Designation: E 751 – 96

An American National Standard

Standard Practice for Acoustic Emission Monitoring During Resistance Spot-Welding[1]

This standard is issued under the fixed designation E 751; 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 procedures for the measurement, processing, and interpretation of the acoustic emission (AE) response associated with selected stages of the resistance spot-welding process.

1.2 This practice also provides guidelines for feedback control by utilizing the measured AE response signals during the spot-welding process.

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 Evaluating Agencies that Perform Nondestructive Testing[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 The AE produced during the production of a spot-weld can be related to weld quality parameters such as the strength and size of the nugget, the amount of expulsion, and the amount of cracking. Therefore, in-process AE monitoring can be used both as an examination method, and as a means for providing feedback control.

5. Basis of Application

5.1 *Personnel Qualification*—Nondestructive Testing (NDT) personnel 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, or similar document. The practice or standard used and its applicable revision shall be specified in the contractual agreement between the using parties.

5.2 *Qualification of Nondestructive Agencies*—If specified in the contractual agreement, NDT agencies shall be qualified and evaluated in accordance with 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. Ordering Information

6.1 If the spot-weld monitoring or process control methods described in this practice are performed as a service, the following items should be addressed in the purchase specification, and are subject to agreement between the purchaser and the supplier:

6.1.1 Description of the welded parts in terms of geometry, dimensions, number and position of welds, and materials.

6.1.2 Description of the welding machine, type and dimensions of the electrodes, type of weld controller, welding schedule, and distance between the welding head and the controller.

6.1.3 Location and mounting method for the acoustic emission sensors, and design of the mounting fixture, as appropriate.

6.1.4 In the event that the process is actually controlled by acoustic emission, the circuit requirements associated with the electronic interface to the weld controller to ensure synchronous operation.

6.1.5 The performance and limiting AE parameters which were predetermined.

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

Current edition approved May 10, 1996. Published July 1996. Originally published as E 751 – 80. Last previous edition E 751 – 80 (1991)$^{\epsilon 1}$.

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

[3] Available from American Society for 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.

6.1.6 Method of recording or reporting (that is, form and content of the report), if applicable.

6.1.7 Technical qualifications of the personnel performing the examination. These should be based on a documented program that certifies personnel for conducting AE examinations.

7. Principles of Application

7.1 The resistance spot-welding process consists of several stages. These are the set-down of the electrodes, squeeze, current flow, forging, hold time, and lift-off. Various types of acoustic emission signals are produced during each of these stages. Often, these signals can be identified with respect to the nature of their source. The individual signal elements may be greatly different, or totally absent, in various materials, thicknesses, and so forth. Fig. 1 is a schematic representation showing typical signal elements which may be present in the AE signature from a given spot-weld.

7.2 Most of the depicted AE signal features can be related to factors of weld quality. The AE occurring during set-down and squeeze can often be related to the condition of the electrodes and the surface of the parts. The large, often brief, signal at current initiation can be related to the initial resistance, and the cleanliness of the part. For example, burning through of certain oxide layers contributes to the acoustic emission response during this time.

7.2.1 During current flow, plastic deformation, nugget expansion, friction, melting, and expulsions produce AE signals. The signals caused by expulsion (spitting or flashing, or both) generally have large amplitudes and can be distinguished from the rest of the acoustic emission associated with nugget formation. Fig. 2 shows typical AE response signals during current flow for both d-c and a-c welding.

7.2.2 Following termination of the welding current, some materials exhibit appreciable AE noise during solidification which can be related to nugget size and inclusions. As the nugget cools during the hold period, AE can result from solid-solid phase transformations and cracking.

7.2.3 During the lift-off stage, separation of the electrode from the part produces signals that can be related to the condition of the electrode as well as the cosmetic condition of the weld.

7.3 Using time, and amplitude or energy discrimination, or both, the AE response corresponding to each stage can be separately detected and analyzed. Although the AE associated with each stage of the spot-welding process can be relevant to weld quality, this practice only gives detailed consideration to the AE generated by nugget formation and expansion, expulsion, and cracking.

8. Apparatus

8.1 *Acoustic Emission System*:

8.1.1 The AE sensor should be a contacting type having an appropriate frequency response within the range from 0.1 to 1.0 MHz. Free resonances associated with electrode vibrations may necessitate the use of sensors with a frequency response in the range from 0.30 to 1.0 MHz.

8.1.2 The electronic instrument should contain adjustable amplification over the range from 40 to 100 dB, or an equivalent amplification and adjustable threshold. The instrument should be capable of performing time and amplitude or energy discrimination. Using some timing reference, it is necessary to detect the AE contained within a certain time interval and within a certain signal or energy amplitude range. This is required for each characteristic stage of the AE signal that is to be separately measured. Thus, the instrument should contain one or more signal amplitude or energy level detectors, timing gates, and counters. It should also contain a comparator and signaling output if it is used for on-line monitoring.

8.1.3 If feedback control is to be used, the instrument should

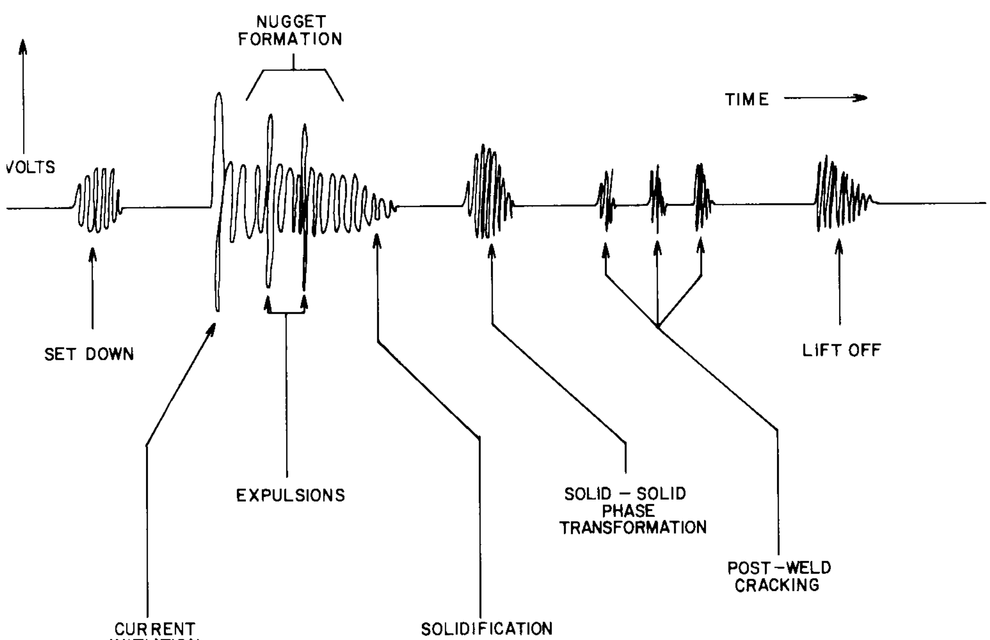

FIG. 1 Typical AE Response Signals During Resistance Spot Welding

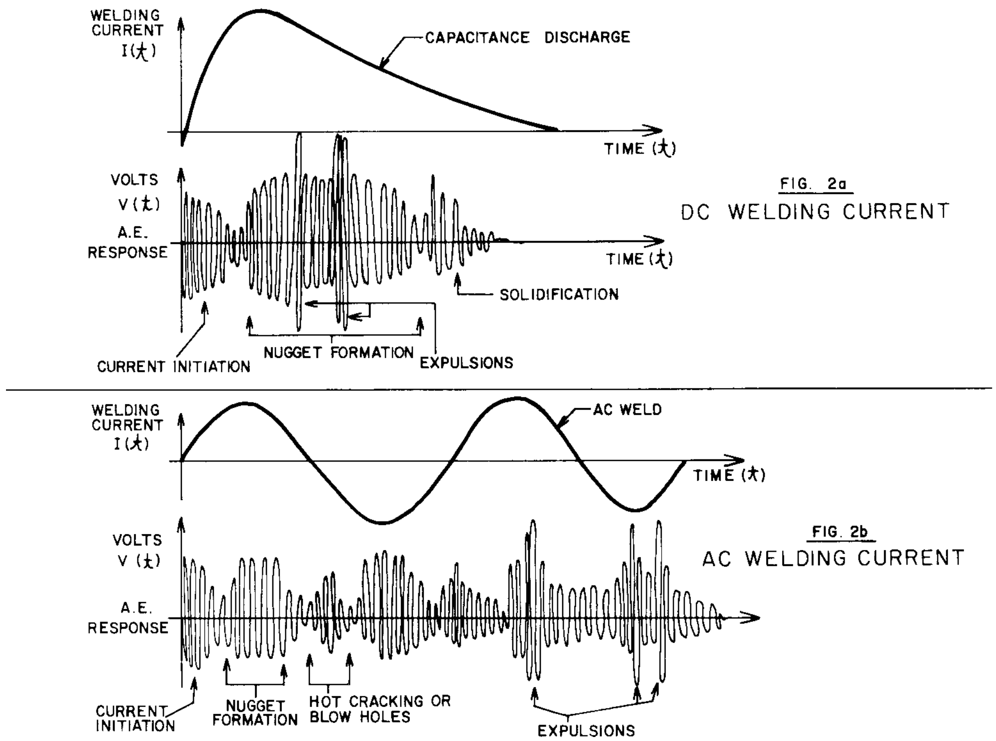

FIG. 2 Typical AE Response Signals During Current Flow

facilitate the selection of an optimum AE level, and it should generate an appropriate control signal whenever this level is exceeded. This control signal should terminate the welding synchronously with the zero-crossing points of the weld current.

8.2 *Support Equipment*—An analog or digital waveform recorder is normally used for performing measurements. A means for detecting current initiation independent from the AE signals should be available.

8.3 *Data-Recording Devices* (optional)—If it is desired to record processed AE data permanently, a digital printer, tape recorder, or similar device must be interfaced with the AE instrument.

8.4 *Audio or Visual Alarm*—An alarm can be used in applications where the acceptability of individual spot welds is to be determined in real-time, and where no record of rejected welds is necessary.

8.5 *Print-out Device*—A print-out device may be used to provide a permanent record, and it is usually employed as follows:

8.5.1 Whenever a permanent record is necessary to document the quality of individual welds, the printer should print out such information as is necessary to segregate and identify rejectable welds.

8.5.2 When the joined parts contain a large number of spot-welds, and the integrity of the product does not depend on the quality of individual welds but rather on the number of unacceptable welds expressed as a percentage of the total number of welds. The print-out should consist of a weld sequence number and a running percentage of unacceptable welds when the individual spot-welds are identifiable by sequence number.

8.5.3 If weld identification is not possible, then the welding apparatus should be equipped with an automatic marking attachment. With the markings and the records, the acceptability of the welded part can be based on the percentage of unacceptable welds and their location distribution.

9. Procedure

9.1 *Sensor and Preamplifier Attachment*—The sensor should be mounted to the lower (grounded) electrode or electrode holder. If the measurements are to be made only as a periodic sampling of weld quality, a liquid couplant may be used provided that it is periodically replenished and calibration of the system response is maintained. For sustained monitoring, such as on-line AE examination or control of each nugget, the sensor should be permanently mounted using an epoxy adhesive or a similar material. A preamplifier is usually positioned near the sensor. However, when the instrumentation is located less than 1 m from the sensor, the gain otherwise supplied by the preamplifier may be incorporated into the main amplifier of the instrument.

9.2 *Preliminary Measurements*—The AE signal from a single spot-weld should be displayed on a waveform recorder. A wire coil or Hall effect sensor positioned near an electrode can be used as a current sensor, thus providing a timing reference and trigger signal for viewing and measuring the AE signal. This reference signal can be also obtained through an appropriate interconnection to the weld controller. Having established a typical AE trace, characteristic stages should be identified and one or more selected as an AE examination parameter. For example, weld quality indicators may be obtained from the AE response to nugget formation, expulsion, or cracking.

9.2.1 *New Applications*—If the instrumentation was not previously applied to a specific welding problem, preliminary