

Committee of Experts on the Transport of Dangerous Goods and on the Globally Harmonized System of Classification and Labelling of Chemicals

Sub-Committee of Experts on the Transport of Dangerous Goods

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Item 6 (c) of the provisional agenda

Miscellaneous proposals for amendments to the Model Regulations on the Transport of Dangerous Goods: portable tanks

Sub-chapter 6.9.3 “Requirements for design, construction, inspection and testing of fibre reinforced plastic (FRP) service equipment for portable tanks” and amendments to Sub-chapters 6.7.2.5.11, 6.9.1 and 6.9.2.5

Submitted by the Russian Federation on behalf of the informal working group on fibre reinforced plastic (FRP) service equipment for portable tanks

1. The informal working group on FRP service equipment for portable tanks met on 28 November 2022 in conjunction with the 61st session of the TDG Sub-Committee and discussed the comments received through correspondence and via teleconferences since 2 September 2022.

Discussions in working group

2. The informal working group on FRP service equipment for portable tanks has not worked out major amendments to the original text presented in ST/SG/AC.10/C.3/2022/62.

3. However, the informal working group has fruitfully discussed and processed the received comments and remarks.

4. Please find updated text in the Annex. For easy reference please find below the updates with relevant comments for easy reference and discussion.

5. Remark (*) for applicability of FRP service equipment to metallic portable tanks has been proposed in amendments to 6.9.1 sub-chapter considering the comments from the experts from the Netherlands and the United Kingdom.

6. Amendments to sub-chapters 6.7.2.5.11 and 6.9.2.5 were proposed for harmonization.

7. The last sentence of “Coupon-samples” definition “Coupon-samples shall be manufactured by the same technology as the appropriate FRP service equipment” was replaced to paragraph 6.9.3.4.2 from in 6.9.3.1 as requirement. “Are” was replaced by “shall be” in order to emphasize the requirement.

8. The new paragraph 6.9.3.2.2.2 “Relevant provisions of 6.9.2.2.2 shall be applied to FRP service equipment manufacturer’s quality system” was added considering comments from UK and Nederland experts. “Should” was replaced by “shall” in the last sentence of 6.9.3.2.2.1.

9. References to 6.7.2.5.2-6.7.2.5.5 were added.
10. The term “prototype” was replaced by “design” in 6.9.3.5.1. A typo was fixed in 6.9.3.5.2 – “component” was replaced by “competent”.
11. The required material tests were logically ordered in 6.9.3.4. The term “short” was deleted in 6.9.3.2.4.3 in description of reinforcement fibres. A typo was fixed – the word “tank” was replaced by term “FRP service equipment” in 6.9.3.2.4.2.
12. The term “allowables” was replaced by “parameters” in 6.9.3.3.4. The sentence “At least all experiments defined in 6.9.3.4.2 must be performed” was added in order to emphasize the importance of the tests for justification of failure criteria and safety factor K.
13. Relevant publication years were indicated for the testing standards referenced in sub-chapter 6.9.3.
14. New paragraph 6.9.3.6.4 was added “The repair work of FRP service equipment shall be limited to replacement of damaged components by components covered by the type approval of the service equipment”. Therefore, the exceptional inspection of the damaged FRP service equipment was deleted as redundant.
15. The marking of FRP service equipment was brought to accordance with 6.7.2.20.1(d) in terms of pressure.

Actions requested

16. The Sub-Committee is invited to consider the following text (Annex) for adoption instead of the text proposed in ST/SG/AC.10/C.3/2022/62. The changes in the Annex are marked in “track changes mode”.

Annex

Amendments to 6.7.2.5.11 Sub-chapter

Ductile metals shall be used in the construction of service equipment, unless it is FRP service equipment in accordance with Section 6.9.3.

Amendments to 6.9.1 Sub-chapter

6.9.1.4 The requirements of section 6.9.3 are applied to FRP service equipment for portable tanks with shells made of metallic or FRP materials* intended for the carriage of dangerous goods of Classes or Divisions 1, 3, 5.1, 6.1, 6.2, 8 and 9 by all modes of transport.

* The requirements on FRP service equipment have initially been developed for both FPR and metallic shells and their application provides the appropriate level of safety. However, keeping in mind innovative aspects of the requirements provided Administration may consider the application of FRP service equipment with metal tanks.

6.9.1.5 The requirements of 6.7.2.5-6.7.2.9, 6.7.2.11-6.7.2.16 shall be applied to FRP service equipment including metallic parts (springs, fixings and etc.).

Amendments to 6.9.2.5. Sub-chapter

Service equipment, bottom openings, pressure relief devices, gauging devices, supports, frameworks, lifting and tie-down attachments of portable tanks shall meet the requirements of 6.7.2.5 to 6.7.2.17. If any other metallic features are required to be integrated into the FRP shell, then the provisions of 6.9.2.3.8 shall apply. FRP service equipment in accordance with Section 6.9.3 may be used.

Amendments to 6.9.1 Sub-chapter

6.9.1.4 The requirements of section 6.9.3 are applied to FRP service equipment for portable tanks with shells made of metallic or FRP materials intended for the carriage of dangerous goods of Classes or Divisions 1, 3, 5.1, 6.1, 6.2, 8 and 9 by all modes of transport.

6.9.1.5 The requirements of 6.7.2.5-6.7.2.9, 6.7.2.11-6.7.2.16 shall be applied to FRP service equipment including metallic parts (springs, fixings and etc.).

6.9.3 Requirements for design, construction, inspection and testing of fibre reinforced plastic (FRP) service equipment for portables tanks

6.9.3.1 Definitions

For the purposes of this section, the definitions of 6.7.2.1 and 6.9.2.1 are applied excepting for definitions related to metal materials for the construction of the service equipment of portable tanks.

Additionally, the following definitions are applied to FRP service equipment.

FRP service equipment means, stop valves, relief devices, manlids, manhole covers, cleaning hatches and blind flanges made of FRP including metallic parts, e.g. springs, fixings for portable tanks.

Injection molding means a process of melting plastic pellets (thermosetting/ thermoplastic polymers) that once malleable enough, are injected at pressure into a mould cavity, which fills and solidifies to produce the final product.

Compression molding means a process for producing composite parts in a wide range of volumes typically employing a matched metal tool in a heated (normally hydraulic) press to consolidate sheet materials or moulding compounds at relatively high pressures.

Reinforced reaction injection molding (RRIM) means a process of mixing of two or more resins together in the mixing chamber to form a thermosetting polymer under high pressure. Reinforcement agents like glass fibers or mica are added to the mixture. Then the resin mixture is metered into a mold with the help of high pressure pumps or injection cylinders.

Coupon-sample means a FRP sample fabricated and tested in accordance with national and / or international standards to determine design allowables. ~~Coupon samples are manufactured by the same technology as the appropriate FRP service equipment.~~

Inspection-sample means a sample cut out from the FRP service equipment to establish the identity of serial FRP device to the prototype.

FRP constituents means reinforcement fibres and/or particles, thermoset or thermoplastic polymer (matrix), adhesives, and additives.

6.9.3.2 General design and construction requirements

6.9.3.2.1 For the purposes of this section, the requirements of 6.7.2.2.11, ~~6.7.2.5.1-6.7.2.5.6~~, 6.7.2.5.10, 6.7.2.6.3, 6.7.2.8.2, 6.7.2.8.3, 6.7.2.9, 6.7.2.12, 6.7.2.13, 6.7.2.14 and 6.7.2.15 shall be applied to FRP service equipment. The FRP service equipment shall be designed and constructed in accordance with the requirements of a pressure vessel code and national and international standards, applicable to FRP materials and recognized by the competent authority.

6.9.3.2.2 Manufacturer's quality system

6.9.3.2.2.1 FRP service equipment manufacturer shall have a documented quality system ensuring conformity of every item of the serial production the FRP service equipment to the approved prototype. The Quality Assurance Program shall be submitted to the competent authority for approval. All manufacturer's suppliers of material and components for FRP service equipment should have a documented quality system. The quality system ~~should~~ shall be developed in compliance with the general principles of international and national quality standards.

6.9.3.2.2.2 Applicable provisions of 6.9.2.2.2 shall be applied to FRP service equipment manufacturer's quality system.

6.9.3.2.3 *FRP service equipment*

6.9.3.2.3.1 FRP service equipment shall have a rigid appropriate joints to the portable tank shell. The connections shall cause no dangerous local stress concentrations in the shell and the equipment exceeding the design allowables for all operating and test conditions.

6.9.3.2.3.2 FRP service equipment shall be made of suitable materials, capable of operating within a minimum design temperature range of -40 °C to +50 °C, unless temperature ranges are specified for specific more severe climatic or operating conditions (e.g. heating elements), by the competent authority of the country where the transport operation is being performed.

6.9.3.2.3.3 FRP service equipment and its bolted and/or glued joints of the portable tank shell shall be designed and constructed to withstand the test pressure which is not less than 1.5 times the design pressure. Specific provisions are stated for certain substances in the applicable portable tank instruction indicated in column 13 of the Dangerous Goods List and described in 4.2.5, or by the portable tank special provision indicated in column 14 of the Dangerous Goods List and described in 4.2.5.3.

6.9.3.2.3.4 The FRP service equipment shall withstand vibration, service impacts, exposure to substance temperature and environment effects.

6.9.3.2.3.5 Design calculations for FRP service equipment and its joints to the portable tank shell shall be performed by finite element method or the applicable pressure vessel code.

6.9.3.2.3.6 The FRP service equipment shall meet the same requirements as given in 6.9.2.2.3.14 for the carriage of substances with a flash-point of not more than 60 °C.

6.9.3.2.4 *Materials*

6.9.3.2.4.1 Resins.

The processing of the resin mixture shall be carried out in strict compliance with the recommendations of the supplier. This concerns mainly the use of hardeners, initiators and accelerators. The resins can be:

- Unsaturated polyester resins;
- Vinyl ester resins;
- Epoxy resins;
- Phenolic resins.
- Thermoplastic resins.

The heat distortion temperature (HDT) of the resin, determined in accordance with ISO 75-1:2013 and ISO 75-2:2013 shall be at least 20°C higher than the maximum service temperature of the tank, but shall in any case not be lower than 70°C.

6.9.3.2.4.2 Additives.

Additives necessary for the treatment of the resin, such as catalysts, accelerators, hardeners and thixotropic substances as well as materials used to improve the [FRP service equipment](#), such as fillers, colors, pigments etc. shall not cause weakening of the material, taking into account lifetime and temperature expectancy of the design.

6.9.3.2.4.3 Reinforcement fibres.

The reinforcement fibres shall be ~~short~~-chopped or continuous fibres of several types.

6.9.3.2.4.4 FRP service equipment shall be manufactured by compression molding, injection molding, reinforced reaction injection molding or hand lay-up. Other manufacturing technologies may be applied with the agreement of the competent authority.

6.9.3.3 **Design criteria**

6.9.3.3.1 FRP service equipment shall be of a design capable of being stress-analyzed mathematically ~~and~~/or experimentally by resistance strain gauges, or by other methods approved by the competent authority.

6.9.3.3.2 FRP service equipment shall be designed and manufactured to withstand the test pressure specified in 6.7.2.5.6 and 6.9.3.2.3.3.

6.9.3.3.3 At the specified test pressure the maximum tensile relative deformation measured in mm/mm in the FRP service equipment shall not result in the formation of microcracks, and therefore not be greater than the first measured point of elongation based fracture or damage of the resin, measured during tensile tests prescribed under 6.9.2.7.1.2 (c) and 6.9.3.4.1.1.

6.9.3.3.4 For internal test pressure specified in 6.9.3.2.3.3 failure criteria (FC) shall not exceed the following value:

$$FC \leq \frac{1}{K}$$

where:

$$K = K_0 \times K_1 \times K_2 \times K_3 \times K_4 \times K_5$$

where:

K shall have a minimum value of 4.

K_0, K_1, K_2, K_3, K_4 are given in 6.9.2.3.4.

K_5 a factor related to the deterioration in the material properties due to effects of exposure of salt fog and ultraviolet.

$$K_5 = \frac{\sigma_n}{\sigma_{eff}}$$

where σ_n is the nominal (under normal conditions) tensile strength of the FRP material and σ_{eff} is the material tensile strength after consecutive salt fog exposure in accordance with ISO 12944-2:2017, ISO 12944-6:2018, 168 hours at $(35 \pm 2)^\circ\text{C}$ and ultraviolet exposure in accordance with ISO 4892-2, 168 hours at $(23 \pm 2)^\circ\text{C}$. $\sigma_{eff} = \min(\sigma_{eff}^1, \sigma_{eff}^2 \dots \sigma_{eff}^k)$, where $1, 2 \dots k$ – identifiers of substances approved for transportation by the given portable tank. If protective coating is used the samples with the coating shall be fabricate and tested.

A design validation exercise using numerical analysis and a suitable composite failure criteria is to be undertaken to verify that the FRP service equipment are below the allowables. Suitable composite failure criteria include, but are not limited to Strain Invariant Failure Theory, Maximum Strain, or Maximum Stress. Other relations for the strength criteria is are allowed upon agreement with the competent authority. The method, [a proof of suitability for the chosen failure criteria with a list of relevant experiments for all parameters used in the chosen failure criteria](#), and results of this design validation exercise are to be submitted to the competent authority.

The [allowables parameters used in the chosen failure criteria](#) are to be determined using [the relevant experiments to derive parameters required by the chosen failure criteria set out in 6.9.3.4 and the maximum strain in tension prescribed in 6.9.2.3.5](#), combined with factor of safety K_5 ; [the strength values measured according to ISO 527-4:1997 and the maximum strain in tension criteria prescribed in 6.9.2.3.5. At least all experiments defined in 6.9.3.4.2 must be performed.](#)

6.9.3.3.5 Check calculations of the strength for FRP service equipment and its joints to the portable tank shell shall be performed by finite element method. Treatment of singularities shall be undertaken using an appropriate method according to the applicable pressure vessel code.

6.9.3.4 Material testing

6.9.3.4.1 Resins

[Where neat resin specimens are used for the materials testing set out in 6.9.3.4.1.1 and 6.9.3.4.1.2, the resin shall be processed in the same manner as when it is used in a composite material, taking into account mix ratios, resin additives, postcure, and any other parameters deemed relevant to cure.](#)

6.9.3.4.1.1 Resin tensile elongation according to ISO 527-2:2012.

6.9.3.4.1.2 Heat distortion temperature according to ISO 75-1:2013 and ISO 75-2:2013.

6.9.3.4.2 Coupon-samples

Coupon-samples shall be manufactured by the same technology as the appropriate FRP service equipment.

6.9.3.4.2.1 Ultimate tensile strength and elongation according to ISO 527-4:2021.

~~6.9.3.4.2.2 Flexural strength according to ISO 14125:1998.~~

6.9.3.4.2.32 Determination of compressive properties in the in-plane direction according to ISO 14126:1999 + ISO 14126/Cor1:2001

6.9.3.4.2.34 Determination of the in-plane shear stress/shear strain response and shear modulus according to ISO 20337:2018

~~6.9.3.4.2.53 Bearing test according to ISO 12815:2013.~~

6.9.3.4.2.464 Mass density according to ISO 1183-1:2019.

6.9.3.4.2.575 Mass content and composition of the reinforcement fibres according to ~~ISO~~ ISO 1172:1996. The fibre mass content of the coupon-samples shall be between 90% and 100% of the minimum fibre mass content specified for the appropriate FRP service equipment and obtained from testing of the inspection-samples.

6.9.3.4.2.686 The chemical compatibility with the transported substances according to 6.9.2.7.1.3.

6.9.3.4.2.797 Hardness according to ISO 868:2003.

~~6.9.3.4.2.108 Heat distortion temperature according to ISO 75-1:2013 and ISO 75-2:2013.~~

6.9.3.4.2.1189 Creep factor α according to procedure prescribed by 6.9.2.7.1.2(e). The test samples shall be taken according to ISO 14125:1998.

6.9.3.4.2.1290 Aging factor β according to procedure prescribed by 6.9.2.7.1.2(f). The test samples shall be taken according to ISO 14125:1998. This testing may be undertaken on either pristine samples or on samples pre-subjected to salt spray fog exposure conditioning as outlined in 6.9.3.2.4.130.

6.9.3.4.2.130 Salt fog exposure test in accordance with ISO 12944-2:2017, ISO 12944-6:2018, 168 hours at $+(35\pm 2)^{\circ}\text{C}$.

6.9.3.4.2.141 Ultraviolet exposure test in accordance with ISO 4892-2:2013, 168 hours at $+(23\pm 2)^{\circ}\text{C}$.

6.9.3.4.32.11 The additional material tests shall be carried out for determination of material properties required for design calculation.

6.9.3.4.3.1 Flexural strength according to ISO 14125:1998.

6.9.3.4.3.2 Bearing test according to ISO 12815:2013.

6.9.3.4.34 *Inspection-samples*

Prior to testing all coatings shall be removed from the samples. The tests shall cover

6.9.3.4.2.1 - 6.9.3.4.2.8.

6.9.3.5 Design approval

6.9.3.5.1 The competent authority or its authorized body shall issue the type approval certificate for FRP service equipment ~~prototype~~. This certificate shall attest that the ~~prototype~~ design has been surveyed by the authority and is suitable for its intended purpose and meets the requirements of this chapter.

The certificate shall also have the reference that prototype testing was carried out according to 6.9.3.5.2, the information on the substances allowed for transportation, body and seal materials and certificate number.

6.9.3.5.2 The FRP service equipment prototype test report shall include at least the following:

- (a) Results of the material tests used for fabrication of FRP service equipment in accordance with 6.9.3.4.1-6.9.3.4.3.
- (b) Results of tests according to ISO 4126-1:2013 for the appropriate relief devices.
- (c) Results of the pressure tests carried out in accordance with relevant ISO standards where applicable or according to procedure approved by the competent authority. The test pressure shall be not less than the highest of four times the -maximum allowable working pressure (MAWP) of the shell or four times the pressure to which it may be subjected in service by the action of a pump or other device (except pressure relief devices).
- (d) Results the fire resistance test according to ISO 21843:2018.
- (e) Results of the electrical resistance tests according to procedure recognized by the component competent authority.
- (f) Results of the other tests prescribed in applicable pressure equipment standards or codes ~~by~~ in agreement with the competent authority.

6.9.3.5.3 A service life inspection program shall be established, which shall be a part of the operation manual, to monitor the condition of the FRP service equipment at periodic inspections. The service life inspection program shall be approved by the competent authority.

6.9.3.6 Inspection and testing

6.9.3.6.1 FRP service equipment shall be inspected and tested before being put into the service. The initial inspection and test after manufacture shall include a check of the design characteristics and an external examination of FRP service equipment with due regard to the substances to be transported, and a pressure test. Before put the FRP service equipment into service, a leakproofness test and a test of the satisfactory operation shall also be performed. Relief valves should be tested for opening/closing pressure before installation. The initial inspection and testing program shall be approved by the competent authority.

6.9.3.6.2 Periodical inspection and testing of FRP service equipment shall be carried out during inspection of the portable tank according to provisions of 6.7.2.19.2, 6.7.2.19.4, and ~~and~~ 6.7.2.19.5 or 6.9.2.8.1 according to the service life inspection program approved by the competent authority.

~~6.9.3.6.3 The exceptional inspection and test are necessary when FRP service equipment shows evidence of damaged, or leakage, or other conditions that indicate a deficiency that could affect to the integrity of the FRP service equipment. The exceptional inspection shall include non-destructive testing by request of the competent authority.~~

6.9.3.6.43 ~~The inspections and tests in 6.9.3.6.1~~ ~~—and 6.9.3.6.32~~ shall be performed or witnessed by an expert approved by the competent authority or its authorized body.

6.9.3.6.45 ~~In all cases where r~~ The repair work has been carried out onof the FRP service equipment shall be limited to replacement of damaged components by components covered by the type approval of the service equipment. ~~that work shall be approved by the competent authority, taking into account the requirements of this chapter.~~

6.9.3.7 Marking

6.9.3.7.1 Marking of relief devices

Each relief device shall be marked as follows:

- name of the manufacturer and the serial number of the equipment;
- name of body and seal materials.
- type approval certificate number;
- the pressure at which the device is set to discharge (MPa or bar);
- the allowable tolerance at the discharge pressure for spring-loaded devices;
- the rated flow capacity of spring-loaded pressure relief devices under normal conditions (external pressure is 1 bar and ambient temperature is 0 °C) in standard (normal) cubic meters of air per second, nm³/s (determined according to [ISO 4126-7:2013 6.7.2.13.2](#));
- cross-sectional area of spring-loaded pressure relief devices, mm²;
- maximum allowable working pressure (MAWP, MPa or bar);
- external design pressure (if relevant, MPa or bar);
- design temperature range.

6.9.3.7.2 Marking of stop valves

Each stop valves shall be marked as follows:

- name of the manufacturer and the serial number of the equipment;
- name of body and seal materials.
- type approval certificate number;
- designation of the stop device;
- nominal diameter, mm;
- maximum allowable working pressure (MAWP, MPa or bar);
- direction of medium flow;
- design temperature range.

6.9.3.7.3 Marking of manlids and manhole covers

Each manlid and manhole cover shall be marked as follows:

- name of the manufacturer and the serial number of the equipment;
- type approval certificate number;
- name of body and seal materials;
- nominal diameter, mm;
- maximum allowable working pressure (MAWP, MPa or bar);
- test pressure (MPa or bar);
- design temperature range.