FEDERATION INTERNATIONALE DE L'AUTOMOBILE

FIA FORMULA E CHAMPIONSHIP
SUPPLY OF CARS

The Fédération Internationale de l'Automobile (FIA) is the governing body for world motor sport and the federation of the world's leading motoring organisations. It is a non-profit making association and brings together 233 national motoring and sporting organisations from 134 countries on five continents. Its member clubs represent millions of motorists and their families.

The Federation is currently working on the creation of a new high-profile championship, designed to be the flagship of the FIA's sustainable strategy: **the FIA Formula E Championship** ("Championship").

The FIA has set itself the target of launching this Championship in 2013 and is currently working on building its field of cars with the aim of guaranteeing a competition between drivers and manufacturers as from 2013 (first event to take place during the second semester).

As such, the federation is calling for expressions of interest to identify candidates interested in supplying cars in the 2013, 2014 and 2015 Championship under the key parameters defined in Appendix A and in accordance with the safety/technical requirements defined in Appendix B.

The process will consist of three stages:

Stage 1:

Interested candidates are invited to register a formal expression of interest with the FIA Secretariat **before 5 p.m. CET on Tuesday 17 January 2012.**

They may send their formal expression of interest to the FIA Secretariat **(legal@fia.com)**, together with their full contact details and a letter introducing their candidacy.

This letter of candidacy shall, as a minimum, include the information below:

1) The candidate's capabilities

- The candidate's technical backround;

- The candidate's experience in motor sport;
- The candidate's human and financial resources;
- The ability of the candidate to raise and maintain sufficient funding to supply the cars;
- The candidate's experience and vision with regard to new energies;
- The candidate's marketing positioning, promotional and commercial strategy and business. In this respect, the candidate is invited to propose a multi-year business plan that will describe how it intends to recoup the investment required for the design and the production of the cars;
- The main suppliers of components and possible technical partnerships.

2) Commercial offer and business plan

Taking into account that three hypotheses of volumes are defined (24, 12 or 8 cars), the following information shall be provided for those three hypotheses:

- Supply conditions: will the cars be sold or leased to the teams?
- The pricing conditions under which the cars will be provided to the teams (to be presented in a table (year 1, year 2, year 3);
- The details of the technical support that will be provided to the teams and to what extent it is included in the price offer.

In addition, the following three-year costs shall be presented separately:

- R&D;
- Costs relating to the manufacture of the cars;
- Costs relating to the maintenance/exploitation of the cars as well as an evaluation of the budget per season for a two-car team.

This business plan must be based on a three-year involvement in the Championship.

3) Planning

The candidate shall provide:

- A detailed time frame of the development phases for the prototype and for the subsequent cars;
- The date on which it will be in a position to present the prototype to the FIA, taking into account that the deadline has been set for 1 October 2012.

4) Technical specifications

The candidates shall provide the technical specifications of the proposed car including, inter alia, details of:

- Its design and technological description;
- Its performance;

- Its safety-related aspects;
- Its maintenance procedures;
- Its specific sound signature (spectrum, noise level…) and suggestions to enhance this signature (using mechanical vibrations and aerodynamic sound);
- A description of the proposed chargers;
- A description of the infrastructures needed for the exploitation of the cars.

The sound signature and design of the cars will be regarded as crucial elements of the candidate's proposal. Those elements will be assessed by the FIA with particular attention.

5) Optional requirements

The candidate is invited to provide information as regards its ability to encourage the participation of teams in the Championship.

The candidate may also indicate whether it is capable of supplying other cars (GT, Touring cars…) that may take part in support races to the FIA Formula E Championship.

Stage 2:

The FIA will contact those candidates that have sent a formal expression of interest within the deadline stated in Stage 1.

A discussion phase will then begin with the candidates whose expression of interest meets the requirements stated in this document.

The discussion phase will last **until the end of February 2012.**

Stage 3:

According to the results of the various exchanges and discussions, the FIA shall identify the candidates which, in the FIA's sole opinion, best serve the interests of the Championship and the interests of motor sport in general.

The car suppliers identified as capable of supplying cars in the Championship will be notified on 15 March 2012.

The FIA will not be required to give reasons for the acceptance or rejection of any particular proposal.

Miscellaneous

The FIA reserves the right, at its sole discretion:

- to interrupt or make changes to this procedure at any time;
- to allow other car suppliers than those identified within the framework of the present procedure to supply cars in the Championship.

Nothing in this procedure, or in any communication made by the FIA or its representatives or employees, shall constitute a contract between the FIA and any prospective candidate. The FIA shall be under no obligation to accept any expression of interest / proposal submitted.

Furthermore, if, at the sole discretion of the FIA, the FIA considers that no candidate satisfies the FIA's criteria to supply cars in the Championship, the FIA may, *inter alia*, elect not to select any candidate.

APPENDIX A

FIA FORMULA E CHAMPIONSHIP

KEY PARAMETERS

OBJECTIVES

In line with its positioning, the main objectives of the FIA Formula E Championship are defined as follows:

- To serve the FIA as a credible flagship for its CSR agenda in terms of more sustainable mobility;
- To provide a technological showcase for the main stakeholders involved, with a particular focus on established global car manufacturers, new entrants in the automotive market or significant regional players, and EV technology OEM companies;
- To attract wide public interest, including interest from non-traditional motor sport targets, and place a particular focus on young urban audiences;
- To be credible as a sporting and highly professional competition.

CARS - EVENTS

The Championship season should consist of about 8 events per season (as from 2014) and the field should comprise 24 cars. However, its definitive configuration will depend on the number of car suppliers that will be participating in the Championship.

Should more than one car supplier participate, the FIA will proceed to a balance of performance between the cars.

The physical parameters of this balance of performance will be discussed between the FIA and the car suppliers, as soon as the participating car suppliers have been identified.

Each race will consist of about 4 heats per car of 15 minutes each and charging of the cars will be authorised between those heats. Ideally the charging time should not exceed half an hour.

FORMAT

The ambition of the Championship will be to open up a new area of motor sport, so the initial view is that it will not necessarily look like "traditional" motor sport.
The core elements of such an approach will, most notably, involve the following:

- *Use of city centres as potential venues for events*

The events should be held in an urban environment, possibly using the centre of major cities to build provisional, purpose-designed race tracks (avoiding long straights).

In terms of its geographical spread, the target is to give the FIA Formula E Championship a global reach as soon as possible.

- *Educational activities*

With a view to delivering "intelligent entertainment", a strong educational dimension shall be attached to the Championship

- *Support races and other categories*

In between the competitive sections of the FIA Formula E Championship, support races might be held or demonstrations of various natures might take place.

APPENDIX B

Technical Requirements

1) Definitions

1.1) Formula E Car
An automobile designed solely for speed races on circuits or closed courses and which is propelled only by an electric motor.

1.2) Automobile
A land vehicle running on at least four non-aligned complete wheels, of which at least two are used for steering and at least two for propulsion.

1.3) Land Vehicle
A locomotive device propelled by its own means, moving by constantly taking real support on the earth's surface, of which the propulsion and steering are under the control of a driver aboard the vehicle.

1.4) Electric Road Vehicle
Definition according to Electric safety requirements – Article 2.1.

1.5) Bodywork
- The bodywork concerns all entirely sprung parts of the car in contact with the external air stream apart from parts in relation to the mechanical functioning of the electric motors of the drive train, the battery and the running gear.
- Any system controlled by the driver to modify the airflow of all aerodynamic devices when the car is in motion is allowed according to the definition laid down in the present requirements.

1.6) Wheel
Flange and rim.

1.7) Complete Wheel
Wheel and inflated tyre. The complete wheel is considered part of the suspension system.

1.8) Automobile Make
In the case of Formula E racing cars, an automobile make corresponds to a complete car. The Championship Title will be awarded to the manufacturer of the car.

1.9) Event
Any event registered on the FIA Formula E Championship calendar for any year commencing at the scheduled time for scrutineering and sporting checks. Includes all practice and the race itself and ends either at the time for the lodging of a protest under the terms of the Sporting Code or the time when a technical or sporting check has been carried out under the terms of that Code, whichever is the later.

1.10) Weight
Is the total weight of the car including the battery cells and the driver wearing his complete racing apparel, at all times during the event.

1.11) Electric Motor

The electric motor is a rotating machine which transforms electrical energy into mechanical energy.

1.12) Electric Generator

The electric generator is a rotating machine which transforms mechanical energy into electrical energy.

1.13) Rechargeable Energy Storage System (RESS)

General definition according to Electric safety requirements – Article 2.6.

The RESS can only store electrical energy.

A Rechargeable Energy Storage System (RESS), such as a battery, super capacitors, ultra-capacitor, batteries, etc., is a system that is designed to propel the car via the electric motor, recover electric energy from the grid, inductive charging in the pits and from the generator during deceleration or braking. During the race, the RESS cannot be recharged from any fuel-based energy converter inside the car.

The RESS comprises all components needed for the normal operation of the RESS. After finishing the installation laps, the RESS can be fully charged at the starting grid via an external charging system approved by the FIA.

1.14) Traction battery

The traction battery is an RESS and supplies electric energy to the Power Circuit and thus to the traction motor(s) and possibly the auxiliary circuit. The traction battery is defined as any equipment used for the intermediate storage of electrical energy supplied by the conversion of kinetic energy or by a generator or the charging unit. Any on-board battery electrically connected to the Power Circuit is considered to be an integral part of the vehicle's traction battery.

1.15) Capacitors

Definition according to Electric safety requirements – Article 2.6.2

1.16) Battery pack

Definition according to Electric safety requirements – Article 2.6.3.1

1.17) Battery module

Definition according to Electric safety requirements – Article 2.6.3.2

1.18) Battery cell

Definition according to Electric safety requirements – Article 2.6.3.3

1.19) Battery Management System (BMS)

Definition according to Electric safety requirements – Article 2.6.3.5

1.20) Electric Shock

Definition according to Electric safety requirements – Article 2.7

1.21) Maximum working voltage
Definition according to Electric safety requirements – Article 2.8

1.22) Voltage class B
Definition according to Electric safety requirements – Article 2.9

1.23) Conditions for the measurement of the maximum voltage
The maximum voltage will be permanently monitored by the FIA via a Data Recording System (DRS).

1.24) Clearance
Definition according to Electric safety requirements – Article 2.11

1.25) Creepage distance
Definition according to Electric safety requirements – Article 2.12

1.26) Power Circuit
Definition according to Electric safety requirements – Article 2.13

1.27) Power Bus
Definition according to Electric safety requirements – Article 2.13.1

1.28) Insulation types of cables and wires
Definition according to Electric safety requirements – Article 2.13.1.1

1.29) Basic insulation
Definition according to Electric safety requirements – Article 2.13.1.2

1.30) Double insulation
Definition according to Electric safety requirements – Article 2.13.1.3

1.31) Supplementary insulation
Definition according to Electric safety requirements – Article 2.13.1.5

1.32) Reinforced insulation
Definition according to Electric safety requirements – Article 2.13.1.4

1.33) Overcurrent trip (fuses)
Definition according to Electric safety requirements – Article 2.13.2

1.34) General Circuit Breaker (emergency stop switch)
Definition according to Electric safety requirements – Article 2.13.3

1.35) Power Circuit Ground
Definition according to Electric safety requirements – Article 2.13.5

1.36) Electric Chassis Ground, Vehicle Ground and Earth Potential
Definition according to Electric safety requirements – Article 2.14

1.37) Main Ground Point
Definition according to Electric safety requirements – Article 2.14.1

1.38) Live Part
Definition according to Electric safety requirements – Article 2.15

1.39) Conductive part
Definition according to Electric safety requirements – Article 2.16

1.40) Exposed conductive part
Definition according to Electric safety requirements – Article 2.17

1.41) Auxiliary Battery and Circuit
Definition according to Electric safety requirements – Article 2.18.1
The Auxiliary Circuit (Network) consists of all parts of the electrical equipment used for signalling, lighting, the DRS, ECU, sensors, fire extinguishing system or communication. This system can also be charged by the traction battery.

1.42) Auxiliary Ground
Definition according to Electric safety requirements – Article 2.18.2

1.43) Driver Master Switch
Definition according to Electric safety requirements – Article 2.19

1.44) Safety indications
Definition according to Electric safety requirements – Article 2.20

1.45) Cockpit
The internal volume which accommodates the driver.
The cockpit is the internal volume inside the main structure which is defined by the top of the car, the floor, windscreen and cockpit cover, the side panels, the glazed areas and the front and rear bulkheads.

1.46) Cockpit padding
Non-structural parts placed within the cockpit for the sole purpose of improving driver comfort and safety. All such material must be quickly removable without the use of tools.

1.47) Main structure
The fully sprung structure of the vehicle to which the suspension and/or spring loads are transmitted, extending longitudinally from the foremost point of the front suspension on the chassis to the rearmost point of the rear suspension.

1.48) Sprung Suspension
The means whereby all complete wheels are suspended from the body/chassis unit by a spring medium.

1.49) Active suspension
Any system which allows control of any part of the suspension or of the trim height when the car is moving.

1.50) Safety Cell
A closed structure containing the cockpit and the electric storage compartment.

1.51) Composite structure
Non-homogeneous materials which have a cross-section comprising either two skins bonded to each side of a core material or an assembly of plies which form one laminate.

1.52) Telemetry
The transmission of data between a moving car and the pit.

1.53) Camera
Television cameras.

1.54) Camera housing
A device which is identical in shape and weight to a camera and which is supplied by the relevant competitor for fitting to his car in lieu of a camera.

1.55) Brake Calliper
All parts of the braking system outside the safety cell, other than brake discs, brake pads, calliper pistons, brake hoses and fittings, which are stressed when subjected to the braking pressure. Bolts or studs which are used for attachment are not considered to be part of the braking system.

1.56) Electronically controlled
Any command system or process that utilises semi-conductor or thermionic technology.

1.57) Open and closed sections
A section will be considered closed if it is fully complete within the dimensioned boundary to which it is referenced; if it is not, it will be considered open.

2) General Principles / Requirements

2.1) Role of the FIA
The following technical requirements for Formula E cars are issued by the FIA.

2.2) Amendments to the requirements
Changes to these requirements may only be made in accordance with the provisions of the FIA. Each year in December at the latest, the FIA will publish all changes made to these requirements. All such changes will take effect on the 1st of January following their publication. Changes made for safety reasons may come into force without notice.

2.3) Validity
These Technical Requirements will be valid for a minimum of one year beginning on the first of January 2013.

2.4) Doubt over the meaning of the requirements
In event of doubt concerning any element of these Technical Requirements, competitors are entitled to seek written clarification from the FIA. All such questions and their responses will be circulated to all the competitors. All such responses will be considered as the official understanding of the relevant regulation and therefore used by the FIA technical delegate as a complement to the regulation itself.

2.5) Dangerous construction
The stewards of the meeting may exclude a vehicle the construction of which is deemed to be dangerous.

2.6) Material
The use of a metallic material which has a specific yield modulus greater than 40 GPa/g/cm3 is forbidden. The use of magnesium sheet less than 3 mm thick is forbidden. The use of parts made from titanium is authorised, but welding is forbidden for parts of the suspension, steering or braking systems.

2.7) Compliance with the requirements
Automobiles must comply with these requirements in their entirety at all times during an event. Should a competitor introduce a new design or system or feel that any aspect of these requirements is unclear, clarification may be sought from the FIA Electric and New Energy Championships Commission or from the FIA Technical Department. If clarification relates to any new design or system, correspondence must include:
- a full description of the design or system;
- drawings or schematics where appropriate;
- the competitor's opinion concerning the immediate implications on other parts of the car of any proposed new design;
- the competitor's opinion concerning any possible long term consequences or new developments which may come from using any such new designs or systems;
- the precise way or ways in which the competitor feels the new design or system will enhance the performance of the car.

2.8) New systems or technologies
Any new system, procedure or technology not specifically covered by these requirements, but which is deemed permissible by the FIA Technical Department and/or FIA Electric and New Energy Championships Commission, will only be admitted until the end of the Championship during which it is introduced. Following this the Championship Commission will be asked to review the technology concerned and, if they feel it adds no value to Formula E in general, it will be specifically prohibited.

2.9) Measurements
All measurements must be made while the car is stationary on a flat horizontal surface.

2.10) Duty of competitor
It is the duty of each competitor to satisfy the FIA technical delegate and the stewards of the meeting that his automobile complies with these requirements in their entirety at all times during an Event. The design of the car, its components and systems shall, with the exception of safety features, demonstrate their compliance with these requirements by means of physical inspection of hardware or materials. No mechanical design may rely upon software inspection as a means of ensuring its compliance.

3) Homologation Procedure

3.1) Homologation Form
To be defined by the FIA

3.2) Technical Passport
To be defined by the FIA

4) Bodywork Dimensions

4.1) Wheel centre line
The centre line of any wheel shall be deemed to be half way between two straight edges, perpendicular to the surface on which the car is standing, placed against opposite sides of the complete wheel at the centre of the tyre tread.

4.2) Overall dimensions of the car
- The overall width of the car, including complete wheels, must not exceed 1800 mm with the steered wheels in the straight ahead position.
- No part of the bodywork may be more than 1050 mm above the reference plane.

All height measurements will be taken normal to and from the reference plane.
- The maximum total length of the car must not be more than 5200 mm.

4.3) Bodywork facing the ground
With the skid block referred to in Article 4.5 removed, all sprung parts of the car situated from behind the front wheel centre line to the rear wheel centre line, and which are visible from underneath, must form surfaces which lie on one of two parallel planes, the reference plane or the step plane.

A reference surface underneath the car is mandatory. It must:
- be flat, continuous and rigid;
- cover the area which is bounded by two transversal lines, one on the front wheel centre line and the other on the rear wheel centre line, and two longitudinal lines symmetrically to either side of the car centre line;
- have a maximum width of 500 mm;
- have a 50 mm radius (+/-2 mm) on each front corner.

The step plane must be 50 mm above the reference surface.

4.4) Ground clearance

- Any system, other than the suspension, which is designed for modification of the ground clearance is not-permitted;
- No sprung part of the car is allowed lower than the plane generated by the reference surface, except the mandatory skid block described below;
- Friction blocks are not permitted.

4.5) Skid block

One rectangular block (skid block) with a width of 300 mm and a 50 mm radius (+/-2 mm) on each front corner must be affixed underneath the reference surface.

The skid block must:

- Extend longitudinally from 400 mm behind the front axle centre line to 300 mm in front of the rear axle centre line (Drawing 1);
- Have a minimum uniform thickness of 10 mm with a tolerance of +/- 1 mm.
- For the 300 mm at the end, the thickness may taper down to 2 mm.
- Will be made from a homogeneous material with a specific gravity between 1.3 and 1.45.
- After the race, the skid block must have a minimum height of 8 mm on any position.
- In order to establish the conformity of the skid block after use, its thickness will be measured in the holes which must be defined by the FIA.

4.6) Aerodynamic devices

The design of aerodynamic elements is free.
The aerodynamic behaviour of the vehicle can be altered by the driver but only in discrete pre-programmed steps. The number of pre-set steps is free. In case of any failure of these systems, all adjustments must switch automatically to the fail-safe mode which is maximum downforce.
All components creating aerodynamic downforce must be connected to the sprung chassis.
It is allowed to use mechanical energy for operating the aerodynamic devices but it is not permitted to create a vacuum underneath the car by using a fan driven by onboard energy.
The aerodynamic package will be homologated for 1 year.

5) Weight

5.1) Minimum weights

The weight of the car with the driver wearing his complete racing apparel and without the battery cells/capacitors must not be less than 540 kg at all times during the event. The maximum weight of the battery cells and/or capacitor of the RESS must not be higher than 300 kg. The weight of the cells/capacitors will be measured during the homologation. The total weight of the complete car including the driver must not be less than 780 kg.

5.2) Ballast

Ballast may be used, provided it is secured in such a way that tools are required for its removal. It must be possible to affix seals if deemed necessary by the scrutineers.

5.3) Adding during the race

The adding to the car during the race of any liquid or other material whatsoever, or the replacement during the race of any part with another that is materially heavier, is forbidden.

6) Electric Motors & Generator

6.1) Specification of electric motor

The type and number of electric motors is free.

6.2) Traction control

The use of traction control is permitted.

7) Rechargeable Energy Storage System (RESS)

7.1) Design and Installation

Definition according to Electric safety requirements – Article 3.4.1
The design of the RESS is free but it must be homologated by the FIA.
The RESS compartment must be designed in such a way as to prevent short circuits of the RESS poles and of the conductive parts, and any possibility of RESS fluid penetrating into the cockpit and outside of the energy storage compartment must be excluded.
Every module must be fixed to the safety cell with its own fixing devices. In case of any failure of one of the modules or cells, the RESS must be disconnected from the power circuit automatically and it must be ensured that a fire cannot spread from the ignited cell.

7.2) Clearance and creepage distance

Specifications are laid down in Electric safety requirements – Article 3.4.3

7.3) Traction Battery

The traction battery is included as part of the RESS system.

7.4) Specific provisions for batteries

All battery cells must be certified to UN transportation standards 3840 as a minimum requirement for fire and toxicity safety. The certification must be forwarded to the FIA 3 months prior to the first event.

7.5) Battery safety provisions

The battery pack housing must pass the crash test defined by the FIA.

7.6) Power out of RESS and maximum voltage

The maximum total power going out of the RESS is free.
This will be permanently monitored by the FIA.
The maximum voltage is limited to 1kV.
It is not allowed to change any component of the whole power train between qualifying and the race except for damaged parts (to be adapted according to the sporting requirements).

7.7) Declaration of cell chemistry and safety

Any type of cell chemistry is allowed provided the FIA deems the cell chemistry safe. Full details of the chemistry and safety handling must be given to the FIA 3 months in advance of the first event in which it is planned to use the equipment.

Any modification during the season must be sent to the FIA to obtain permission.

The competitor has to supply documents about the cell and pack (module) wherein the producer specifies relevant safety data as follows:

- Battery characteristic diagram showing the battery limits of voltage (U), power (W), temperature (T) and state of charge (SOC). Also, a safety certification must be given to the FIA 3 months in advance.
- The competitor must supply a contingency plan describing how to handle the battery pack in case of overheating (fire) and crash.

7.8) Battery Management System (BMS)

General specifications are laid down in Electric safety requirements – Article 3.4.5.2

Temperature control must be considered within the battery management system to prevent thermal runaway during overload or battery failure and must operate throughout the whole event, even when the car is parked in the parc fermé, as well as in the garage and during loading.

9) Electrical Equipment and Safety Provisions

9.1) General electrical safety

Specifications are laid down in Electric safety requirements – Article 3.1.

9.2) Control electronics

The ECU must be designed to run from a car system supply provided by an auxiliary battery.

9.3) Power electronics

Specifications are laid down in Appendix J-Article 253E – Article 3.5.

9.4) General Circuit Breaker

All vehicles must be equipped with a General Circuit Breaker, of a sufficient capacity and that can be operated easily by a trigger button from the driver's seat when the driver is seated in a normal and upright position, with the safety belts fastened and the steering wheel in place, and from the outside, to cut off all electric transmission devices. 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 or the external switch. The external button of the General Circuit Breaker must be located below the windscreen on the driver's side, i.e. on the left-hand side of the vehicle when facing in the direction of travel.

The button must be marked with a red spark in a white-edged blue triangle with a base of at least 12 cm.

In a minor crash, all energy sources of the Power Circuit must be switched off automatically by electric switches or contactors. In a severe crash, the full RESS must be switched off automatically and the energy supply cables must be disconnected automatically from the RESS. Those arrangements must be validated by the failure mode analysis submitted by the homologation. General specifications are laid down in Electric safety requirements – Article 2.13.3 and Article 3.18.

9.5) Driver Master Switch (DMS)

All vehicles must be equipped with a Driver Master Switch specified in Electric safety requirements – Article 3.16.

The RESS must fall automatically in case of an impact which causes a minimum shock of 20g.

9.6) Data acquisition

Data acquisition is free.

9.7) Telemetry

Telemetry systems must operate at frequencies which have been approved by the FIA.

Pit to car telemetry is prohibited.

9.8) Driver radio

Other than authorised connections to the FIA ECU, any voice radio communication system between car and pits must be stand-alone and must not transmit or receive other data.

9.9) Accident data recorder (ADR)

a) The recorder must be fitted and operated:

- in accordance with the instructions of the FIA;
- symmetrically about the car centre line and with its top facing upwards;
- with each of its 12 edges parallel to an axis of the car;
- less than 50 mm above the line d-e;
- in a position within the cockpit which is readily accessible at all times from inside the cockpit without the need to remove the skid block or floor;
- such that the entire unit lies between 30% and 50% of the wheelbase of the car;
- via anti-vibration mountings giving a clearance of 5 mm to all other objects;
- with its connectors facing forwards;
- such that its status light is visible when the driver is seated normally;
- such that the download connector is easily accessible when the driver is seated normally and without the need to remove bodywork.

b) The recorder must be connected to two external 500g accelerometers which are solidly bolted to the safety cell, on the car centre line, using four 4 mm bolts. One must be as close to the nominal car centre of gravity as practical and the other as far forward as possible inside the safety cell. The forward accelerometer may be mounted to the underside of the top surface provided it is solidly bolted to a structural part of the safety cell.

c) The recorder must be powered from a nominally 12V supply at all times when the car's electronic systems are powered.

d) An ADR and two accelerometers must be fitted to each car at all times during an event and at all tests attended by more than one team.

e) An ADR must be powered from an auxiliary battery which is also used by the ECU and fire extinguishing system.

9.10) Lighting equipment

All cars must have two red lights in working order throughout the event which:
- have been supplied by an FIA designated manufacturer published in FIA Technical List N° 19;
- face rearwards at 90° to the car centre line and the reference plane;
- are clearly visible from the rear;
- are mounted nominally 900 mm from the car centre line on each side;
- are mounted 300 mm (+/-5 mm) above the reference plane;
- can be switched on by the driver when seated normally in the car.

The two measurements above will be taken to the centre of the rear face of the light unit.

9.11) Cables, lines, electrical equipment

Brake lines, electrical cables and electrical equipment must be protected against any risk of damage (stones, corrosion, mechanical failure, etc.) when fitted outside the vehicle, and against any risk of fire and electrical shock when fitted inside the bodywork.

9.12) Protection against electrical shock

Protection must be guaranteed according to Electric safety requirements – Article 3.7

9.13) Equipotential bonding

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 equipotentially bonded to the car chassis with wires or conductive parts of an appropriate dimension. See Electric safety requirements – Article 3.8.

9.14) Isolation resistance requirements

All electrically live parts must be protected against accidental contact as laid down in Electric safety requirements – Article 3.9.

9.15) Additional protection measures for the AC circuit

Additional protection measures are laid down in Electric safety requirements – Article 3.9.1.

9.16) Isolation surveillance of chassis and Power Circuit

An isolation surveillance system should be used to monitor the status of the isolation barrier between the voltage class B system and the chassis. Configurations are laid down in Electric safety requirements – Article 3.10.

9.17) Power Circuit

Power circuit specifications are laid down in Electric safety requirements – Article 3.11.

9.18) Power Bus

Specifications are laid down in Electric safety requirements – Article 3.12.

9.19) Power Circuit wiring

The power circuit comprises the RESS, the converter (chopper) for the drive motor(s), the contactor(s) of the General Circuit Breaker, fuses, the generator(s) and the drive motor(s). All cable and wire specifications are laid down in Electric safety requirements – Article 3.13.

9.20) Power Circuit connectors, automatic disconnection

Power Circuit connectors may not have live contacts on either the plug or the receptacle unless they are correctly mated. Specifications are laid down in Electric safety requirements – Article 3.14.

9.21) Insulation strength of cables

All electrically live parts must be protected against accidental contact according to Electric safety requirements – Article 3.15.

9.22) Overcurrent trip (fuses)

Fuses and circuit breakers (but never the motor circuit breaker) count as overcurrent trips. Extra fast electronic circuit fuses and fast fuses are appropriate.
Overcurrent trips are specified in Electric safety requirements – Article 3.19.

9.23) Safety Indications

All cars must be fitted with an RESS status light which:
- Is in working order throughout the Event even if the main hydraulic, pneumatic or electrical systems on the car have failed.
- Faces upwards and is recessed into the top of the survival cell no more than 150 mm from the car centre line and the front of the cockpit opening.
- Is green only when the system is shut down and no electrical insulation fault has been detected.
- Remains powered for at least 15 minutes if the car comes to rest with its engine stopped.
- Is marked with a “HIGH VOLTAGE” symbol.

Specifications are laid down in Electric safety requirements – Article 3.22.

9.24) Charging units

Charging units must satisfy the requirements laid down in Electric safety requirements – Article 3.20.
The competitor must supply the relevant technical and safety documents about the charging unit to the FIA 3 months prior to the first event.

9.25) References

References are laid down in Electric safety requirements – Article 3.25.

10) Transmission Systems

10.1) Transmission Types

The transmission system is free for two (2) wheels or four (4) wheels to be driven.
It is prohibited to change any components of the transmission system between qualifying and the race (according to the sporting regulations).

10.2) Gear ratios

The number of reduction gear ratios is free.

10.3) Reverse drive

All cars must be able to be driven by the driver in reverse direction at any time during the event with the electric motor.

10.4) Differential

The torque management is free.

11) Suspension and Steering Systems

11.1) Active suspension

Active suspension is forbidden.

11.2) Sprung suspension

Cars must be fitted with sprung suspension.
The suspension system must be so arranged that its response results only from changes in load applied to the wheels.

11.3) Material of suspension device

All suspension components must be made from metallic materials with a specific density not exceeding 40 GPa/kg/dm³. This is also compulsory for all suspension uprights with the exception of rollers and balls in the wheel bearings.

11.4) Suspension geometry

With the steering wheel fixed, the position of each wheel centre and the orientation of its rotation axis must be completely and uniquely defined by a function of its principally vertical suspension travel, save only for the effects of reasonable compliance which does not intentionally provide further degrees of freedom.
- Any powered device which is capable of altering the configuration or affecting the performance of any part of the suspension system is forbidden.
- No adjustment may be made to the suspension system while the car is in motion.

11.5) Suspension members

a) With the exception of minimal local changes of section for the passage of hydraulic brake lines, electrical wiring and wheel tethers or the attachment of flexures, rod ends and spherical bearings, the cross sections of each member of every suspension component, when taken normal to a straight line between the inner and outer attachment points, must:
- intersect the straight line between the inner and outer attachment points;
- have a major axis no greater than 100 mm;
- have an aspect ratio no greater than 3.5:1;
- be nominally symmetrical about its major axis.

The major axis will be defined as the largest dimension of any such cross section.
b) When assessing compliance with Article 11.5.a, suspension members having shared attachment points will be considered by a virtual dissection into discrete members.
No major axis of a cross section of a suspension member, when assessed in accordance with Article 11.5.a above, may subtend an angle greater than 5° to the reference plane when projected onto, and normal to, a vertical plane on the car centre line with the car set to the nominal design ride height.

c) Non-structural parts of suspension members are considered as bodywork.
d) Redundant suspension members are not permitted.
e) In order to help prevent a wheel from becoming separated in the event of all suspension members connecting it to the car failing provision must be made to accommodate flexible tethers, each with a cross sectional area greater than 110 mm². The sole purpose of the tethers is to prevent a wheel from becoming separated from the car; they should perform no other function. The tethers and their attachments must also be designed in order to help prevent a wheel from making contact with the driver's head during an accident. Each wheel must be fitted with two tethers.
Each tether must have its own separate attachments at both ends which:
- are able to withstand a tensile force of 70 kN in any direction within a cone of 45° (included angle) measured from the load line of the relevant suspension member;
- on the safety cell are separated by at least 100 mm measured between the centres of the two attachment points;
- on each wheel/upright assembly are located on opposite sides of the vertical and horizontal wheel centre lines and are separated by at least 100 mm measured between the centres of the two attachment points;
- are able to accommodate tether end fittings with a minimum inside diameter of 15 mm.

Furthermore, no suspension member may contain more than one tether.
Each tether must exceed 450 mm in length and must utilise end fittings which result in a tether bend radius greater than 7.5 mm.

11.6) Steering

Any steering system which permits the re-alignment of more than two wheels is not permitted.
- No part of the steering wheel or column, nor any part fitted to them, may be closer to the driver than a plane formed by the entire rear edge of the steering wheel rim. All parts fixed to the steering wheel must be fitted in such a way as to minimise the risk of injury in the event of a driver's head making contact with any part of the wheel assembly.
- The steering wheel, steering column and steering rack assembly must pass an impact test.

11.7) Power steering

Power steering is permitted but such system may not carry out any function other than reducing the physical effort required to steer the car and must allow the steering to continue to function when all hydraulic and/or electric power is shut down.

12) Brake Systems

12.1) Brake circuits and pressure distribution

At least two separate hydraulic circuits operated by the same pedal are compulsory:
- The only connection allowed between the two circuits is a mechanical system for adjusting the brake force balance between the front and rear axles.

No device or system is permitted between the master cylinders and the callipers:
- Sensors to collect information, stop lights switches or mechanical brake pressure controls adjustable by means of tools are not considered as "systems" and they must be fitted at the very exit of the master cylinders.

12.2) Brake callipers

The section of each calliper piston must be circular.
The body of the callipers must be made from aluminium alloy with a modulus of elasticity no greater than 80Gpa.

12.3) Brake discs and pads

Material: free.
Discs: one per wheel maximum.
Any anti-lock braking function and any power braking function are prohibited.

12.4) Liquid cooling

Liquid cooling of the brakes is prohibited.

12.5) Electric braking

Electric braking is allowed. Its function is to ensure the braking of the car strictly in conformity with the order given by the driver. Its function cannot, in any circumstances, be to provide the driver with any additional support.
In particular, this system must:

- Ensure balanced and stable braking, whatever the amount of energy recovered. It must ensure a constant front / rear braking load distribution (sum of the electrical and hydraulic efforts) which can be adjusted only manually by the driver.
- Ensure, for each axle, equal braking power left and right and guarantee, in addition, identical hydraulic pressures and, for vehicles for which the electric torque does not pass through a differential, identical electric torques left and right.
- Ensure a level of braking effort directly linked to the brake pedal effort.
- Ensure a design of the braking system that can brake the car only via the hydraulic system, without any electric braking power, in order to ensure safety should there be a failure of the electrical system
- Have no servo-control on wheel slip.

The FIA will monitor the pressure supplied to each calliper and the electric torque transmitted to each wheel.
Before the homologation of the vehicle, the FIA will request a complete and detailed dossier describing the system and any necessary simulations to verify that the system is in compliance with the requirements, and that a dossier on the reliability of the system has been compiled by the manufacturer, and may define additional parameters that the FIA might wish to check, depending on the specific system presented by the manufacturer.

13) Wheels and Tyres

13.1) Location

Wheels can be external to the bodywork in plan view or housed within wheel arches.

13.2) Number of wheels

The number of wheels is fixed at four (4).

13.3) Wheel material
Metallic
One-piece wheels are mandatory.

13.4) Wheel & Rim dimensions
Wheel:
Maximum width: 14"
Maximum diameter: 28"

Rim:
Imposed diameter: 18" maximum.
Rims must be symmetrical and the diameters measured at the level of the inner and outer rim edges of a wheel must be identical, with a tolerance of +/- 1.5 mm;
Wheel tethers are defined in the Appendix to these requirements (Article 11.5.e).

13.5) Supply of tyres
All tyres must be used as supplied by the manufacturer, without any modification or treatment such as cutting or grooving. The application of solvents or softeners is prohibited. This applies to dry- and wet-weather tyres.
The same type of tyres must be used in qualifying and the race (according to the sporting regulations).
If, in the opinion of the appointed tyre supplier and the FIA technical delegate, the nominated tyre specification proves to be technically unsuitable, the stewards may authorise the use of additional tyres to a different specification.

13.6) Tyre gases
Tyres may only be inflated with air or nitrogen.
- Any process the intent of which is to reduce the amount of moisture in the tyre and/or in its inflation gas is forbidden. Any device to alter the tyre pressure by any mechanical or electronic device while the car is running is forbidden.

13.7) Wheel attachment
Free.
- If the wheel is attached by means of a single nut, a safety spring (painted red or "dayglo" orange) must be on the nut whenever the car is running, and it must be put back after every wheel change.
- any other method of retaining the wheel attachment system may be used, provided it has been approved by the FIA.

13.8) Sensors
Sensors for the pressure and the temperature of the tyres when the car is in motion are strongly recommended.
If these sensors are used, there must be at least one warning light to notify the driver of a possible failure.

14) Cockpit

14.1) Cockpit opening

In order to ensure that the opening giving access to the cockpit is of adequate size, the template shown in Drawing 2 will be inserted into the safety cell and bodywork. During this test the steering wheel, steering column, seat and all padding required (including fixings), may be removed and:

- The template must be held horizontal and lowered vertically from above the safety cell.
- Referring to Drawing 2, the edge of the template which lies on the line a-b-c-d-e must be no less than 1800 mm behind the line A-A shown in Drawing 5.
- The forward extremity of the cockpit opening, even if structural and part of the safety cell, must be at least 50 mm in front of the steering wheel.
- The driver must be able to enter and exit the cockpit by opening a cover (when a cover is used) as defined in Drawing 4 and by removing the steering wheel. When seated normally, the driver must be facing forwards and the rearmost part of his crash helmet may be no more than 125 mm forward of the rear edge of the cockpit entry template.
- From his normal sitting position, with all seat belts fastened and whilst wearing his usual driving equipment, the driver must be able to remove the steering wheel, open the cockpit cover (when a cover is used) and get out of the car within 7 seconds, and then replace the steering wheel within a total of 10 seconds. For this test, the position of the steered wheels will be determined by the FIA technical delegate and, after the steering wheel has been replaced, steering control must be maintained.

14.2) Steering wheel

The steering wheel must be fitted with a quick release mechanism operated by pulling a concentric flange installed on the steering column behind the wheel.

14.3) Internal cross section

A free vertical cross section**,** which allows the outer template shown in Drawing 3 to be passed vertically through the cockpit to a point 100 mm behind the face of the rearmost pedal when in the inoperative position, must be maintained over its entire length. The only things which may encroach on this area are the steering wheel and any padding that is required by Article 15.7.

- A free vertical cross section, which allows the inner template shown in Drawing 3 to be passed vertically through the cockpit to a point 100 mm behind the face of rearmost pedal when in the inoperative position, must be maintained over its entire length. The only thing which may encroach on this area is the steering wheel.
- The driver, seated normally with his seat belts fastened and with the steering wheel removed, must be able to raise both legs together so that his knees are past the plane of the steering wheel in the rearward direction. This action must not be prevented by any part of the car.

14.4) Position of driver’s feet

The safety cell must extend from behind the electrical power storage system in a forward direction to a point at least 300 mm in front of the driver’s feet, with his feet resting on the pedals and the pedals in the inoperative position.

When he is seated normally, the soles of the driver's feet, resting on the pedals in the inoperative position, must not be situated forward of the front wheel centre line.

14.5) Test for helmet removal

With the driver seated in his normal driving position in the car which he is entered to race, wearing a cervical collar appropriate to his size and with the seat harness tightened, a member of the medical service must demonstrate that the helmet which the driver will wear in the race can be removed from his head without bending the neck or spinal column.

14.6) Temperature inside the cockpit

For all cars using a cockpit cover, an effective ventilation and/or air conditioning system must be installed so that the inner temperature of the cockpit does not rise more than 5°C above the outside temperature at any time when the driver is sitting in the car and the cockpit cover is closed.

14.7) Cockpit opening mechanism

For all cars using a cockpit cover, a proper mechanism for opening the cover must be installed so that it can be opened by the driver from inside at any time when the car is stopped, as well as from outside by marshals after an accident.
The cockpit cover must be closed at any time when the car is in motion.

14.8) Windscreen areas

The windscreen can be part of the cockpit cover, made from one piece of laminated glass or equivalent material approved by the FIA.
The principal windscreen or cockpit cover must pass a dynamic load test defined by the FIA.

14.9) Cockpit Cover

The use of a cockpit cover is free.
If a cockpit cover is built, it must cover the full cockpit opening as defined in Drawings 2 and 4.
- The cockpit cover in the open position must provide normal access to the cockpit through the opening specified in Article 14.1. Viewed from the front, the cockpit cover structure must have, at a minimum height of 750 mm from the line d-e (Drawing 2), an opening with a minimum width of 400 mm in between the structure. The shape must be constant in between 400 mm measured from the rear of the cockpit opening (Drawing 7).
- Opening (hinges) or locking (locks) devices must be designed to allow a quick release of the entire cover from the interior and from the exterior of the cockpit in case of emergency. They need prior written agreement from the FIA.
- Cockpit Covers made of polycarbonate are permitted.
- Viewed from the side:

The perimeter of the transparent area of the side windows must allow the fitting of a rectangle measuring 225 mm (perpendicular to the reference surface) x 600 mm (parallel to the reference surface and measured from the front edge of the cockpit opening). The base of this rectangle must be at a minimum height of 575 mm from the line d-e (Drawing 2). The principal cockpit cover must pass a dynamic and static load test defined by the FIA.

15) Safety Equipment

15.1) Roll Over Structure

All cars must have two roll structures which are designed to help prevent injury to the driver in the event of the car overturning.

The principal structure at the rear edge of the cockpit opening must be at least 980 mm above the line d-e (Drawing 2) at a point 30 mm behind the cockpit entry template (Drawing 4). In order that a car may be lifted quickly in the event of stopping on the circuit, the principal rollover structure must incorporate a clearly visible unobstructed opening designed to permit a strap, with a section measuring 60 mm x 30 mm, to pass through it.

-The second structure must be in front of the steering wheel but no more than 250 mm forward of the top of the steering wheel rim in any position.

While the driver is sitting at the wheel, the helmet must be at a minimum distance of 70 mm from the line connecting the tops of the front and rear rollover structures (Drawing 4).

-The principal structure must pass a static load test, details of which may be found in Article 18. Furthermore, each team must supply detailed calculations which clearly show that the structure is capable of withstanding the same load when the longitudinal component is applied in a forward direction.

The second structure must pass a static load test, details of which may be found in Article 18.2.

15.2) Structure behind/below the driver:

The parts of the safety cell immediately behind and below the driver which separate the cockpit from the electric storage compartment may be situated according to the line a-b-c-d-e shown in Drawing 2. The parts of the safety cell beside the driver which house the electric storage compartment may be situated no higher than 500 mm above the line d-e.

15.3) Safety Cell

a) The safety cell must have an opening for the driver, the minimum dimensions of which are given in Article 14.1.

b) Any other openings in the safety cell must be of the minimum size to allow access to mechanical and electrical components.

c) An impact-absorbing structure must be fitted in front of the safety cell. This structure need not be an integral part of the safety cell but must be solidly attached to it. It must have a minimum external cross section, in horizontal projection, of 9000 mm² at a point 50 mm behind its forward-most point and, furthermore, no part of the cross section taken at this point may lie more than 500 mm above the line d-e (Drawing 2).

c) Referring to Drawing 5:

The external width of the safety cell between the lines B-B and C-C must be no less than 450 mm and must be at least 60 mm wider on each side than the cockpit opening when measured normal to the inside of the cockpit opening. These minimum dimensions must be maintained over a height of at least 350 mm.

The width of the safety cell may taper forward of the line B-B but, if this is the case, the outer surface must not lie closer to the car centre line than a plane which has a linear taper to a minimum width of 300 mm at the line A-A.

The minimum width must be arranged symmetrically about the car centre line and must be maintained over a height of at least 400 mm at the line B-B and 275 mm at the line A-A. The height at any point between A-A and B-B must not be less than the height defined by a linear taper between these two sections. When assessing the minimum external cross sections of the safety cell, radii of 50 mm at the line B-B, reducing at a linear rate to 25 mm at the line A-A, will be permitted. Following the application of the permitted radii, the external cross sections of the safety cell between the lines A-A and B-B must, over their respective minimum widths, have a minimum height of 300 mm at the line B-B reducing at a linear rate to a minimum height of 225 mm at the line A-A. The minimum height of the safety cell between the lines A-A and B-B need not be arranged symmetrically about the horizontal centre line of the relevant section but must be maintained over its entire width. The maximum height of the safety cell between the lines A-A and B-B is 625 mm above the line d-e (Drawing 2). The minimum height of the safety cell between the lines B-B and C-C is 550 mm from the line d-e (Drawing 2).

d) When the test referred to in Article 14.1 is carried out and the template is in position with its lower edge 525 mm above the line d-e (Drawing 2), the shape of the safety cell must be such that no part of it is visible when viewed from either side of the car. The parts of the safety cell which are situated each side of the driver's head must be no more than 550 mm apart. In order to ensure that the driver's head is not unduly exposed and for him to maintain good lateral visibility he must, when seated normally and looking straight ahead with his head as far back as possible, have his eye visible when viewed from the side. The centre of gravity of his head must lie below the top of the safety cell at this position. When viewed from the side of the car, the centre of gravity of the driver's head will be deemed to be the intersection of a vertical line passing through the centre of his ear and a horizontal line passing through the centre of his eye.

e) In order to give additional protection to the driver in the event of a side impact, a flat test panel of uniform construction, which is designed and constructed in order to represent a section of the safety cell sides, must pass a strength test. Details of the test procedure may be found in Article 19.7.

Referring to Drawing 5, with the exception of local reinforcement and/or inserts, all parts of the safety cell which are as wide as or wider than the minimum widths stipulated in Article 15.3, including any radii applied, must be manufactured to the same specification as a single panel which satisfies the requirements of Article 19.7. Furthermore, parts to this tested specification must cover an area which:

- begins no less than 250 mm high at the line A-A tapering at a linear rate to a minimum of 400 mm high at the line B-B;
- lies between two horizontal lines 100 mm and 500 mm above the line d-e (Drawing 2) between the line B-B and the rear of the safety cell.

f) Panels no less than 6.2 mm thick must then be permanently attached to the safety cell sides. These panels must:

- in a longitudinal sense, cover the area lying between the line B-B and a vertical plane 50 mm to the rear of the rear edge of the cockpit entry template. A 50 mm horizontal linear taper may be included at both ends;
- in a vertical sense, cover the area lying between two horizontal planes 100 mm and 550 mm above the line d-e (Drawing 2);
- be constructed from 16 plies of Zylon and two plies of carbon; precise lay-up details must be followed and may be found in appendix to these requirements;
- be permanently attached to the safety cell with an appropriate adhesive which has been applied over their entire surface.

Cut-outs in these panels totalling 35,000 mm² per side will be permitted for fitting around side impact structures, wiring loom holes and essential fixings.
g) One further panel, which may be made in a maximum of three parts but which is no less than 3.0 mm thick, must then be permanently attached to the safety cell. This panel must:
- in a longitudinal sense, cover the area lying between a vertical plane 300 mm to the rear of the line A-A and a vertical plane 650 mm forward of the rear edge of the cockpit entry template. A 25 mm horizontal linear taper may be included at both ends;
- in a vertical sense, cover every part of the outer skin of the safety cell in the area lying between two horizontal planes 60 mm and 550 mm above the reference plane. This will not apply at the top of this panel, where any radius permitted by Article15.3.c falls, nor inside the minimum permitted chassis width, nor for the area fitted with the panel defined by Article 15.3.f.
- If made in more than one part, have all adjacent parts overlapping by a minimum of 25 mm. These overlaps may include linear tapers in the thickness of both parts;
- overlap the panel defined by Article 12.3.f, along all joining edges by a minimum of 25 mm. These overlaps may include linear tapers in the thickness of both parts;
h) be constructed from seven plies of Zylon and two plies of carbon; precise lay-up details must be followed and may be found in appendix to these requirements.
- be permanently attached to the safety cell with an appropriate adhesive which has been applied over its entire surface including all overlapping joints.
Cut-outs in this panel totalling 15,000 mm² per side will be permitted for fitting around wiring loom holes and essential fixings.

15.4) Fire extinguisher
All cars must be fitted with a fire extinguishing system which will discharge into the cockpit and into the electric storage system compartment. Only ABC extinguisher types usable for the chemistry of the installed RESS and specified for the voltage level at the Power Bus are allowed. Specification is laid down in Electric safety requirements – Article 3.23.
The system must work in any position, even when the car is inverted.
- All extinguisher nozzles must be suitable for the extinguishant and be installed in such a way that they are not directly pointed at the driver. All parts of the extinguishing system must be situated within the safety cell and all extinguishing equipment must withstand fire.
- Any triggering system having its own source of energy is permitted/is connected to the auxiliary battery. It must be possible to operate all extinguishers should the main electrical circuits of the car fail.
The driver must be able to trigger the extinguishing system manually when seated normally with his safety belts fastened and the steering wheel in place.
All cars must be equipped with an extinguishing system homologated by the FIA in accordance with Article 253-7, with the exception of the means of triggering from the outside. The means of triggering from the outside must be combined with the circuit breaker switch and be operated by a single lever. It must be marked with a letter "E" in red inside a white circle at least 100 mm in diameter and with a red edge.

15.5) Rear view device
Two rear view mirrors, one on each side, must provide efficient visibility to the rear.
Each mirror must have a minimum size of 100 cm². They can be replaced by a camera which displays the picture on screen in the cockpit, fully visible by the driver and with a minimum size of 100 cm².

It must be assured that the driver, seated normally, can clearly see the vehicles following him. For this purpose, the driver shall be required to identify any letter or number, 150 mm high and 100 mm wide, placed anywhere on boards behind the car, the positions of which are detailed below :

Height:	From 400 mm to 1100 mm from the ground.
Width:	2000 mm either side of the centre line of the car.
Position:	10 m behind the rear axle line of the car.

15.6) Safety belts

It is mandatory to wear two shoulder straps, one abdominal strap and two straps between the legs. These straps must be securely fixed to the car and must comply with FIA standard 8853/98 and Article 253-6.

15.7) Cockpit padding

All cars must be equipped with three areas of padding for the driver's head which:

- are so arranged that they can be removed from the car as one part;
- are located by two horizontal pegs behind the driver's head and two fixings, which are clearly indicated and easily removable without tools, at the front corners;
- are made from a material which is suitable for the relevant ambient air temperature;
- are covered, in all areas where the driver's head is likely to make contact, with two plies of Aramid fibre/epoxy resin composite pre-preg material in plain weave 60gsm fabric with a cured resin content of 50% (+/-5%) by weight;
- are positioned so as to be the first point of contact for the driver's helmet in the event of an impact projecting his head towards them during an accident.
- The first area of padding for the driver's head must be positioned behind him and be between 75 mm and 90 mm thick over an area of at least 40,000 mm². If necessary, and only for driver comfort, an additional piece of padding no greater than 10 mm thick may be attached to this headrest, provided it is made from a similar material which incorporates a low friction surface.
- Whilst he is seated normally, the two further areas of padding for the driver's head must be positioned in an area bounded by two vertical lines and one horizontal line through the front, rear and lower extremities of the driver's helmet (on the car centre line) and the upper surface of the safety cell. Each of these must cover an area greater than 33,000 mm² when viewed from the side of the car and be no less than 95 mm thick, this minimum thickness being maintained to the upper edges of the safety cell and over their entire length. The minimum thickness will be assessed perpendicular to the car centre line but a radius no greater than 10 mm may be applied along their upper inboard edges. If necessary, and only for driver comfort, an additional piece of padding no greater than 10 mm thick may be attached to these headrests, provided they are made from a similar material which incorporates a low friction surface.
- Forward of the side areas of padding, further cockpit padding must be provided on each side of the cockpit rim. The purpose of the additional padding is to afford protection to the driver's head in the event of an oblique frontal impact and it must therefore be made from the same material as the other three areas of padding. These extensions must:
- be symmetrically positioned about the car centre line and form a continuation of the side areas of padding;
- be positioned with their upper surfaces at least as high as the safety cell over their entire length;

- have a radius on their upper inboard edge no greater than 10 mm;
- be positioned in order that the distance between the two is no less than 320 mm;
- be as high as practicable within the constraints of driver comfort.
- All of the padding described above must be so installed that if movement of the driver's head, in any expected trajectory during an accident, were to compress the foam fully at any point, his helmet would not make contact with any structural part of the car. Furthermore, for the benefit of rescue crews, all of the padding described above must be installed using the system described in appendix to these requirements. The method of removal must also be clearly indicated.
- No part of the padding described above may obscure sight of any part of the driver's helmet when he is seated normally and viewed from directly above the car.
- In order to minimise the risk of leg injury during an accident, additional areas of padding must be fitted each side of, and above, the driver's legs.

These areas of padding must:
- be made from a material described in appendix to these requirements;
- be no less than 25 mm thick over their entire area;
- cover the area situated between points lying 50 mm behind the centre of the point at which the second roll structure test is carried out and 100 mm behind the face of the rearmost pedal when in the inoperative position;
- cover the area above the line A-A shown in Drawing 3.

15.8) Seat fixing and removal

In order that an injured driver may be removed from the car in his seat following an accident, all cars must be fitted with a seat which, if it is secured, must be done so with no more than two bolts. If bolts are used they must:
- be clearly indicated and easily accessible to rescue crews;
- be fitted vertically;
- be removable with the same tool for all teams and which is issued to all rescue crews.
- The seat must be equipped with receptacles which permit the fitting of belts to secure the driver and one which will permit the fitting of a head stabilisation device.
- The seat must be removable without the need to cut or remove any of the seat belts.
- Details of the tool referred to above.

15.9) Head and neck supports

No head and neck support worn by the driver may be less than 25 mm from any structural part of the car when he is seated in his normal driving position.

15.10) 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 Electric safety requirements – Article 3.3.

15.11) Safe/Live signage

The Safe / Live Signage must be activated jointly by both the Driver Master Switch (DMS) and the General Circuit Breaker (GCB).

If the Power Circuit is switched on (condition to drive the vehicle) by both the DMS and the GCB, the Power Circuit will be energised and turn to Live condition. Two redundant RED lights symbolising "danger high voltage" must be activated on the dashboard, as well as one

red light, at the site of the external breaker, to clearly show that it could be life-threatening to work on the Power Circuit.
If the Power Circuit is switched off by the DMS and/or the GCB, the Power Circuit will be de-energised and discharged (no voltage on Live components). Both red dashboard lights and the red tail light will be switched off to clearly show that the Power Circuit is dead and it is now safe to work on the vehicle.

16) Car Construction

16.1) Permitted materials

The following is the list of permitted materials. These are the only materials permitted to be used in the construction of the Formula E Car, provided only that in all cases the material is available on a non-exclusive basis and under normal commercial terms to all competitors.
Permitted materials:
1) Aluminium alloys.
2) Silicon carbide particulate reinforced aluminium alloy matrix composites.
3) Steel alloys.
4) Cobalt alloys.
5) Copper alloys containing ≤ 2.5% by weight of Beryllium.
6) Titanium alloys (but not for use in fasteners with <15 mm diameter male thread).
7) Magnesium alloys.
8) Nickel based alloys containing 50% < Ni < 69%.
9) Tungsten alloy.
10) Thermoplastics: monolithic, particulate filled, short fibre reinforced.
11) Thermosets: monolithic, particulate filled, short fibre reinforced.
12) Carbon fibres manufactured from polyacrylonitrile (PAN) precursor. (*)
13) Carbon fibres manufactured from polyacrylonitrile (PAN) precursor which have
- a tensile modulus ≤ 550GPa;
- a density ≤ 1.92 g/cm3;
- unidirectional or planar reinforcement within their pre-impregnated form, not including three dimensional weaves or stitched fabrics (but three dimensional preforms and fibre reinforcement using Z-pinning technology is permitted);
- no carbon nanotubes incorporated within the fibre or its matrix;
- a permitted matrix, not including a carbon matrix.
14) Aramid fibres.
15) Poly (p-phenylene benzobisoxazole) fibres (e.g. “Zylon”).
16) Polyethylene fibres.
17) Polypropylene fibres.
18) E and S Glass fibres.
19) Sandwich panel cores: Aluminium, Nomex, polymer foams, syntactic foams, balsa wood and carbon foam.
20) The matrix system utilised in all pre-impregnated materials must be epoxy, cyanate ester, phenolic, bismaleimide, polyurethane, polyester or polyimide based. (*)
21) The matrix system utilised in all pre-impregnated materials must be epoxy, cyanate ester or bismaleimide based.
22) Monolithic ceramics.

Materials marked (*) are permitted only for parts classified as either front, rear or side impact structures, side intrusion panels or suspension members as regulated by Articles 15.3.c, 15.3.e, 15.3.f, 11.5 of the Technical Requirements respectively.

Exceptions:

1) All electrical components (e.g. control boxes, wiring looms, sensors).
2) All seals & rubbers (e.g. rubber boots, o-rings, gaskets, any fluid seals, bump rubbers).
3) Fluids (e.g. water, oils).
4) Tyres.
5) Coatings and platings (e.g. DLC, nitriding, chroming).
6) Paint.
7) Adhesives.
8) Thermal insulation (e.g. felts, gold tape, heat shields).
9) All currently regulated materials (e.g. fuel bladder, headrest, extinguishant, padding, skid block).
10) Brake friction materials.

- No parts of the car may be made from metallic materials which have a specific modulus of elasticity greater than 40GPa / (g/cm3). Tests to establish conformity will be carried out in accordance with FIA Test Procedure 03/02.

16.2) Safety cell safety requirements

The safety cell and frontal absorbing structure must pass an impact test against a solid vertical barrier placed at right angles to the car centre line. Details of the test procedure may be found in Article 17.2.a + 17.2.b.

- Between the front and rear roll structures, impact-absorbing structures must be fitted on each side of the safety cell and must be solidly attached to it. The purpose of these structures is to protect the driver and the battery pack, if located in this area, in the event of a lateral impact and, in order to ensure this is the case, a lateral strength test in the vicinity of any position defined by the FIA must be carried out successfully. Details of the test procedure may be found in Article 19.2.

The safety cell and one of these impact-absorbing structures must pass an impact test, details of the test procedure may be found in Article 17.3. If these structures are not designed and fitted symmetrically about the car centre line, a successful impact test must be carried out on them both.

- The safety cell must also be subjected to six separate static load tests:

1) on a vertical plane passing through the centre of the electric power storage compartment;
2) on a vertical plane passing through the rearmost point at which the outer end of the forward-most front wheel tether would make contact with the safety cell when swung about the inner attachment;
3) on any position of the cockpit entry template defined by the FIA;
4) from beneath the electric power storage compartment;
5) on each side of the cockpit opening;
6) from beneath the cockpit floor.

Details of the test procedures may be found in Article 19.2.

- To test the attachments of the frontal, side and rear impact-absorbing structures, static side load tests must be carried out. Details of the test procedures may be found in Articles 19.6, 19.8 and 19.9.

16.3) Electric Power Storage cell specification
The specifications must be not less than those of the driver's safety cell.

16.4) Firewalls
- A perfectly sealed panel no less than 6.2 mm thick must then be permanently attached between the driver's safety cell and the electric power storage system cell if it is made of two separate units.
It must be constructed from 16 plies of Zylon and two plies of carbon.
- Any holes in the firewall must be of the minimum size for the passage of controls and cables, and must be completely sealed.

17) Impact Testing
All test conditions and details on frontal, side and rear tests as well as the steering column test are laid down in appendix to these requirements.

18) Roll Structure Testing
All details on the principal and second roll structure tests are laid down in appendix to these requirements.

19) Static Load Testing
All test conditions and details on static load tests are laid down in appendix to these requirements.

20) Television Cameras and Timing Transponders

20.1) Presence of cameras and camera housings
To be defined by the FIA

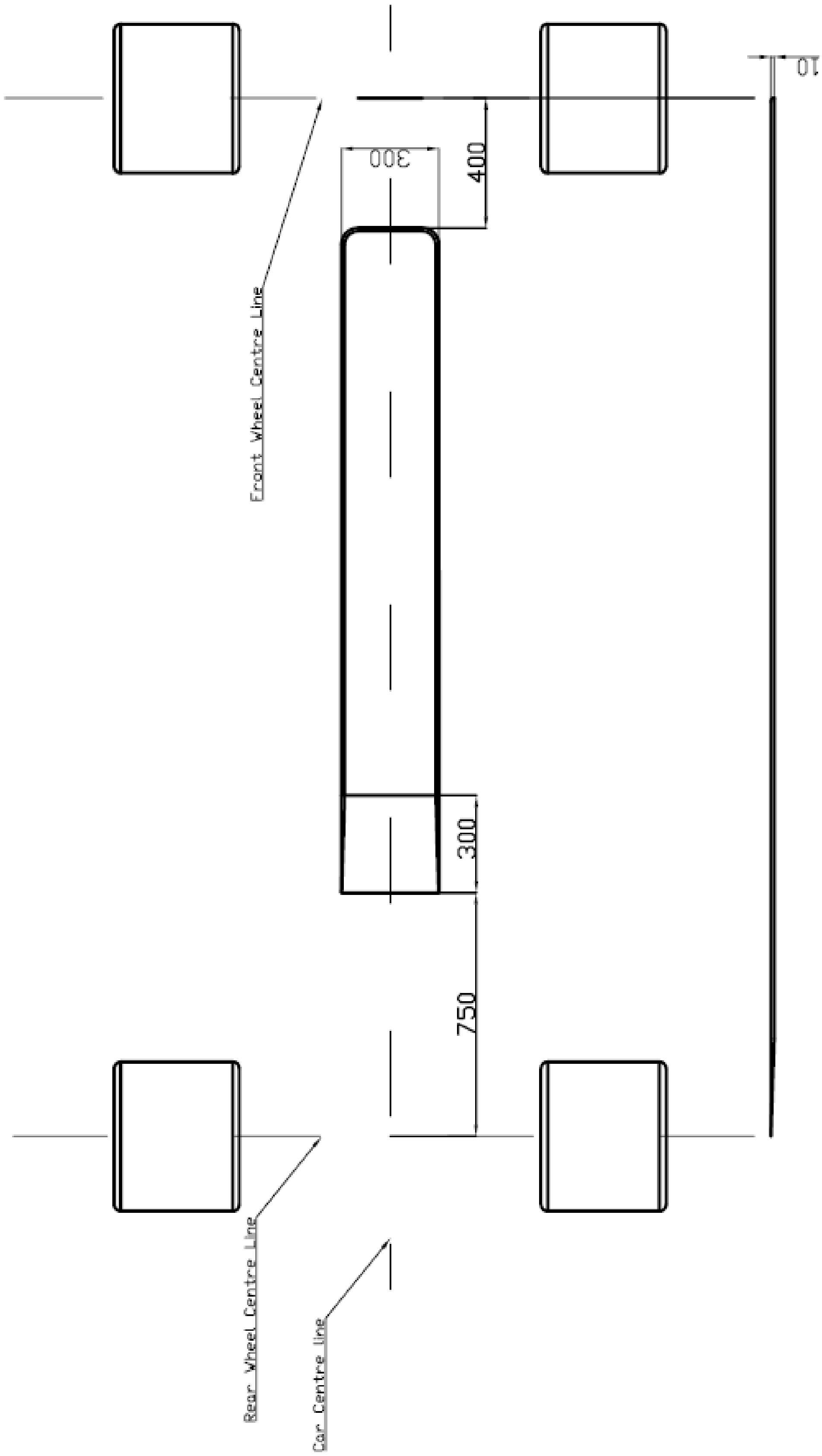
20.2) Location and fitting of camera equipment
To be defined by the FIA

20.3) Transponders
All cars must be fitted with one timing transponder supplied by the officially appointed timekeepers. This transponder must be fitted in strict accordance with the instructions of the timekeepers.

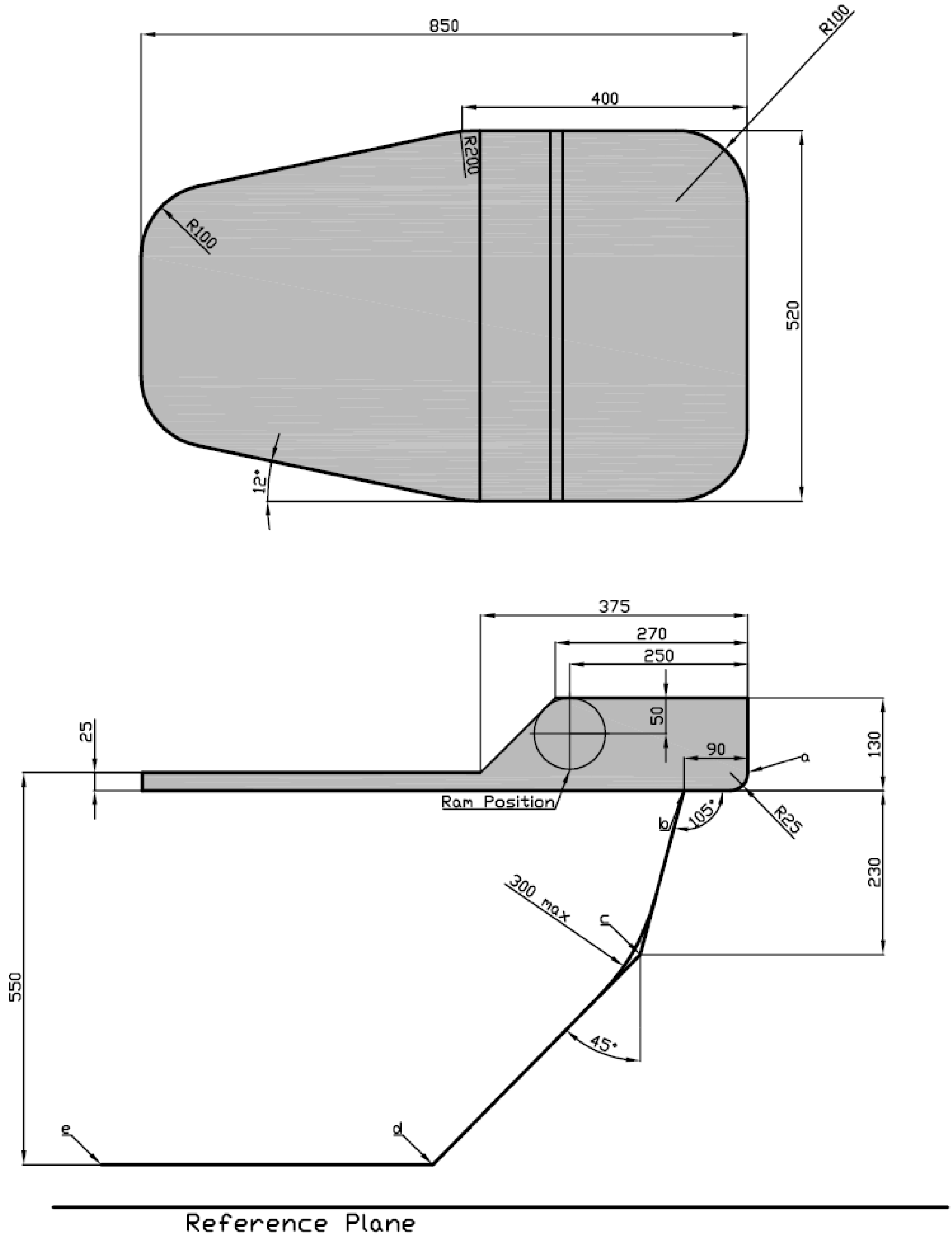
21) Final Text

21.1) Language
The final text for these requirements shall be the English version should any dispute arise over their interpretation.

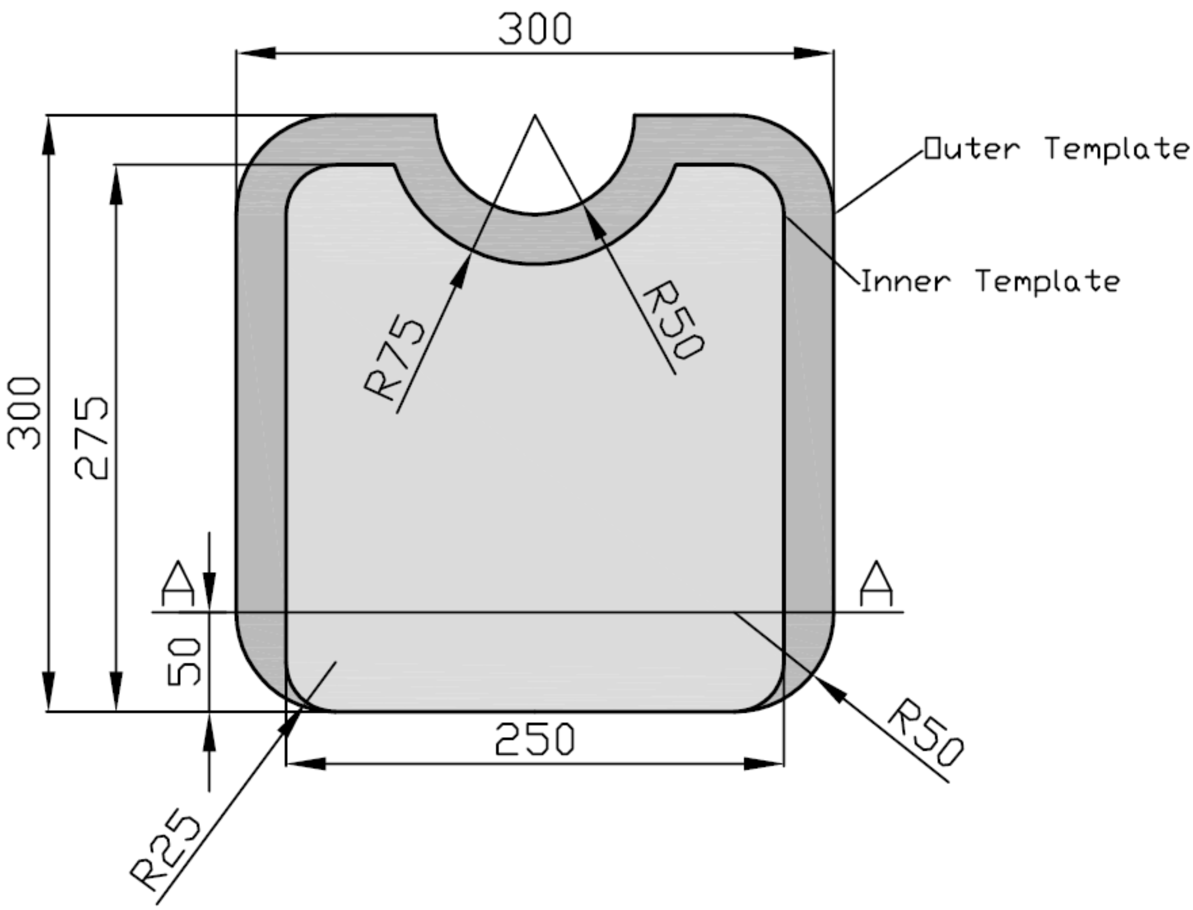
Drawing 1: Skid Block (Article 4.7)



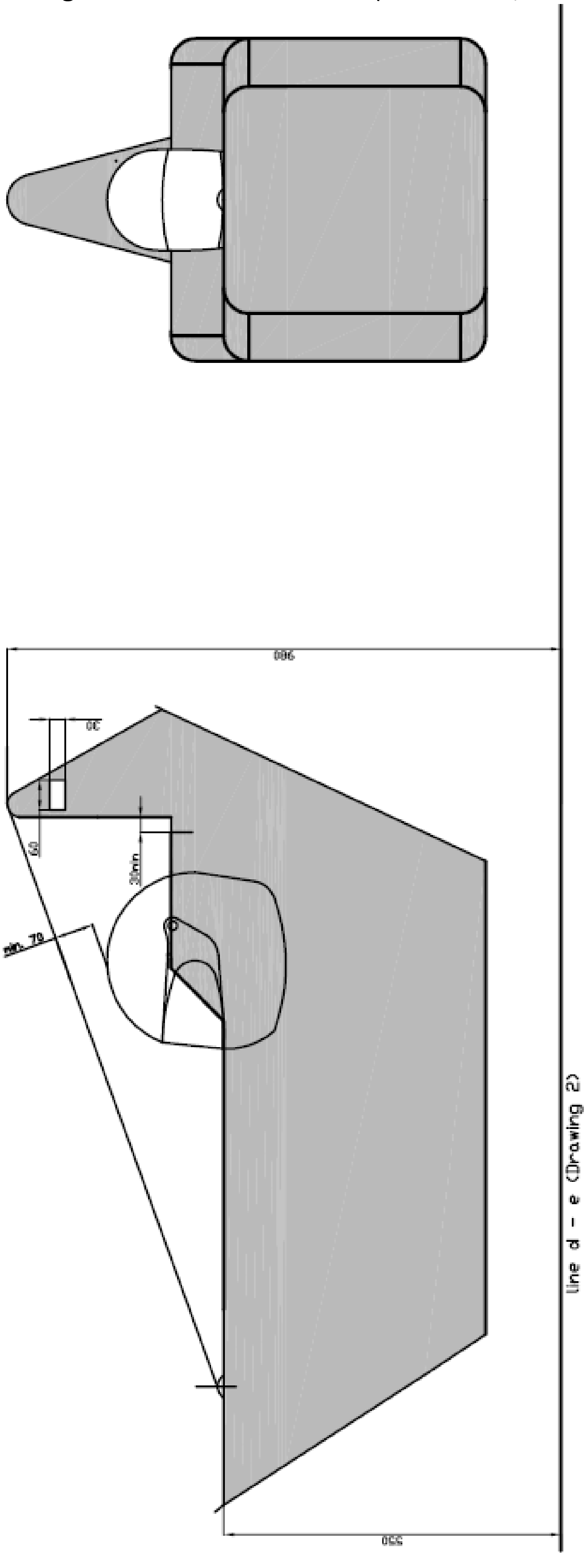
Drawing 2: Cockpit Template (Article 14.1)



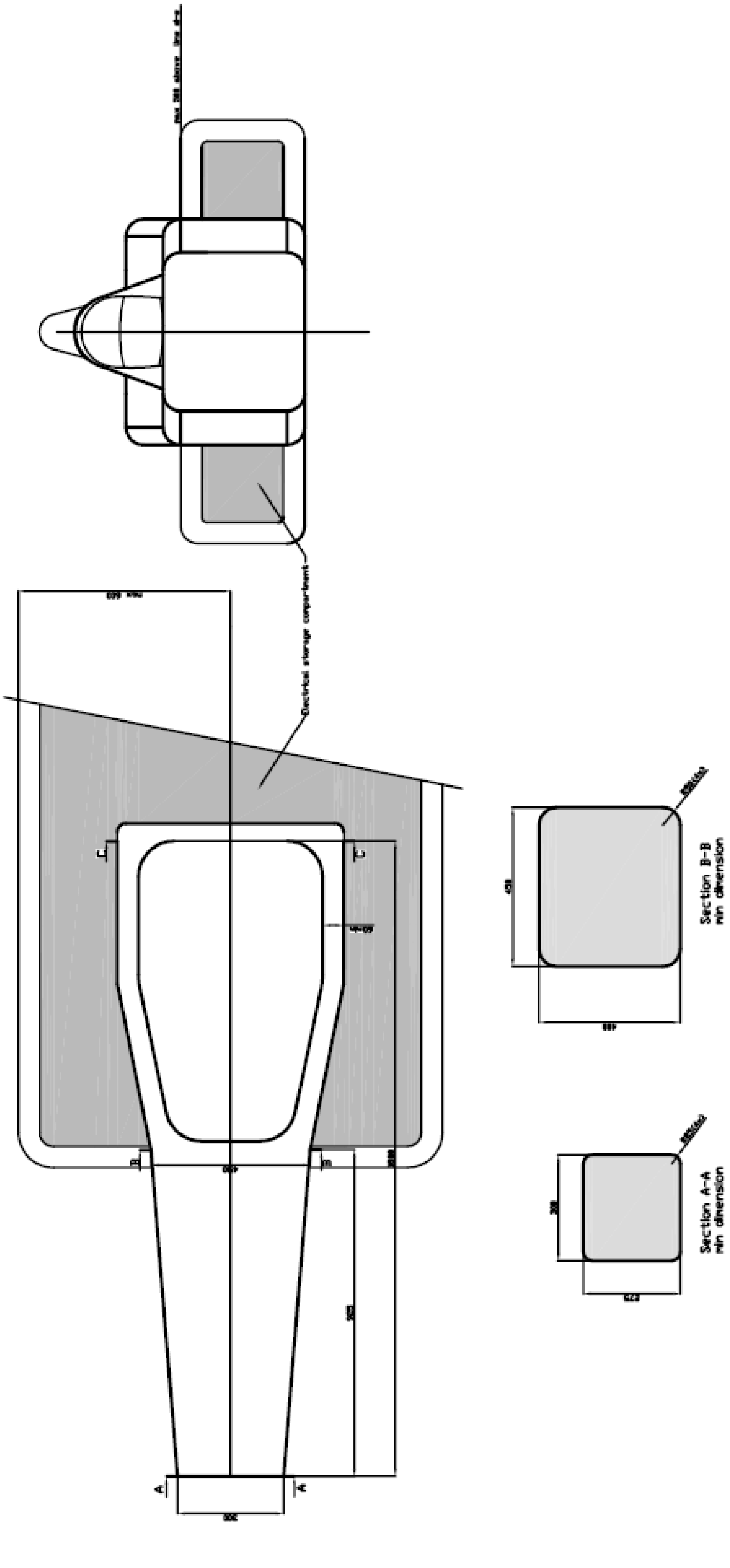
Drawing 3: Cockpit Cross Section Template (Article 14.3)



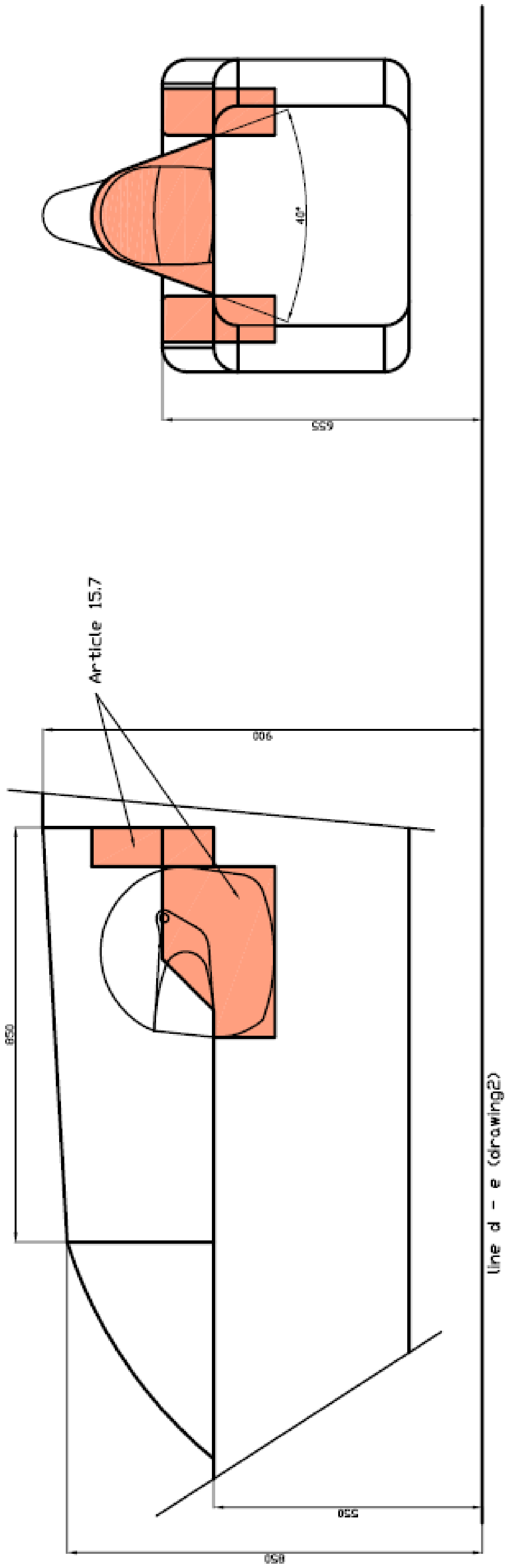
Drawing 4: Roll Over Structure (Article 14.7, Article 15.1)



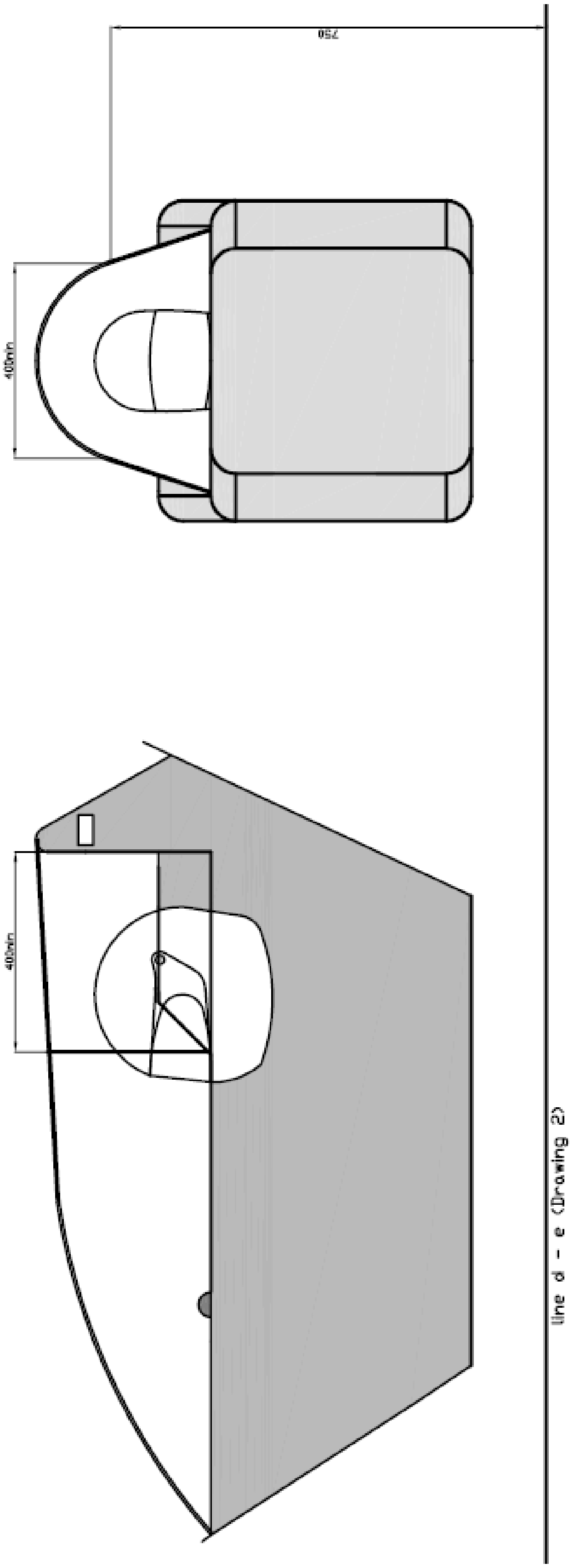
Drawing 5: Safety Cell (Article 15.3)



Drawing 6:	Cockpit Padding (Article 15.7)



Drawing 7: Cockpit Cover (Article 14.9)



ELECTRIC SAFETY REQUIREMENTS
@ ELECTRIC AND HYBRID ELECTRIC RACING VEHICLES

Table of Contents

ARTICLE 1 - Purpose of the document

The purpose of this document is to collate a number of design solutions and concepts that competitors who have been involved in electrical drive systems development consider to be best practice. It is intended as a reference document for the FIA and those competitors involved in developing or assessing the safety of any future electrical drive system for electric and hybrid vehicles.

If applicable, the document refers to best standards for road-going cars predominantly published by the "International Organization for Standardization (ISO)" to establish generally agreed safety measures and procedures. The document ends with a list of the standards used.

1.1 Safety Policy

Motivation for competitor high voltage safety policy:

It is recommended that competitors set out a clear statement of intent regarding high voltage safety, including schematics of the principle circuits and safety features of the system, so that the design can be validated easily and the FIA can be informed about the safety concept. An appendix for "best practice" is available as a guideline, upon request from the FIA.

1.2 Failure Isolation Policy

In all expected conditions of deployment, a single point of failure of the electric drive system must not cause an electric shock hazardous to the life of any person.

1.2.1 Expected conditions

Expected conditions include build/service/maintenance (on or off the car), normal car use, abnormal car use (including driving accidents, collisions, debris impacts), unexceptional car failures, unexceptional electric drive system failures (including, for example, overheating, software error, vibration failure of component [these may decrease with system maturity]).

1.2.2 Single point of failure

- A "single point of failure" [referencing the "expected conditions" that are listed above] cannot, therefore, include failures that are unexceptional or reasonably expected (thus, for the avoidance of any doubt, abnormal but unexceptional car use or failures of the car or electric drive system must not erode the level of hazard protection demanded by the policy).
- A "single point of failure" which is undetected or undetectable and allows continued deployment must then be classed as an "expected condition" and must not erode the level of hazard protection demanded by the policy.

1.2.3 Two levels of isolation

The policy presumes a minimum of two levels of isolation in all "expected conditions" with a very high reliability of each (thereby achieving a compounded extremely low probability of dual point of failure). Any aspect of design or procedure that is intended to serve as isolation but is not expected to achieve a normal benchmark of very high reliability must be considered an unexceptional risk and, therefore, an "expected condition" and must not erode the level of hazard protection demanded by the policy.

1.2.4 Electric shock hazardous to the life of any person

Electric shock (2.7) hazardous to the life of any person is generally considered to be given by a sustained body connection to a source of more than 60 V DC or 30 V AC rms (values taken from ISO/DIS 6469-3.2:2010).

ARTICLE 2 – Definitions

2.1 Electric Road Vehicle

A (pure) electric road vehicle is an electrically propelled and infrastructure independent, exclusively electrically supplied road vehicle in which electric energy is transformed by electrical machine(s) into mechanical energy for traction purposes (from EN 13447).

2.2 Hybrid Electric Vehicle

The International Organization for Standardization defines a hybrid electric vehicle (HEV) as: "a vehicle with at least one RESS (2.6) and one fuelled power source for vehicle propulsion" (ISO 6469-1:2009).

2.2.1 Full Hybrid Electric Vehicle

A hybrid vehicle is one in which the electric motor is able not only to assist the IC engine but also to propel the vehicle without the help of the IC engine, in the so-called zero emission mode. The range of the zero emission mode in a full hybrid could be several kilometres or fewer.

2.2.2 Plug-In Hybrid Electric Vehicle

A plug-in hybrid electric vehicle (PHEV) is a hybrid vehicle, which has a large, high-capacity battery pack that can be recharged by being plugged into normal household power outlets, as well as using the on-board charging capabilities of regular hybrids. While regular electric hybrids require a combination of regenerative braking and energy from the engine to recharge the RESS and propel the vehicle, plug-ins can operate either as electric vehicles with an internal combustion engine backup generator or as a regular full hybrid vehicle with a high-capacity battery pack.

2.3 Series Production Vehicles

Vehicles according to one of the Groups listed in Art. 251-Category I of Appendix J of which the production of a certain number of identical units within a certain period of time has been verified at the request of the manufacturer, and which are destined for normal sale to the public. Vehicles must be sold in accordance with the type approval registration documents for public road use.

2.4 Competition cars

Vehicles according to Art. 251-Category II of Appendix J, built as series production vehicles in small quantities, or single or as prototypes, and destined solely for competition.

2.5 Internal Combustion Engine

The internal combustion (IC) engine is the on-board energy converter for fuel energy and originates from the series production for the specific vehicle model or is an FIA homologated engine.

2.6 Rechargeable Energy Storage System (RESS)

A Rechargeable Energy Storage System (RESS) is the complete energy storage device, comprising an energy storage medium (e.g. flywheel, capacitor, battery etc..), the components to mount, monitor, manage and protect the storage medium including everything needed for normal operation of the RESS with the exception of all cooling liquid and cooling equipment located outside the RESS housing(s).

The RESS is designed to recover kinetic energy from the car during deceleration or braking, store that energy and then make it available to propel the car. The RESS may be recharged from the fuel-based energy converter or, for plug-in hybrids and pure electric vehicles, directly from the grid.

2.6.1 Flywheel system

A flywheel system is a mechanical or electromechanical system capable of storing and releasing energy by means of a rotating mass system, such as the rotor of an electric motor/generator.

2.6.2 Capacitors

A capacitor (electrolytic capacitor, Electric Double Layer Capacitor (EDLC) named “Super Capacitor” or “Ultra Capacitor”) is a device to store electric energy in the electric field or, in the case of the EDLC, a system in which an electric charge is stored, permitting the adsorption and desorption of the ions in an electrolyte to electrodes.

2.6.3 Traction battery

The traction battery is a RESS and supplies electric energy to the Power Circuit and thus to the traction motor(s) and possibly the auxiliary circuit (2.18). The traction battery is defined as any equipment used for the intermediate storage of electrical energy supplied by the conversion of kinetic energy or by a generator or by the charging unit (for plug-in hybrids and pure electric vehicles). Any on-board battery electrically connected to the Power Circuit is considered to be an integral part of the vehicle's traction battery. The traction battery consists of numerous electrically connected battery cells grouped together in battery modules.

2.6.4 Battery pack

A battery pack is a single mechanical assembly optionally housed by a battery compartment, comprising battery modules, retaining frames or trays, fuses and contactors, as well as a battery management system. The RESS may comprise more than one battery pack connected together with suitably protected cables/connectors between the packs.

2.6.5 Battery module

A battery module is a single unit containing one cell or a set of electrically connected and mechanically assembled cells. The Battery Pack(s) may comprise more than one Battery Module connected together to obtain higher current or voltage. These connections are inside the Battery Pack.

2.6.6 Battery cell

A cell is an electrochemical energy storage device of which the nominal voltage is the electrochemical couple nominal voltage, made of positive and negative electrodes, and an electrolyte.

2.6.7 Energy capacity of the traction battery

The capacity C1 is the capacity of the battery in Ah at the normal battery operating temperature and for a complete battery discharge within 1 hour. The on-board energy is calculated by the product of the nominal voltage of the vehicle's traction battery in volts and the capacity C1 in Ah. The energy capacity must be expressed in Wh or kWh respectively.

2.6.8 Battery Management System

The Battery Management System (BMS) is part of the RESS and an important safety system. It comprises a monitoring and optionally a charge-balancing circuit to keep all cells, at any time and under any charge or discharge conditions, within the specified voltage range given by the battery manufacturer.

2.7 Electric shock

Physiological effect resulting from an electric current passing through a human body (from ISO/DIS 6469-3.2:2010).

2.8 Maximum working voltage

Highest value of AC voltage root-mean-square (rms) or of DC voltage, which may occur in an electric system under any normal operating conditions according to the manufacturer's specifications, disregarding transients (from ISO 6469-1:2009).

2.9 Voltage class B

Classification of an electric component or circuit as belonging to voltage class B, if its maximum working voltage is > 30 V AC and $\leq$1000 V AC, or > 60 V DC and $\leq$1500 V DC, respectively (from ISO 6469-1:2009).

2.10 Conditions for the measurement of the maximum voltage

The maximum voltage must be measured at least 15 minutes after the charging of the RESS has ended.

2.11 Clearance

Shortest distance in air between conductive parts.

2.12 Creepage distance

Shortest distance along the surface of a solid insulating material between two conductive parts.

2.13 Power Circuit

The Power Circuit consists of all those parts of the electrical equipment that are used for driving the vehicle. The Power Circuit comprises the RESS (2.6), the power electronics (converter, chopper) (3.5) for the drive motor(s) (3.6), the contactor(s) of the General Circuit Breaker (2.13.3), the Driver Master Switch (2.19), the manually operated Service Switch (3.4.1h), fuses (2.13.2), cables and wires (2.13.1.1), connectors (3.2 and 3.14), the generator(s) and the drive motor(s).

2.13.1 <u>Power Bus</u>

The Power Bus is the electric circuit used for energy distribution between the generator, the RESS (e.g. traction battery) and the propulsion system, which consists of the power electronics and the drive motor(s).

2.13.1.1 <u>Insulation types of cables and wires</u>

The following definitions are in accordance with ISO 8713:2005.

2.13.1.2 <u>Basic insulation</u>

Insulation of live parts (2.15) necessary to provide protection against contact (in a no-fault condition).

2.13.1.3 <u>Double insulation</u>

Insulation comprising both basic insulation and supplementary insulation.

2.13.1.4 <u>Reinforced insulation</u>

Insulation system applied to live parts, which provides protection against electric shock; equivalent to double insulation.

NOTE: The reference to an insulation system does not necessarily imply that the insulation is a homogeneous piece. It may comprise several layers, which cannot be tested individually as either basic insulation or supplementary insulation.

2.13.1.5 Supplementary insulation

Independent insulation, applied in addition to basic insulation, in order to provide protection against electric shock in the event of a failure of the basic insulation.

2.13.2 Overcurrent trip (fuses)

An overcurrent trip is a device that automatically interrupts the electrical current in the circuit in which it is installed if the level of this current i exceeds a defined limit value for a specific period of time (i^2t).

2.13.3 General Circuit Breaker

The term General Circuit Breaker refers collectively to the relays or contactors which are actuated by the Emergency Stop Switches (2.13.4) to isolate all the electrical systems in the vehicle from any power sources.

- The contactor(s) used for the General Circuit Breaker must be a spark-proof model. In order to prevent contact melting of the contactor its [I^2t] (ampere squared seconds characteristics, representing heat energy dissipated on the breaker contacts during switching) must be sufficient to guarantee the proper operation of the General Circuit Breaker even under surge current conditions, in particular those occurring during the connection of the RESS to the Power Bus. If appropriate, a pre-charge relay should be used to prevent welding of the contacts.
- The General Circuit Breaker MUST use mechanical contacts. Semiconductor devices are not permitted.
- The contactor must guarantee operation under crash conditions.

2.13.4 Emergency Stop Switches

The Emergency Stop Switches control the General Circuit Breaker.

2.13.5 Power Circuit Ground

Power Circuit Ground is the ground potential of the electrical Power Circuit. Typically this is the –U_B pole of the RESS, or 50 % of the RESS voltage (see Figure 3, Figure 4, Figure 5 and Figure 6.

2.14 Electric Chassis Ground, Vehicle Ground and Earth Potential

Electric Chassis (Vehicle and Bodywork) Ground, hereinafter named “Chassis Ground”, is the electrical reference potential (earth potential if the vehicle is recharged from the grid) of all conductive parts of the bodywork including the chassis and the safety structure. Auxiliary ground must be connected to chassis ground. The conductive cases of the RESS and of Power Circuit units such as motor(s) and contactors must have robust connections to Chassis Ground.

2.14.1 Main Ground Point

The distribution of high currents in a network must be made in a star-point configuration and not in a loop, in order to avoid potential shifts resulting from current flows. The star-point of the electrical reference potential is henceforth named “Main Ground Point”.

2.15 Live part

Conductor or conductive part intended to be electrically energized in normal use.

2.16 Conductive part

Part capable of conducting electric current.

NOTE: Although not necessarily electrically energized in normal operating conditions, it may become electrically energized under fault conditions of the basic insulation.

2.17 Exposed conductive part

Conductive part of the electric equipment, which can be touched by a test finger according to IPXXB and which is not normally live, but which may become live under fault conditions (from ISO/DIS 6469-3.2:2010).

NOTE 1: This concept is relative to a specific electrical circuit: a live part in one circuit may be an exposed conductive part in another [e.g. the body of a vehicle may be a live part of the auxiliary network but an exposed conductive part of the Power Circuit].

NOTE 2: For the specification of the IPXXB test finger, see ISO 20653 or IEC 60529.

2.18 Auxiliary Circuit

The Auxiliary Circuit (Network) consists of all those parts of the electrical equipment used for signalling, lighting or communication and optionally to operate the IC engine.

2.18.1 <u>Auxiliary battery</u>

The auxiliary battery supplies energy for signalling, lighting or communication and optionally to the electrical equipment used for the IC engine. A galvanically isolated DC to DC converter powered by the traction battery (2.6.3) may be used as a substitute for the auxiliary battery. Voltage of the auxilarry battery or DC/DC converter must be under 60V.

2.18.2 <u>Auxiliary Ground</u>

Auxiliary Ground is the ground potential of the Auxiliary Circuit. Auxiliary Ground must have a robust connection to Chassis Ground.

2.19 Driver Master Switch

The Driver Master Switch (DMS) is a device to energise or de-energise the Power Circuit under normal operating conditions:

• with the exception of all electrical equipment needed to run the IC engine; and

• with the exception of the systems needed — to monitor the isolation resistance between Chassis Ground and Power Circuit and — to monitor the maximum voltage between Chassis Ground and Power Circuit Ground.

2.20 Safety indications

Safety indications must clearly show the “Live” or “Safe” condition of the Power Circuit. “Live” means that the Power Circuit is energised and “Safe” means that the Power Circuit is off.

ARTICLE 3 - Electrical equipment and safety provisions

3.1 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 (2.9) 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.

Figure 1: 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 <u>must use the highest standards for road going cars as a minimum electrical safety standard</u>.

3.2 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 (3.4.2) 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.

3.3 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).

3.4 Rechargeable Energy Storage System (RESS)

3.4.1 <u>Design and installation</u>

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 fulfil crash test requirements and must be approved by the FIA.
c) A crash test with a dummy RESS is mandatory. The dummy must have an identical weight and stiffness as the original RESS. It should include all components except the cells, which have to be replaced by a dummy with size and density as cells.
d) 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.
e) Crash test standards are defined in the respective class and by the FIA Safety Department
f) 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.

g) 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 give by the cells supplier) Gas must be evacuate at the rear of the car.
h) 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, …)
i) The RESS must include two independent systems to prevent overcurrent.
j) All accessible conductive parts of the RESS and of the wiring must have double isolation.
k) On each compartment belonging to the Power Circuit the symbols warning of “High Voltage” must be displayed (see 3.1 e).
l) Cable insulation must have a service temperature rating of at least -20 °C to +150 °C.

3.4.2 Clearance and creepage distance

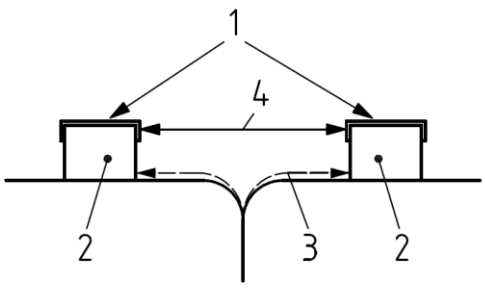
This sub-clause taken from ISO 6469-1:2009 deals with the additional leakage-current hazard between the connection terminals of a RESS, including any conductive fittings attached to them and any conductive parts (2.16), due to the risk of electrolyte or dielectric medium spillage from leakage under normal operating conditions (see Figure 2).

This sub-clause does not apply to maximum working voltages (2.8) of the Power Circuit (2.13) 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:
   $d \geq 0.25\ U + 5$, 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 (2.15) and the electric chassis ground (2.14):
   $d \geq 0.125\ U + 5$, 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 (2.11) between conductive surfaces shall be a minimum of 2.5 mm.



1 conductive surface
2 connector terminal (RESS pack or RESS)
3 creepage distance
4 clearance

Figure 2: Creepage distance and clearance

3.4.3 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.

3.4.4 Specific provisions for Batteries

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

3.4.4.1 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 event 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 3.4.4.2.

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 (3.4.4.2) 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.

3.4.4.2 Battery Management System

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

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

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

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

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

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

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

3.4.5 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.

3.4.6 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.

3.5 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.

3.6 Electric motors

3.6.1 Capacitive coupling

a) Capacitive couplings between a voltage class B (2.9) potential and electric chassis (2.14) 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 (2.15) and the electric chassis (2.14) shall be < 0.2 Joule at its maximum working voltage (2.8). 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 C_C (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: $U_{ac} = U_{INF} \frac{C_C}{C_B + C_C}$.
   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 C_B (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:

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

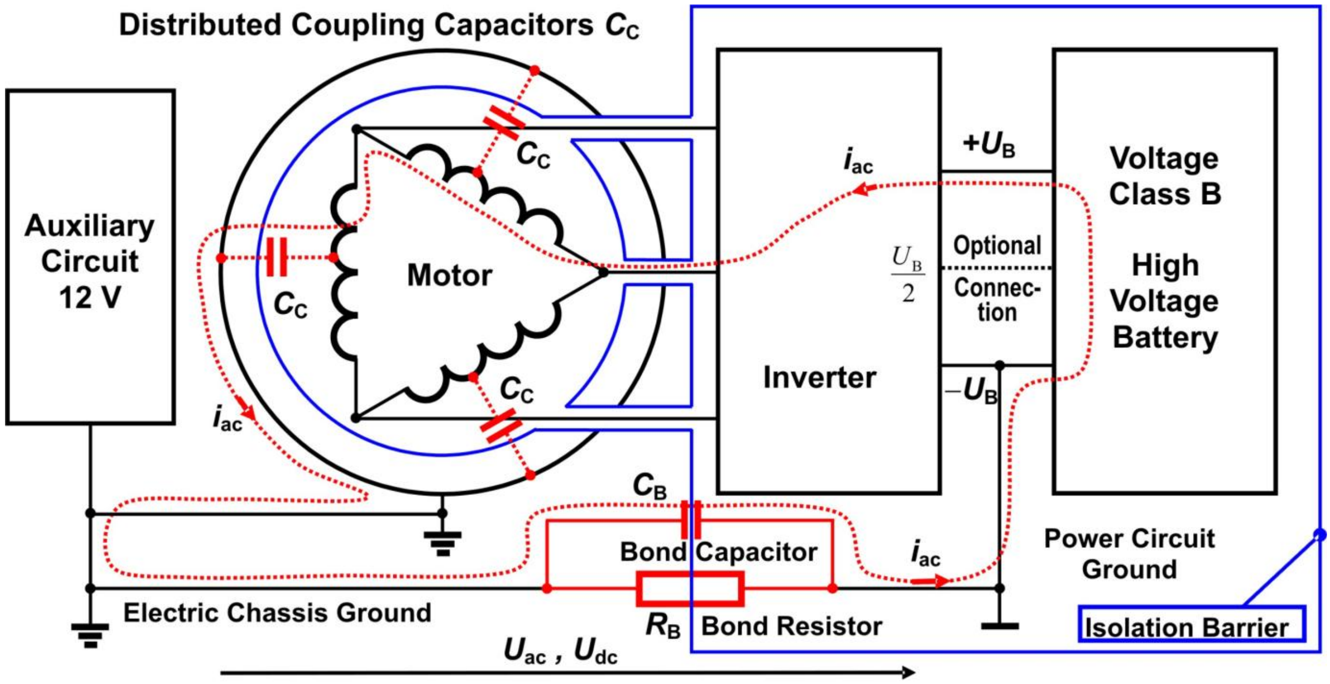


Figure 3: Non-conductive inverter case and battery compartment. Due to distributed capacitances between stator windings, rotor and case capacitive coupling results in an AC current i_{ac} flow across the isolation barrier between the Power Circuit and the electric chassis. A bond capacitor C_B of an 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.

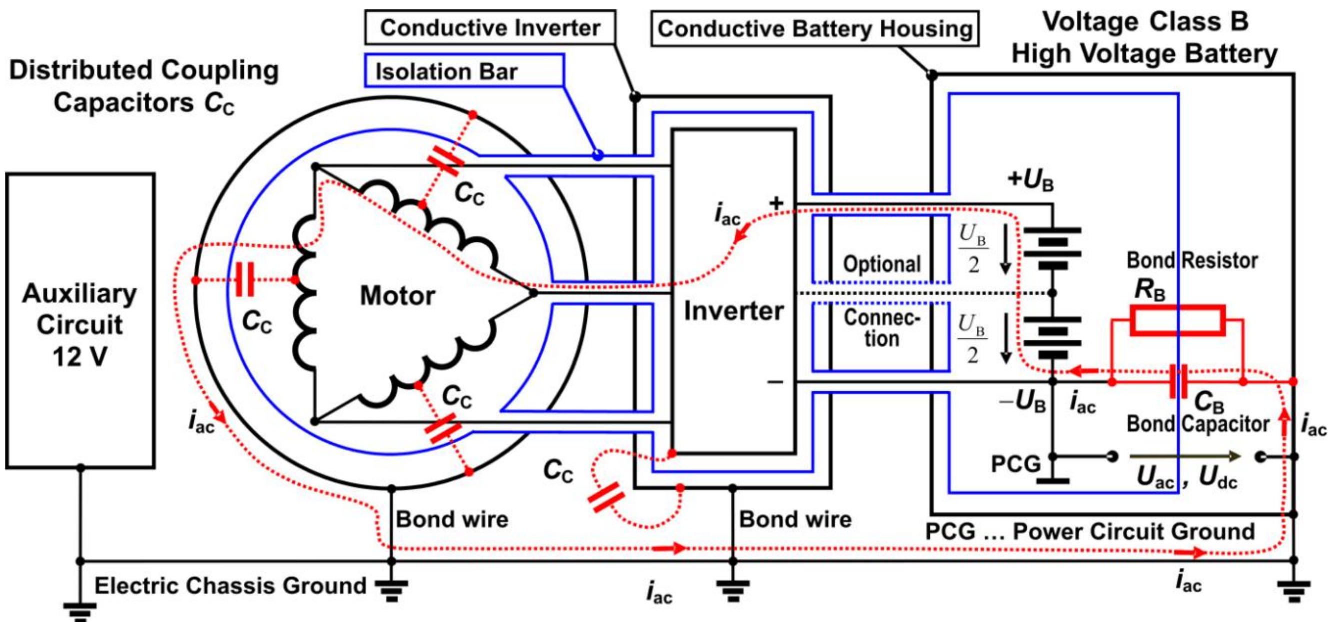


Figure 4: The conductive inverter case and battery compartment is bonded to the Electrical Chassis Ground. The bond resistor R_B and capacitor C_B are connected from the Electrical Chassis Ground to the Power Circuit Ground, which is, in this case, the battery minus $-U_B$.

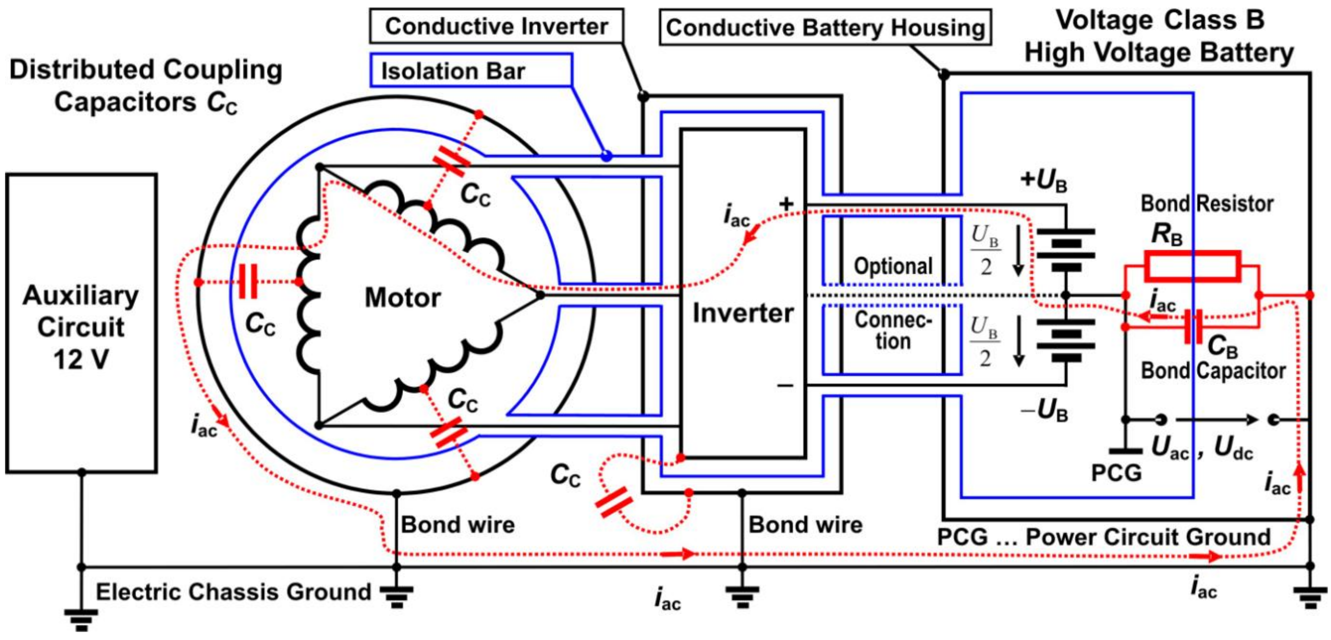


Figure 5: The conductive inverter case and battery compartment is bonded to the Electrical Chassis Ground. The bond resistor R_B and capacitor C_B are connected from the Electrical Chassis Ground to the Power Circuit Ground, which is, in this case, 50 % of the battery voltage $+U_B$.

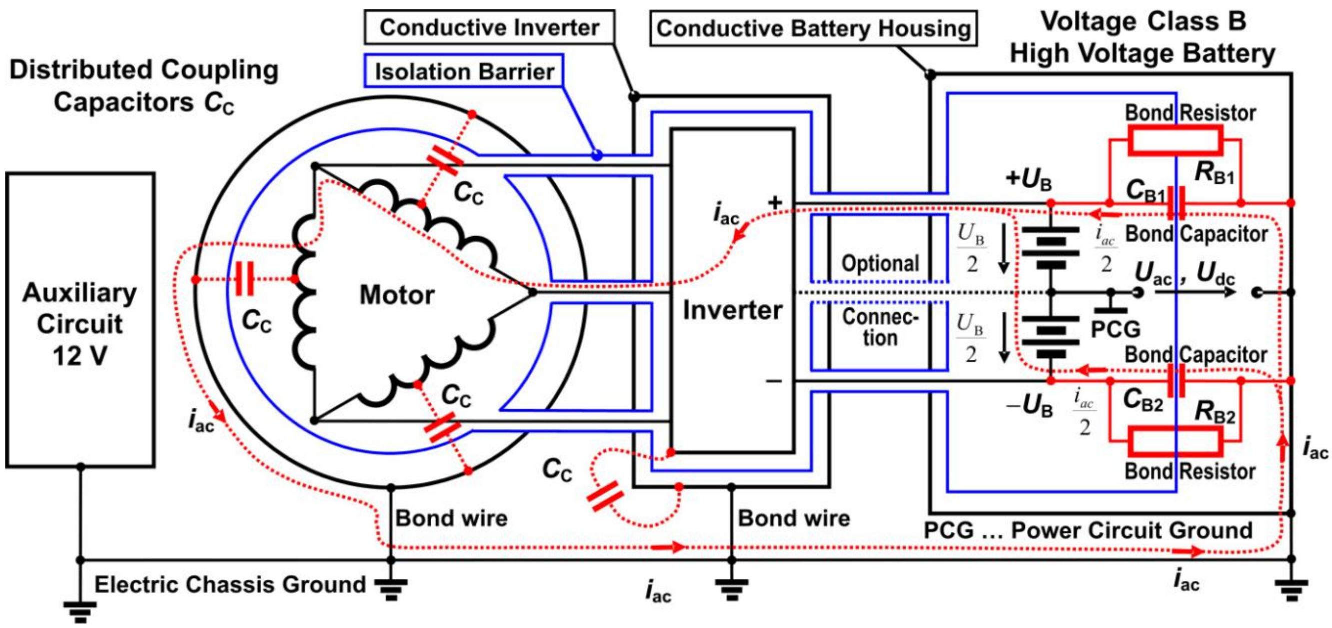


Figure 6: The conductive inverter case and battery compartment is bonded to the Electrical Chassis Ground. The bond resistors R_{B1} and R_{B2} and the bond capacitors C_{B1} and C_{B2} are connected from the Electrical Chassis Ground to the battery terminals $+U_B$ and $-U_B$ resulting in a Power Circuit Ground at 50 % of the battery voltage $+U_B$.

d) The bond resistor R_B (see Figure 3, Figure 4 and Figure 5, optionally: $R_B = \frac{R_{B1} \cdot R_{B2}}{R_{B1} + R_{B2}}$, see Figure 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.

3.7 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.

3.8 Equipotential bonding

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

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

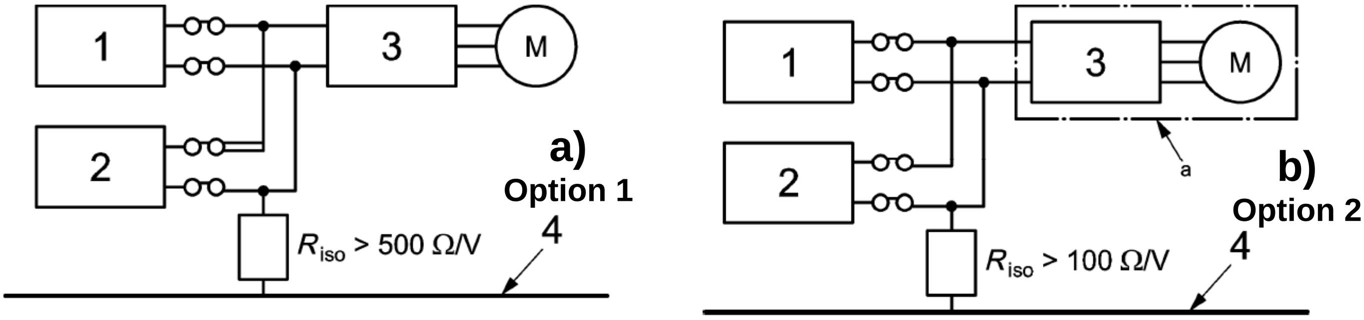
c) Any components that require equipotential bonding will be connected to the Main Ground Point (2.14.1) with a resistance to prevent a dangerous touch voltage (30 V AC) given an AC coupling fault at a certain level of parasitic capacitance.

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.

3.9 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 (2.8).

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.



1…fuel cell system, 2…traction battery, 3…inverter, 4…vehicle electric chassis, a… AC circuit

Figure 7: Isolation resistance requirements for voltage class B systems with conductively connected AC and DC circuits. **NOTE:** The figure is based on 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 3.9.1 is applied to the AC circuit.

3.9.1 <u>Additional protection measures for the AC circuit</u>

One or a combination of the following measures, in addition to or instead of the basic protection measures as described in (3.1), 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.

3.10 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 (2.9) 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 paragraph 3.9.
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.

c) A device to protect people against electric DC shocks is,

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

3.11 Power Circuit

In cases where the voltage of the Power Circuit (2.13) belongs to voltage class B (2.9), this Power Circuit must be electrically separated from the chassis (body) and from the Auxiliary Circuit by adequate insulators.

3.12 Power Bus

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.

3.13 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 (3.10) will serve as trigger device for an isolation fault.

c) The outer covering of cables and harness for voltage class B (2.9) 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.

3.14 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.

3.15 Insulation strength of cables

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

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

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

d) Every part of the electrical equipment, including wires and cables, must have a minimum insulation resistance between all live components and the bodywork.
- For equipment belonging to the voltage class B system, the insulation resistance to the chassis must be at least 500 Ω/V (ISO/DIS 6469-3.2:2010).
- The measurement of the insulation resistance must be carried out using a DC voltage of at least 100 volts. Tests must be carried out to validate and quantify the insulation resistance of the vehicle in wet conditions.

3.16 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 belts fastened and the steering wheel in place.
- The DMS must be separate from the General Circuit Breaker.

3.17 General Circuit Breaker

a) All vehicles must be equipped with a General Circuit Breaker (2.13.3) 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 the General Circuit Breaker MUST instantaneously:
- ➢ isolate both + Ve and – Ve 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 +Ve and –Ve 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.

3.18 Emergency Stop Switches

a) One Emergency Stop Switch (2.13.4) must be easily operable by the driver when seated normally in the vehicle with belts 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.

3.19 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.

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

3.20 Charging units (off board)

a) The mains galvanically isolated charging unit (charger) for electric or plug-in hybrid electric vehicles (see Art. 2.2.2) has to fulfil all safety provisions set out in the applicable rules in the country in which the respective event takes place.
b) The charger must have a fuse (fuses) to protect the charging cable(s).
c) 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.)
d) Movement of the car must be automatically inhibited while connected to the grid.
e) DC charging cable connector(s) must be polarized and arranged so that incorrect polarity connection is impossible.
f) The charger main switch must disconnect ALL power current-carrying supply conductors.
g) The vehicle traction system must be checked for ground faults before charging commences.
h) The vehicle traction system must not be energized while the battery is under charge.
i) Charging must always be done under the supervision of the BMS (2.6.8).

3.21 Auxiliary battery

a) The auxiliary battery must never be used to recharge the traction battery. Throughout the duration of the event, 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 (2.6.3) 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).

3.22 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).
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).
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.

3.23 Fire extinguisher

a) Fire extinguishers are compulsory at speed events and must be in compliance with Appendix J according to the relevant Class.
b) Only ABC extinguisher types usable for fuel extinction, compatible with the chemistry of the installed RESS and specified for the voltage level of the Power Bus, are allowed.
c) More than one type of fire extinguisher may be necessary to cope with the different types of flammable components.

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

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

3.25 <u>References</u>

ISO 6469-1:2009:	Art. 2.2, Art. 2.8, Art. 2.9, Art. 3.4.2, Art. 3.6.1 and Art. 3.10
ISO/DIS 6469-3.2:2010:	Art. 1.2.4, Art. 2.7, Art. 2.17, Art. 3.1, Art. 3.2, Art. 3.6.1, Art. 3.7 Art. 3.9, Art. 3.9.1, Art. 3.10 and Art. 2.15
ISO 7010:	Art. 3.1
ISO 8713:2005:	Art. 2.13.1.1
ISO 20653:	Art. 2.17 and Art. 3.3
ISO/DIS 14572:2010:	Art. 3.13
IEC/TS 60479-1:2005:	Art. 3.9
IEC/TS 60479-2:2005:	Art. 3.9
IEC 60529:	Art. 2.17
IEC 60664:	Art. 3.2
IEC 60664-1:	Art. 3.4.2
IEC 60950-1:	Art. 3.6.1
EN 13447:	Art. 2.1
US (8.75R5.75/12.5):	Art. 3.13
Japan (8.8R5.8/12.5):	Art. 3.13

ECE-R 100/01 (WP.29/2010/52) Dec. 2010, Annex 4: Art. 3.6.1

Safety Requirements

Safety structure & Crash absorbers

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1. Summary

For the Formula E Championship 2013, the FIA plans to introduce new standard safety structures for the future E-cars. These safety structures are subject to the safety requirements described in this report.

The safety structure, consisting of a CFRP-Safety cell, has to meet the FIA safety standards. The safety structures have to meet the requirements according the FIA Appendix J Article 277 Free Formula Technical Regulations and its links to Article 258A Technical Regulations for Sports Cars, Article 275 2012 Formula 3 Technical Regulations and 2011 F1 Technical Regulations.

According to these requirements the Formula E safety structures will be subjected to the following tests:

- FIA safety cell static side load test,
- FIA energy storage compartment(s) static side load test,
- FIA energy storage compartment(s) static vertical load test,
- FIA frontal absorbing structure side load test,
- FIA frontal absorbing structure impact test,
- FIA main rollover structure tests,
- FIA rear absorbing structure side load test,
- FIA rear absorbing structure impact test,
- FIA side absorbing structure impact test,
- FIA dynamic T-bone Impact test,
- FIA steering column test.

A trolley test will be carried out with the frontal, the side and the rear absorbing structures. The test for the frontal crash absorber will be carried out with a velocity of 15 m/s and a trolley mass of 850 kg.

The test for the rear crash absorber will be carried out with a velocity of 11 m/s and a trolley mass of 850 kg.

For the two side crash absorbers a trolley with a mass of 850 kg and a velocity of 10 m/s will be used.

2. Introduction

The following images give an overview of all crash relevant safety structures. Depending on the type of crash test any numbers of these components are subject to FIA approval.

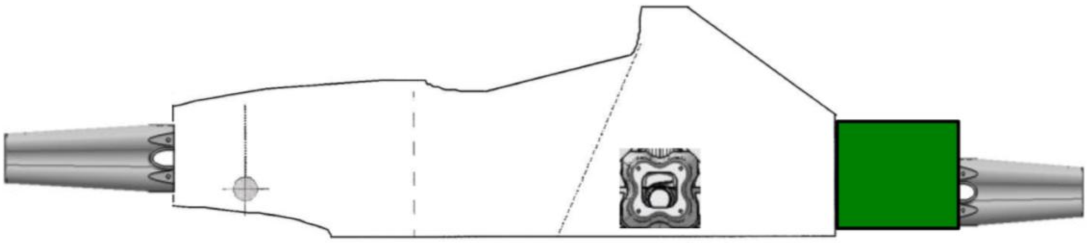

Figure 1 Safety cell with crash relevant safety structures, side view

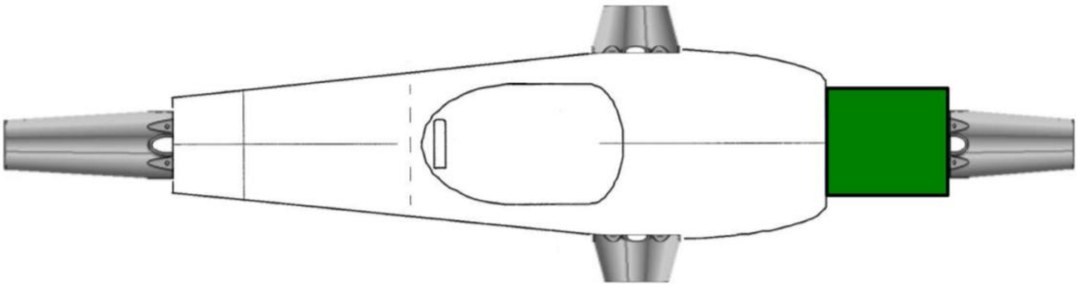

Figure 2 Safety cell with crash relevant safety structures, top view

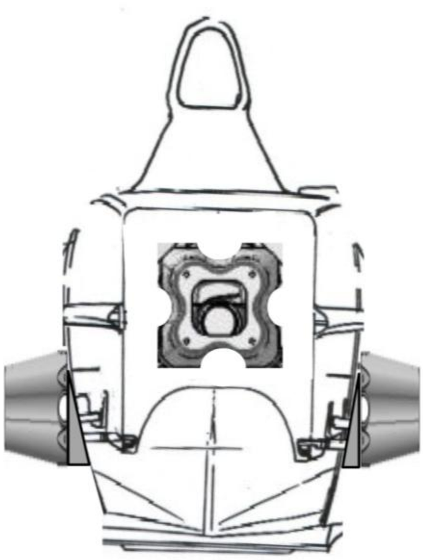

Figure 3 Safety cell with crash relevant safety structures, front view

3. Homologation

3.1 Overview

The following safety structures are subject of FIA approval:

- Safety cell
- Energy storage compartment(s)
- Frontal absorbing structure
- Main rollover structures
- Rear absorbing structure
- Side absorbing structure
- Steering column

For a detailed description of the requirements and test set-up, please refer to the Annex B: Procedure for the Approval of “Safety Structures for Sports Cars, Formula 1 Cars, Formula 3 Cars" provided by the FIA.

3.2 Safety cell

3.2.1 General requirements

The safety cell must be successively subjected to the static side load tests defined in section 3.2.2. The safety cell used for the tests must be in its final manufacturing stage. The safety cell, dismounted from the test rig, must be made available to the technical delegate for photos and weighting at the most suitable time for the testing centre.

3.2.2 Static side load tests

3.2.2.a Front static side load test:

A constant transverse and horizontal load must be applied through a ball-joint at the centre of area of a pad on a vertical plane passing halfway between the front axle centreline and the top of the front rollover structure.

3.2.2.b Central static side load test:

A constant transverse and horizontal load must be applied through a ball-joint at the centre of area of a pad in the cockpit area on a vertical plane passing through the centre of the seat belt lap strap fixings (middle position if several positions possible).

3.2.2.c Loads to be applied:
50 kN

3.2.2.d Conditions for the load application:

The pads must:

- be 100 mm wide and 300 mm high,
- conform to the shape of the safety cell at that section,
- be placed against the outermost sides of the safety cell with the lower edge of the pad at the lowest part of the safety cell at that section.

The edges in contact with the safety cell must be rounded with a radius of 3 mm maximum.
It is permissible to place rubber, maximum 3 mm thick, between the pads and the safety cell.
The load must be applied in less than 3 minutes and maintained for a minimum of 30 seconds.

3.2.2.e Support:

The safety cell must be fixed onto the test device in such a way that its transversal displacement is left free and its rigidity not modified. This transversal displacement must be blocked through a pad identical to the one used to apply the load and positioned symmetrically relative to it.

Lashing straps will be used to secure the safety cell to the test device, longitudinal displacement must be prevented through pads at each end of the safety cell (see Figure 4). The pads at both ends of the safety cell must have enough clearance so that the rigidity of the safety cell is not modified.

3.2.2.f Required safety structures: Safety cell

3.2.2.g Acceptance criteria:

The test is passed if the following criteria are fulfilled:

1. No structural failure of the inner or outer surfaces of the safety cell.
2. The permanent deformation, measured over the load axis at the level of the top of the pads across the inner surfaces of the safety cell, must be less than 1 mm after the load has been released for 1 minute.

The displacement sensors must be positioned in between the inner surfaces. Deformation of the inner surfaces will be measured before and after the test.

If measurement across the inner surfaces is not possible, the measurement shall be taken on the external surfaces as close as possible to the top of the pads.

The test centre must provide the load / deformation graph for each test. The graph will be obtained via sensors inside the hydraulic cylinder used to apply the load.

3.2.2.h Figures:

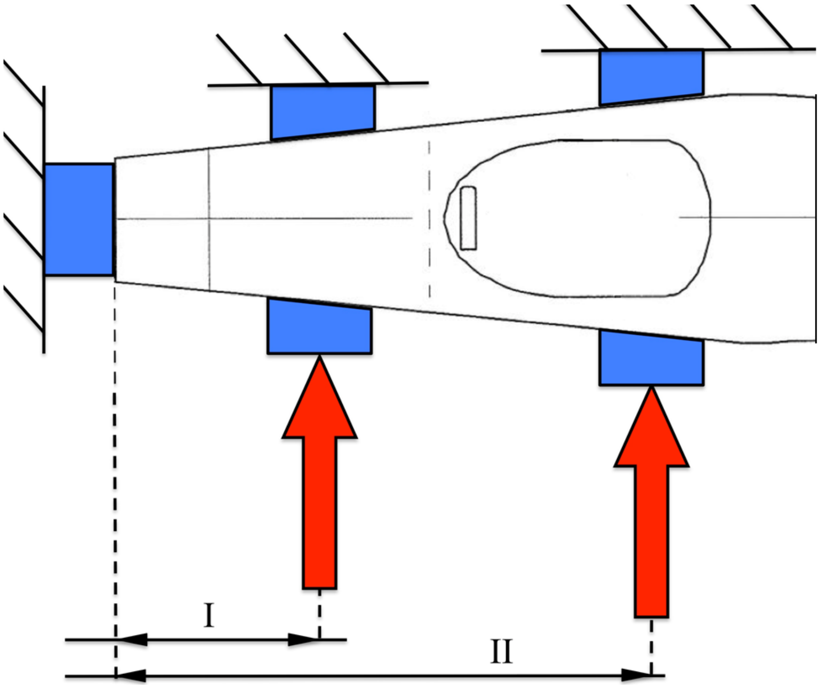

Figure 4 Safety Cell static side load test (schematic diagram)

The safety cell must be subjected to two separate static side load tests.

3.2.2.a Between front axle centreline and top of front rollover structure: I

3.2.2.b Centre of the seat belt lap strap fixings (middle position): II

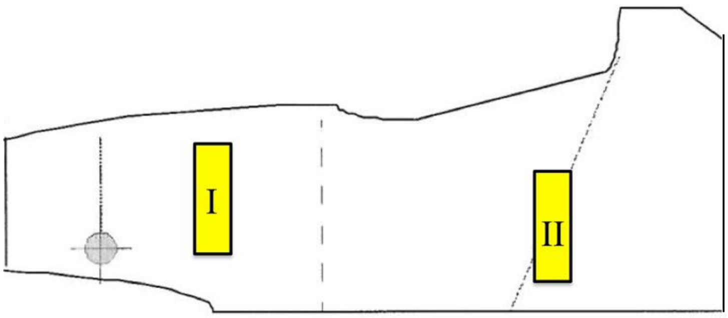

Figure 5 Safety Cell static side load test load application points

3.3 Energy storage compartment(s)

This Article will be applied if external energy storage compartments will be used.

3.3.1 General requirements

The energy storage compartment(s) must be subjected to the static side load test defined in sections 3.2.2. The energy storage compartment(s) used for the tests must be in its final manufacturing stage.

The energy storage compartment(s), dismounted from the test rig, must be made available to the technical delegate for photos and weighting at the most suitable time for the testing centre. The test must be possible in any location of the energy storage compartment.

3.3.2 Static load tests

3.3.2.a Longitudinal, tranverse and vertical static load tests:

- Longitudinal test :
  A constant longitudinal and horizontal load must be applied through a ball-joint at the centre of area of a pad in any location of the energy storage compartment(s) define by FIA.

- Transverse test :
  A constant transverse and horizontal load must be applied through a ball-joint at the centre of area of a pad in any location of the energy storage compartment(s) define by FIA.

- Vertical test :
  A constant vertical load must be applied through a ball-joint at the centre of area of a pad in any location of the energy storage compartment(s) define by FIA.

3.3.2.b Loads to be applied: 50 kN

3.3.2.c Conditions for the load application:

The pad must:

- be 100 mm wide and 300 mm high,
- conform to the shape of the safety cell at that section,
- be placed against the outermost sides of the safety cell with the lower edge of the pad at the lowest part of the safety cell at that section.

The edges in contact with the safety cell must be rounded with a radius of 3 mm maximum.
It is permissible to place rubber, maximum 3 mm thick, between the pads and the safety cell.
The load must be applied in less than 3 minutes and maintained for a minimum of 30 seconds.

3.3.2.d Support:

The energy storage compartment(s) must be fixed onto the test device in such a way that its displacement is left free and its rigidity not modified. This displacement must be blocked through a pad identical to the one used to apply the load and positioned symmetrically relative to it.

Lashing straps will be used to secure the compartment(s) to the test device, longitudinal displacement must be prevented through pads at each end of the compartment (see Figure 8). The pads at both ends of the compartment(s) must have enough clearance so that the rigidity of the compartment(s) is not modified.

3.3.2.e Required safety structures: Safety cell

3.3.2.f Acceptance criteria:

The test is passed if the following criteria are fulfilled:

1. No structural failure of the inner or outer surfaces of the energy storage compartment(s) and safety cell.
2. The permanent deformation, measured over the load axis at the level of the top of the pads across the inner surfaces of the safety cell and the energy storage compartment(s), must be less than 1 mm after the load has been released for 1 minute.

The displacement sensors must be positioned in between the inner surfaces. Deformation of the inner surfaces will be measured before and after the test. If measurement across the inner surfaces is not possible, the measurement shall be taken on the external surfaces as close as possible to the top of the pads.

The test centre must provide the load / deformation graph for each test. The graph will be obtained via sensors inside the hydraulic cylinder used to apply the load.

3.3.2.h Figures:

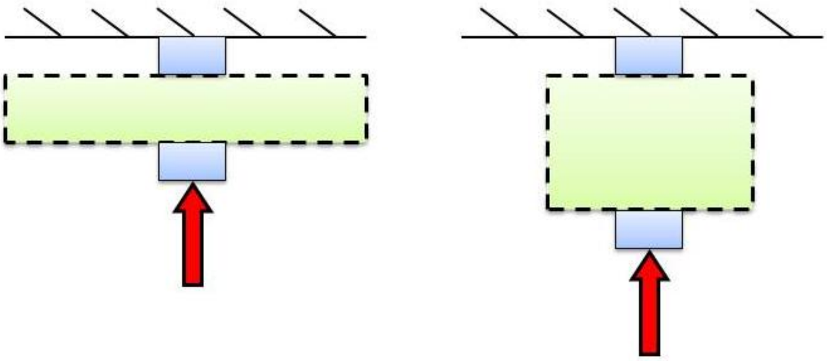

Figure 6 FIA homologation, energy storage compartment(s) static side load test (schematic diagram)

3.2.2c Centre of area of the energy storage section in side elevation

3.4 Frontal absorbing structure

3.4.1 General requirements

The frontal absorbing structure, mounted on the safety cell, must be subjected successively to a static side load test (section 3.4.2) and an impact test (section 3.4.3). The frontal absorbing structure and the safety cell used for the tests must be in their final manufacturing stage.

3.4.2 Static side load test

Prior to the test, the frontal absorbing structure must be made available to the technical delegate for photos, weighing and inspection.

3.4.2.a Load to be applied:

A constant transverse and horizontal load of 40 kN, passing through a vertical and transverse plane situated 550 mm forward of the front axle centreline, must be applied through a pad to one side of the frontal absorbing structure fixed to the complete safety cell.

3.4.2.b Condition for the load application:

The pad is identical to the one used in the static side load tests on the safety cell. The centre of area of the pad must pass through the vertical and transverse plane mentioned above and the midpoint of the height of the structure at that section.

The load must be applied in less than 3 minutes and maintained during at least 30 seconds.

3.4.2.c Support:

The complete safety cell must be solidly secured to a flat plate without increasing the strength of the attachments being tested, and must be blocked laterally through a pad of identical dimensions to the one used to apply the load.

The pad will be positioned at the frontal crash absorber adapter after the junction with the frontal absorbing structure.

To prevent longitudinal motion and rotation about the vertical axis, the safety cell will also be fixed at the bell housing mounting points.

3.4.2.d Required safety structures:

Safety cell, main rollover structure, frontal crash absorber, frontal crash absorber adapter.

3.4.2.e Acceptance criteria:

The structure must be able to be normally dismounted and mounted back after the test. There must be no failure of the structure or of any attachment between the structure and the safety cell, or of the safety cell itself.

3.4.2.f Figures:

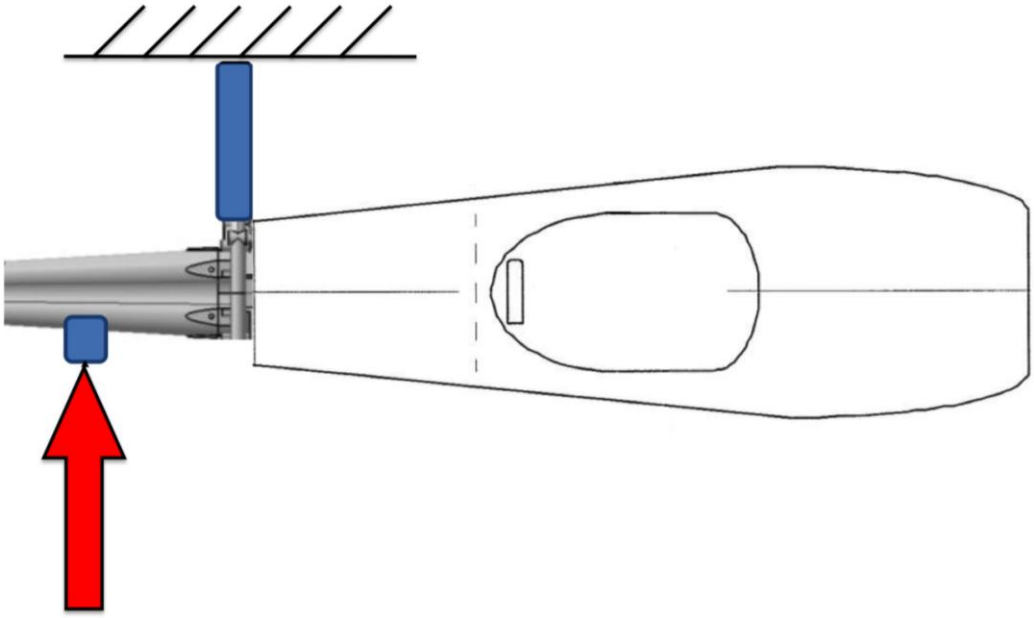

Figure 7 Frontal absorbing structure, support and load application, top view

The complete safety cell must be solidly secured to a flat plate and must be blocked laterally through a pad, positioned at the adapter directly behind the crash absorber. A load of 40 kN, passing through a vertical and transversal plane situated [to be defined – around 500 mm) forward of the front axle centreline, must be applied to one side of the frontal absorbing structure.

3.4.3 Impact test I

3.4.3.a General requirements:

The frontal absorbing structure, mounted on the complete safety cell, must be subjected to an impact test against a solid, vertical barrier placed at right angles to the longitudinal axis of the car. The frontal absorbing structure and the complete safety cell must previously have been subjected to the static side load test.

Any mechanical component normally situated between the structure and the safety cell (braking system, steering, etc.) must be installed for the impact test.

3.4.3.b Test conditions:

The complete safety cell must be solidly fixed to the trolley through its bell housing and rocker point mounting points, without increasing its impact resistance.

An additional retaining device between the safety cell and the trolley is permitted (e.g. strap). The combined centre of gravity of the safety cell and trolley should pass through the centre of the crash absorber (see Figure 7).

For the impact test the following test set up is required:

- In the energy storage compartment(s) must be installed and carry the same mass as in the real car.
- A dummy weighing at least 75 kg must be installed in the safety cell with the safety belts fastened. With the safety belts unfastened, the dummy must be able to move forwards freely in the cockpit.
- The fire extinguisher bottles must be installed and filled up with extinguishant.
- If a supplementary battery (same weight as the one installed in the real car) is necessary, it must be installed for the test in its assigned collocation.
- The servo pump and the servo pump fastener used in the real car must be installed.

Prior to the test, the battery and the extinguishers must be dismounted and made available to the technical delegate for photos and weighing.

The dummy will be installed once the technical delegate has inspected the safety belts fixings.

The total mass M_T of the trolley and the structures to be tested must be 850 kg with a tolerance of +1% / -0 and the impact speed must be equal to 14 m/s.
Note: The Impact speed is measured immediately before impact.

<u>3.4.3.c Required safety structures:</u>

Safety cell, skid block, electric motor dummy any mechanical component normally situated between the front absorbing structure and the safety cell, frontal crash absorber, frontal crash absorber adapter, energy storage compartment, steering rack, supplementary battery (if used), fire extinguisher, servo pump.

The electric motor dummy must be of a similar type as the electric motors used in the real car, but not identical.

<u>3.4.3.d Acceptance criteria:</u>

1. The peak deceleration over the first 150mm of deformation must not exceed 10g.
2. The peak deceleration over the first 60kJ energy absorption does not exceed 20g.
3. The average deceleration of the trolley must not exceed 40 g. It is calculated from the unfiltered deceleration data, from the instant of impact (T0 defined by electronic contact) to the first instant the trolley speed is less than 0 m/s (V0).
4. The deceleration in the chest of the dummy must not exceed 60 g for a cumulative time of more than 3 ms (Σt_i measured at 60g ≤ 3 ms) The deceleration in the chest of the dummy (the resultant of the decelerations measured along the three axes) must be measured with channel frequency class CFC 180.

OR:

1. The peak force over the first 150mm of deformation does not exceed 75kN.
2. The peak force over the first 60kJ energy absorption does not exceed 150kN.
3. The average deceleration of the trolley does not exceed 40g.
4. The peak deceleration in the chest of the dummy does not exceed 60g for more than a cumulative 3ms, this being the result data from three axes.

Furthermore there must be no damage to the safety cell and RESS compartments or to the mountings of the safety belts or fire extinguishers or battery.

The unfiltered acceleration data of the trolley used as an acceptance criterion is obtained by calculating the average of unfiltered decelerations measured by at least two single axis sensors located symmetrically about the longitudinal centreline of the trolley (direction of impact).

The test centre must also provide the graph of the deceleration of the trolley filtered with channel frequency class CFC 60.

After the test, the frontal absorbing structure must be dismounted from the safety cell.
Note: After the test, the technical delegate must void the FIA homologation labels of the safety belts. The safety belts used for the test will not be re-usable for racing.

<u>3.4.3.e Figures:</u>

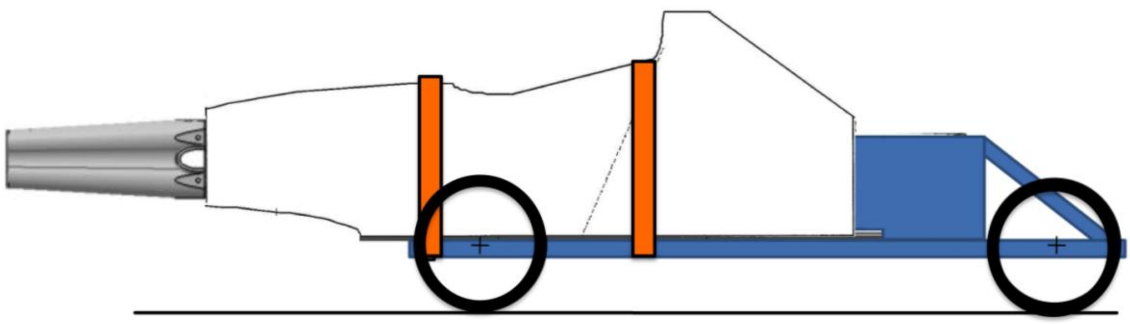

Figure 8 Impact test, support and load application, side view

The complete safety cell must be solidly fixed to the trolley through its rearward fixings (e.g. motor fixings??). A lashing strap must be added at the front edge of the safety cell. The combined CoG of the safety cell and trolley should pass through the centre of the crash absorber.

3.4.4 Impact test II

A 50mm (+/-1mm) thick aluminum plate should be attached to the front bulkhead of the Safety cell through the mounting points of the frontal impact absorbing structure. The plate should:

- measure 375mm (+/-1mm) wide x 375mm (+/-1mm) high;
- be fitted symmetrically about the car centre line;
- be fitted in a vertical sense in order to ensure force distribution is similar to that measured during the first frontal test;
- have four M10 x 30mm holes in the outer face arranged in a 125mm square pattern about its geometric centre.

The test laboratory will then fit a 5mm thick 300mm x 275mm steel plate to these holes using a 5mm washer stack.

A dummy of the RESS with the same dimension and weight must be used.

A dummy weighing at least 75kg must be fitted with safety belts fastened.

However, with the safety belts unfastened, the dummy must be able to move forwards freely in the cockpit. For the purposes of this test, the total weight of the trolley and test structure shall be 850kg (+1%/-0) and the velocity of impact not less than 14 metres/second.

The impact wall must be fitted with six 60kN crush tubes which develop a combined 360kN as follows:

- 2 x 60kN from T-zero to T-end, directed into the two lower M10 attachment points.
- 2 x 60kN from T-100mm to T-end, directed into the two upper M10 attachment points.
- 2 x 60kN from T-200mm to T-end, directed into the sled.

The resistance of the test structure must be such that following the impact there is no damage to the safety cell or to the mountings of the safety belts.

3.5 Main rollover structure

3.5.1 General requirements

Each rollover structure must be subjected successively to the static load tests. During the tests the rollover structures must be secured to the safety cell. Prior to any test, the rollover structures must be made available to the technical delegate for photos and weighing.

The rollover structures, the devices securing them to the safety cell, and the safety cell must be in their final manufacturing stage.

3.5.2 Test set-up

3.5.2.a Conditions for the load application:

The resultant of the specified loads shall be applied through a circular rigid flat pad with a diameter of 200 mm, positioned perpendicularly to the axis of this resultant.

The pad must have no degree of freedom about the load generating device (e.g. jack) onto which it is secured.

It is permitted to place rubber with a maximum thickness of 3 mm between the pad and the safety cell.

If the rollover structure is not directly accessible, the load may be applied onto the safety cell, through an adapter fitting the cell's local shape. The area of the contact surfaces of this adapter must be less than or equal to that of a disc with a diameter of 200 mm.

3.5.2.b Support:

The safety cell must be supported on its underside on a plate that has the contour of the bottom side of the safety cell. Additionally, the safety cell is fixed through its rearward mounting points and wedged laterally by pads 100 mm wide and 300 mm high.

For the lateral fixing the pads required for the static side load test of the safety cell may be used. The rear mount points of the main rollover structure which are normally fixed on the gearbox may be fixed on the test rig.

3.5.2.c Required safety structures: Safety cell, main rollover structure

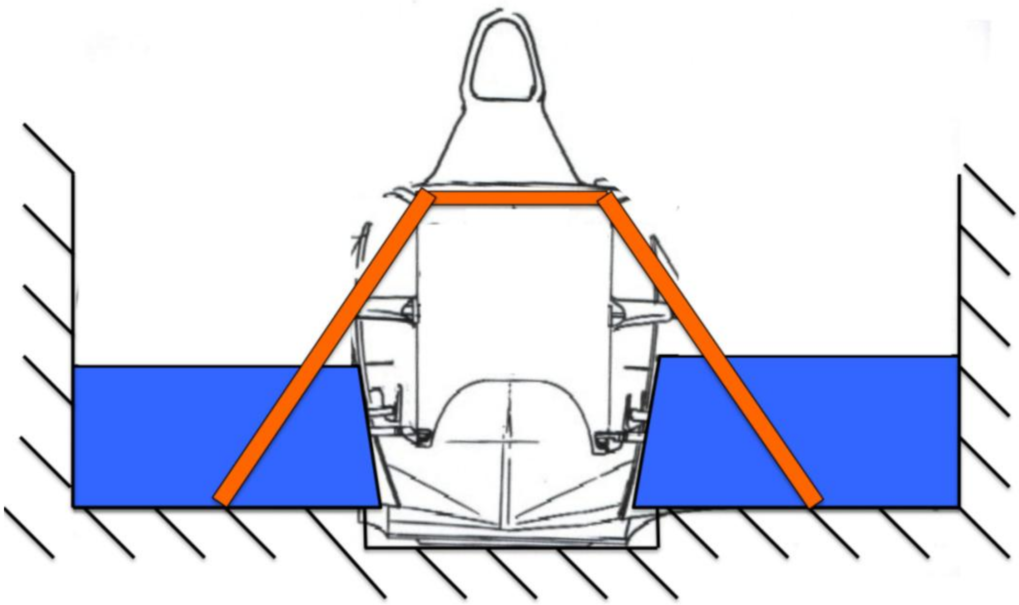

Figure 9 Main rollover structure, support, front view

The safety cell must be supported on its underside on a contoured plate, fixed to the test rig through its (e.g. electric motor) mounting points and wedged laterally by pads 100 mm wide and 300 mm high.

3.5.3 Front structure – vertical load

A vertical load of 75 kN must be applied on the top end of the A-pillar, downward and in front of the driver. There will be no adapter used to apply the load.

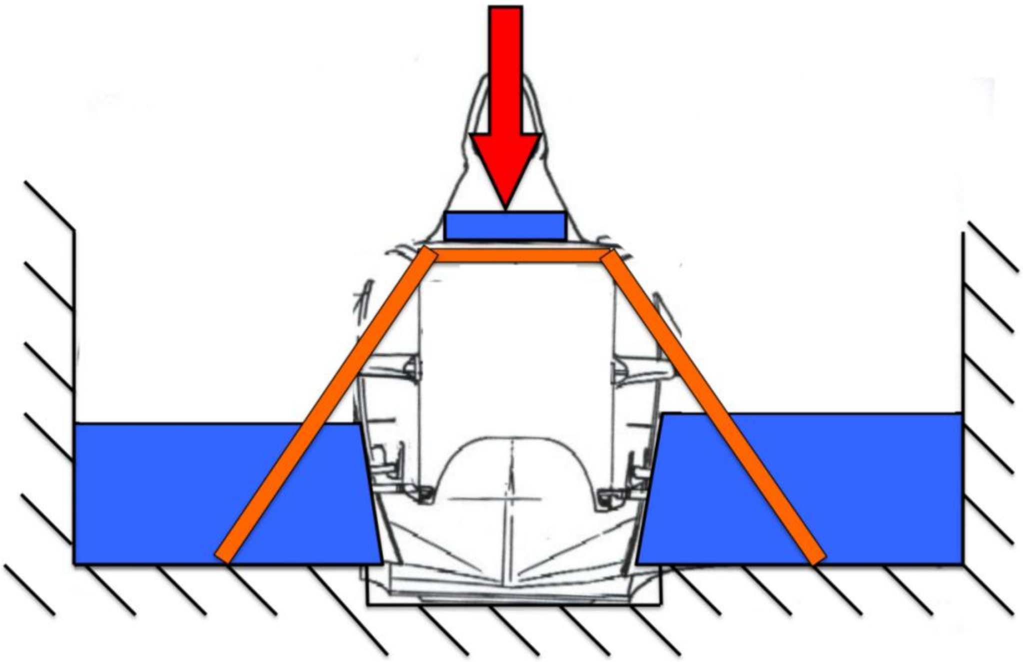

Figure 10 Front rollover structure, load application A-pillar, front view

3.5.4 Rear structure combined load

The resultant of the following loads must be applied on top of the structure, behind the driver:

- 60 kN longitudinally rearward
- 50 kN transversally inward
- 90 kN vertically downward.

As the combined load has a component in transversal direction, the geometry of the main rollover structure does not allow for a load application at the centreline of the driver's seat. Therefore, the resultant load is applied at the rear left edge of the main rollover structure.

To apply the load, it is necessary to use an adapter fitting the local shape of the main rollover structure. The area of the adapter surfaces in contact with the main rollover structure must be less than or equal to that of a disc with a diameter of 200 mm.

Prior to the test the FIA will be provided with drawings of the adapter in order to approve the adapter geometry.

3.5.5 Acceptance criteria

When the target load of any of the above tests is reached, the deformation measured along the axis of load application must be less than 50 mm. Any structural failure must be limited to 100 mm below the top of the rollover structure when measured vertically. For these tests, a plastic deformation without a crack or a fracture is not considered as a structural failure.

The deformation along the axis of load application is measured at the inside of the main rollover structure at a point as close to the pad as possible. The test centre must provide the load / deformation graph for each test. The technical delegate may require any complementary deformation measurement (e.g. deformation of test rig) if he deems necessary.

For the rear structure longitudinal load test the lowest point of contact between the disc with a diameter of 200 mm and the main rollover structure is likely to be about 110 mm below the top of the rollover structure in vertical direction. In this case any structural failure must be limited to 100 mm below the lowest point of contact.

3.6 Rear crash absorbing structure

3.6.1 General requirements

The rear absorbing structure, mounted on the complete safety cell (including any mechanical component normally situated between the rear absorbing structure and the safety cell must be installed), must be subjected successively to a static side load test and an impact test.

The rear absorbing structure and the complete safety cell used for the tests must be in their final manufacturing stage.

3.6.2 Rear absorbing structure static side load test

Prior to the test, the rear absorbing structure must be made available to the technical delegate for photos, weighing and inspection.
F1 regulations article 18.8

<u>3.6.2.a Load to be applied:</u>

A constant transverse and horizontal load of 40 kN , passing through a vertical and transverse plane situated 400 mm rearward of the rear axle centreline, must be applied through a pad to one side of the rear absorbing structure fixed to any mechanical component normally situated between the rear absorbing structure and the safety cell must be installed.

<u>3.6.2.b Conditions for the load application:</u>

The pad is identical to the one used in the static side load test of the front absorbing structure.

The centre of area of the pad must pass through the vertical and transverse plane mentioned above and the mid point of the height of the structure at that section.

The load must be applied in less than 3 minutes and maintained for a minimum of 30 seconds.

3.6.2.c Support:

The complete safety cell must be solidly secured to a flat plate without increasing the strength of the attachments being tested, and must be blocked laterally through a pad of identical dimensions to the one used to apply the load. The pad will be positioned at the gearbox after the junction with the rear absorbing structure. To prevent longitudinal motion and rotation about the vertical axis, the safety cell will also be fixed at the rearward mounting points.

At the discretion of the FIA it may also be acceptable to execute the test without the safety cell. In this case the absorbing structure will be mounted on it adapter and solidly fixed to the test rig.

3.6.2.d Required safety structures:

Safety cell, main rollover structure, any mechanical component normally situated between the rear absorbing structure and the safety cell, rear crash absorber.

At the discretion of the FIA the test may be carried out only with the rear crash absorber.

3.6.2.e Acceptance criteria:

The structure must be able to be normally dismounted and mounted back after the test.
There must be no failure of the structure or of any attachment between the absorbing structure and the safety cell, or of the safety cell itself.

3.6.2.f Figures:

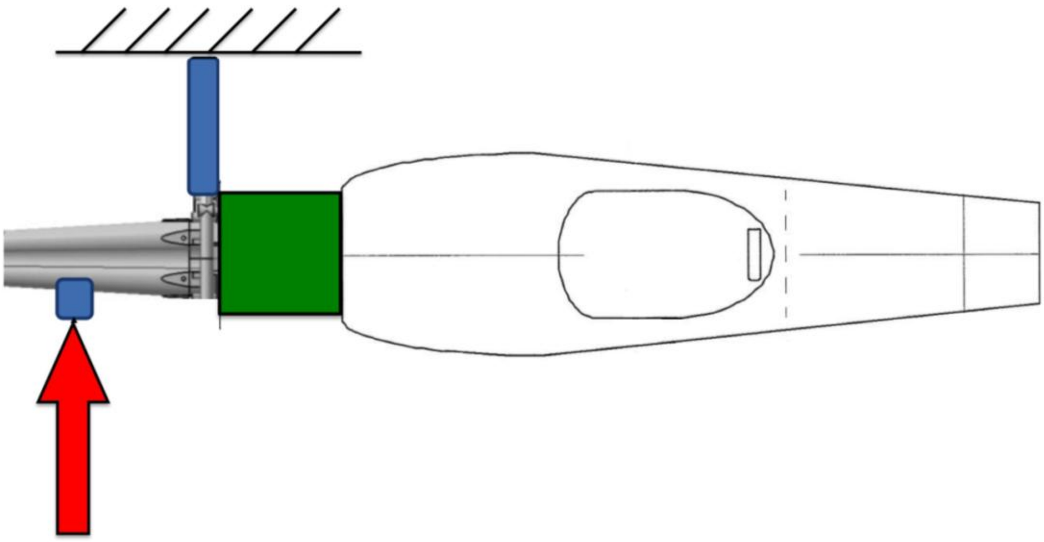

Figure 11 Rear absorbing structure, support and load application, top view
The complete safety cell must be solidly secured to a flat plate and must be blocked laterally through a pad, positioned at the gearbox directly behind the crash absorber. A load of 30 kN, passing through a vertical and transversal plane situated [to be defined – around 500 mm] behind the rear axle centreline, must be applied to one side of the rear absorbing structure.

3.6.3 Rear absorbing structure impact test

3.6.3.a General requirements:

The rear absorbing structure, mounted on the complete safety cell, must be subjected to an impact test against a solid, vertical barrier placed at right angles to the longitudinal axis of the car.

The rear absorbing structure and the complete safety cell must previously have been subjected to the static side load test.

Any mechanical component normally situated between the rear absorbing structure and the safety cell must be installed for the impact test.

3.6.3.b Test conditions:

The complete safety cell must be solidly fixed to the trolley, without increasing its impact resistance.

An additional retaining device between the safety cell and the trolley is permitted (e.g. strap). The combined centre of gravity of the safety cell and trolley should pass through the centre of the rear crash absorber.

For the impact test the following test set up is required:

- A dummy weighing at least 75 kg must be installed in the safety cell with the safety belts fastened. With the safety belts unfastened, the dummy must be able to move forwards freely in the cockpit.
- The fire extinguisher bottles must be installed and filled up with extinguishant.
- Mechanical components e.g. servo pumps, controller used in the real car must be installed.

Prior to the test, the mechanical components and the extinguishers must be dismounted and made available to the technical delegate for photos and weighing.

The dummy will be installed once the technical delegate has inspected the safety belts fixings.

At the discretion of the FIA it may also be acceptable to execute the test without the safety cell. In this case the mechanical component normally situated between the rear absorbing structure and the safety cell and the safety structure will be solidly fixed to the trolley.

The total mass M_T of the trolley and the structures to be tested must be 850 kg with a tolerance of +1/-0% and the impact speed must be equal to 10 m/s.
Note: The Impact speed is measured immediately before impact.

3.6.3.c Required safety structures:

Safety cell, skid block, mechanical components normally situated between the rear absorbing structure and the safety cell, rear crash absorber, fire extinguisher, (if required) servo pump, controller.

At the discretion of the FIA the test may be carried out only with mechanical components normally situated between the rear absorbing structure and the safety cell and rear crash absorber.

3.6.3.d Acceptance criteria:

The impact test is passed if the following criteria are fulfilled:

1. The peak deceleration over the first 225mm of deformation does not exceed 20g.
2. The maximum deceleration does not exceed 20g for more than a cumulative 15ms, this being measured only in the direction of impact.
3. There must be no damage to the safety cell or to the mountings of the safety belts or fire extinguishers.

The unfiltered acceleration data of the trolley used as an acceptance criterion is obtained by calculating the average of unfiltered decelerations measured by at least two single axis sensors located symmetrically about the longitudinal centreline of the trolley (direction of impact).
The test centre must also provide the graph of the deceleration of the trolley filtered with channel frequency class CFC 60.

After the test, the rear absorbing structure must be dismounted from the safety cell.
Note: After the test, the technical delegate must void the FIA homologation labels of the safety belts. The safety belts used for the test will not be re-usable for racing.

3.6.3.e Figures:

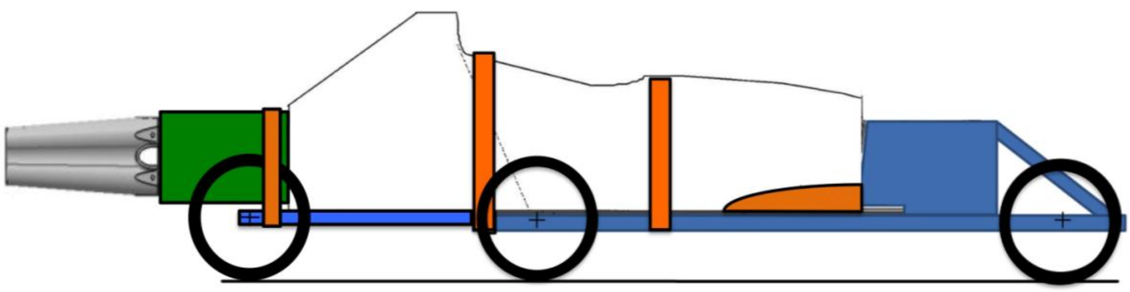

Figure 12 FIA homologation, rear impact test, support and load application, side view
The complete safety cell must be solidly fixed to the trolley through its rearward mounting points e.g. electric motor mounting points. A lashing strap must be added at the bellhousing. The combined CoG of the safety cell and trolley should pass through the centre of the crash absorber.

3.7 Side crash absorbing structure (Idem F1 16.4)

All parts which could materially affect the outcome of the test must be fitted to the test structure which must be solidly fixed to the ground and a solid object, having a mass of 850kg (+1%/-0) and travelling at a velocity of not less than 10 metres/second, will be projected into it.

The object used for this test must:

- Incorporate an impactor assembly, the specification of which may be found in the Appendix to these requirements.
- Be positioned in order that its centre of area strikes the structure 300mm (+/-25mm) above the reference plane and at a point 500mm (+/-3mm) forward of the rear edge of the cockpit opening template.

During the test the striking object may not pivot in any axis and the survival cell may be supported in any way provided this does not increase the impact resistance of the parts being tested. The impact axis must be perpendicular to the car centre line and parallel to the ground

The resistance of the test structure must be such that during the impact:

- The average deceleration of the object, measured in the direction of impact, does not exceed 20g.
- The force applied to any one of the four impactor segments does not exceed 80kN for more than a cumulative 3ms.
- The energy absorbed by each of the four impactor segments must be between 15% and 35% of the total energy absorption.

Furthermore, all structural damage must be contained within the impact absorbing structure.

This test must be carried out on the survival cell subjected to the higher loads in the static tests and on the side impact absorbing structure(s) which were subjected to test.

3.8 Impact testing of the steering column

3.8.a General requirements:
The steering column (including the steering wheel) must be subjected to the impact test described below.

All components used for this test must be in their final manufacturing stage.

Prior to the test, all components of the steering column as well as the steering wheel must be made available to the technical delegate for photos and weighing.

In particular, the energy absorbing device must be available as a spare.

3.8.b Test conditions:

A solid hemispherical object with a diameter of 165 mm (±1 mm) and a mass of 8 kg (+1/-0%) must be projected onto the steering wheel at a velocity of at least 7 m/s along the axis of the main part of the steering column (rotation axis of the wheel). The centre of the hemisphere must impact the centre of the steering wheel situated on the axis of the main part of the steering column.

The steering wheel of the real car, the steering column, all bearings, all brackets used in between the steering column and the chassis, the steering rack assembly and any part which could materially affect the outcome of the test must be mounted on a test structure firmly fixed to the ground which reproduces exactly the mounting of the steering system in the car. The test structure may not modify in any way the impact resistance of the parts being tested.

During the test, the hemispherical object may not pivot about any axis.

3.8.c Acceptance criteria:

During the test, the peak deceleration of the object, measured over the direction of impact with channel frequency class CFC 600, must not exceed 80 g for more than a cumulative 3 ms (Σt_i measured at 80 g ≤ 3 ms).

After the test, all substantial deformation must be limited to the steering column and the steering wheel.
The steering wheel quick-release mechanism must still function normally for dismounting the steering wheel from the steering column.