TNT

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Focus

Manufacturing NDT Reference Standards

by Phil Herman, Jr.

In the world of NDT, our ability to consistently assess the severity of discontinuities relies on the use of NDT *reference standards*. We can think of them as comparators or constants against which other things are measured. Because it would be impossible to obtain samples containing real and consistently reliable defects for use as reference standards, the NDT industry must rely on manufactured samples, intact parts containing artificial discontinuities. By careful comparison to these, a technician is able to make a pass or fail determination. Like any other gage, the accuracy of NDT reference standards is critical, and knowing exactly what has been machined, and to what extent, is vital.

Using NDT Reference Standards

Reference, or *calibration standards* as they are often called, are used to standardize and calibrate NDT test equipment to ensure the ability of the equipment to correctly detect the signals that the particular equipment setup and procedure are sensitive to. An example would be a tube standard containing four *electrical discharge machined* (EDM) notches machined at 10 percent of the nominal wall thickness. These precisely machined notches approximate the maximum allowable defect as stipulated by the governing code or standard, thus allowing the inspector to set up or calibrate the test equipment to identify those signals that exceed the responses of the notches. This type of *application specific* standard is typical of both immersion ultrasonic and eddy current inspections and would be used at the start of each inspection, again at each shift change or after every few hours as the inspection procedure requires. This ensures that the equipment is operating correctly and that responses are measured consistently between calibrations.

Examples of items machined to include artificial discontinuities include: pipe, plate, fasteners, aircraft wheels and engine components, turbine blades and disks, pistons, projectiles and surgical implants. The artificial or machined discontinuities that are required in these application specific test standards are carefully selected to best represent those discontinuities expected in the item under test and may include flat-bottomed holes, side-drilled holes, micro holes, pits, wall loss, tube wear, surface and subsurface notches, simulated corrosion and more. The goal is to make the standard as realistic and accurate as possible.

Another type of standard used by NDT technicians is the *standard test block*. Standard test blocks are *nonrepresentative* tools, meaning that they are not manufactured from actual parts. Rather, they are of simplified design and contain manufactured discontinuities such as holes, angles, radii and more. Examples of ultrasonic test blocks are: the IIW (International Institute of Welding) block, the distance sensitivity calibration (DSC) block, the ASME angle beam block, step blocks, and the ASTM (American Society for Testing and Materials) flat bottom hole blocks (see Figs. 1 and 2). All of these blocks, and other types not listed here, serve the same basic purpose: to standardize and calibrate test equipment to ensure that it is functioning properly. *Step blocks* are a simple example to illustrate this point. In order to calibrate an ultrasonic thickness gage, the technician uses a block that covers the range of thicknesses he will be inspecting to calibrate the unit. Using the 0.100 inch (2.54 mm) step on the typical 5-step block, the technician ensures that the unit is reading thickness as accurately as possible. Because sound travels at different speeds through different materials, it is important to calibrate using a block of the specific alloy to be tested. For this reason, block manufacturers offer standard test blocks in most common alloys and can make them in less typical alloys as well.

Standard test blocks for eddy current testing are also common with those containing surface

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Fifteen years ago, most reference standards were produced for the aerospace and nuclear power industries. The smallest notch that could be accurately machined in them was the width of a human hair, about 0.003 in. Today, reference standards with notches one third that width are produced with electrical discharge machining. And, the industries requiring them are increasingly diverse. Still, because NDT equipment and technology continue to improve, manufacturers of reference standards are challenged by the NDT community to "make it smaller." Technicians who use reference standards and calibration blocks daily may not be aware of the detail that goes into the manufacture of this vital aspect of their work. "Manufacturing NDT Reference Standards" is an informative look at an interesting part of our industry.

This issue contains the last article in the "FYI" UT calibration series,"Equipment Maintenance". The "FYI" series on Radiography begins with "Radiation Safety" in the October issue.

The "Practitioner Profile" highlights Paul Petersen, recipient of the *Lou DiValerio Technician of the Year Award* for 2005. There's also an interesting feature by John Brunk detailing couplant substitutions he's made over the years in "Chewing Gum and Other Useful Testing Accessories".

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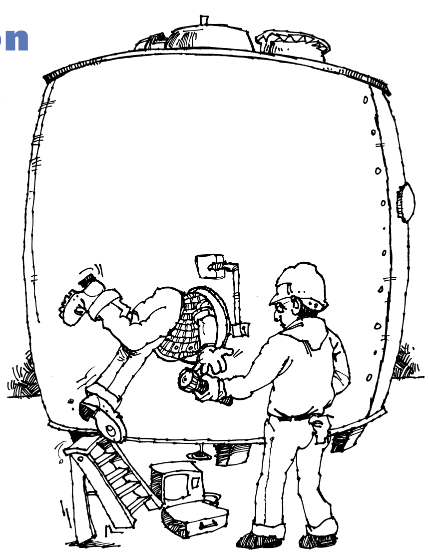
Tech Toon



New meaning for term "interference fit".

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and/or bolt hole cracks being the most popular (see Fig. 3). Since electrical conductivity and resistivity vary by alloy, eddy current test blocks must also match the alloy being tested. While UT and ET seem to constitute the bulk of the reference standard and test blocks manufactured, there are plenty of standards in use today for MT, PT, and RT.

Figure 1. ASTM E164 IIW-Type 1 test block in 1018 Steel.

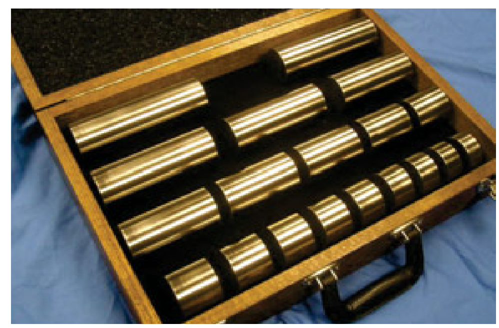

Figure 2. ASTM E428 distance amplitude set of 19 flat bottom hole (FBH) blocks in 4340 steel.

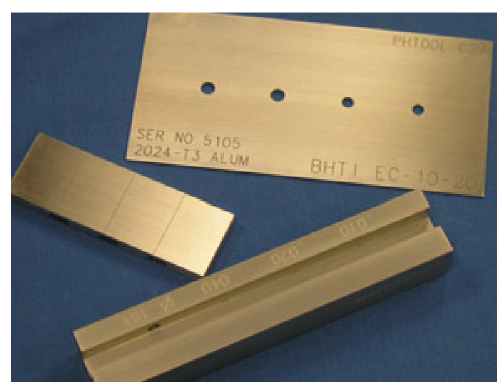

Figure 3. Examples of eddy current test standards with notches produced with electrical discharge machining. Standards (top to bottom) contain bolt hole notches, surface notches, and corner radius notches.

Using Reference Standards in Personnel Qualification. In addition to their use in calibrating equipment and in making pass or fail determinations, reference standards and test blocks can also be used by test examiners to assess the proficiency of NDT personnel performing inspections. When used in this manner, standards are often called *personnel qualification props* or simply test props. An application specific example of this type of use would be a welded plate containing a random pattern of micro holes that is given to an inspector to verify the inspector's proficiency in finding porosity using liquid penetrant testing.

Using Reference Standards in Research. Researchers and engineers developing new or improved NDT technologies use reference standards to push the limits of conventional defect detection. Phased array ultrasonics, digital radioscopy, and acoustic microscopes are examples of newer technologies that have made rethinking reference standards and defect sizes necessary. As technology continues to improve, manufacturers of reference standards are continually challenged to produce increasingly smaller and narrower defects once thought impossible.

Electrical Discharge Machined Reference Standards

Reference standards containing electrical discharge machined (EDM) notches are typically produced from an otherwise acceptable production item supplied by the manufacturer of the part or the test lab performing the inspection. A length of tubing, a section of wheel, or a turbine blade is shipped to the facility that will be manufacturing the reference standard. This item is inspected to ensure that there are no pre-existing defects that would make it a poor candidate for a master. The item must also match the geometry, alloy, heat treat condition, and surface finish of the test items as closely as possible.

The EDM process is a nonconventional machining process in which material is removed very precisely under carefully controlled conditions. The cutting is done with an electrode that is configured to yield the artificial defect desired. For example, an electrode used to produce a notch that is 0.004 inch (0.10 mm) in width, will be 0.003 inch (0.076 mm) in thickness and a few thousandths of an inch shorter in length than the desired notch (Fig. 4). This electrode may be mounted to cut or burn a notch on the outside or inside diameter of a tube, and may be oriented axially or circumferentially to the tube axis (see Fig. 5). The electrical discharge machine is set to parameters for the combination of workpiece and electrode material selected and the notch is machined. A *cast replica* of the resulting notch is made and examined at high magnification to ensure the expected dimensions (depth, width, and length) were achieved (see Fig. 6). If not, a repeatable setup allows the electrode to drop back into the notch to deepen it if needed. Cross-sections of the cast replica are archived as objective evidence of the as-built (final) sizes that will be recorded on the certification report. This process of electrode machining, workpiece setup, notch cutting and

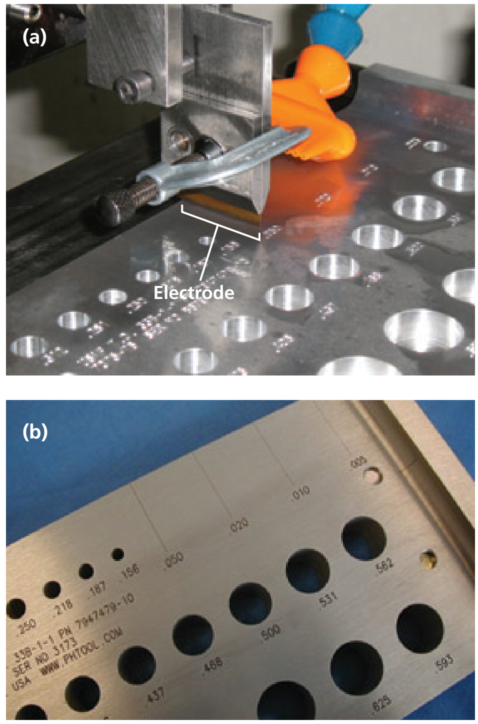

Figure 4. Images of a US Air Force general purpose eddy current standard in 7075-T6 aluminum showing (a) a 0.002 in. (0.05 mm) thick EDM electrode as it removes material to create a notch 0.050 in. (1.27 mm) deep × 1.00 in. (25.4 mm) long and (b) the completed standard with resultant notches.

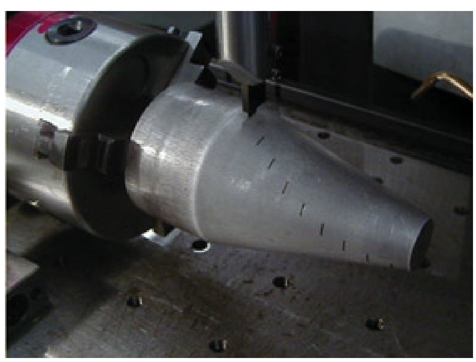

Figure 5. Missile tailcone standard with circumferentially oriented EDM notches in helical pattern.

replication and inspection is repeated for each notch until all the notches on the standard are completed.

Hole Machining. Flat-bottomed, side-drilled and micro hole standards are normally made from supplied items or from mockups made to simulate the test objects. Depending on diameter and depth, holes can be machined by conventional machining (drilling) or EDM. Access or material hardness may make EDM the logical choice over drilling. For example, machining pits in tube or pipe inside diameters (IDs) by drilling is impossible without first sectioning the part for tooling access. Sectioning the part is rarely a good option. However, EDM allows

Figure 6. Video measurement system measuring the cross-section of a cast replica of an EDM notch.

manufacturers to cut an ID pit without sectioning.

Standard Test Blocks

Standard (nonrepresentative) test blocks are machined in the same manner as other metal parts, using normal machine shop equipment such as saws, milling machines, lathes, surface grinders and engravers. There are many specifications that govern the manufacture of standard test blocks. The most common are from ASTM (specifically ASTM E127, E164, and E428), ASME, and AWS.

Ensuring Quality and Traceability of Raw Materials. As with any good manufacturing process, there are several important things to consider when manufacturing test blocks. Good quality raw materials of the correct alloys are the place to start. Most specifications list the desired alloy, or leave it up to the manufacturer of the blocks and the client to make the right decision. Next, a careful pre-machining ultrasonic inspection of the raw material is performed to determine that the stock is as free from pre-existing discontinuities as is possible to detect. It is important throughout the machining process that *heat/lot number traceability* is maintained. The heat/lot number is assigned by the producing mill each time an alloy is made to indicate the product of one melting in one furnace. Its use is important because, although separate runs may have the same specifications, the resulting material will have slightly different characteristics. Thus, maintaining heat/lot number traceability means that the material can be identified with the alloy, specific heat or lot and the producing mill of origin.

Final Processing. Once inspected, raw material is sawn into oversized pieces and then deburred before being sent to the milling department where *computer numerically controlled* (CNC) mills machine the blank test blocks slightly oversized. These blanks are now ready to be surface-ground to size before final machining in

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the CNC mills. The grinding process ensures that the surface finish required is obtained, and allows for the degree of squareness and parallelism that is essential to high-quality test blocks. From here, the ground blanks are loaded into dedicated fixtures in the CNC mills for profile milling of required angles and radii, hole drilling and machine engraving of degree tick marks and other identification (see Fig. 7). Finished blocks next are hand-polished before undergoing dimensional and visual inspection.

Protective Coatings. Blocks made in corrodible alloys such as steel and aluminum are often protected by either nickel plating or anodizing. It is important to note that these finishes are extremely thin coatings and do not eliminate the need to wipe off and lubricate blocks after use with couplant or water. Upon return from the outside processor for coating, test blocks undergo a final inspection before being packaged and placed in stock for eventual shipment to the customer.

NIST Traceability

All reference standards and test blocks include a *dimensional certification report* stating that the test block meets applicable specifications. Most standards also require certification of final dimensions of notches and/or holes. Not merely close approximations of accuracy, these dimensions must be carefully obtained, reliable, and repeatable dimensions traceable to the National Institute of Standards and Technology (NIST). *NIST traceable* means that an unbroken chain of comparisons to stated reference standards exists, with stated uncertainties that express the range of values that are to be reasonably expected when a measurement is made. Simply put, in order for the claim of NIST traceability to have merit, measuring equipment used to determine actual measurements of the reference standard in production must be calibrated using *masters* that are directly traceable to NIST using metrology procedures that are clearly understood and under control.

Figure 7. Machining an IIW block in a computer numerically controlled mill.

Metrology Grade Masters. Examples of metrology grade gages and inspection tools include gage blocks and laser-engraved glass scales. *Gage blocks* are accurately (±6 millionths of an inch) machined thickness blocks used to calibrate measuring and test equipment such as micrometers and dial indicators. An ideal tool to calibrate video measurement systems, the *glass scale* is a piece of glass with accurately laser-engraved markers at every 0.001 in.

Conclusion

The meticulous attention given to the manufacture of reference standards enables accurate equipment calibration. Reference standards prepared and used in strict accordance with well-designed specifications ensures that inspection data can be reliably matched against inspection norms. **TNT**

Phil Herman Jr. is President and CEO of PH Tool Reference Standards located in Telford, Pennsylvania and is a member of the Philadelphia chapter of ASNT. Manufacturing NDT reference standards and test blocks for industry since 1973, PH Tool has customers in more than 70 countries. To contact the author, email <philjr@phtool.com> or call (888) 553-9245.