

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

28 June 2022

Sub-Committee of Experts on the Transport of Dangerous Goods

Sixtieth session

Geneva, 27 June-6 July 2022

Item 6 (c) of the provisional agenda

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

Report of the informal working group on FRP service equipment for portable tanks

Transmitted by Chair of the informal working group

1. The informal working group on FRP service equipment for portable tanks held online meeting on 27 June 2022 in conjunction with the sixtieth session of the TDG Sub-Committee. Representatives from different member governments and industry participated in the discussion and improvement of the baseline document referred to in informal document INF.41 (41st session).

Discussions in working group

2. The working group focused on the development and justification of the regulations for the FRP service equipment applicable for the metallic and FRP portable tanks.
3. The working group summarized and discussed in detail the comments received through informal correspondence and teleconferences in-between the sessions.
4. Additional work is necessary based on the today's discussion on:
 - - the generic definition for the applicable manufacturing technologies;
 - - the manufacturer's quality system;
 - - testing standards for the design approval;
 - - the initial and exceptional inspections.

Actions requested

5. The Sub-Committee is invited to consider the report of the working group and the current sub-chapter 6.9.3 (Annex).
6. The working group will continue to correspond through e-mail and teleconferences in-between the sessions.
7. The working group suggests having a one-day hybrid session running concurrently with the forthcoming 61th session of the TDG Sub-Committee.

Annex

6.9.1.4 The requirements of section 6.9.3 apply to FRP stop valves, relief devices and manholes 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.).

Propose to update the header of Chapter 6.9 when 6.9.3 is finished.

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 apply except for definitions related to metal materials for the construction of the stop valves, relief devices and manholes of portable tanks.

Additionally, the following definitions apply to FRP stop valves, relief devices and manholes.

FRP service equipment means, stop valves, relief devices, manlids, cleaning hatches, blind flanges, manhole covers 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.

Hand lay-up means a process of building up or placing layers of composite fiber in a sequenced layup using a matrix of resin and hardener.

Generic definition for the applicable technologies???

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, applicable to FRP materials, recognized by the competent authority.

6.9.3.2.2 Manufacturer's quality system

6.9.3.2.2.1 For the purposes of this section, the requirements of 6.9.2.2.2 apply for the construction of the FRP service equipment of portable tanks.

The FRP IWG will continue working on the *Manufacturer's quality system* paragraph.

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 $-40\text{ }^{\circ}\text{C}$ to $+50\text{ }^{\circ}\text{C}$, 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 Special requirements for the carriage of substances with a flash-point of not more than $60\text{ }^{\circ}\text{C}$.

- The FRP service equipment installed to the portable tanks used for the carriage of flammable liquids of class 3 with a flash-point of not more than $60\text{ }^{\circ}\text{C}$ shall be constructed so as to ensure the elimination of static electricity from the various component parts so as to avoid the accumulation of dangerous charges. **(The chair will check it for flash-point more than $60\text{ }^{\circ}\text{C}$).**
- The electrical surface resistance of the FRP service equipment as established by measurements shall not be higher than 10^9 ohms. This may be achieved by the use of additives in the resin such as metal or carbon network.
- The discharge resistance to earth as established by measurements shall not be higher than 10^7 ohms.
- The electrical resistance between the FRP service equipment and the portable tank shell contacting to each other shall not exceed 10 ohms.

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 $20\text{ }^{\circ}\text{C}$ higher than the maximum service temperature of the tank, but shall in any case not be lower than $70\text{ }^{\circ}\text{C}$.

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 tank, 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 fibres of several types.

6.9.3.2.4.4 FRP service equipment shall be manufactured by compression molding, injection molding or reinforced reaction injection molding. 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 6.9.3.2.3.3. (The chair and Dr. Luke Djukic will check another loading cases).

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).

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.

K₀, K₁, K₂, K₃, K₄ are given in 6.9.2.3.4.

K₅ 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, ISO 12944-6, 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 and results of this design validation exercise are to be submitted to the competent authority.

The allowables are to be determined using experiments to derive parameters required by the chosen failure criteria combined with factor of safety **K**, the strength values measured

according to ISO 527-4:1997 and the maximum strain in tension criteria prescribed in 6.9.2.3.5.

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*

6.9.3.4.1.1 Resin tensile elongation according to ISO 527-2.

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*

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

6.9.3.4.2.2 Flexural strength according to ISO 14125:1998.

6.9.3.4.2.3 Bearing test according to ISO 12815:2013.

6.9.3.4.2.4 Mass density according to ISO 1183-1.

6.9.3.4.2.5 Mass content and composition of the reinforcement fibres according to ISO 1172. 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.

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

6.9.3.4.2.7 Hardness according to ISO 868.

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

6.9.3.4.2.9 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.

6.9.3.4.2.10 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.

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

6.9.3.4.3 *Inspection-samples*

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

6.9.3.4.3.1 Ultimate tensile strength and elongation according to ISO 527-4.

6.9.3.4.3.2 Flexural strength according to ISO 14125:1998.

6.9.3.4.3.3 Bearing test according to ISO 12815:2013.

6.9.3.4.3.4 Mass density according to ISO 1183-1.

6.9.3.4.3.5 Mass content and composition of the reinforcement fibres according to ISO 1172.

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

6.9.3.4.3.7 Hardness according to ISO 868.

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

6.9.3.5 Design approval

6.9.3.5.1 The competent authority or its authorized body shall issue the design approval certificate for each new FRP service equipment. This certificate shall attest that

the FRP service equipment has been surveyed by that authority, is suitable for its intended purpose and meets the requirements of this chapter. When a series of FRP service equipment are manufactured without change in the design, the certificate shall be valid for the entire series. The certificate shall refer to the test report, the substances or group of substances allowed to be transported, the materials of construction of the body and main parts and an approval number.

6.9.3.5.2 The prototype test report for the purpose of the design approval shall include the following:

- (a) Results of the material tests used for fabrication of FRP service equipment in accordance with 6.9.3.4.1, 6.9.3.4.2 and 6.9.3.4.3.
- (b) Results of FRP service equipment tests according to ISO 4126 for the appropriate relief devices.
- (c) Results of FRP service equipment tests according to EN 14432 for product discharge and air inlet valves and EN 14433 for foot valves. **(The FRP IWG will justify applicability of the mentioned EN standards. Is it possible to change EN for ISO if applicable? Look at ADR for metallic equipment).**
- (d) Results of FRP service equipment tests according to 6.7.2.3.2 or procedure approved by the competent authority for the manholes.
- (e) Results the fire resistance test according to ISO 21843:2018.
- (f) Results of electrical resistance tests according to procedure recognized by the component authority.
- (g) The prototype shall be inspected for compliance with the design type specification. This shall include an internal and external inspection and measurement of the main dimensions.

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 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. **(Dr. Luke Djukic and Mr. Michail Ognev will suggest the appropriate update.)**

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 6.7.2.19.5 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 the integrity of the FRP service equipment. The extent of the exceptional inspection and test shall depend on the amount of damage or deterioration of the FRP service equipment. It shall include at least periodic inspection and test according to 6.7.2.19.5 and if necessary non-destructive testing (e.g., acoustic emissions, ultrasonic evaluation, thermographic). **(Mr. Michail Ognev will propose the update).**

6.9.3.6.4 The inspections and tests in 6.9.3.6.1 – 6.9.3.6.3 shall be performed or witnessed by the competent authority.

6.9.3.6.5 In all cases where repair work has been carried out on the FRP service equipment, that work shall be approved by the competent authority, taking into account the requirements of this chapter.

6.9.3.7 Marking (to be discuss on online meetings in-between the sessions)

6.9.3.7.1 Marking of relief devices

Each relief device shall be clearly and permanently marked with the following:

- name or manufacturer's trademark;
- the pressure at which the devise 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 4126-7:2004);
- cross-sectional area of spring-loaded pressure relief devices, mm²;
- design temperature range;
- name of manufacturer, serial number and relevant catalogue number (model);
- brand of body material.

6.9.3.7.2 Marking of stop valves

Each stop valves shall be marked as follows:

- name or manufacturer's trademark;
- designation of the stop device model or number by catalogue;
- nominal diameter, mm;
- test pressure, MPa and maximum allowable working pressure;
- direction of medium flow;
- design temperature range;
- brand of body material.

6.9.3.7.3 Marking of manholes

Each manhole cover shall be marked as follows:

- name or manufacturer's trademark;
 - designation of the manholes model or number by catalogue;
 - nominal diameter, mm;
 - design temperature range;
 - test pressure, MPa and maximum allowable working pressure;
 - brand of material.
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