PART 9
Recognition Training for Liquid Penetrant Inspectors

TRAINING OF LIQUID PENETRANT INSPECTORS

Penetrant is a widely used nondestructive test method. Penetrant is also inexpensive and easy to perform. Still, missing a crack in a critical component at a fracture critical location can be catastrophic. The formal training and experience hours are critical. Classroom instruction should follow a national, standardized curriculum such as that in ASNT CP 105. Any certificates representing the course completion should reference the document and include the training hours. The classroom instruction should be administered by a qualified individual. All standards for training, qualification, and certification outline a minimum number of experience hours required before the candidate can take the certification examination. The practical examinations of a certification examination are required to include the method and techniques within that method that the candidate might perform in the inspector's daily routine. (In the case of ASTM E 1219, penetrant testing is the method, and Type I, method C, form D is a technique within the method.) It is very important that the examination cover the required techniques so an administrator of the exams can truly state a certification. A certification is written testimony of the individual's qualifications in the work environment. Without proper quality training under the guidance of a Level II inspector, the candidate will have a very difficult time trying to pass a properly administered certification examination.

The experience hours need to be obtained under the guidance of a Level II or Level III in the penetrant test method. During this time, the candidate should be exposed to all the components of the penetrant test process at the facility. These hours of experience obtained should be organized to expose the candidate to the different processes and scenarios the candidate will be engaged in when working independently. It is also important for an organization to select a candidate for training who has been with the organization and is familiar with the types of components and or structures to inspect. This familiarity helps the candidate build a strong working knowledge of the discontinuities that need to be evaluated.

SAMPLE ANOMALOUS TEST OBJECTS

The most effective means for training penetrant inspectors to recognize and identify discontinuities is frequent reference to a collection of test objects with typical discontinuities. Test objects that have been rejected because of discontinuities should be clearly marked or partially damaged so that they will not be confused with acceptable test objects. The test objects with known discontinuities could be processed with regular production test objects. This would serve two purposes: the inspector in training could be judged for discontinuity recognition and at the same time, the inspector could become familiar with the type of discontinuity indication considered to be cause for rejection. However, with continued processing, the known discontinuities will clog with penetrant and developer residues. Special cleaning of the test objects with clogged discontinuities will be necessary to keep using them for recognition training.

Dye penetrants tend to kill the fluorescent qualities in fluorescent penetrants. After a test object has been inspected with dye penetrant, it is not desirable to attempt to reprocess with fluorescent penetrant. The results will not be reliable. In all cases, test objects should be cleaned thoroughly and degreased before reprocessing.

CAUSES OF DISCONTINUITIES

It is possible to examine an indication of a discontinuity and to determine its cause as well as its extent. Such an appraisal can be made if something is known about the manufacturing processes to which the part has been subjected. The extent of the indication or accumulation of penetrant will show the extent of discontinuity, and the breadth and brilliance will be a measure of its depth. Deep cracks will hold more penetrant and therefore will be broader and more brilliant. Very fine openings can hold only small amounts of penetrant and therefore will appear as fine lines.

Although many factors influence the exact size and shape of indications from penetrant testing, most typical discontinuities are easy to recognize. A line of penetrant signifies a crack, lap, cold shut, seam, or other long discontinuity. A spot or blob denotes a hole, large or small.

Standards for acceptance or rejection can be established by photographing typical indications and pairing them with sectioned test objects showing the discontinuities causing those indications.

Part 10
Specifications for Evaluation of Liquid Penetrant Indications

SPECIFICATIONS AND REFERENCES FOR LIQUID PENETRANT INTERPRETATION

Some industries have prepared standards for evaluation and acceptance or rejection of hardware on the basis of penetrant indications. These can be anything from quite general to very detailed. Penetrant users may find some of these helpful or may prefer to prepare their own. If penetrant inspectors are working under a contract, it is mandatory that they determine and conform to the specifications to which the contracting agency intends to hold them.

Commonly, a general statement may be encountered, such as “The inspection department shall pass only those parts that are free of penetrant indications. Parts showing penetrant indications should be referred to the metallurgy or design departments for disposition. The metallurgy or design department shall decide which parts shall be accepted, reworked or rejected.”

ASTM E 433, *Standard Reference Photographs for Liquid Penetrant Inspection*, contains reference photographs to be used as a means of establishing and classifying types and characteristics of surface discontinuities detectable by penetrant testing (ASTM E 433). They may be used as a reference for acceptance standards, specifications, and drawings. However, no attempt has been made to establish limits of acceptability or the extent of the metallurgical discontinuity.

Blueprint Notations Controlling Interpretation of Penetrant Indications

Ideally, the manufacturer’s drawing or print for the test part or surface under examination will specify the nondestructive test method or methods required for acceptance. Moreover, it will either specify the acceptance or rejection criteria or refer the inspector to supplemental documents such as acceptance or rejection specifications. If critical parts are involved (such as nuclear hardware or jet engine components), an expert in evaluation of indications may have to be called on for a judgment.

ACCEPTANCE CRITERIA IN LIQUID PENETRANT TESTING

To establish acceptance or rejection criteria, it may be necessary to conduct an extensive correlation study between nondestructive test indications and destructive test results. This is the ultimate procedure, but even it may leave some doubt because discontinuities or indications do not always occur in exactly the same place, with the same frequency, or to the same extent.

It should be obvious that a number of factors enter into the final judgment of acceptability of test objects during penetrant testing, including: (1) the metal or metal alloy involved; (2) if a nonmetallic surface, the composition of the nonmetal; (3) locations of the penetrant indications, for example, in critical radii, on edges that will be ground off, in test objects designed for high strength applications, or in thick sections that may allow for removal without sacrifice of function; (4) whether or not the surface or surfaces are repairable by welding or other means; and (5) the cost of the object. It may be that the cost of a new part is so low that the expense of repair or rework of an anomalous part is not warranted. Conversely, of course, one would not want to discard an expensive piece of hardware that could be reworked at a considerable saving over the cost of a new part.

In summary, it can be seen that penetrant evaluation is dependent on several factors that are not easily standardized. Further work in detecting, defining, describing, and evaluating indications could be very helpful to the science of penetrant testing.

EXAMPLES OF INTERPRETATION GUIDES BASED ON APPEARANCE OF LIQUID PENETRANT INDICATIONS

In some cases, specifications provide a guide to test object evaluation based primarily on the size, shape, or location of penetrant indications. For such purposes, a linear penetrant indication is defined as having a length greater than three times the width. Rounded penetrant indications are those indications that are circular or elliptical with the length less than three times the width. In some code applications, unacceptable discontinuities are then defined in terms such as (1) any crack or linear indication; (2) rounded indications greater than 5 mm (0.2 in.) in dimension; (3) four or more rounded indications in a line separated by 1.5 mm (or 0.06 in.) or less, edge to edge; and (4) ten or more rounded indications in any 37.5 cm^2 (6.0 in.^{2}) of surface with the major dimension of this area not to exceed 150 mm (6.0 in.). The area must be taken in the most unfavorable location relative to the indications being evaluated.

REPRESENTATIVE AEROSPACE MANUFACTURER'S LIQUID PENETRANT TEST INTERPRETATION GUIDE

A typical aerospace manufacturer's process specification requires that visual inspection areas shall be illuminated with essentially white light. The intensity of white light at the visual test level shall be equivalent to at least 750 lx (70 ftc). Fluorescent penetrant testing shall be conducted in a suitable darkened area (with an ultraviolet radiation intensity of at least 10 W/m^2 (1000 µW/cm^2) and background illumination preferably not exceeding 20 lx (2.0 fc). The following lists the criteria for test object acceptance or rejection in accordance with the aerospace company's quality requirements.

1. Propagating discontinuities, regardless of location, are cause for rejection unless completely removed within drawing tolerances. Propagating discontinuities are those discontinuities that, because of their nature or geometry, may enlarge in any way during service life. Included are linear porosity, laps, seams, and cracks.
2. Any indication discernible as a crack when observed with 10× magnification shall be rejectable.
3. Nonpropagating imperfections are acceptable and do not require removal if the dimensional and smoothness requirements established on the engineering drawing can be met.

Table 5 lists one company's acceptance and rejection criteria for commonly used aerospace materials and conditions. Questionable conditions are required to be referred to quality control engineering for resolution. Rejected test objects shall be disposed of in accordance with the applicable procedures.

ACCEPTANCE CRITERIA FOR LIQUID PENETRANT TESTING OF CAST TURBINE BLADES

An example of how one manufacturer handles the penetrant test requirements for gas turbine engine turbine blades and vanes is to issue a specification that covers the acceptance or rejection criteria for visual, radiographic, and penetrant indications. The specification indicates that drawings shall designate zones on the casting identified by letters A, B, C, and so on. Each of these letters (or grades) as defined in this specification establishes different degrees of allowable discontinuities for visual, fluorescent penetrant, and radiographic testing. The zones for each casting are established by the manufacturer's materials engineering and stress analysis group.

Table 5. Typical aerospace manufacturer's liquid penetrant testing acceptance and rejection criteria.

Material and Discontinuity	Aluminum	Copper	Magnesium	Nickel	Stainless Steel	Iron Alloy	Titanium	High Temperature Alloy
Bar Stock								
cracks	N	N	N	N	N	N	N	N
seams	N	N	N	N	N	N	N	N
Castings								
cold shuts	Q	Q	Q	Q	Q	Q	Q	Q
cracks	N	N	N	N	N	N	N	N
porosity	A	A	Q	A	A	A	A	A
sand blisters	A	A	A	A	A	A	A	A
shrinkage	Q	Q	Q	Q	Q	Q	Q	Q
Extrusions								
blisters	N	N	N	N	N	N	N	N
broken surface	N	—	N	—	N	N	N	N
deep scratches	Q	Q	Q	Q	Q	Q	Q	Q
die drag	Q	Q	Q	Q	Q	Q	Q	Q
die weld cracks	N	N	N	—	—	—	—	—
cracks	N	N	N	N	N	N	N	N
inclusions	Q	Q	N	Q	Q	Q	N	Q
metal pick up	A	A	A	A	A	A	A	A
pitting	A	Q	N	Q	Q	A	N	Q
Forgings								
cracks	N	N	N	N	N	N	N	N
inclusions	Q	Q	N	Q	Q	Q	N	Q
laps	N	N	N	N	N	N	N	N
Formed Part								
cracks	N	N	N	N	N	N	N	N
inclusions	Q	Q	N	Q	Q	Q	N	Q
metal pick up	A	A	A	A	A	A	A	A
orange peel	Q	Q	Q	Q	Q	Q	Q	Q
Heat Treated								
cracks	N	N	N	N	N	N	N	N
scale	—	—	—	—	—	A	A	A
Machined parts								
cracks	N	N	N	N	N	N	N	N
grinding cracks	N	N	N	N	N	N	N	N
tool marks	Q	Q	N	Q	Q	Q	N	Q
Plate								
cracks	N	N	N	N	N	N	N	N
inclusions	Q	N	N	Q	Q	Q	N	Q
laminations	N	N	N	N	N	N	N	N
pitting	A	Q	N	Q	Q	A	N	Q
scratches	A	A	N	A	A	A	N	A
Sheet								
cracks	N	N	N	N	N	N	N	N
inclusions	Q	Q	N	Q	Q	Q	N	Q
laminations	N	N	N	N	N	N	N	N
pitting	A	Q	N	Q	Q	A	N	Q
scratches	A	A	N	A	A	A	N	A

A = Acceptable.
N = Not acceptable.
Q = Questionable.

The specification emphasizes the importance of carefully controlled penetrant testing and the necessity to record on the technique card or other applicable document the exact techniques used to process the test objects. In a number of specifications, porosity bleedout diameters are specified as accept or reject criteria. These maximum acceptable size limits for penetrant indications apply to the bleedout indication, viewed immediately after wiping the indication only one time with a swab or cloth dampened with a suitable solvent. The recurrence of the fluorescent penetrant indication after once wiping clean is referred to as *bleedback*.

Positive surface discontinuities (excess metal), such as mold ridge, fins, bumps, and others, generally are not considered potential stress raisers when not associated with severe undercutting at their bases. These discontinuities are permissible

Table 6. Example of acceptance standards for nondestructive testing of cast turbine blades and vanes.

Grade	Visual Testing	Liquid Penetrant Testing	Radiographic Testing
Grade A	No defects allowed	No bleedback allowed	No defects allowed
Grade B	Negative flaw of diameter ≤ 0.4 mm (0.016 in.) and estimated depth ≤ 0.2 mm (0.008 in.) or 20 percent of local drawing minimum thickness, whichever is less Any number allowed if clearly spaced ≥ 3 mm (0.12 in.) apart	Bleedback of diameter ≤ 0.4 mm (0.016 in.) Any number allowed if clearly separated a distance ≥ 3 mm (0.12 in.) apart	Diameter ≤ 0.4 mm (0.016 in.) Any number allowed if clearly separated a distance ≥ 3 mm (0.12 in.) apart, and each does not exceed 20 percent of the local drawing specified thickness
Grade C	Allows same flaws as Grade B, plus four negative flaws per side of 0.4 to 0.8 mm (0.016 to 0.032 in.) diameter and estimated depth ≤ 0.2 mm (0.008 in.) or 20 percent of local drawing minimum thickness, whichever is less, if clearly separated a distance ≥ 3 mm (0.12 in.) apart	Bleedback ≤ 0.4 mm (0.016 in.) diameter Allows any number, plus four 0.4 to 0.8 mm (0.016 to 0.032 in.) diameter indications per side if all indications clearly separated a distance ≥ 3 mm (0.12 in.)	Allows same indications as in Grade B, plus 0.4 to 0.8 mm (0.016 to 0.032 in.) diameter limited to four places per area designated, if clearly separated a distance ≥ 3 mm (0.12 in.), none exceeding 20 percent of local drawing specified thickness
Grade D	This grade is usually assigned to blade root serrations and allows essentially same flaws as under Grade C except that there shall be no 0.4 to 0.8 mm (0.016 to 0.032 in.) indications in serration root radii; not more than two 0.2 to 0.8 mm (0.008 to 0.032 in.) indications per serration; and not more than four 0.2 to 0.8 mm (0.008 to 0.032 in.) indications in all serrations on each side of blade	Bleedback allowed same as in grade C except that there shall be no 0.4 to 0.8 mm (0.016 to 0.032 in.) indications in serration root radii; not more than two 0.4 to 0.8 mm (0.008 to 0.032 in.) indications per serration; and not more than four 0.4 to 0.8 mm (0.008 to 0.032 in.) indications in all serrations on each side of blade	Same as Grade C

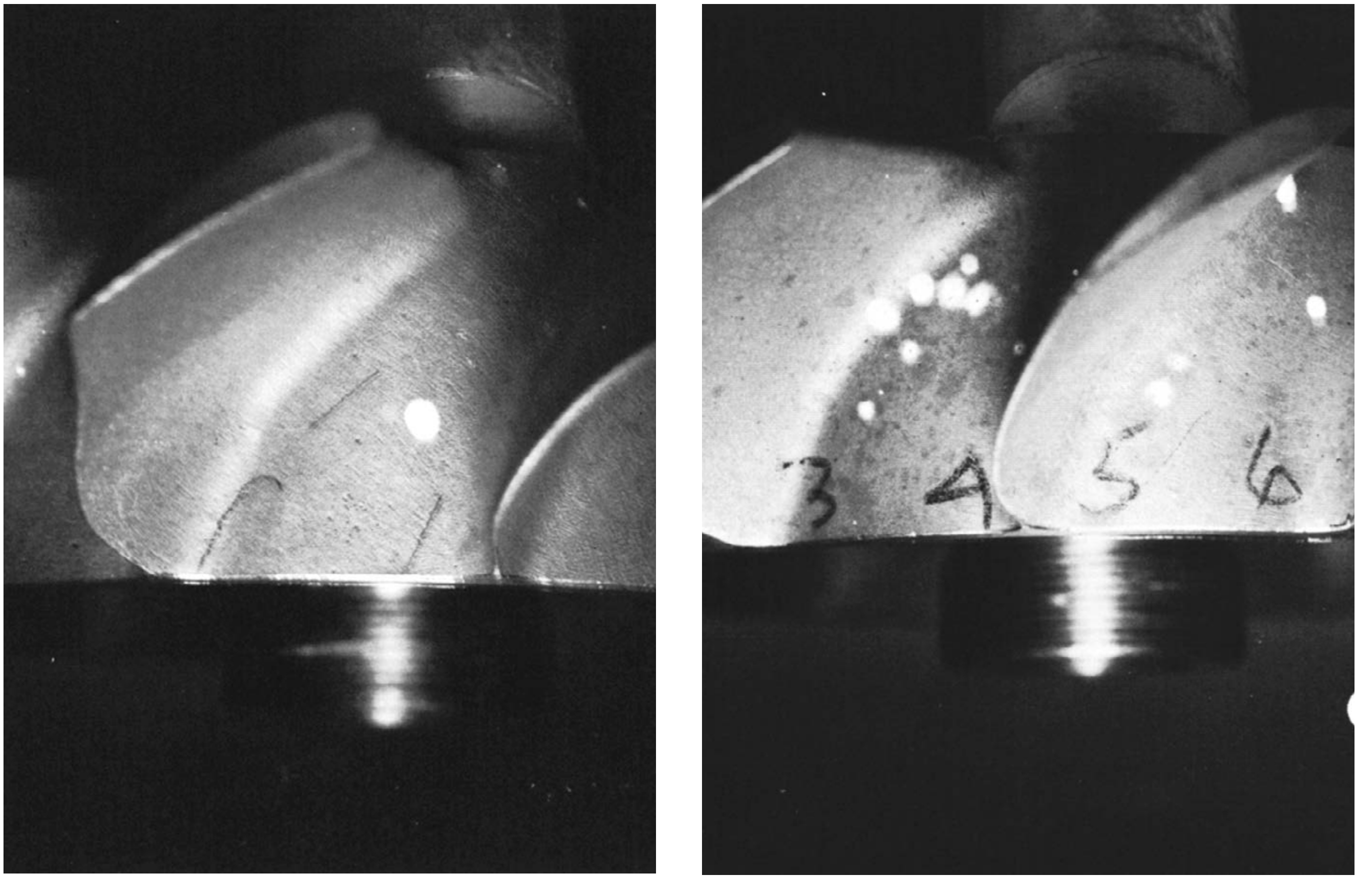
(Continued on next page).

Table 6. Example of acceptance standards for nondestructive testing of cast turbine blades and vanes (continued).

Grade	Visual Testing	Liquid Penetrant Testing	Radiographic Testing
Grade E	Allows same flaws as Grade B, plus four negative flaws per side of 0.4 to 1.5 mm (0.016 to 0.06 in.) diameter and an estimated depth ≤ 0.5 mm separated (0.02 in.) or 25 percent of the local drawing thickness, whichever is least, if clearly separated a distance ≥ 6 mm (0.24 in.) apart Negative flaws of diameter ≤ 0.8 mm (0.032 in.) allowed if spaced ≥ 3 mm (0.12 in.)	Allows same bleedback as in Grade B, plus four bleedback indications per side of 0.4 to 1.5 mm (0.016 to 0.06 in.) diameter if clearly separated a minimum of 6 mm (0.24 in.) apart Allows indications ≤ 0.8 mm (0.032 in.) diameter if spaced 3 mm (0.12 in.) apart	Allows same indications as in Grade B, plus diameter ≥ 0.4 to 1.5 mm (0.016 to 0.06 in.) limited to four places per area designated if clearly a distance ≥ 3 mm (0.12 in.) apart and each does not exceed 20 percent of the local drawing specified thickness Allows indications of diameter ≤ 0.8 mm (0.032 in.) if spaced ≥ 3 mm (0.12 in.) apart
Stock surfaces, all grades	Negative defects allowed to depth of machining stock Negative flaws of ≤ 0.1 mm (0.004 in.) diameter shall be considered not interpretable and shall be acceptable regardless of location if clearly separated by ≥ 2.5 mm (0.1 in.) Cracks, folds, cold shuts, or linear flaws (width 1/3 its length) are not allowed	For any grade, bleedback allowed to depth of machining stock Negative flaws of ≤ 0.1 mm (0.004 in.) diameter shall be considered not interpretable and shall be acceptable regardless of location if clearly separated by ≥ 2.5 mm (0.1 in.) Cracks, folds, cold shuts or linear flaws (width 1/3 its length) are not allowed	Unlimited flaws allowed to depth of machining stock Negative flaws of ≤ 0.1 mm (0.004 in.) diameter shall be considered not interpretable and shall be acceptable regardless of location if clearly separated by ≥ 2.5 mm (0.1 in.) Cracks, folds, cold shuts, or linear flaws (width 1/3 its length) are not allowed

on turbine blade and vane castings provided they can be removed without exceeding the minimum dimensions on the drawings and are removed by approved techniques of grinding and polishing.

Negative discontinuities may be either propagating (cracks, cold shuts, folds) or nonpropagating (oxide pits, small gas holes, shallow smooth bottomed depressions). Propagating discontinuities are not acceptable regardless of location. Negative discontinuities of the nonpropagating type are acceptable to the limits set forth in Table 6. Any of the above listed discontinuities that occur in areas with stock to be removed in later operations shall not be immediate cause for rejection. Such discontinuities may be removed within the stock allowance limits to ascertain that the requirements of this company's standards are met. Figure 37 shows examples of working standards and interpretation guides provided for shop personnel for the case of an aluminum fan casting.



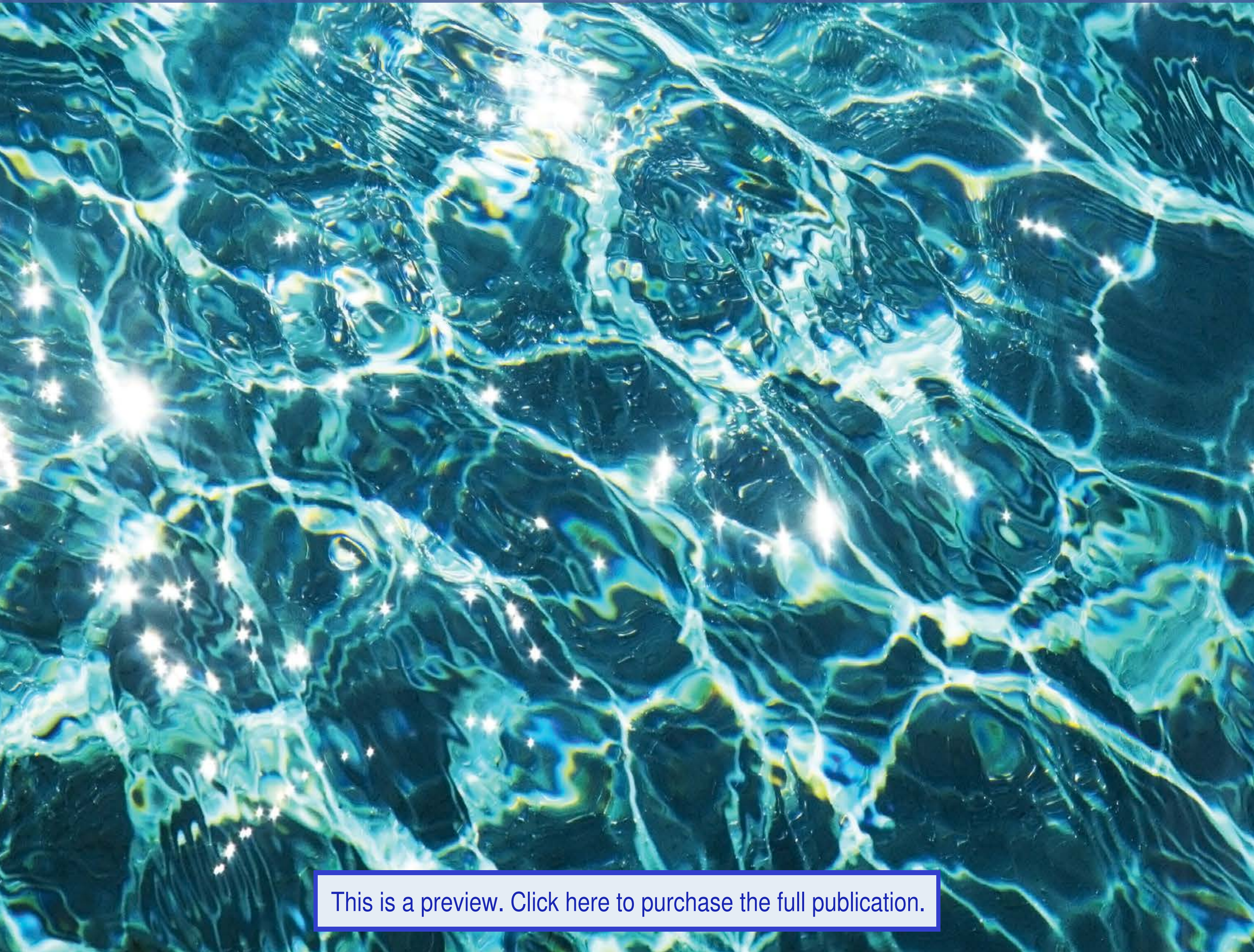
(a) (b)

Figure 37. Example of working standard and interpretation guide for shop personnel inspecting 356-T6 aluminum fan casting for porosity bleedout diameter: (a) indications in fan blade fillet area (cause for rejection because area is highly stressed so indications propagate through part thickness); (b) indications in rim of fan, which has heavy wall thickness and is subject to lower stress levels. Probing indicates depths of about 0.3 mm (0.01 in.). Experience has indicated that these have never extended through fan rim and therefore will not be detrimental to use of fan.

CHAPTER 6

SURFACE PREPARATION

and Cleaning



CONTENTS

CONTRIBUTORS

Michael L. White
Met-L-Chek
Santa Monica, California