ASNT Level II Study Guide

Liquid Penetrant Testing Method

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Introduction

Overview of the Study Guide

This study guide contains basic information intended to prepare a candidate for Level II penetrant inspection examinations administered within the ASNT Central Certification Program (ACCP). This study guide does not present all of the knowledge necessary for certification; the candidate is expected to supplement this guide with the recommended references that follow.

This study guide is divided into three chapters; Chapter 1 and Chapter 2 cover the information found on the Level II General (written) Examination, and Chapter 3 covers the information found on the Level II Hands-on Practical Examination. At the end of Chapter 1, there are questions typical of those that could appear within a portion of the Level II General Examination. These questions contain references for further study, and they are intended to aid the candidate in determining his/her comprehension of the material.

Following each section of Chapter 1 is a "Recommended Reading" box containing references to where additional information on the subjects identified can be found. Listed under "Reference" there is an acronym for a book (*NDT Handbook* = HB, *Liquid Penetrant Programmed Instruction Book* = PI, and *Principles and Applications of Liquid Penetrant Testing Classroom Training Text* = PA) followed by a colon and the specific page range where the topic is discussed.

At the end of the study guide there are several appendices relevant to successful preparation for the ACCP Level II liquid penetrant inspection examinations, particularly Appendix 1, which describes pertinent NDT qualification and certification documents allowing for better understanding of the NDT qualification and certification options available to industry.

Acknowledgments

The authors acknowledge the support of the AlliedSignal Aerospace NDT Network and the ASNT Technical Services Department staff.

Recommended References

Nondestructive Testing Handbook, second edition: Volume 2, *Liquid Penetrant Tests* [ASNT order #126]

Principles and Applications of Liquid Penetrant Testing Classroom Training Text, [ASNT order #2204]

Liquid Penetrant Testing Programmed Instruction Handbook, PI-4-2 (ASNT/General Dynamics) [ASNT order #1502]

Resource Materials

ASM Metals Handbook, 9th edition, Volume 17, *Nondestructive Evaluation and Quality Control, Liquid Penetrant Inspection*, [ASNT order #105]

Recommended Practice No. SNT-TC-1A, 1992 edition [ASNT order #2050]

ANSI/ASNT CP-189-1995: Standard for Qualification and Certification of Nondestructive Testing Personnel [ASNT order #2505]

ASNT Central Certification Program (ACCP) [ASNT order #6001]

ASTM E 165, *Standard Test Method for Liquid Penetrant Examination*

Chapter 1
Overview of Liquid Penetrant Testing

History of Liquid Penetrant Testing

Liquid penetrant inspection is one of the oldest methods of nondestructive testing (NDT). Its origin is generally attributed to the inspection of wheel axles in the railroad industry in the 1890s. It was noticed that after oil was wiped off of the part surface, it would reappear where a crack or other type of discontinuity was located. This discovery led to the "Oil and Whiting" test. Parts were immersed in oil and then wiped with rags dampened with kerosene. Powdered chalk was used to dust the surface to increase the visibility of any oil leaking back onto the part surface. Today's liquid penetrant testing evolved from the Oil and Whiting test through continual improvements to the type of oil used, the addition of dyes, and the creation of special removers and developers.

Principles of Liquid Penetrant Testing

Liquid penetrant testing (PT) is based on the ability of a liquid to seep into cavities that are open to the surface and remain in the cavity when the excess liquid is removed. The liquid remaining in the cavity is then drawn out to form an indication that is much more visible than the cavity itself. The PT inspection method is used as a nondestructive evaluation (NDE), nondestructive inspection (NDI) and NDT tool for detecting surface discontinuities in solid, nonporous materials. It is used on wrought, cast metal, and metal alloys, weldments, powdered metals, plastics, ceramics, and glass. A variety of materials and application methods allow for some adjustment of the process sensitivity to certain types of discontinuities, surface conditions and of material types.

PT is one of the most widely used NDT inspection methods in industry. Its ability to detect small discontinuities open to the surface regardless of their orientation or the shape of the part. With proper sequencing of the PT process in manufacturing and the use of appropriate cleaning methods with trained and certified operators, PT inspection is a very reliable, accurate, and effective surface inspection process.

Advantages of the Penetrant Process

The following are advantages of the liquid penetrant process:

1. very small surface discontinuities can be detected,
2. a wide variety of materials can be tested,
3. complex geometrical shapes can be inspected in a single operation,
4. various sensitivities and processing methods are available,
5. it is relatively easy to use,
6. it can be portable, and
7. when compared to other testing methods, it has a low cost.

Disadvantages of the Penetrant Process

The following are disadvantages of the liquid penetrant process:

1. only discontinuities that are open to the surface can be detected;
2. porous materials cannot be tested;
3. surfaces must be clean and free of paint, coatings, soil, moisture, and contaminants;
4. it cannot be used following metal smearing operations such as shot peening, sand blasting, certain machining operations (unless material is acid etched to remove smeared metal);

5. some materials (rubber and plastics) may be adversely affected by the penetrant's petroleum base;
6. it is very dependent on operator skill; and
7. it can cause dryness, cracking, and/or irritation to skin under prolonged contact.

Recommended Reading

Subject	Reference*
history of liquid penetrant testing	HB:19-20; PA:13; PI:1-8
basic principles of liquid penetrant testing	HB:20; PA:13-14; PI:1-1 to 1-14
advantages and disadvantages of liquid penetrant testing	HB:20-23, 558; PA:15-16; PI:7-1 to 7-8

*See *Introduction* for explanation of references.

Basics of the Penetrant Process

The basic penetrant process can be divided into three steps; apply the penetrant, remove the excess surface penetrant, and develop the indication. However, the process must be preceded by appropriate surface preparation and cleaning methods, indications must be evaluated after processing, and parts must be cleaned after testing.

Preparation of Parts for Penetrant Testing

Final examination by the penetrant process should be performed following all operations that may cause or expose discontinuities on the part surface. Examples of these operations are heat treating, machining, welding, bending and straightening.

The penetrant process should be performed before any treatments that smear the surface of the part (i.e., honing, lapping, sanding, deburring, sand or vapor blasting). If these types of operations are performed, the parts must be chemically etched before the penetrant process to obtain any meaningful results.

Penetrant inspection also should be performed before operations such as peening, plating, painting, anodizing, or any other surface coating operations.

Surface Condition

The surface condition of a part must be evaluated before the penetrant process begins. The condition of the surface plays a critical role in the success or failure of the PT process to form an indication from a discontinuity.

Coatings such as paint and plating interfere with the penetrant's ability to enter a discontinuity by covering or filling the cavity. Indications produced on coated surfaces are generally from discontinuities in the paint or plating rather than those in the base material. Anodized coatings are very porous. Absorption of the penetrant can mask discontinuities by making relevant indications indistinguishable from the anodized surface of the part.

Operations that deform the surface such as grinding, cutting, shot peening, sand blasting and vapor honing, can cover discontinuities by smearing a thin layer of metal over the opening, which reduces its size or seals it completely. Since PT inspection cannot detect anything below the surface, this thin coating of metal prevents the penetrant liquid from entering the cavity and forming an indication. These operations also can cause discontinuities in the material and performing the PT process before the metal smearing operation is not always an option. In such cases, the material should be chemically etched following the mechanical operation and prior to the PT process.

Surface Contamination

The most common surface condition that adversely affects the PT process is the presence of oils, grease, dirt, rust, scale, carbon deposits or other contaminants. These materials may prevent the penetrant from entering the discontinuity, they may absorb the penetrant and mask indications, or they may chemically react with the penetrant materials and reduce the penetrant's effectiveness. Precleaning of components using the appropriate method to remove the type of contaminants encountered before PT inspection is critical. Table 1.1 lists common contaminants that affect the penetrant process.

Penetrant Application

The type of penetrant applied may be a visible dye, fluorescent dye, or a combination of the two (dual mode).

Penetrant may be applied by various methods as listed in Table 1.2. Care should be taken to ensure complete coverage of the areas of interest, regardless of how the penetrant is applied. Brushing and spraying can fail to cover areas completely and immersion can trap air and prevent penetrant (or emulsifier when rinsing) from contacting the part surface.

Temperature

The temperature of the penetrant materials and the part must be within an acceptable range for processing. ASTM E 165 specifies a temperature range of 10-38 °C (50-100 °F).

Table 1.1: Precleaning

Contaminant	Effects on the Penetrant Process
Carbon, varnish	Bridge/fill voids, produce residual background, cause false indications
Heavy oils	Fill voids, fluoresce, cause dye degradation
Light oils	Fill voids, fluoresce, cause dye degradation
Oil with solid particles	Fill voids, fluoresce, cause false indications, cause dye degradation
Paint	Bridge voids, produce residual background, cause false indications
Penetrant material residue	Fill voids, interfere with indication formation
Scale, oxide, corrosion	Bridge/fill voids, produce residual background, cause false indications
Smeared metal	Bridge/fill voids

Table 1.2: Penetrant application

Type of Penetrant	MIL-I-25135 Designation	Sensitivity Levels	Method of Application*	Lighting Required
Fluorescent	I	1/2, 1, 2, 3, 4	Spray, dip, brush	Ultraviolet
Visible	II	1	Spray, dip, brush	Visible
Dual mode		1	Spray, dip, brush	Visible/ Ultraviolet

*Spray may be manual, pressurized, or electrostatic.

Penetrant Dwell

The total time the penetrant remains on the part surface is the penetrant dwell. The time required for a penetrant to enter a discontinuity is dependent on temperature, the type of discontinuities, and the possibility of contaminants entrapped within discontinuities. Large, shallow discontinuities require less dwell time than small, tight cracks. Discontinuities free from contaminants require less dwell time than discontinuities with entrapped soil because there is less space for penetrant inside the cavity.

The standard minimum is 5 minutes with the exception of in-service parts. If service fatigue cracks are suspected, the minimum time required is often 2 hours, but for stress corrosion up to 4 hours may be required. If the dwell exceeds 1 hour, applying fresh penetrant every hour improves the rate of penetration and prevents the penetrant from drying on the part surface. If the penetrant evaporates to a point of becoming tacky, the part should be completely cleaned and reprocessed.

Penetrant Removal Method

The method for removal of the excess penetrant is accomplished by water wash, hydrophilic emulsification, lipophilic emulsification, or solvent wipe.

The removal of penetrant from the part surface must be accomplished without removing it from within a discontinuity. An optimum amount of removal must be obtained. Too little removal will cause an excessive penetrant background and indications will be indistinguishable from the part surface. If too much is removed from the discontinuity, a weak indication or no indication will be formed. The methods for removing surface penetrant and the ASTM E 165 designation are:

1. Method A - Water-washable
2. Method B - Post-emulsifiable, Lipophilic
3. Method C - Solvent-removable
4. Method D - Post-emulsifiable, Hydrophilic

Table 1.3 lists the advantages and disadvantages of the various removal methods.

Mixing Penetrant with Water

Methods A, B, and D require rinsing with water at some point in the process. Oil-based penetrants cannot be removed with water unless chemicals are introduced that allow the oil to mix with water. This material is called the emulsifier. It is contained within water-washable penetrants and introduced during the dwell time of post-emulsifiable penetrants. A coarse water spray or an air-agitated immersion are the standard practices used at the stage where parts are water-rinsed.

Water Spray Rinse

The size of the droplets, pressure, temperature, and angle of a water spray rinse can affect removal of the penetrant. Most industry and military specifications limit acceptable water temperature to 10-38 °C (50-100 °F) at a pressure not to exceed 276 kPa (40 psi). The spray nozzle should be a minimum of 30 cm (12 in.) from the part at an angle between 45 and 70 degrees.

Air-agitated Immersion Rinse

An air-agitated immersion rinse is a removal method that must maintain adequate water circulation and air agitation. Experiments to determine the amount of rinsing required for specific processes should be performed before the actual inspection. The water temperature requirements are the same as for the water spray method.

Removal of Fluorescent Penetrants

Fluorescent penetrant should be removed in a darkened area equipped with UV lighting regardless of the removal method.

Water-washable (Method A)

Water-washable penetrants contain emulsifying agents that make the oil miscible ("mixable") with water. The penetrant may be removed with a manual or automatic coarse water spray, by manually wiping, or by immersion in an air-agitated water wash. The rinsing operation must be monitored closely to avoid overwashing. Washing should be stopped as soon as an acceptable background level is observed.

Table 1.3: Method of removal

Remover Material	MIL-I-25135 Designation	Advantages and Primary Uses	Disadvantages
Water	A	Fewer processing steps Reduced processing time Lower cost Elimination of the emulsifier station	No control of emulsifier Critical rinse time Effects of water contamination Low sensitivity
Lipophilic Emulsifier	B	Wide, shallow discontinuities Supplied ready for use	Extra processing steps Critical rinse time Poor results on rough surfaces Water and penetrant contamination Disposal of used materials
Solvent	C	Portable Localized areas, field applications Wash station not required	Over-removal of penetrant Time consuming for large parts or high volume Flammable
Hydrophilic Emulsifier	D	Small, tight discontinuities Wide, shallow discontinuities Post rinse time less critical Reduced background on rough surfaces Emulsifier touchup during final rinse	Extra processing steps Must maintain concentration levels Contamination from penetrant High cost

Lipophilic Emulsifier (Method B)

Removal is performed by introducing an oil-based emulsifier as a separate process step. Lipophilic emulsifier acts by diffusing the surface penetrant. It is usually applied by immersion. Brushing or wiping may cause streaking due to uneven emulsification and is not recommended. This system offers more control and has fewer problems with over and under washing compared to the water-washable method. The emulsifier dwell may be anywhere between 5 seconds up to 5 minutes. ASTM E 1417 limits lipophilic emulsifiers to a 3 minute maximum dwell time. Finding the optimum time for specific conditions is generally accomplished through experimentation. Experience under similar circumstances related to the type and size of suspected defects, surface roughness of the part, temperature of materials, water contamination levels of the penetrant and emulsifier can be used for a guideline. If the emulsification time is either too short or too long, the part must be entirely cleaned and reprocessed with an adjusted emulsifier dwell.

Following the appropriate dwell, the part should be quickly sprayed with water wash to stop the diffusion process. This reduces the possibility of over-emulsification of a surface while other areas are being rinsed. Once the diffusion process is halted, the emulsified penetrant is rinsed using the same methods as the water-washable method.

Solvent-removable (Method C)

Solvent remover is usually supplied in aerosol spray cans. The solvent works by diluting the surface penetrant. The part is first wiped with clean, dry, lint-free cloths or towels. After the major portion of penetrant has been wiped from the surface with dry cloths, the solvent is sprayed lightly onto a clean cloth. The cloth should be moistened lightly with solvent, not saturated. The surface of the part should be wiped until just a trace of penetrant is observed on the cloth. Extreme caution must be used to avoid excessive removal.

Hydrophilic Emulsifier (Method D)

This process is similar to method B except that the emulsifier is water-based and uses detergent action rather than diffusion to remove the surface penetrant. Emulsification of the penetrant within a discontinuity is less likely to occur with hydrophilic emulsifier than with lipophilic emulsifier. This allows complete removal of surface penetrant and improves contrast for inspection. Prerinsing the part after the penetrant dwell is recommended for hydrophilic emulsification processing. The prerinse is performed using the water spray techniques described for water-washable penetrant. Prerinsing should be held to the minimum time required to remove the bulk of surface penetrant. Immediately following the prerinse, the hydrophilic emulsifier should be applied by spraying or immersion. Agitation of the emulsifier is required to produce the detergent (scrubbing) action that removes the penetrant. The optimum emulsification time must be determined through experimentation for the particular application. The emulsifier concentration for spray methods is limited to 5%. Immersion method concentration levels can vary from 5% to 35% depending on the manufacturer. Do not exceed the concentration levels suggested by the manufacturer for immersion methods. The emulsifier dwell time should not exceed 2 minutes.

Develop the Indication

An indication may be self-developed, which relies entirely on capillary action to draw the penetrant onto the surface. Development is normally enhanced with a developing agent. Developer is available in dry, water-soluble, water-suspended, or solvent-suspended forms.

Drying

The need to dry parts after penetrant removal depends on the removal method used and the type of developer that will be applied. When aqueous developer is used (water-soluble and water-suspended), parts are dried after the developer is applied. When dry or nonaqueous developer is used, parts are dried before the developer is applied.

Drying for the solvent-removal process is accomplished by evaporation. For water-washable and emulsified applications, parts are dried at room temperature or in a recirculating forced-air oven. Parts should be rotated while drying and pools of water should be removed. Oven drying time should not be any longer than the minimum time necessary to dry the part. Oven temperature should never exceed the manufacturer's recommendation.

Inspection

A vital part of the PT process is the evaluation of the results. Indications must be reviewed for their relationship to discontinuities in the material. Consideration must be given to the type of material, size, shape, and processing history of the part that is being inspected. Processing history includes information specific to the part and may include forming, casting, welding, machining, heat treating, or other manufacturing operations.

When properly performed, the penetrant process will provide visible indications at all relevant surface discontinuities.

Penetrant Inspection Documents

Penetrant testing is conducted with a specific technique in accordance with a written procedure. The technique defines the process variables (dwell, emulsification, etc.) specifically for the part being inspected. The technique should reference the acceptance criteria as per contract, engineering drawing, specification, or standard.

The procedure is a general inspection instruction that defines the materials, equipment, cleaning, and process methods that may be used. It defines the minimum and maximum times, temperatures, pressures, etc. for each step in the penetrant process. Requirements for personnel qualification and certification are also defined.

Procedures are based on the requirements of industry or military specifications, standards, or codes. These specifications define the requirements for personnel, materials, processing methods and/or acceptance criteria. Examples include ASTM E 165, ASTM E 1417, MIL-STD-6866, MIL-STD-271, MIL-STD-410, NAV-SEA 250-1500, and ASME Sec. V.

Acceptance criteria generally indicates the maximum size of allowable indications. It may define a total number or a total area for acceptable indications over a specified surface area of a part. A minimum distance for separation between rounded indications may also be defined based on the size of the largest indication. Weldments and castings are often photographically displayed as accept and reject examples of various types of indications. These reference standards also assist in determining the type of discontinuity that caused the indication.

Visual Requirements

Penetrant inspection standards and specifications have minimum requirements for an inspector's visual acuity and color perception. Visual acuity (the ability to resolve details) decreases as light levels decrease. The ability to distinguish between colors is necessary to locate indications. An individual with red-green color blindness may not be able to distinguish indications at various levels of brightness because of the penetrant's colors. Fluorescent penetrant inspection requires an inspector to allow for visual adjustment to the darkened area. Eyes become adapted to the dark after approximately 5 minutes.

Periodic eye examinations by qualified medical personnel are recommended for those involved in the interpretation of penetrant indications.

Identifying Indications

Inspector training and experience are necessary for determining the relevancy of an indication. Evaluating indications correctly is a skill learned by working with experienced inspectors and observing the interpretation process until sufficient knowledge is gained. Effective evaluation can not be mastered from classroom training.

Indications as small as 0.4 mm (0.015 in.) may be considered relevant and may affect the serviceability of a part. Inspection may result in multiple indications being observed that must be determined to be relevant or nonrelevant, and interpreted as acceptable or rejectable.

According to ASTM 1316, a relevant indication is "an NDT indication that is caused by a condition or type of discontinuity that requires evaluation." The relevancy of an indication is determined by the inspector's judgment alone. The acceptance or rejection of relevant indications is determined by criteria specified on the part drawing, in referenced inspection specifications or standards, or in a contractual agreement.

Relevant indications are the result of penetrant bleedout from an unintentional change or discontinuity on the part surface. Relevant indications must be evaluated for size, location, and type according to the specified acceptance criteria to determine if the discontinuity is cause for rejection of the part. All discontinuities are not necessarily rejected.

According to ASTM 1316, a nonrelevant indication is "an NDT indication that is caused by a condition or type of discontinuity that is not rejectable. False indications are nonrelevant." Nonrelevant indications are caused by intentional changes of the part surface. Sheet metal fittings, rolled flanges, threads, splines are examples of features inherent in a part's design that may form nonrelevant indications.

According to ASTM 1316, a false indication is "an NDT indication that is interpreted to be caused by a discontinuity at a location where no discontinuity exists." False indications are caused when the penetrant comes into contact with the part after processing. Penetrant on the inspection table surface or on the operator's hands can create false indications. False and nonrelevant indications may potentially mask relevant indications. Cleaning and reprocessing a part for inspection is required when false indications are noted.

Indication Appearance

There are three general types of relevant indications; continuos linear, intermittent linear, and rounded or nearly rounded.

Continuous linear indications may be caused by cracks, seams, laps, or lack of fusion. They may be wide or narrow depending on the severity of the discontinuity. The edges may appear smooth or jagged. Linear is defined as having a length to width ratio of greater than three-to-one.

Nonrelevant indications often appear as a continuous line in the base of threads or press fit sections of a part. The location of the indication can be useful in the evaluation. Examination with magnification is also used by experienced inspectors familiar with the manufacturing operations and the type of discontinuities associated with those operations.

Intermittent linear indications are caused by the same types of discontinuities that produce narrow continuous linear indications. Discontinuities that appear as intermittent indications are not completely open at the surface, are smeared on the surface, or may be partially filled with contaminants.

Rounded or nearly rounded indications are the result of porosity, gas holes, shrinkage, inclusions, or may be from weld spatter on the part surface. Rounded is defined as having a length-to-width ratio of less than three-to-one.

Formation of Discontinuities

There are three times during the life of a part where discontinuities can be introduced. They may exist in the raw material, they may result from forming and machining, or they may be caused by service conditions. Table 1.4 lists common discontinuities that can be detected with penetrant inspection.

Inherent discontinuities form during the solidification process of molten metals in castings and ingots. Welding produces many of the same discontinuities when the metal becomes molten and flows during the process. Discontinuities occur when the material, or a portion thereof, cools too slowly or too fast, is subjected to localized moisture or other material that creates gas pressure buildup, or develops internal stresses after solidification.

Forming operations that involve hot and cold working can produce new discontinuities or alter the appearance of existing discontinuities in forging, extruding, and rolling operations.

Table 1.4: Types of discontinuities

Discontinuity	Product	Appearance
Burst	Forge	Broad starburst
Center bead crack	Weld	Continuous/intermittent linear, tight, or open
Cold shut	Cast	Half-moon to linear, smooth
Crater crack	Weld	Starburst
Fatigue crack	Service related	Continuous linear, tight, or open
Fold	Cast	L/I, L/C, tight
Grinding crack	Any form machined	Linear, tight, random multiple
Heat-affected zone (HAZ) crack	Weld (in the base metal)	Linear, tight, emanating from weld
Hot tear	Cast	Linear, tight, or open
Inclusion	All	Near-rounded
Lack of fusion or penetration	Weld	Linear parallel to weld
Lamination	Forge, roll	Linear, tight
Lap	Forge	Linear, tight
Microshrinkage	Cast	Round, porous
Pipe	Forge	Linear, tight
Porosity	Cast, weld	Round, randomly dispersed
Quench crack	Any form heat treated	Linear, tight, or open
Shrinkage crack	Cast	Linear emanating from void
Stress corrosion crack	Service related	Linear, tight, or wide

Machining can expose subsurface discontinuities or contribute to the formation of new discontinuities during grinding, lapping, milling, cutting, and lathing operations.

Service related discontinuities may be the result of existing weaknesses in the part that were not detected during manufacturing. The existing condition may have initially been extremely small and undetectable. Additionally, service related discontinuities may be the result of fatigue from repetitive cyclic loads, service loads, corrosion, residual stress, and stress corrosion.

Post-cleaning

Residue from the penetrant process can be detrimental during further processing or during the service of a part. It can also interfere with future penetrant inspections. Penetrants remaining on a part may adversely affect plating, anodizing, and welding operations. Residual oils on liquid oxygen system components can result in an explosion. Penetrant remaining in discontinuities can dry or disrupt the mechanics of penetrant in later inspections. Developers may act as an abrasive when left on contact areas of moving parts, they can absorb moisture and cause corrosion, and they may absorb penetrant in subsequent processing masking indications or creating a high residual background. Developers become harder to remove with time. Most developers can be removed with water and wiping or by scrubbing.

Recommended Reading

Subject	Reference*
surface condition, cleaning	HB:223-226; PA:27-38; PI:8-25
penetrant application	HB:20-22; PA:46-55; PI:3-14 to 3-32
removal	HB:20-22, 24-30, 38-42; PA:57-72; PI:Chapter 4
drying	HB:20-21, 44-46, 94-95; PA:74-75; PI:5-7 to 5-12
inspection	HB:432-433, 452-460, 497-498; PA:94-102; PI:6-1
visual requirements	PA:94; PI:6-1
identifying indications	HB:322-388; PA:96, PI:6-1
formation of discontinuities	HB:135-136, 333-335; PA:97-102; PI:6-5 to 6-14
post-cleaning	HB:124-125, 244-247; PA:37-38; PI:6-15

*See *Introduction* for explanation of references.

Penetrant Principles

There are a number of different penetrants available with different sensitivities for different materials. These penetrants also have certain characteristics and properties that make them useful in revealing discontinuities.

Penetrant Characteristics and Properties

To detect discontinuities, the penetrant must coat the area of interest in a continuous and uniform manner and it must migrate into small cavities that are open to the surface. These cavities are often invisible to the naked eye.

Surface tension, wetting ability, and capillary action are the mechanisms that enable a liquid to perform well as a penetrant material. Light oils are generally used for penetrants because of these characteristics.

Surface Tension

Molecules of a liquid are subjected to the attraction of surrounding molecules. The attraction of like molecules is called "cohesion." This attraction has no effect at the interior of the liquid because the force is equalized by the attraction from all directions. However, molecules at the surface are pulled back toward the interior of the liquid by the molecules below. This contraction of the surface creates what is called "surface tension." As the cohesive force increases, the surface tension also increases.

Wetting Ability

The attraction of dissimilar molecules is called "adhesion." If the adhesive force between a liquid and a surrounding solid is weaker than the cohesive force of the liquid, the liquid will contract and pull away from the surface, forming a contact angle greater than 90°. If the adhesive force is stronger than the cohesive force, the liquid will flow and adhere to the solid to a point where the adhesive and cohesive forces are equalized in the liquid. If the liquid forms an angle of less than 90° to the surface, the individual droplets will merge into a uniform coating "wetting" the surface (Figure 1).

Capillary Action

Capillary action is easily illustrated by inserting a capillary tube into a clear container of liquid. Inside the tube, a liquid with high surface tension will rise above the liquid level outside of the tube. The low contact angle causes the liquid to curve up the tube wall while the surface tension pulls the liquid downward at the center of the liquid. These forces working together create "capillary rise" (Figure 2a). A liquid that does not have sufficient wetting ability will keep the liquid inside the tube below the level outside (Figure 2b), or at the same level (Figure 2c).

Capillary rise enables the penetrant to enter discontinuities. A discontinuity acts like a capillary tube and the ability of a penetrant to climb the walls of a discontinuity is the mechanism used to enter the discontinuity. Capillary rise will occur even though the discontinuity is not open on both ends like the tube. The penetrant will not completely fill the cavity due to trapped air, which will exert an outward force on the penetrant (Figure 3).

Physical Properties of Penetrants

Physical properties of penetrant include viscosity, volatility, specific gravity, flash point, and thermal stability.

Viscosity

Viscosity measures the flow rate of a liquid. Higher viscosity liquids flow more slowly than less viscous liquids. Increasing the temperature

Figure 1: Contact angle

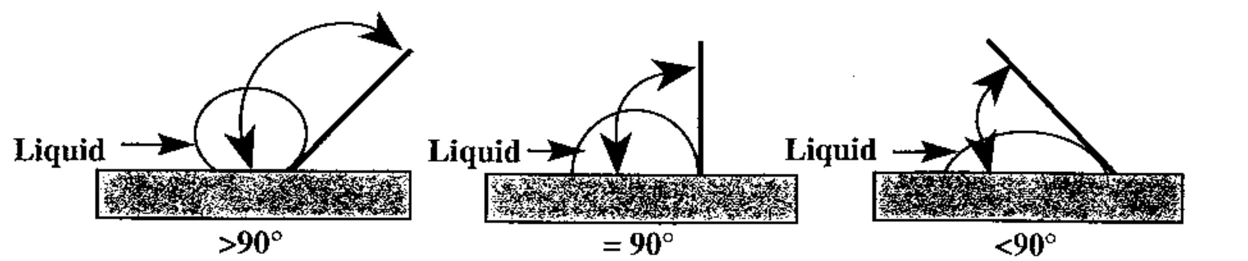


Figure 2: Contact angle in a capillary tube

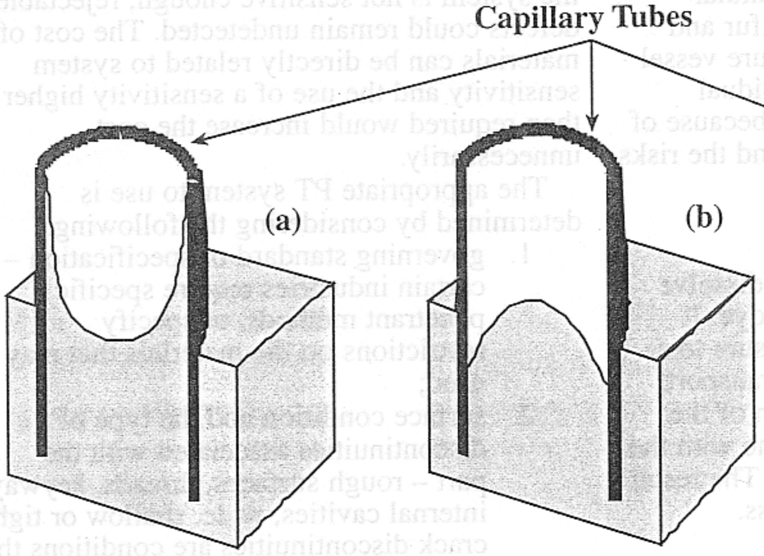
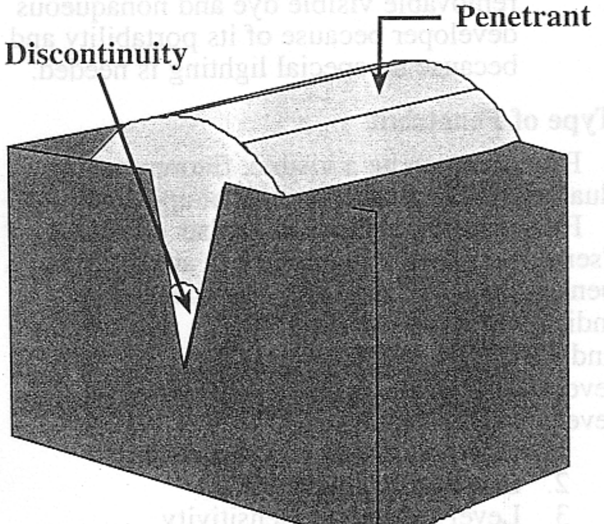


Figure 3: Penetrant over discontinuity



of a liquid lowers its viscosity. Viscosity does not affect the ability of the penetrant to enter a discontinuity; however, the viscosity of a penetrant does affect the rate of penetration and the penetrant dwell time. Penetrants with a higher viscosity will require longer dwell times than less viscous penetrants.

Volatility

Volatility indicates the boiling point of a liquid. Low volatility means a high boiling point. Highly volatile liquids are not desirable for penetrants because of their rapid evaporation, which results in the drying of the penetrant on a part during the dwell, and the loss of penetrant materials in open tanks.

Specific Gravity

The ratio of a liquid's density to that of distilled water is the liquid's specific gravity. A penetrant's specific gravity is less than 1 due to its oil base.

Flash Point

The temperature at which a liquid's vapors become flammable is its flash point. The flash point does not affect the performance of a penetrant but it is considered for safety reasons.

Thermal Stability

Thermal stability is related to the tendency of dyes used in penetrant materials to lose their brightness or color when exposed to elevated temperatures for an extended time. This loss of color is referred to as "heat fade." The ability of a penetrant to resist this loss is its thermal stability.

Chemical Properties of Penetrants

Inertness

Penetrant processing materials must be inert to the material composition of the part being processed. Nickel-based alloys, titanium, and austenitic stainless steels are susceptible to hydrogen embrittlement and intergranular corrosion from small amounts of sulfur and halogen residues. Nuclear and pressure vessel codes limit the sulfur or chlorine residual content to 1% by weight maximum because of their extensive use of these metals and the risks involved with any system failure.

Solvent Ability

The penetrant oil must be able to dissolve and maintain a sufficient amount of dye. It must retain the dye throughout exposure to a wide range of temperatures during transport, storage, and processing. If separation of the dye occurs, it is difficult to recombine with the penetrant oil even in small amounts. The result is reduced performance of the process.

Removability

Removability is the ease with which excess surface penetrant is sufficiently removed without removing it from discontinuities. Good removability is critical for reducing or eliminating residual background.

Water Tolerance

Water-washable penetrants must be capable of tolerating a certain amount of water contamination.

Penetrant System

PT inspection is defined by the materials used to perform the process. The variations in the PT process produce several system sensitivities.

System Sensitivity

The sensitivity of a system is defined as a measure of the smallest flaw which will produce a discernible indication. The six basic penetrant system sensitivity levels, in order of decreasing sensitivity are:

1. post-emulsifiable fluorescent,
2. solvent-removable fluorescent,
3. water-washable fluorescent,
4. post-emulsifiable visible dye,
5. solvent-removable visible dye, and
6. water-washable visible dye

The sensitivity used must meet the needs of the circumstances. If a system is selected that is too sensitive, the results may be misleading and time will be wasted in the evaluation process. If the system is not sensitive enough, rejectable defects could remain undetected. The cost of materials can be directly related to system sensitivity and the use of a sensitivity higher than required would increase the cost unnecessarily.

The appropriate PT system to use is determined by considering the following:

1. governing standard or specification – certain industries require specific penetrant methods, or specify restrictions on the materials that may be used;
2. surface condition and the type of discontinuities associated with the part – rough surfaces, threads, keyways, internal cavities, wide, shallow or tight crack discontinuities are conditions that can affect the optimum choice for a penetrant system; and
3. location, size of the part, quantity, and coverage required – field inspections are most often performed with solvent-removable visible dye and nonaqueous developer because of its portability and because no special lighting is needed.

Type of Penetrant

Penetrant can be a visible, fluorescent, or dual mode dye (used for special applications).

Fluorescent penetrant is further defined by a "sensitivity level" category. The sensitivity of a penetrant is related to the brightness of an indication when measured with a photometer and compared to a standard. There are five levels for fluorescent dyes. The sensitivity levels are defined as:

1. Level 1/2: ultra low sensitivity,
2. Level 1: low sensitivity,
3. Level 2: medium sensitivity,
4. Level 3: high sensitivity, and
5. Level 4: ultrahigh sensitivity.

Fluorescent penetrant contains a dye that is visible under UV light. To view the indications, inspection is performed in a darkened area with an ultraviolet light source.

Visible penetrant uses a red dye that is highly visible when contrasted against a white developer coating the part surface. Inspection must be performed under white light.

Tables 1.5 and 1.6 compare the types of penetrant and sensitivities.

Table 1.5: Comparison of fluorescent penetrant sensitivity levels

Level	Primary Uses and Advantages	Disadvantages
1/2 and 1	In-process inspection – minimal background Complex geometry Porous surfaces	Least sensitive
2	In-process inspection Final inspection	Poor sensitivity on smooth surfaces Moderate background on rough surfaces
3	In-process and final inspection Sensitive to small, tight discontinuities	High background on rough surfaces
4	In-process and final inspection Very sensitive to small, tight discontinuities	High background on rough surfaces

Table 1.6: Comparison of penetrant types

Type	Primary Uses and Advantages	Disadvantages
I	In-process and final inspections Wide, shallow and tight crack discontinuities Failure analysis	Requires special lighting Requires electricity
II	In-process inspection of surfaces machined in further processing. Field inspections with portable kit Localized area of large parts	Less sensitive than Type I Does not perform well for wide, shallow discontinuities

Penetrant Materials Testing

Water Content

Water-washable penetrants are analyzed for water content each month or any time stratification or cloudiness is noted. Water content should not exceed 5% by volume.

Separation of Constituents and Loss of Fluorescence

Penetrants shall be compared with unused samples for separation of constituents and loss of fluorescence each month or whenever stratification or cloudiness is noted. Significant separation and loss of fluorescent brightness or cloudiness shall not be permitted.

Washability

The washability of penetrants shall be determined each month. Materials not passing the washability test shall be discarded and replaced with fresh material.

Sensitivity Comparison

Penetrants shall have a sensitivity comparison performed each month. The sensitivity of penetrant samples shall be comparable to the unused reference sample.

Recommended Reading

Subject	Reference*
penetrant properties	PA:39-44; PI:3-1 to 3-9
systems	PI:8-1 to 8-23

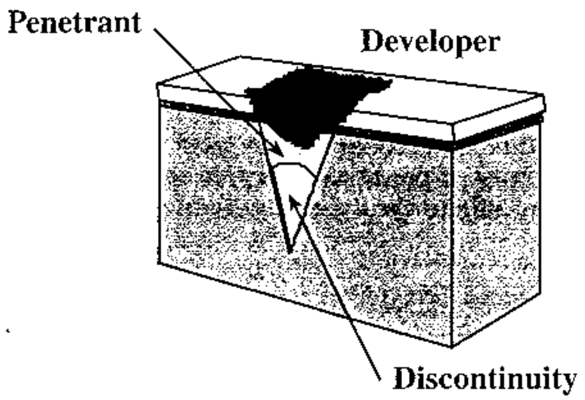
*See *Introduction* for explanation of references.

Developer

Penetrant remaining in a discontinuity is drawn out by the same capillary forces that draw it into the cavity. The adhesive force between the penetrant liquid and the solid surface will cause the penetrant to be drawn back out of the discontinuity. The cohesive force of the liquid will stop its rise out of the discontinuity at the point where it is balanced by the adhesive force.

If the discontinuity is large, the penetrant drawn to the surface can be visible without further processing. Developer is applied to aid the detection of smaller discontinuities. Developers provide an absorbent surface containing fine capillary paths that assist in drawing penetrant out of a discontinuity. This provides a much larger penetrant indication surface area (Figure 4). Observation of indications is further enhanced by the contrasting background that the developer provides.

Figure 4: Developer enhancement of discontinuity



Types of Developer

The following are types of developers:

1. dry powder,
2. water-soluble,
3. water-suspended,
4. nonaqueous solvent-suspended, and
5. specific application.

Table 1.7 lists a comparison of the various developer forms.

Dry Powder

Dry developer is a light, fluffy powder that clings to the part in a fine film. Dry developer is easy to use and has good development properties for fluorescent penetrant. Under ultraviolet light, metal surfaces appear deep violet in color which contrasts well with the bright yellow-green fluorescence of the penetrant. Dry developer does not interfere with this contrast because it dusts the surface lightly but does not coat it. It does not work well for visible penetrant because it does not provide a contrasting background. If dry developer becomes wet, clumping may occur. Clumping limits or eliminates the developer's capillary action. Dry developer in tanks may become fluorescent if it is recycled excessively. Fluorescent specks or particles may cause false indications. Dry developer in a powder bulb is often kept in the inspection area and applied to a part surface that has been wiped during evaluation.

Water-soluble

This type of aqueous developer is dissolved in water and forms a translucent film. Water-soluble developer can be used for fluorescent dyes, but it is not recommended for use with visible dye or the water-washable removal method. Water in the developer may remove

Table 1.7: Developer types

Material Form/ MIL-I-25135 Designation	Method of Application	Application Sequence	Dwell Time	Advantages and Primary Uses	Disadvantages
Dry	dust/fog, dip, spray	After drying	1/2 Penetrant dwell to 4 hrs	Easy to use Easy to remove Good for Type I	Not for Type II Parts must dry first Penetrant contaminated
Water-soluble	spray, flow, dip	Before drying	1/2 Penetrant dwell to 2 hrs	Needs no agitation Easy to remove Applies thin coat	Acts as detergent Not for Method A Not for Type II Bacteria/fungus Evaporation
Water-suspended	spray, flow, dip	Before drying	1/2 Penetrant dwell to 2 hrs	Visible coating Surface contact	Critical immersion Frequent agitation Not for Method A Difficult to remove
Solvent-suspended	spray	After drying	10 min. to 1 hr	Most sensitive High contrast No oven required Portable	Expensive Flammable Not for large areas Frequent agitation Erratic spray

water-washable penetrant from discontinuities. Water-soluble developer can save time during processing because drying is included in the developer dwell time. Water-soluble developer is supplied as a dry concentrate that must be mixed and maintained at the proper ratio of developer to water. The developer should be checked at regular intervals for penetrant contamination and water evaporation.

Water-suspended

Suspended aqueous developer does not dissolve in water so it must be thoroughly agitated just before application to suspend the particles in water. The development of indications does not begin until the moisture is completely evaporated from the developer. The thickness of the coating and its white color work well with visible dyes. Parts should be checked to ensure a uniform coating of developer has been applied. Water-suspended developer is supplied as a dry concentrate that must be mixed and maintained at the proper ratio of developer to water. The developer should be checked at regular intervals for penetrant contamination and water evaporation.

Nonaqueous

Nonaqueous solvent-suspended developer is supplied in aerosol spray cans. It may be used for all penetrant types and methods. The developer is applied after drying and it is considered to be the most sensitive developer method available. Because nonaqueous solvent-suspended developers are provided in sealed containers, mixing of concentrate levels and process controls are not required. The developer must be thoroughly agitated before spraying and should be applied in a thin, uniform coat. The spray does not cover larger surfaces quickly and each part must be separately sprayed while the developer constantly agitated. It can be difficult to obtain a consistent, even coating of developer when using this method.

Specific Application

Specific application developers are designed for use with only certain specified penetrant materials. They must be qualified with a particular penetrant system for use. An example would be qualification of a specific manufacturer's visible dye, hydrophilic post-emulsifiable penetrant with a dry developer.

Recommended Reading

Subject	Reference*
developer	HB:92-102; PA:76-82; PI:Chapter 5

*See *Introduction* for explanation of references.

Material and Process Control Tests

Successful penetrant processing relies on properly functioning material and equipment. Penetrant materials can be degraded or contaminated during use. Process system variables of time, temperature, and pressure along with material concentration, contamination, consistency, etc. must be verified as acceptable at regular intervals. Equipment used for verification may also require scheduled calibration. Tables 1.8 and 1.9 contain standard process control requirements and equipment calibration.

Ultraviolet light intensity, emulsifier concentration, ambient white light intensity and penetrant area cleanliness are examples of typical process controls that may be specified in the penetrant inspection procedure.

Ultraviolet Light Intensity

Intensity of the ultraviolet light in the inspection booth is checked with a calibrated UV light intensity meter.

Ultraviolet light intensity should be 1,000 microwatts per centimeter squared ($\mu W/cm^2$) minimum at the inspection table surface.

Emulsifier Concentration

To check emulsifier concentration (refractive method) of hydrophilic post-emulsifiable penetrant systems the following procedure should be used:

1. Lift the refractometer cover plate to expose the prism.
2. Use the plastic dip stick supplied with the instrument to spread a small amount of emulsifier over the prism surface.
3. Close the cover plate and point the instrument toward a light source. Look

Table 1.8: Typical equipment calibration

Equipment	Where Used	Calibration Tolerance	Item
Temperature gage	Spray water rinse/wash station	±1 °C (±2 °F)	3 months
Pressure gage	Spray water rinse/wash station	±2% of scale	3 months
Timers	Penetrant, emulsifier, rinse, dry stations	±1 second	3 months
White light meter	Type II lighting/ambient light for Type I	±10%	6 months
Ultraviolet light meter	Ultraviolet light intensity	±10%	6 months
Refractometer	Hydrophilic emulsifier concentration	±2% of scale	1 year
Temperature gage	Drying oven	±5.6 °C (±10 °F)	6 months
Measuring equipment	Inspection booth — measuring indications	±0.1% of scale	1 year

Table 1.9: Typical process control requirements

Process Element	System	Requirement	Item
Water wash pressure	Method A, B, D	276 kPa (40 psi) maximum	Each shift
Water wash temperature	Method A, B, D	10-38 °C (50-100 °F)	Each shift
Oven temperature	Method A, B, D	71 °C (160 °F) maximum	Each shift
Systems performance	All	meet minimum code requirements	Daily
Ultraviolet intensity	Type I	1,000 $\mu W/cm^2$ minimum at part surface	Daily
White light intensity	Type II	1,076 lx (100 ftc) minimum at part surface	Daily
Ambient light intensity	Type I	20 lx (2 ftc) maximum at part surface	Weekly
Area cleanliness	Type I	no fluorescent contamination (fluffy not caked)	Daily
Lipophilic emulsifier water content	Method B	≤5%	Monthly
Lipophilic emulsifier concentration	Method D	immersion: manufacturer requirements, spray: ≤5%	Weekly
Aqueous developer		check concentration with hydrometer	Weekly
Dry developer condition		no fluorescent contamination	Daily
Fluorescent brightness	Type I	≥90% of unused material sample	Quarterly
Penetrant water content	Method A	≤5%	Monthly
Penetrant removability	Method A	comparison to unused material sample	Monthly
Penetrant sensitivity	All	comparison to unused material sample	Weekly

through the eyepiece and take the reading at the point where the dividing line between light and dark crosses the scale. (Tilting the instrument with respect to the light source may be required to obtain optimum contrast between light and dark boundary.)

4. Clean the instrument after each use. Wipe the prism and cover plate with a soft cloth or tissue paper moistened with water, then wipe dry. If the prism surface and cover plate are not well cleaned before the next use erroneous or fuzzy reading may result.

Ambient White Light Intensity

The ambient white light intensity in the darkened inspection booth is verified by ultraviolet light(s) and the use of a white light meter. The ambient white light intensity should not exceed 22 lx (2 ftc) at the inspection surface.

Penetrant Inspection Area Cleanliness

The cleanliness of the inspection booth is checked for any contamination of fluorescent penetrant, developer powder or other residue that could affect the interpretation.

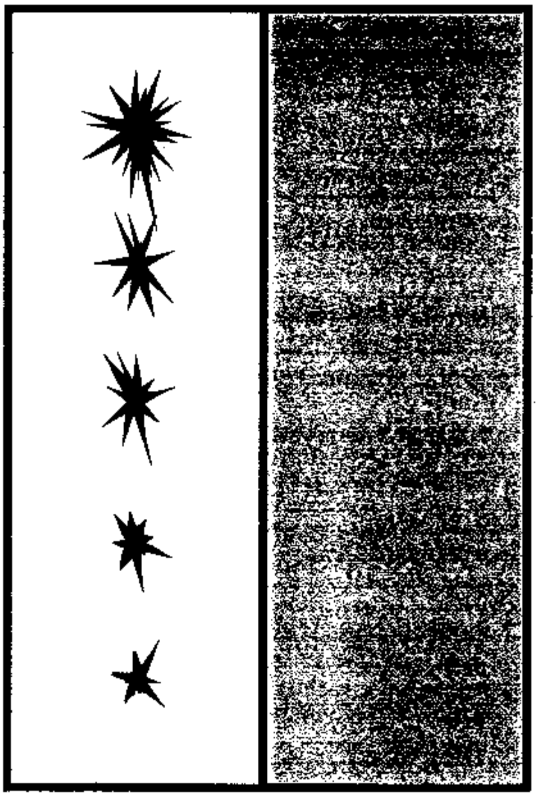
Penetrant System Monitor

The penetrant system monitor panel (Figure 5) is a commonly used reference standard for monitoring the overall performance of the penetrant system. It is processed through all stations of the penetrant production line to verify that all aspects of the process (dwell time, temperatures, removal, lighting, drying, developing, etc.) are functioning together.

The following is typical of procedure requirements for processing the panel:

1. Ensure the panel is dry.
2. Examine under ultraviolet light for residual penetrant. Residual fluorescence shall be cause for cleaning or replacement.
3. Process the panel per standard procedure and production technique using minimum process times.
4. Examine the processed panel under ultraviolet light. Compare results to the correspondingly numbered reference photograph. Results shall be as follows:
   a. removability: At least 75% of the grit blasted panel surface shall show no evidence of background fluorescence.
   b. sensitivity: The minimum number of crack indications visible shall be as follows: Level1/2 and 1: three indications; Level 2: four indications; Level 3 and 4: five indications.
5. If the system performance is unacceptable, replace materials (i.e., penetrant, emulsifier, developer) as applicable, and recheck.

Figure 5: Penetrant system monitor panel



6. After completion of the test, place the panel in an ultrasonic cleaner. Ultrasonically clean for at least 30 minutes. Leave panel immersed in ultrasonic cleaner until next usage (keep lid on ultrasonic cleaner to minimize evaporation).

Recommended Reading

Subject	Reference*
materials and process controls	HB:77, 192-209, 406-411; PA:113-136

*See *Introduction* for explanation of references.

Equipment

Penetrant processing equipment can vary from a few spray cans and cloths to computer-controlled, fully automated systems. Table 1.10 lists materials common to portable and stationary penetrant process lines.

Ultraviolet Lighting

UV light is required when Type I (fluorescent) penetrant is used. The fluorescence of the penetrant assists in locating small, difficult-to-see discontinuities. The UV light consists of a mercury bulb housed with a filter that is powered by a constant voltage transformer producing wavelengths in the range of 320 to 400 nm. The minimum intensity of the UV light should be 1,000 $\mu W/cm^2$ at the inspection surface. A warm-up time is required for the mercury bulb to reach full intensity and should remain on to avoid cycling, which reduces the life of the bulb. Regular cleaning of the bulb and filter is required to remove dust, oil, dirt, and fluorescent contamination that can reduce the UV light intensity.

For remote processing when electricity is available, portable enclosures or heavy tarps may be used to obtain sufficient darkness to perform evaluations.

Table 1.10: Manual processing equipment

Stationary	Portable
Penetrant Application	
Spray booth — standard or electrostatic	Penetrant spray can
Immersion tanks	
Brushes, cotton swabs, etc.	
Dwell/drain area	
Timer for penetrant dwell	
Penetrant Removal	
Coarse water spray	Solvent spray can
Ultraviolet light (Type I)	Cloths/rags
White light (Type II)	Portable ultraviolet light (Type I)
Emulsifier tanks and/or spray apparatus	Tarp
Water rinse spray and/or tank	
Water pressure and temperature gages	
Timer for emulsifier dwell	
Drying/Development	
Hot-air recirculating oven	Developer spray can or powder bulb
Oven temperature gage	
Developer dip tank, fog chamber, or spray area	
Developer dwell area	
Timer for developer dwell	
Inspection	
Ultraviolet light and darkened booth (Type I)	Portable ultraviolet light (Type I)
White light (Type I and II)	Tarp
Magnifier, measuring devices	Magnifier, measuring devices
Solvent	Solvent
Developer powder bulb or spray can	Developer spray can or powder bulb

Stationary Processing Equipment

Requirements vary depending on the type of penetrant and removal method used. The system may consist of a deep sink next to a small tank of penetrant that sits under a rack where the parts drain after dipping, and a bench on which to place parts after removing them from the penetrant. Stationary processing equipment can be more elaborate with electrostatic sprayers for penetrant application, semi-automatic emulsification and/or rinsing, and developer stations run by the push of a button. Parts may be moved by hoists or conveyors, automatically lowered and processed in emulsifier immersion stations, or automatically processed through a water rinse operation.

Portable Processing Equipment

Penetrant is available in kits packaged with spray cans of penetrant, remover, and developer. They are generally a visible, solvent-removable system, but they are also available with water-washable dye, lipophilic emulsifier, and fluorescent dye. The developer is always nonaqueous.

Automated Equipment

Fully automated PT systems process materials through cleaning, penetrant application, dwell and removal, drying, and developer application and dwell time without an operator. Automatic loading and unloading capabilities also can be incorporated in some systems. Automated systems are custom-designed for specific applications of high volume processing. The elimination of inconsistencies in dwell and rinse time associated with human processing is the major advantage. The disadvantages are the cost and inflexible nature of the system.

Semi-automated systems may have conveyors to move parts to the various stations where processes are manually performed, or may include automated emulsifier, rinse, and/or oven and developer stations.

Automated processing ends at the entrance to the inspection area. Human inspectors are almost always required to evaluate indications resulting from the process.

Recommended Reading

Subject	Reference*
equipment	HB:154-177; PA:103-111; PI:Chapter 9

*See *Introduction* for explanation of references.

Chapter 1
Questions

1. One disadvantage of liquid penetrant inspection is that:

   a. penetrant materials may cause drying and cracking of the skin.
   b. large subsurface discontinuities with openings to the surface will not form indications.
   c. it can only be used with nonferrous material.
   d. cleaning is always required before and after processing.

   PA:16

2. Which of the following is not a physical property associated with penetrant materials?

   a. Solvent resistance.
   b. Flash point.
   c. Viscosity.
   d. Chemical inertness.

   PA:41-42

3. The removal of smeared metal by chemical processes is called:

   a. grit or sand blasting.
   b. machining.
   c. etching.
   d. quenching.

   PA:36

4. A standard classification for a type of developer is:

   a. water-soluble.
   b. water-washable.
   c. non-fluorescent.
   d. solvent-removable.

   PA:76

5. A penetrant inspection cannot find:

   a. surface porosity.
   b. surface cracks.
   c. an internal cavity.
   d. a surface forging lap.

   PA:16

6. Which of the methods listed below is most sensitive for detecting fine, tight surface cracks?

   a. Visible dye, water-washable.
   b. Visible dye, post-emulsifiable.
   c. Fluorescent, water-washable.
   d. Fluorescent, post-emulsifiable.

   PA:98

7. The term used to describe the total time that penetrant remains on the workpiece is:

   a. immersion.
   b. drain.
   c. dwell.
   d. pre-soak.

   PA:14; PI:3-16

8. Developer assists in the detection of discontinuities by:

   a. providing a contrasting background.
   b. emulsifying the penetrant bleedout.
   c. providing a clean surface.
   d. providing a dry surface.

   PA:73

9. Difficulties with removal of a post-emulsifiable penetrant during the rinse operation can be overcome by:

   a. reapplying a coating of emulsifier.
   b. using conditioned (soft) water during the washing operation.
   c. cleaning, then completely reprocessing the part using a longer emulsification time.
   d. increasing the water temperature during the washing operation.

PA:66; PI:4-20

10. Excessive removal of penetrant may result in:

    a. undetected discontinuities during evaluation.
    b. an excessive background that inhibits the evaluation process.
    c. the need to apply the developer twice to obtain significant bleedout.
    d. small, tight cracks that are easily detected on parts with a smooth surface.

PA:14

11. Which of the following is an advantage of a fluorescent water-washable penetrant system compared to a fluorescent post-emulsifiable penetrant system?

    a. Water-washable is superior for testing critical in-service parts.
    b. Water-washable has fewer processing steps.
    c. Only wet developer may be used with post-emulsifiable penetrants.
    d. Water-washable penetrants will more readily detect fine, tight cracks in weldments.

PA:62-63

12. Which of the following is not an advantage of post-emulsifiable fluorescent penetrants?

    a. High sensitivity level to detect very fine defects.
    b. They are easily removed with water after proper emulsification dwell time.
    c. They are easily removed from sand castings after proper emulsification dwell time.
    d. They have higher tolerance to variations in the removal process when compared to water-washable penetrants.

PA:62

13. When using the visible, solvent-removable process, after the penetrant dwell time, excess penetrant is removed by:

    a. spraying solvent on the part and then wiping with clean, dry rag or paper towel.
    b. wiping off excess penetrant with a clean, dry rag or paper towel, moistening the part with solvent, and rewiping the part.
    c. wiping off excess penetrant with a clean, dry rag or paper towel, moistening a clean cloth with solvent and rewiping the part.
    d. wiping off excess penetrant with a clean, dry rag or paper towel, then rewiping with a cloth soaked with solvent.

PA:67

14. When using a fluorescent, post-emulsifiable penetrant, the best emulsification time is:

    a. 10 seconds.
    b. 5 seconds.
    c. 2-3 seconds.
    d. determined by experimentation.

PA:65

15. What type of developer is the least sensitive for locating fine discontinuities?

    a. Solvent-suspended.
    b. Water-soluble
    c. Water-suspended.
    d. Dry powder.

PI:5-6 to 5-7

16. The most sensitive penetrant system is:

   a. fluorescent, post-emulsifiable
   b. visible, solvent-removable.
   c. fluorescent, solvent-removable.
   d. fluorescent, water-washable.

PA:98

17. One method for applying dry developer to a localized area of a large part is with:

   a. a brush.
   b. a powder bulb.
   c. an aerosol can.
   d. an immersion tank.

PA:81

18. Pre-wash and post-wash stations are an advantage when using which of the following penetrant methods?

   a. Visible, lipophilic post-emulsifiable.
   b. Fluorescent, hydrophilic post-emulsifiable.
   c. Visible, water-washable.
   d. Fluorescent, lipophilic post-emulsifiable.

PA:69

19. The specific gravity of wet developer is measured with a:

   a. developer gage.
   b. hydro-gage.
   c. balance scale.
   d. hydrometer.

PI:7-12

20. Which of the following describes the comparator that is used to monitor the process performance of the penetrant system?

   a. A panel with one half chrome plated containing five crack centers, and the other half grit blasted.
   b. A cracked aluminum block with a groove in the center.
   c. A chrome plated panel with fine cracks across the face to a depth equal to the plating thickness.
   d. Ceramic coated block with fine cracks extending around the entire panel.

PA:119

21. Ultraviolet light intensity is measured with:

   a. a digital or analog UV-A meter.
   b. a photographic light meter.
   c. an infrared meter.
   d. a standard white light meter.

PA:91

22. What instrument is used to check hydrophilic emulsifier concentration?

   a. A hydrometer.
   b. A capillary fill barometer.
   c. A centrifuge tube.
   d. A refractometer.

PA:124-125

23. The penetrant performance characteristic known as "sensitivity" is defined as the:

   a. brightness observed in an indication.
   b. ability to produce a visible indication from a small, tight linear discontinuity.
   c. volume percentage of penetrant that remains in a discontinuity after processing.
   d. ability to enter a discontinuity to form an indication.

PA:44

24. A group of nearly rounded indications located in an area that transitions between thick and thin sections of aluminum castings is known as:

   a. shrinkage cracks.
   b. gas holes.
   c. laminations.
   d. cracks due to heat treating.

PA:99

25. Processing a part with developer residue remaining from a previous penetrant inspection may result in:

   a. an enhanced background contrast.
   b. a more rapid formation of indications.
   c. a greatly reduced formation of indications.
   d. the elimination of a second application of developer.

PA:31

26. For intermediate dwell times, applying fresh penetrant 15 minutes before removal assists the process by increasing the:

a. rate of evaporation.
b. time required for the removal operation.
c. rate of penetration.
d. sensitivity of the penetrant.

PA:55

27. How does an increase in temperature affect the viscosity of a penetrant?

a. It becomes more viscous and decreases in flow rate.
b. It becomes less viscous and decreases in flow rate.
c. It becomes more viscous and increases in flow rate.
d. It becomes less viscous and increases in flow rate.

PA:52

28. Repeated or cyclic loads below the yield strength of a material can cause:

a. service cracking.
b. fatigue cracking.
c. intergranular cracking.
d. thermal cracking.

PA:100

29. Grinding checks or cracks are caused by:

a. localized overheating.
b. a slow feed rate.
c. unequal heating or cooling.
d. rapid cooling from high temperatures.

PA:99

30. Elongated inclusions found in bar stock are called:

a. seams.
b. laps.
c. stringers.
d. contaminants.

PA:98

31. An advantage of the post-emulsification fluorescent penetrant process is that it:

a. is very good on rough surfaces such as sand castings.
b. has fewer operations than other penetrant processes.
c. can be used on anodized surfaces.
d. can be used to detect wide, shallow discontinuities.
e. can be easily removed from threaded parts and blind holes.

PA:61-62; PI:4-10

32. What comparison standard has control over the depth and quantity of cracks?

a. A chrome-nickel test panel.
b. A cracked aluminum test block.
c. A ceramic test block.
d. A grit blast panel.

PA:116-117

33. Compared to a certified Level I inspector, a Level II inspector:

a. can process all forms of a product.
b. is authorized to approve all penetrant procedures.
c. requires more formal training hours and work experience.
d. can determine the acceptance criteria for a part.

PA:84

34. A limitation on materials used to inspect nickel alloy welds in a nuclear or pressure vessel system is that the penetrant materials should have:

a. sulfur and halogen residual of 10% or less by weight.
b. sulfur, chlorine and fluorine residual of 1% or less by weight.
c. chlorine and halogen residual of 5% or less by weight.
d. halogen and fluoride residual of 10% or less by weight.

PA:139

35. A weld discontinuity that appears star-shaped with small indications emanating from a central point is a:

    a. burst.
    b. grinding crack.
    c. crater crack.
    d. heat-affected zone (HAZ) crack.

PA:100

36. Multiple round or nearly round indications scattered on a weld are the result of:

    a. crater pits.
    b. undercut.
    c. porosity.
    d. weld laps.

PA:100

37. Which of the following would not be the cause of a nonrelevant indication?

    a. Penetrant on the inspection table.
    b. An improperly cleaned surface.
    c. A corrosion crack.
    d. Penetrant trapped in the threads of a part.

PI:6-1 to 6-3

38. The periodic checks performed to assure that the penetrant testing system is functioning are called:

    a. process control tests.
    b. maintenance tests.
    c. certification tests.
    d. performance evaluations.

PI:7-12

39. A relevant indication in a casting may be caused by:

    a. a burst.
    b. a crater crack.
    c. laminations.
    d. porosity.

PI:6-4

40. The relative size of a surface discontinuity is estimated based on the indication intensity and the:

    a. amount of bleedout.
    b. size and shape.
    c. direction of bleedout.
    d. area located.

PI:6-5

41. Which of the following is a nonrelevant indication found during penetrant inspection?

    a. Marks on the part due to penetrant on the inspector's hands.
    b. A press fit insert ring in the bore of a shaft.
    c. Linear indications on a heat treated weldment.
    d. Dry developer residue.

PA:94

42. A visual method used as acceptance criteria for a part uses:

    a. sized wires.
    b. a calibrated scale.
    c. a TAM Panel.
    d. referenced photographs.

PI:6-14

43. The purpose of a penetrant system monitor is to provide:

    a. a method of estimating the cost of inspection.
    b. verification of the overall processing system performance.
    c. standardization for performing process controls.
    d. the means to reject test objects.

PA:118-119

44. Using a weld standard for interpretation of indications provides:

    a. reliable acceptance criteria.
    b. an accurate method to determine repair costs.
    c. the format for a test report.
    d. the means to reject linear indications.

PA:94; PI:6-5

45. Dry developer is checked for fluorescent contamination by:

    a. comparing the in-use developer to new material.
    b. processing a TAM Panel.
    c. a laboratory examination for chemical composition.
    d. viewing under an ultraviolet light for fluorescent specks.

PA:131

46. Ultraviolet lights over a fluorescent penetrant wash station are used to:

    a. verify a uniform coating of penetrant has been applied to the part.
    b. verify the emulsifier covers the entire surface.
    c. monitor the removal of surface penetrant.
    d. check the cleanliness of parts prior to processing.

PI:4-26

47. An advantage of inspecting forgings with the penetrant process is that:

    a. it can detect any type of discontinuity associated with forgings.
    b. there are no limitations to the part size or shape.
    c. forging scale does not interfere with the test.
    d. penetrant materials do not have any adverse affects on any alloy that is forged.

PA:98

48. Discontinuities that may be found in aluminum extrusions are:

    a. porosity and inclusions.
    b. laminations.
    c. cracks.
    d. laps and seams.

PA:98

49. Which of the following discontinuities are associated with forgings?

    a. Tears.
    b. Cracks.
    c. Bursts.
    d. Blow holes.

PA:98

Chapter 1
Answers

1.	a	14.	d	27.	d	40.	a
2.	a	15.	c	28.	b	41.	b
3.	c	16.	a	29.	a	42.	d
4.	a	17.	b	30.	c	43.	b
5.	c	18.	b	31.	d	44.	a
6.	d	19.	d	32.	a	45.	d
7.	c	20.	a	33.	c	46.	c
8.	a	21.	a	34.	b	47.	b
9.	c	22.	d	35.	c	48.	d
10.	a	23.	b	36.	c	49.	c
11.	b	24.	a	37.	c		
12.	c	25.	c	38.	a		
13.	c	26.	c	39.	d		

Chapter 2
Procedure Comprehension and Instruction Preparation (PCIP) Examination

Overview of the PCIP Examination Process

Candidates for ASNT Central Certification Program (ACCP) Level II certification come from different industries with differing experiences and unique terminology regarding what constitutes written directions that guide an individual in performing a nondestructive test. Some of the terms that may be familiar are procedure, instruction, job card, technique, and practice; often words like "specific" and "general" appear with these terms to further define the level of detail these written directions convey. To maintain consistency within the ACCP examination process, ASNT adopted a particular set of terms. The following description of these terms is presented to familiarize the candidate with the ACCP examination terminology.

Definitions of PCIP Examination Terminology

Specification

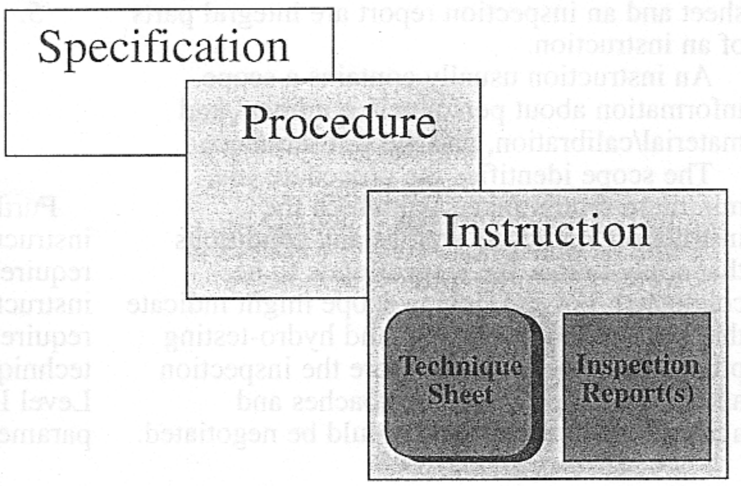
Figure 2.1 shows the hierarchy of ACCP documents. It begins with a specification that is usually received from a client and it often references a national standard or code. A specification is a list of requirements and qualifying conditions for the test object and the NDT that is to be performed on the test object. For the purposes of the ACCP, the specification is not significant; however, the Level II candidate should understand what a specification is in relationship to the other ACCP documents.

Procedure

A procedure is a written description that establishes minimum requirements for performing an NDT method on any object and it is written in accordance with established standards, codes, or specifications. A procedure is written by certified Level III personnel in that NDT method for which the procedure applies. Its primary purpose is for use in developing NDT instructions. A procedure may be used to perform an NDT technique; however, due to its rather general nature concerning requirements, conditions, and limitations for an NDT method, it demands greater knowledge, some interpretation, and judgment on the part of the inspector in order to develop a specific NDT technique and apply it to a specific part.

The PCIP portion of the ACCP Level II General Written Examination requires a candidate to read and comprehend a procedure. Because Level III personnel prepare procedures

Figure 2.1: The hierarchy of ACCP documents – note that the technique sheet and inspection report are integral parts of the instruction



within the ACCP, each procedure will be different. However, a procedure will generally have a structure similar to the following:

1. scope,
2. references,
3. personnel certification requirements,
4. equipment and materials requirements,
5. calibration and verification requirements,
6. part preparation requirements,
7. test sequence requirements,
8. interpretation and evaluation requirements,
9. documentation requirements,
10. instruction and technique sheet requirements, and
11. post-inspection requirements.

Instruction

An instruction is a description of the steps to be followed when performing an NDT technique on a specific part or a set of similar parts, developed in conformance with a procedure. An instruction is written by personnel certified to at least Level II in that NDT method for which the instruction applies. Its primary purpose is to provide sufficient direction to enable Level I and Level II personnel, as applicable, to perform an NDT technique that yields consistent and repeatable testing results. While a procedure is generally written around an NDT method, an instruction provides specific details concerning a particular technique for a given NDT method. An instruction is also valuable because it reduces or eliminates different inspector interpretations of a procedure or divergent NDT techniques performed on the same test object. A technique sheet and an inspection report are integral parts of an instruction.

An instruction usually contains a scope, information about personnel/equipment and material/calibration, and the test sequence.

The scope identifies the procedure (the minimum requirements) to which the instruction applies as well as any conditions that apply before the inspection is to be conducted. For example, a scope might indicate that heat treating, forming, and hydro-testing processes be performed before the inspection and that preapproval of approaches and agreements to exclusions should be negotiated. The title or the scope should indicate the NDT method and technique of interest.

The personnel/equipment and materials/calibration categories are addressed under separate headings or within other areas of the instruction such as the test sequence or the technique sheet as appropriate. While some techniques are relatively simple and require less headings, others are complex and require a greater number of headings to efficiently inform the inspector of the necessary details.

The test sequence is the step-by-step listing of actions that are to be taken in the order in which they are to be carried out. Generally, each step is an action and it should begin with a verb such as "prepare," "conduct," "verify," "interpret," or "report." To guide the candidate in performing the inspection, reference to the applicable technique sheet should be made where quantitative or graphical information is to be used.

Technique Sheet

A technique sheet identifies all of the parameters required to set up the technique for which the instruction applies. A technique sheet should have a diagram that shows the test object and pertinent areas of inspection. It may be necessary to present more than one view to adequately inform other inspectors of the set-up. The part's identification and acceptance criteria are also present on the technique sheet.

Included in a technique sheet are:

1. equipment settings (e.g., temperature, time, pressure);
2. part identification, material, and other unique information;
3. areas of inspection interest;
4. acceptance criteria; and
5. identification and certification of the individual who developed and wrote the instruction, the date it was written and revised, and it should be cross referenced to the applicable instruction.

Further, a technique sheet accompanies any instruction and identifies all parameters required to set up the technique for which the instruction applies. Technique parameter requirements are to be incorporated into a technique sheet that, when used by a qualified Level II or Level I, will address the operational parameters necessary to conduct the inspection.

The text of the instruction, being broader-based, identifies all of the steps to be taken including nonquantitative matters such as the general administration of the test and the recording of test results. The generally qualitative text of the instruction follows the generally quantitative, technical requirements listed in the technique sheet. Specific quantitative values, or values of limited extent, are to be used in the technique sheet (as opposed to the broad allowable ranges commonly found in standards and procedures).

A typical listing of the contents of an PT technique sheet based on a visible liquid penetrant, solvent-removable technique is shown in Table 2.1.

Details of penetrant application and removal as well as developer application will vary considerably depending on the technique. Details concerning the sequence of processing steps, areas of interest, areas with different acceptance criteria and possibly different processing parameters, additional equipment and materials to be used, time(s) of removal/rinse applications, drying and development as well as the temperature setting to be selected are all necessary. See Figure 2.2 (page 39) for a sample technique sheet.

Inspection Report

An inspection report usually identifies all detected discontinuity indications and whether they have been interpreted as relevant or nonrelevant. Identified relevant indications are evaluated as acceptable or rejectable in accordance with the part's acceptance criteria. The inspection report should include the location, direction, and dimensions of all rejectable indications detected on the part(s), and the identification of the rejectable part(s). The inspection report may include the location, direction, and dimensions of all acceptable indications detected on the part(s).

Forms used for reporting inspection results, logging actions, and other record keeping and administrative actions are to be addressed in the instruction. The forms to be used in recording the results of the inspection should be identified and included as attachments to the instruction, because they are required actions while performing NDT to an instruction. A typical listing of the contents of a PT report form based on a visible liquid penetrant, solvent-removable technique is shown in Table 2.2.

While a procedure is generally written around an NDT method, an instruction provides specific details concerning a particular technique for a given NDT method.

Table 2.1: PT technique sheet information based on a visible liquid penetrant, solvent-removable technique

Categories	Relevant Information (as applicable)
Test part	identification, model, material, product form
Authorization	contract number, drawing number, instruction number
Equipment and materials	visible liquid penetrant, solvent remover, developer, brush, cloth
Sketch of part/setup	reference markings, areas of interest, areas to be plugged/masked
Acceptance criteria	relevant and nonrelevant indications, acceptable/rejectable indications, length, diameter, groups, particular discontinuities of interest
Part preparation	cleaning, coating removal, etching, etc.
Author's identification	name, level, date, revision

Table 2.2: PT report form based on a visible liquid penetrant, solvent-removable technique

Categories	Relevant Information (as applicable)
Test part	identification, model, surface condition
Authorization	instruction number, technique sheet number
Calibration and verification	lighting
Coverage	areas inspected (in.^{2}, ft^2, etc.)
Test results	rejectable indications, sizes, locations, etc.
Sketch of results	location, orientation, etc.
Inspector	name, level, date, revision

For each instruction there is an accompanying technique sheet and inspection report. The instruction identifies and details all information not on the technique sheet. The instruction's quantitative details are contained in the technique sheet and not in the instruction's general text. See Figure 2.3 (page 40) for a sample instruction report.

Figure 2.4 (page 41) summarizes the contents of a specification, a procedure, an instruction sheet, a technique sheet, and an inspection report.

Format of the PCIP Examination

The PCIP portion of the ACCP Level II General Examination examines the candidate's ability to comprehend a procedure and requires the candidate to demonstrate the ability to prepare an instruction for NDT personnel with respect to a given procedure and technique parameters. However, during the examination the candidate is not required to write an instruction from beginning to end. Instead, a technique sheet and an inspection report form are provided so the candidate can extract information from the given procedure, make technique judgments, and then complete the appropriate areas on the technique sheet and inspection report. The candidate's comprehension of the given procedure and his/her ability to prepare instructions is further assessed by approximately 30 multiple-choice questions (these multiple-choice questions are in addition to the minimum of 60 multiple-choice General Examination questions that assess the candidate's knowledge of fundamentals and principles in the method). Figure 2.5 (page 42) graphically presents the PCIP portion of the Level II General Examination in relation to the entire Level II General Examination.

Figure 2.2: Sample technique sheet

Technique Sheet

Test Part Identification	Authorization
Material: Aluminum **Form:** ☐ Weldment ☐ Forging ☒ Casting **Part Identification No.:** A-456-04	**Instruction No.: I-238-PT** **Candidate:** David Smith **Date:** 10-14-96

Equipment and Materials

Penetrant: ☐ Fluorescent, Water-washable ☒ Fluorescent, Post-emulsifiable ☐ Visible, Solvent-removable
Developer: ☐ Dry ☒ Nonaqueous Wet
Light Intensity Meter: ☐ Visible ☒ UV
Other Supplies: ☐ Hydrometer ☒ Pressure Gage ☒ Ultraviolet Light ☒ Temperature Gage

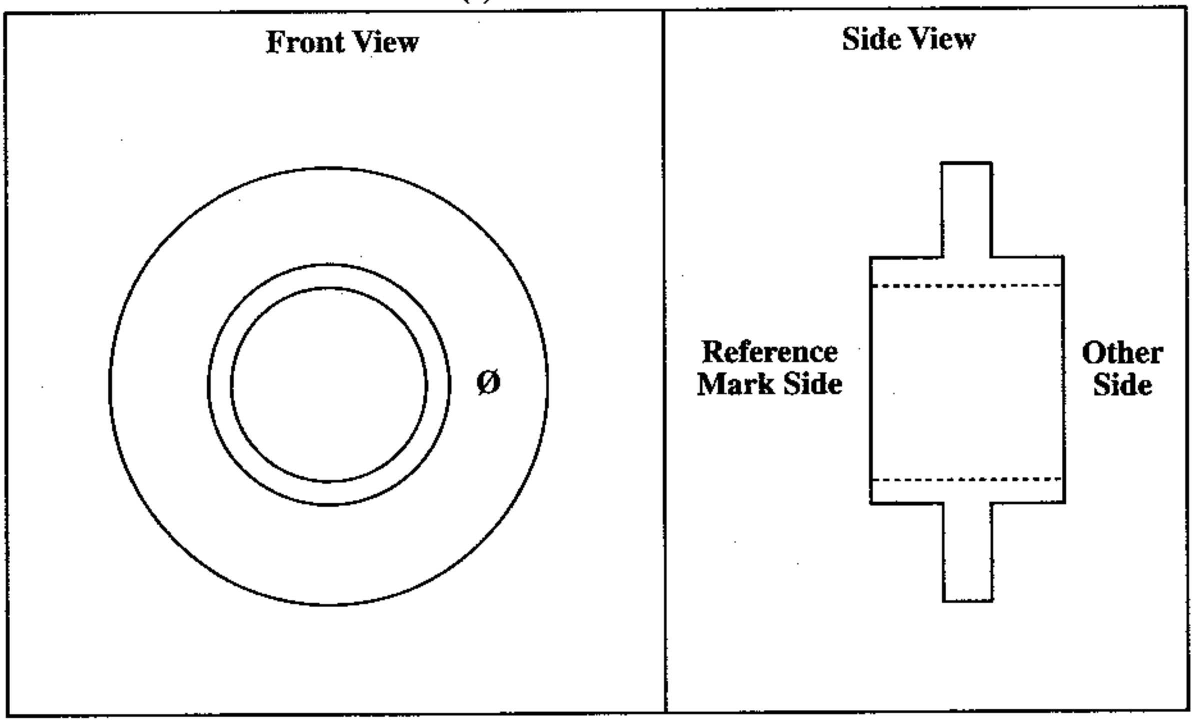
Operating Parameters

Cleaning: ☒ Pre-cleaning ☒ Post-cleaning

Penetrant Dwell Time:	10	(minutes)
Prerinse Time (PE Technique):	60	(seconds)
Emulsification Contact Time:	120	(seconds)
Emulsification Drain Time:	90	(seconds)
Final Rinse Time:	120	(seconds)
Drying Time:	30	(minutes)
Development Time:	10	(minutes)

Sketch

Area(s) to be tested: 100% PT



Symbols

Test Part Reference Mark: Ø

Figure 2.3: Sample inspection report

Inspection Report

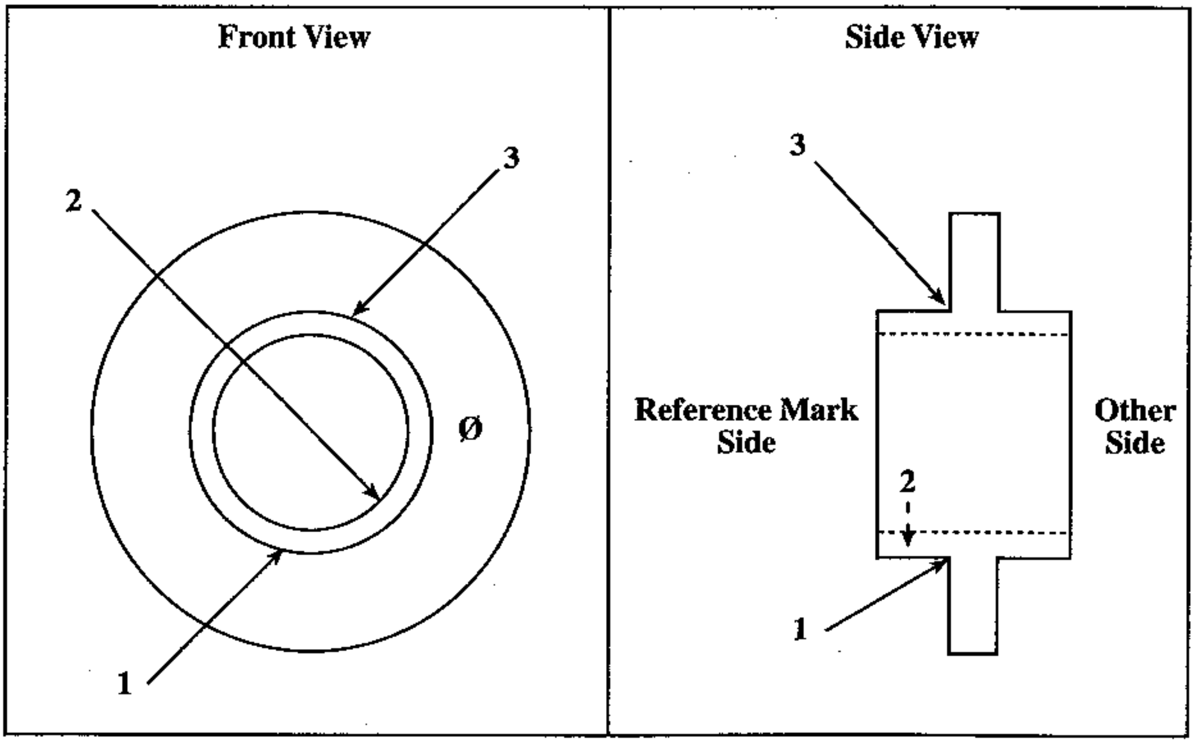
Part Identification No.: A-456-04 **Instruction No.:** I-238-PT **Date:** 10-14-96

Acceptance Criteria: C-456 **Inspector:** David Smith, ACCP Level II

Indication No. (on sketch, below)	Discontinuity Description	Measured Size/Attributes (units = in./mm)	Allowable Size/Attributes (units = in./mm)	Disposition	
				Reject	Accept
1	porosity	1 at 0.063/2	indications less than 0.063/2 are nonrelevant		X
2	linear	length = 1.125/29	none allowed	X	
3	porosity	1 ≥ 0.250/6	indications greater than or equal to 0.250/6 are rejectable	X	

Sketch

(use one or both sketches as necessary)



Symbols

Test Part Reference Mark: Ø

Figure 2.4: Contents of a *Specification*, a *Procedure*, an *Instruction Sheet*, a *Technique Sheet*, and an *Inspection Report*

Specification

- What and where to inspect
- How to inspect (usually to a referenced code or standard)
- Acceptance criteria (if not in the reference materials)
- What and how to report results
- Who can inspect (certification)

Procedure

- Minimum requirements for the NDT method in general, including technique limitations:
  - Scope
  - References
  - Personnel certification requirements
  - Equipment and materials requirements
  - Calibration and verification requirements
  - Part preparation requirements
  - Test sequence requirements
  - Interpretation and evaluation requirements
  - Marking, reporting and other documentation requirements
  - Requirements for instructions including technique sheets and inspection reports
  - Post-inspection requirements

Instruction

Description of the steps to be followed when performing an NDT technique (developed in conformance with a procedure)

Technique Sheet

- Test part identification
- Authorization
- Inspection areas of interest
- Part diagrams
- Equipment and materials
- Equipment settings
- Details of processing
- Acceptance criteria
- Cleaning/part preparation
- Other unique information
- Author's name, certification, and date

Scope

Test sequence

Other categories as necessary

Inspection Report(s)

- Test part identification
- Authorization
- Equipment and materials
- Calibration and verification
- Coverage
- Test results
- Sketch of results
- Other unique information
- Inspector's name, certification, and date

Figure 2.5: PCIP portion of the Level II General Examination in relation to the entire Level II General Examination

Level II Liquid Penetrant General Examination

Part A (general multiple-choice portion)

- answer 60 multiple-choice questions that assess the candidate's knowledge of fundamentals and principles

Part B (PCIP portion)

- provided with a procedure and supplementary information such as acceptance criteria
- complete technique sheet and inspection report
- answer 30 multiple-choice questions

Chapter 3
Level II Hands-on Practical Examination

Overview of the Level II Hands-on Practical Examination

The Level II Hands-on Practical Examination assesses the candidate's ability to perform liquid penetrant testing, including the capability to interpret and evaluate test results. There are two categories of Hands-on Practical Examinations, a General Hands-on Practical Examination and a Specific Hands-on Practical Examination. An additional examination associated with the Specific Hands-on Practical Examination is the Specific Written Examination.

General Hands-on Practical Examination

The General Hands-on Practical Examination requires the candidate to perform NDT using different types of equipment and materials in the liquid penetrant method on a number of different product forms, some of which contain discontinuities. This Practical Examination is intended to qualify the candidate's ability to perform NDT over a range of applications. The matrix shown in Figure 3.1 lists the detailed requirements that the candidate must satisfy during the Practical Examination. The matrix allows some flexibility on the part of the candidate in choosing the combination of techniques and product forms for the Practical Examination; however, the number of actual test specimens is determined by ASNT.

Each combination in Figure 3.1 involves a particular liquid penetrant testing instruction including a technique sheet and an inspection report. The candidate will be expected to use each applicable instruction (with technique sheet and inspection report) to perform applicable calibration and/or system performance verification, to perform applicable PT, and to detect applicable relevant and/or nonrelevant discontinuities. The candidate will complete the inspection report and document significant test parameters along with the location, orientation, and size of the indications. The candidate will then apply the given acceptance criteria and evaluate the discontinuity indications. The key difference between the General Hands-on Practical Examination and the Specific Hands-on Practical Examination is that the General Hands-on Practical Examination is intended to qualify the candidate's ability to perform NDT over a broad range of applications.

Specific Hands-on Practical Examination

The Specific Hands-on Practical Examination may be required by an industrial sector (an industrial sector is an industry, product form or area of technology that possesses common characteristics with respect to NDT considerations) and is similar to the General Hands-on Practical Examination except that it is intended to qualify the candidate's ability to perform NDT over a limited range of specialized applications. Specific Hands-on Practical Examinations exist because an industrial sector has unique NDT considerations not normally encountered outside that particular industry.

For example, if the foundry or metal casting industry determines that NDT technicians perform a limited number of PT techniques to unique codes, standards or specifications for the purpose of detecting particular discontinuities that have little in common with other product forms or manufacturing processes, then it would be desirable for them to establish an industrial sector. Henceforth, as an industrial sector, there would be a Specific Hands-on Practical Examination that might involve a number of different metal castings (alloy, process, geometry) and different PT techniques.

Figure 3.1 Matrix of possible combinations of penetrant techniques, product forms, and corresponding instructions for Level II General Hands-on Practical Examinations

Liquid Penetrant Testing Method (PT) Matrix Selection Form

Make selection by placing an **X** in the appropriate spaces of the following table in accordance with the corresponding criteria (see below). Those spaces of the table that are blackened out *are not* available selections.

Technique	Product Form		
	Welds	Castings	Forgings
Fluorescent, Water-washable			
Fluorescent, Post-emulsifiable			
Visible, Solvent-removable			

Criteria

The candidate must perform liquid penetrant testing such that two (2) of the three (3) different techniques and two (2) of the three (3) different product forms are used. Both visible and fluorescent techniques must be used.

After completing this form, ensure that it has been filled out correctly by completing the following checklist. If any of the following items cannot be answered with a "yes" then the matrix has been incorrectly filled out and requires further attention.

1. Only two (2) spaces in the matrix are marked with an **X**. ☐ yes
2. Two (2) different techniques have been selected. ☐ yes
3. Two (2) different product forms have been selected. ☐ yes
4. One (1) visible technique has been selected. ☐ yes
5. One (1) fluorescent technique has been selected. ☐ yes

Specific Written Examination

The Specific Written Examination may be required by an industrial sector in conjunction with either a General Hands-on Practical Examination or Specific Hands-on Practical Examination. The Specific Written Examination assesses a candidate's specific knowledge of practices and techniques unique to the industrial sector, including applicable procedures, codes, standards, specifications, test equipment and materials.

Continuing with the foundry or metal casting industrial sector example, it would be the Specific Written Examination that would assess a candidate's knowledge and understanding of applicable procedures, codes, standards, specifications, test equipment and materials as they are used in testing practices and techniques unique to this industrial sector. An industrial sector may even request that this examination be used for assessing the candidate's knowledge of particular variations of industrial sector manufacturing processes as they relate to discontinuities.

Continuing with the foundry or metal casting industrial sector example, casting discontinuities, as a result of green-sand molds, can be quite different than those as a result of dry-sand molds and the candidate may need to know this to accurately perform interpretation and evaluation of casting discontinuity indications.

Appendix 1
Standard Terminology for the Liquid Penetrant Examination

This standard terminology is adapted from ASTM E 1316-94.

Angstrom unit – A unit of length which may be used to express the wavelength of electromagnetic radiation, that is light. One angstrom unit is equal to 0.1 nanometres.

Background – The surface of the test part against which the indication is viewed. It may be the natural surface of the test part or the developer coating on the surface.

Ultraviolet light – Electromagnetic radiation used for NDT in the range of wavelength 330-390 nm (3,300-3,900 Å).

Ultraviolet light filter – A filter that transmits near-ultraviolet radiation while absorbing other wavelengths.

Bleedout – The action of an entrapped liquid penetrant in surfacing from discontinuities to form indications.

Blotting – The action of the developer in soaking up the penetrant from the discontinuity to accelerate bleedout.

Carrier – A liquid, either aqueous or nonaqueous, in which liquid penetrant examination materials are dissolved or suspended.

Clean – Free of contaminants.

Contaminant – Any foreign substance present on the test surface or in the inspection materials that will adversely affect the performance of liquid penetrant materials.

Contrast – The difference in visibility (brightness or coloration) between an indication and the background.

Defect – One or more flaws whose aggregate size, shape, orientation, location, or properties do not meet specified acceptance criteria and are rejectable.

Detergent remover – A penetrant remover that is a solution of a detergent in water.

Developer – A material that is applied to the test surface to accelerate bleedout and to enhance the contrast of indications.

Developer, aqueous – A suspension of developer particles in water.

Developer, dry powder – A fine, free-flowing powder used as supplied.

Developer, liquid film – A suspension of developer particles in a vehicle that leaves a resin/polymer film on the test surface after drying.

Developer, nonaqueous – Developer particles suspended in a nonaqueous vehicle prior to application.

Developer, soluble – A developer completely soluble in its carrier, not a suspension of powder in a liquid, which dries to an absorptive coating.

Developing time – The elapsed time between the application of the developer and the examination of the part.

Discontinuity – A lack of continuity or cohesion; an intentional or unintentional interruption in the physical structure or configuration of a material or component.

Dragout – The carryout or loss of penetrant materials as a result of their adherence to the test piece.

Drain time – That portion of the dwell time during which the excess penetrant or emulsifier drains from the part.

Drying oven – An oven used for increasing the evaporation rate of rinse water or an aqueous developer vehicle from test parts.

Drying time – The time required for a cleaned, rinsed or wet developed part to dry.

Dwell time – The total time that the penetrant or emulsifier is in contact with the test surface, including the time required for application and the drain time.

Electrostatic spraying – A technique for attaining a uniform coating in which the material sprayed is given an electrical charge.

Eluant – A liquid used to extract one material from another, as in chromatography.

Emulsification time – The time that an emulsifier is permitted to remain on the part to combine with the surface penetrant prior to removal. Also called emulsification dwell time.

Emulsifier – A liquid that interacts with an oily substance to make it water-washable.

Emulsifier, hydrophilic – A water-based liquid used in penetrant examination that interacts with the penetrant oil rendering it water-washable.

Emulsifier, lipophilic – An oil based liquid used in penetrant examination that interacts with the penetrant oil rendering it water-washable.

Etching – The removal of surface material by chemical or electrochemical methods.

Evaluation – A review, following interpretation of the indications noted, to determine whether they meet specified acceptance criteria.

False indication – A NDT indication that is interpreted to be caused by a discontinuity at a location where no discontinuity exists.

Family – A complete series of penetrant materials required for the performance of a liquid penetrant examination.

Flaw – An imperfection or discontinuity that may be detectable by NDT and is not necessarily rejectable.

Flaw characterization – The process of quantifying the size, shape, orientation, location, growth, or other properties, of a flaw based on NDT response.

Fluorescence – The emission of visible radiation by a substance as a result of, and only during the absorption of ultraviolet light radiation.

Footcandle – The illumination on a surface, 1 ft^2 in area, on which is uniformly distributed a flux of 1 lm (lumen). It equals 10.8 lm/m^2.

Immersion rinse – A means of removing surface penetrant in which the test part is immersed in a tank of either water or remover.

Imperfection – A departure of a quality characteristic from its intended condition.

Indication – Evidence of a discontinuity that requires interpretation to determine its significance.

Inspection – Visual examination of the test part after completion of the liquid penetrant processing steps.

Interpretation – The determination of whether indications are relevant or nonrelevant.

Liquid penetrant examination – A nondestructive test that uses suitable liquids that penetrate discontinuities open to the surface of solid materials and, after appropriate treatment, indicate the presence of discontinuities.

Nondestructive testing (NDT) – The development and application of technical methods to examine materials or components in ways that do not impair future usefulness and serviceability in order to detect, locate, measure, and evaluate discontinuities, defects, and other imperfections; to access integrity, properties, and composition, and to measure geometrical characteristics.

Nonrelevant indication – A NDT indication that is caused by a condition or type of discontinuity that is not rejectable. False indications are nonrelevant.

Over-emulsification – Excessive emulsifier dwell time that results in the removal of penetrants from some discontinuities.

Over-washing – Too long or too vigorous washing, or both, which results in removal of penetrants from some discontinuities.

Penetrant – A solution of suspension of dye.

Penetrant comparator – An intentionally flawed specimen having separate but adjacent areas for the application of different liquid penetrant materials so that a direct comparison of their relative effectiveness can be obtained. It can also be used to evaluate liquid penetrant techniques, liquid penetrant systems, or test conditions.

Penetrant, fluorescent – A penetrant that emits visible radiation when excited by an ultraviolet light.

Penetrant, post-emulsifiable – A liquid penetrant that requires the application of a separate emulsifier to render the excess surface penetrant water-washable.

Penetrant, solvent-removable – A liquid penetrant so formulated that most of the excess surface penetrant can be removed by wiping with lint-free material, with the remaining surface penetrant traces removable by further wiping with a lint-free material lightly moistened with solvent remover.

Penetrant, visible – A liquid penetrant that is characterized by an intense color, usually red.

Penetrant, water-washable – A liquid penetrant with a built-in emulsifier.

Pooling – The existence of excessive amounts of penetrant, emulsifier, or developer in an incompletely drained area.

Post-cleaning – The removal of residual liquid penetrant examination materials from the test part after the penetrant examination has been completed.

Post emulsification – A penetrant removal technique employing a separate emulsifier.

Pre-cleaning – The removal of surface contaminants from the test part so that they will not interfere with the examination process.

Relevant indication – A NDT indication that is caused be a condition or type of discontinuity that requires evaluation.

Rinse – The process of removing liquid penetrant examination materials from the surface of a test part by means of washing or flooding with another liquid, usually water. The process is also termed wash.

Solvent remover – A volatile liquid penetrant used to remove excess penetrant from the surface being examined.

Temperature envelope – The temperature range over which a particular penetrant inspection test will operate.

Viscosity – The property of a fluid that presents a resistance to shearing flow.

Visible light – Electromagnetic radiation in the 400-700 nm wavelength range.

Visual adaptation – The adjustment of the eyes when one passes from a bright to a darkened place.

Water tolerance – The amount of water that a penetrant or emulsifier can absorb before its effectiveness is impaired.

Wetting action – The ability of a liquid to spread over and adhere to solid surfaces.

Appendix 2
Standard Guidelines for the Liquid Penetrant Examination

1.0 Purpose

1.1 These guidelines show the requirements for liquid penetrant examination. They are intended as reference material for the examinee. The examinee will be given a specific liquid penetrant examination instruction for the performance of the practical examination.

2.0 Scope

2.1 This guideline describes visible and fluorescent liquid penetrant examination. It will detect discontinuities open to the surface such as cracks, seams, laps, cold shuts, laminations, or lack of fusion. Liquid penetrant examination can be applied to semi-finished material, finished material, and welds and it can be effectively used in the examination of nonporous, metallic materials, both ferrous and nonferrous. From the test equipment and product forms made available, the examinee must select that which is necessary to properly perform the examination.

2.2 The examinee must use this guideline together with the matrix shown in Figure 3.1 (page 44).

2.3 The examinee shall interpret, evaluate and recommend disposition of selected samples in accordance with the Acceptance Criteria Samples which are contained in Appendix 3.

2.4 For each test sample examined, the examinee must complete a report with a sketch outlining the indications detected as shown in Figure 2.3 (page 40).

3.0 Equipment and Materials

3.1 Liquid penetrant examination materials consist of fluorescent and visible penetrants, emulsifiers (oil-based and water-based; fast and slow acting), solvent removers and developers. A family of liquid penetrant examination materials consists of the applicable penetrant, emulsifier or remover, and developer as recommended by the manufacturer. Intermixing of materials from various manufacturers is prohibited.

4.0 Classification of Penetrant Test Methods

4.1 Liquid penetrant examination methods are classified as shown in Table A2.1.

Table A2.1: Classification of penetrant examination methods and types

Type I - Fluorescent Penetrant Examination	
Method A	Water-washable
Method B	Post-emulsifiable, lipophilic
Type II - Visible Penetrant Examination	
Method A	Water-washable
Method C	Solvent-removable

5.0 Surface Preparation

5.1 The temperature of the penetrant materials and the surface of the part to be tested shall be between 10-38 °C (50 and 100 °F) throughout the examination.

5.2 Prepare, clean, and dry the area to be examined and any adjacent area within 25.4 mm (1 in.).

5.3 Remove oil and grease by using cleaning solvents or vapor degreasing. Drying time prior to the application of penetrant shall be 5 minutes.

6.0 Sequence of Operation

6.1 Application of Penetrant

6.1.1 After the part has been cleaned and dried the penetrant is applied to the surface to be examined so that the entire part or area under examination is completely covered with penetrant.

6.1.2 The penetrant shall be applied by dipping, brushing, flooding or spraying.

6.2 Penetrant Dwell Time

6.2.1 After application, allow excess penetrant to drain from the part (care should be taken to prevent pools of penetrant from forming on the part), while allowing for proper penetrant dwell time. The length of time the penetrant must remain on the part to allow proper penetration shall be 15-25 minutes.

6.3 Penetrant Removal

6.3.1 Water Washable

6.3.1.1 After the required dwell time, the excess penetrant on the surface of the part shall be removed with water using a water spray.

6.3.1.2 The temperature of the water shall be maintained within the range of 10-38 °C (50-100 °F).

6.3.1.3 Spray-rinse water pressure shall not be greater than 276 kPa (40 psi).

6.3.1.4 Rinse time shall not exceed 120 seconds.

6.3.2 Hydrophilic Emulsifier

6.3.2.1 Prerinsing — Directly after the required dwell time, the part shall be prerinsed with water prior to emulsification.

6.3.2.1.1 Water should be free of contaminants that could clog spray nozzles or leave a residue on parts.

6.3.2.1.2 The water temperature shall be maintained within the range of 10-38 °C (50-100 °F).

6.3.2.1.3 Spray rinse at a water pressure of 172-276 kPa (25-40 psi).

6.3.2.1.4 Prerinse time shall be the least possible time (60 seconds maximum) to provide a consistent residue of penetrant on parts.

6.3.2.1.5 Drain water trapped in cavities.

6.3.2.2 Application of Emulsifier — After the required penetration time and following the prerinse, the residual surface penetrant on the part must be emulsified by immersing the part in a emulsifier bath or by spraying the part with the emulsifier thereby rendering the remaining residual surface penetrant water-washable in the final rinse station.

6.3.2.3 Immersion — For immersion application, parts are completely immersed in the emulsifier bath. The hydrophilic emulsifier should be gently agitated throughout the contact cycle.

6.3.2.3.1 Bath concentration should be 20%.

6.3.2.3.2 Bath temperature should be maintained between 10-38 °C (50-100 °F).

6.3.2.3.3 Immersion contact time should not exceed 120 seconds or the maximum time stipulated by the part or material specification.

6.3.2.3.4 Emulsifier drain time begins immediately after parts have been withdrawn from the emulsifier tank and continues until the parts are washed in the final rinse station. The drain time should be kept to a minimum and should not exceed 90 seconds.

6.3.2.4 Spray Application — All part surfaces shall be evenly and uniformly sprayed to effectively emulsify the residual penetrant on part surfaces to render it water washable.

6.3.2.4.1 The concentration of the emulsifier for spray application shall not exceed 5%.

6.3.2.4.2 Temperature shall be maintained at 10-38 °C (50-100 °F).

6.3.2.4.3 The spray pressure shall be 172 kPa (25 psi) maximum for air and 276 kPa (40 psi) maximum for water.

6.3.2.4.4 Contact time should be kept to a minimum and shall not exceed 120 seconds.

6.3.2.5 Post-rinsing of Hydrophilic Emulsified Parts — Effective post-rinsing of emulsified penetrant from the surface can be accomplished using either manual, semi-automated, or automated water immersion or spray equipment or combinations thereof.

6.3.2.5.1 Immersion Post-rinsing — Parts shall be completely immersed in the water bath with air or mechanical agitation.

6.3.2.5.1.1 The temperature of the water shall be relatively constant and be maintained within the range of 10-38 °C (50-100 °F).

6.3.2.5.1.2 The maximum dip rinse time should not exceed 120 seconds.

6.3.2.5.2 Spray Post-rinsing — Spray rinse water pressure shall be 276 kPa (40 psi) and the maximum spray rinse time shall not exceed 120 seconds.

6.3.2.6 If the emulsification and final rinse steps are not effective, as evidenced by residual surface penetrant after emulsification and rinsing, dry and re-clean the part and reapply the penetrant for the prescribed dwell time.

6.3.3 Solvent-removable Penetrants

6.3.3.1 Removal of Excess Penetrant — After the required penetration time, the excess penetrant is removed insofar as possible, by using wipers of a dry, clean, lint-free material and repeating the operation until most traces of penetrant have been removed. Then, using a lint-free wipe lightly moistened with solvent remover, the remaining traces are gently wiped to avoid removing penetrant from discontinuities. Avoid the use of excess solvent.

6.3.3.2 If the wiping step is not effective, as evidenced by difficulty in removing the excess penetrant, dry the part, and reapply the penetrant for the prescribed dwell time.

6.3.3.3 Flushing the surface with solvent following the application of the penetrant is prohibited.

6.4 Drying

6.4.1 Drying the surface of the part is necessary prior to applying dry or nonaqueous developers or following the application of the aqueous developer. Drying time will vary with the size, nature and number of parts under examination.

6.4.2 Drying Methods — Parts can be dried by using a hot-air recirculating oven, a hot or cold air blast, or by exposure to ambient temperature, particularly when excess surface penetrant was removed with a solvent. Temperature of the part shall remain in the range of 10-38 °C (50-100 °F).

6.4.3 Drying Time Limits — Do not allow parts to remain in the drying oven any longer than is necessary to dry the surface. Drying time should not exceed 30 minutes. Drying temperature must not exceed 71 °C (160 °F).

6.5. Developer Application

6.5.1 Modes of Application — There are various modes of effective application of the various types of developers such as dusting, immersing, flooding or spraying.

6.5.2 Dry Powder Developer — Dry powder developers shall be applied immediately after drying in such a manner as to ensure complete part coverage. Parts may be immersed in a container of dry developer or in a fluid bed of dry developer. They can also be dusted with the powder developer through a hand powder bulb or a conventional or electrostatic powder gun. It is common and effective to apply dry powder in an enclosed dust chamber, which creates an effective and controlled dust cloud. Other means suited to the size and geometry of the specimen may be used, provided the powder is dusted evenly over the entire surface being examined. Excess powder may be removed by shaking or tapping the part, or by blowing with low-pressure 34-70 kPa (5-10 psi) dry, clean, compressed air.

6.5.3 Aqueous Developers — Aqueous developers should be applied to the part immediately after the excess penetrant has been removed and prior to drying. Aqueous developers should be applied in such a manner as to ensure complete, even, part coverage. Caution should be exercised when using an aqueous developer with water-washable penetrants to avoid possible stripping of indications. Aqueous developers may be applied by spraying, flowing, or immersing the part. Immerse parts only long enough to coat all of the part surfaces with the developer. Then remove the parts from the bath and allow to drain. Drain all excess developer from recesses and trapped sections to eliminate pooling of developer, which can obscure discontinuities.

6.5.4 Nonaqueous Wet Developers — After the excess penetrant has been removed and the surface has been dried, apply developer by spraying in such manner as to ensure complete coverage with a thin, even film of developer. Dipping or flooding parts with nonaqueous developers is prohibited.

6.5.5 Developing Time — The length of time the developer is to remain on the part prior to examination should be not less than 10 minutes. Developing time begins immediately after the application of dry powder or as soon as the wet (aqueous or nonaqueous) developer coating is dry. The maximum permissible developing time is 20 minutes.

7.0 Evaluation

7.1 It is good practice to observe the bleedout while applying developer as an aid in interpreting and evaluating indications.

7.2 Linear indications are those indications in which the length is more than three times the width.

7.3 Rounded indications are those indications which are circular or elliptical with the length equal to or less than three times the width.

7.4 Fluorescent Light Examination — Examine fluorescent penetrant indications under an ultraviolet light in a darkened area. Visible ambient light should not exceed 21 lx (2 ftc). The measurement should be made with a suitable photographic-type visible light meter on the surface being examined.

7.4.1 Ultraviolet Light Level Control — Ultraviolet light intensity, minimum of 1,000 $\mu W/cm^2$, should be measured on the surface being examined, with a suitable ultraviolet light meter. Reflectors and filters should be checked daily for cleanliness and integrity. Cracked or broken ultraviolet filters should be replaced immediately.

7.4.2 Ultraviolet Light Warm-up — Allow the ultraviolet light to warm-up for a minimum of 10 minutes prior to its use or measurement of the intensity of the ultraviolet light emitted.

7.4.3 Visual Adaptation — The examiner shall be in the darkened examination area for at least 3 minutes prior to examination so that the eyes will adapt to dark viewing.

7.5 Visible Light Examination

7.5.1 Visible Light Level — Visible penetrant indications can be examined in either natural or artificial light. A minimum light intensity at the examination surface of 1,076 lx (100 ftc) is recommended.

7.6 Evaluation

7.6.1 Interpretation shall be based on the size of the indication.

8. Acceptance Criteria

8.1 Refer to Appendix 3, *Sample Liquid Penetrant Acceptance Criteria.*

9.0 Post-cleaning

9.1 Post-cleaning shall be performed with solvent.

10.0 Documentation

10.1 Complete all required items listed in Figure 2.2 (page 39) and Figure 2.3 (page 40).

Appendix 3
Sample Liquid Penetrant Examination Acceptance Criteria

The Sample Liquid Penetrant Examination Acceptance Criteria is intended as reference material for the examinee. The examinee will be given a Specific Liquid Penetrant Examination Acceptance Procedure for the performance of his practical examination in the product forms chosen in Figure 3.1 (page 44).

An indication of an imperfection may be larger than the imperfection that causes it; however, the size of the indication is the basis for acceptance evaluation.

Castings

Linear Indications

1. 8 mm (0.3 in.) long for materials up to 13 mm (0.5 in.) thick;
2. 13 mm (0.5 in.) long for materials 13-25 mm (0.5-1 in.) thick;
3. 18 mm (0.7 in.) long for materials over 25 mm (1 in.) thick.
4. For linear indications, the indications must be separated by a distance greater than the length of an acceptable indication. A linear indication is one with length in excess of 3 times the width.

Rounded Indications

1. 8 mm (0.3 in.) diameter for materials up to 13 mm (0.5 in.) thick;
2. 13 mm (0.5 in.) diameter for materials over 13 mm (0.5 in.) thick.
3. Four or more rounded indications in a line separated by 3 mm (0.1 in.) or less edge to edge are unacceptable. Rounded indications are those not defined as linear indications.

Welds or Forgings

Only imperfections producing indications with major dimensions greater than 2.5 mm (0.063 in.) shall be considered relevant imperfections.

Linear Indications

1. 5 mm (0.2 in.) long for materials 13 mm (0.5 in.) or less thick;
2. 10 mm (0.4 in.) long for materials over 13-25 mm (0.5-1 in.) thick;
3. 15 mm (0.6 in.) long for materials over 25 mm (1 in.) thick.
4. For linear indications, the indications must be separated by a distance greater than the length of an acceptable indication. A linear indication is one with length in excess of 3 times the width.

Rounded Indications

1. 5 mm (0.2 in.) diameter for materials up to 13 mm (0.5 in.) thick;
2. 8 mm (0.3 in.) diameter for materials over 13 mm (0.5 in.) thick.
3. Four or more rounded indications in a line separated by 3 mm (0.1 in.) or less edge to edge are unacceptable.
4. Ten or more indications in any 15 cm^2 (6 $in.^2$) of area whose major dimension is no more than 15 cm (6 in.) with the dimensions taken in the most unfavorable location relative to the indications being evaluated are unacceptable.
5. Rounded indications are those not defined as linear indications.

Appendix 4
Qualification and Certification of NDT Personnel

Overview of Personnel Qualification and Certification

Qualification and certification of NDT personnel in the United States (U.S.) has traditionally been through employer-managed programs based on *Recommended Practice No. SNT-TC-1A*, or operated in accordance with the *ASNT Standard for Qualification and Certification of Nondestructive Testing Personnel (ANSI/ASNT CP-189)*. ASNT first issued *SNT-TC-1A* in 1968 while *ANSI/ASNT CP-189* was first issued in 1991. Since 1977, ASNT has actively supported employer-managed NDT qualification and certification programs by offering ASNT NDT Level III certification by examination in various NDT methods to U.S. NDT personnel and to NDT personnel from countries all over the world.

As the global marketplace continues to expand, the need for global standards increases. Global standards help increase harmonization between countries, industries, and technical societies, help facilitate international commerce, and foster mutual acceptance among partners of NDT personnel qualification and certification. With this in mind, ASNT, in 1996, began implementing a new NDT personnel qualification and certification program entitled the ASNT Central Certification Program (ACCP). The purpose of the ACCP is to provide Level III, Level II, and Level I NDT personnel with independent, transportable certification by examination for national and international acceptance. The ACCP is uniquely flexible in that it allows for qualification and certification that satisfies any number of requirements including those of *ISO 9712 - Non-destructive Testing: Qualification and Certification of Personnel.*

The following sections provide an overview of *SNT-TC-1A, ANSI/ASNT CP-189, ISO 9712* and the ACCP.

Recommended Practice No. SNT-TC-1A

This document is intended to be a guideline for employers to establish their own written practice for the qualification and certification of their NDT personnel. It is not intended to be used as a strict specification. This document was first issued in 1968 and was revised in 1975, 1980, 1984, 1988, 1992, and 1996. The current edition of *SNT-TC-1A*, (1996), includes the following NDT methods:

1. acoustic emission testing (AE),
2. electromagnetic testing (ET),
3. leak testing (LT),
4. liquid penetrant testing (PT),
5. magnetic particle testing (MT),
6. neutron radiographic testing (NR),
7. radiographic testing (RT),
8. infrared/thermal testing (IR),
9. ultrasonic testing (UT),
10. vibration analysis (VA), and
11. visual and optical testing (VT).

SNT-TC-1A defines three levels of NDT qualification (Level I, Level II, Level III) as well as the recommended education, training, and experience requirements for each level. It also establishes the different types of examinations for each level of qualification.

1. Level III:
   a. Basic Examination (required only once independent of the number of methods),
   b. Method Examination (for each method), and
   c. Specific Examination (for each method).
2. Level II:
   a. General Examination (for each method),
   b. Specific Examination (for each method), and
   c. Practical Examination (for each method).
3. Level I:
   a. General Examination (for each method),
   b. Specific Examination (for each method), and
   c. Practical Examination (for each method).

SNT-TC-1A recommends the minimum number of questions for each written examination and the format for practical examinations.

The following excerpts from Section 9 of *SNT-TC-1A* present details concerning certification:

9.1 Certification of all levels of NDT personnel is the responsibility of the employer.

9.2 Certification of NDT personnel shall be based on demonstration of satisfactory qualification in accordance with Sections 6, 7, and 8, as modified by the employer's written practice.

9.3 At the option of the employer, an outside agency may be engaged to provide NDT Level III services. In such instances, the responsibility of certification is retained by the employer.

9.4 Personnel certification records shall be maintained on file by the employer and should include the following:
1. Name of certified individual.
2. Level of certification and NDT method.
3. Educational background and experience of certified individuals.
4. Statement indicating satisfactory completion of training in accordance with the employer's written practice.
5. Results of the vision examinations prescribed in 8.2 for the current certification period.
6. Current examination copy(ies) or evidence of successful completion of examinations.
7. Other suitable evidence of satisfactory qualifications when such qualifications are used in lieu of the specific examination prescribed in 8.8.3(b) or as prescribed in the employer's written practice.
8. Composite grade(s) or suitable evidence of grades.
9. Dates of certification and/or recertification and the dates of assignments to NDT.
10. Signature of employer's certifying authority.

The following portions from Section 9 of *SNT-TC-1A* presents details concerning recertification:

9.5 Recertification
1. All levels of NDT personnel shall be recertified periodically in accordance with one of the following criteria:
   a. Evidence of continuing satisfactory performance.
   b. Reexamination in those portions of the examinations in Section 8 deemed necessary by the employer's NDT Level III.
2. Recommended maximum recertification intervals are:
   a. Levels I and II — 3 years, and
   b. Level III — 5 years.
3. NDT personnel may be reexamined any time at the discretion of the employer and have their certificates extended or revoked.
4. The employer's written practice should include rules covering the duration of interrupted service that requires reexamination and recertification.

ANSI/ASNT CP-189

This document is the U.S. consensus standard for qualification and certification of NDT personnel. The current edition of *ANSI/ASNT CP-189* (1995) includes the NDT methods of AE, ET, LT, MT, NR, PT, RT, VT and UT. It identifies five categories of NDT qualification (Level III, Level II, Level I, Trainee, NDT Instructor); however, only Level III, Level II and Level I personnel are certified while a qualified NDT Instructor is designated by an NDT Level III.

In much the same manner as *SNT-TC-1A*, *ANSI/ASNT CP-189* requires the employer to establish a "procedure" (*SNT-TC-1A* uses the term "written practice") for the qualification and certification of NDT personnel. This standard defines the education, training, and experience requirements for each category of qualification. It also establishes the different types of examinations for each level of qualification.

1. Level III:
   a. ASNT NDT Level III certificate (with a currently valid endorsement for each method in which employer certification is sought).
   b. Specific Examination (for each method),
   c. Practical Examination (for each method; prepare an NDT procedure), and
   d. Demonstration Examination (for each method; hands-on practical examination).
2. Level II:
   a. General Examination (for each method),
   b. Specific Examination (for each method), and
   c. Practical Examination (for each method).
3. Level I:
   a. General Examination (for each method),
   b. Specific Examination (for each method), and
   c. Practical Examination (for each method).

Candidates who fail an examination are required to receive additional documented training addressing the deficiencies that caused failure, or wait at least thirty days before reexamination. *ANSI/ASNT CP-189* requires an NDT Level III with a valid ASNT NDT Level III certificate in the applicable method to be responsible for development, administration and grading of examinations; however, in no case is it permitted that an examination be prepared or administered by one's self or by one's subordinate.

Similar to *SNT-TC-1A*, this standard specifically provides the employer with the option to engage the services of an outside organization to perform the duties of an NDT Level III. *ANSI/ASNT CP-189* states that the training requirements for an NDT Level III are satisfied if the individual holds a current ASNT NDT Level III certificate in the applicable NDT method.

Section 5 of *ANSI/ASNT CP-189* presents details concerning certification:

5.1 Procedure. The employer shall develop and maintain a procedure detailing the program that will be used for qualification and certification of NDT personnel in accordance with this standard.

5.2 Procedure Requirements. The procedure shall describe the minimum requirements for certifying personnel in each NDT method and the levels of qualification desired. The procedure shall satisfy the requirements of this standard. The procedure shall include, as a minimum, the following:

a. personnel duties and responsibilities including, if the employer has more than one NDT Level III for a specific method, the employer shall designate one individual as the principal NDT Level III for each such method;
b. training requirements;
c. experience requirements;
d. examination requirements;
e. records and documentation requirements, including control, responsibility, and retention period; and
f. recertification requirements.

5.3 Approval. The employer's certification procedure shall be approved by an NDT Level III designated by the employer.

Certification also requires successful completion of vision examinations administered in accordance with a procedure, and by personnel approved by the NDT Level III.

Recertification of NDT Level I and Level II personnel is required to be by examination in accordance with certification examination requirements, at least every three years. Recertification of NDT Level III personnel, as a minimum, requires verification of the individual's ASNT NDT Level III certificate for currency in each method for which recertification is sought.

ISO 9712

ISO 9712 is an international standard that establishes a system for the qualification and certification of personnel to perform industrial NDT. Instead of employer-managed certification programs, *ISO 9712* requires certification be conducted by a central, independent body that must be a nonprofit organization with no direct involvement in the training of NDT personnel and that is recognized by the NDT community or the ISO member body of the country concerned.

ISO 9712 introduces a certification process that uses a national certifying body to administer procedures for certification of NDT personnel, and a qualifying body authorized by the national certifying body, to prepare and administer certification examinations. An examination center may be authorized by the national certifying body, or through a qualifying body to administer certification examinations. *ISO 9712* uses the term "industrial sector" to describe an area of industry or technology using specialized NDT that requires specific skill, knowledge, equipment, or training to achieve satisfactory performance.

ISO 9712 defines three levels of NDT qualification (Level 1, Level 2, Level 3) as well as the education, training, and experience requirements for each level of qualification. It also establishes the different types of examinations for each level of qualification.

1. Level 3:
   a. Basic Examination (required only once independent of the number of methods),
   b. Method Examination [for each method; integrating application of the method to the applicable industrial sector(s), and includes drafting one or more procedures in the applicable industrial sector(s)], and
   c. Practical Examination (for each method; Level 2 Hands-on Practical Examination is required when the Level 3 candidate does not hold appropriate Level 2 certification).
2. Level 2:
   a. General Examination (for each method),
   b. Specific Examination [for each method; related to the applicable industrial sector(s)], and
   c. Practical Examination [for each method; related to the applicable industrial sector(s)].
3. Level 1:
   a. General Examination (for each method),
   b. Specific Examination [for each method; related to the applicable industrial sector(s)], and
   c. Practical Examination [for each method; related to the applicable industrial sector(s)].

Certification requires documented evidence of satisfactory vision in accordance with requirements listed in *ISO 9712*. There are a number of requirements associated with validity of certification including no significant interruption of work in the method(s) for which one is certified.

Recertification requirements include continued satisfactory work activity relevant to certification without significant interruption. Recertification is required at least every five years from the date of certification. Every other recertification period, or at least every ten years, the certified individual is also required to pass a limited practical examination if Level I or II, or a written examination if Level III.

ASNT Central Certification Program (ACCP)

The ACCP was adopted by the ASNT Board of Directors 13 July 1996. The ACCP establishes the system for central certification of NDT personnel administered and maintained by ASNT. The purpose of ACCP is to provide independent, transportable NDT certification by examination to promote national and international acceptance of NDT certification and reduce multiple audits of certification programs. The ACCP was developed to improve NDT reliability and accuracy through enhanced performance of personnel as demonstrated by the ACCP examinations and accompanying qualification requirements. The ACCP is intended to provide customers and prospective employers with clear expectations of NDT personnel competency and proficiency.

Management of the ACCP is the responsibility of the Certification Management Board (CMB), which is a standing committee of ASNT. An authorized qualifying body (AQB) may be used to prepare and administer NDT qualification examinations and an authorized examination center (AEC) may be used to administer NDT qualification examinations.

Within the ACCP there are several options available to satisfy employer, employee and industry needs. The ACCP is unique in that it allows for qualification and certification that addresses any number of requirements including those of *SNT-TC-1A*, *ANSI/ASNT CP-189*, *MIL-STD-410*, *ISO 9712*, and other international sources of NDT qualification and certification programs based on *ISO 9712*. It also provides a mechanism for specific practical and written examinations to better accommodate industries where product-forms or areas of technology demand specialized NDT. The ACCP uses a combination of traditional practices, national and international conventions and newly evolved concepts to create a system of central certification which represents the next generation of NDT personnel qualification and certification.

ACCP terminology is of key importance; the following are definitions from the ACCP document:

2.1 *ACCP certification*: The process whereby ASNT certifies that an individual has met the requirements of this document for ACCP Level III, ACCP Level II, or ACCP Level I.

2.2 *ASNT NDT Level III*: An individual who, having passed ASNT administered Basic and Method(s) Examinations, holds a current, valid ASNT NDT Level III certificate in at least one method.

2.3 *Authorized examination center* (AEC): A site with facilities and personnel, independent of the employer, approved by the ASNT Certification Management Board (CMB) to administer NDT qualification examinations.

2.4 *Authorized qualifying body (AQB)*: A competent organization, independent of the employer, approved by the ASNT CMB to prepare and administer NDT qualification examinations.

2.5 *Certificate*: Written testimony of qualification.

2.6 *Certification Management Board (CMB)*: Formerly known as the National Certification Board (NCB), this is a standing committee of ASNT that is responsible for managing the ACCP.

2.7 *Employer*: The corporate, private, or public entity that employs personnel for wages or salary.

2.8 *Employer authorization*: The process whereby an employer's ACCP Level III or ASNT NDT Level III reviews the certificates of ASNT Central Certification for the employer's NDT personnel, determines if further examination (see job specific examinations in paragraph 7.5.) is required, and then, on behalf of the employer, authorizes personnel to perform NDT for that employer.

2.9 *Endorsement*: Written testimony of a particular qualification.

2.10 *Guidance*: See *supervision*.

2.11 *Industrial sector (IS)*: An industry, product-form or area of technology that possesses common characteristics with respect to NDT considerations.

2.12 *Instruction*: A description of the steps to be followed when performing an NDT technique; developed in conformance with a procedure.

2.13 *Procedure*: A written description that establishes minimum requirements for performing an NDT method on any object, written in accordance with established standards, codes, or specifications.

2.14 *Qualification*: Demonstration or possession of education, skills, training, knowledge, and experience required for personnel to properly perform NDT to a level as specified in this document.

2.15 *Recertification examination*: An examination administered by the CMB expressly for the purpose of recertification.
2.16 *Recertification*: The process of extending one's certification after the initial period of validity, and maintaining certification for individual periods thereafter.
2.17 *Renewal*: Same as recertification.
2.18 *Specific procedure*: Same as instruction.
2.19 *Supervision*: The act of an ACCP Level II, ACCP Level III, or ASNT NDT Level III directing the application of NDT performed by other NDT personnel, which includes the control of actions involved in the preparation of the test, performance of the test, and reporting of test results.

The ACCP refers to a number of appendices, each traceable to a source (e.g., *SNT-TC-1A*, *ANSI/ASNT CP-189*, *ISO 9712*, etc.) of differing qualification requirements (education, training, and experience). There are three levels of qualification: Level III, Level II, and Level I. The examinations for each level of qualification are:

1. Level III: candidates with a current, valid ASNT NDT Level III certificate in a method shall be considered to have met all prerequisites, except vision, in that method and to have passed the Basic Examination and the Method Examination.
   a. Basic Examination (required only once independent of the number of methods).
   b. Method Examination (for each method).
   c. Procedure Preparation Examination (for each method).
   d. Hands-on Practical Examination (for each method; general or specific as applicable).*
2. Level II:
   a. General Examination (for each method; includes Procedure Comprehension and Instruction Preparation (PCIP) portion).
   b. Hands-on Practical Examination (for each method; general or specific as applicable).*
3. Level I:
   a. General Examination (for each method; includes Instruction Comprehension portion).
   b. Hands-on Practical Examination (for each method; general or specific as applicable).*

Certification requires documented evidence of satisfactory vision in accordance with requirements listed in the ACCP document. There are a number of requirements associated with validity of certification including no significant interruption of work in the method(s) for which one is certified.

Recertification requirements include continued satisfactory work activity, relevant to certification, without significant interruption. Recertification is required at least every five years from the date of certification. Every other recertification period, or at least every ten years, the certified individual is also required to pass a recertification examination applicable to the level of recertification.

*At the option of the industrial sector (IS), a Specific Written Examination may be required in conjunction with, or in addition to, the Hands-on Practical Examination(s).

The American Society for Nondestructive Testing, Inc. Order #6101