Ultrasonic technician performance test for boiler tube thickness measurement

Scope

This procedure has been developed by a TAPPI Task Group to offer a basis for evaluating the skills of technicians who measure the thickness of boiler tubes from the external surface using manual instruments. Use of this procedure is prudent when surveying the thickness of recovery boiler tubes, where high reliability is important to avoid a potential smelt-water reaction and explosion from a water leak. The evaluation includes a background interview of each technician, as well as an operative test to objectively determine the technician's ability to accurately calibrate an ultrasonic thickness unit and measure the thickness of boiler tubes in a test panel. This procedure is written for bare carbon steel tubes but can be applied to other materials (e.g. chromized, composite, weld overlaid) if representative test panels are prepared. Technician skills for using specialized ultrasonic test equipment, such as semi-automated scanners, could be addressed by appropriate modifications to this procedure.

Safety precautions

This performance test is designed for individuals expected to make measurements in a boiler. This work requires the following:

- Confined space entry procedures, including maintaining air quality in the boiler spaces, following lockout/tagout procedures, and protection from falling material
- Use of required personal protective equipment
- Access platforms and scaffolding that conforms to government and industry standards
- Functionality and proper use of electrical safety devices

Personnel

The personnel qualification and certification program of the contracting organization shall be in accordance with ASNT's SNT-TC-1A (latest edition) or CAN/CGSB's 48.9712. It is recommended that at a minimum, all ultrasonic thickness technicians be experienced and have training equivalent to that of an ASNT Level I ultrasonic technician. In addition, Level II or III technicians shall be on the job site to instruct, supervise, and verify appropriate performance by the Level I technicians. In addition to Level I certification, experience in actual boiler tube thickness measurement is important.
It is recommended that all ultrasonic thickness technicians be qualified by the mill through this testing procedure. The test should be conducted by a mill representative or third party knowledgeable of ultrasonic testing. Qualification should be effective for one year providing the technician maintains employment with the same contractor and performs satisfactorily in the field. The mill should retest any technician whose performance is questionable, and revoke his/her qualification if warranted by either unacceptable test or field performance.

Fabrication of test panels

It is recommended that the test panels used in the evaluation of the technician be fabricated from tubes of comparable thickness, diameter, and configuration as those in the boiler to be surveyed. In some cases, it may be more practical to adopt a standard membrane test panel configuration. The standard panel should be of membrane-wall construction if it is to be used for any membrane-wall boilers. Details of test panels are shown in Figs. 1-3.

Fig. 1. Boiler tube thickness test panel for membrane wall construction.
Fig. 2. Boiler tube thickness test panel for tangent tube construction.

Each panel should consist of eight tube sections approximately 63.5 mm (2.5 in.) long.

It is often convenient to make the test panels from tube sections removed from service. Used tubes will have a natural wear pattern, as well as the same sound entry surface as those in the boiler. Extremely pitted tubes are unlikely to provide a representative surface.

The tubes should be sectioned to gain access to the interior surface. When using membrane panel tubes, the tubes should be cut flush with the cold side of the membrane (see Fig. 1). When fabricating a panel to simulate a tangent tube boiler, loose tubes may be used (see Fig. 2).

The tube panel should be deburred and sandblasted after cutting to size. The interior surface of the tubes should then be ground to varying degrees, to give a wide deviation in thicknesses throughout the panel. The minimum thickness should not be less than 1.25 mm (0.050 in.). This thickness approaches the lower measurement limit of the typical transducer used to perform surveys.

Fig. 3. Suggested machined defects for boiler tube thickness test panels.

In addition to thinning the tubes by grinding or machining, a minimum of two defects should be machined into the test area of the test panel (see Fig. 3). One defect should be a simulated lamination, produced by milling a 10 mm × 40 mm (0.375 × 1.5 in.) longitudinal slot into the tube, from the interior surface. This simulated lamination...
must be on the interior surface and have a flat bottom. A second defect, simulating localized caustic gouging, should be produced by milling a 1 in. long, longitudinal slot in the tube, using a 3.18-mm (0.125 in.) diameter, rounded cutter. The depths of these slots should be approximately one half the tube wall thickness.

Since thickness measurements are taken on the side of the tube nearest the membrane, defects with wall thickness reductions should be included near the membrane (or side of the tube for tangent tubes) to ensure the technician can find internal defects.

The interior surface of the tube panel should be concealed, for example by mounting within a wooden frame, to hide the defects and thinned areas.

The test area should consist of a 25-mm (1 in.) wide band in the center of the tube section. The band should be defined by painting the extremities adjacent to the inspection area. The band should be equally divided into left, center, and right sectors. These sectors should also be defined by painting or vibratory etching the dividing points on each tube. The tubes should be numbered left to right as numbers 1 through 8. Each tube panel also should have a permanent serial number attached.

The completed test panel should be ultrasonically examined by a number of ultrasonic technicians to establish a consensus-based thickness key sheet. This process has been found to be advantageous over physical measurements of the tubes.

Pretest preparation

Mill responsibilities

The technician qualification test requirements should be stipulated in all bid and contract specifications. A copy of the mill's qualification test procedure should be provided in advance to the contractor.

A mill or third party representative should be responsible for administering the qualification test to each technician before that technician begins work in the boiler. It is recommended that the test administrator be a qualified ultrasonic technician, or at least knowledgeable in the testing method. The administrator should not have any business relationship with the technician’s employer.

The ultrasonic technician interview and practical examination should be conducted at a convenient indoor location, and in a manner that is not disruptive to the boiler inspection. The location should not be distractive to the technician who will be testing under time constraints. The maximum number of technicians who can be tested simultaneously will be controlled by the number of test panels, but no more than three technicians should be tested simultaneously by one individual. The total time allotted for the interview and performance test should be approximately 25 minutes.

Required materials provided by the contractor

One or more ultrasonic instruments of the type to be used in the boiler survey will be available to the technicians being tested. Instruments that display the ultrasonic signal trace (A-scan) should have documentation showing current horizontal and vertical linearity calibration in accordance with ASTM E317. ASME Section V, stipulates ultrasonic units should be calibrated quarterly, and after any electrical repairs are performed on the unit. If there is any question about the calibration of the unit, the contractor should be prepared to verify linearity calibration at the job site.

It should be noted that units with a digital display and no A-scan capability are unsuitable for evaluation of tubes with flaws, and are not recommended for critical boiler tube thickness survey applications.

The transducer used in the test should be the same as that used in the actual boiler tube thickness inspection. Recommended transducers used in boiler thickness inspections are flat-faced 5-MHz, 6.35-mm (1/4 in.) diameter dual-element, and 8-MHz (Krautkramer FH2E, or equivalent), sensing element 6.35 mm (1/4 in.) in retainer casing for a total diameter of 9.53 mm (3/8 in.). Increasing frequency generally improves sensitivity and resolution, but it may also increase signal loss due to surface roughness. Increasing the diameter generally makes the transducer harder to manipulate and decreases the percentage of surface area in contact with the tube surface, causing a loss in signal amplitude. However, larger diameter transducers with concave curved faces can be used if the curve matches the tube diameter.

The contractor should provide the same water-soluble ultrasonic couplant for testing, as to be used for the boiler survey.

The contractor should provide a single carbon steel reference standard for the calibration phase of the test. For composite tubes or weld overlay tubes, calibration standards shall be made using materials of similar construction.
The calibration standard should be machined from tubing with the same ultrasonic characteristics as boiler tubing. The standard should have the same or a very similar curvature as the boiler tubes to be inspected. The standard should have precisely machined steps encompassing a thickness range from 1.25 to 2.50 mm (0.050 to 0.100 in.) at the thinnest step, and a final step having a thickness equal or greater than the nominal thickness of the boiler tubes to be surveyed. Each step should be within plus or minus 0.05 mm (0.002 in.) of the thickness measured with a micrometer.

**Required materials provided by the mill**

- The mill should develop a standardized technician qualification form similar to Appendix A.
- The mill should develop a standardized interview form similar to Appendix B.
- The mill should have two or more fabricated test panels as described above.
- A timer, clock, or stop watch should be available to monitor each test.

**Administering the test**

1. The ultrasonic technician should first complete the interview form (Appendix A).
2. Then the performance test should be administered as follows.
   (a) The ultrasonic instrument should be warmed up, then turned off and adjusted out of calibration. Any stored programs that automatically calibrate the instrument should be deactivated.
   (b) The test panel should be placed flat on the table top, with the tube face up, permitting free access to the test area. Alternatively, the test panel may be placed in the vertical position on a fixture to more closely simulate the actual position of the boiler tubes.
3. Following is an example of verbal instructions given before the test:

   “The purpose of this examination is to test your ability to calibrate and use the ultrasonic instrument. This qualification is required of all technicians prior to working in the mill's boiler. If successfully completed, you will be qualified to perform ultrasonic thickness surveys in the mill's boilers for one year, after which you must requalify. It is the mill's prerogative to ask you to re-qualify at its discretion. A copy of your qualification will be maintained by the mill.

   “In the first part of this examination, you should calibrate the ultrasonic instrument in accordance with your employer’s procedure. A maximum of five minutes is allowed for this step. Following calibration, you are to measure the thickness of all of the tubes on the test panel. Proceed from the left tube, number 1, to the right tube, number 8. Scan the full area within the painted or etched lines, and report the thinnest reading from the left, center, and right sectors. If your unit has recording capabilities, data for each tube sector should be saved in the unit. Report the minimum thickness readings as accurately as you can. Report in the comments section any internal abnormalities that you observe, such as laminations, grooves, and pitting. Report internal discontinuities only, not test surface corrosion or pitting. Do not move the panel or examine the back side. You will have fifteen minutes to complete the thickness measurement portion of the test, and if you are not finished by then, you will be allowed an additional grace time of five minutes.

   “Keep in mind the following recommendations; they will enhance your score:
   “You have slightly over one-half minute to scan each sector, so move rapidly. Don't get hung-up on an area. If you are having trouble with an area, move on to the next sector. When the panel is done, use the remaining time to examine the trouble area.
   “I will advise you of the time remaining after ten to twelve minutes. If you have not completed the panel after fifteen minutes, you can use up to five minutes of the grace period to complete the test. Your score will be penalized slightly for this, but it is essential that you complete the test.
   “There is no bonus for finishing in less than 15 minutes, so if you finish early you may want to go back and recheck your work.
   “You will not be allowed to take away any record of your test data, other than your final score.
   “Do you have any questions? If not, you can now begin the calibration.”

4. The examiner should verify that the technician has completed the qualification form (Appendix B) and noted the correct panel serial number on the form. Calibration of the ultrasonic unit should be verified as accurate and completed within the five-minute time frame. Also, the actual time required to complete the thickness test portion of the examination should be recorded on the qualification form.
Scoring the performance test and re-testing interview

The results should be scored as soon as possible following the examination. The score should be calculated using the following format, and an example of testing results is also shown in Appendix C:

NUMBER OF READINGS: ("Key" is correct thickness)

≤0.127 mm (0.005 in) above or below Key: ____ × –1 = ____

> 0.127 to 0.254 mm (0.005-0.010 in.) above or below Key: ____ × 1 = ____

> 0.254 to 0.381 mm (0.010-0.015 in.) above or below Key: ____ × 3 = ____

> 0.381 mm (0.015 in.) above or below Key: ____ × 5 = ____

Correctly Identified As Defects: ____ × –2 = ____

TIME FACTOR:

Minutes Over 15: ____ × 1 = ________

SCORE = ________

Following is a suggestion for judging the performance of the technician:

• The technician should be qualified for one year if his/her score is 15 or below.
• Should be required to retest on a different test panel if his/her score is 16 to 30.
• At the mill's risk, can be qualified to work on the current survey only, if the retest score is 16 to 30.
• Should not be qualified to take ultrasonic readings in the boiler if his/her original test and retest score is above 30.

Retesting should be administered after an interview and review of the performance test results with the examiner, the contractor's supervisor and the technician. The purpose of the interview is to assure the technician has sufficient prior training and experience, and to pinpoint the specific cause of his/her failing grade (e.g., faulty test equipment, test anxiety or did not understand the instructions.)

Technicians who fail the retest should be disqualified from performing ultrasonic survey work at the mill until she/he has received additional formal training in ultrasonic testing.

After the test is scored the technician can be given a report of his or her score. However, no records of test data obtained by the technician should be taken away by the technician after the test. The technician should be required to delete any “saved” data on the unit.

Disposition of qualification forms

For multi-facility corporations, it may be convenient for a central department to be assigned to maintain the test panels and a file of technician test results (pass or fail). A current listing of qualified technicians should be made available to all of the corporation's facilities to eliminate duplication of testing for those technicians who may work at more than one mill during the tenure of his/her qualification. This information also may become useful for the statistical evaluation of a contractor's overall performance. The information also may detect a flawed test panel or key sheet, if an inordinate number of technicians fail the test on one panel, but consistently do well when retested on other panels.

The test results should be discussed with the supervision of the contracting NDT company. However, copies of the test results should not be distributed. In addition, with the exception of the NDT company, there should be no discussion or distribution of test results outside the corporation.
Keywords

Corrosion, Inspection, Nondestructive tests, Recovery boilers, Ultrasonic tests, Qualification

Additional information

Effective date of issue: October 16, 2018
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Cody Stevens, Corrosion Probe, Inc.
Jimmy West, International Paper Co.

References

5. “Ultrasonic testing (UT) for tube thickness in black liquor recovery boilers.” TAPPI TIP 0402-18. Available from TAPPI, P.O. Box 105113, Atlanta, GA 30348-5113.
### NDT TECHNICIAN QUALIFICATION FOR BOILER TUBE THICKNESS TESTING

Technician Name: ____________________________ Date: ____________ Time of Day: ______
Employed by: ____________________________ Test or Retest: ____________________________
UT Level: __________ (A minimum of Level I is required)
Qualification for ______________ A-scan, ______________ Digital, ______________ Combination
Test Instrument (Make, Model): ____________________________
Search Unit: __________ MHz Diam: ________________ Flat or Concave ____________________________
Test Panel No. ____________________________

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<th>Tube No.</th>
<th>Thickness, Inches</th>
<th>Remarks</th>
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Additional Comments: ___________________________________________________________

Technician Signature: ___________________________________________________________

(To be Completed by Interviewer)

Test Conducted at (Location) ____________________________ Time Required to Complete Test ____________________________
Type of Instrument: ______________ A-scan, ______________ Digital, ______________ Combination
Test Score: ______

The Technician has performed the test in accordance with ______________, and has ______ passed/____ failed to pass the requirements.

Organization: ________________________________________________________________

By_________________________________________ Date ____________________________
Appendix B.

**NDT TECHNICIAN INTERVIEW**

The intent of the technician interview is to assist both the mill/plant engineer and the purchasing agent in the evaluation of NDT companies. The interview shall be conducted on the job site and in a manner that is not disruptive to the inspection. Interview forms can be made available to the NDT company so that they can be filled out ahead of time.

1. Technician Name:

2. Present Employer:

3. Length of Time Employed by Present NDT company: _________ Years ________ Months

4. Length of Time Employed by Previous NDT company: _________ Years ________ Months

5. NDT CERTIFICATIONS PRESENTLY HELD IN ACCORDANCE WITH ASNT RECOMMENDED PRACTICE (SNT-TC-1A) or CAN/CGSB:

<table>
<thead>
<tr>
<th>Discipline</th>
<th>Level</th>
<th>Date of Certification</th>
<th>Approximate Number of Experience Months</th>
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6. NDT instrument being used (type and calibration due date):

7. Additional Comments:

8. Technician's Signature: ___________________________ Date: _______

9. Interviewer's Signature: ___________________________ Date: _______
Appendix C.

EXAMPLE OF SCORING A TEST

This example assumes the technician took the ultrasonic performance examination using a machine reading in “mils” (1/1000 inch). There were 24 test sites on the eight tubes, and two internal “defect” locations. The technician completed the test within the allotted 15 minutes. After evaluation of the test results, the number of his recorded values varying from the “Key” thickness and the number of defects found are summarized below:

\[
\begin{align*}
\leq 0.005 \text{ in. above or below Key} &= 11. \text{ Therefore: } 11 \times (-1) = -11 \\
> 0.005-0.010 \text{ in. above or below Key} &= 8. \text{ Therefore: } 8 \times 1 = 8 \\
> 0.010-0.015 \text{ in. above or below Key} &= 4. \text{ Therefore: } 4 \times 3 = 12 \\
> 0.015 \text{ in. above or below Key} &= 1. \text{ Therefore: } 1 \times 5 = 5 \\
\text{Correctly Identified As Defects} &= 1. \text{ Therefore: } 1 \times (-2) = -2 \\
\text{TIME FACTOR: Zero Minutes Over 15.} \text{ Therefore: } 0 \times 1 = 0
\end{align*}
\]

The Score equals the sum: \[\text{SCORE} = 12\]

The technician’s score met the requirements of 15 or below, so he or she passes, and should be qualified to work in the mill’s boilers for a period of one year. Had the score exceeded 15, the technician would have retested immediately in an attempt to qualify. If the second test was within a score of 16 to 30, the technician would have qualified for the current boiler survey, but would need to retest for any future boiler surveys.