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

**25 June 2021**

**Sub-Committee of Experts on the Transport of Dangerous Goods**

**Fifty-eighth session**
Geneva, 28 June-2 July 2021
Item 6 (c) of the provisional agenda
**Miscellaneous proposals for amendments to the Model Regulations on the Transport of Dangerous Goods: portable tanks**

# Proposal for Sub-chapter 6.9.3 "Requirements for design, construction, inspection and testing of fibre reinforced plastic (FRP) stop valves, relief devices and manholes for portable tanks"

**Submitted by the Russian Federation**

## General

1. The Committee of Experts on the Transport of Dangerous Goods and on the Globally Harmonized System of Classification and Labelling of Chemicals on its tenth session has been reported amendments to the twenty-first revised edition of the Recommendations on the Transport of Dangerous Goods, Model Regulations (ST/SG/AC.10/48/Add.1). The amendments include the new Chapter 6.9 "Requirements for the design, construction, inspection and testing of portable tanks with shells made of fibre reinforced plastics (FRP) materials" and the appropriate update of Chapter 4.2 related to Chapter 6.9.

2. Keeping in mind that currently stop valves, relief devices and manholes made of metallic materials are installed in all types of portable tanks, the Russian Federation would like to bring to the attention of the Sub-Committee the fact that this service equipment has shorter service life in comparison with the service life of the tank itself in long-haul transport and intensive trans-shipment of the transported substances, especially when transporting corrosive substances.

3. The Russian Federation believes that the use of FRP materials in the construction of the mentioned service equipment leads to an increased service life and a reduction of repair and replacement costs.

4. The Russian Federation has acquired certain experience in using FRP materials for the fabrication of stop valves, relief devices and manholes as well as on their repair and inspection. The obtained experience are summarized in Annex I "6.9.3 Requirements for design, construction, inspection and testing of fibre reinforced plastic (FRP) valves, relief devices and manholes for portable tanks".

5. In view of the above, the Russian Federation would like to initiate discussions on the development of the new section 6.9.3 "Requirements for design, construction, inspection and testing of fibre reinforced plastic (FRP) stop valves, relief devises and manholes for portable tanks".

## Requested actions

6. The Russian Federation invites the Sub-Committee to:

(a) review the proposed draft of section 6.9.3: “Requirements for design, construction, inspection and testing of fibre reinforced plastic (FRP) stop valves, relief devices and manholes for portable tanks”;

(b) invite experts to contribute to development of the new section 6.9.3 “Requirements for design, construction, inspection and testing of fibre reinforced plastic (FRP) valves, relief devises and manholes for portable tanks”;

(c) entrust the development of the new section 6.9.3 to an informal working group.

# Annex I

## 6.9.3 Requirements for design, construction, inspection and testing of fibre-reinforced plastic (FRP) stop valves, relief devices and manholes for portables tanks

### 6.9.3.1 Application and general requirements

6.9.3.1.1 The requirements of section 6.9.3 apply to stop valves, relief devices and manholes manufactured from FRP for portable tanks 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.

6.9.3.1.2 In recognition of scientific and technological advances, the technical requirements of this section may be varied by alternative arrangements. These alternative arrangements shall offer a level of safety not less than that given by the requirements of this section with respect to compatibility with the transported substances and the ability of portable tanks to withstand impact, loading and fire conditions. For international transport, alternative arrangement shall be approved by the applicable competent authorities.

### 6.9.3.2 Requirements for the design, construction, inspection and testing

#### 6.9.3.2.1 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 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 and manholes made of FRP 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.

*Coupon-sample means* a FRP sample constructed and tested in accordance with national and / or international standards to determine design allowables;

*Inspection-sample* means a sample cut out from the FRP device 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.

#### 6.9.3.2.2 General design and construction requirements

6.9.3.2.2.1 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 and 6.7.2.13 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.

6.9.3.2.2.1 Manufacturer’s quality system

6.9.3.2.2.1.1 For the purposes of this section, the requirements of 6.9.2.2.2.1, 6.9.2.2.2.2, 6.9.2.2.2.4 and 6.9.2.2.2.5 apply for the construction of the FRP service equipment of portable tanks.

6.9.3.2.2.1.2 Under the quality system, the following minimum requirements shall be met for each FRP service equipment manufactured:

(a) Use of an inspection and test plan (ITP);

(b) Visual inspections;

(c) Verification of fibre and resin (matrix) fraction by means of documented control process;

(d) Verification of fibre and resin quality and characteristics by means of certificates or other documentation;

(e) Verification of whichever is applicable of formed thermoplastic resin characteristic or degree of cure of thermoset resin, by direct or indirect means (e.g. Barcol test or differential scanning calorimetry) to be determined in accordance with 6.9.2.7.1.2 (h), or by creep testing of a representative sample or parallel-shell specimen in accordance with 6.9.2.7.1.2 (e) for a period of 100 hours;

(f) Documentation of whichever is applicable of thermoplastic resin forming processes or thermoset resin cure and post-cure processes; and

(g) Retention and archiving of inspection-samples for future inspection and shell verification for a period of 5 years.

6.9.3.2.2.2 FRP service equipment

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

6.9.3.2.2.2.2 FRP service equipment 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.

6.9.3.2.2.2.3 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.

6.9.3.2.2.2.4 The failure internal pressure shall be not less than the highest of the following pressures:

1) four of the MAWP;

2) four of the pressure to which the FRP device may be exposed during operation when the pump or other devices are operated with the exception of pressure relief devices.

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

6.9.3.2.2.2.6 Design calculations for FRP service equipment and its joints to the portable tank shell shall be performed by finite element method.

6.9.3.2.2.2.7 The strength of bolted and glued joints of the FRP service equipment to the portable tank shell shall be confirmed by testing of the tank according to 6.7.2.3.2.

6.9.3.2.2.2.8 Special requirements for the carriage of substances with a flash-point of not more than 60 °C.

1) 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°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.

2) The electrical surface resistance of the FRP service equipment as established by measurements shall not be higher than 109 ohms. This may be achieved by the use of additives in the resin such as metal or carbon network.

3) The discharge resistance to earth as established by measurements shall not be higher than $10^7$ ohms.

4) The electrical resistance between the FRP service equipment and the portable tank shell contacting to each other shall not exceed 10 ohms.

6.9.3.2.2.3 Materials

6.9.3.2.2.3.1 Resins.

1) 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.

2) The resins shall be:

- Unsaturated polyester resins;

- Vinyl ester resins;

- Epoxy resins;

- Phenolic resins.

- Thermoplastic resins.

3) 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**.**

6.9.3.2.2.3.2 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.

6.9.3.2.2.3.3 Reinforcement fibres. The reinforcement fibres shall be short-chopped fibres of several types.

6.9.3.2.2.3.4 FRP service equipment shall be manufactured by compression molding or injection molding. Other manufacturing technologies may be applied with the agreement of the competent authority.

**6.9.3.2.3 Design criteria**

6.9.3.2.3.1 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.

6.9.3.2.3.2 FRP service equipment shall be designed and manufactured to withstand the test pressure specified in 6.9.3.2.2.2.

6.9.3.2.3.3 At the specified test pressure the maximum tensile relative deformation measured in mm/mm in the FRP device 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).

6.9.3.2.3.4 For internal test pressure specified in 6.9.3.2.3.2 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:

$\boldsymbol{K}$ shall have a minimum value of 4.

$\boldsymbol{K_0}$ – a strength factor. For the general design, the value for $\boldsymbol{K_0}$ shall be equal to or more than 1.5.

$\boldsymbol{K_1}$ – a factor related to the deterioration in the material properties due to effects of chemicals:

$$K_1 = \frac{\sigma_n}{\sigma_{eff}},$$

where $\sigma_n$ is the nominal (under normal conditions) tensile strength of the material and $\sigma_{eff}$ is the material tensile strength after chemical exposure in accordance with ISO 175, 168 hours at +(23±2)°C.

$\sigma_{eff} = \min(\sigma_{eff}^1, \sigma_{eff}^2 \ldots\ldots \sigma_{eff}^k)$, where *1,2….k* – identifiers of substances approved for transportation by the given portable tank.

$\boldsymbol{K_2}$ – a factor related to the service temperature and the thermal properties.

$$K_2 = \frac{\sigma_n}{\sigma_{temp}},$$

where $\sigma_{temp}$ the material tensile strength under service temperature.

$\sigma_{temp} = \min(\sigma_{temp}^1, \sigma_{temp}^2 \ldots\ldots \sigma_{temp}^k)$, *1,2….k* – temperature identifiers.

$\boldsymbol{K_3}$ – a factor related to the fatigue of the material,

$$K_3 = \frac{\sigma_n}{\sigma_N},$$

where $\sigma_N$ - failure stress for a given number of loading cycles.

$\boldsymbol{K_4}$ – a factor related to the deterioration in the material properties due to effects of salt fog:

$$K_4 = \frac{\sigma_n}{\sigma_{sf}},$$

where $\sigma_{sf}$ - tensile strength after salt fog exposure in accordance with ISO 12944-2, ISO 12944-6, 168 hours at +(35±2)°C.

$\boldsymbol{K_5}$ – a factor related to the deterioration in the material properties due to effects of ultraviolet exposure:

$$K_5 = \frac{\sigma_n}{\sigma_{UV}},$$

where $\sigma_{UV}$ - tensile strength after ultraviolet exposure in accordance with ISO 4892-2, 168 hours at +(23±2)°C.

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 as per 6.9.3.2.5.1.2.1and the maximum elongation strain criteria prescribed in section 6.9.2.3.5.

6.9.3.2.3.5 The requirements of 6.9.2.3.5 apply for the construction of the FRP service equipment of portable tanks.

6.9.3.2.3.6 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.

#### 6.9.3.2.4 Design approval

6.9.3.2.4.1 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.

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

(a) Results of the material tests used for fabrication of FRP service equipment in accordance with 6.9.3.2.6;

(b) Results the fire resistance test in accordance with test according to resolution IMO A.753(18);

(c) Results of pressure test in accordance with 6.9.3.2.2.2.2;

(d) Results of body failure internal pressure tests in accordance with 6.9.3.2.2.2.4 (for the stop valves);

(e) Test results during operation in the temperature range from -40 ° C to + 50 ° C in accordance with 6.9.3.2.2.2.3;

(f) Results of electrical resistance tests in accordance with 6.9.3.2.2.2.8.

6.9.3.2.4.3 A service life inspection program shall be established, which shall be a part of the operation manual, to monitor the condition of the FRP device at periodic inspections. The inspection program shall focus on the critical stress locations identified in the design analysis performed under 6.9.3.2.3.6. The inspection method shall take into account the potential damage mode at the critical stress location (e.g., tensile or shear stress). The inspection shall be a combination of visual and non-destructive testing (e.g., acoustic emissions, ultrasonic evaluation, thermographic).

6.9.3.2.4.2 A representative prototype of FRP device shall be subjected to tests as specified below.

6.9.3.2.4.2.1 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.

#### 6.9.3.2.5 Additional provisions applicable to FRP service equipment

6.9.3.2.5.1 Material testing.

6.9.3.2.5.1.1 Resins. Resin tensile elongation shall be determined in accordance with ISO 527-2. Heat distortion temperature shall be determined in accordance with ISO 75-1.

6.9.3.2.5.1.2 *Coupon-samples.*

6.9.3.2.5.1.2.1 The following properties shall be determined:

- ultimate tensile strength according to ISO 527-4;

- ultimate compressive strength according to ISO 14126;

- ultimate flexural strength according to ISO 178.

The strength properties shall be determined using specimens manufactured by the same technology as applied to the appropriate FRP device.

6.9.3.2.5.1.2.2 Mass density according to ISO 1183–1.

6.9.3.2.5.1.2.3 Mass content and composition of the reinforcement fibres according to ISO 1172. The fibre mass content of the coupon-specimens shall be between 90% and 100% of the minimum fibre mass content specified for the appropriate FRP device.

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

6.9.3.2.5.1.2.5 The chemical compatibility of FRP material with the transported substances shall be confirmed according to ISO 175.

6.9.3.2.5.1.2.6 Hardness according to ISO 868.

6.9.3.2.5.1.2.7 The efficiency of whichever is applicable of thermoplastic resin forming characteristics or thermoset resin cure and post-cure processes are to be determined using one or more of the following methods:

(i) Direct measurement formed thermoplastic resin characteristics or thermoset resin degree of cure: glass transition temperature (Tg) or melting temperature (Tm) determined using differential scanning calorimetry (DSC) via ISO 11357-2:2016; or

(ii) Indirect measurement of formed thermoplastic resin or thermoset resin degree of cure:

- HDT via ISO 75-1:2013;

- Tg or Tm using thermo-mechanical analysis (TMA) via ISO 11359-1:2014;

- Dynamic thermo-mechanical analysis (DMA) via ISO 6721-11:2019:

- Barcol testing via ASTM D2583:2013-03 or EN 59:2016.

6.9.3.2.5.1.3 Inspection-samples.

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

6.9.3.2.5.1.3.1 Mass density according to ISO 1183–1.

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

6.9.3.2.5.1.3.3 The chemical compatibility of FRP materials with the transported substances shall be confirmed according to ISO 175. Upon agreement with the competent authority other methods for verification of chemical compatibility may be used.

6.9.3.2.5.1.3.4 Hardness according to ISO 868.

6.9.3.2.5.1.4 Testing of FRP service equipment.

6.9.3.2.5.1.4.1 The pressure test shall be conducted by method agreed with the competent authority. This method shall cover general requirements of ISO 5208.

6.9.3.2.5.1.4.2 The leakproofness test shall be conducted by method agreed with the competent authority. This method shall cover general requirements of ISO 5208.

6.9.3.2.5.1.4.3 The FRP service equipment shall be exposed to the fire resistance test according to resolution IMO A.753(18).

**6.9.3.2.6 Inspection and testing**

6.9.3.2.6.1 Inspection and testing of FRP service equipment shall be carried out as per provisions of 6.9.3.2.4.2.

6.9.2.8.2 In addition, the initial and periodic inspections shall follow the service life inspection program and any associated inspection methods per 6.9.3.2.4.3.

6.9.2.8.3 The initial inspection and test shall verify that construction of the FRP service equipment is made in accordance with the quality system required by 6.9.3.2.2.1.

**6.9.3.2.7 Retention of samples**

Inspection-sample for each manufactured FRP service equipment shall be maintained for future inspection and shell verification for a period of five years from the date of the initial inspection and test and until successful completion of the required five-year periodic inspection.

**6.9.3.2.8 Marking**

6.9.3.2.8.1 Marking of pressure relief devices.

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

- the pressure at which the valve 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, $nm^3/s$ (determined according to ISO 4126-1:2004 and ISO 4126-7:2004);

- cross-sectional area of spring-loaded pressure relief devices, $mm^2$;

- design temperature range;

- name of manufacturer, serial number and relevant catalogue number (model);

- valve body material brand.

6.9.3.2.8.2 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.

6.9.3.2.8.3 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.