Draft

AUTOMOTIVE INDUSTRY STANDARD

Requirements for the protection of fuel (Liquid CNG/LPG) system and safety of electric power train in the event of rear impact of the motor vehicle

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INTRODUCTION

The Government of India felt the need for a permanent agency to expedite the publication of standards and development of test facilities in parallel when the work on the preparation of the standards is going on, as the development of improved safety critical parts can be undertaken only afterthe publication of the standard and commissioning of test facilities. To thisend, the erstwhile Ministry of Surface Transport (MOST) has constituted apermanent Automotive Industry Standard Committee (AISC) vide order No. RT-11028/11/97-MVL dated September 15, 1997. The standards prepared by AISC will be approved by the permanent CMVR Technical Standing Committee (CTSC). After approval, the Automotive Research Association of India, (ARAI), Pune, being the secretariat of the AISCommittee, will publish this standard.

1.0 The purpose of this standard is to bring about an improvement in the construction of the rear of vehicles and, in particular, those areas which influence the protection of the fuel systems (Liquid/CNG/LPG) (fuel tanks etc.) and safety of electric power train in the event of rear impact of a vehicle.

2.0 For improving the crash worthiness of a vehicle in the event of rear impact, the seating system should comply with the provisions of seats and seat anchorages standard IS 15546 amended time to time. AIS-101 and IS 15546 together would improve crash worthiness in rear impacts.

3.0 While preparing these AIS considerable assistance is derived from following international standards:

UN R34 (Suppl. 2 to 02 series of amendments(20.12.2012))	Uniform provisions concerning the approval of vehicles with regard to theprevention of fire risks
UN R 153 (Rev 3/Add. 152) (5 march 2021)	Approval of vehicles with regard to fuel system integrity and safety of electric power train in the event of a rear-end collision
FMVSS 303 (30 June 1995)	Fuel System Integrity of Compressed Natural Gas (CNG) Vehicles
CMVSS 301.1 (28 February 2004)	LPG Fuel System Integrity

4.0 The AISC panel and Automotive Industry Standards Committee (AISC) responsible for preparation of this standard are given in Annex C and Annex D *(To be included).*

Requirements for the protection of fuel system (Liquid/CNG/LPG) and safety of electric power train in the event of rear impact of the motor vehicle

1.0	**Scope**
1.1	This standard applies to the vehicles of categories M1 [with a total permissible mass not exceeding 3,500 kg] defined in AIS-053/IS-14272 with regards to the protection of fuel system (Liquid/CNG/LPG) and electric power train operating on high voltage in the event of rear impact.
1.2	At the request of the manufacturer, vehicles other than those mentioned in paragraph 1.1 may be approved under this standard.
2.0	**References**
2.1	AIS-053/ / IS-14272 Automotive Vehicles - Types - Terminology
3.0	**Definitions**
3.1	"Approval of a vehicle" means the approval of a vehicle type with regard to:
3.1.1	The protection of the fuel system (Liquid/CNG/LPG) and safety of electric power train in the event of rear impact.
3.2	**"Vehicle type"** means a category of power-driven vehicles which do not differ in such essential respects as:
3.2.1	The length and width of the vehicle in so far as they have an effect on the results of the impact test prescribed in this standard.
3.2.2	The structure, dimensions, lines and materials of the part of the vehicle rearward of the transverse plane through the "R" point of the rearmost seat in so far as they have an effect on the results of the impact test prescribed in this standard.
3.2.3	The position of the fuel tank(s) in the vehicle in so far as it has an effect on the requirements of this standard.
3.2.4	The structure, shape, dimensions and materials (plastic / metal) of the fuel tank(s) in so far as they have an effect on the results of the impact test prescribed in this standard.
3.2.5	The sitting (front, rear or centre) and the orientation (transversal or longitudinal) of the engine, in so far as they have an effect on the result of the impact test procedure as prescribed in this standard.
3.2.6	Characteristics and sitting of fuel feed system (pump, filters, etc.) in so far as they have an effect on the results of the impact test prescribed in this standard.
3.2.7	The characteristics and sitting of the electrical installation in so far as they have an effect on the results of the collision tests prescribed in this standard.
3.2.8	The lines and inside dimensions of the passenger compartment in so far as they have an effect on the results of the impact test prescribed in this standard.

3.2.9	The unladen kerb mass, in so far as there is an effect on the result of the impact test prescribed in this standard.
3.2.10	The locations of the REESS, in so far as they have an effect on the result of the impact test prescribed in this standard.
3.3	**“Unladen kerb Mass”** means the mass of the vehicle in running order, unoccupied and unladen but complete with fuel, coolant, lubricant, tools and a spare wheel (if provided as standard equipment by the vehicle manufacturer).
3.4	**"Transverse plane"** means the vertical transverse plane perpendicular to the median longitudinal plane of the vehicle;
3.5	**"Passenger compartment"** means the space for occupant accommodation, bounded by the roof, floor, side walls, doors, outside glazing, front bulkhead and rear bulkhead, or rear gate, as well as by the electrical protection barriers and enclosures provided for protecting the occupants from direct contact with high Voltage live parts.
3.6	**"Liquid Fuel Tank"** means the tank(s) designed to contain the liquid fuel, as defined in paragraph 3.7. Used primarily for the propulsion of the vehicle excluding its Accessories (filler pipe, if it is a separate element, filler hole, cap, gauge,connections to the engine or to compensate interior excess pressure, etc.);
3.7	**"Capacity of the fuel tank"** means the fuel-tank capacity as specified by the manufacturer.
3.8	**"Liquid fuel"** means a fuel which is liquid in normal temperature and pressure.
3.9	**"High voltage"** means the classification of an electric component or circuit, if its Working voltage is > 60 V and ≤ 1,500 Direct current (DC) or > 30 V and ≤1,000 V Alternating current (AC) roots – mean – square (rms).
3.10	**"Rechargeable electrical energy storage system (REESS)"** means the rechargeable energy storage system that provides electric energy for electrical propulsion. A battery whose primary use is to supply power for starting the engine and/or lighting and/or other vehicle auxiliary systems is not considered as a REESS. The REESS may include the necessary systems for physical support, thermal management, electronic controls and casing.
3.11	**"Electrical protection barrier"** means the part providing protection against any direct contact to the high voltage live parts.
3.12	**"Electric power train"** means the electrical circuit which includes the traction motor(s), and may also include the REESS, the electric energy conversion system, the electronic converters, the associated wiring harness and connectors, and the coupling system for charging the REESS.

3.13	**"Live parts"** means conductive part(s) intended to be electrically energized under normal operating conditions.
3.14	**"Exposed conductive part"** means the conductive part which can be touched under the provisions of the protection degree IPXXB, which is not normally energized, but which can become electrically energized under isolation failure conditions. This includes parts under a cover that can be removed without using tools.
3.15	**"Direct contact"** means the contact of persons with high voltage live parts.
3.16	**"Indirect contact"** means the contact of persons with exposed conductive parts.
3.17	**"Protection degree IPXXB"** means protection from contact with high voltage live parts provided by either an electrical protection barrier or an enclosure and tested using a Jointed Test Finger (protection degree IPXXB) as described in paragraph A.7.4 of Annex A.
3.18	**"Working voltage"** means the highest value of an electrical circuit voltage root-mean-square (rms), specified by the manufacturer, which may occur between any conductive parts in open circuit conditions or under normal operating conditions. If the electrical circuit is divided by galvanic isolation, the working voltage is defined for each divided circuit respectively.
3.19	**"Coupling system for charging the Rechargeable Electrical Energy Storage System (REESS)"** means the electrical circuit used for charging the REESS from an external electrical power supply including the vehicle inlet.
3.20	**"Electrical chassis"** means a set made of conductive parts electrically linked together, whose electrical potential is taken as reference.
3.21	**"Electrical circuit"** means an assembly of connected high voltage live parts which is designed to be electrically energized in normal operation.
3.22	**"Electronic converter"** means a device capable of controlling and/or converting electric power for electric propulsion.
3.23	**"Enclosure"** means the part enclosing the internal units and providing protection against any direct contact.
3.24	**"High Voltage Bus"** means the electrical circuit, including the coupling system for charging the REESS that operates on a high voltage, where electrical circuits are galvanically connected to each other and fulfill the specific voltage condition, only the components or parts of the electric circuit that operate on high voltage is classified as a high voltage bus.
3.25	**"Solid insulator"** means the insulating coating of wiring harnesses, provided in order to cover and prevent the high voltage live parts from any direct contact.

3.26	**"Automatic disconnect"** means a device that when triggered, conductively separates the electrical energy sources from the rest of the high voltage circuit of the electric power train.
3.27	**"Aqueous electrolyte"** means an electrolyte based on water solvent for the compounds (e.g. acids, bases) which provides conducting ions after its dissociation.
3.28	**"Electrolyte leakage"** means the escape of electrolyte from REESS in the form of liquid.
3.29	**"Non-aqueous electrolyte"** means an electrolyte not based on water as the solvent.
3.30	**"Normal operating conditions"** includes operating modes and conditions that can reasonably be encountered during normal operation of the vehicle including driving at legal speeds, parking or idling in traffic, as well as, charging using chargers that are compatible with the specific charging ports installed on the vehicle. It does not include, conditions where the vehicle is damaged, either by a crash, road debris or canalization, subjected to fire or water submersion, or in a state where service and or maintenance is needed or being performed.
3.31	**"Specific voltage condition"** means the condition that the maximum voltage of a galvanically connected electrical circuit between a DC live part and any other live part (DC or AC) is ≤ 30 V AC (rms) and ≤ 60 V DC. Note 1: When a DC live part of such an electrical circuit is connected to chassis and the specific voltage condition applies the maximum voltage between any live part and the electrical chassis are ≤ 30 V AC (rms) and ≤ 60 V DC. Note 2: For pulsating DC voltages (alternating voltages without change of polarity) the DC threshold shall be applied.
3.32	**"Average Temperature"** For calculating fuel system pressure drop, the average temperature measurement, either ambient air near the vehicle, or, when possible, fuel system (N2) temperature (in degrees Kelvin), is made at the start of fuel leakage test time (just following the cessation of motion) and every 15 minutes following the cessation of motion until the test time of 60 minutes is complete. The sum of the temperatures taken, divided by 5, yields the average temperature.
3.33	**"Bi-Fuel CNG Vehicle"** A vehicle equipped with two independent fuel systems, one of which is designed to supply CNG and the second to supply a fuel other than CNG.

3.34	**"CNG/LPG Fuel Container or CNG/LPG Fuel Tank"** A tank or container designed to store CNG/LPG as motor fuel onboard a motor vehicle.
3.35	**"CNG/LPG Fuel System"** All components used to store, direct, control, and/or supply CNG/LPG to a vehicle engine.
3.36	**"Dedicated CNG/LPG Vehicle"** A vehicle equipped with one fuel system designed to operate only on CNG/LPG.
3.37	**"Dual Fuel CNG/LPG Vehicle"** A vehicle which is fueled by two fuels simultaneously, one of which is CNG/LPG and the second of which is a fuel other than CNG/LPG.
3.38	**"Fuel Leakage (CNG/LPG Fuel Systems)"** Fuel system pressure drop due to system breaches loss of fitting integrity, other than pressure losses due to variations in ambient temperature.
3.39	**Fuel System Volume [V_{FS}]** The internal volume (in liters) of the fuel container and the fuel lines up to the first pressure regulator.
3.40	**"High Pressure Portion of a Fuel System"** All the components from and including each CNG/LPG fuel container up to, but not including, the first pressure regulator.
3.41	**"Shut off Valve"** Valve used to stop the flow of fuel system leading from one portion of the fuel system to another. These devices may be operated either manually or automatically and are, regardless of type, to be in the open (allowing flow) position during testing.
3.42	**"Service Pressure"** The internal pressure of a CNG/LPG fuel container (as specified by the manufacturer)when filled to design capacity with CNG/LPG at 20ºC.
4.0	**Application for approval**
4.1	The application for approval of a vehicle type with regard to the protection of the fuel system (Liquid/CNG/LPG) and safety of electric power train in the event of rear impact shall be submitted by the vehicle manufacturer or by his duly accredited representative.
4.2	It shall be accompanied by the below mentioned documents in triplicate and by the following particulars:
4.2.1	A detailed description of the vehicle type with respect to its structure, dimensions, lines and constituent materials.

4.2.2	Drawings of the vehicle showing the vehicle type in front, side and rear elevation and design details of the rear part of the structure; and
4.2.3	Particulars of the vehicle's unladen kerb mass.
4.3	A vehicle representative of the type to be approved shall be submitted to the testing agency responsible for conducting the approval tests.
4.3.1	A vehicle not comprising all the components proper to the type may be accepted for test provided that it can be shown that the absence of the components omitted has no detrimental effect on the results of the test, so far as the requirements of this standard are concerned.
4.3.2	The testing agency responsible for conducting the tests may allow the same vehicle as is used for tests prescribed by other standards (including tests capable of affecting its structure) to be used also for the tests prescribed by this standard; and the vehicle may be weighted to an extent not exceeding 10 per cent of its unladen kerb mass with additional weights rigidly secured to the structure in such a way as not to affect the behavior of the structure of the passenger compartment during the test.
4.4	It shall be the responsibility of the vehicle manufacturer for approval to show that acceptance of the variants referred to in paragraph 4.3.1. Is compatible with compliance with the requirements of this standard.
5.0	**Requirements**
5.1	When the vehicle has undergone the test referred to in paragraph 6 below, the provisions in paragraph 5.2 shall be fulfilled. A vehicle with all parts of the fuel system installed in front of the midpoint of the wheelbase is deemed to fulfill the provisions in paragraph 5.2.1. A vehicle with all parts of the electric power train operating on high voltage installed in front of the midpoint of the wheelbase is deemed to fulfill the provisions in paragraph 5.2.2. A vehicle with all parts of the CNG/LPG fuel system is installed in front of the midpoint of the wheelbase is deemed to fulfill the provisions in paragraph 5.2.3.
5.2	Following the test conducted in accordance with the procedure laid down in Annex A and Annex B of this standard, following provisions with regard to fuel system integrity and safety of electric power train shall be fulfilled.
5.2.1	In the case of a vehicle propelled by liquid fuel, compliance with paragraphs 5.2.1. 1 to 5.2.1.2 shall be shown.
5.2.1.1	No more than slight leakage of liquid from the fuel-feed installation shall occur on collision.

5.2.1.2	If there is continuous leakage in the fuel installation after the collision, the rate-of leakage shall not exceed 30 g/min; if the liquid from the fuel installation mixes with liquids from the other systems, and if the several liquids cannot be easily separated and identified, the continuous leakage shall be evaluated from all the fluids collected.
~~5.2.1.3~~	~~No fire maintained by the fuel shall occur.~~
~~5.2.1.4~~	~~During and after the impacts described in paragraph 6 the battery shall be kept inposition by its securing device.~~
5.2.2	In case of a vehicle equipped with an electric power train operating on high voltage, the electric power train and the high voltage systems which are galvanically connected to the high voltage bus of the electric power train shall meet the requirements in paragraphs 5.2.2.1 to 5.2.2.3
5.2.2.1	**Protection against electrical shock** After the impact, the high voltage buses shall meet at least one of the four criteria specified in paragraph 5.2.2.1.1 to paragraph 5.2.2.1.4 below. If the vehicle has an automatic disconnect function, or device(s) that conductively divide the electric power train circuit during driving condition, at least one of the following criteria shall apply to the disconnected circuit or to each divided circuit individually after the disconnect function is activated. However, criteria defined in 5.2.2.1.4. Below shall not apply if more than a single potential of a part of the high voltage bus is not protected under the conditions of protection degree IPXXB. In the case that the crash test is performed under the condition that part(s) of the high voltage system are not energized and with the exception of any coupling system for charging the REESS which is not energized during driving, the protection against electrical shock shall be proved by either paragraph 5.2.2.1.3. or paragraph 5.2.2.1.4 for the relevant part(s).
5.2.2.1.1	**Absence of high voltage** The voltages U_b, U_1 and U_2 of the high voltage buses shall be equal or less than 30 VAC or 60 VDC within 60s after the impact when measured in accordance with paragraph A.6.2 of Annex A.
5.2.2.1.2	**Low electrical energy** The Total Energy (TE) on the high voltage buses shall be less than 0.2 J when measured according to the test procedure as specified in paragraph A.6.3 of Annex A with the formula (a). Alternatively, the Total Energy (TE) may be calculated by the measured voltage U_b of the high voltage bus and the capacitance of the X- capacitors (C_x) specified by the manufacturer according to formula (b) of paragraph A.6.3 of Annex A. The energy stored in the Y-capacitors (TE_{y1}, TE_{y2}) shall also be less than 0.2 J. This shall be calculated by measuring the voltages U_1 and U_2 of the high

	voltagebuses and the electrical chassis, and the capacitance of the Y-capacitors specified by the manufacturer according to formula (c) of paragraph A.6.3 of Annex A.
5.2.2.1.3	**Physical protection** For protection against direct contact with high voltage live parts, the protection degree IPXXB shall be provided. The assessment shall be conducted in accordance with paragraph A.6.4 of AnnexA. In addition, for protection against electrical shock which could arise from indirect contact, the resistance between all exposed conductive parts of electrical protection barriers/enclosures and the electrical chassis shall be lower than 0.1 Ω and the resistance between any two simultaneously reachable exposed conductive parts of electrical protection barriers/enclosures that are less than 2.5m from each other shall be less than 0.2 Ω, when there is current flow of at least 0.2 A. This resistance may be calculated using the separately measured resistances of the relevant parts of electric path. This requirement is satisfied if the galvanic connection has been made by welding. In case of doubt or the connection is established by means other than welding, measurement shall be made by using one of the test procedures described in paragraph A.6.4 of Annex A.
5.2.2.1.4	**Isolation resistance** The criteria specified in the paragraphs 5.2.2.1.4.1 and 5.2.2.1.4.2 below shall be met. The measurement shall be conducted in accordance with paragraph A.6.5 of Annex A.
5.2.2.1.4.1	**Electric power train consisting of separate DC- or AC-buses** If the AC high voltage buses and the DC high voltage buses are galvanically isolated from each other, isolation resistance between the high voltage bus and the electrical chassis (Ri, as defined in paragraph A.6.5 of Annex A) shall have a minimum value of 100 Ω/V of the working voltage for DC buses, and a minimum value of 500 Ω/V of the working voltage for AC buses.
5.2.2.1.4.2	**Electric power train consisting of combined DC- and AC-buses** If the AC high voltage buses and the DC high voltage buses are conductively connected, they shall meet one of the following requirements: **(a)** Isolation resistance between the high voltage bus and the electrical chassis shall have a minimum value of 500 Ω/V of the working voltage; **(b)** Isolation resistance between the high voltage bus and the electrical chassis shall have a minimum value of 100 Ω/V of the working voltage and the AC bus meets the physical protection as described in paragraph 5.2.2.1.3; **(c)** Isolation resistance between the high voltage bus and the electrical chassis

	shall have a minimum value of 100 Ω/V of the working voltage and the AC bus meets the absence of high voltage as described in paragraph 5.2.2.1.1.
5.2.2.2	**Electrolyte leakage**
5.2.2.2.1	**In case of aqueous electrolyte REESS** For a period from the impact until 60 minutes after the impact, there shall be no electrolyte leakage from the REESS into the passenger compartment and not more than 7 per cent by volume of the REESS electrolyte with a maximum of 5.0 ltr leaked from the REESS to the outside of the passenger compartment. The leaked amount of electrolyte can be measured by the usual techniques of determining liquid volumes after its collection. For containers containing Stoddard, colored coolant and electrolyte, the fluids shall be allowed to separate by specific gravity and then measured.
5.2.2.2.2	**In case of non-aqueous electrolyte REESS** For a period from the impact until 60 minutes after the impact, there shall be no liquid electrolyte leakage from the REESS into the passenger compartment or luggage compartment and no liquid electrolyte leakage to outside the vehicle. This requirement shall be verified by visual inspection without disassembling any part of the vehicle. The manufacturer shall demonstrate compliance in accordance with paragraph A.6.6 of Annex A.
5.2.2.3	**REESS retention** REESS shall remain attached to the vehicle by at least one component anchorage, bracket, or any structure that transfers loads from REESS to the vehicle structure, and REESS located outside the passenger compartment shall not enter the passenger compartment. The manufacturer shall demonstrate compliance in accordance with paragraph A.6.7 of Annex A.
5.2.3	In case a vehicle is using CNG or LPG as a fuel, shall meet the requirements mentioned in 5.2.3.1 to 5.2.3.3 as applicable to either CNG or LPG fuel system.
5.2.3.1	For CNG vehicles, the pressure drop in the high pressure portion of the fuel expressed in kilopascals (kPa), When measured for first time from the time of collision through the 60-minutes period following cessation of motion shall not exceed. **1. 1062 kPa (154 psi)** **2. 895 (T/V_{FS}); whichever is higher** T is the average temperature of the test gas (in Kelvin) V_{FS} is the internal volume of the fuel container and fuel lines up to the first pressure regulator (in liters).

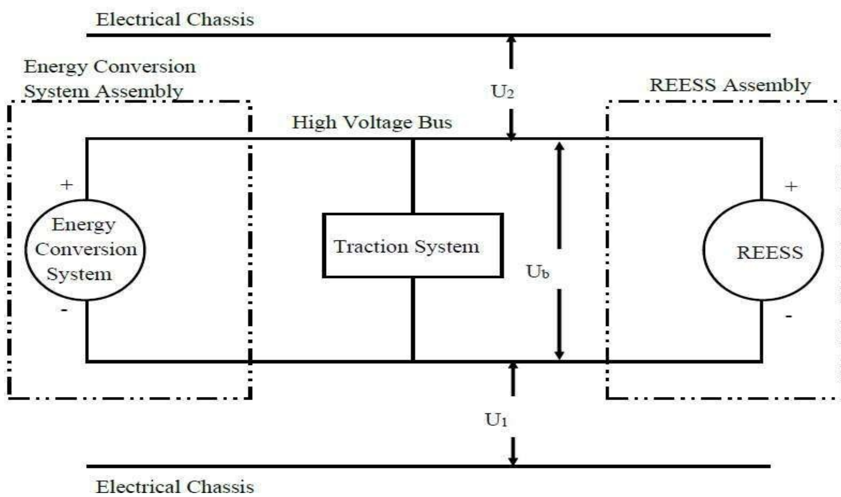
5.2.3.2	For LPG vehicles, there shall not be a fuel spillage more than 142 g from the fuel system for 90 minutes after motion of the vehicle has ceased. The temperature – corrected pressure in the high- pressure portion of the fuel system shall not decreases to less than 95 per cent of the initial system pressure during the one-half hour period after motion of the vehicle ceased.
5.2.3.3	The CNG/LPG fuel tank shall not be disengaged or separated from the attachment point. It should be attached to at least one attachment point.
6	**Tests**
6.1	The vehicle's compliance with the requirements of paragraph 5 above shall be checked by the method set out in Annex A or Annex B applicable to this standard.
7	**Modifications of the vehicle type**
7.1	Every modification of the vehicle type shall be notified to the testing agency which approved the vehicle type. The testing agency may then either:
7.1.1	Consider that the modifications made are unlikely to have appreciable adverse effects, and that in any case the vehicle still meets the requirements; or
7.1.2	Require a further test report.
7.2	Without prejudice to the provisions of paragraph 7.1. above, a variant of the vehicle whose unladen mass is lower or does not exceed by more than 25% from that of the approval-tested vehicle shall not be regarded as a modification of the vehicle type.
8	**Criteria for extension of type approvals**
8.1	Criteria for extension of approval shall be as mutually agreed between the testing agency and vehicle manufacturer.

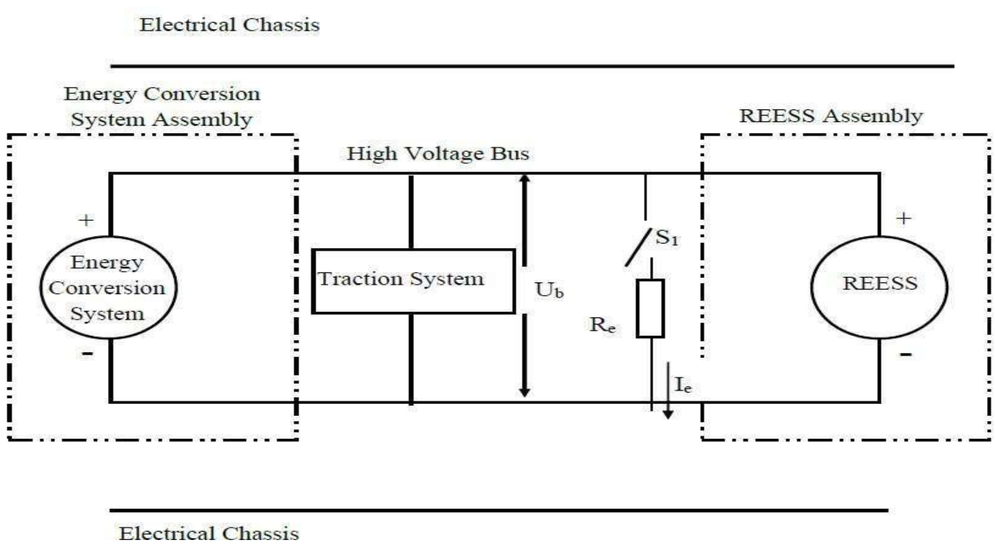
Annexure A
Test Procedure (see 6.1)

A.1	**Purpose and scope**
A.1.1	The purpose of the test is to simulate the conditions of rear-end collisionby another vehicle in motion.
A.2	**Installations, procedures and instruments**
A.2.1	**Testing ground** The test area shall be large enough to accommodate the impactor (striker) propulsion system and to permit after-collision displacement of the impacted vehicle and installation of the test equipment. The part in which vehicle collision and displacement occur shall be horizontal, flat and uncontaminated, and representative of a normal, dry, uncontaminated road surface.”
A.2.2	**Impactor (striker)**
A.2.2.1	The impactor shall be of steel and of rigid construction.
A.2.2.2	The impacting surface shall be flat, not less than 2,500 mm wide, and 800 mm high, and its edges shall be rounded to a radius of curvature of between 40 and 50mm. It shall be covered with layer of plywood 20 ±2 mm thick.
A.2.2.3	At the moment of collision the following requirements shall be met:
A.2.2.3.1	The impacting surface shall be vertical and perpendicular to the median longitudinal plane of the impacted vehicle;
A.2.2.3.2	The direction of movement of the impactor shall be substantially horizontal and parallel to the median longitudinal plane of the impacted vehicle;
A.2.2.3.3	The maximum lateral deviation tolerated between the median vertical line of the surface of the impactor and the median longitudinal plane of the impacted vehicle shall be 300 mm. In addition, the impacting surface shall extend over the entire width of the impacted vehicle;
A.2.2.3.4	The ground clearance of the lower edge of the impacting surface shall be 175 ± 25mm.
A.2.3	**Propulsion of the impactor**
A.2.3.1	The impactor may either be secured to a carriage (moving barrier) or form part of a pendulum.
A.2.4	**Special provisions applicable where a moving barrier is used**
A.2.4.1	If the impactor is secured to a carriage (moving barrier) by a restraining element, the latter shall be rigid and be incapable of being deformed by the collision; the carriage shall at the moment of collision be capable of moving freely and no longer be subject to the action of the propelling device.
A.2.4.2	The velocity of collision shall be between 35 and 38 km/h.
A.2.4.3	The aggregate weight (mass) of carriage and impactor shall be 1,100 ± 20 kg.

A.2.5	**Special provisions applicable where a pendulum is used**
A.2.5.1	The distance between the centre of the impacting face and the axis of rotation of the pendulum shall be not less than 5 m.
A.2.5.2	The impactor shall be freely suspended by rigid arms rigidly secured to it. The pendulum so constituted shall be substantially incapable of being deformed by the collision.
A.2.5.3	Arresting gear shall be incorporated in the pendulum to prevent any secondary collision by the impactor on the test vehicle.
A.2.5.4	At the moment of collision the velocity of the centre of percussion of the pendulum should be between 35 and 38 km/h.
A.2.5.5	The reduced mass "mr" at the centre of percussion of the pendulum is defined as a function of the total mass "m", of the distance "a"* between the centre of percussion and the axis of rotation, and of the distance "I" between the centre of gravity and the axis of rotation, by the following equation: **mr = m (I/a)**
A.2.5.6	The reduced mass "mr" shall be 1,100 ± 20 kg.
A.2.6	**General provisions relating to the mass and velocity of the impactor**
A.2.6.1	If the test has been conducted at a collision velocity higher than those prescribed in paragraphs A.2.4.2 and A2.5.4 and/or with a mass greater than those prescribed in paragraphs A2.4.3 and A2.5.6, and the vehicle has met the requirements prescribed, the test shall be considered satisfactory.
A.3	**State of vehicle under test**
A.3.1	The vehicle under test shall either be fitted with all the normal components and equipment included in its unladen kerb mass or be in such condition as to fulfill this requirement so far as the components and equipment of concern to the passenger compartment and the distribution of the mass of the vehicle as a whole, in running order, are concerned.
A.3.2	The fuel tank shall be filled to at least 90 per cent of its capacity either with fuel or with a non-inflammable liquid having a density and a viscosity close to those of the fuel normally used. All other systems (brake-fluid header tanks, radiator, etc.) may be empty. The CNG/LPG storage system(s) of CNG/LPG powered vehicles shall be prepared in accordance with Annex B.
A.3.3	At the choice of the vehicle manufacturer, a gear may be engaged and the brakes may be applied.
A.3.4	The doors should be latched but not locked.
A.3.5	Electric power train adjustment.
A.3.5.1	The REESS shall be at any state of charge, which allows the normal operation of the power train as recommended by the manufacturer

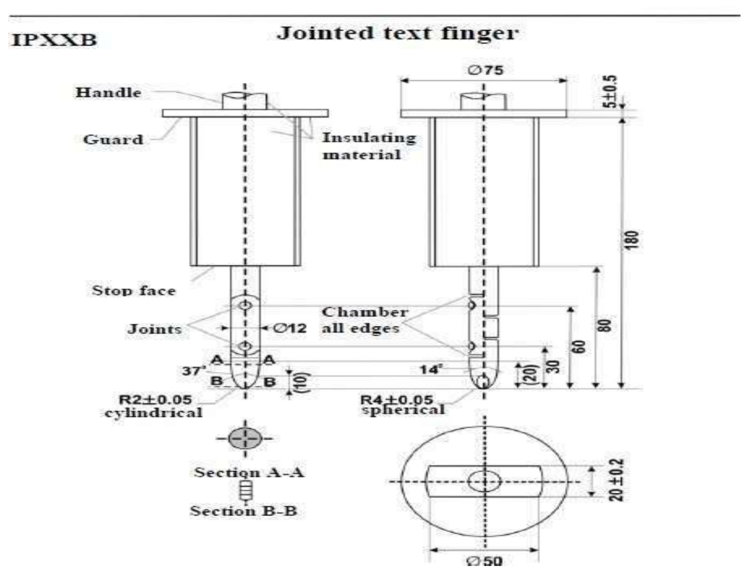
A.3.5.2	The electric power train shall be energized with or without the operation of the original electrical energy sources (e.g. engine-generator, REESS or electrical energy conversion system), however:
A.3.5.3	By the agreement between test agency and manufacturer it shall be permissible to perform the test with all or parts of the electric power train not being energized in so far as there is no negative influence on the test result. For parts of the electric power train not energized, the protection against electrical shock shall be proved by either physical protection or isolation resistance and appropriate additional evidence.
A.3.5.4	In the case where an automatic disconnect is provided, at the request of the manufacturer, it shall be permissible to perform the test with the automatic disconnect being triggered. In this case it shall be demonstrated that the automatic disconnect would have operated during the impact test. This includes the automatic activation signal as well as the galvanic separation considering the conditions as seen during the impact.
A.3.6	If the manufacturer so requests, the following derogations shall be permitted.
A.3.6.1	The test agency responsible for conducting the test may allow the same vehicle as is used for test prescribed by other standards (including tests capable of affecting its structure) to be used for the tests prescribed by this standard.
A.3.6.2	The vehicle may be weighted to an extent not exceeding 10 per cent of its unladen mass with additional masses rigidly secured to the structure in such a way as not to affect the fuel system integrity and the safety of electric power train during the test.
A.4	**Measuring instruments**
A.4.1	The instruments used to record the speed referred to in paragraphs A.2.4.2 and A.2.5.4 above shall be accurate to within one per cent.
A.5	**Equivalent test methods**
A.5.1	Equivalent test methods are permitted provided that the conditions referred in this standard can be observed either entirely by means of the substitute test or by calculation from the results of the substitute test.
A.6	**Test procedures for the vehicles equipped with electric power train**
This section describes test procedures to demonstrate compliance to the electrical safety requirements of paragraph 5.2.2 of this standard.	
A.6.1	**Test setup and equipment** If a high voltage disconnect function is used, measurements are to be taken from both sides of the device performing the disconnect function. However, if the high voltage disconnect is integral to the REESS or the energy conversion system and the high-voltage bus of the REESS or the energy conversion system is protected according to protection degree IPXXB following the impact test, measurements may only be taken between the device performing

	the disconnect function and the electrical loads. The voltmeter used in this test shall measure DC values and have an internal resistance of at least 10 mΩ.
A.6.2	The following instructions may be used if voltage is measured. After the impact test, determine the high voltage bus voltages (U_b, U_1 and U_2) (see Figure 1 below). The voltage measurement shall be made no earlier than 10 seconds, but, not later than 60 seconds after the impact. This procedure is not applicable if the test is performed under the condition where the electric power train is not energized. Figure 1 **Measurement of U_b, U_1, U_2** 
A.6.3	**Assessment procedure for low electrical energy** Prior to the impact a switch S_1 and a known discharge resistor R_e is connected in parallel to the relevant capacitance (ref. Figure 2 below).
(a)	Not earlier than 10 seconds and not later than 60 seconds after the impact the switch S_1 shall be closed while the voltage U_b and the current I_e are measured and recorded. The product of the voltage U_b and the current I_e shall be integrated over the period of time, starting from the moment when the switch S_1 is closed (tc) until the voltage U_b falls below the high voltage threshold of 60 V DC. The resulting integration equals the Total Energy (TE) in joules. $$TE = \int_{tc}^{th} U_b \, x \, I_e dt$$
(b)	When U_b is measured at a point in time between 10 seconds and 60 seconds after the impact and the capacitance of the X-capacitors (C_x) is specified by the manufacturer. Total Energy (TE) shall be calculated according to the following formula: $TE = 0.5 \text{ x } C_x \text{ x } U_b^2$

(c)	When U_1 and U_2 (see Figure 1 above) are measured at a point in time between 10 seconds and 60 seconds after the impact and the capacitances of the Y-capacitors (C_{y1}, C_{y2}) are specified by the manufacturer. Total Energy (TE_{y1}, TE_{y2}) shall be calculated according to the following formulas: $TE_{y1} = 0.5 \times C_{y1} \times U_1^2$ $TE_{y2} = 0.5 \times C_{y2} \times U_2^2$ This procedure is not applicable if the test is performed under the condition where the electric power train is not energized. Figure 2 **e.g. measurement of high voltage bus energy stored in X-capacitors** 
A.6.4	**Physical protection** Following the vehicle impact test any parts surrounding the high voltage components shall be, without the use of tools, opened, disassembled or removed. All remaining surrounding parts shall be considered part of the physical protection. The jointed test finger described in Figure 3 shall be inserted into any gaps or openings of the physical protection with a test force of 10 N ± 10 per cent for electrical safety assessment. If partial or full penetration into the physical protection by the jointed test finger occurs, the jointed test finger shall be placed in every position as specified below. Starting from the straight position, both joints of the test finger shall be rotated progressively through an angle of up to 90° with respect to the axis of the adjoining section of the finger and shall be placed in every possible position. Internal electrical protection barriers are considered part of the enclosure.

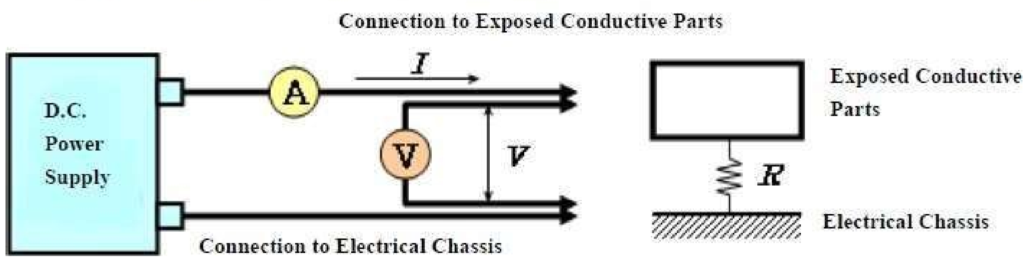
<table>
<tr><td></td><td>
If appropriate a low-voltage supply (of not less than 40 V and not more than 50 V)in series with a suitable lamp should be connected, between the jointed test finger and high voltage live parts inside the electrical protection barrier or enclosure.

Figure 3
Joint Test Finger



Material: metal, except where otherwise specified linear dimensions in mm.
Tolerances on dimensions without specific tolerance:
(a) On angles: +0°0′0″/-0°0′10″;
(b) On linear dimensions:
(i) ≤25 mm: +0/-0.05 mm;
(ii) >25 mm: ±0.2 mm

Both joints shall permit movement in the same plane and the same direction through an angle of 90° with a 0 to +10° tolerance.
The requirements of paragraph 5.2.2.1.3 of this standard are met if the jointed test finger described in Figure 3 is unable to contact high voltage live parts.
If necessary, a mirror or a fiberscope may be used to inspect whether the jointed test finger touches the high voltage buses.
If this requirement is verified by a signal circuit between the jointed test finger and high voltage live parts, the lamp shall not light.
</td></tr>
<tr><td>A.6.4.1</td><td>Test method for measuring electric resistance:</td></tr>
<tr><td>(a)</td><td>Test method using a resistance tester
The resistance tester is connected to the measuring points (typically, the electrical chassis and electro conductive enclosure/electrical protection barrier) and the resistance is measured using a resistance tester that meets the specification that follows:</td></tr>
</table>

(i)	Resistance tester: Measurement current at least 0.2 A;
(ii)	Resolution: 0.01 Ω or less;
(iii)	The resistance R shall be less than 0.1 Ω.
(b)	**Test method using DC power supply, voltmeter and ammeter** The DC power supply, voltmeter and ammeter are connected to the measuring points (Typically, electrical chassis and electro conductive enclosure/electrical protection barrier). The voltage of the DC power supply is adjusted so that the current flow becomes at least 0.2 A. The current "I" and the voltage "U" are measured. The resistance "R" is calculated according to the following formula: **R = U / I** The resistance R shall be less than 0.1 Ω. *Note:* If lead wires are used for voltage and current measurement, each lead wire shall be independently connected to the electrical protection barrier/enclosure/electrical chassis. Terminal can be common for voltage measurement and current measurement. Example of the test method using DC power supply, voltmeter and ammeter is shown below. Figure 4 **Example of test method using DC power supply** 
A.6.5	**Isolation resistance**
A.6.5.1.	**General** The isolation resistance for each high voltage bus of the vehicle is measured or shall be determined by calculating the measurement values of each part or component unit of a high voltage bus. All measurements for calculating voltage(s) and electrical isolation are made after a minimum of 10 s after the impact.
	Measurement method The isolation resistance measurement is conducted by selecting an appropriate measurement method from among those listed in paragraphs A.2.1. To A.2.6.1

A.6.5.2	of this annex, depending on the electrical charge of the live parts or the isolation resistance. The range of the electrical circuit to be measured is clarified in advance, using electrical circuit diagrams. If the high voltage buses are conductively isolated from each other, isolation resistance shall be measured for each electrical circuit. Moreover, modifications necessary for measuring the isolation resistance may be carried out, such as removal of the cover in order to reach the live parts, drawing of measurement lines and change in software. In cases where the measured values are not stable due to the operation of the on- board isolation resistance monitoring system, necessary modifications for conducting the measurement may be carried out by stopping the operation of the device concerned or by removing it. Furthermore, when the device is removed, a set of drawings will be used to prove that the isolation resistance between the live parts and the electrical chassis remains unchanged. These modifications shall not influence the test results. Utmost care shall be exercised to avoid short circuit and electric shock since this confirmation might require direct operations of the high-voltage circuit.
A.6.5.2.1.	Measurement method using DC voltage from external sources.
A.6.5.2.1.1	**Measurement instrument** An isolation resistance test instrument capable of applying a DC voltage higher than the working voltage of the high voltage bus shall be used.
A.6.5.2.1.2	**Measurement method** An isolation resistance test instrument is connected between the live parts and the electrical chassis. The isolation resistance is subsequently measured by applying a DC voltage at least half of the working voltage of the high voltage bus. If the system has several voltage ranges (e.g. because of boost converter) in conductively connected circuit and some of the components cannot withstand the working voltage of the entire circuit, the isolation resistance between those components and the electrical chassis can be measured separately by applying at least half of their own working voltage with those components disconnected.
A.6.5.2.2.	Measurement method using the vehicles own REESS as DC voltage source.
A.6.5.2.2.1	**Test vehicle conditions** The high voltage-bus is energized by the vehicle's own REESS and/or energy conversion system and the voltage level of the REESS and/or energy conversion system throughout the test shall be at least the nominal operating voltage as specified by the vehicle manufacturer.

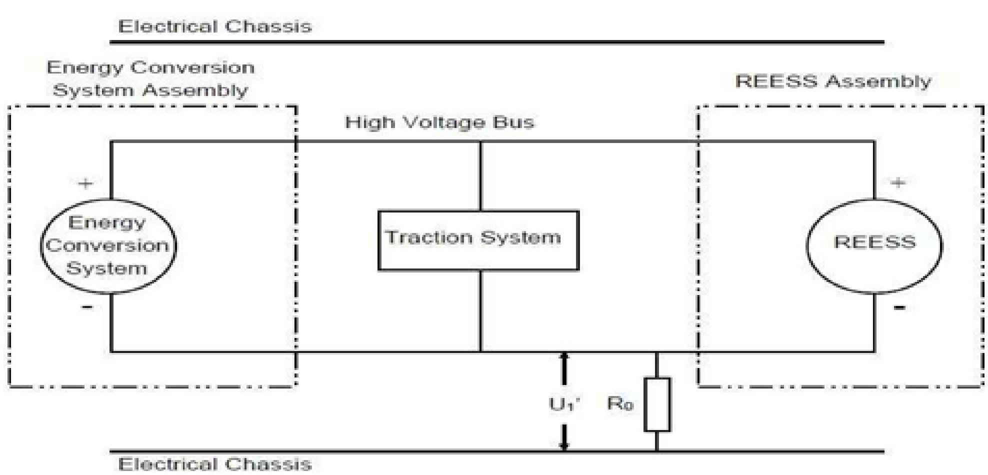
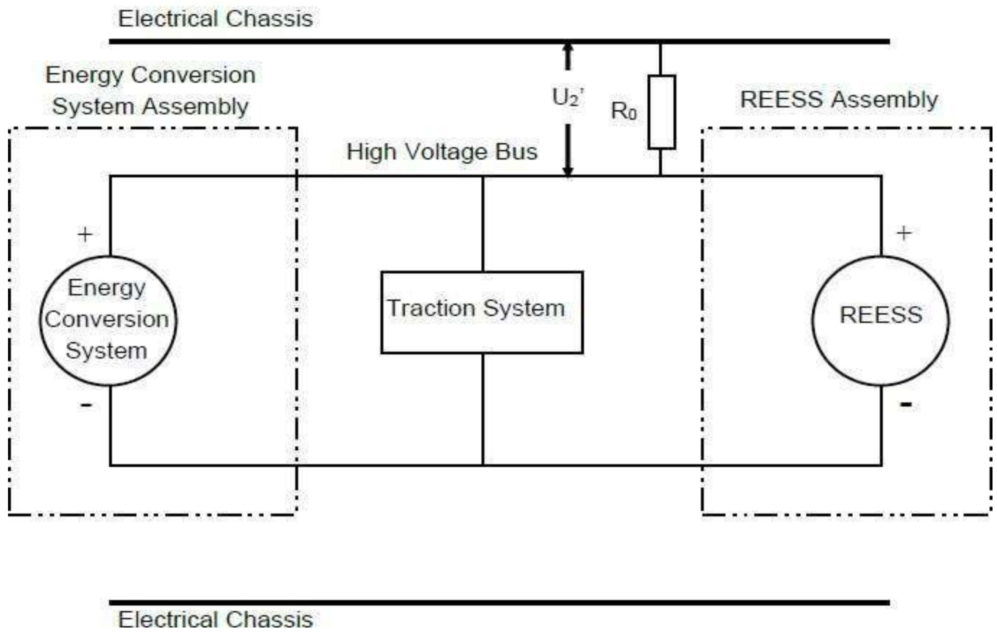
A.6.5.2.2.2.	Measurement method.
A.6.5.2.2.2.1	**First step** The voltage is measured as shown in Figure 1 and the high voltage bus voltage (U_b) is recorded.
A.6.5.2.2.2.2	**Second step** The voltage (U_1) between the negative side of the high voltage bus and the electrical chassis is measured and recorded (see Figure 1).
A.6.5.2.2.2.3	**Third step** The voltage (U_2) between the positive side of the high voltage bus and the electrical chassis is measured and recorded (see Figure 1).
A.6.5.2.2.2.4	**Fourth step** If U_1 is greater than or equal to U_2, a standard known resistance (R_o) is inserted between the negative side of the high voltage bus and the electrical chassis. With Ro installed, the voltage ($U_{1'}$) between the negative side of the high voltage bus and the electrical chassis is measured (see Figure 5). The electrical isolation (R_i) is calculated according to the following formula: $R_i = Ro*U_b*(1/U_1' - 1/U_1)$ Figure 5 Measurement of U_1'  If U_2 is greater than U_1, insert a standard known resistance (R_o) between the positive side of the high voltage bus and the electrical chassis. With Ro installed, measure the voltage ($U_{2'}$) between the positive side of the high voltage bus and the electrical chassis (see Figure 6). The electrical isolation (R_i) is calculated according to the following formula: $R_i = R_o*U_b*(1/U_{2'} - 1/U_2)$

	Figure 6 **Measurement of U_2'** 
A.6.5.2.2.2.5	**Fifth step** The electrical isolation value Ri (in Ω) divided by the working voltage of the high voltage bus (in V) results in the isolation resistance (in Ω/V). ***Note:*** The standard known resistance Ro (in Ω) should be the value of the minimum required isolation resistance (Ω/V) multiplied by the working voltage (V) of the vehicle plus/minus 20 per cent. Ro is not required to be precisely this value since the equations are valid for any Ro; however, a Ro value in this range should provide a good resolution for the voltage measurements.
A.6.6	**Electrolyte leakage** An appropriate coating, if necessary, may be applied to the physical protection (casing) in order to confirm if there is any electrolyte leakage from the REESS after the impact test.
A.6.7	**REESS retention** Compliance shall be determined by visual inspection.

Annexure B
Test Procedure (see 6.1)
Test Procedure for evaluation of fuel leakage in case of CNG/LPG powered vehicles

B.1	**Purpose and scope**
B.1.1	This annexure specifies requirements for the integrity of motor vehicle fuel systems using compressed natural gas (CNG) or Liquid petroleum gas (LPG), including the CNG/LPG fuel systems of bi-fuel, dedicated, and dual fuel CNG/LPG powered vehicles The purpose of this standard is to reduce deaths and injuries occurring from fires that result from fuel leakage during and after motor vehicle crashes.
B.2	**Pre-Test Conditions**
B.2.1	Test vehicle fuel storage system pressure shall be measured by at least one electronic pressure transducer with an accuracy of at least 0.1% over the pressure range of at least 0 to 4,000 psi and together with the recording equipment, shall have a potential error of no greater than ± 15.4 psi under test conditions. The transducer(s) must further be capable of making pressure measurements prior to, during and post Vehicle-barrier impacts of up to 48 kmph (including shock loads of 50 Gs).
B.2.2	**Fuel System Capacity (Pressure – CNG Fuel System)**
B.2.2.1	Prior to conducting the crash test, instrumentation is installed in the high pressure portion of a fuel system in location(s) mutually agreed between the manufacturer and testing agency to perform the required pressure and temperature measurements, if the standard vehicle does not already possess instrumentation with the required accuracy mentioned in B2.1.
B.2.2.2	The CNG storage system is then purged, if necessary, following manufacturer directions to remove impurities from the container before filling the storage system with nitrogen 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: $P_{target} = NWP \times (273+T_o)/288$ Where NWP is the Nominal Working Pressure (MPa), to be the ambient temperature to which the storage system is expected to settle and Ptarget is the targeted fill pressure after the temperature settles.
B.2.2.3	The high pressure portion of a fuel system is filled to a minimum of 95 % percent of the targeted fill pressure and allowed to settle (stabilize) prior to conducting the crash test.

B.2.2.4	The main stop valve and shut-off valves for CNG gas, located in the downstream piping, are in normal driving condition immediately prior to the impact.
B.2.3	**Fuel System Capacity (for liquid fuel system of bi/dual fuel vehicles)**
B.2.3.1	With the test vehicle on a level surface, pump the fuel from the vehicle's fuel tank and then operate the engine until it stops.
B.2.3.2	Fill the tank to 90 % of its capacity with water well mixed with blue color.
B.2.4	**Electric Fuel Pump Operation and Shutoff Valve Operation** If the vehicle has an electrically driven fuel pump that normally runs when the vehicle'selectrical system is activated, it shall be operating at the time of the barrier crash. If the vehicle has any electric shutoff valves that are normally open when the electrical system is activated, they (and all manually operated shutoff valves) are to be open at the time of the barrier crash. Further, any electric shutoff valve that prevents sensing of system pressure by the pressure transducer when closed must remain open for the initial pressure measurement. Any valve shall be open for a period of one minute to equalize system pressure. NOTE: when it is required to drain acid from vehicle's battery prior to impact test (for protection of test personnel), it may be necessary to install a 12 volt dry cell battery in the test vehicle to be connected to the vehicle's battery terminals. The vehicle's ignition switch shall be placed in the "ON" position prior to the impact test.
B.2.5	**Fuel System Capacity (Pressure – LPG Fuel System)**
B.2.5.1	The LPG fuel container shall be filled with water to a level simulating the weight of the quantity of LPG required to fill it to 80% of its capacity.
B.2.5.2	Those portions of the LPG fuel system that normally contain propane in its liquid phase, other than the fuel container, shall be filled with water to the normal operating level.
B.2.5.3	The high-pressure portion of the fuel system shall be pressurized using nitrogen to 140 kPa below its maximum operating pressure, as specified by the vehicle manufacturer, and the measured change in fuel system pressure shall be appropriately adjusted to compensate for changes in atmospheric conditions occurring during the test. The adjusted value shall be compared with the stipulated limit value.
B.2.5.4	The fuel system pressure shall stabilize to ambient temperature before testing may be conducted.
B.2.5.5	All fuel system manual shutoff valves shall be in the open position, to simulate the engine running, at the time of the barrier crash.

	If any electric shutoff valves prevent sensing of the pressure in the high-pressure portion of the fuel system by the pressure transducer when closed, they must be open for both the pre-test pressure measurement and after the vehicle ceases motion from the impact. All such electric shutoff valves shall be open for a period of one minute prior to completing the pre-test fuel system pressure measurement and for 30 minutes after the vehicle ceases motion from the impact.
B.2.5.6	If the vehicle has any fuel system electric shutoff valves that are normally open when the electrical system is activated, they shall be open at the time of the barrier crash and shall be set to close on impact. The pressure measurement shall be made using a location on the high-pressure portion of the fuel system that is in accordance with the vehicle manufacturer's recommendation.
B.3	**Post Crash Measurements & Observations**
B.3.1	**In case of CNG** Observe the pressure drop for the period of 60 minutes at the interval of not more than 15 minutes after the cessation of the vehicle. The pressure drop shall not exceed:- (1) 1,062 kPa (154psi). (2) 895 (T/V_{FS}); whichever is higher Remarks:- 1) At least 05 readings for CNG are required 2) Requirement of Pressure Drop is defined in Cl. 5.2.3 where T is the average temperature of the test gas in degrees Kelvin, stabilized to ambient temperature before testing, where average temperature (T) is calculated by measuring ambient temperature at the start of the test time and then every 15 minutes until the test time of 60 minutes is completed; the sum of the ambient temperatures is then divided by five to yield the average temperature (T); and where V_{FS} is the internal volume in liters of the fuel container and the fuel lines up to the first pressure regulator.
B.3.2	**In case of LPG** Observe the pressure drop for the period of 90 minutes at the interval of not more than 15 minutes after the cessation of the vehicle. **Remarks:-** 1) At least 07 readings for LPG are required 2) Requirement of Pressure Drop is defined in Cl. 5.2.3