82 Specifications of the compressed hydrogen storage system

Refer to: R134 00-S2

82.1 Effective date and Scope:

From 2017/4/1, all types of hydrogen storage system using in vehicles of category symbols M and N shall comply with this regulation.

82.2 Definitions:

82.2.1 "Burst disc" means the non-reclosing operating part of a pressure relief device which, when installed in the device, is designed to burst at a predetermined pressure to permit the discharge of compressed hydrogen.

82.2.2 "Check valve" means a non-return valve that prevents reverse flow in the vehicle fuel line.

82.2.3 "Compressed hydrogen storage system (CHSS)" means a system designed to store hydrogen fuel for a hydrogen-fuelled vehicle and composed of a pressurized container, pressure relief devices (PRDs) and shut off device(s) that isolate the stored hydrogen from the remainder of the fuel system and its environment.

82.2.4 "Container" (for hydrogen storage) means the component within the hydrogen storage system that stores the primary volume of hydrogen fuel.

82.2.5 "Date of removal from service" means the date (month and year) specified for removal from service.

82.2.6 "Date of manufacture" (of a compressed hydrogen container) means the date (month and year) of the proof pressure test carried out during manufacture.

82.2.7 "Enclosed or semi-enclosed spaces" means the special volumes within the vehicle (or the vehicle outline across openings) that are external to the hydrogen system (storage system, fuel cell system and fuel flow management system) and its housings (if any) where hydrogen may accumulate (and thereby pose a hazard), as it may occur in the passenger compartment, luggage compartment and space under the hood.

82.2.8 "Exhaust point of discharge" means the geometric centre of the area where fuel cell purged gas is discharged from the vehicle.

82.2.9 "Fuel cell system" means a system containing the fuel cell stack(s), air processing system, fuel flow control system, exhaust system, thermal management system and water management system.

82.2.10 "Fuelling receptacle" means the equipment to which a fuelling station nozzle attaches to the vehicle and through which fuel is transferred to the vehicle. The fuelling receptacle is used as an alternative to a fuelling port.

82.2.11 "Hydrogen concentration" means the percentage of the hydrogen moles (or molecules) within the mixture of hydrogen and air (equivalent to the partial volume of hydrogen gas).

82.2.12 "Hydrogen-fuelled vehicle" means any motor vehicle that uses compressed gaseous hydrogen as a fuel to propel the vehicle, including fuel cell and internal combustion engine vehicles. Hydrogen fuel for passenger vehicles is specified in ISO 14687-2: 2012 and SAE J2719: (September 2011 Revision).

82.2.13 "Luggage compartment" means the space in the vehicle for luggage and/or goods accommodation, bounded by the roof, hood, floor, side walls, being separated from the passenger compartment by the front bulkhead or the rear bulkhead.

82.2.14 "Maximum allowable working pressure (MAWP)" means the highest gauge pressure to which a pressure container or storage system is permitted to operate under normal operating conditions.

82.2.15 "Maximum fuelling pressure (MFP)" means the maximum pressure applied to compressed system during fuelling. The maximum fuelling pressure is 125 per cent of the Nominal Working Pressure.

82.2.16 "Nominal working pressure (NWP)" means the gauge pressure that characterizes typical operation of a system. For compressed hydrogen gas containers, NWP is the settled pressure of compressed gas in fully fuelled container or storage system at a uniform temperature of 15 deg. C.

82.2.17 "Pressure relief device (PRD)" means a device that, when activated under specified performance conditions, is used to release hydrogen from a pressurized system and thereby prevent failure of the system.

82.2.18 "Rupture" or "burst" both mean to come apart suddenly and violently, break open or fly into pieces due to the force of internal pressure.

82.2.19 "Safety relief valve" means a pressure relief device that opens at a preset pressure level and can re-close.

82.2.20 "Service life" (of a compressed hydrogen container) means the time frame during which service (usage) is authorized.

82.2.21 "Shut-off valve" means a valve between the storage container and the vehicle fuel system that can be automatically activated; which defaults to the "closed" position when not connected to a power source.

82.2.22 "Single failure" means a failure caused by a single event, including any consequential failures resulting from this failure.

82.2.23 "Thermally-activated pressure relief device (TPRD)" means a non- reclosing PRD that is activated by temperature to open and release hydrogen gas.

82.2.24 "Vehicle fuel system" means an assembly of components used to store or supply hydrogen fuel to a fuel cell (FC) or internal combustion engine (ICE).

82.3 Specifications of the compressed hydrogen storage system shall according to suitable type and range of principle：

82.3.1 The same brand and type series.

82.3.2 The same state of stored hydrogen fuel; compressed gas.

82.3.3 The same nominal working pressure (NWP).

82.3.4 The same structure, materials, capacity and physical dimensions of the container.

82.3.5 The same structure, materials and essential characteristics of TPRD, check valve and shut-off valve, if any.

82.4 Applicants apply for certification test shall provide at least necessary testing object (or the essential part of vehicle for test) and submit the documents as below:

82.4.1 Specification documents for paragraph 82.3 and the testing object’s drawings and/ or photographs.

82.4.2 Power Plant

82.4.2.1 Hydrogen storage system

82.4.2.1.1 Hydrogen storage system designed to use liquid / compressed (gaseous) hydrogen.

82.4.2.1.1.1 Description and drawing ;

82.4.2.1.1.2 Make(s) ;

82.4.2.1.1.3 Type(s).

82.4.2.1.2 Container(s)

82.4.2.1.2.1 Make(s) ;

82.4.2.1.2.2 Type(s) ;

82.4.2.1.2.3 Maximum Allowable Working Pressure (MAWP) (MPa) ;

82.4.2.1.2.4 Nominal working pressure(s) (MPa) ;

82.4.2.1.2.5 Number of filling cycles ;

82.4.2.1.2.6 Capacity(litres) ;

82.4.2.1.2.7 Material ;

82.4.2.1.2.8 Description and drawing.

82.4.2.1.3 Thermally-activated pressure relief device(s)

82.4.2.1.3.1 Make(s) ;

82.4.2.1.3.2 Type(s) ;

82.4.2.1.3.3 Maximum Allowable Working Pressure (MAWP) (MPa) ;

82.4.2.1.3.4 Set pressure ;

82.4.2.1.3.5 Set temperature ;

82.4.2.1.3.6 Blow off capacity ;

82.4.2.1.3.7 Normal maximum operating temperature ;

82.4.2.1.3.8 Nominal working pressure(s)(MPa) ;

82.4.2.1.3.9 Material ;

82.4.2.1.3.10 Description and drawing ;

82.4.2.1.3.11 Qualified VSTD documents;

82.4.2.1.4 Check valve(s)

82.4.2.1.4.1 Make(s) ;

82.4.2.1.4.2 Type(s) ;

82.4.2.1.4.3 Maximum Allowable Working Pressure (MAWP) (MPa) ;

82.4.2.1.4.4 Nominal working pressure(s) (MPa) ;

82.4.2.1.4.5 Material ;

82.4.2.1.4.6 Description and drawing ;

82.4.2.1.4.7 Qualified VSTD documents;

82.4.2.1.5 Automatic shut-off valve(s)

82.4.2.1.5.1 Make(s) ;

82.4.2.1.5.2 Type(s) ;

82.4.2.1.5.3 Maximum Allowable Working Pressure (MAWP) (MPa) ;

82.4.2.1.5.4 Nominal working pressure(s) and if downstream of the first pressure regulator, maximum allowable working pressure(s) (MPa) ;

82.4.2.1.5.5 Material ;

82.4.2.1.5.6 Description and drawing;

82.4.2.1.5.7 Qualified VSTD documents ;

82.4.3 The applicant shall supply documentation (measurements and statistical analyses) that establish the midpoint burst pressure of new storage containers, BP_O.(According to paragraph 82.5.1.1)

82.4.4 The documents which are required when carry out this regulation.

82.5 Specifications of the compressed hydrogen storage system

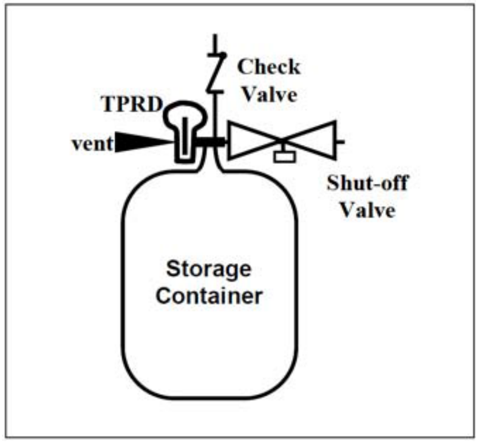
This part specifies the requirements for the compressed hydrogen storage system. The hydrogen storage system consists of the high pressure storage container and primary closure devices for openings into the high pressure storage container. Figure 1 shows a typical compressed hydrogen storage system consisting of a pressurized container, three closure devices and their fittings (shall conform to “Specifications of specific components for the compressed hydrogen storage system” regulated in “VSTD”). The closure devices shall include the following functions, which may be combined

(a) TPRD;

(b) Check valve that prevents reverse flow to the fill line; and

(c) Automatic shut-off valve that can close to prevent flow from the container to the fuel cell or internal combustion engine. Any shut-off valve, and TPRD that form the primary closure of flow from the storage container shall be mounted directly on or within each container. At least one component with a check valve function shall be mounted directly on or within each container.

Figure 1: Typical compressed hydrogen storage system



All new compressed hydrogen storage systems produced for on-road vehicle service shall have a NWP of 70 MPa or less and a service life of 15 years or less, and be capable of satisfying the requirements of paragraph 82.5. The hydrogen storage system shall meet the performance test requirements specified in this paragraph.

The qualification requirements for on-road service are:
(a) Verification tests for baseline metrics
(b) Verification test for performance durability (hydraulic sequential tests)
(c) Verification test for expected on-road system performance (pneumatic sequential tests)
(d) Verification test for service terminating system performance in Fire
(e) Verification test for performance durability of primary closures.

The test elements within these performance requirements are summarized in Table 1. The corresponding test procedures are specified in paragraph 82.6.

Table 1: Overview of performance requirements

5.1.	Verification tests for baseline metrics
5.1.1.	Baseline initial burst pressure
5.1.2.	Baseline initial pressure cycle life
5.2.	Verification test for performance durability (sequential hydraulic tests)
5.2.1.	Proof pressure test
5.2.2.	Drop (impact) test
5.2.3.	Surface damage
5.2.4.	Chemical exposure and ambient temperature pressure cycling tests
5.2.5.	High temperature static pressure test
5.2.6.	Extreme temperature pressure cycling
5.2.7.	Residual proof pressure test
5.2.8.	Residual strength Burst Test
5.3.	Verification test for expected on-road performance (sequential pneumatic tests)
5.3.1.	Proof pressure test
5.3.2.	Ambient and extreme temperature gas pressure cycling test (pneumatic)
5.3.3.	Extreme temperature static gas pressure leak/permeation test (pneumatic)
5.3.4.	Residual proof pressure test
5.3.5.	Residual strength burst test (hydraulic)
5.4.	Verification test for service terminating performance in fire
5.5.	Requirements for primary closure devices

82.5.1 Verification tests for baseline metrics

82.5.1.1 Baseline initial burst pressure

Three (3) containers shall be hydraulically pressurized until burst. The manufacturer shall supply documentation (measurements and statistical analyses) that establish the midpoint burst pressure of new storage containers,

BP_O.

All containers tested shall have a burst pressure within +/-10 per cent of BP_O and greater than or equal to a minimum BPmin of 225 per cent NWP.

In addition, containers having glass-fibre composite as a primary constituent to have a minimum burst pressure greater than 350 per cent NWP.

82.5.1.2 Baseline initial pressure cycle life

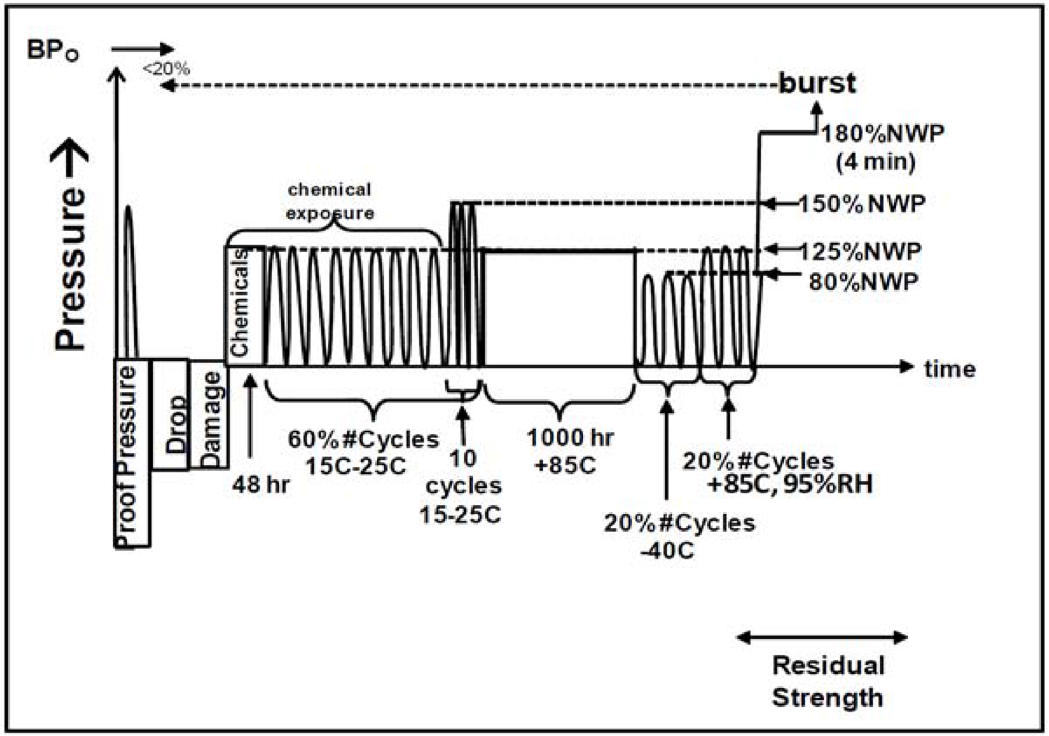
Three (3) containers shall be hydraulically pressure cycled at 20 (+/-5) deg. C to 125 per cent NWP (+2/-0 MPa) without rupture for 22,000 cycles or until a leak occurs. Leakage shall not occur within 11,000 cycles for a 15-year service life.

82.5.2 Verification tests for performance durability (Hydraulic sequential tests)

If all three pressure cycle life measurements made in paragraph 82.5.1.2. are greater than 11,000 cycles, or if they are all within +/- 25 per cent of each other, then only one (1) container is tested in paragraph 82.5.2. Otherwise, three (3) containers are tested in paragraph 82.5.2.

A hydrogen storage container shall not leak during the following sequence of tests, which are applied in series to a single system and which are illustrated in Figure 2. Specifics of applicable test procedures for the hydrogen storage system are provided in paragraph 82.6.3.

Figure 2: Verification test for performance durability (hydraulic)



82.5.2.1 Proof pressure test

A storage container is pressurized to 150 per cent NWP (+2/-0 MPa) and held for at least 30 sec (Paragraph 82.6.3.1. test procedure).

82.5.2.2 Drop (impact) test

The storage container is dropped at several impact angles (Paragraph 82.6.3.2. test procedure).

82.5.2.3 Surface damage test

The storage container is subjected to surface damage (Paragraph 82.6.3.3. test procedure).

82.5.2.4 Chemical exposure and ambient-temperature pressure cycling test

The storage container is exposed to chemicals found in the on-road environment and pressure cycled to 125 per cent NWP (+2/-0 MPa) at 20 (+/-5) deg. C for 60 per cent number of Cycles pressure cycles (paragraph 82.6.3.4. test procedure). Chemical exposure is discontinued before the last 10 cycles, which are conducted to 150 per cent NWP (+2/-0 MPa).

82.5.2.5 High temperature static pressure test.

The storage container is pressurized to 125 per cent NWP (+2/-0 MPa) at >85 deg. C for at least 1,000 hours (Paragraph 82.6.3.5. test procedure).

82.5.2.6 Extreme temperature pressure cycling.

The storage container is pressure cycled at < -40 deg. C to 80 per cent NWP (+2/-0 MPa) for 20 per cent number of Cycles and at > +85 deg. C and 95 (+/-2) per cent relative humidity to 125 per cent NWP (+2/-0 MPa) for 20 per cent number of Cycles (Paragraph 82.6.2.2. test procedure).

82.5.2.7 Hydraulic residual pressure test.

The storage container is pressurized to 180 per cent NWP (+2/-0 MPa) and held at least 4 minutes without burst (paragraph 82.6.3.1.test procedure).

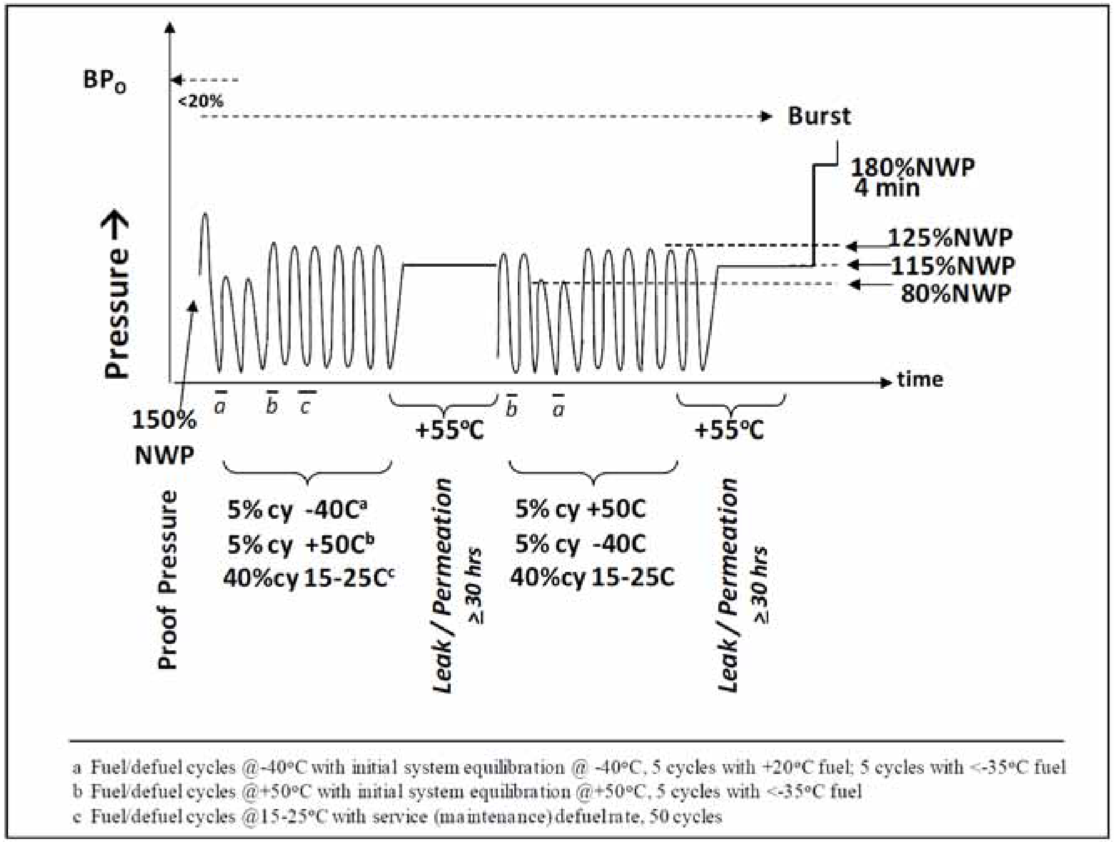
82.5.2.8 Residual burst strength test

The storage container undergoes a hydraulic burst test to verify that the burst pressure is at least 80 per cent of the baseline initial burst pressure (BP_O) determined in paragraph 82.4.3. (paragraph 82.6.2.1. test procedure).

82.5.3 Verification test for expected on-road performance (Pneumatic sequential tests)

A hydrogen storage system shall not leak during the following sequence of tests, which are illustrated in Figure 3. Specifics of applicable test procedures for the hydrogen storage system are provided in paragraph 82.6.

Figure 3: Verification test for expected on-road performance (pneumatic/hydraulic)



82.5.3.1 Proof pressure test

A system is pressurized to 150 per cent NWP (+2/-0 MPa) for at least 30 seconds (paragraph 82.6.3.1. test procedure). A storage container that has undergone a proof pressure test in manufacture may be exempted from this test.

82.5.3.2 Ambient and extreme temperature gas pressure cycling test

The system is pressure cycled using hydrogen gas for 500 cycles (paragraph 82.6.4.1 test procedure).

(a) The pressure cycles are divided into two groups: Half of the cycles (250) are performed before exposure to static pressure (paragraph 82.5.3.3.) and the remaining half of the cycles (250) are performed after the initial exposure to static pressure (paragraph 82.5.3.3.) as illustrated in Figure 3;

(b) The first group of pressure cycling, 25 cycles are performed to 80 per cent NWP (+2/-0 MPa) at ≤ -40 deg. C, then 25 cycles to 125 per cent NWP (+2/-0 MPa) at ≥ +50 deg. C and 95 (+/-2) per cent relative humidity, and the remaining 200 cycles to 125 per cent NWP (+2/-0 MPa) at 20 (+/- 5) deg. C;

The second group of pressure cycling, 25 cycles are performed to 125 per cent NWP (+2/-0 MPa) at ≥+50 deg. C and 95 (+/-2) per cent relative humidity, then 25 cycles to 80 per cent NWP (+2/-0 MPa) at ≤ -40 deg. C, and the remaining 200 cycles to 125 per cent NWP (+2/-0 MPa) at 20 (+/- 5) deg. C.

(c) The hydrogen gas fuel temperature is ≤ -40 deg. C;

(d) During the first group of 250 pressure cycles, five cycles are performed with fuel having a temperature of +20 (+/-5) deg. C after temperature equilibration of the system at ≤ -40 deg. C; five cycles are performed with fuel having a temperature of ≤ -40 deg. C; and five cycles are performed with fuel having a temperature of ≤ -40 deg. C after temperature equilibration of the system at ≥ +50 deg. C and 95 per cent relative humidity;

(e) Fifty pressure cycles are performed using a de-fuelling rate greater than or equal to the maintenance de-fuelling rate.

82.5.3.3 Extreme temperature static pressure leak/permeation test.

(a) The test is performed after each group of 250 pneumatic pressure cycles in paragraph 82.5.3.2.;

(b) The maximum allowable hydrogen discharge from the compressed hydrogen storage system is 46 ml/hr/l water capacity of the storage system. (paragraph 82.6.4.2. test procedure);

(c) If the measured permeation rate is greater than 0.005 mg/sec (3.6 Nml/min), a localized leak test is performed to ensure no point of localized external leakage is greater than 0.005 mg/sec (3.6 Nml/min) (paragraph 82.6.4.3. test procedure).

82.5.3.4 Residual proof pressure test (hydraulic)

The storage container is pressurized to 180 per cent NWP (+2/-0 MPa) and held at least 4 minutes without burst (Paragraph 82.6.3.1. test procedure).

82.5.3.5 Residual strength burst test (hydraulic)

The storage container undergoes a hydraulic burst to verify that the burst pressure is at least 80 per cent of the baseline initial burst pressure (BP_O) determined in paragraph 82.4.3. (paragraph 82.6.2.1. test procedure).

82.5.4 Verification test for service terminating performance in fire

This section describes the fire test with compressed hydrogen as the test gas. Compressed air may be used as an alternative test gas.

A hydrogen storage system is pressurized to NWP and exposed to fire (paragraph 82.6.5.1. test procedure). A temperature-activated pressure relief device shall release the contained gases in a controlled manner without rupture.

82.5.5 Requirements for primary closure devices

The primary closure devices that isolate the high pressure hydrogen storage system, namely TPRD, check valve and shut-off valve, as described in Figure 1, shall be tested and type-approved in accordance with Part II of this Regulation and produced in conformity with the approved type.

Retesting of the storage system is not required if alternative closure devices are provided having comparable function, fittings, materials, strength and dimensions, and satisfy the condition above. However, a change in TPRD hardware, its position of installation or venting lines shall require a new fire test in accordance with paragraph 82.5.4.

82.5.6 Labelling

A label shall be permanently affixed on each container with at least the following information: name of the manufacturer, serial number, date of manufacture, MFP, NWP, type of fuel (e.g. "CHG" for gaseous hydrogen), and date of removal from service. Each container shall also be marked with the number of cycles used in the testing programme as per paragraph 82.5.1.2. Any label affixed to the container in compliance with this paragraph shall remain in place and be legible for the duration of the manufacturer's recommended service life for the container.

Date of removal from service shall not be more than 15 years after the date of manufacture.

82.6 Test procedures for the compressed hydrogen storage system

82.6.1 Test procedures for qualification requirements of compressed hydrogen storage are organized as follows:

(a) The test procedures for baseline performance metrics (requirement of paragraph 82.5.1. of this Regulation)
(b) The test procedures for performance durability (requirement of paragraph 82.5.2. of this Regulation)

(c) The test procedures for expected on-road performance (requirement of paragraph 82.5.3. of this Regulation)
(d) The test procedures for service terminating performance in fire (requirement of paragraph 82.5.4. of this Regulation)
(e) The test procedures for performance durability of primary closures (requirement of paragraph 82.5.5. of this Regulation)

82.6.2 Test procedures for baseline performance metrics (requirement of paragraph 82.5.1 of this Regulation)

82.6.2.1 Burst test (hydraulic)

The burst test is conducted at 20 (+/-5) deg. C using a non-corrosive fluid. The rate of pressurization is less than or equal to 1.4 MPa/sec for pressures higher than 150 per cent of the nominal working pressure. If the rate exceeds 0.35 MPa/sec at pressures higher than 150 per cent NWP, then either the container is placed in series between the pressure source and the pressure measurement device, or the time at the pressure above a target burst pressure exceeds 5 seconds. The burst pressure of the container shall be recorded.

82.6.2.2 Pressure cycling test (hydraulic)

The test is performed in accordance with the following procedure:

(a) The container is filled with a non-corrosive fluid;
(b) The container and fluid are stabilized at the specified temperature and relative humidity at the start of testing; the environment, fuelling fluid and container skin are maintained at the specified temperature for the duration of the testing. The container temperature may vary from the environmental temperature during testing;
(c) The container is pressure cycled between 2 (+/-1) MPa and the target pressure at a rate not exceeding 10 cycles per minute for the specified number of cycles;
(d) The temperature of the hydraulic fluid within the container is maintained and monitored at the specified temperature.

82.6.3 Test procedures for performance durability (requirement of paragraph 82.5.2. of this regulation)

82.6.3.1 Proof pressure test

The system is pressurized smoothly and continually with a non-corrosive hydraulic fluid until the target test pressure level is reached and then held for the specified time.

82.6.3.2 Drop (impact) test (unpressurized)

The storage container is drop tested at ambient temperature without internal pressurization or attached valves. The surface onto which the containers are dropped shall be a smooth, horizontal concrete pad or other flooring type with equivalent hardness.

The orientation of the container being dropped (in accordance with the requirement of paragraph 82.5.2.2.) is determined as follows: One or more additional container(s) shall be dropped in each of the orientations described below. The drop orientations may be executed with a single container or as many as four containers may be used to accomplish the four drop orientations.

(i) Dropped once from a horizontal position with the bottom 1.8 m above the surface onto which it is dropped;

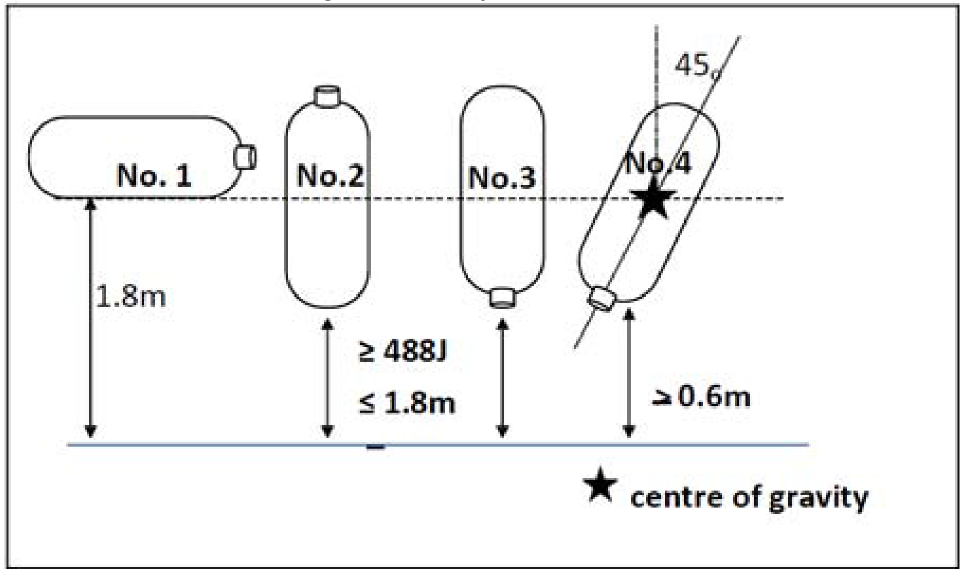
(ii) Dropped once onto the end of the container from a vertical position with the ported end upward with a potential energy of not less than 488 J, with the height of the lower end no greater than 1.8 m;

(iii) Dropped once onto the end of the container from a vertical position with the ported end downward with a potential energy of not less than 488 J, with the height of the lower end no greater than 1.8 m. If the container is symmetrical (identical ported ends), this drop orientation is not required;

(iv) Dropped once at a 45 deg. angle from the vertical orientation with a ported end downward 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 a centre of gravity of 1.8 m above the ground.

The four drop orientations are illustrated in Figure 4.

Figure 4: Drop orientations



No attempt shall be made to prevent the bouncing of containers, but the containers may be prevented from falling over during the vertical drop tests described above.

If more than one container is used to execute all drop specifications, then those containers shall undergo pressure cycling according to paragraph 82.6.2.2. until either leakage or 22,000 cycles without leakage have occurred. Leakage shall not occur within 11,000 cycles.

The orientation of the container being dropped in accordance with the requirement of paragraph 82.5.2.2. shall be identified as follows:

(a) If a single container was subjected to all four drop orientations, then the container being dropped in accordance with the requirement of paragraph 82.5.2.2. shall be dropped in all four orientations;

(b) If more than one container is used to execute the four drop orientations, and if all containers reach 22,000 cycles without leakage, then the orientation of the container being dropped in accordance with the requirement paragraph 82.5.2.2. is the 45 deg. orientation (iv), and that container shall then undergo further testing as specified in paragraph 82.5.2.;

(c) If more than one container is used to execute the four drop orientations and if any container does not reach 22,000 cycles without leakage, then the new container shall be subjected to the drop orientation(s) that resulted in the lowest number of cycles to leakage and then will undergo further testing as specified in paragraph 82.5.2.

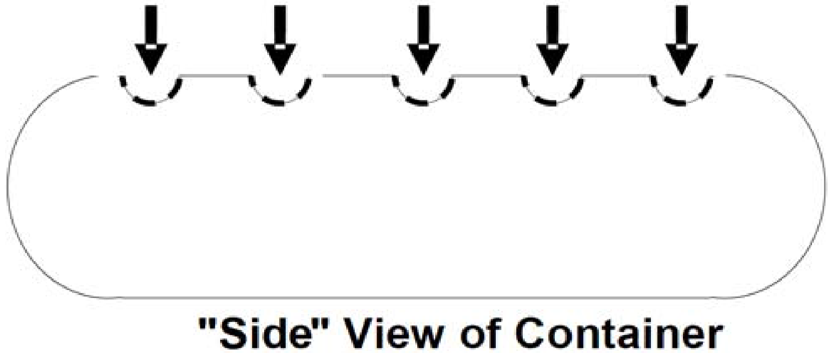
82.6.3.3 Surface damage test (unpressurized)

The test proceeds in the following sequence:

(a) Surface flaw generation: Two longitudinal saw cuts are made on the bottom outer surface of the unpressurized horizontal storage container along the cylindrical zone close to but not in the shoulder area. The first cut is at least 1.25 mm deep and 25 mm long toward the valve end of the container. The second cut is at least 0.75 mm deep and 200 mm long toward the end of the container opposite the valve;

(b) Pendulum impacts: The upper section of the horizontal storage container is divided into five distinct (not overlapping) areas 100 mm in diameter each (see Figure 5). After 12 hours preconditioning at < -40 deg. C in an environmental chamber, the centre of each of the five areas sustains the impact of a pendulum having a pyramid with equilateral faces and square base, the summit and edges being rounded to a radius of 3 mm. The centre of impact of the pendulum coincides with the centre of gravity of the pyramid. The energy of the pendulum at the moment of impact with each of the five marked areas on the container is 30 J. The container is secured in place during pendulum impacts and not under pressure.

Figure 5: Side view of container



82.6.3.4 Chemical exposure and ambient-temperature pressure cycling test

Each of the 5 areas of the unpressurized container preconditioned by pendulum impact (paragraph 82.6.3.3.) is exposed to one of five solutions:

(a) 19 per cent (by volume) sulphuric acid in water (battery acid);
(b) 25 per cent (by weight) sodium hydroxide in water;
(c) 5 per cent (by volume) methanol in gasoline (fluids in fuelling stations);
(d) 28 per cent (by weight) ammonium nitrate in water (urea solution); and
(e) 50 per cent (by volume) methyl alcohol in water (windshield washer fluid).

The test container is oriented with the fluid exposure areas on top. A pad of glass wool approximately 0.5 mm thick and 100 mm in diameter is placed on each of the five preconditioned areas. A sufficient amount of the test fluid is applied to the glass wool sufficient to ensure that the pad is wetted across its surface and through its thickness for the duration of the test.

The exposure of the container with the glass wool is maintained for 48 hours with the container held at 125 per cent NWP (+2/-0 MPa) (applied hydraulically) and 20 (+/-5) deg. C before the container is subjected to further testing.

Pressure cycling is performed to the specified target pressures according to paragraph 82.6.2.2. of this Annex at 20 (+/-5) deg. C for the specified numbers of cycles. The glass wool pads are removed and the container surface is rinsed with water the final 10 cycles to specified final target pressure are conducted.

82.6.3.5 Static pressure test (hydraulic)

The storage system is pressurized to the target pressure in a temperature-controlled chamber. The temperature of the chamber and the non-corrosive fuelling fluid is held at the target temperature within +/-5 deg. C for the specified duration.

82.6.4 Test procedures for expected on-road performance (paragraph 82.5.3. of this Regulation)

(Pneumatic test procedures are provided; hydraulic test elements are described in paragraph 82.6.2.1.)

82.6.4.1 Gas pressure cycling test (pneumatic)

At the onset of testing, the storage system is stabilized at the specified temperature, relative humidity and fuel level for at least 24 hours. The specified temperature and relative humidity is maintained within the test environment throughout the remainder of the test. (When required in the test specification, the system temperature is stabilized at the external environmental temperature between pressure cycles.)

The storage system is pressure cycled between less than 2 (+0/-1) MPa and the specified maximum pressure (+/-1 MPa). If system controls that are active in vehicle service prevent the pressure from dropping below a specified pressure, the test cycles shall not go below that specified pressure. The fill rate is controlled to a constant 3-minute pressure ramp rate, but with the fuel flow not to exceed 60 g/sec; the temperature of the hydrogen fuel dispensed to the container is controlled to the specified temperature. However, the pressure ramp rate should be decreased if the gas temperature in the container exceeds +85 deg. C. The defuelling rate is controlled to greater than or equal to the intended vehicle's maximum fuel-demand rate. The specified number of pressure cycles is conducted. If devices and/or controls are used in the intended vehicle application to prevent an extreme internal temperature, the test may be conducted with these devices and/or controls (or equivalent measures).

82.6.4.2 Gas permeation test (pneumatic)

A storage system is fully filled with hydrogen gas at 115 per cent NWP (+2/-0 MPa) (full fill density equivalent to 100 per cent NWP at +15 deg. C is 113 per cent NWP at +55 deg. C) and held at > +55 deg. C in a sealed container until steady-state permeation or 30 hours, whichever is longer. The total steady-state discharge rate due to leakage and permeation from the storage system is measured.

82.6.4.3 Localized gas leak test (pneumatic)

A bubble test may be used to fulfil this requirement. The following procedure is used when conducting the bubble test:

(a) The exhaust of the shut-off valve (and other internal connections to hydrogen systems) shall be capped for this test (as the test is focused on external leakage). At the discretion of the tester, the test article may be immersed in the leak-test fluid or leak-test fluid applied to the test article when resting in open air. Bubbles can vary greatly in size, depending on conditions. The tester estimates the gas leakage based on the size and rate of bubble.

(b) Note: For a localized rate of 0.005 mg/sec (3.6 Nml/min), the resultant allowable rate of bubble generation is about 2,030 bubbles per minute for a typical bubble size of 1.5 mm in diameter. Even if much larger bubbles are formed, the leak should be readily detectable. For an unusually large bubble size of 6 mm in diameter, the allowable bubble rate would be approximately 32 bubbles per minute.

82.6.5 Test procedures for service terminating performance in fire (paragraph 82.5.4. of this Regulation)

82.6.5.1 Fire test

The hydrogen container assembly consists of the compressed hydrogen storage system with additional relevant features, including the venting system (such as the vent line and vent line covering) and any shielding affixed directly to the container (such as thermal wraps of the container(s) and/or coverings/barriers over the TPRD(s)).

Either one of the following two methods are used to identify the position of the system over the initial (localized) fire source:

(a) Method 1: Qualification for a generic (non-Specific) vehicle installation

If a vehicle installation configuration is not specified (and the type approval of the system is not limited to a specific vehicle installation configuration) then the localized fire exposure area is the area on the test article farthest from the TPRD(s). The test article, as specified above, only includes thermal shielding or other mitigation devices affixed directly to the container that are used in all vehicle applications. Venting system(s) (such as the vent line and vent line covering) and/or coverings/barriers over the TPRD(s) are included in the container assembly if they are anticipated for use in any application. If a system is tested without representative components, retesting of that system is required if a vehicle application specifies the use of these type of components.

(b) Method 2: Qualification for a specific vehicle installation

If a specific vehicle installation configuration is specified and the type approval of the system is limited to that specific vehicle installation configuration, then the test setup may also include other vehicle components in addition to the hydrogen storage system. These vehicle components (such as shielding or barriers, which are permanently attached to the vehicle's structure by means of welding or bolts and not affixed to the storage system) shall be included in the test setup in the vehicle-installed configuration relative to the hydrogen storage system. This localized fire test is conducted on the worst case localized fire exposure areas based on the four fire orientations: fires originating from the direction of the passenger compartment, luggage compartment, wheel wells or ground-pooled gasoline.

82.6.5.1.1 The container may be subjected to engulfing fire without any shielding components, as described in paragraph 82.6.5.2.

82.6.5.1.2 The following test requirements apply whether Method 1 or 2 (above) is used:

(a) The container assembly is filled with compressed hydrogen gas at 100 per cent of NWP (+2/-0 MPa). The container assembly is positioned horizontally approximately 100 mm above the fire source;

(b) Localized portion of the fire test:

(i) The localized fire exposure area is located on the test article furthest from the TPRD(s). If Method 2 is selected and more vulnerable areas are identified for a specific vehicle installation configuration, the more vulnerable area that is furthest from the TPRD(s) is positioned directly over the initial fire source;

(ii) The fire source consists of LPG burners configured to produce a uniform minimum temperature on the test article measured with a minimum 5 thermocouples covering the length of the test article up to 1.65 m maximum (at least 2 thermocouples within the localized fire exposure area, and at least 3 thermocouples equally spaced and no more than 0.5 m apart in the remaining area) located 25 (+/-10) mm from the outside surface of the test article along its longitudinal axis. At the option of the manufacturer or testing facility, additional thermocouples may be located at TPRD sensing points or any other locations for optional diagnostic purposes;

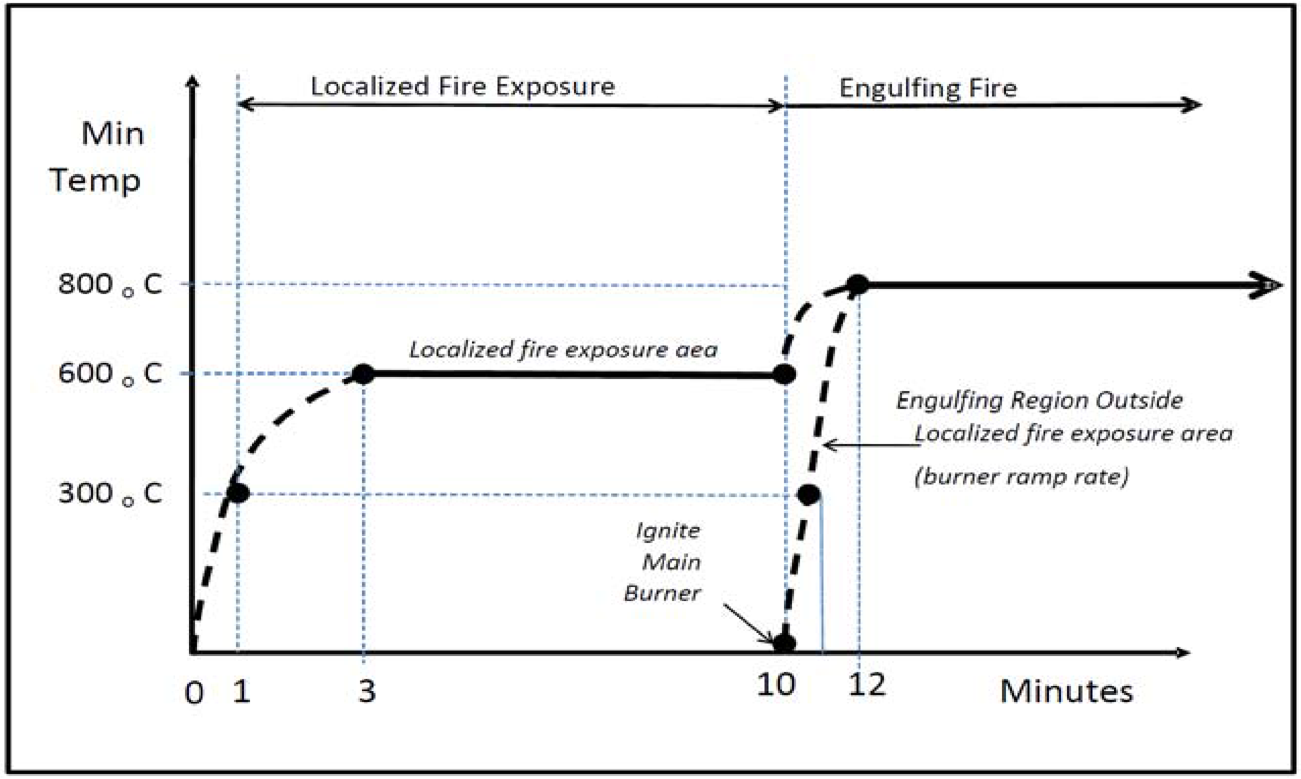
(iii) Wind shields are applied to ensure uniform heating;

(iv) The fire source initiates within a 250 (+/-50) mm longitudinal expanse positioned under the localized fire exposure area of the test article. The width of the fire source encompasses the entire diameter (width) of the storage system. If Method 2 is selected, the length and width shall be reduced, if necessary, to account for vehicle-specific features;

(v) As shown in Figure 6 the temperature of the thermocouples in the localized fire exposure area has increased continuously to at least 300 deg. C within 1 minute of ignition, to at least 600 deg. C within 3 minutes of ignition, and a temperature of at least 600 deg. C is maintained for the next 7 minutes. The temperature in the localized fire exposure area shall not exceed 900 deg. C during this period.

Compliance to the thermal requirements begins 1 minute after entering the period with minimum and maximum limits and is based on a 1-minute rolling average of each thermocouple in the region of interest. (Note: The temperature outside the region of the initial fire source is not specified during these initial 10 minutes from the time of ignition.).

Figure 6: Temperature profile of fire test



(c) Engulfing portion of the fire test

Within the next 2-minute interval, the temperature along the entire surface of the test article shall be increased to at least 800 deg. C and the fire source is extended to produce a uniform temperature along the entire length up to 1.65 m and the entire width of the test article (engulfing fire). The minimum temperature is held at 800 deg. C, and the maximum temperature shall not exceed 1,100 deg. C.

Compliance to thermal requirements begins 1 minute after entering the period with constant minimum and maximum limits and is based on a 1-minute rolling average of each thermocouple.

The test article is held at temperature (engulfing fire condition) until the system vents through the TPRD and the pressure falls to less than 1 MPa. The venting shall be continuous (without interruption), and the storage system shall not rupture. An additional release through leakage (not including release through the TPRD) that results in a flame with length greater than 0.5 m beyond the perimeter of the applied flame shall not occur.

Table 2: Summary of fire test protocol

	Localized Fire Region	Time Period	Engulfing Fire Region (Outside the Localized Fire Region)
Action	Ignite Burners	0-1 Minute	No Burner Operation
Minimum temperature	Not specified		Not specified
Maximum temperature	Less than 900 deg. C		Not specified
Action	Increase temperature and stabilize fire for start of localized fire exposure	1-3 Minutes	No Burner Operation
Minimum temperature	Greater than 300 deg. C		Not specified
Maximum temperature	Less than 900 deg. C		Not specified
Action	Localized fire exposure continues	3-10 Minutes	No Burner Operation
Minimum temperature	1-minute rolling average greater than 600 deg. C		Not specified
Maximum temperature	1-minute rolling average less than 900 deg. C		Not specified
Action	Increase temperature	10-11 Minutes	Main Burner Ignited at 10 minutes
Minimum Temperature	1-minute rolling average greater than 600 deg. C		Not specified
Maximum temperature	1-minute rolling average less than 1,100 deg. C		Less than 1,100 deg. C
Action	Increase temperature and stabilize fire for start of engulfing fire exposure	11-12 Minutes	Increase temperature and stabilize fire for start of engulfing fire exposure
Minimum temperature	1-minute rolling average greater than 600 deg. C		Greater than 300 deg. C
Maximum temperature	1 minute rolling average less than 1,100 deg. C		Less than 1,100 deg. C
Action	Engulfing fire exposure continues	12 Minutes - end of test	Engulfing fire exposure continues
Minimum temperature	1-minute rolling average greater than 800 deg. C		1-minute rolling average Greater than 800 deg. C
Maximum temperature	1 minute rolling average less than 1,100 deg. C		1-minute rolling average less than 1,100 deg. C

(d) Documenting results of the fire test

The arrangement of the fire is recorded in sufficient detail to ensure the rate of heat input to the test article is reproducible. The results include the elapsed time from ignition of the fire to the start of venting through the TPRD(s), and the maximum pressure and time of evacuation until a pressure of less than 1 MPa is reached. Thermocouple temperatures and container pressure are recorded at intervals of every 10 sec or less during the test. Any failure to maintain specified minimum temperature requirements based on the 1-minute rolling averages invalidates the test result. Any failure to maintain specified maximum temperature requirements based on the 1-minute rolling averages invalidates the test result only if the test article failed during the test.

82.6.5.2 Engulfing fire test:

The test unit is the compressed hydrogen storage system. The storage system is filled with compressed hydrogen gas at 100 per cent NWP (+2/-0 MPa). The container is positioned horizontally with the container bottom approximately 100 mm above the fire source. Metallic shielding is used to prevent direct flame impingement on container valves, fittings, and/or pressure relief devices. The metallic shielding is not in direct contact with the specified fire protection system (pressure relief devices or container valve).

A uniform fire source of 1.65 m length provides direct flame impingement on the container surface across its entire diameter. The test shall continue until the container fully vents (until the container pressure falls below 0.7 MPa). Any failure or inconsistency of the fire source during a test shall invalidate the result.

Flame temperatures shall be monitored by at least three thermocouples suspended in the flame approximately 25 mm below the bottom of the container. Thermocouples may be attached to steel cubes up to 25 mm on a side. Thermocouple temperature and the container pressure shall be recorded every 30 seconds during the test.

Within five minutes after the fire is ignited, an average flame temperature of not less than 590 deg. C (as determined by the average of the two thermocouples recording the highest temperatures over a 60 second interval) is attained and maintained for the duration of the test.

If the container is less than 1.65 m in length, the centre of the container shall be positioned over the centre of the fire source.

(a) If the container is greater than 1.65 m in length, then if the container is fitted with a pressure relief device at one end, the fire source shall commence at the opposite end of the container.

(b) If the container is greater than 1.65 m in length and is fitted with pressure relief devices at both ends, or at more than one location along the length of the container, the centre of the fire source shall be centred midway between the pressure relief devices that are separated by the greatest horizontal distance.

The container shall vent through a pressure relief device without bursting.