

# Date Distributed: April 30, 2018

**NATIONAL BOARD**

**SUBGROUP FRP**

 Minutes

Meeting of April 23rd, 2018

Orlando, FL

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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 NBIC SG FRP meeting was called to order by Mr. Bernie Shelley at 1:18pm local time.

1. **Introduction of Members and Visitors**
2. **Review of the Roster (See Page 4)**
3. **Announcements**

Mr. Jonathan Ellis has replaced Mr. Bradley Besserman as secretary of Subgroup FRP.

1. **Adoption of the Agenda**

Motion was made by Mr. Shelley to adopt the agenda. This motion was seconded and approved.

1. **Approval of the Minutes of April 2017 Meeting**

The minutes from the April 2017 SG FRP meeting in San Juan, PR are published on the National Board website.

1. **Action Items**

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| **Item Number: NB11-1901** | **NBIC Location: Part 1** | **No Attachment** |
| **General Description:** Add guidance for the safe installation of high pressure composite pressure vessels operating in close proximity to the public |
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| **Subgroup:** FRP**Task Group:** D. Keeler (PM)**Meeting Action:** Mr. Ellis informed the group that this item had been approved by NBIC Subcommittee Installation prior to this meeting, and that the item will be on the Main Committee agenda at the July 2018 NBIC meeting. |

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| **Item Number: NB15-2202** | **NBIC Location: Part 1** | **No Attachment** |
| **General Description:** Add checklist for the safe installation of high pressure composite pressure vessels operating in close proximity to the public |
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| **Subgroup:** FRP**Task Group:** D. Keeler (PM)**Meeting Action:** The group discussed Subcommittee Installation’s comments on this item. Mr. Rex Smith of SC Installation had reached out to the group for clarification on this item in January, and the group agreed that additional correspondence from Mr. Dale Keeler would be sent to address the subcommittee’s questions.  |

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| **Item Number: NB16-1401** | **NBIC Location: Part 2, S10** | **No Attachment** |
| **General Description:** Revise and update Supplement 10 on Inspection of CRPVs |
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| **Subgroup:** FRP**Task Group:** N. Newhouse (PM), M. Gorman, A. Pollock**Meeting Action:** The task group finished an initial proposal for this item, and requested that it be sent out for a Review and Comment ballot to gather input from the group. This plan was approved by the group. |

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| **Item Number: NB16-1402** | **NBIC Location: Part 3** | **Pages 5-8** |
| **General Description:** Life extension for high pressure vessels above 20 years |
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| **Subgroup:** FRP**Task Group:** M. Gorman (PM)**Meeting Action:** Mr. Mike Gorman provided his completed proposal to the subgroup. Mr. Shelley requested that the proposal be letter balloted to Subgroup FRP at the conclusion of the meeting.  |

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| **Item Number: NB16-1403** | **NBIC Location: Part 3, S4** | **No Attachment** |
| **General Description:** Add information on repair of high pressure vessels |
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| **Subgroup:** FRP**Task Group:** N. Newhouse (PM)**Meeting Action:** Project ManagerMr. Norm Newhouse is working to develop a proposal. |

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| **Item Number: 17-137** | **NBIC Location: Part 3, S4** | **Pages 9-10** |
| **General Description:** Remove "sand" blasting and replace with "abrasive" in Part 3, S4.18.2 |
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| **Subgroup:** FRP**Task Group:** T. Cowley (PM)**Meeting Action:** Mr. Terry Cowley submitted an updated proposal and requested that it be letter balloted to the group. |

1. **Additional Business**
2. **Future Meetings**

October 22nd 2018 – Las Vegas, NV

April 2019 – Ft. Lauderdale, FL

1. **Adjournment**

Motion was made by Mr. Shelley to adjourn the meeting at 1:48 pm local time. The motion was seconded and approved.

Respectfully submitted,

Jonathan Ellis

Jonathan Ellis

NBIC Secretary

**ATTACHMENTS**



**Supplement 14**

**Life Extension of High Pressure Fiber Reinforced Plastic Pressure Vessels**

**S14.1 Scope**

This document may be used to evaluate whether the service life of high pressure fiber reinforced plastic pressure vessels (FRP) can be extended for an additional lifetime. High pressure means vessels with a working pressure from 3,000 psi (20 MPa) to 15,000 psi (103 MPa). For vessels intended for cyclic service, fatigue testing of new vessels is carried out by the vessel manufacturer to be certain that the vessel will not fail in service and such testing is typically required by regulatory authorities. Fatigue design and testing is the starting point for consideration of life extension.

**S14.2 General**

1. The procedure for in-service testing of high pressure composite pressure vessels, **Supplement 10** herein, is incorporated by reference into this procedure for life extension of high pressure composite pressure vessels. Supplement 10 is based on acoustic emission (AE) testing, specifically modal AE (MAE) testing. The MAE inspection procedure employs detection and analysis techniques similar to those found in seismology and SONAR. Much as with earthquakes, transient acoustical impulses arise in a composite material due to the motion of sources such as the rupture of fibers. These transients propagate as waves through the material and, if properly measured and analyzed by the methods in Supplement 10, the captured waves reveal, for example, how many fibers have ruptured. Similar information about other sources is also determinable, such as the presence and size of delaminations. Delaminations can play a significant role in vessel fatigue life, particularly delaminations near the transition regions and in the heads. The rupture behavior can be used to determine the integrity of the vessel. However, the development of criteria for life extension (LE) requires an understanding of the vessel design and fatigue life.
2. Fatigue testing of out of life vessels is a crucial part of the life extension process. It is used to validate the mechanical behavior of the vessels and to develop the numerical values for the allowables in the MAE pass/fail criteria for the particular design, material and construction.

**S 14.3 Life Extension Procedure**

1. New vessel fatigue life testing data shall be obtained from the Manufacturer’s Design Report (MDR) and the number of cycles in a lifetime shall be determined from the MDR. The type of vessel under consideration for life extension shall have been shown through testing to be capable of sustaining at least three lifetimes of cycles to developed fill pressure followed by a subsequent burst test at a pressure greater than minimum design burst pressure.
2. An evaluation of the service the vessel has seen should take into account any operational conditions that may have differed from those used in the design testing and analysis. Such conditions include for example exposure to more severe weather than expected, more cycles per year, constant high temperature and humidity, chemical attack or any other of a number of conditions under which operations take place that were not specifically included in testing at manufacture. Any such conditions shall be listed on the attached form. If no such conditions exist, it shall be so noted on the form. The test program delineated herein shall be revised to reflect the modified conditions as documented by the user and submitted for approval to the proper authorities.
3. Data and records for all vessels considered for life extension shall be kept and made readily available to inspectors or examination personnel. This includes an operating log, number of operating cycles since the previous examination, total number of operating cycles, examinations, examination techniques and results, maximum operating pressure and any unexpected pressures, temperatures, temperature cycles, damage events or other significant events that were outside the intended operating parameters or conditions.
4. A life extension test program shall be carried out for each type of vessel under consideration. Type of vessel means the particular manufacturer, materials (fiber and resin), water volume and design. If the type of vessel passes all requirements, then that type shall be eligible for life extension testing. If such a vessel passes the life extension MAE test its lifetime can be extended for one additional lifetime in five-year increments. In order to maintain life extension a vessel must be requalified every five years using the MAE test.

**S14.4 Life Extension Test Program**

1. The type of vessel under consideration for LE shall be noted. Manufacturer, place of manufacture and manufacturing date shall be recorded. The vessel dimensions shall be recorded. The specific fiber, matrix and winding pattern shall be recorded. If the fiber, matrix and winding pattern are not available from the manufacturer, then a vessel of the type under consideration shall be used to verify the winding pattern (hoop and helical angles and number of plies) through destructive testing.
2. Ten out-of-life vessels of the particular type shall be tested in the manner described herein. MAE techniques shall be applied to every vessel tested. Analysis of the MAE data is described herein. Two strain gages, one in the 0-degree and one in the 90-degree direction, shall be applied to every vessel pressure tested under this program. The purpose of strain gage data is to compute the 0 and 90 modulus values and to confirm that the modulus values of the material do not vary during the fatigue cycling required herein. Strain data shall be recorded and analyzed as described later on.
3. The LE test program proceeds by Steps. If the Step 1 is not successful, then there is no need to proceed to Step 2, and so forth.

**S14.5 Life Extension Test Program Steps**

S14.5.1 Step 1

Three vessels shall be selected from the ten and pressurized to burst. The vessels shall be inspected for visible damage, i.e., cuts, scrapes, discolored areas, and the vessel appearance shall be documented with photographs. MAE testing shall be done in conjunction with this testing as specified in Supplement 10, except for transducer spacing, pressurization plan and accept/reject criteria values. The values in Supplement 10 are for requalification testing. The transducer spacing shall be determined by the distance at which the 400 kHz component of a suitable pulser source is detectable along the axis of the vessel (essentially across the hoop fibers) and in the perpendicular direction (essentially parallel to the hoop fibers). Detectable means that the resulting signal component has an amplitude with at least a signal to noise ratio of 1.4. Transducer frequency response calibration and energy scale shall be carried out as specified in SUPPLEMENT 10. The pressurization plan shall follow that in ASME Section X Mandatory Appendix 8, i.e., there shall be two pressure cycles to test pressure with holds at test pressure as prescribed therein, however, the time interval between the two cycles may be reduced to one minute. For the purposes of life extension, the fiber fracture energy and BEO (background energy oscillation) values shall be as specified below.

1. No BEO greater than 2 times the quiescent energy (see Supplement 10) shall be observed up to test pressure or during pressure holds.
2. No fiber break event energy shall be greater than 24 x 103 x UFB (see Supplement 10) during the second pressurization cycle.
3. No single event shall have an energy greater than 24 x 105 x UFB during the second pressurization cycle.

Note: The numerical values specified in b) and c) can be adjusted through documented testing and stress analysis methods in order to account for the particular design, material and construction.

1. At least two sensors shall remain on each vessel all the way to burst in order to establish the BEO pressure for this type of vessel.
2. Plots of stress versus strain shall show linear behavior up to 90% of burst pressure.
3. The burst pressures of all three vessels shall be greater than the minimum design burst pressure.
4. If the burst pressure of any one of the three vessels is not greater than the minimum design burst pressure, then these vessels shall not be eligible for life extension and there is no need to proceed with Step 2 below.

Note: It is possible that one or more of the vessels selected had damage not obvious to visual inspection. If during this burst testing phase the MAE test identifies a vessel as damaged, the substitution of three other randomly selected vessels is allowed.

S14.5.2 Step 2

If the vessels pass Step 1, fatigue testing shall be carried out on a minimum of three vessels of the same type being considered for life extension.

1. Prior to testing, the vessels shall be inspected for visible damage, i.e., cuts, scrapes, discolored areas, and the vessel appearance shall be documented with photographs.
2. Prior to fatigue testing, MAE testing as specified in Step 1 shall be done in conjunction with the fatigue testing, hereinafter called the MAE test or MAE testing, in order to determine the suitability of the vessels for fatigue testing, i.e., that they pass the MAE test.
3. Next, the vessels shall be subjected to fatigue cycles. Pressure shall be 100 psi +0, -50% to at least 1.05 x working pressure. Vessels shall survive one and one-half (1.5) additional lifetimes. If they survive then they shall be tested by an MAE test as was done prior to fatigue cycling.
4. Provided they pass the MAE test, they shall be burst tested. At least two sensors shall remain on each vessel all the way to burst in order to establish that the BEO (background energy oscillation) pressure for the fatigued vessels is consistent, i.e., is the same percentage of ultimate, with that of the vessels tested in Step 1.
5. Plots of stress versus strain shall show linear behavior up to 90% of burst pressure.
6. The burst pressures at the end of the fatigue testing shall be greater than or equal to the minimum design burst. If the burst pressure of any one of the three vessels is not greater than the minimum design burst pressure, then these vessels shall not be eligible for life extension.

S14.5.3 Step 3

If the vessels pass Step 2, impact testing shall be carried out on a minimum of three vessels of the same type being considered for life extension.

1. Prior to testing, the vessels shall be inspected for visible damage, i.e., cuts, scrapes, discolored areas, and the vessel appearance shall be documented with photographs. Prior to impact testing, MAE testing shall be done in order to determine the suitability of the vessels for impact testing, i.e., that they pass the MAE test.
2. Two vessels shall be subjected to an ISO 11119.2 drop test and then subjected to the MAE test. If they pass the MAE test, then one vessel shall be burst tested. At least two sensors shall remain on the vessel all the way to burst in order to establish that the BEO (background energy oscillation) pressure for the fatigued vessels is consistent, i.e., is the same percentage of ultimate, with that of the vessels tested in Step 1.
3. Plots of stress versus strain shall show linear behavior up to 90% of burst pressure.
4. If the burst pressure is not greater than the minimum design burst pressure, then these vessels shall not be eligible for life extension.
5. If the first vessel passes the burst test, the other dropped vessel shall be fatigue cycled and subsequently subjected to the MAE test and, if it passes, shall be burst tested under the same conditions as before. If the vessel fails during fatigue cycling, i.e., bursts or leaks, then these vessels shall not be eligible for life extension.
6. If the modulus changes by more than 10%, then these vessels shall not be eligible for life extension. The strain gages should be mounted in a location that is away from the impact zone.
7. The burst pressure at the end of the fatigue testing of the dropped vessel shall be greater than or equal to the minimum design burst. The vessels shall have MAE testing applied during burst testing as before and the BEO shall be consistent with the previously established percent of burst ±10%.

S14.5.4 Step 4

If the vessels pass Step 3, cut testing shall be carried out on a minimum of two vessels of the same type being considered for life extension.

1. Prior to testing, the vessels shall be inspected for visible damage, i.e., cuts, scrapes, discolored areas, and the vessel appearance shall be documented with photographs. Prior to cut testing, MAE testing shall be done in order to determine the suitability of the vessels for cut testing, i.e., that they pass the MAE test.
2. Two vessels shall be subjected to an ISO 11119.2 cut test and then subjected to the MAE test. If they pass, then one shall be burst tested under all the conditions and procedures delineated in Step 2. If the burst pressure is not greater than the minimum design burst pressure, then these vessels shall not be eligible for life extension.
3. If the cut vessel passes, then the other cut vessel shall be fatigue cycled as described in Step 2 and subsequently subjected to the MAE test and then burst tested with at least two MAE sensors remaining on and monitoring the vessel as before. If it does not survive fatigue cycling, then these vessels shall not be eligible for life extension.
4. The burst pressure at the end of the fatigue testing of the cut vessel shall be greater than or equal to the minimum burst pressure specified by ISO 11119.2.

If the vessel type passes Steps 1 to 4, then that type is eligible for life extension. An out of life vessel of the type subjected to the program above may have its life extended for one additional lifetime if it passes the MAE test. The vessel shall pass the MAE test at subsequent five-year intervals or at one-third of the lifetime, whichever is less, in order to continue in service. The vessel shall be labeled as having passed the NBIC life extension test.

**Item 17-137:**

Part 3, S4.18.2.1 2) d. 2. and 4.

1. Applying Test Patches to Verify Adequate Surface Preparation
	1. Test patches should be applied to any substrate that will require a secondary bond to determine the integrity of the primer bond prior to the application of the laminate.
	2. The subsequent steps shall be followed:
		1. Apply the primer (0,003 -0.005 in. (0.08 to 0.13 mm)) to the prepared surface, and allow primer to cure.
		2. Coat the primed surface with the same resin to be used in the laminate repair. Apply 4 in. (100 mm) x 14 in. (360 mm) piece of polyester, such as Mylar®, strip to one edge of primed area. Allow the polyester film to protrude from beneath the patch.
		3. Apply two layers of 1-1/2 oz/sq. ft (0.46 kg/sq. m) chopped strand mat saturated with the same resin that will be used for the repair. Mat shall be 12 in. (305 mm) x 12 in. (305 mm) square.
		4. Allow the mat layers to cure completely, this may be verified by checking the hardness of the laminate.
		5. Pry patch from surface using a screwdriver, chisel, or pry bar.
		6. A clean separation indicates a poor bond.
		7. Torn patch laminate or pulled substrate indicates that the bond is acceptable.
	3. If the bond is not adequate, go back to step a) and repeat the procedure.

**Note:** If the repair area is smaller than the test patch dimensions, decrease the test patch size accordingly.

* 1. As a last resort, if the previous procedure does not provide an adequate bond, the permeated laminate must be handled differently using the following procedure:
		1. Hot water wash the equipment.
		2. Abrasive blast to achieve a 0.003 to 0.005 in. (0.08 to 0.12 mm) anchor pattern, and allow to completely dry.
		3. Prime with the recommended primer, an area 12 in. (305 mm) x 12 in. (305 mm) and apply a test patch.
		4. Prime a second spot 12 in. (305 mm) x 12 in. (305 mm) and prime with a recommended alternate primer.
		5. Allow this primer to cure.

Part 3, S4.18.2.2 2)

1. …
2. Note that any cracks, delaminations, or permeated surfaces must be removed. If the damage is deeper than the corrosion barrier and the material removed reaches the structural laminate, the vessel is not repairable. An adequate size abrasive or proper sanding disc must be used to obtain a 0.002 to 0.003 in (0.05 to 0.08 mm) anchor pattern to the area that requires the repair.
3. Preparation of any surface requires that basic rules, common to all substrates, be followed. These rules are as outlined below:
	1. Surface must be free of contaminants;
	2. Surface must be structurally sound;
	3. Surface must have adequate anchor pattern;
	4. Surface must be dry;
	5. Surface must be primed with recommended primer.

**Note:** After the surface has been properly prepared, it must be kept clean and dry until laminating can be started. Dust, moisture, or traces of oil that come in contact with the surface may act as a mold release or act to inhibit the cure and prevent a good secondary bond. Laminating should be done within two hours of the surface preparation.