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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 (both liquid and gaseous). 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.

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# 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 :

| Propriété - Property | Unités - Units | Min. | Max. | Méthodes de test - Test methods |
|---|---|---|---|---|
| RON | | 95.0(1) | 102.0(1) | ISO 5164<br>ASTM D2699 |
| MON | | 85.0(1) | 90.0(1) | ISO 5163<br>ASTM D2700 |
| Densité - Density<br>(à - at 15°C) | kg/m³ | 720.0 | 785.0 | ISO 12185<br>ASTM D4052 |
| Oxygène - Oxygen | % m/m | | 3.7 | EN ISO 22854(2) / EN 13132(2)<br>/<br>Analyse élémentaire - Elemental Analysis<br>ASTM D5622 |
| Méthanol - Methanol | % v/v | | 3.0 | EN 1601<br>ou – or<br>EN 13132<br>ou – or<br>EN ISO 22854 |
| Azote - Nitrogen | mg/kg | | 500(4) | ASTM D4629<br>ASTM D5762 |
| Soufre - Sulphur | mg/kg | | 10 | ISO 20846(2)<br>ASTM D5453 |
| Plomb - Lead | mg/l | | 5 | EN 237<br>ASTM D3237<br>ou – or<br>ICP-OES |
| Manganèse - Manganese | mg/l | | 2.0 | ASTM D3831<br>ou – or<br>(ICP-OES) EN 16136 |
| Benzène - Benzene | % v/v | | 1.00 | ISO 12177<br>ASTM D5580<br>ISO 22854(2)<br>ASTM D6839<br>EN 238 |
| Oléfines - Olefins | % v/v/ | | 18.0 | ISO 22854<br>ASTM D6839 |
| Aromatiques - Aromatics | % v/v | | 35.0 | ISO 22854<br>ASTM D6839 |
| Total de di-oléfines<br>Total di-olefins | % m/m | | 1.0 | GC-MS<br>ou – or<br>HPLC |
| Total de styrène et dérivés d'alkyl<br>Total styrene and alkyl derivatives | % m/m | | 1.0 | GC-MS<br>avec – with GC-FID |
| Stabilité à l'oxydation<br>Oxidation Stability | minutes | 360 | | ISO 7536<br>ASTM D525 |
| DVPE | kPa | | 80(6) | ISO 13016-1(2)<br>ASTM D4953<br>ASTM D5191(2) |

| Caractéristiques de distillation - Distillation characteristics | | | | |
|---|---|---|---|---|
| A - At E70°C | % v/v | 20.0 | 52.0 | ISO 3405/ ASTM D86 |
| A - At E100°C | % v/v | 46.0 | 72.0 | ISO 3405<br>ASTM D86 |


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| | | | | |
|---|---|---|---|---|
| A - At E150°C | % v/v | 75.0 | | ISO 3405<br>ASTM D86 |
| Point d'ébullition final<br>Final boiling point | °C | | 210 | ISO 3405<br>ASTM D86 |
| Résidu - Residue | % v/v | | 2.0 | ISO 3405<br>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 :

| Propriété - Property | Unités - Units | Min. | Max. | Méthodes de test - Test methods |
|---|---|---|---|---|
| Densité - Density<br>(à - at 15°C) | $kg/m^3$ | 820.0 | 845.0 | ISO 12185<br>ASTM D4052 |
| Indice de cétane(2)<br>Cetane Number(2) | | | 60.0(1) | ISO 5165<br>ASTM D613 |
| Indice de cétane dérivé (DCN) (2)<br>Derived Cetane Number (DCN) (2) | | | 60.0(1) | EN 15195<br>ASTM D6890<br>EN16715 |
| Soufre - Sulphur | mg/kg | | 10 | ISO 20846<br>ASTM D5453 |
| Hydrocarbures aromatiques polycycliques<br>-<br>Polycyclic Aromatic Hydro-carbons | % m/m | | 8.0 | IP 548<br>ASTM D6591<br>(Carburants sans FAME – FAME-free fuels)<br>EN 12916<br>(Carburants contenant ou non des FAME – FAME-containing and FAME free fuels) |
| FAME | % v/v | | 7.0 | EN 14078<br>ASTM D7371 |
| Teneur en eau<br>Water content | mg/kg | | 200 | EN ISO 12937 |
| Contamination totale<br>Total Contamination | mg/kg | | 24 | EN12662 |
| Température limite de filtrabilité (TLF)<br>Cold filter plugging point (CFPP) | °C | | -5 | EN 116<br>ASTM D6371 |
| Point d'éclair<br>Flash point | °C | 55 | | EN ISO 3679<br>EN ISO 2719(4)<br>ASTM D93 |
| Pouvoir lubrifiant<br>Lubricity | µm | | 460 | ISO12156-1<br>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.


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| | |
|---|---|
| (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:

| Propriété - Property | Unités - Units | Min. | Max. | Méthodes de test - Test methods |
|---|---|---|---|---|
| Teneur en ester<br>Ester content | % m/m | 96.5 | | EN 14103 |
| Densité (à 15 °C)<br>Density (at 15°C) | kg/m³ | 860.0 | 900.0 | EN ISO 12185<br>ASTM D4052 |
| Indice de cétane<br>Cetane number | | | 70.0 | EN ISO 5165<br>ASTM D613 |
| Indice de cétane dérivé<br>Derived cetane number (DCN) | | | 70.0 | EN 15195<br>ASTM D6890<br>EN16715 |
| Soufre<br>Sulphur | mg/kg | | 10(1) | EN ISO 20846<br>ASTM D5453 |
| Teneur en eau<br>Water content | mg/kg | | 500 | EN ISO 12937 |
| Contamination totale<br>Total contamination | mg/kg | | 24 | EN12662 : 2008 |
| Viscosité (à 40 °C)<br>Viscosity (at 40°C) | mm²/s | 1.90 | 6.00 | EN ISO 3104<br>ASTM D445 |
| Température limite de filtrabilité (TLF)<br>Cold filter plugging point (CFPP) | °C | | -5 | EN 116<br>ASTM D6371 |
| Point d'éclair<br>Flash point | °C | 93 | | EN ISO 3679<br>ASTM D93 |
| Stabilité à l'oxydation (à 110 °C)<br>Oxidation stability (at 110 °C | Heures | 6 | | EN 15751(2) / EN 14112 |
| Indice d'acide / Valeur<br>Acid Number/ Value | mg KOH/g | | 0.5 | ASTM D664<br>EN14104 |
| Ester méthylique d'acide linolénique<br>Linolenic Acid ME | % m/m | | 12 | EN 14103 |
| Méthanol<br>Methanol | % mm | | 0.20 | EN 14110 |
| Glycérol libre<br>Free Glycerol | % m/m | | 0.02 | EN 14105<br>ASTM D6584 |
| Métaux Groupe I (Na+K)<br>Group I Metals (Na+K) | mg/kg | | 5 | EN 14108 (Na)<br>EN 14109 (K) |
| Métaux Groupe II<br>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:

| Paramètre – Parameter | Formule – Formula | Méthodes de test - Test methods |
|---|---|---|
| Cétane et DCN (Max.)<br>Cetane and DCN (Max.) | 60.0 + (0.10 x B) | Comme ci-dessus (B.2.2)<br>As above (B.2.2) |
| Teneur en FAME (Min % v/v)<br>FAME Content (Min % v/v) | 0.95 x B(1) | EN 14078/ ASTM D7371 |


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| | | |
|---|---|---|
| Densité Min. (kg/m$^3$)<br>Density Min. (kg/m$^3$)<br><br>Densité Max. (kg/m$^3$)<br>Density Max. (kg/m$^3$) | 820.0 + (0.40 x B)<br><br>845.0 + (0.55 x B) | Comme ci-dessus (B.2.2)<br>As above (B.2.2) |
| Teneur en eau (Max. mg/kg)<br>Water Content (Max. mg/kg) | 200 + (3.0 x B)(1) | Comme ci-dessus (B.2.2)<br>As above (B.2.2) |
| Point d'éclair (Min. °C)<br>Flash Point (Min. °C) | 55(1) | Comme ci-dessus (B.2.2)<br>As above (B.2.2) |
| Stabilité à l'oxydation (Heures min.)<br>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:

| **Propriété - Property** | **Unités - Units** | **Min.** | **Max.** | **Méthodes de test - Test methods** |
|---|---|---|---|---|
| Densité (à 15 °C)<br>Density (at 15 °C) | kg/m$^3$ | 765.0 | 800.0 | EN ISO 12185<br>ASTM D4052 |
| Indice de cétane<br>Cetane number | | | 80.0(1) | EN ISO 5165<br>ASTM D613 |
| Indice de cétane dérivé<br>Derived Cetane Number (DCN) | | | 80.0(1) | EN 15195<br>ASTM D6890<br>EN16715 |
| Teneur en FAME<br>FAME content | % v/v | | 7.0 | EN 14078 |
| Soufre<br>Sulphur | mg/kg | | 5(2) | EN ISO 20846<br>ASTM D5453 |
| Teneur totale en aromatique<br>Total aromatic content | % m/m | | 1.1 | EN 12916 |
| Contamination totale<br>Total contamination | mg/kg | | 24 | EN12662 |
| Viscosité (à 40 °C)<br>Viscosity (at 40 °C) | mm$^2$/s | 2.00 | 4.50 | EN ISO 3104<br>ASTM D445 |
| Température limite de filtrabilité (TLF)<br>Cold filter plugging point (CFPP) | °C | | -5 | EN 116<br>ASTM D6371 |
| Point d'éclair<br>Flash point | °C | 55 | | EN ISO 3679<br>EN 2719(3)<br>ASTM D93 |
| Stabilité à l'oxydation<br>Oxidation stability | Heures<br>Hours | 20 | | EN 15751 |
| Pouvoir lubrifiant - 60 °C<br>Lubricity – 60 °C | µm | | 460 | EN ISO12156-1<br>ASTM D6079 |
| **Caractéristiques de distillation - Distillation characteristics** | | | | |
| Evaporé à 250 °C<br>Evaporated at 250 °C | % v/v | | 65 | EN ISO 3405 |
| Evaporé à 350 °C<br>Evaporated at 350 °C | %v/v | 85 | | EN ISO 3405 |
| 95 % v/v d'évaporation à<br>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:

| Paramètre – Parameter | Formule – Formula | Méthodes de test - Test methods |
|---|---|---|
| Cétane et DCN (Max.) - Gazole<br>Cetane and DCN (Max.) – Petroleum Diesel | 60 + (0.2 x P) | Comme ci-dessus (B.2.3)<br>As above (B.2.3) |
| Cétane et DCN (Max.) - Biodiesel<br>Cetane and DCN (Max.) – Biodiesel | 70 + (0.1 x P) | Comme ci-dessus (B.2.3)<br>As above (B.2.3) |
| Teneur totale en aromatiques (Max. % m/m)<br>Total Aromatic Content (Max. % m/m) | 8.0 – (0.069 x P) | Comme ci-dessus (B.2.3)<br>As above (B.2.3) |
| Densité Min. (kg/m³)<br>Density Min. (kg/m³)<br><br>Densité Max. (kg/m³)<br>Density Max. (kg/m³) | 820.0 + (0.40 x B)<br><br>845.0 + (0.55 x B) | Comme ci-dessus (B.2.3)<br>As above (B.2.3) |
| Stabilité à l'oxydation - Mélanges biodiesel uniquement (Heures min.)<br>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:

| Paramètre – Parameter | Formule – Formula | Méthodes de test - Test methods |
|---|---|---|
| Cétane et DCN (Max.)<br>Cetane and DCN (Max.) | (60D+70B+80P)/100 | Comme ci-dessus (B.2.2)<br>As above (B.2.2) |
| Hydrocarbures aromatiques polycycliques (Max. % m/m)<br>Polycyclic Aromatic Hydrocarbons (Max. % m/m) | (8.0D+0.0B+1.1P)/100 | EN 12916 |
| Teneur en FAME (Min % v/v)<br>FAME Content (Min % v/v) | 0.95 x B | EN 14078<br>ASTM D7371 |
| Teneur en eau (Max. mg/kg)<br>Water Content (Max. mg/kg) | (200D+500B+200P)/100 | Comme ci-dessus (B.2.2)<br>As above (B.2.2) |
| Point d'éclair (Min. °C)<br>Flash Point (Min. °C) | 55 | Comme ci-dessus (B.2.2)<br>As above (B.2.2) |
| Stabilité à l'oxydation (Heures min.)<br>Oxidation stability (Min. hours) | 6 | EN 15751 |

In the case of a ternary blend, any density between 765.0 kg/m³ and 900.0 kg/m³ 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 recognised 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).


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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:

| Propriété - Property | Unités - Units | Min. | Max. | Méthodes de test - Test methods |
|---|---|---|---|---|
| Oxygène<br>Oxygen | % m/m | | 7.5 | EN ISO 22854<br>EN 13132(2)<br>Analyse élémentaire – Elemental Analysis<br>ASTM D5622 |
| Oléfines<br>Olefins | % v/v | | Rapport<br>Report | ISO 22854<br>ASTM D6839 |
| Aromatiques<br>Aromatics | % v/v | | 40.0 | ISO 22854/ ASTM D6839 |
| Méthanol (1)<br>Methanol (1) | % v/v | | 3.0 | EN 1601<br>EN 13132<br>EN ISO 22854 |
| **Caractéristiques de distillation - Distillation characteristics** | | | | |
| A E120 °C | % v/v | 73.0 | | ISO 3405<br>ASTM D86 |
| A E135 °C | % v/v | 77.0 | | ISO 3405<br>ASTM D86 |


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| | | | | |
|---|---|---|---|---|
| A E150 °C | %v/v | 83.0 | | ISO 3405<br>ASTM D86 |
| Point d'ébullition final<br>Final Boiling Point | °C | | 210 | ISO 3405<br>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:

| Propriété - Property | Unités - Units | Min. | Max. | Méthodes de test - Test methods |
|---|---|---|---|---|
| Ethanol + Teneur plus élevée en mono-alcools saturés ($C_3$-$C_5$)<br><br>Ethanol + Higher saturated ($C_3$-$C_5$) mono-alcohols content | %v/v | 50 | 85 | ASTM D5599/ EN1601 |
| Teneur plus élevée en mono-alcools saturés ($C_3$-$C_5$)<br><br>Higher saturated ($C_3$-$C_5$) mono-alcohols content | %v/v | | 6.0 | ASTM D5599/ EN1601 |
| Méthanol - Methanol | %v/v | | 1.0 | ASTM D5599/ EN1601 |
| Teneur en éthers (5 atomes de carbone ou plus)<br><br>Ethers (5 or more C atoms) content | %v/v de la teneur en non-alcool<br><br>%v/v of the non-alcohol content | | 22.0 | ASTM D5599/ EN1601 |
| RON | | | Report | ISO 5164(1)<br>ASTM D2699(1) |
| MON | | Report | | ISO 5163(1)<br>ASTM D2700(1) |
| Densité (à 15°C)<br>Density (at 15°C) | kg/m³ | 725.0 | 794.0 | EN ISO 12185/ ASTM D4052 |
| DVPE | kPa | 35 | 80(2) | EN 13016-1/ ASTM D5191 |
| Point d'ébullition final<br>Final Boiling Point | °C | | 210 | ISO 3405/ ASTM D86 |
| Teneur en cuivre<br>Copper content | mg/kg | | 0.10 | EN 15837 |
| Teneur en phosphore<br>Phosphorus content | mg/l | | 0.15 | EN 15487/ EN 15837/ ASTM D3231 |
| Soufre - Sulphur | mg/kg | | 10.0 | ASTM D5453/ ASTM D7039<br>EN 16997(3)<br>EN 15485/ EN 15486/ EN 15837 |
| Teneur en sulfates<br>Sulphate Content | mg/kg | | 4.0 | EN 15492 |
| Stabilité à l'oxydation<br>Oxidation Stability | (min.) | 360 | | ISO 7536/ ASTM D525 |
| Gomme existante (lavée au solvant)<br>Existent Gum (solvent washed) | mg/100ml | | 5 | ASTM D381/ EN ISO 6246 |
| Acidité totale (en acide acétique) | %m/m | | 0.005 | EN 15491/ ASTM D7795 |


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| | | | | |
|---|---|---|---|---|
| Total acidity (as acetic acid) | | | | |
| Chlorure inorganique<br>Inorganic Chloride | mg/kg | | 1.2 | ASTM D7319/ ASTM D7328<br>EN 15492 |
| Eau<br>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

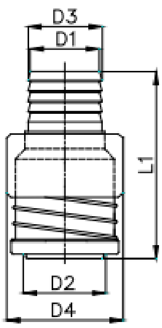
Only air may be mixed with the fuel as an oxidant.

## 6. Refuelling procedure

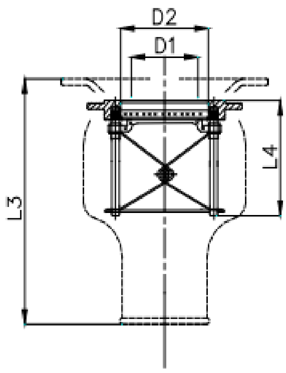
Standardized coupling:

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

**266-1 (Version A)**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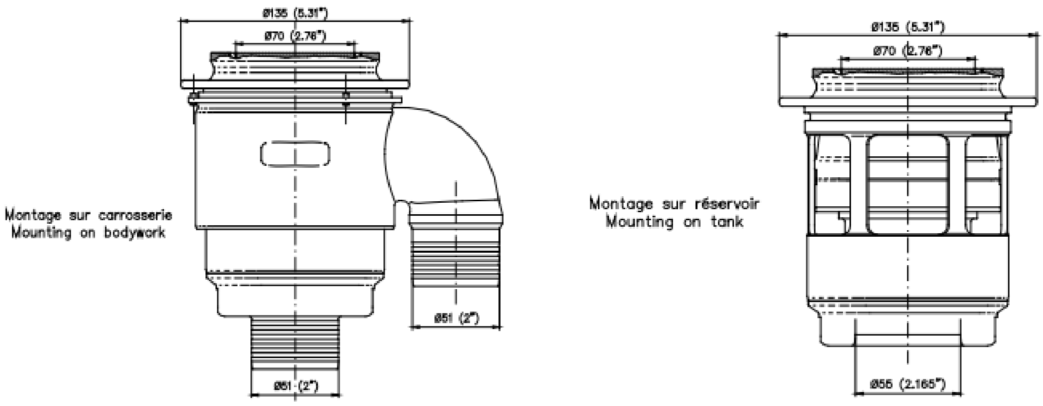
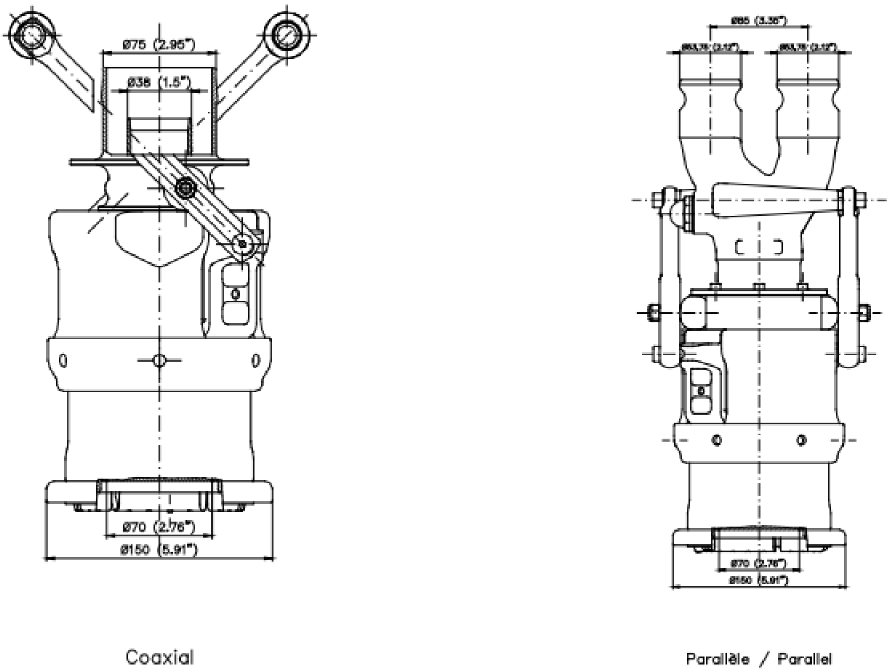



Female Coupling

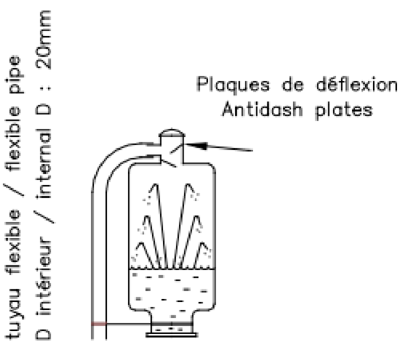



Male Coupling

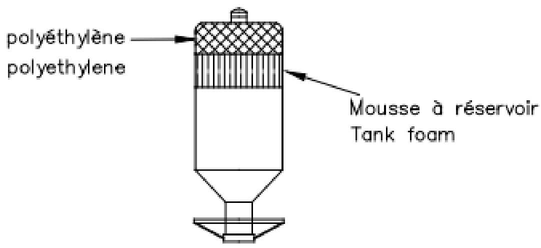
**266-1 (Version B)**

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.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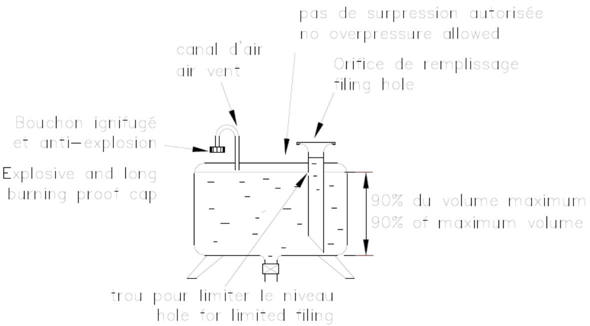
The application of the following is recommended:

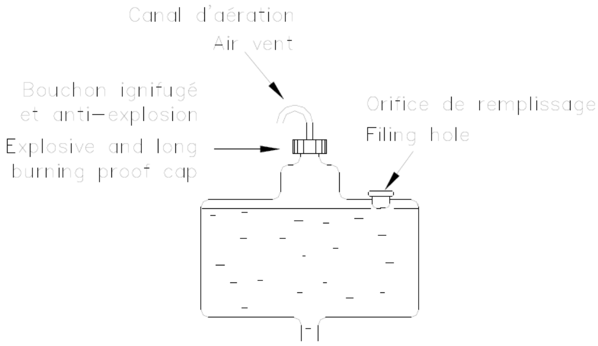
- Each pit must be equipped with two aircraft type grounding connections.
- The refuelling system (including tower, tank, hose, nozzle, valves and vent bottle) must be connected to one of the above grounding connections for the entire duration of the competition.
- The car must be connected, at least 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 Figure 1) 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.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**Dessin 1 / Figure 1**
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


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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 Figure 2).

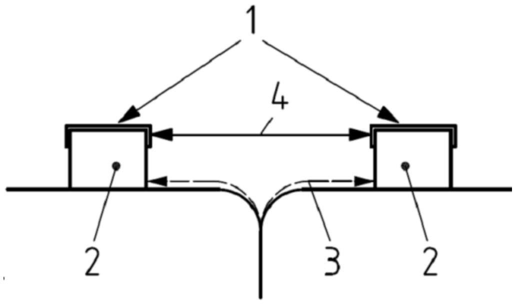
This sub-clause does not apply to maximum working voltages (Appendix J – Article 251.3.1.9) of the Power Circuit (Appendix J – Article 251.3.1.14) lower than 60 V DC.

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 Figure 2):

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 millimetres (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.




**Dessin 2 / Figure 2**

**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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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 Figure 3) 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:

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


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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 Figure 3, Figure 4 and Figure 5, optionally: $C_B = C_{B1} + C_{B2}$, see Figure 6) 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:

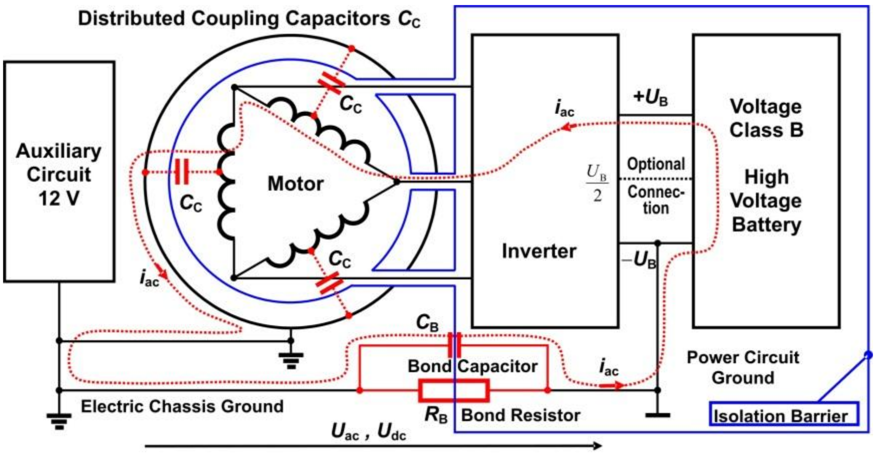
$$C_{B\,\min} = C_C\left(\frac{U_{INV}}{U_{ac\,\max}} - 1\right) = 3\ \text{nF}\left(\frac{500\ \text{V}}{30\ \text{V}} - 1\right) = 47\ \text{nF}$$

d. The bond resistor RB (see Figure 3, Figure 4 and Figure 5, optionally:

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

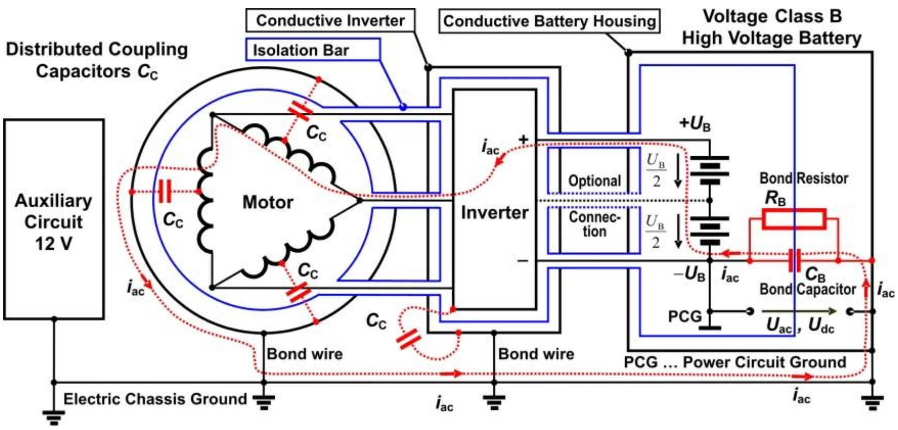
see Figure 6) limits the DC voltage $U_{dc}$ across the isolation barrier between the Power Circuit and Chassis Ground. The value of the bond resistor should be at least 500 Ω/V referred to the maximum working voltage $+U_B$ of the voltage class B system (charging). The measurement procedure to check 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, Annex 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.




**Dessin 3 / Figure 3**

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.




**Dessin 4 / Figure 4**

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 $-U_B$.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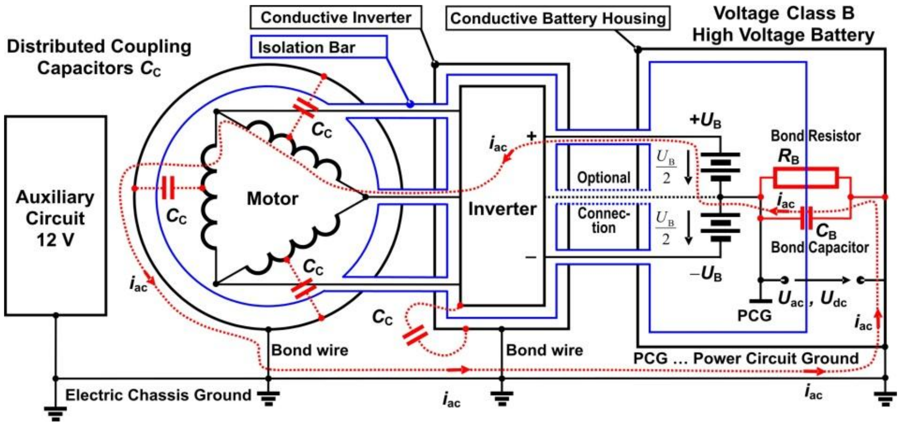
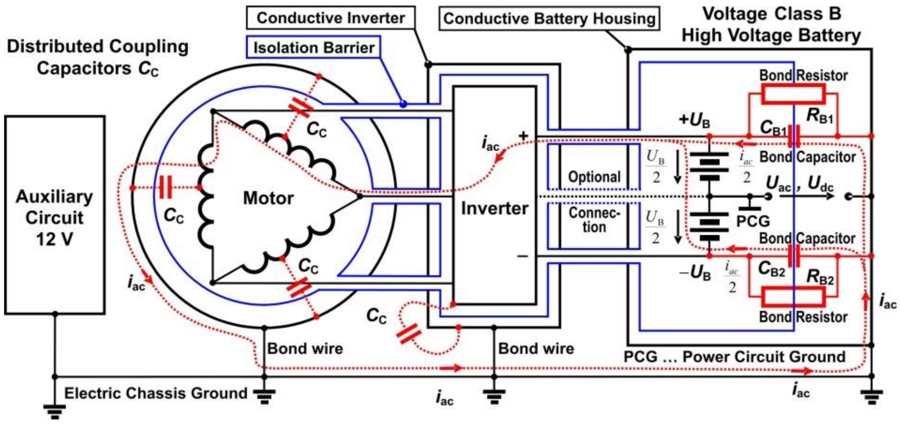



**Dessin 5 / Figure 5**

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 $+U_B$.




**Dessin 6 / Figure 6**

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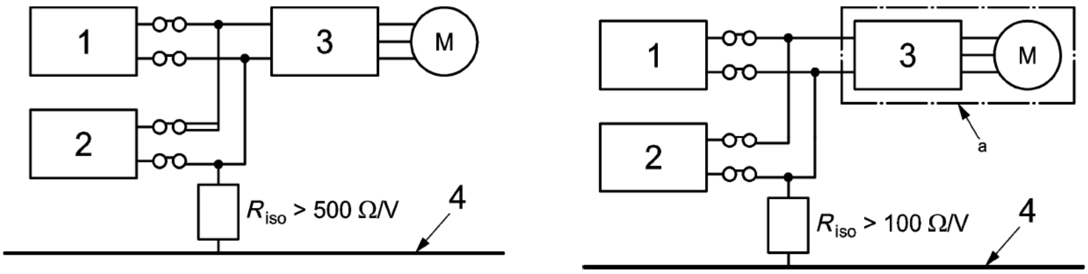
c. Any components that require equipotential bonding will be connected to the Main Ground Point (Appendix J – Article 251.3.1.15.1) with a resistance to prevent a dangerous touch voltage (30 V AC) given an AC coupling fault at a certain level of parasitic capacitance.

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).

NOTE :
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.




**Dessin 7 / Figure 7**

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 Figure 7) 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;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- 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 (Annexe 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.


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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 (Annexe 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 |


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| | | |
|---|---|---|
| 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.


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| | | | 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


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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 HYDROGEN VEHICLES

## 1. General safety

Unless otherwise mentioned in the present regulations or requested by the FIA, the compressed hydrogen storage system and specific components must be certified according to UNECE regulation R134 Part I and II respectively.
Fuel system components must comply with the requirements of the international standard ISO 12619 series.
A hazard analysis in relation to hydrogen must be submitted to the FIA. This analysis may use an FMEA (Failure Mode and Effect Analysis), FMECA (Failure Mode and Effect Critical Analysis), FTA (Fault Tree Analysis), or another appropriate method, and shall determine potential single hardware and software failures or conditions which could form a hazard for persons in or around the vicinity of the vehicle.
The requirements given in the present regulations shall be met across the range of environmental and operational conditions for which the vehicle is designed to operate, as specified by the vehicle
manufacturer.
The components of the hydrogen fuel system shall be located, installed, and protected in such a way that no damage can be caused by vehicle vibrations under normal operational conditions as specified by the vehicle manufacturer-The FIA reserves the right to add further requirements as deemed necessary.

## 2. Eligible vehicles

The present regulation is applicable to hydrogen-fuelled vehicles equipped with fuel cell(s) or internal combustion engine(s).

## 3. Compressed hydrogen storage system

The compressed hydrogen storage system must be certified according to UNECE regulation R134 Part I. Additional requirements in the present document apply in relation with the special conditions of use.

### 3.1. Maximum Nominal Working Pressure (NWP)

The nominal working pressure (NWP) must not exceed 70 MPa.

### 3.2. Quantity of Compressed Gaseous Hydrogen (CGH2)

The mass of compressed hydrogen per pressure container must not exceed 8 kg.

### 3.3. Determination of operating temperature range

The expected operating temperature in relation to the conditions of use and the refuelling protocol must be determined. The maximum operating temperature must not exceed +85°C. If the determined lowest temperature is below -40°C, the following tests to the UNECE regulation R134 must be repeated considering the expected temperature extreme that may be reached:

| | |
|---|---|
| 5.2.6 | Extreme temperature pressure cycling |
| 5.3 | Verification test for expected on-road performance (sequential pneumatic tests) |
| 5.3.1 | Proof pressure test |
| 5.3.2 | Ambient and extreme temperature gas pressure cycling test (pneumatic) |
| 5.3.3 | Extreme temperature static gas pressure leak/permeation test (pneumatic) |
| 5.3.4 | Residual proof pressure test |
| 5.3.5 | Residual strength burst test (hydraulic) |
| 6.1 (c) | (Annex 4, paragraph 1.3) |
| 6.2 (c) | (Annex 4, paragraph 2.3) |

A report detailing the results must be submitted to the FIA for validation.

### 3.4. Design and Installation


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The vehicle manufacturer must prove, by whatever means, that the pressure container and the related high-pressure hydrogen components (NWP greater than 3.0 MPa) installed in the vehicle as per the installation requirements given in this regulation has been designed in such a way that, in normal conditions and when subjected to extreme conditions (i.e., crash or fire), the mechanical integrity of the pressure container and related equipment is guaranteed, neither the pressure container nor the fastening mechanism itself, nor any of the anchorage points or other components can come loose or get damaged.

Compressed hydrogen storage system(s) must be installed within a compartment (structure, as defined in Art. D.5).

## 4. Detection systems

Temperature sensor(s) must be installed in the pressure container to prevent the maximum temperature from being exceeded during refuelling operations and prevent the temperature from going below the minimum permissible temperature during use.

Additionally, pressure sensor(s) must be mounted in the pressure container(s), or directly downstream of the shut-off valve, to provide information on any abnormal pressure drops indicative of potential leak(s) from the pressure container(s) accessories (check valve, TPRD and other fittings), as well as for the implementation of the refuelling protocol with a communication system.

Hydrogen gas leakage detectors must be installed and detect any leak that could lead to the accumulation of a hazardous concentration of hydrogen as per the 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 % |

They must be tested in accordance with Regulation R134, Annex 5, paragraph 3, considering the warning and shut-down thresholds as defined above.

## 5. Compressed hydrogen storage system compartment(s)

Every compressed hydrogen storage system must be installed within a compartment. Several compressed hydrogen storage systems may share the same compartment.

The compartment structure must be an integral part of the survival cell or the roll cage/spaceframe depending on the vehicle category concerned. In the case of survival cell, the compartment and the survival cell must form a continuous structure generated in the same moulding process. A bolted access-hatch on the bottom face may be possible, upon request to the FIA with all the technical details.

The functions of the compartment(s) are multi-fold:

- to monitor and ventilate hydrogen leaks in a controlled way;
- to provide an extra level of protection to the compressed hydrogen storage system in case of external impact, especially to the valving systems, or fire;
- to provide a level of protection for driver and surrounding individuals in case of hydrogen explosion following a leak inside the compartment;
- to mitigate risks to the cockpit environment.

### 5.1. Fire resistance

All faces of the compartment(s) must be made of a fire-resistant material (according to the UL94 V0 standard).

### 5.2. Sealing

The compartment(s) must be sealed and surround the pressure container(s) except for ventilation openings.

The gas tightness should be checked by using a suitable method such as tracing gas methods described in EN 60068-2-17 (method Qm) or any other equivalent method. The leak flowrate should not be over 1 Pa.cm^3/s.

### 5.3. Ventilation

The compartment(s) must be equipped with ventilation system and openings connected to the exterior to prevent the build-up of an ignitable concentration of hydrogen in running conditions as well as when the car is stationary (in the garage, on track, etc.).

The ventilation shall be designed to ensure that the hydrogen concentration in the air within the compartment shall not be greater at any time than 1% by volume when considering any leak of the CHSS system with a constant volumetric flow rate of 118 NL/min.


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### 5.4. Gas explosion venting protective system

The compartment(s) may optionally be equipped with gas explosion venting protective system to evacuate the overpressure safely to the outside in case of ventilation failure or of high leak rate.

In this case, the compartment(s) must be designed to withstand the overpressure until the gas explosion venting protective system opens.

## 6. Equipment in potentially explosive atmospheres

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 so designed that the opening of equipment parts which might be sources of ignition is possible only 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.

Equipment designed and tested according to IEC 60079 series with EPL Gb for group IIC meet this requirement.

## 7. Fuel cell system

The fuel cell system shall be designed to minimize the risk associated with typical hazardous situations associated with the fuel cell technology (see e.g., Annex A of IEC 62282-2-100) and tested against these hazardous situations with adequate recognised testing protocols (IEC 62282-2-100 although not applicable to vehicle can be used as a reference or GB/T 23645-2009 Test method of fuel cell power system for passenger car).

The fuel cell system shall be designed to resist specific racing conditions (acceleration, vibration).

## 8. Requirements regarding the materials

Materials used in the construction of the compressed hydrogen storage system must comply with the requirements and associated tests as per the international standard ISO 19881.
The selection of a suitable material for any components that comes into contact with hydrogen in normal operation requires consideration of the following:

- Compatibility with hydrogen (i.e. embrittlement, etc.).
- Compatibility with the operating environment.
- Corrosion resistance.

Potential for exposure to extreme temperature, Standards such as ISO 11114-4, ISO/TR 15916 and EN 10229 contain useful specifications for the selection of materials in combination with the test methods defined in the ISO 12619 series.

## 9. Valves

The hydrogen fuel system must be equipped with the following valves, as outlined below in the present document.
Valves and system components must be mounted properly and in accordance with the requirements set out in the ISO 21266-1:2018 standard. They must be protected against possible damages resulting from the normal operation of the car, including usual maintenance/repairs during races, and crash situations. Technical failure, human error and external causes must be taken into consideration for the safe location of these components.

Vehicle manufacturers shall provide documentation of the mounting procedure of the valves and their fittings within the vehicle and define precise maintenance guidelines, to avoid any hydrogen leak during normal operations or in case of a crash.

### 9.1. Automatic shut-off valves

Automatic shut-off valve(s) must be certified according to UNECE regulation R134 Part II.
Automatic shut-off valve(s) must be fail-safe and prevent flow from the compressed hydrogen storage system to the fuel cell system or ICE and be mounted directly on or within the pressure container. All shut-off valves must close during any of the following events:

- Hydrogen leak detection by the measurement of a hydrogen concentration inside the cockpit environment greater than the set thresholds as defined in Art. D.4 of the present document.
- Hydrogen leak detection through an abnormal pressure drop.
- Disfunction of the fuel cell system or ICE resulting from hydrogen concentration around the exhaust line greater than the set thresholds as defined in Art. D.4 of the present document.
- Impact of the vehicle in any direction above the set acceleration threshold values (via on-board accelerometers).
- Activation of the emergency shut-off.

### 9.2. Check valves

Check valve(s) must be certified according to UNECE regulation R134 Part II.


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Check valve(s) must be located along the refuelling line and prevent back flow from the pressure container(s) to the filling orifice once the filling dispenser has been disconnected.

It is required to install a minimum of two check valves in series to increase the reliability, one in the compressed hydrogen storage system (attached to the pressure container(s)) and the other one at the fuelling receptacle(s) (as required in the R134). Both check valves must offer an effective barrier to the backflow to the filling line independently of the position of the automatic shut-off valve.

### 9.3. Excess flow valve

The high-pressure line must be equipped with an excess flow valve inside, and optionally outside, every pressure container or a functionally equivalent system to control the gas leakage in the event of an abnormal flow (see Appendix A – ISO 21266-1).

### 9.4. Manual cylinder valve(s)

Each compressed hydrogen storage system must be equipped with a manual valve rigidly attached to it or incorporated in the cylinder head. It shall be able to isolate the pressure container content from the automatic valve.

## 10. Hydrogen discharge systems

### 10.1. Thermally activated Pressure Relief Device (TPRD)

The compressed hydrogen storage system must be equipped with [1] TPRD per pressure container. TPRD(s) must be certified according to UNECE regulation R134 Part II.

TPRD(s) must be protected from dirt and water ingress and must be located as far away as possible from sources of ignition in the vehicle.

Any major leak resulting from the accidental opening of the TPRD must be detected by the pressure drop measured within the pressure container or in the high-pressure line.

The outlet of the vent line(s), for hydrogen gas discharge from TPRD(s) of the storage system shall be protected by a cap.
The vent exhaust of the TPRD(s) must be located/oriented so as to limit the consequences (thermal effect distance) in case of activation and allow for safe escape of the driver and safe intervention. The vent exhaust(s) design and orientation will be dependent upon the vehicle category concerned.

### 10.2. Pressure Relief Valve (PRV)Remotely activated discharge system

To be completed in the next revision of the present draft regulations.

### 10.3. Over-pressure protection for the medium and low-pressure systems

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

## 11. Liquid hydrogen storage systems

See Appendix 2.

## 12. Cryo-compressed hydrogen storage systems

To be completed in the next revision of the present draft regulations.

## 13. Specific provisions for refuelling

The refuelling connection devices must comply with the international standard ISO 17268.

### 13.1. Fuelling receptacle(s)

The fuelling receptacle(s) must not be mounted within the external energy-absorbing elements of the vehicle (e.g. bumper) and must not be installed in places where hydrogen gas could accumulate and where ventilation is not sufficient. The fuelling receptacle(s) must be protected from dust and water. It must be kept clean to protect the downstream components (i.e., leaking check valve) and free of water to avoid freezing when refiling at -40°C.

The filling line shall be equipped with a filter to prevent penetration of particles in the hydrogen storage system and protect downstream valves and pressure regulator.

The fuelling receptacle(s) shall be able to withstand a minimum of 1000 N of loading in any direction without its gas tightness being affected (e.g. in the case of a refuelling hose breakaway).

### 13.2. Fuelling protocol

The refueling station must be compliant with the requirements of ISO 19880-1 and local regulations. It must be approved by local authorities as applicable.
The station and vehicle must comply with the refueling protocol requirements a) or b) as detailed below:

**a) Standard protocol:**


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The station shall use the protocols with communication defined by SAE J2601 for light duty vehicles or SAE J2601-2 for heavy duty vehicles. It must be noted that the exact requirements within SAEJ2601 are linked to a maximum total volumetric capacity of the compressed hydrogen storage system.
The vehicle must be equipped with a data transmission interface according to SAE J2799 to communicate with the fuelling station. The temperature and pressure inside the pressure container(s) must be communicated during refuelling to the fuelling station, as well as any car malfunction.

**b) Bespoke protocol, in which case:**

- Use a protocol with two-way communication specifically designed for a specific car.
- The protocol must be approved both by the car manufacturer and by a competent independent body approved by FIA.
- The fueling of a vehicle that has not been approved for this specific protocol must be made impossible by technical means (examples are provided by ISO 19880-1).
- The car manufacturer and refueling station manufacturer must demonstrate that the new protocol doesn't lead to any damage to the tank that could result to immediate or delayed hazardous situation. If the pressure ramp rate exceeds the pressure ramp rate that was applied in the gas pressure cycling test (R134 4.1) The gas pressure cycling test must be applied with the new pressure ramp rate. Same success criteria will be applied as the R134.
- The refueling station manufacturer must bring the demonstration that the station has been validated according to the requirements of ISO 19880-1.
- Both the car manufacturer and the station manufacturer must demonstrate that the communication interface and protocol has also been validated by an independent body.

In the event that the refuelling is interrupted by the station refuelling must not be possible until an appropriate checklist has been completed.
The car should be equipped with a system that prevents starting whilst the fuelling nozzle is connected to the car.

It is prohibited to have an ignition source within a predefined perimeter of the refuelling dispenser. The predefined perimeter must comply with applicable regulations and in relation to the prescriptions of the refuelling dispenser manufacturer.

Measures against electrostatic discharges of the vehicle at the receptacle should be taken. In particular:
Before refueling (or draining) begins, the car connector and the refueling (or draining) equipment must be connected electrically grounded.
All metallic parts of the refueling installation, from the coupling to the main supply tank and its rack must also be electrically grounded.

## 14. Qualification tests

The compressed gaseous hydrogen system and system components, both on their own and when installed in the vehicle must be subjected to specific test conditions, as specified in separate document CGH2 vehicles test requirements.

### 14.1. Vibration testing

Components of the hydrogen system must be subjected to a vibration test representative of typical vibration levels during race conditions. Unless otherwise specified in the safety test requirements for each vehicle category, the vibration test procedure must be applied according to the ISO 12619 series and ISO 19882, where applicable.

The resistance of TPRD(s) must be tested based on the specific vibrations that typically occur in race conditions and severe crash conditions (without fire).

### 14.2. Fire testing

Fire testing must be performed on the compressed hydrogen storage system according to Regulation R134, Annex 3 and the following clarifications: paragraph 5.1, Method 2 (worst-case localised fire exposure area to be approved by the FIA) and paragraph 5.2.

For both tests, the following results must be reported to the FIA:

- the elapsed time from ignition of the fire to the start of venting through the TPRD(s);
- the maximum pressure and time of evacuation until a pressure of less than 1 MPa is reached.

## 15. Operating procedures

Operating procedures for normal and emergency conditions must be established and reviewed as appropriate by the FIA.

## 16. Purging

Provisions within the vehicle and outside should be considered to purge safely any hydrogen contained in the low-pressure LP (below 0.45 MPa) and medium-pressure MP (up to 3.0 MPa) lines.

## 17. Safety indicators

Safety indicators warn if the vehicle is in a hazardous state and are required for all vehicle Classes. Data transmissions with visible and audible signals should have redundancy to prevent any single-point failure from the detection system.

These indicators must:

- Be visible to the driver while in the driver's designated seating position with the steering wheel fitted and seat belt fastened.
- Be visible to personnel surrounding/rescuing the vehicle from the outside.
- Use a high reliability device, for example LED, or similar, and be mounted in a way so as not to be confused with rain or brake lights. They must be suitable for the expected lighting conditions; for example, they must be visible under both daylight and night-time driving conditions.


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- Trigger when concentration levels defined in Art. D.4 are reached or detection system malfunction exists and the ignition locking system is in the "On" ("Run") position or the propulsion system is activated. They must remain powered for at least 15 minutes after the actuation of the general circuit breaker.

Any major leak resulting from the accidental opening of the TPRD must be detected by the pressure drop measured within the pressure container or on the high-pressure line, a warning must be sent to the driver.
When exceeding the expected temperature range (Art. D.3.3), a warning must be sent to the driver.
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.

## 18. Labelling

To be completed in the next revision of the present draft regulation.

## ANNEXE 1 / APPENDIX 1

Specific test requirements for ele

## ANNEXE 2 / APPENDIX 2

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