Designation: E 1211 – 02

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

This standard is issued under the fixed designation E 1211; 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 noncontact sensors see Test Method E 1002), or sensors attached to the system via acoustic waveguides (for additional information, see Terminology E 1316), and may be used for continuous inservice 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. This practice is not intended to provide a quantitative measure of leak rates.

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

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:*

E 543 Practice for Agencies Performing Nondestructive Testing[2]

E 650 Guide for Mounting Piezoelectric Acoustic Emission Sensors[2]

E 750 Practice for Characterizing Acoustic Emission Instrumentation[2]

E 976 Guide for Determining the Reproducibility of Acoustic Emission Sensor Response[2]

E 1002 Test Method for Leaks Using Ultrasonics[2]

E 1316 Terminology for Nondestructive Examinations[2]

2.2 *ASNT Documents:*

Recommended Practice SNT-TC-1A for Nondestructive Testing Personnel Qualification and Certification[3]

ANSI/ASNT CP-189 Standard for Qualification and Certification of Nondestructive Testing Personnel[3]

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

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

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[2] *Annual Book of ASTM Standards*, Vol 03.03.

[3] Available from American Society for Nondestructive Testing, 1711 Arlingate Plaza, PO Box 28518, Columbus, Ohio 43228-0518.

[4] Available from Aerospace Industries Association of America, Inc., 1250 Eye St., NW, Washington, DC 20005.

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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.

5. Basis of Application

5.1 *Personnel Qualification*

5.1.1 If specified in the contractual agreement, personnel performing examinations to this standard shall be qualified in accordance with a nationally 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.

5.2 *Qualification of Nondestructive Agencies*

5.2.1 If specified in the contractual agreement, NDT agencies shall be qualified and evaluated as described in Practice E 543. The applicable edition of Practice E 543 shall be specified in the contractual agreement.

5.3 *Timing of Examination*

5.3.1 The timing of examination shall be in accordance with 7.1.7 unless otherwise specified.

5.4 *Extent of Examination*

5.4.1 The extent of examination shall be in accordance with 7.1.4 and 10.1.1.1 unless otherwise specified.

5.5 *Reporting Criteria/Acceptance Criteria*

5.5.1 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 standard, they shall be specified in the contractual agreement.

5.6 *Reexamination of Repaired/Reworked Items*

5.6.1 Reexamination of repaired/reworked items is not addressed in this standard 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 E 650 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 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. Verification of Equipment Performance

9.1 Characterization 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 E 750) 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 E 976) 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 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 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 E 976).

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*:

10.1.1 Before beginning the acoustic emission monitoring, ensure that the following requirements are met:

10.1.1.1 Evaluate attenuation effects, that is, the change in signal amplitude with sound-propagation distance, so as to define the effective area covered by each individual sensor; and in the case of sensor sub-groups, the maximum distance between sensing points.

10.1.1.2 Ensure that sensors are placed at the predetermined positions. If it is necessary to modify these positions during installation, record the new sensor locations. Record the method of attachment of the sensors and the couplant used.

10.1.1.3 Review the operating schedule to identify all potential sources of extraneous acoustic noise such as nozzle-plug movement, pump vibration, valve stroking, personnel movement, fluid flow, and turbulence. Such sources may require acoustic isolation or control so that they will not mask relevant leak emission within the vessel or structure being examined. Uncontrolled generation of acoustic interference by conditions such as rain, sleet, hail, sand, wind (for unprotected vessels), chipping, or grinding, shall be evaluated and its effect minimized by acoustic isolation insofar as is practical. A record shall be made of such sources.

10.2 *Acoustic Emission Monitoring*:

10.2.1 The noise level of each channel or each group shall be continuously or periodically recorded, as required. Pressure or other significant parameters, or both, will normally be recorded to allow correlation with the acoustic emission data response.

10.2.2 When an increase in noise level attributable to a leak has been detected, the examiner shall inform the system owner who will then look for the origin of the leak and its nature. If the leak is found to be outside the area of interest on the structure being monitored (extraneous leak) it must be stopped or reduced to a level necessary to ensure satisfactory monitoring. If extraneous leaks cannot be stopped, then the effect of such signals on the acoustic emission system sensitivity shall be noted. A report shall be prepared following the visual (or other) examination for leaks.

11. Report

11.1 Report the following information:

11.1.1 Date of examination,

11.1.2 Identity of examining personnel,

11.1.3 Sensor characteristics and locations,

11.1.4 Method of coupling sensors to the structure,

11.1.5 Acoustic emission system and its characteristics,

11.1.6 Operating conditions,

11.1.7 Initial calibration records,

11.1.8 In-situ equipment verification results,

11.1.9 Results of measurements,

11.1.10 Analysis and verification of results,

11.1.11 Results of visual (or other) examination(s),

11.1.12 Presentation of the numbers and locations of leaks detected,

11.1.13 Analysis of background noise measurements,

11.1.14 Estimate of quality of measurement and causes of any reduced sensitivity, and

11.1.15 Conclusions and recommendations.

12. Keywords

12.1 acoustic emission; continuous monitoring; hydrotest; leak detection; nondestructive testing; piping systems; pressure vessels

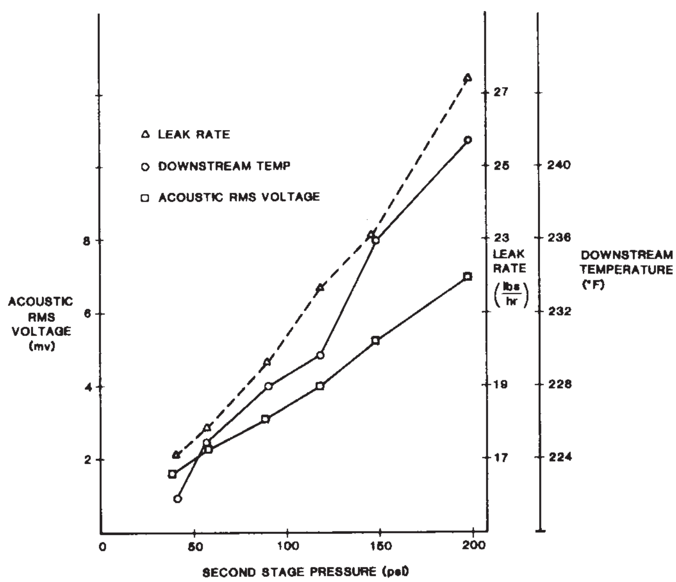
APPENDIX

(Nonmandatory Information)

X1. APPLICATIONS EXAMPLES

X1.1 The following examples were selected to illustrate application of acoustic emission leak detection, and are not intended to provide detailed descriptions of the application.

X1.1.1 *Acoustic Emission Leak Detection of a Safety/Relief Valve*—A safety/relief valve having a leaking pilot-disk seat was examined under laboratory conditions in order to determine the correlation of the leak noise with leak rate or second-stage pressure. The leak rate, downstream temperature, and the RMS voltage of the acoustic signal were plotted against the second-stage pressure in Fig. X1.1. The acoustic emission sensor was clamped onto the external housing of the pilot works. The signal was band-pass filtered in the range from 5 to 10 kHz. The downstream temperature was measured by a thermocouple in the vicinity of the "pilot valve discharge line." As the second stage pressure increased from 40 to 200 psi (280 to 1400 kPa), the leak rate increased 59 %, the temperature increased 9 %, and the acoustic emission RMS voltage increased 370 %. Therefore, the sensitivity of the acoustic detection was excellent (see Fig. X1.1).



NOTE 1—0°F = 32°C.

NOTE 2—1 psi = 6.9 kPa.

FIG. X1.1 Example of Acoustic Emission Leak Detection in a Safety/Relief Valve of a Nuclear Power Plant

X1.1.2 *Acoustic Emission Leak Detection from Seawater Ball Valves*—The U.S. Navy Acoustic Valve Leak Detector (AVLD) monitors leak-associated acoustic emission energy in the frequency range of 10 to 100 kHz. This frequency range was chosen because there is significant energy emitted by leaky valves, and energy in this range is rapidly attenuated with increasing distance from the source. Therefore, background noise can be electronically separated from the signal. Fig. X1.2 shows the estimated leak rate versus acoustic emission level for a 4-in. ball valve.

X1.1.3 *Acoustic Emission Leak Detection of a Submerged Crude Oil Transfer Line*—A section of 12-in. diameter steel pipe terminating on an offshore drilling platform was examined for confirmation of a suspected leak. During acceptance hydro testing of the line it was noted that pressure decayed at about 60 psi/h (410 kPa/h) starting at about 3200 psig (22 MPa). The suspected source of leakage was at the spool piece flanges. Signal level readings were taken on the 12-in. riser on the platform after the pressure on the pipe was elevated to 3200 psig (22 MPa). These signal readings were compared with readings taken on two adjacent pipes, and on the nearest support leg for the structure (see Table X1.1). The additional readings were used to determine the amount of signal that was caused by sea motion and other structural interfering noise.

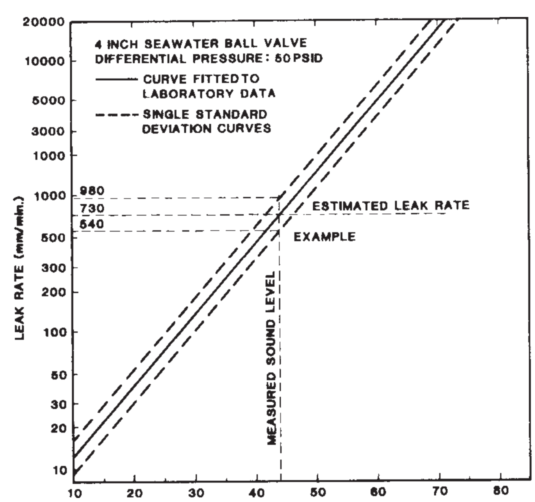


FIG. X1.2 Estimating Leak Rate from Acoustic Emission Level in 4-In. Seawater Ball Valves

TABLE X1.1 Signal Readings

Location	RMS Reading	Comment
6-in. pipe riser	0.200 at 60 dB gain	reference
10-in. pipe riser	0.210 at 60 dB gain	reference
12-in. pipe riser	0.300 at 60 dB gain	leaking pipe
Corner support leg	0.210 at 60 dB gain	reference
Location	RMS Reading	Comment
6-in. pipe riser	0.200 at 60 dB gain	reference
10-in. pipe riser	0.200 at 60 dB gain	reference
12-in. pipe riser	0.200 at 60 dB gain	leak noise is stopped
Corner support leg	0.210 at 60 dB gain	reference

The initial readings were taken with the platform in a shut-down condition and all construction workers onshore. The readings indicated about a 50 % increase in signal level on the leaking pipe as compared to the other two risers and the support leg. This indicated leakage in close proximity to the detection point, in effect, verifying that leakage was in the connecting spool piece flanges. Following tightening by a diver of the identified leaking flange, the acoustic emission examiner determined that the leak had been stopped. No further indications of leakage were detected; either by mechanical means (pressure drop) or by acoustic emission.

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