Standard Practice for Acoustic Emission Monitoring of Structures During Controlled Stimulation[1]

This standard is issued under the fixed designation E569/E569M; 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 acoustic emission (AE) monitoring of structures, such as pressure vessels, piping systems, or other structures that can be stressed by mechanical or thermal means.

1.2 The basic functions of an AE monitoring system are to detect, locate, and classify emission sources. Other methods of nondestructive testing (NDT) may be used to further evaluate the significance of reported acoustic emission sources.

1.3 *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.

1.4 *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]

E543 Specification for Agencies Performing Nondestructive Testing

E650 Guide for Mounting Piezoelectric Acoustic Emission Sensors

E750 Practice for Characterizing Acoustic Emission Instrumentation

E1316 Terminology for Nondestructive Examinations

E2374 Guide for Acoustic Emission System Performance Verification

2.2 *Other Documents:*[3]

SNT-TC-1A Recommended Practice for Nondestructive Testing Personnel Qualification and Certification

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

2.3 *AIA Standard:*

NAS-410 Certification and Qualification of Nondestructive Testing Personnel[4]

3. Terminology

3.1 *Definitions*—Definitions of terms relating to acoustic emission may be found in Section B of Terminology E1316.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *AE activity*—the presence of acoustic emission during an examination.

3.2.2 *active source*—one which exhibits increasing cumulative AE activity with increasing or constant stimulus.

3.2.3 *critically active source*—one which exhibits an increasing rate of change of cumulative AE activity with increasing or constant stimulus.

3.2.4 *AE source intensity*—average energy, counts or amplitude per hit.

3.2.5 *intense source*—one in which the AE source intensity of an active source consistently exceeds, by a specified amount, the average AE source intensity of active sources.

3.2.6 *critically intense source*—one in which the AE source intensity consistently increases with increasing stimulus or with time under constant stimulus.

4. Summary of Practice

4.1 Acoustic emission examination of a structure usually requires application of a mechanical or thermal stimulus. Such stimulation produces changes in the stresses in the structure. During stimulation of a structure, AE from discontinuities (such as cracks and inclusions) and from other areas of stress concentration, or from other acoustic sources (such as leaks,

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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 Aerospace Industries Association of America, Inc. (AIA), 1000 Wilson Blvd., Suite 1700, Arlington, VA 22209-3928, http://www.aia-aerospace.org.

*A Summary of Changes section appears at the end of this standard loose parts, and structural motion) can be detected by an instrumentation system, using sensors which, when stimulated by stress waves, generate electrical signals.

4.2 In addition to immediate evaluation of the emissions detected during the application of the stimulus, a permanent record of the number and location of emitting sources and the relative amount of AE detected from each source provides a basis for comparison with sources detected during the examination and during subsequent stimulation.

5. Significance and Use

5.1 Controlled stimulation i.e. the application of mechanical or thermal load, can generate AE from flawed areas of the structure. Sources may include flaw growth, oxide fracture, crack face stiction and release on load application, and crack face rubbing.

5.2 The load range above normal service (peak) load is used to propagate fatigue cracks in the plastically strained region ahead of the crack tip. Crack propagation may not be a reliable source of AE, depending on the alloy and microstructure, the amount (rate) of crack extension, and possibility of brittle fracture in a segment of crack extension.

5.3 Load increases resulting in significant ductile tearing may produce less emission than expected for the amount of crack growth. Processes that result in more brittle cleavage fractures are more detectable and produce more emission for smaller amounts of flaw growth. These include corrosion fatigue and stress corrosion cracking modes of flaw growth, and would also be more likely in cast or welded structures than in fabricated (forged, rolled or extruded) structures. Distributed defect structures such as hydrogen embrittlement, or creep cavitation in high temperature steels may also produce significant emission without evidence of an existing crack-like flaw.

5.4 Application and relaxation of load can produce secondary mechanically-induced emission that is not related to flaw extension. This includes crack face stiction release on loading—usually evidenced by emission at the same rising load value regardless of peak load; or crack face rubbing on load release as the fracture surfaces come back together.

5.5 The load rate can be a significant concern as instrumentation can become saturated with AE activity. The ability to differentiate real data from background noise can be compromised.

5.6 Background noise must be fully investigated and minimized before any AE monitoring can begin.

6. Basis of Application

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

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 and 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 Testing 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 *Timing of Examination*—The timing of the examination shall be in accordance with a contractual agreement or with an established internal procedure.

6.5 *Extent of Examination*—Many applications will require an arrangement of sensors such that all areas of the structure are monitored. In other applications, only a portion of the structure may require monitoring.

6.6 *Reporting Criteria/Acceptance*—Reporting criteria for the examination results shall be in accordance with Sections 11, 12, and 13.

6.7 *Reexamination of Repaired/Reworked Items*—Reexamination of repaired/reworked items is not addressed in this standard and if required shall be specified in a contractual agreement.

7. Examination Preparation

7.1 Before the examination begins, make the following preparations for AE monitoring:

7.1.1 Determine the type, number, and placement of sensors. This requires knowledge of both material and physical characteristics of the structure and the features of the instrumentation. This determination is also dependent upon the required precision and accuracy of the examination.

7.1.2 Establish communications between the control point for the application of the stimulus and the AE examination control center.

7.1.3 Provide a means for continuously recording a measure of the stimulus.

7.1.4 Identify potential sources of extraneous acoustic noise, such as vibration, friction, and fluid flow. Such sources may require acoustic isolation or control, in order not to mask valid acoustic emissions.

7.1.5 Attach the sensors; both the couplant and sensing device must be compatible with the surface conditions and the composition of the structural material being examined (see Guide E650).

7.1.6 Verify the AE monitoring system in accordance with Section 9 and Guide E2374.

8. Safety Precautions

8.1 When examining vessels, ambient temperature should not be below the ductile-brittle transition temperature of the pressure vessel construction material.

9. Calibration and Verification

9.1 Annual calibration and verification of pressure transducer, AE sensors, preamplifiers (if applicable), signal processor (particularly the signal processor time reference), and AE electronic waveform generator 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 (verification) must be performed any time there is concern about signal processor performance. A waveform generator should be used in making evaluations. Each signal processor channel must respond with peak amplitude reading within ±2 dBV of the electronic waveform generator output.

9.3 A system performance verification (see Guide E2374) must be conducted immediately before, and immediately after, each examination. Performance verifications can also be conducted during the examination if there is any suspicion that the system performance may have changed. A performance verification uses a mechanical device to induce stress waves into the structure at a specified distance from each sensor. Induced stress waves stimulate a sensor in a manner similar to acoustic emission. Performance verifications verify performance of the entire system (including couplant).

9.3.1 The preferred technique for conducting a performance verification is a pencil lead break. Lead should be broken on the structure at a distance of 100 mm [4 in.] from the sensor centerline. 2H lead, 0.3 mm [0.012 in.] diameter, 2 - 3 mm [0.08 - 0.12 in.] long should be used (see Fig. 5 of Guide E976). If circumstances require different values to be used, the values used shall be documented in the examination report.

9.3.2 *Location Sensitivity Check*—A simulated AE source (such as a pencil lead break) is created on the surface of the structure in order to check location sensitivity. Sensor source location sensitivity is determined as follows.

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

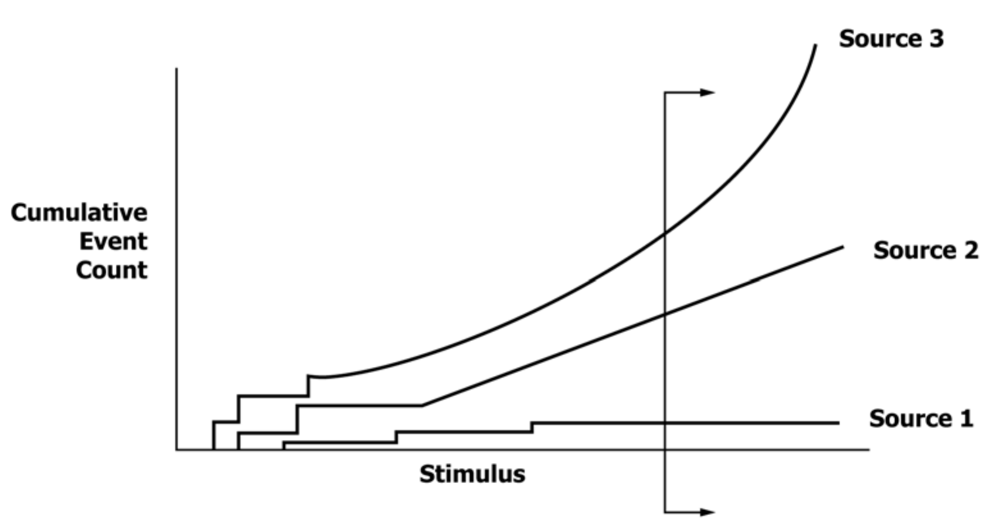
9.3.2.2 *Source Location Algorithm Sensitivity Check*—Each channel shall have the same system examination threshold. Two or more sensors define the structure mounted sensor array. The simulated AE source generated in each structure mounted sensor array shall be detected by the minimum number of sensors required to locate the source within ±5 % of sensor spacing.

10. Examination Procedure

10.1 Acoustic emission data may be accumulated during or after stimulation of the structure, or both, as specified in the written procedure.

10.1.1 During application of the stimulus, the locations of acoustic sources are usually determined through analysis of the times of arrival of AE signals at multiple sensors. Such analysis may be performed through the use of an analysis computer. The computer accumulates and analyzes data over a specified parametric range. Examples of parameters are pressure, time, and stress. Each channel shall have the same system examination threshold. As the stimulus is applied, record the number and location of emitting sources and the amount of AE detected from each source. The AE rate at one or more sensors may be monitored and displayed in real time during stimulation. If the acoustic emission activity indicates a critically intense source, the AE operator shall stop the examination and notify the owner of the structure or his designee immediately. The cause of the AE increase shall be investigated before continuing the stimulation schedule.

10.1.2 Continuous emission from any leak in a structure stimulated by pressure can mask acoustic emission from sources near the leak. Effects of leaks on acoustic emission measurements should be eliminated to adequately examine pressure boundaries. Knowledge of attenuation in the structure and the response of sensors affected by leak noise may help localize the leak.



NOTE 1—To the right of the vertical line, Source 1 is inactive, Source 2 is active, and Source 3 is critically active.

FIG. 1 Schematic Representation of Three Different Source Types

10.1.3 Following the examination, repeat the performance verification in accordance with 9.3.

11. Examination Records

11.1 All system performance verification data and instrument adjustments, including equipment description and performance data, shall be included in the records of the examination with all pertinent qualification/certification records and be signed by the responsible AE examiner. The information recorded should be sufficient to permit complete reanalysis of the results. This information should include, but not be limited to:

11.1.1 Location of AE examination, material, physical characteristics of the structure, and manufacturer's data sheet or tag data.

11.1.2 Sensor specifications, including size, sensitivity, frequency response, method of attachment, type of couplant, type and length of connecting cables.

11.1.3 Sensor locations.

11.1.4 Functional descriptions of signal conditioners, processors, and display equipment.

11.1.5 Stimulation schedule, AE monitoring procedures, and results of all sensitivity checks.

11.1.6 Method of stimulation and examination schedule.

11.1.7 Permanent data record of the measured AE signal parameters, in analog or digital form.

11.1.8 Stimulation medium temperature, ambient air temperature.

12. Interpretation of Results

12.1 All results shall be summarized on an appropriate layout map, displayed or tabulated, or both, for ready reference and interpretation. This layout or tabulation shall display the location and classification of each source with pertinent comments.

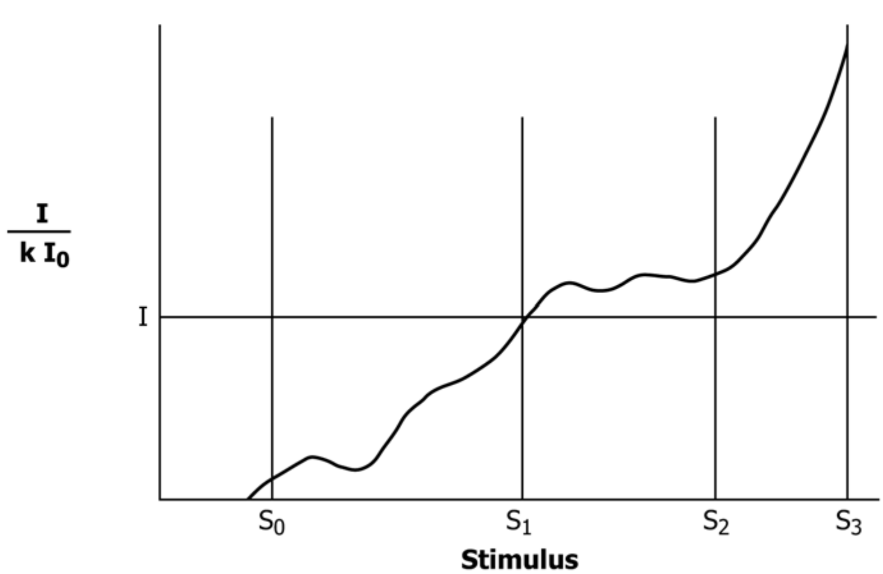
12.1.1 *Source Location*—All location data resulting from analysis shall be presented in a manner consistent with the previously established calibration accuracy.

12.1.2 *Source Classification*—Sources are usually classified with respect to their acoustic activity and intensity.

12.1.2.1 A source's acoustic activity is normally measured by event count or emission count. A source is considered to be *active* if its AE activity continues to increase with increasing or constant stimulus. A source is considered to be *critically active* if the rate of change of its AE activity with respect to the stimulus, consistently increases with increasing stimulation, or if the rate of change of its AE activity with respect to time, consistently increases with time under constant stimulus (see Fig. 1).

12.1.2.2 Preferred intensity measures of a source are its: average detected energy per event, average emission count per hit, or average amplitude per hit. A source is considered to be *intense* if it is active and its intensity measure consistently exceeds, by a specified amount, the average intensity of active sources. The intensity of a source can be calculated for increments of the stimulus or of hits. It is noted that, if there is only one active source, the intensity measure of the source is the average intensity of all sources, and therefore the intrinsic comparison no longer is applicable. In this case, it is necessary to classify the source through comparison with results from similar examinations. (See Fig. 2.)

12.1.2.3 When using source location algorithms, in addition to activity and intensity, another characteristic of each detected AE source that should be considered for source classification is the size of the "region" of the located source. The clustering of the located events from a sharp discontinuity, such as a crack, is usually dense, while regions of plastic deformation associated with, for example, corrosion pits, result in source areas that show more uncertainty in the definition of their size, the events being contained rather sparsely in the region. In most



NOTE 1—Four different regions are shown: prior to S_0, the source was inactive; between S_0 and S_1, the source was of low intensity; between S_1 and S_2, the source is classified as intense; between S_2 and S_3, the source is classified as critically intense.

FIG. 2 Source Intensity, *I* , Divided by a Weighted Average Intensity of All Sources, kI_0, Plotted Against the Stimulus, *S*

cases, a growing crack is considered to be the more serious defect. However, activity and intensity may not suffice for distinguishing between the two. Normally, there is subjective judgment on what size of location bundle or cluster constitutes an isolated source.

12.1.3 *Source Evaluation*—Sources are usually evaluated by their activity or intensity. The procedure shall specify definitions for critically active and critically intense.

12.1.4 The significance of AE activity detected on a first hit sensor or zone location algorithm will be more easily definable if specific quantities (for example, 5 hits per sensor; 200 counts per sensor to operating pressure) are used.

12.1.5 Indications located with AE should be examined by other techniques; for example, visual, ultrasonics, dye penetrants, etc.

13. Report

13.1 A report should contain at least the examination record, the interpretation of results, the method used for source location, and source locations indicated on a diagram of the vessel.

14. Keywords

14.1 active source; clustering; controlled stimulation; critically active source; critically intense source; intense source; leaks; loose parts; mechanical stress; pressure vessel; source location; source classification; thermal stress

SUMMARY OF CHANGES

Committee E07 has identified the location of selected changes to this standard since the last issue (E569 - 07) that may impact the use of this standard. (January 1, 2013)

(1) Added new units statement, 1.3, to Scope for a Combined standard.
(2) Modified all values in standard to meet the Combined Units standard including 9.3.1.
(3) Added Section 5, Significance and Use.