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APPENDIX J – ARTICLE 266

ENERGY REGULATIONS FOR COMPETITION VEHICLES

A. INTRODUCTION

This appendix defines the general regulatory framework applicable to all energy sources used in FIA competitions, namely liquid fuels, electric power, and hydrogen. Its objective is to establish common principles that ensure safety and promote the transition towards greener mobility. Specific provisions related to each energy type are detailed in the following sections.

Preliminary notices and terms

1. The contents of this Appendix (including health and safety, sporting or technical matters) taken in isolation may not be suitable or appropriate for each and every motor sport event (which incorporates all of the following activities: i) motor sports competitions, practices, tests, reconnaissance's / "recce's"and demonstrations, ii) any associated entertainment, marketing or commercial activities and iii) any engineering, scrutineering, maintenance or other technical activities, and begins from the time the relevant locations where these activities are taking place are made accessible to any persons, and ends when the relevant locations are closed to access or the activities end, whichever occurs later). For the avoidance of any doubt, compliance with this Appendix in isolation does not guarantee the safety of a particular motor sport event or of the participants to a particular motor sport event.

2. It is the full responsibility of all users of this Appendix to ensure that they understand and comply with any relevant obligations or duties relating to health and safety, product design, construction/manufacturing or consumer law which are placed on them under i) any applicable National Sporting Authority requirements, regulations and safety standards ("**ASN Regulations**"), ii) FIA requirements, regulations and safety standards ("**FIA Regulations**") and/or iii) any relevant transnational, national and/or local laws, regulations, directives and decrees passed by the government, a quasi-governmental entity or by any entity which has the same authority as the government in any applicable country or other territory, including all applicable local, state and federal laws, and any industry practices, codes of practice and/or codes of conduct incorporated into any of the foregoing, and all binding court orders, decrees, and any decisions and/or rulings of any competent authority that are relevant ("**Applicable Laws**"). The FIA assumes no responsibility in relation to such understanding or compliance, including specifically in relation to the safe, competent and effective manufacture and use of the car structures, systems and components, which will remain the sole responsibility of the relevant manufacturers or users.

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4. If there is any conflict, or any doubt as to a conflict, between the contents of this Appendix and Applicable Laws, Applicable Laws always take precedence. If it is possible to comply both with Applicable Laws and this Appendix (subject to all appropriate adaptations as per paragraph 3), users of this Appendix should endeavor to do so.

5. The technology utilized in motor sport vehicles, equipment, structures, installations and products is subject to ongoing change and development, as well as good and best practice evolving over time. As a result, this Appendix is subject to ongoing review and amendment over time.

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   a. the user of this Appendix and its Representatives agree to waive any rights and/or claims, agree to release, hold harmless and not to sue the FIA or its Representatives in relation to any claims, liabilities, costs, expenses, damages and losses (including those referred to in paragraph 6 above); and

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   in each case arising from the use or implementation of, or reliance placed on the contents of, this Appendix in relation to a particular motor sport event.

B. SPECIFIC REQUIREMENTS FOR FUEL - COMBUSTIVE

The fuel is accepted or rejected according to ASTM D3244 standard with a confidence limit of 95%.
If the fuel available locally for the event does not comply with the specifications below, the ASN of the organising country must ask the FIA for a waiver in order to enable the use of such a fuel.

1. Petrol

The fuel must comply with the following specifications :

Property	Units	Min.	Max.	Test methods
RON		95.0(1)	102.0(1)	ISO 5164 ASTM D2699
MON		85.0(1)	90.0(1)	ISO 5163 ASTM D2700
Density (at 15°C)	kg/m³	720.0	785.0	ISO 12185 ASTM D4052
Oxygen	% m/m		3.7	EN ISO 22854(2) / EN 13132(2) Elemental Analysis ASTM D5622
Methanol	% v/v		3.0	EN 1601 or EN 13132 or EN ISO 22854
Nitrogen	mg/kg		500(4)	ASTM D4629 ASTM D5762
Sulphur	mg/kg		10	ISO 20846(2) ASTM D5453
Lead	mg/l		5	EN 237 ASTM D3237 or ICP-OES
Manganese	mg/l		2.0	ASTM D3831 or (ICP-OES) EN 16136
Benzene	% v/v		1.00	ISO 12177 ASTM D5580 ISO 22854(2) ASTM D6839 EN 238
Olefins	% v/v/		18.0	ISO 22854 ASTM D6839
Aromatics	% v/v		35.0	ISO 22854 ASTM D6839
Total di-olefins	% m/m		1.0	GC-MS or HPLC
Total styrene and alkyl derivatives	% m/m		1.0	GC-MS with GC-FID
Oxidation Stability	minutes	360		ISO 7536 ASTM D525
DVPE	kPa		80(6)	ISO 13016-1(2) ASTM D4953 ASTM D5191(2)

Distillation characteristics				
At E70ºC	% v/v	20.0	52.0	ISO 3405/ ASTM D86
At E100°C	% v/v	46.0	72.0	ISO 3405 ASTM D86
At E150°C	% v/v	75.0		ISO 3405 ASTM D86

Final boiling point	°C		210	ISO 3405 ASTM D86
Residue	% v/v		2.0	ISO 3405 ASTM D86

(1) A correction factor of 0.2 for MON and RON shall be subtracted for the calculation of the final result in accordance with EN 228: 2012.
(2) Preferred method.
(3) A stabilising agent must be added.
(4) Octane boosting nitro compounds are not permitted.
(5) If at an event the competitor has, by necessity, used a local fuel with a high sulphur content, then any sample taken from the car in the subsequent event will be considered compliant if the sulphur content is less than 50mg/kg.
(6) The maximum DVPE may rise to 100 kPa for winter competitions.

The only oxygenates permitted are paraffinic mono-alcohols and paraffinic mono-ethers (of 5 or more carbon atoms per molecule) with a final boiling point below 210°C.

The addition of a lubricant on current sale is permitted in fuels for use in 2-stroke engines.

2. Diesel

2.1. Petroleum Diesel

The fuel must be gas oil corresponding to the following specifications :

Property	**Units**	**Min.**	**Max.**	**Test methods**
Density (at 15°C)	kg/m³	820.0	845.0	ISO 12185 ASTM D4052
Cetane Number(2)			60.0(1)	ISO 5165 ASTM D613
Derived Cetane Number (DCN) (2)			60.0(1)	EN 15195 ASTM D6890 EN16715
Sulphur	mg/kg		10	ISO 20846 ASTM D5453
Polycyclic Aromatic Hydro-carbons	% m/m		8.0	IP 548 ASTM D6591 (FAME-free fuels) EN 12916 (FAME-containing and FAME free fuels)
FAME	% v/v		7.0	EN 14078 ASTM D7371
Water content	mg/kg		200	EN ISO 12937
Total Contamination	mg/kg		24	EN12662
Cold filter plugging point (CFPP)	°C		-5	EN 116 ASTM D6371
Flash point	°C	55		EN ISO 3679 EN ISO 2719(4) ASTM D93
Lubricity	µm		460	ISO12156-1 ASTM D6079

(1) At the discretion of the FIA the maximum Cetane and Derived Cetane numbers may be increased to 70.0 for FIA International competitions /Championships and/or at the discretion of the ASN of the organising country for national/local competitions or championships. See also Articles B.2.2, B.2.3 and B.2.4 for blended diesels.
(2) Either the Cetane Number or the Derived Cetane Number must be analysed. It is not necessary for both analyses to be performed.
(3) If at an event the competitor has, by necessity, used a local fuel with a high sulphur content, then any sample taken from the car in the subsequent event will be considered compliant if the sulphur content is less than 50mg/kg.
(4) Preferred method.

2.2. Biodiesel (B100)

Biodiesel must conform to the following specifications:

Property	Units	Min.	Max.	Test methods
Ester content	% m/m	96.5		EN 14103
Density (at 15°C)	kg/m³	860.0	900.0	EN ISO 12185 ASTM D4052
Cetane number			70.0	EN ISO 5165 ASTM D613
Derived cetane number (DCN)			70.0	EN 15195 ASTM D6890 EN16715
Sulphur	mg/kg		10(1)	EN ISO 20846 ASTM D5453
Water content	mg/kg		500	EN ISO 12937
Total contamination	mg/kg		24	EN12662 : 2008
Viscosity (at 40°C)	mm²/s	1.90	6.00	EN ISO 3104 ASTM D445
Cold filter plugging point (CFPP)	°C		-5	EN 116 ASTM D6371
Flash point	°C	93		EN ISO 3679 ASTM D93
Oxidation stability (at 110 °C	Heures	6		EN 15751(2) / EN 14112
Acid Number/ Value	mg KOH/g		0.5	ASTM D664 EN14104
Linolenic Acid ME	% m/m		12	EN 14103
Methanol	% mm		0.20	EN 14110
Free Glycerol	% m/m		0.02	EN 14105 ASTM D6584
Group I Metals (Na+K)	mg/kg		5	EN 14108 (Na) EN 14109 (K)
Group II Metals	mg/kg		5	EN 14538

(1) If at an event the competitor has, by necessity, used a local fuel with a high sulphur content, then any sample taken from the car in the subsequent event will be considered compliant if the sulphur content is less than 50mg/kg.

(2) In the case of a dispute over the oxidation stability this method shall be used.

If biodiesel is blended with a petroleum diesel then the following parameters can vary according to the following formulae, where B is the percentage (volume) of biodiesel in the blended mixture:

Parameter	Formula	Test methods
Cetane and DCN (Max.)	60.0 + (0.10 x B)	As above (B.2.2)
FAME Content (Min % v/v)	0.95 x B(1)	EN 14078/ ASTM D7371
Density Min. (kg/m³) Density Max. (kg/m³)	820.0 + (0.40 x B) 845.0 + (0.55 x B)	As above (B.2.2)
Water Content (Max. mg/kg)	200 + (3.0 x B)(1)	As above (B.2.2)
Flash Point (Min. °C)	55(1)	As above (B.2.2)
Oxidation Stability (Min. hours)	6(1)	EN 15751

(1)	This also applies to blends of biodiesel with paraffinic diesel.

Prior to the use of any blended diesel, the competitor must inform the FIA or the ASN of the organising country the proportion of the various blending stocks. In the absence of this information, the percentage (v/v) of biodiesel will be taken as the percentage (v/v) FAME content (by EN 14078/ ASTM D7371).

2.3. Paraffinic Diesel (Including HVO)

Paraffinic diesel must conform to the following specifications:

Property	Units	Min.	Max.	Test methods
Density (at 15 °C)	kg/m³	765.0	800.0	EN ISO 12185 ASTM D4052
Cetane number			80.0[(1)]	EN ISO 5165 ASTM D613
Derived Cetane Number (DCN)			80.0[(1)]	EN 15195 ASTM D6890 EN16715
FAME content	% v/v		7.0	EN 14078
Sulphur	mg/kg		5[(2)]	EN ISO 20846 ASTM D5453
Total aromatic content	% m/m		1.1	EN 12916
Total contamination	mg/kg		24	EN12662
Viscosity (at 40 °C)	mm²/s	2.00	4.50	EN ISO 3104 ASTM D445
Cold filter plugging point (CFPP)	°C		-5	EN 116 ASTM D6371
Flash point	°C	55		EN ISO 3679 EN 2719[(3)] ASTM D93
Oxidation stability	Heures Hours	20		EN 15751
Lubricity – 60 °C	µm		460	EN ISO12156-1 ASTM D6079
Distillation characteristics				
Evaporated at 250 °C	% v/v		65	EN ISO 3405
Evaporated at 350 °C	%v/v	85		EN ISO 3405
95% v/v Recovered	°C		360	EN ISO 3405

(1)	At the discretion of the FIA the maximum Cetane may be increased to 90.0 provided the fuel contains a minimum of 50% AS HVO or AS diesel.
(2)	If at an event the competitor has, by necessity, used a local fuel with a high sulphur content, then any sample taken from the car in the subsequent event will be considered compliant if the sulphur content is less than 50mg/kg.
(3)	Preferred method.

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If a paraffinic diesel is blended with a petroleum diesel or bio-diesel the following parameters can vary according to the following formulae, where P is the percentage (volume) of paraffinic diesel in the blended mixture:

Parameter	Formula	Test methods
Cetane and DCN (Max.) – Petroleum Diesel	60 + (0.2 x P)	As above (B.2.3)
Cetane and DCN (Max.) – Biodiesel	70 + (0.1 x P)	As above (B.2.3)
Total Aromatic Content (Max. % m/m)	8.0 – (0.069 x P)	As above (B.2.3)
Density Min. (kg/m^3) Density Max. (kg/m^3)	820.0 + (0.40 x B) 845.0 + (0.55 x B)	As above (B.2.3)
Oxidation Stability- Biodiesel blends only (Min. hours)	6	EN 15751

Prior to the use of any blended diesel, the competitor must inform the FIA or the ASN of the organising country the proportion of the various blending stocks. In the absence of this information, the percentage (v/v) of biodiesel will be taken as the percentage (v/v) FAME content (by EN 14078/ ASTM D7371).

2.4. Ternary diesel mixtures

Ternary blends of petroleum, bio- and paraffinic diesels must meet the specifications of petroleum diesel in Article B.2.1. However, the following parameters can vary according to the following formulae, where D is the percentage (volume) of petroleum diesel, B is the percentage (volume) of biodiesel and P is the percentage (volume) of paraffinic diesel in the blended mixture:

Parameter	Formula	Test methods
Cetane and DCN (Max.)	(60D+70B+80P)/100	As above (B.2.2)
Polycyclic Aromatic Hydrocarbons (Max. % m/m)	(8.0D+0.0B+1.1P)/100	EN 12916
FAME Content (Min % v/v)	0.95 x B	EN 14078 ASTM D7371
Water Content (Max. mg/kg)	(200D+500B+200P)/100	As above (B.2.2)
Flash Point (Min. °C)	55	As above (B.2.2)
Oxidation stability (Min. hours)	6	EN 15751

In the case of a ternary blend, any density between 765.0 kg/m^3 and 900.0 kg/m^3 will be allowed.

Prior to the use of any blended diesel, the competitor must inform the FIA or the ASN of the organising country the proportion of the various blending stocks. In the absence of this information, the percentage (v/v) of biodiesel will be taken as the percentage (v/v) FAME content (by EN 14078/ ASTM D7371) and the remaining fraction will be regarded as petroleum diesel.

3. Advanced Sustainable (AS) Fuels

3.1. Definition

An advanced sustainable (AS) fuel in this specification comprises AS components that are composed solely of certified compounds and refinery streams, and fuel additives.

For the purposes of this regulation, co-processing of these certified compounds or refinery streams is permitted.

Co-processing is the procedure of processing feedstocks blended of sustainable and non-sustainable origin. Quantification is carried out by mass-balancing [(1)] the proportion of sustainable input material and calculating the share of sustainable-based material, on an equivalent basis, to one or several products. Verification of the methodology shall be through a recognized voluntary sustainability scheme certification (e.g. ISCC) of the component production facility. Sustainability documentation (e.g. PoS) can then be issued by the component plant operator to their customers identifying the proportion of the final product which is advanced sustainable (AS).

An AS component is one that is certified to have been derived from a renewable feedstock of non biological origin (for example, a RFNBO), municipal waste, or non-food biomass.

The AS components must achieve a greenhouse gas (GHG) emissions saving, relative to fossil-derived gasoline, of at least that defined for the transport sector in the EU Renewable Energy Directive RED [(2,3,4)], which was current on January 1st in the year prior to the relevant Championship.

Such biomass includes, but is not limited to, lignocellulosic biomass (including sustainable forest biomass), algae, agricultural residues or waste, and dedicated non-food energy crops grown on marginal land unsuitable for food production.

RFNBOs are considered renewable when they are produced entirely using new renewable electricity generation capacity. Pre-commercial plants producing RFNBOs do not need to use electricity from new renewable electricity generating capacity. They may use renewable energy certificates and/or low-carbon hydrogen guarantees-of-origin certificates to improve their GHG emission reduction.

Biocomponents from food crops can be regarded as an advanced sustainable component only if they have already fulfilled their food purpose (e.g. waste vegetable oil because it has already been used and is no longer fit for human consumption).

Furthermore, the biomass, from which the advanced sustainable component was made, must not originate from land with high biodiversity such as undisturbed primary forest or woodland, land designated for nature protection or highly biodiverse grassland, and were in this state in or after January 2008.

Additionally, the biomass must not originate from any land with high-carbon stock such as wetlands and peatlands.

The GHG savings calculation takes into account any net carbon emissions from land-use change, the energy used in harvesting and transporting the biomass and the production and processing of the advanced sustainable component.

In any process where sustainable energy is used, this must be surplus to the local domestic requirements. Pre-commercial plants, producing AS fuel or AS fuel components may use renewable energy certificates and/or low-carbon hydrogen guarantees-of-origin certificates to improve their GHG emission reduction.

A **Pre-commercial plant** is one that has a total maximum production capacity of all AS products of 40,000m^3 per year, with a minimum production capacity of 5m^3 per year.

Where available, GHG emission savings will be taken from the current EU Renewable Energy Directive (RED) or other equivalent, internationally recognised sources.

(1) ^{14}C testing by ASTM D6866 may also be required (for example, as proof of the declared concentration of bio-component in the fuel)
(2) Article 29, Section 10(c) of Directive (EU) 2018/2001 for biofuels, and Article 25, Section 2 for RFNBO
(3) In fuels where the AS components can represent less than 100% of the fuel, the GHG emission saving requirement applies only to that part of the fuel comprising AS components.
(4) Where a number of AS components are present in the fuel, it is permitted to include AS components with individual GHG emission savings below the minimum values stipulated in (1) above, provided that the total GHG emission saving of the AS components complies with the minimum required.

3.2. AS Petrol

For the purposes of this article, an AS petrol is a petrol that complies with Article B.3.1. Any AS petrol that either contains or is produced from ethanol, containing non-AS denaturant required by legislation, may contain the carbon equivalent of the non-AS material in the final petrol blend.

Any petrol with a minimum of 50% (v/v) AS components, as defined in Article B.3.1, must comply with the specifications in Article B.1, with the following exceptions:

Property	Units	Min.	Max.	Test methods
Oxygen	% m/m		7.5	EN ISO 22854 EN 13132(2) Elemental Analysis ASTM D5622
Olefins	% v/v		Report	ISO 22854 ASTM D6839
Aromatics	% v/v		40.0	ISO 22854/ ASTM D6839
Methanol (1)	% v/v		3.0	EN 1601 EN 13132 EN ISO 22854
Distillation characteristics				
A E120 °C	% v/v	73.0		ISO 3405 ASTM D86
A E135 °C	% v/v	77.0		ISO 3405 ASTM D86
A E150 °C	%v/v	83.0		ISO 3405 ASTM D86
Final Boiling Point	°C		210	ISO 3405 ASTM D86

(1) A stabilising agent must be added.
(2) Preferred method.

As with all fuels, it is important that any AS petrol is accompanied by a Material Safety Data Sheet (MSDS).

3.3. AS Diesel

An AS diesel is a diesel that complies with the AS fuel definition in Article B.3.1 and the specifications in Article B.2.

3.4. High Ethanol Content Fuel

For the purposes of this article, high ethanol content fuel must contain only AS components, as defined in Article B.3.1 and comply with the following specifications:

Property	Units	Min.	Max.	Test methods
Ethanol + Higher saturated (C_3-C_5) mono-alcohols content	%v/v	50	85	ASTM D5599/ EN1601
Higher saturated (C_3-C_5) mono-alcohols content	%v/v		6.0	ASTM D5599/ EN1601
Methanol	%v/v		1.0	ASTM D5599/ EN1601
Ethers (5 or more C atoms) content	%v/v of the non-alcohol content		22.0	ASTM D5599/ EN1601
RON			Report	ISO 5164(1) ASTM D2699(1)
MON		Report		ISO 5163(1) ASTM D2700(1)
Density (at 15°C)	kg/m^3	725.0	794.0	EN ISO 12185/ ASTM D4052
DVPE	kPa	35	80(2)	EN 13016-1/ ASTM D5191
Final Boiling Point	°C		210	ISO 3405/ ASTM D86

Copper content	mg/kg		0.10	EN 15837
Phosphorus content	mg/l		0.15	EN 15487/ EN 15837/ ASTM D3231
Sulphur	mg/kg		10.0	ASTM D5453/ ASTM D7039 EN 16997(3) EN 15485/ EN 15486/ EN 15837
Sulphate Content	mg/kg		4.0	EN 15492
Oxidation Stability	(min.)	360		ISO 7536/ ASTM D525
Existent Gum (solvent washed)	mg/100ml		5	ASTM D381/ EN ISO 6246
Total acidity (as acetic acid)	%m/m		0.005	EN 15491/ ASTM D7795
Inorganic Chloride	mg/kg		1.2	ASTM D7319/ ASTM D7328 EN 15492
Water	%m/m		1.00	ASTM E1064/ EN 15489

(1) A correction factor of 0.2 for MON and RON shall be subtracted for the calculation of the final result in accordance with EN 228: 2012 Primary high-octane reference fuels must be used for calibration.
(2) The maximum DVPE may rise to 100 kPa for winter competitions.
(3) Preferred method.

4. Alternative Fuels

The use of any other fuel is subject to approval by the FIA or the ASN of the organising country upon receipt of a written request.

4.1. Hydrogen Fuel

Type 1 = Gaseous Hydrogen

- Internal combustion engine vehicle application : Purity >=95%.
- PEM fuel cell vehicle application : purified to a minimum mole fraction as specified in "ISO 14687:2019 Hydrogen fuel quality - product specification" Purity >= 99.99% called Hydrogen 4.0 (also acceptable for internal combustion engine vehicle).

Type 2 = Liquid Hydrogen

- Internal combustion engine vehicle application : Purity >=95%.
- PEM fuel cell vehicle application : purified to a minimum mole fraction as specified in "ISO 14687:2019 Hydrogen fuel quality - product specification" Purity >= 99.99% called Hydrogen 4.0 (also acceptable for internal combustion engine vehicle.

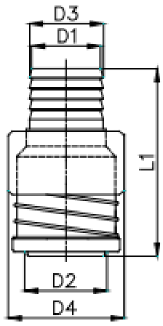
5. Oxidant

Only air may be mixed with the fuel as an oxidant.

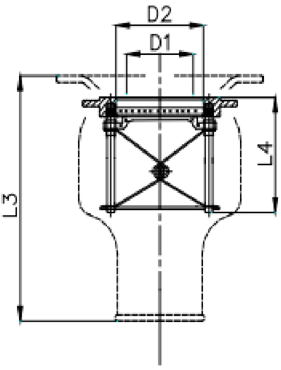
6. Refuelling procedure

Standardized coupling:
In case of a centralized system provided by the circuit or a system provided by the competitors, the refuelling hose must be provided with a leak-proof coupling to fit the standardized filler mounted on the car (in accordance with Drawing 266-1; the interior diameter D must not exceed 50 mm). All cars must be provided with a fuel filler complying with this diagram. This leak-proof fitting must comply with the dead man principle and must not therefore incorporate any retaining device when in an open position (spring-loaded, bayonet, etc.). The air vent(s) must be equipped with non-return and closing valves having the same closing system as that of the standard filler and having the same diameter. During refuelling the outlets of the air-vents must be connected with the appropriate coupling either to the main supply tank or to a transparent portable container with a minimum capacity of 20 liters provided with a closing system rendering it completely leak-proof.

	D1	D2	D3	D4	L1
PP20M	2.0"	2.5"	2.25"	3.7"	6.3"
PP20MR	1.5"	2.5"	1.75"	3.7"	6.3"
PF20MS	1.5"	2.5"		3.7"	6.9"
PP15M	1.5"	2.0"	1.75"	3.3"	5.7"
PF30M	1.25"	1.65"	1.45"	2.68"	4.64"
PF40M	1.25"	1.65"	1.45"	2.68"	4.64"
PP125M	1.25"	1.75"	1.5"	2.9"	5.1"



	D1	D2	L3	L4
PP20F	2.0"	2.5"	6.75"	3.25"
PP20FR	2.0"	2.5"	6.75"	3.25"
PF31F	1.75"	2.12"	5.3"	3"
PF41F	1.75"	2.12"	5.7"	3.38"
PP15F	1.5"	2.0"	6.75"	3.25"
PP125F	1.25"	1.75"	6.25"	3.1"



Prise male / Push pull series male

Prise femelle / Push pull series female

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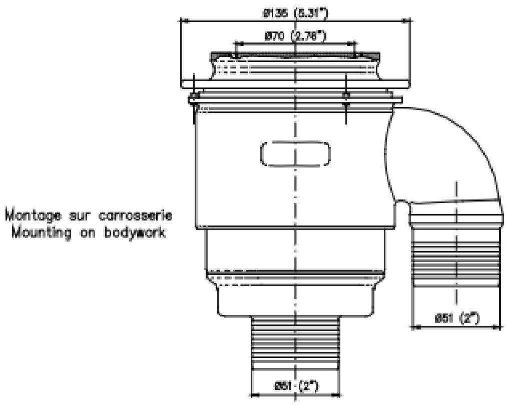
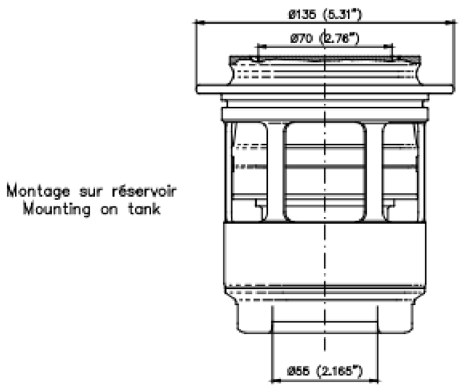
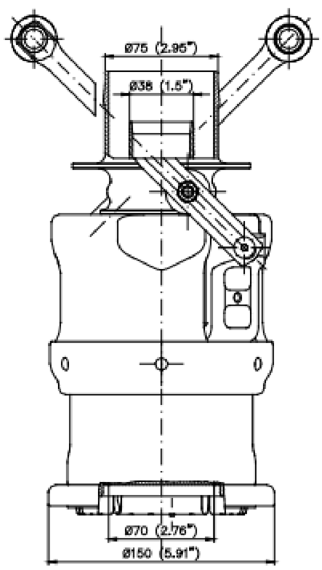
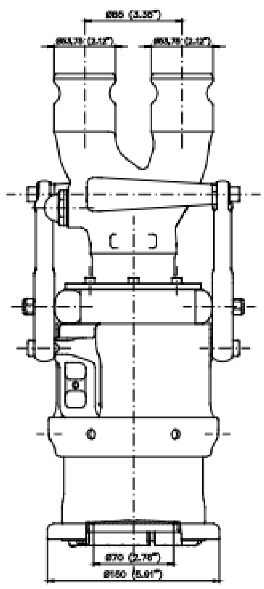




Female Coupling



Coaxial



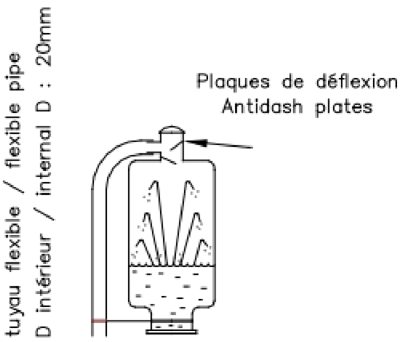
Parallèle / Parallel

Male Coupling

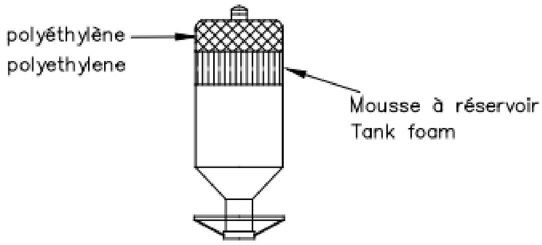
266-1 (Version B)

The venting catch tanks must be empty at the beginning of the refuelling operation. In cases where the circuits are unable to provide the competitors with a centralized system, they have to refuel according to the above procedure. The level of the reserve tank may in no case be more than 3 meters above the level of the track where the refuelling is carried out. This applies to the whole duration of the competition.

The overflow bottles must conform to one of the Drawings 266-2 or 266-3.



266-2



266-3

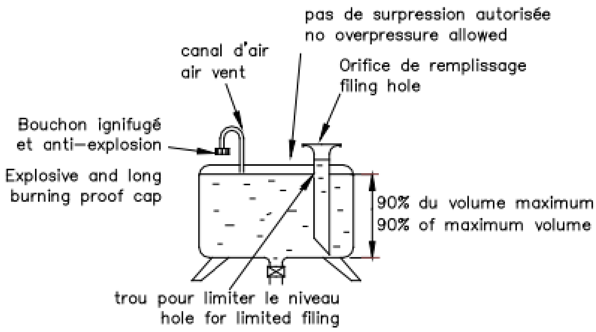
The reserve tank and all metal parts of the refuelling system from the coupling over the flow meter up to the tank and its rack must be connected electrically to the earth.

The application of the following is recommended:

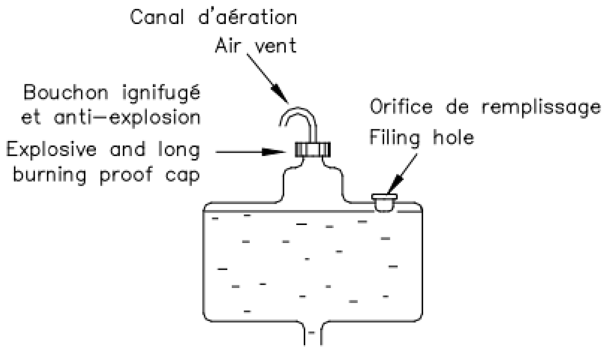
- Each pit must be equipped with two aircraft type grounding connections.
- The refuelling system (including tower, tank, hose, nozzle, valves and vent bottle) must be connected to one of the above grounding connections for the entire duration of the competition.
- The car must be connected, at least momentarily, to the other grounding connection as soon as it stops in the pit.
- No fuel hose connection (fill or vent) unless and until conditions 2 and 3 have been fulfilled.
- All fuel-handling pit crew members must wear non-static protective clothing.

The refuelling tank may be one of the following:

- Models made of rubber, of the type FT3-1999, FT3.5-1999 or FT5-1999, built by an approved manufacturer, or
- Tanks conforming to one of the Drawings 266-4 or 266-5.



266-4



266-5

Application :

For Touring Cars (Group A), refer to the general prescriptions of the FIA Championships.

7. Tank ventilation

It is authorized to equip a tank with ventilation exiting through the car roof.

8. Installation of the FT3-1999, FT3.5-1999 or FT5-1999 tank

The FT3-1999, FT3.5-1999 or FT5-1999 tank may be placed either in the original location of the tank or in the luggage compartment.
There must be an orifice to evacuate any fuel which may have spread into the tank compartment.
The position and the dimension of the filler hole as well as that of the cap may be changed as long as the new installation does not protrude beyond the bodywork and guarantees that no fuel leaks into one of the interior compartments of the car.
If the filler hole is situated inside the car, it must be separated from the cockpit by a liquid-tight protection.

C. SPECIFIC REQUIREMENTS FOR ELECTRICALLY POWERED VEHICLES

1. General electrical safety

a. It must be ensured that a single point of failure of the electric or hybrid electric system cannot cause an electric shock hazardous to the life of any person and that the components used cannot cause injury under any circumstances or conditions (rain, etc.), whether during normal operation or in unforeseeable cases of malfunction.

b. The components used for protecting persons or objects must reliably fulfil their purpose for an appropriate length of time.

c. There must not be any exposed live conductive parts in the voltage class B (Appendix J – Article 251.3.1.10) system.

d. Protection against direct contact shall be provided by one or both of the following (from ISO/DIS 6469-3.2:2010):
- basic insulation of the live parts (2.15).
- barriers/enclosures, preventing access to the live parts.

The barriers/enclosures may be electrically conductive or non-conductive.

e. In cases where the voltage of the Power Circuit belongs to voltage class B (2.9), symbols warning of "High Voltage" (see 266-6) must be displayed on or near the protective covers of all electrical equipment that can run at high voltage. The symbol background shall be yellow, and the bordering and the arrow shall be black, in accordance with ISO 7010. Each side of the triangle should measure at least 12 cm but may be reduced to fit onto small components.

266-6

Signalisation des composants et circuits de classe de tension B / Marking of voltage class B components and circuits

f. All electric and hybrid electric vehicles must comply with the requirements of the national authorities in the country in which the vehicle races in respect of the standardisation and control of electrical installations. The electrical safety for electric and hybrid electric racing vehicles must use the highest standards for road going cars as a minimum electrical safety standard.

2. Protection of cables, lines, connectors, switches, electrical equipment

a. Electrical cables and electrical equipment must be protected against any risk of mechanical damage (stones, corrosion, mechanical failure, etc.) as well as any risk of fire and electrical shock.

b. The voltage class B components and wiring shall comply with the applicable sections of IEC 60664 on clearances, creepage distances (Appendix J – Article 251.3.1.13) and solid insulation; or meet the withstand voltage capability according to the withstand voltage test given in ISO/DIS 6469-3.2:2010.

c. A plug must physically only be able to mate with the correct socket of any sockets within reach.

3. Protection against dust and water

All parts of the electrical equipment must be protected using an IP class (see e.g. ISO 20653) specified in the respective Appendix J vehicle Class. However, IP 55 type protection must be used as a minimum (fully dust-proof and proof against streaming water).

4. Rechargeable Energy Storage System (RESS)

4.1. Design and installation

a. Each Group listed in Art. 251 of Appendix J, Category I or Category II using an electric drive train must individually specify, in the respective Appendix J, the maximum weight and/or energy content of the RESS.

b. The RESS should be housed within the survival cell of the vehicle. If the RESS is not housed in the survival cell the location and mounting must be approved by the FIA.

c. The vehicle manufacturer must prove, by whatever means, that the RESS installed in the vehicle has been designed in such a way that even when subjected to a crash:
- the mechanical and electrical safety of the RESS is secured; and
- neither the RESS nor the fastening device itself nor its anchorage points can come loose.

d. All approval tests required (see Appendix 1) must be carried out by a "Testing centre for crash tests and static tests recognized by the FIA" (Technical List n°4), with an FIA technical delegate.

For each day of presence (physical or remote) of an FIA technical delegate, the manufacturer will be charged according to a fee decided annually by the FIA.
On receipt of the report from the technical delegate, the FIA will confirm to the manufacturer in writing that the system is successfully tested.
The manufacturer will provide all complementary information and documents that the FIA deems necessary for drawing up the approval
Any modification of a system previously approved by the FIA must be submitted by the car manufacturer to the FIA Technical Department. The latter reserves the right to require that new tests be carried out to proceed with the approval of the modification.

e. The RESS compartment(s) must be designed to prevent short circuits of the conductive parts, in the event of a RESS compartment or component deformation; and any risk of harmful liquids entering the cockpit must be eliminated. This compartment must completely surround the RESS with the exception of ventilation openings connected to the outside, and it must be made of a fire-resistant (M1 ; A2s1d1 euroclass), robust and RESS fluid-tight material.

f. Any RESS compartment(s) must prevent the build-up of an ignitable gas/air or dust/air concentration inside the compartment(s). Venting system must be present to evacuate the quantity of gas that can be spread by 3 cells in 10s during thermal runaway (data given by the cells supplier). Gas must be evacuated at the rear of the car.

g. The RESS must be capable of being isolated from the Power Circuit by at least two independent systems (e.g. relays, detonators, contactors, a manually operated Service Switch, etc.). There must be at least one manually operated system and one automatic system (control by BMS, ECU,…).

h. The RESS must include two independent systems to prevent overcurrent.

i. All accessible conductive parts of the RESS and of the wiring must have double isolation.

j. On each compartment belonging to the Power Circuit the symbols warning of “High Voltage” must be displayed (see Article C.1e).

k. Cable insulation must have a service temperature rating of at least -20 °C to +150 °C.

4.2. Clearance and creepage distance

This sub-clause taken from ISO 6469-1:2009 deals with the additional leakage-current hazard between the connection terminals of a RESS, including any conductive fittings attached to them and any conductive parts (Appendix J – Article 251.3.1.17), due to the risk of electrolyte or dielectric medium spillage from leakage under normal operating conditions (see 266-7).

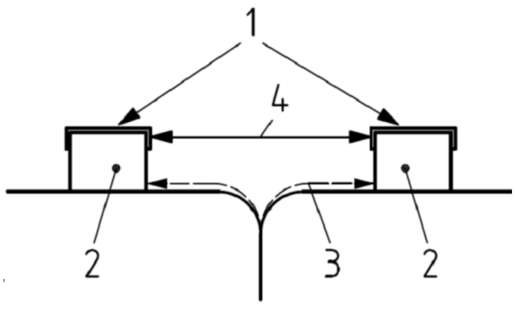
This sub-clause does not apply to maximum working voltages (Appendix J – Article 251.3.1.9) of the Power Circuit (Appendix J – Article 251.3.1.14) lower than 60 V DC.

If electrolyte leakage cannot occur, the RESS must be designed according to IEC 60664-1. The pollution degree shall be suitable for the range of application.

If electrolyte leakage could occur, it is recommended that the creepage distance (2.12) be as follows (see 266-7):

a. In the case of a creepage distance between two RESS connection terminals:
d > 0.25 U + 5, where:
d is the creepage distance measured on the tested RESS, in millimeters (mm);
U is the maximum working voltage between the two RESS connection terminals, in volts (V).

b. In the case of a creepage distance between live parts (Appendix J – Article 251.3.1.16) and the electric chassis ground (Appendix J – Article 251.3.1.15):
d 0.125 U + 5, where:
d is the creepage distance between the live part and the electric chassis, in millimetres (mm); U is the maximum working voltage between the two RESS connection terminals, in volts (V). The clearance (Appendix J – Article 251.3.1.12) between conductive surfaces shall be a minimum of 2.5 mm.



266-7

Creepage distance and clearance

1 Conductive surface
2 Connector terminal (RESS pack or RESS)
3 Creepage distance
4 Clearance

4.3. Mounting of Batteries and Ultra (Super) Capacitors

Cells and capacitors have to be mounted properly, in order to withstand a crash test without major mechanical deformation resulting in cell failure.

4.4. Specific provisions for Batteries

Battery cells must be certified to UN transportation standards as a minimum requirement for fire and toxicity safety.

4.4.1. Declaration of cell chemistry

Any type of cell chemistry is allowed provided the FIA deems the cell chemistry safe.

a. The basic chemistry and safety requirements of the battery must be given to the FIA three months in advance of the first competition in which it is to be used, if its chemistry does not belong to the list below:
   - Lead-Acid
   - Zinc-Bromium
   - Nickel-Metal-Hydride
   - Lithium (Lithium-Ion and Lithium-Polymer)

b. No modification to a battery cell itself or to a homologated module or pack is permitted.

c. For lead-acid batteries, only valve-regulated types (gel-types) are permitted.

d. Lithium batteries must be equipped with a battery management system. The specific provisions are set out in Article C.4.4.2.

e. The competitor has to supply documents from the cell and pack (module) producer specifying safety relevant data.

f. The cell supplier must provide the safety instructions for the specific cell chemistry.

g. The safety of the cell in combination with a Battery Management System (Article C.4.4.2) is required if the cell needs to have a UN certification for air transportation.

h. The competitor has to supply a contingency plan describing how to handle the battery pack in case of overheating (fire) and crash.

4.4.2. Battery Management System

a. The Battery Management System (BMS) is an important safety system and thus part of the battery pack and must be connected to the cells and the battery pack at all the times except for shipping or when set to rest condition.

b. The BMS must, in general, be appropriate for the battery chemistry, as recommended by the cell manufacturer.

c. For cells prone to thermal runaway it is strictly prohibited to operate the cells (modules) outside the specifications established by the cell manufacturer.

d. Temperature control must be considered in the battery management system to prevent thermal runaway during overload or battery failure.

e. Heat generation under any first-failure condition, which could form a hazard to persons, shall be prevented by appropriate measures, e.g. based on monitoring of current, voltage or temperature.

f. The BMS is a security system; it must detect internal faults and has to trigger power reduction delivered from/to the battery or has to switch off the battery if the BMS considers battery operation unsafe.

g. The assembly of the battery cells in a battery pack must be carried out by a manufacturer with the appropriate technology. The specification of the battery pack, modules and cells, as well as a document from the said manufacturer attesting to the safety of the produced battery pack, must be verified and approved by the ASN in advance.

4.5. Specific provisions for Ultra (Super) Capacitors

a. The competitor has to supply documents about the capacitor type.

b. No modification to a capacitor itself or to a homologated module or pack is allowed.

c. The competitor has to supply safety related documents from the capacitor and pack (module) producer.

d. The competitor has to supply a contingency plan describing how to handle the pack in case of overheating (fire) or crash.

4.6. Specific provisions for Flywheel Systems

a. It is up to the competitor to prove, by whatever means, that the Flywheel System compartment is strong enough to withstand a system failure, e.g. a rotor crash at full flywheel speed.

b. Driver (and co-driver) safety has to be guaranteed by the competitor under all vehicle conditions, even if subjected to a crash.

c. The competitor has to supply safety related documents from the flywheel producer.

5. Power electronics

The power electronics (converter, chopper) must be designed with the necessary equipment to detect major faults, e.g. short circuits, over/under voltage, and must have a mechanism to shut down the electric drive train system if a serious fault is detected.

6. Electric motors

Provisions or devices must be foreseen to obtain best possible vehicle stability in case of a single locked wheel resulting from a malfunction of the electric drive train or the electric motor.

- A single motor propels in a conventional way the drive axle with a differential (this is a well approved and highly reliable solution).
- The motor is coupled to a single driven wheel by means of a clutch (shear pin) and planetary gear.
- In case of single locked wheel an automatic system may lock the opposite wheel of the axle.

6.1. Capacitive coupling

a. Capacitive couplings between a voltage class B (Appendix J – Article 251.3.1.10) potential and electric chassis (Appendix J – Article 251.3.1.15) usually result from Y capacitors, used for EMC reasons, or parasitic capacitive couplings.
ISO/DIS 6469-3.2:2010 constitutes:
   - For DC body currents caused by discharge of such capacitive couplings when touching DC high voltage that the energy of the total capacitance between any energized voltage class B live part (Appendix J – Article 251.3.1.16) and the electric chassis (Appendix J – Article 251.3.1.15) shall be < 0.2 Joule at its maximum working voltage (Appendix J – Article 251.3.1.9). Total capacitance should be calculated based on designed values of related parts and components.
   - For AC body currents caused by such capacitive couplings when touching AC high voltage that the AC body current shall not exceed 5 mA, with the measurement in accordance with IEC 60950-1.

b. Any motor driven by a converter (chopper, power electronics) will show capacitive coupling to its case, etc., to a degree dependent on its design. There is always a target to minimise this given that it is a waste of energy but it cannot be eliminated.

c. Capacitive coupling introduced by distributed capacitances CC (see 266-8) results in an AC current i_{ac} flow between the Power Circuit and an electric chassis, including bodywork. Hence, a non-galvanic connection with a bonding capacitor C_B between the Power Circuit and chassis ground must be introduced, in order to limit the maximum AC voltage U_{ac} between Power Circuit Ground and chassis to a safe voltage level less than 30 V AC rms.

The bond capacitor C_B and the lumped coupling capacitances C_C represent an AC voltage divider for the inverter output voltage U_{INV}. Hence, the AC isolation barrier voltage U_{ac} calculates to:

$$U_{ac} = U_{INF} \frac{C_C}{C_B + C_C}$$

The above calculation gives an estimate of the isolation barrier voltage U_{ac} as the AC current i_{ac} is far from sinusoidal. Hence, measurements must prove that the voltage U_{ac} is reduced by the bonding capacitor CB (see 266-8, 266-9 and 266-10, optionally: $C_B = C_{B1} + C_{B2}$, see 266-11) to a safe voltage level less than 30 V AC rms.

An example for a rough estimate of the minimum value of the bonding capacitor $C_{B\,min}$:

We assume: U_{INF} = 500 V AC, the distributed coupling capacitances add up to C_C = 3 nF and the maximum permissible isolation barrier voltage U_{ac} = 30 V rms.

Hence, the minimum bond capacitor value $C_{B\,min}$ calculates to:

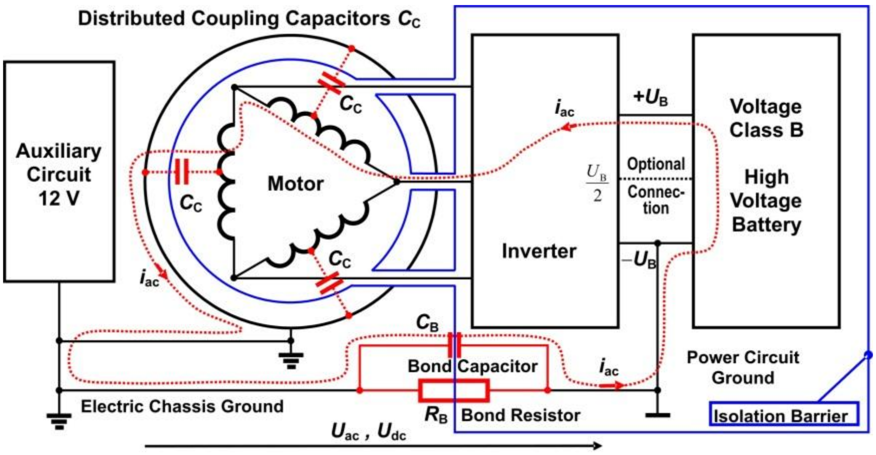
$$C_{B\min} = C_C\left(\frac{U_{INV}}{U_{ac\max}} - 1\right) = 3\text{ nF}\left(\frac{500\text{ V}}{30\text{ V}} - 1\right) = 47\text{ nF}$$

d. The bond resistor RB (see 266-8, 266-9 and 266-10, optionally:

$$R_B = \frac{R_{B1} \cdot R_{B2}}{R_{B1} + R_{B2}}$$

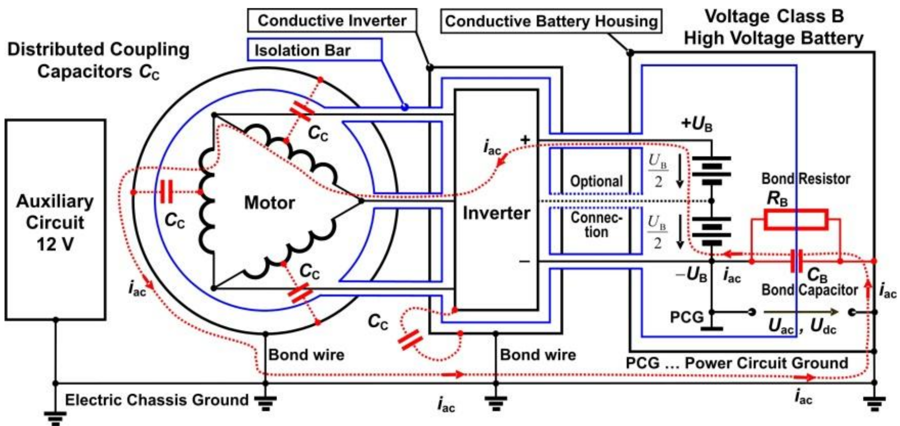
see 266-11) limits the DC voltage U_{dc} across the isolation barrier between the Power Circuit and Chassis Ground. The value of the bond resistor should be at least 500 Ω/V referred to the maximum working voltage $+U_B$ of the voltage class B system (charging). The measurement procedure to check the value of the bond resistors R_{B1} and R_{B2} is given in the ECE agreement ECE-R 100/01 (WP.29/2010/52), Nov./Dec. 2010, Appendix 4 “Isolation Resistance Measurement Method“ and in the standard ISO 6469-1:2009(E), Article 6.1 “Isolation Resistance of the RESS“.

e. Manufacturer can propose its own technical solution that should be approved by FIA.



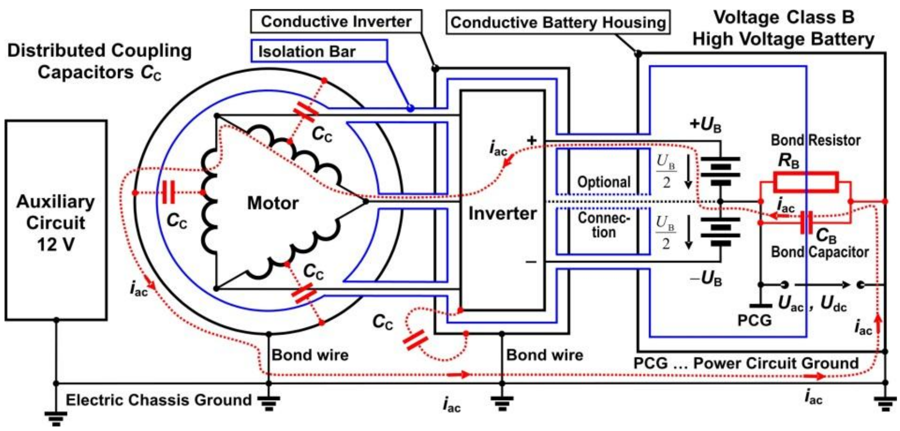
266-8

Non-conductive inverter case and battery compartment.
Due to distributed capacitances between stator windings, rotor and case capacitive coupling results in an AC current i_{ac} flow across the isolation barrier between the Power Circuit and the electric chassis. A bond capacitor C_B of an adequate size reduces the voltage U_{ac} to a safe voltage level. The nominal voltage of the bond capacitor must be specified for at least the maximum output voltage of the inverter.



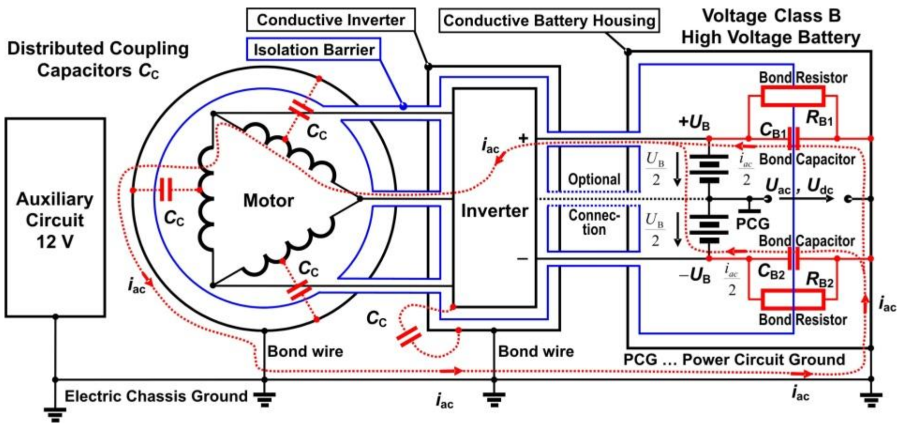
266-9

The conductive inverter case and battery compartment is bonded to the Electrical Chassis Ground. The bond resistor R_B and capacitor C_B are connected from the Electrical Chassis Ground to the Power Circuit Ground, which is, in this case, the battery minus $-U_B$.



266-10

The conductive inverter case and battery compartment is bonded to the Electrical Chassis Ground. The bond resistor R_B and capacitor C_B are connected from the Electrical Chassis Ground to the Power Circuit Ground, which is, in this case, 50 % of the battery voltage $+U_B$.



266-11

The conductive inverter case and battery compartment is bonded to the Electrical Chassis Ground. The bond resistors R_{B1} and R_{B2} and the bond capacitors C_{B1} and C_{B2} are connected from the Electrical Chassis Ground to the battery terminals $+U_B$ and $-U_B$ resulting in a Power Circuit Ground at 50 % of the battery voltage $+U_B$.

7. Protection against electrical shock

a. In no part of the electrical equipment may there be voltage exceeding voltage class B (2.9) limits.

b. ISO/DIS 6469-3.2:2010 constitutes: As a general rule, exposed conductive parts of voltage class B electric equipment, including exposed conductive barriers/enclosures, shall be bonded to the electric chassis for potential equalization according to the following requirements:
   - All components forming the potential equalization current path (conductors, connections) shall withstand the maximum current in a single failure situation.
   - The resistance of the potential equalization path between any two exposed conductive parts of the voltage class B electric circuit, which can be touched simultaneously by a person, shall not exceed 0.1 Ω.

c. No part of the chassis or bodywork should be used as a current return path except for fault currents.

d. Between the Power Circuit Ground and the chassis (body) of the vehicle, no more than 60 V DC or 30 V AC respectively are allowed.

e. An electronic monitoring system must continuously check the voltage level between Chassis Ground (= Auxiliary Power Ground) and Power Circuit Ground. If the monitoring system detects a DC or an AC voltage with a voltage level of more than 60 V DC or 30 V AC, at a frequency below 300 kHz the monitoring circuit must respond (within less than 50 ms) and trigger the actions to be specified in the respective vehicle Class.

8. Equipotential bonding

a. To mitigate the failure mode where a high voltage is AC coupled onto the car's low voltage system it is mandatory that all major conductive parts of the body are equipotential bonded to the car chassis with wires or conductive parts of an appropriate dimension.

b. Bonding is required for any component to which a wire, cable or harness connects, or passes in close proximity, and which is able to conduct current by means of a single point of insulation failure and, furthermore, is capable of being touched by the driver whilst seated in the car or by mechanics during a pit stop or by marshals and medical staff during rescue operations.

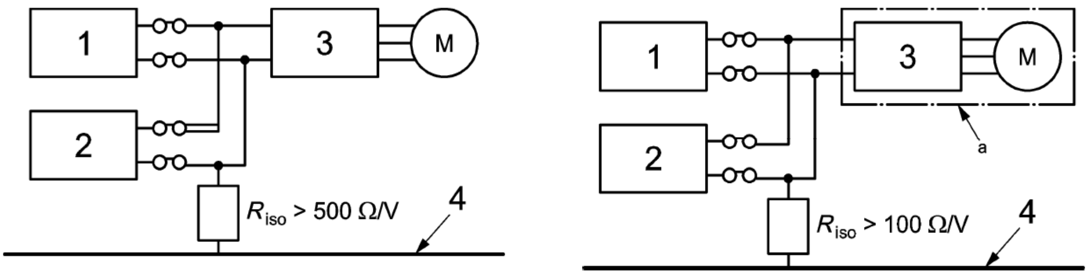
c. Any components that require equipotential bonding will be connected to the Main Ground Point (Appendix J – Article 251.3.1.15.1) with a resistance to prevent a dangerous touch voltage (30 V AC) given an AC coupling fault at a certain level of parasitic capacitance.

d. The Main Ground Point (2.14.1) has to be specified individually for each vehicle Class using an electric drive train in the respective Appendix J Article.

9. Isolation resistance requirements

ISO/DIS 6469-3.2:2010 constitutes: If the protection measures chosen require a minimum isolation resistance, it shall be at least 100 Ω/V for DC circuits and at least 500 Ω/V for AC circuits. The reference shall be the maximum working voltage (Appendix J – Article 251.3.1.9).

<u>NOTE :</u>
A hazard of electric shock occurs when electric currents, depending on value and duration, pass through the human body. Harmful effects can be avoided if the current is within zone DC-2 in Figure 22 for DC or zone AC-2 in Figure 20 for AC respectively of IEC/TS 60479-1, 2005. The relation of harmful body currents and other wave forms and frequencies is described in IEC/TS 60479-2. The isolation resistance requirements of 100 Ω/V for DC or 500 Ω/V for AC allow body currents of 10 mA and 2 mA respectively.



266-12

1 Fuel cell system
2 Traction battery
3 Inverter
4 Vehicle electric chassis
a AC circuit

Isolation resistance requirements for voltage class B systems with conductively connected AC and DC circuits.

NOTE :
The figure is based on a fuel cell hybrid electric vehicle (FCHEV) as an example.

To meet the above requirement for the entire circuit it is necessary to have a higher isolation resistance for each component, depending on the number of the components and the structure of the circuit to which they belong. If DC and AC voltage class B electric circuits are conductively connected (see 266-12) one of the following two options shall be fulfilled :

- Option 1 : meet at least the 500 Ω/V requirement for the combined circuit; or
- Option 2 : meet at least the 100 Ω/V requirements for the entire conductively connected circuit, if at least one of the additional protection measures as defined in Article C.9.1 is applied to the AC circuit.

9.1. Additional protection measures for the AC circuit

One or a combination of the following measures, in addition to or instead of the basic protection measures as described in (Article C.1), shall be applied to provide protection against single failures to address the failures, for which it is intended (from ISO/DIS 6469-3.2:2010) :

- Addition of one or more layers of insulation, barriers, and/or enclosures.
- Double or reinforced insulation instead of basic insulation.
- Rigid barriers/enclosures with sufficient mechanical robustness and durability, over the vehicle service life.

NOTE :
The rigid barriers/enclosures include (but are not limited to) power control enclosures, motor housings, connector casings and housings, etc. They may be used as a single measure instead of basic barriers/enclosures to meet both basic and single failure protection requirements.

10. Isolation surveillance between chassis and Power Circuit

a. An isolation surveillance system must be used to monitor the status of the isolation barrier between the voltage class B (Appendix J – Article 251.3.1.10) system and the chassis.

b. The surveillance system must measure the DC insulation resistance R_{iso} between the conductive parts of the chassis (body) and the entire conductively connected voltage class B circuit. The minimum insulation resistance R_{iso} is given in Article C.9.
The reaction of the system in case an isolation defect is detected will be specified individually for each vehicle class in Appendix J of the ISC and must follow the provisions specified in ISO/DIS 6469-3.2:2010.
A device to protect people against electric DC shocks is for example, the Bender A-ISOMETER iso-F1.

c. The measurement procedure given in ISO 6469-1:2009 must be used to check and calibrate the on-board isolation surveillance system. Two separate isolation resistance values must be checked :
   - the isolation resistance R_{iso} of the entire conductively connected voltage class B system referred to the electric chassis;
   - the isolation resistance R_{iso} of the RESS when disconnected from the Power Circuit.

11. Power Circuit

In cases where the voltage of the Power Circuit (Appendix J – Article 251.3.1.14) belongs to voltage class B (Appendix J – Article 251.3.1.10), this Power Circuit must be electrically separated from the chassis (body) and from the Auxiliary Circuit by adequate insulators.

12. Power Bus

At all times the maximum voltage on the Power Bus must never exceed 1000V.
Voltage across capacitors belonging to the Power Bus must fall below 60 Volt within 2 seconds after disconnection of all energy sources (generator, RESS and charging unit) from the Power Bus.

13. Power Circuit wiring

a. All cables and wires connecting electrical power components (e.g. motor, generator, inverter and RESS) with an ampacity of more than 30 mA must have an additional built-in sense wire or coaxial conductive shield that is insulated from the Power Circuit. The sense wire allows the detection of insulation faults or broken power wires. If there is an insulation failure or a broken power wire, an electronic monitoring system must detect the isolation defect. The reaction of the system should an isolation defect be detected will be specified individually for each vehicle Class listed in Appendix J.

b. The sense wire or Power Circuit wire shielding must be connected to chassis ground. In such a case, the isolation surveillance system (Article C.10) will serve as trigger device for an isolation fault.

c. The outer covering of cables and harness for voltage class B (Appendix J – Article 251.3.1.10) circuits, not within enclosures or behind barriers shall be marked in orange.

   NOTE 1 :
   Voltage class B connectors may be identified by the harnesses to which the connector is attached.

   NOTE 2 :
   Specifications of orange colour are given e.g. in ISO/DIS 14572:2010, in US (8.75R5.75/12.5) and in Japan (8.8R5.8/12.5) according to the Munsell colour system.

d. Power Circuit wires exposed to stress (e.g. mechanical, thermal, vibration, etc.) must be secured within proper cable guides, enclosures and insulating conduits.

14. Power Circuit connectors, leading contacts, automatic disconnection, etc.

a. Power Circuit connectors must not have live contacts on either the plug or the receptacle unless they are correctly mated. An automatic system must detect if a Power Circuit connector is de-mated, for example with shorter alarm contacts within the same connector, and inhibit/remove High Voltage from both the plug and the receptacle. If the connector was live when de-mated, the high voltage must be switched off immediately and any residual voltage on the contacts of both the plug and the receptacle discharged to a safe level within 2 seconds unless otherwise specified in the Vehicle Class. It is not permitted to have live terminals protected only by a removable connector cap.

b. Connector environmental sealing to IP 67 in the mated condition.

c. Connector environmental sealing to IP 66 from the contact face to cable assy in the de-mated condition.

d. Connector minimum dielectric withstands 1.5 kV at 98% relative humidity (RH) (to cater for environments with high humidity).

e. Connector minimum dielectric withstands 5 kV at 40% RH.

f. If fully shrouded "touchproof” contacts on both pin and socket, plug and receptacle connectors are required, it must be specified in the vehicle Class.

g. Minimum connector service current rating suitable for the average effective current, NOT maximum expected current in service. E.g. during a phase short circuit event.

h. Connector shell able to withstand high levels of vibration.

i. Connector in service temperature rating of -20C to +150°C or greater to cater for air transportation and on-track running.

j. Provide mechanism for provisioning strain relief and sealing to cable assembly.

k. Provide "snatch free" disconnection in case of accident, without damage to connector shell, which could expose high voltage on either plug or receptacle. The connector must part before the cable is damaged.
   Exception : Components inside the Safety Cell (Appendix J – Article 251.3.1.29) and connected by cables belonging to the Power Circuit (Appendix J – Article 251.3.1.14) do not need to use snatch free disconnection.

15. Insulation strength of cables

a. All electrically live parts must be protected against accidental contact. Insulating material not having sufficient mechanical resistance, i.e. paint coating, enamel, oxides, fibre coatings (impregnated or not) or insulating tapes, are not allowed.

b. Each electrical cable must be rated for the respective circuit current and must be insulated adequately.

c. All electrical cables must be protected from overcurrent faults according to the capacity of the individual conductors.

d. Every part of the electrical equipment, including wires and cables, must have a minimum insulation resistance between all live components and the bodywork.

   - For equipment belonging to the voltage class B system, the insulation resistance to the chassis must be at least 500 Ω/V (ISO/DIS 6469-3.2:2010).
   - The measurement of the insulation resistance must be carried out using a DC voltage of at least 100 volts. Tests must be carried out to validate and quantify the insulation resistance of the vehicle in wet conditions.

16. Driver Master Switch

All racing vehicles must be equipped with a Driver Master Switch (DMS).

- The DMS must be capable of being operated by the driver when seated in the driving position with the safety harnesses fastened and the steering wheel in place.
- The DMS must be separate from the General Circuit Breaker.
- In case the DMS is switched to active, the vehicle must slowly creep forward without the accelerator pedal pressed like with IC engine cars equipped with an automatic gear box when the gear lever is moved from the neutral (N) or park (P) position to drive (D) otherwise the car may be left unattended in “active mode” (DMS on) and accidental touching of the accelerator will cause vehicle movement.

17. General Circuit Breaker

a. All vehicles must be equipped with a General Circuit Breaker (Appendix J – Article 251.3.1.14.3) of a sufficient capacity. Care must be taken, however, that the installation of the circuit breaker does not result in the main electrical circuit being located close to the driver.

b. If actuated by an emergency stop switch (C.18) or by the optional system for detecting a crash, the General Circuit Breaker MUST instantaneously :
   - isolate both +Ue and -Ue poles of each battery pack of the RESS from the remainder of the Power Circuit (RESS to the loads such as the power electronics and the electric motor),
   - disable any torque production from any electric motor,
   - enable the active discharge circuits within the Power Circuit,
   - isolate the Auxiliary battery from the Auxiliary Circuit (Auxiliary battery and possibly the alternator from the loads such as lights, hooters, ignition, electrical controls, etc.), and
   - immediately stop the internal combustion engine in a hybrid vehicle.

c. The location and marking of the General Circuit Breaker must be specified in the vehicle Class.

d. If an automatic system for detecting a crash is specified in a vehicle Class it must automatically actuate the General Circuit Breaker.

e. Each device of the General Circuit Breaker used to isolate +Ue and -Ue poles of each battery pack must be part of this battery pack.

f. The electronics units (ECU,BMS,…) which control the General Circuit Breaker must stay alive at least 15 minutes after any opening of the General Circuit Breaker.

18. Emergency Stop Switches

a. One Emergency Stop Switch (Appendix J – Article 251.3.1.14.4) must be easily operable by the driver and codriver when seated normally in the vehicle with harnesses fitted and the steering wheel in place;

b. At least one Emergency Stop Switch must be operable from outside the vehicle for closed cars.

c. The Emergency Stop Switches may NOT be used as the Driver Master Switch.

d. If required by the Vehicle Class, an Emergency Stop Switch may also operate the fire extinguishers.

Table 1 : Actuating (= contact opening = current interruption = off) the General Circuit Breaker (GCB, C.17 and Appendix J – Article 251.3.1.14.3) by the Emergency Stop Switches (ESS, C.18 and Appendix J – Article 251.3.1.14.4) and by the Driver Master Switch (DMS, C.16 and Appendix J – Article 251.3.1.20)

	ESS actuated	ESS released
DMS on	GCB off	GCB on
DMS off	GCB off	GCB off

Table 2 : Enabling (= active = switched on = on) the active discharge circuits (C.14 and C.17.b) within the Power Circuit (C.14 and Appendix J – Article 251.3.1.14)
by the Emergency Stop Switches (ESS, C.18 and Appendix J – Article 251.3.1.14.4) and by the Driver Master Switch (DMS, C.16 and Appendix J – Article 251.3.1.20)

	ESS actuated	ESS released
DMS on	Discharge syst. on	Discharge syst. off
DMS off	Discharge syst. on	Discharge syst. off (*)

(*) The active discharge circuits must be disabled (off) to prevent overload of the system as long as the vehicle is still in motion and recuperation energy is available from the drive motors.

19. Overcurrent trip (fuses)

a. The RESS must be equipped with a fuse or equivalent to handle the situation where a short circuit internal to the battery or Super (Ultra) Capacitor enclosure occurs. Any such fuse must be tested and demonstrated to work in a realistic load case.

b. Fuses and circuit breakers (resettable electromechanical fuse) are acceptable overcurrent trips. Extra-fast electronic circuit fuses and fast fuses are appropriate types.

c. A current-limiting device like a fuse must be fitted inside the RESS compartment and also in an adequate location in each electric Power Circuit.

d. Overcurrent trips must, under no circumstances, replace the General Circuit Breaker (emergency stop switch).

20. Charging units (off board)

a. The mains galvanically isolated charging unit (charger) for electric or plug-in hybrid electric vehicles (Appendix J – Article 251.3.1.6.2) has to fulfil all safety provisions set out in the applicable rules in the country in which the respective competition takes place.

b. The charger must connect the grid's earth potential to the vehicle ground (Appendix J – Article 251.3.1.15).

c. The charger must have a fuse (fuses) to protect the charging cable(s).

d. The connector at one end of the charging cable must part before the cable is damaged. (For example by using a non-latching/locking type of connector).

e. Movement of the car must be automatically inhibited while connected to the grid.

f. DC charging cable connector(s) must be polarized and arranged so that incorrect polarity connection is impossible.

g. The charger main switch must disconnect ALL power current-carrying supply conductors.

h. The vehicle traction system must be checked for ground faults before charging commences.

i. The vehicle traction system must not be energized while the battery is under charge.

j. Charging must always be done under the supervision of the BMS (Appendix J – Article 251.3.1.7.).

21. Auxiliary battery

a. The auxiliary battery must never be used to recharge the traction battery. Throughout the duration of the competition, the battery supplying the auxiliary electrical circuit must have a voltage below 60 V.

b. If a DC to DC converter powered by the traction battery (Appendix J – Article 251.3.1.7.3) is used as a substitute for the auxiliary battery, an adequate energy reserve in the traction battery must be maintained at all times if a lighting system is required for the vehicle class (to meet National and/or International Standards or requirements).

22. Safety Indicators

a. Safety indicators warn if the vehicle is in a hazardous state and are required for all vehicle Classes.

b. The colour, location, function and connection requirements are specified in the vehicle Class, and must fulfil the following requirements, unless another system is in place.

c. These indicator 'lamps' must use a high reliability device, for example LED, semaphore, or similar, and the colour must be red and mounted not to be confused with rain light or brake light.

d. They must be suitable for the expected lighting conditions; for example, they must be visible in direct sunlight.

e. The indicators must warn the driver and personnel that the Power Circuit is on and the vehicle might move unexpectedly. They must be visible to the driver when seated normally with the steering wheel fitted and also visible to personnel attending the vehicle from the outside.

f. If required by the Vehicle Class, a method of preventing the accidental driving of the vehicle when the driver is not seated must be provided.

g. The indications must show when there is a voltage on the Power Circuit above 60 V DC (or a voltage sufficient to move the vehicle, whichever is the lesser).

Ready-to-move light
In order to indicate that the car can move if the throttle pedal is activated, a white light (at the front) and an orange light (at the rear) must light up and illuminate the front, respectively the rear of the car parallel to the centre line of the car.

			Rain Light		Ready-to-Move Light	
State by order of priority (1 higher)	**Description**	**Condition**	**On Duration**	**Off Duration**	**On Duration**	**Off Duration**
1	High voltage OFF	Power bus voltage < 60V	Off		Off	
2	RESS Charging	Connected to off-board charger and Power bus voltage > 60V	50 ms	2000 ms	50 ms	2000 ms

3	Car on regen or end of race energy	Battery regen power > 15kW or end of race power cut	250 ms	250 ms	250 ms	250 ms
4	"car energised" with a gear engaged (or virtual gear). Meaning "car ready to move"	Power bus voltage > 60V and gear engaged	Always on		Always On	
5	High voltage ON. Meaning "car energised"	Power bus voltage > 60V	1000 ms	1000 ms	1000 ms	1000 ms

h. The indication must be fail-safe, using at least two independent circuits which are routed so that they are unlikely to both be damaged in the event of a crash.

i. The indicators must :
- be powered from independent isolated power supplies (DC-to-DC converters) running directly on the Power Bus; or may have independent power supplies (rechargeable batteries).
- remain powered for at least 15 minutes after the actuated of the general circuit breaker.

j. If required by the Vehicle Class, additional indicators must show when there is an isolation fault. This will require the indications to operate after the Power Circuit is switched off and so will require an independent supply for the indications and a defined procedure for shutting down the vehicle.

Indications must be visible from any point around the car, manufacturer may install multiple device to achieve it.

Light Status	RESS Status
GREEN	SAFE
RED Flashing	DANGER (System Defect)

23. Fire extinguisher

a. Fire extinguishers must be in compliance with Appendix J according to the relevant Class.

b. Systems mounted
Only systems with an extinguishing medium proven to not create a conductive atmosphere and in compliance with the below list are authorized:
- Novec 1230
- FX G-TEC FE36
- FK 5-1-12
- Monnex

c. More than one type of fire extinguisher may be necessary to cope with the different types of flammable components.
There must also be two exterior handles which may be operated from a distance by a hook.
Furthermore, a means of triggering from the outside must be combined with the general circuit breaker switches.

Manual extinguishers:
They must comply with Article 252.7.3 and can either be ABC powder extinguishers or have an extinguishing medium proven to not create a conductive atmosphere and in compliance with the below list:

- Novec 1230
- FX G-TEC FE36
- FK 5-1-12
- Monnex

24. Emergency Measures on Electrical/Chemical Disposal/Treatment in the Event of Collision/Fire

Provisions taken from the document "Fire Fighter Safety and Emergency Response for Electric Drive and Hybrid Electric Vehicles" may be used.

D. SPECIFIC REQUIREMENTS FOR LIQUID HYDROGEN VEHICLES

1. FOREWORD AND SCOPE

This regulation was prepared under the direction of the FIA H2 Working Group, with the support of the FIA H2 Expert Panels. It forms part of the FIA's broader energy transition roadmap, which defines the introduction of sustainable power sources in motor sport and supports the development of hydrogen-fuelled power units across different disciplines.

Prior to the decision of the World Motor Sport Council of 28 February 2024, the FIA's regulatory work was primarily focused on compressed gaseous hydrogen, as it was the only technology considered relevant at the time. Following this decision, with liquid hydrogen having since reached a higher level of maturity and for performance and safety reasons, the FIA has committed to promoting and imposing the use of liquid hydrogen as quickly as possible. Regulatory development has therefore been redirected towards liquid hydrogen technologies.

As a result, this regulation defines the general rules and requirements for the design, integration, and usage of a liquid hydrogen system in an eligible vehicle. Liquid hydrogen has been identified by the FIA as a key solution for future motor sport applications due to its low storage volume and mass, making it particularly suited to highly demanding competitive environments where optimization and packaging constraints are critical.

This regulation therefore includes safety requirements, performance tests, refuelling and defuelling protocols, and the homologation procedure related to liquid hydrogen technology. It addresses the car structures, systems, and components up to the interface between the vehicle and the refuelling station. Additional liquid hydrogen requirements may be defined in the regulations of the relevant vehicle class.

Specific requirements applicable to vehicles powered by compressed gaseous hydrogen remain included in Appendix J, Article 266. They are retained in their current state of knowledge for reference purposes only and are presented in the appendix of this regulation.

2. DEFINITIONS - NOMENCLATURE

- On-Tank Valve (OTV).
- Boil-off system: system that limits any pressure rise in the hydrogen storage container(s) in nominal conditions, typically induced by the normal warming of the tank and its contents.
- Burst disc: (GTR13) “"Burst disc" is 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.”
- Check valve: (GTR13) “"Check valve" is a non-return valve that prevents reverse flow.”
- Container: (GTR13) “"Container" (for hydrogen storage) is the pressure-bearing component on the vehicle that stores the primary volume of hydrogen fuel in a single chamber or in multiple permanently interconnected chambers.”
- Date of manufacture: (GTR13) “"Date of manufacture" […] is the date (month and year) of the proof pressure test or final inspection test carried out by the manufacturer.”
- Fuelling receptacle: (GTR13) “"Fuelling receptacle" is 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.”
- Hydrogen-fueled vehicle: (GTR13) “"Hydrogen-fueled vehicle" indicates any motor vehicle that uses compressed gaseous or liquefied hydrogen as a fuel to propel the vehicle, including fuel cell and internal combustion engine vehicles. Hydrogen fuel for the vehicles is specified in ISO 14687:2019-2 and SAE J2719_202003.”
- Liquefied hydrogen storage system (LHSS): (GTR13) “"Liquefied hydrogen storage system" indicates liquefied hydrogen storage container(s), PRDs, shut-off device, a boil-off system and the interconnection piping (if any) and fittings between the above components.”
- Lower flammability limit (LFL): (GTR13) “"Lower flammability limit (LFL)" is the lowest concentration of fuel in the air at which a gaseous fuel mixture is flammable at normal temperature and pressure. The lower flammability limit for hydrogen gas in air is conservatively 4 per cent by volume based on quiescent environment.”
- Maximum allowable working pressure (MAWP): (GTR13) “"Maximum allowable working pressure (MAWP)" is the highest pressure to which a container or hydrogen storage system is permitted to operate under normal operating conditions.”
- Pressure relief device (PRD): (GTR13) “"Pressure relief device (PRD)" is 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.”
- Pressure relief valve (PRV): (GTR13) “"Pressure relief valve" is a pressure relief device that opens at a preset pressure level and can re-close.”
- Rupture or burst: (GTR13) “"Rupture" or "burst" both mean to come apart suddenly and violently, break open or fly into pieces due to the force of internal pressure” or external forces.
- Service life: (GTR13) “"Service life" […] indicates the time frame during which service (usage) is authorized.”
- Single failure: (GTR13) “"Single failure" is a failure caused by a single event, including any consequential failures resulting from this failure.”
- Upper flammability limit (UFL): (GTR13) “"Upper flammability limit (UFL)" is the highest concentration of fuel in the air at which a gaseous fuel mixture is flammable at normal temperature and pressure. The upper flammability limit for hydrogen gas in air is conservatively 65 per cent by volume based on quiescent environment.”
- Vehicle fuel system: (GTR13) “"Vehicle fuel system" is an assembly of components used to store or supply hydrogen fuel to a fuel cell (FC) or internal combustion engine (ICE).”
- Barrier: separation between two fluids, typically a valve.
- Functional Scheme: functional diagram of a system, detailing pipes and instrumentation (e.g. valves, sensors) and from which the functioning principle of the said system may be understood.
- Engaged coupling: Male and female parts are in contact and bottomed out but without mechanical locking.
- Locked coupling: the coupling is engaged and mechanically locked. The intercouling is airtight and sanitized.
- Connected coupling: the coupling is locked, and valves are open.
- Section of pipe: continuous part of pipe between two valves where LH2 may be trapped when valves are closed.
- Power unit (PU).

3. HOMOLOGATION

For use in FIA Motorsport environment such as International Series, FIA Categories, FIA Championships or specific applications subject to prior agreement with the FIA Technical Department, any Manufacturer has the possibility to homologate a car working with LH2 technology.
To do so, the Manufacturer must justify that the car complies with the design and performance requirements defined in this regulation and must submit to the FIA a technical dossier which at least includes:

- Technical description of the car and compliance with design and performance requirements.
- Detailed schedule of the project elaboration, including targets for homologation and introduction in FIA events.
- CAD drawings of the H2 parts and their installations in the vehicle.
- A Functional Scheme shall be submitted, showing all key LH2 components (tank, pump, safety valves, sensors…).
- Fault Tree Analysis of the entire H2 system, highlighting the most critical situations resulting from hardware or software sequential or synchronized failures.
- Risk analysis of the teams' operations linked to H2 including mitigation measures.
- Approval from relevant local authorities for the use of LH2 technology where the vehicle is intended to run.

Both the manufacturer and user of a homologated car working with LH2 technology must take whatever steps are required at any time by the FIA, in its absolute discretion, to demonstrate that the car is in conformity with the corresponding technical dossier.

The FIA will analyze the technical dossier and check the successful completion of all the requirements to deliver the final homologation.

4. GENERIC

4.1. GTR13 and other standards

Unless otherwise stated in these regulations or requested by the FIA, the components related to LH2 technology and their fittings must comply with the requirements of the UNECE GTR13 regulation supplemented by the international standards ISO 19881 (new version in preparation), ISO 19882, ISO 12619, ISO 19887, ISO 21266-1, ISO 13985, ISO 13984 for aspects that are not fully covered by GTR13.

- ISO 19881:2018 Gaseous hydrogen — Land vehicle fuel containers
- ISO 19882:2018 Gaseous hydrogen — Thermally activated pressure relief devices for compressed hydrogen vehicle fuel containers
- ISO 12619-1:2014 Road vehicles — Compressed gaseous hydrogen (CGH2) and hydrogen/natural gas blends fuel system components
- ISO 19887-1:2024 Gaseous Hydrogen — Fuel system components for hydrogen-fueled vehicles
- ISO 21266-1:2018 Road vehicles — Compressed gaseous hydrogen (CGH2) and hydrogen/natural gas blends fuel systems
- ISO 13985:2006 Liquid hydrogen — Land vehicle fuel tanks
- ISO 13984:1999 Liquid hydrogen — Land vehicle fuelling system interface

4.2. Car integration

Any H2 (GH2 and LH2) systems or components must be safely integrated in a vehicle and must be compliant with all mechanical requirements (loads, accelerations, vibrations, cryo-temperatures, pressures …), including mechanical loads due to thermal dilatation when using liquid hydrogen. They must be designed, located, installed, and protected so that no damage can be caused by vehicle vibration under normal operating conditions.
Particular care must be taken in the installation of safety components, especially PRDs, which must withstand vibrations and accelerations.

4.3. Material

The materials used for components related to H2 usage in nominal conditions, depending on their position and function within the H2 system, require:

- Compatibility with liquid and gaseous hydrogen, including embrittlement issues.
- Compatibility with the operating environment.
- Corrosion resistance.
- Compatibility with operations at high temperature (+85°C).
- Compatibility with operations at very low temperature (-253°C / 20K).

4.4. Equipment in a potentially explosive atmosphere

Electrically conductive housings of components in possible flammable areas should be bounded to the electric chassis to prevent inadvertent ignition of hydrogen discharges.
Electrical Equipment must be so designed and constructed as to prevent ignition sources arising, even in the event of frequently occurring disturbances (including shocks and vibrations) or expected malfunction.
Equipment parts must be so designed and constructed that their stated surface temperatures are not exceeded, even in the case of risks arising from abnormal situations anticipated by the manufacturer and that they cannot be the source of electrostatic discharges capable of igniting hydrogen mixtures with air.
Equipment must be designed and constructed so that the opening of parts that may be sources of ignition is only possible under non-active conditions or via appropriate interlocking systems. The opening of such parts must not occur in race conditions under the effect of vibrations/acceleration nor in crash conditions.
For example, equipment designed and tested according to IEC 60079 series with EPL Gb for group IIC meet this requirement.

4.5. Specific Test Requirements for LH2 Powered Vehicles

LH2 components and LH2 powered vehicle are subjected to specific test requirements described in Appendix 5

5. LIQUID HYDROGEN STORAGE SYSTEM LHSS

5.1. Generic requirements for LHSS

5.1.1. Functioning Principles

The LHSS must fulfil the functioning principles described in the drawing in Appendix 3.
“Functioning principles” means:

- Ensuring the same communication / connection between the elements of the tank system as represented in the drawing
- Replicating the functions described in the drawing

Should any dispute arise over the interpretations of the drawings in Appendix 3 and the text, the final understanding of these regulations shall be the text.

5.1.2. Sub-assemblies

The LHSS is divided into sub-assemblies: Compartment, Tank, Overpressure Management System, Refuelling/Defuelling System, Powertrain Supply System and Electronics, all described with their specific nomenclatures in Appendix 3 and which requirements are explained in the paragraphs 5.2 to 5.7 below.

5.1.3. Barrier requirements

At any time while the car is running, a direct connection between LH2 lines and the air is strictly forbidden. A double barrier with helium must be incorporated into each connection to ensure that a single failure of an LH2 valve can never lead to an LH2 leak into the air.
During the refuelling procedure, the double barrier will be temporarily removed to allow LH2 and GH2 flows and will be restored at the end of the procedure by introducing helium between the LH2 lines and the air.
The double barrier can be implemented using two valves or integrated directly into specific equipment (e.g., coupling).
Double barrier with GH2 instead of helium is allowed on conditions pipes are vacuum insulated and their volumes are low enough to prevent major risks to the LHSS in the event of a pipe burst.

5.1.4. Service life (validity)

The service life of the LHSS expires five years after the date of manufacture. For example, a LHSS manufactured on 1 January 2025 will be "Not valid after January 2030".

5.1.5. Piping Connection

Piping and connection assembly must be welded or screwed.
External temperatures of H2 piping shall not be lower than 0°C when system working in nominal conditions, at reference ambient conditions.

5.1.6. Components compatibility

Some components might fulfil only the requirements of nominal working conditions. In case the possibility of occurrence of conditions out of the component homologation windows has not been eliminated in the risk analysis (i.e. PRD for pressure), then a specific sensor raising an alarm must be implemented and a dedicated action plan defined.

i.e. a GH2 component is homologated for a temperature window of -40°C to + 85°C but the risk that very low temperatures under -40°C can be seen in case of upstream heat exchanger malfunction. In this case a temperature transmitter must be implemented upstream this component and a dedicated strategy must be developed.

5.1.7. Ventilation system

Any volume in the car that may build-up H2 concentration at an ignitable level (cockpit, engine bay, fuel-cell casing, H2 tank) must be equipped with a ventilation system (extractor fan) and/or openings connected to the exterior to prevent the build-up of an ignitable concentration of H2 in running conditions as well as when the car is stationary (in the garage, on track, etc.).

Ventilation exit openings must be safely routed away from the cockpit and potential sources of ignition.
Ventilation of the cockpit should be designed to never recirculate H2 from other events/ventilation of the car.
The components of ventilation system must be qualified for ATEX Zone [ATEX directive 99/92/EC + ATEX directive: 2014/34/EU]
The ventilation system must:

- be powered from independent isolated power supplies running directly from the electrical system or may have independent power supplies (rechargeable batteries)
- remain powered for at least 15 minutes after activation

The extractor fan must work as a vacuum system which extracts and guides GH2 out of the compartment and of the car.
Design and installation shall be part of the Risk analysis as requested in article 3.

5.2. Compartment

The tank and the safety devices of the LHSS must be protected by a structural compartment.
All the surfaces of the compartment must be:

- constructed to a laminate that passes the intrusion test defined in Appendix 5, unless more stringent requirements are defined in the specific vehicle Class
- made of a fire-resistant material (according to the UL94 V0 standard)

The compartment must be designed with sufficient openings of appropriate dimensions to enable the natural evacuation of GH_2 and must not include any geometries that could lead to GH_2 accumulation, regardless of the vehicle’s orientation or operating conditions. This must be verified through CFD simulations.
In addition to the requirements specified in paragraph 5.1.7, the compartment must be equipped with an extractor fan which volumetric flow must be at least 500 Ncm3/s.

5.3. Tank

5.3.1. Material

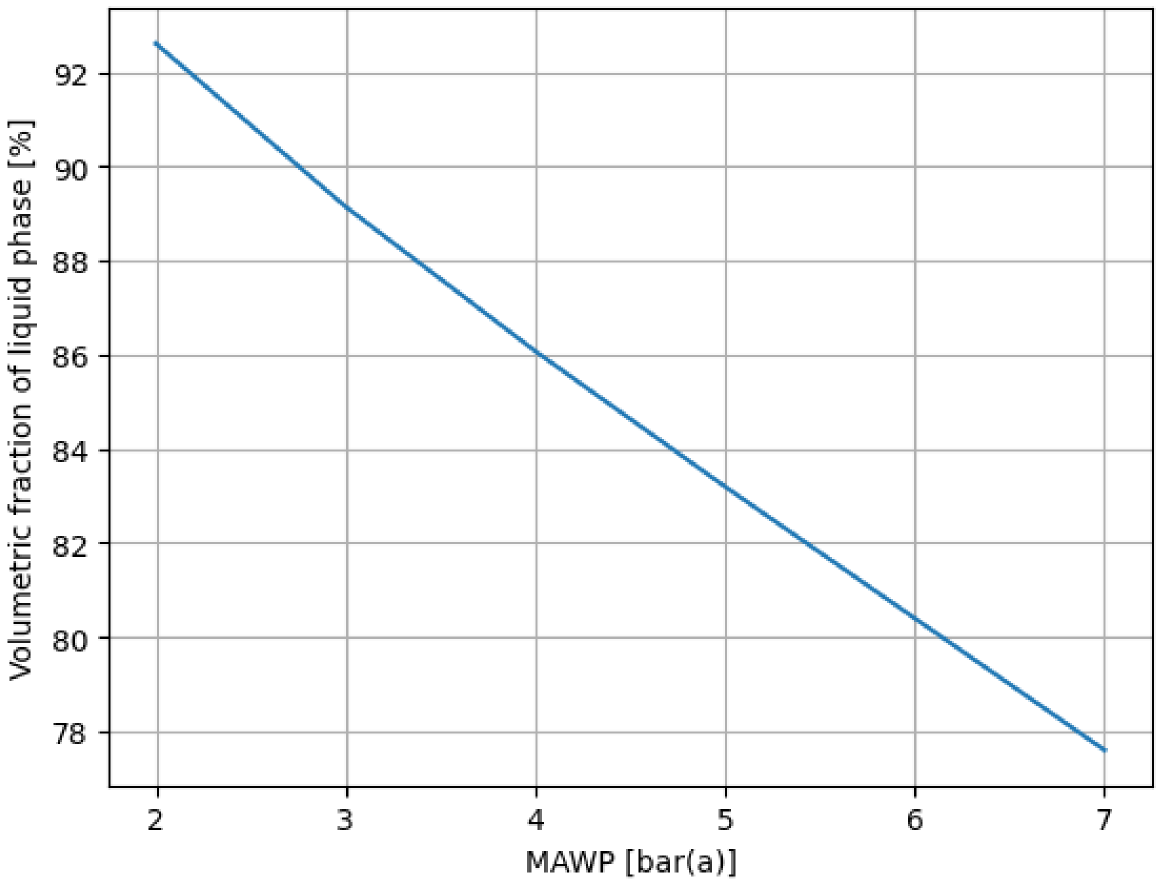
The inner skin of the tank, as well as the outer skin if present, must comply with all mechanical requirements (loads, accelerations, vibrations, cryogenic temperatures, pressures, etc.), including mechanical loads resulting from thermal dilatation when using liquid hydrogen. It must be made of a material that satisfies the conditions prescribed in Section 4.3.

5.3.2. Working pressures

The Maximum Allowed Working Pressure of the tank (MAWP tank) must be set at a maximum of 7.0 bar (absolute).
The MAWP tank value must be declared as part of the LHSS homologation.

5.3.3. Maximum quantity

The maximum mass of hydrogen carried in the tank (liquid and gas) must not exceed 22kg.
A lower maximum mass may be defined in the specific technical regulation of the car category or championship concerned.
The volumetric fraction of LH2 in the tank, when at saturation Temperature corresponding to $MAWP_{tank}$ must not exceed 97%.
To guarantee the above condition, the sensor for maximum quantity level detection must be installed in the tank according to the following curve. The position of the sensor must be declared and checked as part of the LHSS homologation.



Note: this curve gives the equivalence between 97% of the tank volume occupied by LH2 at saturation Temperature corresponding to $MAWP_{tank}$ and the tank volume occupied by LH2 @ 20°K / 1 bar for the same overall quantity of H2 in the tank (liquid + gas).

5.3.4. Double Wall Insulation

The tank must be equipped with a double wall insulation which will guarantee:

- the thermal insulation required for the category (Dormancy time, max GH2 boil off flow).
- a double sealing in case of LH2 leakage out of the inner wall.

Insulation can be made through various materials or technologies (including vacuum, MLI, …) but must not induce additional risk of damage when failing compared to standard vacuum jacket insulation.
The Maximum Allowed Working Pressure of the Double Wall Insulation (MAWP Double Wall) must be lower than 2bar(a) and lower than the MAWP tank.
Usage of flammable materials or gas in the double wall is forbidden.

5.3.5. Reference Dormancy Time and Reference Boil-Off Flow

The Reference Dormancy Time is the time needed for a full tank filled in “Dormancy time test” conditions to open the boil-off valve.

A full tank filled in "Dormancy time test" conditions is a tank filled with maximum allowable volumetric fraction of LH2 and liquid/gas mixture at saturation Temperature corresponding to 1bar. The tank must be on stand-by, in standard ambient conditions. PU, pumps and devices linked to the LHSS must be switched off and must not act on the H2 liquid/gas mixture. The only source of pressure and temperature variation in the H2 liquid/gas mixture should be the heat transfer from the outside.
The Reference Dormancy time of the tank must stay over the value defined in the specific technical regulation of the concerned car category or championship.
Once Reference Dormancy Time elapsed, when the boil-off phase starts, the GH2 flow must not exceed 0.01 Nm3/s (0.81g/s) until the tank is at the minimum level. Additionally, the boil-off flow shall be such that the tank pressure remains below the Maximum Allowable Working Pressure (MAWP).
The Reference Dormancy time may also be referred to as Reference boil-off time.

5.4. Powertrain Supply System

The paragraph below gives the design requirements for the fuel system which allows the LH2 distribution from the tank to the PU.

5.4.1. Working Pressure

The Maximum Allowed Working Pressure of the Powertrain Supply System (MAWP PSS), downstream the main pump, must not exceed 120 bar (absolute).

5.4.2. Pump architecture

Four different architectures for pump installation are allowed: no pump, internal pump, external pump or double-stage pump.

5.4.3. Supply Heat exchanger

The powertrain supply system can be equipped with a supply heat exchanger to adapt temperature and pressure of H2 before feeding the Powertrain.

5.4.4. GH2 Buffer tank

A GH2 buffer tank might be installed on the warm side of the powertrain supply, downstream of the hydrogen pressure pump. The limitations of this tank are defined by the product of maximum operating pressure (MAWP [bar(a)]) and volume (V [L]) at that pressure at 20°C, whereas the product R of MAWP and Volume cannot exceed 700 and MAWP cannot exceed 100 [bar(a)].

- R = MAWP x V
- Rmax < 700 [bar*L]
- MAWP < [100 bar(a)]

Unless otherwise mentioned in the present regulation, the buffer tank must fulfil the following paragraphs of Appendix 2 (Specific requirements for gaseous hydrogen vehicles):

- Art 5.1.4 operating temperature range
- Art 5.1.5 Design and installation
- Art 5.2.1 and 5.2.2 Temperature sensors and pressure sensors
- Art 5.3 Compartment
- Art 5.5 Valves
- Art 5.6 Hydrogen discharge systems

The tank must be equipped with an OTV protection structure to avoid the decapitation of the OTV/vessel interface and thus mitigate the risk of uncontrolled decompression of the tank. This structure must:

- protect the OTV/vessel interface from impacts at any angle (in particular radially or longitudinally relative to the vessel)
- be designed and suitably connected to the vessel in a way to ensure that the relative forces between the OTV and the vessel remain below levels that could cause potential failures
- not increase the risk of damaging the vessel

5.4.5. Shut-off valve

One controlled fail-safe normally-closed shut-off valve (SOV-CA) must be implemented in the Powertrain Supply system.
It must be fail-safe, prevent any flow from the tank to the powertrain, and be mounted directly on or within the tank
It must close during any of the following events:

- Hydrogen leak detection corresponding to the measurement of a hydrogen volumetric concentration greater than 0.4% inside the cockpit environment (sensor D1) or greater than 2% in any other confined spaces of the vehicle
- Hydrogen leak detection through an abnormal pressure drop
- Impact of the vehicle in any direction above set acceleration threshold values defined by the manufacturer (via on-board accelerometers)

When the shut-off valve closes for any of the events listed above, it must force the upstream pump (if exists) to stop.

5.5. Refuelling / defuelling system

The paragraph below gives the design requirements for refuelling/defuelling interface.

5.5.1. Working pressures

The Maximum Allowed Working Pressure of the Refuelling and Defuelling line (MAWP R/D) depends on the championship and car category and must be set at a value justified by a dedicated risk assessment provided by the manufacturer and the fuel provider.

5.5.2. GH2 return line

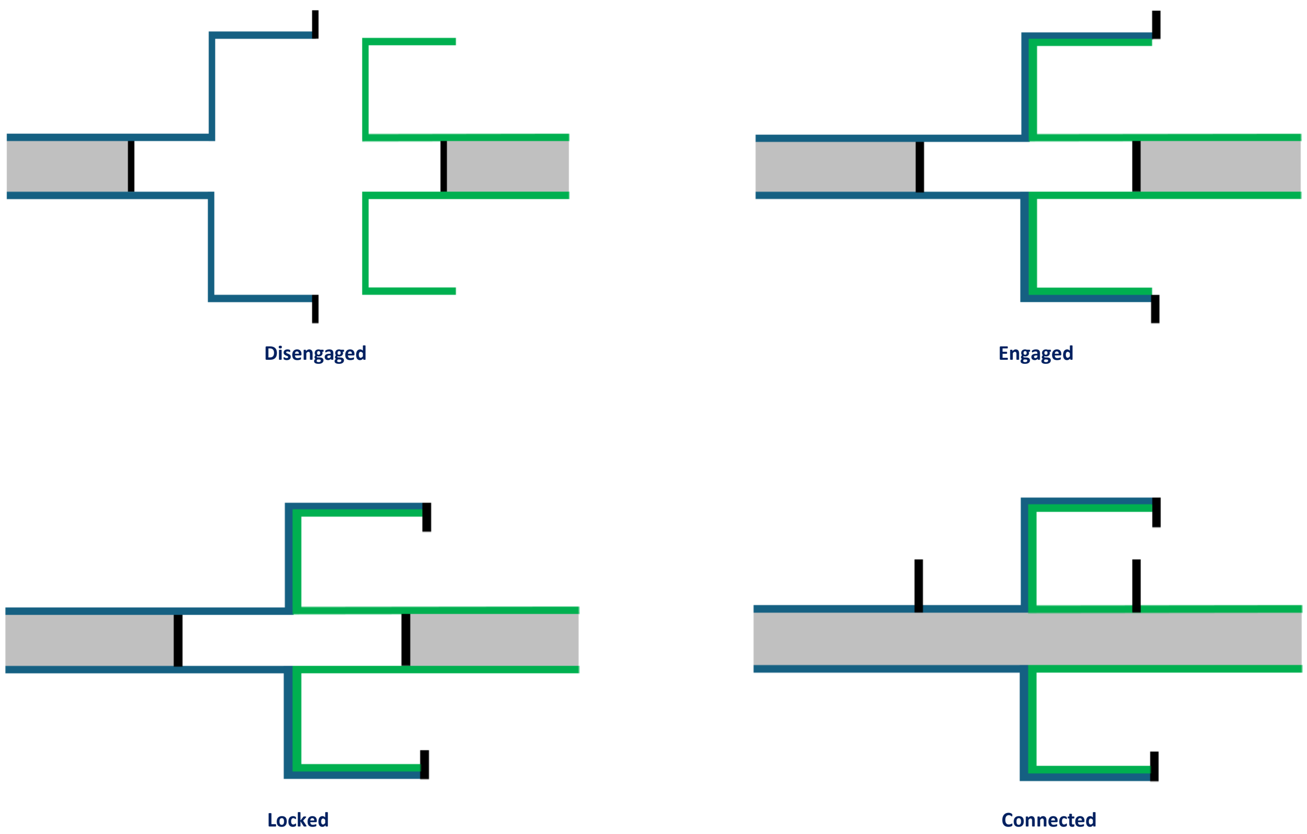
GH2 return line shall be compatible with LH2 presence in terms of material and tightness

5.5.3. Coupling

The coupling for refuelling shall be compatible with liquid hydrogen, gaseous hydrogen, ISO 14687 gaseous helium and gaseous nitrogen.
The coupling must integrate the following functions:

- A status detection device (engaged, locked or connected coupling detection). The different coupling status are described in the figure below.
- A local air evacuation system using GHe to avoid transferring and diluting the air embedded in the coupling interface inside the vehicle.
- On the refuelling station side, a "dry disconnect" or "break away" system which would keep both the tank and the flexible closed in case of brutal disconnection when refuelling.

The coupling shall be equipped with local void insulation to avoid ice accretion.
Locking and unlocking the coupling must not require external energy input and must be fully achievable by the operator.
LH2 coupling shall be tested and validated according to the 7.4.4.2 GTR13 test (external leakage test).
The numbers of connections and disconnections of coupling components shall be compatible with life duration of LH2 tank without requiring maintenance or replacement of the parts.



5.5.4. Valve status & monitoring

Valve status shall be indicated through car controller, for each life phases and specially during refuelling and defuelling (feedback system):

- Open position
- Close position
- Real position (%) if regulation is required

Depending on the position of the valve in the system, its status may be deducted by measuring the pressure before and after the valve, as well as detecting a temperature drop (LH2 flow detection).
Loss of valve status information shall be indicated and different from initial valve status during process.

5.5.5. Tank spillage

One sensor shall be implemented to manage the risk of tank spillage. The activation of this sensor shall provide an automatic stop of refuelling process.
The Inertia of system shall be considered to stop the level of tank before reaching the maximum allowable volumetric fraction of LH2.

5.5.6. Defuelling

The LHSS shall be compatible to defuelling phase to totally remove the liquid hydrogen from the tank.
The LHSS may be equipped with a dedicated defuelling line fulfilling the barrier requirements: direct connection between LH2 lines and the air is strictly forbidden.

5.5.7. Refuelling / Defuelling / Sanitation protocols

To perform refuelling, defuelling or sanitation of the tank, the car, PU, and pumps must be stopped. The PU feed must be closed. Car grounding and ECU connection must be established.

The refuelling station and the vehicle must execute a synchronized sequence of valve opening and closing operations on both sides, coordinated by the refuelling station, as described in the protocol in Appendix 6.
Information exchange between the car and the refuelling station must include exhaustive data on safety and integrity status of the car, valve status, pressure, and temperature.
To anticipate and optimize the refuelling process, information exchange between the car and the refuelling station is permitted via telemetry while the car is running.

5.5.8. Shut-off valves for refuelling/defuelling

Two controlled fail-safe normally-closed shut-off valves (SOV-RFL-IN and SOV-RFL-OUT) must be implemented on the refuelling/defuelling system: one on the tank ingoing pipe and one on the tank outgoing pipe.
It must be fail-safe, prevent any flow from the tank and be mounted directly on or within the tank

They must remain closed except during specific designated phases of the refuelling, defuelling and sanitation protocols.
Both shut-off valves must specifically close during any of the following events:

- Hydrogen leak detection corresponding to the measurement of a hydrogen volumetric concentration greater than 0.4% inside the cockpit environment (sensor D1) or greater than 2% in any other confined spaces of the vehicle
- Hydrogen leak detection through an abnormal pressure drop
- Impact of the vehicle in any direction above set acceleration threshold values defined by the manufacturer (via on-board accelerometers)

These valves may be integrated into the coupling receptacle but must satisfy the criteria listed below.

5.6. Overpressure Management system

5.6.1. Generic

The Overpressure Management System is the combination of safety devices (such as PRDs, including PRVs and burst discs, as well as pipes, non-return valves, etc.), designed to maintain the integrity of the LHSS in the event of a malfunction.
The Overpressure Management System should not be activated under nominal operating conditions and is triggered when pressures in the LHSS exceed any MAWP.
The Overpressure Management System must:

- stay active at low temperature regardless of the vehicle’s orientation or operating conditions
- avoid any risk of freezing with LH2 contact

The safety devices composing the Overpressure Management System must be consistent with the volume and flow of GH2 to evacuate.
The safety devices used to mitigate risks on the same sub assembly, must be different in terms of technology to manage risk of common mode.
Redundant safety devices shall be designed to prevent a hazardous condition when a component fails.
As such, in most cases, PRV and BD are coupled, with BD serving as secondary safety device in case of PRV malfunction, failure or if the evacuated flow is not sufficient.

5.6.2. Pipes

Two safety devices shall be implemented per section of pipe to manage overpressure.
One of them must be independent (autonomous) and must not require any source of energy to work properly.
A single safety device on a pipe section is allowed under the following conditions:

- The pipe is fully enclosed within the compartment.
- The maximum volume of LH2 that could be trapped in the pipe is low enough to prevent major risks to the LHSS in the event of a pipe burst.
- The safety device is autonomous and does not require any external energy source to function properly.

5.6.3. Tank: Boil-off valve

The tank must be equipped with a controlled boil-off valve (BO-PRV-TK) which must:

- be a re-closing type pressure relief valve
- be located on a dedicated line directly from the tank
- open below MAWP tank
- limit the pressure in the container to a value lower than MAWP tank in the GTR13 7.4.2.1 Boil-off test

5.6.4. Tank: Primary PRD

The tank must be equipped with a Primary Pressure Relief Device (PRD1-PRV-TK), which must:

- be a re-closing type pressure relief valve
- be in parallel to the boil-off valve (BO-PRV-TK)
- open below or at MAWP tank and above the Boil-off valve opening pressure
- limit the pressure in the tank to not more than 110% of MAWP tank (gauge) in the GTR13 7.4.2.3. Vacuum loss test (if applicable)

5.6.5. Tank: Secondary PRD

The tank must be equipped with a Secondary Pressure Relief Device (PRD2-BD-TK) which must:

- be a burst disc
- be located on a dedicated line directly from the tank
- not open below 110% of the set pressure (gauge) of the Primary Pressure Relief Device (PRD1-PRV-TK)
- limit the pressure inside the container to not more than 150% of MAWP tank (gauge) in the GTR13 7.4.2.3. Vacuum loss test (if applicable)

The routing to both primary and secondary PRD must be designed and installed in such a way that liquid hydrogen would not come into direct contact with them during refuelling/defuelling nor in case the car is overturned.

5.6.6. Catalyst

The LHSS must integrate a hydrogen catalyst system which must process or consume the hydrogen that is vented from:

- BO-PRV-TK and PRD1-PRV-TK
- CV-RFL-CP (Refuelling + Pump - Check Valve)
- This catalyst must consist of the following components, in stream order:
  - a restrictor
  - a check valve (CV-CAT-H2)
  - a connection for an air intake line, itself consisting of the following components in stream order:
    - an air inlet (from the outside)
    - a filter
    - an air compressor
    - a check valve (CV-CAT-AIR)
  - a catalytic bed (CAT)
  - a filter
  - a vent exhaust to the outside (VE-CAT)

The catalyst must be sized to purge at least 0.01 Nm3/s of GH2 with a safety factor of x1.5.
The catalyst must be designed to work efficiently without external energy supply, including energy needed for air supply.
The catalyst must be placed out of the compartment.

5.6.7. Emergency PRV

The catalyst must be equipped with an emergency pressure relief valve (PRV-CAT) which must:

- be a re-closing type pressure relief valve
- be located on a dedicated vent exhaust line that starts upstream of the catalyst / check valve / restrictor and downstream of BO-PRV-TK and PRD1-PRV-TK
- open at a pressure such that the catalyst does not reach its MAWP
- limit the pressure in the container to not more than 110% of MAWP tank (gauge) in the GTR13 7.4.2.3. Vacuum loss test (if applicable)

5.6.8. Double wall insulation (Jacket) - Pressure Release Devices

The double wall insulation must be equipped with two Pressure Release Devices in parallel.
One must be a Pressure Relief Valve (PRV-VAC) connected to the double wall insulation with a specific piping and must open at MAWP $_{\text{Double Wall}}$ +1.1 bar.
The other one must be a burst disc (BD-VAC) and limit the pressure in the jacket to a maximum of MAWP $_{\text{Double Wall}}$ + 2.3 bar.

5.6.9. Refuelling: Pressure Release Devices and check valve

The refuelling line must be equipped with two Pressure Relief Devices in parallel.
One of the PRDs must be a Pressure Relief Valve.
Both PRDs must be calibrated with two different values (minimum variation: 10%).
The second PRD can be a burst disc.

5.6.10. Powertrain Supply System - Pressure Relief Devices

The Powertrain Supply system must be equipped with two independent Pressure Relief Devices, connected downstream of the pump.
The first Pressure Relief Device must be a PRV and must open below or at MAWP PSS (gauge) and limit the pressure to a maximum of 110% of the MAWP PSS (gauge).
The second Pressure Relief Device must:

- not open below 110% of the set pressure (gauge) of the first Pressure Relief Device
- limit the pressure in the container to a maximum of:
  - 136% of the MAWP PSS (gauge) if a Pressure Relief Valve is used
  - 150% of the MAWP PSS (gauge) if a burst disc is used

The architecture of the Powertrain Supply System must be such that, in nominal configuration, PRD are protected from inactivation at low temperature (freezing by contact with LH2).
The vent valve can be active / controlled.

If the pump is fully or partially external to the tank and its technology such that it fully blocks the H2 flow when not running, the same valve assembly must be installed upstream of the external pump.

5.6.11. Vent exhausts

The LHSS must be equipped with the following vent exhausts:

- Catalyst vent exhaust (VE-CAT)
- Cryo line vent exhaust (VE-CRYO)
- Warm line vent exhaust (VE-WARM)
- Tank vent exhaust (VE-TANK)
- LHSS compartment vent exhaust (VE-COMP)
- Double wall insulation vent exhaust (VE-DW)

The vent circuits must be located and oriented to limit risks and consequences of a hydrogen leakage.
Vent circuits must be operating whatever the position of the vehicle (including vehicle on the roof)
Design and installation shall be part of the Risk analysis as requested in article 3.

The vent exhausts must be located/oriented:

- to limit the consequences (thermal effect distance) in case of activation and allow for safe escape of the driver and safe intervention.
- to limit the risk of line constriction during a crash

All the vent exhausts must be connected to two single final vent exhausts symmetrically positioned on both sides of the car, the target being to manage easily with external tool all the GH2 produced when the car is stopped (refuelling procedure or service operation in the garages) and mitigate the risk of full obstruction of the vent exhausts.

The vent exhausts must be compatible with the connectors used in the championship by the refuelling stations and the safety operators.
The vent exhausts must be labelled with a specific symbol.

5.7. Electronics

5.7.1. Control Unit

The LHSS must be equipped with a dedicated control unit (CU-LHSS).
It must be connected to all sensors and actuators related to tank management and refuelling / defuelling operations.
It must assess and report its safety status at any time by controlling H2 safety lights and associated sound module.
The control unit shall output the current safety level (related to H2 risks) in visible and audible forms to inform users inside and outside the vehicle.
If any breach is detected, it must be able to take any action necessary to turn the system back into a safe condition.
This system must be able to autonomously check the tank for at least 30 minutes after the car is turned off.

5.7.2. Connection and Interface

CAN or Ethernet connection with the control unit must be used as an interface to ensure the successful completion of the refuelling/defuelling processes which allow LH2 flow management and synchronized sequences of operations to open / close valves on both the refuelling station and the vehicle tank system.
The datalink and fluidic connection interface must be located more than 50 cm from the refuelling coupling.
The datalink connection must ensure the grounding connection of the car.
The datalink connection needs to be established prior to start of refuelling / defuelling sequence. The refuelling station controls the overall process, the tank controller unit acts as a slave.
Tank control unit must be connected to the FIA logger through a dedicated CAN line. (Exchanged data must be defined in a DBC file).

5.7.3. Sensors

The LHSS must be equipped with the sensors described in Appendix 4.

- Tank sensors

To manage the temperature and pressure inside the tank, two temperature sensors and two pressure sensors must be implemented in the tank.

- Fuel level sensors

Two sensors must be implemented to detect, during the refuelling operation, when the maximum volume of LH2 allowed in the tank is reached.
Another sensor must be implemented to manage the low fuel level.
To monitor the quantity of LH2, a fuel-level sensor must be implemented in the tank.
This fuel-level sensor can be used as one of the two sensors implemented for maximum fuel level alert and as the low fuel level sensor too.
During the refuelling process, the fuel level sensors must send an alert to the operators via the ECU and automatically trigger the stop of the refuelling process when the maximum allowable LH_2 volume in the tank is reached.

- Powertrain Supply Sensors

To manage the temperature and pressure in the Powertrain Supply system, it must be equipped with one temperature sensor and one pressure sensor.

- Refuelling / Defuelling sensors

Pressure sensors and temperature sensors shall be implemented for pipe to detect LH2 or GH2/ He presence during nominal process.

5.7.4. Actuators

The storage system must be equipped with the actuators described in Appendix 4.

5.7.5. Detection Systems

Safety detection systems must be installed to detect and control the possible effects of hazards, such as vessel damages, leaks, ignitions, fires, hydrogen concentrations above set thresholds, etc. This should include but not be limited to, a sufficient number of detection systems within any part of the car including cockpit, PU, and hydrogen storage systems. The exact number and positions are to be defined in accordance with the overall installation within the car.

5.7.6. H2 Safety Indicators

H2 Safety Indicators are made of 3 main devices, meant to warn people interacting with the vehicle that a hazard has been detected:

- Safety lights: a light device positioned to be visible from outside the vehicle.
- Audible warning: triggered alongside the safety lights, a sound module producing an audible warning.
- Warning signals for drivers: safety light repeater in the cockpit and dashboard messages.

5.7.7. H2 Safety Lights

Safety Lights are designed to warn surrounding people (ex: Marshals, rescuers, mechanics…) if the vehicle is in a hazardous state. They shall be able to detect and alert both risks related to hydrogen or risks related to high voltage.

a/ Safety lights design

The H2 safety light system (power and monitoring) shall be fail-safe, using at least two independent circuits which are routed so that they are unlikely to both be damaged in the event of a crash. It shall be managed, driven and powered by the H2 tank control unit (cf. article 5.7.1). It shall include a back-up battery to power the H2 Safety Lights in case the LV power of the car is turned off or out of order for a period of at least 30 minutes.

It shall be a black frame with an illuminated "H2" logo.
The H2 illuminated pattern should be 50 (+/-5) mm both in height and length.
The flashing pattern shall be: 5Hz (200ms ON / 200ms OFF).

HV safe	**Green** steady
HV unsafe	**Red** blinking

+

H2 safe	"H2-pattern" **steady** Yellow
H2 unsafe	"H2-pattern" **blinking** Yellow

The H2 safety lights shall be active:

- When the car is powered ON (LV system active)
- When the car is running (H2 system active)
- At least 30min after the car is powered OFF

b/ H2 Safety lights installation

The H2 Safety lights shall be mounted outside the car to be visible from any point around the car. To deliver that, at least 3 modules shall be installed but it is recommended to install 4 modules. The lights shall be visible by the driver, seated in his racing seating position with seat belt fastened. If necessary, an extra light module can be installed in the cockpit with an adapted level of brightness.

c/ H2 Safety lights logic

The list below provides the minimum requirements for the activation of the H2 safety lights (flashing). If the designer of the hydrogen system deems necessary to add more triggers, this shall be approved by the FIA beforehand.

- Leak detected by a measuring of pressure or flow at any place in the H2 system (tank, fuel line, fuel-cell…)
- H2 concentration reached the warning level as prescribed in art 266-C.4 (cf table below)

Zone	Threshold % by volume	
	Warning	Shut down
Cockpit environment	0.3 %	0.4 %
Compressed hydrogen storage system compartment(s)	0.75 %	1 %
Fuel Cell / ICE	0.75 %	1 %
Fuel Cell Exhaust Line	3 %	4 %

- Pressure release valve is OPEN uncontrolled/unexpected
- Over Pressure Management System of any LHSS sub assembly is activated.
- Tank pressure is out of the normal operating window (values to be declared in the car homologation form)
- Any failure of any monitoring system mentioned above (ex: sensor failure)

5.7.8. H2 Safety Audible Alert

Alongside the H2 safety lights, an audible warning shall be activated at the same time as the H2 Safety lights flash. It shall be powered in the same manner as the safety lights (fail-safe). It shall be at 3500Hz and 85dB (measured in open area, at 2m radius around the car, 1m high from the ground level) and follow the same pattern of 200ms ON / 200ms OFF. The actual sound shall be submitted to the FIA for approval and be listed in the car homologation form.

5.7.9. Warning signals for driver

In combination with the safety lights, a list of alert messages shall appear on the driver display as an overlay. The list and detailed messages shall be validated by the FIA and listed in the car homologation form. The message shall at least indicate the root cause of the fault:

- H2 leak + "location"
- H2 concentration + "location"
- Activation/opening of "safety valve name"
- H2 safety monitoring failure

APPENDIX 1:

Specific Test
Requirements for Elec

APPENDIX 2:

Specific
Requirements for Gas

APPENDIX 3:

LHSS Functional
Scheme Components

Functional
Scheme.pdf

APPENDIX 4:

H2 Detectors			Pressure & Temperature sensors		
D1	Highest point of the cockpit	Range TBC	PT1.1	LH2 tank gaseous bubble	Range TBC
D2	Top of the Engine / Fuel Cell bay	Range TBC	PT1.2	Tank vacuum jacket	Range TBC
D3	After exit of exhaust tube in the exhaust gas flow	Range TBC	PT2	Zylon wall zone	Range TBC
D4	H2 tank compartment	Range TBC	PT3	Upstream heat exchanger	Range TBC
D5	Liquid to gaseous phase changing routing	Range TBC	PT4	Downstream heat exchanger	Range TBC
D6	Refuelling receptacle	Range TBC	PT5	Upstream pressure regulator	Range TBC
D7	Overpressure valve group exit	Range TBC	PT6	Downstream pressure regulator	Range TBC
D8	LH2 pump	Range TBC	PT7	Upstream LH2 pump	Range TBC
D9	GH2 return line	Range TBC	PT8	Downstream LH2 pump	Range TBC
D10	Overpressure valve	Range TBC	PT9	Exhaust tip	Range TBC
D11	Tank valve	Range TBC	PT10	Upstream refuelling line	Range TBC
D12	Internal enclosure tank	Range TBC	PT11	Downstream refuelling line	Range TBC
D13	ICE crankcase	Range TBC	PT12	Upstream external heater	Range TBC
D14	ICE dry-sump oil tank	Range TBC	PT13	Downstream external heater	Range TBC
D15	Low pressure regulator	Range TBC	PT14	Downstream high pressure shut off valve	Range TBC

Designation	Type	Function	State
Tank boil off valve	Spring load mechanical	Evacuate boil off generated overpressure from tank hull	Normally closed
Tank overpressure relief valve	Spring load mechanical	Protect tank from overpressure due to exhaust boil off	Normally closed
Refuelling overpressure valve	Spring load mechanical	Protect refuelling line from overpressure	Normally closed
Refilling overpressure burst disc	Metal plate	Protect refuelling line from overpressure	Normally closed
Exhaust drain valve	Pneumatic + spring loaded	Evacuate H2 burned by catalyst downstream of OBV	Normally closed
Tank burst disc	Metal plate	Protect tank hull from bursting in case of BOV and PRV failure	Normally closed
Cryogenic shut-off valve	Pneumatic + spring loaded	Allow LH2 supply to LH2 pump	Normally closed
Warm shut-off valve	Pneumatic + spring loaded	Allow GH2 supply to power plant	Normally closed
Chill down valve	Pneumatic + spring loaded	Recirculate LH2 to chill down tank to cryogenic storage temperature	Normally closed
Vacuum hull thermofuse valve	Glass bulb + spring loaded	Accelerate boil off in case of fire to enhance H2 evacuation via PRV	Normally closed
On tank valve	Eletromechanical or pneumatic + spring loaded	Control refuelling path from receptacle to tank	Normally closed

APPENDIX 5:

Specific Test
Requirements for LH2

APPENDIX 6:

LHSS Refuelling
Protocol.pdf