Designation: E2191/E2191M – 16

Standard Practice for Examination of Gas-Filled Filament-Wound Composite Pressure Vessels Using Acoustic Emission[1]

This standard is issued under the fixed designation E2191/E2191M; 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 guidelines for acoustic emission (AE) examination of filament-wound composite pressure vessels, for example, the type used for fuel tanks in vehicles which use natural gas fuel.

1.2 This practice requires pressurization to a level equal to or greater than what is encountered in normal use. The tanks' pressurization history must be known in order to use this practice. Pressurization medium may be gas or liquid.

1.3 This practice is limited to vessels designed for less than 275 bar [4,000 psi] maximum allowable working pressure and water volume less than 1 m^3 or 1000 L [35.4 ft^3].

1.4 AE measurements are used to detect emission sources. Other nondestructive examination (NDE) methods may be used to gain additional insight into the emission source. Procedures for other NDE methods are beyond the scope of this practice.

1.5 This practice applies to examination of new and in-service, Type II, filament-wound composite pressure vessels.

1.6 This practice applies to examinations conducted at ambient temperatures above 20°C [70°F]. This practice may be used at ambient temperatures below 20°C [70°F] if provision has been made to fill to the tank's rated pressure at 20°C [70°F]. Also that the test temperature must not exceed the glass transition temperature of the matrix material.

1.7 *Units*—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.

1.8 *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.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

E543 Specification for Agencies Performing Nondestructive Testing

E650 Guide for Mounting Piezoelectric Acoustic Emission Sensors

E976 Guide for Determining the Reproducibility of Acoustic Emission Sensor Response

E1316 Terminology for Nondestructive Examinations

E2374 Guide for Acoustic Emission System Performance Verification

2.2 *Natural Gas Vehicle Standard:*[3]

American National Standard for Basic Requirements for Compressed Natural Gas Vehicle (NGV) Fuel Containers ANSI/AGA/NGV2

2.3 *Compressed Gas Association Standard:*[4]

Pamphlet C-6.4, Methods for Visual Inspection of AGA NGV2 Containers

2.4 *U.S. Department of Transportation Reference:*[5]

NHTSA Federal Motor Vehicle Safety Standard No. 304, March 27, 1995

2.5 *ASNT Standards:*[6]

ANSI/ASNT CP-189, Standard for Qualification and Certification of Nondestructive Testing Personnel

SNT-TC-1A, Recommended Practice for Nondestructive Testing Personnel Qualification and Certification

[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.

Current edition approved Feb. 1, 2016. Published February 2016. Originally approved in 2002. Last previous edition approved in 2010 as E2191 - 10. DOI: 10.1520/E2191_E2191M-16.

[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 National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.

[4] Available from Compressed Gas Association (CGA), 4221 Walney Rd., 5th Floor, Chantilly, VA 20151-2923, http://www.cganet.com.

[5] Available from Standardization Documents Order Desk, DODSSP, Bldg. 4, Section D, 700 Robbins Ave., Philadelphia, PA 19111-5098, http://www.dodssp.daps.mil.

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

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

2.6 *International Standards Organization (ISO) Standards:*[7]
ISO 9712 Nondestructive Testing—Qualification and Certification of NDT Personnel

3. Terminology

3.1 *Definitions*—See Terminology E1316 for general terminology applicable to this practice.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *AE test pressure, n*—110 % of the greatest pressure that the examination article contains during previous service. Usually 125 % of the filling pressure is an acceptable AE examination pressure. (Normally, gas is heated when compressed during the filling process; hence, tanks are filled to more than rated service pressure). After filling, pressure should settle to rated service pressure as gas temperature within the tank becomes equal to ambient temperature.

3.2.2 *detectability distance, n*—the maximum distance from a sensor at which a defined simulated AE source can be detected by the instrumentation with defined settings and using appropriate pressurization medium.

4. Summary of Practice

4.1 AE sensors are mounted on a vessel and emission is monitored while the vessel is pressurized to the "AE examination pressure."

4.2 This practice provides guidelines for the detection of AE from structural flaws in the composite overwrap in gas-filled, filament-wound composite pressure vessels. Damage mechanisms which produce AE include: resin cracking, fiber debonding, fiber pullout, fiber breakage, delamination and bond failure. Flaws in liner portions of a vessel may not be detected.

4.3 This practice and others found in ASTM, ASME, ASNT, SPI relate Acoustic Emission to applied load on the composite material. At relatively low load (safe operating conditions) the acoustic emission from the composite material is low. At higher loads (unsafe operating conditions) the slope of the AE versus load curve changes drastically. In some cases this phenomenon can be identified and quantified by a single AE parameter (that is, AE counts).

4.4 Structurally insignificant flaws or processes (for example, leaks) may produce emission.

4.5 This practice is convenient for periodic examination of vessels in-service.

4.6 Gas-filled filament-wound pressure vessels which exhibit unacceptable levels of AE should be examined by other methods; for example, visual, ultrasound, dye penetrant, etc., and may be repaired and re-examined in accordance with government regulations and manufacturers guidelines. Repair and repair examination procedures are outside the scope of this practice.

4.7 Any number of pressure vessels may be examined simultaneously as long as the appropriate number of sensors and instrumentation channels are used.

5. Significance and Use

5.1 Due to safety considerations, the Compressed Gas Association (CGA) and others have produced guidelines which address in-service inspection of NGV fuel containers (see 2.2 – 2.4). AE examination is listed as an alternative to the minimum three-year visual examination which generally requires that the container be removed from the vehicle to expose the entire container surface. The AE method allows "in-situ" examination of the container.

5.1.1 Slow-fill pressurization must proceed at flow rates that do not produce background noise from flow of the pressurizing medium. Acoustic emission data are recorded throughout a pressurization range (that is, 50 % to 100 % of AE examination pressure).

5.1.2 Fast-fill pressurization can be used if hold periods are provided. Acoustic emission data are recorded only during the hold periods.

NOTE 1—Fast-fill pressurization is less appropriate for carbon (or graphite) composites due to the lower sensitivity of carbon fibers to stress rupture compared to other fibers.

5.1.3 Background noise above the threshold will contaminate the AE data and render them useless. Users must be aware of the following common causes of background noise: high fill rate (measurable flow noise); mechanical contact with the vessel by objects; electromagnetic interference (EMI) and radio frequency interference (RFI) from nearby broadcasting facilities and from other sources; leaks at pipe or hose connections and airborne particles, insects, rain and snow. This practice should not be used if background noise cannot be eliminated or controlled.

5.2 Sensitivity is influenced by factors that affect elastic wave propagation, sensor coupling and signal processor settings.

5.3 It is possible to measure AE from AE sources that cannot be verified by other NDE methods.

6. Basis of Application

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

6.2 *Personnel Qualification*—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, 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.

6.3 *Qualification of Nondestructive Test 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.

[7] 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.