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Transport of gases: miscellaneous

Transport of gas tanks for motor vehicles

Submitted by the experts from Germany and France[1]

Introduction

1. Due to the development and increasing use of alternative propulsion systems for vehicles, there is a need for the transport of filled gas tanks. Currently, the following technologies are used:

- Vehicles powered by compressed natural gas (CNG)
- Vehicles powered by liquefied petroleum gas (LPG)
- Vehicles powered by compressed or liquefied hydrogen gas (H_2, internal combustion or fuel cell)

2. Usually, tanks to be fitted in vehicles are transported either empty or filled with inert gas at low pressure. However, there is also a need for the transport of filled tanks as described below.

3. When a tank is replaced at a repair shop, this shop usually does not have the equipment needed to empty the tank (completely). The demounted tank then has to be transported in a filled state for disposal or recycling. This may also be the case when a demounted tank is transported to an inspection site, e.g. in the case of a warranty claim.

[1] In accordance with the programme of work of the Sub-Committee for 2015-2016 approved by the Committee at its seventh session (refer to ST/SG/AC.10/C.3/92, paragraph 95 and ST/SG/AC.10/42, para. 15).

4. Moreover, for the simplification of the production process, there is also a need to transport new filled hydrogen tanks to the assembly facility. Usually, the tank is tested for leakage by means of an inert gas at the production facility and then transported further at low pressure. At the assembly facility, the tank then has to be flushed with hydrogen several times to ensure that the required mixing ratio in the fuel cell is achieved. The fuel cell is sensitive to contaminations of the fuel gas. If the tank was already tested for leakage with hydrogen or hydrogen mixtures, the effort required for eliminating the inert gas at the assembly facility would be considerably lower.

5. As the vehicle tanks are not gas receptacles that fulfil the requirements of Chapter 6.2, it is currently not possible to transport filled tanks. For European land transport, this issue has been regulated for some time now (SP660 of RID/ADR/ADN). To make transport operations possible beyond this, provisions for the transport of gas in gas tanks for vehicles should also be included in the United Nations Model Regulations.

Background information

6. Hydrogen and some CNG tanks for vehicles are made from composite materials in order to reduce the total weight of the vehicle. These composite storage containers consist of two layers: an inner liner that prevents gas leakage/permeation (usually made of metal or a thermoplastic polymer) and an outer layer that provides structural integrity (usually made of metal or thermoset resin-impregnated fibre-reinforced composite material wrapped around the gastight inner liner).

7. The gas tanks are either mounted as single tanks or as tank systems consisting of several gas cylinders. In the event of a fire, thermally activated pressure relief devices (TPRD's) provide a controlled release of the gas from the compressed hydrogen storage containers before the high temperatures in a fire weaken the containers and cause a hazardous rupture. TPRD's are designed to rapidly discharge the entire contents of the container. TPRD's do not reseat or allow re-pressurization of the container; therefore, storage containers and TPRD's cannot be reused after having been exposed to a fire or high temperatures.

8. To permit their use in motor vehicles, in many countries, gas tanks are approved within the framework of the vehicle homologation procedures. In the international context, two international treaties addressing this subject were concluded under the auspices of the United Nations Economic Commission for Europe (UNECE):

– The 1958 Agreement concerning the adoption of uniform technical prescriptions for wheeled vehicles, equipment and parties which can be fitted and/or be used on wheeled vehicles and the conditions for reciprocal recognition of approvals granted on the basis of these prescriptions, and its addenda hereafter called “ECE Regulations”;

– The 1998 Agreement concerning the Establishing of Global Technical Regulations for wheeled vehicles, equipment and parts which can be fitted and/or be used on wheeled vehicles, (and the Global Technical regulations (GTRs) established pursuant to this Agreement).

Approvals based on these ECE Regulations and GTRs are valid in countries which are Contracting Parties to these agreements and have adopted the Regulations. The 1958 Agreement provides for mutual recognition of the approvals. The following regulations, in particular, form the basis for the approvals of both passenger and commercial vehicles:

- ECE Regulation No. 67 on the approval of specific equipment of motor vehicles using liquefied petroleum gases in their propulsion system and the approval of vehicles fitted with specific equipment for the use of liquefied petroleum gases in their propulsion system
- ECE Regulation No. 110 on the installation of specific components in motor vehicles using compressed natural gas (CNG) in their propulsion system
- ECE Regulation No. 115 on the installation in motor vehicles of liquefied petroleum gas (LPG) and compressed natural gas (CNG) retrofit systems, which makes reference to the above-mentioned ECE Regulations
- The Global Technical Regulation N°.13 on hydrogen and fuel cell vehicles (ECE/TRANS/180/Add.13): besides many other requirements for the homologation of hydrogen-powered vehicles, it contains performance requirements as well as test conditions and procedures for hydrogen storage systems (see also table in the Annex), high-pressure closures, pressure relief devices, and fuel lines. The GTR was developed on the basis of existing regulations, directives, and international standards from all regions and will be accepted globally. In the European Union, type approvals for hydrogen vehicles are granted based on Regulations Nos. 79/2009/EC and 406/2010/EU implementing Regulation 79/2009/EC.
- A proposal for a new ECE Regulation on hydrogen and fuel cell vehicles (ECE/TRANS/WP.29/2014/78) was adopted during the 164th session of the World Forum for Harmonization of Vehicle Regulations (WP.29). A reference to this new ECE Regulation could be included in the Model Regulation after it has been accepted by the Contracting Parties to the 1958 Agreement and published[2].

9. Additionally, ISO standards have been developed for CNG powered vehicles and CNG tanks: ISO 11439 lays down requirements for high pressure gas cylinders used for the on-board storage of natural gas as fuel for automotive vehicles. ISO 15500 focuses on compressed natural gas (CNG) fuel systems for road vehicles.

10. The components of a typical compressed hydrogen storage system are listed below. The system includes the container and all other components that form the primary pressure boundary that prevents hydrogen from escaping the system. In this case, the following components are part of the compressed hydrogen storage system:

(a) Container;

(b) Check valve;

(c) Shut-off valve;

(d) Thermally-activated pressure relief device (TPRD).

[2] If accepted by Contracting Parties, this Regulation should be numbered 134 and should enter into force on 15 June 2015.

11. The basic technical parameters of gas fuel tanks are summarised in the following table:

Gas	LPG	CNG	H_2
UN Numbers/Proper Shipping Name	UN 1011/Butane UN 1075/Petroleum Gases, liquefied UN 1965/Hydrocarbon gas mixture, liquefied UN 1969/Isobutane UN 1978/Propane	UN 1971/Methane, compressed UN 1954/Compressed gas, flammable, n.o.s.	UN 1049/Hydrogen compressed UN 1966/Hydrogen, refrigerated liquid
Volume of receptacles (L)	~50	10-120	75-250
Nominal working pressure (bar)	12-30	200-250	350-700
Net empty weight of receptacle (kg)	10-50	4,5-110	80-250
Material	Steel or composite liners	Steel or composite liners	Composite with various liners

12. As the GTRs lay down global requirements, it is proposed to use them as a reference in the special provision proposed in this document. Hydrogen can also be used as a liquefied gas; however, the safety requirements have not been fully evaluated nor have test procedures been exhaustively examined for feasibility and relevance to known failure conditions. Therefore the proposed special provision is not to be applicable to liquid hydrogen storage tanks. The proposed provisions are also not to be applicable to storage systems in which hydrogen is bonded chemically (metal hydrides).

13. The ECE Regulations and ISO standards for CNG and LPG tanks and the GTR and – for the European Union - Regulation (EU) No. 406/2010 for hydrogen gas receptacles provide a high level of safety (see Annex for selected test requirements). The tests were developed to demonstrate that the tank is capable of performing critical functions. These comprise functions related to the usage of a vehicle including fuelling/de-fuelling, parking in extreme conditions and performance in a fire. Manufacturers are expected to monitor the reliability, durability and residual strength of representative production units throughout the entire life of a vehicle. As the GTR No. 13 is the most recent outcome of expert discussions on global vehicle homologation, it is particularly suitable for providing a high level of safety for the transport of filled H_2 tanks.

Proposal

14. Amend the Model Regulations as follows:

Chapter 3.2. Dangerous Goods List

For UN No 1011, 1049, 1075, 1954, 1965, 1969, 1971, 1978 add special provision xxx in column 6

Add the following special provision "xxx" to Chapter 3.3:

"xxx For the transport of fuel gas containment systems designed to be fitted in motor vehicles containing this gas the provisions of sub-section 4.1.4.1, Chapter 5.2, Chapter 5.4 and Chapter 6.2 of these Regulations need not be applied, provided the following conditions are met:

(a) The fuel gas containment systems shall meet the requirements of ECE Regulation No. 67 Revision 2[3] or ECE Regulation No. 115[4] in case of LPG tanks, ECE regulation No. 110 Revision 1[5] or ECE Regulation No. 115[6] in case of CNG tanks, the Global Technical Regulation (GTR) No. 13[7] or ISO 14439/ISO 15500[8] in case of hydrogen pressure tanks, as applicable.

(b) The fuel gas containment systems shall be leakproof and shall not exhibit any signs of external damage which may affect their safety.

NOTE 1: *Criteria may be found in standard ISO 11623:2002 Transportable gas cylinders – Periodic inspection and testing of composite gas cylinders (or ISO CD 19078 Gas cylinders – Inspection of the cylinder installation, and requalification of high pressure cylinders for the on-board storage of natural gas as a fuel for automotive vehicles).*

NOTE 2: *If the fuel gas containment systems are not leakproof or overfilled or if they exhibit damage that could affect their safety, they shall only be carried in salvage pressure receptacles in conformity with these Regulations*.

(c) If a fuel gas containment system is equipped with two valves or more integrated in line, two valves must be closed as to be gastight under normal conditions of transport. If only one valve exists or only one valve works all openings with the exception of the opening of the pressure relief device shall be closed as to be gastight under normal conditions of transport.

(d) Fuel gas containment systems shall be transported in such a way as to prevent obstruction of the pressure relief device or any damage to the valves and any other pressurised part of the fuel gas containment systems and unintentional release of the gas under normal conditions of transport. The fuel gas containment system shall be secured in order to prevent slipping, rolling or vertical movement.

(e) Fuel gas containment systems shall satisfy the provisions of 4.1.6.1.8 (a), (b), (c), (d) or (e).

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[3] ECE Regulation No. 67 (Uniform provisions concerning: I. Approval of specific equipment of motor vehicles using liquefied petroleum gases in their propulsion systems; II. Approval of a vehicle fitted with specific equipment for the use of liquefied petroleum gases in its propulsion system with regard to the installation of such equipment)

[4] ECE Regulation No. 115 (Uniform provisions concerning the approval of: I. Specific LPG (liquefied petroleum gases) retrofit systems to be installed in motor vehicles for the use of LPG in their propulsion systems; II Specific CNG (compressed natural gas) retrofit systems to be installed in motor vehicles for the use of CNG in their propulsion system)

[5] ECE Regulation No. 110 (Uniform provisions concerning: I. Specific components of motor vehicles using compressed natural gas (CNG) in their propulsion system; II. Vehicles with regard to the installation of specific components of an approved type for the use of compressed natural gas (CNG) in their propulsion system)

[6] ECE Regulation No. 115 (Uniform provisions concerning the approval of: I. Specific LPG (liquefied petroleum gases) retrofit systems to be installed in motor vehicles for the use of LPG in their propulsion systems; II Specific CNG (compressed natural gas) retrofit systems to be installed in motor vehicles for the use of CNG in their propulsion system)

[7] Global technical regulation No. 13**:** Global technical regulation on hydrogen and fuel cell vehicles (ECE/TRANS/180/Add.13).

[8] ISO 11439: Gas cylinders — High pressure cylinders for the on-board storage of natural gas as a fuel for automotive vehicles and ISO 15500 Road vehicles - Compressed natural gas (CNG) fuel systems

(f) The marking and labelling provisions of Chapter 5.2 shall be met unless fuel gas containment systems are consigned in a handling device. If this is the case then the markings and danger labels shall be affixed to the handling device.

(g) Documentation

Every consignment that is transported in accordance with this special provision shall be accompanied by a transport document, containing at least the following information:

(i) The UN number of the gas contained in the fuel gas containment systems, preceded by the letters "UN";

(ii) The proper shipping name of the gas;

(iii) The division number;

(iv) The number of fuel gas containment systems;

(v) In the case of liquefied gases the total mass of gas of each fuel gas containment system and, in the case of compressed gases, the total water capacity of each fuel gas containment system followed by the nominal working pressure;

(vi) The names and the addresses of the consignor and the consignee.

(i) to (v) shall appear in accordance with the following examples:

Example 1: "UN 1971 natural gas, compressed, 2.1, 1 vehicle fuel gas containment system of 50 l in total, 200 bar".

Example 2: "UN 1965 hydrocarbon gas mixture, liquefied, n.o.s., 2.1, 3 vehicle fuel gas storage systems, each of 15 kg net mass of gas".

Annex

Test requirements for gas pressure receptacles

Test Requirement	Transportable gas cylinders - fully wrapped composite cylinders (EN 12245) as referred to in ADR/RID 6.2.4.1	CNG vehicle homologation requirements(E CE R 110)	ISO 11439 Gas cylinders — High pressure cylinders for the on-board storage of natural gas as a fuel for automotive vehicles	ISO 15500 Road vehicles - Compressed natural gas (CNG) fuel systems	Regulation EC 79/2009 and Commission Regulation (EU) 406/2010 on type-approval of hydrogen-powered motor vehicles	Global technical Regulation on hydrogen and fuel cell vehicles (ECE/TRANS/180/Add.13)
PW/PH	300/450	200/300	200/300	200/500	700/1050	700/1050
Burst Pressure(min)	> 225%	> 450 bar and > stress ratio (calculation)	> 450 bar and > stress ratio (calculation)		> 225 % NWP (=PW) (up to 350 % for glass fibres)	> 225% NWP; +/- 10% of BP_0** Containers made of glass fibres as major constituent: 350 % NWP
Load cycle (LC) at ambient temperature	500 LC/year at PH	1000 LC/year at 125 % (NWP=PW)	1000 LC/year at 125 % (NWP=PW)	48.000 5…300bar 20°C	up to 45000 test cycles (2 bar/125 % of NWP) no disrupture/only leakage	125 % NWP without rupture for 22,000 cycles, without leakage for a minimum of 5500 cycles no disrupture/only leakage
Load Cycle (Extreme temperature)	At +65 °C: 5000 LC at PH at 95 % rel. Humidity 5000 LC at NWP	500 LC/a at 130 % NWP and 95 % rH at 65°C and 500 LC at -40°C	48h at 65°C and 95 % rel humidity; 10.000 cycles 20…260bar 65°C cool down to -40°C 10.000 cycles 20…200bar -40°C	1000 high-temp 10…300bar; 85°C 1000 low-temp 5…150bar; -40°C	48h at 85°C and 95 % rel humidity; 7500 pressure cycles between 2 bar and 125 % NWP – stabilisation at room temperature; cool down to -40°C and 7500 pressure cycles	500 LC (up to 150 % NWP at -40°C, +20°C and 50 °C) no leakage, no rupture
Flaw Tolerance	2 notches 1 mm, 50 % wall thickness 1st cylinder burst test: >4/3 x PH	Notches > as identifiable at visual inspection 3000 LC at 260 bar no leakage; 12000 LC at 260 bar no burst	Two cuts: 1. 1.25 mm deep and 25 mm long; 2. 0.75 mm deep and 200 mm	-	Two notches (25 mm long and 1,25 mm deep; 200 mm long; 0,75 mm deep) 3000 pressure cycles (2 bar- 125 % NWP) without	Two cuts: 1. 1.25 mm deep and 25 mm long; 2. 0.75 mm deep and 200 mm

Test Requirement	Transportable gas cylinders - fully wrapped composite cylinders (EN 12245) as referred to in ADR/RID 6.2.4.1	CNG vehicle homologation requirements(ECE R 110)	ISO 11439 Gas cylinders — High pressure cylinders for the on-board storage of natural gas as a fuel for automotive vehicles	ISO 15500 Road vehicles - Compressed natural gas (CNG) fuel systems	Regulation EC 79/2009 and Commission Regulation (EU) 406/2010 on type-approval of hydrogen-powered motor vehicles	Global technical Regulation on hydrogen and fuel cell vehicles (ECE/TRANS/180/Add.13)
	2nd cylinder: 1000 LC at 2/3 PH No further leakage/ without burst		20.000 cycles 260bar No burst, leakage shall not occur within a number of min. 3000 cycles leak before burst		breakage or leakage	No burst, leakage shall not occur within a number of min. 5500 cycles
Permeation	X test gas > X filling 672 h at 2/3 PH X ml/h/L max X=0.25 or individ.	CNG/90 % N_2/10% He steady state at NWP max. 0.25 ml/h/L	500h 0,25cm³/h/l Methane 200bar	-	500 h or steady state > 48 h at NWP Max. 6 Nccm/h/L	115 % NWP at 50°C for 30 h or until steady state whichever is longer 46 Nml/h/L
Impact (bullet)	no burst after 45°-entry	no burst after 45°-entry at NWP	NWP+10bar No burst after 45°-entry for Typ 4	-	no burst after 45°-entry at NWP	omitted
Impact (drop)	1 drop from a height of 1,2 m on to a steel plate in five different positions	- horizontally with the bottom 1.8 m above the surface onto which it was dropped, - vertically on each end with 1.8 m above the surface, -at 45° angle onto a dome from a height such that the center of gravity was at 1.8m followed by pressure cycles up to 125 % NWP	Drop 45 ° angle: center of gravity 1.8 m 488J 20.000 cycles with 260bar After 3000 cycles leak before burst allowed	-	omitted	Drop 45 ° angle: centre of gravity 1.8 m Two drops to the ends of container: centre of gravity 1.8 m height Drop from a horizontal position: 1.8 m from the bottom of the container followed by 5500 pressure cycles
Bonfire	590°C after 2 min with PRD at 100 % PW	590°C after 5 min with PRD*** at 100 % NWP	590°C after 5 min with PRD*** at 100 % NWP	600 °C ± 10 °C 2min. 20bar	590°C after 2 min with PRD at 100 % NWP (Pressure release over PRD; no disrupture)	590°C after 3 minutes with PRD; at 100 % PRD The container shall vent through the

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						pressure relief device without bursting