Hydrogen Rules 2024/25

draft version 1.4 July 16th, 2024

Preface & Foreword

This version of the Hydrogen Rules 2024/25 is a preliminary version to provide a basis for discussion at the events. Teams are welcome to give feedback at the end of the judging at the Hydrogen Concept Challenge or submit it at a later date by email to: hydrogen@fs-world.org

After the last events in September are over, a final version will be published in autumn, where feedback from teams and sponsors can be incorporated.

In order to give an indication of where changes are most likely to be made and evaluated after the judging of the Hydrogen Concept Challenge, these rules are labeled TBD= to be discussed

G: General

G1: Hydrogen cars

G1.1.1 In addition to the existing CV / CV hybrid class and EV class categories, Formula Student vehicles powered by hydrogen are also planned for the future.

G1.1.2 Each event decides independently from year to year whether it will allow hydrogen-powered vehicles.

G1.1.3 For 2025 and 2026 it is allowed to use existing CV or EV Formula Student cars which were 2021 or later at any official formula student event and make them run on hydrogen.

G2: Target group of the rules

G2.1.1 For teams that do not build a hydrogen-powered vehicle, only the FSG Rules apply.

G2.1.2 The Hydrogen Rules is aimed at teams of both classes. It includes both:
- Hydrogen fuel cell technology within the existing EV class - short: [EV-H2]
- Hydrogen combustion within the existing CV / CV hybrid class - short: [CV-H2]

G2.1.3 For teams building a hydrogen-powered vehicle, the Hydrogen Rules and the FSG Rules apply, whereby the Hydrogen Rules apply in the event of a conflict.

G3: Hydrogen Concept Challenge 2024

G3.1.1 The Hydrogen Concept Challenges, which have been taking place since 2023, are used to introduce the teams to the topic of hydrogen.

G3.1.2 The Hydrogen Concept Challenge is a static event in which a hydrogen-powered powertrain is to be presented to the judges. The judging will be separate for each team.

G3.1.3 The judging lasts 30 minutes, with the team presenting their concept for the hydrogen-based powertrain in the first 15 minutes, followed by a 15-minute question and answer session similar to the Design Event. A video may also be used for the presentation, whereby the teams themselves are responsible for the equipment required to play the video.

G3.1.4 Prior to the events, a concept paper in text form with images and/or diagrams must be submitted as a PDF (export Word file as PDF) (up to 10 pages) by 2024-07-17 23:59. It is a separate document and not part of the Engineering Design Report (EDR).

G3.1.5 The submission for all events takes place centrally via the following e-mail: hydrogen@fs-world.org

G3.1.6 Further information on the Hydrogen Concept Challenge can be found on the Formula Student events website.

F: Fuel and Fuel System

F1: Fuel

F1.1.1 The allowable forms of power in addition to those covered by the Formula Student rules (Gasoline, E85 and Electric) are specified as, Hydrogen combustion and Hydrogen fuel cell.

F1.1.2 Only hydrogen grade 5.0 (gaseous form) or hydrogen ISO14687 grade D may be used as fuel.

F1.1.3 For alternative powertrains, in addition to the fuel that is available for cars built to the CV rules, the organizers will seek to secure the supply of appropriate fuels to support alternative powertrains, but this cannot currently be guaranteed.

F2: Location of Fuel System

F2.1.1 All parts of the fuel system and the hydrogen tanks must be contained within the Primary Structure Envelope and when located less than 350 mm from the ground must be shielded from front, side or rear impacts with a structure built to T3.2 from the Formula Student Rules. There must be a distance of minimum 25 mm from the hydrogen tank, and/or HV-accumulator, and /or fuel cell to the Primary Structure Envelope.

F2.1.2 All parts of the fuel system and the hydrogen tank must be located behind a firewall as defined in T4.8 in the Formula Student Rules.

F2.1.3 **TBD:** The hydrogen tank or other hydrogen-containing components can be accommodated in the side pod if they are built as a structural side pod. The structure of the structural side pod must comply with T3.2 of the Formula Student rules and must protect against front, side or rear impact.

F2.1.4 If a structural side pod is used, a firewall must protect the driver sitting in the car and also when leaving the vehicle.

F2.1.5 The axis of the hydrogen tank must not point at the driver.

F2.1.6 The hydrogen tank and other parts with hydrogen inside must be insulated from any heat sources that can reach a temperature of 85°C or higher or at a distance that would make a surface temperature of the hydrogen tank of 85°C not possible (e.g. brake discs in some distance), e.g. the exhaust system.

F2.1.7 There must be 1 mm aluminum or steel floor to protect the hydrogen tank and other parts with hydrogen inside from stone chippings and other parts thrown up.

F2.1.8 No buffering volume in the low pressure system is allowed.

F3: Hydrogen Tank

F3.1.1 The hydrogen tank must be a part available for purchase by anyone, designed and constructed for the pressure used and for the use with hydrogen, certified by an accredited testing laboratory (typically in the country of origin) and marked or stamped accordingly.

F3.1.2 **TBD:** There is a standard formula student hydrogen tank, which the teams should use.

F3.1.3 **TBD:** Hydrogen Tank must be constructed according to an applicable standard or pressure vessel code.

F3.1.4 Hydrogen tanks with external defects, such as abrasion, cuts or chemical attack, larger than the limits defined in their design standard or code, may not be used. Any such external defect, if present, is to be assessed and the assessment documented for review by the officials.

F3.1.5 The hydrogen tank must be securely mounted to the frame or mono and must be assembled according to manufacturer’s recommendations.

F3.1.6 **TBD:** A tank pressure relief device (TPRD) must be mounted directly on the hydrogen tank. The requirement here is that the TPRD vent needs to be routed to a safe location on the vehicle. In automotive, this is typically the rear left wheel.

F3.1.7 **TBD:** A pressure regulator that limits the downstream pressure of the hydrogen to maximum 10 bar for cars with a fuel cell and or to 30 bar for hydrogen combustion cars needs to be either included in the on tank valve assembly or mounted directly downstream of the hydrogen tank and its protective devices (e.g. TPRD, block valve, etc.)

F3.1.8 The hydrogen tank should have a quick connector to allow the removal of the hydrogen tank for refueling in less than 15 minutes. The quick connector is attached to the pressure valve from rule F3.1.7.

F3.1.9 Quick couplings must not be designed as screw connections. Stainless steel compression fittings certified to EC-79 are recommended.

F3.1.10 TBD: When a hydrogen tank with an appropriate pressure and temperature rating is used, the system can be refilled at a hydrogen refueling station. Note that a normal working pressure (NWP) of 350bar is temperature compensated and can reach 1,375x NWP and 85°C. If these ratings are met, the system can be fitted with a receptacle according to ISO17268 or SAE J2600(both are harmonized) for the appropriate pressure level (H35).

The following graphic aims to give an impression of how the system can look and is not intended to be exhaustive. Additional components can be installed as required.

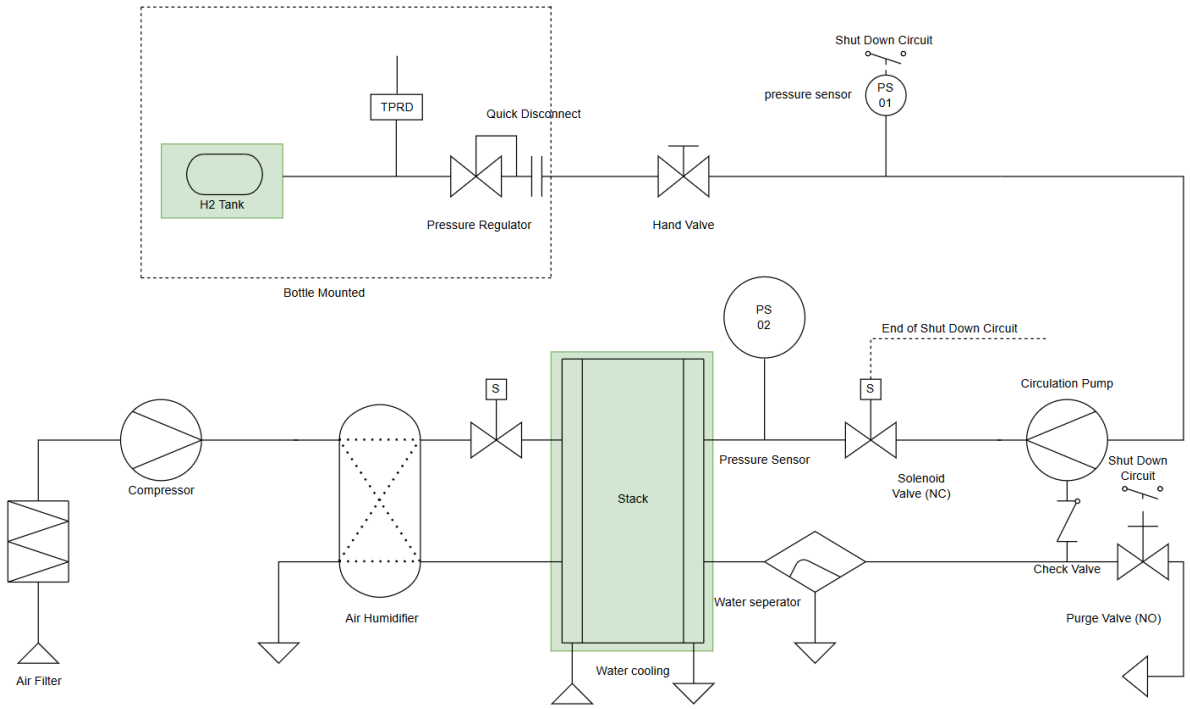

Figure 1: Schematic representation of hydrogen-related parts of a fuel cell vehicle

F4: Lines and Fittings

F4.1.1 All lines, fittinge, tanks, regulators, solenoid valves and other equipment exposed to pressurized gas must be appropriately certified for use with the gas being used and for the maximum possible operating pressure of the system and must be assembled according to manufacturer's recommendations.

F4.1.2 Seamless steel pipes made from stainless steel are favored for the transport of hydrogen. In places where a flexible line is necessary and sensible, the lines should have a steel braiding, are polymer lined on the inside (for low H2 permeation) and most often also on the outside must be approved for use with hydrogen.

F4.1.3 **TBD:** Stainless steel with at least 12 % nickel is required as a material for metallic components manufactured in-house.

C: Hydrogen Combustion Cars

C1: Engine

C1.1.1 **TBD:** Any alternatively fuelled combustion engine, whether the sole prime mover or part of a hybrid powertrain, must use a reciprocating 4 stroke cycle internal combustion engine. The engine can be modified within the restrictions of the rules whereby the displacement is limited to 1600 cc. Number of cylinders is unlimited.

C1.1.2 It is allowed to intake and/or inject in the combustion chamber non-combustible substances with the goal of reducing the tendency of abnormal combustion phenomena. This is allowed for hydrogen CV cars only.

C1.1.3 Direct injection (DI) and port fuel injection (PFI/MPI) is allowed.

C1.1.4 The injection pressure is limited to 30 bar.

C1.1.5 **TBD:** The pressure at direct injection must be below the limit specified by the manufacturer for the injection system used. The rail and the injector and any necessary connector must be properly dimensioned, designed, manufactured and assembled in order to widerstand the expected loads.

C1.1.6 A system must be used in the intake system, at the smallest possible distance from the engine, to prevent backfiring.

C2: Boosting

C2.1.1 Boosting is permitted.

C2.1.2 Turbocharging and/or supercharging of any kind and drive system is allowed.

C2.1.3 Boosting systems can be driven by any means e.g. belts, gears, electrically or any combination of drive systems.

C2.1.4 Belts, gears, chains etc. need a scatter shield as defined in T7.3 in the Formula Student Rules.

C3: Hybrid

C3.1.1 Making a combination of CV hybrid with hydrogen combustion is allowed.

C4: Power Limitation

C4.1.1 **TBD:** The hydrogen mass flow is unlimited.

C4.1.2 The air mass flow is unlimited.

C4.1.3 The maximum permitted quantity of hydrogen on board of CV-H2 cars is 1 kg.

E: Hydrogen Fuel Cell Cars

E1: Fuel Cell

E1.1.1 There is no limitation of the size or power of the fuel cell.

E1.1.2 **TBD:** There is a standard formula student fuel cell, which the teams can use.

E2: Location of the Fuel Cell and HV-components

E2.1.1 The fuel cell, inverter, high voltage accumulator and other HV-components must be contained within the Primary Structure Envelope and when located less than 350 mm from the ground must be shielded from front, side or rear impacts with a structure built to T3.2 from the Formula Student Rules.

E2.1.2 **TBD:** Mounting these parts in structural sidepods is allowed.

E2.1.3 All parts of the fuel system and hydrogen tank must be located behind a firewall as defined in T4.8 in the Formula Student Rules.

E3: Power Limitation

E3.1.1 The hydrogen mass flow is unlimited.

E3.1.2 The air mass flow is unlimited.

E3.1.3 **TBD:** The maximum fuel tank capacity for EV-H2 cars is 500 g.

E3.1.4 The capacity of the HV accumulator is not limited, supercapacitors are allowed.

E3.1.5 **TBD:** Maximum power of the tractive system at the input of the inverter(s) < 100 kW.

E3.1.6 For the Endurance, a minimum of 50% of the tractive energy must come from the fuel cell.

E3.1.7 For rule E3.1.6 tractive energy is the time integral over the Endurance run of the electrical power measured at the input of the inverter(s). This will be supervised by a datalogger.

E3.1.8 For rule E3.1.6 fuel cell energy is the time integral over the Endurance run of the electrical power measured, with a second data logger, at the output of the fuel cell system.

E3.1.9 Both data loggers will be provided by the event organizers.

S: Safety

S1: Hydrogen Safety Officer

S1.1.1 Every participating team has to appoint two to four Hydrogen Safety Officers (HSO) for the competition.

S1.1.2 The HSOs are responsible for all work on the hydrogen system carried out on the vehicle during the competition. The HSOs are responsible for all work on the car that is carried out with the hydrogen tank installed.

S1.1.3 The HSOs are the only persons in the team who may declare the vehicle hydrogen safe, in order for work to be performed on any system of the vehicle by the team.

S1.1.4 An HSO must always be with the car when the hydrogen tank is installed and must carry out the installation and removal themselves and then declare the vehicle safe for further work.

S1.1.5 At least one HSO must be contactable by phone at all times during the competition.

S1.1.6 The HSOs must be valid team members and they must have a student status, see rule A4.2.6.

S1.1.7 The HSOs must attend practical and theoretical training for working on hydrogen like DGUV FBHM-99 level E2 or equal and be held by an external expert. A certificate of the training must be shown at Scrutineering.

S1.1.8 The vehicle number, the university name, and the ESOs phone numbers must be displayed and written in Roman Sans-Serif characters of at least 20 mm high on the hydrogen tank or it's cover. The characters must be clearly visible and placed on a high-contrast background.

S2: Shutdown Circuit

S2.1.1 All equipment and parts of the Shutdown Circuit must be be the same than in the common Formula Student Rules.

S2.1.2 **TBD:** The following additional sensors must also be implemented in the Shutdown Circuit: Pressure sensors in the low and high pressure part of the fuel system, temperature sensor from the hydrogen tank and other critical parts like fuel cells. Cars with fuels cells need also the sensor from S3.1.3 in the Shutdown Circuit.

S2.1.3 When the shutdown circuit is triggered, no more gas may flow from the hydrogen tank into the high and the low pressure part of the fuel system. This must be solved with a valve which is closed if there is no power.

S2.1.4 When the shutdown circuit is triggered the engine and/or fuel cell and HV-accumulator must be switched off.

S2.1.5 **TBD:** When the shutdown circuit is triggered the pressure at the low pressure part of the fuel system must be drained with a valve that is open when there is no power supply.

The following graphic aims to give an impression of how the system can look and is not intended to be exhaustive. Additional components can be installed as required.

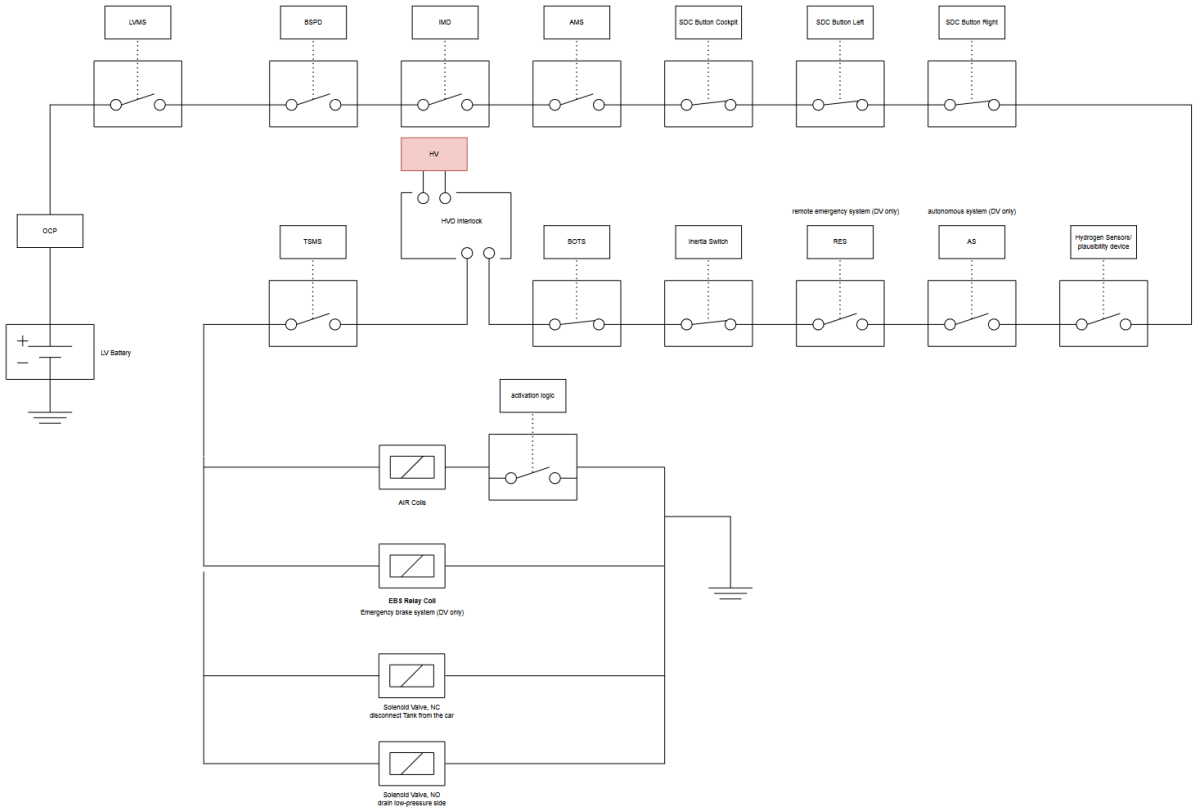

Figure 2: Schematic diagram of a shutdown circuit for hydrogen-powered vehicles

S3: Ventilation

S3.1.1 Any leaked gas should be able to freely dissipate without pockets of gas accumulating.

S3.1.2 Covers that clad or cover components containing hydrogen must have openings of at least 6 mm at local high points through which hydrogen can escape. no venting holes in direct sight of the driver.

S3.1.3 In hydrogen fuel cell cars there must be hydrogen sensors in the container of the stack.

S4: Arrival and departure to the event

S5.1.1 The hydrogen tank must be removed from the vehicle and must be at a low positive pressure (e.g. 1-10 bar) or purged with nitrogen (possibly air afterwards).

S5.1.2 If possible, the hydrogen tank should not be transported in the driver's cab.

S5.1.3 During the journey, the teams must comply with the rules for securing loads, in particular for hydrogen tanks, of the respective country. The transport regulations of dangerous goods must be also checked by the teams.

S5.1.4 The teams must return the hydrogen tank to the event organizers as soon as they reach the campsite or the event site and receive a certificate with which they can collect the hydrogen tank later.

S5: Pits and tools

S5.1.1 No cars, hydrogen tanks or other devices with hydrogen inside are allowed in the pits.

S5.1.2 Each team has to own a hydrogen leak detector and bring that to the hydrogen-specific Scrutineering.

S6: Storage of the hydrogen tank and refueling

S6.1.1 Storage of the hydrogen tanks should be dry, protected from direct sunlight and allow air exchange during the whole season. The hydrogen tanks should must be at a low positive pressure (e.g. 1-10 bar) or purged with nitrogen (possibly air afterwards).

S6.1.2 Team members do not have access to the area where the hydrogen tanks are stored on the event site.

S6.1.3 The refueling of the hydrogen tanks is carried out by the event organizer outside the vehicle in a secured area. At least one HSO from the team must be present.

S6.1.4 The hydrogen tanks will be handed out at the earliest for hydrogen-specific scrutineering and otherwise only for the dynamic disciplines and for testing in the Testing Area.

S6.1.5 When the teams leave the Dynamic Area, Testing Area or the area for hydrogen-specific Scrutineering, they must return the hydrogen tanks.

S6.1.6 Each team must provide a hand cart with safety devices similar to EV 8.1 from the Formula Student Rules to handle the hydrogen tank at the eventside. Team name and car number must be written on the cart.

S6.1.7 Do not pull, roll, push or drop the hydrogen tanks.