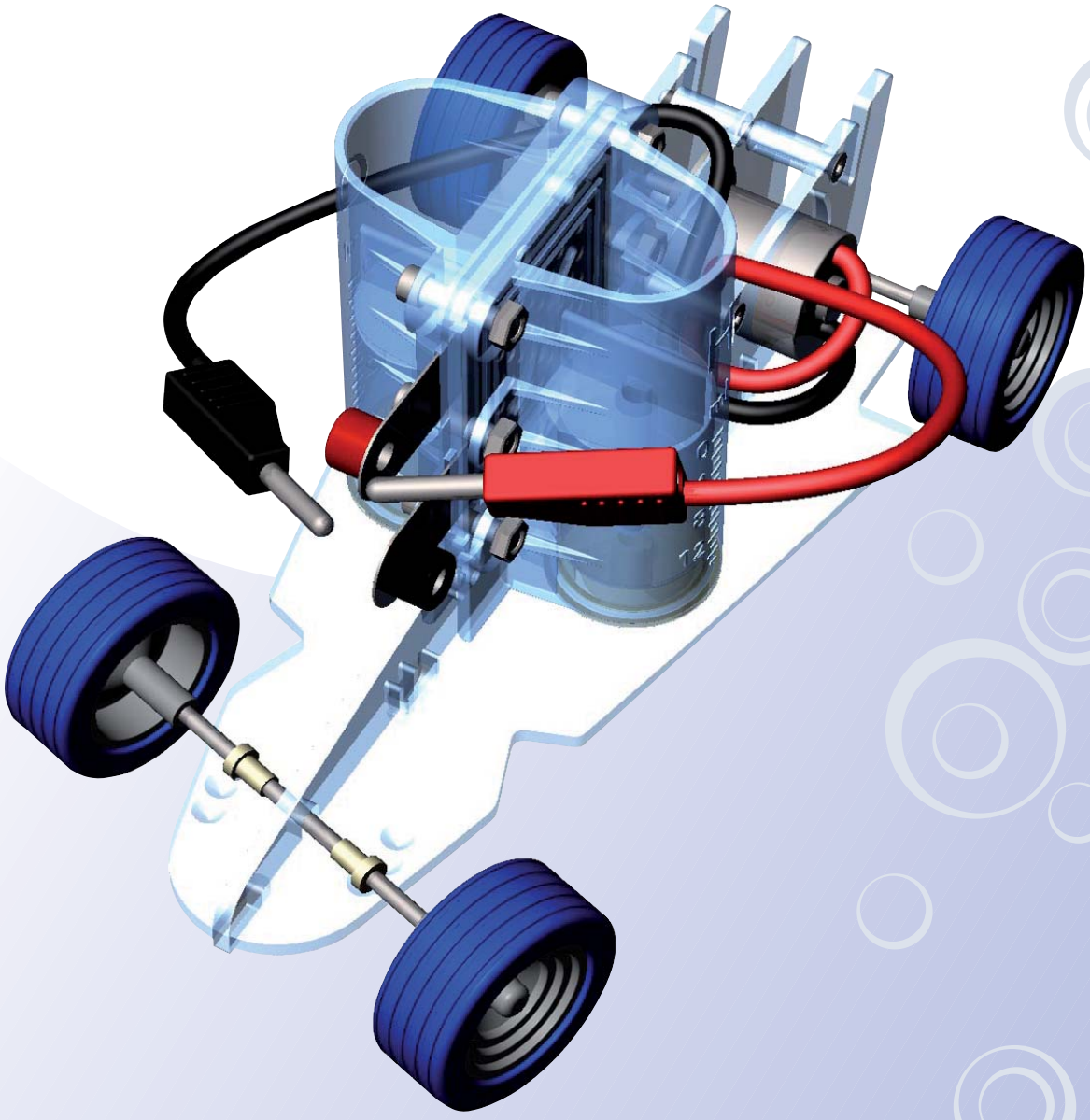
Heliocentris

Dr FuelCell® Model Car

Instruction Manual



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Instruction Manual for Dr FuelCell® Model Car

Version 4.1.4

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Germany

Content

Preface

Over the past decade, fuel cells have been recognized as a workable alternative to existing power technologies. In the developing new economy the continued growth of fuel cells is assured.

We at Heliocentris hope that the experiences your students have with the Dr FuelCell® Model Car give them some knowledge about fuel cells, and spark their interest in the wider subject of sustainable solar hydrogen technology.

We hope that they are encouraged to seek ways of living that are beneficial to our earth and all its inhabitants.

1 About This Document

This document is intended to help you easily get your Dr FuelCell® Model Car running and set it up for further experiments. These experiments are described in detail in the Teacher's Guide provided with your Model Car.

1.1 Symbols and Signs

1.1.1 Symbols

In this document following symbols and signs are used:

Symbol	Meaning
➔	Here you have to do something
1.	Here you have to do something and have to pay attention to the order
✓	This is a prerequisite you need to complete before starting the next step or an item you need for the completion of the next step
•, -	Item of a list

Table 1-1 Symbols used in this document

1.1.2 Warning Signs

The warning signs appear as follows:

⚠ **RISK LEVEL**
Type and source of danger are described here! Possible consequences if safety measures are not heeded are described here. ➔ Safety measure to be heeded is given here.

Following risk levels are present when working with the product:

⚠ CAUTION
Dangerous situation! If safety measures are not observed, minor injuries may occur.

NOTICE
Dangerous situation! If safety measures are not observed, damage to equipment may occur.

Useful hints appear as follows:

TIP
Useful hint.

1.2 Further Applicable Documents

In addition to this Instruction Manual the Model Car is delivered with the following documents:

- Teacher's Guide
- Quick Guide

2 General Safety

The Model Car is constructed according to state of the art. Nevertheless, improper operation or abuse can present danger to:

- The health of the operator and observers
- The unit itself and other items of property

2.1 For Your Safety

This information on general safety is supplemented by specific warnings throughout this Manual. These warnings explain how to act, in order to protect yourself or other persons or property from injury or damage.

➔ Keep this Manual available at all times.

➔ Read and completely understand this Manual.

➔ Adhere to the local statutory regulations.

➔ Follow safety instructions and warnings.

➔ Give this Manual to subsequent owners of the Model Car.

2.1.1 Intended Use

The Model Car is solely constructed for experiments and demonstrations on hydrogen technology and its components. The Model Car may only be used for experimentation and demonstration purposes. It is only intended to be used as an electrolyzer and a fuel cell.

2.1.1.1 Prohibited Use

The Model Car may **not** be used for:

- Generating electricity and hydrogen for any other purposes than described in this Instruction Manual or in the Teacher's Guide
- Storing or collecting more than minimal amounts of hydrogen (appr. 30 mL)
- Measuring voltage and current with other than components of the Dr FuelCell® package
- Continuous electrolysis

Components or products delivered by or purchased from Heliocentris may not be used in aviation or space flight (including models).

2.1.2 Operators

The Model Car is intended only for persons over age 12. Young persons over age 12 should use the kit only under the supervision and guidance of qualified adults. The adults must ensure appropriate handling. They must be aware of the possible dangers.

Students using the equipment must be supervised by experienced teaching staff. When students are performing experiments, the teacher should distribute the relevant student section of the Teacher's Guide for the Model Car and have available in the laboratory copies of the Quick Guide to the Model Car.

2.1.3 Protective Gear

➔ Wear protective goggles when conducting experiments.

2.2 Location Condition

The components of the Dr FuelCell® Model Car must be assembled and operated on an even and stable, water resistant horizontal base, at a recommended height of 75...85 cm (30...34").

The room must be well ventilated.

Room and equipment must meet the local statutory regulations.

2.3 Shipping and Transport

Prior to shipping or transporting the Model Car:

➔ Always empty the distilled water.

For shipping:

➔ Use only the original storage container.

2.4 Safety Measures

For your own safety:

➔ Only use Dr FuelCell® components, unless stated otherwise in the experiment descriptions in the Teacher's Guide.

➔ Do not connect the Dr FuelCell® components to AC power supplies.

The reversible fuel cell produces hydrogen, an explosive gas.

➔ Avoid open flames near the components.

➔ Do not smoke.

2.4.1 In Case of Emergency

If leaking hydrogen ignites:

1. Immediately disconnect the power supply from the reversible fuel cell to stop hydrogen production.
2. Initiate all fire-fighting measures.
3. Ensure that everyone keeps a safe distance from the components.

2.5 Electromagnetic Compatibility

The load measurement box complies with Electromagnetic Compatibility (EMC) Directive 2004/108/EC.

2.6 Warranty

The warranty period for the Dr FuelCell® Model Car is 12 months from the date of delivery. The warranty covers only faults that occur in the context of proper use through no fault of the operator.

The guarantee covers missing components only at the time of delivery. Certain characteristics, such as the power and life span of the reversible fuel cell, are not guaranteed.

Warranty does not cover faults that occur if:

- The operator caused damage by improper operation
- The equipment was arbitrarily repaired or altered
- Third parties caused damage because the operator neglected his / her duty of supervision

3 What's in the Box? – Functional Description

In the following chapter you will find a short functional description of the components of the Model Car.

3.1 Contents of the Kit

TIP

A detailed parts list is provided in *TECHNICAL DATA* on page 39.

Two different packages are available: Demo and Complete. Each package is delivered with an Instruction Manual, Teacher's Guide, a Quick Guide and a CD-ROM containing these manuals.

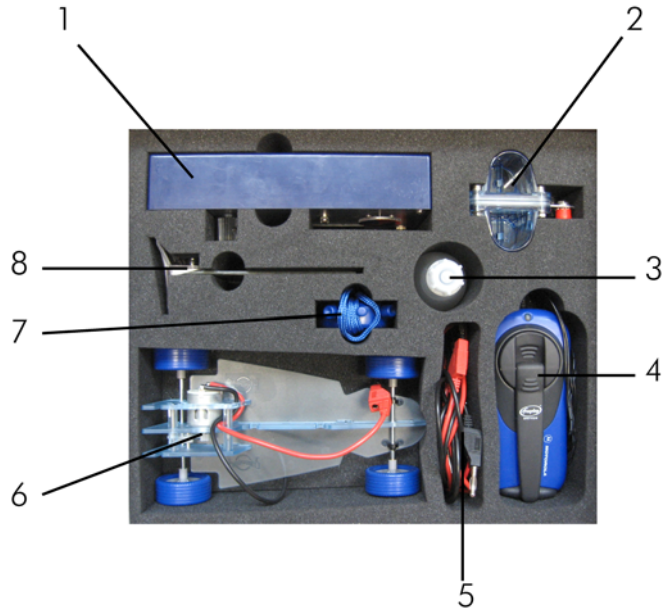

Fig. 3-1 Contents of the kit

1	Load measurement box, batteries included	5	Patch cords red / black (Complete 3 of each color, Demo 1 of each color)
2	Reversible fuel cell with stoppers	6	Car with motor
3	Bottle with distilled water	7	Stopwatch, batteries included
4	Hand generator	8	Solar Panel

3.2 Solar Panel

The solar panel is a source of power to operate the electrolyzer and perform investigations with the Model Car.

The solar panel generates power when illuminated by the sun or bright light.

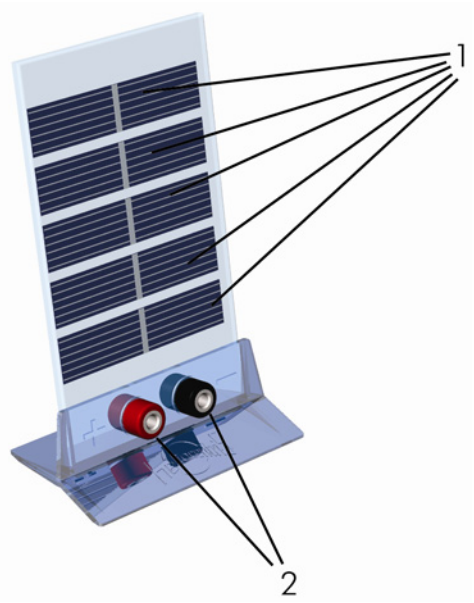

Fig. 3-2 Solar panel

1 Solar cells

2 Banana jack terminals (positive / negative)

3.3 Hand Generator (not Provided with the Demo Package)

As an alternative to the solar panel, the hand generator can be used to generate power.

The hand generator generates power when the crank is turned.

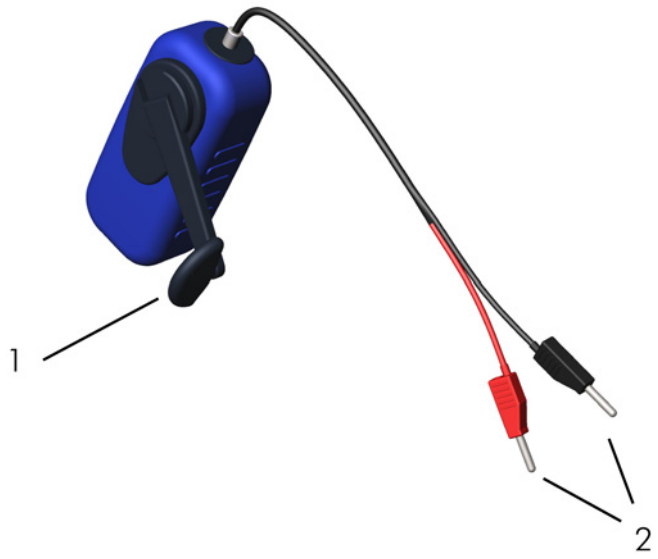

Fig. 3-3 Hand generator

1 Crank

2 Banana jacks (positive / negative)

3.4 Reversible Fuel Cell

The reversible fuel cell is the central device of the Model Car. It serves as an electrolyzer to produce hydrogen and oxygen (chemical power) and store them in the storage cylinders.

The reversible fuel cell generates (electrical) power when it consumes the hydrogen and oxygen from the storage cylinders.

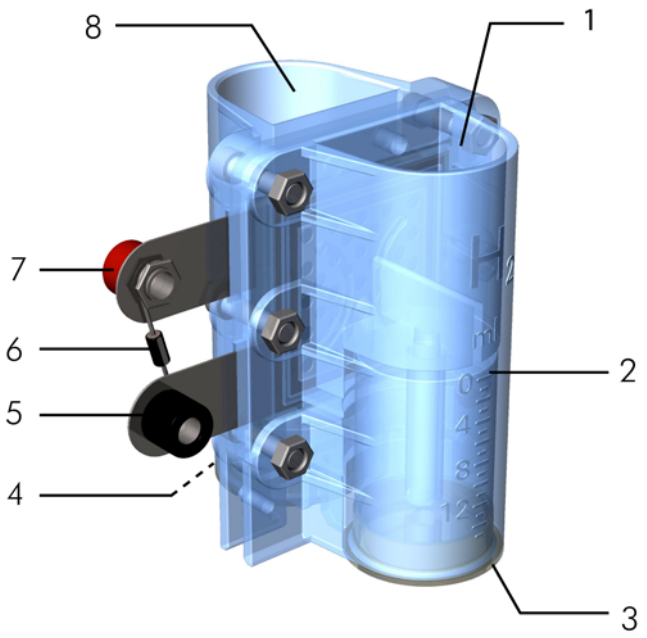

Fig. 3-4 Proton Exchange Membrane reversible fuel cell

1	Overflow compartment hydrogen side	5	Banana jack negative terminal
2	Hydrogen storage	6	Protective diode
3	Hydrogen side stopper	7	Banana jack positive terminal
4	Storage cylinder oxygen side (hidden)	8	Overflow compartment oxygen side

3.5 Car and Motor

The motor of the car is powered by the fuel cell, or the solar panel, or both.

The car is steerable; it can run straight or a circle.

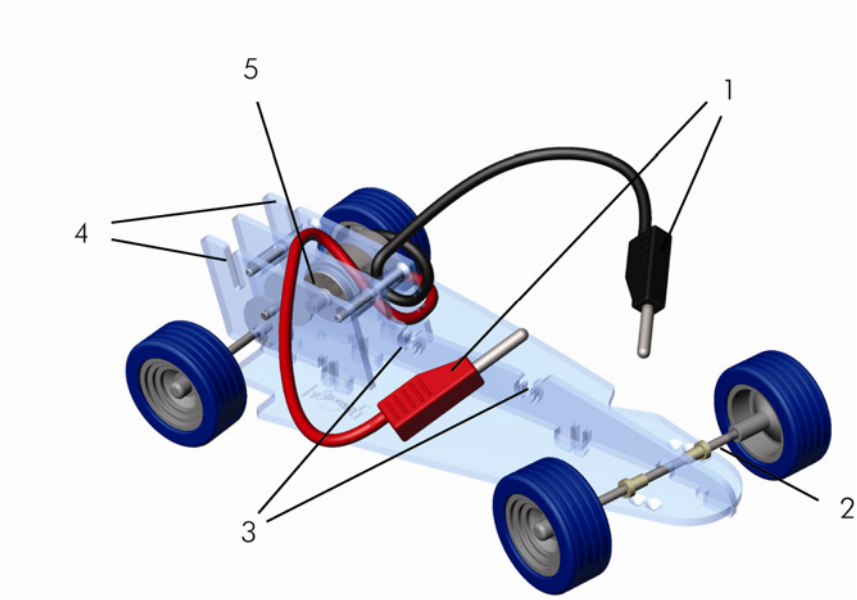

Fig. 3-5 Car chassis

1	Banana jacks (positive / negative)	4	Slots for attaching solar panel
2	Steerable front axle	5	Rear-engine with rear-wheel drive
3	Notches for attaching reversible fuel cell		

3.6 Load Measurement Box (not Provided with the Demo Package)

With the load measurement box it is possible to measure characteristic curves and to perform quantitative investigations.

The load measurement box contains an ammeter in series with a selectable load and a voltmeter.

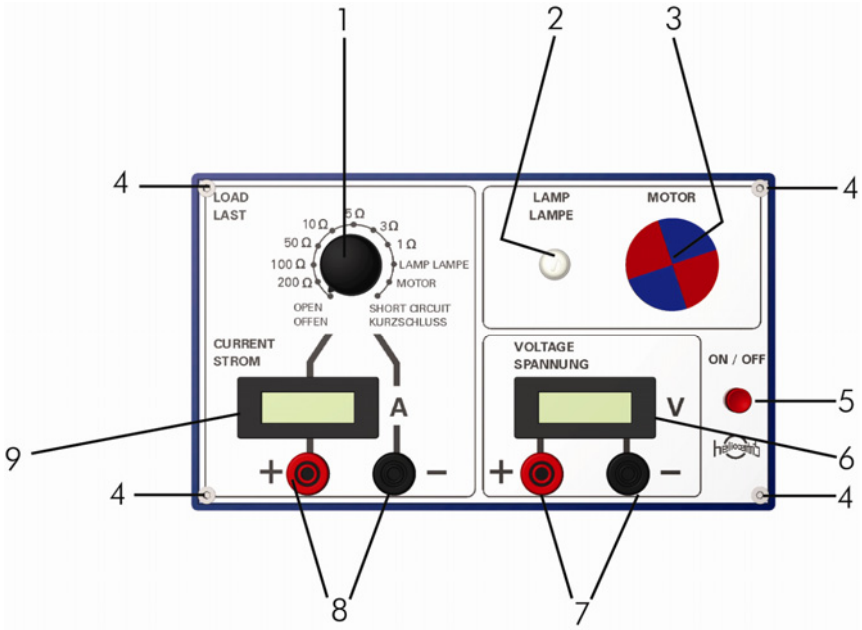

Fig. 3-6 Load measurement box

1	Load knob	6	Voltmeter display
2	Demonstration lamp	7	Banana jack voltmeter terminals
3	Demonstration motor	8	Banana jack ammeter terminals
4	Screws to access battery holders	9	Ammeter display
5	ON / OFF button		

TIP

A wiring diagram of the load measurement box can be found in chapter *TECHNICAL DATA* on page 39.

3.7 Stopwatch

To calculate time dependent parameters a stop watch for measuring time is supplied with the package.

Fig. 3-7 Stop watch

1	Split / Reset button	3	Start / Stop button
2	Mode button	4	Display

4 Getting Started

This chapter describes the steps you have to accomplish before letting the car run and performing measurements on the load measurement box. These steps are:

- Choosing a suitable location
- Filling the fuel cell with distilled water
- Starting to produce hydrogen

When you have completed these three steps, you will be ready to run the car and to measure.

4.1 Preliminaries

⚠ **CAUTION**
Ignition of hydrogen! Skin burns and damage to the reversible fuel cell. ➔ No open flames or smoking.

4.1.1 Where to Set Up the Model Car

The base on which to set up the Model Car should be:

- Even and stable
- At a recommended height of 75...85 cm (30...34")
- Well ventilated

4.1.2 Unpacking

You should have received the package in perfect condition. Nevertheless:

➔ Check for completeness.

➔ Check the contents for visible damage.

In the event of transport damages:

➔ Contact your supplier.

4.1.3 Additional Equipment

In order to get the Model Car running you need additional equipment.

Light

To supply the solar panel with light you need:

- The sun
- Bright light

TIP

A good source of indoor illumination is a 100...120 Watt Parabolic Aluminized Reflector (PAR) light bulb.
Illumination with sunlight is only recommended on a very sunny day.

NOTICE

Overheating of the solar panel!

Malfunctioning of or permanent damage to the solar cells.

➔ Only use light sources with a maximum power of 120 W.

➔ Keep a minimum distance of 20 cm (8 inches) between light source and solar panel.

➔ Do **not** concentrate light with a reflector.

Distilled water

To supply the reversible fuel cell with an electrolyzable liquid you need:

- Distilled water

NOTICE

Only use distilled water!

Tap water or other liquids will permanently damage the membrane of the reversible fuel cell.

TIP

If students are using the reversible fuel cell without close supervision, it is recommended that you place a notice “Don’t use this Water!” on the water faucets.

4.2 How to Fill the Reversible Fuel Cell

NOTICE

Only use distilled water!

Tap water or other liquids will permanently damage the membrane of the reversible fuel cell.

- ✓ Even and stable base has been chosen
- ✓ Reversible fuel cell
- ✓ Distilled water

1. Place the reversible fuel cell upside down (numbers facing down) on the flat surface.
2. Remove the stoppers.

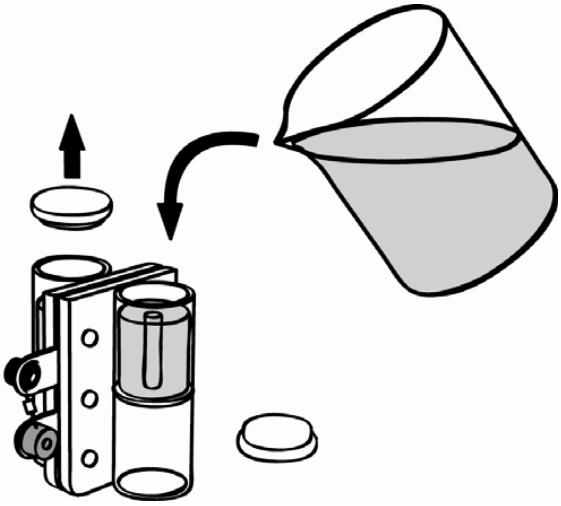

Fig. 4-1 Filling the reversible fuel cell with distilled water

3. Pour distilled water into both storage cylinders until the water reaches the tops of the small tubes in the center of the cylinders.
4. Tap the reversible fuel cell lightly to help water flow into the area surrounding the membrane and metal current-collecting plates.
5. Add more water until it starts to overflow into the tubes in the cylinder.
6. Place the stoppers back onto the cylinders. Make sure no air is trapped inside the cylinder.

TIP

A small air bubble in the order of 0.5 mL will not cause problems and can be ignored.

7. If the membrane has not been used for a while and has dried out: Leave it to soak for about 10 minutes.
8. Turn the reversible fuel cell right side up.

The reversible fuel cell is now filled with distilled water.

4.3 How to Produce Hydrogen

Producing hydrogen (and oxygen) consists of:

- Setting up the solar panel
- Connecting it to the filled reversible fuel cell

or

- Setting up the hand generator or an alternative source of energy
- Connecting it to the filled reversible fuel cell

4.3.1 How to Set Up the Solar Panel

✓ Light source

When using artificial light

NOTICE

Overheating of the solar panel!

Malfunctioning of or permanent damage to the solar cells.

➔ Only use light sources with a maximum power of 120 W.

➔ Keep a minimum distance of 20 cm (8 inches) between light source and solar panel.

➔ Do **not** concentrate light with a reflector.

1. Set up the solar panel facing the light source keeping a minimum distance of 20 cm (8 inches).
2. Make sure to aim the solar panel directly at the light source in a perpendicular direction.
3. Make sure the light source illuminates the solar panel evenly and leaves no dark spots.

Solar panel and light source are aligned.

When using sunlight

TIP

Sunlight is only recommended as a light source on a very sunny day.

➔ Set up the solar panel facing the sun making sure no dark spots / shades are present on the solar panel.

4.3.2 How to Connect Solar Panel and Reversible Fuel Cell

In order to produce hydrogen, the reversible fuel cell needs to be connected to the source of electrical energy, in this case the solar panel.

✓ The reversible fuel cell is filled with distilled water

✓ The solar panel is aligned with the light source

✓ 1 red and 1 black patch cord

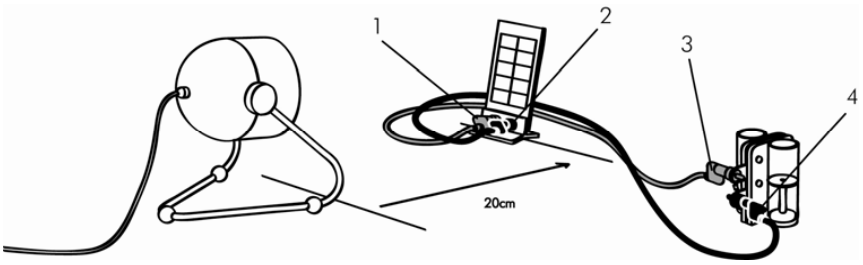

Fig. 4-2 Connecting solar panel and reversible fuel cell

CAUTION

Overpressure in reversible fuel cell!

Injuries due to objects shooting out, when the top of the overflow compartments of the storage cylinders is obstructed.

➔ Do not block the top of the overflow compartments of the storage cylinders.

➔ Always wear eye protection.

1. Connect the red (positive) terminal of the solar panel (1) to the red (positive) terminal of the reversible fuel cell (3).

NOTICE

Short circuit of reversible fuel cell!

Hot spots in the membrane, leading to deterioration of the membrane.

➔ Do not short circuit the reversible fuel cell.

2. Repeat step 1 with the black patch cord (2, 4) and the negative terminals.

The reversible fuel cell is now connected to the energy source and will immediately start producing hydrogen and oxygen.

3. Turn out the light source when enough hydrogen is produced.

⚠ CAUTION
Hot surface of solar panel and lamp! Skin burns. ➔ Do not touch the hot surface of the solar panel or lamp. ➔ Allow solar panel / lamp to cool down before touching it.

4. Disconnect solar panel from reversible fuel cell.

4.3.3 How to Use the Hand Generator

Instead of the solar panel, the hand generator can be used to supply energy as well.

✓ The reversible fuel cell is filled with distilled water

✓ Hand generator

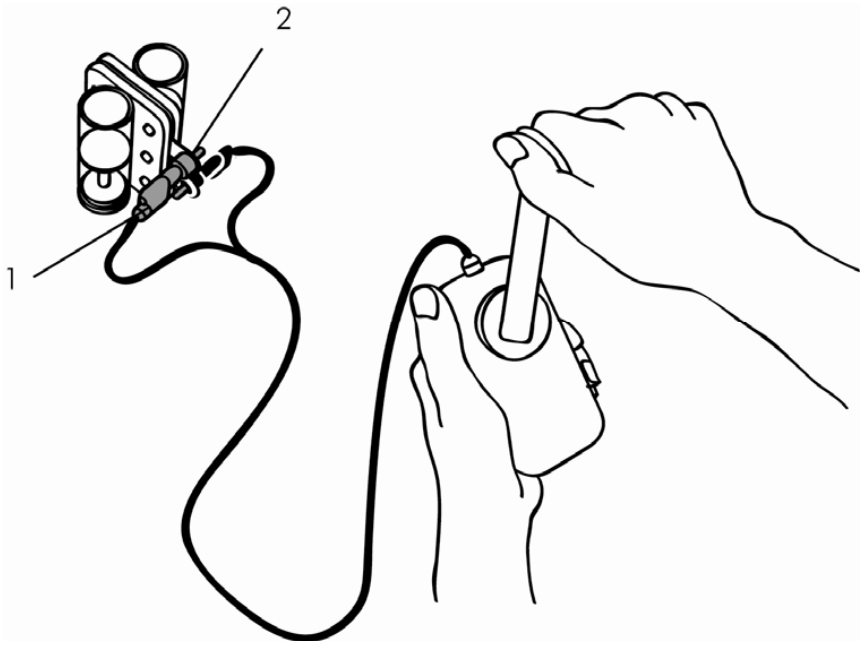

Fig. 4-3 Connecting the hand generator with the reversible fuel cell

1. Connect the red (positive) terminal of the hand generator to the red (positive) terminal of the reversible fuel cell (1).
2. Repeat step 1 with the black patch cord and the negative terminals (2).
3. Turn the crank of the hand generator (direction does not matter).

Green diode at the hand generator lights up and hydrogen production starts.

4. Stop turning when enough hydrogen is produced.
5. Disconnect hand generator from reversible fuel cell.

4.3.4 Other Sources of Energy

NOTICE

High currents!

Damage to the reversible fuel cell.

➔ Do not apply currents higher than 500 mA to the reversible fuel cell.

You may use any other alternative power sources, e.g.:

- A regulated laboratory power supply, set to a maximum current of 500 mA, with a maximum voltage of 2 V
- A different solar panel with the same current / voltage limits
- A rechargeable lead acid cell (2 V)

TIP

Alkaline or rechargeable NiCd batteries are not suitable – the voltage of a single cell is too low, and the voltage of two cells is too high.

4.3.5 How to Terminate the Hydrogen and Oxygen Production

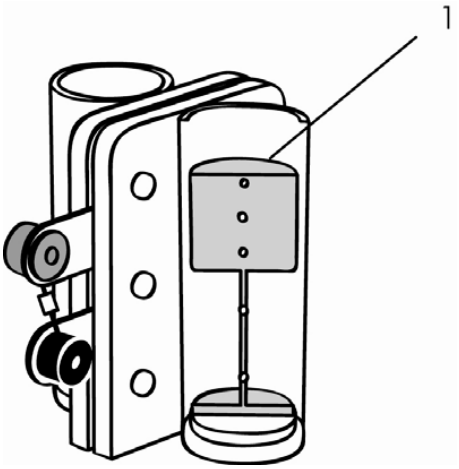

Fig. 4-4 Hydrogen has pushed water out

The reversible fuel cell is fully charged when the water in the hydrogen storage has been completely pushed into the reservoir on top (1).

TIP

A typical reversible fuel cell of the Dr FuelCell type will produce 12 mL hydrogen in 10...11 minutes at 150 mA.

When the hydrogen has filled the whole storage cylinder:

1. Disconnect the reversible fuel cell from the energy source by unplugging the banana jacks.

The reversible fuel cell stops producing hydrogen and oxygen.

2. Remove the energy source.

The hydrogen production is now finished.

4.3.6 How to Purge Air from the Reversible Fuel Cell

To ensure optimum fuel cell performance, continue producing hydrogen until the water in the oxygen storage has also been completely pushed into the reservoir on top.

TIP

When purging air from the reversible fuel cell, you will no longer be able to demonstrate the 2:1 hydrogen / oxygen ratio.

CAUTION

Overpressure in reversible fuel cell!

Injuries due to objects shooting out, when the top of the overflow compartments of the storage cylinders is obstructed.

- ➔ Do not block the top of the overflow compartments of the storage cylinders.
- ➔ Always wear eye protection.

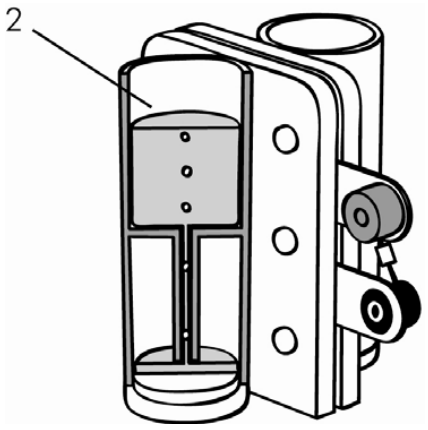

Fig. 4-5 Purging reversible fuel cell

When the oxygen has filled the whole storage cylinder (2):

- ➔ Disconnect the reversible fuel cell from the energy source by unplugging the banana jacks.

The reversible fuel cell stops producing hydrogen and oxygen.

If not enough hydrogen was produced, see *TROUBLESHOOTING* on page 43 for remedies.

5 Get Your Fuel Cell Running

When the reversible fuel cell is fully charged with hydrogen it is ready to power the model car or to measure its characteristic curves with the load measurement box.

> **CAUTION**
>
> **Ignition of hydrogen!**
>
> Skin burns and damage to the reversible fuel cell.
>
> ➔ No open flames or smoking.

5.1 How to Get the Model Car Running

✓ Hydrogen has been produced

✓ The reversible fuel cell is disconnected from the energy source

> **NOTICE**
>
> **Short circuit of the reversible fuel cell!**
>
> Hot spots on the membrane, leading to deterioration of the membrane.
>
> ➔ Do not short circuit the reversible fuel cell.

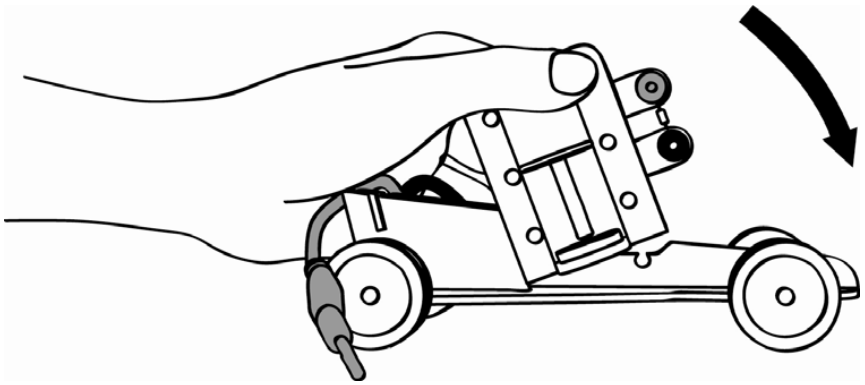

Fig. 5-1 Connecting the Model Car

1. Choose a suitable location: flat, smooth and unobstructed.
2. With the red and black terminals facing towards the front of the car, place the reversible fuel cell into the notches on the model car until it audibly clicks into place.
3. Connect the red (positive) banana jack with the red (positive) terminal and the black (negative) banana jack with the black (negative) terminal.

The car will start running.

TIP

By turning the front axle (three positions are possible) you can let the car run in a circle.

5.2 How to Use the Load Measurement Box (not Provided with the Demo Package)

5.2.1 How to Measure the Current and the Voltage of the Electrolysis

NOTICE

Voltage too high at load measurement box!

Deterioration of the contacts, loads and meters.

➔ Do not apply more than 3 V to the load measurement box.

CAUTION

Overpressure in reversible fuel cell!

Injuries due to objects shooting out, when the top of the overflow compartments of the storage cylinders is obstructed.

➔ Do not block the top of the overflow compartments of the storage cylinders.

➔ Always wear eye protection.

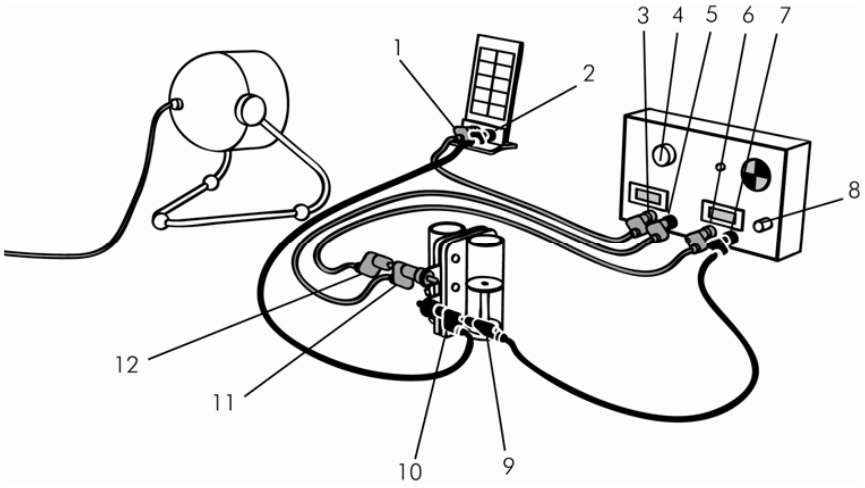

Fig. 5-2 Connecting the solar panel with the load measurement box

✓ Load measurement box

✓ 3 red and 2 black patch cords

✓ Solar panel is aligned with light source

✓ Reversible fuel cell filled with distilled water

NOTICE

Overheating of the solar panel!

Malfunctioning of or permanent damage to the solar cells.

➔ Only use light sources with a maximum power of 120 W.

➔ Keep a minimum distance of 20 cm (8 inches) between light source and solar panel.

➔ Do not concentrate light with a reflector.

To connect the solar panel and reversible fuel cell to the load measurement box:

1. Connect the red (positive) terminal of the solar panel (1) to the red (positive) terminal of the ammeter (3).
2. Connect the black (negative) terminal of the solar panel (2) to the black (negative) terminal of the reversible fuel cell (10).
3. Connect the red (positive) terminal of the reversible fuel cell (11) with the black (negative) terminal of the ammeter (5).
4. Connect the black (negative) terminal of the reversible fuel cell (9) with the black (negative) terminal (7) of the voltmeter.
5. Connect the red (positive) terminal of the reversible fuel cell (12) with the red (positive) terminal of the voltmeter (6).
6. Push the *ON / OFF* button.
7. Set the *LOAD* knob (4) to *SHORT CIRCUIT*.
8. Read out the values on the displays.
9. Turn the load measurement box *OFF* when you have finished all your measurements:

   ➔ Turn off the light source.

   ➔ Push the *ON / OFF* button.

TIP

For ideal operation of the solar panel (observing the minimum distance to the light source) the current should be 0.150 A or more.

5.2.2 How to Measure Current and Voltage of the Reversible Fuel Cell

✓ 2 red and 2 black patch cords

✓ Fuel cell filled with hydrogen

✓ Load measurement box

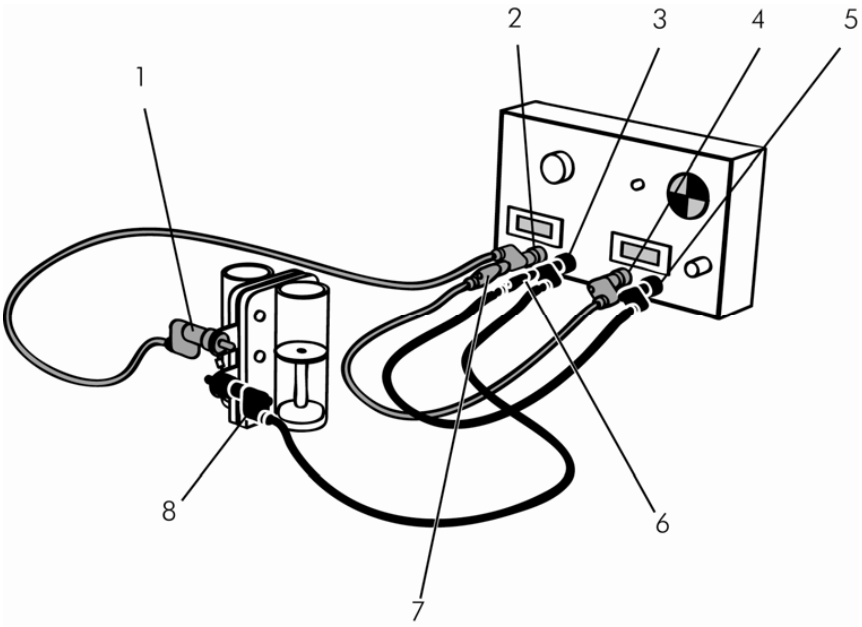

Fig. 5-3 Connecting the reversible fuel cell with the load measurement box

How to connect the reversible fuel cell with the measurement box

To connect the reversible fuel cell to the load measurement box:

1. Set the *LOAD* knob to *OPEN*.
2. Connect the red (positive) terminal of the reversible fuel cell (1) to the red (positive) terminal (2) of the ammeter.
3. Repeat step 2 for the black (negative) terminals (8, 3).
4. Connect the red (positive) terminal of the ammeter (7) with the red (positive) terminal of the voltmeter (4).
5. Repeat step 4 for black (negative) terminals (5, 6).

The reversible fuel cell is ready to be measured.

How to measure current and voltage with the load measurement box

NOTICE

Over current at the reversible fuel cell membrane!

Damage to the reversible fuel cell membrane.

➔ Do not set the load knob to *SHORT CIRCUIT*.

6. Set the *LOAD* knob to the desired resistance.
7. Push the *ON / OFF* button.
8. Read out the current on the ammeter display.
9. Read out the voltage on the voltmeter display.

How to use the demonstration lamp as a load

10. Set the *LOAD* knob to *LAMP*.

The demonstration lamp starts to glow.

11. Read out the current on the ammeter display.
12. Read out the voltage on the voltmeter display.

How to use the demonstration motor as a load

13. Set the *LOAD* knob to *MOTOR*.

The motor starts to run.

14. Read out the current on the ammeter display.
15. Read out the voltage on the voltmeter display.

TIP

If you attempt to measure voltage or current at the model car motor with the load measurement box, electrical noise from the motor can produce false meter readings.

Turn the load measurement box *OFF* when you have finished all your measurements:

➔ Push the *ON / OFF* button.

The numbers in the displays disappear.

5.2.3 How to Use the Stopwatch

For some measurements you may want to measure time dependent parameters.

Fig. 5-4 Stopwatch

How to measure time

1. Press the *MODE* button (2) until the display shows: 0:00▫▫.
2. Press the *START / STOP* button (3).

The beginning of the measurement is indicated by a beep.

3. Press the *START / STOP* button (3) again to stop the measurement.

The end of the measurement is indicated by a beep.

4. Press the *SPLIT / RESET* button (1) to reset timing.

The reset is indicated by a beep.

To return to the time-of-day mode:

➔ Press the *MODE* button (2).

How to set time and date

1. Press the *MODE* button (2) until the digits for seconds and current day start blinking.
2. With the *START / STOP* button (3) set the seconds.
3. Press the *SPLIT / RESET* button (1).

The display shows blinking digits for the minutes.

4. With *START / STOP* button (3) set the minutes.
5. Press the *SPLIT / RESET* button (1).

The display shows blinking digits for the hours.

6. With the *START / STOP* button (3) set the hours.
7. Press the *SPLIT / RESET* button (1).

The display shows blinking digits for the day.

8. With the *START / STOP* button (3) set the day.
9. Press the *SPLIT / RESET* button (1).

The display shows blinking digits for the month.

10. With the *START / STOP* button (3) set the month.
11. Press the *SPLIT / RESET* button (1).

The display shows blinking digits for the weekday.

12. With the *START / STOP* button (3) set the weekday.
13. Press the *MODE* button (2) to return to the normal time-of-day mode.

Date and time are set.

How to set the alarm time

1. Press the *MODE* button until the digits for the hours start blinking.
2. With the *START / STOP* button set the alarm hour.
3. Press the *SPLIT / RESET* button (1).

The display shows blinking digits for the minutes.

4. With the *START / STOP* button (3) set the alarm minutes.
5. Press the *MODE* button (2) to return to the normal time-of-day mode.

The alarm time is set.

How to switch the alarm on and off

1. Press and hold the *SPLIT / RESET* button (1).
2. While holding the *SPLIT / RESET* button (1), press the *START / STOP* button (3).

In the display a small bell appears and a beep sounds.

6 How to Shut Down the Dr FuelCell® Model Car

6.1 How to Dismantle and Store the Dr FuelCell® Model Car

How to dismantle the Dr FuelCell® Model Car

1. Switch off the source of light (if you used artificial light).
2. Disconnect all components.
3. Remove the stoppers from the reversible fuel cell and pour out the water.

NOTICE

Gas Diffusion Layer gets too wet!

Deterioration of the fuel cell membrane.

➔ Do not store the reversible fuel cell filled with water.

TIP

Do not put the stoppers back in place, but store them in the compartment of the original container.

How to store the Model Car

4. Allow the reversible fuel cell to dry.
5. Store the components of the Model Car in the compartments of the original container.
6. Store the Model Car in a place that is protected against vibration, dust / dirt and unauthorized access.
7. Store the components at temperatures between 10 °C and 35 °C (50...95 °F).

6.2 Disposal

6.2.1 Batteries

Batteries must not be disposed with other wastes.

- ➔ Recycle batteries.
- ➔ Check with any retailer of household type batteries in your area for battery disposal information.

6.2.2 System

The system must not be disposed with other wastes.

- ➔ Dispose of electronic devices in accordance with the guidelines concerning electrical and electronic devices.
- ➔ Check with your local council for recycling facilities in your area.

7 Technical Data

7.1 Parts List

Designation	Demo package	Complete package
Solar panel	1	1
Reversible fuel cell with stoppers	1	1
Car with motor	1	1
Load measurement box	–	1
Stopwatch	1	1
Patch cord, red	1	3
Patch cord, black	1	3
Hand generator	–	1
Bottle	1	1
Instruction Manual	1	1
Quick Guide	1	1
Teacher's Guide	1	1
Documentation on CD-ROM	1	1

Table 7-1 Parts list

7.2 Specifications

7.2.1 Solar Panel

Characteristics	Value
Operating and storage temperature	10…65 °C (50...149 °F)
Length / width / height	52 mm × 70 mm × 130 mm (2.04" × 2.8" × 5.11“)
Weight	60 g
Typical parameters measured during illumination with a 120 Watts PAR lamp, provided by Heliocentris, at a distance of 20 cm. With a load of 10 Ω at the operating point:	
Open circuit voltage	2.5 V
Short circuit current	200 mA
Operating current	180 mA
Operating voltage	2 V
Operating power	360 mW

Table 7-2 Specifications solar panel

7.2.2 Reversible Fuel Cell

Characteristics	Value
Length / width / height	70 mm × 80 mm × 80 mm (2.75" × 3.14" × 3.14“)
Weight (unfilled)	140 g (2.1 oz)
Operating temperature	10…40 °C (50…104 °F)
Storage temperature	5…40 °C (41...104 °F)
Gas storage	2 × 15 mL
Electrolyzer operation	
Working voltage	1.4...1.8 V
Current	0...500 mA
Rate of hydrogen production, maximum	3.5 mL / min
Fuel cell operation	
Operating voltage	0.5...0.9 V
Operating current	500 mA
Operating power	250 mW

Table 7-3 Specifications reversible fuel cell

7.2.3 Car and Motor

Characteristics	Value
Length / width / height	195 mm × 110 mm × 50 mm (7.7" × 4.3" × 2“)
Motor operating voltage	0.5...3 V
With reversible fuel cell	
Rate of hydrogen consumption	3…5 mL / min
Running time of car	3…5 min

Table 7-4 Specifications car and motor

7.2.4 Load Measurement Box

The Load Measurement Box complies with the following regulations:

- EMC 2004/108/EC

Characteristics	Value
Length / width / height	190 mm × 110 mm × 85 mm (7.5" × 4.3" × 3.3“)
Weight	410 g (14.5 oz)
Ammeter travel range	0…2 A
Voltmeter travel range	0…20 V DC
Batteries	9 V ANSI-1604A or IEC-6LR61 (2)
Demonstration motor	
Operating voltage / current	0.2…3 V / 10…15 mA
Demonstration lamp	
Operating voltage / current	0.6…1.55 V / 80 mA
Maximum load voltage	3 V (at 1 Ω , maximum load voltage is 1 V)
Adjustable resistor	1 Ω, 3 Ω, 5 Ω, 10 Ω, 50 Ω, 100 Ω, 200 Ω, *Open* and *Short Circuit*

Table 7-5 Specifications load measurement box

7.2.4.1 Wiring Diagram of the Load Measurement Box

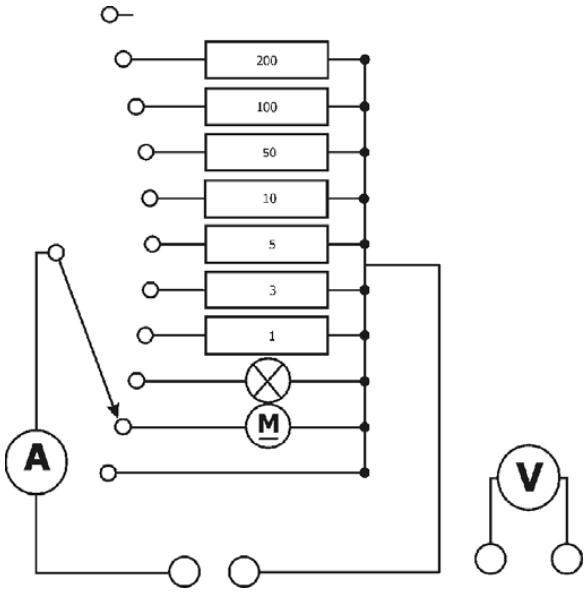

Fig. 7-1 Wiring of the load measurement box

7.2.5 Hand Generator

Characteristics	Value
Operating temperature	5...50 °C (40...120 °F)
Weight	270 g (8.68 oz)
Height / width / length	55 mm × 55 mm × 137 mm (2.17" × 2.17" × 5.39")
Open-circuit voltage	2.1 V

Table 7-6 Specifications hand generator

8 Troubleshooting

Even though the Model Car is designed for problem-free operation, it may happen that you encounter some problems.

8.1 Solar Panel Test

- ✓ Light source (recommended: 100...120 W PAR light bulb)
- ✓ Solar panel
- ✓ Load measurement box
- ✓ 2 patch cords

To check the solar panel, proceed as follows:

1. Connect solar panel directly to the ammeter terminal.
2. Set the *Load* knob to 10 Ω.
3. Push the *ON/ OFF* button.

> **NOTICE**
>
> **Overheating of the solar panel!**
>
> Malfunctioning of or permanent damage to the solar cells.
>
> - ➔ Only use light sources with a maximum power of 120 W.
> - ➔ Keep a minimum distance of 20 cm (8 inches) between light source and solar panel.
> - ➔ Do **not** concentrate light with a reflector.

4. Set up the solar panel facing the light source, keeping a minimum distance of 20 cm (8 inches).

With the 120 W PAR light bulb shining brightly and evenly over the entire surface of the solar panel, the ammeter shows at least 150 mA. Lights with less power will result in significantly lower output of the solar panel.

8.2 Electrolyzer Test

- ✓ Solar panel
- ✓ Load measurement box

TIP

If the load measurement box is not available, you can perform this test with an ammeter and a voltmeter.

- ✓ Reversible fuel cell filled with distilled water, see *HOW TO FILL THE REVERSIBLE FUEL CELL* on page 21
- ✓ 3 red and 2 black patch cords

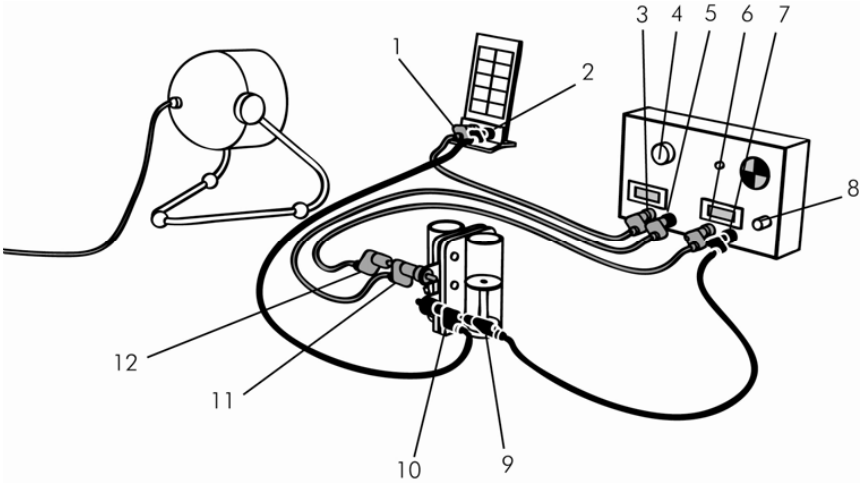

Fig. 8-1 Electrolyzer test

1. Connect the red (positive) terminal of the solar panel (1) to the red (positive) terminal of the ammeter (3).
2. Connect the black (negative) terminal of the solar panel (2) to the black (negative) terminal of the reversible fuel cell (10).
3. Connect the red (positive) terminal of the reversible fuel cell (11) with the black (negative) terminal of the ammeter (5).
4. Connect the black (negative) terminal of the reversible fuel cell (9) with the black (negative) terminal (7) of the voltmeter.
5. Connect the red (positive) terminal of the reversible fuel cell (12) with the red (positive) terminal of the voltmeter (6).
6. Push the *ON / OFF* button.
7. Set the *LOAD* knob (4) to *SHORT CIRCUIT*.

8. Adjust the light source so that the current amounts to 150...200 mA.
9. Check the voltage on the voltage display.

The voltage should amount to 1.6...1.7 V.

If the voltage is greater than 2 V the cause could be that the membrane has run dry:

10. Turn the reversible fuel cell upside down and let it soak for 30 min.
11. Repeat steps 7 – 9.

If the voltage is still greater than 2 V, the membrane is defective:

➔ Contact Heliocentris to report the problem; see *SERVICE* on page 57.

The following diagram illustrates the travel ranges of current and voltage of the electrolyzer.

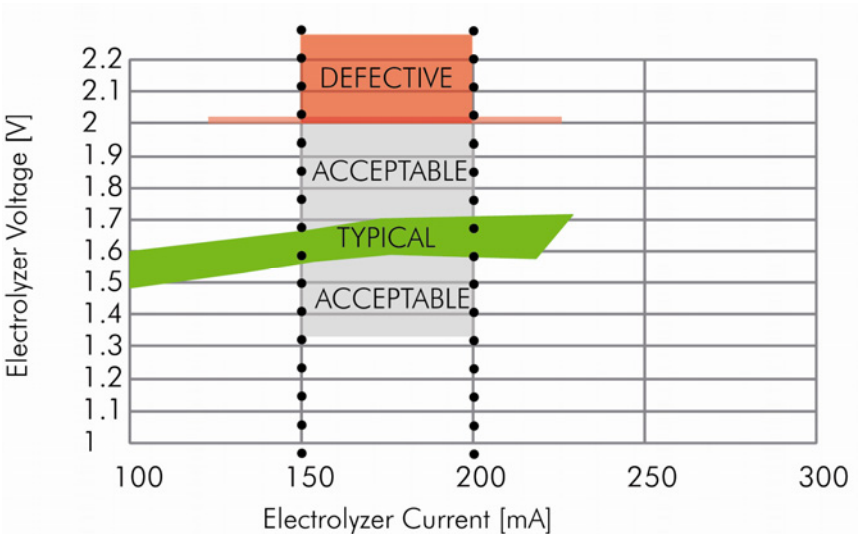

Fig. 8-2 Electrolyzer test

8.3 Fuel Cell Test

- ✓ Light source (recommended: 100...120 W PAR light bulb)
- ✓ Solar panel
- ✓ Load measurement box
- ✓ Reversible fuel cell
- ✓ 2 red and 2 black patch cords

TIP

If the load measurement box is not available, you can perform this test with a 1...3 Ω resistor and an ammeter and a voltmeter.

1. Produce 10 mL hydrogen; see *HOW TO PRODUCE HYDROGEN* on page 22.
2. Purge the reversible fuel cell; see *HOW TO PURGE AIR FROM THE REVERSIBLE FUEL CELL* on page 27.
3. Connect the reversible fuel cell for measuring voltage and current; see *HOW TO MEASURE CURRENT AND VOLTAGE OF THE REVERSIBLE FUEL* Cell on page 32.
4. Set the *LOAD* knob to 10 Ω and wait for 3 minutes.
5. Set the *LOAD* knob to 1 Ω.

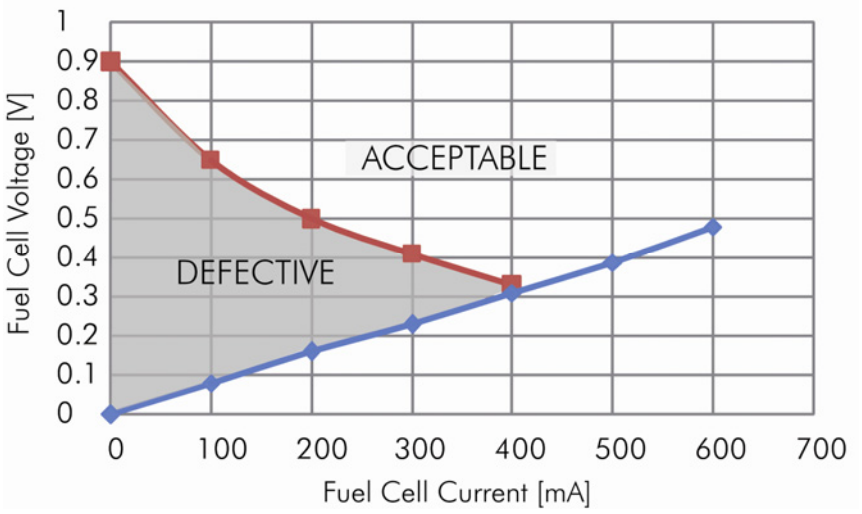

Fig. 8-3 Fuel cell test

6. Read out voltage and current displayed on the load measurement box.

7. Match measured current and voltage on the graph above.

If the operating point is within the defective area, the membrane of the reversible fuel cell might be too wet. In this case:

1. Produce hydrogen for 15 min.
2. Repeat steps 4 – 7.

If performance improves but the operating point is still within the defective area, repeat steps 8 and 9.

TIP

To improve the fuel cell performance, empty the fuel cell and leave it open for a day. If the operating point is still within the defective area, contact Heliocentris, see *SERVICE* on page 57.

If your operating point remains within the defective area, contact Heliocentris; see *SERVICE* on page 57.

8.4 Problems and their Remedies

TIP

The problems are arranged alphabetically.

What's the trouble?	Possible cause?	Remedy!
Ammeter and/or voltmeter do not display as expected when the load measurement box is acting a load for the reversible fuel cell.	Improper connections or *LOAD* setting.	In the typical fuel cell-load measurement box set up, the load measurement box provides a load that you select; see page 31. The ammeter displays the current flowing through this load. Use the *LOAD* knob to select a load, but do **not** select *SHORT CIRCUIT*. The voltmeter section of the load measurement box is not internally connected to anything else; it simply measures the voltage difference between whichever two points you connect to its terminals.

What's the trouble?	Possible cause?	Remedy!
Ammeter does not display expected current when the load measurement box is measuring current flowing through electrolyzer.		In the typical solar panel – load measurement box – electrolyzer set up, the name load measurement box is misleading as the box does not supply any load; instead the electrolyzer is the load. You are using the box only as an ammeter. You should set the *LOAD* knob to *SHORT CIRCUIT* so the meter simply measures the current flowing through the "A" terminals. Setting *LOAD* to any other position will impede the current and give unexpected results. The voltmeter section of the load measurement box is not internally connected to anything else. The voltmeter measures the voltage difference between whichever two points you connect to its terminals.
Car does not run as quickly or as long as the car in another kit does.	Variations in fuel cell performance and motor.	This is normal.
Car motor does not run, even when the car is held above the surface.	Lacking hydrogen and oxygen in storage cylinders.	Ensure that you have properly run the electrolyzer, and that enough hydrogen and oxygen are present in the cylinders.
Car motor does not run, even when the car is held above the surface.	Reversible fuel cell not connected to motor.	Check connections, including soldered connections at the motor. Try lifting the car off the surface, and manipulating the wires. If the motor runs intermittently, the connections are faulty. Contact Heliocentris to report the problem with your car; see *SERVICE* on page 57.

What's the trouble?	Possible cause?	Remedy!
Car motor does not run, even when the car is held above the surface.	Motor faulty	Remove reversible fuel cell and try this test. Holding the car, momentarily touch the motor cables to a 1.5 V battery. The wheels should turn rapidly. If not, the motor is faulty and you should contact Heliocentris to report the problem with your car; see *SERVICE* on page 57.
Car motor does not run, even when the car is held above the surface.	Problem in the reversible fuel cell.	If you have eliminated other causes above, the reversible fuel cell must be faulty. If you have a load measurement box, you could perform the Fuel Cell Test on page 46 for confirmation. Contact Heliocentris to report the problem with your reversible fuel cell; see *SERVICE* on page 57.
Car moves slowly, or only for a short time.	Hydrogen/oxygen mixed with air.	Ensure you have made at least 10 mL of hydrogen. For optimum fuel cell performance, make even more hydrogen, continuing until even the oxygen side is "overflowing" and oxygen bubbles rise through the reservoir; see *HOW TO PURGE AIR FROM THE REVERSIBLE FUEL CELL* on page 27.
Car moves slowly, or only for a short time.	Floor surface too rough.	Put car on a smooth and clean floor. It will not run on most types of carpet.
Car moves slowly, or only for a short time.	Membrane in the reversible fuel cell not thoroughly wet.	If the reversible fuel cell is new or has not been used for a few months, fill it with distilled water and leave it to rest without turning it right side up.

What's the trouble?	Possible cause?	Remedy!
Car moves slowly, or only for a short time.	Gas Diffusion Layer in the fuel cell is too wet.	Run the reversible fuel cell as an electrolyzer for about 15 min and / or pour out the water and let the fuel cell dry for a couple of hours (up to 3 days).
Car runs but stops when there is a bit of hydrogen left (less than 2 mL).	Various causes, often because of membrane conditions.	If the amount of remaining gas in the hydrogen cylinder is less than 2 mL, there is no problem; this is normal. However, for optimum fuel cell performance, you could try making hydrogen for a longer time, continuing until even the oxygen side is "overflowing" and oxygen bubbles rise through the reservoir; see *HOW TO PURGE AIR FROM THE REVERSIBLE FUEL CELL* on page 27.
Car runs but stops when there is some hydrogen left (more than 2 mL).	Fuel cell faulty.	If you have eliminated other causes above, the reversible fuel cell must be faulty. If you have a load measurement box, you could perform the Fuel Cell Test on page 46 for confirmation. Contact Heliocentris to report the problem with your reversible fuel cell; see *SERVICE* on page 57.
Erratic current and voltage displayed when load measurement box is attached to car motor.	Voltage spikes from the motor armature.	If you attempt to use the load measurement box ammeter or voltmeter to measure current or voltage at the model car motor, electrical noise from the motor will produce false meter readings. The meters are designed for use with the demonstration lamp and motor, and resistive loads supplied in the load measurement box. They will not measure current and voltage at the car motor.

What's the trouble?	Possible cause?	Remedy!
Higher than normal voltage when first connecting load.	Surface layer on the catalyst.	If you connect the load measurement box voltmeter to the fuel cell immediately after using it as an electrolyzer, you will see a voltage displayed that is greater than the ideal reversible fuel cell voltage – more than 1.23 V. Because of a transient surface layer on the catalyst, the initial output voltage of the device is higher than the voltage of a normal reversible fuel cell. This layer disappears in a few seconds of use.
LOAD knob has become misaligned.	Setscrew came loose or knob was forced past its stop.	At full clockwise it should stop at *SHORT CIRCUIT*, and at full counter-clockwise it should stop at *OPEN*. Loosen setscrew and attach knob to the shaft in the correct position.
No output, or low output at load measurement box.	Improper connections to load measurement	Check that patch cords are routed correctly. Ensure patch cords are secure. If faulty, contact Heliocentris to report the problem; see *SERVICE* on page 57.
No output, or low output at load measurement box.	Load measurement box is adding resistance	If you are using the load measurement box in the solar panel-load-measurement-box-electrolyzer-set up, set the LOAD knob to SHORT CIRCUIT
No output, or low output with solar panel connected.	Faulty solar panel or low light.	Perform the Solar Panel Test; see page 43.

What's the trouble?	Possible cause?	Remedy!
No hydrogen production or slow hydrogen production (more than 12 minutes for 10 mL hydrogen).	Improper connection between solar panel and electrolyzer.	Check that solar panel-electrolyzer connections are correct: positive to positive, negative to negative. If you are using the load measurement box, set LOAD knob to SHORT CIRCUIT. Check for open or intermittent patch cords. If faulty, contact Heliocentris to report the problem, see *SERVICE* on page 57.
No hydrogen production or slow hydrogen production (more than 12 minutes for 10 mL hydrogen).	Faulty solar panel or low light. Light source is not aligned with the solar panel.	Perform the Solar Panel Test; see page 43. Check if the light source has the correct power range. Align the solar panel with the light source.
No hydrogen production or slow hydrogen production (more than 12 minutes for 10 mL hydrogen).	Electrolyzer failure because impure water has been used.	If you have eliminated the above causes, the electrolyzer must be faulty. For confirmation, you could perform the Electrolyzer Test on page 44 before contacting Heliocentris to report the problem with your reversible fuel cell; see *SERVICE* on page 57.
Numbers on one or both the LCD displays are not visible.	Exhausted batteries.	Because each meter has its own battery, one meter can lose its display although the other works normally; see *HOW TO REPLACE THE LOAD MEASUREMENT BOX BATTERY* on page 56.
Water leaking from reversible fuel cell.	Stoppers in the cylinders shrink.	Remove stopper and press it flat, expanding it. Replace the stopper and watch for further leaks; see *HOW TO RE-SHAPE* the Stoppers on page 56.

What's the trouble?	Possible cause?	Remedy!
Water leaking from reversible fuel cell.	Fracture in the reversible fuel cell body.	Inspect for visible cracks. If so, contact Heliocentris to report the problem with your reversible fuel cell; *SERVICE* on page 57.

Table 8-1 Troubleshooting

9 Maintenance and Service

In general no special maintenance work has to be performed.

9.1 How to Clean the Dr FuelCell® Model Car

NOTICE

Liquids other than distilled water entering the reversible fuel cell!

Damage to the membrane.

➔ Prevent other liquids from entering the reversible fuel cell.

➔ Use distilled water to clean the reversible fuel cell. The plastic surfaces of the other components can be cleaned with a mild cleaner as well.

9.2 How to Replace the Stopwatch Battery

If the stopwatch display is fading, the battery must be replaced.

✓ Small Phillips screw driver at hand

✓ Alkaline Button Cells type LR44

1. On the back of the stopwatch, loosen the four screws.
2. Remove the cover.
3. Remove the old battery.
4. Insert the new battery.
5. Close the cover and tighten the screws.
6. Dispose of the batteries according to your local regulations.

9.3 How to Re-shape the Stoppers

With time and exposure to heat, the stoppers on the bottom of the storage cylinders may shrink slightly, resulting in water leakage.

Take the following measures:

1. Turn the reversible fuel cell upside down.
2. Remove the stoppers.
3. Place one stopper on the table and place the palm of your hand on the stopper.
4. Press on the stoppers forcefully.
5. If necessary, refill the storage cylinders with distilled water.
6. Put the stopper back into place.
7. Turn the reversible fuel cell right side up and check for leakage.
8. If necessary repeat steps 1 – 7.

9.4 How to Replace the Load Measurement Box Battery

If one or both of the meter displays are fading, the batteries must be replaced. Each meter has its own battery.

- ✓ Small Phillips screw driver at hand
- ✓ 2 Batteries type ANSI-1604A or IEC-6LR61

1. Remove the four screws in the corners of the load measurement box with a small Phillips screw driver.
2. Carefully lift off the front panel.
3. Remove the two old batteries.
4. Insert the new batteries.
5. Put the panel back in place and tighten the screws.
6. Dispose of the batteries according to your local regulations.

9.5 Service

If you are having problems with the Model Car and were not able to remedy these problems with the help of the Troubleshooting chapter, contact:

Heliocentris Energiesysteme GmbH

Rudower Chaussee 29

12489 Berlin

Germany

Phone +49 (0)30 – 340601-700

Fax +49 (0)30 – 340601-599

e-mail: support@heliocentris.com

A Heliocentris customer service representative will contact you and instruct you how to proceed. If the representative asks you to return the device for repair or replacement, you must ensure proper and safe packaging.

Heliocentris is not responsible for damage caused by improper packing and shipping. Devices for which the warranty has expired are shipped at your cost.

If you wish, you may instead contact the local dealer where you bought your Model Car to handle your complaint.

Heliocentris

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