Designation: E2661/E2661M – 20$^{\epsilon 1}$

# Standard Practice for Acoustic Emission Examination of Plate-like and Flat Panel Composite Structures Used in Aerospace Applications[1]

This standard is issued under the fixed designation E2661/E2661M; 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.

ε[1] NOTE—An editorial change was made to the References section in November 2020.

## 1. Scope*

1.1 This practice covers acoustic emission (AE) examination or monitoring of panel and plate-like composite structures made entirely of fiber/polymer composites.

1.2 The AE examination detects emission sources and locates the region(s) within the composite structure where the emission originated. When properly developed AE-based criteria for the composite item are in place, the AE data can be used for nondestructive examination (NDE), characterization of proof testing, documentation of quality control, or for decisions relative to structural-test termination prior to completion of a planned test. Other NDE methods may be used to provide additional information about located damage regions. For additional information, see X1.1 in Appendix X1.

1.3 This practice can be applied to aerospace composite panels and plate-like elements as a part of incoming inspection, during manufacturing, after assembly, continuously (during structural health monitoring), and at periodic intervals during the life of a structure.

1.4 This practice is meant for fiber orientations that include cross-plies, angle-ply laminates, or two-dimensional woven fabrics. This practice also applies to 3-D reinforcement (for example, stitched, z-pinned) when the fiber content in the third direction is less than 5 % (based on the whole composite).

1.5 This practice is directed toward composite materials that typically contain continuous high modulus greater than 20 GPa [3 Msi] fibers.

1.6 *Units*—The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system are not necessarily exact equivalents; therefore, to ensure conformance with the standard, each system shall be used independently of the other, and values from the two systems shall not be combined.

1.7 *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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.8 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

## 2. Referenced Documents

2.1 *ASTM Standards:*[2]

E543 Specification for Agencies Performing Nondestructive Testing
E976 Guide for Determining the Reproducibility of Acoustic Emission Sensor Response
E1067 Practice for Acoustic Emission Examination of Fiberglass Reinforced Plastic Resin (FRP) Tanks/Vessels
E1106 Test Method for Primary Calibration of Acoustic Emission Sensors
E1316 Terminology for Nondestructive Examinations
E1781 Practice for Secondary Calibration of Acoustic Emission Sensors
E2533 Guide for Nondestructive Testing of Polymer Matrix Composites Used in Aerospace Applications

2.2 *Other Documents:*

ANSI/ASNT CP-189 ASNT Standard for Qualification and Certification of Nondestructive Testing Personnel[3]
ISO 9712 Non-destructive Testing—Qualification and Certification of NDT Personnel[4]

[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.

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[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.

[4] Available from International Organization for Standardization (ISO), 1, ch. de la Voie-Creuse, CP 56, CH-1211 Geneva 20, Switzerland, http://www.iso.org.

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

NAS-410 NAS Certification and Qualification of Nondestructive Personnel (Quality Assurance Committee)[5]
SNT-TC-1A Recommended for Personnel Qualification and Certification of Nondestructive Testing Personnel[3]

## 3. Terminology

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

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *characteristic damage state, n*—transverse matrix cracking during the virgin loading of a composite; often resulting in reaching a limit of the crack density prior to reaching failure.

3.2.1.1 *Discussion*—Results in a reduction of stiffness of the composite. For additional information, see X1.2.

3.2.2 *flat panel composite, n*—any fiber reinforced composite lay-up consisting of laminas (plies) with one or more orientations with respect to some reference direction that result in a two-dimensionally flat article of finite thickness (typically relatively thin).

3.2.3 *plate-like composite, n*—any fiber-reinforced composite lay-up consisting of laminas (plies), which is not strictly flat, but for purposes of the AE examination, can be considered as a two-dimensional (2-D) structural plate for wave propagation and for location of the region of AE source origin.

3.2.3.1 *Discussion*—Applies for a minimum radius of curvature of greater than about 2 m [6 ft], so curvature does not change group velocities.

3.2.4 *quasi-isotropic lay-up, n*—a plate where the group velocities of both the fundamental modes have been shown to be independent of propagation direction; for example: $[+45/-45/0/90]_s$ (**1**).[6]

3.2.5 *wideband AE sensors, n*—wideband (broadband) AE sensors, when calibrated according to Test Method E1106 or Practice E1781, exhibit displacement or velocity response over several hundred kHz with a coefficient of variation of the response in dBs that does not exceed 10 %.

3.2.6 *wideband-based (modal) AE techniques, n*—AE techniques with wideband AE sensors that subject waveforms of the signals to combined time and frequency analysis to obtain mode-based arrival times (for source location calculations) and modal amplitudes for potential source identification.

3.2.6.1 *Discussion*—Note that mode-based arrival times can also be obtained with resonant sensors, but only at certain experimentally determined frequencies.

## 4. Summary of Practice

4.1 This practice consists of subjecting flat composite panels or plate-like composite structures to loading or stressing while monitoring with sensors that are sensitive to AE (transient displacement waves) caused by the creation of micro-damage, growing flaws, and friction-based sources. For additional information, see X1.3.

4.2 This practice provides an approach to determine the local regions of origin of the AE sources and any potential local regions of large accumulation(s) of AE sources.

4.3 This practice can provide an approach to use AE-based criteria to determine the significance of flaws.

## 5. Significance and Use

5.1 This AE examination is useful to detect micro-damage generation, accumulation, and growth of new or existing flaws. The examination is also used to detect significant existing damage from friction-based AE generated during loading or unloading of these regions. The damage mechanisms that can be detected include matrix cracking, fiber splitting, fiber breakage, fiber pull-out, debonding, and delamination. During loading, unloading, and load holding, damage that does not emit AE energy will not be detected.

5.2 When the detected signals from AE sources are sufficiently spaced in time so as not to be classified as continuous AE, this practice is useful to locate the region(s) of the 2-D test sample where these sources originated and the accumulation of these sources with changing load or time, or both.

5.3 The probability of detection of the potential AE sources depends on the nature of the damage mechanisms, flaw characteristics, and other aspects. For additional information, see X1.4.

5.4 Concentrated damage in fiber/polymer composites can lead to premature failure of the composite item. Hence, the use of AE to detect and locate such damage is particularly important.

5.5 AE-detected flaws or damage concentrated in a certain region may be further characterized by other NDE techniques (for example, visual, ultrasonic, etc.) and may be repaired as appropriate. Repair procedure recommendations and the subsequent examination of the repair are outside the scope of this practice. For additional information, see X1.5.

5.6 This practice does not address sandwich core, foam core, or honeycomb core plate-like composites due to the fact that currently there is little in the way of published work on the subject resulting in a lack of a sufficient knowledge base.

5.7 Refer to Guide E2533 for additional information about types of defects detected by AE, general overview of AE as applied to polymer matrix composites, discussion of the Felicity ratio (FR) and Kaiser effect, advantages and limitations, AE of composite parts other than flat panels, and safety hazards.

## 6. Basis of Application—Personnel Qualification—Contractual Agreement

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

6.2 *Personnel Qualification*—Unless contractually agreed otherwise, personnel performing examinations to this practice

[5] Available from Aerospace Industries Association (AIA), 1000 Wilson Blvd., Suite 1700, Arlington, VA 22209, http://www.aia-aerospace.org.

[6] The boldface numbers in parentheses refer to the list of references at the end of 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, ISO 9712, or a similar document. They shall be 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*—Unless contractually agreed otherwise, NDT agencies shall be qualified and evaluated as described in Specification E543. The applicable edition of Specification E543 shall be specified in the contractual agreement.

6.4 *Procedure and Techniques*—The procedures and techniques to be utilized shall be as specified in the contractual agreement. In particular, the contractual agreement should state whether full monitoring of the test sample is required or if only partial monitoring of certain expected critical areas is required.

6.5 *Timing of Examination*—The timing of examination shall be in accordance with 1.3, unless otherwise specified.

6.6 *Reporting Criteria*—Reporting criteria for the examination results shall be in accordance with Section 12, unless otherwise specified.

## 7. Apparatus

7.1 Refer to Fig. 1 for a typical AE system block diagram showing key components.

7.2 *AE Sensors:*

7.2.1 The selection of a wideband or resonant sensor is described here. For information on the frequency content of AE waves, see X1.6. For a scientific method to select sensors whose best frequency response corresponds to the frequency range of the highest amplitudes of the AE waves, see X1.7.

7.2.1.1 Wideband sensors can be used along with waveform recording to enhance AE data analysis by the application of wideband-based AE techniques. A wideband sensor should be chosen with relatively flat response (Test Method E1106 or Practice E1781) from about 50 kHz to 400 kHz. For additional information, see X1.7 for plates less than 2 mm thick and X1.8.

7.2.1.2 If resonant sensors are used, the best choice is a sensor with its primary resonance in the lower portion of a 50 kHz to 400 kHz frequency band. Sensors with a lower frequency resonance of about 25 kHz to 50 kHz can be used to increase sensor spacing (for example when a limited number of AE channels are available [see Practice E1067]) in AE testing of composites, but such sensors increase the likelihood that unwanted extraneous noise will be recorded. To minimize the effects of airborne noise the lower resonant-frequency sensors can be wrapped with sound absorbing material.

7.2.2 Sensors should be shielded against electromagnetic interference (EMI) through proper design practice or differential (anti-coincidence) element design, or both.

7.2.3 Sensors should have omni-directional response, with directional variations not exceeding 4 dB from the average peak response of the set of sensors.

7.3 *Sensor Couplant:*

7.3.1 The sensors must be acoustically coupled (to remove air from between the sensor face and the composite surface) directly to the test sample. Commercially available couplants for ultrasonic flaw detection may be used. Silicone-based

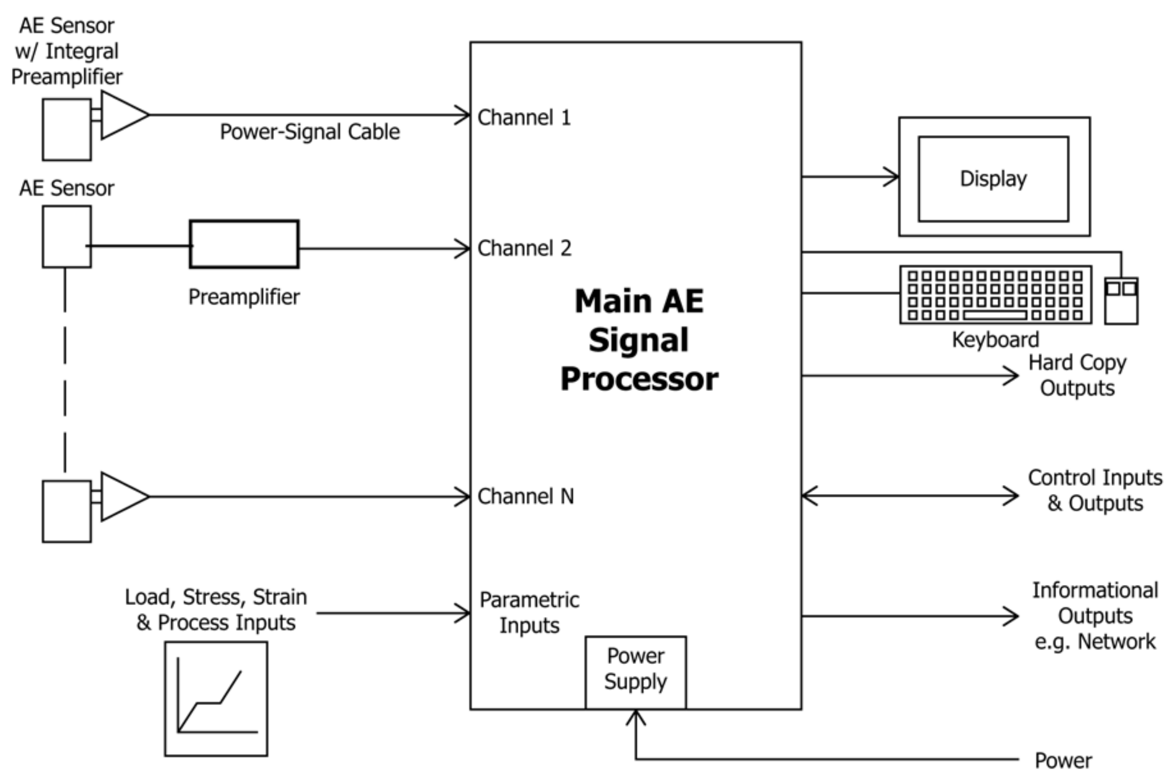


FIG. 1 AE System Block Diagram