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Standard Practice for Leak Detection and Location Using Surface-Mounted Acoustic Emission Sensors[1]

This standard is issued under the fixed designation E1211/E1211M; 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 describes a passive method for detecting and locating the steady state source of gas and liquid leaking out of a pressurized system. The method employs surface-mounted acoustic emission sensors (for non-contact sensors see Test Method E1002), or sensors attached to the system via acoustic waveguides (for additional information, see Terminology E1316), and may be used for continuous in-service monitoring and hydrotest monitoring of piping and pressure vessel systems. High sensitivities may be achieved, although the values obtainable depend on sensor spacing, background noise level, system pressure, and type of leak.

~~1.2The values stated in inch-pound units are to be regarded as the standard. SI units are provided for information only.~~

1.2 *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.

1.3 *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
E976 Guide for Determining the Reproducibility of Acoustic Emission Sensor Response
E1002 Practice for Leaks Using Ultrasonics
E1316 Terminology for Nondestructive Examinations
E2374 Guide for Acoustic Emission System Performance Verification

2.2 *ASNT 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 Document:*

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

3. Summary of Practice

3.1 This practice requires the use of contact sensors, amplifier electronics, and equipment to measure their output signal levels. The sensors may be mounted before or during the examination period and are normally left in place once mounted rather than being moved from point to point.

3.2 Detection of a steady-state leak is based on detection of the continuous, broadband signal generated by the leak flow. Signal

[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 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.**

detection is accomplished through measurement of some input signal level, such as its root-mean-square (RMS) amplitude or average signal level.

3.3 The simplest leak test procedure involves *only* detection of leaks, treating each sensor channel individually. A more complex examination requires processing the signal levels from two or more sensors together to allow computation of the approximate leak location, based on the principle that the leak signal amplitude decreases as a function of distance from the source.

4. Significance and Use

4.1 Leakage of gas or liquid from a pressurized system, whether through a crack, orifice, seal break, or other opening, may involve turbulent or cavitational flow, which generates acoustic energy in both the external atmosphere and the system pressure boundary. Acoustic energy transmitted through the pressure boundary can be detected at a distance by using a suitable acoustic emission sensor.

4.2 With proper selection of frequency passband, sensitivity to leak signals can be maximized by eliminating background noise. At low frequencies, generally below 100 kHz, it is possible for a leak to excite mechanical resonances within the structure that may enhance the acoustic signals used to detect leakage.

4.3 This practice is not intended to provide a quantitative measure of leak rates.

5. Basis of Application

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

5.2 *Personnel Qualification*

5.2.1 If specified in the contractual agreement, personnel performing examinations to this practice 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.

5.3 *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.

5.4 *Timing of Examination*—The timing of examination shall be in accordance with 7.1.7 unless otherwise specified.

5.5 *Extent of Examination*—The extent of examination shall be in accordance with 7.1.4 and 10.1.1.1 unless otherwise specified.

5.6 *Reporting Criteria/Acceptance Criteria*—Reporting criteria for the examination results shall be in accordance with 10.2.2 and Section 11 unless otherwise specified. Since acceptance criteria are not specified in this practice, they shall be specified in the contractual agreement.

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

6. Interferences

6.1 External or internal noise sources can affect the sensitivity of an acoustic emission leak detection system. Examples of interfering noise sources are:

6.1.1 Turbulent flow or cavitation of the internal fluid,

6.1.2 Noise from grinding or machining on the system,

6.1.3 Airborne acoustic noise, in the frequency range of the measuring system,

6.1.4 Metal impacts against, or loose parts frequently striking the pressure boundary, and

6.1.5 Electrical noise pick-up by the sensor channels.

6.2 Stability or constancy of background noise can also affect the maximum allowable sensitivity, since fluctuation in background noise determines the smallest change in level that can be detected.

6.3 The acoustic emission sensors must have stable characteristics over time and as a function of both the monitoring structure and the instrumentation system examination parameters, such as temperature.

6.4 Improper sensor mounting, electronic signal conditioner noise, or improper amplifier gain levels can decrease sensitivity.

7. Basic Information

7.1 The following items must be considered in preparation and planning for monitoring:

7.1.1 Known existing leaks and their distance from the areas to be monitored should be noted so that their influence on the capabilities of the method can be evaluated.

7.1.2 Type of vessel, pipeline, or installation to be examined, together with assembly, or layout drawings, or both, giving sufficient detail to establish dimensions, changes of shape likely to affect flow characteristics, positions of welds, and the location of components such as valves or flanges, and attachments to the vessel or pipe such as pipe hangers where leaks are most likely to arise. Regions with restricted accessibility due to walls, the existence or location of cladding, insulation, or below surface components must be specified.

7.1.3 When location of the peak is of primary interest, quantitative information regarding the leakage rates of interest and whenever possible the type of leak is necessary.

7.1.4 Extent of monitoring, for example, entire volume of pressure boundary, weld areas only, etc.

7.1.5 Material specifications and type of surface covering (for example paint or other coating) to allow the acoustic propagation characteristics of the structure to be evaluated.

7.1.6 Proposed program of pressure application or process-pressure schedule, specifying the pressurization schedule together with a layout or sketch of the pressure-application system and specifying the type of fluid used during the examination, for example, gas, water, or oil.

7.1.7 Time of monitoring, that is, the point(s) in the manufacturing process, or service life at which the system will be monitored, or both.

7.1.8 Frequency range to be used in the monitoring equipment.

7.1.9 Environmental conditions during examination that may affect instrumentation and interpretation of results; for example, temperature, moisture, radioactivity, vibration, pressure, and electromagnetic interference.

7.1.10 Limitations or restrictions on the sensor mounting procedure, if applicable, including restrictions on couplant materials.

7.1.11 The location of sensors or waveguides and preparation for their installation to provide adequate coverage of the areas specified in 7.1.3. Where particular sections are to be examined with particular sensors, the coverage of the vessel or system by sensor subgroups shall be specified. The sensor locations must be given as soon as possible, to allow positioning difficulties to be identified.

7.1.12 The communications procedure between the acoustic emission staff and the control staff, the time intervals at which pressure readings are to be taken, and the procedure for giving warning of unexpected variations in the pressure system.

7.1.13 Requirements for permanent records, if applicable.

7.1.14 Content and format of examination report, if required.

7.1.15 Acoustic Emission Examiner qualifications and certification, if required.

8. Apparatus

8.1 *Sensors*—The acoustic emission sensors are generally piezoelectric devices and should be mounted in accordance with Practice E650 to ensure proper signal coupling. The frequency range of the sensors may be as high as 1 MHz, and either wideband or resonant sensors may be employed. The higher frequencies can be used to achieve greater discrimination against airborne or mechanical background noise.

8.2 *Amplifiers*—Amplifiers/preamplifiers should have sufficient gain to allow the signal processing equipment to detect the level of acoustic background noise on the pressurized system. The sensor/amplifier bandwidth should be selected to minimize background noise.

8.3 *Signal Processor*—The signal processor measures the RMS level, the acoustic emission signal power, the average signal level, or any other similar parameters of the continuous signal. A leak location processor to compute the source location from signal levels and attenuation data may be included. Alarm setpoints may also be included as a processor function.

8.4 *Leak Signal Simulator*:

8.4.1 A device for simulating leaks should be included to evaluate the effectiveness of the monitoring system. The following could be considered: a sensor on the pressure boundary driven from a random-noise generator, a small water jet, or a gas jet.

8.4.2 When leak location processing is to be performed, leak simulation should be carried out initially over a sufficiently large number of diverse points to verify proper operation of the location algorithm.

9. System Performance Verification

9.1 System performance verification consists of two stages. The first stage concerns periodic calibration and verification of the equipment under laboratory conditions. This procedure is beyond the scope of this practice (see Practice E750) but the results must be made available to the system owners if requested. The second stage concerns in-situ verification to check the sensitivities of all channels and the satisfactory operation of the detection equipment. For every verification operation, a written procedure shall be prepared.

9.2 In-situ sensitivity check of all sensors should be performed by placing a leak signal simulator (see Guide E976) at a specified distance from each sensor and recording the resulting output level from the amplifier, as referred to the amplifier input terminal. Amplifier gains may also be adjusted as appropriate to correct for sensitivity variations.

9.3 Periodic system verification checks shall be made prior to the examination and during long examinations (days) or if any environmental changes occur. The relative verification check is accomplished by driving various sensors or activating various leak simulation devices such as water or gas jets (see Guide E2374) and measuring the outputs of the receiving sensors. The ratio of the outputs of two receiving sensors for a given injection point should remain constant over time. Any change in the ratio indicates a deviation in performance. In this way, all sensors on a system may be compared to one or several reference signals and proper adjustments made (see Guide E976).

9.4 When leak location calculations are to be performed, the acoustic attenuation between sensors should be characterized over the frequency band of interest, especially if the presence of discontinuities, such as pipe joints, may be suspected to affect the uniformity of attenuation. The measurements should then be factored into the source location algorithm.

10. Procedure

10.1 *Pre-Examination Requirements* :