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THE NATIONAL BOARD OF BOILER AND PRESSURE VESSEL INSPECTORS

NATIONAL BOARD INSPECTION CODE
FRP TASK GROUP

AGENDA

Meeting of April 1st, 2026
Virtual via MS Teams

The National Board of Boiler & Pressure Vessel Inspectors
1055 Crupper Avenue
Columbus, Ohio 43229-1183
Phone: (614)888-8320
FAX: (614)847-1828

1. **Call to Order**
   The meeting will be called to order at 12:30p.m. Eastern Time

2. **Introduction of Members and Visitors**

3. **Announcements**

4. **Adoption of the Agenda**

5. **Approval of the Minutes of the October 2025 Meeting**
   The minutes can be found on the National Board website:
   https://www.nationalboard.org/Index.aspx?pageID=13&ID=18

6. **Review of Rosters**
   a. Membership Nominations

   b. Membership Reappointments
      i. None.
   c. Officer nominations
      i. None.
7. **Action Items**

Item Number: NB16-1402	**NBIC Location: Part 2**	**Attachment Page 1**
General Description: Life extension for high pressure vessels above 20 years **Subgroup:** FRP **Task Group:** M. Gorman (PM), N. Newhouse, J. Eihusen **October 2025 Meeting Action:** It was reported that the proposal was being balloted to Subcommittee Inspection. **Update:** The Subcommittee Inspection ballot failed to pass. Several members felt that the proposal was more like a detailed instruction manual instead of offering general guidance. Because of this, they felt that the proposal fell outside the scope of NBIC Part 2. One commenter suggested putting the proposal into ASME Section V, while others suggested reworking the proposal to better fit the scope of Part 2.		

Item Number: I25-95	NBIC Location: Part 1, S11.3	Attachment Page 17
General Description: Clarification on Section S11.3 - Clearances **Subgroup:** FRP **Task Group:** None assigned. **Explanation of Need:** This is an inquiry regarding Part 1, S11.3 of the NBIC 2025 standard. In this section, it states that the stacking of pressure vessels is permitted. However, the minimum clear space between pressure vessels shall be 1 ft and 2 ft horizontally. I have seen ASME tanks at various facilities where the pressure vessels are not separated 1 ft vertically and 2 ft horizontally. Does this rule mean that individual pressure vessels can be stacked but must adhere to the 1ft vertical and 2ft horizontal clear space rule? Or can a bundle of pressure vessels together be considered as one pressure vessel and not have to adhere to this rule? **April 2026 Meeting Action:**		

8. **Additional Business**

Follow-up items from October 2025 meeting:

- Part 3, S4.16.4 a) 2) – is 100 sq. in. an appropriate number?
    - Mr. Shelley stated that RTP-1 sets a percentage of surface area as limit for routine repairs.
    - Using a percentage of the surface area was an agreeable solution to the group. In discussing which percentage to use, the group settled on using 100 sq. in. or 3% of the surface area, whichever is greater. This would be limited to the corrosion barrier. Mr. Shelley and Mr. Beckwith will work on a proposal now that a direction has been made clear.
- Part 3, S4.18.2.5 b) – requiring a pressure test in accordance with the original code of construction.
    - Mr. Beckwith should have an update by the next meeting.
- Fiberglass Storage Tank Inspection Procedures (from FRPI)
    - Mr. Eisberg announced that several testing scenarios are coming up to compare with the results of UT Comp methods. Mr. Eisberg is working with the Australian government to evaluate water treatment vessels for determining life cycle.
- API-579-1/ASME FFS-1
    - Ms. McCauley stated that the group should continue to monitor progress for this standard, as things are moving quickly.

9. **Future Meetings**

January 13-16, 2026 – Salt Lake City, UT (virtual attendance options will be available)
October 2026 – NBIC FRP Task Group Meeting

10. **Adjournment**

Respectfully submitted,
Jonathan Ellis
Secretary

Supplement XX

NBIC Life Extension/Continuation Testing of ASME High Pressure Carbon Fiber Reinforced Plastic (CFRP) Section X Class III Pressure Vessels

SXX.1 General

An ASME CFRP vessel without inflicted damage from external forces is quite a robust structure with a very long fatigue life. Until recently, ASME Section X Class III CFRP pressure vessels had a 20-year service life limit. That limitation has been removed. However, this vessel class has been in use for less than 20 years and it is important to assess and verify the safety of these vessels considering the gases could be at 15,000 psi or over 1,000 bar. The procedure herein describes how to do modal acoustic emission (MAE) testing of ASME Section X Class III CFRP vessels in order to determine if the service life can be safely extended or continued beyond 20 years for up to an additional twenty (20) years beyond the date of manufacture listed on the vessel's label. Life extension could be called life continuation for the newer vessels that have no specified life, however, life extension is the term used herein for both. Each extended life vessel is subject to requalification testing by MAE testing every five years in order to continue in service for up to 20 years.

SXX.2 Scope

This document applies to ASME Section X Class III CFRP pressure vessels. The vessels can be either fully overwrapped with a load-bearing liner (commonly called Type 3 vessels) or fully overwrapped with a non load-bearing (e.g., plastic) liner (commonly called Type 4 vessels).

SXX.3 References

ASNT-SNT-TC-1A (Recommended Practice Outlines for Qualification of Non-destructive Testing Personnel) or equivalent (e.g., ISO 9712) – Qualifications and certification of NDT personnel.

CGA C.6.2 (STANDARD FOR VISUAL INSPECTION AND REQUALIFICATION OF FIBER REINFORCED HIGH PRESSURE CYLINDERS) or ISO 11623, Gas Cylinders – Composite cylinders and tubes – Periodic inspection and testing.

ISO 19016 Gas cylinders — Cylinders and tubes of composite construction — Modal acoustic emission (MAE) testing for periodic inspection and testing.

SXX.4 ASME Section X Class III High Pressure CFRP Pressure Vessels Background

Many pressure vessels are fabricated by filament winding with carbon fiber reinforcement in an epoxy matrix. ASME vessels are fabricated under Section X, Mandatory Appendix 8. The materials, construction and testing procedures laid out in Appendix 8 must be followed carefully and thoroughly documented.

Once stressed, all composite materials will have internal characteristic damage states consistent with all the many studies found in the open literature on the subject. There will be both matrix damage and fiber damage caused by voids and other defects. Such characteristic damage does not compromise the use or safety of the vessels. Further, there are defects inherent in the fibers and it is well-known that these defects cause fibers (filaments) to fail (rupture) at different loads and times. Again, this is normal and expected behavior. What is not expected is the rupture of a large number of fibers (on the order of a tow or greater) simultaneously at the same position in a vessel. This requires a significant stress concentration of the kind caused by damage that has been inflicted on the vessel by external forces. If a significant stress concentration exists, it is possible for that stress concentration to reduce burst pressure to a value below that required by the safety factor.

Defects in carbon fibers are randomly distributed along the fibers and that carbon fiber strengths follow a Weibull probability distribution. Weaker fibers in a vessel will fail during proof testing after which very few fibers fail at operating pressure under normal service conditions. Stress concentrations that develop in service can cause fibers to fail during subsequent requalification testing. These are usually few in number and serve to relieve stress concentrations. They do not lessen the integrity of the vessel. Fibers normally begin to fail in large numbers once the pressure in the vessel exceeds around 90% of ultimate.

Well-manufactured CFRP pressure vessels are very robust because of the way a fiber break redistributes loads to neighboring fibers and even to the same fiber itself at a distance from a break called the ineffective fiber length. A broken fiber is unloaded only at the ruptured ends. Beyond the ineffective length the fiber is fully loaded again. This is the key reason that these vessels are so rugged and safe.

There are many possibilities for harming a pressure vessel, for example, fire damage. Other types of damage are cuts and impact. Experience, as well as many research studies, has shown that CFRP materials are essentially notch insensitive. For example, in an ISO notch test for Type 3 vessels an axial cut is made halfway through the depth of the cylindrical wall of the vessel with a length in the axial direction of five times the wall thickness. Extensive testing has shown that the effect of such a notch in a typical CNG tank is a burst pressure reduction of typically less than 20%. A CNG tank with an operating pressure of 3,600 psi and a safety factor of 2.25, must burst at 8100 psi or above. A typical design yields a burst pressure of around 10,000 psi, and, in such a case, a 20% reduction in burst pressure reduces the safety factor to just under the 2.25 requirement. The test described herein focuses on ensuring that vessels containing a stress concentration of 1.2 or more are removed from service.

SXX.5 Background for Modal Acoustic Emission (MAE)

Note: ISO/TS 19016 contains much additional information on MAE testing, including definitions of terms, and is highly recommended.

Modal acoustic emission (MAE) testing is a type of acoustic emission test (AT) that attempts to make a direct connection between elastodynamic theory predictions of the waveform type, energy and frequency content expected from various damage mechanisms in materials. For this reason the stress waves are measured with absolutely calibrated broadband transducers. The waveforms are digitally captured and stored. Each waveform is analyzed to determine the type of damage event that produced it. For example, a fiber break stress wave can be distinguished from stress waves of other damage mechanisms found in CFRP composite materials. The ability to do this has been reduced to a set of rules in the case of CFRP pressure vessel testing and programmed in software to automatically identify sources and numbers, much as in other fields of acoustics such as SONAR. Research on the effects of various damage mechanisms has taken MAE testing even further. MAE testing is currently used for in-service requalification testing of high pressure CFRP pressure vessels used in transportation under USDOT and Transport Canada rules and regulations. It is also approved for life extension testing of self-contained breathing apparatus pressure vessels under USDOT rules and regulations. The accept/reject criteria use four MAE allowance factors F1, F2, M1 and M2, which are defined and described below.

SXX.6 MAE Allowance Factors and Accept/Reject Criteria

F1 the fiber rupture energy allowed during testing in any single MAE event. The single fiber break energy is calculated by the formula given in this document and divided into the MAE event energy. The number obtained is the number of fibers that ruptured in near proximity to one another simultaneously. The values of F1 for different vessel circumferences and test pressures are given in Table 1.

F2 is the largest single event energy. Delamination and frictional emission wave energies can be much greater than fiber break wave energies. F2 shall be set at 100 x F1.

M1 is the allowed energy rise in the background energy (BE). The background energy is the minimum energy in a windowed portion of the waveform.

M2 is the allowed peak to peak excursion between neighboring maxima and minima of an N point moving average calculated from all BE values.

It is well-known that production vessels have a range of burst pressures. This is driven by statistical variations in the materials and fabrication variables. In these vessels, the random distribution of defects in the materials leads to a statistical failure process.

The hoop fibers control the burst pressure. For example, an axially cut ISO notch cuts across tens or even hundreds of thousands of hoop fibers. A heavily notched vessel always fails at the notch if it is undamaged elsewhere. MAE testing detects fiber ruptures and counts the number of fiber breaks represented by the energy in each fiber break event during a pressure test.

In addition to direct detection of fiber breaks, the MAE test also determines if there is a rise and oscillation of the background energy (BE) level. Energy oscillations are caused when fibers under load rupture, release energy in the form of stress waves (acoustic emission) and their load is transferred through shear in the matrix to neighboring fibers. The rising pressure in a test provides the energy input for the oscillation process as the overloaded fibers fail and transfer their load. All pressure vessels exhibit continuing BEO at some point during pressurization to burst. There is a statistical nature to this process due to the randomness of defects. BEO is never expected at operating pressure or test pressure in a good vessel.

Another way MAE testing detects damage is through frictional emission. Frictional emission is caused by the rubbing of fracture surfaces against each other as the vessel is pressurized and depressurized. Frictional events can be very energetic, far surpassing the energies in fiber breaks. It is mostly detected at lower pressure upon pressurization and depressurization, particularly depressurization when the fracture surfaces are closing upon one another. Frictional emission is usually present and persistent in CFRP vessels even when there is no new damage. It is especially evident after impact damage has caused significant delamination in the vessel.

SXX.7 Personnel Qualifications

The person doing the type testing shall be a senior technical person (SRT – Senior Review Technologist) who holds a degree in mechanical engineering, physics or closely related engineering science discipline and who has extensive experience with MAE testing, plate wave theory, composite materials, laminated plate theory, composite failure models, damage types and their effects, as well as CFRP pressure vessel manufacturing, pressure testing and burst testing, or a Level III technician certified by ISO 9762 or equivalent (e.g., ASNT TC-1A) with equivalent knowledge and experience.

Requalification testing shall be conducted by a Level I or Level II or a person who holds a bachelor's degree in mechanical engineering or physics, and who is trained and under the direct supervision of the SRT or Level III.

SXX.8 General Test Procedure

MAE transducers shall be acoustically coupled to the vessel under test and connected to waveform recording equipment. Waveforms shall be recorded and stored on digital media as the vessel is pressurized. All analysis shall be done on the waveforms. The waveforms of interest are the E (Extensional Mode) and F (Flexural Mode) plate waves. Prior to pressurization, the velocities of the earliest arriving frequency in the E wave and the latest arriving frequency in the F wave shall be measured in the circumferential direction in order to characterize the material and set the sample time (the length of the wave window). The E and F waves shall be digitized and stored for analysis. The test pressure shall be recorded simultaneously with the MAE events.

SXX.9 Equipment

a) Testing System - A testing system shall consist of: 1) sensors; 2) preamplifiers; 3) high pass and low pass filters; 4) amplifiers; 5) A/D (analog-to-digital) converters; 6) a computer program for the collection of data; 7) computer and monitor for the display of data; and 8) a computer program for analysis of data.

Examination of the waveforms event by event shall always be possible and the waveforms for each event shall correspond precisely with the pressure and time data during the test. The computer program shall be capable of detecting the first arrival channel. This is critical to the acceptance criteria below.

Sensors and recording equipment shall be checked for a current calibration sticker or a current certificate of calibration.

b) Sensor Calibration

Sensors shall have a flat frequency response from 50 kHz to 400 kHz. Deviation from flat response (signal coloration) shall be corrected by using a sensitivity curve obtained with a Michelson interferometer calibration system similar to the apparatus used by NIST (National Institute for Standards and Technology). Sensors shall have a diameter no greater than 0.5 in. (13 mm) for the active part of the sensor face. The aperture effect shall be taken into account. Sensor sensitivity shall be at least 0.05 V/ nm.

c) Scaling Fiber Break Energy

The wave energy shall be computed by the formula:

$$U = \frac{1}{Z}\int V^2 \; dt$$

which is the formula for computing energy in the MAE signal, where V is the voltage in volts (V) and Z is the input impedance in ohms (Ω). A rolling ball impact setup shall be used to create an acoustical impulse in an aluminum plate. The measured energy in the wave shall be used to scale the fiber break energy. This scaling is illustrated later on.

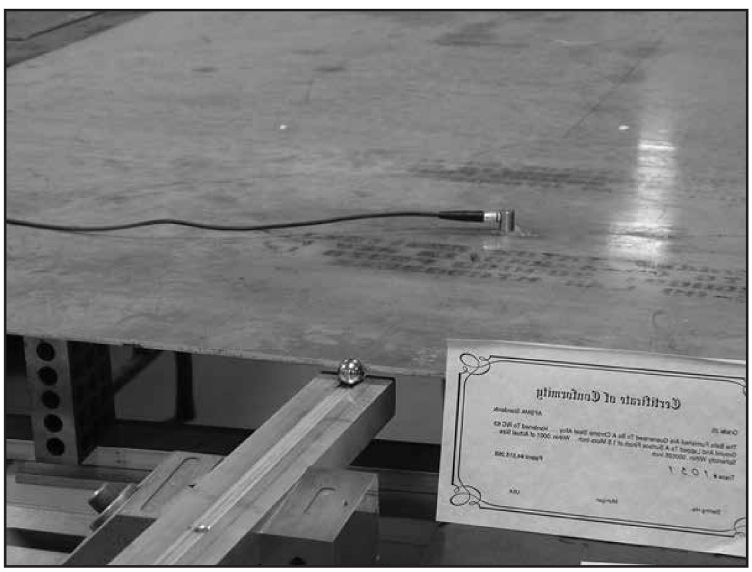

FIGURE SXX.9-c1 ROLLING BALL IMPACT CALIBRATION SETUP

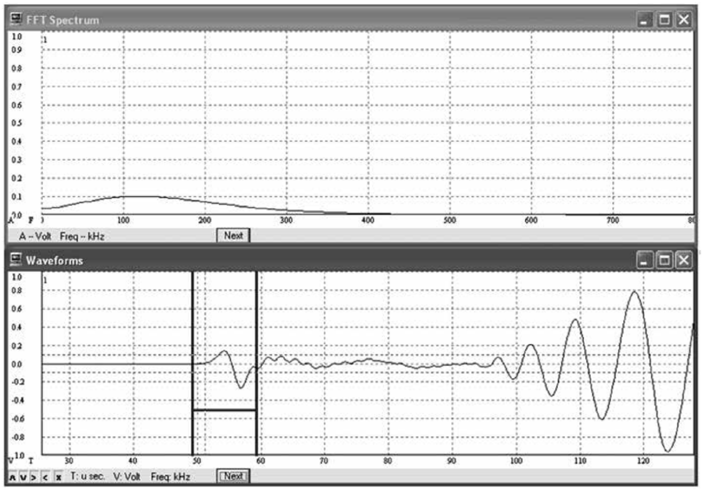

FIGURE SXX.9-c2 FRONT END WAVEFORM - The front end of waveform created by rolling ball impact calibration setup is shown in Figure SXX.9-c2. A Fast Fourier transform (FFT) shows that the center frequency of the first cycle is approximately 125kHz.

The impact setup, an example of which is shown in Figure SXX.9-c1, shall be arranged as follows. The steel ball shall be ½ inch (13 mm) in diameter. The steel ball is a type typically used in machine shops for measuring taper and is commercially available. The ball shall be made of chrome steel alloy hardened to R/C 63, ground and lapped to a surface finish of 1.5 micro-inch (0.0000381 mm), within 0.0001 inch (0.0025 mm) of actual size and sphericity within 0.000025 inch (0.00064 mm). The plate shall be made of 7075 T6 aluminum, be at least 4 ft x 4 ft (1200 mm X 1200 mm) in size, the larger the better to avoid reflections, be 1/8 inch (3.2 mm) in thickness and be simply supported by steel blocks. The inclined plane shall be aluminum with a machined square groove 3/8 inch (9.5 mm) wide which supports the ball and guides it to the impact point. The top surface of the inclined plane shall be positioned next to the edge of the plate and stationed below the lower edge of the plate such that the ball impacts with equal parts of the ball projecting above and below the plane of the plate. A mechanical release mechanism shall be used to release the ball down the plane.

The ball roll length shall be 12 inch (305 mm) and the inclined plane angle shall be 6 degrees. The impact produces an impulse that propagates to sensors coupled to the surface of the plate 12 inches (305 mm) away from the edge. The sensors shall be coupled to the plate with vacuum grease. The energy of the leading edge of the impulse, known as the wave front shall be measured. The vertical position of the ball impact point shall be adjusted gradually in order to “peak up” the acoustical signal, much as is done in ultrasonic testing where the angle is varied slightly to peak up the response. The center frequency of the first cycle of the E wave shall be confirmed as 125 kHz ± 10 kHz. See Figure 2. The energy value in joules of the first half cycle of the E wave shall be used to scale the fiber break energy, as illustrated there. This shall be an “end to end” calibration meaning that the energy shall be measured using the complete MAE instrumentation (sensor, cables, preamplifiers, amplifiers, filters and digitizer) that are to be used in the actual testing situation.

The energy linearity of the complete MAE instrumentation (sensor, cables, preamplifiers, amplifiers, filters and digitizer) shall be measured by using different roll lengths of 8, 12 and 16 inches (203, 305, and 406 mm).

The start of the E wave shall be from the first cycle of the waveform recognizable as the front end of the E wave to the end of the E wave which shall be taken as 10 microsecond (μs) later. (The time was calculated from the dispersion curves for the specified aluminum plate.) A linear regression shall be applied to the energy data and a goodness of fit R2 > 0.9 shall be obtained.

d) Preamplifiers and Amplifiers – low noise and high fidelity are important to achieve the required sensitivity.

e) Filters - A high pass filter of 20 kHz shall be used. A low pass filter shall be applied to prevent digital aliasing that occurs if frequencies higher than the Nyquist frequency (half the sampling rate) are in the signal.

f) A/D - The sampling speed and memory depth (wave window length) are dictated by the test requirements and calculated as follows: Vessel length = L inches (meters). Use C_E = 0.2 in./μs (5080 m/s) and C_F = 0.05 in./μs (1270 m/s), the speeds of the first arriving frequency in the E wave and last arriving frequency in the F wave, respectively, as a guide. The actual dispersion curves for the material shall be used if available.

L / C_E = T1 μs. This is when the first part of the direct E wave will arrive.

L / C_F = T2 μs. This is when the last part of the direct F wave will arrive.

(T2 – T1) x.1.5 is the minimum waveform window time and allows for pretrigger time.

The recording shall be quiescent before the front end of the E wave arrives. This is called a “clean front end”. The sampling rate, or sampling speed, shall be such that aliasing does not occur. A minimum of 2 MHz is recommended.

The recording system (consisting of all preamplifiers, amplifiers, filters and digitizers beyond the sensor) shall be calibrated by using a 20 cycle long tone burst with 0.1 V amplitude at 100, 200, 300, and 400 kHz. The system shall display an energy of

$$U = V^2\, NT/2Z \ \ (J)$$

at each frequency, where V=0.1 volts, N = 20, Z is the preamplifier input impedance in ohms (Ω) and T is the period of the cycle in seconds (s).

SXX.9.1 SENSOR PLACEMENT

At least two sensors shall be used in any MAE test regardless of vessel size so that electromagnetic interference (EMI) is easily detected by simultaneity of arrival. Sensors shall be placed at equal distances around the circumference of the vessel on the cylindrical portion of the vessel adjacent to the tangent point of the dome such that the distance between sensors does not exceed 24 in. (610 mm). Adjacent rings of sensors shall be offset by ½ a cycle. For example, if the first ring of sensors is placed at 0, 120, and 240 degrees, the second ring of sensors is placed at 60, 180, and 300 degrees. This pattern shall be continued along the vessel length at evenly spaced intervals, such intervals not to exceed 24 in. (610 mm) along the axis of the vessel, until the other end of the vessel is reached. See Figure SXX.9.1. The diameter referred to is the external diameter of a vessel.

Maximum distance between sensors in the axial and circumferential directions shall not exceed 24 inches (609 mm) as measured along the cylinder axis. The diagonal distance created by offsetting every other row will be greater than 24 inches. This spacing allows for capturing the higher frequency components of the acoustic emission impulses and high channel count wave recording systems are readily available. If it is demonstrated that the essential data can still be obtained using a greater distance, and the authority having jurisdiction concurs, the spacing may be adjusted accordingly.

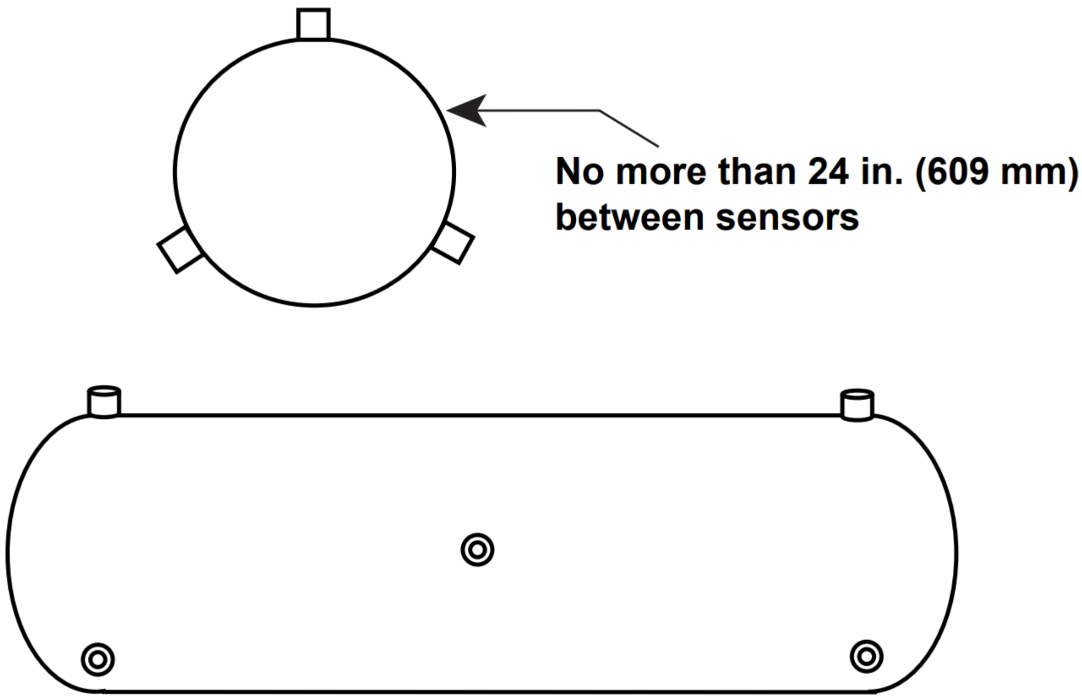

FIGURE SXX.9.1 SENSOR SPACING AND PATTERN. No more than 24 in. (609 mm) between sensors as measured along the cylinder axis. The diagonal distance to neighboring sensors created by offsetting every other row will be greater than 24 inches.

SXX.10 Analysis Procedure and Accept/Reject Criteria

Before applying the evaluation procedure below all noise must be eliminated from the data set. Noise comes in many forms with characteristic features. See ISO 19016 for detailed information about the different types of noise waveforms. Only events with clean front ends shall be used for accept/reject evaluation.

a) In order to determine if fiber bundle breakage has occurred during the filling operation the frequency spectra of the direct E and F waves shall be examined and the energies in certain frequency ranges shall be computed as given below.

b) Definitions

Energies (U) in the ranges are defined as:

50 – 400 kHz: U0

100 – 200 kHz: U1

250 – 400 kHz: U2

The criteria for determining if high frequency spectrum events have occurred is given by the following formulas:

U0 ≥ (U_{FBB})

U2 / (U1 + U2) ≥ 15%

U2 / U0 ≥ 10%

U_{FBB} is the energy of a fiber bundle break calculated using the average breaking strength from the manufacturer's data or independent test data. The manufacturer's data shall be used if available. The formula that shall be used for calculating average fiber break energy in joules (J) is

$$U_{FB} = \frac{1}{2}(E * A * \delta * \varepsilon^2)$$

where E is the Young's modulus of the fiber in pascals (Pa), ε is the strain to failure of the fiber, A is area of the fiber in square meters (m2), and δ is the ineffective fiber length in meters (m) for the fiber and matrix combination. If the ineffective length is not readily available, ten (10) times the fiber diameter shall be used.

c) Example of Fiber Break Energy Calculation

Suppose d = 7 μm, E = 69.6 GPa and ε = 0.01 (average breaking strain) for some carbon fiber. Using A = πd2 /4 and δ = 10d,

$$U_{FB} = \frac{1}{2}(E * A * \delta * \varepsilon^2)$$

$$U_{FB} = 13.4 * \ 10^{-9} \ (J)$$

d) Example of Scaling Calculation

Suppose that the rolling ball impact (RBI) acoustical energy measured by a particular high fidelity MAE transducer is U^{AE}_{RBI} = 5 x 10-10 J and the impact energy U_{RBI} = 1.9 x 10-3 J (due to gravity). A carbon fiber with a break energy of $U_{FB} = 13.4 \times 10^{-9}$ J would correspond to a wave energy of

$U^{AE}_{FB} = U_{FB} \times U^{AE}_{RBI} / U_{RBI}$

$U^{AE}_{FB} = 13.4 \times 10^{-9}$ J x 5 x 10^{-10} J / 1.9 x 10^{-3} J

$U^{AE}_{FB} = 3.5 \times 10^{-15}$ J.

This is the number that is used to calculate the value of U_{FBB} that is used in the fiber break criterion.

e) Amplifier Gain Correction All energies shall be corrected for gain. (20 dB gain increases apparent energy 100 times and 40 dB gain 10,000 times.)

f) Accept/Reject Criteria

Criterion 1: $U_{FBB} \leq F1 \times U_{FB}$, where U_{FB} has been calculated and scaled by the rolling ball impact energy as in the examples below. If this criterion is not met, significant fiber bundle break damage has occurred during the test and the vessel shall be removed from service.

Criterion 2. For a vessel to be acceptable no AE event shall have an energy greater than (F2) x U_{FB} at anytime during the test.

Criterion 3. Background energy of any channel shall not exceed 10 times the quiescent background energy of that channel.

Criterion 4. Any oscillation in background energy with a factor of two excursion between minima and maxima shows that the vessel is struggling to handle the pressure. Pressure shall be reduced immediately, and the vessel removed from service.

Table SXX.10: MAE allowance factors for vessels with a 2.25 safety factor and 3,600 psi working pressure. Common vessel diameters (or circumferences) are given. Weibull parameters for the probability calculation were shape = 5 and scale = 508 ksi. Common winding pattern of OXOXO, where O=hoop and X=helical.

Fiber T700			
Working Pressure	3600 psi		
Test Pressure	5400 psi	4500 psi	
Circumference (in.)	F1	F1	
25.13	2500	1000	
50.26	10000	4200	
100.52	42000	17000	
157	104000	41000	

The allowance factors in Table SXX.10 assume T700 carbon fiber in an epoxy matrix. Values for other carbon fibers can be calculated from material properties found in the open literature. The shape parameter is a measure of dispersion. The greater the dispersion in fiber strength, the more fibers that fail at lower pressures including test pressures. The scale parameter is a 30% knockdown of the published 5000 MPa (725 ksi) fiber strength.

SXX.11 NBIC Vessel Life Extension Information Form

This needs to be filled out only once and attached to the test form below for each vessel of the same type undergoing requalification for an additional five years beyond 20 years from the manufacturing date stated on the vessel's original label.

Fiber Manufacturer's data: Fiber strength, X __________ (Pa or psi)

Fiber Young's Modulus, E _______________ (Pa or psi)

Fiber Diameter, d ______________ (micron or in.)

Vessel overall length ______________ (cm or in.)

Vessel cylindrical section length ______________ (cm or in.)

Vessel circumference ________________________ (cm or in.)

Fiber Break Energy Calculation

The formula for fiber break energy shall be used

$U_f = (½ X^2/E)(pi\ d^2/4)\delta$,

where E is fiber Young's modulus (Pa), X is fiber strength (Pa) , d is fiber diameter (m), pi is 3.14 and δ is the ineffective fiber length. If the ineffective length is unknown, a value of 10 shall be used.

Calculated value of fiber break energy U_f _______________ (Joule)

This value shall be input into the software for evaluating energies in waveforms of detected fiber breaks.

MAE Recording Equipment Data

Equipment Manufacturer__________________

Model Name/Number_____________________

Number of recording channels used _____________

Digitization Rate_____________ (must be equal or greater than 2 MHz)

Number of bits for A/D converter ___________________

Number of points per waveform ____________________

Number of pretrigger points per waveform______________

Note: The equivalent to discreet waveform data capture shall be produced by software if streaming capture is used. Must be capable of determining first arrival channel for every MAE event.

Has the equipment been calibrated? Date of Calibration______________

Calibration method? (Toneburst frequency = 100 kHz, number of cycles = 20 and voltage amplitude = 0.1 V) ____

Toneburst generator Model __________________________ Calibration date ______________

Calculated energy of calibration toneburst _____________ (Joule)

Measured energy of calibration toneburst ______________ (Joule)

Amplifier gain in addition to preamplifier gain to be used during testing __________ (dB)

Transducer Data

Transducer Manufacturer and Model Number _______________________________

Published bandwidth ___________________

Integral preamplifier? Y/N If yes, the gain is _________ (dB).

Transducers must be calibrated using the Rolling Ball Impact (RBI). They must also be absolutely calibrated using a Michelson Interferometer or other methods equivalent to ASTM E1106-12. Sensor sensitivity shall be at least 0.05 V/nm at the preamplifier input. MAE sensors shall have a diameter no greater than 0.5 inch for the active part of the face and the aperture effect shall be considered for MAE testing.

Calibration Date _____________

Is absolute calibration curve attached to this form? If not, testing shall not be performed.

Has transducer energy RBI conversion factor been measured? If not, testing shall not be performed.

Transducer energy conversion factor determined from RBI ______________

Transducer Spacing and Pattern

Standard pattern is no more than 24 inch intervals between sensors around the circumference and between rows of sensors on an axial line from one end of the cylindrical portion of the vessel to the other as specified earlier. Alternatively, attenuation measurements can made that allow a greater distance to be used between transducers in either the axial or circumferential directions provided that the frequencies necessary to determine fiber break events are detectable. This means the amplitude of the 400 kHz component of a 0.3mm 2H Pentel pencil lead break on the surface at one transducer is at least a factor of 1.4 above the noise level when measured at the nearest distant axial and circumferential transducers. The amplitude of the 400 kHz frequency component of the detected waveform shall be noted.

400 kHz amplitude at axial transducer spacing ____________________ (Volt)

400 kHz amplitude at circumferential transducer spacing ____________________(Volt)

Total number of transducers used in test _______________

Describe and provide a rough sketch below of the alternative spacing pattern to be used based on attenuation measurements.

Pressurization

Pressure shall be applied hydrostatically by a computer-controlled system. Proper precautions should be observed for test personnel safety.

A pressure output voltage shall be supplied to the MAE instrumentation according to the voltage level requirement of the MAE recording system.

Pressure gage type and model ___________________

MAE transducers shall be attached and checked for proper functioning either by recording pencil lead breaks or auto-sensor test results. The quiescent background energy shall be recorded automatically for every channel just before pressurization begins.

SXX.12 ASME Section X Class III Pressure Vessel Requalification/Life Extension Test Report Form

MAE Test Technician

Technician Name ______________________________________

Certification Agency and Certification Number ____

Or

Certifying Authority, Certification Level, and Certification Date

____

Vessel Data

Vessel Manufacturer   ____

Date Manufactured ___________________________________

Operating Pressure ____________________________

Service (e.g., CNG, hydrogen) ____________________

Vessel Serial Number ____________________________

Date of last requalification test __________________________

Visual Examination

Note: The VE must be performed prior to running an MAE test.

The VE procedure and accept/reject criteria can be found in Section X Mandatory Appendix 8.

VE performed by _________________________

Date ____________________________

Result (Pass or Fail. Note reason for failure.) ____

Test Procedure

The test shall be conducted with modern MAE equipment. Modern means that the equipment is automated to the point that the test technician is a running a software program that can compute and display live during the test any violation of the accept/reject criteria. The test technician shall verify that the values (numbers) of the criteria have been input into the software. The MAE instrumentation, including the MAE transducers, shall be fully calibrated as described earlier in this document. The MAE instrumentation shall be fully capable of all displays, waveform acquisition and storage as previously described.

The technician shall verify amplifier gain settings, waveform digitizer settings, have been properly input. The pressure gage input shall be verified as working properly. All required data capture and evaluation plots shall be displayed on the computer screen.

1. Verify each transducer has a current calibration document.

2. Record serial number (S/N) and calibration date for each transducer used in the test.

3. Verify all transducers are well-coupled mechanically and acoustically to the vessel.

4. An auto-sensor test shall be performed, and the acoustical response of each transducer shall be recorded by the computerized equipment. In case a transducer response is 6 dB below the average response level, the technician can recouple it and retest the response. If it is still not acceptable, it shall be replaced with a similar transducer and the new transducer's S/N and calibration date noted.

5. Connect pressure gage to MAE equipment and verify signal.

6. A leak check shall be performed at 10% of test pressure. Pressure shall be increased at a rate of not less than 10 psi/sec but not greater than 100 psi/sec. Pressurization rate shall not permit flow noise. Pressure shall be held at 125% of operating pressure for five minutes before proceeding to test pressure. Test pressure shall be held for fifteen minutes. Pressure shall be reduced to zero psi. After pressure is reduced to zero, a transducer coupling check should be performed (auto-sensor test) and documented.

Note: The vessel under test may still be in service. The test may be conducted by pressurizing pneumatically, in which case the MAE test pressure will be lower than the normal hydrostatic test pressure of 3/2 or 5/3 of working pressure. If the MAE test pressure is lower than that used in the type testing (for example, if fill pressure or developed pressure is used) the appropriate accept/reject criteria shall be provided by the SRT in writing and noted here.

The MAE computer shall display waveforms for each channel, events and pressure versus time, and background energy versus time. If an accept/reject violation occurs, the pressure shall be reduced, and the vessel rejected for life extension/continuation.

The following numbers shall be noted immediately following the MAE test:

The pressure at which the BE energy first rises by more than 2 times the quiescent background energy shall be noted. BE initial rise pressure _____________ (psi) and energy level ______________ (Joule). (If no rise, so state.) There shall be no rise in BE greater than 10 x the quiescent energy.

The pressure at which a fall and subsequent rise of the BE (called background energy oscillation or BEO) with a peak-to-peak energy greater than a factor of two (2) shall be noted. BEO Pressure ____________ (psi) (If no oscillation, so state.) There shall be no oscillations with a peak-to-peak energy greater than 2.

Highest event energy ______________ (Joule) Shall be less than F2 x Uf.

Highest fiber break event energy ____________ (Joule) Shall be less than F1 x Uf.

Do all the numbers meet the MAE A/R criteria? Yes/No (Circle one.)

7. All the waveforms for a vessel that fails shall be saved and provided to the SRT. The waveforms for a vessel that passes can be discarded, but the test displays at the final pressure showing that the accept criteria have been met shall be attached to this form, a copy of which shall be retained with the vessel records by the owner of the vessel. A copy shall be retained by the entity performing the test for a period of six (6) years.

8. A vessel that has passed shall have a label attached stating approval for continued service for five years.

NBIC Interpretation Item I25-95
Submitted by Christopher Ferro (cferro@qtww.com)
3/5/2026

THE NATIONAL BOARD OF BOILER AND PRESSURE VESSEL INSPECTORS

Subject:	Clarification on Section S11.3 - Clearances
NBIC Location:	2025 NBIC Part 1, S11.3
Statement of Need:	I would like clarification on this section of the standard to see if my interpretation is correct.
Background Information:	I am a design release engineer, and I work for a pressure vessel manufacturer that is looking to make ASME tanks. This requirement will severely restrict the number of pressure vessels that we can bundle together inside one container.
Proposed Question:	I have an inquiry regarding Section S11.3 of the NBIC 2025 standard. In this section, it states that the stacking of pressure vessels is permitted. However, the minimum clear space between pressure vessels shall be 1 ft and 2 ft horizontally. I have seen ASME tanks at various facilities where the pressure vessels are not separated 1 ft vertically and 2 ft horizontally. Does this rule mean that individual pressure vessels can be stacked but must adhere to the 1ft vertical and 2ft horizontal clear space rule? Or can a bundle of pressure vessels together be considered as one pressure vessel and not have to adhere to this rule? Thank you very much.
Proposed Reply:	Pressure vessels that are organized in a bundle should not have to adhere to the 1ft and 2ft horizontal requirements. This can be very limiting to tank manufacturers who are attempting to store many pressure vessels into one container to maximize the high energy demands of CNG customers.
Committee's Question:	
Committee's Reply:	
Rationale:	

NBIC Interpretation Item I25-95
Submitted by Christopher Ferro (cferro@qtww.com)
3/5/2026

SUPPLEMENT 11
INSTALLATION OF HIGH-PRESSURE COMPOSITE PRESSURE VESSELS

S11.3 CLEARANCES

The pressure vessel installation shall allow sufficient clearance for normal operation, maintenance, and inspection. Stacking of pressure vessels is permitted. The minimum clear space between pressure vessels shall be 1 ft. vertical and 2 ft. horizontal. Vessel nameplates shall be visible for inspection after installation. The location of vessels containing flammable compressed natural gas fluids shall comply with the requirements of the National Fire Protection Association's (NFPA) NFPA 52, Vehicular Natural Gas Fuel Systems Code. The location of vessels containing hydrogen or other flammable fluids shall comply with NFPA 2, Hydrogen Technologies Code. The vessel owner shall document the vessel pressure and pipe diameters used as a basis for compliance with NFPA 2 location requirements.