# 80kW Fuel Cell System

# User Instruction

# Disclaimer

This manual contains safety guidelines and operational recommendations. However, this does not mean that this manual can cover all circumstances. The customer is responsible for meeting all local safety requirements to ensure the safety of the fuel cell system during operation, maintenance and storage.

Horizon reserves the right to modify the User Instructions from time to time and at its sole discretion. It is the responsibility of the User to verify the accuracy of the information in the User Instructions with Horizon to ensure optimal performance of the fuel cell for the User's installation and operational circumstances

**The following actions will invalidate the fuel cell system warranty:**

- Disassemble or improperly tamper with the fuel cell system under any circumstances.
- Operate the fuel cell system in a manner not specified in the system settings or in the user manual for a specific product.
- Damage to a fuel cell system by accident, mis-operation, man-made damage or negligence.
- Hydrogen is supplied to the fuel cell system from a hydrogen source that does not meet the requirements from User Instructions.
- Hydrogen is supplied to the fuel cell system at a hydrogen source pressure not in conformity with the requirements from User Instructions.

*Under no circumstances should the user dismantle or tamper with the system. In case of disassembly or tampering, the warranty will be void. If you have any questions or need help with the system or its technology, please contact Horizon.*
**Jason@horizonfuelcell.com**

# Revision history

| Revision history | | | |
|---|---|---|---|
| **Revision#** | **Description** | **Author** | **Date** |
| 1.0 | The first edition | Kevin Ren | 2023/8/1 |
| | | | |

# Content

# 1. Product Uses and Functions

## 1.1. Product Uses

The 80kW fuel cell system of Horizon Fuel Cell Technologies (Horizon) is one of the best fuel cell systems in the hydrogen fuel cell industry. It is mainly applied in the following fields:

1. It can be used as a direct source of power or range extender for vehicles such as trucks, buses, coaches, tractors, rail transit and other electric transportation vehicles.
2. It can be used as a standalone or backup power supply for industrial and commercial users including hospitals, schools and other businesses. It can also be used as an energy storage system to balance power connected to an electricity grid.

## 1.2. Product Function

A hydrogen fuel cell is a generator that converts the chemical energy of hydrogen and oxygen directly into electrical energy. The basic principle is that hydrogen releases electrons at the anode by a catalyst, and the electrons are conducted to the cathode through an external circuit. Protons are transferred to the cathode through a proton exchange membrane (PEM) and interact with oxygen under the action of the catalyst to generate water, electricity and heat. The fuel cell system has the following advantages:

1. High efficiency: the fuel cell directly converts chemical energy into electric energy without intermediate conversion between heat energy and mechanical energy (generator).
2. Zero emissions: the fuel cell is fueled by hydrogen and oxygen, and the only emission is clean water. It works without carbon monoxide or carbon dioxide, also does not emit sulfur or any particulates. Therefore, hydrogen fuel cell

vehicles are truly zero-emission, zero-pollution vehicles, hydrogen fuel is the ideal vehicle fuel.

3. Short refilling time: hydrogen fuel cell vehicles use hydrogen storage tanks to store fuel. Hydrogen refilling time is about 5-10 minutes, providing continuous operation of a vehicle with typical range of 300-500 kilometers.

# 2. Product Performance Description

## 2.1. Working Principle

A fuel cell system is a power generation device that converts the chemical energy of hydrogen and oxygen directly into electric energy. Its core component is the fuel cell stack. For an operating fuel cell system, it also requires the matching oxygen supply system, hydrogen supply system, heat dissipation system and electrical control system.

Ambient air passes through an air filter, is pressurized by an air compressor before an intercooler cools the compressed air down before it passes through a humidifier and finally enters the fuel cell stack.

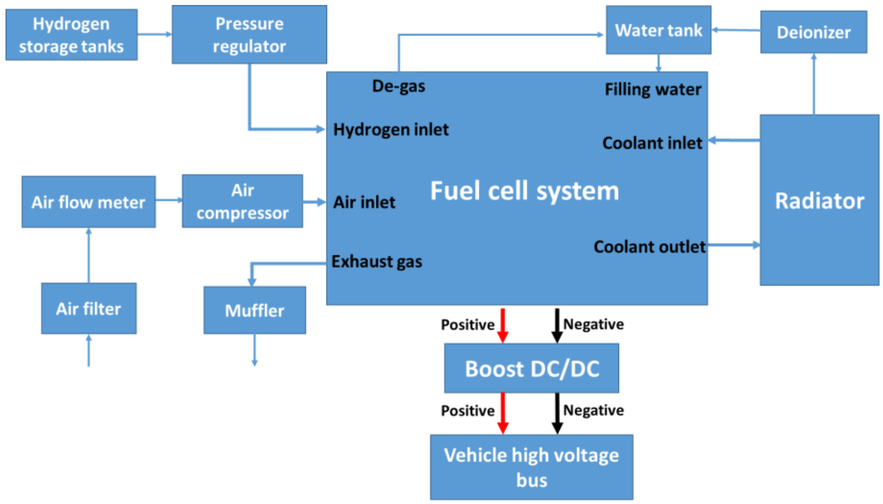
Hydrogen, stored at 350 Bar in storage tanks, passes through a decompression device and enters a hydrogen heat exchanger that heats the hydrogen before it enters the fuel cell stack. Hydrogen and oxygen react to generate water, electricity and heat. The heat generated by the reaction is dissipated by a radiator.

The generated electricity is boosted by a inverter to match the vehicle voltage. It directly supplies the motor and electrical components of the vehicle, or power to the auxiliary batteries.

The water produced by the reaction is discharged into the atmosphere along with the air remaining in the reaction and a trace amount of hydrogen that has not fully reacted.

The working principle diagram of the fuel cell system is shown in Figure 2-1 below.

Figure 2-1 Working principle diagram of the gas power system




## 2.2. Product Operating Conditions

### 2.2.1. Requirements of Fuel and Coolant

To ensure the normal operation of the fuel cell system, there are strict requirements for hydrogen, air, and coolant. The detailed requirements are shown in Table 2-1 below.

Table 2-1 gas and liquid specifications

| Type | Specifications |
|---|---|
| Hydrogen（＞99.97%） | |
| Other ingredients | ＜300ppm |
| | ＜2ppm CO2 |
| | ＜0.1ppm CO |
| | ＜5ppm $H_2O$ |
| | ＜2ppm hydrocarbon |
| | ＜5ppm $O_2$ |
| | ＜300ppm He |
| | ＜100ppm $N_2$、 Ar |
| | ＜ 0.004ppm $H_2S$, COS, $CS_2$, mercaptans |
| | ＜ 0.01ppm of formaldehyde |
| | ＜0.2 ppm formic acid |
| | ＜0.1ppb NH3 |

| | |
|---|---|
| | ＜ 0.05 ppm halogenated compounds |
| Air | |
| Oxygen | ＞20.95% |
| Nitrogen | ＜78.08% |
| Other gas components | |
| | ＜0.1ppm CO |
| | ＜1% $CO_2$ |
| | ＜1ppm $O_3$ |
| | ＜0.01ppm $SO_2$ |
| | ＜0.04ppm Hydrogen sulfide |
| | ＜0.025ppm NO |
| | ＜0.05ppm $NO_2$ |
| | ＜0.008ppm Volatile organic compounds |
| | ＜0.01ppb $NH_3$ |
| Atmospheric particle composition | |
| | ＜90μg/m$^3$ PM10 |
| | ＜15μg/m$^3$ PM2.5 |
| Cooling fluid | |
| | 50% deionized water + 50% glycol |
| | particle size＜100μm |
| | Conductivity＜5μs/cm |

**Note:**

- Choose the coolant carefully. Ordinary coolant may not be applicable. The additives may cause the conductivity to be too high or the insulation resistance of the system to be too low. Therefore, please check with Horizon about the manufacturer and model of the coolant before using with the fuel cells.
- Ethylene glycol is a toxic reagent. Drink or inhaling steam, may cause physical health problems, the operation of ethylene glycol must follow the product instructions.

### 2.2.2. High and Low Voltage Power Distribution Requirements

Parts of the fuel cell system require high and low voltages for operation. The power requirements are as shown in Table 2-2:

Table 2-2 High and Low Voltage Power Supply Requirement table

| No. | Distribution form | Demand voltage | Demand power | Note |
|---|---|---|---|---|
| 1 | High voltage distribution | 450~720VDC（Lithium bus voltage） | 10kW (starting heating for low temperature) | ≤15min |
| 2 | Low voltage power distribution | 16~32VDC,rated 24VDC | 500W | **24 V normal power** |

### 2.2.3. Introduction of Matching Air Compressor

The 80kW system needs an external oxygen supply system. After physical matching and system verification, Horizon recommends air compressor which has high pressure ratio, large flow and low noise.

The performance parameters of air compressor are shown in Table 2-3. The map of the air compressor is shown in Figure 2-2:

Table 2-3 Introduction of Air Compressor

| Number | Project parameters | Unit | Minimum | Maximum | Note |
|---|---|---|---|---|---|
| 1 | Matching stack power | kW | 60 | 120 | |
| 2 | Power | kW | - | 20.5 | Rated 15kW |
| 3 | Speed range | Rpm | 20000 | 95000 | |
| 4 | Outlet flow | g/s | 0 | 154 | Rated 114g/s |
| 5 | Outlet air pressure | kPa | 101 | 290 | Continuous work |
| 6 | Inlet air pressure | kPa | 80 | 101 | |
| 7 | Inlet ambient temperature | ℃ | -30 | 45 | |
| 8 | System transient response time | Sec. | - | 3 | From 20%RPM speed to maximum speed |

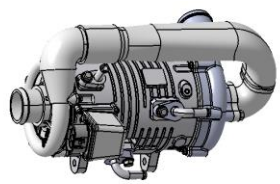
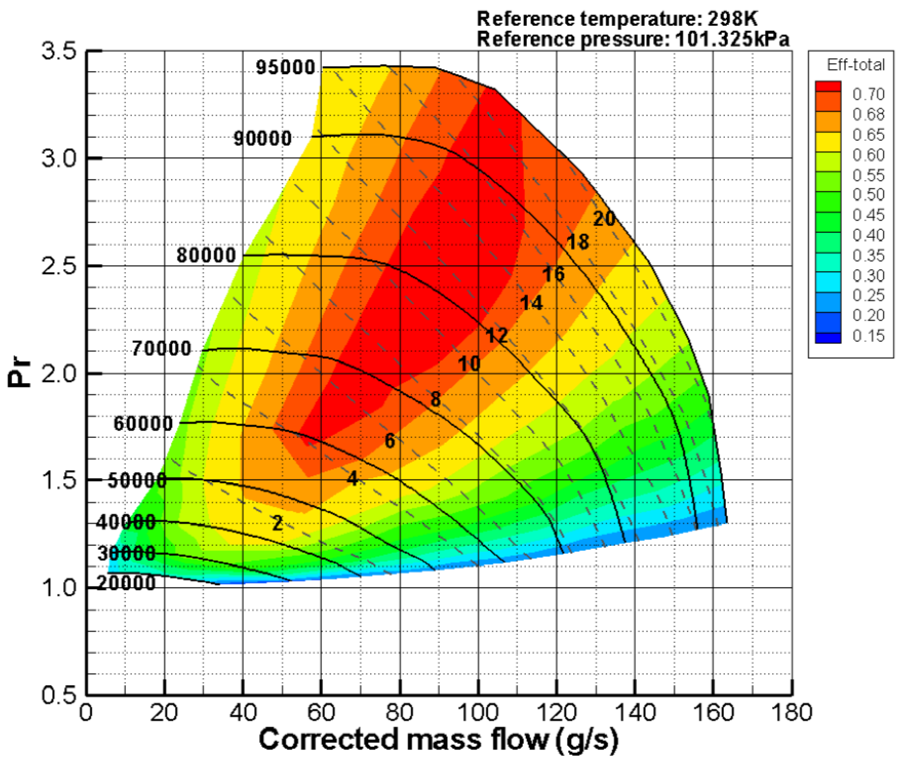
| | | | | | |
|---|---|---|---|---|---|
| 9 | Protection grade | - | - | IP67 | |
| 10 | Weight | Kg | 13.9 | | |
| 11 | Air compressor with controller graphics | |  | | |

Figure 2-2： Air Compressor MAP Diagram



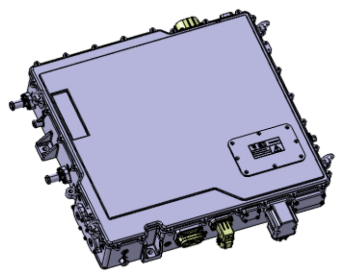

### 2.2.4. Introduction of Matching DCDC

The 80kW system requires an external DCDC. After physical matching and system verification, Horizon recommends the model DCDC. The performance parameters of DCDC are shown in Table 2-4 below. The appearance of the DCDC is shown in Figure 2-3 below:

Table 2-4： DCDC Performance Parameters

| | | | |
|---|---|---|---|
| 1 | DCDC weight(kg） | 48kg | |
| 2 | Rated power(kW) | 170kW | |
| 3 | Efficiency(%) | ≥97.5% | load≥10% |
| 4 | Input Current(A) | rated 550A | |
| 5 | Input Voltage (VDC) | 70~560VDC | rated 330VDC |
| 6 | Output Current(A) | 300A@560V | rated |
| 7 | Output Voltage(VDC) | 400 V~750 V | rated 560V |

Figure 2-3：DCDC Appearance Diagram



### 2.2.5. Introduction of Matching Pumps

The 80kW system needs a matching water pump. After physical matching and system verification, Horizon recommends the model. The performance parameters of the water pump are shown in table 2-5, the appearance of the pump is shown in figure 2-4, and the characteristic curve of the pump is shown in figure 2-5:

Table 2-5 Parameters of the water pump

| No. | Item | Parameter | Note |
|---|---|---|---|
| 1 | Rated voltage (V) | 545 | |
| 2 | Operating voltage range (V) | 400-750 | |
| 3 | Low voltage platform (V) | 9-32 | |
| 4 | Rated flow and head | 210L/min@135kpa | |
| 5 | Input power (W) | ⩽900 | |
| 6 | Load time (s) | ≤3（10%-90%） | |
| 7 | The motor type | Permanent magnet synchronous machine | |

| | | | |
|---|---|---|---|
| 8 | rated speed (rpm) | 4500 | |
| 9 | Ambient temperature (℃) | -40~85 | |
| 10 | Liquid temperature (℃) | -30~90 | |

Figure 2-4 Appearance Diagram of the Pump

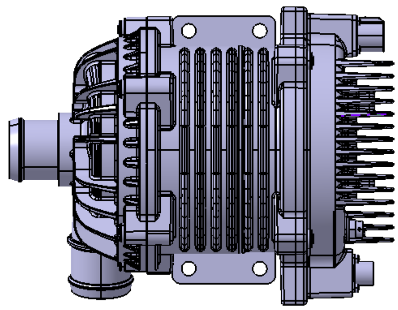
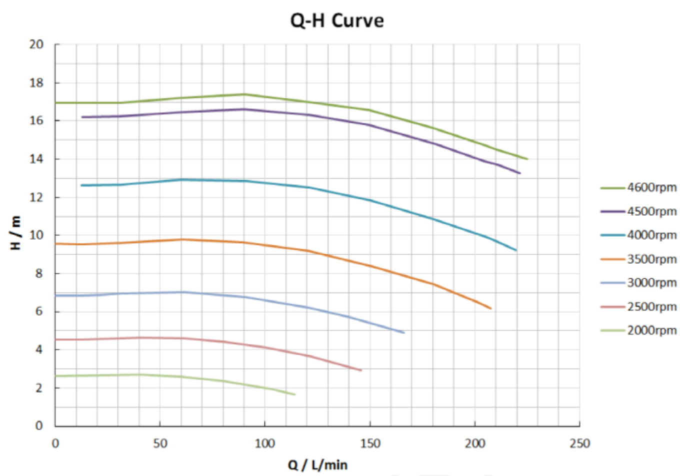


Figure 2-5 Characteristic Curve of the Pump




### 2.2.6. Auxiliary Cooling Requirements

The main DC/DC and air compressor and controller cooling cannot be integrated into the fuel cell cooling system. It needs to be integrated into the Auxiliary cooling system. The heat dissipation and flow requirements are shown in Table 2-7.

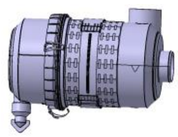
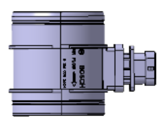
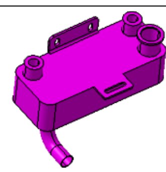
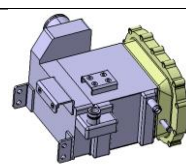
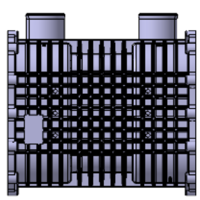
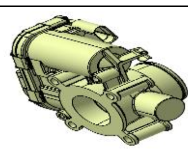
Table 2-7：Vehicle Cooling Demand Table

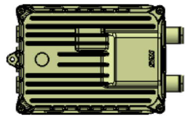
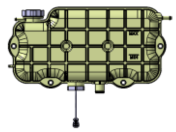
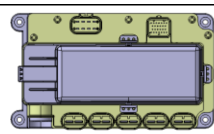
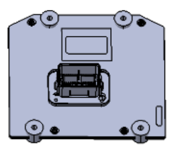
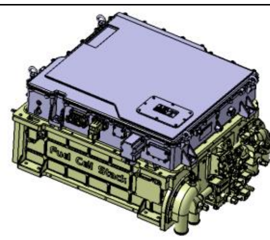
| No. | Name | Corresponding System rated power point （kW） | Coolant flow rate （L/min) | Inlet/Outlet temperature （℃） | Alarm temperature （℃） | Coolant flow resistance (kPa) | Heat loss （kW) | Coolant pressure(kPa) | Interface （mm) |
|---|---|---|---|---|---|---|---|---|---|

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Boost DCDC | 100 | 15-20 | -40-65 | 85 | ＜38 | 3.93 | ＜250 | φ20 |
| 2 | Air compressor | 15 | 6-10 | -30~65 | 180 | ＜40 | 1.4 | ＜200 | |

### 2.2.7 Introduction of Other Core Parts

Table 2-8：Summary of Core Components

| No. | Item | Figure | Role |
|---|---|---|---|
| 1 | Air filter |  | Purifies air |
| 2 | Air flow meter |  | Monitor / feedback of air flow |
| 3 | Hydrogen heat exchanger |  | Increases the temperature of the hydrogen |
| 4 | Intercooler |  | Reduces the temperature of the air entering the stack |
| 5 | Humidifier |  | Adds moisture to the air entering the stack |
| 6 | Throttle |  | Adjusts the internal operating pressure of the stack |

| | | | |
|---|---|---|---|
| 7 | PTC heater |  | Heating for low temperature cold start |
| 8 | Water tank |  | Replenish water to the system |
| 9 | Deionizer |  | Absorbs the ions in the coolant, reducing the conductivity of the coolant |
| 10 | Low voltage distribution box |  | Provides low voltage distribution to the system |
| 12 | Controller |  | Control system that communicates between system and vehicle |
| 13 | Fuel cell stack (Integrated DC) |  | Oxygen and hydrogen react to generate an output voltage |

## 2.3. Product Performance

The performance parameters of 80kW product is shown in Table 2-9:

Table 2-9 80kW Fuel Cell System Parameters

| **80kW Fuel Cell System Technical Parameter (9.2B Stack)** | | | |
|---|---|---|---|
| **No.** | **Item** | **Technical Parameter** | **Remark** |
| 1 | System Rated/Peak Power(kW) | 80/81 | Recommended output power is between 20-90% |
| 2 | Stack Power (kW) | 99 | |
| 3 | Stack Current Range（A） | 0-500 | |

| | | | |
|---|---|---|---|
| 4 | Stack Operating Voltage Range /Rated Voltage(V) | 182-330/211 | |
| 5 | Boost DC Output Voltage Range | 450-720VDC | Need to match power battery voltage |
| 6 | Boost DC Output Current Range | 0-250A | |
| 7 | Stack Number(pcs) | 330 | Optional CVM voltage detection |
| 8 | Ambient Temperature(℃) | -30-45 | |
| 9 | System Operating Temperature(℃) | -30-83 | |
| 10 | Response Time(s,start-up to idle) | ≤30 | Ambient temperature > 5 ° C |
| 11 | Response Time(s,start-up to 90% rated power) | ≤15 | System thermal engine status |
| 12 | Idle power to down time at room temperature（S） | ≤120 | ≥5℃ |
| 13 | Idle power to down time at low temperature（S） | ≤180 | @-30℃ |
| 14 | At -30℃ low temperature start time (min) | ≤15 | |
| 15 | Vehicle high voltage delay power off time（min） | ≥11 | Used for system low-temperature -30℃ shutdown purging |
| 16 | Maximum response power of dynamic loading and unloading（kW/S） | 3/5 | |
| 17 | Idle Power（kW） | ≤12 | 15% Rated system output power |
| 18 | Mass(kg) | ≤160 | Excluding DC/DC and radiator weight |
| 19 | System Dimension (mm，including DCDC) | 941*703*641 | Actual drawing shall prevail |
| 20 | System mass power density（W/kg） | ≥500 | |
| 21 | Rated point efficiency(%) | ≥43 | Boost DC efficiency and radiator fan power are not included |

| | | | |
|---|---|---|---|
| 22 | Max efficiency(%) (at idle power) | ≥60% | |
| 23 | High voltage protection class | IP67 | |
| 24 | Max Altitude（m） | ≤2000 | When the value exceeds 1000m, the system reduces the power output |
| 25 | System noise（dB） | ≤89 | |
| 26 | Fuel (Hydrogen requirement) | Purity≥99.97% | GB/T 37244-2018 |
| 27 | Hydrogen utilization（%） | ≥97% | |
| 28 | Inlet pressure of the hydrogen injection module（MPag） | 1.2±0.15 | Gauge pressure |
| 29 | Nominal pressure range for anode and cathode media(kPag) | 140/120 | Gauge pressure |
| 30 | Hydrogen consumption（g/min） | ≤105 | |
| 31 | Air consumption（g/s） | ≤130 | |
| 32 | Water flow rate（L/min） | ≥210 | |
| 33 | Rated point heat dissipation（kW） | ≤110 | BOL |
| 34 | Coolant | DI water or Fuel cell specific coolant | BASF，Dynalene, Dike |
| 35 | System insulation resistance(Ω/V) | ≥500 | Reserved ground hole, M8 bolt; The positive and negative stages of the fuel cell system are respectively tested for 500V insulation of the housing |
| 36 | Vehicle insulation alarm value | level 3:100<br>level 2：300<br>level 1：500 | level 1 and 2 fuel cell systems shut down normally, and the level 3 fuel cell system stopped abruptly |
| 37 | Vehicle pure electric insulation requirements（MΩ） | ＞3 | |
| 38 | Communication methods | CAN 2.0B | Baud rate 250/500K optional |

| | | | |
|---|---|---|---|
| 39 | 24V low voltage platform(V) | 18-32 | |
| 40 | 24V low power supply requirements（W） | ≤500 | Vehicle provides system control power supply |
| 41 | Hydrogen pipe joint leakage(ppm) | ≤5 | |
| 42 | Installation | It is recommended under the vehicle cab | If installed in other positions, add protection against rain, sun, and collision |

# 3. Product Installation Instructions

## 3.1. Product External Interface Description

80kW has a total of 9 mechanical interfaces

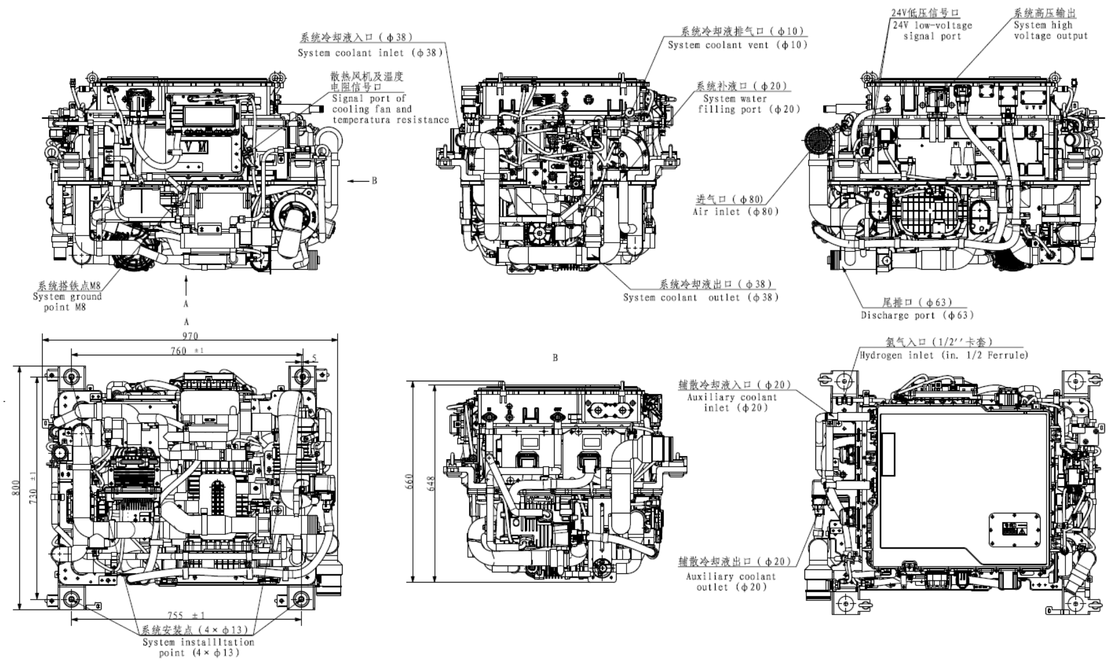
That is, hydrogen interface, system air inlet, system exhaust air outlet, system cooling water inlet, system cooling water outlet, system exhaust port, system replenishment port, Auxiliary heat dissipation cooling inlet, Auxiliary heat dissipation cooling outlet. the specifications of each interface are shown in Table 3-1, and the detailed location of the interface is shown in Figure 3-1:

Table 3-1：80kW Interface Specification Sheet

| No. | Item | Reserved Interface specification | External description |
|---|---|---|---|
| 1 | Hydrogen inlet | 1/2 inch（the tube inserting） | 1/2 inch 316L steel pipe |
| 2 | System air inlet | Φ80 joint (OD) | Φ80 Silicone tube (inside diameter) |
| 3 | System exhaust gas out | φ63 joint (OD) | φ63 Silicone tube (inside diameter) |
| 4 | System cooling inlet | Φ38 joint (OD) | Φ38 Silicone tube (inside diameter) |
| 5 | System cooling outlet | Φ38 joint (OD) | Φ38 Silicone tube (inside diameter) |

| | | | |
|---|---|---|---|
| 6 | System exhaust port | Φ10 joint (OD) | Φ10 Silicone tube (inside diameter) |
| 7 | System replenishment port | Φ20 joint (OD) | Φ20 Silicone tube (inside diameter) |
| 8 | Auxiliary heat dissipation cooling inlet | Φ20 joint (OD) | Φ20 Silicone tube (inside diameter) |
| 9 | Auxiliary heat dissipation cooling outlet | Φ20 joint (OD) | Φ20 Silicone tube (inside diameter) |

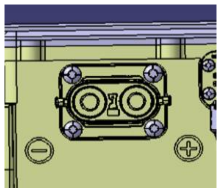
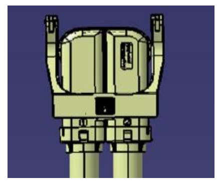
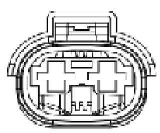
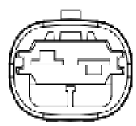
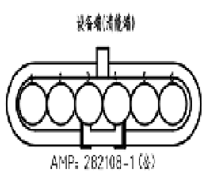
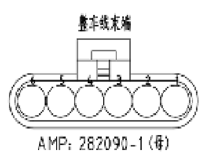
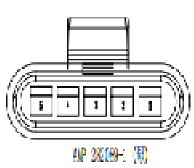
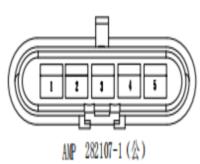
Figure 3-1：Interface Location Map




## 3.2. Electrical Interface Description

External connectors are needed to connect the fuel cell system with the vehicle. External connectors are shown in table 3-2:

Table 3-2：External connector description

| 80KW fuel cell system-vehicle electrical interface | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| No. | Name | Pin no. | Pin definition | Fuel cell harness / device end plug model | Vehicle harness / device end connector model | wire size（mm²） | Line length / outlet position | Remarks |
| 1 | High voltage interface | 1(A) | DC output negative |  HVMC2PMV103 (Amphenol) (Socket) |  HVMC2P12FV150 (Amphenol) (plug) | 50 | According to 3D model | High voltage wire and plug shall be provided by the vehicle |
| | | 2(B) | DC output positive | | | 50 | According to 3D model | |
| 2 | 24V - grounding | | 24V- | Y8-25 | Y8-25 | 25 | According to 3D mod | Fuel cell system frame to vehicle girder grounding |
| 3 | 24 V normal power | 1 | 24V+ |  AMP 1544317-1 |  AMP 1544334-1 | 6 | According to 3D model | 24V power, voltage range 19-28VDC, required power: rated 330W, peak 450W. Required to be connected in parallel to the vehicle battery. |
| | | 2 | Plug | | | | | |
| 4 | Low voltage signal port | 1 | DC24V ON |  |  | 1 | According to 3D model | DC24V power on, with delayed power-off function. |
| | | 2 | Spared | | | | | Spare port |
| | | 3 | Spared | | | 0.5mm²Twisted pair shield wire | | Spare port |
| | | 4 | CAN_H | | | | | Communicate with the whole vehicle, and the Qingneng equipment has no CAN terminal resistance |
| | | 5 | CAN_L | | | | | |
| | | 6 | CAN GND | | | | | |
| 5 | CAN debugging interface | 1 | CAN1_H |  AMP：282089-1 |  AMP:282107-1 | 0.5mm²Twisted pair shield wire | According to 3D model | CAN debugging port 1 is reserved for docking to the cab. |
| | | 2 | CAN1_L | | | | | |
| | | 3 | CAN GND | | | | | |
| | | 4 | CAN2_H | | | 0.5mm²Twisted pair shield wire | | CAN debugging port 2 is reserved for docking to the cab. |
| | | 5 | CAN2_L | | | | | |

### 3.3. Detailed Installation Instructions

The fuel cell system is an independent system, which is generally installed in the vehicle cabin and fixed under the vehicle cab through four fixed points. The installation location requires reserved maintenance space. It is recommended to use grade 10.9 M12 hexagonal flange carbon steel bolts for installation, with a recommended installation torque of 120 ± 5N. m and a quantity of 4. The specific installation steps are as follows:

1. Lift the fuel cell system to the installation position under the driver's cab of the vehicle, and lock the bolts and nuts connecting the fuel cell system to the entire vehicle;
2. Install fuel cell air filters, deionizers, water filters, radiators, etc. in the reserved positions of the vehicle, and install pipelines and fixed brackets between various components;
3. Installation of wiring harnesses, hydrogen pipes, and connectors for connecting the fuel cell system to the hydrogen supply system;
4. Installation of high and low voltage connectors for connecting the entire vehicle to the fuel cell system;
5. Check the fixation of the system, as well as all pipelines and circuits, and complete the installation of the fuel cell system.

# 4. System Running

The fuel cell system is equipped with a set of electrical control system. This system can allow engineers to perform manual, automatic or monitoring operations on the fuel cell system, and it is also equipped with an automatic alarm and protection devices. When the fuel cell system in operation fails, it will automatically send out an alarm signal or even shut down to ensure that the fuel cell system is in a normal working state at any time or notify the engineer for targeted maintenance.

## 4.1. Run the Operation Process

### 4.1.1. Routine Inspection Before Starting

Drivers are advised to check the fuel cell system before driving（Early stage of vehicle operation）:

1. Visual inspection of the stack module. Check the fuel cell stack module for damage, deformation, scratches on the surface, etc.

2. Hydrogen concentration detection. Use a hydrogen leak detector to detect the hydrogen concentration above the system. If there is a hydrogen leak, please open the hydrogen valve in the ventilation state to find the leak point, and tighten the leak point connector.

3. Interface inspection: fuel cell system cooling line interface is no leakage, loose; Hydrogen pipeline joints are fixed firmly and reliably; Stack cooling water inlet and outlet pipe interface is not loose, no leakage; Air pipe clamp is not loose, fixed firmly; The external plug-in of CAN cable is connected properly without loosening. The 24V low-voltage cable harness is properly connected, and the ground cable is firmly and reliably fixed.

4. Tank water level check. The water level of the water tank needs to be within the normal level. If the water level is insufficient, the specified coolant must be added.

5. Radiator inspection. Inspect the radiator for damage or deformation and for leaks.

### 4.1.2. Boot Process

•Fuel cell system for stationary power stations

1. Turn on the 24V power.

2. Apply high voltage and check whether the fuel cell input high voltage is normal or fluctuating.

3. The system status changes from 7 (self-checking) to 4 (standby).

4. If it is the first time to start the Fuel Cell System, follow the ‘Fuel Cell System Testing Operating Instructions’ to control the water pump and discharge the air bubbles in the coolant loop.

5. Start the fuel cell system. After receiving the startup signal, the fuel cell system will determine whether it needs to be heated at a low temperature in standby mode, and the general time will not exceed 15min. When the temperature meets the startup, it will enter the system state 1(starting, generally not more than 100S). After the system is powered on,

it enters system state 2(running) and responds to the operating power received by the fuel cell system in real time. If the fuel cell system fails during startup or operation, the system will enter state 5(shutdown). After the shutdown is completed, the system enters status 3(fault). At this time, you can check the cause of the failure of the fuel cell system according to the fault level and fault code of the fuel cell system. After handling the fault, you can power on and start the fuel cell system again.

•Fuel cell system for vehicles

1. Turn on the 24V power switch.

2. Turn the key on the vehicle, the fuel cell system wakes up, and the system phase enters 7(self-checking).

3. After the vehicle provides high voltage to the fuel cell system and sends a high voltage connection signal, the fuel cell system starts self-checking, and enters the standby state after the self-checking is completed.

4. The vehicle can determine whether the fuel cell system needs to be started according to the current vehicle status.

5. Start the fuel cell system. After receiving the startup signal, the fuel cell system will determine whether it needs to be heated at a low temperature in standby mode, and the general time will not exceed 15min. When the temperature meets the startup, it will enter the system state 1(starting, generally not more than 100S). After the system is powered on, it enters system state 2(running) and responds to the operating power received by the fuel cell system in real time. If the fuel cell system fails during startup or operation, the system will enter state 5(shutdown). After the shutdown is completed, the system enters status 3(fault). At this time, you can check the cause of the failure of the fuel cell system according to the fault level and fault code of the fuel cell system. After handling the fault, you can power on and start the fuel cell system again.

### 4.1.3. Working Process

1. Real-time monitoring of the related parameters and status is required during system operation. The items to be monitored are: communication state (with or without interference, error frame, load rate, delay or acceleration), loading rate, output voltage and current.

2. During the system operation, it cannot be in the idle state or the rated power output state for a long time. It is necessary to minimize the idle and rated time and the number of start-stop times of the system,  to avoid the system's rapid load increase or decrease.

***Notes on operation:***

•Run at least 1 or 2 times at 80% power at least every month.

•Try to avoid frequent power ON/OFF.

•If it is not running for a long time or running at low power for a long time, it needs to run at60%~90% power for 10-30 minutes at startup to recover performance.

#### 4.1.4. Shutdown Process

- Fuel cell system for stationary power stations

1. Stop the system and the system status changes from 5 (shutdown) to 4 (standby).
2. Turn off the high voltage power, disconnect the 24V power, and turn off the hydrogen supply.

- Fuel cell system for vehicles

1. Fuel cell vehicles need to have high-low rolling power off function.
2. The vehicle sends shutdown instructions to the fuel cell system and continuously supplies power to the fuel cell system through high voltage power-off delay.
3. After the shutdown of the fuel cell system is completed, the state of the fuel cell system is changed from 5(shutdown) to 4(standby), and the vehicle is disconnected from the high voltage of the fuel cell system.
4. Disconnect the 24V power supply.

### 4.2. Safety Protection in Usage

1. Using the time gap in operation, check the fuel cell system regularly for abnormalities such as water leaks, gas leaks, and hydrogen tail row openings or other abnormal sounds, identify and deal with them timely, and check whether the water tank level is normal in real time.

2. Collect system operation data in time, download and record system data on a regular

basis.

3. Avoid operating the system in areas with severe air pollution (such as: black smoke, burning whip, heavy dust, etc.).

4. No open flames are allowed around the system.

### 4.3. System Communication Protocol

For more information, please refer to: Communication Protocol.

### 4.4. System Error

For more information, please refer to the Error Code Table.

# 5. Maintenance and Repair

## 5.1. Maintenance of Fuel Cell System

The daily maintenance of the fuel cell system is divided into: daily inspection and maintenance, weekly inspection and maintenance, monthly inspection and maintenance and long-term parking inspection and maintenance. The following is a brief description in the form of a table.

Table 5-1： Daily Inspection and Maintenance Record of Fuel Cell System

| No. | Maintenance item | Specific operation method | Estimated time | Note |
|---|---|---|---|---|
| 1 | After starting, observe whether the parameters are normal | Start the vehicle after it is electrified, observe the parameters through the display screen as well as visual inspection. | 5min | If there is a fuel cell system failure, please contact Horizon after-salers |

Table 5-2 Weekly Inspection and Maintenance Record of Fuel Cell System

| No. | Maintenance | Specific operation method | Estimated | Note |
|---|---|---|---|---|

| | item | | time | |
|---|---|---|---|---|
| 1 | Check the level of coolant | Visually check tank level | 3min | When it is below the MIN line of the minimum scale, timely fill the fuel cell special antifreeze to the level not higher than the MAX line of the maximum scale line |
| 2 | System hydrogen leak detection | The system is electrified, hydrogen is fed through system control, and leakage is detected by hand-held measuring instrument. | 5min | If the hydrogen concentration meter shows a hydrogen leak of more than 25ppm, tighten the joint until it shows less than 5ppm. If a single connector is tightened for more than three times, replace it with a new one. |
| 3 | System clean | If the hydrogen concentration meter shows a hydrogen leak of more than 25ppm, tighten the joint until it shows less than 5ppm. If a single connector is tightened for more than three times, replace it with a new one. | 5min | Clean with no foreign matter |

Table 5-3 Monthly Inspection and Maintenance Record of Fuel Cell System

| No. | Maintenance item | Specific operation method | Estimated time | Note |
|---|---|---|---|---|
| 1 | High and low voltage electrical components | Check whether the high and low voltage plug-in is loose, whether the wiring harness is firmly fixed, and whether there is wear | 5min | Each high voltage and low voltage plug-in of the system has a latch. Visually check whether the latch is in place. If the latch is not installed, the plug-in is loose. Example: The plug-in latch is in place |

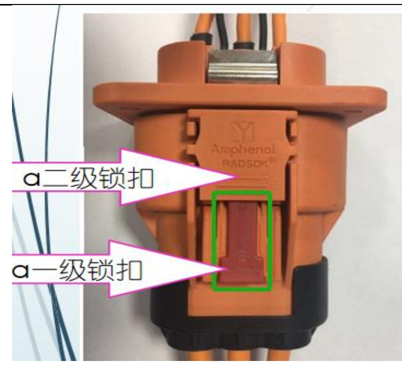
| | | | | |
|---|---|---|---|---|
| | | | |  |
| 2 | System component fixation inspection | Check components such as water filters, water tanks, air filters, silencers, deionizers, etc. for firmness, and check bolts for looseness | 5min | If it is loose, tighten it according to torque requirements. For details, see Torque requirements. |
| 3 | Radiator inspection | Check the radiator surface for foreign objects | 5min | If yes, clean it up in time |
| 4 | Air inlet, air filter inlet | Check the air inlet inlet, dust cap and air filter inlet for blockage, catkins, etc | | If yes, clean it up in time |
| 5 | Fixture of system and pipe line | Check whether the bolts are loose or worn, and whether the clamps on the pipeline are loose. | | If it is loose, tighten it according to torque requirements. For details, see Torque requirements. |

Table 5-4 Fuel Cell System Long-term Parking (more than 30 days) Maintenance Record Sheet

| No. | Maintenance project | Specific operation method | Estimated time | Note |
|---|---|---|---|---|
| 1 | Long downtime before storage | Ensure that the fuel cell is normally shut down and purged, and the 24V power main brake is closed. If the planned shutdown time is greater than 90 days, the fuel cell system and the coolant in the pipeline need to be emptied. | 10min | (special antifreeze for fuel cell must be used when the lowest ambient temperature is below 5℃) |

| | | | | |
|---|---|---|---|---|
| 2 | Fuel cell system operates regularly | Open the 24V handle switch, start the fuel cell to work for more than 20 minutes, and then shut down the vehicle normally | 30min | The fuel cell starts and stops once a month |

## 5.2. Maintenance of system Components

### 5.2.1. System component maintenance list

Regularly check of fuel cell system is required to make sure fuel cell and vehicle system running safely。Users need to maintenance and record based on period as shown in below tab 5-5.

Tab 5-5 Maintenance list

| No. | Item | Maintenance category | Maintenance cycle | Remarks |
|---|---|---|---|---|
| 1 | Coolant filter | 1、Cleaning<br>2、Exchange | 1、10,000km<br>2、50,000km or 2 year | If the coolant needs to be drained, simultaneous cleaning of the coolant filter is recommended |
| 2 | Air filter element | 1、Cleaning and dusting<br>2、Exchange | 1、5,000km<br>2、10,000km | Based on the actual operating environment, the final replacement mileage is subject to actual conditions |
| 3 | Deionizer | Exchange | 5,000km（It is recommended the first replacement at 3000km） | The deionizer replacement depends on the alarm threshold of the vehicle insulation value, the vehicle and system insulation value, etc. The final replacement mileage is subject to the actual situation |

| | | | | |
|---|---|---|---|---|
| 4 | Fuel cell specific coolant | Exchange | 30,000km or 1 year | |
| 5 | H2 concentration sensor | Calibration | 1time/year | |
| 6 | Fix point and connector | Check | 10,000km/time | Check all fixed points and connectors of the fuel cell system once every 10,000 kilometers to check whether the connections of fixed points and connectors are loose<br>For fixed points and connectors, see Section 6 of 1.2.2. |
| 7 | Radiator | Cleaning and dusting | 5,000km | |
| 8 | Hydrogen leakage detection at each joint of the system hydrogen circuit | Power on the vehicle normally, let the fuel cell system start working for 5 minutes, turn off the vehicle key, and normally shut down the system, and detect the leakage points of each joint through the handheld hydrogen concentration measuring instrument. | 10,000km | If the hydrogen concentration meter shows a hydrogen leak of more than 25ppm, tighten the joint until it shows less than 5ppm. If a single connector is tightened for more than three times, replace it with a new one. |
| 9 | Low voltage distribution box fuse | check | 5,000km | Multimeter Check whether the fuse works |

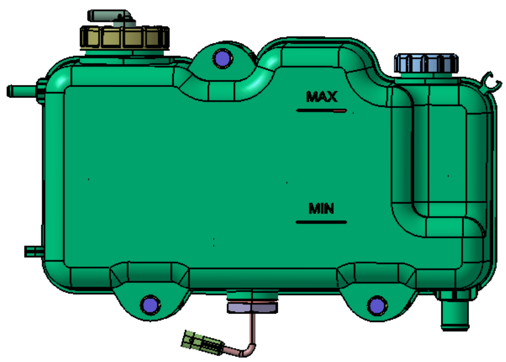
### 5.2.2 Maintenance operations of system components

### 1、 Regularly check of coolant is required for fuel cell system

1) If the minimum ambient temperature is below 5 ° C, all coolant needs to be replaced with fuel cell antifreeze. Select a fuel cell antifreeze whose freezing point is lower than the lowest ambient temperature based on the lowest ambient temperature.

2) Fill according to the liquid level every month, and the water level of the water tank should be between the minimum MIN and the maximum MAX water level, as shown in Figure 5.1 below.

Figure 5.1 Filling water tank




**2、Radiator maintenance**

1）Make sure vehicle is in "P" status, fuel cell system is power off and vehicle is cut off from high and low voltage system

2）Use high-pressure air gun to clean up branches, leaves, and other foreign objects inside the protective net, and use high-pressure air to purge the electronic fan blades and motor grooves to clean up the deposited dust;

3）Use high-pressure water gun (≤5bar) to clean the surface of the radiator, and clean the dust, catkins, leaves and other foreign matters deposited on the fins of the radiator;

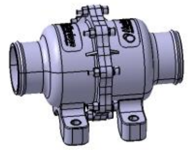
4）Dry radiator fan by using high pressure air.

**3、regularly check coolant filter**

1）Make sure vehicle is in "P" status, fuel cell system is power off and vehicle is cut off from high and low voltage system

2）drain and recycle coolant, remove coolant filter, using high pressure water to clean filter screen

3）Re-install coolant filter and refill the coolant to radiator



coolant filter

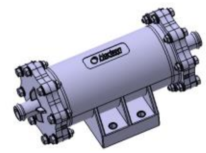
**4、Deionizer change procedures**

1） Lower the coolant in the system to the level below the deionizer

2） loosen bracket of two ends；

3） replace old deionizer with new one；

4） install brackets of two ends

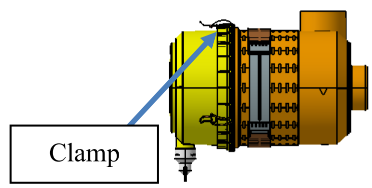


**5、Air filter change procedures:**

1）loosen five clamps of air filter；

2）take out used filter screen and replace with new one；

3）Combine the shell and fix five clamps.




**6、Check fixed points and connector connection**

1）Check whether bolts are loose at the mounting point, radiator, air compressor, intercooler humidifier integrated module, water pump, electric reactor, DC, ground points, and bonding points.

2）Check whether the DCL 24V negative terminal grounding point, DCL 24V positive power supply fuse box, high voltage component shell grounding point, 4, heat dissipation fan 24V negative power supply grounding point, fuel point system and vehicle grounding point, fixing bolts are loose.

3）The 24V positive fuse of the heat dissipation fan is a power supply plug. Check whether the plug latch is in place.

### 5.2.3. Torque requirements for standard parts and universal parts

| Bolt | Corresponding torque | Clamp | Corresponding torque |
|---|---|---|---|
| M5 | 5±0.5N.M | Clamp 11-20 | 3±0.5N.M |
| M6 | 10±1.0N.M | Clamp 14-27 | 3±0.5N.M |

| | | | |
|---|---|---|---|
| M8 | 24±2.4N.M | American double clamp 17-32 | 5.4±0.8N.M |
| M10 | 45±4.5N.M | German double compensation clamp 25-40 | 5.4±0.8N.M |
| M12 | 75±7.5N.M | German double compensation clamp 30-50 | 5.4±0.8N.M |
| | | German double compensation clamp 40-60 | 5.4±0.8N.M |
| | | German double compensation clamp 60-80 | 5.4±0.8N.M |
| | | American double clamp 22-32 | 5.4±0.8N.M |
| | | Heavy clamp with pad 30-80 | 8±0.8N.M |

### 5.3. After-sales

If the problem of maintenance of the fuel cell system cannot be solved, please contact Horizon technical support.

## 6. Transportation and Storage

### 6.1. System Transportation

- During transportation, the product should not be subjected to severe vibration, impact or placed upside down.
- The transportation temperature should be in the range of -20 ℃ ~ 40 ℃.
- The product should be able to adapt to sea and air transportation conditions.

- When the product is transported by sea or air, it should be sealed and packed with other protective measures to avoid unnecessary damage.

## 6.2. System Storage

- The product is placed in a dry and ventilated environment, and the storage temperature is in the range of 5 ℃ ~ 35 ℃.

**Long term storage**

- Long-term storage means that the system will not boot for more than 1 month
- The fuel cell system has a long-term storage of its recoverable attenuation, which requires that it be turned on once a month for at least 20 minutes each time.

# 7. Safety

Fuel cell stacks generate high voltage electricity, and high temperature, high pressure gas and liquid flow when the fuel cell system is running. Please strictly observe all warnings, cautions and safety instructions. Failure to follow these instructions may result in safety accidents such as burns, electric shocks, and electric shocks.

## 7.1. General Safety

1. The fuel of the fuel cell system is hydrogen and oxygen, so open flames are strictly prohibited.
2. In the non-operating state, there may be residual voltage in the fuel cell stack. Check the voltage before maintenance.
3. When the system is running, please make sure that all interfaces, screens and electrical enclosures are firmly connected.
4. Do not place or use the fuel cell stack in a humid environment.
5. When operating a fuel cell stack or system, remove jewelry, watches, rings, and metal objects to avoid short circuits.

## 7.2. Safety at High Temperature and High Pressure

1. When operating in an outdoor environment, the temperature of the fuel cell stack can reach 80 ° C and above. Do not touch the stack during the operation of the stack or within a short period of time after the stack comes to a stop.
2. When high-pressure gas is used in fuel cell stacks or auxiliary systems, there may be a risk of shock. Before opening each pipeline and fittings, the entire circuit needs to be depressurized.
3. The fuel cell stack is assembled under high pressure. Do not disassemble the stack at will.

## 7.3. Safety at High Voltage

1. Before operating the stack, connect the positive and negative voltages of the stack to a suitable load.
2. If the electrical equipment is not completely insulated somewhere, electric leakage of stack may occur. Leakage may occur inside or outside the stack module. Minimize the leakage, ensure that all electrical equipment and wires in the stack module are completely insulated, and ensure that electrical equipment are insulated.
3. Select the high-voltage wiring harness of the stack according to the required voltage, current and insulation temperature. According to the specific application and operating environment of the end customer, it meets the conditions of rated voltage, current load, rated insulation temperature, etc.
4. In the case of vehicle insulation failure, never touch conductive parts such as bus or connectors.
5. Ensure that all electrical interfaces and electrical connectors are properly installed and connected. It is not necessary to apply great force when installing electrical interfaces and electrical connectors to avoid damage to the stack.
6. Please avoid the following unsafe situations:

- Incorrect grounding;
- Foreign substances or debris appear between the components of the stack and the hardware, resulting in a reduction in insulation performance;

- Operate electrical wires or electrical equipment with wet hands, or touch wet ground;
- Use worn wires;
- Each electrical interface is incorrectly connected or reconnected multiple times;
- Short circuit occurred;

## 7.4. Safety of Hydrogen

1. Hydrogen is a colorless, odorless, highly flammable gas.
2. When operating hydrogen, strictly follow the specifications and the recommendations of the gas supplier.
3. Hydrogen is non-toxic, but will consume oxygen in the air and cause hypoxia. No alarm will occur before an accident occurs.

Hydrogen molecules are smaller than any other gas molecule, so hydrogen molecules are difficult to dissolve. Hydrogen can diffuse through a variety of air-tight materials. Fuel pipelines, non-welded connections, non-metallic materials, such as gaskets, O-rings, pipe threads, packaging, etc. may have potential leak points or penetration points. Moreover, because the molecular size of hydrogen is small, it will produce great buoyancy and diffusivity, so the leaked hydrogen will diffuse, and it will soon be diluted in the atmosphere. The hydrogen leak rate of the stack will gradually increase with the increase of the service life of the stack.

The responsibility for detecting and mitigating hydrogen leaks is up to the customer. Hydrogen leaks that originate from the stack, can be quickly detected by a hydrogen detector. It is important to have warning systems in place before the hydrogen / oxygen mixture reaches a flammable concentration.

## 7.5. Safety of Stack Ablation

When the stack is operating, it may cause internal stack ablation. The following conditions may cause stack ablation:

- When operating the stack, the stack is severely under-hydrogenated (insufficient exhaust, the stack is in a supercooled operating state for a long time);

- Operate the stack beyond its maximum operating temperature.

## 7.6. Safety of Hypoxia

When the stack is operating, it consumes oxygen. When the stack is poorly ventilated and the floor space is small, special attention needs to be paid to the oxygen concentration to not fall lower than health requirements.

## 7.7. Warning Sign Description

(1) Cautious of high temperature warning signs:


（2）Cautious of electric shock warning signs:


（3）Prohibition of stepping warning signs


（4）Antifreeze warning sign