Designation: E 2076 – 00

Standard Test Method for Examination of Fiberglass Reinforced Plastic Fan Blades Using Acoustic Emission[1]

This standard is issued under the fixed designation E 2076; 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 test method provides guidelines for acoustic emission (AE) examinations of fiberglass reinforced plastic (FRP) fan blades of the type used in industrial cooling towers and heat exchangers.

1.2 This test method uses simulated service loading to determine structural integrity.

1.3 This test method will detect sources of acoustic emission in areas of sensor coverage that are stressed during the course of the examination.

1.4 This test method applies to examinations of new and in-service fan blades.

1.5 This test method is limited to fan blades of FRP construction, with length (hub centerline to tip) of less than 10 ft, and with fiberglass content greater than 15 % by weight.

1.6 AE measurements are used to detect emission sources. Other nondestructive examination (NDE) methods may be used to evaluate the significance of AE sources. Procedures for other NDE methods are beyond the scope of this test method.

1.7 Values stated in inch-pound units are to be regarded as the standard. SI units given in parentheses are provided for information only.

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.*

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 1067 Practice for Acoustic Emission Examination of Fiberglass Reinforced Plastic Resin (FRP) Tanks/Vessels[2]

E 1106 Method for Primary Calibration of Acoustic Emission Sensors[2]

E 1316 Terminology for Nondestructive Examinations[2]

2.2 *ASNT Documents:*

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

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

2.3 *Military Standards:*

MIL-STD-410 Nondestructive Testing Personnel Qualification and Certification[4]

2.4 *Aerospace Industries Association Document:*

NAS 410 Certification and Qualification of Nondestructive Testing Personnel[5]

3. Terminology

3.1 *Definitions*—For definitions of terms used in this test method, see Terminology E 1316.

4. Summary of Test Method

4.1 This test method consists of subjecting individual FRP fan blades to increasing load while monitoring with sensors that are sensitive to acoustic emission (transient stress waves) caused by growing flaws.

4.2 This test method provides guidelines to determine the zonal location of structural flaws in FRP fan blades.

4.3 The test load, applied at the blade tip is calculated to provide 100 % of the maximum allowable operating (bending) load at the blade-hub interface.

4.4 This test method is intended to simulate the bending load. Torsional and centrifugal loads are not simulated by this test method.

4.5 Structurally insignificant flaws may produce acoustic emission.

[1] This test method is under the jurisdiction of ASTM Committee E-07 on Nondestructive Testing and is the direct responsibility of Subcommittee E07.04 on Acoustic Emission Method.

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

[3] Available from American Society for Nondestructive Testing, Inc., 1711 Arlingate Lane, Columbus, OH 43228.

[4] Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

[5] Available from Aerospace Industries Association of America, Inc., 1250 Eye St. NW, Washington D.C. 20005.

5. Significance and Use

5.1 The AE examination method detects structurally significant flaws in FRP structures via test loading. The damage mechanisms that are detected in FRP include resin cracking, fiber debonding, fiber pullout, fiber breakage, delamination, and secondary bond failure.

5.2 Flaws in unstressed areas will not generate detectable AE.

5.3 Flaws located with AE may be examined by other methods.

6. Basis of Application

6.1 *Personnel Qualification*—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.

6.2 *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.

6.3 *Extent of Examination*—The extent of examination shall be in accordance with 10.2 unless otherwise specified.

6.4 *Reporting Criteria/Acceptance Criteria*—Reporting criteria for the examination results shall be in accordance with Section 12 unless otherwise specified. Since acceptance criteria, for example, for reference radiographs, are not specified in this test method, they shall be specified in the contractual agreement.

6.5 *Reexamination of Repaired/Reworked Items*—Reexamination of repaired/reworked items is not addressed in this test method, and if required, shall be specified in the contractual agreement.

6.6 *Personnel Training*—It is recommended that personnel performing the examination have additional training on the following topics:

6.6.1 Basic technology of AE from FRP;

6.6.2 Failure mechanism of FRP;

6.6.3 AE instrument and sensor checkout on FRP;

6.6.4 Loading of FRP components for AE testing;

6.6.5 Data collection and interpretation; and

6.6.6 Examination report preparation.

7. Apparatus

7.1 Essential features of the apparatus required for this test method are shown in Fig. 1. Specifications are provided on Annex A1.

7.2 Couplant must be used to acoustically couple sensors to the blade surface. Adhesives that have acceptable acoustic properties and ultrasonic couplants are acceptable.

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

7.4 Sensors are to be positioned on the fan mounting drive hub for background noise detection only; on the blade within 6 in. (152.4 mm) of the shank; on the blade midway between the shank and the blade tip; and within 6 in. (152 mm) of the blade tip for background noise detection only. Additional sensors may be added when more complete coverage is desired.

NOTE 1—The sensors indicated in Fig. 1 may be placed on either the top or bottom surface of the blade.

7.5 Instrumentation shall be capable of recording AE hits above a low-amplitude threshold, AE hits above a high-amplitude threshold (both within a specific frequency range) and have sufficient channels to localize AE sources in real time. Hit detection is required for each channel. An AE hit amplitude measurement is recommended for sensitivity verification. Amplitude distributions are recommended for flaw characterization.

7.6 Preamplifier may be enclosed in the sensor housing or in a separate enclosure. If a separate preamplifier is used, sensor cable length, between the sensor and the preamplifier, must not result in a signal loss of greater than 3 dB. Typically, 6 ft (1.8 m), is acceptable.

7.7 Power/signal cable length (between preamplifier and signal processor) shall not result in a signal loss of greater than 3 dB. Typically, 500 ft (152.4 m) is acceptable.

7.8 Signal processors are computerized instruments with independent channels that filter, measure, and convert analog

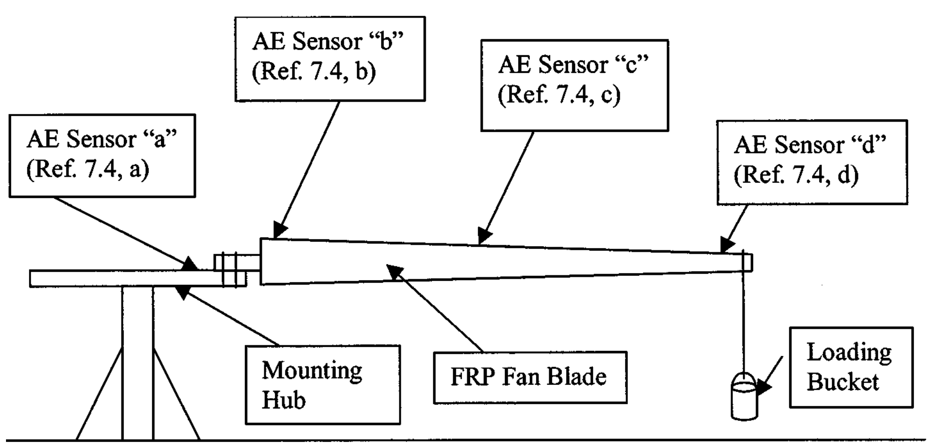

FIG. 1 Apparatus

information into digital form for display and permanent storage. A signal processor must have sufficient speed and capability to independently process data from all sensors simultaneously. The signal processor should provide capability to filter data for replay.

7.9 A video monitor is used to display processed data in various formats. Display format may be selected by the examiner.

7.10 A data storage device, such as a magnetic disk, is used to store data for replay and archiving.

7.11 Hard-copy capability should be available from a graphics/line printer or equivalent device.

8. Safety Precautions

8.1 *Safety*—All site safety requirements unique to the test location shall be met.

9. Calibration and Standardization

9.1 Annual calibration and verification of AE sensors, preamplifiers, if applicable, signal processor, and AE electronic waveform generator should be performed. Equipment should be adjusted so that it conforms to the equipment manufacturer's specifications. Instruments used for calibration must have current accuracy certification that is traceable to the National Institute for Standards and Technology (NIST).

9.2 Routine electronic checks must be performed on a monthly basis or at any time there is concern about signal processor performance. An AE electronic waveform generator should be used in routine electronic checks. Each signal processor channel must respond with peak amplitude readings within ± 2 dB of the electronic waveform generator output.

9.3 Routine sensor checks must be performed on a monthly basis or at any time that there is concern about the sensor performance. Peak amplitude response and electronic noise level should be recorded. Sensors can be stimulated by a pencil lead break in accordance with Guide E 976. Sensors which are found to have peak amplitudes or electronic noise more than 3 dB greater than the average of the group of sensors to be used during the examination should be replaced.

9.4 A system performance check must be conducted immediately before and immediately after each examination. A system performance check utilizes a mechanical device to induce stress waves into the structure. The induced stress waves must be nondestructive and simulate emission from a flaw. System performance checks verify the sensitivity of each system channel (including the couplant).

9.4.1 The preferred technique for conducting a system performance check utilizes a pencil lead break. Lead should be broken on the surface (see Fig. 4 of Guide E 976) at a specified distance, typically 4 in. (101.6 mm) from the sensor.

9.4.2 System channels which are found to have performance outside of specified values should be repaired or replaced. Values should be specified such that the sensitivity of channels used in the same test differ by no more than 6 dB.

10. Test Procedure

10.1 *General Guidelines*—Each fan blade is subjected to programmed increasing tip load, up to a predetermined maximum value (test load), while being monitored by sensors that detect acoustic emission (stress waves) caused by growing structural flaws.

10.1.1 Blade tip load shall be controlled so as to not exceed a load rate of 33 % of test load per minute.

10.1.2 Background noise shall be minimized and identified. Excessive background noise is cause for suspension of the loading. In the analysis of examination results, background noise should be properly discounted, if the source is determined to be irrelevant to mechanical integrity.

10.2 *Loading*—Determine the test load from the blade manufacturer's specifications. The blade may be loaded once or twice depending upon the outcome of the first loading. If the acoustic emission activity generated by the first loading exceeds the criteria then an immediate second loading shall be applied. If the blade meets the acceptance criteria on the first loading then the second loading is not required. Fig. 2 shows the recommended loading sequence. The following is a practical way to achieve the desired blade tip load.

10.2.1 Secure the shank of the blade in an appropriate holder at its operating pitch (blade parallel to the floor). This will usually be the blade manufacturer's drive hub arrangement (see also Fig. 1).

10.2.2 Suspend an empty water container at the tip end of the blade. Padding is recommended to reduce the possibility of extraneous noise and physical damage to the surface of the blade tip.

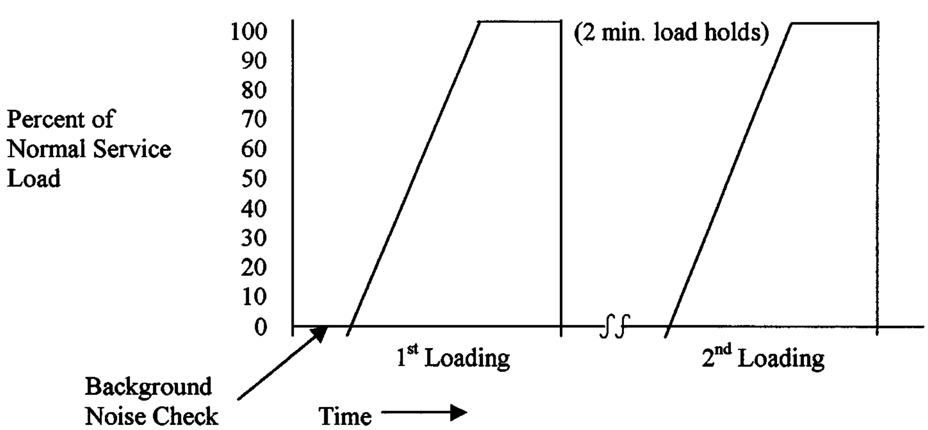

FIG. 2 Graph of Fan Blade Testing Sequence

10.2.3 Fill the water container with a sufficient amount of water to equal the maximum desired test load at the blade tip. For example, for a typical 50-lb (22.7-kg) test load, the filling rate should not exceed 2 gal (7.6 L)/min (see 10.1.1).

10.2.4 Hold the test load for two minutes and record test results.

10.2.5 Remove the load from the blade tip.

10.2.6 Evaluate the acoustic emission activity according to Section 11. If the blade meets the acceptance criteria, no further testing is required. If it fails to meet the criteria proceed with steps 7 and 8.

10.2.7 Immediately replace the empty water container and refill the container with water equal to the maximum desired test load at the blade tip. Filling rate should not exceed the requirement in 10.1.1.

10.2.8 Hold the test load for two minutes and record test results.

10.3 *Data Recording*—The following AE data are to be recorded for each blade examined by this procedure:

10.3.1 Maximum dB during loading, or number of hits above the high-amplitude threshold. (See Practice E 1067, Annex A2).

10.3.2 Number of hits above the low-amplitude threshold (see Practice E 1067, Annex A2) during two-minute hold at test load.

10.3.3 Total number of hits above the low-amplitude threshold during loading.

10.3.4 Indicate most active sensor location.

11. Evaluation

11.1 Evaluation based on emissions during load hold is particularly significant. Continuing emissions indicate continuing damage. Generally, background noise will be at a minimum during load hold. Emissions continuing during load hold periods is a condition on which accept-reject criteria may be based.

11.2 Evaluation based on high-amplitude hits is important. These hits often are associated with major structural damage. High-amplitude hits (above the high amplitude threshold) is a condition on which accept-reject criteria may be based.

11.3 Evaluation based on total hit count above the low-amplitude threshold is important. These hits often are associated with the overall condition of the part, including secondary bonds, delamination and compression damage. Total hits is a condition on which accept-reject criteria may be based.

12. Report

12.1 The test report shall include the following information:

12.1.1 Complete identification of fan blade, including material type, approximate weight percent of fiberglass method of fabrication, manufacturer's name and code number, date and maximum load of any previous tests, and all previous history.

12.1.2 Fan blade sketch or manufacturer's drawing with dimensions of equipment and sensor location.

12.1.3 Couplant type.

12.1.4 Ambient temperature during test.

12.1.5 Test sequence, including loading rate, hold times, and hold levels.

12.1.6 Comparison of examination data with specified accept-reject criteria.

12.1.7 Show on sketch or manufacturer's drawing the location of any suspect areas found that require further evaluation.

12.1.8 Any unusual effects or observations during or prior to the examination.

12.1.9 Dates of examination.

12.1.10 Name(s) of examiner(s).

12.1.11 *Instrumentation Description*—Complete description of AE instrumentation including manufacturer's name, model number, sensor type, system gain, serial numbers or equivalent, software title and version number, etc.

13. Precision and Bias

13.1 This test method is believed to represent common practice. It has been confirmed by laboratory and field testing results, but no round robin tests have been made to determine the precision and reliability of this test method. The accuracy of this test is dependent on the operational procedure used and the training and qualification of the operators.

14. Keywords

14.1 acoustic emission; FRP fan blades

ANNEX

(Mandatory Information)

A1. INSTRUMENTATION SPECIFICATIONS

A1.1 Sensors

A1.1.1 AE sensors shall be sensitive in the 100 to 300 kHz frequency band.

A1.1.2 Sensitivity shall be determined by Method E 1106. Sensitivity shall be greater than 65 dB (referred to 1 V/(m/s), over the frequency range 100 to 300 kHz.

A1.1.3 Sensitivity within the 100 to 300 kHz range shall not vary more than 3 dB over the intended range of temperatures in which sensors are used.

A1.1.4 Sensors shall be shielded against electromagnetic interference through proper design practice.

A1.1.5 Sensors shall be electrically isolated from conductive surfaces by means of a shoe (a wear plate).

A1.2 Signal Cable

A1.2.1 The signal cable which connects sensor and preamplifier shall not be longer than 6 ft (1.83 m). Integral preamplifier sensors meet this requirement.

A1.2.2 Signal cable shall be shielded against electromagnetic interference.

A1.3 Couplant

A1.3.1 Couplant shall provide adequate ultrasonic coupling efficiency throughout the test.

A1.3.2 Couplant must be temperature stable over the temperature range intended for use.

A1.3.3 Adhesives may be used if they satisfy ultrasonic coupling efficiency and temperature stability requirements.

A1.4 Preamplifier

A1.4.1 Preamplifier shall have noise level no greater than 7μV rms (referred to a shorted input) within the bandpass range.

A1.4.2 Preamplifier gain shall vary no more than ± 1 dB within the frequency band and temperature range of use.

A1.4.3 Preamplifier shall be shielded from electromagnetic interference.

A1.4.4 Preamplifiers of differential design shall have a minimum of 40 dB common mode rejection.

A1.4.5 Preamplifier shall include a bandpass filter with a minimum of 24 dB/octave signal attenuation above and below the 100 too 300 kHz frequency band.

A1.5 Power/Signal Cable

A1.5.1 Power/signal cables provide power to the preamplifiers and conduct amplified signals to the main processor. These shall be shielded against electromagnetic interference. Signal loss shall be less than 1 dB/100 ft (30.48 m) of cable length. Standard coaxial cable generally is adequate. Signal loss from a power/signal cable shall be no greater than 3 dB.

A1.6 Power Supply

A1.6.1 A stable, grounded, power supply that meets the signal processor manufacturer's specification shall be used.

A1.7 Signal Processor

A1.7.1 Electronic circuitry gain shall be stable within ± 2 dB in the temperature range 40 to 100°F (4.4 to 37.8°C).

A1.7.2 Threshold shall be accurate within ± 2 dB.

A1.7.3 Measured AE parameters shall include peak amplitude, arrival time, and duration for each hit.

A1.7.4 Peak amplitude shall be accurate within ± 2 dBV.

A1.7.5 Arrival time at each channel shall be accurate to within ± 1 μs.

A1.7.6 Duration shall be accurate to within ± 10 μs.

APPENDIX

(Nonmandatory Information)

X1. EXAMPLE INSTRUMENT SETTINGS & ACCEPTANCE CRITERIA

X1.1 A database and acceptance criteria are established for some specified FRP fan blade types.

X1.2 Criteria for acceptance were established while working with AE equipment with set-up conditions listed in Table X1.1.

X1.3 *Acceptance Criteria*:

X1.3.1 For the blade to be acceptable, it must pass all of the following criteria. If a blade exceeds one or more of the following criteria it may be reexamined immediately.

X1.3.1.1 No AE hits greater than 70 dB.

X1.3.1.2 No more than five AE hits during final load hold.

X1.3.1.3 No more than 20 AE hits total.

TABLE X1.1 Acoustic Emission Equipment, Characteristics and Set-Up Conditions

Sensor sensitivity (Method E 1106)	−65 dBV ref. 1V/m/s, at ~150 kHz
Couplant	Silicone grease
Preamplifier gain	40 dB (×100)
Preamplifier filter	100 to 300 kHz bandpass
Power/signal cable length	<500 ft
Signal processor threshold	32 dBV (for example, 1 μV = 0 dBV at preamplifier input)
Signal processor filter	100 to 300 kHz bandpass
Dead time	10 ms
Background noise	<27 dBV (for example, 1 μV = 0 dBV at preamplifier input)
Sensitivity check	(lead break 4in >75 dBV (for example, 1 μV = 0 dBV at from sensor using 0.3 mm, 2H lead) preamplifier input)