II

(Non-legislative acts)

REGULATIONS

COMMISSION REGULATION (EU) No 406/2010

of 26 April 2010

implementing Regulation (EC) No 79/2009 of the European Parliament and of the Council on type-approval of hydrogen-powered motor vehicles

(Text with EEA relevance)

THE EUROPEAN COMMISSION,

Having regard to the Treaty on the Functioning of the European Union,

Having regard to Regulation (EC) No 79/2009 of the European Parliament and of the Council of 14 January 2009 on type-approval of hydrogen-powered motor vehicles, and amending Directive 2007/46/EC ([1]), and in particular Article 12 thereof,

Whereas:

(1) Regulation (EC) No 79/2009 is a separate Regulation for the purposes of the Community type-approval procedure provided for by Directive 2007/46/EC of the European Parliament and of the Council of 5 September 2007 establishing a framework for the approval of motor vehicles and their trailers, and of systems, components and separate technical units intended for such vehicles (Framework Directive) ([2]).

(2) Regulation (EC) No 79/2009 lays down fundamental provisions on requirements for the type-approval of motor vehicles with regard to hydrogen propulsion, for the type-approval of hydrogen components and hydrogen systems and for the installation of such components and systems.

(3) From entry into force of the present Regulation manufacturers should be able to apply for the EC whole-vehicle type-approval of hydrogen-powered vehicles on a voluntary basis. However, some of the separate Directives in the context of the Community type-approval procedure under Directive 2007/46/EC or some of their requirements should not apply to hydrogen-powered vehicles, since the technical characteristics of hydrogen-powered vehicles differ significantly from conventional ones, for which those type-approval Directives were essentially designed. Pending the amendment of those Directives to include specific provisions and test procedures on hydrogen-powered vehicles, it is necessary to set out transitional provisions in order to exempt hydrogen-powered vehicles from those Directive or some of their requirements.

(4) Adopting harmonised rules on hydrogen receptacles, including receptacles designed to use liquid hydrogen, is necessary in order to ensure that hydrogen vehicles can be refuelled throughout the Community in a safe and reliable manner.

(5) The measures provided for in this Regulation are in accordance with the opinion of the Technical Committee — Motor Vehicles,

HAS ADOPTED THIS REGULATION:

Article 1

Definitions

For the purposes of this Regulation, the following definitions shall apply:

(1) ‘Hydrogen sensor’ means a sensor used to detect hydrogen in air;

(2) ‘Class 0 component’ means high-pressure hydrogen components including fuel lines and fittings containing hydrogen at a nominal working pressure greater than 3,0 MPa;

([1]) OJ L 35, 4.2.2009, p. 32.

([2]) OJ L 263, 9.10.2007, p. 1.

(3) 'Class 1 component' means medium-pressure hydrogen components including fuel lines and fittings containing hydrogen at a nominal working pressure greater than 0,45 MPa and up to and including 3,0 MPa;

(4) 'Class 2 component' means low-pressure hydrogen components including fuel lines and fittings containing hydrogen at a nominal working pressure up to and including 0,45 MPa;

(5) 'Fully wrap' means over-wrap with the filaments wound around the liner both in the circumferential and longitudinal directions of the container;

(6) 'Hoop wrap' means over-wrap with the filaments wound in a substantially circumferential pattern over the cylindrical portion of the liner, so that the filaments do not carry any significant load in the longitudinal direction of the container;

(7) 'Nm^3' or 'Ncm^3' means a volume of dry gas that occupies a volume of 1 m^3 or 1 cm^3 at a temperature of 273,15 K (0 °C) and an absolute pressure of 101,325 kPa (1 atm);

(8) 'Service life' means the life in years during which the containers may safely be used in accordance with the service conditions;

(9) 'Type of hydrogen system' means a group of hydrogen systems which do not differ either as regards their trade name or mark of their manufacturer or as regards the hydrogen components included therein;

(10) 'Vehicle type with regard to hydrogen propulsion' means a group of vehicles which do not differ as regards the state of the hydrogen used or the main characteristics of its hydrogen system(s);

(11) 'Type of hydrogen component' means a group of hydrogen components which do not differ in any of the following aspects:

(a) trade name or mark of their manufacturer;

(b) classification;

(c) main function;

(12) 'Electronic control system' means a combination of units, designed to cooperate in the production of the stated vehicle control function by electronic data processing;

(13) 'Complex electronic vehicle control systems' mean electronic control systems which are subject to a hierarchy of control in which one electronically controlled function may be overridden by a higher-level system/function and become part of the complex system;

(14) 'Container' means any system used for the storage of cryogenic hydrogen or compressed gaseous hydrogen, excluding any other hydrogen components which may be attached to or fitted inside the container;

(15) 'Container Assembly' means two or more containers with integral interconnecting fuel lines, protectively encased inside a housing shell or protective frame;

(16) 'Duty Cycle' means one start up and shut down cycle of the hydrogen conversion system(s);

(17) 'Filling cycle' means a pressure increase of more than 25 per cent of the working pressure of the container due to an external source of hydrogen;

(18) 'Pressure regulator' means a device used to control the delivery pressure of gaseous fuel to the hydrogen conversion system;

(19) 'First pressure regulator' means the pressure regulator having the container pressure as its inlet pressure;

(20) 'Non-return valve' means a valve that allows hydrogen to flow in only one direction;

(21) 'Pressure' means gauge pressure measured in MPa against atmospheric pressure, unless otherwise stated;

(22) 'Fitting' means a connector used in a piping, tubing or hose system;

(23) 'Flexible fuel line' means flexible tubing or a hose through which hydrogen flows;

(24) 'Heat exchanger' means a device for heating the hydrogen;

(25) 'Hydrogen filter' means a filter used to separate oil, water and dirt from hydrogen;

(26) 'Automatic valve' means a valve that is not operated manually, but by an actuator, with the exception of non-return valves as defined in point 20;

(27) 'Pressure relief device' means a non-reclosing device that, when activated under specified conditions, is used to release fluid from a pressurised hydrogen system;

(28) 'Pressure relief valve' means a reclosing pressure activated device that, when activated under specified conditions, is used to release fluid from a pressurised hydrogen system;

(29) ‘Refuelling connection’ or ‘receptacle’ means a device used to fill the container at the filling station;

(30) ‘Removable storage system’ means a removable system within a vehicle that houses and protects one or more container(s) or a container assembly;

(31) ‘Removable storage system connector’ means the hydrogen connection device between a removable storage system and the section of the hydrogen system permanently installed in the vehicle;

(32) ‘Auto-frettage’ means a pressure application procedure used in manufacturing composite containers with metal liners, which strains the liner past its yield point sufficiently to cause permanent plastic deformation, which results in the liner having compressive stresses and the fibres having tensile stresses at zero internal pressure;

(33) ‘Liner’ means a part of a container that is used as a gas tight inner shell, on which reinforcing fibres are filament wound to reach the necessary strength;

(34) ‘Ambient temperature’ means a temperature range of 20 °C ± 10 °C;

(35) ‘Units’ mean the smallest divisions of system components for the purposes of Annex VI, as these combinations of components are treated as single entities for purposes of identification, analysis or replacement;

(36) ‘Ground clearance of the vehicle’ means the distance between the ground plane and the underside of the vehicle;

(37) ‘Safety device’ means a device that ensures safe operation within the normal operating range or the permissible fault range of the system;

(38) ‘Hydrogen conversion system’ means any system designed for the conversion of hydrogen into electrical, mechanical or thermal energy and includes, for example, the propulsion system(s) or auxiliary power unit(s);

(39) ‘Impermissible fault range’ of a process variable means the range within which an unwanted event is to be expected;

(40) ‘Leak test gas’ means hydrogen, helium or an inert gas mixture containing a demonstrated detectable amount of helium or hydrogen gas;

(41) ‘Normal operating range’ of a process variable means the range planned for its values;

(42) ‘Outer pressure’ means the pressure acting on the convex side of the inner tank or outer jacket;

(43) ‘Outer jacket’ means the part of the container that encases the inner tank(s) and its insulation system;

(44) ‘Rigid fuel line’ means tubing that has not been designed to flex in normal operation and through which hydrogen flows;

(45) ‘Boil off management system’ means a system that renders boil off gas harmless in normal conditions;

(46) ‘Safety instrumented systems’ mean process control systems that prevent an impermissible fault range from being reached by an automatic intervention in the process;

(47) ‘Batch’ means a quantity of successively produced finished containers having the same nominal dimensions, design, specified materials of construction, process of manufacture, equipment for manufacture and, where appropriate, conditions of time, temperature and atmosphere during heat treatment;

(48) ‘Equipment of the container’ means all devices that are fixed directly to the inner tank or outer jacket of the container;

(49) ‘Finished container’ means a container that is typical of normal production, complete with external coating including integral insulation specified by the manufacturer, but free from non-integral insulation or protection;

(50) ‘Burst pressure’ means the pressure at which the container ruptures;

(51) ‘Permissible fault range’ of a process variable means the range between the normal operating range and the impermissible fault range;

(52) ‘Boil off system’ means a system that in normal conditions vents the boil-off before the pressure relief device of the container(s) opens;

(53) ‘Manual valve’ means a manually operated valve;

(54) ‘Safety concept’ means measures designed to ensure safe operation even in the event of a failure or random faults;

(55) ‘Usage monitoring and control system’ means a system that counts the filling cycles and prevents further use of the vehicle when a predetermined number of filling cycles is exceeded;

(56) ‘Fuel supply line’ means the line that supplies hydrogen to the hydrogen conversion system(s);

(57) ‘Composite container’ means a container constructed of more than one material;

(58) 'Over-wrap' means resin impregnated continuous filaments used as reinforcement around a liner;

(59) 'Auto-frettage pressure' means the pressure within the over-wrapped container at which the required distribution of stresses between the liner and the over-wrap is established;

(60) 'Boundary of functional operation' means the boundaries of the external physical limits within which a system is able to maintain control;

(61) 'Range of control' means the range over which the system is likely to exercise control with regard to an output variable;

(62) 'Transmission links' mean the means used for interconnecting distributed units for the purpose of conveying signals, operating data or an energy supply;

(63) 'Higher-level systems/functions' mean controls that employ additional processing and/or sensing provisions to modify vehicle behaviour by commanding variations in the normal function(s) of the vehicle control system.

Article 2

Administrative provisions for EC type-approval of a vehicle with regard to hydrogen propulsion

1. The manufacturer or his representative shall submit to the type-approval authority the application for EC type-approval of a vehicle with regard to hydrogen propulsion.

2. The application shall be drawn in accordance with the model of the information document set out in Part 1 of Annex I.

The manufacturer shall provide the information set out in Part 3 of Annex I for periodic requalification by inspection during the service life of the vehicle.

3. If the relevant requirements set out in Part 1 of Annex III or Part 1 of Annex IV, Annex V and Annex VI are met, the approval authority shall grant an EC type-approval and issue a type-approval number in accordance with the numbering system set out in Annex VII to Directive 2007/46/EC.

A Member State may not assign the same number to another vehicle type.

4. For the purposes of paragraph 3, the type-approval authority shall deliver an EC type-approval certificate established in accordance with the model set out in Part 2 of Annex I.

Article 3

Administrative provisions for EC component type-approval of hydrogen components and systems

1. The manufacturer or his representative shall submit to the type-approval authority the application for EC component type-approval for a type of hydrogen component or hydrogen system.

The application shall be drawn up in accordance with the model of the information document set out in Part 1 of Annex II.

2. If the relevant requirements set out in Annex III or Annex IV are met, the approval authority shall grant an EC component type-approval and issue a type-approval number in accordance with the numbering system set out in Annex VII to Directive 2007/46/EC.

A Member State may not assign the same number to another type of hydrogen component or hydrogen system.

3. For the purposes of paragraph 2, the type-approval authority shall deliver an EC type-approval certificate established in accordance with the model set out in Part 2 of Annex II.

Article 4

For the purpose of the EC whole-vehicle type-approval of hydrogen-powered vehicles in accordance to Articles 6 and 9 of Directive 2007/46/EC, the following shall not apply:

(1) Council Directive 80/1268/EEC [1];

(2) Council Directive 80/1269/EEC [2], as regards hydrogen-powered vehicles propelled by internal combustion engine;

(3) Annex I to Council Directive 70/221/EEC [3];

(4) Section 3.3.5 of Annex II and Section 4.3.2 of Appendix 1 to Annex II to Directive 96/27/EC of the European Parliament and of the Council [4];

(5) Section 3.2.6 of Annex II and Section 1.4.2.2 of Appendix 1 to Annex II to Directive 96/79/EC of the European Parliament and of the Council [5].

(1) OJ L 375, 31.12.1980, p. 36.
(2) OJ L 375, 31.12.1980, p. 46.
(3) OJ L 76, 6.4.1970, p. 23.
(4) OJ L 169, 8.7.1996, p. 1.
(5) OJ L 18, 21.1.1997, p. 7.

Article 5

EC component type-approval mark

Every hydrogen component or hydrogen system conforming to a type in respect of which EC component type-approval has been granted pursuant to this Regulation shall bear an EC component type-approval mark as set out in Part 3 of Annex II.

Article 6

Entry into force

This Regulation shall enter into force on the 20th day following its publication in the *Official Journal of the European Union*.

This Regulation shall be binding in its entirety and directly applicable in all Member States.

Done at Brussels, 26 April 2010.

For the Commission
The President
José Manuel BARROSO

LIST OF ANNEXES

ANNEX I

Administrative Documents for EC type-approval of vehicles with regard to hydrogen propulsion

PART 1

MODEL

INFORMATION DOCUMENT No …

relating to EC type-approval of a vehicle with regard to hydrogen propulsion

The following information shall be supplied in triplicate and include a list of contents. Any drawings shall be supplied in appropriate scale and in sufficient detail on size A4 or on a folder of A4 format. Photographs, if any, shall show sufficient detail.

If the systems or components have electronic controls, information concerning their performance shall be supplied.

0.	GENERAL	
0.1.	Make (trade name of manufacturer): …	
0.2.	Type: …	
0.2.1	Commercial name(s) (if available): …	
0.3.	Means of identification of type, if marked on the vehicle (1) (b): …	
0.3.1.	Location of that marking: …	
0.4.	Category of vehicle (c): …	
0.5.	Name and address of manufacturer: …	
0.8.	Name(s) and address(es) of assembly plant(s): …	
0.9.	Name and address of the manufacturer's representative (if any): …	
1.	GENERAL CONSTRUCTION CHARACTERISTICS OF THE VEHICLE	
1.1	Photographs and/or drawings of a representative vehicle: …	
1.3.3.	Powered axles (number, position, interconnection): …	
1.4.	Chassis (if any) (overall drawing): …	
3.	POWER PLANT	
3.9.	**Hydrogen propulsion**	
3.9.1.	Hydrogen system designed to use liquid hydrogen / Hydrogen system designed to use compressed (gaseous) hydrogen (1)	
3.9.1.1.	Description and drawing of the hydrogen system: …	
3.9.1.2.	Name and address of the manufacturer(s) of the hydrogen system used for the propulsion of the vehicle: …	
3.9.1.3.	Manufacturer's system code(s) (as marked on the system, or other means of identification): …	
3.9.1.4.	Automatic shut-off valve(s): yes/no (1)	
3.9.1.4.1.	Make(s): …	
3.9.1.4.2.	Type(s): …	
3.9.1.4.3.	Maximum Allowable Working Pressure (MAWP) (1) (2)	MPa
3.9.1.4.4.	Nominal working pressure(s) and if downstream of the first pressure regulator, maximum allowable working pressure(s) (1) (2): …	MPa
3.9.1.4.5.	Operating temperature (1): …	
3.9.1.4.6.	Number of filling cycles or duty cycles as appropriate (1): …	
3.9.1.4.7.	Approval number: …	
3.9.1.4.8.	Material: …	
3.9.1.4.9.	Operating principles: …	
3.9.1.4.10.	Description and drawing: …	

3.9.1.5. Check valve(s) or non-return valve(s): yes/no (1)

3.9.1.5.1. Make(s): …

3.9.1.5.2. Type(s): …

3.9.1.5.3. Maximum Allowable Working Pressure (MAWP) (1) (2) … MPa

3.9.1.5.4. Nominal working pressure(s) and if downstream of the first pressure regulator, maximum allowable working pressure(s) (1) (2): … MPa

3.9.1.5.5. Operating temperature (1): …

3.9.1.5.6. Number of filling cycles or duty cycles as appropriate (1): …

3.9.1.5.7. Approval number: …

3.9.1.5.8. Material: …

3.9.1.5.9. Operating principles: …

3.9.1.5.10. Description and drawing: …

3.9.1.6. Container(s) and container assembly: yes/no (1)

3.9.1.6.1. Make(s): …

3.9.1.6.2. Type(s): …

3.9.1.6.3. Maximum Allowable Working Pressure (MAWP) (1) (2) … MPa

3.9.1.6.4. Nominal working pressure (1) (2): … MPa

3.9.1.6.5. Number of filling cycles (1): …

3.9.1.6.6. Operating temperature (1): …

3.9.1.6.7. Capacity: … litres (water)

3.9.1.6.8. Approval number: …

3.9.1.6.9. Material: …

3.9.1.6.10. Operating principles: …

3.9.1.6.11. Description and drawing: …

3.9.1.7. Fittings: yes/no (1)

3.9.1.7.1. Make(s): …

3.9.1.7.2. Type(s): …

3.9.1.7.3. Nominal working pressure(s) and if downstream of the first pressure regulator, maximum allowable working pressure(s) (2): … MPa

3.9.1.7.4. Number of filling cycles or duty cycles as appropriate: …

3.9.1.7.5. Approval number: …

3.9.1.7.6. Material: …

3.9.1.7.7. Operating principles: …

3.9.1.7.8. Description and drawing: …

3.9.1.8. Flexible fuel line(s): yes/no (1)

3.9.1.8.1. Make(s): …

3.9.1.8.2. Type(s): …

3.9.1.8.3. Maximum Allowable Working Pressure (MAWP) (1) (2) … MPa

3.9.1.8.4. Nominal working pressure(s) and if downstream of the first pressure regulator, maximum allowable working pressure(s) (1) (2): … MPa

3.9.1.8.5. Operating temperature (1): …

3.9.1.8.6. Number of filling cycles or duty cycles as appropriate (1): …

3.9.1.8.7. Approval number: …

3.9.1.8.8. Material: …

3.9.1.8.9. Operating principles: …

3.9.1.8.10. Description and drawing: ……………………………………………………………………

3.9.1.9. Heat exchanger(s): yes/no (1)

3.9.1.9.1. Make(s): ……………………………………………………………………

3.9.1.9.2. Type(s): ……………………………………………………………………

3.9.1.9.3. Maximum Allowable Working Pressure (MAWP) (1) (2) …………………………… MPa

3.9.1.9.4. Nominal working pressure(s) and if downstream of the first pressure regulator, maximum allowable working pressure(s) (1) (2): …………………………… MPa

3.9.1.9.5. Operating temperature (1): ……………………………………………………………………

3.9.1.9.6. Number of filling cycles or duty cycles as appropriate (1): ……………………………

3.9.1.9.7. Approval number: ……………………………………………………………………

3.9.1.9.8. Material: ……………………………………………………………………

3.9.1.9.9. Operating principles: ……………………………………………………………………

3.9.1.9.10. Description and drawing: ……………………………………………………………………

3.9.1.10. Hydrogen filter(s): yes/no (1) ……………………………………………………………………

3.9.1.10.1. Make(s): ……………………………………………………………………

3.9.1.10.2. Type(s): ……………………………………………………………………

3.9.1.10.3. Nominal working pressure(s) and if downstream of the first pressure regulator, maximum allowable working pressure(s) (1) (2): …………………………… MPa

3.9.1.10.4. Number of filling cycles or duty cycles as appropriate (1): ……………………………

3.9.1.10.5. Approval number: ……………………………………………………………………

3.9.1.10.6. Material: ……………………………………………………………………

3.9.1.10.7. Operating principles: ……………………………………………………………………

3.9.1.10.8. Description and drawing: ……………………………………………………………………

3.9.1.11. Hydrogen leakage detection sensors: ……………………………………………………………………

3.9.1.11.1. Make(s): ……………………………………………………………………

3.9.1.11.2. Type(s): ……………………………………………………………………

3.9.1.11.3. Maximum Allowable Working Pressure (MAWP) (1) (2) …………………………… MPa

3.9.1.11.4. Nominal working pressure(s) and if downstream of the first pressure regulator, maximum allowable working pressure(s) (1) (2): …………………………… MPa

3.9.1.11.5. Operating temperature (1): ……………………………………………………………………

3.9.1.11.6. Number of filling cycles or duty cycles as appropriate (1): ……………………………

3.9.1.11.7. Set values: ……………………………………………………………………

3.9.1.11.8. Approval number: ……………………………………………………………………

3.9.1.11.9. Material: ……………………………………………………………………

3.9.1.11.10. Operating principles: ……………………………………………………………………

3.9.1.11.11. Description and drawing: ……………………………………………………………………

3.9.1.12. Manual or automatic valve(s): yes/no (1) ……………………………………………………………………

3.9.1.12.1. Make(s): ……………………………………………………………………

3.9.1.12.2. Type(s): ……………………………………………………………………

3.9.1.12.3. Maximum Allowable Working Pressure (MAWP) (1) (2) …………………………… MPa

3.9.1.12.4. Nominal working pressure(s) and if downstream of the first pressure regulator, maximum allowable working pressure(s) (1) (2): …………………………… MPa

3.9.1.12.5. Operating temperature (1): ……………………………………………………………………

3.9.1.12.6. Number of filling cycles or duty cycles as appropriate (1): ……………………………

3.9.1.12.7. Approval number: ……………………………………………………………………

3.9.1.12.8. Material: ……………………………………………………………………

3.9.1.12.9.	Operating principles: ...	
3.9.1.12.10.	Description and drawing: ...	
3.9.1.13.	Pressure and/or temperature and/or hydrogen and/or flow sensor(s) (1): yes/no (1) ...	
3.9.1.13.1.	Make(s): ...	
3.9.1.13.2.	Type(s): ...	
3.9.1.13.3.	Maximum Allowable Working Pressure (MAWP) (1) (2) ...	MPa
3.9.1.13.4.	Nominal working pressure(s) and if downstream of the first pressure regulator, maximum allowable working pressure(s) (1) (2): ...	MPa
3.9.1.13.5.	Operating temperature (1): ...	
3.9.1.13.6.	Number of filling cycles or duty cycles as appropriate (1): ...	
3.9.1.13.7.	Set values: ...	
3.9.1.13.8.	Approval number: ...	
3.9.1.13.9.	Material: ...	
3.9.1.13.10.	Operating principles: ...	
3.9.1.13.11.	Description and drawing: ...	
3.9.1.14.	Pressure regulator(s): yes/no (1) ...	
3.9.1.14.1.	Make(s): ...	
3.9.1.14.2.	Type(s): ...	
3.9.1.14.3.	Number of main adjustment points: ...	
3.9.1.14.4.	Description of principle of adjustment through main adjustment points: ...	
3.9.1.14.5.	Number of idle adjustment points: ...	
3.9.1.14.6.	Description of principles of adjustment through idle adjustment points: ...	
3.9.1.14.7.	Other adjustment possibilities: if so and which (description and drawings): ...	
3.9.1.14.8.	Maximum Allowable Working Pressure (MAWP) (1) (2) ...	MPa
3.9.1.14.9.	Nominal working pressure(s) and if downstream of the first pressure regulator, maximum allowable working pressure(s) (1) (2): ...	MPa
3.9.1.14.10.	Operating temperature (1): ...	
3.9.1.14.11.	Number of filling cycles or duty cycles as appropriate (1): ...	
3.9.1.14.12.	Input and output pressure: ...	
3.9.1.14.13.	Approval number: ...	
3.9.1.14.14.	Material: ...	
3.9.1.14.15.	Operating principles: ...	
3.9.1.14.16.	Description and drawing: ...	
3.9.1.15.	Pressure relief device: yes/no (1) ...	
3.9.1.15.1.	Make(s): ...	
3.9.1.15.2.	Type(s): ...	
3.9.1.15.3.	Maximum Allowable Working Pressure (MAWP) (1) (2) ...	MPa
3.9.1.15.4.	Operating temperature (1): ...	
3.9.1.15.5.	Set pressure (1): ...	
3.9.1.15.6.	Set temperature (1): ...	
3.9.1.15.7.	Blow off capacity (1): ...	
3.9.1.15.8.	Normal maximum operating temperature: (1) (2) ...	°C
3.9.1.15.9.	Nominal working pressure(s) (1) (2): ...	MPa
3.9.1.15.10.	Number of filling cycles (Class 0 components only) (1): ...	
3.9.1.15.11.	Approval number: ...	

3.9.1.15.12. Material: ...

3.9.1.15.13. Operating principles: ...

3.9.1.15.14. Description and drawing: ...

3.9.1.16. Pressure relief valve: yes/no (1) ...

3.9.1.16.1. Make(s): ...

3.9.1.16.2. Type(s): ...

3.9.1.16.3. Nominal working pressure(s) and if downstream of the first pressure regulator, maximum allowable working pressure(s) (1) (2): ... MPa

3.9.1.16.4. Set pressure (1): ...

3.9.1.16.5. Number of filling cycles or duty cycles as appropriate (1): ...

3.9.1.16.6. Approval number: ...

3.9.1.16.7. Material: ...

3.9.1.16.8. Operating principles: ...

3.9.1.16.9. Description and drawing: ...

3.9.1.17. Refuelling connection or receptacle: yes/no (1) ...

3.9.1.17.1. Make(s): ...

3.9.1.17.2. Type(s): ...

3.9.1.17.3. Maximum Allowable Working Pressure (MAWP) (1) (2) ... MPa

3.9.1.17.4. Operating temperature (1): ...

3.9.1.17.5. Nominal working pressure(s) (1) (2): ... MPa

3.9.1.17.6. Number of filling cycles (Class 0 components only) (1): ...

3.9.1.17.7. Approval number: ...

3.9.1.17.8. Material: ...

3.9.1.17.9. Operating principles: ...

3.9.1.17.10. Description and drawing: ...

3.9.1.18. Removable storage system connector: yes/no (1) ...

3.9.1.18.1. Make(s): ...

3.9.1.18.2. Type(s): ...

3.9.1.18.3. Nominal working pressure(s) and maximum allowable working pressure(s) (2): ... MPa

3.9.1.18.4. Number of duty cycles: ...

3.9.1.18.5. Approval number: ...

3.9.1.18.6. Material: ...

3.9.1.18.7. Operating principles: ...

3.9.1.18.8. Description and drawing: ...

3.9.2. Further documentation ...

3.9.2.1. Process diagram (flow chart) of the hydrogen system ...

3.9.2.2. System layout including electrical connections and other external system (inputs and/or outputs etc.) ...

3.9.2.3. Key to symbols used in documentation ...

3.9.2.4. Adjustment data of pressure relief devices and pressure regulators ...

3.9.2.5. Layout of cooling/heating system(s) including Nominal or Maximum Allowable Working Pressure (NAWP or MAWP) and operating temperatures ...

3.9.2.6. Drawings showing requirements for installation and operation.

Explanatory notes:

(1) Delete where not applicable (there are cases where nothing needs to be deleted when more than one entry is applicable).

(2) Specify the tolerance

(b) If the means of identification of type contains characters not relevant to describe the vehicle, component or separate technical unit types covered by this information document, such characters shall be represented in the documentation by the symbol '?' (e.g. ABC??123??).

(c) Classified according to the definitions set out in Part A of Annex II to Directive 2007/46/EC.

Appendix to information document

Statement of Service for Hydrogen Containers

Manufacturer identification	Manufacturer name: Manufacturer address:
Container identification	Container identification: Nominal working pressure: MPa Type: Diameter ([1]): mm Length ([1]): mm Internal volume: litres Empty weight: kg Container threads:
Container service life	Maximum service life: years Maximum number of fillingcycles: cycles
Container fire protection system	Pressure relief device manufacturer: Pressure relief device identification: Pressure relief device drawing number(s):
Container support method	Support method: neck/cylinder mounting ([2]) Support drawing number(s):
Container protective coatings	Purpose of protection: Protective coating drawing number(s):
Container design description	Container drawing numbers: Container drawings shall show at least the following information: — Reference to this Regulation and the container type — Principal geometrical dimensions including tolerances — Container materials — Container mass and internal volume including tolerances — Details of the exterior protective coating — Container fire protection system
Container corrosion inhibitor	Container corrosion inhibitor used: yes/no ([2]) Corrosion inhibitor manufacturer: Corrosion inhibitor identification:
Additional information	1. Manufacturing data including tolerances where appropriate: — Tube extrusion, cold deformation, tube drawing, end forming, welding, heat treatment and cleaning processes for the metal manufacturing of all containers designed to use liquid hydrogen and type 1, 2 and 3 containers designed to use compressed (gaseous) hydrogen — Reference to the manufacturing procedure — Acceptance criteria for non-destructive examination (NDE) — Composite manufacturing processes and auto-frettage according to section 3.7.2. of Part 2 to Annex IV for the manufacturing of type 2, 3 and 4 containers designed to use compressed (gaseous) hydrogen — Final manufacturing inspection of surface finish, thread details and principal dimensions 2. A table summarising the results of stress analysis

Container statement of service	The manufacturer hereby states that the container design is suitable for use during the specified service life in the service conditions set out in section 2.7 of Annex IV to Regulation (EU) No 406/2010. Manufacturer: Name, position and signature: Place, date:

Explanatory notes

(1) May be replaced by other dimensions defining the shape of the container.

(2) Delete as appropriate.

PART 2

MODEL

Maximum format: A4 (210 × 297 mm)

EC TYPE-APPROVAL CERTIFICATE

Stamp of type-approval authority

Communication concerning:

— EC type-approval (1)

— extension of EC type-approval (1)

— refusal of EC type-approval (1)

— withdrawal of EC type-approval (1)

of a type of a vehicle with regard to hydrogen propulsion (1)

with regard to Regulation (EC) No 79/2009, as implemented by Regulation (EU) No 406/2010.

EC type-approval number:

Reason for extension:

SECTION I

0.1. Make (trade name of manufacturer):

0.2. Type:

0.2.1. Commercial name(s) (if available):

0.3. Means of identification of type, if marked on the vehicle (2):

0.3.1. Location of that marking:

0.4. Category of vehicle (3):

0.5. Name and address of manufacturer:

0.8. Name(s) and address(es) of assembly plant(s):

0.9. Name and address of the manufacturer's representative (if any):

SECTION II

1. Additional information (where applicable): see Addendum

2. Technical service responsible for carrying out the tests:

(1) Delete where not applicable

(2) If the means of identification of type contains characters not relevant to describe the vehicle, component or separate technical unit types covered by this information document, such characters shall be represented in the documentation by the symbol '?' (e.g. ABC??123??).

(3) As defined in Annex II, Section A of Directive 2007/46/EC.

3. Date of test report:

4. Number of test report:

5. Remarks (if any): see Addendum

6. Place:

7. Date:

8. Signature:

Attachments: Information package.

Test report.

Addendum

to EC type-approval certificate No …

relating to EC type-approval of a vehicle with regard to hydrogen propulsion

1. Additional information

1.1. Vehicle equipped with hydrogen system designed to use liquid hydrogen / hydrogen system designed to use compressed (gaseous) hydrogen (1)

2. Type-approval number of each hydrogen component or system installed on the vehicle type to comply with this Regulation

2.1. Hydrogen system(s):

2.2. Automatic shut-off valve(s):

2.3. Check valve(s) or non-return valve(s):

2.4. Container(s) and container assembly:

2.5. Fittings:

2.6. Flexible fuel line(s):

2.7. Heat exchanger(s):

2.8. Hydrogen filter(s):

2.9. Hydrogen leakage detection sensors:

2.10. Manual or automatic valve(s):

2.11. Pressure and/or temperature and/or hydrogen and/or flow sensor(s) (1):

2.12. Pressure regulator(s):

2.13. Pressure relief device:

2.14. Pressure relief valve:

2.15. Refuelling connection or receptacle:

2.16. Removable storage system connector:

3. Remarks:

(1) Delete where not applicable

PART 3

Information to be provided for inspection

1. Manufacturers shall provide:

   (a) recommendations for inspection or testing of the hydrogen system during its service life;

   (b) information on the need for periodic inspection and the necessary frequency in the owners' manual of the vehicle or by means of a label close to the location of the statutory plate according to Council Directive 76/114/EEC ([1]).

2. Manufacturers shall make the information specified in section 1 available to approval authorities and the competent authorities in the Member States responsible for the periodic inspection of vehicles in the form of manuals or by means of electronic media (e.g. CD-ROM, on-line services).

([1]) OJ L 24, 30.1.1976, p. 1.

ANNEX II

Administrative documents for EC component type-approval of hydrogen components and systems

PART 1

MODEL

INFORMATION DOCUMENT No

relating to EC component type-approval of a hydrogen component or system

The following information shall be supplied in triplicate and include a list of contents. Any drawings shall be supplied in appropriate scale and in sufficient detail on size A4 or on a folder of A4 format. Photographs, if any, shall show sufficient detail.

If the systems or components have electronic controls, information concerning their performance shall be supplied.

0. GENERAL

0.1. Make (trade name of manufacturer): ……

0.2. Type: ……

0.2.1 Commercial name(s) (if available): ……

0.2.2 Reference or part number of the component (1): ……

0.2.3 Reference(s) or part number(s) of the component(s) in the system (1):

0.2.4 Reference or part number of the system (1): ……

0.5. Name(s) and address(es) of manufacturer: ……

0.7. Location and method of affixing of the EC type-approval mark(s):

0.8. Name(s) and address(es) of assembly plant(s): ……

0.9. Name and address of the manufacturer's representative (if any): ……

3.9. Hydrogen propulsion (1): ……

3.9.1. Hydrogen system designed to use liquid hydrogen / Hydrogen system designed to use compressed (gaseous) hydrogen / Hydrogen component designed to use liquid hydrogen / Hydrogen component designed to use compressed (gaseous) hydrogen (1): ……

3.9.1.1. Description and drawing of the hydrogen system (1): ……

3.9.1.2. Name and address of the manufacturer(s) of the hydrogen system (1): ……

3.9.1.3. Manufacturer's system code(s) (as marked on the system, or other means of identification) (1): ……

3.9.1.4. Automatic shut-off valve(s): yes/no (1) ……

3.9.1.4.1. Make(s): ……

3.9.1.4.2. Type(s): ……

3.9.1.4.3. Maximum Allowable Working Pressure (MAWP) (1) (2) …… MPa

3.9.1.4.4. Nominal working pressure(s) and if downstream of the first pressure regulator, maximum allowable working pressure(s) (1) (2): …… MPa

3.9.1.4.5. Operating temperature (1): ……

3.9.1.4.6. Number of filling cycles or duty cycles as appropriate (1): ……

3.9.1.4.7. Approval number: ……

3.9.1.4.8. Material: ……

3.9.1.4.9. Operating principles: ……

3.9.1.4.10. Description and drawing: ……

3.9.1.5. Check valve(s) or non-return valve(s): yes/no (1) ……

3.9.1.5.1. Make(s): ……

3.9.1.5.2. Type(s): ……

3.9.1.5.3. Maximum Allowable Working Pressure (MAWP) (1) (2) …… MPa

3.9.1.5.4.	Nominal working pressure(s) and if downstream of the first pressure regulator, maximum allowable working pressure(s) (1) (2): …	MPa
3.9.1.5.5.	Operating temperature (1): …	
3.9.1.5.6.	Number of filling cycles or duty cycles as appropriate (1): …	
3.9.1.5.7.	Approval number: …	
3.9.1.5.8.	Material: …	
3.9.1.5.9.	Operating principles: …	
3.9.1.5.10.	Description and drawing: …	
3.9.1.6.	Container(s) and container assembly: yes/no (1) …	
3.9.1.6.1.	Make(s): …	
3.9.1.6.2.	Type(s): …	
3.9.1.6.3.	Maximum Allowable Working Pressure (MAWP) (1) (2) …	MPa
3.9.1.6.4.	Nominal working pressure (1) (2): …	MPa
3.9.1.6.5.	Number of filling cycles (1): …	
3.9.1.6.6.	Operating temperature (1): …	
3.9.1.6.7.	Capacity: …	litres (water)
3.9.1.6.8.	Approval number: …	
3.9.1.6.9.	Material: …	
3.9.1.6.10.	Operating principles: …	
3.9.1.6.11.	Description and drawing: …	
3.9.1.7.	Fittings: yes/no (1) …	
3.9.1.7.1.	Make(s): …	
3.9.1.7.2.	Type(s): …	
3.9.1.7.3.	Nominal working pressure(s) and if downstream of the first pressure regulator, maximum allowable working pressure(s) (2): …	MPa
3.9.1.7.4.	Number of filling cycles or duty cycles as appropriate: …	
3.9.1.7.5.	Approval number: …	
3.9.1.7.6.	Material: …	
3.9.1.7.7.	Operating principles: …	
3.9.1.7.8.	Description and drawing: …	
3.9.1.8.	Flexible fuel line(s): yes/no (1) …	
3.9.1.8.1.	Make(s): …	
3.9.1.8.2.	Type(s): …	
3.9.1.8.3.	Maximum Allowable Working Pressure (MAWP) (1) (2) …	MPa
3.9.1.8.4.	Nominal working pressure(s) and if downstream of the first pressure regulator, maximum allowable working pressure(s) (1) (2): …	MPa
3.9.1.8.5.	Operating temperature (1): …	
3.9.1.8.6.	Number of filling cycles or duty cycles as appropriate (1): …	
3.9.1.8.7.	Approval number: …	
3.9.1.8.8.	Material: …	
3.9.1.8.9.	Operating principles: …	
3.9.1.8.10.	Description and drawing: …	
3.9.1.9.	Heat exchanger(s): yes/no (1) …	
3.9.1.9.1.	Make(s): …	
3.9.1.9.2.	Type(s): …	

3.9.1.9.3.	Maximum Allowable Working Pressure (MAWP (1) (2)	MPa
3.9.1.9.4.	Nominal working pressure(s) and if downstream of the first pressure regulator, maximum allowable working pressure(s) (1) (2):	MPa
3.9.1.9.5.	Operating temperature (1):	
3.9.1.9.6.	Number of filling cycles or duty cycles as appropriate (1):	
3.9.1.9.7.	Approval number:	
3.9.1.9.8.	Material:	
3.9.1.9.9.	Operating principles:	
3.9.1.9.10.	Description and drawing:	
3.9.1.10.	Hydrogen filter(s): yes/no (1)	
3.9.1.10.1.	Make(s):	
3.9.1.10.2.	Type(s):	
3.9.1.10.3.	Nominal working pressure(s) and if downstream of the first pressure regulator, maximum allowable working pressure(s) (1) (2):	MPa
3.9.1.10.4.	Number of filling cycles or duty cycles as appropriate (1):	
3.9.1.10.5.	Approval number:	
3.9.1.10.6.	Material:	
3.9.1.10.7.	Operating principles:	
3.9.1.10.8.	Description and drawing:	
3.9.1.11.	Hydrogen leakage detection sensors:	
3.9.1.11.1.	Make(s):	
3.9.1.11.2.	Type(s):	
3.9.1.11.3.	Maximum Allowable Working Pressure (MAWP) (1) (2)	MPa
3.9.1.11.4.	Nominal working pressure(s) and if downstream of the first pressure regulator, maximum allowable working pressure(s) (1) (2):	MPa
3.9.1.11.5.	Operating temperature (1):	
3.9.1.11.6.	Number of filling cycles or duty cycles as appropriate (1):	
3.9.1.11.7.	Set values:	
3.9.1.11.8.	Approval number:	
3.9.1.11.9.	Material:	
3.9.1.11.10.	Operating principles:	
3.9.1.11.11.	Description and drawing:	
3.9.1.12.	Manual or automatic valve(s): yes/no (1)	
3.9.1.12.1.	Make(s):	
3.9.1.12.2.	Type(s):	
3.9.1.12.3.	Maximum Allowable Working Pressure (MAWP) (1) (2)	MPa
3.9.1.12.4.	Nominal working pressure(s) and if downstream of the first pressure regulator, maximum allowable working pressure(s) (1) (2):	MPa
3.9.1.12.5.	Operating temperature (1):	
3.9.1.12.6.	Number of filling cycles or duty cycles as appropriate (1):	
3.9.1.12.7.	Approval number:	
3.9.1.12.8.	Material:	
3.9.1.12.9.	Operating principles:	
3.9.1.12.10.	Description and drawing:	

3.9.1.13.	Pressure and/or temperature and/or hydrogen and/or flow sensor(s) (1): yes/no (1)	
3.9.1.13.1.	Make(s):	
3.9.1.13.2.	Type(s):	
3.9.1.13.3.	Maximum Allowable Working Pressure (MAWP) (1) (2)	MPa
3.9.1.13.4.	Nominal working pressure(s) and if downstream of the first pressure regulator, maximum allowable working pressure(s) (1) (2):	MPa
3.9.1.13.5.	Operating temperature (1):	
3.9.1.13.6.	Number of filling cycles or duty cycles as appropriate (1):	
3.9.1.13.7.	Set values:	
3.9.1.13.8.	Approval number:	
3.9.1.13.9.	Material:	
3.9.1.13.10.	Operating principles:	
3.9.1.13.11.	Description and drawing:	
3.9.1.14.	Pressure regulator(s): yes/no (1)	
3.9.1.14.1.	Make(s):	
3.9.1.14.2.	Type(s):	
3.9.1.14.3.	Number of main adjustment points:	
3.9.1.14.4.	Description of principle of adjustment through main adjustment points:	
3.9.1.14.5.	Number of idle adjustment points:	
3.9.1.14.6.	Description of principles of adjustment through idle adjustment points:	
3.9.1.14.7.	Other adjustment possibilities: if so and which (description and drawings):	
3.9.1.14.8.	Maximum Allowable Working Pressure (MAWP) (1) (2)	MPa
3.9.1.14.9.	Nominal working pressure(s) and if downstream of the first pressure regulator, maximum allowable working pressure(s) (1) (2):	MPa
3.9.1.14.10.	Operating temperature (1):	
3.9.1.14.11.	Number of filling cycles or duty cycles as appropriate (1):	
3.9.1.14.12.	Input and output pressure:	
3.9.1.14.13.	Approval number:	
3.9.1.14.14.	Material:	
3.9.1.14.15.	Operating principles:	
3.9.1.14.16.	Description and drawing:	
3.9.1.15.	Pressure relief device: yes/no (1)	
3.9.1.15.1.	Make(s):	
3.9.1.15.2.	Type(s):	
3.9.1.15.3.	Maximum Allowable Working Pressure (MAWP) (1) (2)	MPa
3.9.1.15.4.	Operating temperature (1):	
3.9.1.15.5.	Set pressure (1):	
3.9.1.15.6.	Set temperature (1):	
3.9.1.15.7.	Blow off capacity (1):	
3.9.1.15.8.	Operating temperature (1):	
3.9.1.15.9.	Normal maximum operating temperature (1) (2):	°C
3.9.1.15.10.	Nominal working pressure(s) (1) (2):	MPa
3.9.1.15.11.	Number of filling cycles (Class 0 components only) (1):	
3.9.1.15.12.	Approval number:	
3.9.1.15.13.	Material:	

3.9.1.15.14. Operating principles: …

3.9.1.15.15. Description and drawing: …

3.9.1.16. Pressure relief valve: yes/no (1) …

3.9.1.16.1. Make(s): …

3.9.1.16.2. Type(s): …

3.9.1.16.3. Nominal working pressure(s) and if downstream of the first pressure regulator, maximum allowable working pressure(s) (1) (2): … MPa

3.9.1.16.4. Set pressure (1): …

3.9.1.16.5. Number of filling cycles or duty cycles as appropriate (1): …

3.9.1.16.6. Approval number: …

3.9.1.16.7. Material: …

3.9.1.16.8. Operating principles: …

3.9.1.16.9. Description and drawing: …

3.9.1.17. Refuelling connection or receptacle: yes/no (1) …

3.9.1.17.1. Make(s): …

3.9.1.17.2. Type(s): …

3.9.1.17.3. Maximum Allowable Working Pressure (MAWP) (1) (2) … MPa

3.9.1.17.4. Operating temperature (1): …

3.9.1.17.5. Nominal working pressure(s) (1) (2): … MPa

3.9.1.17.6. Number of filling cycles (Class 0 components only) (1): …

3.9.1.17.7. Approval number: …

3.9.1.17.8. Material: …

3.9.1.17.9. Operating principles: …

3.9.1.17.10. Description and drawing: …

3.9.1.18. Removable storage system connector: yes/no (1) …

3.9.1.18.1. Make(s): …

3.9.1.18.2. Type(s): …

3.9.1.18.3. Nominal working pressure(s) and maximum allowable working pressure(s) (2): … MPa

3.9.1.18.4. Number of duty cycles: …

3.9.1.18.5. Approval number: …

3.9.1.18.6. Material: …

3.9.1.18.7. Operating principles: …

3.9.1.18.8. Description and drawing: …

3.9.2. Further documentation …

3.9.2.1. Process diagram (flow chart) of the hydrogen system …

3.9.2.2. System layout including electrical connections and other external system (inputs and/or outputs etc.) …

3.9.2.3. Key to symbols used in documentation …

3.9.2.4. Adjustment data of pressure relief devices and pressure regulators …

3.9.2.5. Layout of cooling/heating system(s) including Nominal or Maximum Allowable Working Pressure (NAWP or MAWP) and operating temperatures …

3.9.2.6. Drawings showing requirements for installation and operation.

Explanatory notes:

(1) Delete where not applicable (there are cases where nothing needs to be deleted when more than one entry is applicable).

(2) Specify the tolerance.

Appendix to information document

Statement of Service for Hydrogen Containers

Manufacturer identification	Manufacturer name:	
	Manufacturer address:	
Container identification	Container identification:	
	Nominal working pressure:	MPa
	Type:	
	Diameter (1):	mm
	Length (1):	mm
	Internal volume:	litres
	Empty weight:	kg
	Container threads:	
Container service life	Maximum service life:	years
	Maximum number of filling cycles:	cycles
Container fire protection system	Pressure relief device manufacturer:	
	Pressure relief device identification:	
	Pressure relief device drawing number(s):	
Container support method	Support method:	neck/cylinder mounting (2)
	Support drawing number(s):	
Container protective coatings	Purpose of protection:	
	Protective coating drawing number(s):	
Container design description	Container drawing numbers:	
	Container drawings shall show at least the following information:	
	— Reference to this Regulation and the container type	
	— Principal geometrical dimensions including tolerances	
	— Container materials	
	— Container mass and internal volume including tolerances	
	— Details of the exterior protective coating	
	— Container fire protection system	
Container corrosion inhibitor	Container corrosion inhibitor used: yes/no (2)	
	Corrosion inhibitor manufacturer:	
	Corrosion inhibitor identification:	
Additional information	1. Manufacturing data including tolerances where appropriate:	
	— Tube extrusion, cold deformation, tube drawing, end forming, welding, heat treatment and cleaning processes for the metal manufacturing of all containers designed to use liquid hydrogen and type 1, 2 and 3 containers designed to use compressed (gaseous) hydrogen	
	— Reference to the manufacturing procedure	
	— Acceptance criteria for non-destructive examination (NDE)	
	— Composite manufacturing processes and auto-frettage according to section 3.7.2. of Part 2 to Annex IV for the manufacturing of type 2, 3 and 4 containers designed to use compressed (gaseous) hydrogen	
	— Final manufacturing inspection of surface finish, thread details and principal dimensions	
	2. A table summarising the results of stress analysis	

Container statement of service	The manufacturer hereby states that the container design is suitable for use during the specified service life in the service conditions set out in section 2.7 of Annex IV to Regulation (EU) No 406/2010. Manufacturer: Name, position and signature: Place, date:

Explanatory notes:
(1) May be replaced by other dimensions defining the shape of the container.
(2) Delete as appropriate.

Specifications of containers designed to use compressed (gaseous) hydrogen

Material specification	Applicable to Material						Details
	Steel	Aluminium alloy	Plastic liner	Fibre	Resin	Coating	
Material manufacturer	✔	✔	✔	✔	✔		
Type of material	✔	✔	✔	✔	✔		
Material identification	✔	✔	✔	✔	✔		
Heat treatment definition	✔	✔					
Chemical composition	✔	✔					
Cold- or cryoforming procedure	✔						
Welding procedure definition	✔	✔					

Specifications for material tests	Applicable to Material						Specified material value
	Steel	Aluminium alloy	Plastic liner	Fibre	Resin	Coating	
Tensile test	✔	✔	✔				
Charpy impact test	✔						
Bend test	✔	✔					
Macroscopic examination	✔						
Corrosion test		✔					
Sustained load cracking test		✔					
Softening temperature test			✔				
Glass transition temperature test					✔		
Resin shear strength test					✔		
Coating test						✔	
Hydrogen compatibility test	✔	✔	✔	✔	✔		

Specifications for container tests		Specified design value
	Burst Test	
	Ambient Temperature Pressure Cycle Test	
	LBB Performance Test	
	Bonfire Test	
	Penetration Test	
	Chemical Exposure Test	
	Composite Flaw Tolerance Test	
	Accelerated Stress Rupture Test	
	Extreme Temperature Pressure Cycle Test	
	Impact Damage Test	
	Leak Test	
	Permeation Test	
	Boss Torque Test	
	Hydrogen Gas Cycling Test	

PART 2

MODEL

Maximum format: A4 (210 × 297 mm)

EC TYPE-APPROVAL CERTIFICATE

Stamp of type-approval authority

Communication concerning:

— EC type-approval (1)
— extension of EC type-approval (1)
— refusal of EC type-approval (1)
— withdrawal of EC type-approval (1)

of a type of hydrogen component

with regard to Regulation (EC) No 79/2009, as implemented by Regulation (EU) No 406/2010.

EC type-approval number:

Reason for extension:

SECTION I

0.1. Make (trade name of manufacturer):

0.2. Type:

0.3. Means of identification of type, if marked on the component (2)

0.3.1. Location of that marking:

0.5. Name and address of manufacturer:

0.7. In the case of components and separate technical units, location and method of affixing of the EC approval mark:

0.8. Name(s) and address(es) of assembly plant(s):

0.9. Name and address of the manufacturer's representative (if any):

SECTION II

1. Additional information (where applicable): see Addendum

2. Technical service responsible for carrying out the tests:

(1) Delete where not applicable
(2) If the means of identification of type contains characters not relevant to describe the vehicle, component or separate technical unit types covered by this information document, such characters shall be represented in the documentation by the symbol '?' (e.g. ABC??123??).

3. Date of test report:

4. Number of test report:

5. Remarks (if any): see Addendum

6. Place:

7. Date:

8. Signature:

Attachments: Information package.

Test report.

Addendum

to EC type-approval certificate No …

relating to EC component type-approval of a hydrogen component or system

1. Additional information

1.1. Hydrogen system designed to use liquid hydrogen / Hydrogen system designed to use compressed (gaseous) hydrogen / Hydrogen component designed to use liquid hydrogen / Hydrogen component designed to use compressed (gaseous) hydrogen [1]

2. Specifications and test results

2.1. Containers designed to use compressed (gaseous) hydrogen

2.1.1. Container material specifications

Material specification		Applicable to Material						Details
		Steel	Aluminium alloy	Plastic liner	Fibre	Resin	Coating	
	Material manufacturer	✓	✓	✓	✓	✓		
	Type of material	✓	✓	✓	✓	✓		
	Material identification	✓	✓	✓	✓	✓		
	Heat treatment definition	✓	✓					
	Chemical composition	✓	✓					
	Cold- or cryoforming procedure	✓						
	Welding procedure definition	✓	✓					

2.1.2. Container material test results

Material test		Applicable to Material						Specified material value	Test value
		Steel	Aluminium alloy	Plastic liner	Fibre	Resin	Coating		
	Tensile test	✓	✓	✓					
	Charpy impact test	✓							
	Bend test	✓	✓						
	Macroscopic examination	✓							

[1] Delete where not applicable

Material test		Steel	Aluminium alloy	Plastic liner	Fibre	Resin	Coating	Specified material value	Test value
		Applicable to Material							
	Corrosion test		✓						
	Sustained load cracking test		✓						
	Softening temperature test			✓					
	Glass transition temperature test					✓			
	Resin shear strength test					✓			
	Coating test						✓		
	Hydrogen compatibility test	✓	✓	✓	✓	✓			

2.1.3. Container test results

Container test		Specified design value	Test result
	Burst Test		
	Ambient Temperature Pressure Cycle Test		
	LBB Performance Test		
	Bonfire Test		
	Penetration Test		
	Chemical Exposure Test		
	Composite Flaw Tolerance Test		
	Accelerated Stress Rupture Test		
	Extreme Temperature Pressure Cycle Test		
	Impact Damage Test		
	Leak Test		
	Permeation Test		
	Boss Torque Test		
	Hydrogen Gas Cycling Test		

3. Restriction of use of the device (if any):

4. Remarks:

PART 3

EC component type-approval mark

1. The EC component type-approval mark shall consist of:

1.1. a rectangle surrounding the lower-case letter ‘e’ followed by the distinguishing letter(s) or number of the Member State which has granted the EC component type-approval:

1	For Germany	19	For Romania
2	For France	20	For Poland
3	For Italy	21	For Portugal
4	For the Netherlands	23	For Greece
5	For Sweden	24	For Ireland
6	For Belgium	26	For Slovenia
7	For Hungary	27	For Slovakia
8	For the Czech Republic	29	For Estonia
9	For Spain	32	For Latvia
11	For the United Kingdom	34	For Bulgaria
12	For Austria	36	For Lithuania
13	For Luxembourg	49	For Cyprus
17	For Finland	50	For Malta
18	For Denmark		

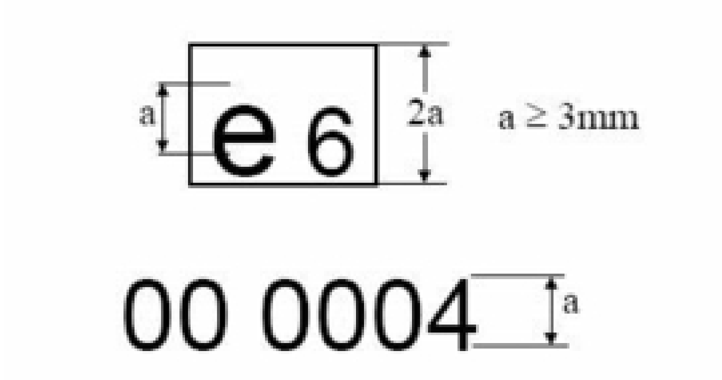
1.2. In the vicinity of the rectangle the ‘base approval number’ contained in Section 4 of the type-approval number preceded by the two figures indicating the sequence number assigned to this Regulation or the latest major technical amendment to Regulation (EC) No 79/2009 or this Regulation. For this Regulation, the sequence number is 00.

2. The component type-approval mark is affixed to the component or system in such a way as to be indelible and clearly legible.

3. An example of a component type-approval mark is contained in the Addendum.

Addendum to appendix 1

Example of a component type-approval mark



Legend: the above component type-approval was issued by Belgium under number 0004. The first two digits (00) indicate that the component was approved according to this Regulation.

ANNEX III

Requirements for hydrogen components and systems designed to use liquid hydrogen and their installation on hydrogen powered vehicles

1. INTRODUCTION

This Annex sets out the requirements and test procedures for hydrogen components and systems designed to use liquid hydrogen and their installation on hydrogen powered vehicles.

2. GENERAL REQUIREMENTS

2.1. The materials used in a hydrogen component or system shall be compatible with hydrogen in its liquid and/or gaseous state according to section 4.11. of Part 3.

PART 1

Requirements for the installation of hydrogen components and systems designed to use liquid hydrogen on hydrogen powered vehicles

1. **General requirements**

1.1. All hydrogen components and systems shall be installed on the vehicle and connected in accordance with best practice.

1.2. The hydrogen system(s) shall show no leaks other than the boil-off at Maximum Allowable Working Pressure (MAWP), i.e. stay bubble-free if using leak-detecting spray.

1.3. The operating temperatures should be:

Internal combustion engine compartment	On board (all types of propulsion systems)
– 40 °C to + 120 °C	– 40 °C to + 85 °C

1.4. Appropriate automatic measures shall be adopted in coordination with the refuelling station to ensure that no uncontrolled hydrogen release occurs during the filling procedure.

1.5. In the event of hydrogen leakage or venting, hydrogen shall not be allowed to accumulate in enclosed or semi-enclosed spaces of the vehicle.

2. **Installation of the hydrogen container on-board of a vehicle**

2.1. The container can be integrated into the vehicle design to provide complementary functions. In such cases the container shall be designed to fulfil the integrated function requirements and the container requirements set out in Part 2.

2.2. When the vehicle is ready for use the lowest part of the hydrogen container shall not reduce the ground clearance of the vehicle. This shall not apply if the hydrogen container is adequately protected, at the front and the sides, and no part of the hydrogen container is located lower than this protective structure.

2.3. The hydrogen container(s) including the safety devices affixed at it must be mounted and fixed so that the following accelerations can be absorbed without breaking of the fixation or loosening of the container(s) (demonstrated by testing or calculation). The mass used shall be representative for a fully equipped and filled container or container assembly.

Vehicle of categories M_1 and N_1:

(a) 20 g in the direction of travel

(b) 8 g horizontally perpendicular to the direction of travel

Vehicles of categories M_2 and N_2:

(a) 10 g in the direction of travel

(b) 5 g horizontally perpendicular to the direction of travel

Vehicles of categories M_3 and N_3:

(a) 6,6 g in the direction of travel

(b) 5 g horizontally perpendicular to the direction of travel

2.4. The provisions of section 2.3 shall not apply if the vehicle is approved according to Directives 96/27/EC and 96/79/EC of the European Parliament and of the Council [1] [2].

(1) OJ L 169, 8.7.1996, p. 1.
(2) OJ L 18, 21.1.1997, p. 7.

3. **Accessories fitted to the hydrogen container**

3.1. *Automatic shut-off valves or non-return valves*

3.1.1. Automatic shut-off valves shall be used in compliance with section 6. of Annex VI to Regulation (EC) No 79/2009, except for the boil-off management system and shall be idle closed.

3.1.2. Refuelling connections or receptacles shall be used in compliance wit section 4. of Annex VI to Regulation (EC) No 79/2009.

3.1.3. In the event that the container is displaced, the first isolating device and, if applicable, the line connecting it to the container shall be protected in such a manner that the shut-off function remains operational and the connection between the device and the container cannot be ruptured.

3.1.4. The automatic valves shall be closed idle (fail-safe).

3.1.5. When another hydrogen conversion system is switched off, irrespective of the position of the activation switch, the fuel supply to the respective hydrogen conversion system shall be switched off and remain closed until the respective hydrogen conversion system is required to operate.

3.2. *Pressure relief devices*

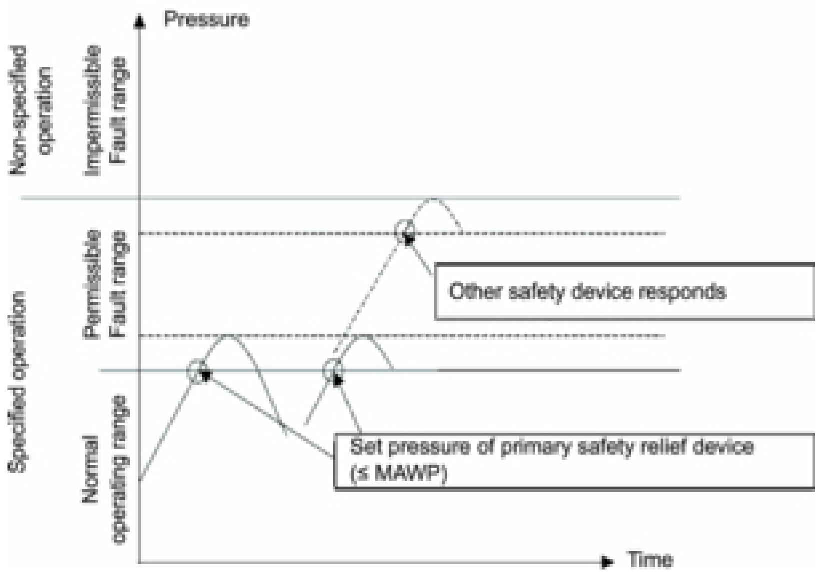
3.2.1. The pressure triggered pressure relief devices shall be fitted to the hydrogen container(s) in such a manner that they must discharge into an atmospheric outlet line that vents outside the vehicle. They shall not discharge at a heat source such as the exhaust. Additionally they shall discharge such that hydrogen cannot enter the inside of the vehicle and/or accumulate in an enclosed space. Additionally the first pressure relief device shall not discharge into a partially enclosed space. In case the secondary pressure relief device is a burst disc and is installed within the inner tank, an appropriate exhaust vent in the outer jacket is required.

3.2.2. In the case of inner tanks, the normal operating range of the inner tank pressure is between 0 MPa and the set pressure of the primary safety relief device which is lower or equal to the Maximum Allowable Working Pressure (MAWP) of the inner tank.

3.2.3. In the case of steel inner tanks, the lower limit of the impermissible fault range corresponds to a pressure higher than 136 per cent of the Maximum Allowable Working Pressure (MAWP) of the inner tank if a safety valve is used as secondary pressure relief device. In case of steel inner tanks, the lower limit of the impermissible fault range corresponds to a pressure higher than 150 per cent of the Maximum Allowable Working Pressure (MAWP) of the inner tank if a burst disk is used as secondary pressure relief device. For other materials an equivalent level of safety is to be applied. The impermissible fault range shall be the pressure at which plastic deformation or bursting of the inner tank occurs as shown in Figure 3.2.

Figure 3.2

Ranges of a steel inner tank



3.3. *Gas tight housing on the hydrogen container(s)*

3.3.1. All non-welded connections of hydrogen-carrying components and the hydrogen components which can leak, that are mounted within the passenger or luggage compartment or other non-ventilated compartment, shall be enclosed by a gas tight housing.

3.3.2. The gas tight housing shall be vented to the atmosphere.

3.3.3. The ventilation opening of the gas tight housing shall be at the highest point of the housing and shall not discharge at a heat source such as the exhaust. Additionally it shall discharge such that hydrogen cannot enter the inside of the vehicle and/or accumulate in an enclosed or partially enclosed space.

3.3.4. There shall be no unprotected ignition sources inside the gas tight housing.

3.3.5. Any connecting system and lead-through in the body of the vehicle for ventilation of the gas tight housing shall have at least the same cross sectional area as the tube of the pressure relief device.

3.3.6. This housing shall be for test purposes hermetically sealed and shall be gas tight at a pressure of 0,5 kPa, i.e. bubble-free for 1 minute and without any permanent deformation.

3.3.7. Any connecting system shall be secured by clamps, or other means, to the gas tight housing and the lead-through to ensure that a gas tight joint is formed.

4. **Rigid and flexible fuel lines**

4.1. Rigid fuel lines shall be secured such that they shall not be subjected to abrasion, critical vibration and/or other stresses.

4.2. Flexible fuel lines shall be secured such that they shall not be subjected to torsional stresses, abrasion is avoided and cannot be squeezed in normal use.

4.3. At the fixing points the fuel lines, flexible or rigid, shall be fitted in such a way that they cannot make a metal to metal contact to prevent galvanic and crevice corrosion.

4.4. Rigid and flexible fuel lines shall be routed to reasonably minimise exposure to accidental damage whether inside e.g. due to placing or movement of luggage or other loads, or outside the vehicle, e.g. due to rough ground or vehicle jacks etc.

4.5. At penetration through the vehicle body or other hydrogen components, the fuel lines shall be fitted with grommets or other protective material.

5. **Fittings or gas connections between the components**

5.1. Stainless steel tubes shall only be joined by stainless steel fittings.

5.2. The number of joints shall be limited to a minimum.

5.3. Any joints shall be made in locations where access is possible for inspection and leak testing.

5.4. In a passenger or enclosed luggage compartment, the fuel lines shall be no longer than reasonably required.

6. **Refuelling connection or receptacle**

6.1. The refuelling connection or receptacle shall be secured against maladjustment and shall be protected from dirt and water. It shall be safe against handing errors.

6.2. The refuelling connection or receptacle shall not be installed in the engine compartment, passenger compartment or in any other unventilated compartment.

6.3. The refuelling line shall be secured at the container as described in section 3.1.1.

6.4. The refuelling connection or receptacle shall have an isolating device according to section 3.1.2.

6.5. It shall be ensured that the propulsion system cannot be operated and the vehicle cannot move while the refuelling connection or receptacle is connected to the filling station.

7. **Electrical installation**

7.1. The electrical components of the hydrogen system shall be protected against overloads.

7.2. Power supply connections shall be tight against the ingress of hydrogen where hydrogen components are present or hydrogen leaks are possible.

8. **Boil-off under normal conditions**

8.1. Boil-off gases shall be rendered harmless by a boil-off management system.

8.2. The boil-off management system shall be designed to accept the boil-off rate of the container(s) under normal operating conditions.

8.3. At start-up and during the operation of the vehicle, a warning system shall be activated to warn the driver in the event of the boil off management system failure.

9. **Other requirements**

9.1. All pressure relief devices and vent line(s) shall be protected against vandalism so far as reasonably practicable.

9.2. The passenger compartment, the luggage compartment and all safety-critical components of the vehicle (e.g. the brake system, electrical insulation) shall be protected against adverse temperature effects due to the cryogenic fuel. Possible leakage of the cryogenic fuel shall be considered when assessing the protection that is required.

9.3. Flammable materials used in the vehicle shall be protected from liquefied air that may condense on un-insulated elements of the fuel system.

9.4. Failure of the heating circuit of the heat exchanger shall not cause leakage from the hydrogen system.

10. **Safety instrumented systems**

10.1. Safety instrumented systems shall be fail-safe, redundant or self-monitoring.

10.2. If the safety-instrumented systems under section 10.1. are fail-safe or self-monitoring electronic systems, the special requirements of Annex VI to this Regulation shall be applied.

11. **Requirements for the inspection of the hydrogen system**

11.1. Each hydrogen system shall be inspected at least every 48 months after the date of its entry into service, and at the time of any re-installation.

11.2. The inspection shall be performed by a technical service, in accordance with the manufacturers specifications set out in Part 3 of Annex I.

PART 2

Requirements for hydrogen containers designed to use liquid hydrogen

1. INTRODUCTION

This Part sets out the requirements and test procedures for hydrogen containers designed to use liquid hydrogen.

2. TECHNICAL REQUIREMENTS

2.1. The design validation of the container by calculation shall be done in accordance with EN 1251-2.

2.2. **Mechanical stresses**

The parts of the container shall withstand the following mechanical stresses:

2.2.1. *Inner tank*

2.2.1.1. Test pressure

The inner tank shall resist the test pressure P_{test}:

$$P_{test} = 1,3\ (MAWP + 0,1\ MPa)$$

with MAWP being the Maximum Allowable Working Pressure of the inner tank in MPa

2.2.1.2. Outer pressure

If an operating mode of the inner tank and its equipment under vacuum is possible, the inner tank and its equipment shall resist an outer pressure of 0,1 MPa.

2.2.2. *Outer jacket*

2.2.2.1. The outer jacket shall resist the Maximum Allowable Working Pressure (MAWP), which is the set pressure of its safety device.

2.2.2.2. The outer jacket shall resist an outer pressure of 0,1 MPa.

2.2.3. *Outer supports*

The outer supports of the full container shall resist the accelerations referred to in section 2.3 of Part 1 without rupture, in which case the allowable stress in the support elements calculated according to linear stress model shall not exceed:

$$\sigma \leq 0,5\ Rm$$

2.2.4. *Inner supports*

The inner supports of the full container shall resist the accelerations referred to in section 2.3 of Part 1 without rupture, in which case the allowable stress in the support elements calculated according to linear stress model shall not exceed:

$$\sigma \leq 0,5\ Rm$$

2.2.5. The requirements of sections 2.2.3. and 2.2.4. do not apply if it can be demonstrated that the tank may support the accelerations referred to in section 2.3 of Part 1 without any leak on the inner tank and all the different pipes upstream of the automatic safety devices, shut off valves and/or non-return valves.

2.2.6. The proof of the dimensioning of the supports of the container can be done either by calculation or by experiment.

2.3. **Design temperature**

2.3.1. *Inner tank and outer jacket*

The design temperature of the inner tank and the outer jacket shall be 20 °C.

2.3.2. *Other equipment*

For all other equipment which is not mentioned under section 2.3.1. the design temperature is the lowest respectively the highest possible operating temperature set out in section 1.3. of Part 1.

2.3.3. The thermal stresses by operating conditions like filling or withdrawal or during the cooling down processes shall be considered.

2.4. **Chemical compatibility**

2.4.1. The materials of the container and its equipment shall be compatible with:

(a) hydrogen, if the parts are in contact with it;

(b) the atmosphere, if the parts are in contact with it;

(c) any other media the parts are in contact with (i.e. coolant etc.).

3. MATERIALS

3.1. The materials shall be composed, manufactured and further treated in a manner that:

(a) the finished products show the required mechanical properties

(b) the finished products which are used for pressurised components and are in contact with hydrogen resist the thermal, chemical and mechanical stresses that they may be subjected to. In particular, the materials of the components in contact with cryogenic temperatures shall be compatible with cryogenic temperatures according to EN 1252-1.

3.2. **Characteristics**

3.2.1. Materials used at low temperatures shall follow the toughness requirements of EN 1252-1. For non-metallic materials low temperature suitability shall be validated by an experimental method, taking into account service conditions.

3.2.2. The materials used for the outer jacket shall ensure the integrity of the insulation system, and their elongation at fracture in a tensile test shall be at least 12 per cent at liquid nitrogen temperature.

3.2.3. A corrosion allowance is not required for the inner tank. A corrosion allowance is not required on other surfaces if they are adequately protected against corrosion.

3.3. **Certificates and proofs of the material characteristics**

3.3.1. The filler materials shall be compatible with the parent material so as to form welds with properties equivalent to those specified for the parent material for all temperatures that the material may encounter.

3.3.2. The manufacturer shall obtain and provide chemical cast analysis and mechanical properties certificates of the material in respect of the steels or other materials used in the construction of the parts subject to pressure. In case of metallic materials the certificate must be at least type 3.1 according to EN 10204 or equivalent. In case of non-metallic materials the certificate must be of equivalent type.

3.3.3. The technical service may carry out analyses and examinations. These examinations shall be carried out either on specimens taken from the materials as supplied to the manufacturer of the container or on the finished containers.

3.3.4. The manufacturer shall make available to the technical service the results of metallurgical and mechanical tests and analyses of parent and filler materials carried out on welds.

3.3.5. Material sheets shall be marked at least with:

— sign of the manufacturer

— material identification number

— batch number

— sign of the inspecting person

3.4. **Design calculation**

3.4.1. Provisions regarding the inner tank:

The design of the inner tank shall be done according to the design rules of EN 1251-2.

3.4.2. Provisions regarding the outer jacket:

The design of the outer jacket shall be done according to the design rules of EN 1251-2.

3.4.3. The general tolerances of ISO 2768-1 shall apply.

4. MANUFACTURING AND MOUNTING OF THE CONTAINER

4.1. Manufacturers of welded containers shall have a welding quality system in operation, taking into account the quality requirements for welding in accordance with EN 729-2:1994 or EN 729-3:1994.

4.2. The welding process shall be approved by the technical service in accordance with EN 288-3:1992/A1:1997, EN 288-4:1992/A1:1997 and EN 288-8:1995.

4.3. Welders shall be approved by the technical service according to EN 287-1:1992/A1:1997, EN 287-2:1992/A1:1997 and for automatic welding operators in accordance with EN 1418:1997.

4.4. Manufacturing operations (e.g. forming and heat treatment, welding) shall be carried out according to EN 1251-2.

4.5. The inspections and the testing of the internal pipe work between the inner tank and the outer jacket: all welded joints of the pipe work shall be subject to 100 per cent non-destructive inspection, wherever possible by radiographic inspection, alternatively ultrasonic test, liquid penetrant testing, helium leakage test, etc.

4.6. The number of joints should be minimised. Joints shall not be permitted within the void between the inner tank and the outer jacket unless they are welded or glued.

4.7. The equipment of the container shall be mounted in a way that the system and its components function in a correct and safe way and are gas tight.

4.8. The container shall be cleaned and dried before operation according to EN 12300.

5. OTHER REQUIREMENTS

5.1. **Protection of the outer jacket**

The outer jacket shall be protected by means of a device preventing bursting of the outer jacket or collapsing of the inner tank.

5.2. **Provisions regarding the insulation**

5.2.1. Under no circumstances may ice be allowed to form on the outer wall of the container under normal operating conditions. At the area of pressure relief pipe, local ice formation is allowed on the outside of the pipe.

5.3. **Level gauge**

5.3.1. A measuring gauge in the driver's compartment shall indicate the level of liquid in the container with an accuracy of +/- 10 per cent.

5.3.2. If the system comprises a float, the latter shall withstand an outside pressure greater than the Maximum Allowable Working Pressure (MAWP) of the inner tank with a minimum coefficient of safety of 2 with respect to the buckling failure criteria.

5.4. **Maximum filling level**

5.4.1. A system shall be provided for preventing the container from being overfilled. This system may work in conjunction with the refuelling station. This system shall bear a permanent marking, indicating the container-type for which it has been designed and if applicable the mounting position and orientation.

5.4.2. The filling process shall not lead to any pressure relief device coming into operation irrespective of time passed during/after the filling process. The filling process shall not lead to operating conditions the BMS (boil-off management system) is not designed for and therefore cannot handle.

5.5. **Marking**

5.5.1. In addition to the EC component type-approval mark set out in Part 3 of Annex II, every container shall also bear a marking with the following data clearly legible:

5.5.1.1. The inner tank:

(a) the name and address of inner tank manufacturer,

(b) the serial number.

5.5.1.2. The outer jacket:

(a) a label as set out in section 3.1 of Annex V;

(b) a prohibition of additional welding, milling and stamping;

(c) an allowed orientation of the tank in the vehicle;

(d) an identification plate with the following information:

i. name of the manufacturer

ii. serial number

iii. water volume in litres

iv. Maximum Allowable Working Pressure (MAWP) [MPa]

v. year and month of manufacturing (e.g. 2009/01)

vi. operating temperature range

the identification plate shall be legible while installed.

5.5.2. The marking method shall not cause localised stress peaks in the structure of the inner tank or the outer jacket.

5.6. **Inspection openings**

Inspection openings are not required in the inner or outer jacket.

6. TESTS AND INSPECTION

6.1. **Tests and inspection for the approval**

For the approval, the technical service shall perform the tests and inspections according to sections 6.3.1. to 6.3.6. on two samples of containers. The samples shall be provided in the applicable state necessary for the inspections. For the approval, samples of the container shall be subjected to the tests according to sections 6.3.7. to 6.3.9. and shall be witnessed by the technical service.

6.2. **Tests and inspection during production**

The tests and inspections according to sections 6.3.1. to 6.3.6. shall be performed on each container.

6.3. **Testing procedures**

6.3.1. *Pressure test*

6.3.1.1. The inner tank and the pipe work situated between the inner tank and the outer jacket shall withstand an inner pressure test at room temperature any suitable media, according to the following requirements.

The test pressure p_{test} shall be:

$$p_{test} = 1{,}3\ (MAWP + 0{,}1\ MPa)$$

with MAWP being the Maximum Allowable Working Pressure of the inner tank in MPa.

6.3.1.2. The pressure test shall be performed before the outer jacket is mounted.

6.3.1.3. The pressure in the inner tank shall be increased at a constant rate until the test pressure is reached.

6.3.1.4. The inner tank must remain under the test pressure at least for 10 minutes to establish that the pressure is not reducing.

6.3.1.5. After the test the inner tank must not show any signs of visible permanent deformation or visible leaks.

6.3.1.6. Any inner tank tested which does not pass the test because of permanent deformation shall be rejected and shall not be repaired.

6.3.1.7. Any inner tank tested which does not pass the test because of leakage may be accepted after repair and retesting.

6.3.1.8. In case of hydraulic test, upon completion of this test, the container shall be emptied and dried until the dew point inside the container is – 40 °C according to EN 12300.

6.3.1.9. A test report shall be drawn up and the inner tank shall be marked by the inspection departments if accepted.

6.3.2. *Leak testing*

After final assembly the hydrogen container shall be leak tested with a gas mixture containing a minimum of 10 per cent of helium

6.3.3. *Verification of the dimensions*

The following dimensions shall be verified:

— for cylindrical container(s) roundness of the inner tank according to EN 1251-2:2000, 5.4

— departure from a straight line of the inner and outer jacket according to EN 1251-2, 5.4

6.3.4. *Destructive and non-destructive tests of welding seams*

The tests shall be performed according to EN 1251-2.

6.3.5. *Visual inspection*

The welding seams and the inner and outer surfaces of the inner and outer jackets of the container shall be inspected visually. The surfaces shall not show any critical damages or defaults.

6.3.6. *Marking*

The marking shall be verified in accordance with section 5.5.

6.3.7. *Burst test*

The burst test shall be performed on one sample of the inner tank, not integrated in its outer jacket and not insulated.

6.3.7.1. Criteria

6.3.7.1.1. The burst pressure shall be at least equal to the burst pressure used for the mechanical calculations. For steel tanks that is:

(a) either the Maximum Allowable Working Pressure (MAWP) (in MPa) plus 0,1 MPa multiplied by 3,25;

(b) or the Maximum Allowable Working Pressure (MAWP) (in MPa) plus 0,1 MPa multiplied by 1,5 and multiplied by Rm/Rp, where Rm means minimum ultimate tensile strength and Rp means minimum yield strength.

6.3.7.1.2. Hydrogen containers made from materials other than steel shall be demonstrated to perform as safely as containers complying with the requirements set out in points 6.3.7.1.1. and 6.3.7.1.2.

6.3.7.2. Procedure

6.3.7.2.1. The tested tank shall be representative of the design and the manufacturing of the type to be approved.

6.3.7.2.2. The test shall be a hydraulic test.

6.3.7.2.3. The tube and piping may be modified to enable the test (purge of dead volume, introduction of the liquid, closing of non-used pipes, etc.)

6.3.7.2.4. The tank shall be filled with water. The pressure shall be increased at a constant rate not exceeding 0,5 MPa/min until burst. When the Maximum Allowable Working Pressure (MAWP) is reached there shall be a wait period of at least ten minutes at constant pressure so that the deformation of the tank shall be checked.

6.3.7.2.5. A system shall enable to look at possible deformations.

6.3.7.2.6. The pressure shall be recorded or written during the entire test.

6.3.7.3. Results

The test conditions and the bursting pressure shall be written in a test certificate signed by the manufacturer and the technical service.

6.3.8. *Bonfire test*

6.3.8.1. Criteria

6.3.8.1.1. The tank shall not burst and the pressure inside the inner tank shall not exceed the permissible fault range of the inner tank. In case of steel inner tanks, the secondary pressure relief device shall limit the pressure inside the tank to 136 per cent of the Maximum Allowable Working Pressure (MAWP) of the inner tank, if a safety valve is used as secondary pressure relief device.

In case of steel inner tanks, the secondary pressure relief device shall limit the pressure inside the tank to 150 per cent of the Maximum Allowable Working Pressure (MAWP) of the inner tank, if a burst disk is used outside the vacuum area as secondary pressure relief device.

In case of steel inner tanks, the secondary pressure relief device shall limit the pressure inside the tank to 150 per cent of the Maximum Allowable Working Pressure plus 0,1 MPa (MAWP + 0,1 MPa) of the inner tank, if a burst disk is used inside the vacuum area as secondary pressure relief device.

For other materials, an equivalent level of safety shall be demonstrated.

The secondary pressure relief device shall not operate below 110 per cent of the set pressure of the primary pressure relief device.

6.3.8.2. Procedure

6.3.8.2.1. The tested tank shall be representative of the design and the manufacturing of the type to be approved.

6.3.8.2.2. Its manufacturing shall be completely finished and it shall be mounted with all its equipment.

6.3.8.2.3. The tank shall already be cooled down and the inner tank shall be at the same temperature as the liquid hydrogen. The tank shall have contained during the previous 24 hours a volume of liquid hydrogen at least equal to half of the water volume of the inner tank.

6.3.8.2.3.1. The tank shall be filled with liquid hydrogen so that the quantity of liquid hydrogen measured by the mass measurement system shall be half of the maximum allowed quantity that may be contained in the inner tank.

6.3.8.2.3.2. A fire shall burn 0,1 m underneath the tank. The length and the width of the fire shall exceed the plan dimensions of the container by 0,1 m. The temperature of the fire shall be at least 590 °C. The fire shall continue to burn for the duration of the test.

6.3.8.2.3.3. The pressure of the tank at the beginning of the test shall be between 0 MPa and 0,01 MPa at the boiling point of hydrogen in the inner tank.

6.3.8.2.3.4. Once the safety device opens, the test shall continue until the blow off of the safety device has finished. During the test the tank shall not burst and the pressure inside the inner tank shall not exceed the permissible fault range of the inner tank. In the case of steel inner tanks, the tank pressure shall not exceed 136 per cent of the Maximum Allowable Working Pressure (MAWP) of the inner tank. For other materials, an equivalent level of safety shall be applied.

6.3.8.3. Results

The test conditions and the maximum pressure reached within the tank during the test shall be recorded in a test certificate signed by the manufacturer and the technical service.

6.3.9. *Maximum filling level test*

6.3.9.1. Criteria

During all the tests necessary for approval, the filling process shall not lead to any pressure relief device coming into operation irrespective of time passed during/after the filling process. The filling process shall not lead to operating conditions the BMS (boil-off management system) is not designed for and therefore cannot handle.

6.3.9.2. Procedure

6.3.9.2.1. The tested tank shall be representative of the design and the manufacturing of the type to be approved.

6.3.9.2.2. Its manufacturing shall be completely finished and it shall be fitted with all its equipment and particularly the level gauge.

6.3.9.2.3. The tank shall already be cooled down and the inner tank shall be at the same temperature as the liquid hydrogen. The tank shall have contained during the previous 24 hours a volume of liquid hydrogen at least equal to half of the water volume of the inner tank.

6.3.9.2.4. The mass of hydrogen or the mass flow rate at the inlet and the outlet of the tank shall be measured with an accuracy better than 1 per cent of the maximum filling mass of the tested container

6.3.9.2.5. The tank shall be completely filled 10 times with liquid hydrogen at equilibrium with its vapour. Between each filling at least a quarter of the liquid hydrogen of the tank shall be emptied.

6.3.9.3. Results

The test conditions and the ten maximum level measured by the added system shall be written in a test certificate signed by the manufacturer and the technical service.

PART 3

Requirements for hydrogen components other than containers designed to use liquid hydrogen

1. INTRODUCTION

This Part sets out the requirements and test procedures for hydrogen components other than containers designed to use liquid hydrogen.

2. GENERAL REQUIREMENTS

2.1. Materials used in hydrogen components shall be compatible with hydrogen in accordance with section 4.11.

2.2. The hydrogen system upstream of the first pressure regulator, excluding the hydrogen container, shall have a Maximum Allowable Working Pressure (MAWP) equal to the maximum pressure the component is subjected to but at least 1,5 times the set pressure of the primary safety relief device of the inner tank and a coefficient of safety not less than that of the inner tank.

2.3. Components downstream of pressure regulator(s) shall be protected against over-pressurisation and shall be designed for at least 1,5 times the outlet pressure (Maximum Allowable Working Pressure (MAWP)) of the first pressure regulator upstream.

2.4. The insulation of the components shall prevent liquefaction of the air in contact with the outer surfaces, unless a system is provided for collecting and vaporising the liquefied air. Then the materials of the components nearby shall be compatible with an atmosphere enriched with oxygen according to EN 1797.

3. TECHNICAL REQUIREMENTS

3.1. **Pressure relief devices**

3.1.1. *Pressure relief devices for the inner tank*

3.1.1.1. The primary pressure relief device for the inner tank shall limit the pressure inside the tank to not more than 110 per cent of the Maximum Allowable Working Pressure (MAWP), even in case of a sudden vacuum loss. This device shall be a safety valve or equivalent and shall be connected directly to the gaseous part under normal operating conditions.

3.1.1.2. The secondary pressure relief device for the inner tank shall be installed to ensure that the pressure in the tank cannot under any circumstances exceed the permissible fault range of the inner tank. In the case of steel inner tanks, the secondary pressure relief device shall limit the pressure in the tank to 136 per cent of the Maximum Allowable Working Pressure (MAWP) of the inner tank, if a safety valve is used as secondary pressure relief device. In case of steel inner tanks, the secondary pressure relief device shall limit the pressure in the tank to 150 per cent of the Maximum Allowable Working Pressure (MAWP) of the inner tank, if a burst disk is used outside the vacuum area as secondary pressure relief device. In case of steel inner tanks, the secondary pressure relief device shall limit the pressure in the tank to 150 per cent of the Maximum Allowable Working Pressure plus 0,1 MPa (MAWP + 0,1 MPa) of the inner tank, if a burst disk is used inside the vacuum area as secondary pressure relief device. For other materials, an equivalent level of safety shall be demonstrated. The secondary pressure relief device shall not operate below 110 per cent of the set pressure of the primary pressure relief device.

3.1.1.3. The sizing of the safety devices shall be done in accordance with EN 13648-3.

3.1.1.4. The two devices referred to in sections 3.1.1.1. and 3.1.1.2. may be connected to the inner tank by the same fuel line.

3.1.1.5. The rating of the pressure relief devices shall be clearly marked. Tampering with the devices shall be prevented by means of a lead seal or equivalent system.

3.1.1.6. Pressure relief valves shall, after discharge, close at a pressure higher than 90 per cent of the set pressure of the pressure relief valve. They shall remain closed at all lower pressures.

3.1.1.7. Pressure relief valves shall be installed on the gaseous fraction area of the hydrogen tank.

3.1.2. *Pressure relief devices for other components*

3.1.2.1. Whenever there is a risk of cryogenic liquid or vapour becoming trapped between two items of equipment on a line, a pressure relief device or a measure ensuring an equivalent level of safety shall be provided.

3.1.2.2. Upstream of the first pressure regulator the set pressure of the safety device which prevents over-pressurisation shall not exceed the Maximum Allowable Working Pressure (MAWP) of the lines and shall not be less than 120 per cent of the Maximum Allowable Working Pressure (MAWP) of the tank, to prevent such valves opening instead of the pressure relief devices for the inner tank.

3.1.2.3. The rating of pressure relief devices downstream of the pressure regulator(s) shall not exceed the Maximum Allowable Working Pressure (MAWP) of the components downstream of the pressure regulator.

3.1.2.4. Pressure relief valves shall, after discharge, close at a pressure higher than 90 per cent of the set pressure of the pressure relief valve. They shall remain closed at all lower pressures.

3.1.3. *Provisions regarding the approval of pressure relief devices*

3.1.3.1. The design, manufacturing and control of the pressure relief devices shall be in accordance with EN 13648-1 and EN 13648-2.

3.1.3.2. In case of boil off system in parallel of the primary safety device, then the safety valve shall be a category B safety device otherwise it shall be a category A safety device according to EN 13648.

3.1.3.3. Maximum Allowable Working Pressure (MAWP): 1,5 × Maximum Allowable Working Pressure (MAWP) of the inner tank or maximum pressure the component is subjected to.

3.1.3.4. Set pressure

3.1.3.4.1. Primary devices of the inner tank: according to section 3.1.1.1.

3.1.3.4.2. Secondary device of the inner tank: according to section 3.1.1.2.

3.1.3.4.3. Pressure relief devices for components other than the tank: according to section 3.1.2.

3.1.3.5. Design temperatures

3.1.3.5.1. External temperature: according to section 1.3 of Part 1.

3.1.3.5.2. Internal temperature: – 253 °C to + 85 °C.

3.1.3.6. Applicable test procedures:

Pressure test	section 4.2
External leakage test	section 4.3
Operational test	section 4.5
Corrosion resistance	section 4.6, only for metallic parts, only for equipment outside of the gas tight housing
Temperature cycle test	section 4.9, only for non-metallic parts

3.1.4. *Lines incorporating pressure relief devices*

3.1.4.1. No isolating device shall be installed between the protected component and the pressure relief device.

3.1.4.2. The lines before and behind the pressure relief devices shall not impede their function and shall be compatible with the criteria defined in sections 3.1.1. to 3.1.3.

3.2. **Valves**

3.2.1. *Provisions regarding the approval of hydrogen valves*

3.2.1.1. The design, manufacturing and checking of the cryogenic hydrogen valves shall be in accordance with EN 13648-1 and EN 13648-2.

3.2.1.2. Maximum Allowable Working Pressure (MAWP): 1,5 × Maximum Allowable Working Pressure (MAWP) of the inner tank or maximum pressure the valve is subjected to.

3.2.1.3. Design temperatures

3.2.1.3.1. External temperature: according to section 1.3 of Part 1.

3.2.1.3.2. Internal temperature:

– 253 °C to + 85 °C for valves before the heat exchanger

– 40 °C to + 85 °C for valves after the heat exchanger

3.2.1.4. Applicable test procedures:

Pressure test	section 4.2
External leakage test	section 4.3
Endurance test	section 4.4 (with 6 000 operation cycles for manual valves with 20 000 operation cycles for automatic valves)
Corrosion resistance	section 4.6, only for metallic parts, only for equipment outside of the gas tight housing
Resistance to dry-heat	section 4.7, only for non-metallic parts
Ozone ageing	section 4.8, only for non-metallic parts
Temperature cycle test	section 4.9, only for non-metallic parts
Seat leakage test	section 4.12

3.3. **Heat exchangers**

3.3.1. Notwithstanding the provision of section 2.1. the Maximum Allowable Working Pressure (MAWP) of the heat exchanger shall be the highest Maximum Allowable Working Pressure (MAWP) of the different circuits.

3.3.2. The exhaust gases from the propulsion system shall not under any circumstances be used directly in the heat exchanger.

3.3.3. A safety system shall be provided to: prevent failure of the heat exchanger; and prevent any cryogenic liquid or gas from entering the other circuit and the system located downstream of it, if it has not been designed for this.

3.3.4. *Provisions regarding the approval of hydrogen valves*

3.3.4.1. Maximum Allowable Working Pressure (MAWP): 1,5 × Maximum Allowable Working Pressure (MAWP) of the inner tank or maximum pressure the component is subjected to.

3.3.4.2. Design temperatures

3.3.4.2.1. External temperature: according to section 1.3 of Part 1.

3.3.4.2.2. Internal temperature: – 253 °C to + 85 °C.

3.3.4.3. Applicable test procedures

Pressure test	section 4.2
External leakage test	section 4.3
Corrosion resistance	section 4.6, only for metallic parts
Resistance to dry-heat	section 4.7, only for non-metallic parts
Ozone ageing	section 4.8, only for non-metallic parts
Temperature cycle test	section 4.9, only for non-metallic parts

3.3.4.4. The manufacturing and mounting of the heat exchanger shall be certified according to sections 4.3. to 4.5 of Part 2.

3.4. **Refuelling connections or receptacles**

3.4.1. The refuelling connections or receptacles shall be protected against contamination.

3.4.2. *Provisions regarding the approval of refuelling connections or receptacles*

3.4.2.1. Maximum Allowable Working Pressure (MAWP): 1,5 × Maximum Allowable Working Pressure (MAWP) of the inner tank or maximum pressure the component is subjected to.

3.4.2.2. Design temperatures

3.4.2.2.1. External temperature: according to section 1.3 of Part 1.

3.4.2.2.2. Internal temperature: − 253 °C to + 85 °C

3.4.2.3. Applicable test procedures

Pressure test	section 4.2
External leakage test	section 4.3
Endurance test	section 4.4 (with 3 000 operation cycles)
Corrosion resistance	section 4.6, only for metallic parts
Resistance to dry-heat	section 4.7, only for non-metallic parts
Ozone ageing	section 4.8, only for non-metallic parts
Temperature cycle test	section 4.9, only for non-metallic parts
Seat leakage test	section 4.12

3.5. **Pressure regulators**

3.5.1. *Provisions regarding the approval of pressure regulators*

3.5.1.1. Maximum Allowable Working Pressure (MAWP): 1,5 × Maximum Allowable Working Pressure (MAWP) of the inner tank or maximum pressure the component is subjected to.

3.5.1.2. Design temperatures

3.5.1.2.1. External temperature: according to section 1.3 of Part 1.

3.5.1.2.2. Internal temperature: at least as given in section 1.3 of Part 1.

3.5.1.3. Applicable test procedures

Pressure test	section 4.2
External leakage test	section 4.3
Endurance test	section 4.4
	(with 20 000 operation cycles)
Corrosion resistance	section 4.6, only for metallic parts, only for equipment outside of the gas tight housing
Resistance to dry-heat	section 4.7, only for non-metallic parts
Ozone ageing	section 4.8, only for non-metallic parts
Temperature cycle test	section 4.9, only for non-metallic parts
Seat leakage test	section 4.12

3.6. **Sensors**

3.6.1. *Provisions regarding the approval of sensors*

3.6.1.1. Maximum Allowable Working Pressure (MAWP): 1,5 × Maximum Allowable Working Pressure (MAWP) of the inner tank or maximum pressure the component is subjected to.

3.6.1.2. Design temperatures

3.6.1.2.1. If operated with ambient temperature: according to section 1.3 of Part 1.

3.6.1.2.2. If operated with cryogenic temperature: lowest operating temperature: – 253 °C, maximum temperature: + 85 °C or + 120 °C as given in section 1.3 of Part 1.

3.6.1.3. Applicable test procedures

Pressure test	section 4.2, only for equipment directly in contact with hydrogen
External leakage test	section 4.3, only for equipment directly in contact with hydrogen
Corrosion resistance	section 4.6, only for metallic parts, only for equipment outside of the gas tight housing
Resistance to dry-heat	section 4.7
Ozone ageing	section 4.8, only for non-metallic parts
Temperature cycle test	section 4.9, only for non-metallic parts

3.7. **Flexible fuel lines**

3.7.1. *Provisions regarding the approval of flexible fuel lines*

3.7.1.1. The design, manufacturing and control of the cryogenic flexible fuel lines shall be in accordance with EN 12434.

3.7.1.2. Maximum Allowable Working Pressure (MAWP): 1,5 × Maximum Allowable Working Pressure (MAWP) of the inner tank or maximum pressure the component is subjected to.

3.7.1.3. Design temperatures

3.7.1.3.1. If operated with ambient temperature: according to section 1.3 of Part 1.

3.7.1.3.2. If operated with cryogenic temperature: lowest operating temperature: – 253 °C, maximum temperature: + 85 °C or + 120 °C as given in section 1.3 of Part 1.

3.7.1.4. Applicable test procedures

Pressure test	section 4.2
External leakage test	section 4.3
Corrosion resistance	section 4.6, only for metallic parts, only for equipment outside of the gas tight housing
Resistance to dry-heat	section 4.7, only for non-metallic parts
Ozone ageing	section 4.8, only for non-metallic parts
Temperature cycle test	section 4.9, only for non-metallic parts
Pressure cycle	section 4.10

3.8. **Provisions regarding electrical components of the hydrogen system**

3.8.1. To prevent electric sparks:

(a) electrically operated devices containing hydrogen shall be insulated in a manner that no current passes through hydrogen containing parts;

(b) the electrical system of the electrically operated device shall be insulated from the body of the vehicle;

(c) the electric circuit insulation resistance (batteries and fuel cells excluded), shall exceed 1 kΩ for each volt of the nominal voltage.

3.8.2. In case of power supply bushing to establish an isolated and tight electrical connection, the electric connection shall be of a hermetic sealed type.

4. TEST PROCEDURES

4.1. **General provisions**

4.1.1. Leakage tests shall be conducted with pressurised gas such as air or nitrogen containing at least 10 per cent helium.

4.1.2. Water or another fluid may be used to obtain the required pressure for pressure test.

4.1.3. All test records shall indicate the type of test medium used, if applicable.

4.1.4. The test period for leakage and pressure tests shall be not less than 3 minutes more than the response time of the sensor.

4.1.5. All tests shall be performed at ambient temperature, unless otherwise stated.

4.1.6. The different components shall be correctly dried before leak test.

4.2. **Pressure test**

4.2.1. A hydrogen containing component shall withstand without any visible evidence of leak or deformation a test pressure of 1,5 times its Maximum Allowable Working Pressure (MAWP) with the outlets of the high pressure part plugged. The pressure shall then be increased from 1,5 to 3 times the Maximum Allowable Working Pressure (MAWP). The component shall not show any visible evidence of rupture or cracks.

4.2.2. The pressure supply system shall be equipped with a positive shut-off valve and a pressure gauge, having a pressure range of not less than 1,5 times nor more than 2 times the test pressure and the accuracy of the gauge shall be 1 per cent of the pressure range.

4.2.3. For components requiring a leakage test, this test shall be performed prior to the pressure test.

4.3. **External leakage test**

4.3.1. A component shall be free from leakage through stem or body seals or other joints, and shall not show evidence of porosity in casting when tested as described in section 4.4.3. at any gas pressure between zero and its Maximum Allowable Working Pressure (MAWP).

4.3.2. The test shall be performed on the same equipment at the following conditions:

4.3.2.1. at ambient temperature;

4.3.2.2. at the minimum operating temperature or at liquid nitrogen temperature after sufficient conditioning time at this temperature to ensure thermal stability;

4.3.2.3. at the maximum operating temperature after sufficient conditioning time at this temperature to ensure thermal stability.

4.3.3. During this test the equipment under test shall be connected to a source of gas pressure. A positive shut-off valve and a pressure gauge having a pressure range of not less than 1,5 times nor more than 2 times the test pressure shall be installed in the pressure supply piping and the accuracy of the gauge shall be 1 per cent of the pressure range. The pressure gauge shall be installed between the positive shut-off valve and the sample under test.

4.3.4. Throughout the test, the sample shall be tested for leakage, with a surface active agent without formation of bubbles or measured with a leakage rate less than 10 cm^3/hour.

4.4. **Endurance test**

4.4.1. A hydrogen component shall be capable of conforming to the applicable leakage test requirements of sections 4.3. and 4.12., after being subjected to the number of operation cycles specified for that component in sections 3.1. to 3.7. of Part 3.

4.4.2. The appropriate tests for external leakage and seat leakage, as described in sections 4.3. and 4.12. shall be carried out immediately following the endurance test.

4.4.3. The component shall be securely connected to a pressurised source of dry air or nitrogen and subjected to the number of cycles specified for that specific component in sections 3.1. to 3.7. of Part 3. A cycle shall consist of one opening and one closing of the component within a period of not less than 10 ± 2 seconds.

4.4.4. The component shall be operated through 96 per cent of the number of specified cycles at ambient temperature and at the MAWP of the component. During the off cycle the downstream pressure of the test fixture shall be allowed to decay to 50 per cent of the MAWP of the component.

4.4.5. The component shall be operated through 2 per cent of the total cycles at the maximum material temperature (according to section 1.3 of Part 1) after sufficient conditioning time at this temperature to ensure thermal stability and at MAWP. The component shall comply with sections 4.3. and 4.12. at the appropriate maximum material temperature (according to section 1.3 of Part 1) at the completion of the high temperature cycles.

4.4.6. The component shall be operated through 2 per cent of the total cycles at the minimum material temperature (according to section 1.3 of Part 1) but not less than the temperature of liquid nitrogen after sufficient conditioning time at this temperature to ensure thermal stability and at the MAWP of the component. The component shall comply with sections 4.3. and 4.12. at the appropriate minimum material temperature (according to section 1.3 of Part 1) at the completion of the low temperature cycles.

4.5. **Operational test**

4.5.1. The operational test shall be carried out in accordance with EN 13648-1 or EN 13648 2. The specific requirements of the standard are applicable.

4.6. **Corrosion resistance test**

4.6.1. Metallic hydrogen components shall comply with the leakage tests referred to in sections 4.3. and 4.12. after being submitted to 144 hours salt spray test according to ISO 9227 with all connections closed.

4.6.2. A copper or brass hydrogen containing component shall comply with the leakage tests referred to in sections 4.3. and 4.12. and after being submitted to 24 hours immersion in ammonia according to ISO 6957 with all connections closed.

4.7. **Resistance to dry-heat test**

The test shall be carried out in compliance with ISO 188. The test piece shall be exposed to air at a temperature equal to the maximum operating temperature for 168 hours. The change in tensile strength shall not exceed + 25 per cent. The change in ultimate elongation shall not exceed the following values:

— maximum increase 10 per cent,

— maximum decrease 30 per cent.

4.8. **Ozone ageing test**

4.8.1. The test shall be in compliance with ISO 1431-1. The test piece, which shall be stressed to 20 per cent elongation, shall be exposed to air at + 40 °C with an ozone concentration of 50 parts per hundred million during 120 hours.

4.8.2. No cracking of the test piece is allowed.

4.9. **Temperature cycle test**

A non-metallic part containing hydrogen shall comply with the leakage tests referred to in sections 4.3. and 4.12. after having been submitted to a 96 hours temperature cycle from the minimum operating temperature up to the maximum operating temperature with a cycle time of 120 minutes, under Maximum Allowable Working Pressure (MAWP).

4.10. **Pressure cycle test**

4.10.1. Any flexible fuel line shall be capable of conforming to the applicable leakage test requirements referred to in section 4.3., after being subjected to 6 000 pressure cycles.

4.10.2. The pressure shall change from atmospheric pressure to the Maximum Allowable Working Pressure (MAWP) of the tank within less than five seconds, and after a time of at least five seconds, shall decrease to atmospheric pressure within less than five seconds.

4.10.3. The appropriate test for external leakage, as referred to in section 4.3. shall be carried out immediately following the endurance test.

4.11. **Hydrogen compatibility test**

4.11.1. The hydrogen compatibility shall be proved according to ISO 11114-4.

4.11.2. The materials of the components in contact with cryogenic temperatures shall be compatible with cryogenic temperatures according to EN 1252-1.

4.12. **Seat leakage test**

4.12.1. The seat leakage tests shall be carried out on samples which have previously been subjected to the external leakage test referred to in section 4.3.

4.12.2. Seat leakage tests shall be conducted with the inlet of the sample valve connected to a source of gas pressure, the valve in the closed position, and with the outlet open. A positive shut-off valve and a pressure gauge having a pressure range of not less than 1,5 times and not more than twice the test pressure shall be installed in the pressure supply piping and the accuracy of the gauge shall be 1 per cent of the pressure range. The pressure gauge shall be installed between the positive shut-off valve and the sample under test. While under the applied test pressure corresponding to the Maximum Allowable Working Pressure (MAWP), observations for leakage shall be made with the open outlet submerged in water or by a flow meter installed on the inlet side of the valve under test. The flow meter shall be capable of indicating, for the test fluid employed, the maximum leakage flow rates permitted within an accuracy of +/- 1 per cent.

4.12.3. The seat of a shut-off valve, when in the closed position, shall not leak at a rate exceeding 10 cm^3/hour at any gas pressure between zero and the Maximum Allowable Working Pressure (MAWP).

4.12.4. A non-return valve, when in the closed position, shall not leak when subjected to any aerostatic pressure between 50 kPa and its Maximum Allowable Working Pressure (MAWP).

4.12.5. Non-return valves if used as a safety device or refuelling connections or receptacles shall not leak at a rate exceeding 10 cm^3/hour during the test.

4.12.6. The pressure relief devices shall not leak at a rate exceeding 10 cm^3/hour at any gas pressure between zero and set pressure minus 10 per cent.

ANNEX IV

Requirements for hydrogen components and systems designed to use compressed (gaseous) hydrogen and their installation on hydrogen powered vehicles

1. INTRODUCTION

This Annex sets out the requirements and test procedures for hydrogen components and systems designed to use compressed (gaseous) hydrogen.

2. GENERAL REQUIREMENTS

2.1. The number of hydrogen components, connections and the length of lines shall be kept to the minimum compatible with safety and the correct functioning of the hydrogen system.

2.2. The manufacturer shall ensure that the materials used in a hydrogen component or system are compatible with hydrogen and expected additives and production contaminants and expected temperatures and pressures.

2.3. Material compatibility with the service conditions defined in section 2.7. shall be demonstrated by the material tests in Parts 2 and 3.

2.4. **Pressure classification**

Hydrogen components shall be classified with regard to their nominal working pressure and function in accordance with points (2), (3) and (4) of Article 1.

2.5. The manufacturer shall ensure that the temperature range is in accordance with section 2.7.5.

2.6. The documentation and test reports shall be sufficiently detailed to enable an independent third party test facility to reproduce the appropriate type-approval tests and test results.

2.7. **Service conditions**

The service life of hydrogen containers shall be specified by the manufacturer and may vary with different applications, however, it shall not exceed 20 years.

2.7.1. *Service life*

The service life of hydrogen containers shall be specified by the manufacturer and may vary with different applications, however, it shall not exceed 20 years.

2.7.2. *Working pressure*

The vehicle manufacturer shall specify the nominal working pressure(s) of the hydrogen components and system. For the components downstream of the first pressure regulator, the MAWP(s) shall also be specified.

The MAWP(s) shall be equal to or shall exceed the set pressure of the overpressure protection specified in section 1.8. of Part 1.

2.7.3. *External surfaces*

The effects on external surfaces of the hydrogen components in their installed position shall be considered in relation to the following:

(a) Water, either by intermittent immersion or road spray;

(b) Salt, due to the operation of the vehicle near the ocean or where ice-melting salt is used;

(c) Ultra-violet radiation and heat radiation from sunlight;

(d) Impact of gravel;

(e) Solvents, acids and alkalis, fertilisers;

(f) Automotive fluids, including gasoline, hydraulic fluids, battery acid, glycol and oils;

(g) Exhaust gases.

2.7.4. *Gas Composition*

Compressed hydrogen gas used for testing shall comply with, or be of greater purity than, the Type 1, Grade A gas composition specified in ISO/TS 14687-2.

2.7.5. *Temperatures*

2.7.5.1. Material temperatures

The normal operating temperature range for materials used in hydrogen components shall be – 40 °C to + 85 °C except if:

(a) the vehicle manufacturer specifies a lower temperature than – 40 °C;

(b) hydrogen components are situated either in an internal combustion engine compartment or directly exposed to the operating temperature of an internal combustion engine, for which the temperature range shall be – 40 °C to + 120 °C.

2.7.5.2. Gas Temperatures

The average gas temperature shall be between – 40 °C to + 85 °C in normal conditions including filling and discharging, unless a lower temperature than – 40 °C is specified by the vehicle manufacturer.

2.7.6. *Filling cycles*

This section is only applicable to Class 0 hydrogen components.

2.7.6.1. General

The number of filling cycles for the hydrogen components shall be 5 000 cycles except as permitted in sections 2.7.6.2. and 2.7.6.3.

2.7.6.2. Number of filling cycles if usage monitoring and control system is installed

Provided that a usage monitoring and control system is installed as part of the hydrogen system, the number of filling cycles for hydrogen components shall be specified by the vehicle manufacturer and may be less than 5 000 cycles, but not less than 1 000 cycles and may vary with different applications based on the design lifetime mileage of the vehicle and range with maximum fuel capacity.

The usage monitoring and control system shall prevent any further use of the vehicle when the specified number of filling cycles is exceeded, until the hydrogen components that have exceeded that value are replaced with new hydrogen components.

The safety concept of the usage monitoring and control system shall be approved in accordance with Annex VI.

2.7.6.3. Reduced number of filling cycles

The vehicle manufacturer may specify a reduced number of filling cycles for hydrogen components, calculated by applying the following formula:

Number of filling cycles based on 20 years service life: 5 000

Design service life: x years; $x \geq 1$

Reduced number of filling cycles: 1 000 + 200*x

The hydrogen components shall be replaced before exceeding their specified service life.

2.7.7. *Duty cycles*

2.7.7.1. General

The number of duty cycles for hydrogen components shall be 50 000 cycles except as permitted in sections 2.7.7.2. and 2.7.7.3.

2.7.7.2. Number of duty cycles if usage monitoring and control system is installed

Provided that a usage monitoring and control system is installed as part of the hydrogen system, the number of duty cycles for hydrogen components may be reduced to less than 50 000 cycles, but not less than 10 000 cycles by the vehicle manufacturer based on the design lifetime of the component.

The usage monitoring and control system shall prevent any further use of the vehicle when the specified number of duty cycles is exceeded, until the hydrogen components that have exceeded that value are replaced with new hydrogen components.

The safety concept of the usage monitoring and control system shall be approved in accordance with Annex VI.

2.7.7.3. Reduced number of duty cycles

The vehicle manufacturer may specify a reduced number of duty cycles for each hydrogen component, calculated by applying the following formula:

Number of duty cycles based on 20 years service life: 50 000

Design service life: x years; $x \geq 1$

Reduced number of duty cycles:

$10\,000 + 2\,000 * x$

The hydrogen components shall be replaced before exceeding their specified service life.

PART 1

Requirements for the installation of hydrogen components and systems designed to use compressed (gaseous) hydrogen on hydrogen powered vehicles

1. GENERAL REQUIREMENTS

1.1. Reasonable precautions shall be taken to avoid failure of other circuits affecting the hydrogen system.

1.2. The hydrogen system shall be pressurised to nominal working pressure using 100 per cent hydrogen and tested for leakage, excluding the container, with a surface active agent without formation of bubbles for three minutes, or by using a demonstrated equivalent method.

1.3. In the event of hydrogen leakage or venting, hydrogen shall not be allowed to accumulate in enclosed or semi-enclosed spaces.

1.4. Hydrogen components that could leak hydrogen and that are mounted within the passenger or luggage compartment or other non-ventilated compartment shall be enclosed by a gas tight housing in accordance with section 10 or by an equivalent solution.

1.5. A minimum pressure of 0,2 MPa shall be maintained in the container or container assembly at ambient temperature.

1.6. All pressure relief devices, other safety components and vent lines shall be protected against unauthorised interference so far as reasonably practicable.

1.7. If the activation of the automatic valve fails, the valve shall switch to the safest mode of operation for the particular application.

1.8. The hydrogen system downstream of a pressure regulator shall be protected against overpressure due to the possible failure of the pressure regulator. If an overpressure protection device is used, the set pressure of such a device shall be lower than or equal to the MAWP for the appropriate section of the hydrogen system.

1.9. A system shall be provided to detect failure in either circuit of a heat exchanger and prevent hydrogen from entering the other circuit(s), if the interface(s) is not able to withstand loss of pressure in either circuit.

2. INSTALLATION OF A CONTAINER ON-BOARD A VEHICLE

2.1. A container or container assembly can fulfil integrated functions of the vehicle. A container or container assembly shall be designed to fulfil the integrated function requirements and the container requirements set out in Part 2.

2.2. A container or container assembly including safety devices shall be mounted and fixed so that the following accelerations can be absorbed without breaking of the fixation or loosening of the container(s) (demonstrated by testing or calculation). The mass used shall be representative for a fully equipped and filled container or container assembly.

Vehicles of categories M_1 and N_1:

(a) +/– 20 g in the direction of travel

(b) +/– 8 g horizontally perpendicular to the direction of travel

Vehicles of categories M_2 and N_2:

(a) +/– 10 g in the direction of travel

(b) +/– 5 g horizontally perpendicular to the direction of travel

Vehicles of categories M_3 and N_3:

(a) +/– 6,6 g in the direction of travel

(b) +/– 5 g horizontally perpendicular to the direction of travel

2.3. The provisions of section 2.2 shall not apply if the vehicle is approved according to Directives 96/27/EC and 96/79/EC.

2.4. Pressure relief device(s) in accordance with section 5 shall form the fire protection system for a container or container assembly to prevent rupture. Thermal insulation or other protective measures shall not influence the response and performance of the pressure relief device(s).

2.5. A container or container assembly with non-metallic liner(s) shall not be installed in the passenger compartment, luggage compartment or other places where ventilation is not sufficient unless integrated into a system which ensures that permeated hydrogen will be vented outside the vehicle, e.g. it is installed inside a gas tight housing in accordance with section 10.

3. REMOVABLE STORAGE SYSTEM

3.1. The components of a hydrogen system within a removable storage system shall fulfil all the requirements of this Regulation as if the hydrogen system were permanently installed in the vehicle.

3.2. A removable storage system may be removed from the vehicle for refilling. The container(s) or container assembly and the hydrogen components forming the removable storage system shall be permanently installed within the removable storage system.

3.3. A removable storage system shall protect the container(s) or container assembly and hydrogen components forming the removable storage system from damage during the handling operations necessary for installation, removal, storage and handling.

3.4. Effective measures shall be taken to prevent unauthorised removal of the removable storage system.

3.5. A single interface for the flow of hydrogen shall be provided between the removable storage system and the part of the hydrogen system permanently installed in the vehicle. The nominal working pressure of the hydrogen system at the interface shall be less than or equal to 3,0 MPa.

3.6. When the removable storage system is installed in the vehicle the connection with the part of the hydrogen system permanently installed in the vehicle shall be made without the use of tools and shall be capable of fulfilling the requirements of sections 1.2. and 2.2.

3.7. At the time of disconnection of the removable storage system, the volume of hydrogen released shall not exceed 200 Ncm^3 and shall not be released near a possible ignition source. The build up of hydrogen due to successive disconnections shall be prevented.

3.8. The part of the removable storage system connector permanently fitted to the vehicle shall be of a unique design for the applicable vehicle type and shall not be compatible with standard refilling nozzles for either hydrogen or other gaseous fuels.

3.9. The flow of hydrogen from a removable storage system shall be prevented if a removable storage system is installed with a higher maximum allowable working pressure than that of the permanent part of the vehicle's hydrogen system.

3.10. Opening of the automatic valve(s) mounted on a container(s) or a container assembly shall not be possible when the removable storage system is not correctly connected to the permanently fixed section of the vehicle's hydrogen system. A vehicle interface system shall verify that a correct connection between the removable container system and the vehicle is established before permitting the automatic valve(s) to open. The vehicle interface system shall also verify that the removable storage system is compatible with the vehicle's hydrogen system before permitting the automatic valve(s) to open.

3.11. Disconnection or removal of the removable storage system shall not be possible unless the automatic valve mounted on a container(s) or a container assembly is in the closed position and no combustion sources are in operation, for example, heaters on the vehicle.

3.12. Use of the hydrogen system shall be prevented if a partial or total failure of the removable storage system connector or electrical connectors between the removable storage system and the vehicle occurs, that may affect the safety of the hydrogen system.

3.13. The installation and removal operations for the removable storage system shall be illustrated on a label attached to the vehicle close to the mounting point of the removable storage system. The label shall also state the nominal working pressure of the container(s) or container assembly and the removable storage system connector.

3.14. A label shall be attached to the removable storage system stating the nominal working pressure of the container(s) or container assembly and the removable storage system connector.

3.15. The EC vehicle type-approval number shall be reproduced on the removable storage system.

4. AUTOMATIC VALVE(S) OR NON-RETURN VALVE(S) FOR ISOLATING A CONTAINER OR CONTAINER ASSEMBLY OR PROPULSION SYSTEM

4.1. Automatic shut-off valves shall be used in compliance with section 6. of Annex VI to Regulation (EC) No 79/2009 and shall be idle closed. If a container assembly is used, the valve shall be mounted directly on or within one container.

4.2. Refuelling connections or receptacles shall be used in compliance wit section 4. of Annex VI to Regulation (EC) No 79/2009. If a container assembly is used, the valve shall be mounted directly on or within one container.

4.3. If a single line is used into the container or container assembly for both refilling and fuel supply, it shall be secured as described in section 4.2. on the refilling line at the junction between the refilling line and the fuel supply line.

4.4. In the event of breakage of the refilling lines or fuel supply line(s), the isolating valves referred to in sections 4.1. and 4.2. shall not be separated from the container or container assembly.

4.5. Automatic valve(s) isolating each container or container assembly, shall close in the event of either a malfunction of the hydrogen system that results in the release of hydrogen or severe leakage between the container or container assembly and the hydrogen conversion system(s).

4.6. The flow of fuel to the propulsion system shall be secured by an automatic valve. This automatic valve shall be operated such that the hydrogen supply to the propulsion system is cut off when the propulsion system is switched off, irrespective of the position of the activation switch, and shall remain so until the propulsion system is required to operate.

4.7. The flow of fuel to other hydrogen conversion system(s) shall be secured by an automatic valve. This automatic valve shall be operated such that the hydrogen supply to other hydrogen conversion system(s) is cut off when the respective hydrogen conversion system is switched off, irrespective of the position of the activation switch, and shall remain so until the hydrogen conversion system is required to operate.

5. PRESSURE RELIEF DEVICE(S)

5.1. For the purposes of containers designed to use compressed (gaseous) hydrogen, a pressure relief device shall be a non-reclosing thermally activated device that prevents a container from bursting due to fire effects.

5.2. A pressure relief device shall be directly installed into the opening of a container or at least one container in a container assembly, or into an opening in a valve assembled into the container, in such a manner that it shall discharge the hydrogen into an atmospheric outlet that vents to the outside of the vehicle.

5.3. It shall not be possible to isolate the pressure relief device from the container protected by the pressure relief device, due to the normal operation or failure of another component.

5.4. The hydrogen gas discharge from pressure relief device shall not be directed:

(a) towards exposed electrical terminals, exposed electrical switches or other ignition sources;

(b) into or towards the vehicle passenger or luggage compartments;

(c) into or towards any vehicle wheel housing;

(d) towards any class 0 component;

(e) forward from the vehicle, or horizontally from the back or sides of the vehicle.

5.5. The internal dimensions of the vent shall not impede the function of the pressure relief device.

5.6. The vent of the pressure relief device shall be protected against blockage, e.g. by dirt, ice, and ingress of water, so far as is reasonably practicable.

5.7. The outlet of the pressure relief device shall be orientated such that if the vent becomes detached from the pressure relief device, the resulting gas flow does not impinge directly on other containers or container assemblies unless they are protected.

6. PRESSURE RELIEF VALVE(S)

6.1. If a pressure relief valve is used, it shall be installed in such a manner that it shall discharge the hydrogen into an atmospheric outlet that vents to the outside of the vehicle.

6.2. It shall not be possible to isolate the pressure relief valve from the hydrogen components or section of the hydrogen system that it protects, by the normal operation or failure of another component.

6.3. The hydrogen gas discharge from pressure relief valves shall not be directed:

(a) towards exposed electrical terminals, exposed electrical switches or other ignition sources;

(b) into or towards the vehicle passenger or luggage compartments;

(c) into or towards any vehicle wheel housing;

(d) towards any class 0 component.

6.4. The vent of the pressure relief valve shall be protected against blockage, e.g. by dirt, ice, ingress of water, etc., so far as is reasonably practicable.

7. RIGID AND FLEXIBLE FUEL LINES

7.1. Rigid fuel lines shall be secured such that they shall not be subjected to critical vibration or other stresses.

7.2. Flexible fuel lines shall be secured such that they shall not be subjected to torsional stresses and abrasion is avoided.

7.3. Rigid fuel lines and flexible fuel lines shall be designed to reasonably minimise stresses in the lines during removal or installation of adjoining hydrogen components.

7.4. At fixing points, rigid fuel lines and flexible fuel lines shall be fitted in such a way that galvanic and crevice corrosion are prevented.

7.5. Rigid fuel lines and flexible fuel lines shall be routed to reasonably minimise exposure to accidental damage whether inside the vehicle, e.g. due to placing or movement of luggage or other loads, or outside the vehicle, e.g. due to rough ground or vehicle jacks etc.

7.6. At passages through the vehicle body or other hydrogen components, the fuel lines shall be fitted with grommets or other protective material.

7.7. If fittings are installed in the passenger or enclosed luggage compartment, the fuel lines and fittings shall be enclosed in a sleeve which meets the same requirements as specified for a gas tight housing in section 10.

8. FITTINGS BETWEEN HYDROGEN COMPONENTS

8.1. The vehicle manufacturer shall ensure that the materials used in fittings are chosen in such a way that galvanic and crevice corrosion are prevented.

8.2. The number of joints shall be limited to a minimum.

8.3. Means shall be specified by the manufacturer for leak testing of joints for the purposes of inspection. If leak testing with a surface active agent is specified, any joints shall be made in locations where access is possible.

9. REFILLING SYSTEM

9.1. The receptacle shall be secured against maladjustment and rotation. The receptacle shall also be protected from unauthorised interference, and the ingress of dirt and water so far as is reasonably practicable, e.g. by a locked hatch. The receptacle shall be safe against reasonably foreseeable handling errors.

9.2. The receptacle shall be installed such that access for refilling shall not be required in the passenger, luggage, or in any other unventilated compartment.

9.3. The receptacle shall not be mounted within the external energy absorbing elements, e.g. bumper.

9.4. The nominal working pressure of the receptacle shall be equal to the nominal working pressure of the Class 0 hydrogen components upstream of and including the first pressure regulator.

9.5. It shall be ensured that the propulsion system or hydrogen conversion system(s) excluding safety devices are not operating and that the vehicle is immobilised while refilling.

9.6. Label(s) shall be provided close to the receptacle, for example inside a refilling hatch, showing the following information:

H_2 gas

'xx' MPa

Where 'xx' = nominal working pressure of the container(s).

10. GAS TIGHT HOUSING

10.1. The gas tight housing shall be vented to the atmosphere.

10.2. The ventilation opening of the gas tight housing shall be at the highest point of the housing when installed in the vehicle, as far as reasonably practicable. It shall not ventilate into a wheel arch, nor shall it be aimed at a heat source such as the exhaust. Additionally it shall vent such that hydrogen cannot enter the inside of the vehicle.

10.3. The electrical connections and components in the gas tight housing shall be constructed such that no sparks are generated.

10.4. During testing the vent line shall be hermetically sealed and the gas tight housing shall meet the leakage requirements of section 1.2. at a pressure of 0,01 MPa and without any permanent deformations.

10.5. Any connecting system shall be secured by clamps, or other means, to the gas tight housing or sleeve and the lead-through to ensure that a joint is formed meeting the leakage requirements of section 10.4.

11. ELECTRICAL INSTALLATION

11.1. The electrical components of the hydrogen system shall be protected against overloads.

11.2. Power supply connections shall be tight against the ingress of hydrogen where hydrogen components are present or hydrogen leaks are possible.

12. SAFETY INSTRUMENTED SYSTEMS

12.1. Safety instrumented systems shall be fail-safe or redundant.

12.2. If safety instrumented systems are fail-safe or self-monitoring electronic systems, the special requirements according to Annex VI shall be applied.

13. REQUIREMENTS FOR THE INSPECTION OF THE HYDROGEN SYSTEM

13.1. Each hydrogen system shall be inspected at least every 48 months after the date of its entry into service, and at the time of any re-installation.

13.2. The inspection shall be performed by a technical service, in accordance with the manufacturers specifications set out in Part 3 to Annex I.

PART 2

Requirements for hydrogen containers designed to use compressed (gaseous) hydrogen

1. INTRODUCTION

This Part sets out the requirements and test procedures for hydrogen containers designed to use compressed (gaseous) hydrogen.

1.1. **Container types**

Containers shall be classified into types according to the type of construction as referred to in point 1 of Annex IV to Regulation (EC) No 79/2009.

2. GENERAL REQUIREMENTS

2.1. The manufacturer is free to design the shape of a container provided that it fulfils all the appropriate provisions laid down in section 3.

2.2. **Container assembly**

2.2.1. A container assembly shall be type-approved as one container if both the container assembly and constituent containers are approved in accordance with the provisions laid down in sections 3 and 4.

2.2.2. Alternatively a container assembly shall be type-approved as one container if the container assembly fulfils the provisions laid down in sections 3 and 4. The constituent containers need not fulfil all the provisions laid down in sections 3 and 4 provided that the container assembly fulfils all the provisions of sections 3 and 4 appropriate to the type of materials and method of construction used.

2.2.3. Notwithstanding the requirements of sections 2.2.1. and 2.2.2., a container assembly shall fulfil the requirements of sections 4.2.4. (bonfire test), 4.2.10. (impact damage test) and 4.2.11. (leak test).

2.2.4. A maximum of four containers per container assembly shall be permitted.

2.2.5. Flexible fuel lines shall not be used as integral interconnecting fuel lines in a container assembly.

3. TECHNICAL REQUIREMENTS

3.1. **General requirements**

Containers shall fulfil the technical requirements specified in sections 3.2. to 3.11.

3.2. **Fire protection**

The container, pressure relief device(s) and any added insulation or protective material shall collectively protect the container from rupture when exposed to fire. The arrangement of the fire protection system shall be specified.

3.3. **Opening threads**

Openings with tapered or straight threads may be used in all container types. Threads shall comply with a recognised international or national standard.

3.4. **Exterior environmental protection**

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

3.5. **Material requirements**

3.5.1. *General*

Materials used shall be suitable for the service conditions specified in section 2.7. Incompatible materials shall not be in contact with each other.

3.5.2. *Steel*

3.5.2.1. Steels for containers and liners shall conform to the material requirements of sections 6.1 to 6.4 of ISO 9809-1 or sections 6.1. to 6.3. of ISO 9809-2 as appropriate.

3.5.2.2. Stainless steels for containers and liners shall conform to sections 4.1. to 4.4. of EN 1964-3.

3.5.2.3. Welded stainless steels for liners of type 3 containers shall conform to sections 4.1. to 4.3. of EN 13322-2 as appropriate.

3.5.3. *Aluminium alloy*

3.5.3.1. Aluminium alloys for containers and liners shall conform to the material requirements of sections 6.1. and 6.2. of ISO 7866.

3.5.3.2. Welded aluminium alloys for liners of Type 3 containers shall conform to sections 4.2. and 4.3. of EN 12862.

3.5.4. *Plastic liner materials*

The material for plastic liners may be thermosetting or thermoplastic.

3.5.5. *Fibres*

The manufacturer of the container shall keep on file for the intended life of the container design the published specifications for composite materials including principal test results, i.e. tensile test, the material manufacturer's recommendations for storage, conditions and shelf life.

The manufacturer of the container shall keep on file, for the intended life of each batch of containers, the fibre manufacturer's certification that each shipment conforms to the manufacturer's specifications for the product.

3.5.6. *Resins*

The polymeric material for impregnation of the fibres may be thermosetting or thermoplastic resin.

3.6. **Burst pressure ratios**

The minimum burst pressure ratios, i.e. the minimum actual burst pressure of the container divided by its nominal working pressure, shall not be less than the values given in Table IV.3.6.

Table IV.3.6.

Minimum Burst Pressure Ratios

		Container type			
Construction		Type 1	Type 2	Type 3	Type 4
All metal		2,25			
Over-wrap	Glass		2,4	3,4	3,5
	Aramid		2,25	2,9	3,0
	Carbon		2,25	2,25	2,25
	Hybrid		(1)		

Explanatory note:

(1) For container designs using hybrid reinforcement, i.e. two or more different structural fibre types, consideration shall be given to the load share between the different fibres based on the different elastic moduli of the fibres. The calculated stress ratios for each individual structural fibre type shall conform to the specified values. Verification of the stress ratios may also be performed using strain gauges. The minimum burst pressure ratio shall be chosen such that the calculated stress in the structural fibres at the minimum burst pressure ratio times nominal working pressure divided by the calculated stress in the structural fibre at nominal working pressure meets the stress ratio requirements for the fibres used.

3.7. **Container manufacturing requirements**

3.7.1. *Type 1 containers*

A forming process shall not be used to close the ends of aluminium alloy containers. The base ends of steel containers that have been closed by forming shall be inspected using NDE or equivalent techniques. Metal shall not be added in the process of closure at the end. Each container shall be examined before end forming operations for thickness and surface finish.

After end forming, containers shall be heat treated to the hardness range specified for the design. Localised heat treatment is not permitted.

If a neck ring, foot ring or attachments for support are provided, they shall be of material compatible with that of the container and shall be securely attached by a method other than welding, brazing or soldering.

3.7.2. *Type 2, 3 and 4 containers*

3.7.2.1. Composite filament winding

When composite containers are fabricated from a liner over-wrapped with continuous filament windings, the filament winding operations shall be computer or mechanically controlled. During winding the principal parameters shall be monitored and kept within specified tolerances, and documented in a winding record. The principal parameters are:

(a) Fibre type including tex value and sizing;

(b) Number of fibre tows per bandwidth;

(c) Type of resin and resin components mix ratio;

(d) Manner of impregnation, weight or volume fraction of resin or fibre;

(e) Winding program reference and winding angle;

(f) Number of winding rotations hoop;

(g) Number of windings cycles helical (type 3 and 4 containers only);

(h) Band width;

(i) Winding tension;

(j) Winding speed,

(k) Temperature of the resin.

3.7.2.2. Curing of thermosetting resins

After completion of filament winding, thermosetting resins shall be cured by heating using a predetermined and controlled time-temperature profile. The time-temperature history shall be documented during the curing.

The maximum curing time and temperature for containers with aluminium alloy liners shall be below the time and temperature that adversely affect the properties of the metal.

For type 4 containers the curing temperature for thermosetting resins shall be at least 10 °C below the softening temperature of the plastic liner.

3.7.2.3. Auto-frettage

Auto-frettage, if used, shall be carried out before the hydraulic test. The auto-frettage pressure shall be within the limits established by the manufacturer.

3.7.2.4. Metallic liners

Welding of stainless steel liners shall conform to sections 6.1., 6.2. and 6.4. of EN 13322-2. Welding of aluminium alloy liners shall conform to sections 4.1.2. and 6.1. of EN 12862.

3.8. **Container markings**

On each container, and where applicable the outer surface of a group of permanently encapsulated containers, the manufacturer shall provide clear permanent markings with a font not less than 6 mm high. Marking shall be made either by labels incorporated into resin coatings, adhesive labels, low stress stamps used on the thickened ends of type 1 and 2 containers, or any combination of the above means of marking. Adhesive labels and their application shall be in accordance with ISO 7225, or an equivalent standard. Multiple labels are allowed and should be located such that mounting brackets do not obscure them. In addition to the EC component type-approval mark set out in Part 3 of Annex II, every container type-approved in accordance with this Regulation shall bear a marking place with the following data clearly legible:

(a) Name of the manufacturer;

(b) A unique serial number for every container;

(c) a label as set out in section 3.2 of Annex V;

(d) Nominal working pressure (MPa) at 15 °C;

(e) Year and month of manufacture, e.g. 2009/01;

(f) 'DO NOT USE AFTER yyyy/mm' where yyyy/mm is the year and month of manufacture plus the approved service life of the container. However, yyyy/mm may be based on the date of dispatch of the container from the manufacturer, provided that it has been stored in a dry location without internal pressure;

(g) 'Number of filling cycles xxxxx' where xxxxx is the number of filling cycles in accordance with section 2.7.6.

3.9. **Batch test requirements**

3.9.1. *Batch test*

3.9.1.1. General

The manufacturer shall conduct batch testing on finished containers that are representative of normal production. The finished containers to be tested shall be randomly selected from each batch. A batch shall not exceed 200 finished containers plus those finished containers to be used in destructive tests, or one shift of successive production, whichever is greater.

The frequency of batch testing can be reduced as follows:

(a) If on 10 sequential batches of containers, none of the vessels leak or rupture within 1,5 times the required number of cycles, then the pressure cycle testing may be reduced to once per 5 batches. If any tested vessel fails to meet the requirement of 1,5 times the number of pressure cycles, then batch testing shall be required for the next five batches to re-establish the reduced frequency of testing.

(b) If on 10 sequential batches of containers, none of the vessels leak or rupture within 2 times the required number of cycles, then the pressure cycle testing may be reduced to once per 10 batches. If any tested vessel fails to meet the requirement of 2 times the number of pressure cycles, then batch testing shall be required for the next ten batches to re-establish the reduced frequency of testing.

(c) If more than 3 months elapse since the last batch pressure cycle test, then a vessel from the next batch of production shall be pressure tested to maintain the reduced frequency.

The following batch tests are required:

(a) One finished container shall be subjected to the ambient temperature pressure cycle test at the frequency given in section 3.9.1.2.;

(b) One finished container, liner or heat-treated test sample that is representative of finished containers or liners, shall be subjected to the other tests specified in Table IV.3.9.;

(c) One finished container shall be subjected to the burst test. If a finished container passes the ambient temperature pressure cycle test the same container may be subjected to the burst test;

(d) If an exterior environmental protective coating is used, e.g. organic coating/paint, one finished container or test sample that is representative of the batch shall be subjected to the coating batch test.

If more containers than required are subjected to the tests, all results shall be documented.

All containers represented by a batch test that fail to meet the specified requirements shall follow the procedures specified in section 3.9.2.

Table IV.3.9.

Batch tests

Test and reference		Applicable to container type				Specified design value	Test value
		1	2	3	4		
(1)	Tensile test	✓	✓ (5)	✓ (5)	✓ (5)		
(2)	Charpy impact test	✓	✓ (5)	✓ (5)			
(3)	Bend test			✓ (5)			
(4)	Macroscopic examination			✓ (5)			
4.1.2.	Softening temperature test				✓ (5)		
4.1.6.	Coating batch test	✓	✓	✓	✓		
4.2.1.	Burst test	✓	✓	✓	✓		
4.2.2.	Ambient temperature pressure cycle test	✓	✓	✓	✓ (6)		
4.2.11.	Leak test			✓ (7)	✓ (6)		
4.2.13.	Boss torque test				✓ (6)		

Explanatory notes:

(1) (a) For steel containers or liners refer to section 10.2. of ISO 9809-1 or section 10.2. of ISO 9809-2 as appropriate;
(b) For stainless steel containers or liners refer to section 7.1.2.1. of EN 1964-3;
(c) For welded stainless steel liners refer to section 8.4. of EN 13322-2;
(d) For aluminium alloy containers or liners refer to section 10.2. of ISO 7866;
(e) For welded aluminium alloy liners refer to sections 7.2.3. and 7.2.4. of EN 12862;
(f) For non-metallic liners refer to section 4.1.1.;

(2) (a) For steel containers or liners refer to section 10.4. of ISO 9809-1 or section 10.4. of ISO 9809-2 as appropriate;
(b) For stainless steel containers or liners refer to section 7.1.2.4. of EN 1964-3;
(c) For welded stainless steel liners refer to section 8.6. of EN 13322-2;

(3) (a) For welded stainless steel liners refer to section 8.5. of EN 13322-2;
(b) For welded aluminium alloy liners refer to sections 7.2.5., 7.2.6. and 7.2.7. of EN 12862;

(4) For welded stainless steel liners refer to section 8.7. of EN 13322-2.

(5) Test on liner material.

(6) The following test sequence shall be used for container type 4: boss torque test (section 4.2.13.), followed by an ambient temperature pressure cycling test (section 4.2.2.), followed by a leak test (section 4.2.11.).

(7) A leak test shall be carried out on all welded metal liners.

3.9.1.2. Frequency of ambient temperature pressure cycling test

Finished containers shall be subjected to the ambient temperature pressure cycling test at a test frequency defined as follows:

(a) One container from each batch shall be pressure cycled for 3,0 times the number of filling cycles in accordance with section 2.7.6.;

(b) If on 10 sequential production batches of containers, none of the pressure cycled containers in point a) leaks or ruptures within 4,5 times the number of filling cycles in accordance with section 2.7.6., then the pressure cycle test can be reduced to one container from every 5 batches of production with the container selected from the first of the 5 batches;

(c) If on 10 sequential production batches of containers, none of the pressure cycled containers in point a) leaks or ruptures within 6,0 times the number of filling cycles in accordance with section 2.7.6., then the pressure cycle test can be reduced to one container from every 10 batches of production with the container selected from the first of the 10 batches;

(d) Should more than 3 months have expired since the last batch of production, then a container from the next batch of production shall be pressure cycle tested in order to maintain the reduced frequency of batch testing in points (b) or (c);

(e) Should any reduced frequency pressure cycle test container points (b) or (c) fail to meet 3,0 times the number of filling cycles in accordance with section 2.7.6., then the batch pressure cycle test frequency in point a) shall be reintroduced for at least 10 production batches in order to re-establish the reduced frequency of batch pressure cycle testing in points (b) or (c);

(f) Should any container referred to in points a), b) or c) fail within 3,0 times the number of filling cycles in accordance with section 2.7.6., then the cause of failure shall be determined and corrected following the procedures in section 3.9.2. The pressure cycle test shall then be repeated on three additional containers from that batch. Should any of the three additional containers fail to meet 3,0 times the number of filling cycles in accordance with section 2.7.6., the batch shall be rejected. The manufacturer shall demonstrate that containers produced since the last successful batch test meet all batch test requirements.

3.9.2. *Failure to meet test requirements*

In the event of failure to meet the test requirements, retesting or reheat treatment and retesting shall be carried out as follows:

(a) If there is evidence of a fault in carrying out a test, or an error of measurement, a further test shall be performed. If the result of this test is satisfactory, the first test shall be ignored;

(b) If the test has been carried out in a satisfactory manner, the cause of the test failure shall be identified.

If the failure is considered to be due to the heat treatment applied, the manufacturer may subject all the containers of that batch to a further heat treatment.

If the failure is not due to the heat treatment applied, all the identified defective containers shall be rejected or repaired by an approved method. The non-rejected containers shall then be considered as a new batch.

In both cases all the relevant prototype or batch tests needed to prove the acceptability of the new batch shall be repeated. If one or more tests prove even partially unsatisfactory, all containers of the batch shall be rejected.

3.10. **Production examination and test requirements**

Production examination and tests shall be carried out on all containers during manufacture and after completion, as follows:

(a) Verification that the principal dimensions and mass of the finished container and of any liner and overwrap are within design tolerances;

(b) Verification of compliance with principal manufacturing parameters, referred to in the appendix to the information document as set out in Part 1 to Annex II, including examination of any specified surface finish with special attention to deep drawn surfaces and folds or laps in the neck or shoulder of forged or spun end enclosures or openings;

(c) For metallic containers and liners, NDE in accordance with Annex B of ISO 9809 or Annex C of EN 1964-3 or Annex B of EN 13322-2 as appropriate, or a demonstrated equivalent method capable of detecting the maximum defect size allowed, to verify that the maximum defect size does not exceed the size specified in the design as determined below.

In addition welded stainless steel liners shall also be examined in accordance with section 6.8.2. of EN 13322-2, and welded aluminium alloy liners shall be examined in accordance with sections 6.2.1. (second section), and 6.2.3. of EN 12862.

The design of type 1, 2 and 3 containers shall identify the maximum allowable defect size at any location in the metal container or liner that will not grow to a critical size within either the specified retest period or service life if no retest is specified. The critical defect size is defined as the limiting through-wall (container or liner) thickness defect that would allow stored gas to be discharged without rupturing the container. Defect sizes for the rejection criteria for ultrasonic scanning or equivalent, shall be smaller than the maximum allowable defect sizes. For type 2 and 3 containers, it shall be assumed that there is no damage to non-metallic materials due to any time-dependent mechanisms. The allowable defect size for NDE shall be determined by an appropriate method.

Containers shall meet the following requirements:

(a) Hardness test for metallic containers and liners in accordance with section 4.1.8.;

(b) Hydraulic test, in accordance with section 4.2.15.;

(c) Leak test for type 4 containers and type 3 with welded metal liners, in accordance with section 4.2.11.;

(d) Verification of markings, in accordance with section 3.8.

A summary of the required production examination and tests for each container is provided in Table IV.3.10.

Table IV.3.10.

Production examination and tests

Production examination and tests and reference		Applicable to container type			
		1	2	3	4
	Principal design dimensions	✓	✓	✓	✓
Appendix to the information document as set out in Part 1 to Annex II	Principal manufacturing parameters	✓	✓	✓	✓
	NDE	✓	✓ (1)	✓ (1)	
4.1.8.	Hardness test	✓	✓ (1)	✓ (1)	
4.2.11.	Leak test			✓ (2)	✓
4.2.15.	Hydraulic test	✓	✓	✓	✓
3.8.	Markings	✓	✓	✓	✓

Explanatory notes:
(1) Test on metallic liner.
(2) A leak test shall be carried out on all welded metal liners.

3.11. **Modifications**

Modifications may be approved in accordance with the reduced test programme specified in Table IV.3.11. Any major changes that are not covered by Table IV.3.11. shall be subjected to full approval testing.

Table IV.3.11.

Approval testing of modifications

	Type of test											
	Materials sections 4.1.1.-4.1.8., as applicable	Hydrogen compatibility section 4.1.7.	Burst section 4.2.1.	Ambient temp. pressure cycling section 4.2.2.	Lbb Performance section 4.2.3.	Bonfire section 4.2.4.	Penetration section 4.2.5.	Chemical exposure section 4.2.6.	Composite flaw tolerance section 4.2.7.	Acc. Stress rupture – section 4.2.8.	Impact damage test section 4.2.10.	Permeation (section 4.2.12.) Boss torque (section 4.2.13.) Hydrogen cycling (section 4.2.14.)
Fibre manufacturer			2, 3, 4	2, 3, 4	2, 3, 4					2, 3, 4	3, 4	
Metallic container or liner material	1, 2, 3	1, 2, 3	1, 2, 3	1, 2, 3	1, 2	1, 2, 3	1, 2, 3	1, 2, 3	2, 3	2, 3	3	
Plastic liner material	4			4				4				4
Fibre material	2, 3, 4		2, 3, 4	2, 3, 4	2, 3, 4	2, 3, 4	2, 3, 4	2, 3, 4	2, 3, 4	2, 3, 4	3, 4	
Resin material							2, 3, 4	2, 3, 4	2, 3, 4	2, 3, 4	3, 4	
Diameter change ≤ 20 %			1, 2, 3, 4	1, 2, 3, 4								
Diameter change >20 %			1, 2, 3, 4	1, 2, 3, 4		1, 2, 3, 4	1, 2, 3, 4		2, 3, 4		3, 4	
Length change ≤ 50 %			1, 2, 3, 4			—						
Length change > 50 %			1, 2, 3, 4	1, 2, 3, 4		1, 2, 3, 4					3, 4	
Nominal working pressure change ≤ 20 % (1)			1, 2, 3, 4	1, 2, 3, 4								
Nominal working pressure change > 20 % (1)			1, 2, 3, 4	1, 2, 3, 4	1, 2, 3, 4	1, 2, 3, 4	1, 2, 3, 4					
Dome shape			1, 2, 3, 4	1, 2, 3, 4								4
Opening size			1, 2, 3, 4	1, 2, 3, 4								
Coating change	2, 3, 4							2, 3, 4				
End boss design												4 (2)
Change in manufacturing process (3)			1, 2, 3, 4	1, 2, 3, 4								
Fire protection system						1, 2, 3, 4						

Explanatory notes: for example: '2, 3' indicates that a test is required for type 2 and 3 containers only.

(1) Only when thickness change is proportional to diameter or pressure change.

(2) A hydrogen cycle test is not required if the stresses in the neck are equal to the original or reduced by the design change (e.g. Reducing the diameter of internal threads, or changing the boss length), the liner to boss interface is not affected, and the original materials are used for boss, liner, and seals.

(3) Any deviation from the parameters in the appendix to the information document as set out in Part 1 to Annex II is considered to be a change in manufacturing process.

4. TEST PROCEDURES

4.1. **Material tests**

Material tests shall be carried out according to Table IV.4.1 and according to the test procedures described in sections 4.1.1-4.1.8.

Table IV.4.1.

Material tests

Material tests	Applicable to material					
	Steel	Aluminium alloy	Plastic liner	Fibre	Resin	Coating
Tensile test (2)	✔	✔	✔			
Charpy impact test (3)	✔					
Bend test (4)	✔ (1)	✔ (1)				
Macroscopic examination (5)	✔ (1)					
Corrosion test (6)		✔				
Sustained load cracking test (7)		✔				
Softening temperature test			✔			
Glass transition temperature test					✔	
Resin shear strength test					✔	
Coating test						✔
Hydrogen compatibility test (8)	✔	✔	✔	✔	✔	

Explanatory notes:

(1) For containers with welded liners only.

(2) (a) For steel containers or liners refer to paragraph 10.2. of ISO 9809-1 or paragraph 10.2. of ISO 9809-2 as appropriate;

(b) For stainless steel containers or liners refer to paragraph 7.1.2.1. of EN 1964-3;

(c) For welded stainless steel liners refer to paragraph 8.4. of EN 13322-2;

(d) For aluminium alloy containers or liners refer to paragraph 10.2. of ISO 7866;

(e) For welded aluminium alloy liners refer to paragraphs 7.2.3. and 7.2.4. of EN 12862;

(f) For non-metallic liners refer to paragraph 4.1.1. of Part 2 to Annex IV;

(3) (a) For steel containers or liners refer to paragraph 10.4. of ISO 9809-1 or paragraph 10.4. of ISO 9809-2 as appropriate;

(b) For stainless steel containers or liners refer to paragraph 7.1.2.4. of EN 1964-3;

(c) For welded stainless steel liners refer to paragraph 8.6. of EN 13322-2;

(4) (a) For welded stainless steel liners refer to paragraph 8.5. of EN 13322-2;

(b) For welded aluminium alloy liners refer to paragraphs 7.2.5., 7.2.6. and 7.2.7. of EN 12862.

(5) For welded stainless steel liners refer to paragraph 8.7. of EN 13322-2.

(6) (a) For aluminium alloy containers or liners refer to Annex A of ISO 7866;

(b) For welded aluminium alloy liners refer to Annex A of EN 12862.

(7) (a) For aluminium alloy containers or liners refer to Annex B of ISO 7866, but excluding the second paragraph of clause B.2.;

(b) For welded aluminium alloy liners refer to Annex B of EN 12862, but excluding paragraph B.2.2.

(8) (a) This test is not required for:

(i) Steels that conform to paragraphs 6.3. and 7.2.2 of ISO 9809-1;

(ii) Aluminium alloys that conform to paragraph 6.1. of ISO 7866.

(b) For other metallic containers or liners, hydrogen compatibility of the material, including welds, shall be demonstrated in accordance with ISO 11114-1 and ISO 11114-4 or section 4.1.7. as appropriate;

(c) For non-metallic materials hydrogen compatibility shall be demonstrated.

4.1.1. *Tensile test*

4.1.1.1. Sampling

The test applies to type 4 containers only.

The test applies to plastic liner materials only.

Type-approval testing — number of liners to be tested: 2

4.1.1.2. Procedure

Mechanical properties for plastic liner materials shall be tested at – 40 °C in accordance with ISO 527-2.

4.1.1.3. Requirements

The test results shall be within the range indicated by the manufacturer in the appendix to the information document as set out in Part 1 to Annex II.

4.1.1.4. Results

The tensile yield strength and ultimate elongation of plastic liner materials shall be presented in a test summary, as specified in the addendum to the EC type-approval certificate as set out in Part 2 to Annex II.

4.1.2. *Softening temperature test*

4.1.2.1. Sampling

The test applies to type 4 containers only.

The test applies to polymeric materials only.

Type-approval testing — number of liners to be tested: 1

Batch testing — number of liners to be tested: 1

4.1.2.2. Procedure

The softening temperature of polymeric materials from finished liners shall be determined based on the A50 method in ISO 306.

4.1.2.3. Requirement

The softening temperature shall be ≥ 100 °C.

4.1.2.4. Results

The softening temperature shall be presented in a test summary, as specified in the addendum to the EC type-approval certificate as set out in Part 2 to Annex II.

4.1.3. *Glass transition temperature test*

4.1.3.1. Sampling

The test applies to type 2, 3 and 4 containers.

The test applies to composite resin materials only.

Type-approval testing — number of samples to be tested: 3

4.1.3.2. Procedure

The glass transition temperature of resin materials shall be determined in accordance with ASTM D3418.

4.1.3.3. Requirements

The test results shall be within the range indicated by the manufacturer in the appendix to the information document as set out in Part 1 to Annex II.

4.1.3.4. Results

Final results from the test shall be documented by a test report and presented in a test summary, as specified in the addendum to the EC type-approval certificate as set out in Part 2 to Annex II. The glass transition temperature to be presented shall be the minimum measured value.

4.1.4. *Resin shear strength test*

4.1.4.1. Sampling

The test applies to type 2, 3 and 4 containers.

The test applies to composite resin materials only.

Type-approval testing — number of samples to be tested: 3

4.1.4.2. Procedure

Resin materials shall be tested on a sample coupon representative of the over-wrap in accordance with ASTM D2344/D2344M.

4.1.4.3. Requirement

After boiling in water for 24 hours the minimum shear strength of the composite shall be 13,8 MPa.

4.1.4.4. Results

The minimum resin shear strength shall be presented in a test summary, as specified in the addendum to the EC type-approval certificate as set out in Part 2 to Annex II.

4.1.5. *Coating test*

4.1.5.1. Sampling

The test applies to all container types where exterior environmental protective coating is used, e.g. organic coating/paint.

Type-approval testing — number of samples to be tested: as specified in the appropriate standards.

4.1.5.2. Procedure and requirement

Coatings shall be evaluated using the following test methods:

(a) Adhesion strength in accordance with ISO 4624, using method A or B as appropriate. The coating shall exhibit an adhesion rating of 4;

(b) Flexibility in accordance with ASTM D522, using Method B with a 12,7 mm mandrel at the specified thickness at – 20 °C. Test samples shall be prepared in accordance with ASTM D522. 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;

(d) Chemical resistance in accordance with ASTM D1308. The test shall be conducted using the open spot test method and 100 hours exposure to a 30 per cent sulphuric 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. This test is not necessary if a test is undertaken in accordance with section 4.2.6.;

(e) Light and water exposure in accordance with ASTM G154, using an exposure of 1 000 hours. There shall be no evidence of blistering. The adhesion shall meet a rating of 3 when tested in accordance with ISO 4624. The maximum gloss loss allowed is 20 per cent;

(f) Salt spray exposure in accordance with ASTM B117, using an exposure of 500 hours. Undercutting shall not exceed 3 mm at the scribe mark. There shall be no evidence of blistering. The adhesion shall meet a rating of 3 when tested in accordance with ASTM D3359;

(g) Resistance to chipping at room temperature using the ASTM D3170. The coating shall have a rating of 7A or better, and there shall not be any exposure of the substrate.

4.1.5.3. Results

Final results from the test shall be presented in a test summary, as specified in the addendum to the EC type-approval certificate as set out in Part 2 to Annex II.

4.1.6. *Coating batch test*

4.1.6.1. Sampling

The test applies to all container types where exterior environmental protective coating is used, e.g. organic coating/paint.

Batch testing — number of containers/samples to be tested per batch: in accordance with section 3.9.1.

4.1.6.2. Procedure and Requirement

Coatings shall be evaluated using the following test methods:

(a) Coating thickness measurement in accordance with ISO 2808. The thickness shall meet the design requirements;

(b) Adhesion strength in accordance with ISO 4624, using Method A or B as appropriate. The coating shall exhibit an adhesion rating of 4.

4.1.6.3. Results

Final results from the test shall be presented in a test summary, as specified in the addendum to the EC type-approval certificate as set out in Part 2 to Annex II.

The manufacturer shall keep the coating thickness and adhesion strength values on file throughout the service life of the container.

4.1.7. *Hydrogen compatibility test*

4.1.7.1. Sampling

The test applies to type 1, 2 and 3 containers in accordance with section 2.1.2. of the addendum to the EC type-approval certificate as set out in Part 2 to Annex II.

Type-approval testing — number of containers or liners to be tested: 3

4.1.7.2. Procedure

Special consideration shall be given to safety when conducting this test.

At ambient temperature use hydrogen to pressure cycle for 3,0 times the number of filling cycles in accordance with section 2.7.6., either:

(a) The container between ≤ 2,0 MPa and ≥ 1,25 times the nominal working pressure, or;

(b) The liner between the pressure levels that shall provide an equivalent liner wall stress as would be present at ≤ 2,0 MPa and ≥ 1,25 times the nominal working pressure for the container.

4.1.7.3. Requirement

The containers or liners shall not fail before reaching 3,0 times the number of filling cycles in accordance with section 2.7.6.

4.1.7.4. Results

Final results from the test shall be documented by a test report and presented in a test summary, as specified in the addendum to the EC type-approval certificate as set out in Part 2 to Annex II.

The manufacturer shall keep the results on file throughout the service life of the container.

4.1.8. *Hardness test*

4.1.8.1. Sampling

The test applies to all containers and to liners of type 1, 2 and 3 containers.

The test applies to metallic materials only.

Production testing — number of containers or liners to be tested: all.

The test shall be carried out after the final heat treatment.

4.1.8.2. Procedure

A hardness test shall be carried out on the parallel wall at the centre and at one of the domed ends of each container or liner in accordance with ISO 6506-1.

4.1.8.3. Requirement

The hardness value shall be in the range specified for the design.

4.1.8.4. Results

The hardness value shall be presented in a test summary, as specified in the addendum to the EC type-approval certificate as set out in Part 2 to Annex II.

The manufacturer shall keep the results on file throughout the service life of the container.

4.2. **Container tests**

4.2.1. *Burst test*

4.2.1.1. Sampling

The test applies to all container types.

Type-approval testing — number of finished containers to be tested: 3

Type-approval testing — number of liners to be tested: 1 (additional test for type 2 containers only)

Batch testing — number of finished containers to be tested per Batch: in accordance with section 3.9.1.

4.2.1.2. Procedure

The container shall be hydraulically burst tested at ambient temperature using the following procedure:

The rate of pressurisation shall be ≤ 1,4 MPa/s for pressures higher than 80 per cent of the nominal working pressure times the burst pressure ratio stated in section 3.6. If the rate exceeds 0,35 MPa/s at pressures higher than 80 per cent of the nominal working pressure times the burst pressure ratio, then either the container shall be placed in series between the pressure source and the pressure measurement device, or the time at pressure above the nominal working pressure times the burst pressure ratio shall exceed 5 seconds.

4.2.1.3. Requirement

The burst pressure of the container shall exceed the nominal working pressure times the burst pressure ratio stated in section 3.6.

In case of type 2 containers, the burst pressure of the liner shall exceed 1,25 times the nominal working pressure.

4.2.1.4. Results

The burst pressure shall be presented in a test summary, as specified in the addendum to the EC type-approval certificate as set out in Part 2 to Annex II.

The manufacturer shall keep the burst pressure value on file throughout the service life of the container.

4.2.2. *Ambient temperature pressure cycle test*

4.2.2.1. Sampling

The test applies to all container types.

Type-approval testing — number of finished containers to be tested: 2

Batch testing — number of finished containers to be tested per batch: in accordance with section 3.9.1.

4.2.2.2. Procedure

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

(a) Fill the container to be tested with a non-corrosive fluid such as oil, inhibited water or glycol;

(b) Pressure cycle for 3,0 times the number of filling cycles in accordance with section 2.7.6., from ≤ 2,0 MPa to ≥ 1,25 times nominal working pressure at a rate not exceeding 10 cycles per minute.

For type-approval, containers shall be cycled until failure occurs or up to 9 times the number of filling cycles.

For batch testing, the requirements of section 3.9.1. shall be followed.

4.2.2.3. Requirement

For type-approval, the containers shall either reach 9,0 times the number of filling cycles without failure, in which case the LBB test in section 4.2.3. is not required, or they shall fail by leakage and not by rupture. For batch testing, the containers shall not fail before reaching 3,0 times the number of filling cycles in accordance with section 2.7.6.

4.2.2.4. Results

The number of cycles to failure, along with the location and description of the failure initiation shall be documented and presented in a test summary, as specified in the addendum to the EC type-approval certificate as set out in Part 2 to Annex II.

The manufacturer shall keep the results on file throughout the service life of the container.

4.2.3. *Leak-Before-Break (LBB) performance test*

4.2.3.1. Sampling

The test applies to all container types. The test is not required if the container design is already proven to exceed 9,0 times the number of filling cycles in accordance with section 2.7.6., when tested in accordance with section 4.2.2.

Type-approval testing — number of finished containers to be tested: 3

4.2.3.2. Procedure

The container shall be tested using the following procedure:

(a) Fill the container to be tested with a non-corrosive fluid such as oil, inhibited water or glycol;

(b) Pressure cycle the container between ≤ 2,0 MPa and ≥ 1,5 times nominal working pressure at a rate of ≤ 10 cycles per minute to 3,0 times the number of filling cycles in accordance with section 2.7.6.

4.2.3.3. Requirement

The containers tested shall either fail by leakage or shall exceed 3,0 times the number of filling cycles in accordance with section 2.7.6. without failure.

4.2.3.4. Results

The number of cycles to failure, along with the location and description of the failure initiation, shall be presented in a test summary, as specified in the addendum to the EC type-approval certificate as set out in Part 2 to Annex II.

4.2.4. *Bonfire test*

4.2.4.1. Sampling

The test applies to all container types.

Type-approval testing — number of finished containers to be tested: minimum 1

4.2.4.2. Procedure

Special consideration shall be given to safety when conducting this test.

The container shall be pressurised to nominal working pressure with hydrogen or a gas with a higher thermal pressure build up. The pressurised container shall be tested as follows:

(a) Place the container in a horizontal position approximately 100 mm above a uniform fire source with a length of 1,65 m. The arrangement of the fire shall be recorded in sufficient detail to ensure the rate of heat input to the container is reproducible. Any failure or inconsistency of the fire source during a test shall invalidate the result;

(b) If the container is ≤ 1,65 m, it shall be positioned centrically above the fire source;

(c) If the container is > 1,65 m and it is fitted with a pressure relief device at only one end, the fire source shall commence at the opposite end;

(d) If the container is > 1,65 m and it is fitted with pressure relief devices at more than one location along its length, the centre of the fire source shall be centred midway between those pressure relief devices that are separated by the greatest horizontal distance;

(e) If the container is > 1,65 m and it is additionally protected by thermal insulation, 2 fire tests shall be performed at nominal working pressure. The container shall be positioned centrically above the fire source in one test, while the fire shall commence at one of the container ends in the other;

(f) Metallic shielding shall be used to prevent direct flame impingement on container valves, fittings, or pressure relief devices. The metallic shielding shall not be in direct contact with the pressure relief devices. Any failure during the test of a valve, fitting or tubing that is not part of the intended protection system for the design shall invalidate the result;

(g) Surface temperatures shall be monitored by at least three thermocouples located along the bottom of the container and spaced not more than 0,75 m apart. Metallic shielding shall be used to prevent direct flame impingement on the thermocouples. Alternatively, thermocouples may be inserted into blocks of metal measuring less than 25 mm × 25 mm × 25 mm;

(h) The fire source shall provide direct flame impingement on the container surface across its entire diameter immediately following ignition;

(i) Thermocouple temperatures and the container pressure shall be recorded at intervals of ≤ 10 seconds during the test;

(j) Within 5 minutes of ignition and for the remaining duration of the test the temperature of at least one thermocouple shall indicate at least 590 °C.

4.2.4.3. Requirement

The container shall vent through the pressure relief device(s) and shall not rupture.

4.2.4.4. Results

The results shall be presented in a test summary, as specified in the addendum to the EC type-approval certificate as set out in Part 2 to Annex II, and shall include at least the following data for each container:

(a) The elapsed time from ignition of the fire to the start of venting through the pressure relief device(s);

(b) The maximum pressure and time of evacuation until a pressure ≤ 1,0 MPa is reached.

4.2.5. *Penetration test*

4.2.5.1. Sampling

The test applies to all container types.

Type-approval testing — number of finished containers to be tested: 1

4.2.5.2. Procedure

The container, complete with protective coating, shall be tested in the following sequence:

(a) Pressurise with compressed gas to nominal working pressure ± 1,0 MPa;

(b) Completely penetrate at least one sidewall of the container by an armour piercing bullet or impactor with a diameter of 7,62 mm or greater. The projectile or impactor shall impact the sidewall at an approximate angle of 45°.

4.2.5.3. Requirement

The Container shall not rupture.

4.2.5.4. Results

The approximate size of the entrance and exit openings and their locations shall be presented in a test summary, as specified in the addendum to the EC type-approval certificate as set out in Part 2 to Annex II.

4.2.6. *Chemical exposure test*

4.2.6.1. Sampling

The test applies to type 2, 3 and 4 containers.

Type-approval testing — number of finished containers to be tested: 1

4.2.6.2. Procedure

The container, including coating if applicable, shall be tested in the following sequence:

(a) The upper section of the container shall be divided into five distinct areas and marked for pendulum impact preconditioning and fluid exposure. The five areas shall each be nominally 100 mm in diameter. The five areas do not need to be oriented along a single line, but shall not overlap;

(b) The approximate centre of each of the five areas shall be preconditioned by the impact of a pendulum body. The steel impact body of the pendulum shall 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 and 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 not be less than 30 J, and as close to that value as possible. During pendulum impact, the container shall be held in position by the end bosses or by the intended mounting brackets. The container shall be unpressurised during preconditioning;

(c) Each of the 5 preconditioned areas shall be exposed to one of five solutions. The five solutions are:

(i) Sulphuric acid — 19 per cent solution by volume in water;

(ii) Sodium hydroxide — 25 per cent solution by weight in water;

(iii) Methanol/gasoline — 5/95 per cent concentration;

(iv) Ammonium nitrate — 28 per cent solution by weight in water;

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

(d) During the exposure, orientate the container with the fluid exposure areas uppermost. Place a pad of glass wool approximately 0,5 mm thick and 100 mm in diameter on each of the five preconditioned exposure areas. 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;

(e) Pressure cycle between ≤ 2 MPa and ≥ 1,25 times nominal working pressure for the number of filling cycles calculated in accordance with section 2.7.6., at a maximum pressurisation rate of 2,75 MPa/s;

(f) Pressurise to 1,25 times nominal working pressure and hold at that pressure for a minimum of 24 hours until the elapsed exposure time (pressure cycling and pressure hold) to the environmental fluids equals at least 48 hours;

(g) Burst test in accordance with section 4.2.1.2.

4.2.6.3. Requirement

The container shall achieve a burst pressure of ≥ 1,8 times nominal working pressure.

4.2.6.4. Results

The burst pressure shall be presented in a test summary, as specified in the addendum to the EC type-approval certificate as set out in Part 2 to Annex II.

4.2.7. *Composite flaw tolerance test*

4.2.7.1. Sampling

The test applies to type 2, 3 and 4 containers.

Type-approval testing — number of finished containers to be tested: 1

4.2.7.2. Procedure

The container, complete with protective coating, shall be tested in the following sequence:

(a) Flaws in the longitudinal direction shall be cut into the over-wrap. The flaws shall be greater than the visual inspection limits as specified by the manufacturer, and at least the following flaws shall be cut in the longitudinal direction into the container sidewall:

(i) 25 mm long by 1,25 mm deep;

(ii) 200 mm long by 0,75 mm deep.

(b) Pressure cycle the flawed container between ≤ 2,0 MPa and ≥ 1,25 times nominal working pressure at ambient temperature for 3,0 times the number of filling cycles in accordance with section 2.7.6.

4.2.7.3. Requirement

The container shall not leak or rupture within 0,6 times the number of filling cycles in accordance with section 2.7.6., but may fail by leakage during the remaining test cycles.

4.2.7.4. Results

The number of cycles to failure, along with the location and description of the failure initiation shall be presented in a test summary, as specified in the addendum to the EC type-approval certificate as set out in Part 2 to Annex II.

4.2.8. *Accelerated stress rupture test*

4.2.8.1. Sampling

The test applies to type 2, 3 and 4 containers.

Type-approval testing — number of finished containers to be tested: 1

4.2.8.2. Procedure

The container, free of any protective coating, shall be tested in the following sequence:

(a) Pressurise to 1,25 times nominal working pressure for 1 000 hours at 85 °C;

(b) Burst test in accordance with section 4.2.1.2.

4.2.8.3. Requirement

The container shall achieve a burst pressure of ≥ 0,85 times the nominal working pressure times the burst pressure ratio given in section 3.6.

4.2.8.4. Results

The burst pressure shall be presented in a test summary, as specified in the addendum to the EC type-approval certificate as set out in Part 2 to Annex II.

4.2.9. *Extreme temperature pressure cycle test*

4.2.9.1. Sampling

The test applies to type 2, 3 and 4 containers.

Type-approval testing — number of finished containers to be tested: 1

4.2.9.2. Procedure

The containers, with the composite wrapping free of any protective coating, shall be hydrostatically cycle tested in the following sequence:

(a) Condition for 48 hours with a temperature ≥ 85 °C and a relative humidity ≥ 95 per cent;

(b) Pressure cycle between ≤ 2,0 MPa and ≥ 1,25 times nominal working pressure at a temperature ≥ 85 °C and a relative humidity ≥ 95 per cent, for 1,5 times the number of filling cycles calculated in accordance with section 2.7.6.;

(c) Stabilise at ambient conditions;

(d) Condition the container and test fluid to a temperature ≤ – 40 °C as measured on the container surface and in the fluid;

(e) Pressure cycle at ≤ – 40 °C between ≤ 2,0 MPa and ≥ nominal working pressure, for 1,5 times the number of filling cycles calculated in accordance with section 2.7.6.;

(f) Leak test ([1]) in accordance with section 4.2.11.;

(g) Burst test in accordance with section 4.2.1.2.

Explanatory note:

([1]) Applies to type 4 containers and type 3 with welded metal liners.

4.2.9.3. Requirement

The containers shall be cycle tested without showing evidence of rupture, leakage, or fibre unravelling.

If leak test is required, the leak test requirements shall be met.

The containers shall not burst at less than 85 per cent of the nominal working pressure times the burst pressure ratio given in section 3.6.

4.2.9.4. Results

The burst pressure shall be presented in a test summary, as specified in the addendum to the EC type-approval certificate as set out in Part 2 to Annex II.

4.2.10. *Impact damage test*

4.2.10.1. Sampling

The test applies to type 3 and 4 containers.

Type-approval testing — number of finished containers to be tested: minimum 1 (all impact tests may be performed on one container, or individual impacts on a maximum of 3 containers).

4.2.10.2. Procedure

4.2.10.2.1. The drop tests shall be performed at ambient temperature without internal pressurisation or attached valves. A plug may be inserted in the threaded ports to prevent damage to the threads and seal surfaces.

The surface onto which the container is dropped shall be a smooth, horizontal concrete pad or similar rigid floor.

The container shall be tested in the following sequence:

(a) Drop once from a horizontal position with the bottom 1,8 m above the ground;

(b) Drop once onto each end of the container from a vertical position with a potential energy ≥ 488 J, but in no case shall the bottom end be more than 1,8 m above the ground;

(c) Drop once at a 45° angle, and then for non-symmetrical or non-cylindrical containers rotate the container through 90° along its longitudinal axis and drop again at a 45° angle, with its centre of gravity 1,8 m above the ground. However, if the bottom 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 the centre of gravity 1,8 m above the ground;

(d) No attempt shall be made to prevent bouncing of the container, but it may be prevented from falling over during the vertical drop test;

(e) Pressure cycle the container between ≤ 2,0 MPa and ≥ 1,25 times nominal working pressure for three times the number of filling cycles calculated in accordance with section 2.7.6.

4.2.10.2.2. Alternatively for containers with a specific coating which indicates that the container was dropped, the drop height and the potential energy as described in 4.2.10.2.1. (a) through (c) shall be half of the values (i.e. 0,9 m instead of 1,8 m, 0,3 m instead of 0,6 m, 244 Joule instead of 488 Joule).

4.2.10.3. Requirements

The container shall not leak or rupture within 0,6 times the number of filling cycles calculated in accordance with section 2.7.6., but may fail by leakage during the remaining test cycles.

Additionally, for containers with a specific coating as referred to under 4.2.10.2.2., as result of the drop this coating shall show clearly visible deformations as specified by the container manufacturer.

4.2.10.4. Results

The number of cycles to failure, along with the location and description of the failure initiation shall be presented in a test summary, as specified in the addendum to the EC type-approval certificate as set out in Part 2 to Annex II.

4.2.11. *Leak test*

4.2.11.1. Sampling

The test applies to type 4 containers and type 3 with welded metal liners.

Type-approval testing — number of finished containers to be tested: 1

Batch testing — number of finished containers to be tested per batch: in accordance with section 3.9.1.

Production testing — number of finished containers to be tested: all

4.2.11.2. Procedure

The container shall be thoroughly dried and pressurised for at least 3 minutes to nominal working pressure with leak test gas.

For batch testing, follow the test sequence given in explanatory note (6) to Table IV.3.9.

4.2.11.3. Requirement

Any leakage detected through cracks, pores, unbonds or similar defects shall cause the container to be rejected. Permeation through the wall in accordance with section 4.2.12. is not considered to be leakage

4.2.11.4. Results

The test results shall be presented in a test summary, as specified in the addendum to the EC type-approval certificate as set out in Part 2 to Annex II. The leakage rate is applicable to tests carried out with 100 per cent hydrogen only. Leakage rates for other gases or gas mixtures shall be converted to an equivalent leakage rate to that for 100 per cent hydrogen.

4.2.12. *Permeation test*

4.2.12.1. Sampling

The test applies to type 4 containers only.

Type-approval testing — number of finished containers to be tested: 1

4.2.12.2. Procedure

Special consideration shall be given to safety when conducting this test.

The container shall be tested in the following sequence:

(a) Pressurise with hydrogen gas to nominal working pressure;

(b) Place in an enclosed sealed chamber at 15 °C ± 2 °C and monitor for permeation for 500 hours or until steady state behaviour is kept for a period of at least 48 hours.

4.2.12.3. Requirements

The steady state permeation rate shall be less than 6,0 Ncm^3 per hour of hydrogen per litre internal volume of the container.

4.2.12.4. Results

The steady state permeation rate shall be presented in a test summary, as specified in the addendum to the EC type-approval certificate as set out in Part 2 to Annex II.

4.2.13. *Boss torque test*

4.2.13.1. Sampling

The test applies to type 4 containers only.

Type-approval testing — number of finished containers to be tested: 1

Batch testing — number of finished containers to be tested per batch: in accordance with section 3.9.1.

4.2.13.2. Procedure

The container shall be tested in the following sequence:

(a) Restrain the body of the container against rotation;

(b) Apply a torque of 2 times the valve or pressure relief device installation torque specified by the manufacturer to each end boss of the container; first in the direction to tighten the threaded connection, then in the direction to loosen, and finally again in the direction to tighten;

(c) For type-approval, the following tests shall also be conducted:

  (i) Leak test in accordance with section 4.2.11.;

  (ii) Burst test in accordance with sections 4.2.1.2. and 4.2.1.3.

For batch testing, follow the test sequence given in explanatory note (6) to Table IV.3.9.

4.2.13.3. Requirement

For type-approval, the container shall meet the leak and burst test requirements.

For batch testing, the container shall meet the leak test requirements.

4.2.13.4. Results

The applied torque, leakage and burst pressure shall be presented in a test summary, as specified in the addendum to the EC type-approval certificate as set out in Part 2 to Annex II. The leakage rate is applicable to tests carried out with 100 per cent hydrogen only. Leakage rates for other gases or gas mixtures shall be converted to an equivalent leakage rate to that for 100 per cent hydrogen.

The manufacturer shall keep the results on file throughout the service life of the container.

4.2.14. *Hydrogen gas cycling test*

4.2.14.1. Sampling

The test applies to type 4 containers and type 3 with welded metal liners.

Type-approval testing — number of finished containers to be tested: 1

4.2.14.2. Procedure

Special consideration shall be given to safety when conducting this test.

The container shall be tested in the following sequence:

(a) Use hydrogen gas to pressure cycle the container between ≤ 2,0 MPa and ≥ nominal working pressure for 1 000 cycles. The filling time shall not exceed 5 minutes. Temperatures during venting shall not exceed the values specified in section 2.7.5;

(b) Leak test in accordance with section 4.2.11.

Section the container and inspect the liner and liner/end boss interface for evidence of any deterioration, such as fatigue cracking or electrostatic discharge.

4.2.14.3. Requirement

The container shall meet the leak test requirements.

The liner and liner/end boss interface shall be free of any deterioration, such as fatigue cracking or electrostatic discharge.

4.2.14.4. Results

The total leakage value shall be presented in a test summary, as specified in the addendum to the EC type-approval certificate as set out in Part 2 to Annex II.

4.2.15. *Hydraulic test*

4.2.15.1. Sampling

The test applies to all container types.

Production testing — number of finished containers to be tested: all

4.2.15.2. Procedure and Requirement

(a) The container shall be pressurised to ≥ 1,5 times nominal working pressure. Under no circumstance may the pressure exceed the auto-frettage pressure;

(b) The pressure shall be maintained for at least 30 seconds to ensure complete expansion. If the pressure cannot be maintained due to failure of the test apparatus, it is permissible to repeat the test at a pressure increased by 0,7 MPa. Not more than two such repeat tests are permitted;

(c) For type 1, 2 or 3 containers, the manufacturer shall define the appropriate limit of permanent volumetric expansion for the test pressure used, but in no case shall the permanent expansion exceed 5 per cent of the total volumetric expansion measured under the test pressure. Permanent expansion is defined as the residual volumetric expansion after the pressure has been released;

(d) For type 4 containers, the manufacturer shall define the appropriate limit of elastic expansion for the test pressure used, but in no case shall the elastic expansion of any container exceed the average batch value by more than 10 per cent. Elastic expansion is defined as the total expansion less the permanent expansion (see point (c));

(e) Any container that does not meet the defined expansion limit shall be rejected, but may still be used for batch test purposes.

4.2.15.3. Results

The results shall be presented in a test summary, as specified in the addendum to the EC type-approval certificate as set out in Part 2 to Annex II.

The manufacturer shall keep the results on file throughout the service life of the container.

PART 3

Requirements for hydrogen components other than containers designed to use compressed (gaseous) hydrogen

1. INTRODUCTION

This Part sets out the requirements and test procedures for hydrogen components other than containers designed to use compressed (gaseous) hydrogen.

2. GENERAL REQUIREMENTS

2.1. Hydrogen components other than containers shall be type approved pursuant to the provisions laid down in this Part.

2.2. Unless otherwise stated in this Regulation, the parts of a removable storage system connector mounted on the removable storage system and on the vehicle shall be treated as separate components.

2.3. Electrical part of a component potentially in contact with ignitable hydrogen-air mixtures shall:

2.3.1. be insulated in such a manner that no current passes through hydrogen containing parts,

2.3.2. be insulated from the:

(a) body of the component;

(b) container or container assembly.

2.4. Welded connections upstream of the first pressure regulator shall be hydraulically pressure tested to three times nominal working pressure without rupturing. Welded connections downstream of the first pressure regulator shall be hydraulically pressure tested to three times maximum allowable working pressure without rupturing.

3. TECHNICAL REQUIREMENTS

3.1. **General requirements**

3.1.1. Unless otherwise stated in this Part all tests shall be performed at ambient temperature.

3.1.2. Explosive gas mixtures shall be prevented from developing during the test procedures described in this Part.

3.1.3. The test period for leakage and pressure tests shall be not less than 3 minutes.

3.1.4. Unless otherwise stated the applied test pressure shall be measured at the inlet of the component under test.

3.1.5. If a component is exposed to the pressure due to refilling operations, then filling cycles shall be used. If a component is exposed to pressure due to the operation of the vehicle, i.e. switching of the vehicle activation switch, then duty cycles shall be used.

3.1.6. In addition to the requirements given below, the manufacturer shall complete all documents referred to in section 4 and submit them to the competent authority when applying for type-approval.

3.1.7. The components shall be subjected to the applicable test procedures as referred to in the table in Annex V to Regulation (EC) No 79/2009. The tests shall be conducted on components that are representative of normal production and shall have the manufacturer's identification marks.

3.1.8. The tests specified in section 4.2. shall be conducted on the same samples of components in the sequence given in the table in Annex V to Regulation (EC) No 79/2009 unless otherwise indicated, e.g. for fittings the corrosion resistance test (4.2.1.) shall be followed by an endurance test (4.2.2.), then by an hydraulic pressure cycle test (4.2.3.), and finally by an external leakage test (4.2.5.). If a component does not contain metallic sub-components the testing shall commence with the first applicable test.

3.2. **Specific requirements**

3.2.1. Approval for a flexible fuel line shall be given for any length with a minimum bending radius specified by the manufacturer and shall be assembled with a specific type of fitting.

3.2.2. Any reinforcing interlayer of a flexible fuel line shall be protected against corrosion either by a cover or by using a corrosion resistant material for the reinforcement(s), e.g. stainless steel. If a cover is used the formation of bubbles between layers shall be prevented.

3.2.3. Flexible fuel lines shall have an electrical resistance of less than 1 mega-ohm per meter.

3.2.4. The profile of the receptacle shall comply with the dimensions set out in Figures 3.2.1. to 3.2.3., depending on its nominal working pressure, where H x means a nominal working pressure of x MPa at 15 °C:

Figure 3.2.1.

H35 Hydrogen receptacle

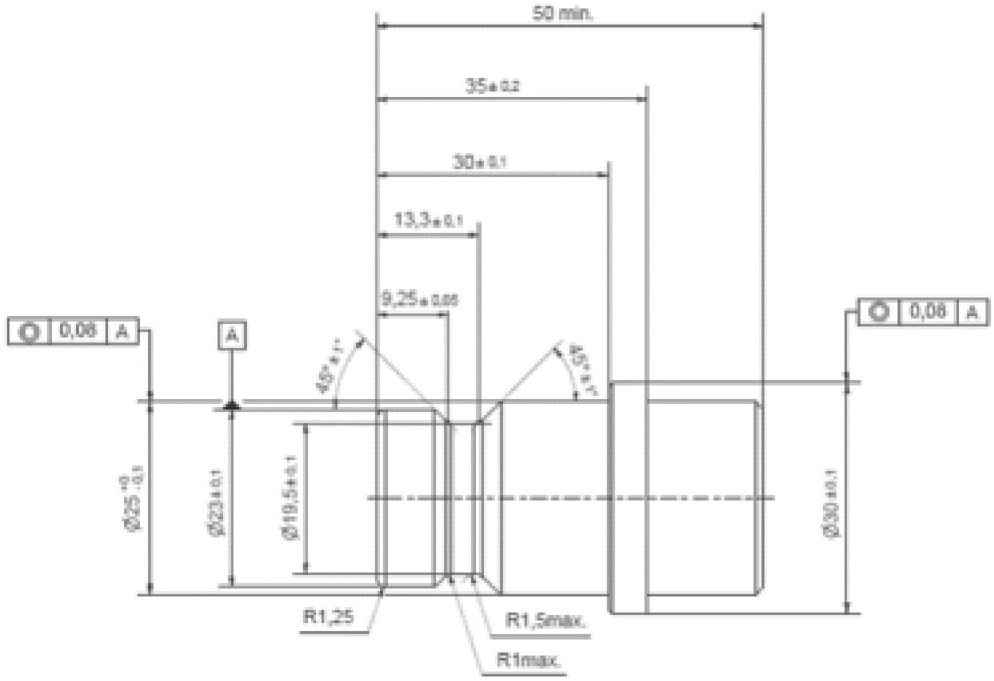


Figure 3.2.2.

H35HF Hydrogen receptacle (high flow for commercial vehicle applications)

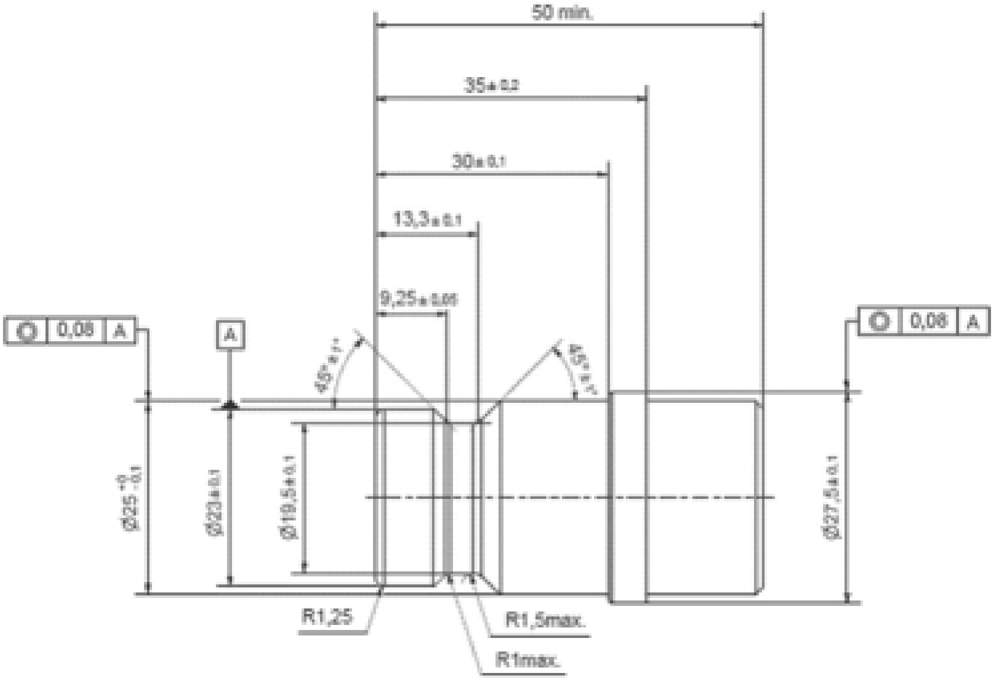
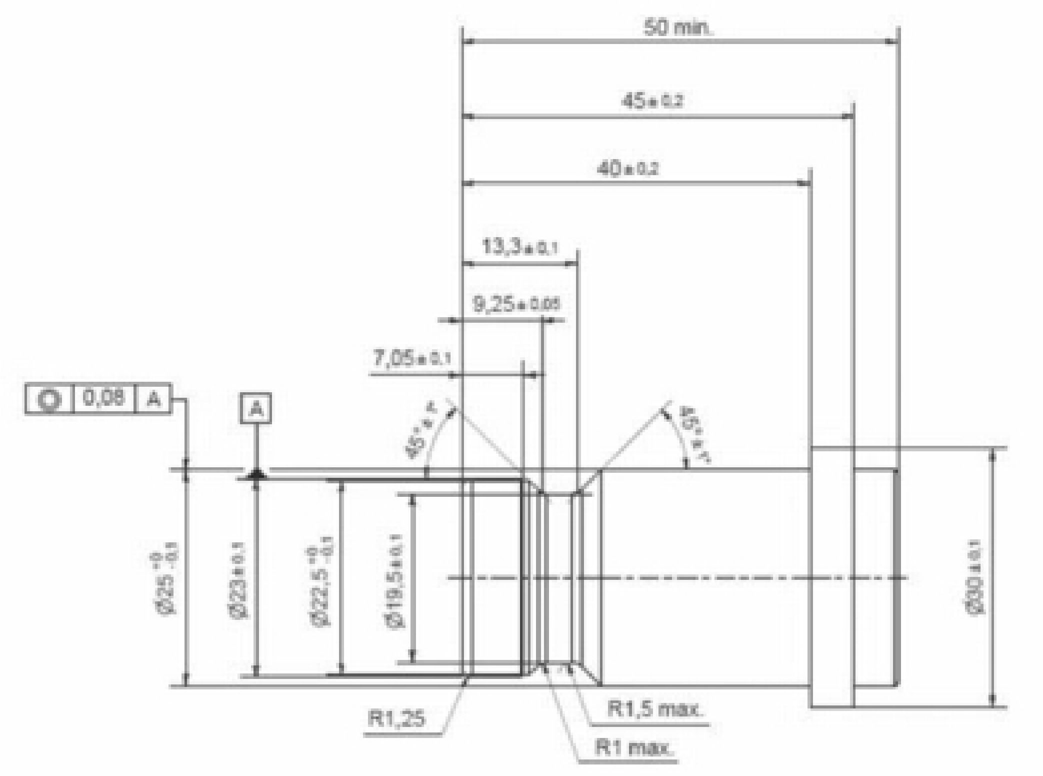


Figure 3.2.3.

H70 Hydrogen receptacle



3.2.5. Sufficient ductility of metallic pipes shall be proved by a bend test according to ISO 8491. Bend radius r should be r ≤ 1,3 times the outer diameter D of the pipe. Bending angle α shall be 180°. After the test no cracks shall be visible. Alternatively the pipe material shall show at least 30 % elongation at break before cold forming or at least 14 % after cold forming.

4. TEST PROCEDURES

4.1. **Material tests**

4.1.1. *Hydrogen compatibility test*

4.1.1.1. Sampling

The test applies to the materials used in a specific component where the material is in contact with hydrogen except:

(a) Aluminium alloys that conform to sections 6.1. and 6.2. of ISO 7866;

(b) Steels that conform to section 6.3. and 7.2.2. of ISO 9809-1.

Number of material samples to be tested: 3

4.1.1.2. Procedure and Requirements

(a) For metallic materials other than those stated above hydrogen compatibility shall be demonstrated in accordance with ISO 11114-1 and ISO 11114-4. Alternatively, manufacturers shall perform material qualification tests in hydrogen environments as anticipated in service. Based on the results, design should take into account the reduction in mechanical properties (ductility, fatigue strength, fracture toughness, etc.) that may occur;

(b) Non-metallic materials: hydrogen compatibility shall be demonstrated.

4.1.1.3. Results

The results of the tests shall be presented in a test summary.

4.1.2. *Ageing test*

4.1.2.1. Sampling

All non-metallic materials used in a specific component shall be tested.

Number of material samples to be tested: 3

4.1.2.2. Procedure and Requirements

Special consideration shall be given to safety when conducting this test.

The test shall be undertaken in accordance with ASTM D572. The sample shall be exposed to oxygen at the maximum material temperature in accordance with section 2.7.5.1. at 2,0 MPa for a period of 96 hours. Either the tensile strength and elongation or the microhardness shall comply with the specifications given by the manufacturer. No visible cracking of the test samples is allowed.

4.1.2.3. Results

The results of the tests shall be presented in a test summary.

4.1.3. *Ozone compatibility test*

4.1.3.1. Sampling

The test applies to elastomer materials where:

(a) A sealing surface is exposed directly to air, e.g. facing seal of a receptacle;

(b) Used as a flexible fuel line cover.

Number of material samples to be tested: 3

4.1.3.2. Procedure and Requirements

The test shall be undertaken in accordance with ISO 1431-1.

The test samples shall be stressed to 20 per cent elongation and exposed to air at + 40 °C with an ozone concentration of 0,5 parts per million for a period of 120 hours.

No visible cracking of the test samples is allowed.

4.1.3.3. Results

The results of the tests shall be presented in a test summary.

4.2. **Component tests**

4.2.1. *Corrosion resistance test*

4.2.1.1. Sampling

Number of components to be tested: 3

4.2.1.2. Procedure and Requirements

Testeta: Metallic components shall be submitted to a 144 hour salt spray test in accordance with ISO 9227 with all connections closed and shall meet the requirements therein.

Test b: A copper alloy component shall also be submitted to 24 hours immersion in ammonia in accordance with ISO 6957 with all connections closed and shall meet the requirements therein.

4.2.1.3. Results

The results of the tests shall be presented in a test summary.

4.2.2. *Endurance test*

4.2.2.1. Sampling

Number of components to be tested: 3

4.2.2.2. Procedures and Requirements

4.2.2.2.1. The component shall be tested in accordance with the following procedure:

(a) Pressurise the component with dry air, nitrogen, helium or hydrogen to nominal working pressure and subject it to 96 per cent of the total number of test cycles in accordance with Table 4.2.2. at ambient temperature. A complete test cycle shall take place over a period of not less than 10 ± 2 seconds. When the valve is in the closed position the downstream pressure shall decay to 0,5 times the nominal working pressure of the component or lower. The component shall fulfil the requirements of the internal and external leakage tests (sections 4.2.4. and 4.2.5. respectively) at this temperature;

(b) The component shall then be operated through 2 per cent of the total number of test cycles at the minimum material temperature in accordance with section 2.7.5.1. after sufficient conditioning time at this temperature to ensure thermal stability. The component shall fulfil the requirements of the internal and external leakage tests (sections 4.2.4. and 4.2.5. respectively) at this temperature;

(c) The component shall then be operated through 2 per cent of the total number of test cycles at the maximum material temperature in accordance with section 2.7.5.1. after sufficient conditioning time at this temperature to ensure thermal stability and at 1,25 times nominal working pressure. The component shall fulfil the requirements of the internal and external leakage tests (sections 4.2.4. and 4.2.5. respectively) at this temperature.

Table 4.2.2.

Test cycles for valves

Component	No. of test cycles
Automatic valve	1,5 times the number of duty cycles or filling cycles in accordance with section 2.7.6. or 2.7.7., as appropriate to the use of the valve.
Manual valve	100
Non-return valve	2,0 times the number of duty cycles or filling cycles in accordance with section 2.7.6. or 2.7.7., as appropriate to the use of the valve.

4.2.2.2.2. *Fittings*

Fittings shall be subjected to 25 connection/disconnection cycles

4.2.2.2.3. *Flexible fuel lines*

The length of the flexible part of the flexible fuel line with its fittings attached, to be used in the following test shall be calculated as follows:

$$L = 4{,}142R + 3{,}57D$$

where:

L = Length of the flexible part of the flexible fuel line

R = Minimum bending radius specified by the manufacturer

D = Outside diameter of the flexible fuel line

The flexible fuel line shall be bent in the manner depicted in Figure 4.2.2. and attached to a fixture in that position by the fittings with which it shall be approved. One end of the flexible fuel line shall be attached to a reciprocating manifold and the other end shall be attached to a stationary manifold connected to a hydraulic supply. The flexible fuel line shall be pressurised quickly by means of a quick opening solenoid valve, such that one cycle consists of holding the pressure at 1,25 times the nominal working pressure for 10 ± 1 seconds (except for flexible fuel lines with a required material temperature of 120 °C where the hold pressure shall be 1,37 times nominal working pressure) and then reducing it to less than 0,1 times the nominal working pressure for 5 ± 0,5 seconds. The total number of test cycles shall be equal to 2,0 times the number of filling cycles or duty cycles as appropriate to the use of the flexible fuel line in accordance with section 2.7.6. or 2.7.7. As appropriate 50 per cent of the test cycles shall be performed at the minimum and the remaining 50 per cent at the maximum material temperature in accordance with section 2.7.5.1.

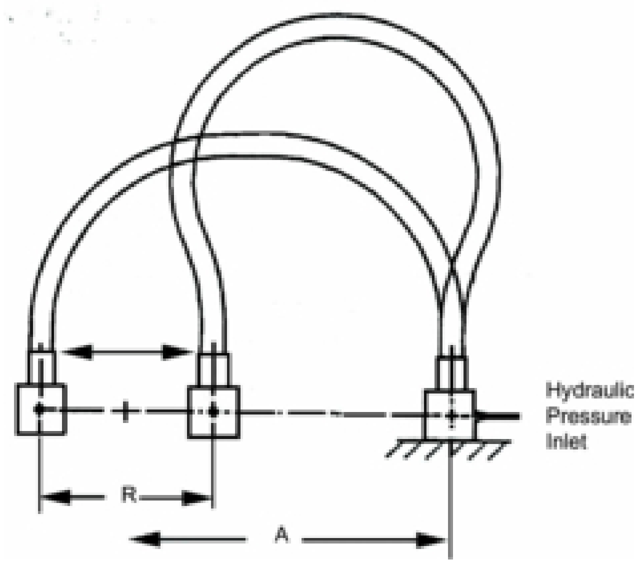
Superimposed on the hydraulic pressure cycles is a flexing cycle. The flexing rate shall be 6 ± 2 per cent of the hydraulic pressure cycling rate. This assures that the flexible fuel line is in a different configuration on each succeeding pressure cycle impulse. The test fixture is shown in Figure 4.2.2. with the distance A calculated as:

$$A = 1{,}75R + D$$

The flexible fuel line shall not show any visible signs of damage.

Figure 4.2.2.

Flex-impulse testing fixture



4.2.2.2.4. *Pressure regulators*

(a) The pressure regulator shall be connected to a source of leak test gas at nominal working pressure and cycled through 95 per cent of the number of duty cycles calculated in accordance with section 2.7.7. One cycle shall consist of flow until stable outlet pressure has been attained, after which the gas flow shall be shutoff by a downstream quick closing valve until stable lockup pressure has been achieved. The pressure regulator shall then fulfil the requirements of the internal and external leakage tests (sections 4.2.4. and 4.2.5. respectively) conducted at ambient temperature;

(b) The inlet of the pressure regulator shall be pressure cycled through 1 per cent of the number of duty cycles from nominal working pressure to 0,5 times the nominal working pressure or less. Subsequently the pressure regulator shall fulfil the requirements of the internal and external leakage tests (sections 4.2.4. and 4.2.5. respectively) conducted at ambient temperature;

(c) The cycling procedure in (a) above shall be repeated at the maximum material temperature in accordance with section 2.7.5.1. and at 1,25 times the nominal working pressure for 1 per cent of the number of duty cycles. Subsequently the pressure regulator shall fulfil the requirements of the internal and external leakage tests (sections 4.2.4. and 4.2.5. respectively) conducted at the maximum material temperature;

(d) The cycling procedure in (b) above shall be repeated at the maximum material temperature and at 1,25 times the nominal working pressure for 1 per cent of the number of duty cycles. Subsequently the pressure regulator shall fulfil the requirements of the internal and external leakage tests (sections 4.2.4. and 4.2.5. respectively) conducted at the maximum material temperature;

(e) The cycling procedure in (a) above shall be repeated at the minimum material temperature in accordance with section 2.7.5.1. and at nominal working pressure for 1 per cent of the number of duty cycles. Subsequently the pressure regulator shall fulfil the requirements of the internal and external leakage tests (sections 4.2.4. and 4.2.5. respectively) conducted at the minimum material temperature;

(f) The cycling procedure in (b) above shall be repeated at the minimum material temperature and at nominal working pressure for 1 per cent of the number of duty cycles. Subsequently the pressure regulator shall fulfil the requirements of the internal and external leakage tests (sections 4.2.4. and 4.2.5. respectively) conducted at the minimum material temperature.

4.2.2.2.5. *Pressure relief devices*

(a) Creep test

Pressure relief devices shall be hydrostatically pressurised to 1,25 times nominal working pressure and held for 500 hours at a temperature (TL) calculated from the following equation:

$$TL = T\ (0{,}057)\ (0{,}34\ \log(T/Tf))$$

where

TL = Test temperature, °C

Tf = Activation temperature of the pressure relief device, °C

T = 82 °C

Log is base 10.

Pressure relief devices shall not show signs of deformation caused by creep and shall fulfil the requirements of the internal leakage test (section 4.2.4.) after being subjected to the above test;

(b) Activation temperature

Following the creep test in a) above, the pressure relief devices shall be pressurised with dry air, nitrogen, helium or hydrogen to nominal working pressure. Subsequently the pressure relief devices shall be exposed to an increasing temperature cycle starting from ambient temperature with a rate not exceeding 10 °C per minute until the specified activation temperature minus 10 °C is reached and then with a rate of not exceeding 2 °C per minute until the pressure relief devices activate. The activation temperature shall be within a range of ± 5 per cent of the manufacturer's specified activation temperature. After activation the pressure relief devices shall show no evidence of fragmentation.

4.2.2.2.6. *Pressure Relief Valves*

Pressurise the pressure relief valve for 25 cycles. A test cycle consists of pressurising the pressure relief valve to the activation pressure causing the pressure relief valve to open and vent. Once the pressure relief valve is venting the inlet pressure shall be reduced causing the pressure relief valve to re-seat. The cycle time shall be a period of 10 ± 2 s. For the final cycle the activation pressure shall be reported and shall correspond to the activation pressure specified by the manufacturer within a range of ± 10 per cent.

4.2.2.2.7. *Receptacles*

Receptacles shall be submitted to a number of connection/disconnection cycles equal to three times the number of filling cycles calculated in accordance with section 2.7.6. For each cycle the receptacle shall be pressurised to 1,25 times the nominal working pressure.

4.2.2.2.8. *Sensors for hydrogen systems*

If a sensor is intended to be installed into a hydrogen component and is subjected to the same number of duty cycles or filling cycles, it shall be subjected to the same endurance test as the hydrogen component into which it is installed.

4.2.2.2.9. *Removable storage system connector*

A removable storage system connector shall be submitted to a number of connection/disconnection cycles equal to three times the number of filling cycles calculated in accordance with section 2.7.6. For each cycle the removable storage system connector shall be pressurised to 1,25 times the nominal working pressure. Subsequently the removable storage system connector shall fulfil the requirements of the external leakage test (section 4.2.5.) when the parts of the removable storage system connector mounted on the vehicle and on the removable storage system are separated and also when connected together.

4.2.2.3. Results

The results of the test shall be presented in a test summary.

4.2.3. *Hydraulic pressure cycle test*

4.2.3.1. Sampling

Number of components to be tested: 3

4.2.3.2. Procedure and Requirements

4.2.3.2.1. *Pressure relief devices*

Pressure relief devices shall be subjected to 1,5 times the number of filling cycles calculated in accordance with section 2.7.6. at both the minimum and maximum material temperatures in accordance with section 2.7.5.1.

The pressure shall periodically change from 2 MPa to 1,25 times nominal working pressure at a rate not exceeding 6 cycles per minute, except when tested at the minimum material temperature when the maximum test pressure shall be nominal working pressure.

If fusible metal is used in a pressure relief device it shall show no additional visible sign of extrusion beyond the initial settling.

4.2.3.2.2. *Components other than pressure relief devices*

Before the cycling test described below, the components shall be subjected to a hydraulic test pressure of 1,5 times nominal working pressure or maximum allowable working pressure as applicable. The components shall not show signs of permanent deformation or visible leaks.

The components shall be subjected to 3 times the number of filling cycles or duty cycles calculated in accordance with section 2.7.6. or 2.7.7.

The pressure shall periodically change from 2,0 MPa to 1,25 times nominal working pressure for components upstream of the first pressure regulator, or from 0,1 times MAWP to MAWP for components downstream of the first pressure regulator, at a rate not exceeding 6 cycles per minute.

Subsequently the component shall fulfil the requirements of the internal and external leakage tests (sections 4.2.4. and 4.2.5.).

4.2.3.3. Results

The results of the tests shall be presented in a test summary.

4.2.4. *Internal leakage test*

4.2.4.1. Sampling

Number of components to be tested: 3

4.2.4.2. Procedure

The components shall be tested using leak test gas and shall be pressurised at the inlet of the component when it is in its characteristic closed position and with the corresponding outlet port open.

The components shall be tested at the following conditions:

(a) At ambient temperature and at 0,02 times nominal working pressure and at nominal working pressure. Where an external leakage test (section 4.2.5.) is also required at this temperature it may be undertaken before the next stage of this test;

(b) At the minimum material temperature in accordance with section 2.7.5.1., after sufficient conditioning time at this temperature to ensure thermal stability and at 0,02 times nominal working pressure and at nominal working pressure. Where an external leakage test (section 4.2.5.) is also required at this temperature it may be undertaken before the next stage of this test;

(c) At the maximum material temperature in accordance with section 2.7.5.1., after sufficient conditioning time at this temperature to ensure thermal stability and at 0,02 times nominal working pressure and 1,25 times nominal working pressure, except for components with a required material temperature of 120 °C where the higher test pressure shall be 1,37 times nominal working pressure.

The component shall be observed for leakage with its outlet port open. The leakage can be determined by a flowmeter installed on the inlet side of the component or by another test method, which has been demonstrated to be equivalent.

4.2.4.3. Requirements

When pressurised, the component shall stay bubble free for three minutes or shall not leak internally at a rate exceeding 10 Ncm^3 per hour.

4.2.4.4. Results

The results of the test shall be presented in a test summary.

4.2.5. *External leakage test*

4.2.5.1. Sampling

Number of components to be tested: 3

4.2.5.2. Procedure

The components shall be tested using leak test gas at the following conditions:

(a) At ambient temperature and at 0,02 times nominal working pressure;

(b) At ambient temperature and at nominal working pressure;

(c) At the minimum required material temperature, in accordance with section 2.7.5.1., after sufficient conditioning time at this temperature to ensure thermal stability and at 0,02 times nominal working pressure and at nominal working pressure;

(d) At the maximum required material temperature, in accordance with section 2.7.5.1., after sufficient conditioning time at this temperature to ensure thermal stability and at 0,02 times nominal working pressure and 1,25 times nominal working pressure, except for components with a required material temperature of 120 °C where the higher test pressure shall be 1,37 times nominal working pressure.

For heat exchangers this test shall only be undertaken on the hydrogen circuit.

4.2.5.3. Requirements

Throughout the test the component shall be free from leakage through stem or body seals or other joints, and shall not show evidence of porosity in casting, demonstrated by a surface active agent without formation of bubbles for 3 minutes or measured with a combined leakage and permeation rate less than 10 Ncm^3 per hour (for flexible fuel lines only 10 Ncm^3 per hour per meter) or it shall be tested by using a demonstrated equivalent test method. The permitted leakage rate is applicable to tests with 100 per cent hydrogen only. Permitted leakage rates for other gases or gas mixtures shall be converted to an equivalent leakage rate to that for 100 per cent hydrogen.

4.2.5.4. Results

The results of the test shall be presented in a test summary.

ANNEX V

Vehicle identification requirements

1. INTRODUCTION

1.1. Hydrogen vehicles shall be equipped with means of identification as set out in this Annex.

2. REQUIREMENTS

2.1. Hydrogen vehicles shall carry labels as specified in section 3 and 4.

2.1.1. In the case of hydrogen vehicles of categories M_1 and N_1 one label shall be installed within the engine compartment of the vehicle and one in the vicinity of the refuelling device or receptacle.

2.1.2. In the case of hydrogen vehicles of categories M_2 and M_3, labels shall be installed: on the front and rear of the vehicle; in the vicinity of the refuelling device or receptacle; and to the side of each set of doors.

2.1.3. In the case of public service hydrogen vehicles of categories M_2 and M_3, the labels installed on the front and rear of the vehicle shall be of the size as set out in section 4.

2.1.4. In the case of hydrogen vehicles of categories N_2 and N_3, labels shall be installed: on the front and rear of the vehicle; and in the vicinity of the refuelling device or receptacle.

2.2. The label shall be either a weather resistant adhesive label or a weather resistant plate.

3. LABELS FOR HYDROGEN VEHICLES

3.1. **Labels for hydrogen vehicles using liquid hydrogen**

The colour and dimensions of the label shall fulfil the following requirements:

Colours:

Background: green

Border: white

Letters: white

Either the borders and letters or the background shall be retro-reflective.

Colorimetric and photometric properties shall comply with the requirements of clause 11 of ISO 3864-1.

Dimensions of the label:

Width:	40 mm (side length)
Height:	40 mm (side length)
Border width:	2 mm

Font size:

Font height:	9 mm
Font thickness:	2 mm

The words shall be in upper case characters and shall be centred in the middle of the label.

3.2. **Labels for hydrogen vehicles using compressed (gaseous) hydrogen**

The colour and dimensions of the label shall fulfil the following requirements:

Colours:

Background:	Green
Border:	White
Letters:	White

Either the borders and letters or the background shall be retro-reflective.

Colorimetric and photometric properties shall comply with the requirements of clause 11 of ISO 3864-1.

Dimensions:

Width:	40 mm (side length)
Height:	40 mm (side length)
Border width:	2 mm

Font size:

Font height: 9 mm

Font thickness: 2 mm

The words shall be in upper case characters and shall be centred in the middle of the label.

4. LABELS FOR PUBLIC SERVICE HYDROGEN VEHICLES OF CATEGORIES M_2 AND M_3 TO BE INSTALLED ON THE FRONT AND REAR OF THE VEHICLE

4.1. **Labels for hydrogen vehicles using liquid hydrogen**

The colour and dimensions of the label shall fulfil the following requirements:

Colours:

Background: green

Border: white

Letters: white

Either the borders and letters or the background shall be retro-reflective.

Colorimetric and photometric properties shall comply with the requirements of clause 11 of ISO 3864-1.

Dimensions of the label

Width: 125 mm (side length)

Height: 125 mm (side length)

Border width: 5 mm

Font size:

Font height: 25 mm

Font thickness: 5 mm

The words shall be in upper case characters and shall be centred in the middle of the label.

4.2. **Labels for hydrogen vehicles using compressed (gaseous) hydrogen**

The colour and dimensions of the label shall fulfil the following requirements:

Colours:

Background:	Green
Border:	White
Letters:	White

Either the borders and letters or the background shall be retro-reflective.

Colorimetric and photometric properties shall comply with the requirements of clause 11 of ISO 3864-1.

Dimensions:

Width:	125 mm (side length)
Height:	125 mm (side length)
Border width::	5 mm

Font size:

Font height:	25 mm
Font thickness:	5 mm

The words shall be in upper case characters and shall be centred in the middle of the label.

ANNEX VI

Safety requirements of complex electronic vehicle control systems

1. INTRODUCTION

This Annex sets out the requirements and test procedures for the safety aspects of complex electronic vehicle control systems.

2. DOCUMENTATION REQUIREMENTS

2.1. **General requirements**

The manufacturer shall provide a documentation package, which describes the basic design of the safety instrumented system and the means by which it is linked to other vehicle systems or by which it directly controls output variables. The function(s) of the safety instrumented system and the safety concept, as laid down by the manufacturer, shall be explained in the documentation. For the purpose of inspections, the documentation shall indicate the means by which the current operational status of the system can be checked.

Documentation shall be provided in two parts:

(a) The formal documentation of the safety instrumented system for the purposes of approval, containing the information listed in sections 2.2. to 2.4. This shall serve as the basic reference for the approval process set out in section 3.

(b) Any additional material and analysis data relevant for the approval of the safety instrumented system.

2.2. **Description of the functions of the safety instrumented system**

A description shall be provided which gives a simple explanation of all the control functions of the safety instrumented system and the methods used to achieve the objectives, including a description of the mechanism(s) by which control is exercised including:

(a) A list of all input and sensed variables and their working range;

(b) A list of all output variables that are controlled by the safety instrumented system and an indication, in each case, of whether the control is direct or via another vehicle system. The range of control exercised on each such variable shall be defined;

(c) Where appropriate to system performance, limits defining the boundary of functional operation.

2.3. **System layout and schematics**

2.3.1. *Inventory of components*

A list shall be provided, collating all the units of the safety instrumented system and mentioning the other vehicle systems that are needed to achieve the control function in question. An outline schematic showing these units in combination shall be provided with both the equipment distribution and the interconnections clearly identified.

2.3.2. *Functions of the units*

The function of each unit of the safety instrumented system shall be outlined and the signals linking it with other units or with other vehicle systems shall be shown. This may be provided by a labelled block diagram or other schematic, or by a description aided by such a diagram.

2.3.3. *Interconnections*

A circuit diagram shall show interconnections within the safety instrumented system for the electric transmission links, by a piping diagram for pneumatic or hydraulic transmission links and by a simplified diagrammatic layout for mechanical transmission links.

2.3.4. *Signal flow and priorities*

There shall be a clear correspondence between these transmission links and the signals carried between units. Priorities of signals on multiplexed data paths shall be stated, wherever priority may be an issue affecting performance or safety.

2.3.5. *Identification of units*

Each unit shall be clearly and unambiguously identifiable to provide corresponding hardware and documentation association. Where functions are combined within a single unit or indeed within a single computer, but shown in multiple blocks in the block diagram for clarity and ease of explanation, only a single hardware identification marking shall be used. The manufacturer shall, by the use of this identification, affirm that the equipment supplied conforms to the corresponding document.

2.3.5.1. The identification defines the hardware and software version and, where the latter changes such as to alter the function of the unit, this identification shall also be changed.

2.4. **Safety concept of the vehicle manufacturer**

2.4.1. The manufacturer shall ensure that the strategy chosen to achieve the safety instrumented system's objectives will not, under non-fault conditions, prejudice the safe operation of systems which are subject to the requirements of this Regulation.

2.4.2. In respect of software employed in the safety instrumented system, the outline architecture shall be explained and the design methods and tools used shall be identified. The manufacturer shall be prepared, if required, to show some evidence of the means by which they determined the realisation of the system logic, during the design and development process.

2.4.3. The manufacturer shall provide the technical service with an explanation of the design provisions built into the safety instrumented system so as to generate safe operation under fault conditions. Possible design provisions for failure in the safety instrumented system are:

(a) Fall-back to operation using a partial system;

(b) Change-over to a separate back-up system;

(c) Removal of the high level function.

2.4.3.1. If the chosen design provision selects a partial performance mode of operation under certain fault conditions, then these conditions shall be stated and the resulting limits of effectiveness defined.

2.4.3.2. If the chosen design provision selects a second (back-up) means to realise the vehicle control system objective, the principles of the change-over mechanism, the logic and level of redundancy and any built in back-up checking features shall be explained and the resulting limits of back-up effectiveness defined.

2.4.3.3. If the chosen design provision selects the removal of the higher-level system/function, all the corresponding output control signals associated with this function shall be inhibited, and in such a manner as to limit the transition disturbance.

2.4.3.4. Higher-level systems/functions shall allow complex systems to automatically change their objectives with a priority which depends on the sensed circumstances.

2.4.4. The documentation shall be supported by an analysis which shows, in overall terms, how the system will behave on the occurrence of any one of those specified faults which will have a bearing on vehicle control performance or safety. This may be based on a failure mode and effect analysis (FMEA), a fault tree analysis (FTA) or any similar process appropriate to system safety considerations. The chosen analytical approach shall be established and maintained by the vehicle manufacturer and shall be provided to the technical service.

2.4.5. The documentation shall set out the parameters being monitored and shall set out the warning signal to be activated for each fault condition defined in section 2.4.3.

3. TEST PROCEDURES

3.1. The functional operation of the safety instrumented system, as set out in the documents referred to in section 2 shall be tested as follows:

3.1.1. *Verification of the function of the safety instrumented system*

In order to establish the normal operational levels, verification of the performance of the vehicle system under non-fault conditions shall be conducted against the manufacturer's basic benchmark specification.

3.1.2. *Verification of the safety concept of section 2.4*

The reaction of the safety instrumented system shall, at the discretion of the technical service, be checked under the influence of a failure in any individual unit by applying corresponding output signals to electrical units or mechanical elements in order to simulate the effects of internal faults within the unit.

3.1.3. The verification results shall correspond with the documented summary of the failure analysis, to a level of overall effect such that the safety concept and execution are confirmed as being adequate.

3.2. The warning signal requirements set out in section 2.4.3. may, in general, be satisfied by one optical signal per complex vehicle system unless any other legislation applicable to the same equipment specifically requires multiple signals.

4. ADDITIONAL REQUIREMENTS

4.1. In case of a failure, the driver shall be warned by a warning signal or a message display. The warning shall be present as long as the fault condition persists, unless the system is deactivated by the driver, e.g. by turning the vehicle activation switch to 'off', or by switching off that particular function if a special switch is provided for that purpose.

ANNEX VII

Standards referenced by this Regulation

References to standards in this Regulation shall be understood to refer to the following versions of the standards:

ISO 188:2007	Rubber, vulcanised or thermoplastic — Accelerated ageing and heat resistance tests
ISO 306:2004	Plastics — Thermoplastic materials — Determination of Vicat softening temperature (VST)
ISO 527-2:1993/Cor 1:1994	Plastics — Determination of tensile properties — Part 2: Test conditions for moulding and extrusion plastics
ISO 1431-1:2004/Amd 1:2009	Rubber, vulcanised or thermoplastic — Resistance to ozone cracking — Part 1: Static and dynamic strain testing
ISO 2768-1:1989	General tolerances — Part 1: Tolerances for linear and angular dimensions without individual tolerance indications
ISO 2808:2007	Paints and varnishes — Determination of film thickness
ISO 3864-1:2002	Graphical symbols – Safety colours and safety signs – Part 1: Design principles for safety signs in workplaces and public areas
ISO 4624:1978	Paints and varnishes — Pull-off test for adhesion
ISO 6506-1:2005	Metallic materials — Brinell hardness test — Part 1: Test method
ISO 6957:1988	Copper alloys — Ammonia test for stress corrosion resistance
ISO 7225:2005	Gas cylinders — Precautionary labels
ISO 7866:1999	Gas cylinders — Refillable seamless aluminium alloy gas cylinders — Design, construction and testing
ISO 8491:2004	Metallic materials — Tube (in full section) — Bend test
ISO 9227:2006	Corrosion tests in artificial atmospheres — Salt spray tests
ISO 9809-1:1999	Gas cylinders — Refillable seamless steel gas cylinders — Design, construction and testing — Part 1: Quenched and tempered steel cylinders with tensile strength less than 1 100 MPa
ISO 9809-2:2000	Gas cylinders — Refillable seamless steel gas cylinders — Design, construction and testing — Part 2: Quenched and tempered steel cylinders with tensile strength greater than or equal to 1 100 MPa
ISO 11114-1:1997	Transportable gas cylinders — Compatibility of cylinder and valve materials with gas contents — Part 1: Metallic materials
ISO 11114-4:2005	Transportable gas cylinders — Compatibility of cylinder and valve materials with gas contents — Part 4: Test methods for selecting metallic materials resistant to hydrogen embrittlement
ISO/TS 14687-2:2008	Hydrogen fuel — Product specification — Part 2: Proton exchange membrane (PEM) fuel cell applications for road vehicles
EN 1251-2:2000/AC:2006	Cryogenic vessels — Transportable vacuum insulated vessels of not more than 1 000 litres volume — Part 2: Design, fabrication, inspection and testing
EN 1252-1:1998/AC:1998	Cryogenic vessels — Materials — Part 1: Toughness requirements for temperatures below – 80 °C
EN 1797:2001	Cryogenic vessels — Gas/material compatibility
EN 1964-3:2000	Transportable gas cylinders — Specification for the design and construction of refillable transportable seamless steel gas cylinders of water capacities from 0,5 litre up to and including 150 litres — Part 3: Cylinders made of seamless stainless steel with an R_m value of less than 1 100 MPa
EN 10204:2004	Metallic products — Types of inspection documents
EN 12300:1998/A1:2006	Cryogenic vessels — Cleanliness for cryogenic service
EN 12434:2000/AC:2001	Cryogenic vessels — Cryogenic flexible hoses

EN 12862:2000	Transportable gas cylinders — Specification for the design and construction of refillable transportable welded aluminium alloy gas cylinders
EN 13322-2:2003/A1:2006	Transportable gas cylinders — Refillable welded steel gas cylinders — Design and construction — Part 2: Stainless steel
EN 13648-1:2008	Cryogenic vessels — Safety devices for protection against excessive pressure — Part 1: Safety valves for cryogenic service
EN 13648-2:2002	Cryogenic vessels — Safety devices for protection against excessive pressure — Part 2: Bursting disc safety devices for cryogenic service
EN 13648-3:2002	Cryogenic vessels — Safety devices for protection against excessive pressure — Part 3: Determination of required discharge — Capacity and sizing
ASTM B117 - 07a	Standard practice for operating salt spray (fog) apparatus
ASTM D522 - 93a(2008)	Standard test methods for mandrel bend test of attached organic coatings
ASTM D572 - 04	Standard test method for rubber — Deterioration by heat and oxygen
ASTM D1308 - 02(2007)	Standard test method for effect of household chemicals on clear and pigmented organic finishes
ASTM D2344 / D2344M - 00(2006)	Standard test method for short-beam strength of polymer matrix composite materials and their laminates
ASTM D2794 - 93(2004)	Standard test method for resistance of organic coatings to the effects of rapid deformation (impact)
ASTM D3170 - 03(2007)	Standard test method for chipping resistance of coatings
ASTM D3359 - 08	Standard test methods for measuring adhesion by tape test
ASTM D3418 - 08	Test method for transition temperatures and enthalpies of fusion and crystallisation of polymers by differential scanning calorimetry
ASTM G154 - 06	Standard practice for operating fluorescent light apparatus for UV exposure of non-metallic materials