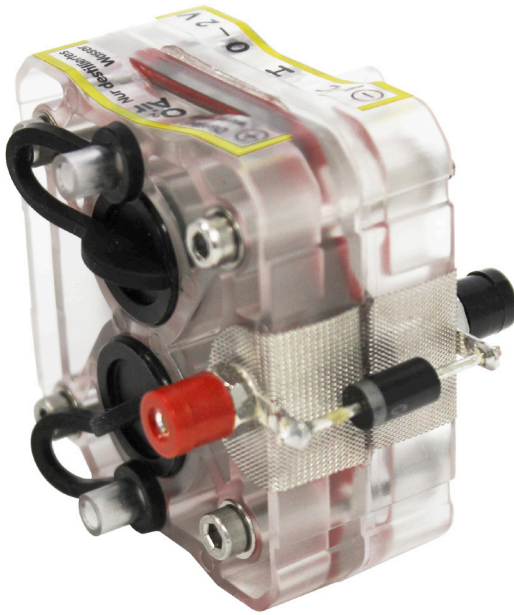


Operating Instructions



R104 - Double Reversible Fuel Cell

Table of contents

03	Intended Use
04	General Safety Precautions
05	H ₂ /O ₂ Mode - Preparation and Operation
07	H ₂ /Air Mode - Preparation and Operation
09	Technical Data
10	Troubleshooting
11	Shutting Down
11	Maintenance
11	Disposal

Intended Use

The equipment described in this manual allows the principles of PEM fuel cells (PEM = proton exchange membrane), PEM electrolyzers and solar modules to be demonstrated, and appropriate measurements to be taken. The equipment has been developed for teaching and demonstration purposes only.

Any other use is prohibited.

WARNING!

Distilled water is required to operate the Tutorial HyRunner. The electrolyser splits this water into hydrogen and oxygen. In the fuel cell, hydrogen (H₂) and oxygen (O₂) react again. These gases can be dangerous if handled improperly. In order to avoid any risks you must follow the recommended safety precautions when using the equipment.

H-TEC cells are clearly color-coded according to their function

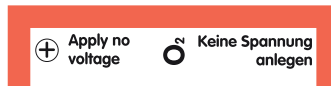
yellow: Reversible Fuel Cell (RFC)
Can be used as FC or EZ



blue: Electrolyzer (EZ)



red: Fuel Cell (FC)



Additional note

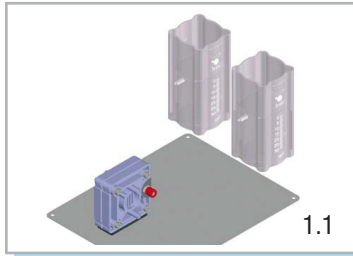
Make sure the polarity is always correct (red = "+", black = "-")!

General Safety Precautions

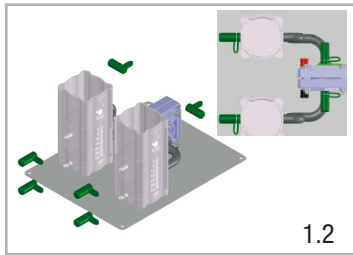
- The units may only be set up and operated by a responsible supervisor.
- **WARNING!** Not suitable for children under 12 years!
- Read the Operating Instructions before setting up the fuel cell. Follow them during use and keep them readily available for reference.
- Wear protective goggles.
- Equipment and gases must be used and stored out of the reach of small children.
- Plug-in power supplies can be dangerous - they are not toys!
- Disconnect the unit from the plug-in power supply and the solar module before cleaning with liquids.
- Unless instructed to the contrary by the manual, do not reverse or short-circuit the connecting terminals.
- The units must not be operated when empty. Always ensure that they contain sufficient water. Pay attention to the water level marks.
- Remove flammable gases, vapours or liquids from the area surrounding fuel cells and electrolyzers. The catalytic materials involved may cause spontaneous ignition.
- Hydrogen and oxygen may escape from the units. Operate the units in wellventilated rooms to ensure that the gases do not accumulate and form explosive mixtures.
- The units may only be operated in display cases if adequate ventilation is guaranteed under all circumstances. The operator is responsible for ensuring this.
- Remove from the vicinity of the units anything that could ignite the hydrogen (e.g. open flame, materials that can become charged with static electricity, substances with a catalytic action).
- Remove from the vicinity of the units all substances that could spontaneously ignite in increased oxygen concentration.
- Do not smoke.
- Hoses, plugs and gas tanks are used for pressure compensation. They must not be fixed or secured with clamps, adhesive, etc.
- Only use the gas storage tanks associated with or supplied with the units. Never connect alternative gas storage tanks.
- The units may only be operated at room temperature and ambient pressure.
- Minimum separation distances must be observed when using solar modules and artificial lights.
- **WARNING!** The surface of solar modules can get very hot during extended operation.
- Make sure students know about any potential dangers and carefully supervise experimentation.
- Remove flammable gases, vapours or liquids from the area surrounding fuel cells and electrolyzers. The catalytic materials involved may cause spontaneous ignition.
- H-TEC Education accepts no responsibility for injuries or damage sustained in the event that these Safety Precautions are not followed.

H₂/O₂ Mode - Set Up & Operation

Set Up



1. Place the two gas storage tanks and the Reversible Fuel Cell on the chassis (Fig. 1.1).



2. Using a hose, connect the bottom connectors of the RFC to the connectors on the fuel cell side of the storage tanks (Fig. 1.2).

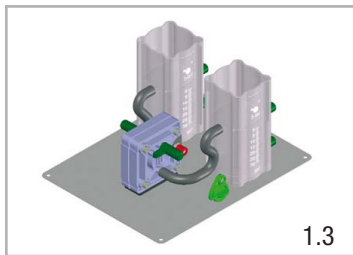
3. Fit caps to the connectors on the electrolysis side of the gas storage tanks (Fig. 1.2).

4. Fit caps to the top gas connectors of the fuel cell (Fig. 1.2).

5. Make sure that the stopper for sealing the air inlet on the RFC is snugly in the inlet (Fig. 1.3).

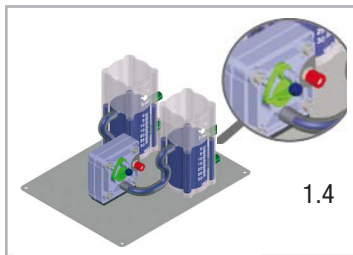
6. Fill both storage tanks with distilled water up to the top mark of the compensation tank.

7. Open the upper caps on both sides of the RFC. Air will escape from the gas storage tanks and the RFC. The cell will be flooded with water. The process is complete when water comes out of the top gas connectors (Fig. 1.4).

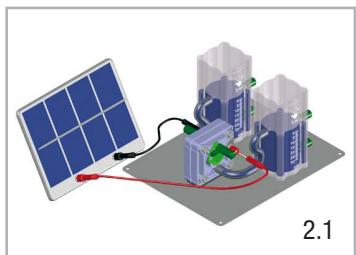


NOTE: The rising water level can easily be seen inside the cell. If air bubbles form they may interfere with the system. Allow the process to run until you see no more air bubbles.

8. Re-cap the gas connectors.

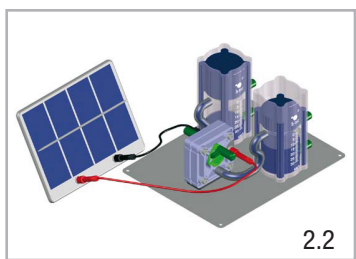


Electrolysis Mode (Gas Production)



1. Use the cables to connect the solar module to the appropriate terminals on the RFC. When doing so, make sure that the polarity is correct (red = "+", black = "-"). The cell will begin to produce hydrogen and oxygen in a 2:1 ratio (Fig. 2.1).

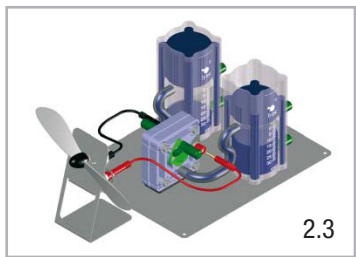
NOTE: If the lighting is not sufficient, you can use a powerful halogen spotlight.



2. Oxygen is produced on the positive side of the cell, and hydrogen on the negative side. The gases collect in the gas storage tanks and displace the water there into the compensation tanks (Fig. 2.2).

NOTE: When the gas storage tanks are full, excess gas will escape in the form of bubbles. When this happens, unplug the solar module from the RFC.

Fuel Cell Mode (Gas Consumption)



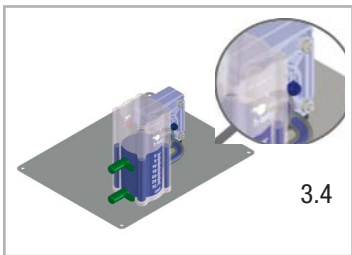
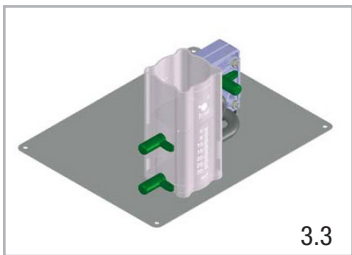
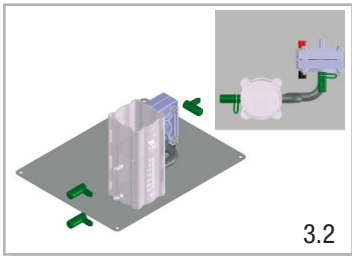
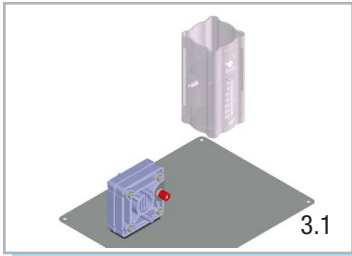
1. When the solar module is unplugged, then plug the wires from the electrical load into the RFC taking care to use correct polarity (red = "+", black = "-"). When switched on, the cell will use the stored gas to generate current, along with water and small amounts of heat (Fig. 2.3).
2. When the gas is used up, the RFC will draw in water. This will cause the motor to stop.
3. When the load stops producing, unplug it and reconnect the solar module. This will resume gas production.

NOTE: TUTORIAL HyRunner does not have a fan, instead connect the RFC to the wires connected to the motor.

NOTE: Make sure the oxygen side of the cell is sufficiently moist. Re-flood the cell if necessary.

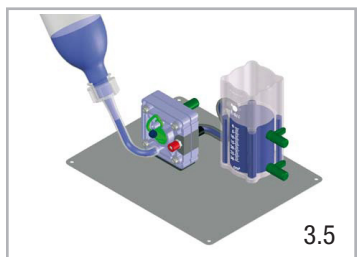
H₂/Air Mode - Set Up & Operation

Set Up



1. Place a gas storage tank and the cell on the chassis (Fig. 3.1).
2. Using a hose, connect the bottom connectors of the RFC to the connectors on the fuel cell side of the storage tanks (Fig. 3.2).
3. Fit caps to the connectors on the electrolysis side of the gas storage tanks (Fig. 3.2).
4. Fit a cap to the top gas connector on the hydrogen side of the fuel cell (Fig. 3.3).
5. Fill the gas storage tank with distilled water up to the top mark of the compensation tank.
6. Open the top cap on the hydrogen side of the RFC. Air will escape from the gas storage tanks and the RFC. The cell will be flooded with water. The process is complete when water comes out of the top gas connectors (Fig. 3.4).
7. Re-cap the gas connector on the hydrogen side.

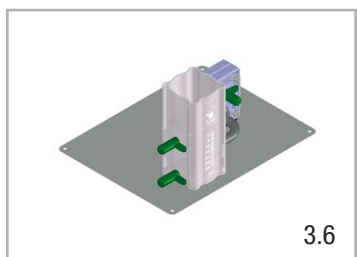
NOTE: The rising water level can easily be seen inside the cell. If air bubbles form they may interfere with the system. Allow the process to run until you see no more air bubbles.



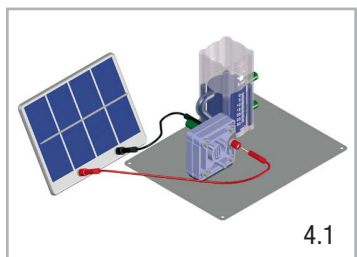
8. Attach a water bottle, or syringe to the bottom connector on the oxygen side of the RFC with tubing (Fig. 3.5).

NOTE: Before flooding the cell, fit the stopper so the water will be well distributed in the cell.

9. Squeeze the bottle to flood the oxygen side of the cell. When the oxygen side is flooded and the bottle is disconnected, the RFC is ready for use (Fig. 3.6).

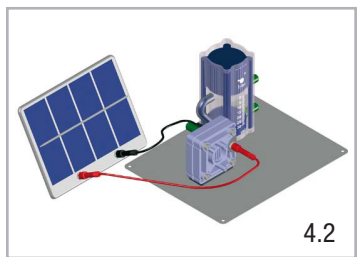


Electrolysis (Gas Production)



1. Remove the stopper.
2. Use cables to connect the solar modules to the terminals on the RFC. When doing so, make sure the polarity is correct (red = "+", black = "-"). The cell will begin to produce hydrogen and oxygen in a 2:1 ratio (Fig. 4.1).

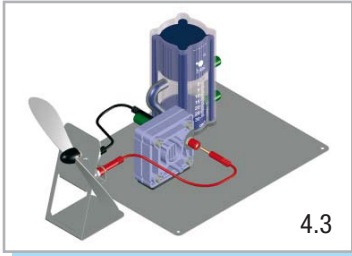
NOTE: If the lighting is not sufficient, you can use a powerful halogen spotlight.



3. Oxygen is produced on the positive side of the cell, and hydrogen on the negative side. As the cell is operated in fuel cell mode with atmospheric oxygen, only the hydrogen will be collected in the gas storage tank and displace the water there into the compensation tank (Fig. 4.2).

NOTE: When the gas storage tanks are full, excess gas will escape in the form of bubbles. When this happens, unplug the solar module from the RFC.

Fuel Cell Mode (Gas Consumption)



1. When the solar module is unplugged, then plug the wires from the electric load into the RFC taking care to use correct polarity (red = “+”, black = “-”). When switched on, the cell will use the stored gas, along with atmospheric oxygen to generate current, along with water and small amounts of heat (Fig. 4.3).
2. When the gas is used up, the RFC will draw in water. This will cause the load to stop.
3. When the load stops, unplug it and reconnect the solar module. This will resume gas production.

NOTE: Make sure the oxygen side of the cell is sufficiently moist. Re-flood the cell if necessary.

Technical Data

Electrolyzer:

H ₂ Production:.....	20 mL/min
O ₂ Production:.....	10 mL/min
Permissible Power:.....	5.5 W @ 1.5A
Electrode Area:.....	2.9 cm ²
Guide value for distilled water:.....	<2 μS/cm
Permitted operating pressure:.....	0 - 20 mbar

Fuel Cell:

H ₂ / O ₂ Operation:.....	1 W @ 750 mA
H ₂ / Air Operation:.....	400 mW @ 300 mA
Electrode Area:.....	2.9 cm ²
Permitted operating pressure:.....	0 - 20 mbar

Troubleshooting

The fuel cell has very little power.

Possible Cause:

- The fuel cell was stored too dry or for too long. A fuel cell with a dry polymer electrolyte membrane (PEM) loses power.

Solution:

- Continue operation. The fuel cell moistens itself during operation which slowly allows it to reach its full capacity again.

No hydrogen is produced when a solar cell is connected.

Possible Cause:

- The light intensity is insufficient.

Solution:

- In order to operate solar modules, either adequate direct sunlight or concentrated light from a powerful electrical light source is required. Energy-saving light bulbs, fluorescent tubes etc. are unsuitable for the operation of solar modules.

The electric load (e.g. fan) connected to the cell does not work, despite hydrogen being present.

Possible Cause:

- There is too much water in the cell. Water in the fuel cell leads to a rapid reduction in power. This condition can occur if the electrolyser runs in permanent operation for too long and pumps water to the hydrogen side of the fuel cell. With reversible cells, it is possible that the cell has not been operated for long enough in electrolysis mode, so that too much water still remains in the cell.

Solution:

- Dry the fuel cell by opening and blowing out the connections, or change back to electrolysis mode by connecting the solar module to the cell.

Despite correct setup, the electrolyser or the fuel cell is not working.

Possible Cause:

- No distilled water was used. The electrolyser and/or the fuel cell has/have sustained irreparable damage.

Should the above-mentioned solutions not remedy the cause of error, please contact H-TEC EDUCATION.

Shutting down

- Continue operating the fuel cells until the consumer (e.g. the motor) stops independently. This allows some water to remain in the fuel cell, moistening the PEM. This procedure also prevents unnecessary discharge of hydrogen.

Before putting the product into storage, observe the following points:

- Close the connections of fuel cells and electrolyzers with caps. This prevents the PEM from drying out. The same applies to stoppers on fuel cells.
- Remove any water droplets from the experimentation plate or vehicle plate with a soft, lint-free cloth. This prevents the formation of water stains.

Maintenance

The components of the product do not require maintenance. The following points should be observed, though:

- Use freshly distilled water for each operation.
- After operation, remove the water from the gas storage tanks.

Disposal

Do not dispose of fuel cells and electrolyzers as general household waste.

WARNING

Fire hazard from catalytic substances
The catalysts for the electrodes of fuel cells and electrolyzers promote burning when they come into contact with flammable substances. Avoid contact with hydrogen, alcohol fumes or other organic fumes. Ensure correct disposal.

According to European regulations, used electric and electronic devices may no longer be disposed of as unsorted household waste. The symbol of the crossed-out wheelie bin indicates the requirement for separate disposal.

Your local waste management company can provide you with additional information about disposal options.



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