



Standard Practice for Acoustic Emission Examination of Cast Iron Yankee and Steam Heated Paper Dryers¹

This standard is issued under the fixed designation E2598/E2598M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This practice provides guidelines for carrying out acoustic emission (AE) examinations of Yankee and Steam Heated Paper Dryers (SHPD) of the type to make tissue, paper, and paperboard products.

1.2 This practice requires pressurization to levels used during normal operation. The pressurization medium may be high temperature steam, air, or gas. The dryer is also subjected to significant stresses during the heating up and cooling down periods of operation. Acoustic Emission data may be collected during these time periods but this testing is beyond the scope of this document.

1.3 The AE measurements are used to detect, as well as, localize emission sources. Other methods of nondestructive testing (NDT) may be used to further evaluate the significance of acoustic emission sources.

1.4 *Units*—The values stated in either SI units or inch-pound units are to be regarded as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standards.

1.5 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 ASTM Standards:²

E278/A278M Specification for Gray Iron Castings for

Pressure-Containing Parts for Temperatures Up to 650°F (350°C)

E543 Specification for Agencies Performing Nondestructive Testing

E569 Practice for Acoustic Emission Monitoring of Structures During Controlled Stimulation

E650 Guide for Mounting Piezoelectric Acoustic Emission Sensors

E976 Guide for Determining the Reproducibility of Acoustic Emission Sensor Response

E1316 Terminology for Nondestructive Examinations

E2374 Guide for Acoustic Emission System Performance Verification

2.2 ASNT Standards:³

SNT-TC-1A Recommended Practice for Nondestructive Testing Personnel

ANSI/ASNT CP-189 Standard for Qualification and Certification of Nondestructive Testing Personnel

3. Terminology

3.1 *Definitions*—See Terminology **E1316** for general terminology applicable to this practice.

4. Summary of Practice

4.1 Each mounted sensor, on the cast iron vessel, monitors while the vessel is stationary and pressurized to normal operating pressure. The vessel may be at ambient, or operating 120°C-230°C [250°F-450°F] temperature.

4.2 Each mounted AE sensor is connected to an acoustic emission signal processor. After a monitoring period (up to 10 minutes) and pre-examination sensor sensitivity checks, pressurization can begin.

4.3 Location

4.3.1 *Zone Location*—Each channel shall have the same system examination threshold. A simulated AE source generated anywhere on the vessel shall be detected by at least one sensor.

¹ This practice is under the jurisdiction of ASTM Committee **E07** on Nondestructive Testing and is the direct responsibility of Subcommittee **E07.04** on Acoustic Emission Method.

Current edition approved Jan. 1, 2013. Published January 2013. Originally approved in 2007. Last previous edition approved in 2007 as E2598 - 07. DOI: 10.1520/E2598_E2598-13.

² For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

³ Available from American Society for Nondestructive Testing (ASNT), P.O. Box 28518, 1711 Arlingate Ln., Columbus, OH 43228-0518, <http://www.asnt.org>.

*A Summary of Changes section appears at the end of this standard



4.3.2 *Source Location*—All location data resulting from analysis shall be presented in a manner consistent with the previously established calibration accuracy. The simulated AE source generated in each structure mounted sensor array shall be detected by the minimum number of sensors required to locate the source within $\pm 5\%$ of sensor spacing.

4.4 Due to the potential for gasketed interfaces (at the heads/manway), multiple metal combinations (metalspray, cast steel-cast iron combinations), high vessel temperature, or random variations in the material velocity of cast iron, accurate source location ($\pm 5\%$ sensor spacing) may not always be possible.

4.5 Once the AE sensor source is localized, further evaluation is begun by observing a “history” of events involving the area [Head tilt (corrosion induced head strain), leak repair, objects through the nip (working contact with another roll), etc.]. This may give further direction to the selection of the NDE method to use for follow-up examination of the AE indication area.

4.6 Secondary examination establishes presence of flaws and measures flaw dimensions.

4.7 Cast iron Yankee dryers can be up to 6.7 m [22 ft] in diameter, 7.3 m [24 ft] long, and weigh 90,000 Kg [200,000 lb], or more. Vessel thickness measurements are available from the paper/tissue machine operator. Cast iron is a brittle metal and has no specific yield point. Yankee dryers must maintain specific dimensional tolerances. When a pressurized Yankee or steam heated paper dryer (SHPD) remains stationary, it fills with condensate at a rapid rate. In an hour, a steam pressurized Yankee or SHPD can fill half way with condensate, doubling the weight on the frame, and the floor. Some Yankee owners have corporate requirements that a cast iron Yankee dryer remain stationary for $\frac{1}{2}$ hour, then rotation is required. Permission is required, if the Yankee is to remain stationary for more time. This issue should be discussed with the responsible person prior to the examination.

4.8 Yankee dryers operate under a heated hood. The hood is in close proximity to the Yankee shell and allows only inches of clearance for the top half of the vessel.

4.9 Cast iron steam heated paper machine dryers are 1.8 m [6 ft] in diameter, or more, and may be 9 m [30 ft] long.

4.10 Gray cast iron experiences a continuing reduction in elastic modulus as it is stressed to increasing higher levels. It is prudent not to stress grey cast iron material beyond its operating stress level.

4.11 Flaws to be found are the same as those in any cast and machined product. Attempts have been made to characterize strength properties of cast irons in compact tension tests. In a TAPPI sponsored laboratory study, two out of three cast iron compact tension specimens experienced unplanned failures. From that experience it was cautioned that “cracks initiated and grew faster than expected resulting in brittle fracture before the process could be halted. The failure of these two coupons demonstrated the rate in which cracks can grow in these materials and the material’s inability to stop a crack once it

begins to grow. In each case, crack advance was extremely rapid and without warning.”⁴

4.12 *Maximum Examination Pressure*—Maximum Allowable Working Pressure for cast iron vessels is set based on ASME (Section VIII) pressure calculations based on thickness, radius, and material strength values, and will not exceed 11 bar [160 psi] and 230°C [450°F] (A278/A278M). When vessels are pressurized, anomalies produce emission at pressures less than normal fill pressure. Historically, if there is damage in a cast iron pressure boundary, AE activity will begin at load/stress levels less than 50 % of operating. Defects as small as 3 mm [$\frac{1}{8}$ in.] have been found using AE, during steam pressurization to operating pressure.

4.13 Pressure increments should not exceed 350 millibar/minute [5 psi/minute]. If pressurization medium is to be steam, the Yankee should have been through the warm-up process.

4.14 Yankee dryers may receive a subsequent examination, if necessary, after the Yankee is rotated to remove any condensate present.

4.15 *Pressurization Schedule*—Pressurization should proceed at rates that allow achieving maximum examination pressure within a 30 minute period. During pressurization, pressure holds are not necessary; however, they may be useful for reasons other than measurement of AE. Pressure hold upon achieving maximum examination pressure may be up to 30 minutes.

4.16 Excess background noise may distort AE data or render the AE measurements useless. Users must be aware of the following common sources of background noise: (measurable filling or flow noise); mechanical contact with the vessel by objects; electromagnetic interference (EMI) from cranes, and radio frequency interference (RFI) from nearby broadcasting facilities and from other sources; leaks at pipe or hose connections, or rain drops. This practice should not be used if background noise cannot be eliminated or controlled.

4.17 Other nondestructive test methods may be used to evaluate the significance of AE sources. Magnetic particle, ultrasonic, and radiographic examinations have been used to establish circumferential position, depth, and dimensions of flaws that produce AE. Procedures for using other NDT methods are beyond the scope of this practice.

5. Significance and Use

5.1 Cast iron Yankee dryers can be up to 6.7 m [22 ft] in diameter, 7.3 m [24 ft] long, and weigh 91,000 Kg [100 tons], or more (refer to Fig. 1). Vessel thickness measurements are available from the paper/tissue machine operator. Cast iron is a brittle metal and has no specific yield point. Yankee dryers must maintain specific dimensional tolerances. When a pressurized Yankee or steam heated paper dryer (SHPD) remains stationary, it fills with condensate at a rapid rate. In an hour, a steam pressurized Yankee or SHPD can fill half way with condensate, doubling the weight on the frame, and the floor.

⁴ Alleveto, C., and Williams D., Acoustic Emission Evaluation of Yankee Dryer Shell Material, 1991 TAPPI Engineering Conference Proceedings, pages 475-480.



FIG. 1 Yankee Dryer Drum

Some Yankee owners have corporate requirements that a cast iron Yankee dryer remain stationary for $\frac{1}{2}$ hour, then rotation is required. Permission is required, if the Yankee is to remain stationary for more time. This issue should be discussed with the responsible person prior to the examination.

5.2 Yankee dryers operate under a heated hood. The hood is in close proximity to the Yankee shell and allows only inches of clearance for the top half of the vessel.

5.3 Cast iron steam heated paper machine dryers are 2 m [6 ft] in diameter, or more, and may be 9 m [30 ft] long.

5.4 Grey cast iron experiences a continuing reduction in elastic modulus as it is stressed to increasing higher levels. It is prudent not to stress grey cast iron material beyond its operating stress level.

5.5 Flaws to be found are the same as those in any cast and machined product. Attempts have been made to characterize strength properties of cast irons in compact tension tests. In a TAPPI sponsored laboratory study, two out of three cast iron compact tension specimens experienced unplanned failures. From that experience it was cautioned that cracks initiated and grew faster than expected resulting in brittle fracture before the process could be halted. The failure of these two coupons demonstrated the rate in which cracks can grow in these materials and the material's inability to stop a crack once it begins to grow. In each case, crack advance was extremely rapid and without warning. (See [Note 1](#).)

NOTE 1—Alleveto, C., and Williams D., Acoustic Emission Evaluation of Yankee Dryer Shell Material, 1991 TAPPI Engineering Conference Proceedings, pages 475-480.

5.6 *Maximum Examination Pressure*—Maximum Allowable Working Pressure for cast iron vessels is set based on ASME (Section VIII) pressure calculations based on thickness, radius, and material strength values, and will not exceed 10 bar [160 psi] and 230°C [450°F] (ASTM A278). When vessels are

pressurized, anomalies produce emission at pressures less than normal fill pressure. Historically, if there is damage in a cast iron pressure boundary, AE activity will begin at load/stress levels less than 50 % of operating. Defects as small as 3 mm [$\frac{1}{8}$ in.] have been found using AE, during steam pressurization to operating pressure.

5.7 Pressure increments should not exceed 0.35 bar [5 psi] per minute. If pressurization medium is to be steam, the Yankee should have been through the warm-up process.

5.8 Yankee dryers may receive a subsequent examination, if necessary, after the Yankee is rotated to remove any condensate present.

5.9 *Pressurization Schedule*—Pressurization should proceed at rates that allow achieving maximum examination pressure within a 30 minute period. During pressurization, pressure holds are not necessary; however, they may be useful for reasons other than measurement of AE. Pressure hold upon achieving maximum examination pressure may be up to 30 minutes.

5.10 Excess background noise may distort AE data or render the AE measurements useless. Users must be aware of the following common sources of background noise: (measurable flow noise); mechanical contact with the vessel by objects; electromagnetic interference (EMI) from cranes, and radio frequency interference (RFI) from nearby broadcasting facilities and from other sources; leaks at pipe or hose connections, or rain drops. This practice should not be used if background noise cannot be eliminated or controlled.

5.11 Other Non-destructive test methods may be used to evaluate the significance of AE sources. Magnetic particle, ultrasonic, and radiographic examinations have been used to establish circumferential position, depth, and dimensions of flaws that produce AE. Procedures for using other NDT methods are beyond the scope of this practice.

6. Basis of Application

6.1 The following items are subject to contractual agreement between the parties using or referencing this standard.

6.2 Personnel Qualification

6.2.1 If specified in the contractual agreement, personnel performing examinations to this standard shall be qualified in accordance with a nationally or internationally recognized NDT personnel qualification practice or standard such as ANSI/ASNT-CP-189, SNT-TC-1A, NAS-410, or a similar document and certified by the employer or certifying agency, as applicable. The practice or standard used and its applicable revision shall be identified in the contractual agreement between the using parties.

6.3 *Qualification of Nondestructive Agencies*—If specified in the contractual agreement, NDT agencies shall be qualified and evaluated as described in Practice E543. The applicable edition of Practice E543 shall be specified in the contractual agreement.

6.4 *Procedures and Techniques*—The procedures and techniques to be utilized shall be as specified in the contractual agreement.

6.5 *Extent of Examination*—The extent of examination includes the entire pressure vessel unless otherwise specified.

6.6 *Reporting Criteria/AE Evaluation Criteria*—Examination results will be reported and compared with AE evaluation criteria. Since acceptance criteria (for example, reference radiographs) are not specified in this practice, they shall be specified in the contractual agreement.

7. Apparatus

7.1 Essential features of the apparatus required for this practice are provided in Fig. 2. Full specifications are in Annex A1.

7.2 Couplant must be used to acoustically connect sensors to the vessel surface. Adhesives that have acceptable acoustic properties, and adhesives used in combination with traditional couplants, are acceptable.

7.3 Sensors should be mounted in accordance with Fig. 3 for location analysis purposes. Sensors may be held in place with magnets, adhesive tape, or other mechanical means. High temperature waveguides may be used but they cannot be welded to the shell of the drum. The attachment method to be used should be reviewed with the dryer owner prior to use.

7.4 The AE sensors are used to detect stress waves produced by cast iron anomalies. Sensors must be held in contact with the vessel wall to ensure adequate acoustic coupling (see E650). Sensors shall be capable of operating in the examination environment (Some operating environments may be up to 230°C [450°F]).

7.5 The preamplifier should be kept as far as possible away from the heat. If a separate preamplifier is used, cable length, between sensor and preamp, must not exceed 2 m [6 ft].

7.6 Power/signal cable length, (that is, the maximum cable length between the preamplifier and processor) should not exceed the manufacturers specification for the device.

7.7 Signal processors are computerized instruments with independent channels that filter, measure, and convert analog information into digital form for display and permanent storage. A signal processor must have sufficient speed and capacity to independently process data from all sensors simultaneously. The signal processor should provide capability to digitally filter data for replay.

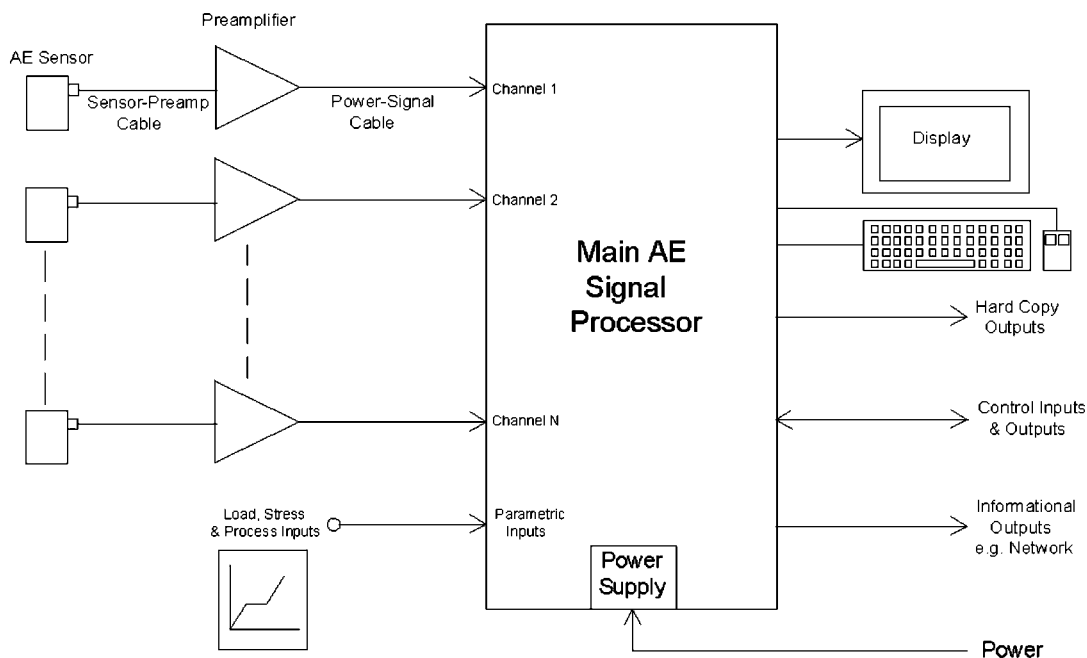


FIG. 2 AE System Block Diagram with Essential Features

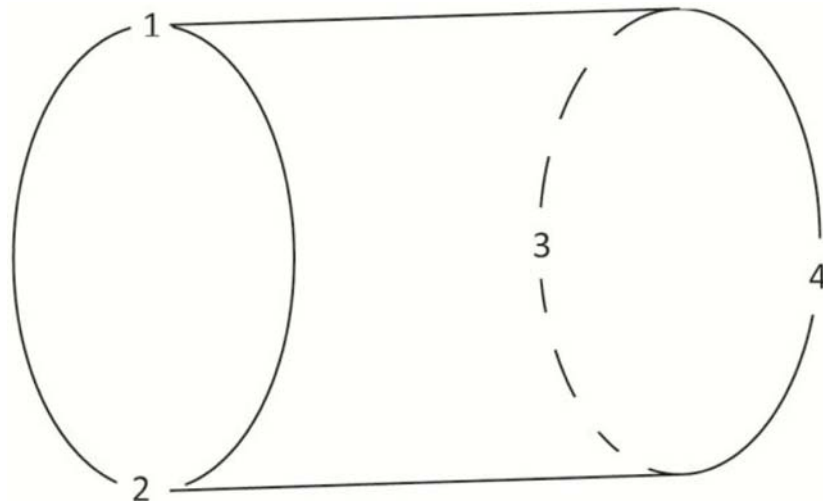


FIG. 3 Preferred AE Sensor Positions on Yankee Heads, with Channel Number

7.7.1 A video monitor should display processed examination data in various formats. Display format may be selected by the equipment operator.

7.7.2 A digital data storage device, such as a hard disk drive, CD, DVD, flash drive or other electronic storage media may be used to provide data for replay or for archives.

7.7.3 Hard copy capability should be available from a printer or equivalent device.

8. Safety Precautions

8.1 As in any pressurization of metal vessels, ambient temperature should not be below the ductile-brittle transition temperature of the pressure vessel construction material.

8.2 This document does not address personnel safety concerns when examining high temperature items.

9. Calibration and Verification

9.1 Annual calibration and verification of AE sensors, preamplifiers (if applicable), signal processor, and AE electronic waveform generator (or simulator) should be performed. Equipment should be adjusted so that it conforms to equipment manufacturer's specifications. Instruments used for calibrations must have current accuracy certification that is traceable to the National Institute for Standards and Technology (NIST).

9.2 Routine electronic evaluations must be performed any time there is concern about signal processor performance. An AE electronic waveform generator or simulator, should be used in making evaluations. Each signal processor channel must respond with peak amplitude reading within ± 2 dB of the electronic waveform generator output.

9.3 A system performance verification must be conducted immediately before, and immediately after, each examination. A performance verification uses a mechanical device to induce stress waves into the material under examination, at a specified distance from each sensor. Induced stress waves stimulate a sensor in the same way as emission from a flaw. Performance verifications verify performance of the entire system (including couplant). (Refer to Guide E2374 for AE system performance verification techniques).

9.3.1 The preferred technique for conducting a performance verification is a pencil lead break (PLB). Lead should be broken on the material surface at a specified distance from each sensor. The 2H lead, 0.3-mm [0.012-in.] diameter, and 2 to 3-mm [0.08 to 0.12-in.] long should be used (see Figure 5 of Guide E976 and Guide E2374).

9.3.2 *Auto Sensor Test (AST)*—An electromechanical device such as a piezoelectric pulser (and sensor which contains this function) can be used in conjunction with pencil lead break as a means to assure system performance. This device can be used to replace the PLB post examination, system performance verification. (Refer to Guide E2374.)

10. Procedure

10.1 Visually examine accessible exterior surfaces of the vessel. Note observations in examination report.

10.2 Use procedures specified in Guide E650 for mounting AE sensors. Sensors must be at the same angular position and should be located at each end of the vessel so that the AE system can determine axial locations of sources in as much of the vessel as possible.

10.3 Adjust signal processor settings.

10.4 Perform a system performance verification at each sensor (see 9.3). Verify that peak amplitude is greater than a specified value. If source location is used, verify that the AE system displays a correct location (see Note 2) for the mechanical device that is used to produce stress waves.

NOTE 2—Due to temperature considerations, a spring-loaded center-punch may be used to produce stress waves

10.5 Begin pressurizing the vessel.

10.6 Monitor during the examination by observing displays that show plots of AE parameters versus time. If unusual response (in the operator's judgment) is observed, interrupt pressurization and conduct an investigation.

10.7 Store all data on mass storage media. Stop the examination when the pressure reaches 100 % of the examination pressure.



10.8 Perform a system performance verification at each sensor (see 9.3). Verify that peak amplitude is greater than a specified value.

10.9 Reduce the pressure in the vessel.

10.10 Raw AE data may be filtered to eliminate emission from nonstructural sources, for example, EMI.

10.11 Replay examination data. Examine any parameter versus time, correlation/distribution plots.

10.12 Based on data replay, determine whether evaluation criteria have been exceeded (see Appendix X1). If so, secondary nondestructive examination may be pursued.

11. Report

11.1 Prepare a written report from each examination. Report the following information:

11.1.1 Name of the owner of the vessel and the vehicle number (if appropriate).

11.1.2 Examination date and location.

11.1.3 Previous test date and previous maximum test pressure. See Note 3.

11.1.4 Maximum allowable working pressure.

11.1.5 Pressurization medium.

11.1.6 Maximum examination pressure.

11.1.7 Locations of AE sources that exceed acceptance criteria.

11.1.8 Signature of examiner.

11.1.9 Visual examination results.

11.1.10 AE examination results.

NOTE 3—If the operator is aware of situations where the vessel was subject to pressures that exceeded normal fill pressure, these should be described in the report.

12. Keywords

12.1 acoustic emission; fatigue crack growth; paper machine rolls; steam heated paper dryers; Yankee Dryer inspection

ANNEX

(Mandatory Information)

A1. INSTRUMENTATION SPECIFICATIONS

A1.1 Sensors

A1.1.1 The AE sensors shall have high sensitivity within the frequency band of 100 to 300 kHz.

A1.1.2 Sensitivity shall be greater than -77 dBV (referred to 1 V/ μ bar [1 V/14.5 μ psi], determined by face-to-face ultrasonic examination) within the frequency range of intended use, for ambient sensors.

A1.1.3 Sensitivity within the range of intended use shall not vary more than 3 dB over the intended range of temperatures in which sensors are used.

A1.1.4 Sensors shall be shielded against electromagnetic interference through proper design practice or differential (anti-coincidence) element design, or both.

A1.1.5 Sensors shall be electrically isolated from conductive surfaces by means of a shoe (a wear plate).

A1.2 Signal Cable

A1.2.1 The sensor signal cable which connects sensor and preamplifier shall not reduce sensor output more than 3 dB. 2 m [6 ft] is a typical maximum length.

A1.2.2 Signal cable shall be shielded against electromagnetic interference. Standard coaxial cable is generally adequate.

A1.3 Couplant

A1.3.1 A couplant shall provide adequate ultrasonic coupling efficiency throughout the examination.

A1.3.2 The couplant must be temperature stable over the temperature range intended for use.

A1.3.3 Adhesives may be used if they satisfy ultrasonic coupling efficiency and temperature stability requirements.

A1.4 Preamplifier

A1.4.1 The preamplifier shall have noise level no greater than 7 μ V rms (referred to a shorted input) within the bandpass range.

A1.4.2 The preamplifier gain shall vary no more than ± 1 dB within the frequency band and temperature range of use.

A1.4.3 The preamplifier shall be shielded from electromagnetic interference.

A1.4.4 The preamplifiers of differential design shall have a minimum of 40 dB common mode rejection.

A1.4.5 The combination of preamplifier and signal processor shall include a bandpass filter with a minimum of 24-dB/octave signal attenuation above and below the 100 to 300-kHz frequency band.

A1.5 Power/Signal Cable

A1.5.1 The power/signal cables provide power to preamplifiers, and conduct amplified signals to the main processor.

A1.5.1.1 These shall be shielded against electromagnetic interference. Signal loss shall be less than 1 dB/30 m [100 ft] of cable length. Standard coaxial cable is generally adequate. Signal loss from a power/signal cable shall be no greater than 3 dB.



A1.6 Power Supply

A1.6.1 A stable, grounded, power supply that meets the signal processor manufacturer's specification shall be used.

A1.7 Signal Processor

A1.7.1 System examination threshold should be set as low as practical.

A1.7.2 System dead time should be set such that an event created by a spring-loaded center-punch produces one locatable event.

APPENDIX

(Nonmandatory Information)

X1. EXAMPLE EVALUATION CRITERIA

X1.1 Over 2000 cast iron vessel tests have been performed using the AE evaluation criteria below. Laboratory cast iron sample evaluations have been copious (for some examples see reference notes in 4.11).

Evaluation criteria for cast iron vessels is not written in the same frame of reference as the criteria for homogenous metals. Small cast iron cracks have been found using criteria below. When properly used the criteria has found small cracks with zone location, and if necessary, linear location analysis. Knowledge of the vessel, cast iron behavior, and operation faults are helpful. Significant condensate loading/test time is also reduced by the elimination of incremental pressure holds. When considering the modulus of elasticity, steel can be twice that of cast iron. Defects cause an area reduction in cast iron modulus of elasticity.

Evaluation criteria for this Appendix were published in 1992 TAPPI Engineering Conference Proceedings "Examining Cast Iron Dryers and Determining Tensile strength":

"The evaluation criteria used for acoustic emission acceptance of SHPD and Yankee dryers are:

Not more than five hits per sensor.

No hits from beginning of designated hold periods.

No hit amplitudes greater than 65 dB.

Evaluation threshold equals 50 dB.

All SHPD and Yankee dryers examined with acoustic emission and exceeding the evaluation criteria may be examined with another NDE method."

SUMMARY OF CHANGES

Committee E07 has identified the location of selected changes to this standard since the last issue (E2598 - 07) that may impact the use of this standard. (XXX 1, 2013)

- (1) Changed designation to a Combined Units standard.
- (2) Changed 1.4 to a Combined Units measurement statement.
- (3) Changed values in the standard to the correct Combined Units format, including 4.1, 4.7, 4.9, 4.12, 4.13, 7.4, 7.5, 9.3.1, A1.1.2, A1.2.1.
- (4) Replaced Standardization with Verification in Section 9 title.

- (5) Updated electronic instrument terms in 7.7.2 and 7.7.3.
- (6) Added Section 5, Significance and Use. Renumbered remaining sections.
- (7) Added Section 12, Keywords.
- (8) Added new Fig. 1 and Fig. 3. Renumbered Fig. 2.



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