 psi	**ASTM E165/E165M-12** Standard Practice for Liquid Penetrant Examination for General Industry

[172 kPa]. (8.6.1.1)

#2: The excess penetrant on the surface being examined **must** be removed by water, usually a washing operation. (7.1.5) Immersion Rinsing (7.1.5.1)… (a) rinse time **should not** exceed 120 s unless… (b) temperature of the water **should** be relatively constant and should be maintained within the range of 50° to 100°F…(c) spray rinse water pressure **should not** be greater than 30 PSI.	**ASTM E 1209-94** Fluorescent Liquid Penetrant Examination Using the Water-Washable Process
#2: Perform the rinsing operation under black light so that it can be determined when the surface penetrant has been adequately removed. (7.1.5) (a) Rinse time - Maximum **should** be specified by part or material specification. (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) Spray rinse water pressure **should** not be greater than 40 psi (275 kPa). (7.1.5.1)	**ASTM E1209-10** Standard Practice for Fluorescent Liquid Penetrant Testing Using the Water-Washable Process
#3: The maximum spray rinse time **should not** exceed 120 seconds unless otherwise specified by part or materials specification. Control rinse water temperature within the range from 50 to 100°F. Spray rinse water pressure **should** be 40 PSI max or in accordance with the manufacturer's instructions. (7.1.6.2)	**ASTM E 1208-94** Fluorescent Liquid Penetrant Examination Using the Lipophilic Post-Emulsification Process
#3: **Spray Post Rin**sing - (a) The maximum spray rinse time **should not** exceed 120 s unless otherwise specified y part or material specification. (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) Spray rinse water pressure **should** be 40 psi max (275 kPa max) or in accordance with the manufacturer's	**ASTM E1208-16** Standard Practice for Fluorescent Liquid Penetrant Testing Using the Lipophilic Post-Emulsification Process

instructions.

#4: Pre-rinsing (7.1.5.1)…(a) control water temperature within the range of 50 to 100°F…(b) spray rinse at water pressure of 25 to 40PSI…(c) pre-rinse time…, nominally 60 s maximum…	**ASTM E 1210-92** Fluorescent Liquid Penetrant Examination Using the Hydrophilic Post-Emulsification Process
#4: **Pre-rinsing** when using a hydrophilic emulsifier bath but not necessary for a spray application of hydrophilic emulsifier: (a) Control water temperature within the range of 50 to 100°F (10 to 38°C) (b) Spray rinse at water pressure of 25 to 40 psi (172 to 275 kPa). (c) Pre-rinse time **should** be maintained at the least possible time to provide a consistent residue of penetrant on parts, nominally 60 s maximum wash time to be as specified by the part or material specification. (7.1.5.1) **Spray Post-Rinsing** (a) Spray rinse water pressure **shall not** exceed 40 psi (275 kPa) when manual, automated, or hydro-air spray guns are used. When hydro-air pressure spray guns are used, the air pressure **shall not** exceed 25 psi (172 kPa). (b) The maximum spray rinse time **should not** exceed 120 s unless otherwise specified by part or materials specification. (c) Control rinse water temperature within the range of 50 to 100°F (10 to 38°C). (7.1.7.1)	**ASTM E1210-16** Standard Practice for Fluorescent Liquid Penetrant Testing Using the Hydrophilic Post-Emulsification Process
#5: **Method A, B & D**: (7.3.1.1) Water pressure adequate to remove the penetrant **shall** be used but **shall not** exceed 40 PSI. The water temperature **shall** be between 50 to 100°F. When Hydro-air nozzles are used the air pressure **shall not** exceed 25 PSI. A coarse spray **shall** be used with a minimum distance of 12 inches when possible between the spray nozzle and the part.	**ASTM E 1417-95a** Practice for Liquid Penetrant Examination

#5: **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)
Manual Spray—For handheld spray guns 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. (7.3.1.1)
Automated Spray - For automated spray systems, the wash parameters **shall** be such that the requirements of 7.8.3 are met. Water temperature shall be maintained between 50 to 100°F [10 to 38°C]. (7.3.1.2)
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]. (7.3.1.4)
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 in 7.3.1.1, 7.3.1.2, and 7.3.1.4. (7.3.2)
Method D Process—Hydrophilic post emulsifiable penetrant **shall** be removed with a water prerinse, application of the hydrophilic emulsifier and then a postrinse.
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 7.3.1.1 or 7.3.1.2 **shall** apply. (7.3.4.1)

Postrinse—After the application and dwell of the hydrophilic emulsifier, the component being examined **shall** be rinsed with water. The spray rinse parameters of 7.3.1.1, 7.3.1.2, and 7.3.1.4 shall apply. (7.3.4.3)	
#6: **Method A, B & D**: Maximum water pressure **shall** be 40 PSI. Water temperature **shall** be between 50° - 100°F. A course spray **shall** be used with a minimum of 12 inches, when possible between the spray nozzle and part. Hydro-air nozzles **shall** be permitted **only** for Level 1 or Level 2 sensitivity processes with a maximum of 25 PSI added air pressure.	**MIL-STD-6866 (1985)** Military Standard – Inspection, Liquid Penetrant
	MIL-STD-6866 (1985) Canceled and replaced by ASTM E1417-95a (Notice 2 dated 1996)
#7: **Method A, B & D**: Water pressure **shall not** exceed 50 PSI and water temperature **shall not** exceed 110°F. (T-644.1)	**ASME (1992)** Boiler and Pressure Vessel Code; Section V; Article 6 – Liquid Penetrant Examination
#7: **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). **Post-Emulsification Penetrants** - The temperature and pressure of the water shall be as recommended by the manufacturer. (T-673.2)	**2010 ASME Boiler & Pressure Vessel Code**, 2011a Addenda, July 1, 2011 - V Nondestructive Examination - Article 6 - Liquid Penetrant Examination
#8: **Method A & B**: Normal line pressure, approximately 10 to 35 PSI, is acceptable and is generally used. Water pressure in excess of 40 PSIG or injection of compressed gases or air into the water system, **shall not** be used. (6-263) Penetrant – emulsifier combinations meeting specification requirements are washable in the temperature range of 60°F to 100°F.	**T.O. 33B-1-1** Air Force Technical Manual (change 2, 1990) – Nondestructive Inspection Methods, Chapter 6

Hot water, 120°F or above **shall not** be used. (6-264) A spray angle, generally of 45 degrees to 70 degrees is most effective. (6-265) Washing of fluorescent penetrant **shall** be done under a black light in a semi-darkened area and the washing stopped when a low background level is reached. (6-266) **Method D**: Pre-Rinse – The cycle **shall** be a coarse spray of plain water for 30 to 120 seconds, at a pressure as low as practically possible not to exceed 40 PSIG, with a water temperature of 55°F to 100°F. (6-293) Post-Rinse – The cycle shall be a plain water spray of 30 to 60 seconds duration, at a line pressure of 10 to 35 PSIG, and with the water at ambient temperature of 55°F to 100°F. Rinsing of fluorescent penetrants shall be accomplished under black light. (6-305)	
#8: Water washing or spray rinsing is usually accomplished in a stationary rinse tank, which is provided with a hose, nozzle, drain, and in the case of fluorescent penetrant, UV-A illumination. Rinsing procedures used for removal of water-washable penetrant, Method "A", and postemulsifiable penetrant, Method "B" (after emulsification), and Method "D" (after remover application) are nearly identical. (2.4.9) **Water Pressure**: Normal line pressure, approximately 10 to 40 psig, is acceptable and is generally used. Water pressures in excess of 40 psig **SHALL NOT** be used. If hydro-air nozzles are used, air pressure shall not exceed 25 psi. **Water Temperature**: Penetrant-emulsifier combinations meeting specification requirements are washable in the temperature range of 50□F (10□C) to 100□F (38□C). Therefore, the rinse water temperature **SHALL** be maintained between 50□F	**TO 33B-1-1** **NAVAIR 01-1A-16-1** **TM 1-1500-335-23** Technical Manual -- Nondestructive Inspection Methods, Basic Theory - 15 October 2016

(10□C) to 100□F (38□C). Where possible, the spray nozzle **SHALL** be held a minimum of 12 inches from the part surface. The total rinse time **SHALL NOT** exceed 120-seconds.	
#9: **Method A**: A course forceful water spray is found to work best – the action being limited to the time it takes to remove only the surface penetrant. The temperature of the water **should** be held between 60 and 110°F. If penetrant is fluorescent, the wash is conducted under black light. (pg. 4-8) **Method B & D**: Not specifically addressed in any detail.	**PI-4-2** Nondestructive Testing Liquid Penetrant Handbook by General Dynamics (fourth edition)
#9: **Water Rinse (Method A, B and D)** page 15 - The water rinse **should** be coarse droplets normally applied at an oblique angle from a distance of about 30 cm (12 in.). The preset pressure **should not** exceed 40 psi (275 kPa), and the temperature **should** be between 10 to 38 °C (50 to 100 °F). When hydro-air nozzles are used, the air pressure **should not** exceed 25 psi (172 kPa).	**ASNT Personnel Training Publications (PTP)** - Liquid Penetrant Testing Classroom Training Book - First Printing January 2005
#10: **Not specifically addressed in any detail.**	**MIL-HDBK-728/3 (1985)** Military Handbook – Liquid Penetrant Testing
#10: No Change - same as above.	**MIL-HDBK-728/3** (NOTICE 1), MILITARY HANDBOOK: LIQUID PENETRANT TESTING (01 JUL 1992), MIL-HDBK-728/3, dated 16 December 1985, has been reviewed and determined to be valid for use in acquisition.
#11: **Method A**: Remove excessive penetrant using water spray. When spray rinse facilities are not available…, rinsing may be performed by swabbing with a clean, lint free cloth saturated with clear water. (6.5.1)	**P.S. 21202 Rev R (1993)** McDonnel Douglas Liquid Penetrant Process

Method B: Remove the emulsifier with water spray or immersion equipment. Effective rinsing has been accomplished when black light are used – (6.5.2.1)
Method D: May be rinsed with a clear water spray prior to emulsification to remove part of the penetrant. The water temperature **must** be between 50°F and 100°F and the pressure **must** be 40 PSI or less. The rinse time **shall not** exceed one minute. (6.5.2.1 note)

#11: **Removal Station (5.1):** Water pressure and temperature gauge viewable by operator:
(1) Water pressure shall not exceed 40 psi (276 kPa)
(2) Range of water temperature is 50 to 100 F (10 to 38 C)
(3) Hydro-air nozzles shall not exceed a maximum air pressure of 25 psi (172 kPa)

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#12: **Water-Emulsifiable Dye-Penetrant Process**: The water-removable combination can then be flushed from the surface of the part by using a *heavy volume* of water or a water spray.
Water-Washable Dye-Penetrant Process: A wide, fan-shaped spray is best, and means **should** be available for practically atomizing the water droplets to achieve faster emulsification. Water at 60°F to 90°F is recommended. (6-16)

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#12: **Water Rinse Removal of Excess Surface Self-Emulsifiable Liquid Penetrant** (Method A): Excessively high water pressures greater than 275 kPa (40 lb_f $in.^{-2}$) or extended rinse times greater than 120 s (2 min) should be avoided to guard against over rinsing, particularly where surface discontinuities may be wide and shallow. Rinse water temperature around 20°C (70°F) is adequate when rinsing… Low temperature rinse water (below 10°C

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	or 50°F) may reduce the ease with which penetrants can be rinsed off the test parts. Some manufacturers of liquid penetrants recommend elevated rinse temperatures of 30 to 45°C (or 90 to 110°F).[Page 50] **Aerospace**: (Method A) - Water pressure adequate to remove the liquid penetrant **shall** be used but **shall not** exceed 275 kPa (40 lb_f $in.^{-2}$). Water temperature **shall** be between 10 to 38°C (50 to 100°F). When hydro air nozzles are used the air pressure **shall not** exceed 172 kPa (25 lb_f $in.^{-2}$). A coarse spray **shall** be used with a minimum distance of 300 mm (12 in.), when possible between the spray nozzle and the part. (page 383)	
	#13: **Rinsing** - For all methods….Rinse time **should** be determined experimentally for specific workpieces; it usually varies from 10 s to 2 min. For spray rinsing, water pressure **should** be constant. A pressure of about 275 kPa (40 psi) is desirable. Most penetrants can be removed effectively with water in a range of 10 to 40°C (50 to 100°F). (pg 83)	**ASM Handbook, Volume 17, Nondestructive Evaluation and Quality Control**
	6.9: Penetrant Removal: **6.9.1**: Is the rinse water controlled to provide a coarse spray?; **6.9.2**: Is the rinse water temperature controlled within the range of 50 °F (10 °C) to 100 °F (38 °C)?; **6.9.3**: Is the rinse water pressure controlled to 40 psi (275 kPa) maximum?; **6.9.7**: If used, is the air pressure on the hydro air nozzle controlled to 25 psi (170 kPa) maximum and monitored at least daily or prior to use?	**Nadcap Audit Criteria AC7114/1 Audit Criteria for Nondestructive Testing Facility Penetrant Survey** - To be used on audits starting on or after 31-Dec-2017.
11. What personnel safety equipment (if any) is required when performing the penetrant method of inspection?	#1: **Scope**: (1.5) This standard does not purport to address all of the safety problems, 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	**ASTM E 165-95** Liquid Penetrant Inspection Method. **Note**: AWS D1.1-92 (Chapter 6 – Inspection) and API Standard 1104 (Section 8.3) states that E 165 **shall** be used for PT applications/procedure.

regulatory limitations prior to use. For specific hazard statements, see notes… **NOTE**: There is no direct reference to using safety equipment (i.e., neoprene gloves, apron, eye protection) when handing penetrant materials.	
#1: **Scope**: (1.5) This standard does not purport to address all of the safety problems, 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.	**ASTM E165/E165M-12** Standard Practice for Liquid Penetrant Examination for General Industry
#2: Same general statement as for E 165 response, plus notes.	**ASTM E 1219-94** Standard Test Method for Fluorescent Liquid Penetrant Examination Using the Solvent-Removable Process
#3: Same general statement as for E 165 response, plus notes.	**ASTM E 1220-92** Standard Test Method for Visible Liquid Penetrant Examination Using the Solvent-Removable Process
#4: Same general statement as for E 165 response, plus notes.	**ASTM E 1417-95a** Practice for Liquid Penetrant Examination
#4: 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. (*the term problems was replaced with the term concerns*) (1.6)	**ASTM E1417/E1417M-16** Standard Practice for Liquid Penetrant Testing
#5: Safety equipment (i.e., eye protection, gloves, apron) are not addressed – nor is there a general safety statement.	**MIL-STD-6866 (1985)** Military Standard – Inspection, Liquid Penetrant
	MIL-STD-6866 (1985) Canceled and replaced by ASTM E1417-95a (Notice 2 dated 1996)

#6: Same as MIL-STD-6866	**ASME (1992)** Boiler and Pressure Vessel Code; Section V; Article 6 – Liquid Penetrant Examination
#6: States conformance to SE-165 [Standard Practice for Liquid Penetrant Examination for General Industry] which is basically a copy of ASTM E-165-09. (T-610)	**2010 ASME Boiler & Pressure Vessel Code**, 2011a Addenda, July 1, 2011 - V Nondestructive Examination - Article 6 - Liquid Penetrant Examination
#7: **AFOSH STD 127-110** provides safety requirements for penetrant inspection. These requirements are mandatory for all Air Force activities. Also, see Safety Summary section for Warnings, Cautions, and other applicable statements.	**T.O. 33B-1-1** Air Force Technical Manual (change 2, 1990) – Nondestructive Inspection Methods, Chapter 6
#7: **Section VIII Liquid Penetrant Inspection Safety**: Sections (2.8) thru (2.8.7.2) addresses specific requirements, precautions and equipment. Air Force Instruction 91-203 or appropriate service directive **SHALL** be consulted for additional safety requirements.	**TO 33B-1-1** **NAVAIR 01-1A-16-1** **TM 1-1500-335-23** Technical Manual -- Nondestructive Inspection Methods, Basic Theory - 15 October 2016
#8: For protection, oil-resistant gloves and apron **should** be worn. Face and eyes **should** be protected by wearing a face shield. (7-16)	**PI-4-2** Nondestructive Testing Liquid Penetrant Handbook by General Dynamics (fourth edition)
#8: **Safety Precautions** (pg 8&9) - Subjects of Fire, Skin Irritation, Air Pollution and Ultraviolet Radiation are discussed.	**ASNT Personnel Training Publications (PTP)** - Liquid Penetrant Testing Classroom Training Book - First Printing January 2005
#9: (3.0) Safety Notice…(3.8)…the use of dust masks, goggles, face shields, water proof aprons and/or clothing is strongly encouraged. Many times hand creams and/or rubber gloves are found to be useful,…	**MIL-HDBK-728/3 (1985)** Military Handbook – Liquid Penetrant Testing
#9: No changes - same as above.	**MIL-HDBK-728/3** (NOTICE 1), MILITARY HANDBOOK: LIQUID PENETRANT TESTING (01 JUL 1992), MIL-HDBK-728/3, dated 16 December

	1985, has been reviewed and determined to be valid for use in acquisition.
#10: (8.) Safety…personnel **shall** refer to the applicable manufacturing procedure or the Component Safety Manual for appropriate personal protective equipment and safe work procedures. (8.1.2)…subcontractors **will** provide their employees with the necessary training, procedures and personal protective equipment…(8.1.3) Neoprene gloves **shall** be worn when handling cleaning and penetrant liquids to prevent skin irritation. (8.2.3 [a])	**P.S. 21202 Rev R (1993)** McDonnel Douglas Liquid Penetrant Process
#10: **WARNING** notes are included throughout the document - Do not take these WARNING(s) to be all inclusive, nor to completely describe hazards or precautionary measures applicable to specific procedures or operating environments. Non-Boeing personnel must refer to their employer's safety instructions for information concerning hazards which may occur during operations described in this specification.	**BSS7039, Rev. C - March 2015** Boeing Specification Support Standard - Liquid Penetrant Inspection
#11: **Penetrant Handling** (7-35) – Penetrants will often cause skin irritation in some people if the skin is continually exposed to the penetrant. The following *suggestions* will greatly reduce irritation by the penetrant: 1. Avoid Contact…wear neoprene gloves. 2. Keep interior of gloves clean. 3. Keep penetrant off clothes. 4. Wash any penetrant from skin with soap and water as soon as possible. 5. Check periodically for traces of fluorescent penetrant on skin, clothes, and inside of gloves by examining under black light.	**ASNT Nondestructive Testing Handbook (Vol I, Section 6)** – Edited by Robert C. McMaster - Copyright 1959
#11: **Part 8. Health and Safety Precautions** - Pages 71 -80 provide input on a mutable of issues regarding	**ASNT Nondestructive Testing Handbook, Third Edition, Volume Two Liquid Penetrant**

Reviewing different approaches to a simple question provides additional insight