INTERNATIONAL

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~~An American National Standard~~

Standard Practice for Acoustic Emission Monitoring During Continuous Welding[1]

This standard is issued under the fixed designation E 749; 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 recommended guidelines for acoustic emission (AE) monitoring of weldments during and immediately following their fabrication by continuous welding processes. The technique is in a developmental stage and is not used routinely on production welding. Depending on the results of ongoing research and preproduction weld monitoring experience, these procedures are subject to change before routine implementation on production welds.

1.2 The procedure described in this practice is applicable to the detection and location of AE sources in weldments and in their heat-affected zone during fabrication, particularly in those cases where the time duration of welding is such that fusion and solidification take place while welding is still in progress.

1.3 The effectiveness of acoustic emission to detect discontinuities in the weldment and the heat-affected zone is dependent on the design of the AE system, the ~~calibration~~ AE system verification procedure, the weld process, and the material type. Materials that have been monitored include low-carbon steels, low-alloy steels, stainless steels, and some aluminum alloys. The system performance must be verified for each application by demonstrating that the defects of concern can be detected with the desired reliability.

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:*

[1] This practice is under the jurisdiction of ASTM Committee ~~E-7~~ E07 on Nondestructive Testing and is the direct responsibility of Subcommittee E07.04 on Acoustic Emission.

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E 543 Practice for Evaluating Agencies~~ that Perform~~ Performing Nondestructive Testing[2]
E 569 Practice for Acoustic Emission Monitoring of Structures During Controlled Stimulation[2]
E 650 Guide for Mounting Piezoelectric Acoustic Emission Sensors[2]
E 1316 Terminology for Nondestructive Examinations[2]

2.2 *ASNT Standards:*[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 *Military Standard:*
MIL-STD-410 Nondestructive Testing Personnel Qualification and Certification[4]

3. Terminology

3.1 *Definitions*—For definitions of terms relating to acoustic emission testing, see Section B of Terminology E 1316.

4. Significance and Use

4.1 Detection and location of AE sources in weldments during fabrication may provide information related to the integrity of the weld. Such information may be used to direct repair procedures on the weld or as a guide for application of other nondestructive evaluation (NDE) methods. A major attribute of applying AE for in-process monitoring of welds is the ability of the method to provide immediate real-time information on weld integrity. This feature makes the method useful to lower weld costs by repairing defects at the most convenient point in the production process. The AE activity from discontinuities in the weldment is stimulated by the thermal stresses from the welding process. The AE activity resulting from this stimulation is detected by AE sensors in the vicinity of the weldment which convert the acoustic signals into electronic signals. The AE instrumentation similar to that described in Practice E 569 processes signals and may provide means for immediate display or indication of AE activity and for permanent recordings of the data.

4.2 Items to be considered in preparation and planning for monitoring should include but not be limited to the following:

4.2.1 Description of the system or object to be monitored or examined,

4.2.2 Extent of monitoring, that is, entire weld, cover passes only, and so forth,

4.2.3 Limitations or restrictions on the sensor mounting procedures, if applicable,

4.2.4 Performance parameters to be established and maintained during the~~ calibration~~ AE system verification procedure (sensitivity, locational accuracy, and so forth),

4.2.5 Maximum time interval between system~~ calibration~~ AE system verification checks,

4.2.6 Performance criteria for purchased equipment,

4.2.7 Requirements for permanent records of the AE response, if applicable,

4.2.8 Content and format of testing report, if required, and

4.2.9 Operator qualification and certification, if required.

5. Basis of Application

5.1 *Personnel Qualification:*

~~5.1.1 Nondestructive Testing (NDT)~~

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, MIL-STD-410, 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~~ specified~~ in the contractual agreement between the using parties.

5.1.2 In those cases in which AE monitoring is restricted to use as a production tool to facilitate immediate repair, monitoring during welding may be performed by production personnel lacking the necessary certification; however, certified personnel should verify that proper procedures are implemented.

5.2 *Qualification of Nondestructive Agencies*—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 *Procedures and Techniques*—The procedures and techniques to be used shall be as described in this practice unless otherwise specified. Specific techniques may be specified in the contractual agreement.

6. Examination Preparation

6.1 The following preparatory procedures should be completed before initiating AE monitoring:

6.1.1 Select the location(s) where the sensor(s) will be acoustically coupled. The sensor(s) should be centrally located near the weldment to provide for optimal AE response from all portions of the weld. If the sensor(s) are piezoelectric, this location should

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[2] *Annual Book of ASTM Standards*, Vol 03.03.
[3] Available from American Society of Nondestructive Testing, 1711 Arlingate Plaza, P. O. Box 28518, Columbus, OH 43228-0518.
[4] Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

be such that the maximum temperature stays substantially below the Curie temperature of the sensor(s). Take care in selecting the sensor mounting locations to avoid contact or disturbance, or both, of the sensor by any of the welding or structural positioning equipment. Typical distances from 6 in. to 1 ft (150 to 300 mm) from the heat-affected zone of the weld are usually satisfactory. Typical fixed sensor placement patterns that have been successfully used are shown in Figs. 1-3.

6.1.1.1 If a fixed contact sensor(s) is used, clean the area(s) where attachment will be made to eliminate loose scale, welding flux, or other debris, and attach the sensor in accordance with Guide E 650.

6.1.1.2 If moving sensors are used, clean the coupling path so that uniform sensitivity is maintained as the sensor moves. Fig. 4 shows side and top views of a typical configuration for moving sensors.

6.1.2 Position and route the signal cables connecting the sensor(s) to the AE instrumentation to avoid contacting the hot weld bead or entangling the welding and positioning equipment.

6.1.3 *Adjustment of Apparatus*:

6.1.3.1 After all sensors are mounted, connected, and operational (without objectionable background noise), the AE monitoring system can then be adjusted using an AE simulator.

6.1.3.2 *Gain Adjustment*—To set the gain for a channel, locate the acoustic emission simulator at a selected distance adjacent to the sensor. Monitor the response to the simulated emission, and adjust the channel gain to a specified amplitude level. Repeat this procedure two times, placing the simulator at the same distance from the sensor but at different azimuthal positions relative to the original simulator positions (see Fig. 5). Record the average gain for the three simulator positions. Repeat the entire procedure for each AE sensor on the structure, and adjust the gains. The average gains for all channels should give responses to the simulator that have peak voltages identical to within ±3 dB.

6.1.4 *Determination of Source-Location Accuracy*—Check the operation of the AE source-location function by analyzing simulated AE signals from several random locations in the weld and on the structure, as well as from any specific critical locations. For each placement of the simulator, determine and record the precision and accuracy of the AE location function. It should be noted that the accuracy of locating the simulator source will not necessarily be the same as for locating a real AE source. During trial welding in multipass configurations, it should be verified that location accuracy is maintained during weld buildup. Experiments indicate that location accuracy depends on the percentage completion of multipass welds.

6.2 Check the integrity of the welding ground return system to eliminate the possibility of diverting the weld currents to the AE instrumentation ground.

7. Apparatus

7.1 The AE apparatus normally consists of sensors, electronic instrumentation, and recording devices. Acoustic emission monitoring during welding places many specialized requirements on AE apparatus due to severe environmental factors and interfering noise sources. The following criteria provide guidelines to aid in minimizing these interfering factors, and maximizing the effectiveness of the monitoring process:

7.1.1 *Sensors* should be used that are capable of operating in the temperature range to be encountered. Use of" high-temperature" sensors or waveguides to isolate conventional sensors may be necessary for multipass, high heat input welds, or welds maintained at elevated preheat temperatures. The sensors should be electrically insulated from the structure under test to ensure that the weld current is not coupled into the AE instrumentation. If the weld current is pulsed or has a significant transient component, differential sensors may aid in suppressing interference.

7.1.2 *Frequency Bandpass Filters* are recommended to minimize background noise interference during AE monitoring of welding. A low-frequency limit to the passband in the vicinity of 100 kHz will aid in minimizing background noise due to mechanical noise sources such as grinding, chipping, and manipulation of the structure under test. Radio frequency interference due to contactors and heavy electrical machinery, as well as the welding arc, may be minimized by use of a high-frequency limit to the passband ranging from 500 kHz to 1 MHz. The sensor operating frequency range should be compatible with the above considerations.

7.2 The *Welding Arc* is a low-level continuous source of AE. To minimize interference from the welding arc, the sensitivity of the AE monitoring apparatus should be adjusted so that arc noise is below the trigger threshold. This sensitivity is the maximum usable AE sensitivity for weld monitoring and varies with different welding methods. Table 1 indicates overall gain for a particular system monitoring welding methods and using typical commercial piezoelectric transducers. This table is for general guideline purposes and not for direct reference.

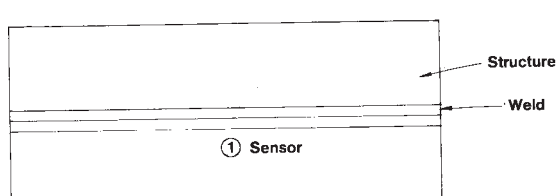

FIG. 1 Typical Sensor Placement for Single Channel AE Monitoring of a Linear Weld

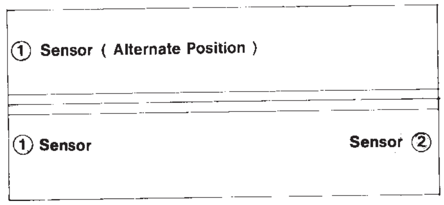

FIG. 2 Typical Sensor Placement for Two-Channel AE Monitoring of a Linear Weld

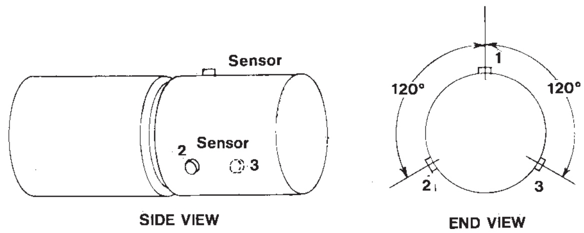

FIG. 3 Typical Sensor Placement for Three-Channel AE Monitoring of a Circular Weld

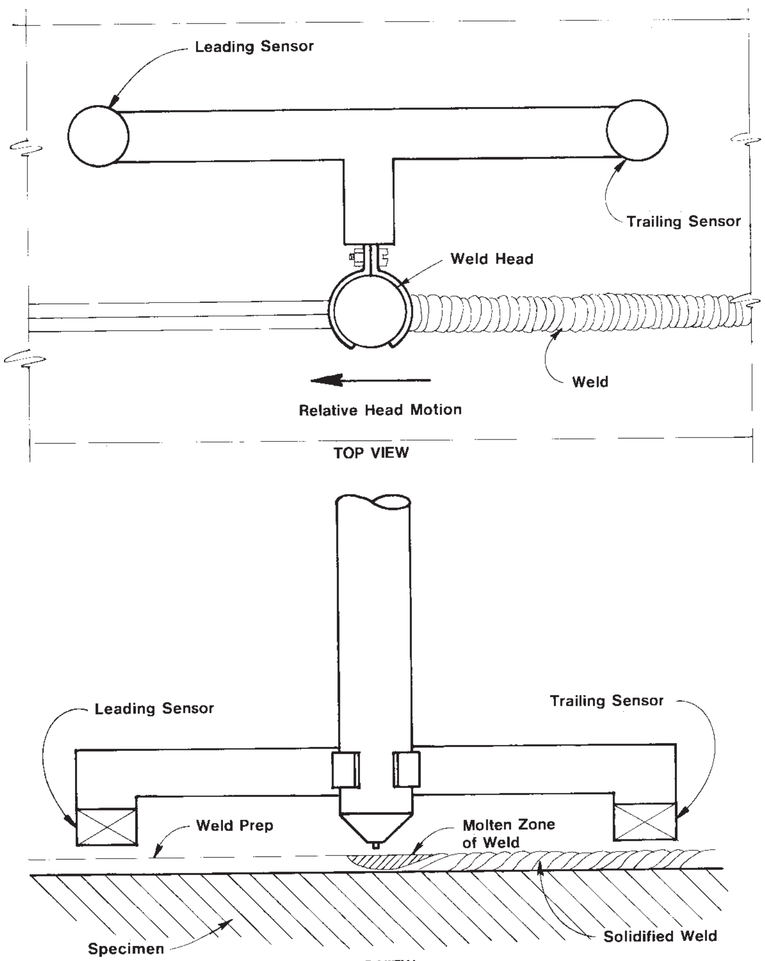

FIG. 4 Moving Sensor Configuration with Sensor Position Fixed Relative to Weld Head

7.3 *Single-Channel AE Instrumentation* employing a single sensor may provide information on the presence of discontinuities in a weld. For low-heat input welds, where the delay time between fusion and AE activity is short, discontinuities may also be located in the weld by noting the presence of unusual AE activity and recording the position of the welding head when such activity occurs. As the weld heat input increases, the delay time between fusion and AE activity usually increases, thus making use of multichannel arrival time interval measurements necessary for AE source location.

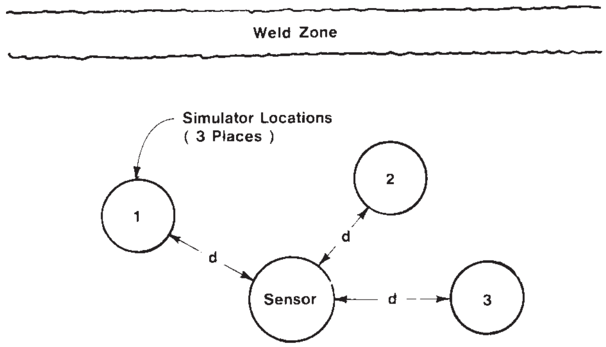

FIG. 5 AE Simulator Positions During Sensor Calibration

TABLE 1 Gain For AE System Utilizing Typical Commercially Available Piezoelectric Sensors Monitoring Typical Weld Methods

Weld Method	AE System Gain Range, dB
Submerged arc (single or tandem wire 800 to 1000 A)	35 to 45
Submerged arc (single wire 400 to 500 A)	45 to 55
Submerged arc (single wire 200 to 400 A)	55 to 65
Gas shielded metal arc (MIG or short arc 150 to 400 A)	50 to 70
Gas shielded tungsten arc (TIG 75 to 250 A)	60 to 80

7.4 The AE apparatus should be capable of providing output signals that are proportional to overall acoustic activity and acoustic emission count rate. In addition, some indication of AE count for each AE event plotted on a time scale, or energy for each event, or peak amplitude for each event similarly plotted is useful for AE monitoring of welds. The latter are particularly useful for acoustically active weld processes such as submerged-arc welding where the presence of solid flux cracking contributes greatly to the AE activity. Experience has shown that for these types of welds, the AE activity from flaws and from normal slag bead cracking may have similar peak amplitudes and energies. To prevent false alarms from acceptable slag bead activity, gated rate monitors can sometimes be used to identify flaw activity which generally consists of groups of AE events occurring at much higher rates than the rate of slag bead events.

8. Examination Procedures

8.1 Acoustic emission data may be accumulated during the welding process. Due to the delay between weld fusion and AE activity, monitoring must continue for a time period following welding to acquire all significant AE data. The AE monitoring time after welding increases with increasing weld heat input, ranging from 10 s for manual gas tungsten (approximately 100 A) to more than 2 min for submerged arc welding (600 to 800 A). The time should be established during developmental monitoring of trial welds.

8.2 The gain-setting procedure should be reapplied at the completion of a weld. For heavy section welds that may take many days to complete, the gain-setting procedure should be reapplied at least once during every work shift (for example, 8 h). All changes in system gain or source location accuracy should be recorded and the system readjusted as necessary.

8.3 Observable conditions that occur in conjunction with unusual AE activity should be recorded to aid in later interpretation of the data. This would include cleanup or chipping and grinding by the welder, for example.

9. Examination Records

9.1 The examination records should contain the following information:

~~9.1.1 Calibration~~

9.1.1 AE system verification data and instrument adjustments (including equipment description and performance data),

9.1.2 Monitoring procedure developed on trial welds,

9.1.3 Material and physical characteristics of the structure,

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

9.1.5 Sensor location(s),

9.1.6 Schedule, procedure, and results of all ~~calibrations,~~ AE system verifications, and

9.1.7 Permanent record of AE indications as defined in Section 9 .

10. Interpretation of Results

10.1 When repairs are made during welding, records of locations are not required. If repairs are made after welding, summarize all results on an appropriate layout map of the weld, or in tabular form, for ready reference and interpretation.

10.2 In general, acoustic emission weld data must be evaluated against a baseline obtained from known acceptable welds of a given type using the specific AE system and from the AE signals from known defects in the same weld type. Significant weld discontinuities may be characterized by increased AE event count, increased rate of AE events, increased AE intensity, or peak amplitude.

11. Report

11.1 If a report is required, it should contain the examination records and interpretation of results.

12. Keywords

12.1 continuous welding; fusion solidification; heat-affected zone; high-temperature sensors; in-process defect location; thermal stress; wave guides