Solving UT Weld Inspection System Problems

Effective ultrasonic weld testing begins with a careful examination of your equipment and testing procedures

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Case data have indicated that more than 50 in-process and posterection audits conducted from 1999 to 2001 resulted in a 100% failure rate for compliance with the ultrasonic inspection section requirements of AWS D1.1, *Structural Welding Code — Steel*, and AWS D1.6, *Structural Welding Code — Stainless Steel*. In addition, an intensive review and UT examination testing following the 1994 earthquake in Northridge, Calif., revealed that even the best UT operators with specific written instructions could not acceptably accomplish the goal of indicating sound and unsound welds.

The aim of this article is to give you insight into the problems associated with UT equipment and what is needed to correct them and what variables exist and how to reduce them. This is a first step toward effective ultrasonic weld testing and avoidance of the results listed above.

The problem of ultrasonic inspection equipment calibration control and reference block variables in relation to inspection efficiency was noted in the literature (Ref. 1) of more than 30 years ago. More than 20 years before that, the Krautkramers had devised several systems that work well but are typically ignored today.

For many individuals and NDE service companies, the question is how good are we? Can we stand an audit? Typically, the answer is no. What is wrong with our weld inspection system? Is it the people, equipment, procedures, or records? The answer in 2004 is the same as it was in 1951: all of the above and none of the above.

More than 50 years later the problem of effective UT of welds has not changed, but due to technology, the solutions have become somewhat more complex. Many of the basic problems arise from equipment calibration and reference standards, others from poor code interpretation and lack of specific written instructions.

Equipment inventories are key to controlling variables. Does your company maintain a UT weld inspection equipment inventory? Probably not. You should inventory all UT equipment and test these items for variability related to test results.

Systematic elimination of "bad" equipment in your inventory will help your inspector reduce errors and increase inspection repeatability.

If you don't know which equipment is good or bad, you must test and sort all equipment. Annex D of AWS D1.1 contains the information and procedures you need to ascertain the usability of each instrument-cable-transducer combination in your UT equipment inventory.

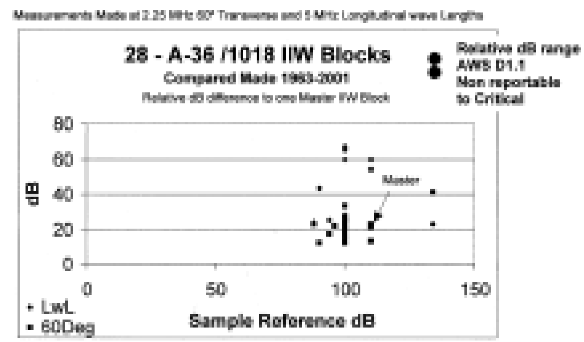

Fig. 1 — Comparison of various IIW blocks.

General UT Test System Problems

Following are some of the potential problems and some of the questions you must ask regarding equipment and practices.

Transducers. Do you maintain a record of transducers and know the effects of transducer sizes (and conditions) on test results?

Cables. A major variable, cables typically wear out faster than transducers or wedges. How do you test them? Visually, electronically, or as part of an ultrasonic weld test system?

UT Instruments. Is annual calibration required by the AWS Code? What's this 40-hour check and what do I do if my UT test system fails it? Should I incorporate this simple test more often in my written practice? What is the most likely cause of failing this test? What is the second most likely cause of failing this test?

Calibration Blocks. What's right and what's wrong? Is a bad test possible if I'm in compliance with the code conditions? (We can assure you that the answer is yes.)

Written Procedures. Doesn't the Code tell us how to do this weld test or how to set up our UT instruments? When are qualified procedures needed? Following are three examples:

◆ Longitudinal wave inspection is NOT permitted without a special procedure.

◆ Distance amplitude corrected (DAC) usage requires an accepted and qualified Special Procedure.

◆ Using smaller transducers than those specified in the code.

The above techniques are typically used every day in weld inspection but without a qualifying procedure. Using them will cause you to fail an audit.

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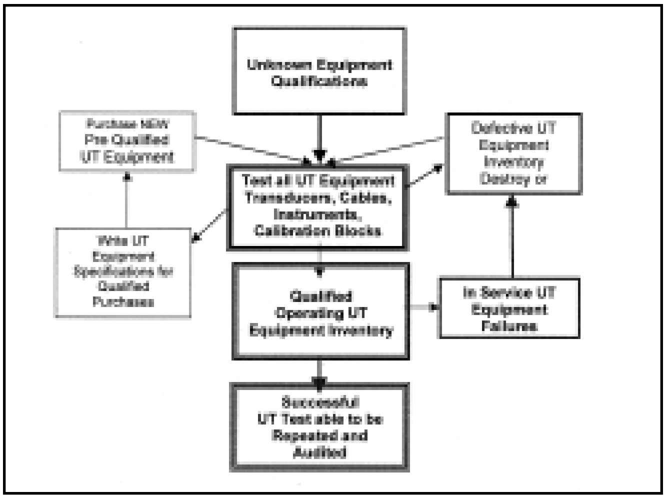

Fig. 2 — Flowchart of equipment testing process.

Testing for UT Equipment Serviceability

Gather, clean, and physically inventory and visually inspect all UT equipment to be used. Destroy the obviously defective items.

1) A good starting point is to select up to three like transducers, cables, and instruments and one calibration block, preferably a NIST traceable IIW block. The National Institute of Standards and Technology (NIST) certification is only on the machine that was used to dimensionally measure the IIW calibration block or maybe just the mechanical reference standard (gauge blocks, optical flat) to set those measurement tools (micrometers, calipers, CMM machines, etc.). There is no U.S. standard for the ultrasonic response from the side-drilled hole in this type of calibration block — Fig. 1.

2) Test the items you have selected using the AWS equipment qualification procedures outlined in AWS D1.1 Section 6.30 as the basis of your calibrations.

Note that for this small group of test equipment, 27 tests may be required (3 × 3 × 3 × 1). These tests must be documented on AWS Form D-8 or its equivalent. Remember to "tune" each combination by varying UT instrument pulser energy waveform damping resistance and receiver bandwidth. Some instruments incorporate a circuit that automatically optimizes these variables every time the instrument is turned on; many others require that the operator perform this optimization. If the instrument is computer based these settings may be stored and recalled for later use. A computer spreadsheet is highly recommended to track your equipment variables.

3) Using this data, you can incorporate the AWS equipment qualification limitations expressed as dB and % linearity to test the remainder of your test equipment inventory.

We recommend that noncompliant equipment be destroyed or repaired (and requalified for use) to prevent its being reintroduced into the usable test equipment inventory on an uncontrolled or emergency basis — Fig. 2.

4) Remember step one? That pesky IIW block, is it accurate? Is it made from plate or a forging, or is it annealed? What alloy is it? Do you use an alternative to that heavy and probably expensive IIW block?

In all probability you use that nice little DSC block described in AWS D1.1. Why? It's light and handy and comes with a NIST equivalent certification. Have you tested its response to your UT system's master IIW block? It is probably four or more decibels "hotter" than the same instrument-cable-transducer-couplant combination response from your IIW block, which means you are oversensitive in your inspection. Your client is removing minor defects that should be ignored. Note that 4 dB is about the range you'd have if you did everything else right from minor to major response (see AWS D1.1 Tables 6.2 and 6.3).

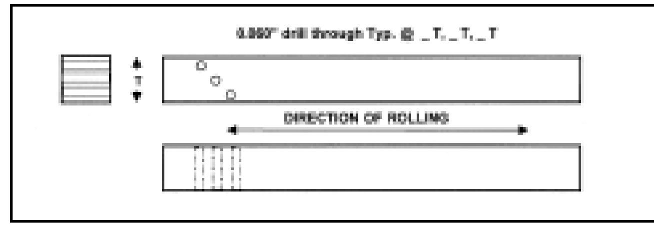

Fig. 3 — Simple alternate reference block. Note: Dimensional tolerances between all surfaces involved in sound referencing or calibrating should be within ±0.005 in. of detailed dimension. The surface finish of all surfaces the sound is applied to or reflected from should not exceed 125 µin., nor should it be smoother than 64 µin. unless the surface to be inspected from is smoother. All holes should have a smooth internal finish (like the surfaces) and should be drilled 90 deg to the material surface. Degree lines and indentation markings should be indented into the material surface so that permanent orientation can be maintained. Using this type block with or without a DAC curve will allow a direct comparison of defect reflectors and the reflections from known side-drilled holes.

The DSC block has a flat-bottomed slot reference reflector that intersects the sound beam differently than does the side-drilled hole of the IIW block. These blocks are different in both amplitude and frequency spectrum responses. You might check and see if there is a specification for the bottom of the DSC slot edges and surface finish. The IIW block hole has an implied surface finish of 125 rms. Your blocks are probably bright nickel plated; this is not in the AWS specifications. Don't worry, that won't matter too much. Your DSC and IIW block calibration reflectors probably have couplant, couplant residue, oil, grease, or rust that change the UT by dropping optimal response decibels for reference calibration. This means you will probably turn up the gain level for the reference calibration setting, resulting in an overly sensitive inspection.

Floss your DSC slot before each use. Clean the IIW block side-drilled holes frequently. Do not ream out these reflectors when rusty. Instead, retire these blocks from service: saw them up or otherwise destroy them.

Figure 3 shows a simple alternate UT calibration block. Use this UT calibration block to program your digital UT instruments.

How Should You Check and Implement Changes?

The following are all good internal tools to use to avoid audit failure.

- Internal audits
- Performance testing
- Random field review
- Nonconformance reports
- Corrective actions. Document these for review of your program's effectiveness.

It is important to define problems as system or operator related because different solutions are required for each. Following are some examples of different types of operator and system problems.

Operator/Training Related

- Air bubbles under wedges — gain too high

- ◆ Bad calibration — gain too low
- ◆ Eight-hour transducer wedge checks — not documented
- ◆ Forty-hour system checks — not documented
- ◆ Technique wrong or not qualified.

System/Training/Level III Related

- ◆ Bad cables — gain too high
- ◆ Bad calibration — gain too low
- ◆ Instrument out of calibration
- ◆ Eight-hour transducer wedge checks — not documented
- ◆ Forty-hour system checks — not documented.
- ◆ Operator not qualified/personnel certification out of date
- ◆ Technique wrong or not qualified
- ◆ Couplant not suited to produce required results.

Qualification and demonstration of the ultrasonic test procedure are an important part of implementing uniform ultrasonic testing. Today's computer-based instruments are capable of storing complex ultrasonic test setups and allow rapid switching from one setup to another. The ability to directly store an indication for later analysis along with all test parameters is a bonus.

The "qualification of ultrasonic test procedure" document should contain the following:

- ◆ Scope of this ultrasonic test technique
- ◆ Applicable code or contract (description of ultrasonic test methodology to be qualified)
- ◆ List of the equipment used including the instrument, cable, transducer, and couplant
- ◆ Applicable code or contractual reference
- ◆ Reference block(s) used
- ◆ Calibration block(s) used
- ◆ Description of ultrasonic test to be qualified
- ◆ Test results
- ◆ Limitation of test
- ◆ NDT Level II-UT demonstrating the test and test date
- ◆ NDT Level III-UT approving the test and approval date
- ◆ Authorized inspector acceptance (yes or no) and the acceptance date.

Documenting your ultrasonic test reports is a crucial key to reviewing system performance.

All UT reports should include the following as a minimum (see AWS Form D-11):

- ◆ Client's name
- ◆ Examination date
- ◆ Specification and/or code and/or procedure number
- ◆ Weld and/or material identification
- ◆ Drawing number, if available
- ◆ UT equipment, make, model, and serial number
- ◆ Couplant manufacturer and type
- ◆ Transducer make, model, size, frequency, angle, and serial number
- ◆ Surface condition and Apx roughness
- ◆ Surface where testing was performed from
- ◆ Calibration block, make, serial number, and type
- ◆ Results of examination
- ◆ Inspector's name and certification level.

Careful review and use of these data will allow you to define problems and improve your overall ultrasonic testing system. ❖

References

1. McGaughey, W. C. 1972. Ultrasonic examination of welds: Comparison of ASME and AWS procedures. *Materials Evaluation* 30(2): 44–48.