



Designation: **E1888/E1888M – 12 E1888/E1888M – 17**

## Standard Practice for Acoustic Emission Examination of Pressurized Containers Made of Fiberglass Reinforced Plastic with Balsa Wood Cores<sup>1</sup>

This standard is issued under the fixed designation E1888/E1888M; 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 ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

### 1. Scope\*

1.1 This practice covers guidelines for acoustic emission (AE) examinations of pressurized containers made of fiberglass reinforced plastic (FRP) with balsa cores. Containers of this type are commonly used on tank trailers for the transport of hazardous chemicals.

1.2 This practice is limited to cylindrical shape containers, 0.5 m [20 in.] to 3 m [120 in.] in diameter, of sandwich construction with balsa wood core and over 30 % glass (by weight) FRP skins. Reinforcing material may be mat, roving, cloth, unidirectional layers, or a combination thereof. There is no restriction with regard to fabrication technique or method of design.

1.3 This practice is limited to containers that are designed for less than 0.520 MPa [75.4 psi] (gage) above static pressure head due to contents.

1.4 This practice does not specify a time interval between examinations for re-qualification of a pressure container.

1.5 This practice is used to determine if a container is suitable for service or if follow-up NDT is needed before that determination can be made.

1.6 Containers that operate with a vacuum are not within the scope of this practice.

1.7 Repair procedures are not within the scope of this practice.

1.8 The values stated in either SI units or inch-pound units are to be regarded separately 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 standard.

1.9 *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.* Specific precautionary statements are given in Section 8.

1.10 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

### 2. Referenced Documents

2.1 *ASTM Standards:*<sup>2</sup>

[E543 Specification for Agencies Performing Nondestructive Testing](#)

[E750 Practice for Characterizing Acoustic Emission Instrumentation](#)

[E976 Guide for Determining the Reproducibility of Acoustic Emission Sensor Response](#)

[E1067 Practice for Acoustic Emission Examination of Fiberglass Reinforced Plastic Resin \(FRP\) Tanks/Vessels](#)

[E1106 Test Method for Primary Calibration of Acoustic Emission Sensors](#)

[E1316 Terminology for Nondestructive Examinations](#)

[E1781 Practice for Secondary Calibration of Acoustic Emission Sensors](#)

<sup>1</sup> 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.

Current edition approved June 15, 2012; June 1, 2017. Published July 2012; June 2017. Originally approved in 1997. Last previous edition approved in 2007; 2012 as E1888/E1888M – 07; E1888/E1888M – 12. DOI: 10.1520/E1888\_E1888M-12; 10.1520/E1888\_E1888M-17.

<sup>2</sup> 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.

\*A Summary of Changes section appears at the end of this standard

E2374 Guide for Acoustic Emission System Performance Verification

2.2 SPI/CARP Standards:<sup>3</sup>

Recommended Practice for Acoustic Emission Testing of Fiberglass Reinforced Plastic Resin (FRP) Tanks/Vessels  
Recommended Practice for Acoustic Emission Testing of Fiberglass Reinforced Plastic Piping Systems

2.3 ANSI/ASNT Standards:<sup>4</sup>

SNT-TC-1A Recommended Practice for Personnel Qualification and Certification in Nondestructive Testing  
ANSI/ASNT CP-189 Standard for Qualification and Certification of NDT Personnel

2.4 AIA Standard:<sup>5</sup>

NAS-410 Nondestructive Testing Personnel Qualification and Certification

2.5 ASME Standard:<sup>6</sup>

Section V, Article 11, Boiler and Pressure Vessel Code

2.6 ISO Standard:<sup>7</sup>

ISO 9712 Non-Destructive Testing: Qualification and Certification of NDT Personnel

### 3. Terminology

3.1 *Definitions*—With the exception of terms defined in 3.2, this practice incorporates by reference all terminology in Terminology E1316 and Practice E1067. First occurrences of terms defined herein are italicized.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *AE trend number*—a number used to designate trends in AE activity which are exhibited by structures during a set of repeated loading cycles (see 9.2).

3.2.2 *Minimum AE activity level*—that level of activity below which AE trend numbers are not robust indicators of the trend (see 9.1)

3.2.3 *Examination pressure*—the highest pressure used while examining a given container. The examination pressure is 1.1 times the maximum allowable working pressure, MAWP (see Section 8).

### 4. Significance and Use

4.1 This practice does not rely on absolute quantities of AE parameters. It relies on trends of cumulative AE counts that are measured during a specified sequence of loading cycles. This practice includes an example of examination settings and acceptance criteria as a nonmandatory appendix.

4.2 Acoustic emission (AE) counts were used as a measure of AE activity during development of this practice. Cumulative hit duration may be used instead of cumulative counts if a correlation between the two is determined. Several processes can occur within the structure under examination. Some may indicate unacceptable flaws (for example, growing resin cracks, fiber fracture, delamination). Others may produce AE but have no structural significance (for example, rubbing at interfaces). The methodology described in this practice prevents contamination of structurally significant data with emission from insignificant sources.

4.3 *Background Noise*—Background noise can distort interpretations of AE data and can preclude completion of an examination. Examination personnel should be aware of sources of background noise at the time examinations are conducted. AE examinations should not be conducted until such noise is substantially eliminated.

4.4 *Mechanical Background Noise*—Mechanical background noise is generally induced by structural contact with the container under examination. Examples are: personnel contact, wind borne sand or rain. Also, leaks at pipe connections may produce background noise.

4.5 *Electronic Noise*—Electronic noise such as electromagnetic interference (EMI) and radio frequency interference (RFI) can be caused by electric motors, overhead cranes, electrical storms, welders, etc.

4.6 *Airborne Background Noise*—Airborne background noise can be produced by gas leaks in nearby equipment.

4.7 Accuracy of the results from this practice can be influenced by factors related to setup and calibration of instrumentation, background noise, material properties, and structural characteristics.

### 5. Basis of Application

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

5.2 *Personnel Qualification:*

<sup>3</sup> Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, <http://www.ansi.org>.

<sup>4</sup> Available from American Society for Nondestructive Testing (ASNT), P.O. Box 28518, 1711 Arlingate Ln., Columbus, OH 43228-0518, <http://www.asnt.org>.

<sup>5</sup> Available from Aerospace Industries Association of America, Inc. (AIA), 1000 Wilson Blvd., Suite 1700, Arlington, VA 22209-3928, <http://www.aia-aerospace.org>.

<sup>6</sup> Available from American Society of Mechanical Engineers (ASME), ASME International Headquarters, Three Park Ave., New York, NY 10016-5990, <http://www.asme.org>.

<sup>7</sup> Available from International Organization for Standardization (ISO), ISO Central Secretariat, BIBC II, Chemin de Blandonnet 8, CP 401, 1214 Vernier, Geneva, Switzerland, <http://www.iso.org>.

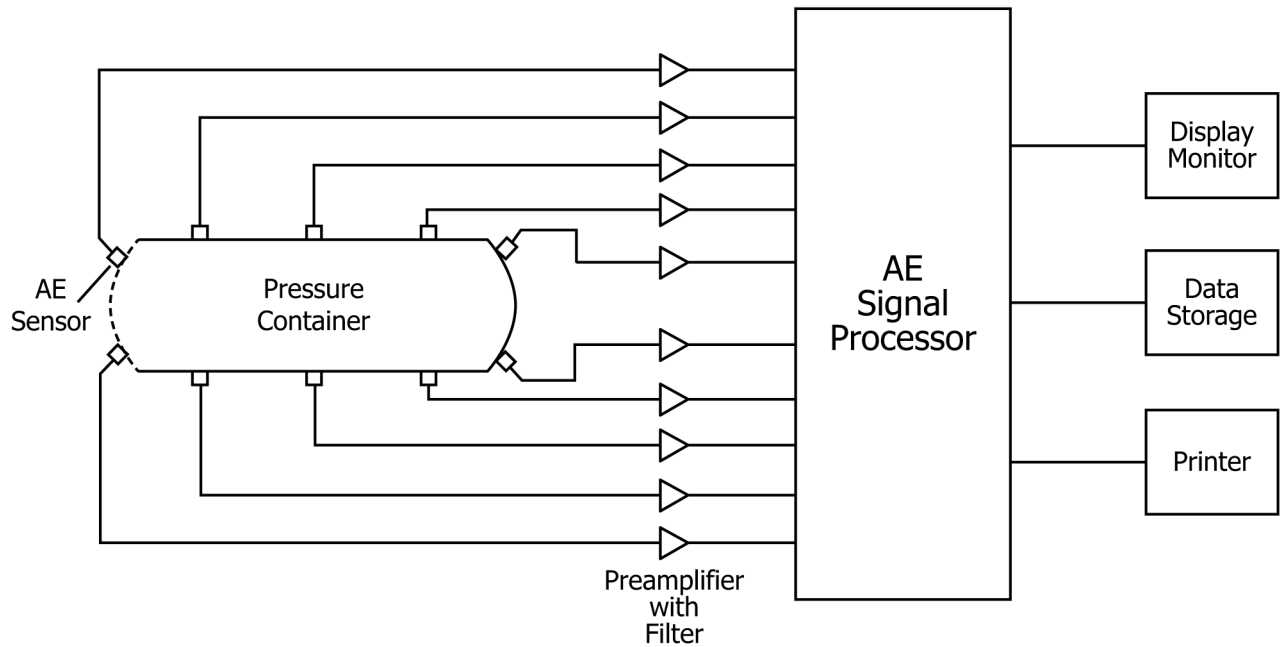


FIG. 1 Recommended Features of the Apparatus

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, ISO 9712, 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.

5.2.2 Also, it is required that personnel performing acoustic emission examination of containers be trained, by attending a dedicated training course on the subject and passing a written examination. The training course shall include appropriate material for NDT Level II qualification in accordance with a recognized NDT personnel qualification practice or standard per 5.2.1. Personnel shall be trained/examined on the following topics:

5.2.2.1 Container construction and terminology,

5.2.2.2 Mechanisms of AE generation in FRP including containers within the scope of this practice,

5.2.2.3 AE instrumentation,

5.2.2.4 Container examination procedures, including loading requirements,

5.2.2.5 Data collection and interpretation, and

5.2.2.6 Examination report and permanent record requirements.

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 1.4 – 1.7 unless otherwise specified.

5.5 *Procedures and Techniques*—The procedures and techniques to be utilized shall be specified in the contractual agreement.

5.6 *Extent of Examination*—The extent of examination shall be in accordance with paragraph 1.2, unless otherwise specified.

5.7 *Reporting Criteria/Acceptance Criteria*—Reporting criteria/acceptance criteria shall be in accordance with Sections 9 and 10 unless otherwise specified.

5.8 *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. Apparatus

6.1 Recommended features of the apparatus required for this practice are provided in Fig. 1. Full specifications are in Annex A1.

6.2 Couplant must be used to acoustically connect sensors to the vessel surface. Adhesives that have acceptable acoustic properties and adhesives used in combination with traditional couplants are acceptable.

6.3 Sensors may be held in place with elastic straps, adhesive tape, or other mechanical means.

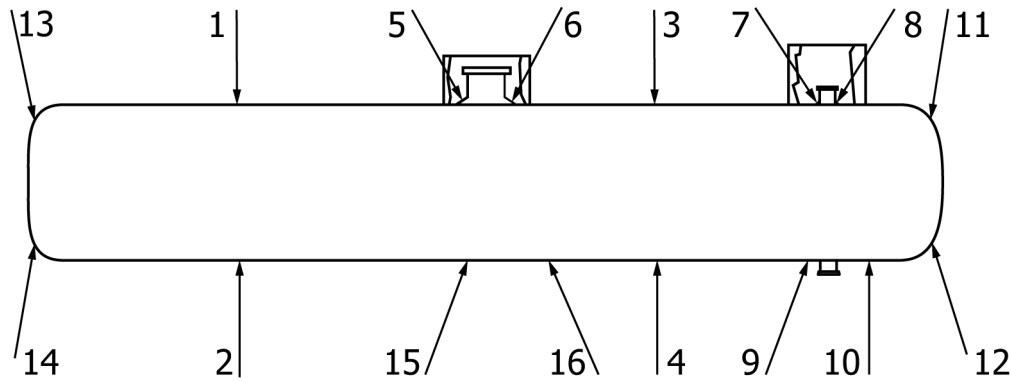


FIG. 2 Typical Examination Configuration Showing AE Sensor Location on a Road Tanker

6.4 Sensor spacing shall be such that a standard 0.5 mm [0.02 in.], 2H pencil lead break (See Guide E976) on any part of a liquid filled container is detected by at least one AE sensor. A 0.3 mm [0.012 in.], 2H pencil lead break may be used which would reduce the sensor spacing. Presence of heads, manholes, and nozzles shall be considered when sensor locations are selected. Fig. 2 shows a typical sensor location scheme for a vessel of 10.8 m [424 in.] length and 1.8 m [72 in.] diameter.

6.4.1 *Attenuation Characterization*—Typical signal propagation losses shall be determined according to the following procedure. This procedure provides a relative measure of the attenuation but may not be representative of a genuine AE source. It should be noted that the peak amplitude from a mechanical pencil lead break may vary with surface hardness, resin condition and cure. Select a representative region of the vessel with clear access along the cylindrical section. Mount an AE sensor and mark off distances of 15 cm [6 in.] and 30 cm [12 in.] from the center of the sensor along a line parallel to the principal direction of the surface fiber. Select two additional points on the surface of the vessel at 15 cm [6 in.] and 30 cm [12 in.] along a line inclined 45 and 90° to the principal direction of the surface fiber, break pencil leads (0.3 mm [0.012 in.] 2H, rather than 0.5 mm [0.02 in.] to avoid possible saturation due to larger signal output) and record peak amplitude. All lead breaks shall be done at an angle of approximately 30° to the surface with a 2.54 mm [0.1 in.] lead extension. The attenuation data shall be retained as part of the original experimental record.

6.4.2 In addition, record the distances from the center of the sensor to the points where hits are no longer detected. Repeat this procedure along lines inclined 45 and 90° to the direction of the original line. The data shall be retained as part of the original experimental record. The minimum distance from the sensor at which the pencil lead break can no longer be detected is known as the threshold distance.

6.5 Acoustic emission sensors are used to detect strain induced stress waves produced by discontinuities. Sensors must be held in contact with the vessel wall to ensure adequate acoustic coupling.

6.6 A preamplifier may be enclosed in the sensor housing or in a separate enclosure. If a separate preamplifier is used, cable length between sensor and preamplifier must not exceed 2 m [78 in.].

6.7 Power/signal cable length (that is, cable between preamplifier and signal processor) shall not exceed 150 m [500 ft].

6.8 Signal processors are computerized instruments with independent channels that filter, measure and convert analog information into digital form for display and permanent storage. A signal processor must have sufficient speed and capacity to independently process data from all sensors simultaneously. The signal processor should provide capability to filter data for replay.

6.9 A video monitor should display processed data in various formats. Display format may be selected by the examiner.

6.10 A data storage device, such as a hard disc or removable media (CD, DVD, or other) device, may be used to provide access data for replay or for archives:archival.

6.11 Hard copy capability should be available from a printer or equivalent output device.

## 7. Calibration and System Performance Verification

7.1 Perform annual calibration and verification of pressure transducer, transducers, AE sensors, preamplifiers (if applicable), signal processor (particularly the signal processor time reference) and AE electronic waveform generator. Adjust equipment 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).

7.2 Perform routine electronic evaluations on a monthly basis-basis, before each examination or at any time there is concern about signal processor performance. Use an AE electronic waveform generator in making evaluations. Each signal processor channel must respond with peak amplitude reading within  $\pm 2$  dB of the expected output value (based on input signal value and amplifier gain values).



TABLE 1 Load Schedule

Cycle Number	Maximum Pressure
1	1/3 Examination Pressure
2	2/3 Examination Pressure
3 to 6	Full Examination Pressure

7.3 Perform routine evaluation of each sensor on a monthly basis, before each examination, or at any time there is concern about the sensors performance. Record peak amplitude response and electronic noise level. Sensors can be stimulated by a pencil lead break or electronic waveform generator with a pulser. Replace sensors that are found to have peak amplitudes or electronic noise more than 5 dB greater or less than the average of the group of sensors to be used during the examination.

7.4 A system performance verification must be conducted immediately before and immediately after each examination (see Guide E2374). A performance check uses a mechanical device to induce stress waves into the vessel wall at a specified distance from each sensor. Induced stress waves stimulate a sensor in the same way as emission from a discontinuity. Performance checks verify performance of the entire system (including couplant).

7.4.1 The preferred technique for conducting a performance check is a pencil lead break. Lead should be broken on the vessel surface no less than 10 cm [4 in.] from the sensor. A 2H lead, 0.3 mm [0.012 in.] diameter, with a 2–3 mm [0.08–0.12 in.] long lead extension should be used (see Fig 4–5 of Guide E976).

## 8. Procedure

8.1 Use liquid (normally water) for the pressure medium. Support containers that are not mounted on a truck frame (as closely as is practical) like in service. Support shall be such as to minimize extraneous noise. Examination data are used to compute “AE trend numbers”. These can be computed while the examination is in progress. These are defined in 9.2.

8.1.1 Apply pre-examination simulated AE to the (liquid filled) container 200 mm [7.9 in.] from each sensor. Include simulated AE counts in examination reports. Make at least five lead breaks, along a 20 cm [8 in.] radius circle, around each sensor. Their average shall be at least  $N_c$  counts per lead break (see X2.2). If fewer counts are measured, examine the system and identify sensor, cable, electronics, coupling or vessel characteristic as cause for low sensitivity. If a system component caused low sensitivity, it should be corrected. If a structural characteristic caused low sensitivity, that should be reported with simulated AE counts.

NOTE 1—Low counts may indicate damaged structure.

### 8.2 Loading:

#### 8.2.1 Pre-Examination Loading:

8.2.1.1 New containers are pre-loaded to 1.15 times MAWP and pressure is held for 20 min, prior to the AE examination. Vent all vessels for at least 15 h prior to the AE examination. Following that, examine the container with the loading schedule in 8.2.2.

8.2.1.2 Treat containers that have been repaired like new containers.

8.2.1.3 Do not pre-load containers that were taken from service.

#### 8.2.2 Examination Loading:

8.2.2.1 Examination pressure shall be equal to 1.1 times MAWP pressure. The load schedule shall be as shown in Table 1 and Fig. 3.

8.2.2.2 Uniformly apply load at a rate less than 10 % of the examination pressure per minute. Load rate shall be as uniform as possible. Remove load, uniformly, at a rate no greater than 10 % of the examination pressure per minute.

8.2.2.3 Background noise should be minimized. Minimize false AE from liquid entering the container during loading by reducing flow rate.

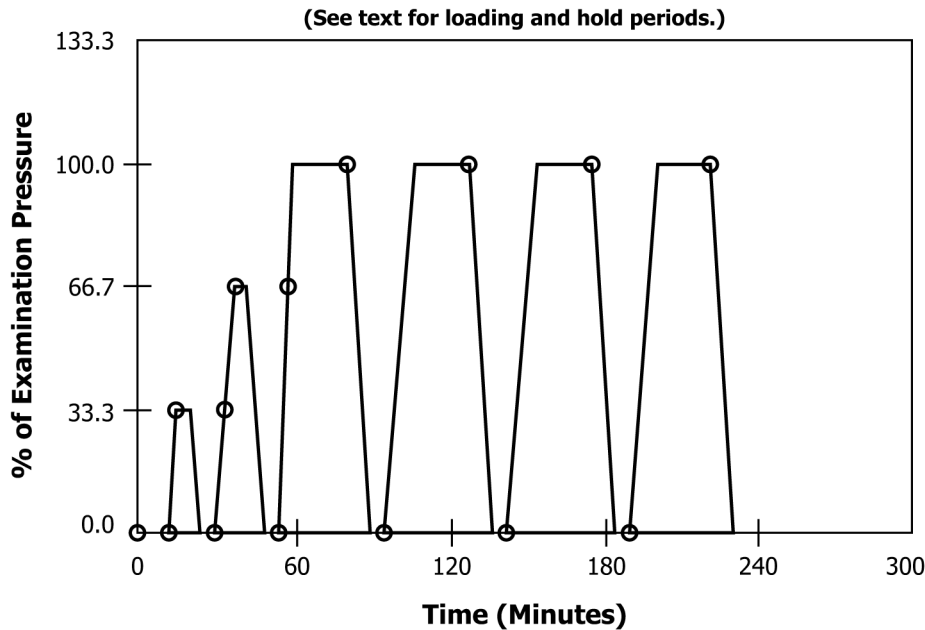
8.2.2.4 Monitor noise from the environment during an initial hold period of at least 10 min. If background noise cannot be eliminated prior to data acquisition, interrupt the examination. Correct background noise problems before examination is resumed or repeated.

8.2.2.5 Duration of hold periods at examination pressure shall be at least 20 min and shall be constant ( $\pm 1$  %) throughout the examination. Duration of all other hold periods shall be 5 min. Pressure fluctuations during hold period shall be limited to  $\pm 1$  % of examination pressure or 2 kPa [0.3 psi], whichever is greater. If pressure has exceeded 2/3 examination pressure, and examination sequence has been interrupted for more than 30 min, release pressure and do not resume the examination until 15 h have passed.

8.3 Zone Location—AE sources are located by noting which sensor first indicates occurrence of an AE event. The source is located near that sensor. Misleading results can be caused by effects of liquid in the container, fiber orientation on stress wave propagation paths, or differences in characteristics of AE signal processor channels. Also the number of sensors used (that is, sensor location density) must be considered when zone location is used effectively.

## 9. Interpretation of Results

9.1 General—Cumulative AE counts from each signal processor channel are used to determine structural integrity of containers. AE trend numbers are measures of trends in AE activity that are observed over repeated loadings. Relative magnitudes of trend



NOTE 1—Circles indicate points at which AE data must be recorded.

FIG. 3 Recommended Loading Schedule for Examining Pressure Containers Using AE Monitoring

numbers from cycle to cycle are used to make accept/reject decisions. Pressure levels and hold durations must be the same if trend number are to be meaningful. Furthermore, AE activity must exceed a certain minimum level before a trend number can be meaningful. If less than minimum AE activity is recorded, the trend number cannot be used. The demarcation value of minimum AE activity, for each channel is:

$$n = 12 \times C \quad (1)$$

where:  $C$  is the average AE count from all lead breaks made during execution of the procedure 8.1.

## 9.2 Definition of AE Trend Number:

9.2.1 In general, an AE trend number is defined as follows:

$$Z_c^{i,j} = A_c^{i,j} / A_c^{f,j} \quad (2)$$

where:

$i$  = cycle number (it ranges from 1 to 6),

$j$  = load level:

$j=1$ , load is  $\frac{1}{3}$  examination pressure

$j=2$ , load is  $\frac{2}{3}$  examination pressure

$j=3$ , load is examination pressure,

$c$  = signal-processor channel number,

$f$  = first cycle where pressure level “ $j$ ” is reached, and

$A_c^{i,j}$  = cumulative AE counts in cycle “ $i$ ”, from load = 0, to load level “ $j$ ” including hold periods (where applicable).

With trend numbers, AE activity is normalized with respect to activity during the initial cycle, at a given load. An example of calculation of trend numbers from examination data is shown in Appendix X1. Trend numbers must be calculated to two decimal places.

## 9.3 Use of Trend Numbers:

9.3.1 *Load Levels  $j = 1$  and 2*—Calculate trend numbers as data becomes available during an examination. However, these numbers shall not be basis for acceptance or rejection. These numbers may be used to detect potential critical situations. If AE trend numbers decrease at a given load as cycle number increases, the container is probably acceptable. If they do not decrease special caution is warranted; examination personnel may decide to terminate the examination.

9.3.2 *Full Examination Pressure (Load Level  $j=3$ )*—Use for acceptance or rejection by following the steps in Appendix X3. If AE trend numbers decrease at a given load as cycle number increases, the container is probably acceptable. If they do not decrease, special caution is warranted; examination personnel may decide to terminate the examination.

## 10. Report

10.1 As a minimum requirement, an examination report shall identify and describe; the container, examination conditions, examination date and results from pencil lead breaks (before and after examination). Also, include examination instrumentation