81 Specifications of a vehicle fuel system incorporating the compressed hydrogen storage system

Refer to: R134 00-S2

81.1 Effective date and Scope:

From 2017/4/1, all vehicle variants of category symbols M and N shall comply with this regulation.

81.2 Definitions:

81.2.1 "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.

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

81.2.3 "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.

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

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

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

81.2.7 "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.

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

81.2.9 "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.

81.2.10 "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.

81.2.11 "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).

81.2.12 "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).

81.2.13 "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.

81.2.14 "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.

81.2.15 "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.

81.2.16 "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.

81.2.17 "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.

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

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

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

81.2.21 "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.

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

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

81.2.24 "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).

81.3 Specifications of a vehicle fuel system incorporating the compressed hydrogen storage system shall according to suitable variant and range of principle：

81.3.1 The same vehicle category symbol.

81.3.2 The same vehicle brand and vehicle type series.

81.3.3 The same basic configuration and main characteristics of the vehicle fuel system.

81.4 Applicants apply for certification test shall provide at least one representative vehicle (or the essential part of vehicle for test) and submit the documents as below:

81.4.1 Vehicle specification documents, drawings and / or photographs described in paragraph 81.3.

81.4.2 General construction characteristics of the vehicle

81.4.2.1 Powered axles (number, position, interconnection).

81.4.2.2 Chassis (if any) (overall drawing).

81.4.3 Power Plant

81.4.3.1 Hydrogen storage system

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

81.4.3.1.1.1 Description and drawing;

81.4.3.1.1.2 Make(s);

81.4.3.1.1.3 Type(s).

81.4.3.1.1.4 The documents that it comply with this regulation.

81.4.3.1.1.4.1 The value of concentrations of test gas. (According to paragraph 81.6.3.1.1.2)

81.4.3.1.1.4.2 The number, location and flow capacity of the release points downstream of the main hydrogen shut-off valve. (According to paragraph 81.6.3.2.1.3)

81.4.3.1.2 Hydrogen leakage detection sensors

81.4.3.1.2.1 Make(s);

81.4.3.1.2.2 Type(s).

81.4.3.1.3 Refueling connection or receptacle

81.4.3.1.3.1 Make(s);

81.4.3.1.3.2 Type(s).

81.4.3.1.4 Drawings showing requirements for installation and operation.

81.4.4 Required documents for carry out the test of this regulation.

81.5 Specifications

This part specifies requirements for the vehicle fuel system, which includes the compressed hydrogen storage system, piping, joints, and components in which hydrogen is present. The hydrogen storage system included in the vehicle fuel system shall conform to “Specifications of the compressed hydrogen storage system” regulated in “VSTD”.

81.5.1 In-use fuel system requirements

81.5.1.1 Fuelling receptacle

81.5.1.1.1 A compressed hydrogen fuelling receptacle shall prevent reverse flow to the atmosphere. Test procedure is by visual inspection.

81.5.1.1.2 Fuelling receptacle label: A label shall be affixed close to the fuelling receptacle; for instance inside a refilling hatch, showing the following information: fuel type (e.g. "CHG" for gaseous hydrogen), MFP, NWP, date of removal from service of containers."

81.5.1.1.3 The fuelling receptacle shall be mounted on the vehicle to ensure positive locking of the fuelling nozzle.

The receptacle shall be protected from tampering and the ingress of dirt and water (e.g. installed in a compartment which can be locked). Test procedure is by visual inspection.

81.5.1.1.4 The fuelling receptacle shall not be mounted within the external energy absorbing elements of the vehicle (e.g. bumper) and shall not be installed in the passenger compartment, luggage compartment and other places where hydrogen gas could accumulate and where ventilation is not sufficient. Test procedure is by visual inspection.

81.5.1.2 Over-pressure protection for the low pressure system (According to paragraph 81.6.6)

The hydrogen system downstream of a pressure regulator shall be protected against overpressure due to the possible failure of the pressure regulator. The set pressure of the overpressure protection device shall be lower than or equal to the maximum allowable working pressure for the appropriate section of the hydrogen system.

81.5.1.3 Hydrogen discharge systems

81.5.1.3.1 Pressure relief systems(According to paragraph 81.6.6)

(a) Storage system TPRDs. The outlet of the vent line, if present, for hydrogen gas discharge from TPRD(s) of the storage system shall be protected by a cap;

(b) Storage system TPRDs. The hydrogen gas discharge from TPRD(s) of the storage system shall not be directed:

(i) Into enclosed or semi-enclosed spaces;

(ii) Into or towards any vehicle wheel housing;

(iii) Towards hydrogen gas containers;

(iv) Forward from the vehicle, or horizontally (parallel to road) from the back or sides of the vehicle.

(c) Other pressure relief devices (such as a burst disc) may be used outside the hydrogen storage system. The hydrogen gas discharge from other pressure relief devices shall not be directed:

(i) Towards exposed electrical terminals, exposed electrical switches or other ignition sources;

(ii) Into or towards the vehicle passenger or luggage compartments;

(iii) Into or towards any vehicle wheel housing;

(iv) Towards hydrogen gas containers.

81.5.1.3.2 Vehicle exhaust system(According to paragraph 81.6.4)

At the vehicle exhaust system's point of discharge, the hydrogen concentration level shall:

(a) Not exceed 4 per cent average by volume during any moving three-second time interval during normal operation including start-up and shut-down;

(b) And not exceed 8 per cent at any time (According to paragraph 81.6.4).

81.5.1.4 Protection against flammable conditions: single failure conditions

81.5.1.4.1 Hydrogen leakage and/or permeation from the hydrogen storage system shall not directly vent into the passenger or luggage compartments, or to any enclosed or semi enclosed spaces within the vehicle that contains unprotected ignition sources.

81.5.1.4.2 Any single failure downstream of the main hydrogen shut-off valve shall not result in accumulations in levels of hydrogen concentration in the passenger compartment according to test procedure in paragraph

81.6.3.2.

81.5.1.4.3 If, during operation, a single failure results in a hydrogen concentration exceeding 3.0 per cent by volume in air in the enclosed or semi-enclosed spaces of the vehicle, then a warning shall be provided (paragraph 81.5.1.6). If the hydrogen concentration exceeds 4.0 per cent by volume in the air in the enclosed or semi-enclosed spaces of the vehicle, the main shut-off valve shall be closed to isolate the storage system. (According to paragraph 81.6.3).

81.5.1.5 Fuel system leakage

The hydrogen fuelling line (e.g. piping, joint, etc.) downstream of the main shut-off valve(s) to the fuel cell system or the engine shall not leak. Compliance shall be verified at NWP (According to paragraph 81.6.5).

81.5.1.6 Tell-tale signal warning to driver

The warning shall be given by a visual signal or display text with the following properties:

(a) Visible to the driver while in the driver's designated seating position with the driver's seat belt fastened;

(b) Yellow in color if the detection system malfunctions (e.g. circuit disconnection, short-circuit, sensor fault). It shall be red in compliance with section paragraph 81.5.1.4.3;

(c) When illuminated, shall be visible to the driver under both daylight and night time driving conditions;

(d) Remains illuminated when 3.0 per cent concentration or detection system malfunction exists and the ignition locking system is in the "On" ("Run") position or the propulsion system is activated.

81.5.2 Post-crash fuel system integrity

The vehicle fuel system shall comply with the following requirements after the vehicle crash tests in accordance with the following Regulations by also applying the test procedures prescribed in paragraph 81.6.

(a) Frontal impact test in accordance with either “Steering control system - The protection of the driver against the steering mechanism in the event of impact ”or “The protection of the occupants in the event of a frontal collision ” regulated in “VSTD”; and

(b) Lateral impact test in accordance with “The protection of the occupants in the event of a lateral collision ” regulated in “VSTD”.

In case that one or both of the vehicle crash tests specified above are not applicable to the vehicle, the vehicle fuel system shall, instead, be subject to the relevant alternative accelerations specified below and the hydrogen storage system shall be installed in a position satisfying the requirements in paragraph 81.5.2.4. The accelerations shall be measured at the location where the hydrogen storage system is installed. The vehicle fuel system shall be mounted and fixed on the representative part of the vehicle. The mass used shall be representative for a fully equipped and filled container or container assembly.

Accelerations for vehicles of categories M1 and N1:

(a) 20 g in the direction of travel (forward and rearward direction);

(b) 8 g horizontally perpendicular to the direction of travel (to left and right).

Accelerations for vehicles of categories M2 and N2:

(a) 10 g in the direction of travel (forward and rearward direction);

(b) 5 g horizontally perpendicular to the direction of travel (to left and right).

Accelerations for vehicles of categories M3 and N3:

(a) 6.6 g in the direction of travel (forward and rearward direction);

(b) 5 g horizontally perpendicular to the direction of travel (to left and right).

81.5.2.1 Fuel leakage limit

The volumetric flow of hydrogen gas leakage shall not exceed an average of 118 Nl per minute for the time interval, delta t, as determined in accordance with paragraph 81.6.1.1 or 81.6.1.2.

81.5.2.2 Concentration limit in enclosed spaces

Hydrogen gas leakage shall not result in a hydrogen concentration in the air greater than 4.0 per cent by volume in the passenger and luggage-compartments (According to paragraph 81.6.2). The requirement is satisfied if it is confirmed that the shut-off valve of the storage system has closed within 5 seconds of the crash and no leakage from the storage system.

81.5.2.3 Container Displacement

The storage container(s) shall remain attached to the vehicle at a minimum of one attachment point.

81.5.2.4 Additional installation requirements

81.5.2.4.1 Requirements on installation of the hydrogen storage system not subject to the frontal impact test:

The container shall be mounted in a position which is rearward of a vertical plane perpendicular to the centre line of the vehicle and located 420 mm rearward from the front edge of the vehicle.

81.5.2.4.2 Requirements on installation of the hydrogen storage system not subject to the lateral impact test:

The container shall be mounted in a position which is between the two vertical planes parallel to the centre line of the vehicle located 200 mm inside from the both outermost edge of the vehicle in the proximity of its container(s).

81.6 Test procedures for a vehicle fuel system incorporating the compressed hydrogen storage system

81.6.1 Post-crash compressed hydrogen storage system leak test

The crash tests used to evaluate post-crash hydrogen leakage are those set out in paragraph 81.5.2. of this Regulation.

Prior to conducting the crash test, instrumentation is installed in the hydrogen storage system to perform the required pressure and temperature measurements if the standard vehicle does not already have instrumentation with the required accuracy.

The storage system is then purged, if necessary, following manufacturer's directions to remove impurities from the container before filling the storage system with compressed hydrogen or helium gas. Since the storage system pressure varies with temperature, the targeted fill pressure is a function of the temperature. The target pressure shall be determined from the following equation:

P_{target} = NWP x (273 + T_o) / 288

where NWP is the Nominal Working Pressure (MPa), T_o is the ambient temperature to which the storage system is expected to settle, and P_{target} is the targeted fill pressure after the temperature settles.

The container is filled to a minimum of 95 per cent of the targeted fill pressure and allowed to settle (stabilize) prior to conducting the crash test.

The main stop valve and shut-off valves for hydrogen gas, located in the downstream hydrogen gas piping, are in normal driving condition immediately prior to the impact.

81.6.1.1 Post-crash leak test: compressed hydrogen storage system filled with compressed hydrogen

The hydrogen gas pressure, P_0 (MPa) and temperature, T_0 (deg. C) are measured immediately before the impact and then at a time interval, delta t (min), after the impact. The time interval, delta t, starts when the vehicle comes to rest after the impact and continues for at least 60 minutes. The time interval, delta t, shall be increased, if necessary, to accommodate measurement accuracy for a storage system with a large volume operating up to 70MPa; in that case, delta t is calculated from the following equation:

delta t = V_{CHSS} x NWP /1,000 x ((-0.027 x NWP +4) x R_s - 0.21) -1.7 x R_s

where R_s = P_s / NWP, P_s is the pressure range of the pressure sensor (MPa), NWP is the Nominal Working Pressure (MPa), VCHSS is the volume of the compressed hydrogen storage system (L), and delta t is the time interval (min). If the calculated value of delta t is less than 60 minutes, delta t is set to 60 minutes.

The initial mass of hydrogen in the storage system is calculated as follows:

P_o' = P_o x 288 / (273 + T_0)

rho_o' = -0.0027 x (P_0')^2 + 0.75 x P_0' + 0.5789

M_o = rho_o' x V_{CHSS}

The final mass of hydrogen in the storage system, M_f, at the end of the time interval, delta $_t$, is calculated as follows:

P_f' = P_f x 288 / (273 + T_f)

rho_f' = -0.0027 x (P_f')^2 + 0.75 x P_f' + 0.5789

M_f = rho_f' x V_{CHSS}

where P_f is the measured final pressure (MPa) at the end of the time interval, and T_f is the measured final temperature (deg. C).

The average hydrogen flow rate over the time interval (that shall be less than the criteria in paragraph 7.2.1.) is therefore

V_{H2} = (M_f-M_o) / delta t x 22.41 / 2.016 x (P_{target} /P_o)

where V_{H2} is the average volumetric flow rate (NL/min) over the time interval and the term (P_{target} /P_o) is used to compensate for differences between the measured initial pressure, P_o, and the targeted fill pressure P_{target}.

81.6.1.2 Post-crash leak test: Compressed hydrogen storage system filled with compressed helium

The helium gas pressure, P_0 (MPa), and temperature T_0 (deg. C), are measured immediately before the impact and then at a predetermined time interval after the impact. The time interval, delta t, starts when the vehicle comes to rest after the impact and continues for at least 60 minutes. The time interval, delta t, shall be increased if necessary in order to accommodate measurement accuracy for a storage system with a large volume operating up to 70MPa; in that case, delta t is calculated from the following equation:

$$\text{delta t} = V_{CHSS} \times NWP / 1{,}000 \times ((-0.028 \times NWP + 5.5) \times R_s - 0.3) - 2.6 \times R_s$$

where $R_s = P_s$ / NWP, P_s is the pressure range of the pressure sensor (MPa), NWP is the Nominal Working Pressure (MPa), V_{CHSS} is the volume of the compressed storage system (L), and delta t is the time interval (min). If the value of delta t is less than 60 minutes, delta t is set to 60 minutes. The initial mass of helium in the storage system is calculated as follows:

$$P_o' = P_o \times 288 / (273 + T_0)$$

$$rho_o' = -0.0043 \times (P_0')^2 + 1.53 \times P_0' + 1.49$$

$$M_o = rho_o' \times V_{CHSS}$$

The final mass of helium in the storage system, M_f, at the end of the time interval, delta t, is calculated as follows:

$$P_f' = P_f \times 288 / (273 + T_f)$$

$$rho_f' = -0.0043 \times (P_f')^2 + 1.53 \times P_f' + 1.49$$

$$M_f = rho_f' \times V_{CHSS}$$

where P_f is the measured final pressure (MPa) at the end of the time interval, and T_f is the measured final temperature (deg. C).

The average helium flow rate over the time interval is therefore

$V_{He} = (M_f-M_o)$ / delta t x 22.41 / 4.003 x (P_{target}/ P_o)

where V_{He} is the average volumetric flow rate (NL/min) over the time interval and the term P_{target}/ P_o is used to compensate for differences between the measured initial pressure (P_o) and the targeted fill pressure (P_{target}).

Conversion of the average volumetric flow of helium to the average hydrogen flow is calculated with the following expression:

$V_{H2} = V_{He} / 0.75$

where V_{H2} is the corresponding average volumetric flow of hydrogen (that shall be less than the requirements in paragraph 81.5.2.1 of this Regulation to comply with).

81.6.2 Post-crash concentration test for enclosed spaces

The measurements are recorded in the crash test that evaluates potential hydrogen (or helium) leakage (paragraph 81.6.1 of this Regulation).

Sensors are selected to measure either the build-up of the hydrogen or helium gas or the reduction in oxygen (due to displacement of air by leaking hydrogen/helium).

Sensors are calibrated to traceable references to ensure an accuracy of +/-5 per cent at the targeted criteria of 4 per cent hydrogen or 3 per cent helium by volume in air, and a full scale measurement capability of at least 25 per cent above the target criteria. The sensor shall be capable of a 90 per cent response to a full scale change in concentration within 10 seconds.

Prior to the crash impact, the sensors are located in the passenger and, luggage compartments of the vehicle as follows:

(a) At a distance within 250 mm of the headliner above the driver's seat or near the top centre the passenger compartment;

(b) At a distance within 250 mm of the floor in front of the rear (or rear most) seat in the passenger compartment;

(c) At a distance within 100 mm of the top of luggage compartments within the vehicle that are not directly affected by the particular crash impact to be conducted.

The sensors are securely mounted on the vehicle structure or seats and protected for the planned crash test from debris, air bag exhaust gas and projectiles. The measurements following the crash are recorded by instruments located within the vehicle or by remote transmission.

The vehicle may be located either outdoors in an area protected from the wind and possible solar effects or indoors in a space that is large enough or ventilated to prevent the build-up of hydrogen to more than 10 per cent of the targeted criteria in the passenger and luggage compartments.

Post-crash data collection in enclosed spaces commences when the vehicle comes to a rest. Data from the sensors are collected at least every 5 seconds and continue for a period of 60 minutes after the test. A first-order lag (time constant) up to a maximum of 5 seconds may be applied to the measurements to provide "smoothing" and filter the effects of spurious data points.

The filtered readings from each sensor shall be below the targeted criteria of 4.0 per cent for hydrogen or 3.0 per cent for helium at all times throughout the 60 minutes post-crash test period.

81.6.3 Compliance test for single failure conditions

Either test procedure of paragraph 81.6.3.1. or paragraph 81.6.3.2. shall be executed:

81.6.3.1 Test procedure for vehicle equipped with hydrogen gas leakage detectors

81.6.3.1.1 Test condition

81.6.3.1.1.1 Test vehicle: The propulsion system of the test vehicle is started, warmed up to its normal operating temperature, and left operating for the test duration. If the vehicle is not a fuel cell vehicle, it is warmed up and kept idling. If the test vehicle has a system to stop idling automatically, measures are taken so as to prevent the engine from stopping.

81.6.3.1.1.2 Test gas: Two mixtures of air and hydrogen gas: 3.0 per cent concentration (or less) of hydrogen in the air to verify function of the warning, and 4.0 per cent concentration (or less) of hydrogen in the air to verify the shut-down function. The proper concentrations are selected based on the recommendation (or the detector specification) by the manufacturer.

81.6.3.1.2 Test method

81.6.3.1.2.1 Preparation for the test: The test is conducted without any influence of wind by appropriate means such as:

(a) A test gas induction hose is attached to the hydrogen gas leakage detector;

(b) The hydrogen leak detector is enclosed with a cover to make gas stay around hydrogen leak detector.

81.6.3.1.2.2 Execution of the test

(a) Test gas is blown to the hydrogen gas leakage detector;

(b) Proper function of the warning system is confirmed when tested with the gas to verify function of the warning;

(c) The main shut-off valve is confirmed to be closed when tested with the gas to verify function of the shut-down. For example, the monitoring of the electric power to the shut-off valve or of the sound of the shut-off valve activation may be used to confirm the operation of the main shut-off valve of the hydrogen supply.

81.6.3.2 Test procedure for integrity of enclosed spaces and detection systems.

81.6.3.2.1 Preparation:

81.6.3.2.1.1 The test is conducted without any influence of wind.

81.6.3.2.1.2 Special attention is paid to the test environment as during the test, flammable mixtures of hydrogen and air may occur.

81.6.3.2.1.3 Prior to the test the vehicle is prepared to allow remotely controllable hydrogen releases from the hydrogen system. The number, location and flow capacity of the release points downstream of the main hydrogen shut-off valve are defined by the vehicle manufacturer taking worst case leakage scenarios under single failure condition into account. As a minimum, the total flow of all remotely controlled releases shall be adequate to trigger demonstration of the automatic "warning" and hydrogen shut-off functions.

81.6.3.2.1.4 For the purpose of the test, a hydrogen concentration detector is installed where hydrogen gas may accumulate most in the passenger compartment (e.g. near the headliner) when testing for compliance with paragraph 81.5.1.4.2. of this Regulation and hydrogen concentration detectors are installed in enclosed or semi enclosed volumes on the vehicle where hydrogen can accumulate from the simulated hydrogen releases when testing for compliance with paragraph 81.5.1.4.3. of this Regulation (see paragraph 81.6.3.2.1.3).

81.6.3.2.2 Procedure:

81.6.3.2.2.1 Vehicle doors, windows and other covers are closed.

81.6.3.2.2.2 The propulsion system is started, allowed to warm up to its normal operating temperature and left operating at idle for the test duration.

81.6.3.2.2.3 A leak is simulated using the remote controllable function.

81.6.3.2.2.4 The hydrogen concentration is measured continuously until the concentration does not rise for 3 minutes. When testing for compliance with paragraph 81.5.1.4.3 of this Regulation, the simulated leak is then increased using the remote controllable function until the main hydrogen shut-off valve is closed and the tell-tale warning signal is activated. The monitoring of the electric power to the shut-off valve or of the sound of the shut-off valve activation may be used to confirm the operation of the main shut-off valve of the hydrogen supply.

81.6.3.2.2.5 When testing for compliance with paragraph 81.5.1.4.2. of this Regulation, the test is successfully completed if the hydrogen concentration in the passenger compartment does not exceed 1.0 per cent. When testing for compliance with paragraph 81.5.1.4.3. of this Regulation, the test is successfully completed if the tell-tale warning and shut-off function are executed at (or below) the levels specified in paragraph 81.5.1.4.3. of this Regulation; otherwise, the test is failed and the system is not qualified for vehicle service.

81.6.4 Compliance test for the vehicle exhaust system

81.6.4.1 The power system of the test vehicle (e.g. fuel cell stack or engine) is warmed up to its normal operating temperature.

81.6.4.2 The measuring device is warmed up before use to its normal operating temperature.

81.6.4.3 The measuring section of the measuring device is placed on the centre line of the exhaust gas flow within 100 mm from the exhaust point of discharge external to the vehicle.

81.6.4.4 The exhaust hydrogen concentration is continuously measured during the following steps:

(a) The power system is shut-down;

(b)Upon completion of the shut-down process, the power system is immediately started;

(c) After a lapse of one minute, the power system is turned off and measurement continues until the power system shut-down procedure is completed.

81.6.4.5 The measurement device shall have a measurement response time of less than 300 milliseconds.

81.6.5 Compliance test for fuel line leakage

81.6.5.1 The power system of the test vehicle (e.g. fuel cell stack or engine) is warmed up and operating at its normal operating temperature with the operating pressure applied to fuel lines.

81.6.5.2 Hydrogen leakage is evaluated at accessible sections of the fuel lines from the high pressure section to the fuel cell stack (or the engine), using a gas leak detector or a leak detecting liquid, such as soap solution.

81.6.5.3 Hydrogen leak detection is performed primarily at joints

81.6.5.4 When a gas leak detector is used, detection is performed by operating the leak detector for at least 10 seconds at locations as close to fuel lines as possible.

81.6.5.5 When a leak detecting liquid is used, hydrogen gas leak detection is performed immediately after applying the liquid. In addition, visual checks are performed a few minutes after the application of liquid to check for bubbles caused by trace leaks.

81.6.6 Installation verification

81.6.6.1 The system is visually inspected for compliance.