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Item 9 of the provisional agenda

Regulation No. 110 (CNG and LNG vehicles)**Proposal for amendments to Regulation No. 110 (CNG and LNG vehicles)****Submitted by the expert from the International Organization for Standardization***

The text reproduced below has been prepared by the expert from the International Organization for Standardization (ISO) to harmonize the requirements for the Compressed Natural Gas (CNG) cylinders in Regulation No. 110 with those of ISO 11439:2013 standard. It is mainly based on ECE/TRANS/WP.29/GRSG/2016/6 taking into account the comments received at the 110th session of the Working Party on General Safety Provisions (GRSG) (see report ECE/TRANS/WP.29/GRSG/89, paras. 33-34). The modifications to the current text of the Regulation are marked in bold characters.

* In accordance with the programme of work of the Inland Transport Committee for 2016–2017 (ECE/TRANS/254, para. 159 and ECE/TRANS/2016/28/Add.1, cluster 3.1), the World Forum will develop, harmonize and update Regulations in order to enhance the performance of vehicles. The present document is submitted in conformity with that mandate.

I. Proposal

Paragraph 2. (References), amend to read (keeping footnote ² unchanged, removing footnote ³ and renumbering all subsequent footnotes):

"2. References

The following standards contain provisions that, through reference in this text, constitute provisions of this Regulation.

ASTM Standards²

ASTM D522-93a Mandrel Bend Test of Attached Organic Coatings

ASTM D1308-87 Effect of Household Chemicals on Clear and Pigmented Organic Finishes

ASTM D2794-93 Test Method for Resistance of Organic Coatings to the Effects of Rapid Deformation (Impact)

ASTM D3170-87 Chipping Resistance of Coatings

ASTM D3359 Standard Test Methods for Measuring Adhesion by Tape Test

ASTM D4814 Standard Specification for Automotive Spark-Ignition Engine Fuel

ASTM D3418 Test Method for Transition Temperatures Polymers by Thermal Analysis

ASTM G154-12a Standard Practice for Operating Fluorescent Light Apparatus for UV Exposure of Nonmetallic Materials

EN Standards³

EN1251-2 2000 Cryogenic vessels. Vacuum insulated vessels of not more than 1,000 litres volume

ISO Standards⁴

ISO 37 Rubber, vulcanized or thermoplastic – Determination of tensile stress-strain properties.

ISO 148-1 Metallic materials – Charpy pendulum impact test – Part 1: Test method

ISO 306-1987 Plastics - Thermoplastic Materials – Determination of Vicat Softening Temperature

ISO 527-2 Plastics – Determination of tensile properties – Part 2: Test conditions for moulding and extrusion plastics

ISO 9227 Corrosion tests in artificial Atmospheres – Salt spray tests

ISO 1307	Rubber and plastics hoses – Hose sizes, minimum and maximum inside diameters, and tolerances on cut-to-length hoses
ISO 1402	Rubber and plastics hoses and hose assemblies – Hydrostatic testing
ISO 14130	Fibre-reinforced plastic composites – Determination of apparent interlaminar shear strength by short-beam method
ISO 1431	Rubber, vulcanized or thermoplastic – Resistance to ozone cracking
ISO 1436	Rubber hoses and hose assemblies – Wire-braid reinforced hydraulic types for oil-based or waterbased fluids – Specification
ISO 1817	Rubber, vulcanized or thermoplastic – Determination of the effect of liquids
ISO 2808	Paints and Varnishes – Determination of film thickness
ISO 4080	Rubber and plastics hoses and hose assemblies – Determination of permeability to gas
ISO 4672	Rubber and plastics – Sub-ambient temperature flexibility tests
ISO 6892	Metallic Materials – Tensile Testing
ISO 6506	Metallic Materials – Hardness test – Brinell Test
ISO 7225	Precautionary Labels for Gas Cylinders
ISO 7866	Refillable seamless aluminium alloy gas cylinders – Design, construction and testing
ISO 9001	Quality Assurance in Design/Development, Production, Installation and Servicing
ISO 9002	Quality Assurance in Production and Installation
ISO 9809-1	Gas cylinders — Refillable seamless steel gas cylinders — Design, construction and testing — Part 1: Quenched and tempered steel cylinders with tensile strength of less than 1,100 MPa
ISO 9809-2	Gas cylinders — Refillable seamless steel gas cylinders — Design, construction and testing — Part 2: Quenched and tempered steel cylinders with tensile strength of greater than or equal to 1,100 MPa
ISO 9809-3	Gas cylinders — Refillable seamless steel gas cylinders — Design, construction and testing — Part 3: Normalized steel cylinders
ISO 12991	Liquefied natural gas (LNG) – transportable tanks for use on board of vehicles

ISO 14469-1	Road Vehicles: compressed natural gas CNG refuelling connector: Part I: 20 MPa (200 bar) connector
ISO 14469-2	Road Vehicles: compressed natural gas CNG refuelling connector: Part II: 20 MPa (200 bar) connector
ISO 15403-1	Natural gas — Natural gas for use as a compressed fuel for vehicles — Part 1: Designation of the quality
ISO/TR 15403-2	Natural gas — Natural gas for use as a compressed fuel for vehicles — Part 2: Specification of the quality
ISO 15500	Road vehicles – Compressed natural gas (CNG) fuel system components
ISO 15500-13	Road vehicles – Compressed natural gas (CNG) fuel system components — Part 13: Pressure relief device (PRD)
ISO 21028-1	Cryogenic vessels – Toughness requirements for materials at cryogenic temperature – Part I: Temperatures below -80 °C
ISO 21029-1	Cryogenic vessels – Transportable vacuum insulated vessels of not more than 1,000 litres volume – Part I: Design, fabrication, inspection and tests
ISO/IEC Guide 25	General requirements for the Technical Competence of Testing Laboratories
ISO/IEC Guide 48	Guidelines for Third Party Assessment and Registration of Supplies Quality System
NACE Standard ⁵	
NACE TM0177-90	Laboratory Testing of Metals for Resistance to Sulphide Stress Cracking in H ₂ S Environments
ECE Regulations ⁶	
Regulation No. 10	Uniform provisions concerning the approval of vehicles with regard to electromagnetic compatibility
USA Federal Regulations ⁷	
49 CFR 393.67	Liquid fuel tanks
SAE Standards ⁸	
SAE J2343-2008	Recommended Practice for LNG Medium and Heavy-Duty Powered Vehicles

³ European Norm.

⁴ International Organization for Standardization.

⁵ National Association of Corrosion Engineers.

⁶ United Nations Economic Commission for Europe; Regulations.

⁷ United States of America Federal Regulations.

⁸ Society of Automotive Engineers."

Paragraph 4.4., amend to read:

"4.4. "Working pressure" means the maximum pressure to which a component is designed to be subjected to and which is the basis for determining the strength of the component under consideration. For LNG tank, the pressure of the LNG tank primary relief valve setting."

Paragraph 4.62., shall be deleted.

Paragraphs 4.63. to 4.75., renumber as paragraphs 4.62. to 4.74.

Annex 3A

Paragraph 1., amend to read:

"1. Scope

Cylinders covered by this annex are classified in Class 0, as described in paragraph 3. of this Regulation, and are:

- | | |
|-------|---|
| CNG-1 | Metal |
| CNG-2 | Metal liner reinforced with resin impregnated continuous filament (hoop wrapped) |
| CNG-3 | Metal liner reinforced with resin impregnated continuous filament (fully wrapped) |
| CNG-4 | Resin impregnated continuous filament with a non-metallic liner (all composite) |

Service conditions to which the cylinders will be subjected are detailed in paragraph 4. of this annex. **This annex uses 20 MPa as a reference working pressure, although other working pressures can be used.**

The service life of the cylinder ...

..."

Paragraphs 4.2. and 4.3., amend to read:

"4.2. Maximum pressures

This annex is based upon a working pressure of 20 MPa settled at 15 °C for natural gas as a fuel with a maximum filling pressure of 26 MPa. Other working pressures may be accommodated by adjusting the pressure by the appropriate factor (ratio); e.g. a 24 MPa working pressure system will require pressures to be multiplied by 1.20. Except where pressures have been adjusted in this way, the cylinder pressure shall be limited to the following:

- (a) A pressure that would settle to 20 MPa at a settled temperature of 15 °C;
- (b) 26 MPa, immediately after filling, regardless of temperature;

4.3. Maximum number of filling cycles

Cylinders are designed to be filled up to 1,000 times per year of service."

Paragraph 4.5., amend to read:

"4.5. Gas composition

4.5.1. General

Cylinders shall be designed to tolerate being filled with natural gas meeting the specification of ISO 15403-1 and ISO/TR 15403-2, and either of dry gas or wet gas as described in paragraph 4.5.2. or 4.5.3., respectively. Methanol and/or glycol shall not be deliberately added to the natural gas.

4.5.2. Dry gas

Water vapour would normally be limited to less than 32 mg/m³ at a pressure dew point of -9 °C at 20 MPa. There would be no constituent limits for dry gas, except for:

Hydrogen sulphide and other soluble sulphides:	23 mg/m ³
Oxygen:	1 per cent by volume

Hydrogen shall be limited to 2 per cent by volume when cylinders are manufactured from steel with an ultimate tensile strength exceeding 950 MPa;

4.5.3. Wet gas

Gas that contains water content higher than **specified in paragraph 4.5.2.** normally meets the following constituent limits;

Hydrogen, sulphide and other soluble sulphides:	23 mg/m ³
Oxygen:	1 per cent by volume
Carbon dioxide:	3 per cent by volume
Hydrogen:	0.1 per cent by volume

Under wet gas conditions, a minimum of 1 mg of compressor oil per kg of y to protect metallic cylinders and liners."

Paragraph 5., amend to read:

"5. **Type approval procedure"**

Paragraph 6.1., amend to read:

"6.1. General

The following requirements are generally applicable to the cylinder types specified in paragraphs 7. to 10. of this annex. The design of cylinders shall cover all relevant aspects which are necessary to ensure that every cylinder produced according to the design is fit for its purpose for the specified service life."

Paragraph 6.3.2.1., amend to read:

"6.3.2.1. Composition

Steels shall be aluminium and/or silicon killed and produced to predominantly fine grain practice. The chemical composition of all steels shall be declared and defined at least by:

- (a) Carbon, manganese, aluminium and silicon contents in all cases;

- (b) Nickel, chromium, molybdenum, boron and vanadium contents, and any other alloying elements intentionally added. The following limits shall not be exceeded in the cast analysis:

<i>Strength</i>	<i>Limit</i>
Sulphur	0.010 per cent
Phosphorus	0.020 per cent
Sulphur and phosphorus	0.025 per cent

"

Paragraph 6.3.3.4., amend to read:

"6.3.3.4. Tensile properties

The mechanical properties of the aluminium alloy in the finished cylinder shall be determined in accordance with paragraph A.1. (Appendix A to this annex). The elongation for aluminium **cylinder material in Type CNG-1 cylinders and aluminium liner material in Type CNG-2 cylinders** shall be at least 12 per cent. **The elongation for aluminium liner material in Type CNG-3 cylinders shall meet the manufacturer's design specifications.**"

Paragraphs 6.3.6. and 6.4., amend to read:

"6.3.6. Plastic liners

The tensile yield strength and ultimate elongation shall be determined in accordance with paragraph A.22. (Appendix A to this annex). Tests shall demonstrate the ductile properties of the plastic liner material at temperatures of -50 °C or lower by meeting the values specified by the manufacturer; the polymeric material shall be compatible with the service conditions specified in paragraph 4. of this annex. In accordance with the method described in paragraph A.23. (Appendix A to this annex), the softening temperature shall be at least 100 °C.

6.4. Test pressure

The minimum test pressure used in manufacture shall be **1.5 times the working pressure;**"

Paragraph 6.7., amend to read:

"6.7. Leak-before-break (LBB) assessment

Types CNG-1, CNG-2 and CNG-3 cylinders shall demonstrate Leak-Before-Break (LBB) performance. The LBB performance test shall be carried out in accordance with paragraph A.6. (Appendix A to this annex). Demonstration of LBB performance is not required for cylinder designs that provide a fatigue life exceeding 45,000 pressure cycles when tested in accordance with paragraph A.13. (Appendix A to this annex)."

Paragraph 6.9., amend to read:

"6.9. Fire Protection

All cylinders shall be protected from fire with pressure relief devices. The cylinder, its materials, pressure relief devices and any added insulation or protective material shall be designed collectively to ensure adequate safety during fire conditions in the test specified in paragraph A.15. (Appendix A to this annex).

Pressure relief devices shall **conform to ISO 15500-13.**"

Paragraph 6.12., amend to read (deleting the last subparagraph):

"6.12. Exterior environmental protection
The exterior of cylinders shall meet ...
...

Any coatings applied to cylinders shall be such that the application process does not adversely affect the mechanical properties of the cylinder. The coating shall be designed to facilitate subsequent in service inspection and the manufacturer shall provide guidance on coating treatment during such inspection to ensure the continued integrity of the cylinder."

Paragraph 6.15.1.(a), replace the reference to "BS 5045, Part 1" by "**ISO 9809-1, Annex B**".

Paragraph 6.15.2., amend to read:

"6.15.2. Maximum defect size
For type CNG-1, CNG-2 and CNG-3 designs, the maximum defect size at any location in the metal cylinder or metal liner that will not grow to a critical size within the specified service life shall be determined. The critical defect size is defined as the limiting through-wall (cylinder or liner) thickness defect that would allow stored gas to be discharged without rupturing the cylinder. Defect sizes for the rejection criteria for ultrasonic scanning, or equivalent shall be smaller than the maximum allowable defect sizes. For type CNG-2 and CNG-3 designs assume that there shall be no damage to composite due to any time-dependent mechanisms; the allowable defect size for NDE shall be determined by an appropriate method **such as that** outlined in the informative Appendix F to this annex."

Paragraph 6.17., amend to read:

"6.17. Change of design
A design change is any change in the selection of structural materials or dimensional change not attributable to normal manufacturing tolerances. Minor design changes shall be permitted to be qualified through a reduced test program. Changes of design specified in Table 6.7 below shall require design qualification testing as specified in the table.

Table 6.1
Material design qualification test

	<i>Relevant paragraph of this annex</i>				
	<i>Steel</i>	<i>Aluminium</i>	<i>Resins</i>	<i>Fibres</i>	<i>Plastic liners</i>
Tensile properties	6.3.2.2.	6.3.3.4.		6.3.5.	6.3.6.
Impact properties	6.3.2.3.				
Sulphide stress cracking resistance	6.3.2.6.				
Sustained load crack resistance		6.3.3.3.			
Stress corrosion cracking		6.3.3.2.			
Shear strength			6.3.4.2.		
Glass transition temperature			6.3.4.3.		
Softening temperature					6.3.6.

...

Table 6.4

Cylinder design qualification tests

<i>Test and annex reference</i>	<i>Cylinder type</i>			
	<i>CNG-1</i>	<i>CNG-2</i>	<i>CNG-3</i>	<i>CNG-4</i>
A.12. Burst	X *	X	X	X
A.13. Ambient temperature/cycle	X *	X	X	X
A.14. Environmental		X	X	X
A.15. Bonfire		X	X	X
A.16. Penetration	X	X	X	X
A.17. Flaw tolerance	X	X	X	X
A.18. High temperature creep		X	X	X
A.19. Stress rupture		X	X	X
A.20. Drop test			X	X
A.21. Permeation				X
A.25. Boss torque test	X			X
A.27. Natural gas cycling				X
A.6. LBB assessment		X	X	
A.7. Extreme temperature/cycle	X	X	X	X

X = required

* = Not required for cylinders designed to ISO 9809 (ISO 9809 already provides for these tests).

...

...

Table 6.7
Change of design

Design change	Type of test												
	Permeation A.21	Cycling A.27	Hydrostatic Burst A.12	LBB A.6	Pressure cycle at ambient temp. A.13	Bon fire A.15	Penetra- tion A.16	Environ- mental A.14	Flaw toler- ance A.17	High temp. creep A.18	Stress rupture A.19	Drop test A.20	Boss torque A.25
Fibre manufacturer			X		X						X	X	
Metal liner material (g)			X	X	X	X	X	X	X	X	X	X(h)	
Plastic liner material	X	X	X			X				X		X	X
Fibre material			X	X	X	X	X	X	X	X	X	X	
Resin material				X			X	X	X	X			
Diameter change ≤ 20 per cent			X		X		X(e)						
Diameter change (b) > 20 per cent			X	X	X	X	X		X			X(i)	
Length change ≤ 50 per cent			X			X(a)							
Length change > 50 per cent			X		X	X(a)						X(i)	
Metall cyclinder material (g)			X	X	X	X	X						
Working pressure change ≤ 20 per cent			X		X								
Dome shape			X	X(f)	X								
Opening size			X(j)	X(i)	X(j)								
Coating change							X(j)						
End boss design (k)	X(c)	X(c)											X(d)
Pressure relief device						X							
Thread													X

X = test required

- (a) Test only required when length increases.
- (b) Only when thickness changes proportional to diameter and/or pressure change.
- (c) Only if boss/liner interface is affected.
- (d) Only if boss/liner or boss composite interface is affected or torque requirements changes.
- (e) Only required if diameter decreases.
- (f) For CNG-1 and CNG-2 designs, only required if designs other than ISO 9809-1.
- (g) Material tests are also required.
- (h) For CNG-3 designs only.
- (i) For CNG-3 and CNG-4 designs only.
- (j) For CNG-2, CNG-3 and CNG-4 designs only.
- (k) For CNG-4 designs only."

Paragraph 7.1., amend to read (deleting the last subparagraph):

"7.1. General

The design shall identify the maximum size of an allowable defect at any point in the cylinder which will not grow to a critical size within the specified retest period, or service life if no retest is specified, of a cylinder operating to the working pressure. Determination of leak-before-break (LBB) performance shall be done in accordance with the appropriate procedures defined in paragraph A.6. (Appendix A to this annex). Allowable defect size shall be determined in accordance with paragraph 6.15.2. above."

Paragraph 7.3.2.(b), replace the reference to "BS 5045, Part 1, Annex I" by "**ISO 9809-1, Annex B**".

Paragraph 7.4., amend to read:

"7.4. Cylinder batch tests

Batch testing shall be conducted on finished cylinders which are representative of normal production and are complete with identification marks. Two cylinders shall be randomly selected from each batch. If more cylinders are subjected to the tests than are required by this annex, all results shall be documented. **Cylinders qualified in accordance with ISO 9809-1, ISO 9809-2, ISO 9809-3 or ISO 7866 are not required to perform the pressure cycling test described in paragraph A.13. (Appendix A to this annex).**

(a) Batch materials ...

...

(c) Periodic pressure cycling test. Finished cylinders shall be pressure cycled in accordance with paragraph A.13. (Appendix A to this annex) at a test frequency defined as follows:

(i) One cylinder ...

...

(iv) Should more than 6 months have expired since the last batch of production, **then** a cylinder from the next batch of production shall be pressure cycle tested in order to maintain the reduced frequency of batch testing in (ii) or (iii) above.

(v) Should any ...

..."

Paragraph 8.3.3.1., amend to read:

"8.3.3.1. Curing of thermosetting resins

If a thermosetting resin is used, the resin shall be cured after filament winding. During the curing, the curing cycle (i.e. the time-temperature history) shall be documented. The curing temperature shall be controlled and shall not affect the material properties of the liner. The maximum curing temperature for cylinders with aluminium liners **shall be below the time and temperature that adversely affect metal properties.**"

Paragraph 8.4.1.(b), replace the reference to "BS 5045, Part 1, Annex 1B" by "**ISO 9809-1, Annex B**".

Paragraph 8.6.4., amend to read:

"8.6.4. **Environmental** test

One cylinder shall be tested in accordance with paragraph A.14. (Appendix A to this annex) and meet the requirements therein."

Paragraph 8.6.8., amend to read:

"8.6.8. High temperature creep test

In designs where the glass transition temperature of the resin does not exceed **102 °C**, one cylinder shall be tested in accordance with paragraph A.18. (Appendix A to this annex) and meet the requirements therein."

Paragraph 10.4., amend to read:

"10.4. Manufacturing requirements

Manufacturing requirements shall be in accordance with paragraph 8.3. above."

Paragraph 10.6.1.(a)(iii), replace "melt temperature" by "softening temperature".

Annex 3A – Appendix A

Paragraph A.1., replace the reference to "ISO 6892" by "ISO 6892-1" (two times).

Paragraph A.2., replace the reference to "ISO 148" by "ISO 148-1".

Paragraphs A.4. to A.10., amend to read:

"A.4. Corrosion tests, aluminium

Corrosion tests for aluminium alloys shall be carried out in accordance with Annex A of **ISO 7866** and meet the requirements therein.

A.5. Sustained load cracking tests, aluminium

The resistance to SLC shall be carried out in accordance with Annex **B** of **ISO 7866** and shall meet the requirements therein;

A.6. Leak-Before-Break (LBB) performance test

Three finished cylinders shall be pressure cycled between not more than 2 MPa and **not** less than **1.5 times the working pressure** at a rate not to exceed 10 cycles per minute. All cylinders shall fail by leakage.

A.7. Extreme temperature pressure cycling

Finished cylinders, with the composite wrapping free of any protective coating, shall be cycle tested, without showing evidence of rupture, leakage, or fibre unravelling, as follows:

- (a) Condition for 48 hours at zero pressure, 65 °C or higher, and 95 per cent or greater relative humidity. The intent of this requirement shall be deemed met by spraying with a fine spray or mist of water in a chamber held at 65 °C;
- (b) Hydrostatically pressurized for 500 cycles times the specified service life in years between not more than 2 MPa and not less than **1.3 times the working pressure** at 65 °C or higher and 95 per cent humidity;
- (c) Stabilize at zero pressure and ambient temperature;

- (d) Then pressurize from not more than 2 MPa to not less than **the working pressure** for 500 cycles times the specified service life in years at -40 °C or lower;

The pressure cycling ...

...

A.8. Brinell hardness test

Hardness tests shall be carried out on the parallel wall at the centre and a domed end of each cylinder or liner in accordance with ISO 6506-1. The test shall be carried out after the final heat treatment and the hardness values thus determined shall be in the range specified for the design.

A.9. Coating tests (mandatory if paragraph 6.12.(c) of Annex 3A is used)

A.9.1. Coating performance tests

Coatings shall be evaluated using the following test methods, or using equivalent national standards.

- (a) Adhesion testing in accordance with **ASTM D3359**, using Method A or B as applicable. The coating shall exhibit an adhesion rating of either 4A or 4B, as applicable;
- (b) Flexibility in accordance with ASTM D522 Mandrel Bend Test of Attached Organic Coatings, using Test Method B with a 12.7 mm (0.5 inch) mandrel at the specified thickness at -20 °C. Samples for the flexibility test shall be prepared in accordance with the ASTM D522 standard. There shall not be any visually apparent cracks;
- (c) Impact resistance in accordance with ASTM D2794. The coating at room temperature shall pass a forward impact test of 18 J (160 in lbs);
- (d) Chemical resistance when tested in general accordance with ASTM D1308. The tests shall be conducted using the Open Spot Test Method and 100 hour exposure to a 30 per cent sulfuric acid solution (battery acid with a specific gravity of 1.219) and 24 hours exposure to a polyalkalene glycol (e.g. brake fluid). There shall be no evidence of lifting, blistering or softening of the coating. The adhesion shall meet a rating of 3 when tested in accordance with ASTM D3359;
- (e) Minimum 1,000 hours exposure in accordance with **ASTM G154**. There shall be no evidence of blistering, and adhesion shall meet a rating of 3 when tested in accordance with **ASTM D3359**. The maximum gloss loss allowed is 20 per cent;
- (f) Minimum 500 hours exposure in accordance with **ISO 9227**. Undercutting shall not exceed **2 mm** at the scribe mark, there shall be no evidence of blistering, and adhesion shall meet a rating of 3 when tested in accordance with ASTM D3359;
- (g) Resistance to chipping at room temperature using ASTM D3170. The coating shall have a rating of 7A or better and there shall not be any exposure of the substrate.

A.9.2. Coating batch tests

(a) Coating thickness

The thickness of the coating shall meet the requirements of the design when tested in accordance with ISO 2808;

(b) Coating adhesion

The coating adhesion strength shall be measured in accordance with **ASTM 3359**, and shall have a minimum rating of 4 when measured using either Test Method A or B, as appropriate.

A.10. Leak test

Type CNG-4 designs shall be leak tested using the following procedure (or an acceptable alternative);

- (a) Cylinders shall be thoroughly dried and pressurized to working pressure with dry air or nitrogen, and containing a detectable gas such as helium;
- (b) Any leakage **detected** shall be cause for rejection. **Leakage is the release of gas through a crack, pore, un-bond or similar defect. Permeation through the wall in conformance to paragraph A.21. below is not considered to be leakage."**

Paragraphs A.12. to A.14., amend to read:

"A.12. Hydrostatic pressure burst test

- (a) The rate of pressurisation shall not exceed 1.4 MPa per second at pressures in excess of 80 per cent of the design burst pressure. If the rate of pressurisation at pressures in excess of 80 per cent of the design burst pressure exceeds 350 kPa/second, then either the cylinder shall be placed schematically between the pressure source and the pressure measurement device, or there shall be a 5 second hold at the minimum design burst pressure;
- (b) The minimum required (calculated) burst pressure shall be at least **the minimum burst pressure specified for the design**, and in no case less than the value necessary to meet the stress ratio requirements. Actual burst pressure shall be recorded. Rupture may occur in either the cylindrical region or the dome region of the cylinder.

A.13. Ambient temperature pressure cycling

Pressure cycling shall be performed in accordance with the following procedure:

- (a) Fill the cylinder to be tested with a non-corrosive fluid such as oil, ed water or glycol;
- (b) Cycle the pressure in the cylinder between not more than 2 MPa and not less than **1.3 times the working pressure** at a rate not to exceed 10 cycles per minute.

The number of cycles to failure shall be reported, along with the location and description of the failure initiation.

A.14. Environmental test

The environmental test shall meet the requirements of Appendix H to Annex 3A."

Paragraph A.15.5., amend to read:

"A.15.5. General test requirements

Cylinders shall be pressurized with natural gas and tested in the horizontal position at both:

- (a) Working pressure;
- (b) 25 per cent of the working pressure (**only if a thermally-activated pressure relief device is not part of the design**).

Immediately following ignition, the fire shall produce flame impingement on the surface of the cylinder along the 1.65 m length of the fire source and across the cylinder diameter. Within 5 minutes of ignition, at least one thermocouple shall indicate a temperature of at least 590 °C.

This minimum temperature shall be maintained for the remaining duration of the test."

Paragraphs A.16. to A.27., amend to read:

"A.16. Penetration tests

A cylinder pressurised to **the working pressure** ± 1 MPa with compressed gas shall be penetrated by an armour piercing bullet with a diameter of 7.62 mm or greater. The bullet shall completely penetrate at least one side wall of the cylinder. **For type CNG-1 designs, the projectile shall impact the side wall at 90°.** For type CNG-2, CNG-3 and CNG-4 designs, the projectile shall impact the side wall at an approximate angle of 45°. The cylinder shall reveal no evidence of fragmentation failure. Loss of small pieces of material, each not weighing more than 45 grams, shall not constitute failure of the test. The approximate size of entrance and exit openings and their locations shall be recorded.

A.17. Composite flaw tolerance tests

For type CNG-2, CNG-3 and CNG-4 designs only, one finished cylinder, complete with protective coating, shall have flaws in the longitudinal direction cut into the composite. The flaws shall be greater than the visual inspection limits as specified by the manufacturer. **As a minimum, one flaw shall be 25 mm long and 1.25 mm in depth and another flaw shall be 200 mm long and 0.75 mm in depth, cut in the longitudinal direction into the cylinder sidewall.**

The flawed cylinder shall then be pressure cycled from not more than 2 MPa to not less than **1.3 times the working pressure** for 3,000 cycles at ambient temperature; The cylinder shall not leak or rupture within the first 3,000 cycles, but may fail by leakage during the **further design lifetime in years times 1,000 cycles (less the 3,000 cycles already performed)**. All cylinders which complete this test shall be destroyed.

A.18. High temperature creep test

This test is required for all type CNG-4 designs, and all type CNG-2 and CNG-3 designs in which the glass transition temperature of the resin matrix does not exceed the maximum design material temperature given in paragraph 4.4.2. of Annex 3A by at least 20 °C. One finished cylinder shall be tested as follows:

- (a) The cylinder shall be pressurised to **1.3 times the working pressure** and held at a temperature of 100 °C for not less than 200 hours;
- (b) Following the test, the cylinder shall meet the requirements of the hydrostatic expansion test A.11., the leak test A.10. (**for Type CNG-4 cylinders only**), and the burst test A.12. above.

- A.19. Accelerated stress rupture test
- For type CNG-2, CNG-3, and CNG-4 designs only, one cylinder free of protective coating shall be hydrostatically pressurised to **1.3 times the working pressure** while immersed in water at 65 °C. The cylinder shall be held at this pressure and temperature for 1,000 hours. The cylinder shall then be pressured to burst in accordance with the procedure defined in paragraph A.12. above except that the burst pressure shall exceed 85 per cent of the minimum design burst pressure.
- A.20. Impact damage test
- One or more finished cylinders shall be drop tested at ambient temperature without internal pressurisation or attached valves. The surface onto which the cylinders are dropped shall be a smooth, horizontal concrete pad or flooring. One cylinder shall be dropped in a horizontal position with the bottom 1.8 m above the surface onto which it is dropped. One cylinder shall be dropped vertically on each end at a sufficient height above the floor or pad so that the potential energy is 488 J, but in no case shall the height of the lower end be greater than 1.8 m. One cylinder shall be dropped at a 45° angle onto a dome from a height such that the centre of gravity is at 1.8 m; however, if the lower end is closer to the ground than 0.6 m, the drop angle shall be changed to maintain a minimum height of 0.6 m and a centre of gravity of 1.8 m.
- The cylinders shall be allowed to bounce on the concrete pad or flooring after the initial impact. No attempt shall be made to prevent this secondary impacting, but the cylinder may be prevented from toppling during the vertical drop tests.**
- Following the drop impact, the cylinders shall be pressure cycled **between 2 MPa and 1.3 times the working pressure at ambient temperature** for 1,000 cycles times the specified service life in years. The cylinders **shall not leak or rupture within the first 3,000 cycles, but may fail only by leakage during the further design lifetime in years times 1,000 cycles (less the 3,000 cycles already performed)**. Any cylinders completing the cycling test shall be destroyed.
- A.21. Permeation test
- This test is only required on type CNG-4 designs. One finished cylinder shall be filled with compressed natural **gas to working pressure**, placed in an enclosed sealed chamber at ambient temperature, and monitored for leakage for **up to 500 hours**, to establish a steady state permeation rate. The permeation rate shall be less than 0.25 ml of natural **gas per hour per litre** water capacity of the cylinder.
- A.22. Tensile properties of plastics
- The tensile yield strength and ultimate elongation of plastic liner material shall be determined at -50 °C using ISO **527-2**, and meet the requirements of paragraph 6.3.6. of Annex 3A.
- A.23. **Softening** temperature of plastics
- Polymeric materials from finished liners shall be tested in accordance with the method described in ISO 306. **The softening temperature shall be at least 100 °C.**
- A.24. Pressure relief device requirements
- Pressure relief devices **shall meet the requirements of ISO 15500-13.**

- A.25. Boss torque test
- The body of the cylinder shall be restrained against rotation and **150 per cent of manufacturer's recommended torque** shall be applied to each end boss of the cylinder, first in the direction to tighten a threaded connection, then in the untightening direction, and in the tightening direction.
- A.26. Resin shear strength
- Resin materials shall be tested on a sample coupon representative of the composite over-wrap in accordance with **ISO 14130**, or an equivalent national standard. Following a 24-hour water boil the composite shall have a minimum shear strength of **13.8 MPa**.
- A.27. Natural gas cycling test
- One finished cylinder shall be pressure cycled using compressed natural gas from less than 2 MPa to working pressure for **1,000** cycles. Each cycle, consisting ...
- ..."

Annex 3A – Appendix F, replace by:

"Annex 3A - Appendix F

Defect size for Non-Destructive Examination (NDE)

For type CNG-1, CNG-2 and CNG-3 designs, three cylinders containing artificial defects that exceed the defect length and depth detection capability of the NDE inspection method required in paragraph 6.15. of Annex 3A, shall be pressure cycled to failure in accordance with the test method in paragraph A.13. (Appendix A to this annex). For type CNG-1 designs having a fatigue sensitive site in the cylindrical part, external flaws shall be introduced on the side wall. For type CNG-1 designs having the fatigue sensitive site outside the side wall, and for type CNG-2 and CNG-3 designs, internal flaws shall be introduced. Internal flaws may be machined prior to the heat treating and closing of the end of the cylinder.

The cylinders shall not leak or rupture in less than 15,000 cycles. The allowable defect size for NDE shall be equal to or less than the artificial flaw size at that location."

Annex 3A – Appendix H, amend to read (including the deletion of paragraphs H.7 and H.8):

"Annex 3A - Appendix H

Environmental test

H.1. Scope

This test is applicable to type CNG-2, CNG-3 and CNG-4 designs only.

H.2. Summary of test method

A cylinder is first preconditioned by pendulum impacts to simulate potential underbody conditions. The cylinder is then subjected **to exposure to fluids, and pressure cycles**. At the conclusion of the test sequence the cylinder will be hydraulically pressured to destruction. The remaining residual burst strength of the cylinder shall be not less than **80** per cent of the minimum design burst strength.

H.3. Cylinder set-up and preparation

The cylinder shall be tested in a condition representative of installed geometry including coating (if applicable), brackets and gaskets, and pressure fittings using the same sealing configuration (i.e. O-rings) as that used in service. Brackets may be painted or coated prior to installation in the immersion test if they are painted or coated prior to vehicle installation.

The upper section will be divided into 5 distinct areas and marked for preconditioning and fluid exposure (**see Figure H.1**). The areas will be nominally 100 mm in diameter. The areas shall not overlap on the cylinder surface. While convenient for testing, the areas need not be oriented along a single line, but shall not overlap the immersed section of the cylinder.

Although preconditioning and fluid exposure is performed on the cylindrical section of the cylinder, all of the cylinder, including the domed sections, should be as resistant to the exposure environments as are the exposed areas.

Figure H.1
Cylinder orientation and layout of exposure areas



H.4. Pendulum impact preconditioning

The impact body shall be of steel and have the shape of a pyramid with equilateral triangle faces and a square base, the summit and the edges being rounded to a radius of 3 mm. The centre of percussion of the pendulum shall coincide with the centre of gravity of the pyramid; its distance from the axis of rotation of the pendulum shall be 1 m. The total mass of the pendulum referred to its centre of percussion shall be 15 kg. The energy of the

pendulum at the moment of impact shall be not less than 30 Nm and as close to that value as possible.

During pendulum impact, the cylinder shall be held in position by the end bosses or by the intended mounting brackets. **The cylinder shall be un-pressurized during preconditioning.**

H.5. **Environment fluid for exposure**

Each marked area is to be exposed to one of five solutions for 30 minutes. The same environment shall be used for each location throughout the test. The solutions are:

Sulphuric acid: 19 per cent solution by volume in water;

Sodium hydroxide: 25 per cent solution by weight in water;

5 per cent Methanol/95 per cent gasoline: gasoline concentration of M5 fuel meeting the requirements of ASTM D4814;

Ammonium nitrate: 28 per cent by weight in water;

Windshield washer fluid (50 per cent by volume solution of methyl alcohol and water)

When exposed, the test sample will be oriented with the exposure area uppermost. A pad of glass wool (approximately 0.5 mm **thick** and **between 90 and 100 mm in diameter**) shall be placed on the exposure area. **Apply an amount of the test fluid to the glass wool sufficient to ensure that the pad is wetted evenly across its surface and through its thickness for the duration of the test, and that the concentration of the fluid is not changed significantly during the duration of the test.**

H.6. **Pressure cycle and hold**

The cylinder shall be hydraulically pressure cycled between not less than 2 MPa and not more than 125 per cent of working pressure for a total of 3,000 cycles. The maximum pressurization rate shall be 2.75 MPa per second. After pressure cycling, the cylinder shall be pressurized to 125 per cent of working pressure and held at that pressure a minimum of 24 hours and until the elapsed exposure time (pressure cycling and pressure hold) to the environmental fluids equals 48 hours."

II. Justification

A detailed justification on the modification proposed above can be found in GRSG-111-02, available at: www.unece.org/trans/main/wp29/wp29wgs/wp29grsg/grsginf111.html.